The Serpent Series:
Precession in the Maya Dresden Codex

By

MICHAEL JOHN GROFE

B.S. (University of Miami) 1993
M.A. (California Institute of Integral Studies, San Francisco) 1998

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Native American Studies

in the

OFFICE OF GRADUATE STUDIES

of the

UNIVERSITY OF CALIFORNIA

DAVIS

Approved:

Martha J. Macri

Matthew G. Looper

Stefano Varese

Committee in Charge

May 2007

Dedicated to
Martha J. Macri

The Serpent Series:
Precession in the Maya Dresden Codex

Michael J. Grofe, Ph.D.

Table of Contents

Acknowledgements

In the journey that has taken me to the completion of this dissertation, I have received immeasurable encouragement, support, and inspiration from my family, friends, mentors, and colleagues. To all of them I owe tremendous gratitude.

It was my father, Jerrold Grofe, who first taught me about the stars, and to appreciate both the wonders of the natural world, and how to foster a sense of unending curiosity. My mother, Kathryn Steppacher, similarly taught me an appreciation of music, reading, and learning from books. She read stories to us from a very early age, and I remember my excitement when she would take us on our regular trips to the library. My grandmother, Jeanette Greenwood, opened up the world for me by keeping me supplied with the latest books from National Geographic, and her unfailing support and belief in me has been a great inspiration. To my brother, Robert Grofe, I owe my inspiration to be a writer, and I still have the very first book we wrote together on an electric typewriter when I was eight years old. All of my family have been a tremendous emotional and financial support throughout my experience in graduate school, and for that I am deeply grateful.

My extended family includes my loved ones and friends, and their presence in my life has been a blessing. I am all too aware that the time I have taken in researching and writing this dissertation has come at the price of my absence from their lives for a time, and I look forward to the opportunity to see all of them more often. I am forever grateful to Richard Buggs for years of support and understanding, and for weathering through so much of this with

me. Likewise, I am thankful to my friends Judy Alexander, Skye Bergen, Ben and Tahnee Burgess, Sara McClelland, Gregory Geiger, Dina Fachin, Jane Haladay, Damian Kellogg, Rocky and Amy Vogler, and Lisa Woodward for their ongoing companionship and support.

In my academic life, I have been very fortunate to have Martha Macri as my major professor, my mentor, and my friend. Martha's passion for learning, her prolific scholarship, and our shared mutual interests made my exploration of Maya hieroglyphic writing and astronomy possible. Through her perennial guidance, her support, and her genuine interest in my research, she has encouraged me to pursue my chosen career. I am deeply honored to have had the opportunity to be her student. Martha introduced me to her colleague Matthew Looper, and I have likewise enjoyed and benefited from Matthew's wide-ranging knowledge and superior scholarship, and his valuable insights concerning this project. Furthermore, my work with Martha and Matthew on the construction of the Maya Hieroglyphic Database Project has allowed me to gain a valuable understanding of the hieroglyphic script, with rapid access to the corpus of Maya inscriptions.

In his passion for teaching and intellectual pursuits, Stefano Varese has served as a model for me in my chosen career as a teacher and scholar. I am grateful for his belief in me, for valuing my work, and for offering me invaluable opportunities as a co-author and co-presenter in the Tercera Mesa Redonda de Monte Alban. Stefano has always been a source of positive encouragement and warm hearted support.

I would also like to thank Victor Montejo. Much of my initial experience in the Native American Studies doctoral program was influenced by the many conversations I had with Victor, which helped to shape some of my theoretical framework within the discipline of Maya Studies. I am grateful for his encouragement to explore this subject from a critical perspective, and for our ongoing dialogue about Maya knowledge.

In the writing of this dissertation, I have received important feedback and encouragement from many of my esteemed colleagues, including Gerardo Aldana, Alonso Mendez, Carol Karasik, Ed Barnhardt, Christopher Powell, John Justeson, Anthony Aveni, Susan Milbrath, Gabrielle Vail and Christine Hernandez. I look forward to continuing our collective discussions in the future.

All images of the Dresden Codex used within this dissertation are taken from the online Förstemann version, made available on the FAMSI website. I am grateful to FAMSI for posting the Dresden Codex as a public resource. I would also like to thank Imaginova Canada, Ltd. for Starry Night Pro, Version 6.0.0 astronomical software. All of the astronomical simulations used in this dissertation were created using this elegant and invaluable program. Only through using Starry Night Pro was I able to visualize, reconstruct, and understand what Maya astronomers were capable of understanding using only their paint, bark paper, and hundreds of years of thoughtful observations.

Michael John Grofe
June, 2007
Native American Studies

The Serpent Series: Precession in the Maya Dresden Codex

Abstract

The Postclassic Maya Dresden Codex contains extensive astronomical records in the form of calendrical and chronological intervals concerning multiple cycles of the sun, the moon, and several visible planets. Hermann Beyer (1943) first demonstrated that a sequence of unusually long intervals of time found within the Dresden Codex describe specific dates separated by intervals of over 30,000 years. Beyer first named this sequence the Serpent Series because its component numerals are written within the coils of undulating serpents. This dissertation project examines the Serpent Series in detail, beginning with a new interpretation of the initial repeated distance number on pages 61 and 69. This unique interval of more than 15,000 years is almost exactly a whole multiple of the sidereal year, returning the sun to precisely the same position against the background of stars, while the position in the tropical year shifts dramatically. Such an accurate calculation suggests that the Maya were observing and recording the precession of the equinoxes. Because it takes approximately seventy-one years for the annual sidereal position of the sun to shift by one day of precession, an accurate calculation of precession requires hundreds of years of recorded observations. The remainder of the dates in the Serpent Series strongly support this proposal, demonstrating not only repeating sidereal positions of the sun over tens of thousands of years, but also an extensive knowledge of lunar

motion, eclipse cycles, and planetary cycles of Mars, Saturn, and Venus that are comparable to current measurements. Furthermore, the data contained within the Serpent Series can be used to reconstruct the means used by the Maya to calculate precession. Namely, Maya astronomers recorded their observations of the sidereal position of total lunar eclipses at fixed points within the tropical year. These observations can be compared to those of Hipparchus, who first recorded the precession of the equinoxes in ancient Greece. However, the values calculated for precession within the Serpent Series are far more accurate than those of their contemporaries, surpassed only by Tycho Brahe and Johannes Kepler in the late sixteenth century.

Preface

This project began as an analysis of the cosmological inscriptions of Palenque, in which I found several examples of dates separated by thousands of years when the sun was in the exact same sidereal position, defined as the position of the sun against the background of stars. From the perspective of an observer on the earth, the sun returns to approximately the same sidereal position at the same time each year. It takes about 71 years for the annual sidereal position of the sun to shift one day. However, over much longer periods of time, the time of year in which the sun returns to the same sidereal position shifts dramatically due to the phenomenon known as the precession of the equinoxes. It thus takes about 26,000 years for the sun to return to the same sidereal position at the exact same time of year.

In the Palenque inscriptions, the precise repetitions of the sun's sidereal position occur on dates separated by intervals of thousands of years. This suggests that the Palenque astronomers had developed the ability to calculate precession with great accuracy. Furthermore, such calculations may have been one of the primary reasons why the Maya chose to reference these specific ancient dates.

Within the framework of precessional calculation, I originally planned to analyze these Palenque dates, and to further re-examine the roles and names of the three deities involved in Palenque cosmology—first labeled GI, GII, and GIII, the Palenque Triad. But the evidence from Palenque, while compelling, is relatively limited without corroboration from other sources that might demonstrate that the Maya were capable of calculating precessional drift. In my search for additional evidence, I turned to a sequence of unusually long intervals of time referenced in the Postclassic Dresden Codex.

Hermann Beyer (1933; 1943) first named this sequence the Serpent Series because its component numerals are written within the coils of undulating serpents. Moreover, he found that they describe specific dates separated by intervals of over 30,000 years. Susan Milbrath (1999:259) first proposed that such vast intervals of time may have something to do with the 26,000 year cycle of the precession of the equinoxes, though the Serpent Series are still poorly understood. I chose to re-examine the Serpent Series, specifically looking for calculations that would indicate an understanding of precession. My subsequent analysis proved to be more fruitful than I had expected, and it here forms the basis of this dissertation project.

I begin the introduction in Chapter One with an overview of the Dresden Codex, and its crucial role in the history of the decipherment of Maya writing and calendrical astronomy. This leads to a discussion of the methodology of the interpretation of Maya astronomy in both the codices and the Classic inscriptions, followed by an exploration of the challenges of interpreting Maya science from a Western perspective, including a discussion of the categories of astrology and astronomy.

Chapter Two provides an astronomical description of the precession of the equinoxes, along with an overview of the history of the discovery of precession in the West, and a critical review of previous suggestions concerning a knowledge of precession in both ancient Babylon and among the ancient Maya.

Chapter Three provides a review of the work of Hermann Beyer (1933; 1943) and Victoria and Harvey Bricker (1988), and a new reading of what I refer to as the Serpent Series Introductory Distance Number. This new reading forms the core of my original research, upon which is based the remainder of the translation of the Serpent Series. The Serpent Series introductory distance number calculates a highly accurate measurement of precessional drift over 15,000 years. Furthermore, the calculations found within the Serpent Series confirm the highly accurate measurement of the Copán tropical year first suggested by John Teeple (1931), based on dates found in the Classic site of Copán. I then discuss the relevance of the Serpent Series Base date, first discussed by Beyer (1943), and its selection based on the tropical year, the Haab', the eclipse year, and the sidereal year.

Chapter Four follows with a discussion of the lunar calculations within the secondary inscriptions from the Serpent Series. These lunar calculations appear to further refine those from the Classic period. I explore the lunar function of Glyphs G, F and Y from the Supplementary Series in the Classic period, and how these demonstrate a precedent for the later, refined calculations appearing in the Dresden Codex.

In Chapter Five, I discuss each of the dates in the Serpent Series with their associated texts, exploring the meanings of Ring Number calculations and the various planetary, lunar and solar cycles implied in these dates.

Lastly, Chapter Six concludes with a discussion of these findings, the new questions raised by this project, and the implications for further research.

Chapter I: Introduction—The Serpent Series

The Dresden Codex and Maya Astronomy

In the late nineteenth century, Ernst Förstemann uncovered a remarkable document, long forgotten on the shelves of the Dresden Library. Of unknown origin, this screen-fold manuscript turned out to be one of only three confirmed Maya hieroglyphic books to survive the Spanish invasion in the sixteenth century. These documents, most likely produced in the Postclassic period between 1200 and 1500 CE, have since been named for the European cities of Dresden, Paris, and Madrid, in whose libraries they reside.[1]

Prior to arriving at the Dresden Library in 1740, the Dresden Codex was apparently in the hands of a private collector in Vienna who sold it to Johann Christian Götze, then the director of the royal library in Dresden. No previous record of the codex exists. Sir Eric Thompson noticed that some of the inscriptions within the Dresden represent Yucatec language. It is likely that this manuscript was among several sent by Cortés as part of the royal fifth to Emperor Charles V of Spain in 1519, following the first contact with the Yucatan (Thompson 1972:16–17; Coe 1989b; 1992:78).

All three of the existing Maya codices are constructed out of amate, a Mesoamerican paper made from the bark fibers of a *Ficus*. A coating of white lime was then applied to the pages to create a clean surface for painting. Unlike similar screen-fold books from Central Mexico, all of the Maya codices are oblong in shape, approximately twice as tall as they are long. The original

---

[1] A fourth Codex, known as the Grolier, surfaced in the 1970's from the private collection of Josué Saenz. Michael Coe included it in the Grolier exhibition, publishing it in The Maya Scribe and His World (1973). However, the authenticity of this fragmentary codex was questioned by Thompson (Coe 1992:226–29).

version of the Dresden Codex contained an unknown number of additional pages, and at some point, the remaining text broke into two fragments that were put back together incorrectly, creating some difficulties with pagination schemes. Stretched to its full length, the surviving portion of the Dresden is 3.5 meters long with 39 leaves, each measuring 9 centimeters high and 20.4 centimeters wide, nearly all of which are meticulously painted on both sides. Out of all of the surviving Maya codices, the Dresden is clearly the most carefully and artistically rendered (Thompson 1972:15). Furthermore, it appears to contain the most extensive astronomical information.

A librarian with a mathematical background, Förstemann determined that the Dresden Codex contains extensive calendrical and chronological information in the form of several interlocking cycles. In his pioneering works, Förstemann (1895; 1901; 1906) found that the ancient Maya scribes utilized a vigesimal counting system recorded with bar and dot numerals and a symbol for zero used in positional notation. Furthermore, from specific intervals mentioned in the codex, he realized that one table within the document contains astronomical information concerning the 584-day average synodic cycle of Venus, whereby Venus returns to the same position relative to the Sun from the perspective of an observer on Earth. In yet another table, Förstemann found information concerning the cycles of the moon.

From a recovered a copy of Diego de Landa's *Relación de las Cosas de Yucatán* from the mid sixteenth century, Charles Brasseur de Bourbourg (1864) revealed the Maya names of the days of the sacred almanac of 260 days, and how it is intercalated with the 365 day solar year, forming the 52-year calendar round (Coe 1992:100-102). While the 365-day year and the 260-day cycle were historically attested throughout Mesoamerica, the Long Count was limited to the Maya region, the Gulf coast and Guatemala. Förstemann was the first to describe this chronological system that counts forward from an Era base date on 4 Ajaw 8 Kumk'u, several thousand years before the Classic Period and before the majority of dates recorded in the Dresden. A summary of Maya time reckoning is provided in the third chapter.

Independently, or perhaps as a result of Förstemann's early work, Joseph Goodman (1897), using the photographs of Alfred P. Maudslay and the drawings of Annie Hunter, successfully identified the presence of the Long Count and the numerical "head variants" in the monumental inscriptions from the Classic Period. Goodman determined that numerals from 0-19 could be written using either the bar –and dot format, or the head variant portraits that personify these numbers.

It was also Goodman (1905) who first correlated the Era base date 4 Ajaw 8 Kumk'u with August 11, 3114 BCE in the Gregorian proleptic calendar (September 6 Julian), later modified by Juan Martinez Hernandez (1926) to August 12, and by Sir Eric Thompson (1927) to August 13 (September 8 Julian). These are the widely accepted (and debated) Goodman-Martinez-Thompson (GMT) correlation constants from the Julian day 584283 to 584285.

Prior to the fuller decipherment of the Maya hieroglyphic script in the mid- to late-twentieth century, interpretations of ancient Maya culture were heavily influenced by the idea that Maya texts both in the codices and in the inscriptions were exclusively concerned with calendrical positions, astronomy, and divinatory astrology. This ahistorical perspective tended to define the ancient Maya as peaceful worshippers of time ruled by benevolent astronomer-priests, and such views were promulgated by Sylvanus Morley and Eric Thompson, among others (Coe 1992:127–130).

Astronomical and calendrical calculations were an enduring preoccupation in the emerging field of Maya studies, since this had been the area in which the greatest initial progress in decipherment took place. Indeed, John Teeple (1931) determined that many of the inscriptions from the Classic period contain precise lunar information in what is called the Supplementary Series. These lunar measurements from the Classic period corroborate those found within the Dresden lunar tables. Gerardo Aldana (2006:52) suggests that, while Teeple's lunar interpretations are still considered accurate, his disregard for historical context tended to reinforce the wider belief that the inscriptions were solely astronomical.

Following Förstemann, the Dresden Codex was understood to be exclusively concerned with astronomy, and subsequent scholars suggested that the numerous other tables found within the codex refer to various planetary cycles. Robert Willson (1924) proposed that a 780-day table on pages 58-59 corresponds to the synodic period of Mars. Likewise, Herbert Spinden (1942) believed that Willson's Mars table actually recorded the cycles of Jupiter, while he proposed that the cycles of every visible planet could be found elsewhere in the Dresden. Often, these astronomical correspondences were used to justify various calendar correlations that were proposed before the GMT was widely accepted.

Thompson (1935; 1972) criticized the growing number of contradictory astronomical interpretations of intervals in the Dresden, noting that a higher percentage of astronomical phenomena were attributed to dates that he believed were incorrectly deciphered. He held that the only planetary period attested in the Dresden is that of Venus, and he concluded that the various other tables throughout the codex were for the sole purpose of calendrical divination. The few examples of astronomically derived tables of Venus and the moon are, in his view, strictly astrological in nature (Thompson 1972:3). However, in defining the purpose of the Dresden computations as exclusively divinatory or astrological, Thompson excluded the possibility that many of these calculations could just as easily incorporate highly refined astronomical observations.

Despite his disagreement with astronomical interpretations, Thompson continued to believe that both the Classic inscriptions and the Postclassic codices contain mostly religious and calendrical information. Like the widespread astronomical interpretations with which he disagreed, Thompson's views relegated Maya writing to a position that tended to uphold the Eurocentric assumption that indigenous peoples do not produce written history, thus creating the need for the Western scholar to construct histories about the native past (Wolf, 1982 in Montejo, 1999). This perspective obviously had also overlooked the existence of the K'iche' *Popol Vuh*, the *Annals of the Kaqchikels*, and the oral histories of the Maya themselves.

The work of Tatiana Proskouriakoff (1960) drastically altered the previous conceptions of the Maya as primarily concerned with astronomy and calendrical divination. Proskouriakoff clearly demonstrated that the majority of the inscriptions from the Classic period contain historical records of the births, accessions to kingship, conquests, and deaths of major dynastic rulers. As Aldana (2006:54) notes:

> This interpretive move pushed astronomy behind the scenes, for if the inscriptions really did record mainly dynastic and ritual records, then astronomy had to be relegated to subtext. Of course this did not end investigations into Maya astronomy, for scholars suggested that rulers still could have used astronomy to time historical accessions and public rituals.

The acceptance among epigraphers of the phonetic and syllabic basis of the writing system in the past thirty years has enabled significant advances in the translation of the Maya script, and this has further reinforced the historical interpretation of the inscriptions. Following a protracted objection to phoneticism among leading scholars over the past century, led in large part by Thompson, a rapid flowering of translation and interpretation emerged. The acceptance of phoneticism was facilitated by Yuri Knorosov's (1955; 1958) ground-breaking essays which made a strong case for the use of Diego de Landa's recorded "alphabet" as a phonetic syllabary. Knorosov's methodology was then refined and utilized for the subsequent decipherment of numerous syllabic and logographic glyphs, a strategy that parallels the de-coding of several ancient scripts.

Knorosov, unlike Thompson, was a student of Egyptian hieroglyphic writing, Chinese, Japanese, and Arabic. His simple proposals were based on his understanding of other non-alphabetic writing systems, and the ways in which Champollion deciphered Egyptian script. Conversely, Thompson was attached, not only to the notion that the Maya script was exclusively ideographic and concerned only with calendrical cycles and divination, but also that the Maya were unique among world civilizations, rendering comparative approaches impossible (Coe 1992: 146-147; 162-163).

Taking into consideration the accepted historical nature of the Classic Maya inscriptions, the Postclassic codices remain unique in that their contents do appear to be largely concerned with astronomical, calendrical, and ritual computations. Nevertheless, the decipherment of the script is essential for a more complete understanding of the text that accompanies the calculations contained in the codices. Several scholars have thus revisited the texts of the Dresden Codex in light of the recent advancements in decipherment. Linda Schele and Nikolai Grube (1997) and Michel Davoust (1997) provide extensive new readings of the Dresden Codex inscriptions. As Thompson suspected, some of the language of the Dresden appears to be Yucatec, in contrast to the almost exclusive Ch'olan characteristics of the Classic monumental texts. However, in many cases, the context and meaning of these various translations are unclear, and a more thorough, interdisciplinary approach is required that takes into account possible astronomical or computational references.

Further research continues to refine our understanding of the astronomical content of the Dresden, though this understanding is far from complete. Thompson (1972) and Floyd Lounsbury (1978; 1983; 1992) provide two different interpretations of the way in which the Venus table can be recycled for use as an ephemeris, to predict the synodic position of Venus. Likewise, Harvey Bricker and Victoria Bricker (1983) suggest that the lunar table could be similarly recycled for the purposes of predicting solar and lunar eclipses. In yet another article, these authors propose that a unique table in the Dresden Codex coordinates eclipse seasons with the seasonal positions of the solstices and equinoxes, and the 365-day year (V. Bricker and H. Bricker 1988).

Despite Thompson's earlier objections, the Brickers revived Willson's (1924) hypothesis concerning the 780-day table in the Dresden as a tool for tracking the synodic position of Mars (V. Bricker and H. Bricker 1986; H. Bricker and V. Bricker 1997). More recently, they have proposed that yet another table in the Dresden can be used to determine the sidereal position of Mars (V. Bricker and H. Bricker 2005). Together with Anthony Aveni, the Brickers propose that the Maya were uniquely concerned with the sidereal position of observable planets for the purposes of divination (H. Bricker et al. 2001; Aveni et al 2003). The Brickers also identified a zodiac of thirteen constellations in two pages from the Paris Codex, indicating that the Maya were interested in specific sidereal positions on the ecliptic (H. Bricker and V. Bricker 1992).

The Maya appear to have been concerned with the commensuration of various cycles. The tables in the Dresden were used to coordinate and harmonize planetary, lunar, and solar cycles with one another (Aveni 1992:87–88). Most frequently, these celestial cycles are coordinated with the 260-day Tzolk'in, and in his analysis of multiple long intervals in the Dresden, Lounsbury (1978) finds that these are most often whole multiples of the Tzolk'in, in combination with other known intervals. While this suggests a form of numerology, it is possible that the Tzolk'in was simply utilized for the purposes of calculation.

Though the exact method of recycling is debated, the Venus table could be used to calculate the long-term periodicity of Venus with extreme accuracy. One run of this table commensurates the synodic cycle of Venus with the 365-day year, the 260-day Tzolk'in, and the lunar synodic month (Aveni 1992). While the table is useful for accurate predictions over long periods of time, Aveni notes that the short-term accuracy may have been sacrificed to allow for conformity with the Tzolk'in (Aveni 2001:190):

> In spite of the rigor with which the astronomers tallied the long-term average of their observations, their table gives no evidence that they paid any attention to short-term deviations. To the modern mind this seems baffling, but evidently it did not bother the Maya. They seemed to be willing to falsify their short-term planetary observations in order to make the planetary motion fit the ritual calendar. We can think of their short-term calculations as mean motions. Their tables became true astronomical ephemeredes only when considered over long intervals.

Aldana (2002:S46; 2006b) challenges Aveni's assumption that this inaccuracy represents a falsification, and he suggests that the variation of the Tzolk'in day on which Venus would first appear could have been used as a stochastically bounded oracle with a predictable method and an unpredictable outcome. The Tzolk'in is used for the purposes of divination throughout Mesoamerica, and Aldana proposes that Maya astronomical science functioned within this framework as an "oracular science".

In echoing some of Thompson's concerns about the astronomical interpretations of Maya records, Aldana (2006:61–62) outlines several problems within the methodology of astronomical research that may lead to false positives. First, many of these studies rely upon the GMT correlation constants, and he asserts that no correlation has yet been proven. Elsewhere, Aldana (2001) provides evidence that he believes casts doubt on these currently accepted correlation constants. If a correlation is incorrect, the numerous celestial events attributed to specific dates would be erroneous. Secondly, in terms of the Classic inscriptions, random dates that may have nothing to do with astronomical observations will often reveal unintended astronomical patterns, particularly if enough such dates are considered. As a result, different interpretations of these dates will often give contradictory results. Lastly, astronomical interpretations often ignore historical context, and they tend to pool unrelated sources of data that may be widely separated by space and time.

Following Lounsbury's methodology, Aldana (2006) proposes that the most reliable astronomical data can be determined from the long intervals that separate two related dates within Maya texts. The canonical cycles used as multiples within these intervals reveal internally consistent intentions that suggest both numerological and astronomical theory. When they are examined together with their associated text, the cycles implied within these intervals may reveal something about their intended meaning. However, there is a general problem with this methodology, in that the intervals chosen do not always appear with textual or iconographic references to astronomical bodies, and the intended meaning of these cycles is often uncertain. Where possible, I would add that an analysis of these intervals and their associated dates and texts with the two widely accepted GMT correlation constants may help to support or refute the validity of these theories. Furthermore, it is possible to compare the astronomical accuracy of various stated intervals with current measurements, particularly where two or more astronomical cycles are implicated.

Yet another problem arises when we attempt to interpret the meaning of astronomical references in the codices. The codices are largely the end product of astronomical and calendrical computations, but we are given little instruction regarding how the Maya astronomers may have used the various tables and dates provided. We are faced with the task of reconstructing knowledge that has been lost. Incomplete understandings of these tables cannot effectively be used to disprove certain calendar correlations simply because they do not conform to our expectations of what we assume to be their intended meanings. However, a more thorough understanding should produce internally consistent results that can be compared to specific correlations.

There are multiple levels of interpretation involved in the discipline of Maya archaeoastronomy, which can be broadly generalized into two categories. First, we can interpret Maya astronomy in terms of raw astronomical data. Because celestial cycles are regular and measurable, it is possible to demonstrate that the Maya were recording and predicting known astronomical events, and it is possible to compare these results with current measurements. Particularly long-range calculations, such as those discussed by Lounsbury and Aldana, can be used to determine the precise values used in Maya astronomical theory, particularly if they approximate current values and if references to astronomical bodies occur in the associated texts. Likewise, it may be possible to determine the errors between the Maya values and current measurements, and how these measurements may have been further refined over time.

Secondly, we can attempt to interpret the meaning of astronomical events within the frameworks of Maya culture. This is a much more challenging and open-ended endeavor, and it is more difficult to substantiate. Nevertheless, both of these levels of interpretation are necessarily interwoven, and the discipline of Maya archaeoastronomy is by nature interdisciplinary, requiring an understanding of observational astronomy, mythology, ethnohistory, archaeology, art history, epigraphy, and linguistics.

Aveni (2001:7) notes that previous research in archaeoastronomy has often dealt with the first mentioned level of interpretation, responding to questions of "how" and what astronomical observations were conducted. This kind of research often focused on "the disclosure of 'amazing facts' about mysterious Indians," that tended to relegate the discipline of archaeoastronomy to the fringes of academia. Aveni believes that current research in archaeoastronomy has developed a more critical, interdisciplinary perspective, and it is now equally concerned with "why" astronomical observations were considered important.

But, we have yet to exhaust all inquiries into the mechanics of Maya astronomical calculations, and we still do not know the extent of their astronomical knowledge. Fortunately, the answers to some of these questions are more easily retrievable from the surviving codical records than are the answers to questions about meaning. The long-term accuracy of Maya astronomical predictions in the Dresden suggests an advanced form of theoretical astronomy. If Maya astronomy was primarily concerned with divination, what oracular purpose might such predictions possibly serve? Aveni (1992:5) remarks:

> When we discover that these books contain calculations that reach into the millions, dates protracted backward toward a mythical creation era that happened 3 millennia before they were written down, and when our studies uncover Mayan predictions of the first pre-dawn appearance of

the planet Venus or a total eclipse, each accurate to the day a century in advance, all without benefit of any astronomical technology and all directed towards metaphysical ends, our fascination becomes awe.

The Persistence of Colonial Interpretations

The exploration of the Maya past is problematic within the context of conceptions of native knowledge and the discourse of decolonization (Tuhiwai-Smith 2001). Postmodern critiques have challenged the authority of the Western scientific academy, exposing its underlying political agenda to maintain current colonialist power structures, and to reproduce forms of knowledge which they alone judge to be admissible. While encompassing multiple and contesting perspectives within a continually evolving Western academia, the colonialist mentality has privileged Western interpretations of the Maya past, while the interpretations and voices of the Maya themselves often remain invisible, othered, and without access to power or legitimacy.

Many archaeologists and interpreters of the Maya past, described as Mayanists (Coe 1992; Montejo 2001), continue to operate under the auspices of a purely objective science. However, Jakaltek scholar Victor Montejo traces the history of Mayanist interpretation to its colonial roots in the writings of Diego de Landa. Montejo asserts that Landa is upheld as the ethnographic authority on Maya culture at the time of contact, and, through Sylvanus Morley, Landa becomes the unquestioned singular source for the Western construction of the Maya (Montejo, 1993:13-14). A critical perspective on Landa is often absent in Mayanist discourse, and subsequent Mayanists formulate their theories based on the a priori recordings, and judgments, of this problematic figure. Often, as a result of poor scholarship, unsubstantiated truths are fabricated and subsequently published and then cited as fact.

We must recognize that Landa's interpretations are severely biased, as he is single-handedly responsible for the wholesale destruction of numerous Maya codices in the Yucatan. His perspective clearly limited his ability to recognize and comprehend the sophistication of Maya science and astronomy, imbedded as he was in the reactionary attitude of the church towards scientific endeavors in sixteenth century Europe:

> These people also used certain glyphs or letters in which they wrote down their ancient history and sciences in their books; and by means of these letters and figures and by certain marks contained in them, they could read about their affairs and taught others to read about them too. We found a great number of these books in Indian characters and because they contained nothing but superstition and the Devil's falsehoods we burned them all; and this they felt most bitterly and it caused them great grief (De Landa in Pagden 1975:124).

Ironically, Landa's own records have been critical for the reconstruction of Maya writing and knowledge. At the same time, his destruction of Maya intellectual history and his biased interpretations have severely limited our current understanding. We will never know the full extent of the science, history, culture, and human lives that were destroyed at the hands of the European invaders. Indeed, the colonial mindset of those foreigners who first described the

Maya continues to shape the way we interpret the few fragmentary records that survived this Mesoamerican holocaust.

Montejo's reflections succinctly portray the power of the West to determine and create the truth of history, despite conflicting evidence to the contrary. The most dangerous political outcome of these discovered truths about the Maya past is their sensationalizing effects in the popular imagination. Montejo explains how primitivist tropes about Maya blood sacrifices were used to justify the Guatemalan army's massacre of entire Maya villages in the Guatemalan civil war. While the Western media ignored these massacres, they chose instead to focus on the constructed truths of a bloody Maya past emerging from the interpretation of the archaeological record (Montejo 1993:14-15). We can see a perpetuation of these distortions in Mel Gibson's film *Apocalypto* (2006). The lack of ethics surrounding Maya studies can thus feed unconscious public notions of the Maya as primitive or as savages, reinforcing the same exaggerated justification for the conquest that was fabricated by the Spanish.

It appears as though Mayanist scholarship can be shaped by the psychological needs of the researcher and the larger culture to project problematic issues or unconscious values onto the silent canvas of ancient Maya civilization. The Maya, past and present, like all indigenous peoples, are often vilified as barbaric savages and simultaneously idealized as noble savages. As we have seen, the Maya were long considered to be peaceful worshippers of time, while a more brutal perspective has emerged in light of historical interpretations. However, New Age interpretations and idealizations of Maya timekeeping persist alongside conceptions of the savage Maya, and the products of scholarly work continue to filter into the popular imagination in predictable ways that serve as a mirror in which the colonial mind seeks to define itself. In this polarizing dynamic, there is rarely any serious consideration of the Maya as real people with a complex and multi-dimensional history.

When comparing Maya astronomical science to the history of astronomy in Europe, there may be an additional resistance to the possibility that Maya science may have been far more advanced than we think. As an indigenous science, Maya astronomy does not fall within the Western canon as having contributed to the history of Western thought. To assert that some Maya measurements may have been more accurate than those of their European counterparts at the time threatens the belief in the superiority of European science. It thereby challenges the colonial assumption that Maya knowledge should naturally be eradicated and replaced by European science. Therefore, the recovery of Maya astronomical knowledge is also a political issue within the discipline of Native American Studies.

Certainly, the discipline of archaeoastronomy has suffered from exaggerated "crackpot" theories about the abilities of Maya astronomers, and it is important to challenge such unsubstantiated claims (Aveni 2001:7). However, the characterization of Maya astronomy as exclusively astrological contributes to the dynamic of devaluing the achievements of the Maya, while upholding the superiority of the West.

Astronomy and Astrology

While several scholars have since challenged his objections to both astronomical and phonetic interpretations of Maya codices, Thompson's thesis concerning their essentially astrological and divinatory purposes is widely accepted. Further support for this thesis can be found in post-contact accounts of those who directly witnessed the contexts in which the codices were used. Diego de Landa described the function of the high priest, the *Achkinmai* or the *Ahaucanma*i (Pagden 1975: 42–43):

> The sciences which they taught were the reckoning of the years, month, and days, and of their feasts and ceremonies, the administration of their sacraments, and of the fateful days and seasons; their manner of divination, and their prophecies, incidents, and cures for sickness, as well as their antiquities and method of reading and writing where by means of their letters and characters they wrote in glyphs which represented the meaning of the writings.

Aveni (1992:4) makes a categorical distinction between the purposes of contemporary observational science and the Maya use of mathematical and astronomical calculations:

> Unlike modern astronomical and calendrical science, the ends of such date reaching were purely astrological and, as Landa implies, confined to a very specialized literate class.

In one respect, Aveni, like Thompson before him, attempts to steer clear of an ethnocentric perspective that may too closely equate a contemporary astronomical understanding with that of the Maya. Elsewhere, Aveni (2001:4) writes, “Modern scientists have been accused of fashioning our ancient ancestors after their own image." The reconstruction of ancient astronomy is therefore problematic in that the astronomical information available to the current researcher makes it easy to speculate regarding the intentions and abilities of ancient astronomers.

However, I contend that it is equally ethnocentric and problematic to assume that, because Maya astronomy may have been primarily astrological in its intent, it was necessarily incapable of highly refined calculations based on recorded observations over long periods of time. Indeed, the distinction between astronomy as science and astrology as pre-scientific appears to be a recent cultural and historical artifact from Europe. This distinction is therefore a construct that subscribes to a linear view of progress toward an inevitable scientific rationality. In his discussion of the development of science in Europe, Stanley Jeyaraja Tambiah (1990:24) writes:

> The Middle Ages and the Renaissance we now know were complex times when the cosmologies, belief systems and intellectual aspirations of scholars simultaneously traversed the domains of astronomy and astrology, chemistry and alchemy, medicine and curative incantations, mathematics and number mysticism.

According to Tambiah, the sharp division that we now perceive between the domains of astronomy and astrology appears only in seventeenth century Protestant thought. At this time, a distinction arose between "magic" defined as "false manipulations of the supernatural and occult powers," and "religion" as a "true" and "rational" system of belief that led to contemporary science. Using this framework, post-Enlightenment revisionist history disregards the astrological inclinations of such pillars of science as Ptolemy, Copernicus, Tycho Brahe, Johannes Kepler, and Isaac Newton (Tambiah 1990:28–31).

Tambiah (1990:54–64) follows Ludwig Wittgenstein's[2] rejection of the influential but widely discredited views of Sir James Frazer, who unquestioningly perpetuates a hierarchical distinction between inferior magic and superior science. In his multi-volume treatise *The Golden Bough* (1911), Frazer asserted that "primitive" beliefs in magic represent false and erroneous causal action. Seated within this evolutionary and ethnocentric paradigm, Frazer believed that science would ultimately displace irrational and false beliefs in magic and religion.

Wittgenstein counters Frazer by suggesting that ritual action and magic are not false causal action, but "expressive action, where the representation itself *is* the fulfillment" (Tambiah 1990:56–58). Wittgenstien cites Frazer's examples of African rituals to bring rain, noting that they are not performed during the dry season as a means to absolutely control the weather at any time. Rather, they are coordinated with the seasonal arrival of the rainy season based on an expression of participation with the cycles of nature. Tambiah cites Wittgenstein (ibid:59):

> And magic always depends on the idea of symbolism and of language. The representation of a wish is, eo ipso, the representation of its fulfillment. Magic, however, brings a wish to life; it manifests a wish. Baptism as washing.—An error only arises when magic is interpreted

[2] Tambiah cites a more recent translation of Wittgenstein's 1930 remarks in A.C. Miles and Rush Rhees (1971:22–48).

> scientifically. When the adoption of a child takes place in such a way that the mother pulls it through her clothes, then it is crazy to believe that there is some error here and that she believes she has given birth to the child.

Tambiah (ibid:59) regards Wittgenstein's argument as akin to a structuralist framework in which the ability to symbolize and draw metaphorical relationships between multiple phenomena is an innate capacity of human imagination and perception. These relationships and representations can take on varied forms in different cultures, and they each invoke entire cosmologies and mythological systems. But there is no need to evaluate these systems in terms of an evolutionary hierarchy of thought, in that the capacity to symbolize is equally present in both the cultures that Frazer defines as primitive and civilized.

We may also call into question Wittgenstein's definition of magic as symbolic representation, which may over-rationalize what may be described in terms of psychological and spiritual experiences. Also, the categorical distinction between magic as false science on one hand, and rational science on the other, forces us to uncomfortably define astrology as magic, and as a deficient form of science. However, within a psychological framework, we could argue that astrology, as we understand it, always exists within systems of power, and it operates to provide persons with the psychological backing they require to carry out their actions. Here, accurate prediction of astronomical events is not the primary purpose. Nevertheless, science itself also always exists within systems of power, and may provide similar psychological reinforcement. Therefore, the purpose of astronomy as a tool for accurate prediction may have been inseparable in some cultural contexts from the astrological purposes of divination and deriving psychological and spiritual power.

Elements of Frazer's argument appear in Karl Popper's (1959:37) rejection of astrology on the grounds that its vague predictions could be used to explain any result that may otherwise contradict a more specific prediction. Tambiah (1990:30) contrasts Popper's ahistorical approach with that of Thomas Kuhn (1970:8–9), who asserts that historical records of astrological predictions reveal that, in fact, they often failed to accurately predict events. The real distinction between astrology and astronomy, Kuhn maintains, is that the astrological tradition never attempted to revise its techniques to formulate and solve astronomical puzzles when predictions failed. However, Tambiah questions whether any real distinction exists between the historical development of astronomy and astrology. The ability to solve mathematical and astronomical problems was thus an inherent characteristic of this singular development. Tambiah writes (ibid:28–29):

> It is clear from the aspirations and activities of personages such as Ficino, Bruno and Dee that the Hermetic philosophy and magic of the Renaissance turned to number symbolism and mathematics as the key to operations, and the subsequent trajectory of both theoretical and applied sciences have vindicated mathematics as one of the master keys by which the forces of nature can be manipulated and harnessed…Similarly playing with number symbolism and systems of universal harmony prepared for mathematics proper.

From our limited knowledge of Maya astronomy, it is apparent that the Maya astronomers were fully capable of solving significant astronomical and mathematical puzzles within a framework that is widely regarded as astrological. Aveni's comments here further contradict Kuhn's distinction between astrology and astronomy (Aveni 1992:17):

> When we penetrate the cosmological meaning of the codices, we learn that here were people quite like ourselves who believed in a universe that could be conceived and described in mathematical terms—and that they could invent certain formal mechanisms capable of generating predictions of future celestial events that could be observed, contemplated, and their results used to improve and adjust their instrument to make future predictions even more precise. Though the ends served by such predictions were founded upon religious and astrological beliefs, certain elements of the whole process begin to sound very much like what we read in the history of science in Western culture. But then, if we are willing to look back a few centuries, we discover that our own inquiry into nature possessed a similar foundation.

I would further caution that a comparison of Maya astronomy with Western astronomy from the Renaissance period should not assume that either one is a deficient ancestral form of a pure, objective science. In either case, we cannot assume that the distinction between astronomy and astrology was inevitable. In our effort to reconstruct past knowledge, we need to maintain a self-critical awareness of our own cultural system and the value judgments we may unconsciously uphold.

We need to re-examine the assumption that astrology represents bad science or a literal misreading of reality. Instead of subscribing to Frazer's positivistic notions of causality, Tambiah (1990:85–86) directs us to the ideas Lucien Lévy-Bruhl (1918; 1966), who proposes that non-Western forms of thought include the idea of participation in the cosmos, and a sense of fundamental identity and mystical unity with a universe that is very much alive. Ritual action therefore takes on the role of organizing human life in accordance with the cosmos, rather than simply attempting to control it through causal action. This participatory mentality does not exclude the simultaneous existence of ritual used to effect causal action, and we can recognize that both mentalities appear in Western and non-Western thought.

Tambiah suggests that, within all cultures, alongside the previous causal mentality exists this complementary "ordering of reality" in which the connection between cause and effect is immediate. This participatory sense of reality is acknowledged in non-Western societies as a profound sense of physical and mystical union, and a participation in "the life of the world," and while it is present in the West, it is eclipsed by, and separated from the rational and scientific (Tambiah 1990: 83–93). Therefore, using the constructed categories of "magic" and "science" to attempt to interpret non-Western cultural systems will invariably reproduce Western conceptions of reality.

We find Lévy-Bruhl's participatory ideas reflected in contemporary discussions of Native American spirituality within the discipline of Native American Studies. Working within the framework of participation, Robin

Ridington (2000) underscores the importance of approaching Native spirituality from the point of view of a progressive conversation, rather than from the stance of a monologue of authority. Indeed, this approach is one which, Ridington asserts, is prevalent among Native peoples themselves within their own traditions:

> Native American Spirituality manifests itself as an ordered, sometimes ecstatic, always respectful conversation with the myriad persons of a sentient universe (Ridington 2000:118)

I propose that the concept of participation and dialogue is of considerable value in any attempt to interpret the meaning of Maya astronomy. Our engagement with the fragmentary records within the Dresden Codex can thus also be seen as an open-ended conversation in which we can compare both the similarities and differences in our perspectives on astronomy, while not seeking to define Maya interpretations with our own limited perspectives. While it is clear that the specialized Maya astronomers viewed the patterns of celestial time as intimately interwoven with the patterns of human lives, we recognize that the interpretations of astronomy likely differed both among individuals within Maya cultures, and across time.

The notion of a conversation with the past, while perhaps somewhat romantic, is particularly useful in the context of discussing the Serpent Series in the Dresden Codex, which contains astronomical records covering thousands of years. The core of this dissertation project is based on a new reading of the Serpent Series as a highly accurate record of the precession of the equinoxes.

Given that the phenomenon of the precession of the equinoxes is the slowest observable astronomical cycle, to calculate it requires multiple generations of accurate record keeping. Therefore, the authors of the Serpent Series themselves were in an ongoing conversation with their own predecessors, who were, in turn, relying on the records of those who came before them. This intellectual inheritance was largely unbroken prior to the arrival of the Spanish, after which Maya literacy and astronomical observations were severely disrupted. However, we are now in a position to engage in this ongoing conversation across time, and reconstruct the sophisticated astronomical knowledge that Maya intellectuals recorded in one of their three surviving manuscripts.

Chapter II: Precession

In this chapter, we will explore the phenomenon of the precession of the equinoxes, its discovery in the West, and previous research suggesting that the Maya were aware of this phenomenon. It will be important to understand the dynamics of precession, as I will hereafter refer to it, in order to comprehend the calculations in the Serpent Series as outlined in the subsequent chapters. Here, I will critically examine not only the history of the discovery of precession in the West, but also the history of the claims proposing an early Babylonian discovery of precession, and the various proposals concerning the relationship between precession and mythological conceptions of multiple world-ages.

The Nature of Precession

The precession of the equinoxes appears as the slow regression of the position of the equinox sun against the background of stars over time. Consequently, the sidereal position of the sun at every point in the tropical (seasonal) year appears to shift backward along the ecliptic by approximately one day in seventy-one years, moving backward throughout the entire zodiac and returning to the same sidereal position and the same position in the tropical year approximately every 26,000 years (**Figure 2.1**). This phenomenon is the result of the slow wobbling of the earth on its axis (**Figure 2.2**). Currently, the north polar axis currently points to Polaris, the North Star. However, this position is not fixed. From the perspective of observers on earth, the axis rotates in a counter-clockwise arc that includes the star Vega, which was a north star some 12,000 years ago, and will be once again some14,000 years from now.

Because the cycle of precession is so slow, it is barely noticeable within a single human lifetime. To calculate the rate of precession therefore requires accurate written records over hundreds of years for both the tropical year, as well as the sidereal year. The **sidereal year** is defined as the time it takes for the earth to return to the same position in it's orbit relative to the fixed stars, such that the sun will appear to return to the same position among the stars. This is slightly longer than the mean tropical year, a result of the slow advancement of the sidereal year over the tropical year with precession. The current value of the sidereal year is approximately 365.256363 days.[1]

The bright light of the sun obscures the stars so that the sidereal position of the sun is not directly observable, except during the extremely rare occurrence of a total solar eclipse. Therefore, the sidereal year and the cycle of precession are only observable by indirect means, making accurate calculations even more challenging. One method is to observe stars appearing on the horizon before or after sunset, and this is often originally used to measure the tropical year. The day in the tropical year on which a star first appears begins to shift over long periods of time. However, because the axis of the earth is wobbling, the longitude of the stars also slowly changes, so that the azimuth of any given star, defined as its position on the horizon, will also

[1] United States Government Printing Office. The Astronomical Almanac for the Year 2000. Washington, DC: Navy Dept., Naval Observatory, Nautical Almanac Office, p. C1, 2000.

shift. This shift may also be measured by comparing it with a fixed point on the horizon such as a hill or a gnomon.

Lastly, the sidereal position of the full moon during a more commonly observable total lunar eclipse will always be directly opposite the sun in the sky, and this is measurable at the horizon. Such measurements can predict the occurrence of eclipses at one of the two nodes where the moon's orbit crosses the apparent path of the sun on the ecliptic. The line from the observer to the setting sun will be the same line used in reverse from the observer to the position of the rising moon on the evening of a lunar eclipse. If the date of a lunar eclipse is then coordinated with a position in the tropical year, an eclipse on the same day far in the future will show a westward shift in sidereal position.

Even by contemporary calculations, the exact rate of precession 15,000 or 30,000 years in the past or future becomes highly theoretical. The current rate accepted by the International Astronomical Union is one complete cycle of precession in 25,772 years, which translates to one day of precession in the same number of days. As the length of the solar year decreases, the length of the precessional cycle is known to be increasing, so that values of the length of the cycle in the past were shorter, though astronomers estimate an average periodicity of 25,700 years over several million years (Hilton 2006; Berger 1976).

A Brief History of Precession

A brief review of the historical record concerning observations of precession is required for a comparison with the possible achievements of the Maya in this area. According to Ptolemy's *Almagest*, the Greek astronomer Hipparchus is said to have discovered the phenomenon of precession in the second century BCE (Toomer 1978). It is possible that precession was historically noticed in several times and places, but it is very difficult to prove this in the absence of explicit written records.

Hipparchus observed the sidereal position of lunar eclipses opposite the position of the sun on the vernal equinox, and he compared his findings with those of Temocharis, some 150 years earlier. He thus first concluded that the stars near the ecliptic in the zodiac were slowly moving, "not less than 1/100° in a year," or 1° in a century. While Hipparchus was apparently cautious about asserting a definite value for precessional drift, given the lack of sufficient data at the time, Ptolemy reaffirmed this initial hypothesis some 285 years later (Evans 1998:259–261).

At the minimum rate of 1° per century, a complete cycle of precession through the entire ecliptic would occur in approximately 36,000 years. While this value is over 10,000 years greater than our current measurement, the apparent error derives mostly from Hipparchus' estimation of the tropical year as 365 days + 1/4 day – 1/300 day, equivalent to 365.2466666 days (ibid.:208–209; Toomer 1978:218). This value, similarly adopted by Ptolemy, produces an error of one day in approximately 224 years when compared with the current value of the tropical year. However, the sidereal year suggested by Hipparchus' calculations can be determined by the following simple equation, where **n** = the time difference between the tropical year and the sidereal year. Hipparchus suggested that it takes 36,000 **n** to make up one complete year, covering 365.2466667 days:

$$\mathbf{36{,}0000n = 365.2466667\ days}$$

$$\mathbf{n = \frac{\underline{365.2466666\ days}}{36{,}000} = 0.010145741\ days}$$

Hipparchus' sidereal year = 365.2466667 days + n = 365.2568124 days

Therefore, Hipparchus' calculations produce a sidereal year much closer to the current value of 365.256363 days, with an error of only one day in 2,226 years. When used together with the current value of the mean tropical year, Hipparchus' sidereal year would produce a significantly reduced precessional cycle of 24,979 years, remarkably close to the current measurement of 25,772 years. As we see below, the Maya measurement of the sidereal year was even more accurate.

Until the Arab astronomers of the ninth century CE, there is little mention of precession after Ptolemy:

> In fact, precession appears never to have become very widely known in antiquity. It is never alluded to by Geminius, Cleomedes, Theon of Smyrna, Minilius, Pliny, Censorinus, Achilles, Chalcidius, Macrobius, or Martianus Capella…The only ancient writers who mention precession besides Ptolemy are Proclus, who denies its existence, and

> Theon of Alexandria, who, in his redaction of Ptolemy's Handy Tables accepts Ptolemy's value of 1° in 100 years (Evans 1998:262).

Comparing their own calculations with those taken at face value from Ptolemy, Arab astronomers in the ninth century concluded that the rate of precession had apparently slowed down. As a result, the alternative theory of trepidation arose to explain these findings. Often attributed to Thabit ibn Qurra, the theory of trepidation, in which the sidereal positions of the equinoxes were seen to oscillate back and forth over 7,000 years within an 8° arc, persisted in medieval Europe until the time of Tycho Brahe in the late Sixteenth Century. Even Copernicus, despite his heliocentric revolution, continued to believe in the existence of trepidation (Evans 1998:274–83). The Europeans did not take into account the ongoing precessional drift, instead they chose to follow the standardized Ptolmaic zodiac that had been permanently fixed to the seasons and to the constellations in which the sun appeared in the first century CE. Thus the present configuration of the European astrological 'sun signs' are no longer representative of the sidereal position of the sun. After 2,000 years, the sun has now drifted backward by one zodiacal constellation.

In the Arab world, the theory of trepidation was not universally accepted. A contemporary of Thabit ibn Qurra, Arab astronomer Al-Battani[2] confirmed a more accurate calculation of the tropical year at 365 days, 5

---

[2] His full name reads: Abu Abdallah Mohammad ibn Jabir ibn Sinan al-Raqqi al-Harrani al-Sabi al-Battani. In Latin: Albatenius, Albategni or Albategnius (Hartner 1970:507).

hours, 46 minutes and 28 seconds, equivalent to 365.2405556 days. This would produce an error of one day in 612 years when compared with the current mean tropical year, far more accurate than any calculations of his predecessors. Questioning trepidation, Al-Battani proposed a precessional drift at a uniform rate of about 1° in 66 years, giving one cycle of precession in 23,760 years (Evans 1998:275; Hartner 1970:511). Combining this value with his results for the tropical year, he calculated a sidereal year of 365.2559276 days, very close to the current value of 365.256363 days, producing an error of only one day in 2,297 years. This is very close to the error found in Hipparchus' calculations, but here Al-Battani's sidereal year is slightly less than the current value, whereas the value obtained by Hipparchus is slightly longer.

Because of the greater accuracy of his calculation of the tropical year, combined with the accuracy of his sidereal year, Al-Battani's estimation of the cycle of precession at 23,760 years is much closer to the actual value than that of Hipparchus. Whereas Hipparchus and Ptolemy grossly overestimated the length of the cycle at 36,000 years, Al-Battani's tropical year produces a closer under-estimation of the cycle. If we use the current value of the mean tropical year, Al-Battani's sidereal year would produce a correction of one complete cycle of precession in 26,588 years, even closer to the current value of 25,772 years.

While the theory of trepidation persisted in Europe through the sixteenth century, Tycho Brahe finally calculated that precession proceeds at the uniform rate of 51″ per year, or one degree in about 71.5 years (Evans

1998:282). This produces one full cycle of precession in 25,781 years, very close to the current accepted value. Using Brahe's extensive data in 1627, Johannes Kepler then confirmed a calculation of the tropical year of 365 days 5hours 48 minutes and 45 seconds (Meeus and Savoie 1992:41). In decimal notation, this is equivalent to 365.2421875 days, only one second less than the current accepted value. With Brahe's calculation of the rate of precession, Kepler's calculation of the tropical year combines to give a sidereal year of 365.2563542 days, very close to the current accepted value of 365.256363 days.

Astro-Mythology and pan-Babylonianism

Gary Thompson (2007) provides a thorough critique of the development of pan-Babylonianism and theories supporting an early development of Babylonian astronomy. In the late nineteenth century, following the decipherment of cuneiform astronomical and mythological texts, several German Assyriologists proposed that the ancient Babylonians first discovered precession, and that this knowledge diffused into later civilizations. Ernst Siecke (1892) popularized astronomical interpretations of folklore and myth, and Eduard Stucken, in *Astralmythen* (1907), broadly asserted that all biblical and world-mythological concepts derive from astronomical myths that originally diffused from ancient Babylon. Assyriologist Hugo Winckler (1903) continued this line of thinking, proposing that the Babylonians had fully developed the zodiac as early as 4,000 BCE, when the sidereal position of the vernal equinox was found in

Gemini. In so doing, he believed he had found a fundamental key to understanding world religion.

Following Winckler, Alfred Jeremias (1903) reiterated the theory that the concept of world-ages developed from early Babylonian observations of the precession of the equinoxes through the zodiac. Gary Thompson (2006) points out that this idea was an amalgamation of universalist theories of religion put forward by Charles DuPuis in 1794, and the late nineteenth century Theospohical ideas of Helena Blavatsky. Nicholas Campion (1999; 2000) thus attributes to Blavatsky the invention of the popular millenarian astrological idea of the Age of Aquarius, defined by the precessional movement of the vernal equinox from Pisces into Aquarius. Blavatsky apparently derived some of her ideas from Hesiod's treatise on the ages of mankind, combined with her interpretation of the Hindu world-ages, known as the Yugas, and a nineteenth century perspective rooted in concepts of racial evolutionism.

The pan-Babylonian approach of Stucken, Winckler and Jeremias, among others, received considerable criticism, particularly from scholars who refuted their claims concerning a significant Babylonian influence within Judeo-Christian tradition. In addition, some supporters of pan-Babylonianism, such as Friedrich Delitzsch, were increasingly anti-Semitic (Gressmann 1906; Thompson 2007). But it was the work of Franz Kugler (1909; 1910) that ultimately dismissed the claims that the Babylonians had a sufficiently developed astronomical understanding prior to 700 BCE. Kugler was a specialist in mathematical archaeoastronomy, and his readings of cuneiform texts provide the basis for the current understanding of Babylonian astronomy.

Nevertheless, while pan-Babylonianism largely fell out of favor soon after Kugler published his findings, Paul Schnabel (1923; 1927) later proposed that Chaldean astronomer Kidinnu discovered precession in the fourth century BCE. However, Otto von Neugebauer (1950) challenged Schnabel's conclusions based on extensive astronomical evidence from cuneiform texts.

Proponents of the astro-mythological approach, such as Leo Frobenius (1904), continued to interpret mythology through the lens of astronomy. His student, Hertha von Dechend, with Giorgio de Santillana (1969), compiled extensive information on comparative mythology in *Hamlet's Mill*. They assert that much of world mythology since the Neolithic derives from the symbolism associated with precession. The authors maintain the pan-Babylonian emphasis on a singular diffusion of these ideas from Mesopotamia. While these parallelisms received much popular attention, Gary Thompson remarks that the lack of definitive proof, the use of spurious sources, and a problematic methodological approach relegated this kind of work to the margins of academia as pseudoscience (Leach 1970; Payne-Gaposchkin 1973; Thompson 2007b). However, subsequent authors have continued to explore some of the ideas from *Hamlet's Mill* within specific historical contexts that do not rely on pan-Babylonian diffusionism.

David Ulansey (1989) provides a detailed argument that the discovery of precession as a movement of the entire celestial sphere led to the development of the syncretic Mithraic tradition in pre-Christian Rome.

Ulansey proposes that Mithraic iconography depicts recognizable zodiacal elements surrounding an adopted Persian deity named Mithras. In what is known as the Tuaroctony, a formulaic image from the subterranean cave-altars known as Mithraeum, Mithras is depicted slaying a bull, which Ulansey believes represents the constellation Taurus. In ancient Persia and Mesopotamia, the sidereal position of the vernal equinox was found in Taurus, but it had since moved into the position of Aries by the second century BCE. Thus, the slaying of the bull may have signified the end of a previous world-age at the hands of Mithras, whose characteristic image is conflated with the constellation Perseus above Taurus.

Mithraism was a secretive tradition based on specialized knowledge that was shared only with initiated members, and Ulansey contends that an awareness of the almost imperceptible movement of the precession of the vernal equinox was the primary inspiration for the Mithraic mysteries. While Hipparchus' discovery of precession seems not to have been widely recognized in Europe, it is possible that this knowledge persisted in the form of guarded mythological references until the advent of Christianity, which apparently both borrowed from and completely displaced Mithraism in ancient Rome by the fourth-century CE. Like that of the later Catholic church, the earlier cosmology of Aristotle held that the universe was unchanging, and the stars were permanently fixed in the progression of the year. Ulansey proposes that the scientific observation of the movement of the entire sphere of stars may have led to new mythological concepts of previous world-ages, vast expanses of time, and a deity whose power to move the heavens exceeded all of those who came before him.

Ulansey's argument is not without criticism, and N.M. Swerdlow (1991) challenges Ulansey's proposal that the torchbearers in the Tauroctony represent the equinoxes, and Swerdlow believes that the precessional associations are questionable. Likewise, Swerdlow contends that the Mithraic tradition was not one based on the exclusive astronomical knowledge of an initiated elite, but a populist religion for common Roman soldiers. Similarly, Roger Beck (2006) critiques Ulansey's approach, among others, as a modern construct of an ancient intellectual tradition in the hands of an imagined, initiated elite. Beck insists that there is too much emphasis on reconstructing doctrine over a more complete investigation of Mithraic membership. Despite this criticism, Ulansey's proposal remains a compelling possibility.

Precession in Mesoamerica?

A cosmology of multiple world-ages is a shared characteristic of Mesoamerican traditions. Both Aztec and Maya traditions recount four or five previous ages, and such conceptions are also found outside Mesoamerica among the Pueblo, Hopi and Navajo peoples, among others. Several authors have thus proposed that the Aztec and Maya systems of reckoning time may have derived from a specific, longstanding knowledge of the cycle of precession.

In his discussion of the dynamics of precession, Anthony Aveni (2000:100) comments:

> We wonder whether Mesoamerican astronomers might have detected this motion. Though we have no solid evidence on this question, we are at least aware that the Maya utilized a zodiac consisting of a band of constellations running along the ecliptic.

That the Maya zodiac found in the Paris codex represents constellations along the ecliptic is still a matter of debate, and Bruce Love (1994:89–102) contends that some of the constellations, such as the possible turtle in Orion, are not on the ecliptic. Gerardo Aldana (2001) alternately maintains that the Paris zodiac is a post-contact document influenced by European concepts of the zodiac. Gregory Severin (1981) originally suggested that the Paris zodiac represents the precessional movement of the vernal equinox through consecutive zodiacal constellations. However, Michael Closs (1983) rejected Severin's hypothesis, and Victoria and Harvey Bricker (1992) have since demonstrated that the ordering of the constellations is not consecutive. Instead, some of the adjacent images of the 'zodiac' are separated by intervals of 168 days, equivalent to six sidereal months, close to the eclipse half-year. Furthermore, the glyph that Severin believed to represent the vernal equinox is now widely recognized as a representation of a solar eclipse (T326).

Based on the Aztec concept of five 'Suns', the world-ages found in the *Leyenda de Los Soles*, the *Historia de los Mexicanos por sus Pinturas* and recorded on the Calendar Stone, Gordon Brotherson (1992:298–99) suggests that the

Aztec were aware of precession. He asserts that the current era consists of 5,200 years, with all five ages combining to account for the 26,000-year cycle of precession. From the *Codex Ríos*, the second and third world-ages appear with 4,000 years each, while the fourth world consists of 4,800 years, and the current era is 5,200 years. The length of the first era is depicted by a somewhat less defined image of a fruiting tree, from which sixteen feathered droplets fall. Brotherson contends that these droplets represent developing forms of the symbol for the 400-year *tzontli* depicted in each subsequent image of the later world-ages. However, there are less than twenty depicted in this image, and a period of 8,000 years (20x400 years) would be needed to complete a 26,000 year cycle when added to the total from the other four ages. For this reason, Brotherson imagines that some of the droplets are still forming, while others have been eaten by the people below. He concludes that this imagery was intentional, and that the Aztec were aware that the precessional cycle is somewhat less than 26,000 years, but this kind of reasoning is difficult to justify.

From the *Tepexic Annals*, Brotherson claims that the Aztec were aware of the sidereal year, which returns to the same position in 1,427 years of 365 days. He explains that this interval is given on page 63 of the Annals by the date 2 Reed in 1681 BCE, and he notes that a specific astronomical glyph is found at 27 Rounds of 52 years, and then at 9-Round intervals (Brotherson 1992:299–300). However, his calculations are inconsistent, and the total of 27 Rounds would be 1,404 years, with 9 more adding up to 1,872 years. Nowhere are 1,427 years clearly implied in this example as it is given.

Brotherson (1992:115) compares the 5,200-year Aztec length of the current creation with the Maya cycle of 5,200 Tuns of 360 days, or 13 B'ak'tuns of 400 Tuns, though these 360-day 'years' are not exactly equivalent to the 365-day years used in the Aztec calculation above.[3] Had he chosen to pursue this comparison further, Brotherson may have had some success with the more specific time calculations of the Maya, but as it stands, his work relies largely upon inferences that are not provable given the evidence.

As discussed in the introduction, several scholars of the ancient Maya have continued to explore the relationship between astronomy and mythology. In his translation of the K'iche' *Popol Vuh*, Dennis Tedlock (1996) provides multiple examples of possible astronomical references, many of which are evident in the ethnographic record. Likewise, in popular works such as *Maya Cosmos*, David Freidel, Linda Schele, and Joy Parker (1993) have used an astro-mythological approach to explain iconographic and hieroglyphic depictions of Maya cosmological concepts and events. However, just as the pan-Babylonianists were dismissed by many scholars in the field, Mayanist authors using an astro-mythological approach have often been criticized for their reliance on mythology to support their ideas (Coe 1989; Aveni 1996; Stuart 2005). At the same time, like the pan-Bablylonianists, such authors have popularized the discipline for a wider audience, and some of their insights are worthy of careful consideration and further examination.

---

[3] See the upcoming review of Maya calendrical and chronological systems.

When coupled with solid evidence, a comparative astro-mythological approach is potentially highly productive.

Using the 584283 GMT correlation between the Maya and Gregorian calendars, John Major Jenkins (1998) developed an astronomical and mythological hypothesis surrounding the rationale for the 13 B'ak'tun end date of the Maya Long Count, approaching on the winter solstice of 2012 CE. In the tradition of *Hamlet's Mill*, Jenkins cites iconographic representations from the Preclassic site of Izapa in combination with mythological themes from the ethnographic record to support his proposal that the Long Count system was specifically created at this site to measure precessional drift. However, no Long Count dates have ever been found at this site.

Using the 584283 GMT correlation, the end of the current era occurs on the winter solstice in 2012 CE, and Jenkins was the first to notice that the sidereal position of the sun on this solstice is very closely in alignment with the position of the galactic center, recognizable as the center of the widest bulge in the Milky Way, though not a specifically visible point. David Kelley (1989) had previously suggested that the Milky Way was used to divide the path of the sun on the ecliptic, and that the dark rift above the great bulge was seen as a place of creation. Jenkins therefore suggests that the end of the current cycle of 13 B'ak'tuns was chosen to represent the time when this alignment takes place, thereby beginning another precessional cycle of 26,000 years. Akin to Brotherson, Jenkins holds that the entire cycle of precession was recognized as consisting of five world-ages of 13 B'ak'tuns each.

To support his thesis, Jenkins proposes multiple mythological references to the sun and the Milky Way within Mesoamerican traditions, including the Milky Way as a giant caiman that swallows a man, with the dark rift as an open mouth and the entrance to the underworld. Following an interpretation that Kelley (1989) suggested, and Schele (1992) later expanded, Jenkins also compares the Milky Way to an upright caiman-tree. However, in all of these examples it is equally plausible that the myths derive from the movement of the sun through the seasonal cycle of the tropical year, as Schele suggests (Freidel, Schele and Parker 1993).

Jenkins amasses a considerable number of mythological parallels and inferences that are unprovable and easily dismissed. While Jenkins supports Vincent Malmstrom's proposal that the Long Count was created in Izapa, Malmstrom (2003) has summarily dismissed Jenkins' assertion concerning the galactic alignment. Malmstrom asserts that, while the Creation date of the current era was back-calculated to begin on the second solar zenith passage of the sun in Izapa[4], the end date is merely an accidental consequence of this choice, 13 B'ak'tuns later. Since Malmstrom uses the 584285 correlation constant to support his theory, the terminal date would fall two days after the winter solstice in 2012 CE. According to Malmstrom, this fact underscores the insignificance of the terminal date. However, Malmstrom does not consider the possibility of error in the calculation of the tropical year, and he provides no explanation for the length of an era as 13 B'ak'tuns. Furthermore, there are

[4] See the discussion below on the tropical year and the Era Base date.

no Long Count dates found in Izapa, though this does not exclude other nearby Preclassic sites at the same latitude, such as Takalik Abaj.

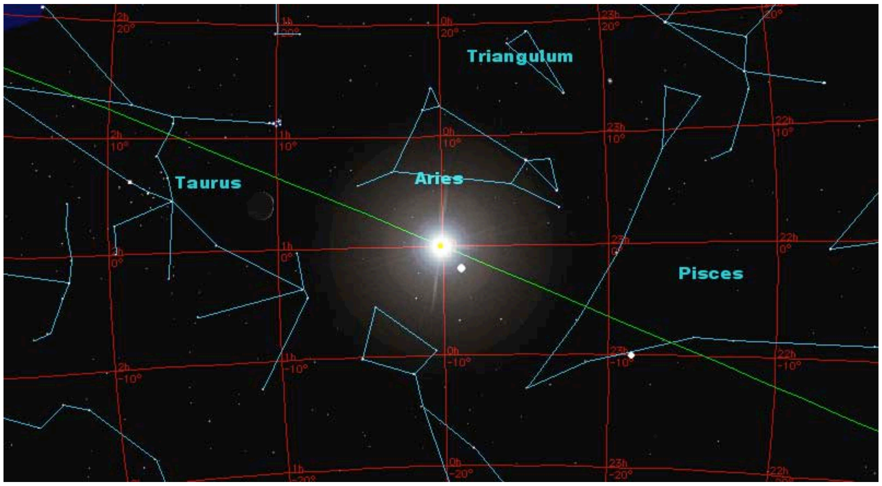
Jenkins has some stimulating ideas, but there is little evidence from the hieroglyphic record that the Maya were concerned about the upcoming arrival of the 13 B'ak'tun completion in 2012. In the corpus of inscriptions the end date is mentioned only once, on Tortuguero Monument 6. The primary focus in most cosmological hieroglyphic texts concerns the previous completion of a 13 B'ak'tun cycle on the Long Count Era Base date 4 Ajaw 8 Kumk'u, at which point the count of B'ak'tuns began again from zero. This is most apparent in the inscriptions from Palenque and Quirigua. However, in both of these examples, the Era Base date is secondary to earlier dates that are cited and paired with historical parallels (Looper 2003). Furthermore, there is no direct evidence that the Maya observed five of these era cycles of equal length, and most ethnographic accounts from various Maya groups specify only three previous creations (Thompson 1972). Of course, ethnographic accounts are not necessarily equivalent to past conceptions of elite and specialized astronomical knowledge, particularly when transmission of this knowledge was disrupted by the Spanish invasion.

Brotherson's parallel betweem the Maya and the Aztec systems is compelling, but again, it is unprovable in the absence of adequate documentation. Furthermore, some examples from Classic period monumental inscriptions count cycles far larger than a 26,000-year cycle. In Coba and Yaxchilan, the next largest cycle above 13 B'ak'tuns is said to be a cycle of 13 Piktuns (13 x 8000 Tuns), with increasing cycles of 13 periods extending as far as 13 x 20^{21} Tuns, with a total on the order of an unfathomable 29 *octillion* years. David Stuart refers to this vast cycle of time as the “Grand Long Count” (Stuart 2006b). Similarly, the Serpent Series from the Postclassic Dresden Codex extends well beyond intervals of 26,000 years. These larger cycles do not disprove Jenkins’ hypothesis, but they seem to de-emphasize the importance he places on the upcoming end of a 26,000-year precessional cycle.

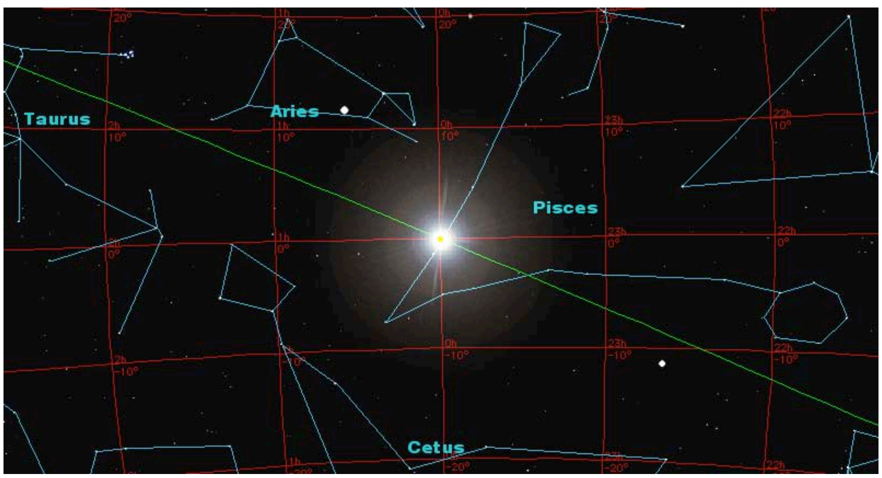
As we approach the end date of 2012, Jenkins resorts to uncritical millenarian ideas. He marginalizes himself with broad assertions that are very popular with a New Age readership, while they tend to render his interpretations suspect for an academic audience:

> Human civilization is transforming at a rate without precedence. The ancient Maya believed that our impending alignment with the Galactic Center is responsible for this transformation. (Jenkins 1998:105)

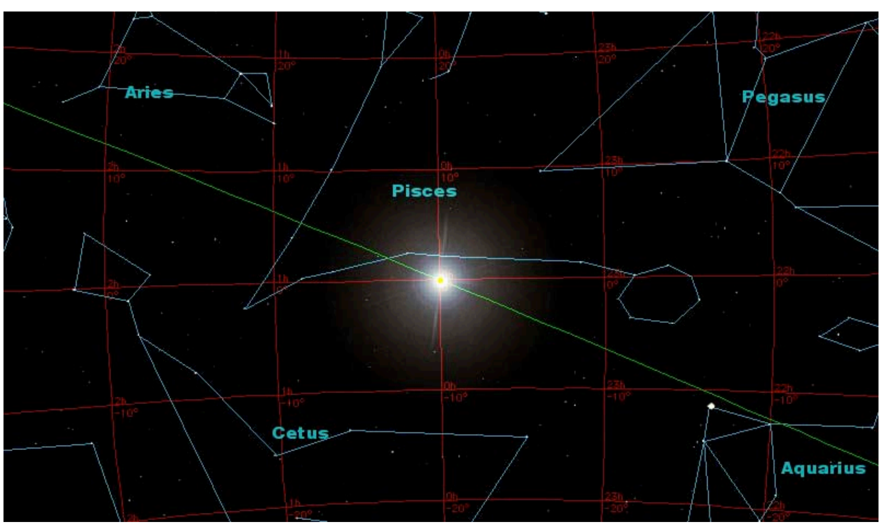
Here, Jenkins reasserts the Theosophical ideas found in *Hamlet’s Mill*. In his attempt to understand what precession may have meant to the ancient Maya and their predecessors, he loses his ability to differentiate what he thinks from what the Maya may have thought, and he loses sight of the task of impartially presenting the evidence, including that evidence which might not support his assertions. As a result, few scholars have seriously entertained Jenkins’ hypothesis that the Maya and their predecessors were capable of calculating precession. However, while it is important to admit limitations in our endeavor to understand how the Maya may have interpreted astronomical observations, the possibility remains that they were aware of precession. Below I will demonstrate that precessional knowledge among the Maya can be mathematically determined from calendrical calculations in the hieroglyphic record found in the Dresden Codex.



a) Vernal Equinox 1000 BCE



b) Vernal Equinox 1 CE
Here, the Vernal Equinox has moved backwards from Aries into Pisces



c) Vernal Equinox 1000 CE
The Vernal Equinox is moving towards Aquarius. It will take almost 26,000 years for the position of the Vernal Equinox to return to the same position.

Figure 2.1: Precession of the Equinoxes
The sidereal position of the sun on the vernal equinox moves one day earlier along the ecliptic approximately every 71 years.

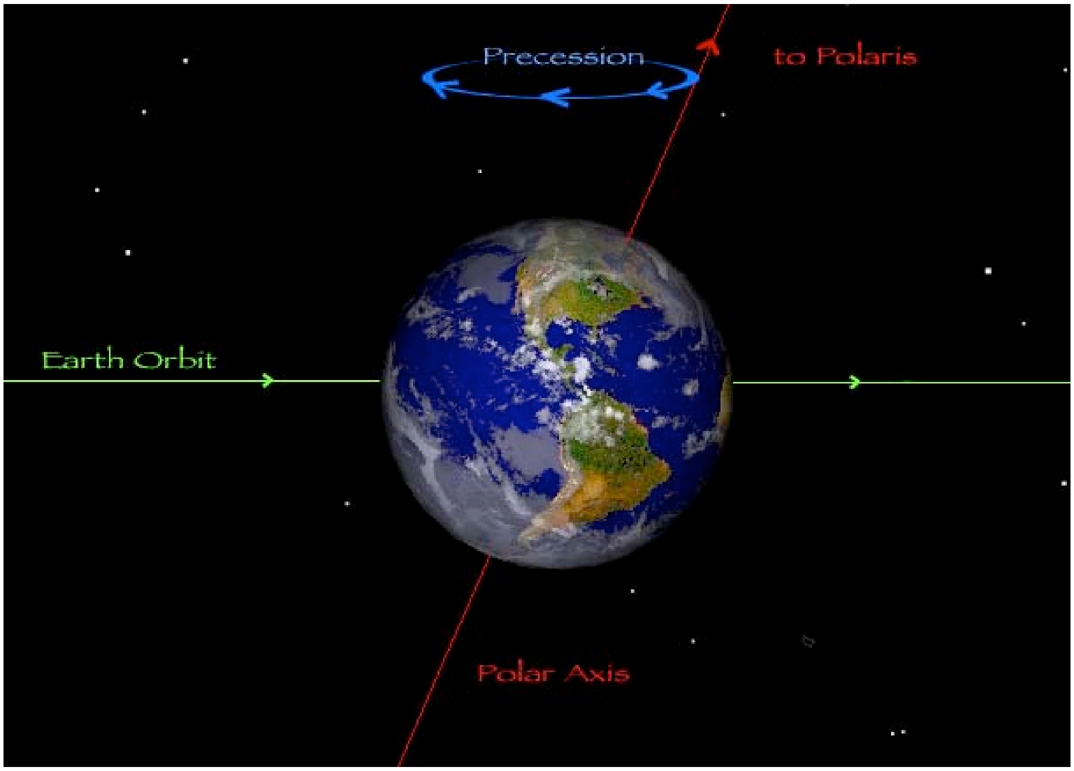


Figure 2.2: Precession occurs when the polar axis of the earth slowly wobbles. Currently, this axis points to the North Star, Polaris. This changes over time.

Chapter III

The Serpent Series Introductory Distance Number:

The Tropical Year and Solar Sidereal Precession

In this chapter, we turn to a specific interval of time, a distance number twice cited as an introduction to two parallel texts within the Dresden Codex. A new translation of this interval forms the basis of this project and provides specific evidence that the Postclassic Maya were capable of accurately calculating precessional drift, while also utilizing a value for the tropical year that similarly appears within Classic Period texts from Copán. We will proceed through the possible meanings of this re-interpreted distance number, which will lead us to the above conclusion, and to the subsequent chapters.

Hermann Beyer first determined that two tables within the Postclassic Maya Dresden Codex refer to a unique base date, some 30,000 years earlier than the base date of the Long Count chronological system (Beyer 1943). Both of these tables have nearly identical initial inscriptions followed by pairs of unusually extended distance numbers that appear within the curves of four undulating serpents on pages 61 and 62 (**Figure 3.1**), and one on page 69 (**Figure 3.2**). Beyer found that the endpoint of one of these "Serpent Numbers" fixes this date relative to the historical Long Count.

Given the tremendously long period of time covered by the Serpent Series, as Beyer named them, Susan Milbrath suggests that they may have had something to do with the 26,000 year cycle of the precession of the equinoxes (Milbrath 1999:259). While she does not provide any definitive proof, the evidence in this chapter strongly supports her proposal. Though the Serpent Series are still poorly understood, a new reading of the introductory inscription that is repeated on pages 61 and 69 in the Dresden suggests that the Maya of the Postclassic were capable of precise calculations of multiple astronomical phenomena, including the tropical year, the sidereal year, and solar precession.

Maya Time Reckoning and the Serpent Series

The 260-day Tzolk'in and the 365-day Haab' are found in various forms throughout Mesoamerica, and these two interlocking cycles of time were used to identify any given day within a 52-year period. The 365-day Haab' is clearly based on the seasonal year, using 18 named 'months' of 20 days each, numbered 0 to 19, with an added five-day period at the end of the year. Because no leap year was added within this system to compensate for the actual length of the tropical year, the Haab' predictably fell behind the tropical year by about one day every four years.

The names used for the Haab' 'months' are those recorded by Landa from the Postclassic Yucatecan (Pagden 1975), using current orthographic conventions:

> Pop, Wo, Sip, Sotz', Sek, Xul, Yaxk'in, Mol, Ch'en, Yax, Sak, Keh, Mak, K'ank'in, Muwan, Pax, K'ayab', Kumk'u and Wayeb' (5-day period)

The 260-day Tzolk'in is composed of a repeating cycle of 13 numerals, together with a cycle of 20 named days. The origin of this cycle is less certain, though it has been the topic of much speculation. The Haab' and the Tzolk'in together compose the Calendar Round, in which a specific day with the same Haab' and Tzolk'in position repeats only after a period of 52-Haab' or 73-Tzolk'in cycles. As recorded by Landa, the Tzolk'in day names are:

> Imix, Ik', Ak'b'al, K'an, Chikchan, Kimi, Manik, Lamat, Muluk, Ok, Chuwen, Eb', B'en, Ix, Men, Kib', Kab'an, Etz'nab', Kawak, Ajaw

Beginning on a day 1 Imix, the following days would be 2 Ik', 3 Ak'bal, 4 K'an up to 13 B'en. Following 13 B'en would be 1 Ix, 2 Men, 3 Kib', etc. The entire Tzolk'in cycle repeats after 260 days with 1 Imix, while a day 1 Imix 1 Pop repeats only after 73 Tzolk'in cycles, equivalent to 52 Haab', the Calendar Round.

For the purposes of identifying specific days within longer expanses of time, the Maya also used the Long Count, a chronological system that counted forward from an Era Base date on 4 Ajaw 8 Kumk'u, several thousand years before the Classic period. The basic unit of the Long Count is the 360-day Tunfootnote, composed of 18 Winals, periods of 20 days each, with a single day identified as a K'in. A K'atun is composed of 20 Tuns, and a B'ak'tun is composed of 20 K'atuns, or 400 Tuns. Long Count positions can therefore be written in the following numerical format:

B'ak'tun . K'atun . Tun . Winal . K'in

The Long Count Era Base date itself is identified as having completed a cycle of 13 B'ak'tuns, at which point the count again returns to zero, and the Long count, Tzolk'in and Haab' position of the Creation date is therefore:

13.00.00.00.00 4 Ajaw 8 Kumk'u

On occasion, the Maya also recorded intervals of time even greater than 13 B'ak'tuns, such as one Piktun, composed of 20 B'ak'tuns. This is relevant to the current discussion concerning the Serpent Series.

Specific dates within the Dresden Codex are often given by calculations involving **Ring Numbers**. Förstemann (1906) identified these, but Willson (1924:24–25) later clarified the way in which they operate. Ring Numbers are intervals of days between the **Era Base** date 4 Ajaw 8 Kumk'u and an earlier **Ring Base** date, where the place-holder for the numeral of days in the interval is circled by an image of a tied red band. Added to this earlier **Ring Base** date is another count of days forward, which Eric Thompson (1972:20–21) refers to as a **Long Round**, leading to a final date within the Long Count that is given as an entry date to be used within a specific table in the codex.

The Serpent Series

Beyer (1943) began his analysis of the Serpent Series base date using the Ring Number calculation on page 63 of the Dresden Codex, column C (**Figure 3.3b**). This example gives all of the necessary information needed to calculate the dates involved. The inscription begins at the top of the page with the Ring Base date 13 Imix 9 Wo. The bottom of the page gives the Era Base date 4 Ajaw 8 Kumk'u. Immediately above the Era Base is the Ring Number, given here as 07.02.14.19, with the last numeral circled by a red ring. Thus, if the Ring Number is subtracted from the Era Base, the Ring Base is reached:

Era Base:	**13.00.00.00.00**	**4 Ajaw 8 Kumk'u**
Ring Number:	**– 07.02.14.19**	
Ring Base:	**12.12.17.03.01**	**13 Imix 9 Wo**

Two Long Round distance numbers are given above the Ring Number on Dresden 63c, one in red and one in black, each leading to a separate Tzolk'in date counted forward from the Ring Base. Using the red Long Round, here given as 10.13.13.03.02, we count forward from the Ring Base to reach the day 13 Ak'b'al 1 K'ank'in, here abbreviated as 13 Ak'b'al. The Long Count positions can be calculated by the following:

Ring Base:	**12.12.17.03.01**	**13 Imix 9 Wo**
Long Round:	**+10.13.13.03.02 =**	
Long Count:	**10.06.10.06.03**	**13 Ak'bal 1 K'ank'in**

Beyer noticed that the date 13 Ak'b'al 1 K'ank'in is also given as a terminal date in the black Serpent Number on page 62, columns C and D (**Figure 3.3a**). Each of the Serpent Numbers counts forward from a **Serpent Base** date 9 K'an 12 K'ayab'. While five of the Serpent Numbers have been shown to have significant errors, Beyer (1933) was able to determine the likely mistakes made in each case. Fortunately, the Serpent Number from page 62, with the terminal date 13 Ak’b’al 1 K’ank’in, is one of the few without any copy errors. Beyer demonstrated that when this Serpent Number, exceeding 34,000 years, is added to the Serpent Base date 9 K’an 12 K’ayab, we indeed reach a day 13 Ak’b’al 1 K’ank’in. Given that the Long Count position of 13 Ak’b’al 1 K’ank’in can be determined from the Ring Number calculation on page 63, column C, Beyer realized that it is possible to determine the relationship between the Serpent Base date 9 K’an 12 K’ayab’ and the Long Count positions of each Serpent Number terminal date:[1]

Serpent Base:	**xx.xx.xx.xx.xx.xx**	**9 K’an 12 K’ayab’**
Serpent Number:	**+ 04.06.09.15.12.19**	
Long Count:	**10.06.10.06.03**	**13 Ak’bal 1 K’ank’in**

Following Beyer, it is possible to determine the interval between the Serpent Base date 9 K’an 12 K’ayab’ and the Long Count Era Base date 4 Ajaw 8 Kumk’u using the following simple calculation:

Serpent Number:	**04.06.09.15.12.19**	**9 K’an 12 K’ayab’ to 13 Ak’bal 1 K’ank’in**
Long Count:	**–10.06.10.06.03**	**4 Ajaw 8 Kumk’u to 13 Ak’bal 1 K’ank’in**
Interval:	**03.16.03.05.06.16**	**9 K’an 12 K’ayab’ to 4 Ajaw 8 Kumk’u**
	= 10,967,536 days	

The Serpent Base date occurs exactly **10,967,536 days** prior to the Long Count Creation date. This is an interval of about 30,028 years, although its significance has yet to be explained. Beyer (1943:404) proposed that the

[1] To account for the Piktun position, and cycles in excess of 13 B’ak’tuns, Beyer (1943) created a fictitious system with which to label the Serpent Base date as (01.11.15.) 3.16.14.11.4 9 K’an 12 K’ayab’, with the Era Base date as (01.11.19.) 00.00.00.00.00 4 Ajaw 8 Kumk’u. This invention is omitted in this discussion because it is untenable.

Serpent Base date may be “a zero point for planetary calculations,” based on the fact that the distance between 9 K’an 12 K’ayab’ and 13 Ak’b’al 1 K’ank’in is 12,454,459 days, exactly 21,329 synodic Venus periods by modern calculations. However, hesitating to ascribe such accuracy to the ancient Maya, he concluded, “this truly astonishing exactitude may be a mere coincidence.”

Victoria and Harvey Bricker (1988) first proposed that the Serpent Series on page 61 and 62 of the Dresden, and the table of multiples that follow, were used to determine the 365 day Haab’ position of the solstices and equinoxes of the tropical year, and the movement of the eclipse seasons. The Brickers suggest that the various dates given in Serpent Number and Ring Number format were used to enter one of the two concurrent tables on pages 65–69. Each of these dates contains one of the five possible Tz’olk’in days used as starting points within the table of 20 multiples of 91 days (1820 days), and further multiples of 1820 days: 3 Chikchan, 3 K’an, 3 Ix, 3 Kimi, and 13 Ak’b’al.

More recently, the Brickers have suggested that the second Serpent Series beginning on page 69 of the Dresden contains a table of multiples of 702 days that were used to determine the sidereal cycle of Mars. These are likewise broken into 13 multiples of 54 days. An additional table containing 28 multiples of 65 provides multiples of 1820 days, the same interval found in the seasonal table from the first Serpent Series (V. Bricker and H. Bricker 2005).

In their original article, the Brickers (1988) interpreted the initial inscription in the Serpent Series as being composed of several distance numbers, in what they refer to as "pictun" notation, given that a known Piktun glyph, equivalent to 8,000 Tuns, appears near the beginning of the inscription. However, their method of determining the intended interval of this distance number is based on several problematic assumptions.[2] Furthermore, they do not offer any explanation for the vast intervals of time invoked by the 9 K'an 12 K'ayab' base date. The following new reading of this introductory inscription provides internal consistency with the tables, and with the remainder of the Brickers' findings, while also demonstrating further utility of the table as an unprecedented astronomical and calendrical instrument.

---

[2] Within both examples of the initial inscription on pages 61 and 69, the Piktun glyph appears without any coefficient, and the Brickers read this as 'zero Piktuns', with the initial distance number as **0 Piktuns 18 B'ak'tuns 0 K'atuns 8 Tuns 0 Winals and 16 k'ins.** However, the inclusion of the high-order position of Piktuns, without any indication of 'zero' suggests that the value is 'one Piktun'. Given that the Winal glyph and position is completely absent in this initial distance number, indicating 'zero Winals', why are the pictuns included? Likewise, the K'atun glyph is preceded by two unusually placed glyphs prefixed by Pawahtun signs, which the Brickers claim to be representations of 'zero', with little supporting evidence (V. Bricker and H. Bricker 1988:S7).

Following the subtraction of 0.18.0.8.0.16 and 0.19 from 4 Ajaw 8 Kumk'u, which appears immediately after these two distance numbers, the Brickers **add** a third distance number at A13 which they read as 1 Piktun, and again they subtract 15.9.1.3 as suggested by the inscription, and the previous work of Beyer (1943). They conclude that the intended date is within the current Long Count cycle as 1.4.2.15.2 3 Ik 5 Zotz. However, no such date is suggested in the remainder of the table, and the day 3 Ik is not one of the five possible entry dates within the table of multiples.

In this scenario, there is no explanation for the <u>purpose</u> of such long distance numbers used to reach a supposed date within the current Long Count cycle, while the 30,000 + year intervals indicated by the Serpent Numbers suggest additional meanings. Therefore, it is worth re-examining this initial inscription to determine if there are any other more likely possibilities within the context of the Serpent Series as a seasonal table.

A New Reading for the Serpent Series Introductory Inscription

In both examples of the inscription that introduces the Serpent Series (**Figure 3.4**), the initial two glyphs are eroded. The first discernable glyphs on page 69, A2-B2, resemble the title of the Palenque Triad, and other deity triads, as **3-lu-ti K'UH** (TIII:59:568:1016)[3], with **K'UH** also visible at B2 on page 61, the previous glyph being eroded. The following sixteen glyphs are equivalent in both inscriptions, and they appear to provide an unusual distance number with several components, as the Brickers suggest (V. Bricker and H. Bricker 1988:S7–8). However, this new reading differs significantly from that proposed by the Brickers. Continuing with A3, both inscriptions appear to read **PÄT-aj** (T79:181), *pätaj* 'is made', followed by the Piktun glyph collocation (T42:200) in B3 with no coefficient. Following Beyer (1943) the Brickers translate the collocation now read as **PÄT-aj** as indicative of subtraction, and they read the Piktun glyph that lacks a coefficient as 'zero Piktuns' (V. Bricker and H. Bricker 1988:S7–S8). However, in this unusual distance number, the Winal glyph is absent altogether, clearly representing zero Winals. If its intended value is also zero, why is the Piktun even represented? It seems more reasonable that the Piktun glyph that appears without a coefficient is understood to have a coefficient of 'one'. Similarly, a Winal glyph without a coefficient appears in the next short distance number, and the Brickers also read this as 'zero', while it also may instead be read 'one' winal. Furthermore, it is likely that this initial distance number relates to both the 9 K'an 12 K'ayab base date and the 4 Ajaw 8 Kumk'u Era Base date,

[3] All glyph codes are categorized by T-numbers from Thompson (1962).

both of which appear in the column below. Given the 30,000+ year intervals (around four Piktuns) found in the Serpent Numbers, we might expect a higher value for this initial distance number beyond one Piktun.

The skeletal-jawed maize deity (T1004b), the head variant for the number 'eighteen' appears in A4, complete with his mirror prefix, followed by the expected B'ak'tun glyphs in B4, as both the unusual T561:285 on page 61 and the more common B'ak'tun bird, T1033, on page 69. The following blocks, A5 and B5, contain an unusual pairing of heads with Pawahtun superfixes (T64), which the Brickers claim to be representations of 'zero'. They offer little supporting evidence for the 'zero' reading apart from the expected coefficient of the K'atun position, and the K'atun glyph following in A6 (V. Bricker and H. Bricker 1988:S7). On the other hand, I propose that like the Piktun glyph, this K'atun without a coefficient should be understood as 'one' K'atun.

The central glyph in the second Pawahtun collocation appears to be the head of a rabbit, which Eric Thompson (1972:80–81) suggests may relate to the rabbit depicted in the mouth of the second serpent on page 61. The central glyph in the first Pawahtun collocation appears to be a skull (T1049), but it does not seem to correspond to the Chak appearing in the mouth of the first serpent. Similarly, while the same pair of Pawahtuns appears in the inscription on page 69, here only one black Chak is depicted in the mouth of a single serpent, and no rabbit is present.

Both the skull and the rabbit have known lunar associations among the Maya (Schele and Grube 1997:171; Milbrath 1999:152–54). Two inverted **SÄK**

(T58) glyphs appear on either side of both the skull and the rabbit, perhaps indicating the reduplicated color term *säk-säk* 'very white' (Hofling and Tesucún 1997:553), or perhaps emphasizing the full moon as 'very bright' (V. Bricker et al. 1998:238). The Pawahtuns are usually associated with the cardinal directions, and here they may indicate two directional positions of the full moon. However, their presence within a distance number is highly irregular, and more information is needed to clarify their purpose.

Following the K'atun glyph without a coefficient in A6, the inscription continues as a distance number with '8 Tuns' in B6. Curiously, on page 61, the bar-and-dot numeral appears along with the head variant for the number eight.The tun sign is infixed in the head variant. No Winal position is given, most likely indicating 'zero Winals'. Finally A7 shows the head variant for 'sixteen' with what appears to read **yo-[OK]K'IN-ni** (T115:567:544:116) in B7 where we would expect simply **K'IN**. The word *ok'in* translates as "evening", literally 'enter-sun' in Yucatec (Martinez Hernandez 1929:713), and *16 y-ok'in* may read 'sixteen are its evenings'. This suggests a count of days reckoned from the point of sunset.

Daniel Flores (1995) has proposed that the Postclassic Maya used the four rotating year-bearers as a tool to keep track of the leap year. The year-bearers are the only four Tzolk'in days on which the 365-day Haab' can begin, and Flores suggests that their associated colors and directional symbolism were used to establish the additional quarter-day interval at which the time of the New Year was recognized. Evidence from Landa suggests that the Postclassic Maya of the Yucatan understood the year to have a length of 365 days and six hours: "From these six hours they made one day every four years and so every four years a year of 366 days" (Pagden 1975:96–97). It is quite possible that the leap year was thus reckoned by shifting the count of the day six hours forward every year. Another reference to such a system may appear further on in the inscription below.

On the other hand, 16 *yok-k'in*, may simply read 'sixteen its foot-sun' or perhaps 'sixteen steps of the sun', with the possible meaning of a count of sixteen days. **OK** (T765) is used to refer to increments of time throughout the Serpent Series in the form of **K'UH(UL)-OK-ki**, (T1016:765:102) found following the Haab' date on page 62, column C, and on page 63, C4 (**Figure 3.3 a, b**).

Taken as a numerical whole, this new reading of the first component of the introductory distance number from the Serpent Series gives 1 Piktun, 18 B'ak'tuns, 1 K'atun, 8 Tuns, 0 Winals and 16 k'ins. In Maya notation, this reads:

1.18.1.8.0.16 = 15,228 Tuns and 16 days = 5,482,096 days

Curiously, 5,482,096 days is almost half of the 10,967,536 day interval separating the Serpent Series base date 9 K'an 12 K'ayab' from the Long Count Creation date on 4 Ajaw 8 Kumk'u. Twice the introductory distance number gives 10,964,192 days, exactly 3,344 days short of the 10,967,536-day interval Perhaps some adjustment was made for an as yet unknown reason that will require further explanation, as will the doubling of this interval.

The first component of the introductory distance number in the Serpent Series gives an interval of 15,228 Tuns and 16 days, or 5,482,096 days.

But before we attempt to discern the meaning of this distance number, we can see that the inscription continues with another possible distance number that concludes with the familiar 4 Ajaw 8 Kumk'u. Again we find the verb *pät-aj* 'is made' in block A8 followed by **ah-WINIK** (T12:521) in B8. This continues with the head variant for the number 'nineteen' in A9, followed by **ah-mi-K'IN** (T12:163:544) in B9 on page 61 and a conflation of a spider monkey and **K'IN** on page 69. In Yucatecan and Ch'olan languages, *ah màax/max* is 'spider monkey' (Bricker et al. 1998:181; Kaufman and Norman 1984:125). Schele and Grube (1997:195) suggest that this substitution of a spider monkey conflated with **K'IN** may read *ah ma k'in*. Although T163/173 is typically thought to read **mi** or **MIX** 'zero' in the Classic inscriptions, both *ma* and *mix* mean 'nothing' in Yucatec (Barrera Vásquez et al. 1980:469, 524), while *ma* and *max* can indicate 'nothing' in Ch'ol (Kaufman and Norman 1984:139; Attinasi 1973). But there is an apparent contradiction if the intended meaning in both of these examples is 'nineteen no-days'.

It is possible that *ah max k'in* is intended for both examples of block B9, and the meaning of this may relate to the association between the sun and a spider monkey. A monkey glyph is used to indicate the **K'IN** position within many Initial Series from the Classic Period (Milbrath 1999:92). This monkey (T755) often wears a headband and contains an **AK'B'AL** (T504) glyph, meaning 'dark, night'. In Ch'orti' *maxa'* means 'twilight, dusk, become dusk' and *maxa'anix* 'very dark, already evening' (Wisdom1950: 525–26). While both spider monkeys and howler monkeys are diurnal, howler monkeys are well known for their vocalizations at dawn and dusk. Perhaps the evening disappearance of monkeys served as a parallel for the setting sun, with a pun on *maxa'* 'dusk'. Milbrath (1999:20, 94–96) suggests that monkey *k'in* variants "may represent a count of days beginning at dusk, the time that the monkey's sun shines, according to the Tzotzil Maya." Similarly, among the Lacandon, the sun is specifically associated with a spider monkey.[4] With the possible reference to y-*ok'in* as 'it's evenings' in the first distance number, this unusual example of a count of evenings as *ah max k'in* may refer to another quarter-day interval within the system of leap year correction as outlined by Landa. While *y-ok'in* may refer to a count of days from the point of sunset, it is possible that *max-k'in* may literally refer to a count from midnight as 'no-sun', the only quarter of the day when no sun is visible.

The use of the *ah* prefixes is unclear in the context of both the winik and the k'in glyphs, though here they may be either honorific or instructional for the reader in the form of the second person ergative pronoun 'your', with *pataj ah winik* as 'is made, your twenty days…'. If this combination of one winik and 19 k'ins indicates another distance number, it would appear to consist of 39 days. This smaller distance number is apparently set apart from the former, perhaps emphasizing its importance. In an unpublished manuscript, Carl Callaway (n.d.) has proposed that *pataj ah winik* relates to the story of the creation of the first twenty-day period in the *Chilam B'alam of Chumayel*. He suggests that this passage describes the formation of *aj winik* 'Mr. 20' out of 'nineteen and zero days' prior to the Creation date on 4 Ajaw

---

[4] Milbrath refers to Laughlin (1977:253) and Laughlin and Karasik (1988:249) for the Tzotz'il "Monkey Sun". For the Lacandon solar spider monkey, Rätsch and Ma'ax (1984), aptly named.

8 Kumk'u. While this may also be the case, in this context I agree with Bricker and Bricker (1988) that this sentence is intended as a small distance number, though I contend that it consists of 39 days, rather than only 19. Further support for this claim can be found within the seasonal table on pages 61–64, where three of the five Tz'olk'in entry dates are at intervals of **39 days apart**. The most common base date **3 Chikchan is 39 days after 3 Kimi,** while **3 K'an follows 39 days after 3 Chikchan**. Thus, this 39-day interval appears to be implicit in the seasonal table following this initial inscription, and such an interval may have been important for the astronomical function of the table.

Combining the first and second distance numbers, and for the moment reading the K'in position as whole days, we can read the entire introductory distance number from the Serpent Series as follows:

<u>First D.N.</u>				
1.18.1.8.0.16	**=**	**15,228 Tuns and 16 K'ins**	**=**	**5,482,096 days**
<u>Second D.N.</u>				
1.19	**=**	**39 K'ins**	**=**	**+ 39 days**
				<u>5,482,135 days</u>

The Long Count Era Base date 4 Ajaw 8 Kumk'u concludes the introductory inscription of the Serpent Series. Following this point, two separate but apparently related inscriptions appear on page 61 and page 69. All of the previous text in the initial inscription is highlighted in blue on page 69, again emphasizing this introductory inscription as a distinct text. We first analyze the initial inscription before moving on to the two separate secondary inscriptions. In so doing, it will be necessary to discuss the ways in which the Maya may have calculated the tropical year.

Tropical Year Calculation in Classic Period Copán: the Second Solar Zenith

The tropical year follows the seasons, measuring the time it takes for the sun to return the same position relative to the axis of the earth. Often, the solstices and equinoxes are used as points of reference, and the current **mean tropical year** of approximately 365.24219 days averages all four of the calculations made from these points, which differ slightly due to changes in the elliptical orbit of the earth (Meeus and Savoie 1992:42).

Numerous architectural alignments throughout the Maya world identify rising and setting points of the sun on solstices and equinoxes, as well as on the days when the sun is at the zenith (Aveni 2001:245–300). Mesoamerican peoples are also known to have measured the unique phenomenon of solar zenith passages through the use of vertical sighting tubes or the shadow on a vertical gnomon (Aveni 2001:265–270). Two zenith passages of the sun occur at different intervals only in the tropics, and these events provide an ideal means by which to accurately measure the tropical year. Given their access to zenith passages of the sun, as well as extensive written records over long periods of time, the Maya are thought to have had an accurate calculation of the tropical year that approximates the mean tropical year.

In all likelihood, the Maya would have understood the tropical year to be a constant much like our mean tropical year. However, contemporary calculations have determined that over the course of thousands of years, the earth's orbit around the sun is speeding up very slowly, amounting to 0.53 seconds per century. Two thousand years in the past, the year was about ten seconds longer than it is at present. Fifteen thousand years ago, the tropical year was about 80 seconds longer than the current cycle. In addition, the rotation of the earth is slowing down due to the gravitational effects of tidal breaking, causing the length of the day to slowly increase over thousands of years (Meeus and Savoie 1992). Therefore, even our current value of the mean tropical year will produce an increasing error if used as a constant over periods of tens of thousands of years. This is particularly significant if we seek to compare our results or the results of the Maya with any sophisticated astronomy program or astronomical tables that may or may not take into account these shifting theoretical values.

Using the position of the Long Count Era Base date of 4 Ajaw 8 Kumk'u, we can hypothetically use the modified 584285 GMT calendar correlation to position the sun on August 13, 3114 BCE.[5] Robert Merrill (1945) and Vincent Malmström (1973) independently noticed that this is the day of the second zenith passage of the sun at 14.8° N latitude, the exact latitude of both Izapa and Copán. Furthermore, only at this latitude are the two solar zenith passages exactly 260 days apart, the length of the 13 x 20 day Tzol'kin used throughout Mesoamerica (Malmström 1997:3–6).[6]

---

[5] All dates are given in modified Gregorian proleptic format to remain consistent with the seasons.

[6] As Malmström (1997:5) found, several scholars had previously noticed the 260-day interval between the two zenith passages near 15° N latitude: Zelia Nuttall (1928), Ola Apenes (1936), and Rafael Girard (1948).

Maya calculations of the tropical year are reckoned in whole numbers of days. The 365 day Haab' clearly derives from the tropical year, though no leap year is used to adjust the continuous movement of this cycle. However, it appears that the Maya were well aware of the advancement of the tropical year over the Haab' by about a quarter of a day per year. Depending on the length of the interval the Maya recorded, a conversion to our decimal notation provides varying degrees of accuracy when compared with the current value of the mean tropical year.

Intervals of 6,940 days are evident in the inscriptions of Copán and in the Dresden Codex, and John Teeple (1931:71) suggests that the Maya equated this interval with the Metonic cycle of nineteen tropical years, nearly equivalent to 235 lunations. However, this calculation implies a value of 365.2631579 days for the tropical year, and it would produce one day of error in only 48 years. It is thus more likely that this interval was used to coordinate the synodic lunar cycle with the tropical year, but it is not useful for much longer time periods.

The Metonic cycle of 6,940 days happens to be exactly 260 days, or one Tzolk'in, less than the length of a K'atun. Therefore, if we count forward 6,940 days from the second solar zenith at Copán, we end again on a second zenith passage. Because Copán is precisely at 14.8º N latitude, counting forward another 260 days to the end of the K'atun brings us exactly to the *first* zenith passage at this latitude. This was surely noticed, and it lends astronomical significance to the K'atun, and thus to the Long Count itself at this latitude.

The eighth century tomb of Jasaw Chan K'awil in Tikal (Burial 116) contained a cache of many incised bones, some of which contain calendrical intervals. One of these bones (Miscellaneaous Text 27) contains two dates, beginning with the Era Base date of 4 Ajaw 8 Kumk'u. The next date is 4 Ben 1 Xul, giving an interval of 2.12.0.13 or 18,733 days, exactly 52 Tuns of 360 days with the addition of 13 days. Most significantly, this is 260 days before 52 tropical years, or 52 Haab' plus 13 days. Again, as with the Metonic cycle, we see that the addition of a 260-day Tzolk'in brings us to another significant event.

To illustrate the terminal positions of this count in linear form:

```
    52 Tuns                                                                52 tr.yr.
>____|________|-----------------------------------260 days ------------------------------|>
      -13 days-  |                                                  |  -13 days-
              18,733 days from origin date                       52 haab
```

The interval suggested by this bone (Misc. Text 27) uses the Calendar Round system of 52 Haab', associating it with 52 Tuns which is 260 days earlier, but with the addition of a 13 day shift. This enables a prediction of the tropical year on the same Tzolk'in day 260 days later, giving a tropical year of 365.25 days. This is essentially a Julian year, with a leap year of an exact quarter-day addition, in that 13 is precisely one quarter of 52, and this serves as a more accurate calculation than the Metonic cycle. Because the actual interval between 52 Tuns plus 13 days and the true solar year is 259.5944 days, the cycle breaks down after periods of over 128 Haab', and this is the very reason that the leap year is omitted at the turn of every odd numbered century in the Gregorian calendar.

Nonetheless, this system could be used within periods under 128 Haab' for any increment of time. Every 52 Haab' requires the addition of 13 days, and the remaining years can then be divided by four, or an extra day can be added every four years, as Landa suggested. For instance, the amount of drift in 77 Haab' will be 13 days for 52 Haab', plus 6 days for the remaining 25 Haab', giving a total of 19 days of drift from 77 Haab' to the true tropical year. Again, this breaks down beyond 128 Haab', and requires a more accurate correction for longer durations of time.

Maya records of much longer intervals demonstrate increasingly accurate measurements of the tropical year. Teeple (1931:70–74) found that two dates from Copán Stela A suggest that the Maya were capable of calculating the tropical year with a high degree of accuracy. The opening date of 9.14.19.08.00 12 Ajaw 18 Kumk'u falls 200 days before the subsequent date marking the turn of the K'atun 9.15.00.00.00 4 Ajaw 13 Yax. Teeple noticed that at this time, the tropical year has advanced on the 365 day Haab' by two years and 200 days when counted from the Era Base date of 4 Ajaw 8 Kumk'u. The Haab' date of 8 Kumk'u falls ten days before the opening date of Stela A on 9.14.19.07.10, giving 3,846 Haab' since the Creation date. Counting forward 200 days from this position then reaches 9.14.19.17.10 7 Ok' 3 Yax which is ten days prior to the turn of the K'atun and almost exactly 3,844 mean tropical years from the Creation date. Using this interval, the

Maya of Copán would then have recognized a tropical year of 365.2419355 days:

9.14.19.17.10 = 1,403,990 days = 3,844 (365.2419355 days)

If Teeple is correct, the Copán tropical year is only 0.0002545 days less than the current value for the mean tropical year of 365.24219 days. This comes to only 22 seconds less than the current value, giving an error of one day in 3,930 years. This error is slightly less than that found in the currently used Gregorian tropical year of 365.2425 days. However, if the Copán year is used over tens of thousands of years, such an error becomes significantly amplified, and this becomes important in the following discussion.

Because the mean tropical year was slightly longer in the past, the error in the Copán year would be slightly larger. The mean tropical year for 731 CE can be estimated using current planetary theory, giving an approximate value of 365.242267 days.[7] The Copán year would then be 0.0003315 days less, equivalent to 28.6 seconds, giving an error of one day in 3,017 years.

---

[7] According to VSOP 87 Planetary theory (Meeus and Savoie 1992):, a theoretical length of the tropical year in the past can be obtained by the following equation, where T= # of days from the epoch J2000 (January 1, 2000 CE) measured in Julian Millennia of 365250 days:

$$365.242\,189\,623 \text{ days} - 0.000\,061\,522\,T - 0.000\,000\,0609\,T^2 + 0.000\,000\,265\,25\,T^3$$

August 12, 731 CE = 463270 days before J2000. Therefore, $T = \frac{-463270}{365250} = -1.268364134$

Tropical year in 731 CE :

$= 365.242\,189\,623 \text{ days} - 0.000\,061\,522(-1.268364134) - 0.000\,000\,0609(-1.268364134)^2 + 0.000\,000\,265\,25\,(-1.268364134)^3$

$= 365.242\,189\,623 \text{ days} + 0.000\,078\,032 + 0.000\,000\,098 - 0.000\,000\,541$

$= 365.242267213$ days

Theoretical calculations for the tropical year on the order of several thousands of years in the past become increasingly more speculative, making it difficult to determine any true value for 3114 BCE.

As Malmström (1997) has reasserted, the modified GMT correlation constant places the Era Base date on August 13, 3114 BCE, the day of the second solar zenith passage at14.8º N latitude. This is the exact latitude of Copán, and using this same GMT correlation, we can see that ten days prior to the turn of the K'atun on 9.15.00.00.00 fell on August 12, 731 CE, one day before the second zenith passage at this site. This apparent error may derive from the method of determining the exact day of the zenith, which can occur two days in a row in some years. Regardless of the slight error in the calculation, using the second solar zenith, the Maya of Copán would then have had an efficient means by which to measure the tropical year with great accuracy. In fact, the creators of the Long Count system itself presumably calculated the position of the solar zenith on the origin date by using a value similar to the Copán tropical year. If true, this is indeed an impressive accomplishment, and it may represent the most accurate measurement of the tropical year in human history, as early as the first appearance of the Long Count—assuming an unbroken count from the earliest attested Long Count dates, such as the Chiapa de Corzo tablet interpreted by Michael Coe as (7.16.)3.2.13 (1994:76), December 8, 36 BCE, using the 584285 GMT constant. A more accurate measurement of the tropical year does not appear until 1627 with the work of Tycho Brahe and Johannes Kepler, who proposed that the mean tropical year is equal to 365.2421875 days (Meeus and Savoie 1992:41).

The Tropical Year and the Haab' in the Serpent Series

From the introductory distance number found in the Serpent Series it may be possible to determine the constant theoretical value used by the Postclassic Maya to calculate the tropical year in the Dresden Codex. Because the distance number in the introduction to the Serpent Series is so long, any errors in the Maya calculation of the tropical year become more apparent if it is possible to determine their intended target dates. If the Maya of Copán and their predecessors were capable of calculating a tropical year that is only theoretically in error by one day in 3,930 years, this value will vary from the current value of the mean tropical year by only a few days over a period of 15,000 years—a relatively insignificant amplification of the error. From the Serpent Series introduction, if we count backwards by the first distance number of 15,228 Tuns + 16 days, then count back an additional 39 days (the second distance number), the result provides multiple possibilities.

First, using our current calculation of the mean tropical year as a <u>theoretical constant</u> of 365.24219 days, we find:

15,228 Tuns +16 days +39 days = 5,482,135 days
= 15009.58857 (365.24219 days)
= 15009 mean tropical years + 214.9703 days.

Subtracting 15,009 years and about 215 days from 4 Ajaw 8 Kumk'u on August 13, 3114 BCE, we reach January 10, 18,123 BCE. This date does not at first seem to be particularly significant. But the theoretical constant for the tropical year presumably used in the Dresden Codex would most likely differ slightly from the current value. If Teeple is correct regarding the Copán tropical year, it is possible that this value continued to be used within the Dresden Codex. Using the Copán tropical year as a constant 365.2419355 days:

15,228 Tuns + 16 days + 39 days = 5,482,135 days
= 15,009 (365.2419355 days) + 218.7900805 days

Subtracting 15,009 years and 218.79 days from August 13, 3114 BCE places the tropical year on January 6, 18,123 BCE. Again, this may not seem significant at first glance. However, as the Brickers (V. Bricker and H. Bricker 1988) have demonstrated, the tables that follow the first Serpent Series on pages 63 –69 can be used to coordinate the tropical year with the New Year of the 365 day Haab' that begins with the twenty-day month Pop. Subtracting the introductory distance number from the Serpent Series from 4 Ajaw 8 Kumk'u, we can easily find the Haab' date within the Calendar Round:

5,482,135 days = 21,085 (260 days) + 35 days
Therefore: 4 Ajaw – 35 days = 8 Chikchan

= 15,019 (365 days) + 200 days
Therefore: 8 Kumk'u – 200 days = 8 Mol

A 218-day interval provides an interesting result. The day 8 Mol is 200 days before 8 K'umku, but it is also **218 day**s **before 1 Pop, the Haab' New Year**. Therefore, because the remainder of the Copán tropical year places the year some 218 days earlier, when we add 218 days to 8 Mol, we find that 1

Pop in 18,122 BCE would occur less than 1 day before the second solar zenith at 14.8º N latitude, where it appears on 4 Ajaw 8 Kumk'u. This positioning appears to be intentional, and it strongly suggests both that the new reading of the Serpent Series introductory distance number is accurate, and that a close approximation of the Copán tropical year continued to be used in the Dresden Codex. However, if the Serpent Series introductory distance number only intends to synchronize the Haab' and the tropical year, two significant points remain unexplained:

> 1) Why would the distance number cite a day 218 days earlier than the second solar zenith, rather than the exact day 1 Pop on the solar zenith itself?
>
> 2) If the Serpent Series were merely attempting to coordinate the Haab' with the tropical year, why wouldn't the table reference the most recent date prior to 4 Ajaw 8 Kumk'u when the second solar zenith fell on a day 1 Pop? This would have occurred 1,434 years earlier (347 day drift = 365 – 18; this synchronization again occurs only 72 years after Creation). Instead, the interval of 15,009 years is almost <u>ten</u> times the 1,508-year Haab'/tropical year cycle, that is, when 1 Pop occurs again on the same day in the tropical year.

The first question can be at least partially explained by the construction of the table following the first Serpent Series on pages 62-69. Using the Copán year in the Serpent Series distance number, we find a remainder of slightly more than 218 days—the same interval required to reach 1 Pop on the second zenith passage when the distance number of 15,009 years and 218 days is subtracted from 4 Ajaw 8 Kumk'u. The Brickers have shown that an interval of **218 days** is implicit within the seasonal table that follows the first Serpent Series. The two most prominent base dates used within the table are 3 Chikchan and 13 Ak'bal, and the shortest distance forward from a day 3 Chikchan to 13 Ak'b'al is in fact 218 days. The upper and lower seasonal tables on pages 65–69 are thus separated by this interval (V. Bricker and H. Bricker 1988:S16–24).

A sufficient astronomical explanation of the interval of 218 days within the mechanics of the tropical year remains unclear. One intriguing possibility arises in the interval between the second solar zenith passage and the vernal equinox. At 14.8° N latitude, this interval is very close to 219 days, depending on the position in the earth's elliptical orbit and the resulting variation in the speed of the earth and the length of the seasons.[8] Throughout the Classic period and into the Postclassic up to 1125 CE, the interval between the second solar zenith at 14.8° N and the vernal equinox as measured at <u>sunrise</u> is very nearly 218.79 days, the same remainder found when using the Copán year to calculate the tropical year in the Serpent Series introductory distance number.

---

[8] Kepler's second law of planetary dynamics holds that the earth moves faster in its elliptical orbit when it is closest to the sun at **perihelion**, and slower when it is the farthest at **aphelion**. Thus the four seasons, measured by the equinoxes and solstices, each differ slightly in length, and these lengths slowly vary over time. The earth's elliptical orbit is also slowly advancing forward relative to the fixed stars. In addition, the wobble of the earth's axis causes the sidereal year, or the position of the earth relative to the fixed stars, to also advance over the tropical year creating precessional drift. The result of these movements is the **anomalistic year**, measuring the earth's return to perihelion every 365.2596358 days. (United States Government Printing Office. The Astronomical Almanac for the Year 2000. Washington, DC: Navy Dept., Naval Observatory, Nautical Almanac Office, p. C1, 2000). The Maya were aware of the changing speed of the sun, and the Cakchiquel refer to the faster sun near the winter solstice as being carried by a deer, while the slower sun near the summer solstice is carried by peccaries (Thompson 1967:38, in Milbrath 1999:22).

Beginning at the moment of the second solar zenith at noon from 14.8º N latitude and counting forward 218 days and 18 hours (218.75 days) places the sun precisely due east at sunrise on the day of the vernal equinox. Perhaps this remainder is intentional. Might this be the meaning of both *y-ok'in* and *ah max k'in* in the first and second components of the introductory distance number? If a count begins at the moment of the solar zenith at noon, and concludes at <u>sunset</u> after the first distance number, and at <u>midnight</u> after the next, these may combine to create a remainder. Yet, if this interval is to be counted *forward* from the second solar zenith, then why would the distance number have us count 15,009 years and over 218 days backward from this point? This requires further explanation as we return to the second question outlined above.

A Note on Tzolk'in Base Days within the Serpent Series

While the Brickers recognize the 218-day interval between the two predominant base days 3 Chikchan and 13 Akb'al, they do not mention the other existing relationships between each of Tzolk'in base days used as entry points in the table of multiples. These intervals are relevant to the tropical year, as outlined in Table 1. As it operates within the seasonal table, it is likely that the 218-day interval between the Tz'olk'in base days of 3 Chikchan and 13 Ak'b'al originated to approximate the tropical year using an ideal second solar zenith at 14.8º N latitude and the vernal equinox as points of reference. As the actual interval is closer to 219 days, a one-day correction for the remainder may have been used. This would be similar to that used to calculate the 365 day Haab' from the 364 day-computing year, whose divisions into 91-day quarters form the basis of the tables of multiples in the Serpent Series. Additionally, the Brickers (1988) noticed the shorter distance between 13 Ak'bal and 3 Chikchan as an interval of 42 days. This interval approximates the number of days between the vernal equinox and the first solar zenith, or between the second solar zenith and the autumnal equinox at14.8° N latitude. Therefore if the second solar zenith falls on a day 3 Chikchan, the first solar zenith will fall 260 days later on the same day 3 Chikchan, thus demonstrating the effectiveness of using Tzolk'in calculations for determining positions in the tropical year at this latitude.

Indeed, the **39-day intervals** between the base days 3 Kimi to 3 Chikchan, and from 3 Chikchan to 3 K'an also appear to have a practical significance for the measurement of reference points within the tropical year at 14.8°N latitude. The perihelion has fallen closer to the December solstice during the past 2,000 years. Because the earth has been moving faster for three months on either side of the perihelion, a shorter interval of 39 days is very close to the distance between the autumnal equinox and the first solar nadir, and between the second solar nadir and the vernal equinox. The second component of the Serpent Series introductory distance number is precisely an interval of 39 days, and perhaps a remainder of 1/2-day indicated by *max-k'in*. If so, 39.5 days is very close to the interval between the equinoxes and nadirs at14.8°N latitude. Milbrath first suggested that the Maya were interested in the solar nadir, and Mendez et al. (2005) have confirmed the presence of architectural alignments with the position of the sun on the horizon at the solar nadir in Palenque's Temple of the Sun.

The remaining base day used in the Serpent Series seasonal table is 3 Ix, and this falls 91 days before 3 Chikchan. The seasonal table is expressed in terms of multiples of 91 days from each of the base dates, and this is a shortened interval between the cardinal points of the solstices and the equinoxes. From 3 Ix to 3 Kimi is 52 days, the very interval between the first solar zenith and the June solstice, and from the June solstice to the second solar zenith at 14.8 ° N latitude. Likewise, from 3 Ix to 3 K'an is 130 days, a half-Tzolk'in. This is an idealized interval between the second solar zenith at 14.8 ° N and the December solstice, and from the December solstice to the first solar zenith. A possible corrective mechanism appears here, given that three days added to 13 Ak'b'al returns us to 3 Kimi. Some of these intervals are one or two days over or under the required length, and with combinations of these intervals over time, the Maya could potentially predict the tropical year, the Haab', and the eclipse seasons over very long periods of time, and they appear to have done exactly that.

Here, it appears that the idealized latitude of 14.8° N was used in the Dresden Codex, though this manuscript itself appears to originate in the Yucatan, far north of this position. This usage suggests both that some of the records in the Dresden Codex were recopied from earlier measurements made at this idealized latitude, and that this specific latitude was utilized throughout Mesoamerica as the latitude at which the two zenith passages are exactly 260 days apart. As Malmström (1997:104, 179) has proposed, alignments to the azimuth position of sunset on August 13, both the zenith at 14.8° N and the Long Count Era Base date, occur throughout Mesoamerica.

The Brickers (1988) have suggested several ways in which multiples of 91 days were added to the base dates given in the Serpent Series as corrections made for the purposes of recycling the seasonal table on pages 65–69. The seasonal table contains inscriptions and iconographic references to positions in the tropical year, the Haab' and the eclipse seasons. The authors have applied a wide range of 91-day multiples to the base dates given until they reach the desired dates that conform to the configurations of the Haab', the tropical year, and the eclipse seasons as depicted in the seasonal table. However, the amount of correction for each base date is not explained, and it appears to be arbitrary. The conformity of the resulting dates to the configurations of the seasonal table is only partially successful. Further, the authors assume that each date provided in the entire Serpent Series is given for the same purpose of recycling the seasonal table in the same way.

Table 1: Intervals between Serpent Series Tzolk'in base days are as follows:

Base Days		Interval	Idealized Solar Position 14.8°N
3 Chikchan to 13 Ak'b'al	=	218 days	2nd Zenith to Vernal equinox (-1) Autumn Equinox to 1st Zenith (-1)
13 Ak'b'al to 3 Chikchan	=	42 days	Vernal equinox to 1st Zenith (+1) 2nd Zenith to Autumn Equinox (+1)
3 Chikchan to 3 K'an 3 Kimi to 3 Chikchan	=	39 days	Autumn Equinox to 1st Nadir 2nd Nadir to Spring Equinox
3 Ix to 3 Chikchan	=	91 days	Equinoxes to Solstices (±2) Solstices to Equinoxes (±2)
3 Ix to 3 Kimi	=	52 days	1st Zenith to Summer Solstice Summer Solstice to 2nd Zenith
13 Ak'b'al to 3 Kimi	=	3 days	correction?
3 K'an to 3 Chikchan 3 Chikchan to 3 Kimi	=	221 days	218 + 3 day correction
3 Ix to 3 K'an 3 K'an to 3 Ix	=	130 days	2nd Zenith to Winter Solstice Winter Solstice to 1st Zenith

While it is clear that the 91-day multiples are used for some kind of long range calculations using the 364-day computing year, it is my assertion that something else is occurring within the dates given in the Serpent Series, and that not all of these dates attempt to correct for a uniform commensuration of the seasonal table based solely on even intervals of 91 days. The five Tzolk'in days used to enter the table of multiples in the Serpent Series may allow for a series of standardized corrections that, when used either separately or multiplied together, would provide for accurate tracking of the tropical year, the Haab', and the eclipse seasons.

Given the tremendously long intervals found in the Serpent Series, we would expect there to be a more systematic approach to determining the long-term periodicities of each cycle. The patterns found within these long intervals may reveal the accuracy of the calculations used. The exact methods of correction may be difficult to ascertain, but the results given are informative. Instead of relying on unstated dates derived from assumed corrections, it may be possible to use the literal information given in the Dresden to determine the motivation for each date within the Serpent Series without assuming that each serves the exact same purpose. We return to an analysis of the Serpent Series dates after thoroughly exploring the meaning of the introductory distance numbers at hand.

The 9 K'an 12 K'ayab' Base Date and the Summer Solstice

Further confirmation of the use of the Copán tropical year can be found within the position of the Serpent Series base date on 9 K'an 12 K'ayab'. Recalling Beyer's (1943) calculations, the interval between 9 K'an 12 K'ayab' and the Long Count Era Base Date on 4 Ajaw 8 Kumk'u can be determined as follows:

Serpent Number:	**04.06.09.15.12.19**	**9 K'an 12 K'ayab' to 13 Ak'b'al 1 K'ank'in**
Long Count:	**– 10.06.10.06.03**	**4 Ajaw 8 Kumk'u to 13 Ak'b'al 1 K'ank'in**
Interval:	**03.16.03.05.06.16**	**9 K'an 12 K'ayab' to 4 Ajaw 8 Kumk'u**
	= 10,967,536 days	

As we have seen, this interval is almost exactly twice the introductory distance number of 5,482,135 days, with a curious difference of only 3,266 days:

2(5,482,135 days) = 10,964,270 days

10,967,536 days - 10,964,270 days = 3,266 days

Again using the Copán tropical year:

10,967,536 days = 30,028 (365.2419355 days) + 51.1607893 days

Subtracting this interval from the second solar zenith on August 13, 3114 BCE places 9 K'an 12 K'ayab' on June 22–23, 33,142 BCE, **exactly on the summer solstice**. Here, 52 days would be the ideal interval between the exact summer solstice and the second solar zenith at14.8º N latitude, depending upon the speed of the sun and the elliptical position of the earth in its orbit. An exact 52-day remainder would result using a slightly different tropical year of 365.2419076 days, though a 51.16-day remainder nevertheless produces a similar result, on or close to the summer solstice. This one-day difference may arise depending upon the method of correction, the method of measuring the solstice point, and at what intervals extra days are added.

On the other hand, if an exact remainder of 52 days to reach the summer solstice is the intention of the 9 K'an 12 K'ayab' base date, a tropical year of 365.2419076 days would still produce the same results using the Copán interval of 1,403,990 days = 3,844 tropical years. While in the Serpent Series introductory distance number of 5,482,135 days, it would produce a slightly larger remainder of 219.20 days. In either case, the highly precise calculation of the summer solstice over 30,000 years in the past appears to confirm the use of the Copán tropical year in the Dresden Codex. This suggests a continuous astronomical tradition inherited from the Classic Period, and the records in the Dresden itself suggest that it refers to observations during this period.

If 9 K'an 12 K'ayab' were calculated to represent the summer solstice, why was a seemingly random Haab' date chosen from over 30,000 years in the past when there were nearly twenty opportunities to find the summer solstice on the New Year 1 Pop in the intervening years? The day 1 Pop occurs 34 days after 9 K'an 12 K'ayab', and if this latter base date marks the summer solstice, 1 Pop would follow in late July, another seemingly arbitrary position in the tropical year. Perhaps something else might explain these choices.

Returning to the unanswered second question, if the Serpent Series were merely attempting to coordinate the Haab' with the tropical year, why wouldn't the table reference the most recent date prior to 4 Ajaw 8 Kumk'u when the second solar zenith fell on a day 1 Pop? Instead much longer intervals are cited. In the introductory distance number from the Serpent Series, we see that the day reached when this number is subtracted from 4 Ajaw 8 Kumk'u is 8 Chikchan 8 Mol. Using the Copán formula, this day falls on January 6, 218 days before the Haab' New Year on 1 Pop, less than one day before the second solar zenith. Apart from this relationship, and the use of the 218-day interval in the table itself, January 6 does not at first seem to be significant. If the Serpent Series were used only for synchronizing the tropical year and the Haab', why wouldn't smaller distance numbers on the order of 1,500 years have been used to place 1 Pop as the endpoint on the second solar zenith? Instead, the distance number references an interval of over 15,000 years. In the case of 9 K'an 12 K'ayab', the resulting interval is over 30,000 years. As Milbrath (1999:259) has proposed, such vast periods of time suggest one of the slowest recognizable astronomical cycles: the precession of the equinoxes.

Precession in the Serpent Series

For purposes of review, the new reading proposed here for the introductory distance number in the Serpent Series is:

15,228 Tuns + 16 days + 39 days	**= 5,482,135 days**
Mean tropical years	**= 15,009 (365.24219 days) + 214. 9703 days**
Copán tropical years	**= 15,009 (365.2419355 days) + 218.79008 days**

Using the current rate of one day of precession in 25,772 days as a theoretical constant in combination with a constant current value for the mean tropical year, the complete distance number of 5,482,135 days in the past gives a precessional drift of 212.7167 days forward in the tropical year, while using a rate of one day of precession in 25,700 years gives a drift of 213.3126 days:

5,482,135 days = 212.7167081 (25,772 days) = 213.3126459 (25,700 days)

The amount of sidereal drift due to precession over this time period is almost exactly equivalent to the shift in the current mean tropical year, but in the opposite direction. A subtraction of the Serpent Series introductory distance number from 4 Ajaw 8 Kumk'u would theoretically place the sun in almost exactly the same sidereal position in Virgo as it appears on August 13, 3114 BCE. At the same time, the position in the tropical year would shift backwards by 215 days, using the current value of the mean tropical year as a constant.

Back calculation gives a precessional drift such that the same sidereal position of the sun will be reached earlier in the year. A 213 day precessional shift is remarkably similar to the 215 day shift reached using the current value of the tropical year, indicating that in the interval specified by this distance number, almost exactly the same sidereal position is theoretically reached, but here it has shifted 215 days earlier in the tropical year. Likewise, using this interval to count forward in time would theoretically produce the same sidereal position of the sun in Virgo, while shifting the tropical year forward by 215 days.

Regardless of any differences between the current value of the mean tropical year and the value apparently used by the Maya, the Serpent Series introductory distance number demonstrates a remarkably accurate calculation of the sidereal year, in which the sun appears to return to the same position relative to the stars. Using the current value for the sidereal year as a constant 365.256363 days shows an apparent error of only two days:

5,482,135 days = 15009(365.256363) + 2.247751132 days

To illustrate this, we begin with the sidereal position of the sun on Virgo on August 13, 3114 BCE, the second solar zenith at 14.8°N (**Figure 3.5a**). Counting backward by 5,482,135 days, using the current value of the mean tropical year (as a constant 365.24219 days), we reach January 10, 18,123 BCE. On this day, the sun is only two days prior to being in the exact same sidereal position in Virgo (**Figure 3.5b**).

If, as it seems, the Maya were using the Serpent Series distance number to determine an exact whole number interval of sidereal years, the value they used for the sidereal year can be determined by dividing the distance number by 15,009 whole sidereal years:

5,482,135 days = 15,009 sidereal years

$$\frac{\textbf{5,482,135 days}}{\textbf{15,009 sidereal years}} = \textbf{365.2565128 days = 1 Maya sidereal year}$$

Compared with the current accepted value of the sidereal year of 365.256363 days, this value produces an error of only one day in 6,676 years. Again, calculations of the sidereal year over periods of many thousands of years are theoretical even by current standards. Regardless, it appears that the Maya obtained a value for the sidereal year amazingly close to the current value, and they would have understandably used this as a constant. This would explain the extremely long distance numbers cited within the Serpent Series. If this is the case, the Maya calculation of the sidereal year is indeed an unprecedented accomplishment in human history. As with the value for the tropical year, a more accurate value of the sidereal year was not calculated until the work of Tycho Brahe and Johannes Kepler in the late sixteenth and early seventeenth centuries (Meeus and Savoie 1992:41; Evans 1998:282).

When combined with the value of the Copán year, the Maya sidereal year provides a specific rate of precession, and the length of the resulting cycle of precession used in this calculation can be determined by dividing the Copán year by the difference between the Maya sidereal year and the Copán tropical year:

Maya sidereal year = 365.2565128 days

Copán tropical year = 365.2419355 days

$$\begin{array}{r} 365.2565128 \text{ days} \\ \underline{-365.2419355 \text{ days}} \\ 0.0145773 \text{ days precession per Copán year} \end{array}$$

Rate of precession = 0.0145773 days/Copán year

$$\frac{365.2419355 \text{ days}}{0.0145773 \text{ days/ year}} = 25{,}055.52712 \text{ Copán tropical years}$$

Because the length of the Copán year differs slightly from the current mean tropical year, the length of the cycle of precession according to these calculations, 25,055.53 years, is somewhat less than the current accepted value of 25,772 years. In Europe, a more accurate value was not proposed until the work of Brahe in the late sixteenth century (Evans 1998:282). Indeed, if the sidereal year apparently calculated by the Maya is combined with the current value of the mean tropical year, an even more accurate result for the precessional cycle is obtained. A value for the cycle of precession of 25,500.75 years is determined by dividing the current mean tropical year by the difference between the Maya sidereal year and the current mean tropical year:

Maya sidereal year = 365.2565128 days

Current mean tropical year = 365.24219 days

$$\begin{array}{r} 365.2565128 \text{ days} \\ \underline{-365.24219 \quad \text{ days}} \\ 0.0143228 \text{ days precession per mean tropical year} \end{array}$$

Rate of precession = 0.0143228 days/mean tropical year

$$\frac{365.24219 \text{ days}}{0.0143228 \text{ days/ year}} = 25{,}500.75334 \text{ mean tropical years}$$

Given the accuracy in the apparent Maya calculation of the sidereal year, it seems likely that the Serpent Series introductory distance number was intended to place the sun in the exact same sidereal position in Virgo where it was on the Era Base date in 3114 BCE. The number of days of precessional drift within this distance number of some 15,009 years would thus be equivalent to the 218.79-day remainder resulting from the use of the Copán tropical year. This calculation constitutes the clearest indication that the Maya had discovered the phenomenon of precessional drift. The equivalence between the 218.79 day remainder and the number of days of precessional drift in one interval of the Serpent Series introductory distance number can be stated as follows, using the value of 0.0145773 days of precesion per Copán tropical year:

S.S.D.N. = 5,482,135 days = 15,009 Copán years + 218.79008 days

Days of precession = 15,009 years (0.0145773 days/ year) = 218.79 days

If the Serpent Series distance number serves to place the sun in the exact same sidereal position, while the tropical year has shifted by some 218–219 days, this would help to explain this unusual remainder. Subtracting the distance number from 4 Ajaw 8 Kumk'u places the tropical year some 218 days prior to the second solar zenith. The day reached would be 8 Chikchan 8 Mol on January 6, 18,123 BCE. According to the Maya calculation, on this day, the sun would theoretically appear in the exact same sidereal position in Virgo as it did on the Era Base date. This date can be reconstructed, based on what we can assume the Maya were attempting to calculate (**Figure 3.6**). It must be stated that the following hypothetical reconstructions do not intend to show actual current projections for these dates, which would use non-constant theoretical rates for both the tropical and sidereal years, and for the length of a day. The sidereal differences between the current measurement and the Maya measurement are only very slight, but the differences in the projected tropical year are increasingly larger over time. The aim here is to visualize the internally consistent results of the calculations that the Maya determined, based on their evident theoretical constants. We have already discussed the accuracy of these calculations, and it would be possible to further compare these dates with current astronomical theory, but that is not the intention here.

Adding 218 days to 8 Chikchan 8 Mol brings us to the Haab' New Year 1 Pop, very close to the second solar zenith[9] in 18,122 BCE (**Figure 3.7a**), but the sidereal position of the sun on this date was in the exact position where the sun was on the vernal equinox in 3114 BCE.

As explained above, 218.79 days is a near ideal interval between the second solar zenith at14.8° N latitude and the vernal equinox. This is compelling, particularly given that the sidereal position of the vernal equinox in 3114 BCE is very close to the Pleiades, which are found at an azimuth near 0° in this year, on the celestial equator that defines the position of the equinoxes (**Figure 3.7b**). Because the sun would be just emerging from conjunction with the Pleiades at this time, this would correspond to the first appearance of the Pleiades, due east on the horizon in the morning.

---

[9] Because of a remainder of 218.79 or 219 days using the Copán tropical year, the actual second solar zenith could theoretically be on 2 Pop. We will explore this slight discrepancy further.

The Pleiades are widely known as an important calendrical reference throughout the world, and particularly in Mesoamerica. For much of Maya history, the disappearance and reappearance of the Pleiades following its conjunction with the sun has coincided with the planting season (Milbrath 1999:258). From Postclassic accounts and into the present, the Yucatec Maya referred to the asterism of the Pleiades as *tz'ab'*, the rattle of a rattlesnake, and in her discussion of the possible function of the Serpent Series, Susan Milbrath (ibid:258–259) proposed that the use of serpent imagery is suggestive of the Pleiades, while the long periods involved in the tables evoke the precession of the equinoxes. The evidence for an awareness of precession by the Maya suggests that she may be correct on both counts.

The Pleiades itself may have been used to determine the sidereal year. In addition, the Pleiades crossed the zenith at14.8° N latitude from 350–200 BCE. While it is difficult to determine whether the knowledge of precession existed among the inventors of the Long Count in the first centuries BCE, the Pleiades were close to an azimuth of 0° on the celestial equator in 3114 BCE, rising due east and setting due west. It is conceivable that this very year of Creation was chosen for this particular reason. Because of the accurate calculations of the sidereal year found in the Serpent Series, it would seem that, by the time the Dresden Codex was written in its final form, the Maya of the Postclassic almost certainly understood the position of the Pleiades in alignment with the vernal equinox in 3114 BCE.

The Serpent Series distance number seems to coordinate the tropical year, the Haab' and the precession of the equinoxes in one elegant formula. The smaller second component of the distance number, set aside as 39 days, also appears to be significant, in that when the first component of the distance number is subtracted, it reaches the exact sidereal position of the autumnal equinox in 3114 BCE in Scorpius (**Figure 3.8**). This position is 39 days forward from the destination point at the sidereal position of the future second solar zenith. In 3114 BCE, an exact interval of 39 days happens to separate the second solar zenith at 14.8º N latitude from the autumnal equinox. However, throughout most of the Maya historical period, this interval was farther from the perihelion and slightly longer, and again, an additional fraction of a day may be indicated by the unusual presence within this 39-day interval of *ah max-k'in* (see the discussion of quarter days above).

As we have seen, the 39-day period that is intrinsic to the seasonal table is best suited for the interval between the nadirs and the equinoxes during most of Maya history. When the Serpent Series introductory distance number is counted forward, we see how this 39-day period becomes important.

Hypothetically beginning on 4 Ajaw 8 Kumk'u on August 13, 3114 BCE and counting forward using the first component of the Serpent Series distance number of 15,228 Tuns and 16 days, we arrive 179 days forward in the tropical year, on February 8, 11,897 CE, the exact day of the second solar nadir at 14.8º N latitude, but approaching the western edge of Virgo (**Figure 3.9a**). Here, the meaning of *y-ok'in* as evening may relate to the measurement of the position of solar nadir at either sunset, or at the precise moment of the nadir at midnight.

Adding the 39 days of the second part of the distance number, and perhaps another half day indicated by the *ah-max-k'in* to February 8, 11,896 CE, we reach the vernal equinox on March 19, 11,897 CE (**Figure 3.9b**). Here the sun would be in the exact sidereal position in Virgo as it was on August 13, 3114 BCE.

Effectively, with the addition of the Serpent Series introductory distance number, the sidereal position of the sun on the second solar nadir becomes the position of the sun on the vernal equinox. I believe the original purpose of this distance number was to be added forward in this way, from the point of the second solar zenith to the vernal equinox, placing the sun on both dates in the same sidereal position.

The same is true if we were to begin on the second solar zenith in 18,122 BCE, near the Pleiades in Taurus (**Figure 3.7a**), and count forward to the vernal equinox in 3114 BCE, again with the sun on both dates in the same sidereal position (**Figure 3.7b**).

Returning to the hypothetical count forward from August 13, 3114 BCE to March 19, 11,897 CE, we find that the Calendar Round reaches a day 13 Men 3 Yax and this is curiously the exact Haab' half-year. The Brickers (1988) noticed that the Haab' half-year is integral to the seasonal tables, and it was thus recognized by the Postclassic Maya. With the Haab half-year on the vernal equinox, the New Year at 1 Pop would be on or very near the autumnal equinox in this year.

The 13 Mak Base Date

The Serpent Series introductory distance number continues beyond 4 Ajaw 8 Kumk'u in the two inscriptions on page 61 and page 69 of the Dresden Codex. From page 69 (**Figure 3.10**), the inscription of the introductory distance number up to 4 Ajaw 8 Kumk'u is highlighted in blue. Beyond this, the inscription continues in block A11 with **5-ta-li** (TV:0552v:24). The word *tal* is an ordinalizer (Stuart 1989), and the most likely reading of this phrase is *ho' tal* 'fifth time'. This is followed by **ta-b'a** (T59:501), which reads *tab*', meaning 'tie'. Harvey Bricker and Victoria Bricker (1983:12; 1988:S7) have proposed that this collocation signifies addition. Yet another distance number follows in A12 as 1 Piktun and 3 Winals, with each numeral followed by the unusual rattlesnake rattle glyph (T207). Milbrath (1999:259) suggests T207 reads **TZAB'** as a reference to the Pleiades in the Serpent Series. Earlier, the Brickers (1988:S7) suggested that, in the context of the Serpent Series distance number, T207 as **TZAB'** connotes an addition following a subtraction, since *tzab'* is 'to gain, recover' in Yucatec. However, T207 is read in the Classic inscriptions as **OCH** 'enter' (Stuart 1998:387f). While the context here does suggest some kind of a mathematical operation, I contend in the upcoming chapter that T207 here reads *hoch* 'to remove' and 'to untie', indicating subtraction.

I will discuss a rationale for the interpretation of T207 and the 1 Piktun 3 Winal distance number in the following chapter. In the meantime, a reading of *ho tal* 'five times' suggests that the original introductory distance number is to be multiplied five times. When we multiply the original distance number, we have:

15,228 Tuns + 55 days = 5,482,135 days

5 (5,482,135 days) = 27,410,675 days = 76,140 Tuns + 275 days

Beginning on 4 Ajaw 8 Kumk'u and adding this vast distance number, we reach a day 13 Mak:

75,097 Haab' + 270 days
8 Kumk'u + 270 days = 13 Mak

Looking further down the inscription in block A17, following the date 9 K'an 12 K'ayab', the exact date 13 Mak appears. This supports the idea that the initial distance number is indeed multiplied five times and added to the Creation date 4 Ajaw 8 Kumk'u to reach this Haab' date. No other explanation for this Haab' date is evident.

If we are to understand the Serpent Series introductory distance number as providing the <u>same</u> theoretical sidereal position in Virgo <u>each</u> time it is added, while the tropical year moves forward some 218-219 days, we see that when this distance number is multiplied five times, not only is the same sidereal position reached, but we also return to almost exactly the same position in the tropical year. Using the Copán year:

5 (5,482,135 days) = 27,410,675 days
= 75,048 (365.2419355 days) – 1.775 days

It is possible that the Maya were using a slightly different value for the tropical year that would give them a 219-day remainder in one addition of the introductory distance number of 5,482,135 days. Multiplying the introductory distance number by five, we would reach an even interval of the tropical year, because five times the remainder of 219 days is very close to a whole number of tropical years:

5 x 219 days = 1,095 days = 3 x 365 days

Assuming that the Maya intended 27,410,675 days as an <u>exact</u> interval of the tropical year, the value for the tropical year used would be:

$$\frac{\mathbf{27{,}410{,}675\ days}}{\mathbf{75{,}048\ tropical\ years}} = \mathbf{365.2419118\ days/tropical\ year}$$

This tropical year provides very similar results for all of the previous calculations, including the Copán year calculation that Teeple proposed. In either case, the elegance of this calculation suggests that the Maya were coordinating the tropical year with the cycle of precession, in that adding five times the Serpent Series introductory distance number to 4 Ajaw 8 Kumk'u brings us to a day 13 Mak that returns both to the second solar zenith on August 13, 71,935 CE, and to the exact same sidereal position in Virgo.

Precession and the 9 K'an 12 K'ayab' date

Doubling the Serpent Series distance number and subtracting it from the day of Era Base date on August 13, 3114 BCE would again theoretically place the sun in the same sidereal position in Virgo, while the Copán tropical year would drift twice the interval of 15,009 years and 218.79 days earlier. The terminal position of the tropical year can then be easily determined:

218.79 days + 218.79 days = 437.58 days
= 365.2419355 days + 72.338 days

30,019 years and 72 days earlier than August 13, 3114 BCE falls on June 2, 33,133 BCE, a seemingly insignificant day in the tropical year, save for the fact that the same sidereal position in Virgo is again theoretically reached. Yet, as we have seen, the Serpent Base Date 9 K'an 12 K'ayab' falls another 3,266 days earlier, equivalent to 8 tropical years and 344 days prior to June 2, bringing us to a position about 20-21 days later within the topical year, or 51-52 days earlier than the second solar zenith, depending on the exact value used. As we have seen, this position would fall on the summer solstice on June 22, 33,142 BCE. But here the sidereal position of the summer solstice would appear in Libra on an irregular day 9 K'an 12 K'ayab' (**Figure 3.13a**).

However, when we examine the theoretical sidereal position of 9 K'an 12 K'ayab' in Libra, some 20-21 days forward from the sidereal position of the Creation in Virgo, we see an interesting parallel with the sidereal position of 1 Pop in 3114 BCE, the year of Creation. The day 8 Kumk'u is exactly 18 days before the day 1 Pop. Using the Copán year and the proposed sidereal year, counting backward 18 days from 9 K'an 12 K'ayab' on the summer solstice in June of 33,142 BCE, the sidereal position of the sun is only three days forward from its position in Virgo on the Era Base date, August 13, 3114 BCE. While 9 K'an 12 K'ayab' is a close approximation of the sidereal position of 1 Pop in 3114 BCE, this does not explain the above three day discrepancy, unless some of the estimates for Maya values of the tropical or sidereal year are in error.

Eighteen days prior to 9 K'an 12 K'ayab' is 4 Kimi 14 Pax, another seemingly arbitrary day, but the day just before that is **3 Chikchan 13 Pax**. Given that 3 Chikchan is the predominant Tzolk'in day used in the Serpent Series tables, it is possible that this was of interest in the calculation. Furthermore, the day 13 Pax appears twice within the Serpent Series—once as a terminal date of a Serpent number on page 61, column D, and once on page 70 in a series of unusual Haab' dates that includes 13 Pax, 0 Pop, and13 Yaxk'in (**Figure 3.11**). Finally, the number 19 appears in block A16 at the very bottom of the inscription on page 61 (**Figure 3.12**), just prior to the date 9 K'an 12 K'ayab', and this may refer to a count 19 days before to 3 Chikchan 13 Pax. As we shall see in the following chapter, the **OCH** (T207) rattle glyphs that appear here after the number 19 suggest subtraction. Yet, again, a 19-day interval would provide a two-day difference from the sidereal position of Creation in Virgo, 21 days earlier than 9 K'an 12 K'ayab'. Nevertheless, the day 3 Chikchan 13 Pax may have provided a point of reference with both the Tzolk'in base day 3 Chikchan and the Haab' day 13 Pax.

Returning to the set of three Haab' dates from page 70 (**Figure 3.11**), a day 13 Pax is 52 days prior to 0 Pop, the last day of the Haab'. As shown above, this is the idealized interval between the June summer solstice and the second solar zenith at 14.8º N latitude. If 13 Pax fell on the summer solstice, the day 0 Pop would fall on the second solar zenith at 14.8º N. From the Dresden New Years pages which follow the Serpent Series, it is apparent that the Maya reckoning of the New Year included *both* the last day of the Haab' on 0 Pop, <u>and</u> the first day of the New Year on 1 Pop, on the latter of which only the year-bearers Ak'b'al, Lamat, B'en and Etzn'ab' can fall (Thompson 1972:89). It is therefore possible that the zenith passage and other points in the tropical year were observed over two days for the sake of precise measurements that shift slightly with the leap year.

A count forward 133 days from 0 Pop on the second solar zenith at 14.8° N would reach very close to the winter solstice on 13 Yaxk'in. Along with these three Haab' dates appears the Tzolk'in day Ajaw, with a coefficient of 10 to the left and 8 above. Beginning on a day 10 Ajaw 13 Pax on the summer solstice and subtracting 180 days, we reach a day 8 Ajaw 13 Yaxk'in, close to the winter solstice. Thus, these two dates, together with 0 Pop on the August 13 second solar zenith, appear to be idealized Haab' intervals for the Long Count Creation latitude at 14.8° N.

These ideal positions of the Haab' are very nearly reproduced in the year 18,123 BCE, after one interval of the Serpent Series distance number is subtracted from the Era Base date in 3114 BCE. As we have seen, the second solar zenith in 18,123 BCE is close to the Haab' New Year on 1 Pop. Likewise, 13 Pax would fall close to the summer solstice in this year, and 13 Yaxk'in would be near the winter solstice, only 15 days earlier than the day 8 Chikchan 8 Mol that is reached by the distance number, which places the sun in the same sidereal position of the Virgo Creation date. Even here, these ideal intervals may be up to two days off, given that the interval between 8 Mol and 0 Pop is only 217 days, whereas the actual interval to reach the second zenith seems to be almost 219 days, the ideal interval between the second zenith and the vernal equinox. Nevertheless, the close correspondence certainly seems relevant here.

If 9 K'an 12 K'ayab' falls on the summer solstice, the Maya seem to have been referencing the 19-day difference between this day and the idealized day of the summer solstice on 13 Pax. In fact, in the year of the base date 9 K'an 12 K'ayab', 33,142 BCE, the day 0 Pop falls exactly 19 days before the second solar zenith at 14.8° N on August 13. Thus, it appears that the idealized Haab' is 19 days earlier than the tropical year at the time of the 9 K'an 12 K'ayab' base date.

But why would the Maya have chosen this configuration, and not a date only 76 years later when 13 Pax falls exactly on the summer solstice and 0 Pop falls on the second solar zenith at 14.8° N latitude? If they were attempting to place 9 K'an 12 K'ayab' in the sidereal position of 0 or 1 Pop in 3114 BCE, why not specify an interval of 17 or 18 days, rather than 19 days to 13 Pax, or 20-21 to the sidereal position of the Creation? Why would the Maya have chosen the summer solstice when it fell in Libra, some 20-21 days after the sidereal position of the Creation in Virgo?

One reason the unusual date 9 K'an 12 K'ayab' was chosen may have to do with the usefulness of this base date as relevant for <u>another</u> latitude. While the solstices and equinoxes are the same regardless of location, the date of the zeniths and nadirs change depending on the latitude at which they are measured. The Dresden Codex itself is a Postclassic document, and the cities of the Postclassic, such as Chichen Itza, Mayapan, and even the more southerly Tayasal, are found far north of the idealized 14.8° N latitude implicit within the August 13 Era Base date of the Long Count. Ideal dates for solar zeniths and nadirs at14.8° N latitude can be found in the Dresden Codex and throughout Mesoamerica, even though most sites were not located this far south. Malmström

(1997:104, 179) has found multiple architectural alignments to solar azimuth positions corresponding to August 13 as far north as Teotihuacan in the Central Valley of Mexico, and Edzná in the Yucatan, though the second solar zenith does not occur on this date in this region. The Long Count Era Base date alone and the use of the 260-day calendar make the 260-day interval between the two zeniths at 14.8° ideal. But local dates for zeniths and nadirs were also inevitably recognized, and the differences between the local and ideal zeniths and nadirs must have been well known for each site.

Perhaps, then, the 9 K'an 12 K'ayab' base date is a local reconfiguration of a base date which implies another latitude. Indeed, in the year 33,142 BCE, the day 1 Pop follows 34 days after the June solstice on 9 K'an 12 K'ayab'. This would place 1 Pop exactly on July 26, the second solar zenith at 19.5° N latitude in the Yucatan. From Landa, we learn:

> The first day of the year for these people was always on the sixteenth of our month of July and on the first of their month of Pop (Pagden 1975:107).

The date July 16 in the Julian calendar corresponds to the Gregorian date July 26 in the mid-sixteenth century, and Juan Pío Perez (1864) tells us that the solar zenith was the very reason for the date of the New Year. Because the Haab' proceeds as a 365-day cycle without a leap year, it drifts back from the tropical year by one day about every four years. Coincidentally, just after the Spanish arrived in the mid-sixteenth century, the Haab' New Year 1 Pop also fortuitously fell on July 26. Malmström (1997:136–138) noticed that the Maya site of Edzná is found precisely at 19.5° N latitude in the Yucatan, and he proposes that the second zenith passage at this site is the likely origin of the July 26 New Year. He further suggests that the Haab' itself was created at this site in 48 CE, the last time 0 Pop fell on this date, though there is little evidence for this, and it is not likely that July 26 was universally recognized as the New Year throughout all sites in Maya history.

The day1 Pop occurs on July 26 in the year of the base date 9 K'an 12 K'ayab', and it is possible that the Dresden Codex was recorded at a site where July 26 was the second solar zenith. The last day of the Haab' on 0 Pop falls exactly on July 25 in the year of the 9 K'an 12 K'ayab' base date, and the above interval of 19 days is the <u>exact</u> interval between July 25 and the idealized August 13 zenith at 14.8° N latitude. This would explain the prevalence of the 19-day interval and thus we find the idealized 13 Pax exactly 19 days before the summer solstice on 9 K'an 12 K'ayab'. The day 12 K'ayab' then appears to be an idealized summer solstice, which places 1 Pop on the second solar zenith at 19.5° N latitude.

But if 9 K'an 12 K'ayab' was chosen to coordinate the Haab' New Year with the second solar zenith at 19.5° N latitude, then why was this particularly remote year chosen, when twenty other such alignments occur in the intervening years between 33,142 BCE and 3114 BCE? It is apparent that such vast intervals of time in the Serpent Series were selected to represent intervals of sidereal precessional drift. In the case of the 9 K'an 12 K'ayab' base date, what is the possible significance of placing the summer solstice in a specific sidereal position in Libra? As we have seen, using the value we have determined for the Maya sidereal year, the position of 9 K'an 12 K'ayab' in Libra is two to three days later than the sidereal position of 1 Pop in 3114 BCE, and farther still from the sidereal position of 0 Pop. A one-day difference between the date 1 Pop and the second zenith passage occurs in the year 18,123 BCE, after subtracting a single interval of the Serpent distance number, and in the 9 K'an 12 K'ayab' the same error would be twice this amount. Using a slightly different calculation of the sidereal year and the tropical year may be the source of these discrepancies, but this would alter the previous calculations of the sidereal year used within the Serpent Series initial distance number in the following way:

The interval between 9 K'an 12 K'ayab and 4 Ajaw 8 Kumk'u is 10,967,536 days. The day 1 Pop is 18 days after 8 K'umku in 3114 BCE. If we add 18 days to the interval of 10,967,536 days, with the intention of reaching a whole interval of the sidereal year, the sidereal year used would actually be an even more accurate 365.2564026 days:

10,967,536 days + 18 days = 10,967,554 days = 30,027 (365.2564026 days)

However, when this value of the sidereal year is used in the Serpent Series introductory distance number of 15,228 Tuns + 55 days, the position reached would be 1.65 days earlier than the same sidereal position. Therefore, if this distance number is subtracted from 4 Ajaw 8 Kumk'u, we reach a position 1.65 days before the sidereal position of the sun in Virgo on the Era Base date. Adding 218 days to reach 1 Pop then places the sun about five days before the sidereal position of the vernal equinox in 3114 BCE. This discrepancy challenges the proposed purpose of the Serpent Series introductory distance number as a whole interval of the sidereal year. The error would be even greater if we add an interval of only 17 days to mimic the difference between 8 Kumk'u and 0 Pop. For parsimonious reasons it seems more likely that something else is going on with the selection of the 9 K'an 12 K'ayab' sidereal position.

Perhaps the sidereal position of 9 K'an 12 K'ayab' in Libra was chosen for local reasons, both in space as well as in time. During the Postclassic, this exact sidereal position in Libra was close to the position of the sun on November 2, the ideal first solar nadir at 14.8° N latitude, from about 1000 to 1200 CE (**Figure 3.13b**). The latest dates mentioned within the text suggest that the Dresden Codex was written precisely during this time period, and many of the Serpent Numbers thus coordinate this 9 K'an 12 K'ayab' position with comparable dates in the Postclassic. The base date 9 K'an 12 K'ayab' on the June solstice would then seem to coordinate the tropical year with an idealized sidereal position of the first solar nadir at 14.8° during the Postclassic, while at the same time, the Haab' New Year 1 Pop would follow 9 K'an 12 K'ayab' on July 26, 33,142 BCE, the second solar zenith at 19.5° N latitude.

But if the sidereal position of the sun in Libra on 9 K'an 12 K'ayab' represents the sidereal position of November 2 as the idealized first solar nadir at 14.8° N in the Postclassic, it still does not fully explain the choice of this sidereal position. Apart from representing a specific time period in the Postclassic when the Dresden may have been written, what is significant about the first solar nadir occuring in this specific sidereal position in Libra that would prompt the authors of the Serpent Series to choose this position and the first solar nadir as important?

If we look at the exact sidereal position of the sun in Libra on 9 K'an 12 K'ayab', the June solstice in 33,142 BCE, we can see that it is almost directly opposite the Pleiades in the sky at this time. We can see this by adding exactly half of a tropical year to reach the December solstice in this year, reaching the point at which the Pleiades have first disappeared in the evening as the sun moves toward conjunction with them (**Figure 3.14a**). An identical configuration appears on April 30, the first solar zenith at 14.8º N latitude in 1100 CE. Such a precise position of the first invisibility of the Pleiades may reflect one of the ways in which the Maya calculated the sidereal year.

But when the sun appears in Libra on 9 K'an 12 K'ayab, a similar phenomenon occurs. After the sun sets and the sky darkens, the Pleiades are immediately visible, rising at opposition on the eastern horizon. In fact, this is close to what would be the last day on which this would occur (**Figure 3.14b**). On the following days, the Pleiades have already risen above the horizon by the time the sky is dark enough to observe them. This may have been another accurate means by which to calculate the sidereal year, utilizing the sidereal position of the sun in Libra as it appears on the 9 K'an 12 K'ayab' base date.

The Pleiades were of particular significance for astronomical observations, and the Maya are known to have made careful observations of the disappearance and reappearance of the Pleiades (Milbrath 1999:258). The vernal equinox in 3114 BCE closely corresponds to the first morning appearance of the Pleiades following conjunction with the sun, and this is also the case with the second solar zenith and the Haab' New Year after a single interval of the Serpent distance number is subtracted from the Creation date. We also see this same sidereal position on the first solar zenith at 19.5° N in May of 1100 CE, some 19 days after the solar zenith at 14.8° N (**Figure 3.14c**). In fact, from the Late Classic period into the Postclassic, the Pleiades would have been very close to the zenith at 19.5° N.

We learn from Bernardo Sahagún that every 52-year Calendar Round, the Aztec new fire was rekindled at the moment the Pleiades crossed the zenith at midnight (Anderson and Dibble 1953). It is quite possible that the Maya also used this auspicious event in the Postclassic as their desired sidereal position for the 9 K'an 12 K'ayab' base date. Jenkins (1998:73–84) proposes that the Postclassic Maya at Chichen Itza were observing the midnight passage of the Pleiades to determine the exact time six months later when the sun would be nearly in alignment with the Pleiades on the first solar zenith. He further suggests that the close observations of the Pleiades every Calendar Round were used to track precession as they were coordinated with the tropical year and the sidereal movement of the zenith. But because it may be difficult to accurately determine the exact point of midnight, two more elements are needed for precise calculations of the zenith position exactly opposite the nadir sun—a lunar zenith and a lunar eclipse.

Barbara Tedlock (1992:189) informs us that the K'iche' Maya in the highlands of Guatemala calculate the time of the solar nadir by noting when the full moon is at the zenith. However, because the path of the moon is inclined by approximately 5° with respect to the path of the ecliptic, and because the phase of the moon is not synchronized with the tropical year, an exact solar nadir will rarely correspond to an exact lunar zenith of the full moon. But a total lunar eclipse close to the day of the solar nadir will place the full moon at the zenith, creating a full lunar zenith. Furthermore, during the Postclassic when the first solar nadir at 14.8° N occurred opposite the Pleiades in the sidereal position of Libra, a total Lunar eclipse would occur on the ecliptic very close to the Pleiades. Along with horizon positions of the sun and moon, the exact zenith of the moon on the night of a total lunar eclipse could be measured using a zenith tube or gnomon, and this would reveal the precise sidereal position of the zenith. Over long enough periods of time, a series of such total lunar eclipses at the zenith could be used to precisely track precessional drift, and this is exactly what the Maya seem to have accomplished.

It is quite possible that lunar eclipses at the first zenith near the Pleiades were used to calculate precessional drift, much as Hipparchus used the shift in the sidereal position of eclipses near the vernal equinox. Having demonstrated that the Serpent Series introductory distance number and the 9 K'an 12 K'ayab' base date both incorporate commensurations of the sidereal year, the tropical year, and the Haab', it is possible that they may additionally contain specific intervals concerning the synodic, sidereal and eclipse cycles of the moon that were utilized in the calculations of precessional drift. The use of lunar Pawahtuns within the Serpent Series distance number suggests a reference to the moon. We begin the next chapter with a re-examination of this theme.

Thus far, the unusual 9 K'an 12 K'ayab' base date may have been chosen based on the following criteria:

1) Tropical Year: the summer solstice in June of 33,142 BCE

2) Haab': 1 Pop at the second solar zenith at 19.5º N latitude in 33,142 BCE

3) Sidereal position:

- the ideal first solar nadir at 14.8º N in 1100 CE
- opposite the Pleiades:
    - Pleiades are last visible rising <u>at the horizon</u> after sunset on 9 K'an 12 K'ayab'
    - first solar zenith in May at 14.8º N in 1100 corresponds to the last evening visibility of the Pleiades
    - Pleiades are at the zenith at 19.5º N in the Postclassic

4) Possible **Lunar** calculations.

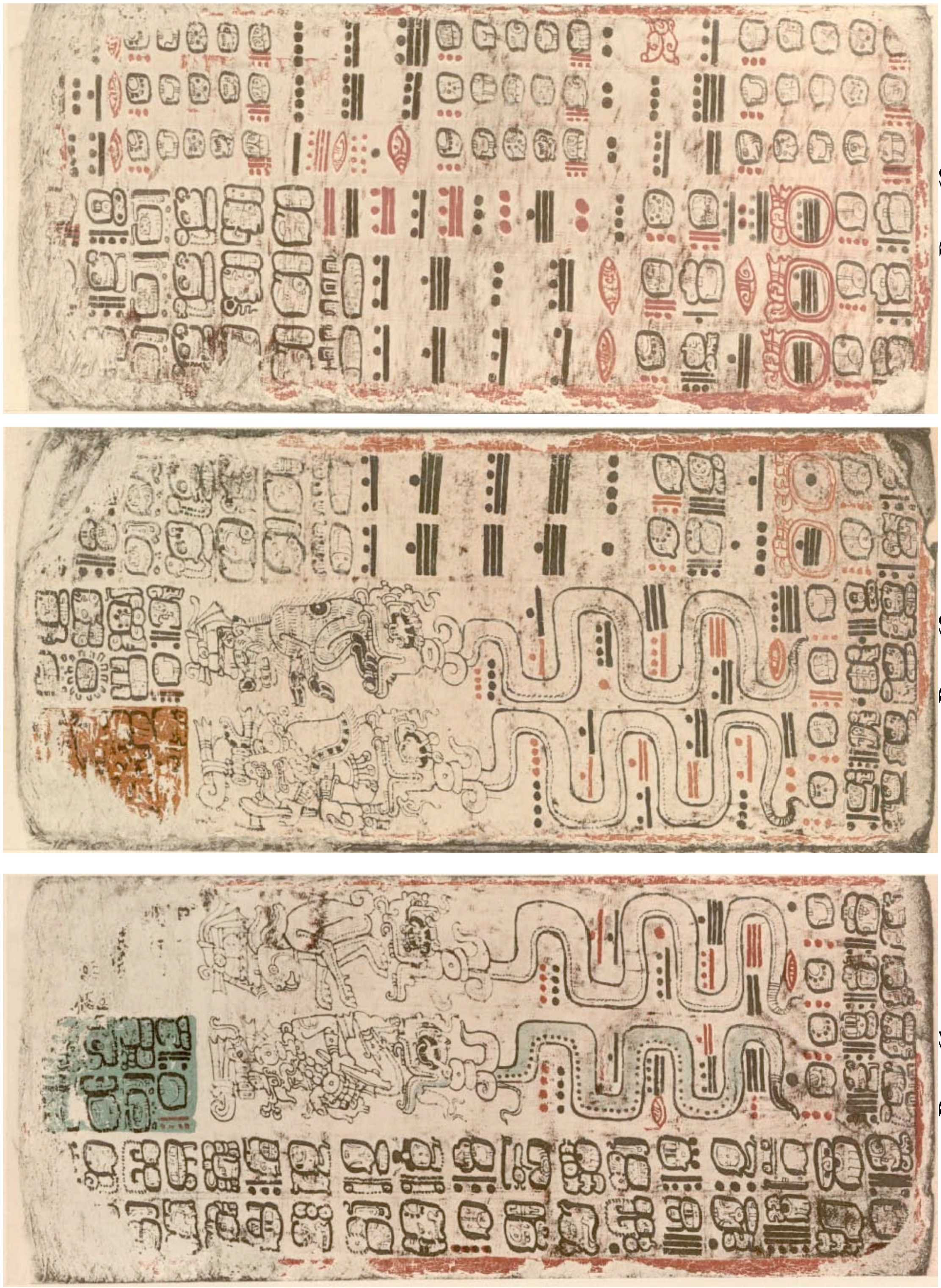
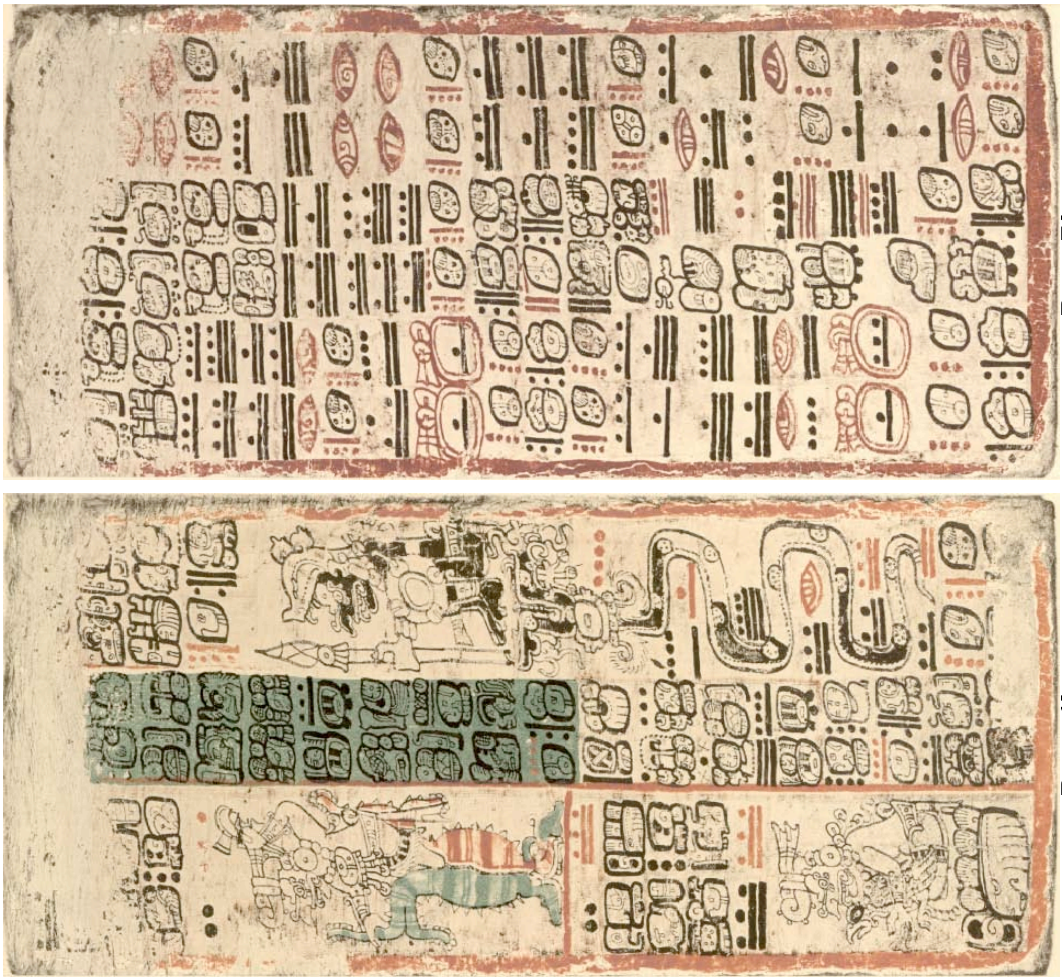


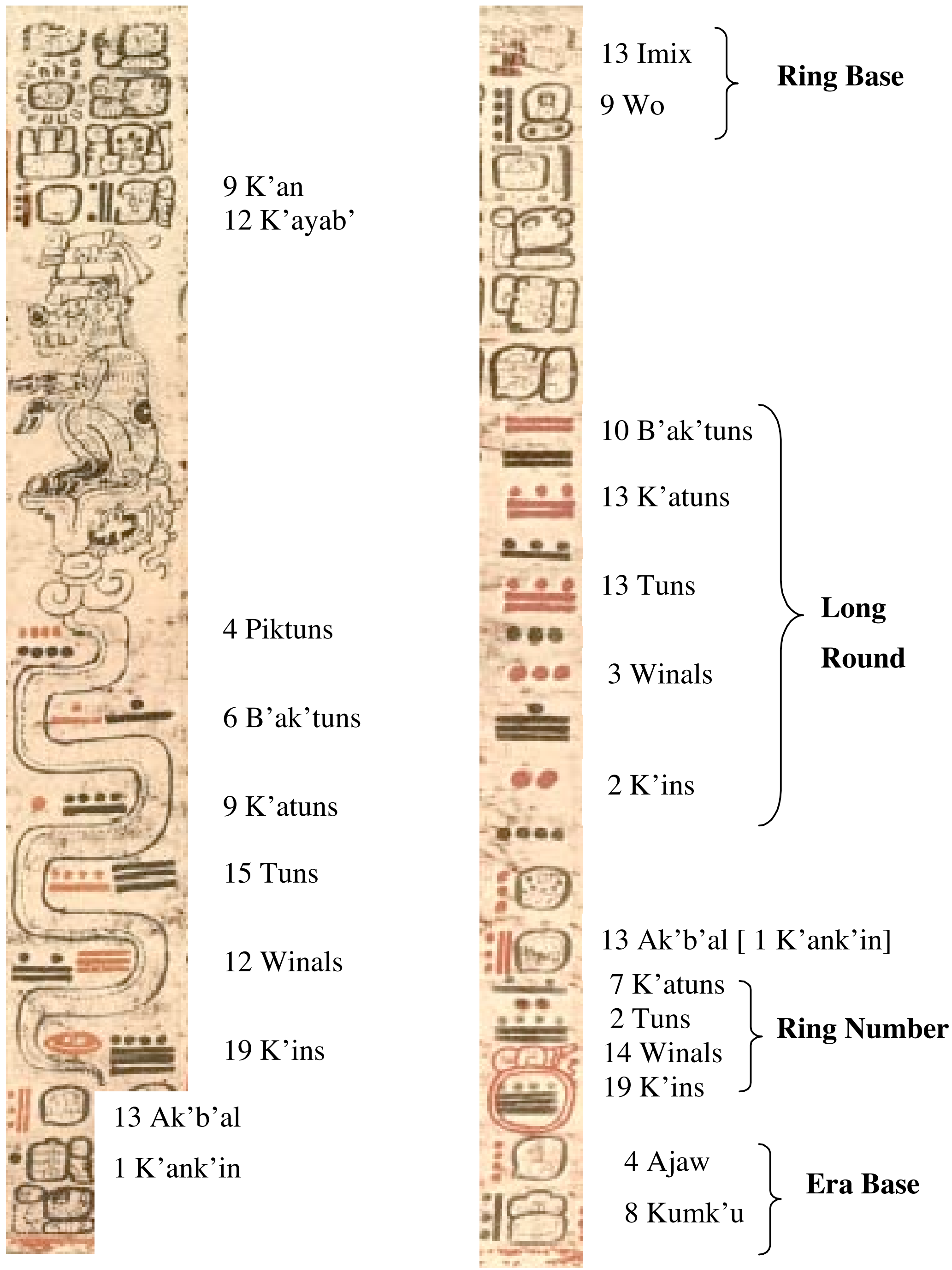
Figure 3.1: Dresden Codex Serpent Series, pages 61–63. Complete tables of multiples follow on pages 63– 64. Seasonal table follows on pages 65–69.



Page 70

Page 69

Figure 3.2: Dresden Codex Serpent Series, pages 69–70.
Complete tables of multiples follow on pages 71– 73.



a) Page 62 Dreden, columns C-D: black Serpent Number.

b) Page 63 Dreden, column C: red Ring Number.

9 K'an 12 K'ayab'
+ 4.6.9.15.12.19 =

13 Ak'bal 1 K'ank'in

Era Base:	13.00.00.00.00	**4 Ajaw 8 Kumk'u**
Ring Number:	- 07.02.14.19 =	
Ring Base:	12.12.17.03.01	**13 Imix 9 Wo**
Long Round:	+10.13.13.03.02 =	
Long Count:	10.06.10.06.03	**13 Ak'bal 1 K'ank'in**
Serpent #:	- 04.06.09.15.12.19 =	
Serpent Base:		**9 K'an 12 K'ayab'**

Figure 3.3 After Beyer (1943) and Bricker and Bricker (1988)

a) Pg. 61 Dresden

b) Pg. 69 Dresden

A1: **??**	B1: **??-la**
A2: **3-lu-ti**	B2: **K'UH**
A3: **PÄT-aj**	B3: **"PIKTUN"***
A4: **18**	B4: **"B'AK'TUN"**
A5: **PAWAH?** [skull]–**SÄK-SÄK**	B5: **PAWAH?** [rabbit] –**SÄK-SÄK**
A6: **"K'ATUN"**	B6: **8-"TUN"**
A7: **16**	B7: **yo-[OK]K'IN-ni**
A8: **PÄT-aj**	B8: **ah-WINIK-ki**
A9: **19**	B9a): **ah-MIX/MAX?-K'IN-ni** b): **AHMAAX?-K:IN-ni**
A10: **4 AJAW**	B10: **8 "KUMK'U"**

* quotation marks are used where terms are not original

Figure 3.4: The Serpent Series Introductory Inscription

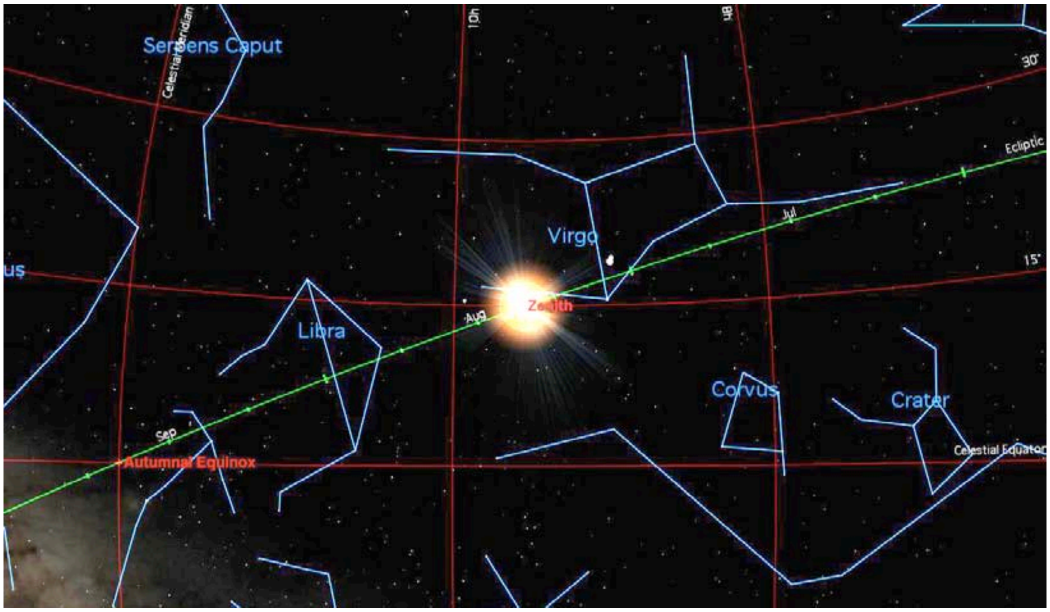


Figure 3.5a: August 13, 3114 BCE. (Gregorian proleptic)
4 Ajaw 8 Kumk'u : Long Count Creation date
Second Solar Zenith at 14.8ºN latitude in Virgo.

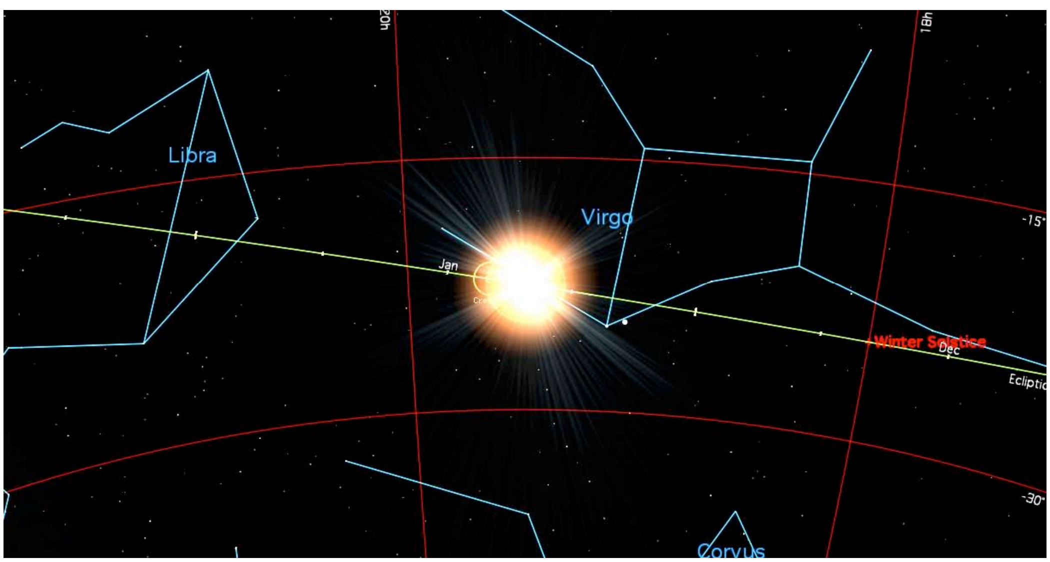


Figure 3.5b: January 10, 18,123 BCE (corrected Gregorian proleptic using <u>current</u> values for Tropical Year and precessional drift)
Subtracting the Serpent Series distance number, the sun is two days before the same sidereal position in Virgo as it is on August 13, 3114 BCE.

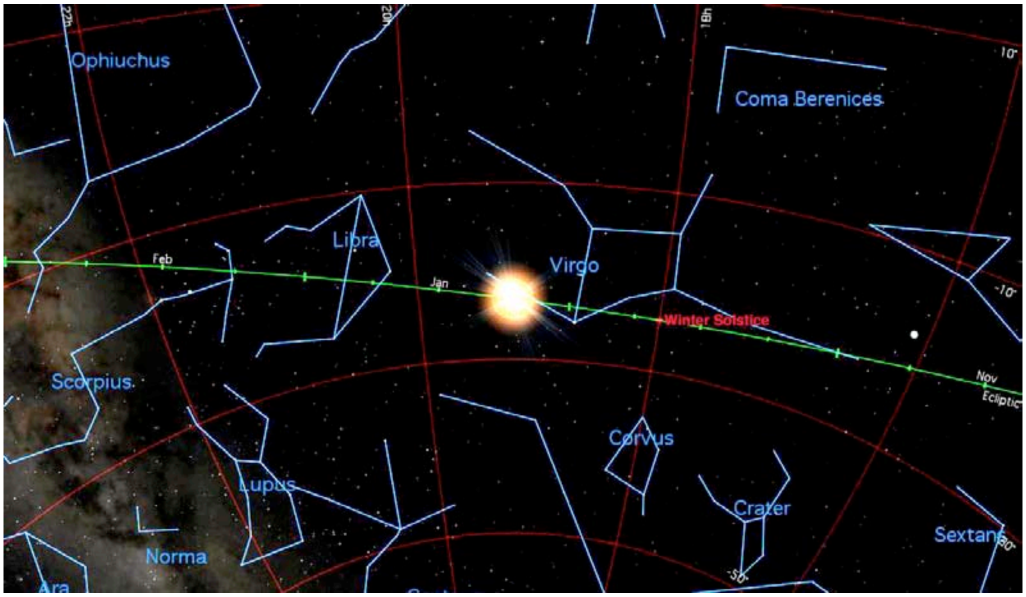


Figure 3.6: January 6, 18,123 BCE (theoretical reconstruction)
8 Chikchan 8 Mol
Subtracting the Serpent Series distance number, the sun is in the exact same sidereal position as it is on August 13, 3114 BCE.

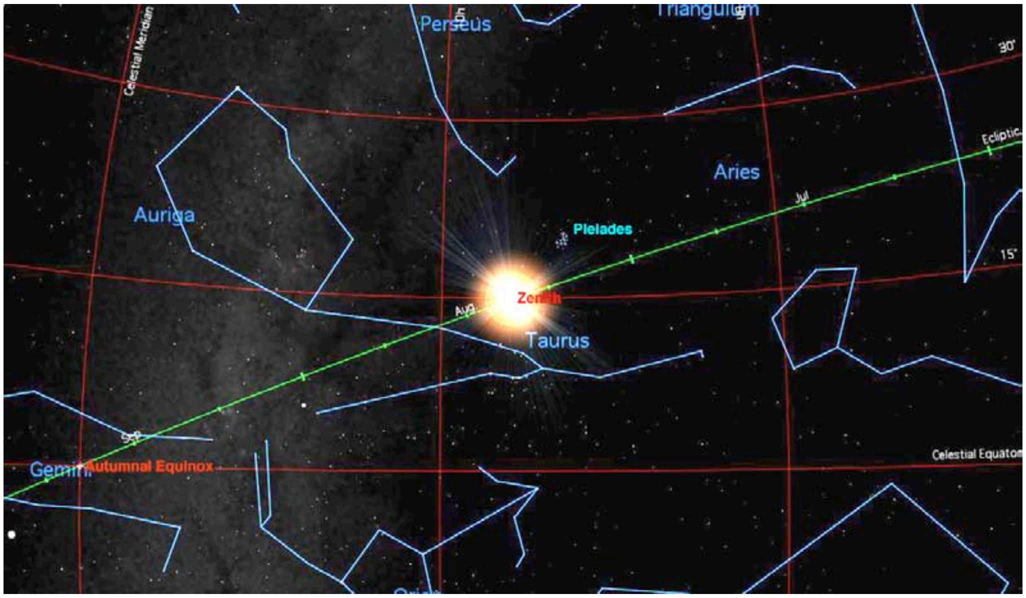


Figure 3.7a: August 12, 18,122 BCE (theoretical reconstruction)
5 Ak'b'al 1 P'op
Adding 218 days to 8 Chikchan 8 Mol, we reach 1 P'op, one day before the Second Solar Zenith (14.8ºN) in Taurus, near the Pleiades.

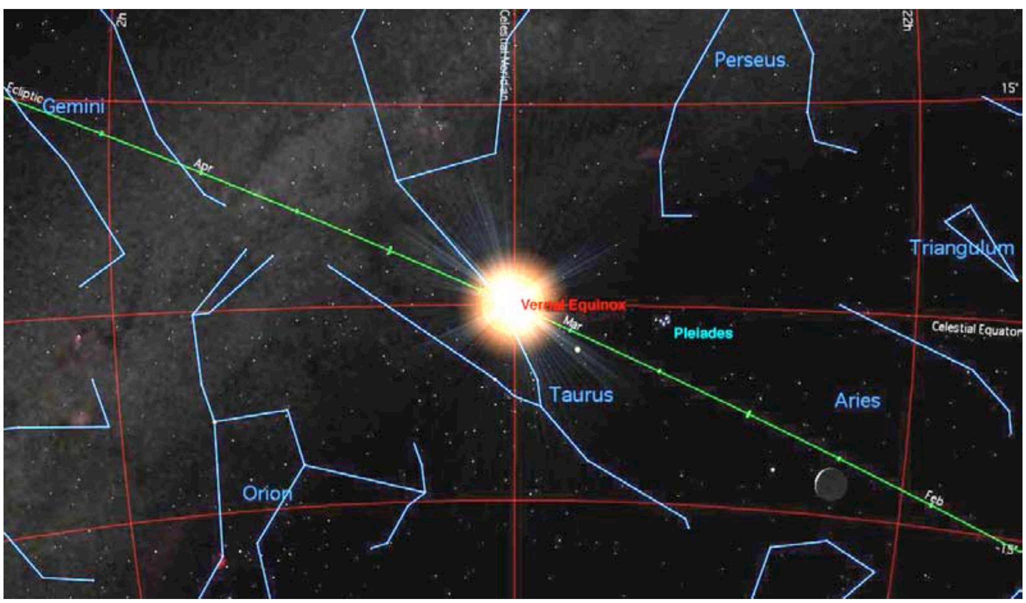


Figure 3.7b: March 19, 3113 BCE (Gregorian proleptic)
219 days forward from the Creation date, we reach the Vernal Equinox in Taurus, near the Pleiades.
First appearance of Pleiades, due East.

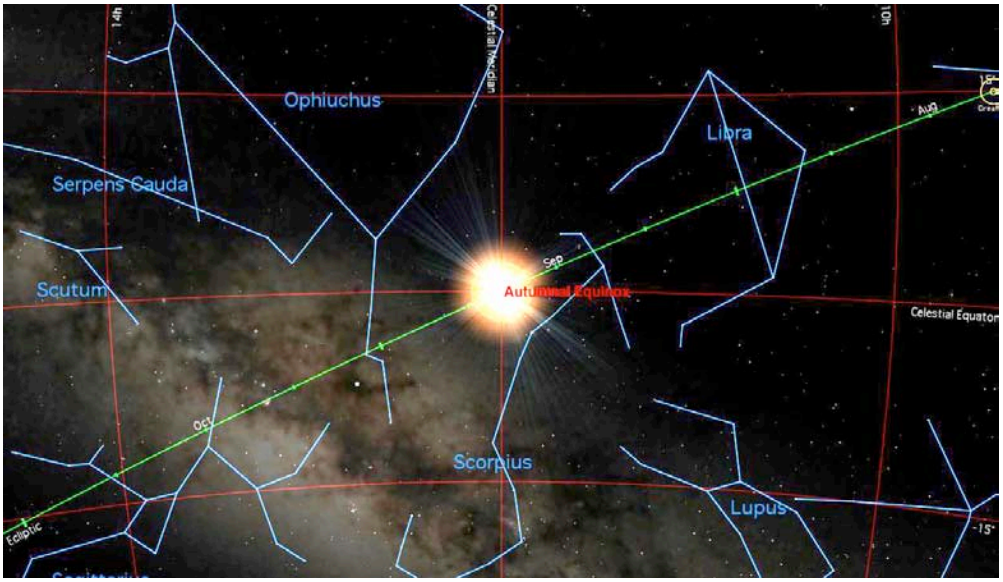


Figure 3.8: September 21, 3114 BCE (Gregorian proleptic)
39 days forward from the Creation date, we reach the
Autumnal Equinox in Scorpius.

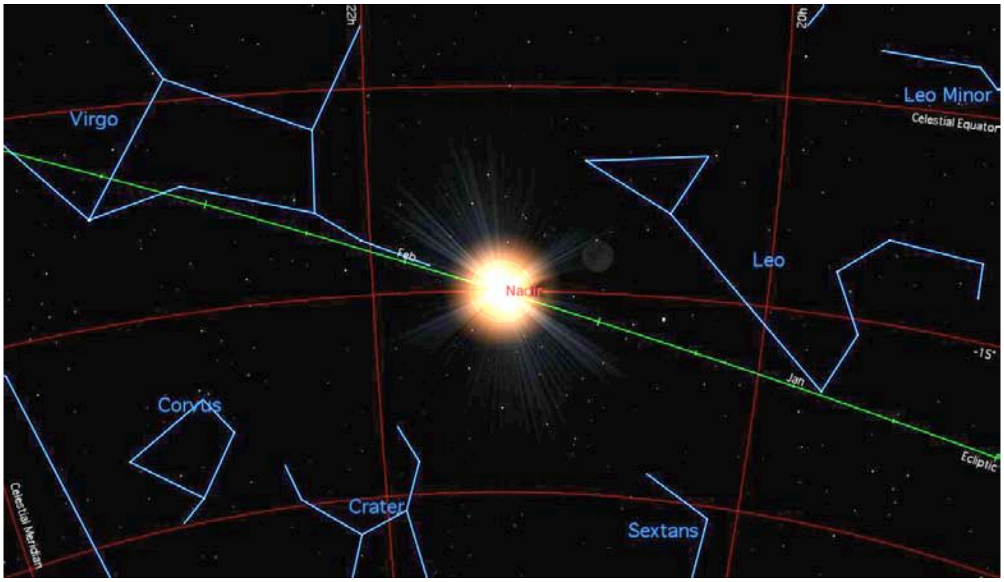


Figure 3.9a: February 8, 11,897 CE (theoretical reconstruction) Adding the first component of the Serpent distance number to the Creation date, we reach the second solar nadir between Leo and Virgo.

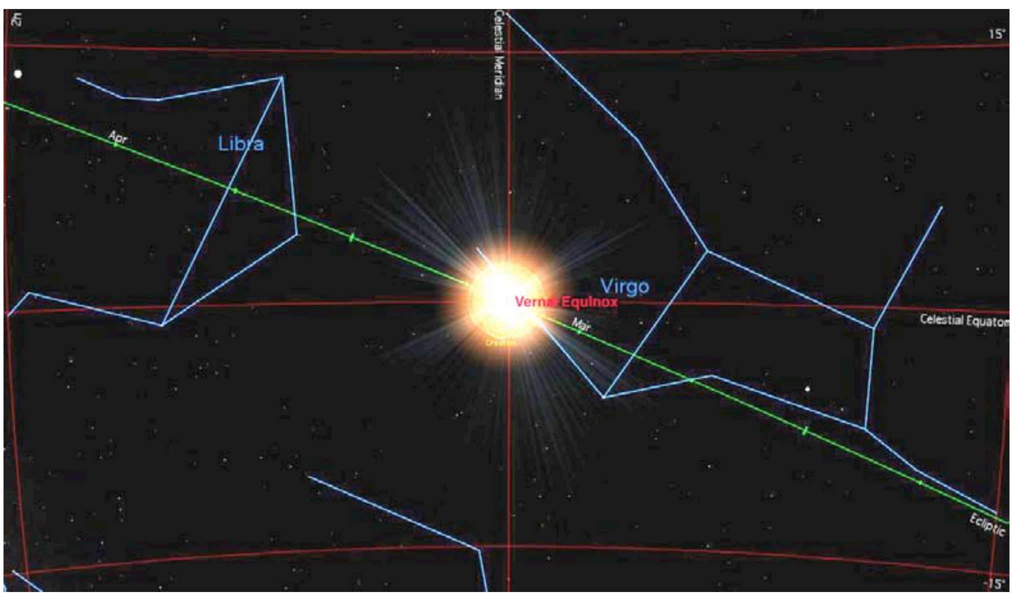


Figure 3.9b: March 19, 11,897 CE **13 Men 3 Yax** (theoretical reconstruction). Adding the entire Serpent distance number to the Creation date, we reach the Vernal Equinox in the same sidereal position in Virgo.

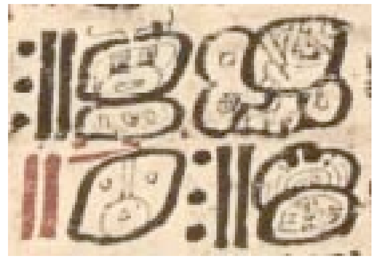


Figure 3.11: Dresden page 70, C12 to B13.
Idealized Haab' dates

Figure 3.10: Dresden page 69, A10 to B18.
Second half of Serpent Inscription

Figure 3.12: Dresden page 61, A-16 to B-18

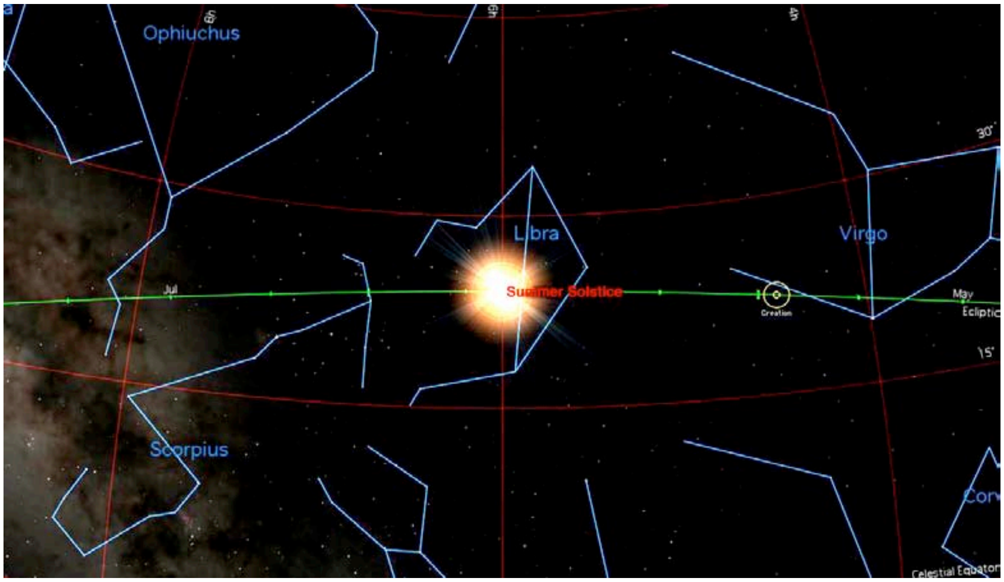


Figure 3.13a: June 22, 33,142 BCE (theoretical reconstruction)
9 K'an 12 K'ayab'. The base date for the Serpent Series falls on the Summer Solstice in Libra.

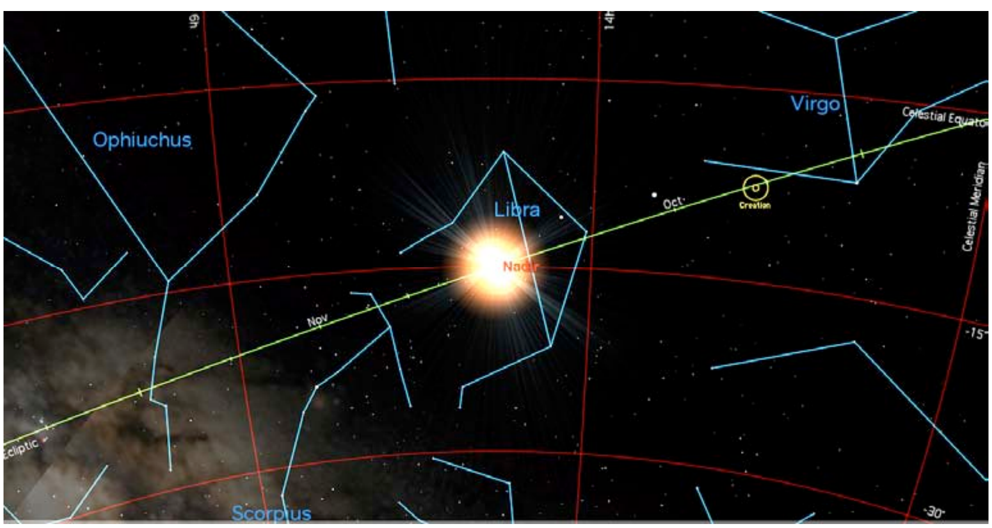


Figure 3.13b: November 2, 1100 CE (Gregorian proleptic)
The first solar nadir at 14.8° N in the Postclassic occurs in the same sidereal position in Libra as on the **9 K'an 12 K'ayab'** base date.

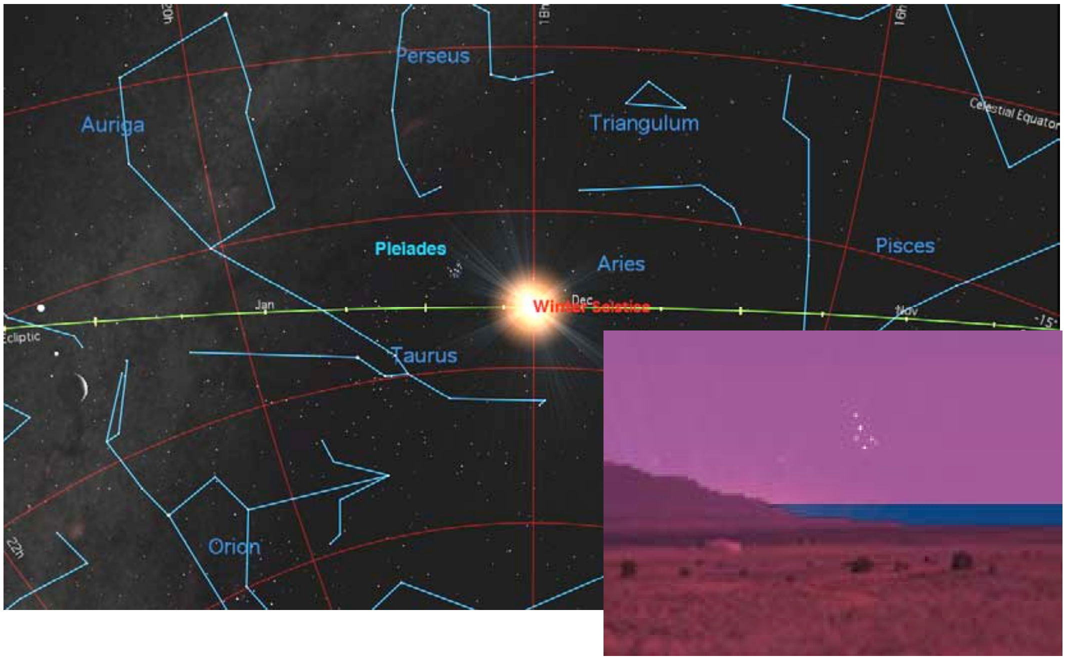


Figure 3.14a: December 23, 33,142 BCE (theoretical reconstruction)
Winter Solstice half a year from 9 K'an 12 K'ayab' base date.
First disappearance of Pleiades. Same sidereal as First Solar Nadir at 14.8° N in 1100 CE.

Figure 3.14b: June 22, 33,142 BCE (theoretical reconstruction)
9 K'an 12 K'ayab'. The Pleiades last rise on the horizon at sunset.

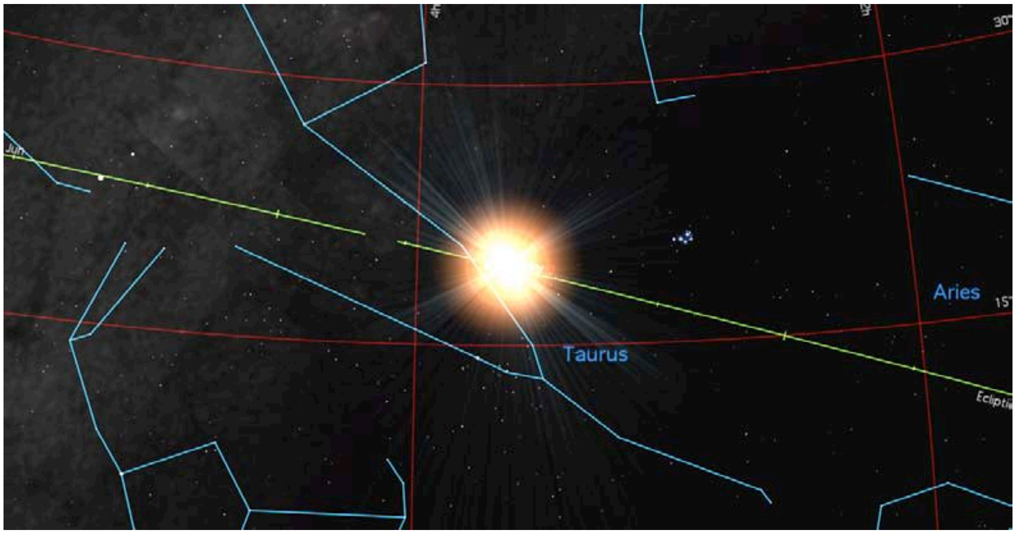


Figure 3.14c: May 20, 1100 CE (Gregorian)
First Solar Zenith at19.5º N latitude. First appearance of Pleiades. Pleiades at zenith azimuth. Same sidereal configuration as Vernal Equinox in 3114 BCE, and Second Solar Zenith in 18,123 BCE.

Chapter IV

Lunar Calculations in the Serpent Series

Having explored the calculations of the sidereal year, the tropical year, and the Haab' within the Serpent Series introductory distance number and the 9 K'an 12 K'ayab' base date, we now examine the references to lunar cycles found within both the Serpent Series introductory distance number, and in the secondary texts that follow. These calculations produce highly accurate values for both the synodic and sidereal lunar cycles, and the eclipse half-year, while providing significant intervals of both the sidereal and tropical years. The eclipse calculations are particularly significant, in that they provide a means by which to track precessional drift over time. Eclipse cycles are implicated in the 9 K'an 12 K'ayab' base date and throughout the Serpent Series. These calculations of eclipse cycles have antecedents in the Classic period Supplementary Series. A new interpretation of Glyphs Y, G, and F shows how they may have been used for the purpose of eclipse predictions.

The Lunar Pawahtuns

Recalling the two unusually placed Pawahtun glyphs following the B'ak'tun position in the Serpent Series introductory distance number, the first appears to be a lunar skull, while the second is a rabbit, also with lunar associations (**Figure 4.1**). The addition of the repeated *sak-sak* 'very bright' supports a reading of these two glyphs as lunar, perhaps each representing the full moon. But why would they be placed within the distance number in this way, and what is the difference between the two representations of the moon? Why would they both have been used here?

The Pawahtuns are four mythical beings known to represent the cardinal directions, each thought to support one corner of the sky. If references to the Pawahtuns refer to directions on the horizon, perhaps the two different lunar glyphs represent two positions of the full moon at different times of the year. An image of a rabbit on the moon is shared throughout the world, and the darker Maria, the 'seas' of the surface of the moon, appear in the recognizable shape of a rabbit. While there are several interpretations of this form, one of the most common, and most obvious, is that of a profile of a sitting rabbit, facing to the left. This is just as distant rabbits appear to an observer in a field. His two ears divide from the Mare Tranquilitatis into the Mare Foecunditatis and the Mare Nectaris. His head is the Mare Serenitatis (**Figure 4.2**).[1]

This image of the lunar rabbit appears upright only on the eastern horizon around the time of the vernal equinox (Martha Macri, personal communication). Because the moon generally follows the path of the sun and the ecliptic, the angle at which it rises changes throughout the seasons. On the vernal equinox, the moon is directly opposite the sun on the ecliptic, at or near due East.[2] Jacob Grimm (1835) noted the seasonal associations that occur between the vernal equinox, the East, Easter, a Germanic Goddess Eostra or Ostara, and the rabbit with its egg of rebirth. As a Pawahtun, this lunar rabbit may represent the full

---

[1] Aveni (2001:68–69) gives a very different configuration for the lunar rabbit, in which the above ears are back legs, but I contend that the above concept is more easily recognizable as a silhouette of a rabbit, and a position that rabbits commonly display in life.

[2] If the full moon is at a node, particularly visible during a lunar eclipse, it is directly opposite the sun. Such an eclipse on the vernal equinox places the rising moon exactly due east. Otherwise, the lunar orbit may vary up to 5° from the apparent path of the sun on the ecliptic.

moon in the East (at sunset) on the vernal equinox. Indeed, when we use the Serpent Series introductory distance number to count forward from the position of the second solar zenith at14.8º N latitude, we arrive at the vernal equinox.

Given the astronomical information contained within the Serpent Series distance number, if the second Pawahtun is a rabbit that represents the full moon on the vernal equinox, might then the first Pawahtun as a lunar skull represent the full moon at the time of the second solar zenith? At this point, the full moon would be directly opposite the sun in the sidereal position of the second solar nadir. The nadir alone may evoke the symbolism of the underworld and death, symbolized by a skull, but this position is not one of the cardinal directions typically personified by a Pawahtun. We can see that when the full moon rises in the position of the second solar nadir, it appears to have rotated clockwise from its position on the vernal equinox. Here, the lunar rabbit appears on his back, and his image is less apparent. In his place, we see the familiar face of the "man in the moon," though again this is not a universally consistent perception (**Figure 4.3**). Might the Maya have seen this as a skull?

From the *Popol Vuh*, a particular passage concerning a ballgame in the underworld of Xibalba invokes the dual symbolism of a lunar rabbit and a lunar skull. When Hunahpu's head is cut off, the lords of Death use it as the ball in their game against the Hero Twins. At this point, Hunahpu's head is replaced by a carved squash, akin to a jack-o-lantern[3], and he is temporarily revived.

---

[3] Macri has also noted the evocative association between Halloween and the appearance of the moon on the horizon as a jack-o-lantern. The folkloric tradition of carved pumpkins, native to the Americas, may have deep roots, perhaps with parallels in Europe.

Meanwhile, a rabbit impersonates the ball and distracts the underworld lords while Hunahpu retrieves his real head (D. Tedlock 1996:127–129). The lunar symbolism of both the carved squash and the rabbit is clear in this passage, and it is possible that the decapitation and the appearance of the rabbit refer to the sidereal position of the moon at two different times of the year—one of them being the vernal equinox.

Because of the sharp angle of the ecliptic on the vernal equinox, the apparent rotation of the rising full moon is at its farthest counter-clockwise point, when the silhouette of the rabbit appears upright, due east. On the second solar zenith at14.8° N latitude, the full moon is very close to its farthest clockwise rotation. Rising in the southeast at the sidereal point of the nadir, the moon resembles a face or skull. However, the actual point at which the moon reaches its maximum clockwise rotation follows a month later, on the autumnal equinox, though the difference between the rotation of the moon on the autumnal equinox and the second solar zenith is almost imperceptible (**Figure 4.4**). Given this ambiguity, and that the nadir is not a cardinal direction, perhaps there is another explanation.

Paired with the rabbit of the east, it is possible that the skull Pawahtun instead represents the cardinal direction of the west. Surely, the west already has a natural association with death and the underworld. In this case, it would follow that the skull Pawahtun would not represent a rising moon in the east, but the <u>setting</u> full moon, due west on the horizon on the morning of the autumnal equinox. In this position, the image of the rabbit is completely inverted, and it is possible that the Maya imagined a completely different image of a skull on the face of the full moon in this western position. It is possible to see the former rabbit ears as the jawbone of a leftward facing skull with a defined cerebrum and a concave eye (**Figure 4.5a**). Indeed, such a large single eye in a leftward facing skull with a visible jawbone is precisely how the stylized glyph for the moon (T682b) is represented by the Maya (**Figure 4.5b**). On the vernal equinox, this skull is facing downward in the west, whereas it is upright on the autumnal equinox. In ethnographic accounts from the Kek'chi and Mopan, the sun is said to have removed one of the moon's eyes because it was shining too brightly at night (Milbrath 1999:31). Likewise, the skull of God A, the Lord of Death, is frequently depicted with an extruded eyeball, perhaps in reference to these stories, and to the image of the skull on the moon with its concave eye.

What is the purpose of including these lunar Pawahtuns, and why would they appear after the B'ak'tun position in the Serpent Series introductory distance number? If we count forward by 1 Piktun and 18 B'ak'tuns, the initial 15,200 Tuns of the distance number, we find that this alone is sufficient to cause a precessional shift such that the sidereal position of the second solar zenith will become the sidereal position of the vernal equinox. Note that in this expanse of time, the exact position of the tropical year does not yet reach from the second solar zenith to the vernal equinox. Instead, this exact interval is specified by the remaining components of the distance number.

It is possible that the Pawahtuns represent a pairing of the solar zenith/lunar nadir (lunar skull) with the vernal equinox (lunar rabbit) implied in the distance number. On the other hand, since Pawahtuns usually represent only the cardinal directions, the pair may simply represent the autumnal equinox in the west (lunar skull) and the vernal equinox in the east (lunar rabbit), and this literally suggests the precession of the equinoxes itself. While our expression "precession of the equinoxes" derives from the observations of Hipparchus, it is quite possible that the Maya described precession in the same way. The fact that the Pawahtuns reference the moon also suggests that the Maya noticed precessional drift and the sidereal year by observing the sidereal position of the full moon. As we have seen, this is precisely one of the ways in which Hipparchus measured precession (Evans 1998). We may also infer from this that the Serpent Series contains specific lunar information, as the Brickers (1988) have previously suggested. This is explored below in the analysis of the distance numbers that follow the Serpent Series introductory distance number on pages 61 and 69.

If we are to understand an intentional ordering of the two Pawahtuns from west to east, they may convey the eastward precessional drift of the sidereal position of the full moon in the tropical year when counting backwards in time, as with the calculation of the 9 K'an 12 K'ayab' base date. If this is their purpose, the position of these Pawahtuns in the distance number suggests that a significant amount of precessional shift appears only after an interval of time on the order of many B'aktuns.

The Lunar Calculations

Beyer noticed that the distance number of 1 [**OCH**] Piktun in A13 of the inscription on page 61 (**Figure 4.6a**) resembles the distance number in A12–A13 on page 69 of 1 [**OCH**] Piktun, 3 [**OCH**] Winals and 1 [**OCH**] K'in, or 1 Piktun and 61 days (**Figure 4.6b**). Furthermore, beneath each of these distance numbers appears another smaller distance number that is nearly equivalent in both examples. From A14–B15 on page 61, this smaller distance number reads 15 K'atuns 9 Tuns 1 Winal and 3 K'ins, while in A14–B15 on page 69 we find 15 K'atuns 9 Tuns 3 Winals and 4 K'ins, with a difference of exactly 61 days. Beyer demonstrated that when either of these smaller distance numbers is subtracted from the larger preceding distance number, the same exact number is reached:

Page 61:	**Page 69:**
1.00.00.00.00.00	**1.00.00.00.03.01**
– 15.09.01.03	**– 15.09.04.04**
19.04.10.16.17	**19.04.10.16.17**

Beyer did not attempt to determine the meaning of these two long distance numbers, but he demonstrated their equivalence, and the apparent subtraction involved. As in the introductory distance number above, the smaller distance numbers follow the verb **PÄT-aj** 'was made', though the Brickers interpret this glyph as indicating subtraction. Each of the numerals in the smaller distance numbers following this verb do not have any **OCH** prefix, as do the larger distance numbers from which they are apparently subtracted. It is therefore plausible that while the **OCH** indicates subtraction, **PÄT-aj** connotes the creation of a positive integer. T**a-b'a** alone seems to indicate addition, while we find the phrase **OCH -ta-b'a** preceding the distance numbers on pages 61, 70 and 73 whose numerals themselves are each preceded by an **OCH** prefix.

OCH as Subtraction

Stuart (1998:387f) has shown that T207 itself usually reads **OCH** 'enter' in the Classic period. In both the Classic inscriptions and in the Dresden Codex, phonetic complements in the form of an affixed **chi** (T671) suggest that T207 was also read **OCH**. The word *och* is attested in colonial Yucatec as a name for a child's rattle[4], and this is likely related to the image of T207 as a rattlesnake rattle. Linda Schele and Nikolai Grube (1997:195) suggest that in some contexts it appears that T207 may have read *hoch* 'to paint, to copy writing', given that an initial weak 'h' is often not represented in the glyphs, and *hoch* could therefore be written as **OCH**. However, we find yet another meaning of *hoch* as 'to remove', 'to untie', 'to empty' 'to pour' and 'to harvest' in Yucatec (Martínez Hernandez 1929:392). These definitions strongly support a meaning related to subtraction within the Serpent Series inscription. As 'untie' and 'subtract', *hoch* would nicely complement the Brickers' (1983:12) reading of *tab'* as 'tie' and 'add'. The metaphor of tying as representative of adding and subtracting numbers is also visible in the symbolism of Ring Numbers, where the image of a tied red ribbon is used to represent a specific number of days added from an earlier base date to reach 4 Ajaw 8 Kumk'u.

Further support for a reading of *hoch* as 'remove' and 'subtract' can be found in the Classic inscriptions where the compound glyph T158 appears in combination with '5 Tuns' to indicate a period of 15 Tuns, or 5 Tuns before the completion of a K'atun (**Figure 4.7a**). This semantic value has long been

---

[4] "*och*: unos cascauelillos pequeños con rostros de zorrillos que ponen a los niños." (Martínez Hernandez 1929:709).

recognized (Kelley1962:34; Justeson 1984:328), but the currently accepted reading of the T158 collocation is **WI'IL** 'last', suggested by Alfonso Lacadena (1994; 1997), based on an apparent substitution for **wi** (T117). However, the two components of T158 are more transparently **OCH** (T567) and the possible verbal suffix -**wa** (T130). In this case, a reading of *och-aw* may indicate 'subtracted', as *tiliw* 'burned' is derived from *til* 'burn'(M. Looper, personal communication).

OCH (T567) is the abbreviated form of the tenth Tzolk'in day **OK** (T765ab) used throughout the Codices (**Figure 4.8**). In its full form, T765 can be used as *och* 'enter' in the Classic inscriptions. Several authors have noted the polyvalence of T765 and T567 as both *ok* and *och* in the Classic and Postclassic (Justeson 1984:357; Love 1991:297f.), and it is likely that the full form of this sign represents a masked opossum, pronounced **uch* in proto-Cholan (Kaufman and Norman 1984:135) and *och* in Yucatec (Martínez Hernandez 1929:709). The abbreviated form (T567) is thus recognizable as the ear of this animal.

The compound T158 only appears in the Classic inscriptions to indicate a removal of '5 Tuns', and never any other interval. The number 'five' is pronounced *ho'* and in several examples, the bar representing 'five' directly prefixes T158, instead of prefixing the Tun, as on Piedras Negras Stela 25, I14 (**Figure 4.7b**) and Yaxchilan Lintel 23, M3. In other example, the 'five' bar prefixes both T158 and the Tun glyph (T528), as on Piedras Negras Lintel 2, X12 (**Figure 4.7c**) and PNG Stela 36, D8. Still other examples include no 'five' at all, but indicate the same subtraction of 5 Tuns, as in Yaxchilan Lintel 52, A2 (**Figure 4.7d**). It is therefore possible that a pun was observed between *ho'* as 'five' and a reading with T158 as **ho-OCH-wa** as a transitive verb meaning *hoch-aw* 'removes', with the meaning 'removes five Tuns'. Indeed, *hohch* in Ch'ortí also relates to words meaning 'pour' (Wisdom 1950:468) and *joch-ol* means 'empty' in Chol.

Throughout the Codices, T158 also appears in many almanacs with an unusual prefix of 'three' (**Figure 4.9**), and this compound has been translated variably as *oxow* 'sultry'(V. Bricker 1986:123); *ox ok wah* 'big feast' (Fox and Justeson 1984:67); *ox och wah* 'abundance of provisions' (Love 1991:298); *and ox wi'il* 'abundance of food' (Schele and Grube 1997:85; Davoust 1997). The contexts of T158 in the Codices suggest a meaning related to agriculture and fertility (Vail 1996:336–337). Given the possible reading of T158 as *hoch-aw*, it is possible that this compound instead reads *ox-hoch-aw* or *ox-hoch-ol*, meaning 'much harvested', with *hòochol* attested as 'harvested' in Yucatec (V. Bricker et al. 1998:108), thereby preserving the agricultural reference.

The B'ak'tun Component and the Lunar Winik Verb

Prior to the Piktun distance number on page 61, the inscription continues beyond 4 Ajaw 8 Kumk'u with a series of associated glyphs from A11 to B12 that are repeated elsewhere in the Serpent Series inscriptions from pages 70 and 73 (**Figure 4.10a–c**). Another eroded example comes from the 91-day table on page 31 (**Figure 4.10d**), where the base date is also 13 Ak'b'al, as it is in the first Serpent Series.

In varying order, this repeating series consists of a lunar glyph (T682b), a form of the verb often read as **u-LOK'?-i** (T327:17v), meaning 'it has emerged' (Schele and Mathews 1993), a B'ak'tun glyph with or without a coefficient, and the addition collocation **ta-b'a** with an **OCH** (T207) prefix. Following each of these examples, we find various distance numbers, with each component again prefixed by **OCH**.

From the example on page 61, immediately before **OCH-ta-b'a** is a B'ak'tun glyph (T1033) in block A12, without any coefficient. Like the examples of the coefficientless Piktun and K'atun glyphs in the introductory distance number above, this likely represents <u>one</u> B'ak'tun. Similarly, the example from page 70 reads 10-B'ak'tuns, followed by **OCH-ta-b'a**. An eroded example from page 73 likewise shows what appears to be 10(+) B'ak'tuns and then **OCH-ta-b'a**. Here, as in the introductory distance number on page 61, we see the bottom of the rare "sky" variant of the B'ak'tun glyph (T561:285).

None of these B'ak'tun glyphs have an **OCH** prefix, and given that they are each followed by **OCH ta-b'a**, and variable distance numbers whose numerals each contain this **OCH** prefix, I propose that the **OCH-ta-b'a** indicates subtraction, and the distance numbers whose numerals contain an **OCH** prefix would then be subtracted from the positive intervals of B'ak'tun multiples. Lastly, it follows that the additional distance number following **PÄT-aj** on pages 61 and 69, whose numerals <u>do not</u> have any **OCH** prefixes would then be added. The reasoning behind these operations is unclear, but the result of these calculations would be consistent with Beyer's model of subtraction, but with the positive and negative integers reversed.

The lunar glyph in these examples appears either alone, as on page 70, with a -**ki** suffix on page 73 and perhaps also on page 31, or with both a final **-na** and a **-ki**. Since the lunar glyph is also used to represent **WINIK** as 'twenty', literally ‘person’ with twenty fingers and toes, the Brickers read the final **-na-ki** as prompting a reading of **WINAK**, though this would be a highland Maya word for ‘person’ or perhaps ‘twenty’, and this is highly unlikely. It is difficult to understand the suffix **-na-ki**, though it may be attributed to scribal error, combining the Classic and Postclassic spellings of *winal* and *winik* From the inscription on page 70, we find the standard form of **WINIK** (T521) meaning ‘twenty days’ in **1-OCH-wi-WINIK-ki** following the lunar glyph as part of the distance number, and it seems less likely that there would be a need to also include the lunar glyph as a redundant representation of ‘twenty’. The lunar glyph (T682b) appears to represent both ‘twenty’ and ‘moon’, and here it is always followed by the verb **u-LOK’**?. It is possible that these glyphs together refer to some appearance of the moon itself.

The secondary inscription on page 61 we then read:

1 B’ak’tun:	**01.00.00.00.00**
– 1 Piktun:	**– 01.00.00.00.00.00**
+ 309 Tuns + 1 Winal + 3 K’ins:	**+ 15.09.01.03**
= 7600 Tuns – 111263 days	**– 18.04.10.16.17**
= 2,624,737 days	

An interval of 2,624,737 days is less than half of the initial Serpent Series distance number. This interval is almost exactly a whole interval of both the synodic lunar cycle and the sidereal lunar cycle, using the current known values. This means that from the starting point to the endpoint of this entire interval, the moon will be in almost exactly the same phase and exactly the same sidereal position against the background of the stars. Consequently, it will also be very close to a whole interval of the sidereal year, but it is not a whole interval of the Copan tropical year:

2,624,737 days
= 88,882 (synodic lunar month of 29.53059 days) – 0.9004 day
= 96,068 (sidereal lunar month of 27.32166 days) – 0.2329 day
= 7,186 (sidereal year of 365.256363 days) – 4.77548 days
= 7186 (Copan tropical year of 365.2419355 days) + 108.45 days

Using the Maya sidereal year calculated from the initial Serpent distance number:

= 7,186 (Maya sidereal year of 365.2565128 days) + 3.699 days

Like the initial distance number in the Serpent Series, this secondary distance number of 2,624,737 days also would place the sun at a different time of year, but in nearly the same sidereal position, with the additional function of placing the <u>moon</u> in nearly the <u>same phase</u> and the <u>same sidereal position</u>. Using the apparent Maya values, subtracting this secondary distance number from the Era Base date 4 Ajaw 8 Kumk'u, the date after which it appears in the inscription, the sun will be only 3.7 days before the same sidereal position in Virgo, while the tropical year shifts some 108 days in this time. Counting back 2,624,737 days from Creation, we reach a date 6 Ak'b'al 6 K'ayab', April 26, 10,300 BCE. This is also only three days before the <u>first</u> solar zenith, which occurs in exactly the same sidereal position of the Creation in Virgo (**Figure 4.11)**. Thus, it is likely that the Maya were looking for the closest approximation of this solar position that corresponded with an even interval of lunar synodic and sidereal cycles. Given the accuracy of the sidereal year in the longer introductory distance number, they would presumably have recognized the three-day discrepancy. This may have been because they were aiming to record yet another lunar phenomenon, as we shall see.

The moon is less than one day before full on August 13, 3114 BCE (it would be full about 7 am the next day in the Maya area), and it appears close to the sidereal position of the second solar nadir (14.8° N) in Pisces on (**Figure 4.12**). Subtracting 2,624,737 days to April 26, 10,300 BCE, we theoretically find the moon in the exact same sidereal position in Pisces, but here it was the sidereal position of the first solar nadir. Most interestingly, the moon on this date is exactly full. Because the moon was one day prior to full on August 13, 3114 BCE, and because the secondary distance number is just short of one day less than a whole synodic lunar cycle, subtracting 2,624,737 days from Creation brings us to a perfect full moon in the same sidereal position in Pisces. Is it possible that the Maya astronomers who developed the Serpent Series were aware of both the synodic and sidereal lunar positions on the Era Base date, and that they were also capable of calculating these positions for much earlier dates? Such accurate calculations represent an extremely refined understanding of lunar motion comparable to current calculations. But perhaps most significantly, the sun and the full moon on this early date of April 26, 10,300 BCE are at opposite nodes, and there would have been a lunar eclipse at the first nadir in Pisces.

The Lunar Calculation on page 69: the 13 Mak date

Beyer (1943) first noticed that the secondary inscription on page 61 relates to that on page 69. Whereas the latter includes the addition and subtraction of 61 days, the difference of 2,768,737 days is equivalent to that found on page 61. To restate Beyer's calculations:

Page 61:	**Page 69:**
1.00.00.00.00.00	**1.00.00.00.03.01**
– 15.09.01.03	**– 15.09.04.04**
19.04.10.16.17	**19.04.10.16.17**

However, the text on page 69 does not include any visible B'ak'tun component. Instead, it is replaced by the previously mentioned multiplication of the initial distance number five times to reach the future date 13 Mak, written below. In the previous chapter, we found that this 13 Mak date will fall on August 13, 71,935 CE, with the sun theoretically in the same sidereal position in Virgo as it was on the Era Base date 4 Ajaw 8 Kumk'u, and on the same second solar zenith at 14.8° N latitude.

Because of the close equivalence of the calculation in the secondary inscriptions on pages 61 and 69, I believe that the B'aktun component is also intended in the inscription on page 69. Indeed, when this same interval of 2,624,737 days (2,768,737 days – 1 B'ak'tun) is subtracted from the interval of five times the initial distance number of 5,482,135 days = 27,410,675 days, the result gives another interval that closely approximates whole intervals of the synodic and sidereal lunar cycles, and another whole interval of the Maya sidereal year:

27,410,675 days – 2,624,737 days = 24,785,938 days

= 839,331 (synodic lunar month of 29.53059 days) – 1.6353 days

= 907,190 (sideral lunar month of 27.32166 days) + 1.2646 days

= 67,859 (Maya sideral year of 365.2565128 days) + 3.70 days

It is possible that the small errors are the result of calculating such a long interval. Nevertheless, they are remarkably accurate, and they again place the moon in the same sidereal position in Pisces and at the same full phase as it appeared on the Era Base date, while the sun again appears in the same sidereal position in Virgo, but here it will be close to the first solar zenith in the year 64,749 CE.

The future 13 Mak date repeats both the same sidereal position of the sun in Virgo and the August 13 second solar zenith at 14.8° N that occurs on the Era Base date 4 Ajaw 8 Kumk'u. Therefore, subtracting the interval of 2,624,737 days from this position will repeat the same configuration as when this interval is subtracted from 4 Ajaw 8 K'umku on page 61 to reach very close to the first solar zenith at 14.8° N. Curiously, this also leads to the conclusion that the larger interval of five times the initial distance number of 5,482,135 days is itself remarkably close to a whole number of both sidereal and synodic lunar cycles:

5 (5,482,135 days) = 27,410,675 days

= 928,213 (synodic lunar month of 29.53059 days) – 2.5357 days

= 1,003,258 (sideral lunar month of 27.32166 days) + 1.0317 days

The Components of Lunar Calculation

While the above lunar calculations appear to be highly accurate, the meaning of adding and subtracting their component intervals is unclear. What is the purpose of subtracting one Piktun from one B'ak'tun? Why not simply record 19 B'ak'tuns? Furthermore, why then the addition of the smaller interval of some 309 Tuns instead of directly recording the length of the resulting interval? Furthermore, it is unclear why an additional 61 days are both added and subtracted on page 69 to apparently reach the same interval that appears on page 61. These intervals may represent the means by which the Maya astronomers calculated specific corrections for larger intervals of time.

The B'ak'tun component always appears together with the lunar **WINIK** (T682b), known to represent 'twenty'. Indeed, the interval of one B'ak'tun is very close to 20 days less than a whole synodic lunar cycle:

1 B'ak'tun = 400 (360 days) = 144,000 days

144,000 days + 20 days = 144,020 days = 4,877 (29.53059 days) – 0.687 days

Given the lunar data recorded throughout the Classic period on K'atun and B'aktun period endings, it is likely that Maya astronomers noticed the 20 day interval added to the length of a B'ak'tun to reach close to a whole synodic lunar cycle. This may be the purpose of the association between the B'ak'tun and the lunar **WINIK**, representing these twenty days. However, for much longer periods of time, on the order of a Piktun, the slight remainder in this B'ak'tun calculation would render it increasingly inaccurate. However, the length of one Piktun itself even closer to a whole number of synodic lunar cycles:

1 Piktun = 8,000 (360 days) = 2,880,000 days = 97526 (29.53059 days) – 0.32 days

Perhaps, for this reason, the interval of one Piktun is used in these lunar calculations. Therefore, subtracting one B'ak'tun from one Piktun will be very close to 20 days longer than a whole number of synodic lunar cycles. The comparatively smaller calculations of some 300 years would then supply the necessary corrections to reach the desired positions of the tropical year, along with whole numbers of both synodic and sidereal lunar cycles. As explained below, these lunar calculations also incorporate eclipse intervals.

The Eclipse Half-Year

The path of the moon is inclined about 5.15^{o} relative to the plane of the earth's orbit around the sun. From an observer's point of view on the earth, the path of the moon does not exactly follow the path of the sun on the ecliptic, and these two paths cross only twice: once at the ascending node, where the path of the moon crosses the ecliptic going north, and once at the descending node, where the path of the moon crosses the ecliptic going south. Lunar eclipses occur when the full moon is close to one node and the sun is close to the opposite node, and the moon crosses the earth's shadow in direct alignment with the sun. The moon may pass through the larger penumbral shadow in a partial lunar eclipse, in which the earth only partially obscures the light from the sun, or it may pass through the smaller umbral shadow, in which the earth completely covers the sun, so that the moon often turns a deep red color (**Figure 4.13**). Solar eclipses occur when both the moon and the sun are close to the same node, and the new moon passes directly in front of the sun, casting its shadow on the earth (**Figure 4.14**).

If the moon followed the exact same path of the sun on the ecliptic, there would be a lunar eclipse on every full moon, and a total solar eclipse on every new moon. Because the plane of the moon's orbit is slightly inclined relative to the plane of the earth's orbit around the sun, eclipses can only occur at the nodes. The two nodes are thus directly opposite each other in the sky, but their position is not fixed, and they regress backwards as the plane of the moon's orbit itself wobbles. If the nodes did not regress, then a solar and lunar eclipse would happen every six months at the same time of year, as it would take the sun exactly one half of a year to reach from one node to the other.

Instead, the regression of the nodes causes the sun to reach a node every 173.31 days, the **eclipse half-year**. The sun will reach the same node in twice this interval, the **eclipse year** of 346.62 days. Eclipses thus occur slightly less than every six months. The moon reaches the same position relative to the stars in 27.32166 days—the sidereal lunar month. Because the nodes regress, it takes the moon slightly less than half of its sidereal month to reach the next node. This is the **half-Draconic month** of 13.60611 days. It takes the moon twice this interval to reach the <u>same</u> node in one **Draconic month** of 27.21222 days, so named for the Chinese dragon said to consume the sun or Moon during eclipses (Aveni 2001:77). While the moon reaches a node quite frequently, it can only cause an eclipse when the phase is either full, opposite the sun, or new, in conjunction with the sun.

On the Era Base date August 13, 3114 BCE, the sun was about 130 days past the ascending node. Amazingly, in 3114 BCE, the nodes were exactly aligned with both equinoxes (**Figure 4.15**). In the secondary distance number from the Serpent Series on page 61, the interval of 2,624,737 days is equal to 15,144 eclipse half-years, with a remainder of 130.36 days. This can be expressed:

2,624,737 days = 15,144 (173.31 days) + 130.36 days

If the Maya were aware that the sun was 130 days past a node on August 13, 3114 BCE, subtracting an interval of 2,642,737 days to reach April 26, 10,300 BCE theoretically places the sun exactly at a node during a full moon, thereby causing <u>a total lunar eclipse of the moon at the first nadir</u> (**Figure 4.16**). It would seem that the Maya were using this equation to coordinate the synodic lunar cycle, the sidereal lunar cycle, the position of the lunar nodes, the eclipse half-year, the tropical year, and the sidereal year in one single interval. Such an exact calculation of this magnitude is thus far unattested among the Maya. Because of the magnitude of the time scale involved, even current measurements of the eclipse year and the lunar cycle become highly theoretical over time.[5] Regardless of whether this back-calculated Maya eclipse prediction reflects reality, it nevertheless provides theoretical constants that are nearly identical to current

[5] Even the astronomical program Starry Night Pro (Imaginova 2006) will calculate the eclipse year no earlier than 6002 BCE, after which point the nodes artificially remain in the same position. For this reason, theoretical lunar eclipse predictions in the Serpent Series are hypothetically reconstructed.

measurements for the eclipse year, the synodic lunar cycle, the sidereal lunar cycle, and the sidereal year. This prediction of an ancient lunar eclipse represents a truly remarkable historical achievement in astronomical theory, if indeed it was deliberate.

We can also see that the final component of the secondary lunar distance number, consisting of 309 Tuns + 1 Winal + 3 K'ins, is also very close to a whole interval of eclipse half-years:

309 Tuns + 1 Winal + 3 K'ins	**= 111,263 days**
	= 642 (173.31 days) – 2.02 days

This interval is not a whole multiple of either the synodic or the sidereal lunar cycles. However, it is an interesting interval of 304 Haab' +303 days. With the addition of 61 days in the related distance number component on page 69, it becomes exactly one day less than 305 Haab', but no longer an even interval of the eclipse half-year. It is apparent that these two distance numbers supply some kind of a correction to the larger Piktun distance numbers subtracted from the Era Base date. In the case of this correction on page 61, the result reaches a lunar eclipse in the same sidereal position as the moon appears on the Era Base date, but here it is at the first nadir, with the sun at the first zenith in the same sidereal position as on the Era Base date in Virgo.

From the lunar eclipse on April 26, 10,300 BCE, we can subtract the 111,263-day correction to reach the uncorrected interval reached by subtracting 7,600 Tuns from the Era Base date. On this date, September 9, 10,604 BCE, the sun reaches to within two days of a node, but the nodes themselves were near the equinoxes, just as they were in 3114 BCE. In fact, when the extra 61 days are subtracted to form the related correction of 111,263 + 61 days = 111,324 days on page 69, the nodes precisely reach both equinoxes. The 111,263-day and 111,324-day intervals may then coordinate the sidereal position of the nodes, and the eclipse half-year over some 300 years.

Re-examining the subtraction of the secondary inscription of 2,624,737 days from the 13 Mak future date reached by multiplying the initial distance number five times, the resulting interval is very close to a whole number of eclipse half-years:

27,410,675 days – 2,624,737 days = 24,785,938 days

24,785,938 days = 143,015 (173.31 days) + 8.35 days

Therefore, when this interval is added to the Era Base date 4 Ajaw 8 Kumk'u, the moon will be in the same position relative to the nodes as it was on the Era Base date. Also, because the moon on this future date will also be in the same sidereal position, and the same phase as it appeared on 4 Ajaw 8 Kumk'u, the sidereal position of the lunar nodes will also be nearly identical to their position on the Era Base Date. Because this future date approximates the first solar zenith at 14.8° N in the year 64,749 CE, the sidereal position of the nodes will no longer occur at the equinoxes at this time, as they did in 3114 BCE.

It is my contention that the B'ak'tun multiples followed by a lunar **WINIK** glyph in combination with the verb **u-LOK'?** and a subtracted distance number specifically refer to lunar phenomena involving the synodic and sidereal cycles of the moon, and the eclipse half-year. Here also, the sidereal year is calculated over very long periods of time.

On page 70 (**Figure 4.10b**) the second example of the series including a B'aktun and the lunar **WINIK** with **u-LOK'?**, appears beneath the three idealized Haab' dates mentioned in the previous chapter, but it is unclear how this distance number may be related to these Haab' positions. Beginning at C14, 10-B'ak'tuns, is followed by **OCH-ta-b'a** in D14. The lunar **WINIK** follows in C15, and the phrase then seems to read down only in column C with the verb **lo-LOK'?** at C16. If this is the same verb in the example on page 61, it is possible that this **lo-** (T580) is here actually another form of **u-** (T513), which is the same glyph on its side. However, this would bring into question both the pronunciation of T327a as **LOK'?**, and Stuart's (1987:41) reading of T580 as **lo**.[6]

Continuing on with the inscription on page 70, we come to the portion of the distance number that is to be subtracted. The head variant for the number 'nine' appears in C17, followed by a K'atun glyph with an **OCH** prefix in C18. An unusual animal head appears in C19, with an infixed **i** (T679) in its eye, followed by a Tun glyph with another **OCH** prefix in C20. Because of the context within an apparent distance number, Thompson (1962:382) proposed that this animal was a head variant of either the number 'five' or 'thirteen', but no other examples exist to support this. Because of the infixed T679, Knorozov (1967:90, 99) proposed that this sign is simply to be read as a personified form of the

---

[6] Houston and Stuart (1996:299), and Stuart, Houston, and Robertson (1999:56) have since questioned T580 as **lo**, and suggest instead a reading of **CHIT**?

syllabic sign for **i**. Here, **i** would seem to function as the conjunction 'and' before the Tun component of the distance number, which in this case has no coefficient and likely reads 'one'. Continuing back in column D, we see **1-OCH-wi-WINIK-ki** in D15. The total amount of this distance number would then appear to be:

10 B'ak'tuns
-9 K'atuns
- 1 Tun
- 1 Winal
= 1,374,820 days

This somewhat shorter distance number appears to be a positive integer, and it may have been added. On the other hand, it appears that it is more productive to subtract it from the Era Base date, or perhaps to add it to an earlier date to reach the Creation. It is therefore possible that the operations of subtraction within these distance numbers are not indicative of whether the whole distance number is added or subtracted. This distance number is not an even interval of the synodic lunar cycle, the sidereal lunar cycle, or the eclipse half-year, but it is close to a whole interval of the Maya sidereal year as calculated in the previous chapter:

1,374,820 days = 3,764 (365.2565128 days) – 5.514 days

When subtracting this interval, the sidereal position of the sun will be five days after the original position. However, the shift in the tropical year will be:

1,374,820 days = 3,764 (365.2419355 days) + 49.3548 days

This 49-day shift backward in the year recalls the idealized 52-day difference between the summer solstice and the second solar zenith at14.8º N latitude. If this distance number is then subtracted from the Era Base date 4 Ajaw 8 Kumk'u on August 13, 3114 BCE, it would reach a day 12 Ajaw 18 Xul on June 25, 6,878 BCE (**Figure 4.17**), just three days after the summer solstice, while this position would be five days after the sun reaches the same sidereal position in Virgo. Therefore, the position of the sun on the summer solstice is only two days away from the same sidereal position in Virgo in which it appeared on 4 Ajaw 8 Kumk'u. Furthermore, we also see that when this distance number is subtracted from 4 Ajaw 8 Kumk'u, the lunar positions on 12 Ajaw 18 Xul have remainders that closely match the remainder of the sidereal year. When this 5.5 day remainder is combined with the above distance number and subtracted from the Era Base date to reach 7 Men 13 Xul on June 19, 6,878 BCE, the synodic and sidereal positions of the sun and moon reflect those of the Era Base date 4 Ajaw 8 Kumk'u. This can be expressed by the following:

1,374,820 days + 5.5 days	**= 1,374,825.5 days**
synodic lunar	**= 46,556 (29.53059 days) – 0.648 days**
sidereal lunar	**= 50,320 (27.32166 days) – 0.43 days**
Maya sidereal year	**= 3,764 (365.2565128 days)**

Because the moon is just less than one day prior to being full on August 13, 3114 BCE, the above interval also reaches an exact full moon on the day 7 Men 13 Xul on June 19, 6,878 BCE, and the moon is in the same sidereal position in which it appeared on the Era Base date in 3114 BCE. The precise full moon on 7 Men 13 Xul suggests that this is why the sidereal and lunar positions have the same slight remainders on this date.

In addition, on the Era Base date of August 13, 3114 BCE, the sun was about 130 days past the ascending node. When 130 days are subtracted from the above interval of 1,374,825.5 days, the resulting interval is very nearly an even multiple of both the eclipse half-year and the eclipse year, and the sun was theoretically at the same ascending node on June 19, 6,878 BCE:

1,374,825.5 days – 130 days	**= 1374695.5 days**
eclipse half-yr	**= 7,932 (173.31 days) – 0.58 days**
eclipse year	**= 3,966 (346.62 days) – 0.58 days**

Because the moon is full and the sun is at the ascending node on 7 Men 13 Xul on June 19, 6,878 BCE, there would also have been a total lunar eclipse on this date in the sidereal position of the winter solstice (**Figure 4.18**), here in Pisces where the second nadir appears in 3114 BCE. Once again, the lunar **WINIK** and the verb **LOK'?** appear to represent specific calculations of lunar synodic and sidereal cycles, the eclipse cycle, the sidereal year, and the tropical year. The date June 19, 6,878 BCE is only two days before the summer solstice. Above the distance number that is used to reach this date, 13 Pax is written as the idealized Haab' date of the summer solstice in the group of three such dates discussed in the previous chapter, where 0 Pop represents the second solar zenith at 14.8° N, and 13 Yaxk'in represents the winter solstice.

The Solar Nodal Passage on the base date 9 K'an 12 K'ayab'

It appears that the Maya were capable of tracking the relationship of the sun and moon to the nodes over very long periods of time. Given this, might we also expect that the 9 K'an 12 K'ayab' base date was chosen with such specific calculations in mind? On the August 13, 3114 BCE Era Base date, the sun was 130 days past the ascending node. We can then determine the position of the sun relative to the nodes on 9 K'an 12 K'ayab' using the 10,967,536-day interval between 9 K'an 12 K'ayab and 4 Ajaw 8 Kumk'u and the eclipse half-year:

10,967,536 days = 63282 (173.31 days) + 132.58 days

The remainder of 132.58 days is very close to 130 days, and indeed, the sun would have been <u>very close to the ascending node</u> on 9 K'an 12 K'ayab' on June 23, 33142 BCE (**Figure 4.19**), which means that an eclipse would have been close to this date. Where was the moon on this date? Again, given that the moon was about one day before full on August 13, 3114 BCE, we can determine the synodic and sidereal position for the moon on 9 K'an 12 K'ayab':

10,967,536 days =

synodic lunar = 371,396 (29.53059 days) – 7.004 days

sidereal lunar = 401,423 (27.32166 days) – 6.722 days

On 9 K'an 12 K'ayab' was neither full nor in the same sidereal position as on 4 Ajaw 8 Kumk'u, but there would have been a total lunar eclipse at the descending node only 6 days before 9 K'an 12 K'ayab' in the sidereal position of the winter solstice near the Pleiades. While errors in the Maya values for the synodic and sidereal lunar cycles may be responsible for the 6-day discrepancy, the high degree of accuracy of the lunar calculations found in the secondary distance number from the Serpent Series introduction on page 61 (2,624,737 days) would not have produced such a large error. Because the remainder in 10,967,536 days is very close to exactly 7 whole days less than a whole multiple of the synodic lunar cycle, it is possible that the position of the moon was intentionally chosen to be 6 days past an eclipse on this date, but why?

It is possible that the multiple other factors incorporated into the choice of the 9 K'an 12 K'ayab' base date took precedence over the exact position of the moon, which changes more rapidly. Thus far, these factors include:

1) Tropical Year: the summer solstice in June of 33,142 BCE
2) Haab': 1 Pop at the second solar zenith at 19.5º N latitude in 33,142 BCE
3) Sidereal position:
- the ideal first solar nadir at 14.8º N in 1100 CE
- opposite the Pleiades:
  - first solar zenith in May at 14.8º N in 1100 corresponds to the last evening visibility of the Pleiades
  - Pleiades are at the zenith at 19.5º N in the Postclassic

4) Eclipse Year: the sun is exactly at the ascending node, with both nodes at the sidereal position of both solstices.

The combined accuracy of all of these calculations is impressive, and incorporating an exact lunar eclipse within all of the above parameters would seem to be nearly impossible. Nevertheless, such a lunar eclipse occurs only 6-days before the 9 K'an 12 K'ayab' date. As we have seen, the secondary Serpent Series distance number of 2,624,737 days accommodates the lunar cycles, while showing a slight remainder for the sidereal and tropical years that is nevertheless very accurate. Conversely, the 9 K'an 12 K'ayab' base date appears to accommodate all of the above factors, while giving a slight remainder for the lunar synodic cycle.

The Serpent Series introductory distance number, consisting of 15,228 Tuns + 55 days, or 5,482,135 days, is also nearly equivalent to a whole multiple of eclipse years, with a remainder of only about 7 days:

5,482,135 days = 15,816 (346.62 days) – 6.92 days

However, this interval is not a whole multiple of lunar synodic or sidereal cycles, and it seems that this introductory distance number was intended to correlate the sidereal year, the tropical year and the Haab', rather than the lunar cycles. Instead, following the introductory distance number, it is the <u>secondary</u> Serpent Series distance number on page 61 that coordinates the lunar cycles with the sidereal and tropical year.

Two additional examples of the Lunar **WINIK** and **LOK'?** distance numbers appear on page 73 and 31 (**Figure 4.10 c, d**), but because portions of these are eroded, we will refrain from attempting to calculate these intervals. The example on page 73 appears to have at least 10 B'ak'tuns in D2, with one **OCH**-K'atun subtracted in E4, and the latter also visible in the example in G6 on page 31.

The Lunar Nodes and the Calculation of the Eclipse Year

The Dresden Codex contains an extensive Lunar Table on pages 51–58 that can be used to track eclipses over long periods of time (Bricker and Bricker 1983). Förstemann's earlier work on the Lunar Table indicated that the Maya of the Postclassic were counting several periods of 177 or 178 days, equivalent to six synodic months, along with occasional periods of 148 days, or five synodic months, to reach possible eclipse position. These corrective groups of five months account for the differential regression of the nodes against the synodic lunar cycle (Förstemann 1901).

The Lunar Table runs for a total of 11,960 days, or 46 Tzolk'ins, nearly equivalent to 405 synodic lunations and 69 eclipse half-years (405 lunations = 11,959.889 days; 69 eclipse half-years = 11,958.39 days), covering an period of almost 33 years. If 11,960 days is understood as a whole interval of 405 lunations, the value for one synodic lunar cycle would be 29.5308642 days, somewhat shorter than the current value of 29.53059 days. From a comparison of lunar data recorded in Classic period texts with back-calculated lunar positions from their mythological texts, Teeple (1931:68) found that the astronomers in Palenque were using this shortened lunar synodic value of 29.53086 days, which produces a significant error of about 10 days over a period of 3,000 years.

If the Dresden Lunar Table of 11,960 days is recycled as it stands, inaccuracies would accumulate over longer intervals, and several authors have attempted to demonstrate how corrections could have been made for extended periods of time (Satterthwaite 1965; Thompson 1972; Lounsbury 1978; H. Bricker and V. Bricker 1983). As Lounsbury (1978:797) notes:

> An "adequate" theory, such as might have allowed the Maya astronomers to move the five-month periods systematically and with proper precision, would have required only that they had known the rate of regression of the node days, or of the eclipse seasons, through their sacred almanac. There is no clear evidence to indicate that they knew this, although the possibility cannot be excluded.

The Lunar Table was intended for reuse over periods of time well beyond 11,960 days. A series of long distance numbers at the start of the table on pages 51–52, along with several widely separated Long Count positions, suggest some kind of recycling. It is not my intention to review the various proposals for how this may have been accomplished, but it is apparent that some kind of systematic correction was used. Given the accuracy of the lunar calculations in the Serpent Series, it appears that this correction was extremely refined. Thus, by the Postclassic, knowledge of the lunar synodic cycle was more accurate than it appears to have been in the Classic period, perhaps a result of the accumulation of many more years of historical data.

The 1,820-day cycle

The 11,960-day lunar cycle also correlates the lunar synodic cycle with the Tzolk'in cycle of 260 days. Lounsbury (1978:804) notes:

> The problem for the Maya astronomers was not simply that of determining the natural cycles of celestial phenomena but, equally important, that of integrating these with the cycle of days in the sacred [Tzolk'in] almanac.

Teeple (1931:90) first demonstrated that three cycles of the eclipse half-year of 173.31 days are nearly equivalent to two Tzolk'in cycles of 260 days:

2 (260 days) = 520 days
3 (173.31 days) = 519.93 days

Because of this correlation, eclipses tend to cluster around specific Tzolk'in dates throughout the Dresden Lunar Table.

A multiple of seven Tzolk'in cycles, another cycle of 1,820 days, appears throughout the Dresden Codex. It is a prominent feature of both of the Serpent Series tables on pages 63–64 and pages 70–73. This period is also equivalent to five cycles of the 364-day computing year, and in Maya notation, it is written as 5.1 0. To my knowledge, the astronomical utility of this cycle has not been previously noted, in that 1,820 days also shifts the <u>sidereal position</u> of the lunar nodes by 1/4 of a year. In other words, if the nodes are in the sidereal position of both solstices, adding 1,820 days will place the nodes at the equinoxes. If the sun begins at a node on the summer solstice, for instance, in 1,820 days the sun will be halfway between the two nodes and in approximately the same position in the tropical year (less some 6 days).

When 1,820 is multiplied twice to give 3,640 days, the sun again reaches a node, because 3,640 is equal to seven double-Tzolk'ins of 520 days each, and 21 eclipse half-years of 173.31 days each, with a remainder of less than half of a day:

3,640 days = 21 (173.31 days) + 0.49 days

Beginning with the sun at a node on the summer solstice and adding 3,640 days, we find that the sun again reaches a node, but now it is about 13 days earlier than the summer solstice.

From page 52 of the Dresden Codex, we find a curious inscription in column D following a series of thirteen long distance numbers (**Figure 4.20**). A Lunar skull appears eroded in D1, followed by a distance number that appears as 8 K'ins in D2, and 1 Winal and 5 Tuns in D3, with **2-ta-b'a** in D4. Beneath this is a column of the number 'thirteen' written in red and repeated thirteen times. The Brickers (1988:13–14) have suggested that *2-tab'* refers to a 'second addition' of an interval of 1828 days, to be added to the distance number immediately to the left in column C (11,960 days +1,820 days) as a correction to the Lunar Table. Another 13 days is added from the column below, while they argue that an unstated 30 days must be subtracted to reach the same base date for recycling the table. Thus, they believe that correction of 3,631 days is to be added to each of the 13 distance numbers appearing in the columns to the left.

However, another possibility exists if we understand *2-tab'* as a doubling of the interval of 1,820 days, setting aside the 8-days that feature prominently above in D2. The 1-Winal and 5-Tun glyphs are included in the same block in D3, and as we have seen, this interval of 1,820 days is common throughout the Codex. Doubling the 1,820-day interval, we have the 3,640-day interval in which the sun again reaches the opposite node, but it is about 13 days earlier in the tropical year. Thus, the column of the number 'thirteen' written thirteen times suggests this multiple of 3,640 days +13 days in which time the opposite node regresses from the same position in the tropical year by 13 days. Furthermore, it appears that this interval of 3,653 days is also to be multiplied thirteen times. In this exact interval of 47,489 days the sun returns to the <u>same</u> node, very close to the same sidereal position and the same position in the tropical year, plus about eight days. It is possible that this is the reference to the eight days given at the top of the inscription, though in this case, eight days would be added to reach the tropical year position only when the entire interval of 47,489 days is <u>subtracted</u> to back-calculate the nodal positions in the tropical year. This interval of 47,489 days is also only about four days greater than a whole multiple of synodic lunar cycles, and less than six days beyond the <u>sidereal</u> year:

13 (3,640 +13 days) = 47,489 days

Eclipse half-year	**= 274 (173.31 days) + 2.056 days**
Copan tropical Yr.	**= 130 (365.2419355 days) + 7.54 days**
Haab'	**= 130 (365 days) + 39 days**
Synodic Lunar	**= 1,608 (29.53059 days) + 3.81 days**
Maya Sidereal Yr.	**= 130 (365.2565123 days) + 5.6534 days**

The effect of this 47,489-day interval will reproduce an eclipse about four days earlier, and this will occur only four days later in the tropical year, while only two days beyond the same sidereal position, due to precession. Such measurements of two total lunar eclipses separated by this interval could then be used to determine that approximately two days of precessional drift had occurred, and these measurements could be further refined over time.

Thus, while the sidereal position of the opposite node recesses from the tropical year by about 13 days every 3,640-day interval, the recession in 13 multiples of 3,640 days is such that adding 169 days (13 x 13) returns the sun to the same node near the same position in the topical year. The total interval of 47,489 days comprises over 130 years, well beyond the 11,960-day Lunar Table. In fact, it is exactly 351 days earlier than four cycles of 11,960 days. Because of the 169-day correction added, the Tzolk'in position will be 169 days later, or 91 days earlier than the starting position. This recalls the efficacy of the 91-day intervals used in the Serpent Series seasonal table on pages 63–65. Furthermore, the interval of 47,489 days is 130 Haab' of 365 days, with a remainder of 39 days. Again, the recurrence of a 39-day interval recalls those used in the base days from the same seasonal table. With adjustment, this 47,489-day interval can be used to track the sidereal year, the tropical year, the Haab', the lunar cycles, and the eclipse year, and this is precisely what the Serpent Series appears to be doing.

If we begin hypothetically with the sun at the ascending node on the summer solstice, and a total solar eclipse on this date, adding 47,489 days places the sun only two days beyond the ascending node, and about eight days after the summer solstice. Subtracting less than four days, another solar eclipse will occur, and at this point, it is less than three days from the same position of the tropical year on which the first eclipse occurred. The same can be done for lunar eclipses opposite the sun in these positions. Because of about two-days of precession, the new eclipse is less than two days after the same sidereal position of the original eclipse. The 3,640-day interval, with the addition of 13 days, and the 47,489-day interval would then be an excellent means by which to track the sidereal position of the nodes through the tropical year. With a small correction for the lunar synodic cycle, it could further be used to track eclipses over long periods of time, and to track the sidereal year and precession.

Returning to the 8-day interval that is written underneath the lunar skull at the top of column D, might this instead relate to the position of the moon? In fact, in one interval of 3,640 days, the moon is about eight days beyond the node:

3,640 days = 123 (29.53059 days) + 7.73743 days

There is no explicit instruction to subtract the interval of eight days from the following interval of twice 1,820 days, but it appears that this is a possibility, given that such a subtraction reaches the same phase of the moon at the same node. Thus, if we begin on an eclipse and add an interval of 3,632 days, we are likely to reach another eclipse. On the other hand, if the 3,640 days is to be subtracted, an eight-day interval could be added to reach a previous eclipse. On occasion, beginning on a lunar eclipse, an eight-day interval could be added to 3,640 days to reach a solar eclipse, but this is not a repeating occurrence, and an eight-day subtraction is more effective for maintaining the same lunar phase, if that is intended. However, because of the eight-day subtraction from the nodal position, the sun and moon will rapidly fall out of alignment with the nodes. Thus the 3,632-day interval is only useful for two repetitions to reach another solar eclipse, and it is not useful beyond four repetitions for lunar eclipses. It remains useful for the purposes of determining the synodic lunar phase over longer periods of time, but in 13 repetitions, the lunar phase is about four days earlier because the remainder is slightly less than eight days, and here the moon would be farthest from a node.

Another possibility exists if 8 days are added to 3,640 days, to which another 13 days are added. This 3,661-day interval is then multiplied thirteen times to give 47,593 days, which both returns the nodes to the same sidereal position, while also returning to moon to almost the same sidereal position and the same node, being almost a whole interval of the draconic month. However, the position of the sun would not be near a node in this interval, and the exact position of the moon is about one day before the node and the same sidereal position:

13 (3640 days + 8 days + 13 days) = 47,593 days

Sidereal Lunar Cycle	**= 1,742 (27.32166 days) – 1.332 days**
Draconic Month	**= 1,749 (27.21222 days) – 1.173 days**
Synodic Lunar Cycle	**= 1,611 (29.53059 days) + 19.22 days**
Eclipse Year	**= 274 (173.31 days) + 106.06 days**

Because the synodic lunar cycle and the eclipse year are not whole intervals in the above calculation, I believe that the previous interval of 47,489 days is the intended calculation. An interval of 47,489 days would be much more useful for tracking the sidereal positions of the nodes, the sun and the moon over long periods of time for the purposes of predicting eclipses and correcting the Lunar Table. Furthermore, it would enable the Maya astronomers to record and observe precession using a method similar to that used by Hipparchus.

Glyph Y and the 1820-day cycle

The utility of the 1,820-day interval for calculating the eclipse half-year and the sidereal position of the nodes is clear, and there is evidence that this cycle was also recognized in the Classic period. Yasugi and Saito (1991) have determined that glyphs Y and Z of the Supplementary Series represent a repeating cycle of seven days. As Lounsbury notes, the Maya were interested in the commensuration of various cycles with the Tzolk'in. If it was coordinated with a specific day in the Tzolk'in, the seven-day cycle of glyphs Y and Z would repeat every 1,820 days, or seven intervals of 260 days.

The name **7-IK'-K'ÄN-NÄL** 'seven black yellow place' appears in the inscriptions from Palenque, Copan and Tikal, and on an onyx vase from Jaina. The name suggests a supernatural toponym, but in three examples, it is paired with another name with a coefficient of 29. This is most prominent on the altar of the Temple of the Sun in Palenque (**Figure 4.21**), a structure known to be associated with eclipses (Mendez et al. 2006). Here, the coefficient of 29 is preceded by a 1, evoking the lunar synodic months of 29 and 30 days found in Glyph A of the Supplementary Series. Teeple (1931:51, 63) confirmed the lunar character of Glyph A as an alternating sequence of 29 and 30 days used to closely approximate the true synodic month. Teeple concluded that these intervals alternated, with several adjustments, to calculate fairly accurate lunar cycles during the Classic period.

Paired with the above lunar name, the name 'seven black yellow place' suggests a reference the cycle of 1,820 days as seven Tzolk'ins. Black is the color that the Maya associate with the west, while yellow is associated with the south (Rosny 1876; Coe 1992:117). If we can understand the directional color associations as sidereal positions in the tropical year where the west signifies the autumnal equinox, and south signifies the southern solstice, in the interval of 1,820 days, the sidereal position of the nodes indeed changes from west-east at both equinoxes to south-north at both solstices.

The Supplementary Series in the Classic Period

Several hundred monumental inscriptions and painted texts from the Classic period demonstrate consistent, codified forms of calendrical and chronological information among the Lowland Maya. The Initial Series that introduces many of these texts begins with the Long Count, followed by the Tzolk'in and the Haab'. These latter two cycles are often separated by what Charles Bowditch (1903;1910:244) first described as the Supplementary Series.

After successfully identifying the Initial Series as equivalent to the Long Count in the Dresden Codex, Joseph Goodman (1897:118) first identified the Supplementary Series in the Classic inscriptions, though he was unable to decipher its meaning. Based upon the presence of numerical coefficients with several recurring glyphs thought to be ideographic images of the moon, Sylvanus Morley concluded that the Supplementary Series provided some kind of a lunar count (Morley 1915:152). He decided that this count is to be read backwards from the position of the last and most regular glyph in the series prior to the Haab' calendar position, and his resulting system of reverse labeling continues to be used for the purposes of analysis. Morley labeled the last glyph in the Supplementary Series Glyph A, and the standard names of the remaining glyphs precede this position as B, C, D, E, F, and G, with a common additional variable glyph between Glyph C and Glyph B designated as Glyph X (Morley 1916). Wyllys Andrews IV later identified two rare glyphs between Glyphs F and E, labeling them Glyphs Z and Y, in agreement with Morley's reverse lettering system (Andrews 1938:30). Thus the sequence of the Supplementary Series, when all elements are present, follows from the Initial Series and Tzolk'in as Glyphs G, F, Z, Y, E, D, C, X, B, and A (**Figure 4.22**).

The lunar information in the majority of the Supplementary Series has since been widely accepted, and Thompson prefered the term Lunar Series to designate Glyphs E through A, separating Glyphs G and F as non-lunar (Thompson 1935; 1971:208, 237). As Teeple demonstrated, Glyph A designates a lunar month of either 29 or 30 days, while Glyphs D and E, whose coefficients range from 1 to 29, record the age of the moon as measured from various points near the new moon (Teeple 1931:48, 51, 63). Glyph C records the position of the moon within an 18 month eclipse cycle, in one of three six month eclipse intervals. This is often followed by Glyph X, a poorly understood series which gives the name of the lunation related to the Glyph C position. Glyph B is simply the phrase 'it's name', in reference to Glyph X and Glyph C (Schele, Grube and Fahsen 1992).

Glyph G and the Lunar Nodes

In an analysis of Glyphs G, J. Eric. Thompson found that Glyph G has nine variations that appear in a continuously repeating cycle. He theorized that these correspond, at least in function, to the nine "Lords of the Nights" of central Mexico which rule over the hours of darkness. He translates the predominant G9 (T545) as the "night sun" (Thompson 1929; 1971:210). Thompson later concluded that Glyph G, and the more standardized Glyph F that follows it, have nothing to do with the lunar cycle, given that they appear to be an arbitrarily repeating sequence. Furthermore, he set them apart from the rest of the Supplementary Series, preferring the term Lunar Series for Glyphs E through A (Thompson 1935; 1971:208, 237). Later Kelley (1972:58) proposed that the Aztec, Zapotec and Maya cycle of nine days represent each of the nine 'planets', modeled after the Hindu *Navagraha*, which includes the sun, the moon, all five visible planets, and the two lunar nodes, Rahu and Ketu, as invisible planets. More recently, Sven Gronemeyer (2006) has proposed that the Maya cycle of nine days represents the growth and development of maize.

While the nine variable glyphs of Glyph G have yet to be translated successfully, Thompson's hypothesis remains as the currently accepted convention, and it is widely believed that this cycle is non-lunar (Coe 1992:132-33; Aveni 2001:156). However, Martha Macri has proposed that these nine originated as the nine days at the end of a month, added to twenty to reach the new moon on the twenty-ninth day. She interprets Glyph G9 as a representation of a possible eclipse, and the time of a new moon (Macri 2005:284).

Yet, several of the variants of Glyph G contain numerical coefficients that may reveal additional information regarding the utility of this cycle. These coefficients do not follow a linear progression of one through nine, so it is unlikely that this is their function. Glyph G1 shows the number nine, G4 the number seven, G5 the number five, and G6 the number nine. Furthermore, the glyphs depicted alongside these coefficients are unique, perhaps indicating that different things are being counted. These suggest some other kind of a count that may relate to G9 as an eclipse.

The image of Glyph G9 (T545) is a half-darkened sun, **K'IN**, conflated with the **yi** curl (T17), and Davoust (1995:585) reads this as *yih k'in* 'old sun' (**Figure 4.23a**). The half-darkened sun appears to relate to the half darkened 'wing-quincunx' glyph (T326) used in the codices to represent solar and lunar eclipses (**Figure 4.23b**). The word *yih* itself means 'old' and 'ripe' in Tzotzil, while *yi* means 'ear of corn' (Delgaty 1964). Likewise, *yih* can also be used in Tzotzil to describe the full moon, compared to an old man, or old maize (Laughlin 1975:74, 385). A similar term for 'full moon' is attested in colonial Yucatec as *yiih u*, while *yiih* alone is given as 'declining moon' (Barrera Vásquez et al. 1980).

In the personified form of Glyph G9, a head variant of a toothless old man appears with an infixed T17 **yi**, and a **NÄL** (T86) prefix, which may suggest 'old' and 'corn', as above. In this case, the **yi** is usually conflated with the half-darkened **K'IN** 'sun' glyph (T545) in his headdress (**Figure 4.24a**). In several other examples, the **yi** is conflated with the face of the old man (**Figure 4.24b**).

Here *näl-yih-k'in*, or *yih-k'in-näl*, seem to refer to 'place of the old sun', perhaps indicated by the darkening, suggesting the end of some kind of a solar cycle, perhaps the location of a solar or lunar eclipse, namely, the lunar nodes.

We also find the example of G9 from Naranjo with a large birthmark on his chin (**Figure 4.24a**). David Bolles (1997) notes that the Yucatec refer to birthmarks as *chib'al yuil* 'bite of the moon' because lunar eclipses are believed to cause birth defects. In Yucatec, *chí'ib'* means 'be bitten' (V. Bricker et al. 1998:70), while in colonial sources, the Yucatec Maya referred to eclipses as *chi'b'il* (Martinez Hernandez 1929:305). Milbrath (1999:26) adds that *chi'b'il* specifically refers to partial eclipses that resemble bite marks. These associations support Macri's suggestion that Glyph G9 relates to eclipse events, though G9 may refer to both lunar and solar eclipses.

Glyph G almost invariably follows the Tzolk'in position, perhaps indicating a relationship between the cycle of 9 and the 260-day cycle. In fact, Thompson (1971:210–11) notes that a specific table on pages 30c–33c in the Dresden records a commensuration of the cycle of 9 with the 260-day cycle. Given that 260 is not divisible by 9, the cycles of 260 and 9 commensurate only in 9 x 260 = 2,340 days. Thompson notes that this exact interval is recorded in the Dresden as a means to integrate the Tzolk'in with the nine Lords of the Night.

The **draconic month** of 27.21222 days marks the time it takes for the moon to reach the same node, regardless of phase, while the **half-draconic month** of 13.60611 days records the time it takes the moon to reach the opposite node, with the effect that the moon reaches a node every 13.60611 days. If we begin with the moon at the node on a solar eclipse, the addition of nine Tzolk'ins (9 x 260 days), or 2,340 days, returns the moon exactly to the node, but at the first quarter. The interval of 2,340 days is also just a quarter of a day short of 86 draconic months:

2,340 days = 86 (27.21222 days) – 0.25092 days

Adding twice the interval of 2,340 days from a solar eclipse, we reach a lunar eclipse. Adding four times this interval, we return to a new moon that is one day prior to another solar eclipse at the same node. Could the cycle of nine be a way of tracking the draconic month, and the position of the moon in relationship to the nodes? If so, it would be a useful tool in the prediction of eclipses.

Recalling that three cycles of the eclipse half-year of 173.31 days are nearly equivalent to two Tzolk'in cycles of 260 days, Teeple (1931:90) first demonstrated how the Tzolk'in can be used to track eclipses. Lounsbury (1978:797) notes that accurate adjustments to the Dresden Lunar Table could be done by tracking the recession of the nodes within the Tzolk'in, though he claims that no evidence exists for such a correction. We have explored the possible ways in which the Lunar Table formula on page 52 of the Dresden could be used to track the eclipse year over long periods of time, but in this case, Glyph G and the cycle of nine may have been used together with the 260-day Tzolk'in to keep track of the draconic month. An examination of the remaining coefficients of Glyph G provides additional evidence that these cycles were used in combination.

Every 260 days, the position of Glyph G decreases by one in the cycle of nine. Adding 260 days to G9 reaches G8, and adding another 260 days reaches

G7, and so on. In nine Tzolk'in cycles of 260 days, we again reach G9. If Glyph G was used to help predict eclipses, we can use an idealized correlation of Glyph G9 with a solar eclipse and count backwards by cycles of 260 days from this position. This provides a linear progression of the same Tzolk'in day associated with the position of Glyph G increasing by one with each 260-day subtraction. So G1 falls 260 days before reaching G9 as an eclipse.

Because the cycle of nine repeats indefinitely, eclipses would rarely occur on days that coincide with G9. However, all other Maya cycles are similarly allowed to continuously repeat, though they may have arisen to keep track of specific astronomical phenomenon, such as the 365-day year, or the 260-day interval between the two solar zenith passages at 14.8º N latitude. Simply keeping track of the relative position within these cycles, each cycle could still be used to track the astronomical phenomenon for which it was originally intended. In the case of the cycle of nine, a correction of zero to four days is all that is required to conform to an idealized cycle with an eclipse coordinated with G9. This is because any eclipse event will be from zero to four days from any occurrence of G9.

Glyph G1

Beginning on the hypothetical solar eclipse at the ascending node on April 8, 2005 CE (**Figure 4.25**), we can ideally associate this date with G9 (though using the 584285 correlation, G1 would have actually fallen on this date, but a simple adjustment of one day is all that is necessary in this case). The common form of Glyph G1 includes the coefficient '9', with T1016, Schellhas' God C head **K'UH**

(Barthel 1952:94) with the T670 **CH'ÄM** hand as 'grasp, take, receive' (Schele and Newsome 1991:4). Together this reads **9-K'UH-CH'ÄM** 'takes nine holy/gods' (**Figure 4.26a**). A rare form of Glyph G1 uses the "fish-in-hand" glyph T714 **TZAK** 'conjure' (Schele 1991:86), with an apparent reading **9-TZAK** (TIX:714), 'nine conjurings' (**Figure 4.26b**). In the Platform from Temple XIX in Palenque, Stuart (2005:63) found in B4 an example of G1 which he reads as **9-CH'ÄM-ma-aj-K'UH**, with the passive verb *ch'ämaj* 'taken'. The word 'taken' might suggest a subtraction of some kind.

Subtracting 260 days, we reach the idealized position of G1 on July 22, 2004 (**Figure 4.27**). Here the coefficient of 9 may have several possible meanings. On July 22, 2004, the moon is exactly <u>9 days before the full moon</u>, but this full moon is not near a node or an eclipse event (**Figure 4.28**). However, this lunar cycle is also <u>nine months before the eclipse</u> event 260 days later on April 8, 2005. In this case, there is also a lunar eclipse on April 24, 2005, nine months after the full moon that follows July 22, 2004. It is possible that the coefficient of nine refers to either of these intervals of nine. Given that 260 days comprises nine lunar months, it is possible that G1 indicates that an eclipse event will take place on the same Tzolk'in day 260 days later on G9.

Glyphs G2 and G3

Glyphs G2 and G3 (**Figure 4.29**) do not have recognizable numerical coefficients associated with them, but Gronemeyer (2006) notes that they each appear to contain the dotted sign **HUL** (T45) 'arrive' (Grube 2002). This is more commonly used in Glyph D to represent the number of days 'arrived' since the new moon. Glyph G2 has not been successfully translated, though its main sign resembles T709 used in Glyph G4, as **AB’AK**. Coe and Kerr (1997:150f.) credit Grube with the reading of T709 meaning *ab’ak/yab’ak* ‘powder, ink, charcoal’. G2 would be 2 x 260 days prior to the eclipse on G9, and this is the double Tzolk’in interval that Teeple (1931) recognized as an eclipse interval. G2 would fall on November 5, 2003, and on this day the moon is very close to the same sidereal position in Pisces as it will be on the G9 eclipse on April 8, 2005. It is also three days prior to a total lunar eclipse on November 8, 2003. Perhaps ‘charcoal’ has something to do with the darkening occurring on a lunar eclipse.

Glyph G3 appears to contain **JANAB’** (Stuart and Houston1994:81), and Gronemeyer reads this compound as **HUL-JAN-NÄL**, meaning ‘the maize flower arrives’. It is unclear whether this may have a corresponding numerical or astronomical reading.

Glyph G4

The next Glyph G with a numerical coefficient is G4, with a coefficient of ‘7’ (**Figure 4.30**). The glyph appears to read **7-AB’AK** (TVII:709), with the possible reading ‘7- charcoal’. Subtracting 4 x 260 days from the G9 solar eclipse on April 8, 2005, we reach the day June 3, 2002 (**Figure 4.31**). On this day, the moon is exactly <u>7 days before another solar eclipse</u> event at the ascending node on June 10, 2002 (**Figure 4.32**). Also, subtracting 7 days from June 3 brings us close to the opposite node, because 7 days is about half of a half-draconic month. Again, it is possible that ‘charcoal’ may have to do with the blackening of an eclipse event. The mathematical relationship between eclipse events associated with G4 and G9 on the same Tzolk'in day 4 x 260 days later can be expressed in terms of draconic months and lunar synodic months as follows:

4 x 260 days = 1,040 days

1,040 days – 7 days = 1,033 days = 38 (27.21222 days) – 1.06 days

= 35 (29.53059 days) – 0.57 days

This interval is only one day from a whole multiple of draconic months, and it is very close to a whole multiple of lunar synodic cycles. Both the draconic month and the synodic month are average periodicities, and in this case, the interval of 1,033 days closely corresponds to an eclipse cycle. Because of slight fluctuations, the predicted eclipse can be within a day of the estimated Tzolk'in position, but this interval can be used effectively for both solar and lunar eclipses. Another eclipse event occurs 1,034 days prior to June 10, 2002 on August 11, 1999. This interval is actually more effective for predicting lunar eclipses over longer periods of time, with a series of partial and total lunar eclipses.

Glyph G05

Glyph G5 has the numerical coefficient of '5', and the glyph itself may be a phonetic reading of **5-HUL-li** (TV:45:24) *5-hul*, meaning 'five arrive' (**Figure 4.33a**). However, the T24 'mirror' may function logographically as a main sign, and Gronemeyer (2006) reads this glyph as the mirror T617. Another interesting variant from the Atkins Museum Lintel has the **CH'ÄM** (T670) hand holding this mirror (**Figure 4.33b**). This is the same glyph commonly seen in G1, and here **5-CHÄM** implies 'take 5', perhaps as some form of subtraction.

5 x 260 days prior to the G9 solar eclipse on April 8, 2005, we reach G5 on September 16, 2001 (**Figure 4.34)**. The moon is just about new on this date, but it is not near a node. However, <u>subtracting 5 days, the moon indeed reaches the ascending node</u> on September 11 (**Figure 4.35**). This would be the only such interval where subtraction is indicated, but this may indeed be the reference of both **5-HUL**, as 5 days after the node, and **5-CHÄM**, as 5 days taken away to reach the node. The lunar synodic month and draconic month intervals would be:

5 x 260 days = 1,300 days

1,300 days = 44 (29.53059 days) + 0.65 days

1,300 days + 5 days = 1,305 days = 48 (27.21222 days) – 1.17 days

The interval of 1,300 days is close to a whole multiple of lunar synodic months, and five additional days is only one day from a whole multiple of draconic months. Again, this interval would not consistently produce the exact same results with fluctuations within the actual draconic month intervals, but in this case, if the moon is at a node five days before it is new, there will be a solar eclipse 5 x 260 days later. In the case of a lunar eclipse interval, if the <u>full moon</u> is five days past a node, there will likely be a lunar eclipse in 5 x 260 days, within a two or three day range.

Because G5 has a coefficient of 5, it is also possible that this number represents 5 intervals of 260 days before an eclipse event at G9, but this would be the only such coefficient to do so. However, if G1 represents nine months before an eclipse event, G5 may demonstrate a similar pattern.

Glyph G6

Glyph G6 is quite rare, and Thompson (1971:fig.34:31) incorrectly confused this glyph with G7, which appears in two common forms. The actual Glyph G6 has a coefficient of '9', and the glyph itself appears to be similar to Glyph Y (**Figure 4.36**). Elsewhere (Grofe 2006) I have suggested that Glyph Y is a form of Unen K'awil, GII from the Palenque Triad, whose name implies both 'Child K'awil' and 'Mirror K'awil', relating to the mirror on the forehead of this infant deity. As we have seen, Glyph Y represents a repeating 7-day cycle (Yasugi and Saito 1991). Whereas Glyph Y may have different coefficients, Glyph G6 always appears to have the coefficient '9'. Indeed, because the 819-day count is a multiple of both the 9-day cycle and the 7-day cycle, every 819-day station falls on a day in which Glyph G is always G6.

Subtracting 6 x 260 days from the G9 solar eclipse at the ascending node on April 8, 2005, we reach G6 on December 30, 2000 (**Figure 4.37a**). On this date, the moon will reach the ascending node nine days later on January 8, 2001 (**Figure 4.37b**). This is also close to the same sidereal position of the moon at the node 5 days before G5 (**Figure 4.35**). A total lunar eclipse on the full moon occurs the next day on January 9 (**Figure 4.38**). The lunar synodic month and the draconic month intervals can be calculated as follows:

6 x 260 days = 1,560 days

1,560 days – 9 days = 1,551 days

In lunar synodic months: 1,551 days = 52 (29.53059 days) +15.41 days

In draconic months: 1,551 days = 57 (27.21222 days) – 0.097 days

This interval is almost exactly a whole multiple of draconic months, and it can be used reliably over long periods of time to determine the position of the moon relative to the node. Because this interval is also one day more than half a synodic lunar cycle, the synodic lunar cycle will differ from the nodal position by about one day in one run of this interval, and this difference will increase over time. However, in some cases, adding nine days will reach both the node and a lunar eclipse. If G9 falls on a lunar eclipse, adding nine days to the previous G6 may reach a solar eclipse.

A commensuration of the 260-day Tzolk'in with the 7-day cycle of Glyph Y could have been used to coordinate the eclipse year with the seasons. Given the correspondence between Glyph G6 and Glyph Y, it is possible that, with corrections like those found so far in the above intervals, the 7-day cycle, the 9-day cycle, and the 260-day cycle were all used together to determine the eclipse year and the draconic month as they move through the tropical year over long periods of time. Indeed, these three cycles commensurate in 20 x 819 days. Lounsbury (1978:807) has noted the importance of this interval of 16,380 days in the Classic period inscriptions from Palenque.

Glyphs G7 and G8

Neither Glyph G7 nor Glyph G8 appears with any certain numerical coefficient. However, Glyph G7 (**Figure 4.39a**) often carries a **na** (T4) prefix, which can signify the ordinal 'first', though in this context, it appears as a prefix to T1008, with the suffix **la** (T178), and together, these form a common collocation for 'north' (Schele 1992:19–22). In some versions of G7, we find **SÄK** (T58), meaning 'white', and white is the color associated with the north. The directional association is unclear here, though 7 x 260 days is the aforementioned interval of 1,820 days, in which the nodes shift their sidereal position from east-west to north-south. Other examples of Glyph G7 appear to be the head variant for the number 'two' (**Figure 4.39b**), and in fact, when we subtract 7 x 260 days from the eclipse at G9 on April 8, 2005, we reach the date of G7 on April 14, 2000, at which time the moon is two days past the ascending node. In fact, this is very close to the same time of year as the future G9 eclipse. When the moon is at the node two days earlier on April 12 (**Figure 4.40**), it is at the first quarter, while the sun is at the midpoint between the nodes, close to the same position in Pisces where the future eclipse will occur. When a quarter moon is at a node, this is also an important predictor for the 9 x 260 day cycle, in that there will be eclipse events from this point both 9 x 260 days in the future, and in the past.

Glyph G8 is represented by a single glyph, T155 (**Figure 4.41a**), which has been read as either **o** or **OL** (MacLeod 1991). Stuart (2006) suggests that T155 may be read **HUL**, as it appears to substitute for the footprint **HUL** (T331) in the Supplementary Series. I believe that T155 is a logograph for a footprint on a road, and it may therefore represent **OK** as 'step', from which may derive the syllabic

o. If so, it may represent the 'step' of one day. Subtracting 8 x 260 days prior to the G9 eclipse event on April 8, 2005, we reach the date July 29, 1999. On this day, the moon is just one day past full, and one day past the descending node, with a lunar eclipse on July 28 (**Figure 4.42**). Some of the versions of G8 appear half-darkened (**Figure 4.41b**), very similar to the eclipse imagery in G9 and in the eclipse glyph from the codices. Yet another appears with a skull beneath it, suggesting an association with the moon (**Figure 4.41c**).

Finally, 9 x 260 days before the G9 eclipse on April 8, 2005, we reach another day G9 on November 11, 1998, and the moon is at the last quarter and at the node. Glyph G and the cycle of nine days could easily be used together with the Tzolk'in to track the position of the moon relative to the lunar nodes. Thus, Maya astronomers could have used it to predict both solar and lunar eclipses.

Glyph F

Given the apparent context of possible draconic month calculations and eclipse predictions using the commensuration of the cycle of 9-days and the 260-day Tzolk'in, what might be the function of Glyph F?

Glyph F, which either follows or is combined with Glyph G, consists of standard repeating elements that have proven to be substitutions for the same word. Invariably, T128 is present as a prefix, and David Stuart (2005:63) reads this glyph as **TI'** 'mouth, lips, edge', while several other scholars have previously suggested a phonetic reading of **k'a**, connoting 'record' (MacLeod 1995; Macri and Looper 2003:296–97). The remaining glyphs clearly substitute for the reading *hú'un* or *hun*. This can be spelled variously as **hu**

(T740), or **HUN** (T665), and **na** (T23), with the final **na** usually appearing on all examples as a phonetic suffix (**Figure 4.44a**). Several recognizable logographs now known to represent **HUN** may also be present, and these have led to various interpretations of Glyph F as references to recorded books (T609b), the Jester God (T1030o) (**Figure 4.44b**), or headbands (T60abdef) (**Figure 4.44c**). Linda Schele suggests that Glyph F represents a headdress worn by each subsequent Lord of the Night, though its meaning remains unclear (Schele 1991; Schele, Grube and Fahsen 1992:2). Stuart (2005:63) suggests that *ti' huun* refers to the 'margin of the page', and he likens this to the recording of the Nine Lords of the Night in the Mixteca-Puebla style codices.

Considering that the various forms of Glyph G that include numerical coefficients may indicate an addition or subtraction of these specific numerals to coordinate the moon with the nodes, and facilitate eclipse prediction, <u>I propose that we may interpret the headband represented in Glyph F as akin to the tied red band used in Ring Numbers in the Dresden Codex</u>. Ring Numbers indicate mathematical operations of addition, 'tying' numbers to one another, while they also imply relationships of subtraction, reaching Ring Base dates prior to the Era Base date. I agree with Stuart's reading of T128 as semantically representing 'mouth', and in this case, 'the mouth of the band' might be equivalent to the placement of numerals within the center of the tied red band in the depiction of Ring Numbers. In fact, many representations of Glyph G appear in the center of the band represented in Glyph F by T60. Therefore, it is possible that the tradition of representing addition and subtraction through the use of Ring Numbers in the Dresden Codex may derive from earlier representations in the Classic Period.

To summarize, I suggest that the cycle of nine days was commensurated with the 260-day Tzolk'in, next to which it appears at the beginning of the Supplementary Series. Together, these cycles tracked the position of the moon relative to the nodes in the draconic month, and thus they would have been useful for the prediction of both solar and lunar eclipses. The following chart summarizes five of the nine Glyphs G:

G	name	translation	possible meaning	to eclipse
G9	**YIH K'IN NÄL**	Old Sun Place	Place of the Eclipse	0 x260
G1	**9-K'UH CHÄM**	9 Holy Taken	+9 mos. to eclipse	1 x 260
	9-TZAK	9 Conjurings	+9 days to full moon	
G4	7-AB'ÄK	7 Charcoal	+7 days to eclipse	4 x 260
G5	5-hu-li	5 Arrive	– 5 days to node	5 x 260
			+ 5 x 260 to eclipse?	
G6	9-Nen K'awil	9-MirrorK'awil	+9 days to node	6 x 260
			+9-10 days to lunar eclipse	

From these five examples, it appears that Glyphs G and F, like the rest of the Supplementary Series, convey lunar information. Therefore, the entire Supplementary Series, including Glyphs G, F, and Y, may be described as a

Lunar Series. These five examples of Glyph G are the only examples that include clear numerical coefficients. If these were used to determine the draconic month for the purposes of eclipse prediction, as it appears above, then it may be possible in the future to determine the meanings of the remaining glyphs from the series that do not include coefficients, namely Glyphs G2, G3, G7, and G8. Likewise, the main element in Glyph G9, the half-darkened **K'IN** (T545), appears elsewhere in the inscriptions, and it will be important to analyze its meanings in these contexts. I propose that, while it clearly represents an eclipse, G9 may also represent the position of the moon at a lunar node as *Yih K'in Näl* 'place of the old sun' and 'place of the eclipse'.

Implications of the Lunar Calculations

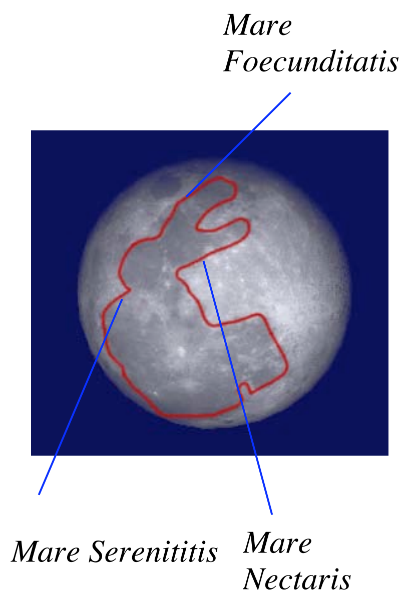
The evidence presented in this chapter shows that the Maya authors of the Postclassic Dresden Codex had accumulated sufficient data to calculate values for the synodic and sidereal lunar cycles and the eclipse year that are comparable to current values. Compared with the evidence from the Classic period, these Postclassic values indicate that a significant refinement and advancement had taken place by the time the Serpent Series was recorded in its final version.

The appearance of the 819-day count in the Western Lowlands and the Usumacinta valley in the late Classic period, with its component cycles of seven, nine, and 260 days, may have been integral in the later refinement of these lunar cycles. Indeed, the same verb used in the 819-day count appears in the Serpent Series (the following chapter explores the use and meaning of this verb). Furthermore, when multiplied by four, the 819-day count is divisible by the 364-

day computing year, also used within the Serpent Series. The cycle of 1,820 days and twice this interval of 3,640 days are useful as a means to track the sidereal positions of the lunar nodes, and the appearance of these intervals in the Lunar Table and throughout the Serpent Series suggests that they were of primary importance. The new interpretations of Glyph Y as a cycle of 7 x 260 days, and Glyph G as representing intervals of 260 days within a 9 x 260 day eclipse prediction cycle, suggest that an earlier knowledge of the recession of the lunar nodes was codified in the Classic period.

Figure 4.1:
The Lunar Pawahtuns

Figure 4.2: Lunar Rabbit rising near due East close to the vernal equinox. March 20th 2000 CE



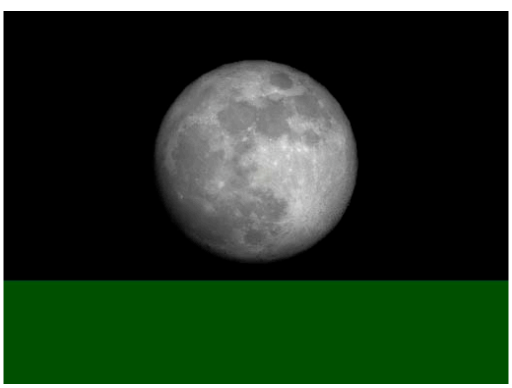


Figure 4.3: "Man-on-the-Moon" Lunar face rising close to the second nadir on August 14,1943 CE

Figure 4.4: Lunar face rising due East close to the autumnal equinox on September 13, 1829 CE

Figure 4.5a: Possible Lunar Skull setting in the West close to the autumnal equinox on September 18, 2005 CE

Figure 4.5b: Lunar skull T682b from pg. 53, Dresden Codex.

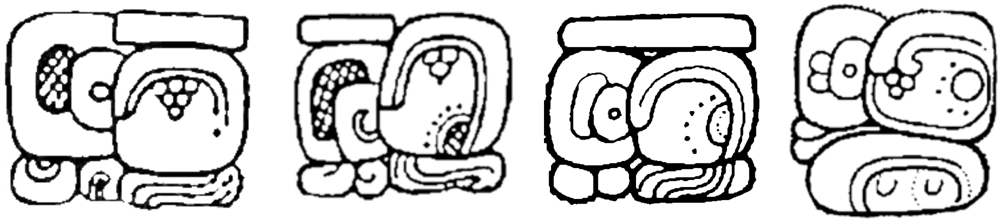
a) Page 61

A10:	**4 AJAW**	B10:	**8 KUMK'U**
A11:	**WINIK-na-ki**	B11:	**u-LOK?-i**
A12:	**"B'AK'TUN"**	B12:	**OCH-ta-b'a**
A13:	**1-OCH-"PIKTUN"**	B13:	**PÄT-aj**
A14:	**15-"K'ATUN"**	B14:	**9-"TUN"**
A15:	**1-wi-WINIK-ki**	B15:	**3-K'IN**
A16:	**19 OCH-b'a**	B16:	**u-ah-AJAW?**
A17:	**OCH-KAN?**	B17:	**ta-b'a**
A18:	**9 K'an**	B18:	**12 K'ayab'**

b) Page 69

C10:	**4 AJAW**	D10:	**8 KUMK'U**
C11:	**5 –ta-li**	D11:	**ta-b'a**
C12:	**1-OCH-PIKTUN**	D12:	**3-OCH-WINIK-ki**
C13:	**1-OCH-K'IN**	D13:	**PÄT-aj**
C14:	**15-K'ATUN**	D14:	**9-TUN**
C15:	**4-WINIK-ki**	D15:	**4-K'IN**
C16:	**9 K'AN**	D16:	**12 K'AYAB'**
C17:	**13 MAK**	D17:	**pa-se-la-aj**
C18:	**K'UHUL- OK-ki**	D18:	**??**

Figure 4.6: The Serpent Series Secondary Inscriptions



a b c d

Figure 4.7: T158 with **5-TUN**, meaning '5 Tuns before the K'atun.

a: PNG Throne 1 se, K'02.
after Montgomery (1990)

b: PNG Stela 25 nw, I14
after Montgomery (1990)

c: PNG Lintel 2, X12
after Stuart (in Schele and Miller 1986:149)

d: YAX Lintel 52, A2
After Graham (CMHI 3:113)

Figure 4.8:
T567 OCH/OK.
Dresden 65a2D3

Figure 4.9: T158 with '3' prefix. Dresden 10b1B2

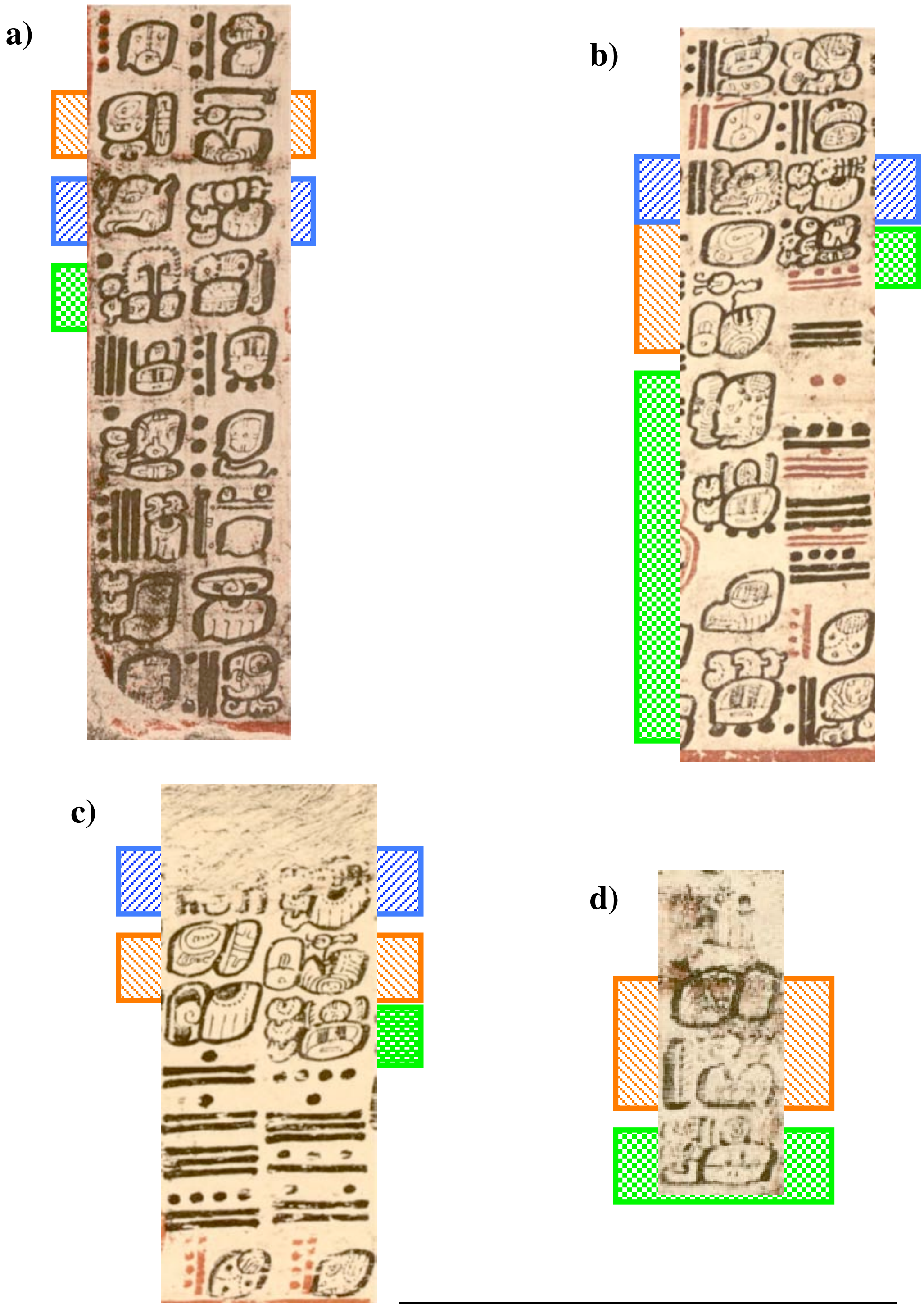


Figure 4.10: B’ak’tun and Lunar verb component
a) Page 61, A11–A13
b) Page 70, C14–C21
c) Page 73, D2–E4
d) Page 31, G3–G6

KEY:
= Lunar **WINIK + u-LOK?**
= **“B’ak’tun”** + **OCH-ta-b’a**
= **OCH** + Distance number

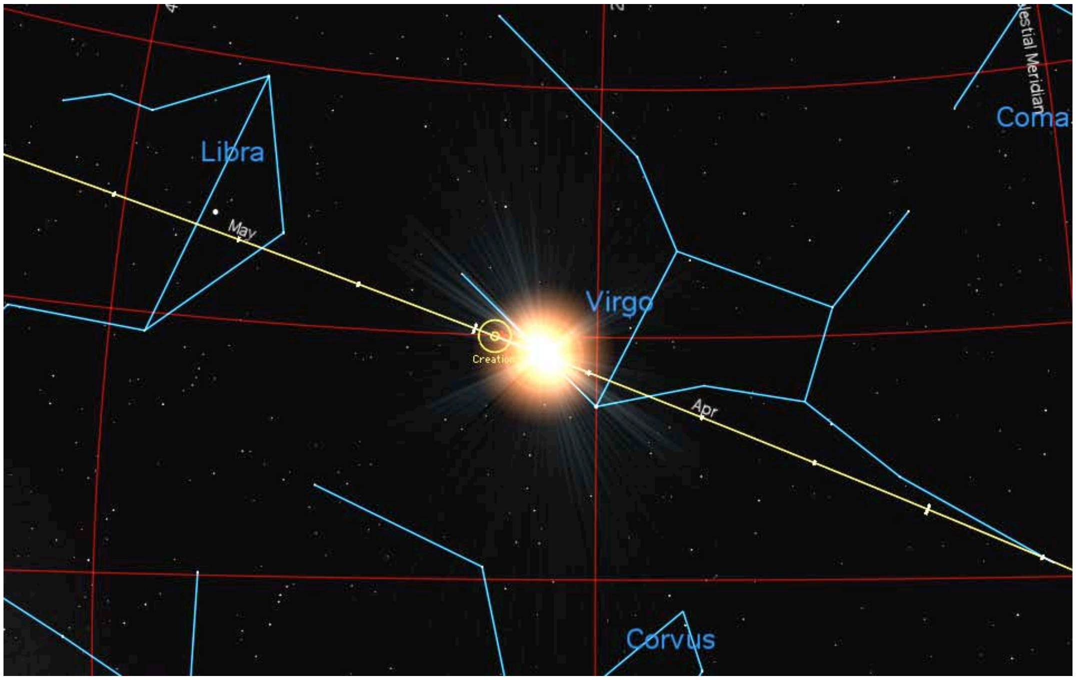


Figure 4.11: 6 Ak'b'al 6 K'ayab', April 26, 10,300 BCE. Theoretical reconstruction. Sun is three days prior to the same sidereal position in Virgo as it is on the Creation date, here the first solar zenith at 14.8° N.

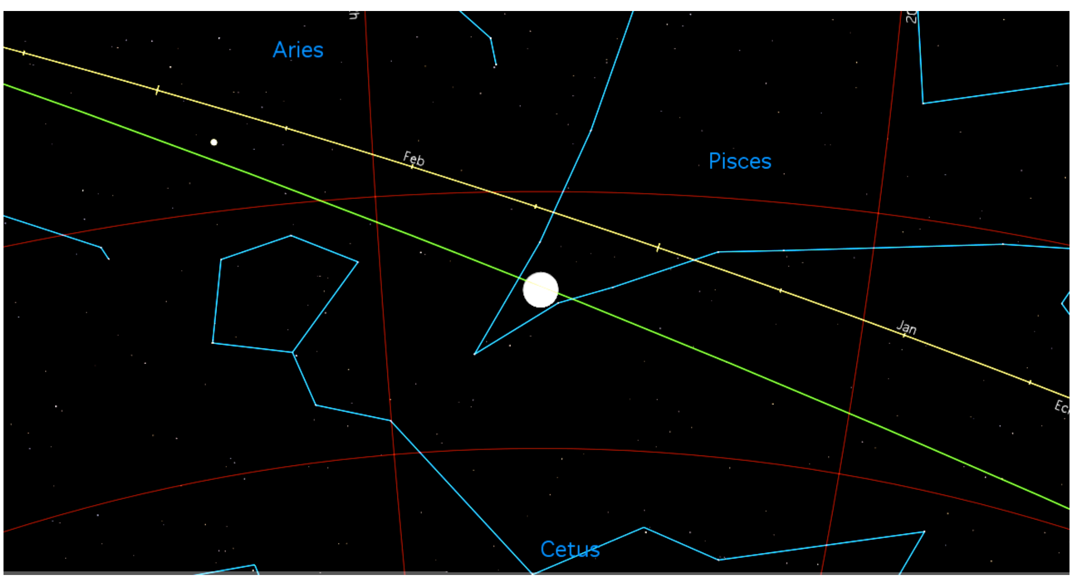


Figure 4.12: August 13, 3114 BCE. Position of the Moon in Pisces, one day before full on the Creation date. Solid line is the path of the moon, notched line is the ecliptic.

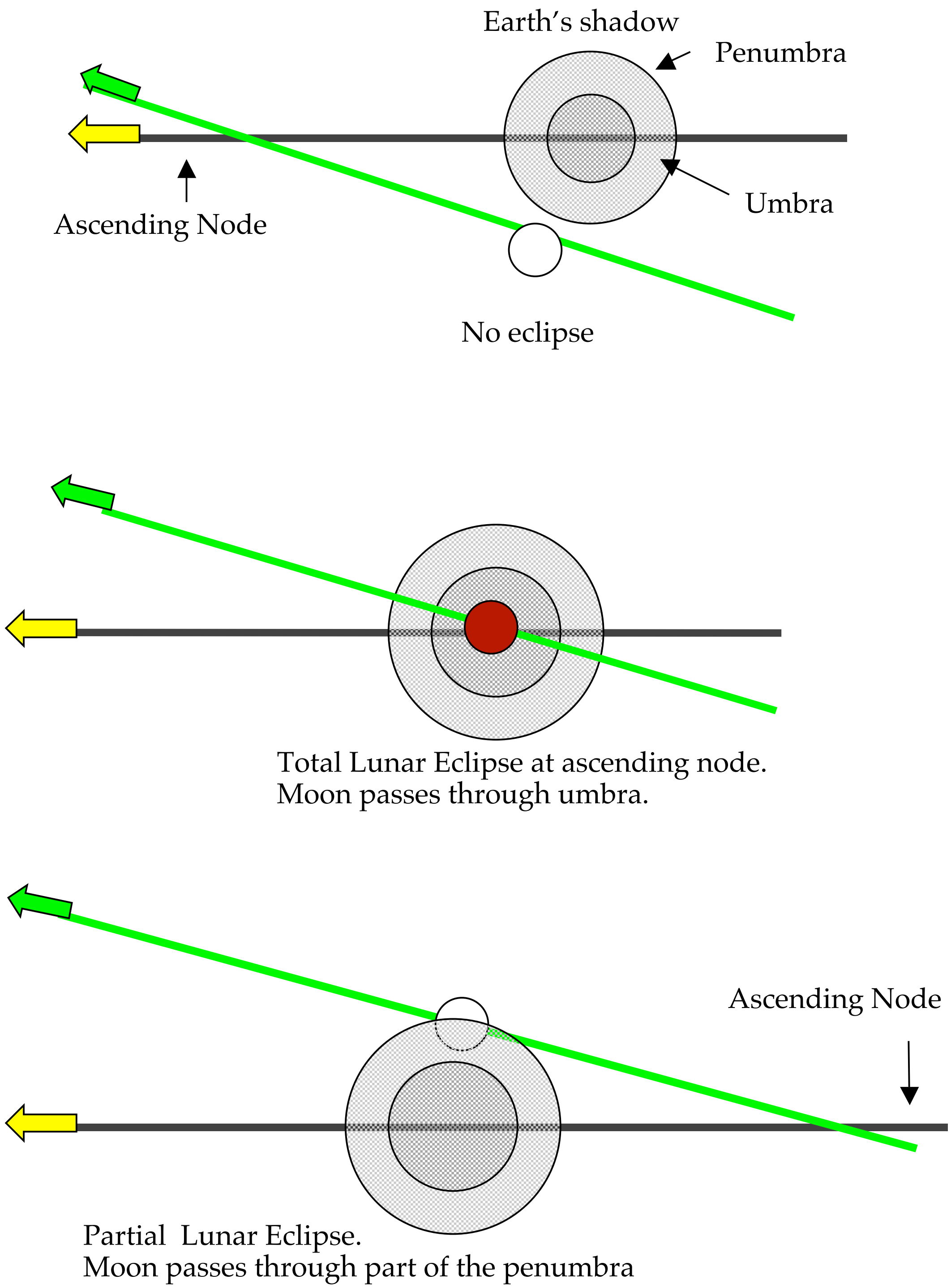


Figure 4.13: Lunar Eclipses
These three images can be seen as three successive lunar months, as the full moon approaches and passes the node. A lunar eclipse occurs when both sun and new moon are at

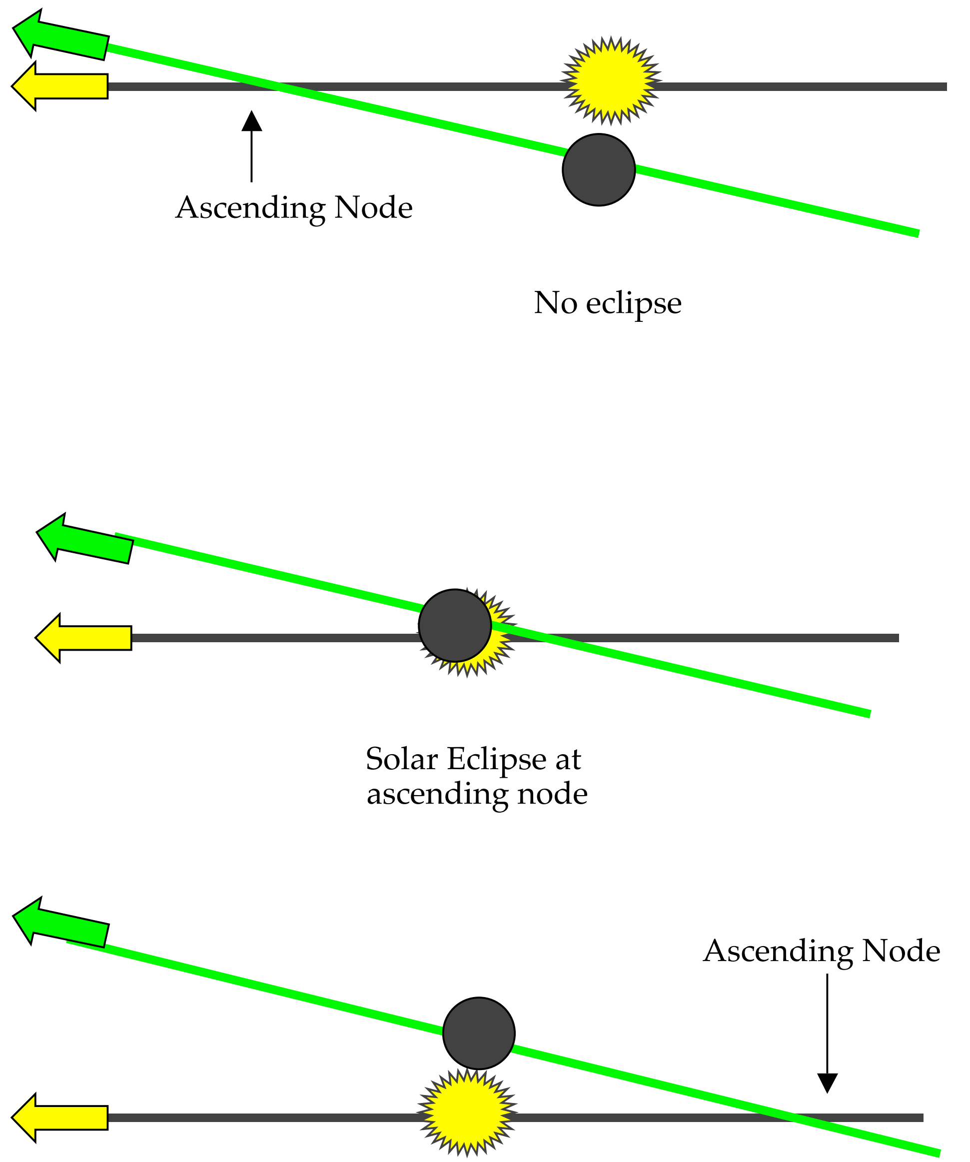


Figure 4.14: Solar Eclipses
These three images could be seen as three successive lunar months, as the sun approaches and passes the node. A solar eclipse occurs when both sun and new moon are at a node.

Or these can be seen as three successive years, where the position of the nodes at the same time of year regresses over time.

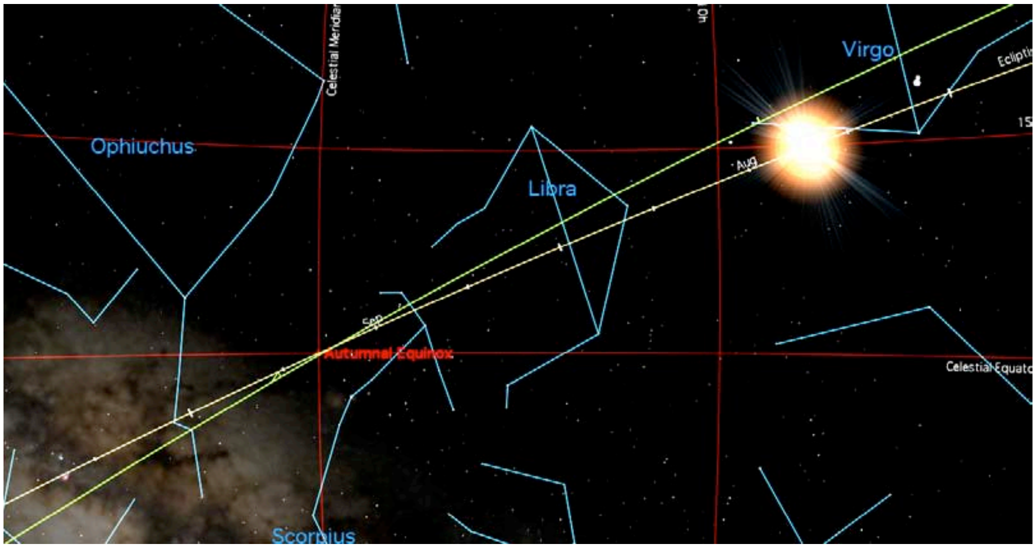


Figure 4.15: Descending node at autumnal equinox position at the time of the Creation on 4 Ajaw 8 Kumk'u, August 13, 3114 BCE.

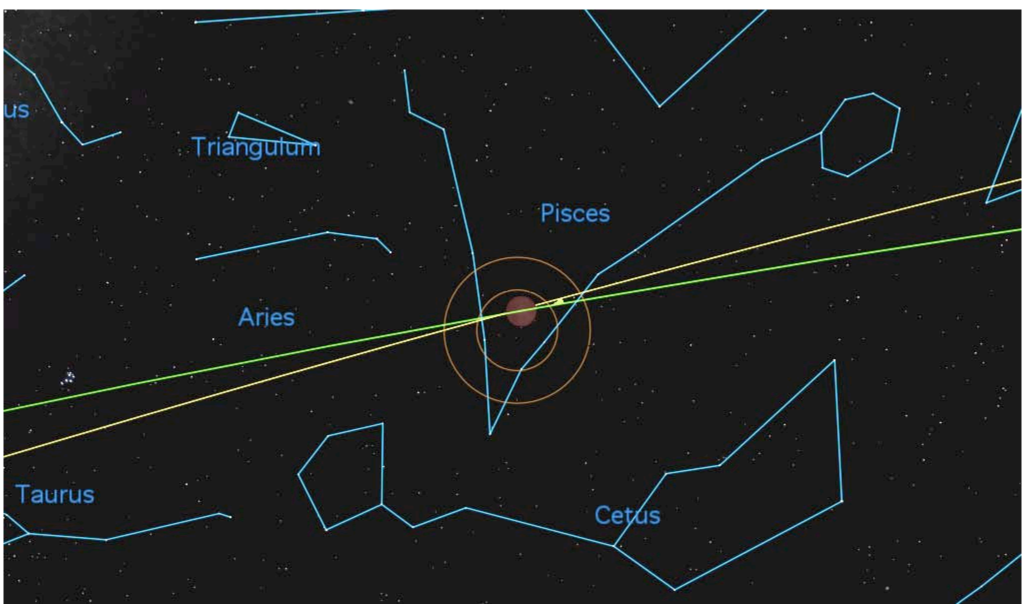


Figure 4.16: April 26, 10,300 BCE, Theoretical reconstruction of total Lunar eclipse in Pisces, the same sidereal position of the moon as on the Creation date, here at first nadir, 14.8° N

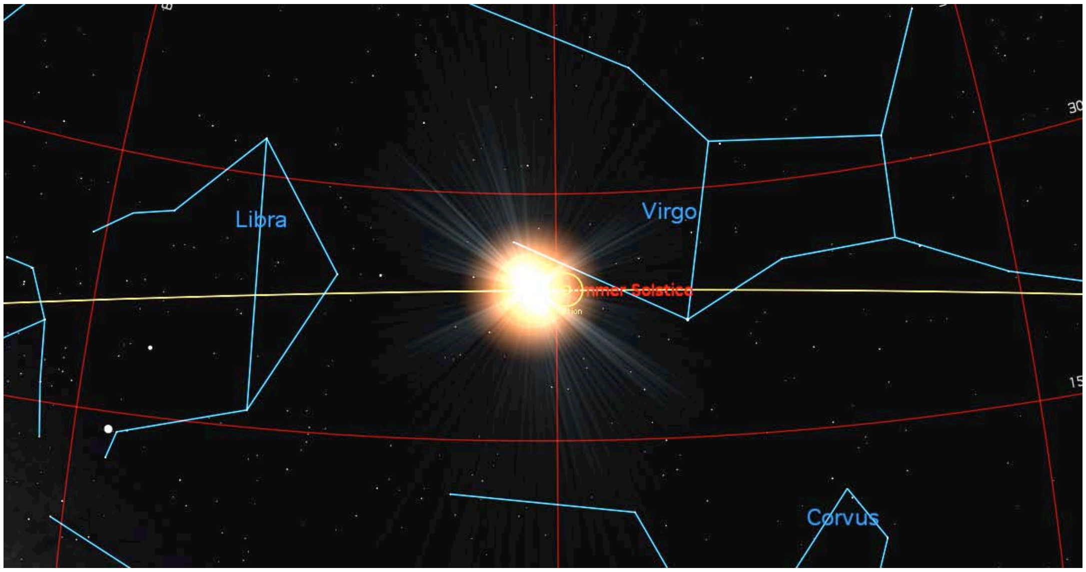


Figure 4.17: 12 Ajaw 18 Xul, June 25, 6,878 BCE. Three days after summer solstice in the sidereal position of Creation in Virgo

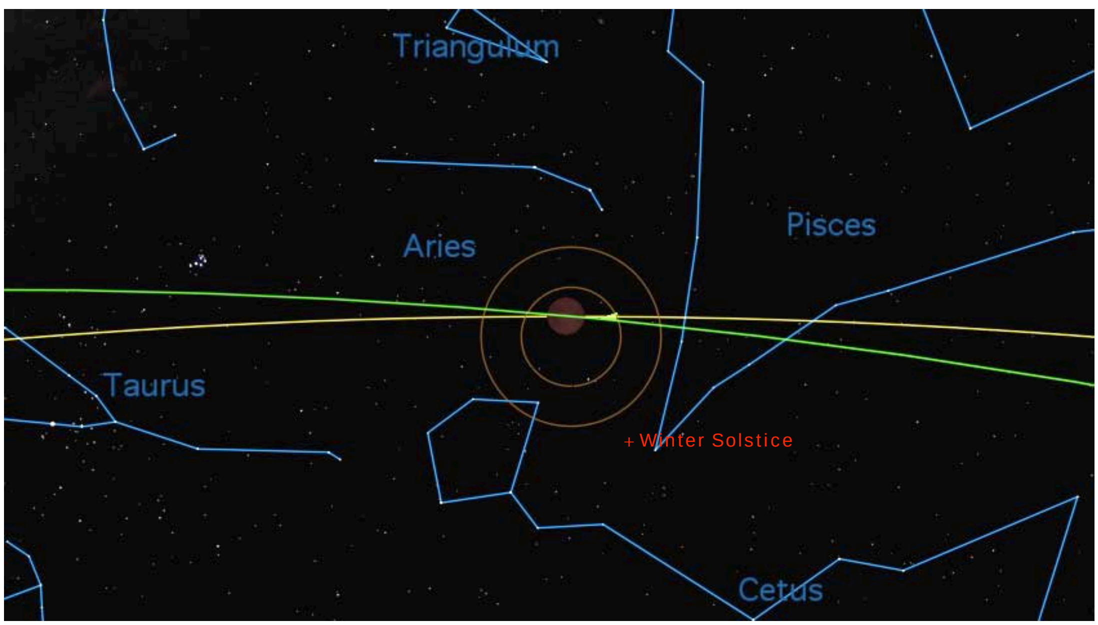


Figure 4.18: 7 Men 13 Xul on June 19, 6,878 BCE. Theoretical reconstruction of total lunar eclipse in Pisces at the sidereal position of the winter solstice.

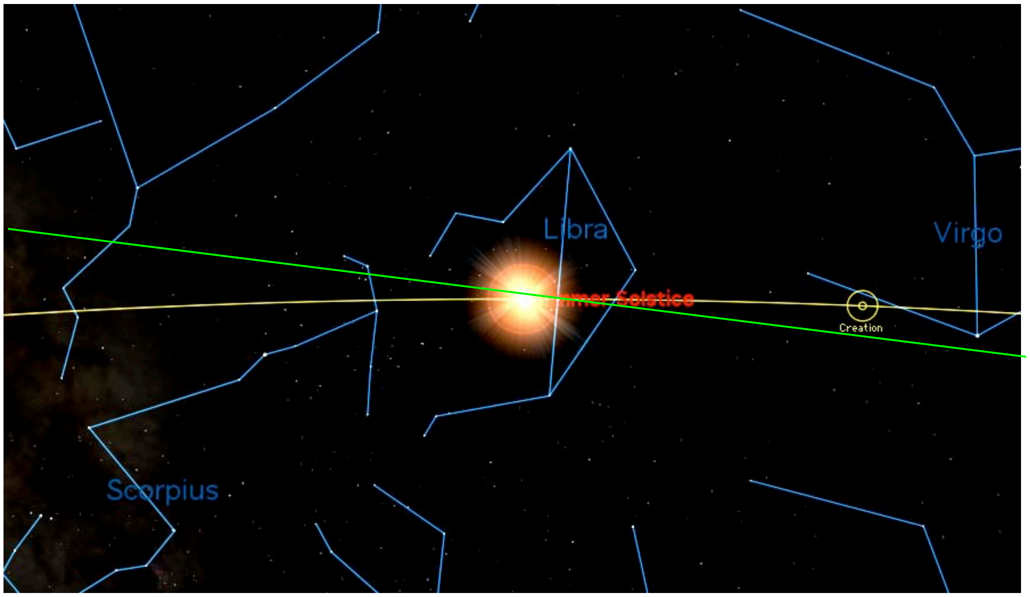


Figure 4.19: 9 K’an 12 K’ayab’ on June 23, 33142 BCE. Theoretical reconstruction, with sun at ascending node

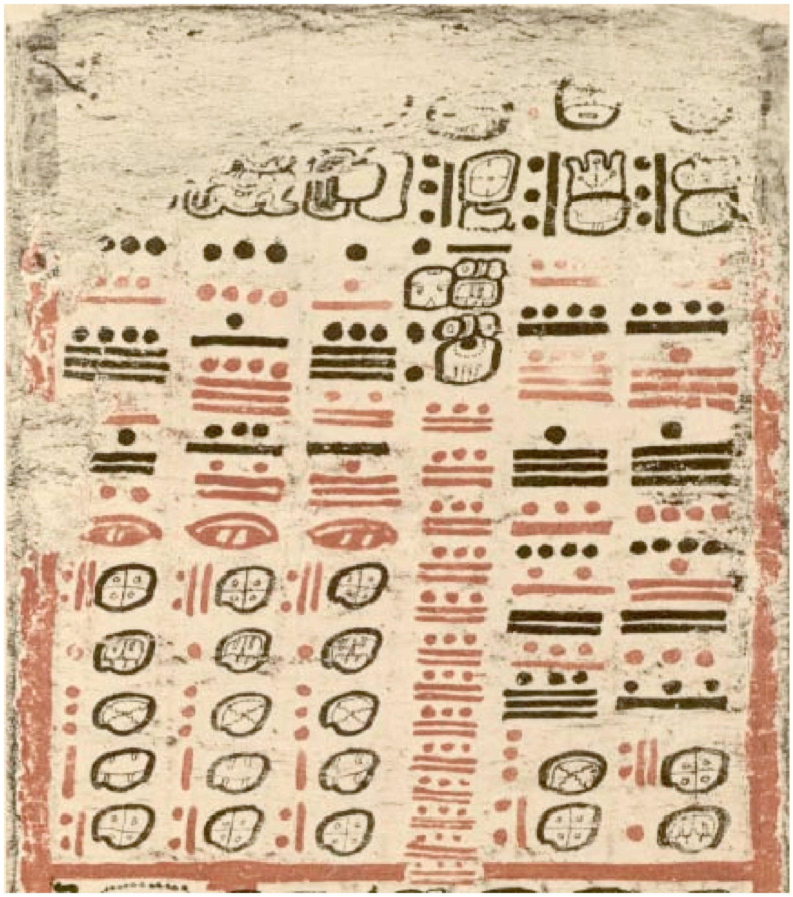


Figure 4.20: Upper half of Page 52, Dresden Codex. Lunar Table introduction. Column D begins with a Lunar Skull, followed by 8 K'ins, 1 Winal & 5 Tuns, 2-*tab'*, followed by the number 13 written 13 times.

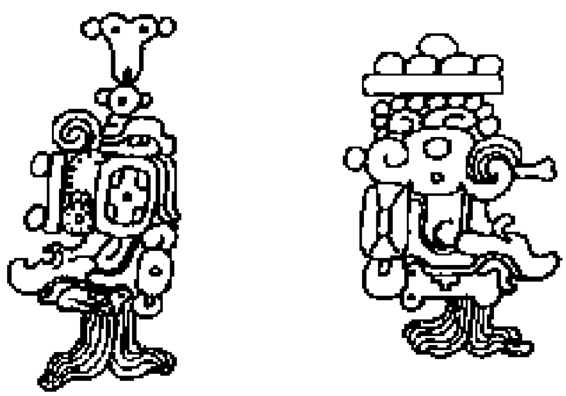


Figure 4.21: 7-Black-Yellow Place personified, paired with 29-30 personified. From Temple of the Sun tablet. After Schele (1992)

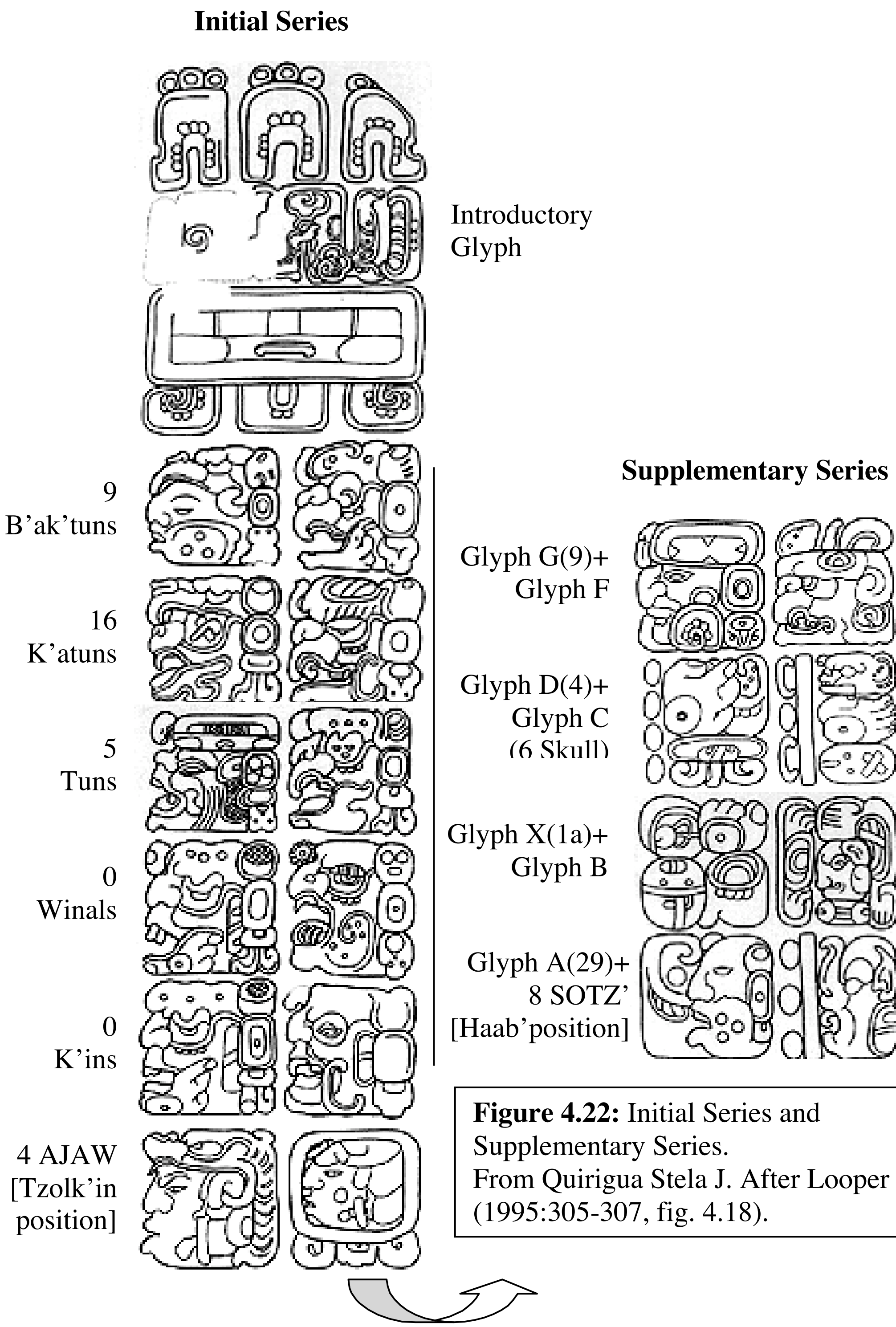


Figure 4.22: Initial Series and Supplementary Series.
From Quirigua Stela J. After Looper (1995:305-307, fig. 4.18).

Figure 4.23: a) T545 half-darkened K'IN from PNG3O1. After Looper in Macri and Looper (2003)
b) "wing quincunx" eclipse glyph from Dresden 54bW2.

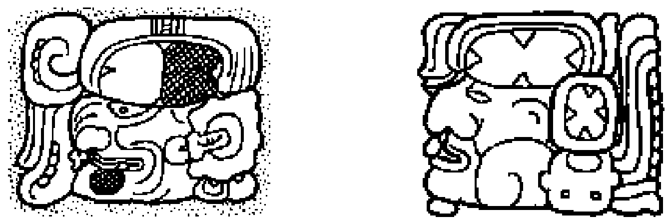


Figure 4.24: Glyph G9 full personified form.
a) NAR Hieroglyphic Stairway 01 Step 05, J3. After Ian Graham (1978:107)
b) QRG Stela D, C15. After Looper (1995:351-354, fig. 5.24)

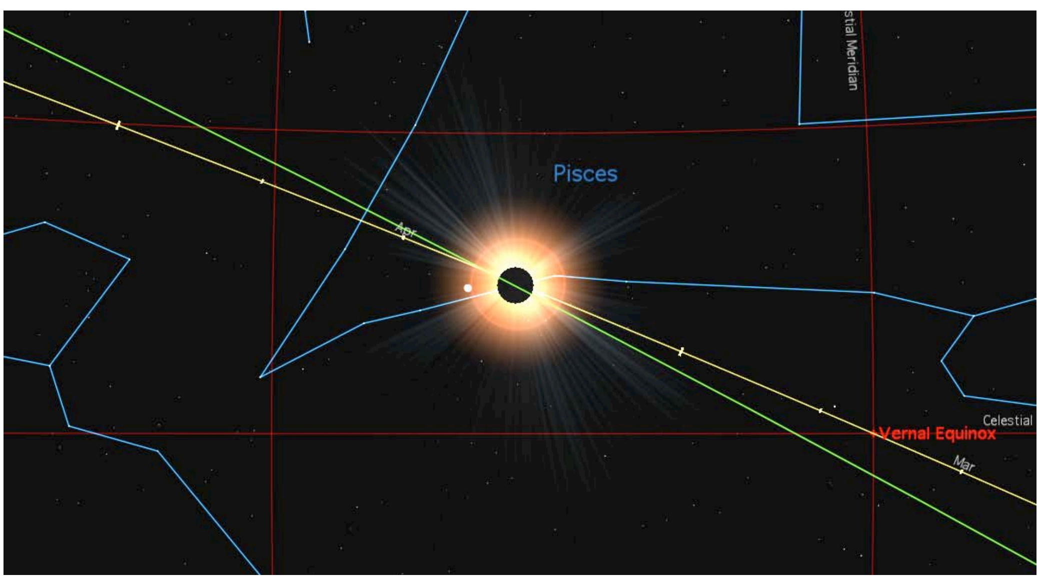


Figure 4.25: Hypothetical Solar Eclipse with G9 on April 8, 2005 CE.

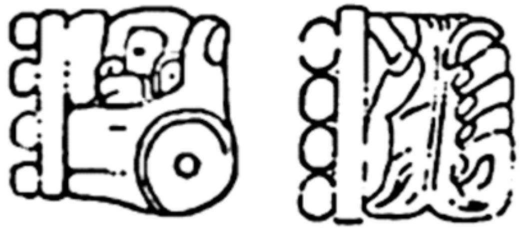


Figure 4.26: Glyph G1
a) 9-K'UH-CH'ÄM, from PNG Stela 25 NW, A9
b) 9-TZAK, from PNG Stela 36 SE, A5.
After Montgomery (1990,1992)

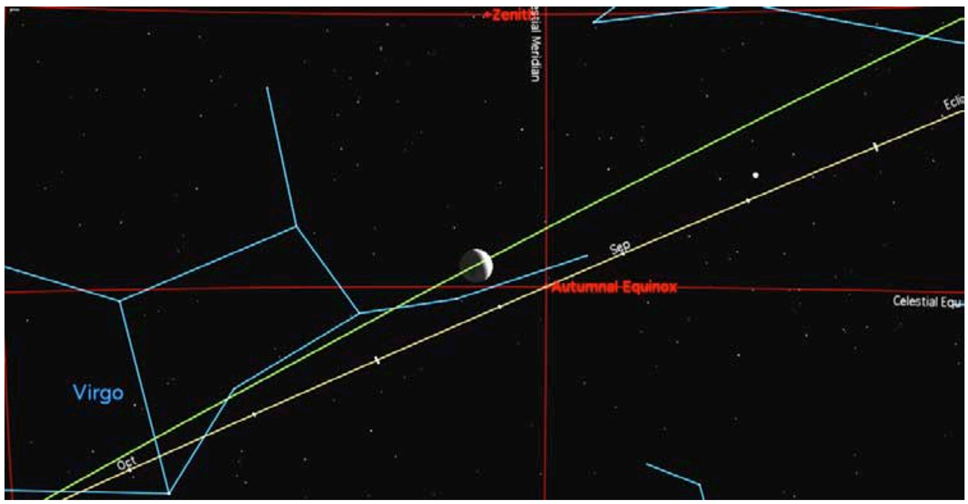


Figure 4.27: Day of G1, July 22nd, 2004, 260 days before G9 on April 8th, 2005.

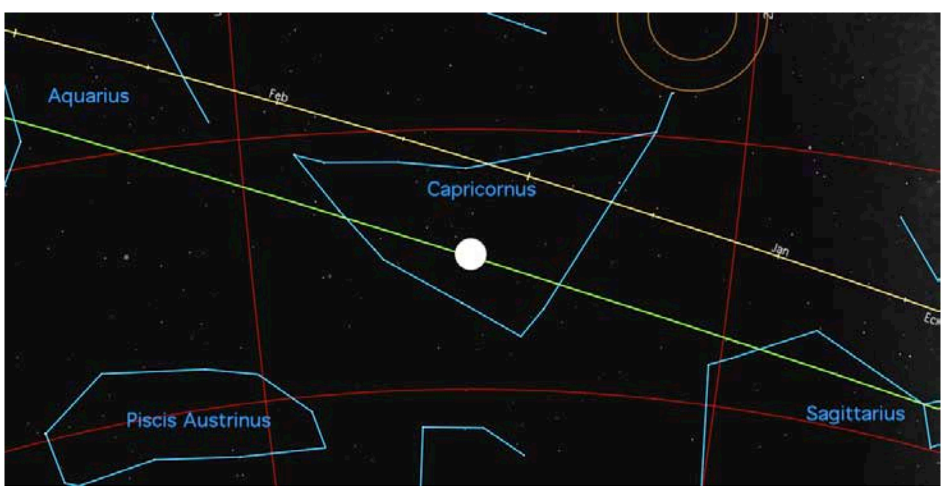


Figure 4.28: Day of G1 + 9 days to full moon on July 31st, 2004

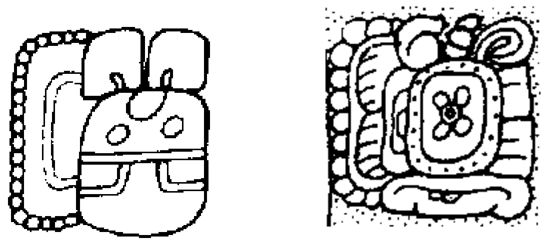


Figure 4.29:
a) **Glyph G2.** From DPL Stela 2, B4.
After Ian Graham, (Graham 1967:12, fig. 7).
b) **Glyph G3** (conflated inside Glyph F). From PAL Temple of the Sun, A9. After Schele (1992).

Figure 4.30: Glyph G4
After Ian Graham, in Houston (1993:111, fig. 4-14)

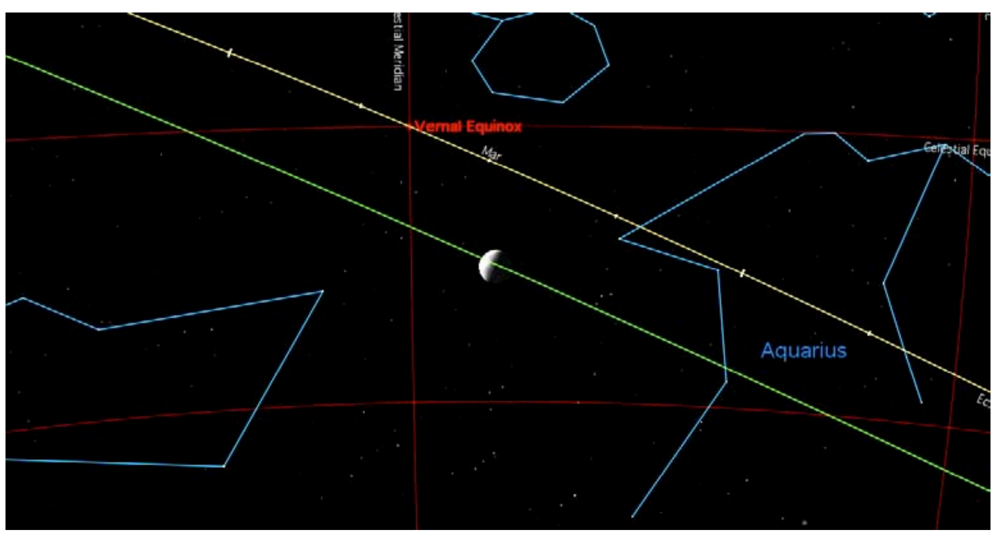


Figure 4.31: Day of G4 on June 3, 2002, 4 x 260 days prior to G9 eclipse on April 8th, 2005. + 7 days to solar eclipse on June 10

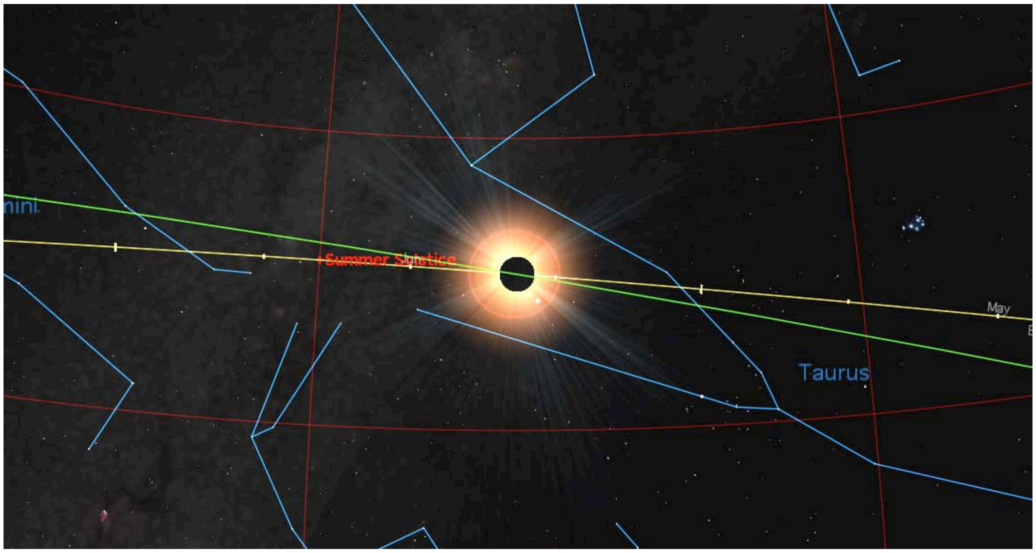


Figure 4.32: Solar eclipse on June 10, 2002, 7 days after G4 on June 3. 4 x 260 days – 7 days before G9 eclipse on April 8, 2005.

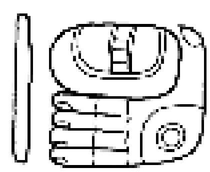


Figure 4.33: Glyph G5
a) Early example of G5 from the Leiden Plaque.
After Schele, (Schele and Miller 1986:320, fig. A3)
b) Rare example of G5 with **CH'ÄM** from the Atkins Museum Lintel. After Gronemeyer (2006).

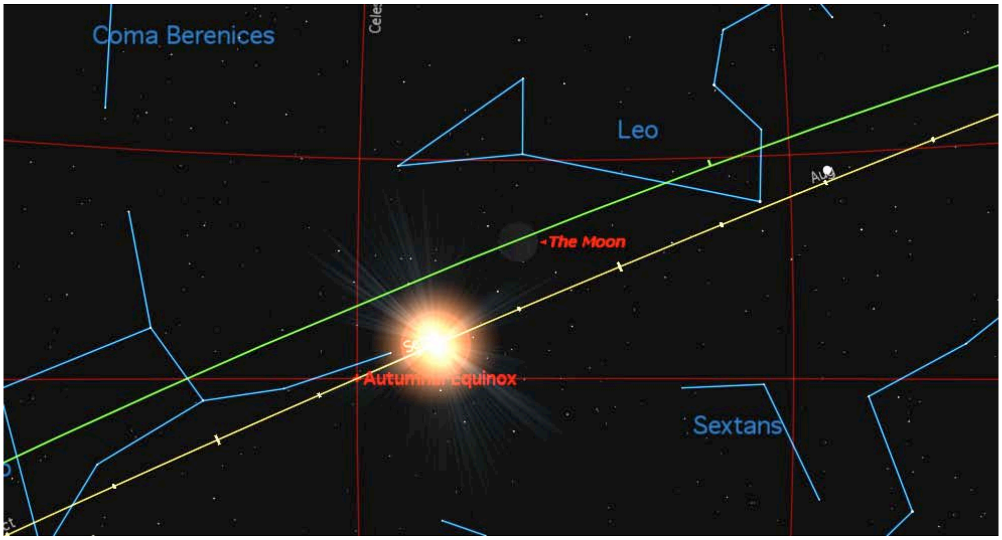


Figure 4.34: New Moon on day of G5 on September 16, 2001.
5 x 260 days before G9 eclipse on April 8, 2005.

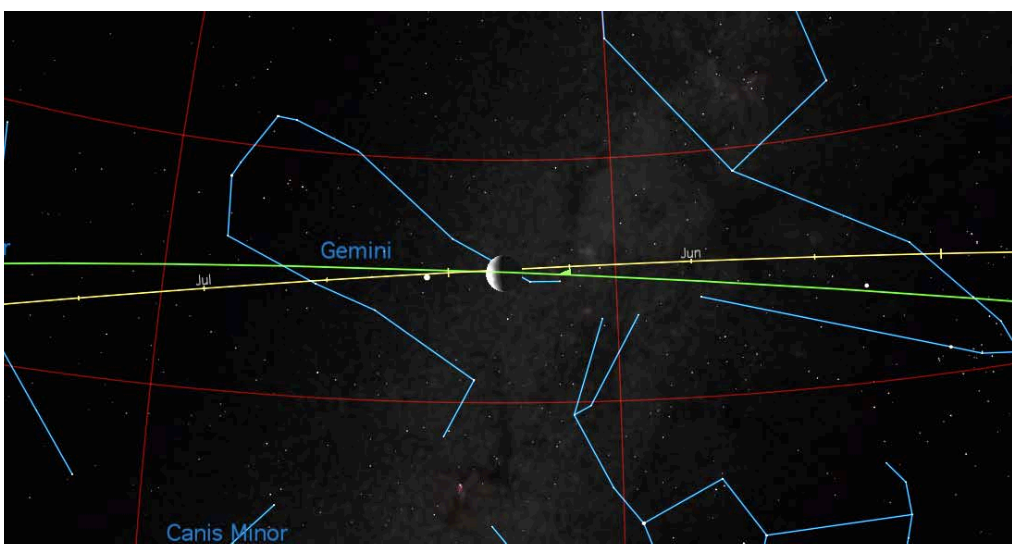


Figure 4.35: G5 – 5 days to ascending node on September 11, 2001.
5 x 260 days + 5 days before G9 eclipse on April 8, 2005.

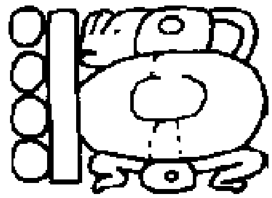


Figure 4.36: Glyph G6. From Yaxchilan, Stela 6, A6. After Carolyn Tate (Tate 1992:193, fig. 88a)

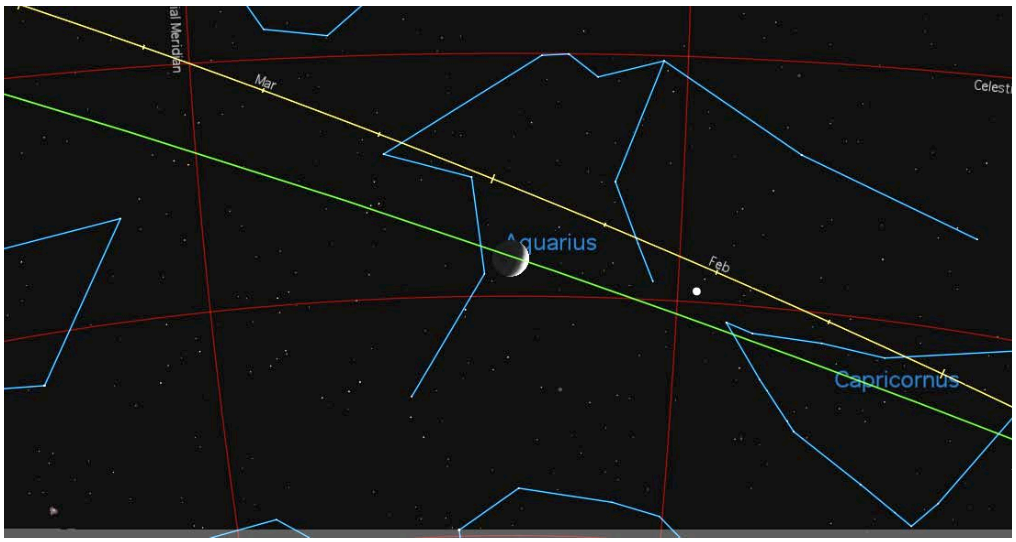


Figure 4.37a: Day of G6 on December 30, 2000, 6 x 260 days prior to G9 eclipse on April 8, 2005. 9 days before node.

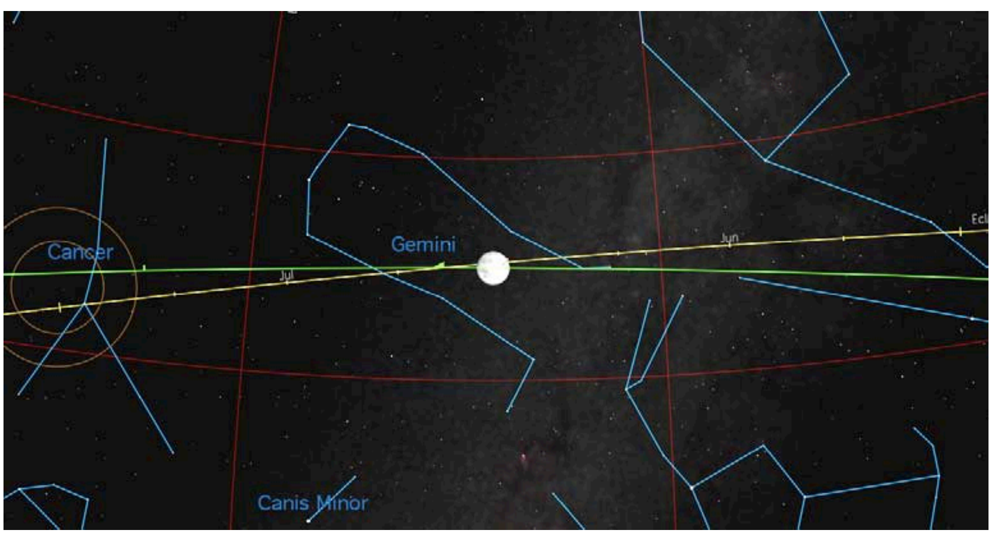
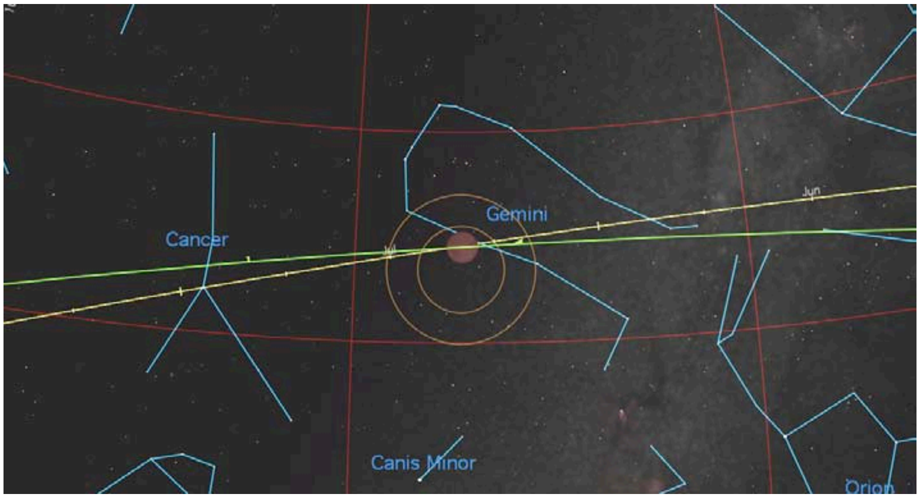
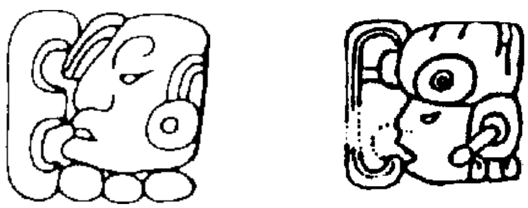


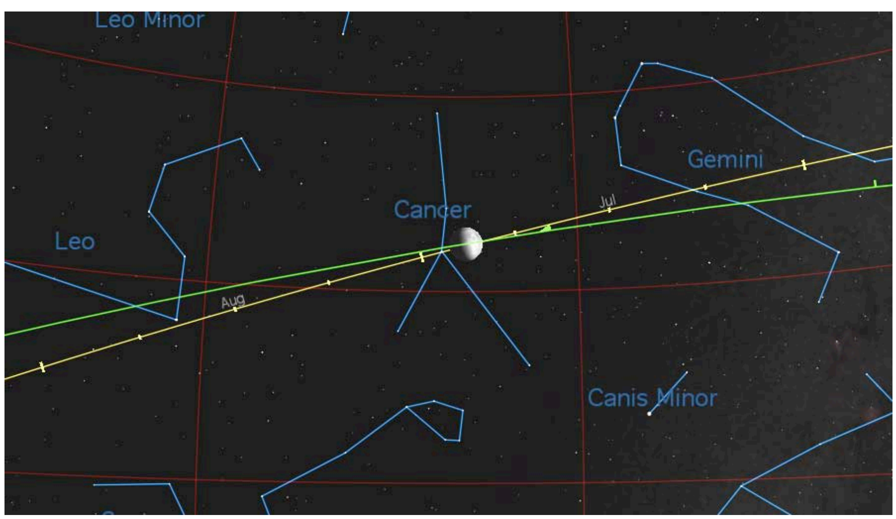
Figure 4.37b: 9 Days after G6 on January 8, 2001, 6 x 260 days – 9 days prior to G9 eclipse on April 8, 2005. Same sidereal position as Figure 4.35.



8ihuug 4.087 Total Lunar eclipse on January 9, 2001, 10 days after G6. 6 x 260 days – 10 days before G9 eclipse on April 8, 2005.



8ihuug 4.097 Glyrh G7. a) From BPK Stela 2.
After Peter Mathews (1980:62, fig. 2).
b) As head variant for 'two' PNG Stela 3. After Montgomery (1990)



8ihuug 4.407 Day of G7 – 2 days on April 12, 2000.
7 x 260 days +2 days before G9 eclipse on April 8, 2005.

a b c

Figure 4.41: Glyph G8
a) From QRG Stela C.
After Looper (Macri and Looper 2003).
b) From SBL PT1
c) From Walter Randal Stela.
b and c after Gronemeyer (2006; Mayer 1980: Pl. 61)

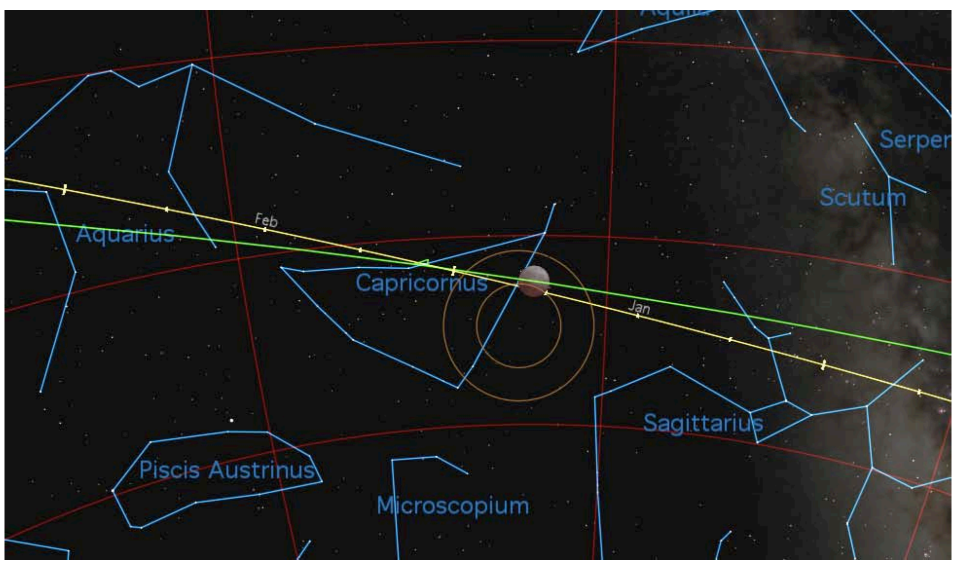


Figure 4.42: G8 – 1 day to Lunar eclipse on July 28, 1999.
8 x 260 days + 1 day before G9 eclipse on April 8, 2005.

Figure 4.43: Glyph F
a) Phonetically spelled with TI?-hu-na (T128:740:23. From YAX Lintel 56. After Ian Graham (1979:121)
b) With Jester God **HUN** (T128:1030o) From Naranjo Stela 13. After Graham (1978:38)
a) With headband HUN (T60abdef) in Ti?-HUN-na (T128:60:24). From QRG Stela J. After Looper (1995:305-307, fig. 4.18)

Chapter V

Serpent Series Dates

In the Serpent Series, there are the ten Serpent Numbers themselves, as well as a series of dates given either in Ring Number format, or simply as Long Count dates. In this chapter, the meanings of each of these dates are discussed in relation to their associated texts. Of particular significance are those dates that repeat significant sidereal positions of the sun, and those that incorporate solar, lunar, and planetary cycles. The following chapter provides detailed descriptions of the astronomical phenomena associated with each date in the Serpent Series. It should be considered a reference section, rather than a continuous narrative. I would have relegated it to an appendix, but a number of repeating patterns found within these dates provide important evidence concerning the multiple astronomical functions of the Serpent Series.

The Serpent Numbers that follow the introductory distance number each count forward from the base date 9 K'an 12 K'ayab'. If the Serpent Series introductory distance numbers were used to calculate the sidereal year and precessional drift, as well as the eclipse year and the synodic and sidereal lunar cycles, might there be further evidence for this in the Serpent Numbers themselves?

One of the difficulties immediately encountered in any further analysis of the Serpent Numbers is that many of them contain calendrical errors. Out of the eight Serpent Numbers on pages 61–63, and the two on page 69, six of these require one or more corrections in either their distance numbers or their terminal dates. Förstemann (1897, 1901, 1905) first noticed these inconsistencies, and he provided his interpretation of the correct intervals. However, as Beyer (1933) later pointed out, all but one of Förstemann's corrections altered the starting point of the base date 9 K'an 12 K'ayab'. Beyer determined that each of the Serpent Numbers counts forward from this base date, and that most of the errors are numerical, except for a misreading of the glyph for the month of Pax as the similarly shaped Sek. In each case, Beyer determined the smallest parsimonious change necessary to correct the errors. Thompson (1972:80) accepts Beyer's emendations as correct interpretation of the Serpent Series (Thompson 1972:80). Identified by their page number and column, the first eight Serpent Numbers are given in the table below as written, and as corrected by Beyer. The apparent errors in the original series are underlined and bolded, while Beyer's corrections are bolded:

Col.	**Serpent Number as written**		**Beyer's corrected Serpent Numbers**	
61C	4.06.**14**.13.15.01	3 Chikchan 18 Xul	4.06.**00**.13.15.01	3 Chikchan 18 Xul
61D	4.06.**00**.11.3.01	3 Chikchan 13 Pax	4.06.**14**.11.03.01	3 Chikchan 13 Pax
61E	4.06.**09**.**16**.10.1	3 Chikchan 13 Yaxk'in	4.06.**10**.**09**.10.01	3 Chikchan 13 Yaxk'in
61F	4.06.01.**09**.**15**.00	3 K'an 12 Yax	4.06.01.**11**.**05**.00	3 K'an 12 Yax
62A	4.06.07.12.04.10	3 Ix 7 **Sek**	4.06.07.12.04.10	3 Ix 7 **Pax**
62B	4.06.11.10.07.02	3 Kimi 14 K'ayab'	4.06.11.10.07.02	3 Kimi 14 K'ayab'
62C	4.06.09.15.12.19	13 Ak'b'al 1 K'ank'in	4.06.09.15.12.19	13 Ak'b'al 1 K'ank'in
62D	4.06.01.09.15.00	3 K'an **16** Wo	4.06.01.09.15.00	3 K'an **17** Wo

The Serpent Numbers in 62B and 62C are without any errors. As we have seen, Beyer used the interval in 62C to determine the base date in the Serpent

Series. Most of the errors in the other Serpent Numbers can be explained very easily, and the corrections are straightforward and reliable:

1) Beyer found that the errors in 61C and 61D reflect a copyist's error in which the K'atun positions of 14 and 00 are reversed.

2) Beyer suggested that in the terminal date in 62A, the month Sek was miscopiedin place of the correct month Pax, which closely resembles the Codical version of Sek. Otherwise, the distance number is correct as written.

3) Förstemann suggested that the terminal Haab' position in 62D was mistakenly written as 16 Wo, an impossibility with the Tzolk'in date 3 K'an, while the correct date is 3 K'an 17 Wo, the exact date reached when this distance number is counted forward from 9 K'an 12 K'ayab', that is clearly written in the column above.

Beyer proposes that the remaining errors in 61E and 61F derive from miscalculations, and both of the distance numbers require a change in two of their numerals. As such, these corrections are somewhat less parsimonious, and therefore less reliable. While they accept the correction in 61E, the Brickers (1988:S50–52) have since questioned Beyer's correction of the Serpent Number in 61F, based on their interpretation of the function of the Serpent Numbers as entry points into a seasonal table. They point out that the distance number in 61F is identical to that in 62D, also with the base day 3 K'an, and they suggest that this latter distance number was mistakenly copied in its entirety where another 3 K'an date was intended. The Brickers thus offer a different correction for this distance number as 4.06.**06.16.13**.00 3 K'an 12 Yax to conform to the seasonal configuration that they believe to be the intention of the series. Though the Bricker's correction requires a change in three of the numerals in the distance number, the fact that the distance number in 61F is identical to that in 62D suggests that this may well be a copyist's error, rather than an error in calculation, as Beyer proposes. However, the Bricker's correction for 61F is not necessarily reliable either, since many 3 K'an 12 Yax dates are possible, and their interpretation of the uniform purpose of the Serpent Numbers as seasonal entry points is questionable. Though Beyer does not discuss them, the additional Serpent Numbers on page 69 are written with no apparent errors, though their Haab' positions are not given in the text. Thompson (1972:22) supplied them:

Col.	**Serpent Number as written**
69E	4.05.19.13.12.08 4 Eb' [5 Ch'en]
69F	4.06.01.00.13.10 9 Ix [12 Sip]

Instead of interpreting the Serpent Numbers as each conforming to a uniform seasonal table, as the Bricker's propose, I believe it is more logical to analyze them as pairs. The Serpent Numbers are clearly paired with a single serpent, and each of these serpents has a different figure emerging from its mouth (**Figure 3.1 and 3.2**). The paired Serpent Numbers also share a unique initial inscription with a varying text for each serpent. A complete text is visible for the fourth serpent on page 62, columns C and D, while nearly complete texts appear for the first serpent on page 61, columns C and D, and for the serpent on page 69, columns E and F. The inscription for the second serpent on page 61 E and F is almost completely eroded, while that for the third serpent on page 62 A and B is barely visible.

The more complete examples of the initial inscriptions above each serpent confirm that, while they all end with the base date 9 K'an 12 K'ayab', the subjects and verbs preceding this base date vary. It is therefore likely that each pair of Serpent Numbers for each individual serpent is specifically related to the shared initial inscriptions above them. While the astronomical information within each pair may be related, it is likely that the astronomical subject of each of the serpents is unique. Furthermore, following the terminal dates for each one of the Serpent Numbers are several related collocations that involve **OK** (T765) 'foot' 'step' or perhaps 'entrance', but with differing prefixes. Some of these prefixes appear to be unique names of personages that are also found in the twelve Ring Numbers within the Serpent Series. An astronomical relationship may therefore exist between the named subjects of these Ring Number dates and the Serpent Numbers that share these subjects. Therefore, it may be possible to determine the astronomical identities of some of these names by comparing the dates with which they appear.

The 819-day Count Verb

Of the twelve Ring Numbers that follow the Serpent Numbers, each uses the verb found in the 819-day count from the Classic period (T588) (**Figure 5.1)**. Schele and Grube (1997:216) read the main sign of this verb as **WA'**, meaning 'to be erected, stood up, put in place', based on the appearance of a prefixed **wa** (T130) in several examples. In the case of the 819-day count, this verb refers to the 819-day station of the deity K'awil. First described by Thompson (1943), the 819-day count proceeds as four periods of 819-days, each associated with a color and direction. The total period of 3,276 days is exactly 9 intervals of the 364-day computing year. Several scholars have suggested that the 819-day position was used specifically as a planetary calculator for Jupiter and Saturn, and perhaps Mercury (Justeson 1989; Powell 1997; Milbrath 1999; Aldana 2001). However, just as the Serpent Series utilizes the 364-day computing year, the 819-day count may have been used with corrections to calculate a number of astronomical phenomena. The Tzolk'in base days of the 819-day stations are very easy to work with, given that each has the numeral 1 in the 13-day cycle, since 819 is evenly divisible by 13. Also, counting backwards by intervals of 819 days requires only that the 20-day name increase by one with each step, so that 819 days before a station on the day 1 Ajaw is the previous station at 1 Imix, etc.

While **WA'** is a widely accepted reading of the 819-day verb (T588), I believe that this remains questionable. The presence of an initial **wa** (T130) does not directly indicate the full pronunciation of what follows. Knorosov (1967:100) first read T588 as **se**, based on the infixed sign **se** (T520). Similarly, Victoria Bricker (1986:212) then read this sign as **tze**, based on the analogous form of the T520 infix found in the Codices as **tze** (T523). I offer the suggestion that this collocation may be a more transparent conflation of the split sign **pa** (T649), as in the month glyph for Pax, and the sign **se** (T520), with a reading of **pa-se** as the word *pas* 'come, arrive, sprout' in Chol (Attinasi 1973). This is the same word that Barbara MacLeod (1990:75–77) found in the Classic collocation for 'dawn'. This verb may then be a Ch'olan loan in the Dresden Codex, derived from earlier use in the 819-day count, or perhaps in the earlier codices that the authors must have referenced.

Throughout the Serpent Series, the 819-day verb includes a -**la** (T178) suffix, with a possible reading of *pasel*, attested in Chol as 'to rise' or 'to dawn', in reference to the sun (Aulie and Aulie et al. 1978:88). As a transitive verb, the proto-Ch'olan **päs* can mean 'to show, uncover' (Kaufman and Norman 1984:128), with *pas* in Ch'orti as 'becoming clear' (Wisdom 1950:558). The 819-day verb also frequently appears as a passive construction of a transitive verb throughout the Serpent Series, with the additional suffix **-aj** (T181), likely forming *paselaj* 'it is shown' or perhaps 'it is revealed'. A similar example from Stela K in Quirigua (at D4) shows the same suffix (**Figure 5.2**).

In the verb from the 819-day count, the **pa** and **se** glyphs are also conflated inside an animal head, and in the one example above from Quirigua Stela K, this appears to be a skull, perhaps alluding to the moon. The majority of the examples of the 819-day verb from the Classic period suggest that this animal is indeed the opossum in the **OK** glyph (T765ab). This is especially apparent at Palenque, where the use of the 819-day count is most prevalent. In one example from the Tablet of the Cross (at A14), the 819-day verb appears in the completive form with the suffixes **-hi-ya**, perhaps reading *pas-hi* 'it dawned' or 'it appeared' or 'it arrived', while the black markings around the animal's eye are those of the **OK** opossum, visible in the Tablet of the Sun (at F2) at the same site (**Figure 5.3)**. Another example from the Tablet of the Sun (at A14) shows the 819-day verb without the split form of **pa** (T649), while the dark marking around the eye is more exaggerated, resembling the more standard form of **pa** (T602) as a darkened cross-hatching (**Figure 5.4**). It is possible that this is a substitution, although several examples of **OK** also have a similar large dark patch above the eye, as in the Table of the Sun (at P8).

The **OK** (T765ab) conflated with the 819-day verb is retained in the examples from the Serpent Series, but it is more difficult to identify as the **OK** opossum. However, in many of these examples, a clear **OK** appears separately following the 819-day verb as **K'UH-OK-ki**, *k'uh ok*. Schele and Grube (1997:141, 232) read this variably as 'the god's foundation' or 'holy traveler'. Alternately, Michel Davoust (1997:245, 313) reads this as either 'the divine foot of' or 'the divine entrance'. However, given the context within systems of counting and calculation, perhaps *k'uh ok* refers to 'divine steps' of the various astronomical bodies in question. Lounsbury (1978:769) notes that the Jakaltek Maya refer to cycles of 40 days as *u yok habil* 'the footsteps of the year' because, similar to the 819-day count, every interval of 40 days has the same 20-day name, while increasing one numeral, or one 'step' in the 13-day cycle. Therefore, I contend that within the Serpent Series, the phrase **pa-se-la-aj K'UH-OK-ki** may read *paselaj k'uh ok* as 'the holy steps are revealed', while the conflation of the 819-day verb with **OK** in the Classic period could have a similar reading. The above example from the Tablet of the Cross in Palenque may then read **pa-se-hi-ya-OK** *pas-hi ok*, 'the steps arrived [at the place of K'awil]'.

The meaning of the **wa** (T130) prefix in the 819-day verb presents a challenge for the reading suggested above, though it may supply the additional meaning of *wa'* 'stood up'. Nevertheless, the new reading I suggest also remains questionable. Therefore, throughout the remainder of this chapter, I tentatively translate the 819-day verb as a questioned *paselaj??* However, the exact reading of this verb has little bearing on the remaining argumentation. Future analyses may clarify the meaning of this verb within the context of both the 819-day count and the Serpent Series.

The Astronomical Significance of the Serpent Numbers

Translated into Long Count format, the Serpent Numbers are given with the following Gregorian proleptic dates using the 584285 GMT correlation. The Gregorian proleptic calendar provides back-calculated Gregorian dates prior to the inauguration of the Gregorian system. For those using astronomy programs that utilize only Julian dates, these are given beneath the Gregorian:

Pair	Col.	Serpent Number (Beyer Corrections)	Long Count	Gregorian CE (Julian CE)
1a	61C	4.06.00.13.15.01 3 Chikchan 18 Xul	09.17.08.08.05	May 27, 779 (May 23, 779)
1b	61D	4.06.14.11.03.01 3 Chikchan 13 Pax	10.11.05.14.05	Oct 2, 1052 (Sep 26, 1052)
2a	61E	4.06.10.09.10.01 3 Chikchan 13 Yaxk'in	10.07.04.03.05	Apr 24, 972**??** (Apr 19, 972**??**)
2b	61F	4.06.01.11.05.00 3 K'an 12 Yax	09.18.05.16.04	Aug 4, 796**??** (Jul 31, 796**??**)
3a	62A	4.06.07.12.04.10 3 Ix 7 Pax	10.04.06.15.04	Oct 30, 915 (Oct 25, 915)
3b	62B	4.06.11.10.07.02 3 Kimi 14 K'ayab'	10.08.05.00.06	Nov 6, 992 (Nov 1, 992)
4a	62C	4.06.09.15.12.19 13 Ak'b'al 1 K'ank'in	10.06.10.06.03	Sep 3, 958 (Aug 29, 958)
4b	62D	4.06.01.09.15.00 3 K'an 17 Wo	09.18.04.08.04	Mar 3, 795 (Feb 27, 795)
5a	69E	4.05.19.13.12.08 4 Eb' 5 Ch'en	09.16.08.05.12	Jul 18, 759 (Jul 16, 759)
5b	69F	4.06.01.00.13.10 9 Ix 12 Sip	09.17.15.06.14	Mar 20, 786 (Mar 16, 786)

Throughout the analysis of Serpent Numbers, we use the Gregorian proleptic dates as a default, with Julian dates in parentheses upon the first mention of these dates for convenience of use with many astronomical programs.

The Brickers (2005) have demonstrated that the Serpent tables starting on page 69 related to the cycles of Mars, and it is equally likely that the other Serpent Numbers convey information about specific planetary cycles. Inscriptions when present, and those dates that are reliable, may provide information on the relationship of each pair of Serpent Numbers to each serpent.

Serpent Number 3a in column 62A (**Figure 5.22**) reveals the clearest evidence that the Serpent Series incorporates a refined knowledge of precession and the lunar nodes. We begin with this Serpent Number from the third serpent. The corresponding Gregorian date for 10.04.06.15.04 3 Ix 7 Pax is October 30, 915 CE (October 25 Julian). On this date, the sun is in Libra in the exact sidereal position it was in on the base date 9 K'an 12 K'ayab', but here it is near the nadir at 14.8° N (**Figure 5.5a**). In addition, on this date, the sun is almost exactly at the ascending node, just as it would have been on 9 K'an 12 K'ayab'. But on the day 3 Ix 7 Pax, there is also a total lunar eclipse, and the moon is exactly at the position of the first zenith at 14.8° N latitude (**Figure 5.5b**). While the lunar eclipse would have been invisible at Maya longitudes, the full moon nonetheless crosses the zenith near midnight, near the Pleiades. This exact positioning is precisely the kind of measurement suggested by the selection of the base date itself, and the suggested way in which the Maya likely determined precession. This position is counted forward from the base date 9 K'an 12 K'ayab', which it directly replicates the sidereal position of the sun in Libra. Such a precise measurement supports the hypothesis that the Serpent Series were used to calculate the sidereal year, the eclipse half year, and the lunar cycles.

The interval from Serpent Number 3a is given as 4.06.07.12.04.10. We can convert this into a number of days, into eclipse years (twice the eclipse half-year of 173.31), and into the proposed Maya sidereal years to demonstrate the precision of this calculation:

4.06.07.12.04.10	**=**	**12,438,810 days**
in eclipse years	**=**	**35,886 (346.62 days) + 4.68 days**
in Maya sidereal years	**=**	**34,055 (365.2565128 days) + 0.5434 days**

Curiously, recalling the idealized intervals between the Tzolk'in base days from the Serpent tables, the day 3 Ix is exactly 52 days before the day 3 Kimi—an idealized interval between the summer solstice and both solar zeniths, or between the winter solstice and both solar nadirs, at 14.8º N. Indeed, the sun is close to the first nadir on the day 3 Ix 7 Pax , October 30, 915 CE. Adding 52 days to 3 Kimi 19 Kumk'u, we reach an exact winter solstice position. This suggests that the base day 3 Kimi may be used to track the tropical year, while the day 3 Ix is tracking both the sidereal year and the eclipse year.

Serpent Number 3b in 62B is paired with 3a in 62A (**Figure 5.22**), though the inscription above their shared serpent is highly eroded. Notably, this is the only serpent inscription with a red background, but the significance of this is not clear. The date given in Serpent Number 3b is 10.08.05.00.06 3 Kimi 14 K'ayab' on November 6, 992 CE (November 1 Julian). On this date, the sun is eight days forward from its sidereal position on 3 Ix 7 Pax, October 30, 915 CE, the above date from Serpent Number 3a (**Figure 5.6a**). Nothing astronomical is immediately apparent on this date, but recalling the relationship between the Serpent Series Tzolk'in base days, the day 3 Kimi is exactly 52 days forward from the day 3 Ix. Counting back 52 days from 3 Kimi 14 K'ayab' to 3 Ix 2 Muwan on September 15, 992 CE (September 10 Julian), we find that <u>the sun indeed reaches a node</u> in Virgo on another day 3 Ix (**Figure 5.6b**), while the moon is about four days prior to an invisible lunar eclipse (one that takes place during the day; that is one that is visible only from the other side of the earth from the Maya) close to the sidereal position of the vernal equinox in Pisces (**Figure 5.6c**). <u>This four-day addition resembles the nodal interval of 47,489 days, or 13 (3640 +13 days) from the Lunar Table on page 52 of the Dresden</u>. If the eclipse interval of 47,489 days is subtracted from the day of a lunar eclipse to back-calculate an earlier lunar eclipse in the same sidereal position, four days would be added to the subtracted interval to reach the date of the eclipse.

On the date 3 Ix 2 Muwan on September 15, 992 CE, the sun is at the ascending node in Virgo, and the moon is four days before a lunar eclipse at the descending node near the sidereal position of the vernal equinox in Pisces. Adding the nodal interval of 47,489 days to 3 Ix 2 Muwan, we reach September 22, 1122 CE (September 17 Julian). On this day, the full moon rises due East in a lunar eclipse visible at Maya longitudes, only one day forward from the Autumnal equinox (**Figure 5.6d**). It is thus quite possible that the Maya calculated the previous eclipse in 922 CE from this momentous eclipse at the later date. The Maya may have first utilized the alignment of the nodes with the tropical year and the equinoxes in the later eclipses as a step towards the more difficult task of back-calculating a lunar eclipse at the precise sidereal position of 9 K'an 12 K'ayab' in Serpent Number 3a.

3 Ix as the Nodal Passage of the Sun

If the Tzolk'in day 3 Ix was used to determine when the sun is exactly at a node in both of the Serpent Numbers from the third serpent, might this also be the case for the remaining Serpent Numbers? After briefly examining the validity of this hypothesis, we return to a further analysis of the Serpent Number pairs.

Serpent Number 1a in 61C leads to the date 09.17.08.08.05 3 Chikchan 18 Xul, May 27, 779 CE (May 23 Julian), with the sun in Taurus. It is 91 days before 3 Chikchan 18 Xul is the day 3 Ix 7 Wo, February 25, 779 CE (February 21 Julian). Indeed the sun is exactly at the node on this earlier day in Pisces, and there is an invisible partial solar eclipse at midnight (**Figure 5.7**). Thus far, in Serpent Numbers 3a, 3b, and 1a, the closest previous day 3 Ix in each of the Serpent dates always corresponds to a nodal passage of the sun.

Serpent Number 1b in 61D leads to a date 10.11.05.14.05 3 Chikchan 13 Pax, October 2, 1052 CE (September 26 Julian), with the sun in Virgo. Again, counting back 91 days, reaches a day 3 Ix 2 Keh, July 3, 1052 CE (June 27 Julian), with the sun only a few days past a node in Gemini (**Figure 5.8**), while the moon is two days prior to an invisible partial solar eclipse. Once again, 3 Ix appears to signify the position of the sun at the node.

For the time being, we will skip over the problematic Serpent Numbers 2a and 2b, and we move on to Serpent Number 4.

Serpent Number 4a on 10.06.10.06.03 13 Ak'b'al 1 K'ank'in, September 3, 958 CE (August 29 Julian). On this day, the sun is has just entered Virgo. Counting back 49 days to the day 3 Ix 12 Sak on July 16, 958 (July 11 Julian), the sun is again exactly at the node on a day 3 Ix, here in Cancer (**Figure 5.9**), while the moon is eight days after a total lunar eclipse.

Serpent Number 4b leads to the date 09.18.04.08.04 3 K'an 17 Wo, March 3, 795 CE (February 27 Julian), with the sun in Pisces. Counting back 130 days from 3 K'an 17 Wo, we reach the day 3 Ix 12 K'ank'in , October 24, 794 CE (October 20 Julian). On this date, once again the sun exactly reaches a node, here in Libra (**Figure 5.10**). October 24, 794 is seven days after a partial lunar eclipse. The prior day 3 Ix invariably appears to represent the sun at a node when we use the 584285 GMT correlation, though the 584283 correlation would work here as well, since a two day difference from the node is relatively insignificant.

Given the pattern of 3 Ix nodal passages common to all six of the reliable Serpent Numbers tested from the Serpent Series on pages 61 and 62, we may be able to test Beyer's corrected dates for the Serpent Numbers 2a and 2b to see if they also conform to the pattern.

Serpent Number 2a on 10.07.04.03.05 3 Chikchan 13 Yaxk'in, April 24, 972 CE (April 19 Julian), the sun appears in Aries. Counting back 91 days to 3 Ix 2 Sip, January 24, 972 CE (January 19 Julian), the sun is not near a node. We may conclude that Beyer's corrected date may be incorrect. However, counting <u>forward</u> 169 days from 3 Chikchan 13 Yaxk'in, we reach a day 3 Ix 2 Pax, October 10, 972 CE (October 5 Julian). The sun not only reaches a node on this day, but it is in the exact sidereal position in Virgo as on the day of the Era Base date in 3114

BCE (**Figure 5.11**). Though none of the previous 3 Ix nodal passages are counted forward from the Serpent Number terminal dates, it is possible that this was also allowable, and that Beyer's correction for Serpent Number 2a is accurate.

The day 3 Ix is 169 days after 3 Chikchan, and 169 days is the same interval from the Lunar Table on page 52 of 13 x 13 days, added to the interval of 13 x 3,640 days to place the sun at the same node and very close to the same sidereal position. Therefore, the Serpent day 3 Chikchan 13 Yaxk'in on April 24, 972 CE is exactly 13 x 3640 days after the day 3 Chikchan 13 K'ank'in on October 3, 842 CE (September 29 Julian), at which time the sun was at the same node, and very close to the same sidereal position in the tropical year as it is on 3 Ix 2 Pax, October 10, 972 CE. Here we see the direct application of the two Tzolk'in base days 3 Chikchan and 3 Ix, and how they could be used to track the sidereal position of the nodes over 130 years.

Serpent Number 2b leads to the date 09.18.05.16.04 3 K'an 12 Yax on August 4, 796 CE (July 31 Julian). Counting back 130 days to 3 Ix 2 Sotz' on March 27, 796 CE (March 23 Julian), the sun exactly reaches a node in Pisces (**Figure 5.12**). It is therefore possible that Beyer's correction for this Serpent Number is also accurate. The Bricker's correction for this Serpent Number gives a starting date of July 10, 900 CE (July 5 Julian). Counting back 130 days to March 2, 700 CE (February 26 Julian), we find that the sun is about 9 days post-nodal. While it is possible that the Brickers correction is considered accurate, Beyer's correction for Serpent Number 2b conforms more closely to the 3 Ix nodal pattern.

Although the two remaining Serpent Numbers from page 69 are part of a separate table that uses two different Tzolk'in base days, 4 Eb' and 9 Ix, do the 3 Ix nodal passages apply to these as well?

Serpent Number 5a leads to a day 09.16.08.05.12 4 Eb' 5 Ch'en, July 18, 759 CE (July 16 Julian). Counting back 118 days to 3 Ix 7 Sip, March 22, 759 CE (March 20 Julian), the sun is exactly at a node in Pisces, very close to the Vernal Equinox (**Figure 5.13**). This example does conform to the nodal pattern of the 3 Ix base date.

Serpent Number 5b leads to a date 09.17.15.06.14 9 Ix 12 Sip, March 20, 786 CE (March 16 Julian). Counting backwards 240 days to 3 Ix 17 Ch'en on July 13, 785 CE (July 9 Julian), the sun is nowhere near the node. However, counting forward only 20 days to 3 Ix 12 Sotz' on April 9, 786 CE (April 5 Julian), the sun is exactly at the ascending node in Aries (**Figure 5.14**). Here may be another example of counting forward to 3 Ix node. Based on the regularity of this pattern, it appears that the day 3 Ix was indeed used to calculate the nodal passage of the sun throughout the Serpent Series.

The table below gives a summary of the Serpent Number terminal dates and their associated solar nodal passages on the closest previous or following 3 Ix date. The two 3 Ix dates that are counted forward are underlined in bold:

3 Ix as Solar Nodal Passage in the Serpent Numbers

#	Terminal Date	Long Count	Gregorian CE	– days	3 Ix Node	Gregorian CE
1a	3 Chikchan 18 Xul	09.17.08.08.05	May 27, 779	91	3 Ix 7 Wo	Feb 25, 779
1b	3 Chikchan 13 Pax	10.11.05.14.05	Oct 2, 1052	91	3 Ix 2 Keh	Jul 3, 1052
2a	3 Chikchan 13 Yaxk'in	10.07.04.03.05	Apr 24, 972	**+169**	**3 Ix 2 Pax**	**Oct 10, 972**
2b	3 K'an 12 Yax	09.18.05.16.04	Aug 4, 796	130	3 Ix 2 Sotz'	Mar 27, 796
3a	3 Ix 7 Pax	10.04.06.15.04	Oct 30, 915	0	3 Ix 7 Pax	Oct 30, 915
3b	3 Kimi 14 K'ayab'	10.08.05.00.06	Nov 6, 992	52	3 Ix 2 Muwan	Sep 15, 992
4a	13 Ak'b'al 1 K'ank'in	10.06.10.06.03	Sept 3, 958	49	3 Ix 12 Sak	Jul 16, 958
4b	3 K'an 17 Wo	09.18.04.08.04	Mar 3, 795	130	3 Ix 12 K'ank'in	Oct 24, 794
5a	4 Eb' 5 Ch'en	09.16.08.05.12	Jul 18, 759	118	3 Ix 7 Sip	Mar 22, 759
5b	9 Ix 12 Sip	09.17.15.06.14	Mar 2, 786	**+20**	**3 Ix 12 Sotz'**	**Apr 9, 786**

The Serpent Pairs and their Inscriptions

We now examine the possible astronomical significance of each Serpent Number pair, along with their shared inscription, when a legible text exists. Doubtless, many existing patterns in the data remain unknown, and further research may to shed light on the multiple purposes of these deliberate calculations. An analysis of the Serpent Number pair from the fifth serpent, with their associated water tables and Ring Number calculations, follows in a separate section.

The First Serpent

An inscription with a blue background precedes the first serpent on page 61 (**Figure 5.15**). The first two glyphs at C1 and D1 are partially eroded. However, C1 appears to be a portrait with a "cruller" eye, a visible ear, and a **-na** (T23) suffix, all characteristics of the Classic period deity known as the Jaguar Paddler (**Figure 5.16a**). In the Classic inscriptions, the Jaguar Paddler is usually paired with his companion, the Stingray Paddler. Stuart (1988:190) notes that the Jaguar Paddler often carries the **-na** suffix, while Stingray Paddler carries a **-ti** (T59) suffix (**Figure 5.16b**), and this suffix is indeed visible in the following glyph D1, above which is most likely the eroded portrait of the Stingray Paddler. When they are mentioned in the Classic inscriptions, the Jaguar Paddler precedes the Stingray Paddler, just as they appear here. To my knowledge, this would be the only known reference to these deities in the Codices.

In some examples from the Classic period, the names of the Paddler deities are written in the form of two paddles, with an **AK'B'AL** (T504) 'night' glyph representing the Jaguar Paddler, and a **K'IN** (T544) 'day' glyph representing the Stingray Paddler (Stuart 1984). Milbrath (1999:126–130) proposes that the Paddler Deities represent the moon (Jaguar) and sun (Stingray) when they are in the sidereal position of crossing the symbolic river of the Milky Way, based on the Classic period dates where the Paddlers are mentioned.

The inscription continues in C2 with **CHAN-na** (T561:23) 'sky', *chan* in Ch'olan languages, followed by what appears to be the homophonous serpent **CHAN-na**, (T764:23), *chan* in Ch'olan. A clearer example of **CHAN-na** is given above the fifth serpent on page 69, at E2. The clear play on words between 'sky' and 'serpent' may refer to the serpent below, while in Colonial and contemporary Maya accounts, the Milky Way itself is compared to a serpent, and Milbrath (1999:282–283) suggests that the name and imagery of the 'sky serpent' in the Classic period may refer to the Milky Way.

The inscription above the first serpent on page 61, continues with the 819-day verb in C3, which I am reading as **pa?-se?-la-aj**, but the following glyph in D3 is not the usual **K'UH-OK-ki**. Instead it appears to be a collocation composed of **MIX**, **MAX** or **mi** (T163), **na** (T537), **chi** (T671) and **b'a** (T501). Davoust reads this as possibly *nal chib'*, meaning 'on the eclipse'. The reading of *chib'* as eclipse is intriguing considering the eclipses involved in the two Serpent Numbers below. We may recall that in Yucatec, *chí'ib'* means 'be bitten' (V. Bricker et al. 1998:70), while in colonial sources, the Yucatec Maya referred to solar and lunar eclipses as *chi'b'il* (Martinez Hernandez 1929:305), and Milbrath (1999:26) adds that *chi'b'il* specifically refers to partial eclipses that resemble bite marks. The previous word *min* or *mina'* in Yucatec in the form of *mina'an* means 'there isn't any', whereas *miná'anchah* means 'disappear' (V. Bricker et al 1998:185). Similarly as *mix*, or perhaps *max,* T163 may refer to 'invisibility', as in the example from the introductory inscription on this same page in which **MAX-K'IN** may refer to 'no sun' or 'midnight'. One possibility is that *mina' chi'b'* refers to an invisible partial solar eclipse closer to midnight.

This inscription for the first serpent ends in C4 and D4 with the base date 9 K'an 12 K'ayab', from which the Serpent Numbers begin. It is therefore likely that this inscription refers to events theoretically calculated for this base date, as we have seen above. Indeed, on the base date, there is no eclipse, if that is the intended meaning of *mina chi'b'*, though the sun is exactly at a node. The entire inscription above the first serpent appears to read:

Jaguar Paddler, Stingray Paddler
Sky Serpent
It is revealed?, no eclipse
9 K'an 12 K'ayab'

This inscription may also relate to astronomical events on the terminal dates in the current era, counted forward with the intervals from both Serpent Numbers. We now examine these intervals in light of the above translation:

1a) The Serpent Number 1a in 61C leads to the date 09.17.08.08.05 3 Chikchan 18 Xul, May 27, 779 CE (May 23 Julian). On this day, the sun in Taurus, just before crossing the Milky Way, and the moon is just on the other side of the Milky Way between Gemini and Cancer (**Figure 5.17**). The moon is in the same sidereal position as it was on the base date 9 K'an 12 K'ayab'. The positions of the sun and moon evoke Milbrath's interpretation of the Jaguar Paddler and Stingray Paddler crossing the river of the Milky Way. We also see that the sun on this date is very close to the exact sidereal position in which there was an invisible partial solar eclipse close to midnight on April 3, 3114 BCE (April 23 Julian), exactly 131 days earlier than the Era Base date (**Figure 5.18**). We have seen from the lunar calculations in the Serpent Series that the Maya were most likely aware that the sun was 130 days past a node on the Era Base date, and it so happens that a solar eclipse also occurred when the sun was at this node. This calculation may have been used in the placement of 9 K'an 12 Kayab' exactly at the node, in that in the interval of 10,967,536 days between 9 K'an 12 K'ayab' and 4 Ajaw 8 Kumk'u, the remainder of the eclipse half-year is precisely132 days.

At the bottom of the page after the date 3 Chikchan 18 Xul, **K'UH-OK** is written with an unusual suffix that resembles **tzi** or **TZIK** (T124). This is the only example of this collocation that has this suffix in place of the usual **ki** (T102). Schele (1991) suggests that T124 here may be a substitution for **ki**. Otherwise, it may represent the Ch'olan word *tzik* 'to count', and we find this same grapheme on page 62 and 63 of the Serpent Series in association with Ring Numbers using the 819-day verb and **K'UH OK-ki**. In these other examples, T124 appears with **le** (T612) as perhaps **TZIK-el**, reading *tzikel* 'the counting'. Schele and Grube (1997:141) come to a similar conclusion for this example, but they read the word as *tzil* 'to count'. A meaning related to counting would make sense in the context of the Serpent Series, and the 'holy steps' used in calendrical computation.

As we have seen, counting 91 days earlier from 3 Chikchan 18 Xul takes us exactly to an invisible partial solar eclipse on a day 3 Ix 7 Wo, February 25, 779 CE (February 21 Julian). This is also very close to midnight, if this is the intended reference of *mina chi'b'*.

1b) Serpent Number 1b in 61D leads to a date 10.11.05.14.05 3 Chikchan 13 Pax, October 2, 1052 CE (September 26 Julian), eight days before the sidereal position of the sun on the Era Base date in Virgo (**Figure 5.19**), a seemingly insignificant date, unless this eight day addition was part of a calculation using the 130 year nodal interval from page 52. The sun is not at a node on this date, but the moon is new. Counting back 91 days to a day 3 Ix 2 Keh, on July 3, 1052 CE (June 27 Julian), we find the sun at a node, but here the sun and moon have switched places with their sidereal positions as given in Serpent Number 1a on 3 Chikchan 18 Xul. Here again, the sun and moon are on either side of the Milky Way, evoking the Jaguar Paddler and Stingray Paddler (**Figure 5.20**). Likewise, the waning moon is in the sidereal position of the solar eclipse on April 3, 3114 BCE. Two days forward is another invisible partial solar eclipse at midnight, possibly relating to *mina chi'b'* in the above inscription.

Beneath the date 3 Chikchan 13 Pax at the bottom of the page, we find what may be Schellhas' aged Goddess I (T1026), with her recognizable conflation with the Ka'ban day glyph, **KAB'** (T171) read *kab'* 'earth'. Her name often appears with a -**ki** (T102) suffix, prompting a Ch'olan reading of *ixik* as 'woman' (Kaufman and Norman 1984:121), and Schele and Grube (1997:122) read this name as 'goddess'. In other youthful examples of Goddess I, several within the Serpent Series, she has a Kab'an curl as a prefix, and Thompson (1971:86) sees the initial curl as Landa's **u** (T120), a Yucatec and Ch'ol word for 'moon'. Thompson proposes that Goddess I is a Moon Goddess who was also a goddess of the earth, with support from the ethnographic record (Thompson 1972:47). Certainly, *Xk'ik'*, the moon goddess from the *Popol Vuh*, emerges from the underworld to live on the earth, and Tedlock translates her K'iche' name is a double play on words for both 'moon' *ik'* and 'blood' *k'ik'* (Tedlock 1996L260). Noticing the use of the **KAB'** glyph in the name of Goddess I, Gabrielle Vail and Andrea Stone (2002) read her full name as **IXIK KAB'** 'lady earth', suggesting that she is primarily an earth deity. However, she often also has a **SÄK** (T58) 'white' prefix (Taube 1992:64), which may suggest the color of the moon, as in the lunar Pawahtuns from the initial inscription.

It is apparent that the Maya differentiated between images of the youthful Goddess I as T1026 with the curl prefix, and similar renderings of T1026 without the curl prefix that resemble the aged Goddess O, *Ix Chel*. Thompson (1971:83) believes that these two goddesses represent the waxing and waning moon as young and old versions of the same lunar deity. Taube (1992:68–69) differentiates between this aged version of Goddess I, and the aged Goddess O as *Ix Chel*, but in fact, we find the portrait of the aged Goddess I followed by the name *chel* spelled **che-le** (T145:612) within the inscription above the fourth serpent on page 62 (D2–C3). Milbrath (1996) further proposes that these aged goddesses are all aspects of the waning moon, and she provides evidence that the Maya continue to regard the moon as aging as it wanes. It is therefore possible that the portrait beneath the date 3 Chikchan 13 Pax in Serpent Number 1b is actually representing the aged lunar deity, and therefore a waning moon. Davoust (1997:221) comes to a similar conclusion, naming this portrait itself **CHEL**.

Beneath the date 3 Chikchan 13 Pax in Serpent Number 1b, the aged Goddess I portrait appears as a prefix for **OK-ki** , with a possible meaning relating to intervals of the moon, specifically in a waning position. Indeed, 91 days earlier on 3 Ix 2 Keh, July 3, 1052 CE, the moon is waning, two days prior to a partial solar eclipse. On this date, the moon is also in the sidereal position of the early solar eclipse in 3114 BCE in Taurus. As mentioned above, this position of the moon is the same sidereal position of the sun in Serpent Number 1a, while the sun on 3 Ix 2 Keh the appears at a node where the moon would have been on the base date 9 K'an 12 K'ayab'. The sidereal position of this early solar eclipse appears several times to throughout the dates in the Serpent Series.

The Second Serpent

The inscription above the second serpent is unfortunately almost entirely eroded (**Figure 5.21**). Likewise, the reliability of these Serpent Numbers remains questionable. If even one of the two Serpent Numbers is incorrect, any conclusions drawn from a comparison of these dates would be erroneous. Therefore, I refrain from interpreting either of these dates. Nevertheless, Serpent Number 2a provides a significant result when 169 days are added to the terminal date 3 Chikchan 13 Yaxk'in, April 24, 972 CE (April 19 Julian), and we reach a day 3 Ix 2 Pax, October 10, 972 CE (October 5 Julian), when the sun reaches a node in the exact sidereal position of the Era Base date in Virgo.

The inscription beneath the date for Serpent 2a appears to read **IXIK KAB'-OK-ki**, perhaps in reference to a waxing moon, which does appear on the terminal date 3 Chikchan 13 Yaxk'in, April 24, 972 CE (April 19 Julian). Likewise, the inscription beneath Serpent 2b seems to read **IX CHEL-OK-ki**, perhaps for the waning moon, which does appear on the terminal date 3 K'an 12 Yax on August 4, 796 CE (July 31 Julian). The rabbit in the serpent's mouth lends further support to a lunar reading, but this is the extent of the available information. The precise meaning of the deities emerging from the serpents mouths are unclear, and the first and third serpents show a Chak with an axe in different poses, similar to his appearance as the protagonist within the seasonal table. These may represent directional and seasonal Chaks, since the inscriptions are blue and red, but the associated pairs of dates do not indicate any identifiable seasonal associations. The Peccary in the mouth of the fourth serpent may refer to a Peccary constellation in Gemini, near the summer solstice, when the sun moves more slowly at its farthest point from the sun at aphelion, and it is carried by peccaries (Milbrath 1999:76). These four deities wear headdresses similar to those worn by the year-bearers on the New Years Pages following the Serpent Series. They may have something to do with the position of the New Year, but the two dates in each serpent pair do not occur at the same time of year, apart from those in the third serpent. Furthermore, the Haab' New Year 1 Pop occurs at different times of year in the two dates in each serpent pair.

However, in the meaning of the figures in the mouth of each serpent may instead refer to the sidereal position of the lunar nodes. Both of the 3 Ix nodal passage dates in the second serpent, on October 10, 972 and March 27, 796, correspond to positions near the equinoxes. Thus, the rabbit in the mouth of the second serpent may correspond the vernal equinox moon, and the cardinal direction of the east, with the nodes found at both equinoxes at these times. Likewise, as representative of Gemini and the summer solstice, the Peccary in the mouth of the fourth serpent may relate to the 3 Ix nodal passage from Serpent Number 4a on July 16, 958, with both nodes not far from the position of the solstices at this time, and the ascending node in Gemini. However, the 3 Ix nodal passage from Serpent Number 4b on October 24, 794 does not seem to conform to this pattern. Therefore, it is unclear how the figures in the mouth of each serpent correspond to both of the dates within each serpent pair.

The Third Serpent

The inscription above the third serpent is largely eroded, and painted on a red background (**Figure 5.22)**. In B3 there is a hint of the same eclipse collocation **chi-b'a** that we saw above the first serpent. As we see, yet another **chi-b'a** is present in the inscription above the fourth serpent in D2, and it is possible that this reference to eclipses was part of all of the inscriptions above each serpent. Certainly, it appears that each Serpent Number could be used to track the eclipse year with the day 3 Ix.

3a) Serpent Number 3a leads to the terminal date 3 Ix 7 Pax on October 30, 915 CE (October25 Julian). As we have seen, this date closely resembles the base date 9 K'an 12 K'ayab' on which the sun is in Libra in the exact sidereal position and at the ascending node (**Figure 5.5a and b**). The inscription beneath the date 3 Ix 7 Pax appears to read **IXIK KAB'-OK-ki**, alluding to a possible waxing moon, but on this date there is a total lunar eclipse, and the moon is exactly at the position of the first zenith at 14.8° N latitude. It is therefore unclear whether **IXIK KAB' OK** refers to a waxing moon, or merely intervals used to calculate the moon, or whether **IXIK KAB'** is significantly different from **IX CHEL** when written with **OK**.

3b) Serpent Number 3b leads to 3 Kimi 14 K'ayab' on November 6, 992 CE (November 1 Julian) (**Figure 5.6a**). On this date, the sun is seven days forward from where it was on 3 Ix 7 Pax, October 30, 915 CE, the above date from Serpent Number 3a. The inscription below the date features **OK-ki** prefixed by a new personage not previously encountered (**Figure 5.23**). Though it is eroded, other examples of this portrait are visible in the Ring Numbers of the Serpent Series, one on this page (p.62, E5), and two more on page 63 (A5 and C5). The full version of this name appears to read **mu-XIB'-b'i** (T19:1037:585). Schele and Grube (1997:141) read T1037 as **na**, and they conclude that this collocation spells *mun* 'the tender or young'. However, on page 63, C5, this name is clearly spelled with a **-b'i** (T585) suffix (**Figure 5.23b**), and Davoust (1997:225) reads it as *muxib'* meaning 'destroyer'. In Colonial Yucatec, *muxub'* means 'to destroy', while *mux* means 'to grind' (Martinez Hernandez 1929:645). **XIB'**, meaning 'man', is used in epithets for the four different Chaks associated with different colors and directions, such as *Chäk Xib' Chak*, literally 'Red Man Chak' (Taube 1992:17). If we take *mux* as 'grind' together with *xib*' as 'man', another reading of this name could be 'ground-up-man', and such a name recalls the episode in the *Popol Vuh* where the twins are incinerated and ground into powder, to be reborn as fish-men (Tedlock 1996:130–132).

In the context beneath the Serpent Number date, it is likely that **mu-XIB'** represents another astronomical body, and we may be able to determine its identity from patterns within each of the dates in which it appears. The most likely candidate is the planet Saturn, the slowest moving of all the visible planets, though Jupiter is also possible. In the Classic period, synodic cycles of both Jupiter and Saturn were apparently tracked together, and several scholars have proposed that the 819-day count was used for such purposes. The 819-day count shares a factor of 21 with idealized 399-day synodic periods of Jupiter (the actual interval is 398.99 days) and idealized 378-day synodic periods of Saturn (378.09 days) (Justeson 1989; Powell 1997; Milbrath 1999; Aldana 2001; 2006). Thus Muxib' may represent intervals of both Jupiter and Saturn cycles.

The terminal date for Serpent Number 3b, November 6, 992 CE, closely corresponds to the second stationary point of the planet Saturn, following its retrograde motion. Also on this date, Jupiter is very close to the zenith at 19.5º N, while it is about 40 days past its first stationary point in Taurus, though its sidereal position does not change much in this interval. Perhaps most significantly, the Long Count position of the terminal date of Serpent Number 3b on 10.08.05.00.06 3 Kimi 14 K'ayab' is also a nearly exact whole multiple of Jupiter's synodic cycle of 398.99 days:

10.08.05.00.06 = 1,499,406 days = 3758 (398.99 days) + 1.58 days

When the earth passes any of the superior planets Mars, Jupiter or Saturn, whose orbits are larger and slower than that of earth, these planets appear to stop against the background of stars at their first stationary point, after which point they appear to move backwards in retrograde motion. At the midpoint of these retrograde periods, the planets are directly opposite the sun, and are brightest and closest to the earth, and in conjunction with the full moon. Finally, when the earth has moved past these planets by a sufficient distance, they appear to stop again at their second stationary point, after which they proceed forward again until disappearing behind the sun in a superior conjunction. Both of these stationary points are useful for accurately calculating the synodic periods of the superior planets. A similar phenomenon happens with Venus and Mercury, whose orbits are nearer to the sun and faster than the earth's, though the midpoint of their retrograde motion is the point of inferior conjunction, when they pass between the earth and the sun.

The position of Saturn is also relevant in the base date 9 K'an 12 Kayab'. Using the current value for the synodic period of Saturn as 378.09 days, we can calculate the synodic position of Saturn on the 9 K'an 12 K'ayab' base date from the interval in Serpent Number 3b:

4.06.11.10.07.02 = 12,466,942 days = 32973 (378.09 days) + 180.43 days

Subtracting 180 days from Saturn's position on the terminal date 3 Kimi 14 K'ayab' on November 6, 992 CE, Saturn is almost exactly at its first stationary point, since 180 days is very close to the interval between Saturn's first and second stationary points. Therefore, on the Serpent Base date 9 K'an 12 K'ayab', Saturn would have been at its first stationary point. This may also have been incorporated in the multiple factors used in the selection of this date.

Also on the terminal date from Serpent 3a, 3 Ix 7 Pax, October 30, 915 CE, Saturn is exactly at its first stationary point in Cancer, though this Serpent Number does not cite **mu-XIB'**. The interval for this Serpent Number is very close to a whole multiple of the synodic period of Saturn:

4.06.07.12.04.10 = 12438810 days = 32899 (378.09 days) + 27 days

Is it possible that **mu-XIB'** was also intended for Serpent Number 3a? We will find confirmation for the astronomical identity of **mu-XIB'** as Saturn in the associated Ring Numbers.

The Fourth Serpent

The inscription above the fourth serpent is completely legible (**Figure 5.24**), and a translation of this inscription provides information relevant to yet another planet. Beginning in C1, **HA-la** (T501:140), followed by **YÄX-CHAK-ki** (T17:668:102) in D1. This is an unusual ordering of the familiar name often read *Yax-Ha'al Chaak*, named on Lintel 2 in Piedras Negras, on Structure 6E1 in Chichen Itza, the Copan Hieroglyphic Stairway, and on multiple Late Classic ceramics (Taube 1992:18–19; Boot 2004). Michael Coe notes that this Chak, with his characteristic fish barbell and shell ear, is nearly identical to GI from the Palenque Triad (Coe 1973:98–99), though GI has a roman nose, while Chak has a serpent nose. Many scholars have identified GI as a deity of Venus.[1] Given that Chak is a rain deity who often appears in association with dates at the beginning of the rainy season, the current interpretation is that Yax Ha'al Chak translates as 'First Rain Chak' (Looper 2003; Boot 2004). However, from Lacandon, we find that *hal* also means 'bright, glow, blaze' and *yáax-hal-e'* translates as "luminescent green" (Cook 2004). Here, the grapheme **HA** would then be a phonetic **ha**-, though no other attested examples of this occur elsewhere. Nevertheless, because *yax*can mean both 'green' and 'first', it is equally plausible that *Yax Hal Chak* translates as 'First Bright Chak' as Venus in its first, brilliant appearance as morning star, and the following collocation similarly suggests GI and Venus.

The next glyph in the inscription above the fourth serpent on page 62 of the Dresden appears as a deity portrait in C2, surrounded by a ring of semicircular rays. In an example of the title of GI from an early Uaxactun vessel, the face glyph of GI is replaced with an Ajaw sign surrounded by a ring of dots. Likewise, Stuart noticed a comparable example of the dotted Ajaw sign incorporated into an iconographic representation of GI in the form of a water

[1] See Lounsbury (1985), Schele and Miller (1986:48–51), Tedlock (1992), and Aldana (2001).

bird headdress found in Palenque's Temple XIX (Stuart 2005:120–123). An identical dotted ring appears around another Palenque glyph for *Yax Päs*[2], 'First Dawn', and it appears that this dotted symbol relates to dawning and shining. Venus is clearly associated with concepts of 'first dawn' and first shine'. For the time being, it is possible that the reference in this serpent inscription is to Venus as *Yax Hal Chak* and GI.

Continuing with the inscription in D2, we see the familiar eclipse collocation **chi-b'a** together with the aged Moon Goddess. Because the following glyphs in C3 read **che-le**, it is likely that this Moon Goddess is **IX CHEL**. Together, *chi'b' Ix Chel* appears to indicate a lunar eclipse. Following this in D3 is an unusual collocation of **wa-bu-yu-ni** (T130:21:62:116), and Davoust (1997:223) suggests a reading of *waan b'uy* 'raised up'. However, *b'uy* in colonial Yucatec refers to "the heat or bad vapor that leaves the earth thin, or the roots of trees rotten; that which damages the cotton, jicamas, and such things, and if they sprout, they are lost" (Martinez Hernandez 1929:158). Likewise, from the same source, we find *waan* (<*vaan*> and <*uaan*> in colonial orthography) as 'the stature or height of a man' and 'standing up, erect' (ibid:893). Therefore, a reading of *b'uy waan* would seem to refer to a crop failure, or damage to growth, perhaps even to the growth of human fetuses. In fact, lunar eclipses are specifically regarded as damaging to fertility, and Milbrath (1999:27) notes:

> The Ch'ortí say that the Moon loses her powers of fecundity during a lunar eclipse (Wisdom 1950:400)… Throughout the Maya area, eclipses are

---

[2] A fragment from the Temple of the Inscriptions (Schele & Mathews 1979).

believed to cause illness and death and to be particularly dangerous to pregnant women (Ilía Nájera 1995:325).

As noted in Chapter Four, the Yucatec refer to birthmarks as *chib'al yuil* 'bite of the moon' because lunar eclipses are believed to cause these kinds of birth defects (Bolles 1997). Here we can also see the direct reference to *chib'al* as 'eclipse'. Thus *b'uy waan* may refer to the damage to the growth of both crops and humanity, as sustained by a lunar eclipse.

Finally, the inscription above the fourth serpent ends with the base date 9 K'an 12 K'ayab', and we may recall that on this date, the moon was in the third quarter, while it was at the ascending node on the summer solstice. Six days earlier, there would have been a total lunar eclipse.

The entire inscription above the fourth serpent appears to read:

Hal Yax-Chak
'GI', Eclipse of Ix Chel
Damage to growth
9 K'an 12 K'ayab'

4a) Serpent Number 4a leads to the date 13 Ak'b'al 1 K'ank'in, September 3, 958 CE (August 29 Julian). On this day, the sun is has just entered Virgo, and Venus is at the exact point of its greatest evening elongation, very close to the nadir at14.8° N latitude (the exact position is 13°) (**Figure 5.25**). This likely refers to the above inscription that mentions *Yax Hal Chak* GI as Venus. This is also the date mentioned as a Ring Number on page 63, and as we have seen in Chapter

Two, Herman Beyer (1943) used this correspondence to determine the placement of the 9 K'an 12 K'ayab' base date within the Long Count.

Beyer determined that the interval between 9 K'an 12 K'ayab' and 13 Ak'b'al 1 K'ank'in is 4.06.09.15.12.19, equivalent to 12,454,459 days. He also noticed that this is almost exactly 21,329 synodic periods of Venus of 583.9213 days, remarking that such a value for the Venus period is accurate to the fourth decimal place when compared with current calculations. Beyer that the 9 K'an 12 K'ayab' base date may have served as a zero date for planetary calculations, but he admits that his observation is mere conjecture (Beyer 1943:404). His proposal was prior to any translation of the associated script, and without recourse to the GMT calendar correlation. Indeed, the Venus elongation occurring on 13 Ak'b'al 1 K'ank'in also occurred on the base date 9 K'an 12 K'ayab', and it appears that the inscription above refers to Venus itself. In fact, the sidereal position of Venus on the 9 K'an 12 K'ayab' base date is very close to the second zenith at 14.8° N in Sagittarius.

It appears that Beyer may have been right, and that the Maya were calculating the synodic periods of both Venus and Saturn with astonishing accuracy. This has profound implications for the recycling of the Venus tables within the Dresden Codex. According to Lounsbury (1978:789), the recycling of the Venus tables as he understands it provides for a value of the synodic period of Venus of 583.92026 days, which would produce too great of an error over the long period of time covered by the Serpent Numbers. However, the Venus table, like the lunar table in the Dresden Codex, requires further study, and an understanding of the exact way in which it functions over long periods of time remains incomplete.

Returning to the Serpent Number 4a on 13 Ak'b'al 1 K'ank'in, counting back 49 days to the day 3 Ix 12 Sak on July 16, 958 CE (July 11 Julian), the sun is again exactly at the node on a day 3 Ix, here in Cancer. This sidereal position of the sun in Cancer happens to be the exact position of the first solar zenith at 19.5° N latitude on May 19 during the year of the Era Base date in 3114 BCE. As we have seen, this is the apparent latitude in the Yucatan at which the second solar zenith occurs on the Haab' New Year following the 9 K'an 12 K'ayab' base date. Thus, it is possible that this segment the Dresden Codex was originally written at this latitude.

On July 16, 958 CE, the moon is in the third quarter, eight days after a total lunar eclipse in Capricorn. Here again we see the eight-day interval from the nodal calculation on page 52 in the Dresden lunar table. Though it would have been invisible at Maya longitudes, it is likely that the Maya were aware of the possibility of this phenomenon, given the inscription above concerning a lunar eclipse. There is no solar eclipse in this month, and the 49-day count back from elongation to 3 Ix does not seem to be significant for any Venus cycle. The significance of Venus appears to be limited to the base date 9 K'an 12 K'ayab', and in the interval to the terminal date 13 Ak'b'al 1 K'ank'in, while the lunar eclipse only pertains to the 3 Ix nodal passage of the sun.

Beneath the terminal date 13 Ak'b'al 1 K'ank'in, we find **K'UH-OK-ki**, 'holy steps' without any specific personage being named. It is not clear why no name appears here, and what exactly prompts the use of various subjects in this context.

4b) Serpent Number 4b leads to the date 3 K'an 17 Wo, March 3, 795 CE (February 27 Julian). On this date, the sun is in Pisces, exactly 219 days prior to the sidereal position of the Era Base date in Virgo (**Figure 5.26**). This evokes the distance number of 15,228 Tuns plus 55 days in the Serpent Series introductory inscription, in which the tropical year and the sidereal year shift by 219 days. In this case, this sidereal position in Pisces represents the position of the second solar zenith when the introductory distance number is added forward from the Era Base date to reach the year 11,896 CE.

On 3 K'an 17 Wo, March 3, 795 CE, a three-day old crescent moon is exactly at the ascending node in Aries. Venus does not appear to be in any significant synodic position, as it was in Serpent 4a. However, counting back 130 days from 3 K'an 17 Wo, we reach the day 3 Ix 12 K'ank'in, October 24, 794 CE (October 20 Julian). On this date, once again the sun exactly reaches a node, here in Libra curiously in the same sidereal position as 0 Pop in 3114 BCE (**Figure 5.10**). In addition, on this date, Venus is in the same sidereal position as the sun appears on the Era Base date in Virgo. The moon on October 24, 794 CE is at the third-quarter in Leo, while seven days earlier there was a partial lunar eclipse in the same sidereal position in which the moon appears on 3 K'an 17 Wo in Aries. Beneath the date 3 K'an 17 Wo, we find the aged Ixik Kab'. This may refer to the waning moon on October 24, 794, while the partial lunar eclipse likely refers to the inscription above.

The Ring Numbers

The remaining dates within the Serpent Series are in the form of Ring Numbers with multiple components and varying subjects. A review of the function of Ring Numbers is relevant to the present discussion. The red rings around the K'in position in each Ring Number signify specific intervals of time that, when added to a back-reckoned Ring Base date, will reach the Era Base date on 4 Ajaw 8 Kumk'u. Another much longer interval is added to the Ring Base, and this interval, known as the Long Round, reaches a base date specified within the tables of multiples in the Serpent Series.

Originally, Förstemann (1906) and later Morley (1915) believed that the Long Round was a Long Count date itself, from which the Ring Number was subtracted to reach the intended base date. Willson (1924) later discovered that the Ring Number itself represents the interval between 4 Ajaw 8 Kumk'u and an earlier Ring Base prior to the Era Base date that is frequently given at the top of the page in Calendar Round format. This calculation accounts for the recording of the Era Base date 4 Ajaw 8 Kumk'u beneath the Ring Number. Whether the Ring Number is subtracted from the Era Base date or added to the Ring Base is a matter of debate, but the current opinion is that the Long Round itself does not represent another position in the Long Count. Thompson (1972:24) explicitly rejects the use of Long Roundas additional Long Count positions implied in the Ring Number calculations.

Lounsbury explains why positions in the current era are given by counting from a base prior to 4 Ajaw 8 Kumk'u:

> The numbers that tell the days from the pre-zero "ring" bases to the related historical dates are contrived numbers—contrived in such a way as to provide, for each historical date, a base which is its like-in-kind in respect to its position in one or more pertinent calendrical or astronomical cycles. The day of the special base thus has significant attributes in common with the historical day whose chronological position is reckoned

from it; and it is, moreover, the last possible one to do so before the beginning of the current era (Lounsbury 1978:806).

Out of the fifteen different Ring Numbers in the Dresden Codex, Lounsbury (1978:806) found that eleven of the Long Rounds used are whole multiples of the 260-day Tzolk'in, four of which are multiples of the 780-day synodic period of Mars, five are multiples of the 364-day computing year, two are multiples of the 9-day cycle. Other relevant cycles include the 2,920-day cycle of eight 365-day years comprising five synodic periods of Venus, and a 2,392-day period of 81 synodic lunar cycles. Lounsbury reasons that the terminal dates within the current era represent specific events, most likely astronomical, while the Long Rounds are "contrived numbers," composed of one or more of the above multiples, with a particular emphasis on the 260-day Tzolk'in. The pre-era Ring Base dates are therefore attempts to calculate the most recent similar astronomical occurrences prior to the Era Base date. However, Lounsbury could not explain why two of the Long Rounds from the Serpent Series have none of the above multiples. One of these is the Ring Number used by Beyer to calculate the base date of the Serpent Series. Furthermore, both unusual Long Rounds use a large Ring Number of 51,419 days—perhaps not the most recent occurrence prior to the Era Base date.

Given the accuracy found within the Serpent Series calculations, the Ring Base dates in the Serpent Series may likewise prove to be astronomically significant. However, where whole multiples of the Tzolk'in or the computing year were counted to reach specific base dates, corrections may have been made to calculate multiple astronomical phenomena, as we have seen in the Serpent

Numbers that count to the nearest day 3 Ix to calculate a solar nodal passage. If these corrections are unstated, it may be difficult to determine the significance of the dates given.

As mentioned earlier, the Brickers (1988) have used the terminal dates calculated using Ring Numbers in the Serpent Series on pages 61–63, together with the terminal dates of the Serpent Numbers, as entry dates within the seasonal table on pages 65–69. However, their method of adding various unexplained corrections in the form of a wide range of 91-day multiples is problematic and not standardized. On the other hand, in a separate article, the Brickers (2005) have demonstrated that the structure of the tables and the dates calculated using Ring Numbers within the second Serpent Series on page 70 provide accurate measurements of the synodic and sidereal cycles of Mars.

The dates calculated using Ring Numbers within the Serpent Series invariably use the 819-day verb **pa-se-la-aj K'UH-OK-ki** with varying astronomical subjects. A thorough examination of the astronomical significance of each of these dates, together with their Ring Base dates, may enable us to determine the identity of the astronomical body or phenomenon in question, and the intended meaning of the dates referenced. A comparison of these results with those from the Serpent Numbers helps to confirm these identities where the subjects are shared. Of particular relevance to the current study are any dates that represent intentional calculations of the sidereal year and precessional drift.

Several errors appear in the Ring Number calculations from the Serpent Series, and Thompson (1972:80, 116) notes that there is a consensus among scholars concerning the appropriate corrections. All of the Ring Numbers appear to be correct, leading to proper base dates prior to 4 Ajaw 8 Kumk'u. Because

Ring Number calculations have multiple steps and anchoring points, a single error is easy to explain and it is often possible to test the correction with the remaining accurate intervals and terminal dates. In some cases, these errors represent displacements of proper dates from one column to another, or a copyist's numerical error, whereas other errors are more difficult to explain, particularly those calculations that contain more than one error. Therefore, it is with a measure of caution that we use any of the corrections from the more unexplainable errors as solid evidence.

62E) The Ring Number calculation on page 62, column E (**Figure 5.27a**) follows immediately after the fourth serpent, and the inscription begins with an eroded Tzolk'in position in E1, followed by the Haab' date 13 Keh. This position represents the Ring Base date. However, the proper Ring Base for the Ring Number below of 1.04.16, equivalent to 456 days, would be 17 Mak. The month Keh would appear in the Ring Base of column F, but the source of the numerical error is unexplained, unless it was taken from the proper Ring Base Haab' date from page 63, column A. Nevertheless, the Ring Number and the Long Round appear to be accurate, as the Ring Base falls on a date 3 K'an, and counting forward with the Long Round, we reach a date 3 Chikchan, and this is given as the terminal date of the calculation below. The inscription continues in E3–E7, with the subject Muxib', and the possible reading:

pa?-se?-la-aj K'UH-OK-ki mu-XIB' CHAK-ki tzi-le

paselaj?? k'uh ok muxib' chak tzil

'the holy steps are revealed?, Muxib' Chak counting'

The Long Round follows with 8.16.15.16.01 and the Calendar Round date 3 Chikchan 13 Sip, a calendrical impossibility, since the number 13 cannot occur with the day Chikchan. The proper Haab' date reached when the Long Round is added to the Ring Base would be 18 Sip, and the scribe apparently left out one bar to make 18. The Ring Number follows as 1.04.16, with the K'in position circled by a tied red ring, and beneath this is the Era Base 4 Ajaw 8 Kumk'u.

Added to the Ring Base of 3 K'an 17 Mak, on the Long Round reaches a Long Count date 8.16.14.11.05 3 Chikchan 18 Sip, July 5, 371 CE (July 4 Julian) (**Figure 5.28a**). The Ring Base itself falls on May 14, 3115 BCE (June 9 Julian) (**Figure 5.28b**). It is immediately apparent when comparing these dates that the sun is in nearly the exact same sidereal position in Cancer on both of them. In other words, the Long Round itself is almost exactly a whole interval of the proposed Maya sidereal year:

8.16.15.16.01 = 1,272,921 days = 3,485 (365.2565128 days) + 2.05 days

Adding the Ring Number to the date 3 Chikchan 18 Sip on July 5, 371 CE, reaches a date October 3, 372 CE (October 2 Julian) with the sun in the same sidereal position in Virgo as on the Era Base date 4 Ajaw 8 Kumk'u (**Figure 5.29**). Thus, contrary to Thompson's assertions, this Long Round can be used as a Long Count position that has an astronomical significance, where the Era Base date and the Ring Base closely parallel the Long Round and the terminal date. This calculation represents yet another support to the argument that the Maya were capable of calculating the sidereal year, and that the Serpent Series introductory distance number was used for this purpose. Furthermore, the Ring Base date on May 14, 3115 BCE is very close to the first solar zenith at 19.5° N latitude.

In addition, in the year 371 CE in which the terminal date 3 Chikchan 18 Sip falls, the Haab' is aligned with the tropical year so as to place the sun on 1 Pop in the sidereal position of Taurus near the Pleiades (**Figure 5.30**), only six days past the first solar zenith passage at 14.8° N latitude, and exactly 219 days after the sidereal position of the Era Base date in Virgo on 8 Mol. This is a direct parallel of the sidereal Haab' positions found when the Serpent Series introductory distance number of 15,228 Tuns + 55 days is subtracted from the Era Base date. At this time, the sun in Taurus on 1 Pop represents both the second solar zenith in this earlier year, 18,123 BCE, as well as the position of the vernal equinox in the Era Base year, 3114 BCE. Here again is a confirmation of the ability of the Maya to coordinate the tropical year, the Haab', and the sidereal year.

When 91 days are subtracted from the terminal date 3 Chikchan 18 Sip to reach a day 3 Ix, the sun is not at one of the lunar nodes as would be expected for the Serpent Numbers. Neither does it reach a node when 169 days are added to the terminal date on the next day 3 Ix. Therefore, it appears that this nodal function of 3 Ix does not apply in the Ring Numbers, whereas the date given appears to align the sidereal year and the Haab' using the 3 Chikchan base day. It is worth mentioning that adding 169 days to reach 3 Ix 7 Keh does reach a winter solstice, and perhaps this base day was also used for this purpose. Adding 91 days to this 3 Ix solstice date to reach the next occurrence of 3 Chikchan, we find the sun almost exactly on the vernal equinox.

In their discussion of the function of Ring Number dates as entry points within the seasonal table on pages 65–69 of the Dresden, the Brickers (1988) propose that 91 days are added to the day 3 Chikchan to reach the next entry point within the seasonal table on a day 3 Kib'. In fact, when 91 days are added to the terminal date 3 Chikchan 18 Sip on July 5, 371 CE, the sun reaches almost exactly the same sidereal position in Virgo as on the Era Base date 4 Ajaw 8 Kumk'u. It is thus possible that the seasonal table applies to this specific sidereal alignment with the Era Base position in Virgo, and that the Brickers are correct about the function of the seasonal table for the Ring Number dates, while the Serpent Numbers appear to function somewhat differently, using the day 3 Ix to track the eclipse year. The fact that the Haab' is aligned in an ideal position also supports the Bricker's assertion that the seasonal table enables a commensuration of the tropical year with the Haab', with 1 Pop close to the first zenith passage of the sun at 14.8º N latitude, here in the sidereal position of the Pleiades.

The subject of the Ring Number calculation in 62E is Muxib'. As mentioned previously, the name Muxib' also appears in Serpent Number 3b, along with an interval closely related to Saturn's stationary point and the synodic and sidereal position of Jupiter. We may thus look to see if the dates in the Ring Number calculation for 62E relate to the position of Saturn and Jupiter. In fact, on the terminal date 3 Chikchan 18 Sip, July 5, 371 CE (July 4 Julian), Saturn is directly at opposition to the sun in Capricorn, exactly in the middle of its retrograde period (**Figure 5.31a**). This sidereal position closely corresponds to the second nadir at 19.5º N in the Postclassic, though it is unclear if this position is relevant. Jupiter is nearby in the sidereal position of the winter solstice in Sagittarius, 37 days before its second stationary point, very close to the solstice position.

Again adding the 456-day Ring Number to the terminal date 3 Chikchan 18 Sip to reach the Long Count position of the Long Round on October 3, 372 CE (October 2 Julian), we find that Saturn and Jupiter are in conjunction in Capricorn (**Figure 5.31b**), and both are very close to their second stationary points–Saturn about 5 days earlier and Jupiter about 10 days (The sidereal movements of these planets close to their stationary points are minimal). It is possible that Muxib' refers to both Saturn and Jupiter together, and that these Long Count positions of Long Rounds are highly significant and not to be discounted.

Conjunctions of Jupiter and Saturn occur about every twenty years and these could be measured with the cycle of the K'atun (Kelley 1985:238). Over several years, these two planets remain close, appearing to follow each other in a back and forth movement of their retrograde periods. If these two planets were known as Muxib' meaning 'ground-up-man', their tandem schooling behavior suggests the twins Hunahpu and Xbalanque who transformed into two fish-men after their burned bones were ground into powder and poured into a river. The full form of the K'atun glyph depicted in the Initial Series Introductory Glyph incorporates the image of two fish, or the syllabic representation of two fish fins (T25). It has been suggested that these two fish may represent the series of conjunctions of Jupiter and Saturn approximately every K'atun.

Curiously, on the Haab' New Year 1 Pop in the year 371 CE, when the sun is in the sidereal position near the Pleiades, Saturn reaches its first stationary point. Given the apparently intentional sidereal alignment of the Haab' on this date, and the mention of Muxib', it is possible that this alignment with Saturn was also intended.

62F) The Ring Base date of the Ring Number calculation on page 62, column F is eroded, with the proper date calculated as 13 K'awak 7 Keh. The inscription continues in F3–F7 with the possible reading (**Figure 5.27b**):

pa?-se?-la-aj K'UH-OK-ki IXIK KAB'CHAK-ki tzi-le

paselaj?? k'uh ok ixik kab' chak tzil

'the holy steps are revealed?, Ixik Kab' Chak counting '

The Long Round follows as 8.16.14.15.04, but the Calendar Round date 13 Ak'b'al 15 Pop is another calendrical impossibility. The proper terminal Haab' date would be 16 Pop, and the scribe apparently left off one dot, just as one bar was left off of the Haab' date to the left in the previous column. The Ring Number follows as 6.1, a smaller interval of 121 days, with the Era Base date below as 4 Ajaw 8 Kumk'u.

Adding the Long Round to the Ring Base, we reach a Long Count position of 8.16.14.09.03 13 Ak'b'al 16 Pop, May 24, 371 CE (May 23 Julian) (**Figure 5.32**). This is the same year as the previous Ring Number calculation in 63E, and the same alignment of the Haab' with the tropical year. Here the terminal date is only 15 days forward from the New Year on 1 Pop; it is very close to the same position in the tropical year and the same sidereal position as in the terminal date from Serpent Number 1a. This is the <u>exact</u> sidereal position of a solar eclipse 132 days prior to the Era Base date on April 3, 3114 BCE, further demonstrating a specific interest in this sidereal position.

As with the previous Ring Number in 63E, the nearest occurrences of 3 Ix do not produce a solar nodal passage. The subject of this inscription is clearly

Ixik Kab'. On May 24, 371 CE, the moon is at the third-quarter, one day past the ascending node, which occurred in the sidereal position of the second nadir. This configuration does not seem particularly significant. But again, adding the Ring Number of 121 days to this date, we reach the Long Count position of the Long Round on 4 K'an 17 Yaxk'in, September 20, 371 CE, very close to the autumnal equinox. On this later date, the waning moon is four days before new, and it passes through the sidereal position of the second zenith at 14.8º N in Leo, having passed the node the day before.

Comparing these positions with the pre-Era Ring Base date 13 K'awak 7 Keh on April 14, 3114 BCE (May 10 Julian), we find the moon on this earlier date in the sidereal position in Libra where the sun appeared on the base date 9 K'an 12 K'ayab'. It is slightly over ten days after the solar eclipse on April 4, indicated by the sidereal position of the sun in the terminal position on May 23, 371 CE. Furthermore, the moon on April 14, 3114 BCE is about to pass through the descending node at the sidereal position of the autumnal equinox in Scorpius on April 15, and there is a partial lunar eclipse on April 17. It is possible that the function of this Ring Number calculation was to coordinate the pre-era solar eclipse event with the sidereal position of this eclipse in a year in which the Haab' is in an idealized position, with the sun on the New Year in the position of the Pleiades and the first solar zenith.

63A) The Ring Number calculation on page 63, column A is largely eroded, but the inscription can be reconstructed (**Figure 5.33a**). The Haab' month Sip is just visible in A2, but this is a likely error, in that the proper Ring Base would be 3 Chikchan 13 Xul, and we see 13 Xul written incorrectly in column B to the right. The phrase appears to be identical to the Ring Number calculation in 62E, with the subject Muxib'. A3-A7 would then appear to read:

pa?-se?-la-aj K'UH-OK-ki mu-XIB' CHAK-ki tzi-le

paselaj?? k'uh ok muxib' chak tzil

'the holy steps are revealed?, Muxib' Chak counting '

The Long Round follows as 8.11.08.07.00, followed by the terminal date of 3 Chikchan 13 K'ank'in. While this is a possible date, the Haab' appears to be in error, as the Long Round added to the Ring Base reaches a day 3 Chikchan 8 K'ank'in, with the consensus that the scribe added an extra bar by mistake. The Ring Number follows as 11.15, 235 days, with the Era Base date below.

Adding the Long Round to the Ring Base, we reach the Long Count date 8.11.07.13.05 3 Chikchan 8 K'ank'in, on February 25, 266 CE (also February 25 Julian) (**Figure 5.34a**). Again, we find no 3 Ix nodal passages. But on this date, Saturn is at its second stationary point in Gemini, as implied by the subject Muxib'. Jupiter is 30 days past conjunction with the sun near the second solar nadir in Aquarius. Moreover, the sun on this day is in almost the same sidereal position as in the terminal date from Serpent Number 4b on March 3, 795 CE (February 27 Julian), once again, 219 days earlier than the sidereal position of the Era Base date in Virgo (**Figure 5.26**). As we have seen, this position in Pisces is the <u>future</u> position of the second solar zenith after adding the Serpent Series introductory distance number to reach the year 11,897 CE. In this case, February 25, 266 CE is 218 days earlier than the sidereal position of the Era Base date, with some room for a one-day difference due to calculation methods and adjustments.

When we add 218 days to reach this position on October 1, we see that the sun has passed through a total solar eclipse 15 days earlier on September 16, and the moon on October 1 is full just beyond the descending node in Pisces, exactly at an azimuth of 0º, setting due west (**Figure 5.34b**). This is an example of an eclipse event close to an equinox. Like Hipparchus, Maya astronomers may have used such events to calculate the precession of the equinoxes.

Again, adding the Ring Number to the terminal date on February 25, 266 CE, we find that the Long Count position of the Long Round appears to be significant, again contradicting Thompson's view that these dates were not implied in the calculation. Adding the Ring Number, we reach the date 4 Ajaw 18 Yaxk'in on October 18, 266 CE (same Julian), at which point Saturn exactly reaches its first stationary point in Cancer, and the sun reaches the exact sidereal position in which it appears on 1 Pop in 3114 BCE. In addition, on this day, Jupiter is exactly at its second stationary point very close to the second nadir at 14.8º N in Aquarius

Comparing these dates with the Ring Base date of 3 Chikchan 13 Xul, on December 21, 3115 BCE, we find the sun in the position of the winter solstice in Aquarius, though the actual solstice is on December 18 due to changes in the position of the perihelion in the tropical year, and the speed of the earth in its elliptical orbit. Nevertheless, during all of Maya history, the interval between the winter solstice and the second solar zenith at 14.8º N latitude was exactly 235 days, and the Maya likely expected December 21 to be a winter solstice. On this date, Jupiter does not seem significant at 60 days prior to its first stationary point in Aries. But Saturn is has reached its first stationary point, and it is in nearly the same sidereal position in Virgo at the second zenith that it was on the day of the

Era Base date on 4 Ajaw 8 Kumk'u, 235 days later. On the Era Base date, Saturn is just 6 days from conjunction with the sun, and it thus happens to be at the azimuth of the second zenith at this time **(Figure 5.35a)**. On the Ring Base date 235 days earlier, on the theoretical winter solstice, it appears in the same sidereal position at its first stationary point **(Figure 5.35b)**.

Perhaps even more intriguing is the apparent synodic and sidereal position of Saturn in the future year 11,897 CE, after adding the introductory distance number to the Era Base date. Given the value of 378.09 days for the synodic period of Saturn:

15,228 Tuns + 55 days = 5,482,135 days = 14,499 (378.09 days) +208 days

On the Era Base date of August 13, 3114 BCE, Saturn is close to conjunction with the sun, and adding 208 days brings the sun close to the vernal equinox, while Saturn is close to its second stationary point, still at the second zenith in Virgo. However, adding the interval 5,482,135 days also brings the sun close to the vernal equinox in 11,897 CE, in the sidereal position of the Era Base date in Virgo. On this future date, Saturn will be close to its second stationary point at the second zenith in Pisces—the exact sidereal position of the sun determined by the Ring Number calculation in 63A on February 25, 266 CE. If intended, this is truly remarkable. This Ring Number calculation appears to coordinate the stationary points of Saturn, Muxib', and the future sidereal position of the second zenith in the year 11,897 CE. It is tempting to conclude that, as a 'destroyer', Muxib' may have been conceived as bringing about the end of very long cycles of time, such as that described by the Serpent Series interval implied within this Ring Number calculation.

63B) The Ring Number calculation on page 63, column B is almost entirely legible (**Figure 5.33b**). Remnants of the Tzolk'in day 13 Ak'b'al are visible in B1, followed by the incorrect Haab' date 13 Xul. As we have seen, this is the correct Haab' position for the previous Ring Number in column A to the left. From the Ring Number below, the proper Ring Base date would be 13 Ak'bal 11 K'ayab'. The inscription in B3–B7 is identical to that on page 62, column F, and it again names the Moon Goddess:

pa?-se?-la-aj K'UH-OK-ki IXIK KAB'CHAK-ki tzi-le

paselaj?? k'uh ok ixik kab' chak tzil

'the holy steps are revealed?, Ixik Kab' Chak counting

The Long Round follows as 8.16.03.13.00, with the terminal date given as 13 Ak'b'al 6 Kumk'u, a possible but apparently erroneous Haab' month and number, with the correct Haab' position as 11 Yaxk'in. Here, the scribe not only left out a bar in the numeral, they apparently confused the two-part month glyph for Yaxk'in with the similarly shaped Kumk'u. While a total of three errors in this Ring Number calculation renders any corrections unprovable, the intervals in the Long Round and the Ring Number appear to be sound. Nevertheless, it is always a possibility that one of these numerical intervals is incorrect, while the Haab' month of the terminal date may not be in error. Therefore, it is with a certain measure of caution that we proceed with an interpretation of the implied dates.

The Ring Number follows as the shortest on record, only 17 days, and the Era Base date 4 Ajaw 8 Kumk'u appears at the bottom of the page. Adding the Long Round to the Ring Base, we reach the terminal date 13 Ak'b'al 11 Yaxk'in on September 18, 360 CE (September 17 Julian). The sun on this date is very close to the same sidereal position of the total solar eclipse from Ring Number 63a on September 16, 266 CE. On September 18, 360 CE, the moon is in the position of the Milky Way between Taurus and Gemini. It is at the third quarter, and it is at its maximum declination from the ecliptic, meaning it is south of the ecliptic by 5º, at the midpoint between the descending and ascending nodes. Because the sidereal position at which this declination is occurring is near the summer solstice, this position happens to allow for the moon to cross the azimuth of the zenith at 14.8º N latitude. The sun on this date is in Virgo (**Figure 5.36a**), here at the very same sidereal position at which the total solar eclipse on September 16, 266 CE took place. This eclipse was found in the Ring Number calculation from column 62 A, when counting back 15 days from the sidereal position of the Era Base date in Virgo. However, there may be yet another reference for this sidereal position.

Again, adding the Ring Number of 17 days to the terminal date, we reach October 5, 360 CE (October 4 Julian) and the sun is exactly three days beyond the sidereal position of the Creation in Virgo (**Figure 5.36b**). The moon on this date appears near the winter solstice in Capricorn but above the ecliptic at the azimuth of the nadir at 19.5º N. It is not clear if this is significant. Comparing these dates with the Ring Base date 17 days before Creation on 13 Ak'b'al 11 K'ayab', July 27 3114 BCE (August 22 Julian), we find that the moon on this date is two days before new and at its maximum northern excursion at the longitude of the summer solstice in Leo, but 5° north of the ecliptic.

But the interval of 17 days is also relevant within the Serpent Series introductory distance number. When counting backwards from the Creation date using the interval of 15,228 Tuns + 55 days to the year 18,123 BCE, we theoretically reach a position in the tropical year 219 days earlier on January 7, but in the same sidereal position in Virgo. Subtracting an additional 17 days, we reach a position in the tropical year exactly 235 days before the second solar zenith on August 13. As we have seen in the previous Ring Number calculation from column 63A, the interval of 235 days before the second solar zenith at 14.8° N latitude reaches the expected winter solstice on December 21. Because the sun is 17 days before the sidereal position of the Era Base date in Virgo on the Ring Base on July 27, 3114 BCE (August 22 Julian), it represents the sidereal position of the winter solstice at the end of the year in 18,124 BCE.

In addition, when we look at position of the synodic and sidereal cycles of the moon after one interval of the introductory distance number from the Serpent Series, we see that the remainder for both cycles is 17 days:

15,228 Tuns + 55 days	**=**	**5,482,135 days**
in synodic lunar cycles	**=**	**185,642 (29.53059 days) +17.211 days**
in sidereal lunar cycles	**=**	**200,651 (27.32166 days) + 16.6 days**

Furthermore, we have not previously determined that this extraordinary distance number is also very close to a whole interval of eclipse years:

15,228 Tuns + 55 days	**=**	**5,482,135 days**
in eclipse years	**=**	**15,816 (364.62 days) – 7.28 days**

This has the effect of nearly reproducing the sidereal position of the nodes, because the sun is expected to return to the same sidereal position in this interval. So when we subtract 17 days to reach the Ring Base on July 27, 3114 BCE, the sidereal position and phase of the moon in Leo, 5 ° north of the ecliptic (**Figure 5.37**), will be the same when one interval of the introductory distance number is subtracted from the Era Base date to reach January 7, 18,123 BCE. It appears that this Ring Number calculation partially determines the sidereal position and phase of the moon on January 7, 18,123 BCE, and the sidereal position of the winter solstice sun 17 days earlier on December 21, 18,124 BCE. The phase of the moon and its approximate sidereal position on this winter solstice can be determined by subtracting another 17 days from the Ring Base to reach July 10, 3114 BCE (August 5 Julian). On this date, the moon is in Capricorn, 5 days prior to full (**Figure 5.38a**).

Returning to the Long Count position of the Long Round on October 5, 360 CE (October 4 Julian) (**Figure 5.38b**), 17 days after the terminal date on 13 Ak'b'al 11 Yaxk'in, September 18, 360 CE (September 17 Julian), we find the moon in the same sidereal position in Capricorn that it appeared on July 10, 3114 BCE, 17 days before the Ring Base. This represents the sidereal position of the moon on the winter solstice in 18,124 BCE, though in 360 CE, the nodes are in a different sidereal position. But this position of the moon would also represent the sidereal position and phase of the moon when <u>twice</u> the introductory distance number is subtracted from the Era Base date. This is precisely what is necessary to reach the

9 K'an 12 K'ayab' base date, only 3,266 days longer than two intervals of the introductory distance number. In fact, 3,266 days is equal to 110 synodic lunar cycles, with another remainder of 17.6351 days. Therefore, in subtracting another 17 days, the terminal date may then approximate the phase of the moon on 9 K'an 12 K'ayab'.

The moon on the terminal date, September 18, 360 CE, is exactly at the third quarter, and six days past the ascending node (**Figure 5.39**). This is identical to the phase of the moon on the 9 K'an 12 K'ayab' base date. But because the sidereal position of the sun on this date is some 36 days prior to the position in Libra in which it appears on 9 K'an 12 K'ayab', the sidereal position of the moon is two days prior to its actual position on this base date, and the sun is not aligned with the nodes in the same way, so there is not a total lunar eclipse near the Pleaides in the month of the terminal date, as there was six days prior to 9 K'an 12 K'ayab'. Nevertheless, the phase of the moon on the terminal date is very accurately compared to the phase of the moon on 9 K'an 12 Kayab'. We can add the interval between 4 Ajaw 8 Kumk'u and the terminal date 8.16.03.13.17 13 Ak'b'al 11 Yaxk'in to the interval between 9 K'an 12 K'ayab' and 4 Ajaw 8 Kumk'u to determine this accuracy:

8.16.03.13.17 = 1,268,523 days

1,268,523 days between 4 Ajaw 8 Kumk'u to 13 Ak'b'al 11 Yaxk'in

10,967,536 days between 9 K'an 12 K'ayab' and 4 Ajaw 8 Kumk'u

1,268,523 days + 10,967,536 days = 12,236,059 days

We then divide this interval by the current value of the synodic lunar cycle:

12,236,059 days = 414,352 (29.53059 days) – 0.0277 days

It is clear from this calculation that the Maya had an extremely refined value for the synodic lunar cycle, as is evident in the secondary distance numbers from the Serpent Series discussed in Chapter Four. All of the above calculations reinforce the proposed use of the introductory and secondary distance numbers in the Serpent Series as highly advanced astronomical tools capable of calculating the sidereal year, the tropical year, the eclipse year, and accurate lunar and planetary periods.

63C red) The last Ring Number calculation associated with the first four serpents contains two Long Rounds that use the same Ring Number and name the same subject in Column 63C (**Figure 5.33c**). One is written in red, and the other in black, with their terminal dates given only as two different Tzolk'in positions. The red interval leads to the same terminal date found in Serpent Number 4a, and Beyer used this Ring Number calculation to determine the chronological position of the 9 K'an 12 K'ayab' base date discussed in Chapter Three.

The Ring Base date is visible in C1–C2 as 13 Imix 9 Wo, and the inscription continues in C3–C6, with the possible reading:

pa?-se?-la-aj K'UH-OK-ki mu-XIB-b'i CHAK-ki

paselaj?? k'uh ok muxib' chak

'the holy steps are revealed, Muxib' Chak'

Here, Muxib' is clearly spelled with a final **-b'i** (T585), while the usual **tzi-le** is apparently left out for lack of space. Inter-written with the black Long Round, the red Long Round follows as 10.13.13.06.02, beneath which is found the two terminal Tzolk'in dates 3 Chikchan and 13 Ak'b'al. The shared Ring Number is the longest recorded as 7.02.14.19, equivalent to 51,419 days, a period of over 140 years. The Era Base date 4 Ajaw 8 Kumk'u appears below.

Adding the Long Round to the Ring Base, we reach the Long Count position 10.06.10.06.03 13 Ak'b'al 1 K'ank'in on September 3, 958 CE (August 29 Julian). This is the exact date Beyer found in Serpent Number 4a (**Figure 5.25**), at which time Venus is at its greatest evening elongation, the same synodic position in which it appears on the 9 K'an 12 K'ayab' base date. Likewise, the previous date 3 Ix 12 Sak on July 16, 958 CE (July 11 Julian) is a solar nodal passage (**Figure 5.9**), and this appears to be the only Ring Number calculation in which this Serpent Number nodal pattern occurs.

On the September 3 terminal date, Saturn is exactly at its second stationary point in Sagittarius, near the sidereal position of the winter solstice in the Milky Way (**Figure 5.40a**). However, Jupiter is not near any stationary point or significant position on this date, though it is at a node in Cancer.

Lounsbury (1978:806) was puzzled by the Ring Number 7.02.14.19, in that it is not composed of any known multiples of smaller cycles. However, this interval of 51,419 days is a near exact whole multiple of Saturn's synodic period of 378.09 days:

51,419 days = 136 (378.09 days) – 1.234 days

This appears to confirm the identity of Muxib' as Saturn. Therefore, adding this distance number to the terminal date 13 Ak'b'al 1 K'ank'in on September 3, 958 CE (August 29 Julian), we reach the Long Count position of the Long Round on 10.13.13.03.02 4 Ik 15 Sak, June 15, 1099 CE (June 9 Julian). On this date, Saturn is also at the exact point of its second stationary point, here in Virgo near the sidereal position of the Era Base date, but north of the ecliptic, as Saturn's orbit differs slightly from the path of the ecliptic (**Figure 5.40b**). On this later date, Jupiter is 31 days past conjunction with the sun. This is not a particularly significant synodic position, but it is in the sidereal position of the first zenith at 19.5º N in Taurus.

The sun on June 15, 1099 CE is also at the descending node in Gemini, six days before the summer solstice. The moon is in Capricorn, four days after an invisible total lunar eclipse in Sagittarius. Interestingly, this is the same sidereal position in which the moon appears on the terminal date, as the Ring Number interval of 51,419 days is very nearly 1,882 sidereal lunar cycles.

The pre-Era Ring Base, over 140 years prior to the Era Base date, takes place on November 3, 3255 BCE (November 28 Julian). This is very close to day of the first solar nadir at 14.8º N, here in Sagittarius. As on the Era Base date in 3114 BCE, Saturn is near conjunction with the sun at this time, given that the Ring Number is a whole multiple of Saturn's synodic period (**Figure 5.41a**). Curiously, when Saturn is directly in conjunction with the sun eight days earlier, there is a partial solar eclipse at the ascending node near midnight (**Figure 5.41b**). Again this 8-day correction recalls the nodal calculations from page 52 in the Dresden lunar table. Furthermore, the position of Saturn in Sagittarius roughly parallels the sidereal position of Saturn on the terminal date, September 3, 958 CE. In fact, when we move to the winter solstice in 958 CE, Saturn is in conjunction with the sun in Sagittarius exactly as it was on the Ring Base, while Jupiter is directly at opposition in Cancer. It is possible that this Sagittarius alignment is the intended reference, and we explore this further in the black Ring Number calculation that shares this same Ring Number

Also, on the Ring Base, November 3, 3255 BCE, Jupiter is near its second stationary point, 30 days later. Here, it is in the sidereal position of Taurus. There is a preponderance of 30-day intervals from significant synodic periods of Jupiter throughout the Muxib' calculations, and it is possible that, while the synodic period of Saturn appears to be a particular focus of these calculations, the intervals chosen may have also coordinated the synodic positions of Jupiter using a 30-day correction, the length of one lunar month. Indeed, on the 9 K'an 12 K'ayab' base date, Jupiter would also be 30 days prior to its first stationary point.

63C black) The black Long Round in the Ring Number calculation on page 63, column C reads 10.08.03.16.04 (**Figure 5.33c**). However, adding this interval to the Ring Base will not reach the stated terminal day 3 Chikchan. The most parsiomonious suggested correction is to change the K'atun value to 13, assuming the scribe may have forgotten a bar in this numeral (Thompson 1972:116). Adding a Long Round of 10.13.03.16.04 to the Ring Base, we reach 3 Chikchan 8 Sak, but there is no way to corroborate the Haab' date, as it is not stated. Nevertheless, the terminal date would be July 14, 949 CE (July 9 Julian). On this day, the sun is in the familiar sidereal position of Cancer (**Figure 5.42**), the sidereal point of the first solar zenith at 19.5º N in 3114 BCE. This position also appears in Serpent Number 4a, and it was likely a position used to coordinate intervals of the tropical year, the sidereal year and the Haab'. As we have seen, the New Year 1 Pop occurs on or near the second solar zenith at 19.5° N at both the time the Dresden was written, and in 33,142 BCE, the year of the base date 9 K'an 12 K'ayab'.

On the terminal date of July 14, 949 CE, neither Jupiter nor Saturn are near their stationary points. Though they are roughly in conjunction in Virgo, neither planet is near a significant sidereal position. However, when we add the Ring Number to the terminal date, we reach the Long Count date of the Long Round 10.13.03.16.04 7 K'an 2 Ch'en, April 29, 1090 CE (April 19 Julian). On this date, Saturn is in the same synodic position as it was on the terminal date, but as we have seen, this position does not appear to be significant. On the other hand, Jupiter is close to its second stationary point on this date, exactly at the second zenith at 19.5° N between Cancer and Leo.

In the year of the terminal date, 949 CE, <u>the New Year 1 Pop is very closely aligned with the winter solstice in Sagittarius, as is the ascending lunar node.</u> When we move to the winter solstice in this year, on December 21, 949 CE (December 16 Julian), the day is 3 Pop, and Saturn has reached its first stationary point in Virgo, while Jupiter is once again 30 days prior to a significant synodic position at its first stationary point in Virgo. On the winter solstice, the moon is six days prior to an invisible total solar eclipse in Sagittarius (**Figure 5.43**), in the same sidereal position of the sun on the Ring Base for this calculation on 13 Imix 9 Wo, November 3, 3255 BCE. As mentioned in the previous red Ring Number calculation, there is a similar solar eclipse eight days before this Ring Base.

Perhaps most significantly, this sidereal position of the winter solstice in Sagittarius, and the Ring Base, is the very same position in which the second solar zenith at 14.8º N latitude would appear, on 19 Pop, in 33,142 BCE, the year of the base day 9 K'an 12 K'ayab', while the New Year 1 Pop would fall on the second solar zenith at 19.5º N in this year. This recalls the position of the sun on the terminal date for this calculation at the sidereal position of this same second zenith at 19.5ºN in Cancer during the year of the Era Base date in 3114 BCE.

Thus it appears that the Maya were using Muxib' calculations to coordinate the cycles of Jupiter and Saturn with the tropical year, the Haab' and the lunar nodes. Ultimately, they may have used these calculations to determine the shift in the sidereal year that places the second solar zenith at 14.8º directly in Sagittarius, the very position of the first nadir in the year of the Era Base date, and the winter solstice at the time of the terminal dates in 949 and 958 CE.

The Fifth Serpent and the Water Tables

In the inscription above the fifth serpent on page 69 (**Figure 5.44**), the first two glyph-blocks in E1 and F1 are eroded. In E2, we see the serpent **CHAN-na** (T764:23) as we saw above the first serpent on page 61. In F2, we find **na-na?-hi** (T23:503?:136), with four clear examples of this collocation in the following tables on pages 71–73. The central glyph T503 is the same as the day glyph **IK**, but it appears to also have a different syllabic value, which Gabrielle Vail (2002) reads T503 as **na**. It is thus possible that the collocation in F2 reads *nah* 'house'.

Every example of the **na-na-hi** collocation follows an unidentified serpent-like glyph with an animal ear that is often preceded by the number 'four', as on page 71, A10. The word 'four' is *chän* in Ch'olan and *kan* in Yucatec and may also be a mnemonic for 'serpent', and Schele and Grube (1997:174) read this serpent as **KAN**. In the example of this serpent from page 71, A10, we can see what appears to be a deer horn. The combination of the horn and the animal ear are indicative of hieroglyphic representations of deer from the Classic period, as in Arroyo de Peidra Stela 1, C4. This deer serpent, known as the *Chihilchan*, is an important mythological animal in the Classic period, and the maize deity is frequently depicted emerging from his mouth in scenes of rebirth (Grube and Nahm 1994:693). Similarly, deities emerge from the mouths of each of the serpents in the Serpent Series.

The *Chihilchan* deer-serpent is likely related to the *Chikchan*, four horned mythological serpents that are associated with bringing rain among the Ch'ortí (Wisdom 1950). The day name Chikchan is taken from these animals, and it appears to be a borrowing of from Ch'olan into Yucatec (Thompson 1962:363–65; Justeson and Campbell 1984). The Brickers (2005) have demonstrated that the tables on pages 71–73 are concerned with the sidereal and synodic cycles of Mars, and with rain and fertility. They refer to these tables as the upper and lower water tables. Indeed, most of the examples of the deer-serpent follow a 'rain-sky' collocation (T137:561), and vertical blue representations of rain appear on the intervals where the deer-serpent is present. If the serpent glyph in the inscription above the fifth serpent is also a deer-serpent, it is possible that the glyph in F1 originally read 'deer'.

The inscription continues in E3, with **CHÄK-che-le** (T109:145:612), followed by the image of the aged Moon Goddess **IX CHEL** with a **TUN-ni** (T1026:528:116) in F3. This appears to be the name of the aged Moon Goddess as *Chäk Ix Chel*, with *chäk* meaning 'red', with *Tun* added. This name repeats in the Ring Numbers on page 70, A3–B3, and it may be a reference to a lunar cycle associated in some way with the year as the Tun. Another example of the name

Chäk Ix Chel appears in an abbreviated form in the Ring Number on page 70, C5. Here, she appears as a portrait of Goddess O preceded by **CHÄK** 'red', and this is identical to her appearance on page 67, where she is indeed painted red.

The inscription ends with the base date 9 K'an 12 K'ayab'; the inscription appears to read:

?? Deer??-
Serpent House
Red Ix Chel Tun
9 K'an 12 K'ayab'

The inscriptions beneath both dates for Serpent Numbers 5a and 5b are unfortunately eroded.

5a) The Serpent Number 5a (**Figure 5.44a**) leads to a day 09.16.08.05.12 4 Eb' 5 Ch'en, July 18, 759 CE (July 16 Julian). The Brickers (2005) demonstrate that the tables following the fifth serpent are concerned with the cycles of Mars, and we see that on this day, Mars is in the sidereal position of the second solar zenith at14.8° N latitude in Leo (**Figure 5.45**). The moon is two days past full on this date in Capricorn, and neither the sun nor the moon are near a node at this time.

Counting back 118 days to the day 3 Ix 7 Sip on March 22, 759 CE (March 20 Julian), the sun reaches the ascending node, very close to the vernal equinox. Two days before, there is a total lunar eclipse only one day after the vernal equinox (**Figure 5.46**). This invisible eclipse thus takes place in the sidereal position of the autumnal equinox, just after the moon sets due west. It is possible that an alignment of the equinox with a total lunar eclipse is the intended meaning of the above inscription where Chäk Ix Chel appears with a Tun. The

Red Ix Chel, in her fierce reptilian appearance may be a direct reference to the blood red appearance of a total lunar eclipse. The Moon Goddess is usually associated with fertility and life-giving aspects, but as we have seen, lunar eclipses are regarded as destructive and damaging to fertility. Chäk Ix Chel therefore may be the Red Moon Goddess as a destroyer and a total lunar eclipse, and this may be the source of confusion between Goddess O as Ix Chel, and Goddess I as the youthful or aged Moon Goddess. The alignment of a total lunar eclipse with the vernal equinox fixes the lunar cycle with the Tun and the tropical year, and as we have seen, such alignments serve as excellent anchoring points for measuring the eclipse year and precessional drift.

5b) Serpent Number 5b (**Figure 5.44b**) leads to a date 9 Ix 12 Sip, March 20, 786 CE (March 16 Julian). This day does not seem to represent any significant cycle of the moon or Mars, but the sun is exactly at the vernal equinox in Pisces (**Figure 5.47**), and this also may relate to the above inscription, fixing this date in relationship to the Tun and the tropical year. On this date, Venus is exactly in the position of its first appearance in the morning as it rises heliacally after inferior conjunction with the sun. The first appearance of Venus after inferior conjunction is associated with spearing in the Venus tables (Lounsbury 1978:778–779), and indeed, we see a black deity identified as God L (Schellhas 1904:34f; Taube 1992:79–88) wearing a deer hide and emerging from the fifth serpent's mouth with a spear and shield. It is likely that he refers to an aspect of Venus. This deity is one of the five Venus spear-bearers in the Dresden Venus table on page 46, the only one who also carries a shield. He is named there with his portrait (T1054), and a prefix that Davoust (1995:565) reads as **ha'** (T164), 'rain'. On the image of God L from page 69, the flayed hide of the deer may represent the sun itself at the end of the winter season, as the Maya are known to have compared the sun to a deer which moves quickly during the winter months as it is passes the perihelion, its closest approach to the sun in its elliptical orbit (Milbrath 1999:76). Indeed, a deer is depicted as a speared victim in the Venus tables on page 47 of the Dresden.

Adding 20 days to 9 Ix 12 Sip, March 20, 786 CE, we reach a day 3 Ix 12 Sotz' on April 9 (April 5 Julian) when the sun exactly reaches the ascending node in Pisces (**Figure 5.13**), just as Venus reaches its second stationary point, rising precisely due east at an azimuth of 0°. There is no prior lunar eclipse near the equinox at this time. Instead, the moon is 2 days after a partial visible solar eclipse in Pisces (**Figure 5.48a**), just after sunrise on April 7 (April 3 Julian), and there is a partial, visible lunar eclipse in Libra on April 22 (April 17 Julian) (**Figure 5.48b**). On the day of this lunar eclipse, Mars reaches its first stationary point in Sagittarius. The Maya seem to have been coordinating the 780-day synodic cycle of Mars (3 x 260 days) with the nodal and eclipse cycles, since the same Tzolk'in day can be used to determine two synodic periods of Mars, equivalent to nine eclipse half-years. Likewise, it appears that this serpent coordinates the synodic cylce of Venus with the above cycles, along with the tropical year.

The Upper and Lower Water Tables, Ring Numbers and Long Counts

In their discussion of what they refer to as the water tables on pages 71–74 of the Dresden (**Figures 5.49–50**), the Brickers (2005) propose that these tables concern the synodic and sidereal position of the planet Mars. In two previous articles, the Brickers (V. Bricker and H. Bricker 1986; H. Bricker and V. Bricker

1997) demonstrate that another shorter table within the Dresden, on pages 43–45, is concerned with the 780-day synodic period of Mars, with its more dramatic period of retrograde motion associated with the so-named square-nosed "Mars Beast" (T794). In the upper water table on pages 71–73, the Brickers (2005) found a period of 702 days, expressed as 13 intervals of 54-days, an interval useful for the tracking the sidereal cycle of Mars from the point of view of a terrestrial observer, taking into account the retrograde motion. Furthermore, a sidereal cycle of 702 days is easy to correlate with the synodic period of Mars, in that 10 x 702 days = 7,020 days = 9 x 780 days.

A canonical cycle of 702 days places Mars in the same sidereal position, but for only four or five repetitions. After this point, the shifting of the sidereal position of the retrograde period changes the sidereal position of Mars dramatically, and then Mars is visible in a similar sidereal position for another four to five repetitions of 702 days. Thus, over longer periods, this interval is not effective for tracking the sidereal position of Mars. However, the much longer interval of 20 x 702 days = 14,040 days is emphasized on the left of the table of multiples on page 73, though thus far, the purpose of this multiple remains unexplained.

The first Ring Number calculation on page 70, column A produces the date 9.13.10.15.14 9 Ix 12 Muwan, December 6, 702 CE (December 2 Julian). Using the 584283 correlation, the Brickers (2005) found that when this date (December 4 Gregorian) is used to enter the upper water table, the two captions in the 54-day intervals from the upper water table that name the Mars Beast (on page 72, A3, and 73, D3) closely correspond to the first and second stationary points of Mars. This is also the case when using the 584285 correlation. In addition, in the second interval of 54 days, a Venus glyph appears (page 72, B3). The Brickers note that this closely corresponds to the last appearance of Venus on January 27 (January 25 Julian) before inferior conjunction. Using the 584285 correlation, this would be January 29, the day of the conjunction itself. The Brickers conclude that this single occurrence of the inferior conjunction of Venus would not be present in subsequent repetitions of the 702-day cycle, and that this only applies to the first multiple using the coincidental 702 CE entry date.

Because of the repeated imagery associated with rain in several columns of both the upper and lower water tables, and from some of the readable inscriptions, the Brickers (2005:225) propose that the Maya believed that the sidereal position of Mars could influence the weather, and perhaps even floods. The last page in the series contains an image of such a flood, with glyphic representations of solar and lunar eclipses, Chäk Ix Chel, and the same black God L or God M from the mouth of the fifth serpent in the guise of a Venus spear-bearer, here with his Muwan owl. Both Chäk Ix Chel and this black deity have a similar profile with the same unusual 'jaguar cruller-eye', often used as the name of God M (T680). Given the identification of Chäk Chel with a total lunar eclipse, it is possible that this black deity, with his shield, represents a solar eclipse. Even the serpent on page 69 is painted half black, as are the eclipse glyphs on page 74 .

Several authors (Thompson 1972; Taube 1988) have proposed that page 74 represents the mythological destruction of the previous world by a great flood, while this mythological reference may also symbolize periodic weather patterns suggested by the inscriptions in the water table. The Brickers (2005:215) relate the flood and eclipse imagery on page 74 with the lower water table, composed of the familiar 1820-day interval, but here broken into 28 periods of 65-days. They conclude that this lower table is unrelated to the Mars sidereal cycle found in the upper water table.

The upper table uses the base day 9 Ix, while the lower table uses 4 Eb'. In the seasonal table following the first four serpents on pages 63–64, the various intervals between the five base days were likely used for specific corrections for various purposes, including the determination of positions in the tropical year, and the position of the solar nodal passage. Contrary to the Brickers' assumption that these two base days and their associated tables are unrelated, it is possible that the interval between them was intentional, and was used for specific purposes. Within the Tzolk'in, the day 9 Ix is exactly 122 days after the day 4 Eb'. Likewise, the nodal day 3 Ix is just 20 days after 9 Ix. The interval of 122 days may therefore make it possible to use both tables in some coordinated way.

A series of four Ring Number calculations appears under a single inscription on page 70 (**Figure 5.51**). This inscription is read in a double column like those above the five serpents. The first two glyphs in A1 and B1 are eroded, but A2–B3 give the possible reading:

pa?-se?-la-aj K'UH-OK-ki CHAK-che-le IXIK KAB'-TUN-ni

paselaj?? k'uh ok Chäk Chel Ixik K'ab' tun

'the holy steps are revealed?, Red Chel Ixik Kab' Tun'

As in the inscription above the fifth serpent, the subject of all four of these Ring Number Calculations is apparently the Red Ix Chel Tun, possibly relating to total lunar eclipses at specific positions within the tropical year, such as the solstices, equinoxes or zeniths and nadirs.

70A top) The first Long Round at the top of column A appears as 9.13.12.10.00, with the terminal base day of 9 Ix (**Figure 5.51**). The Ring Number follows as 1.12.06 with the Era-base 4 Ajaw 8 Kumk'u below. The Ring Base is not given in any of these calculations, and it is unlikely that they all would have appeared in the eroded positions in A1 and B1. However, these can be calculated, and in this case, the Ring Base would have been 9 Ix 7 Xul, 606 days prior to the Era Base date.

Counting forward from the Ring Base using the Long Round, we reach the date 9.13.10.15.04 9 Ix 12 Muwan, December 6, 702 CE (December 2 Julian). This is the date that can be used effectively as an entry point into the upper water table. On this date, the sidereal position of Mars is at the head of Virgo near Leo, about 40 days prior to its first stationary point (**Figure 5.52a**). What is the relationship of this day 9 Ix to the closest previous day 4 Eb'? Subtracting 122 days, we reach August 6, 702 CE (August 2 Julian). On this day, Mars is in the exact sidereal position of the summer solstice in Gemini (**Figure 5.52b**). Could this be an intentional placement? In fact, when we subtract the multiple of 10 x 702 = 9 x 780 days from the terminal date on December 6, 702 CE (December 2 Julian) to reach September 16, 683 CE (September 13 Julian) we find that <u>Mars is at exactly the same sidereal position of the summer solstice in Gemini</u>, while it is in the same synodic phase as it was on the terminal date (**Figure 5.52c**). This is a compelling use of the 122-day interval between 4 Eb' and 9 Ix as a correction to find the same sidereal position of Mars after a longer interval of 10 x 702 days.

To restate this correction:

7,020 days – 122 days = same sidereal position of Mars

Beginning on a day 9 Ix and counting 7,020 days forward to another day 9 Ix, we subtract 122 days to the nearest 4 Eb’ to find the same sidereal position of Mars as the starting date. Because this interval takes into account multiple retrograde periods, it can be used over much longer intervals of time. However, in only two repetitions, the base days and the sidereal position will continuously change. Also, the interval emphasized within the water tables is twice 7,020 days, or 20 x 702 days = 14,040 days. In addition, what can we make of the lower water table that uses the base day 4 Eb’ within an 1820-day interval?

Aside from the conformity of the position of Mars on December 6, 702 CE with the upper water table, it is difficult to determine any other recognizable astronomical significance of this date. However, this position becomes significant within the context of the other Ring Number calculations in this series.

70B top) The Long Round at the top of column B on page 70 (**Figure 5.51**) is given as 9.19.11.13.00. The terminal date is also 9 Ix, and the Ring Number is 4.10.06. The Ring Base would be 9 Ix 2 Ch’en, and the terminal date would be 9.19.07.02.14 9 Ix 17 Ch’en, July 15, 817 CE (July 11 Julian). On this date, the sun is in the familiar sidereal position of Cancer that seems to represent the first solar zenith at 19.5° N in the year of the Era Base date (**Figure 5.53a**). Here, it is closer to the date of the second solar zenith. Mars is nearby, 20 days after conjunction with the sun. Interestingly, this conjunction on June 24 (June 20 Julian) takes place in the exact same sidereal position in Gemini (**Figure 5.53b**) as where Mars appears 122 days before the previous terminal date in 70A. This was the sidereal position of the summer solstice in 702 CE, but due to precession, the Mars conjunction with the sun occurs three days after the summer solstice in 817 CE.

Additionally, the sun on the terminal date of July 15, 817 CE is 20 days pre-nodal. Adding 20 days to a day 3 Ix 17 Yax on August 4, 817 CE (July 31 Julian) brings us to a total lunar eclipse in Aquarius (**Figure 5.54**), and the same evening, the moon passes through the ascending node exactly in the position of the second nadir at 14.8° N. This appears to conform to the inscription concerning Chäk Ix Chel Tun and total lunar eclipses fixed to points in the tropical year. Furthermore, it is also one of the few Ring Number calculations that repeats the 3 Ix nodal passage pattern found in the Serpent Numbers.

But is there an integration of the upper and lower water tables that can be used with the interval of 20 x 702= 14,040 days? Beginning with Mars in Cancer on the terminal date July 15, 817 CE (July 11 Julian) (**Figure 5.53a**), when we add the 14,040 days, Mars does not return to the same sidereal position, though it is in the same phase, in Sagittarius. Likewise, subtracting 122 days to a day 4 Eb′ does not return Mars to the same sidereal position (although subtracting twice 122 days does, using the above stated correction for 7,020 days). However, adding 14,040 days and subtracting 122 days to a day 4 Eb′ and then adding the 1,820-day interval from the lower water table returns us to nearly the same sidereal position of Mars on August 16, 860 CE (August 12 Julian) (**Figure 5.55**). This correction integrates both tables and both base days, 9 Ix and 4 Eb′, to determine the same sidereal position of Mars. We can restate this correction as follows:

14,040 days –122 days + 1,820 days = same sidereal position of Mars

This correction covers a period of slightly over 43 years, but it begins to break down after this due to the shifting of the period of retrograde. In addition, the base days 9 Ix and 4 Eb′ would continually regress and they would not be maintained after only one repetition. However, a solution to this long-term problem may have been found. It becomes apparent in the remaining dates that, indeed, such a solution was found, and that the sidereal position of Mars was coordinated with eclipse cycles and the tropical year over long periods of time.

70A bottom) The Long Round for the Ring Number calculation at the bottom of column A on page 70 is given as 8.06.16.12.00, with terminal day 9 Ix (**Figure 5.51**). The Ring Number follows as 4.06, 86 days, with the Ring Base as 9 Ix 2 K′ank′in. The Long Count position of the terminal date would be 8.06.16.07.14 9 Ix 7 Mak, February 27, 176 CE (February 26 Julian). On this day, Mars is in Taurus near the first zenith at 19.5º N (**Figure 5.56a**). If we subtract 122 days to a day 4 Eb′ 5 Yaxk′in, October 29, 175 CE (October 28 Julian), Mars is in Taurus at the first zenith at 14.8º N, directly at opposition (**Figure 5.56b**), with the sun near the first solar nadir in Scorpius. From this point, if we subtract 1,820 days, we reach November 4, 170 CE (November 3 Julian), and the sun is at the ascending node, while Mars appears near 0º in Virgo (**Figure 5.57**), and the moon is exactly eight days prior to a near total lunar eclipse at the same zenith in Taurus. This recalls the eight-day addition required in the eclipse interval of 2 x 1,820 days from page 52 of the lunar table. Yet another similar eclipse occurs 1,820 –122 days after the terminal date on a day 4 Eb′ 0 Yaxk′in, October 22, 180 CE (**Figure 5.58**). On this date, the sun is in Libra at a node in the exact sidereal position of the base date 9 K'an 12 K'ayab'. This latter eclipse event is similar to that found in the terminal date from Serpent Number 4b. Both of these eclipses suggest a relationship with the Chäk Ix Chel inscription concerning these kinds of lunar eclipses. Here, the day 4 Eb' represents Mars at opposition at the zenith, and the table of 1,820 days can be used to find previous or subsequent lunar eclipses in this same sidereal position.

We have not been examining the Ring Base dates in the previous calculations, but in this case, the Ring Base of 9 Ix 2 Yaxk'in, 86 days prior to the Era Base date, falls on the date May 19, 3114 BCE (June 14 Julian). This sun on this date is in the exact position of the second solar zenith at 19.5º N in Cancer, the sidereal position often repeated throughout the Serpent Series (**Figure 5.59**). Curiously, on the terminal date in 176 CE, Mars appears very close to this zenith at 19.5º N, but here it is in Taurus. Likewise, on the Ring Base date, Mars appears between Libra and Scorpius, exactly where the sun appears when we subtract 122 days from the terminal date to reach 4 Eb' 5 Yaxk'in, October 29, 175 CE (October 28 Julian). It is therefore possible that the Maya were capable of coordinating the sidereal position of the sun with the sidereal position of Mars over very long periods of time.

70B bottom) The Long Round from the bottom of column B on page 70 is given as 8.16.19.11.00 with the other base date 4 Eb' as the terminal date (**Figure 5.51**). The Ring Number is 10.08, 208 days, and the Ring Base would therefore be 4 Eb' 0 Mol. However, the Long Round is in error, as it does not lead to a day 4 Eb'. The simplest solution to this error is that the scribe left off a dot from the Winal position, which should read 11. With a corrected Long Round, the Long Count would reach 8.16.19.00.12 4 Eb' 5 Yax on November 8, 375 CE (November 7

Julian) (**Figure 5.60**). While tentative, this date corresponds to a solar nodal passage in Scorpius, and Mars appears in the same sidereal position in Virgo near 0° in which it appeared in one of the dates from the previous Ring Number on November 4, 170 CE (November 3 Julian) (**Figure 5.57**). In fact, the sidereal positions of the sun, Mars, and the nodes are almost identical on both of these dates, while there is a similar lunar eclipse at the first zenith in Taurus on October 26, 375 CE (October 25 Julian), 13 days before the 4 Eb' 5 Yax terminal date (**Figure 5.61**). From the terminal date itself, we can also subtract 2 x 1,820 days to reach just four days after a total lunar eclipse at the same zenith in Taurus, here in conjunction with Mars in its position at opposition to the sun on November 16, 365 CE (November 15 Julian). Here again two Lunar eclipse events are coordinated with Mars and the tropical year, using the 4 Eb' base day together with the 1,820-day table.

70C) Column C of page 70 has its own inscription that reads as a Long Count date, counted forward from 4 Ajaw 8 Kumk'u, the month position of which is visible in C2 (**Figure 5.51**). This inscription parallels that in 70A and B, with the portrait glyph of Chäk Ix Chel:

pa?-se?-la-aj K'UH-OK-ki CHÄK-IX CHEL

paselaj?? k'uh ok Chäk Ix Chel

'the holy steps are revealed?, Chäk Ix Chel'

The long count is given as the much later date, 10.17.13.12.12. This would be 4 Eb' 5 Pop, but the terminal date 9 Ix is written, with a 4 written above it. The 4 Eb' date corresponds to October 29, 1178 CE (October 22 Julian). The sidereal position of Mars is immediately recognizable on this date (**Figure 5.62a**) as the same from December 6, 702 CE (December 2 Julian), the first terminal date of the Ring Number calculation in the top of column A on page 70 (**Figure 5.52a**). On October 29, 1178 CE, Mars is at the head of Virgo, here also the position of the ascending node. Moreover, when we add 122 days to this date to reach 9 Ix, there is a <u>total lunar eclipse</u> two days forward from 9 Ix, on March 2, 1179 CE (February 23 Julian) <u>exactly in this same sidereal position by the head of Virgo</u> (**Figure 5.62b**). This appears to confirm the use of the interval between these two base days, and it may be the reason why the day 9 Ix appears as the terminal date, just beneath the number four, and this is likely not a scribal error. This total lunar eclipse also conforms to the inscription concerning Chäk Ix Chel as representative of these total lunar eclipse events.

70D) Another Long Count position is given with a unique inscription in column D (**Figure 5.51**). The Era Base date 4 Ajaw 8 Kumk'u appears with the month position visible in D2. Following this is the inscription:

pa?-se?-la-aj K'UH OK-ki EK'-CHAK-ki
paselaj?? k'u ok ek'chak
'the holy steps are revealed?, Black Chak'

Here, we find the unique subject of 'Black Chak' with the **EK'** (T95) 'black' prefix. This is not seen elsewhere in the Serpent Series, and it is quite likely that this name refers to the black deity identified as God L or God M who sits in the mouth of the fifth serpent. He appears to have associations with the inferior conjunction of Venus as a spearer, but I have likewise proposed that he may be a deity representing a solar eclipse, and perhaps this interval will provide support for this.

The Long Count is given as 10.11.03.18.14. This is highly irregular, given that 18 Winals would usually be represented as zero, with the Tun position increased by 1. This unusual form may be the result of calculation methods. 9 Ix is given as the Tzolk'in position, and a corrected Long Count form of 10.11.04.00.14 would indeed reach this base day. The full Calendar Round date should be 9 Ix 7 Sip, on January 10, 1051 CE (January 4 Julian). On this day, the moon again appears in the same sidereal position by the head of Virgo (**Figure 5.63**) in which the total lunar eclipse takes place on March 2, 1179 CE (February 23 Julian) from adding 122 + 2 days to the Long Count in Dresden 70C (**Figure 5.62b**). This is also the sidereal position of Mars on the Long Count from 70C itself (**Figure 5.62a**), October 29, 1178 CE (October 22 Julian), and on the first terminal date of the Ring Number calculation in the top of column A, page 70 (**Figure 5.52a**), on December 6, 702 CE (December 2 Julian). For some reason, this sidereal position was particularly important, and it is highly unlikely that these recurrences are due to chance.

Furthermore, on the Long Count date from Dresden 70D, January 10, 1051 CE (January 4 Julian), Mars appears in the same sidereal position in Virgo near 0° in which it appeared on November 4, 170 CE (November 3 Julian) when subtracting 1,820 days from the terminal date in the bottom Ring Number calculation in 70A, and this is the same position of Mars on the terminal date from the bottom Ring Number calculation in 70B, November 8, 375 CE (November 7 Julian).

<u>The repeating sidereal position by the head of Virgo corresponds closely to the position of what will theoretically be the second solar nadir when adding the first component of the Serpent Series introductory distance number to the Era Base date</u>. This is 15,228 Tuns plus 16 days, before the additional 39 days are added to reach the same sidereal position as the Era Base date on the vernal equinox in 11,897 CE. This second solar nadir occurs on February 9, 11,897 CE, and the sun is not near a node on this day, but it is possible that the Maya were using the positions of Mars and the Moon to determine the sidereal position of this nadir.

We can calculate the position of Mars for this future nadir date from knowing its synodic position on the Era Base date in 3114 BCE, and determining the mean synodic periods of Mars in one interval of 15,228 Tuns plus 16 days:

15,228 Tuns + 16 days = 5,482,096 days

Mars synodic periods = 7028 (780 days) + 256 days

On the Era Base date, Mars was 263 days prior to conjunction with the sun. Therefore, when we add the interval of 5,482,096 days, <u>Mars would be in conjunction with the sun at the second nadir on February 9, 11,897 CE, exactly in the sidereal position by the head of Virgo</u> where it appears on the Long Count date on Dresden 70C, October 29, 1178 CE (October 22 Julian), and on the first terminal date of the Ring Number calculation in the top of column A, page 70, on December 6, 702 CE (December 2 Julian).

However, the additional repeating sidereal position of Mars in central Virgo, historically near an azimuth of 0° and the sidereal position of the autumn equinox, is also the exact position in which it would appear when we add 39 days to the second solar nadir on February 9, 11,897 CE to reach the terminal date of the introductory distance number on the vernal equinox, when the sun appears in the same sidereal position as the Era Base date in Virgo. On this day, the sun would be about 10º forward from Mars on the ecliptic.

Lastly, the inscription on Dresden 70 C names a Black Chak, and on the Long Count date January 10, 1051 CE (January 4 Julian), the sun is a few days pre-nodal, while five days earlier there was a visible, partial lunar eclipse close to the second zenith at 19º N. Partial, umbral lunar eclipses of this kind are effective predictors of upcoming solar eclipses, and indeed, eleven days after January 10, there was an invisible, partial solar eclipse before sunrise when the sun is very close to the second solar nadir at 19.5º N in Capricorn on January 21, 1051 CE (**Figure 5.64**). Though invisible, this solar eclipse may have been the reason for naming the Black Chak as the subject of the inscription.

The two Long Count positions at the top of columns C and D on page 70 apparently relate to lunar and solar eclipse events coordinated with significant positions in the tropical year, while the inscription at the bottom of column C contains the lunar interval of 3,819 Tuns – 20 days, discussed in the previous chapter. When subtracted from the Era Base date, this lunar interval reaches a total lunar eclipse close to the summer solstice in 6,878 BCE. The remaining information in columns C and D on page 70 consists of the idealized Haab' positions for the summer solstice on 13 Pax, the second solar zenith at 14.8º N on 0 Pop, and the winter solstice on 13 Yaxk'in. Therefore, there is a clear relationship between this lunar distance number and the Long Count dates at the top of columns C and D. All of these convey information about eclipse events coordinated with positions in the tropical year.

Two additional, smaller distance numbers of 15.09.15.14 in black, and 14.02.16.12 in red, are inter-written at the bottom of column D, and the Calendar Round for the first interval is given as 9 Ix 12 Pop. However, the Long Count position is unknown, though the Brickers (2005:218–219) apparently believe that this Haab' position is incorrect, and that these are truncated Long Count positions. They suggest that the B'aktun coefficient of 9 is not shown, but this is difficult to support. Furthermore, if it is counted from the same date 8 Ajaw 8 Mol, the interval 15.09.15.14 would reach 9 Ix 12 Pop, but the interval 14.02.16.12 would reach a day 5 Eb' 5 Ch'en. As this is not a proper base day, the interval may be in error.

Two other similar counts appear on the top of page 73, beneath another lunar B'ak'tun count in columns D and E. Column D reads 11.11.15.14 9 Ix, and column E reads 4.16.08.12 9 Eb', though it is likely this would be 4 Eb'. The Brickers suggest that these are also truncated Long Counts with the missing B'ak'tun coefficient of 9. The reconstructed Long Count from Dresden 73D produces a date exactly 20 x 702 days before the first terminal date from the Ring Number calculation at the top of 70 A. However, it is possible that these distance numbers each count from an as yet undetermined Calendar Round 8 Ajaw 8 Mol, to which the black distance number 15.09.15.14, at the bottom of 70D, can be added to reach the stated date 9 Ix 12 Pop. All four of these distance numbers are found in association with the larger lunar B'ak'tun intervals above them. In fact, the distance number 15.09.15.14 from the bottom of 70D closely resembles the added correction within the secondary distance number from the Serpent Series introduction of 15.09.03.01 from page 61, and 15.09.04.03 from page 69. Without any certainty about their intended positions in the Long Count, the purposes of these distance numbers, and their relationship to the lunar B'aktun intervals remains unclear, and further work is required to determine their intended meaning.

Implications of the Serpent Series Dates

From the combined evidence provided by the dates and their associated texts in the Serpent Series, one of the most significant findings concerns the usage of the base day 3 Ix as representative of a solar nodal passage throughout the Serpent Numbers. Serpent Number 3a, which cites a total lunar eclipse directly on this 3 Ix date, is the clearest example of a configuration which repeats the exact sidereal position of the sun that theoretically would have occurred at a nodal passage in Libra on the 9 K'an 12 K'ayab' base date. This supports the previous assertion that the authors of the Dresden Codex were tracking precession and the sidereal year, and that they were fully aware of the sidereal configuration implied by the 9 K'an 12 K'ayab' base date over 30,000 years in the past. The total lunar eclipse in Serpent Number 3a, and the repeating 3 Ix nodal passages of the sun also strongly support the 584285 correlation constant.

Because much of the associated text has eroded above two of the Serpents, it is difficult to determine the specific intended meaning of these intervals. However, where the text is visible, it suggests several important references relating to eclipses. Other references to planetary cycles of Venus, Mars and Saturn appear throughout the Serpent Series dates. The identification of Saturn as Muxib' has not been previously recognized. Furthermore, the base days within the water tables can be used to correct for the sidereal position of Mars over long periods of time. The water tables appear to function as a means to commensurate the occurrence of lunar and solar eclipses with fixed positions in the tropical year, while Mars appears to function as a specific marker in this regard.

Future analyses of these dates will likely produce additional insights, and it is still unclear how the various tables in the Serpent Series were used to calculate and correct for a number of different astronomical periodicities over vast intervals of time. Nonetheless, it is evident that they were used for these purposes, and the values used for the synodic and sidereal planetary, lunar, and solar cycles are remarkably similar to current values.

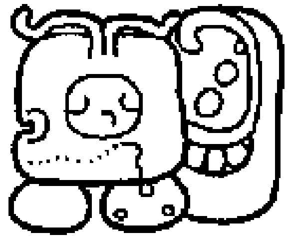


Figure 5.1: 819-day Count verb as **pa?-se?-la-aj**
a) From Dresden 70C3–4
b) From QRG Stela K, D4, after Looper (1995).

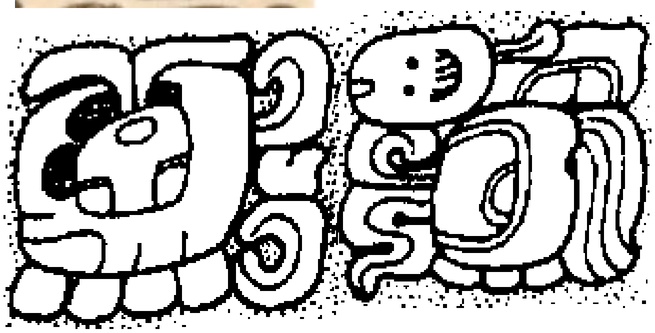


Figure 5.2: 819-day Count verb as **pa?-se?-hi-ya with K'AWIL-la-??**
From PAL T. Cross, A14-B14.
After Schele (1992).

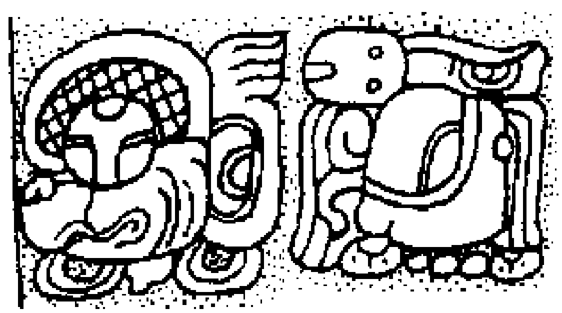


Figure 5.3: ta-OK-te
From PAL T. Sun, F2.
After Schele (1992).

Figure 5.4: 819-day verb with darkened **pa** (T602)?
From PAL T. Sun, A14–B14.
After Schele (1992).

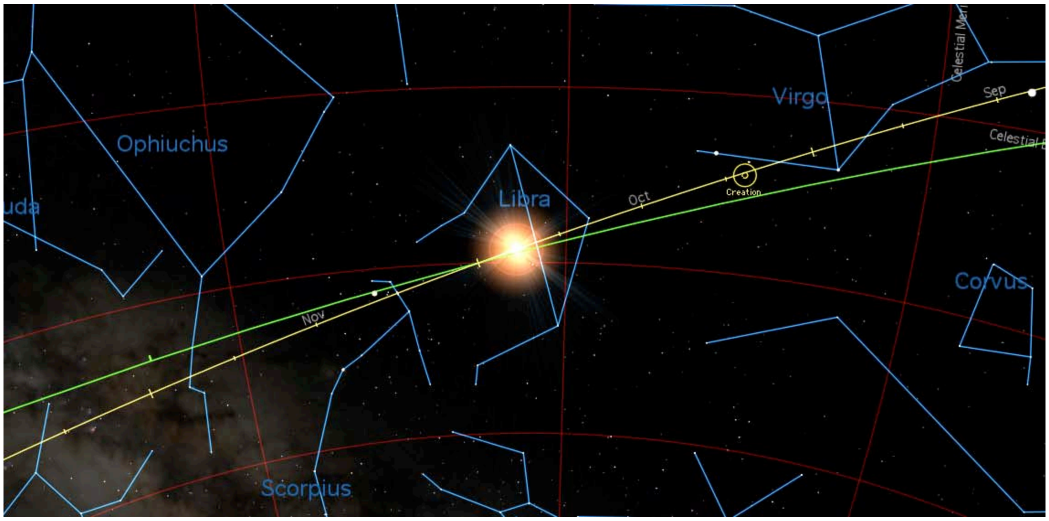


Figure 5.5a: Serpent Number 3a. 3 Ix 7 Pax on October 30, 915 CE (Oct. 25 Julian). Sun is at the ascending node in the exact same sidereal position in Libra as on the Serpent Base Date 9 K'an 12 K'ayab', near the first nadir, 14.8º N.

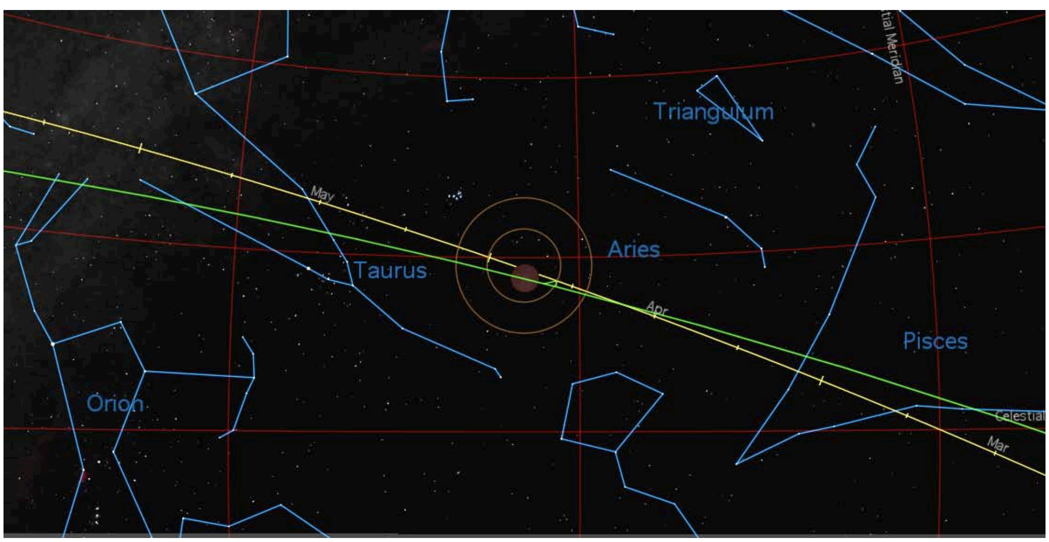


Figure 5.5b: Serpent Number 3a. 3 Ix 7 Pax on October 30, 915 CE (Oct. 25 Julian).

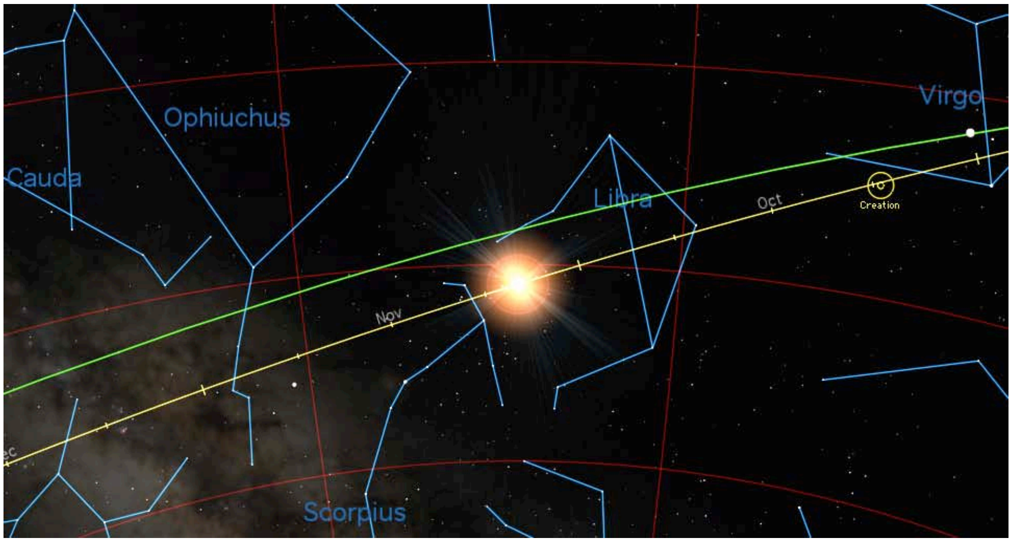


Figure 5.6a: Serpent Number 3b. 3 Kimi 14 K'ayab' on
November 6, 992 CE (Nov. 1 Julian).
Sun is eight days forward from its sidereal position in Serpent Number 3a

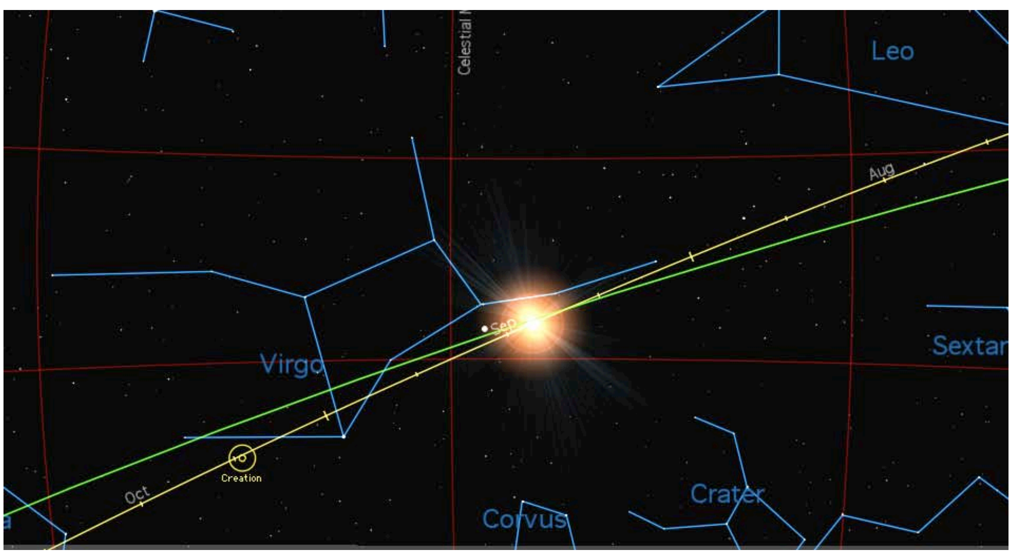


Figure 5.6b: Serpent Number 3b. 3 Kimi 14 K'ayab' – 52 days to
3 Ix 2 Muwan on September 15, 992 AD (Sept. 10 Julian)
Sun at ascending node in Virgo on a day 3 Ix.

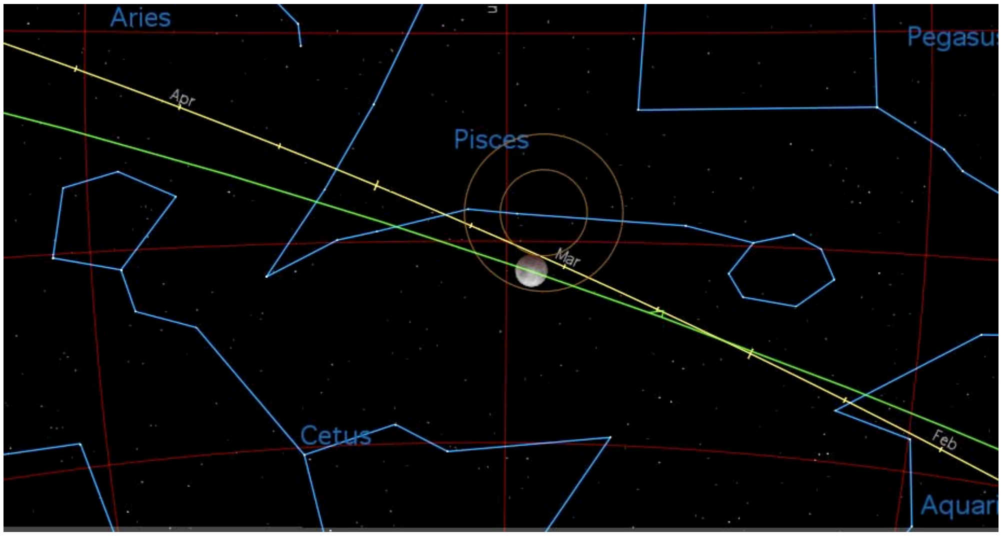


Figure 5.6c: Serpent Number 3b. September 19, 992 CE (Sept 14 Julian). 3 Kimi 14 K'ayab' – 52 days to 3 Ix 2 Muwan on September 15, 992 CE + 4 days to September 19, 992 CE. Lunar eclipse near day of autumnal equinox.

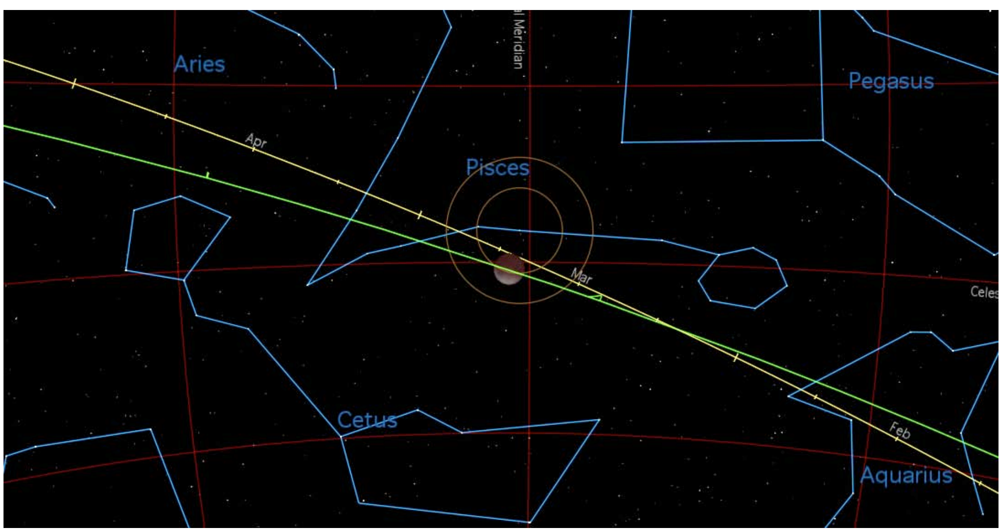


Figure 5.6d: September 22, 1122 CE (Sept. 17 Julian).
3 Ix 2 Muwan on September 15, 992 CE (Sept. 10 Julian) + the eclipse interval of 47,489 days to Lunar eclipse due east on autumnal equinox.

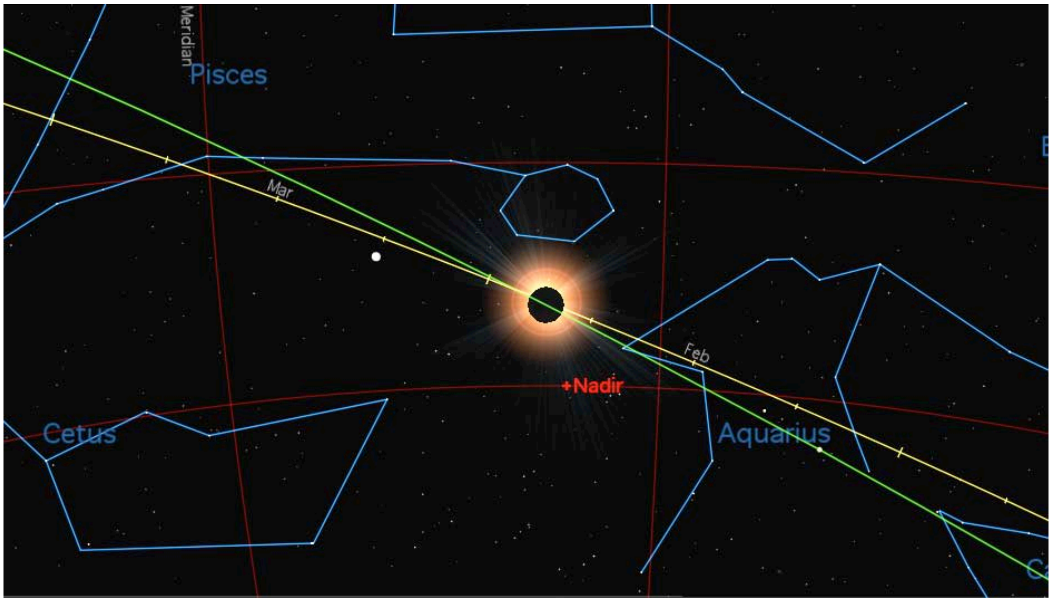


Figure 5.7: 3Ix date prior to Serpent Number 1a. 3 Ix 7 Wo, February 25, 779 CE (Feb. 21 Julian). The sun is exactly at the node in Pisces, and there is an invisible partial solar eclipse at midnight

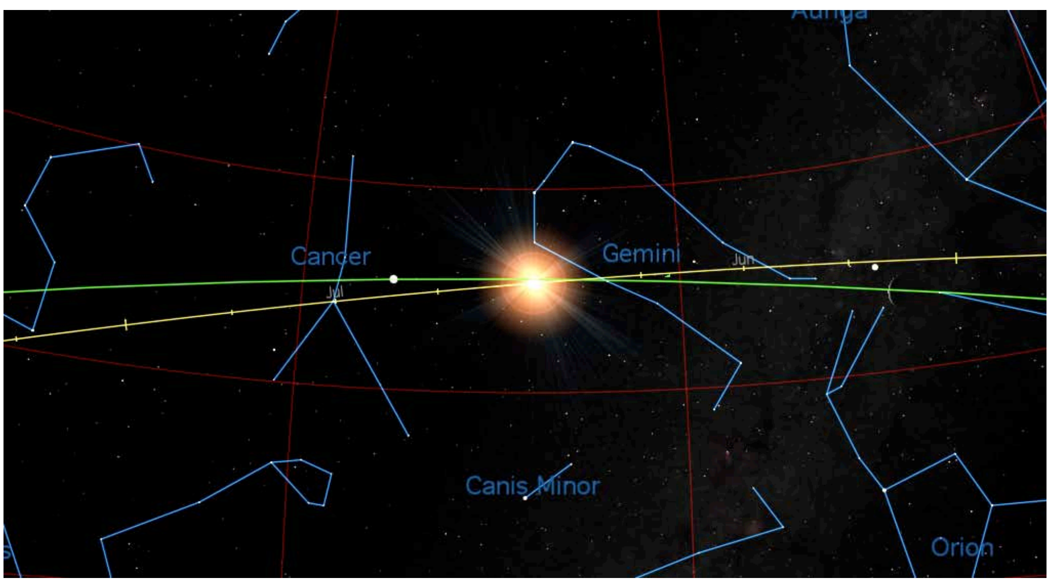


Figure 5.8: 3Ix date prior to Serpent Number 1b. 3 Ix 2 Keh, July 3, 1052 CE (June 27 Julian). The sun is only a few days past a node in Gemini.

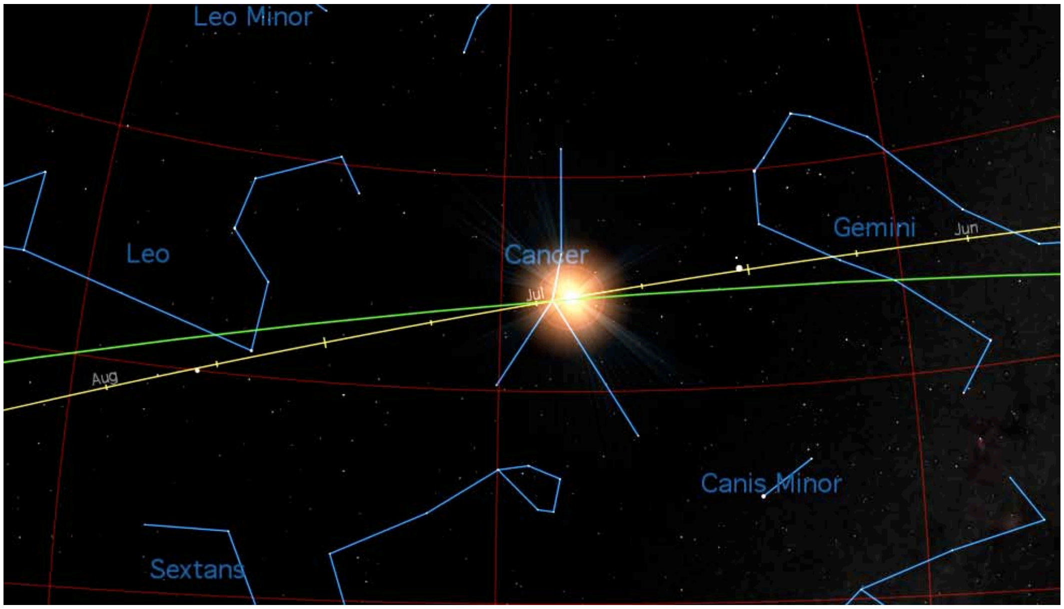


Figure 5.9: 3Ix date prior to Serpent Number 4a. 3 Ix 12 Sak on July 16, 958 (July 11 Julian). The sun is exactly at the node on a day 3 Ix, here in Cancer

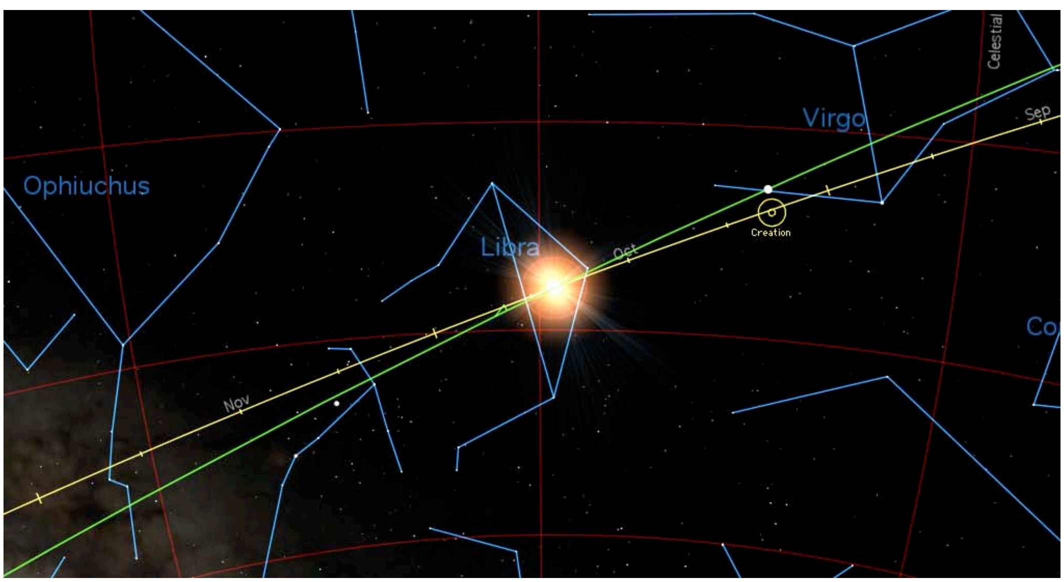


Figure 5.10: 3Ix date prior to Serpent Number 4b. 3 Ix 12 K'ank'in , October 24, 794 CE (Oct. 20 Julian). The sun is exactly at the node on a day 3 Ix, here in Libra.

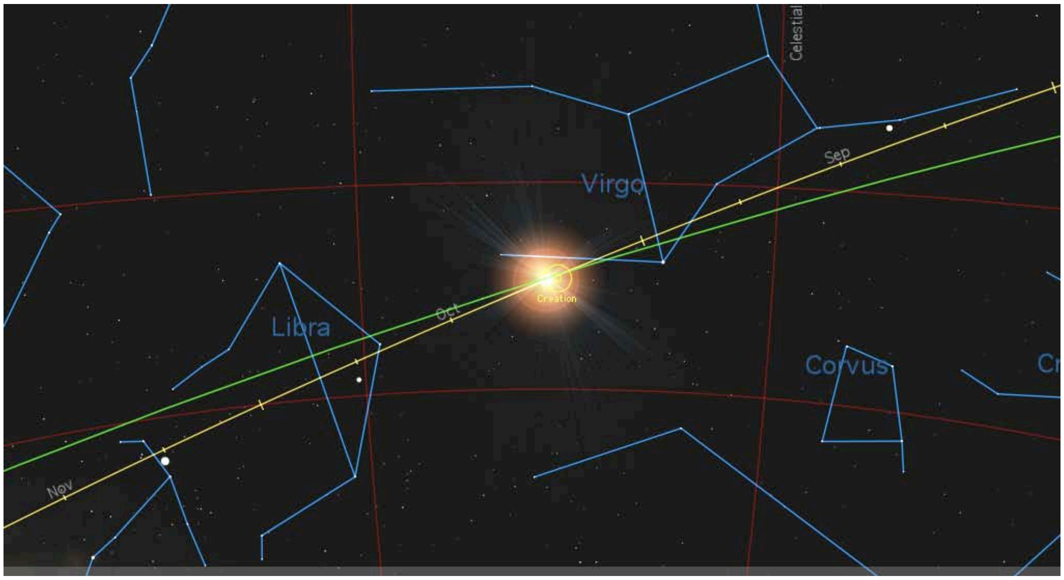


Figure 5.11: 3Ix date <u>after</u> Serpent Number 2a. 3 Ix 2 Pax, October 10, 972 CE (Oct. 5 Julian). Sun is at the ascending node in the exact sidereal position in Virgo as on the day of Creation in 3114 BCE.

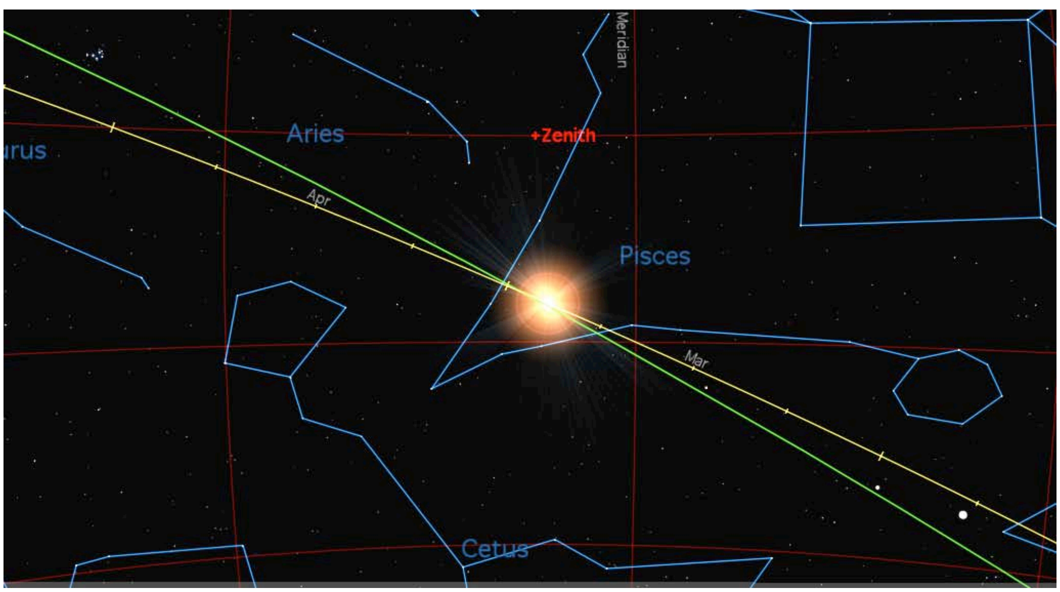


Figure 5.12: 3Ix date prior to Serpent Number 2b. 3 Ix 2 Sotz' on March 27, 796 CE (March 23 Julian). The sun exactly reaches a node in Pisces.

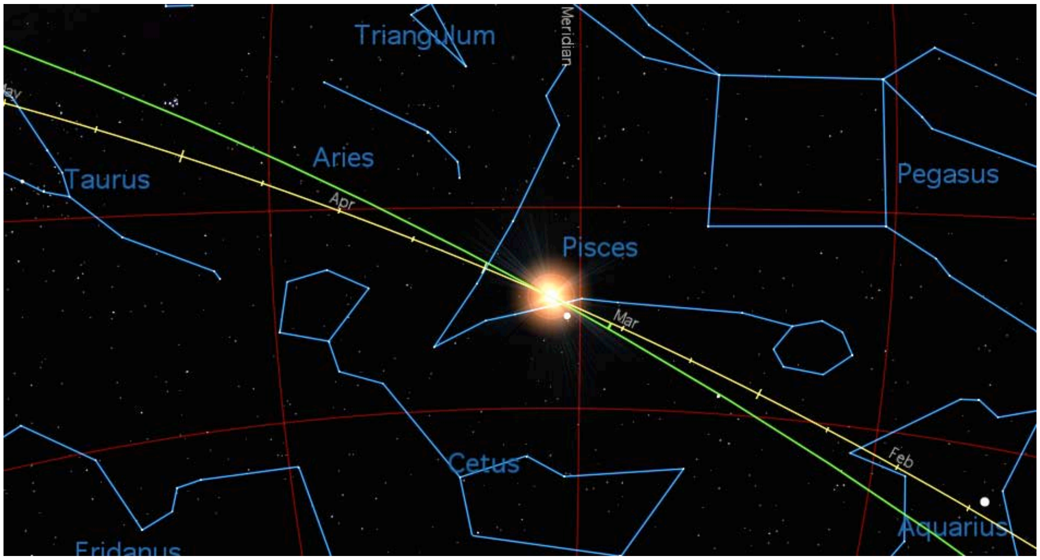


Figure 5.13: 3Ix date prior to Serpent Number 5a. 3 Ix 7 Sip, March 22, 759 CE (March 20 Julian). Sun at node in Pisces

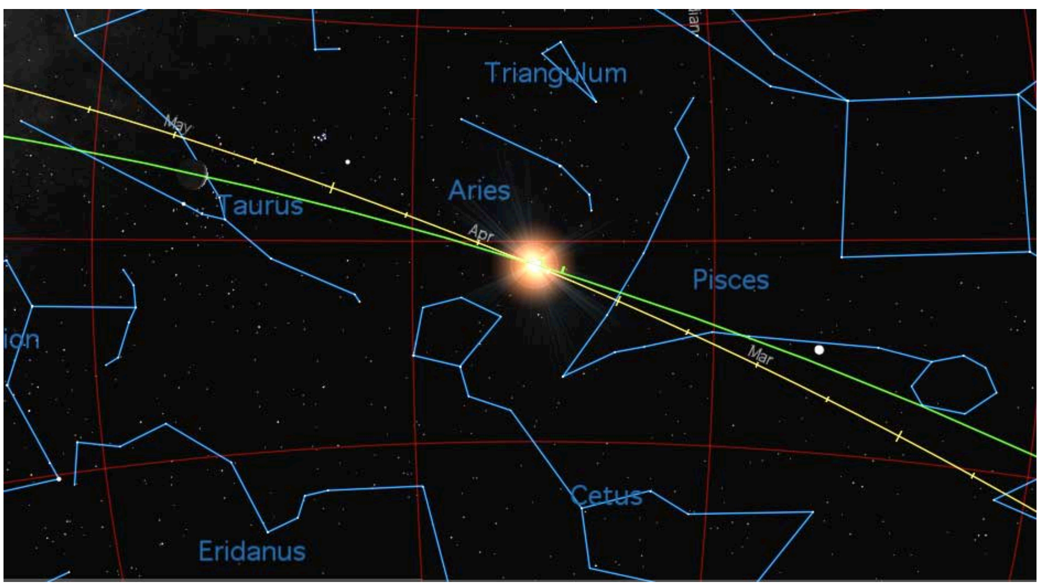


Figure 5.14: 3Ix date <u>after</u> Serpent Number 5a. 3 Ix 12 Sotz' on April 9, 786 CE (April 5 Julian). Sun is exactly at the ascending node in Aries.

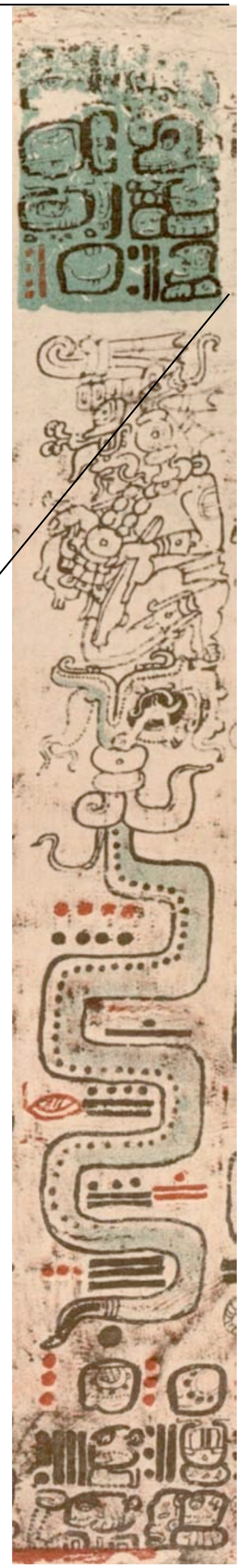


Figure 5.15: First Serpent with inscription.
Dresden page 61C–D.

a)

b)

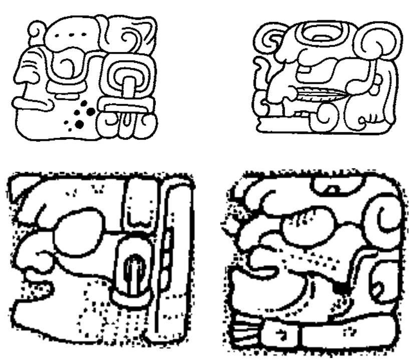


Figure 5.16: a) Jaguar Paddler from DPL Stela 8 and Stingray Paddler from QRG Stela C. After Looper (Macri and Looper 2003).
b) Jaguar Padler-**na** and
Stingray Paddler-**ti**. After William R. Coe (Jones and Satterthwaite 1982:fig. 81c)

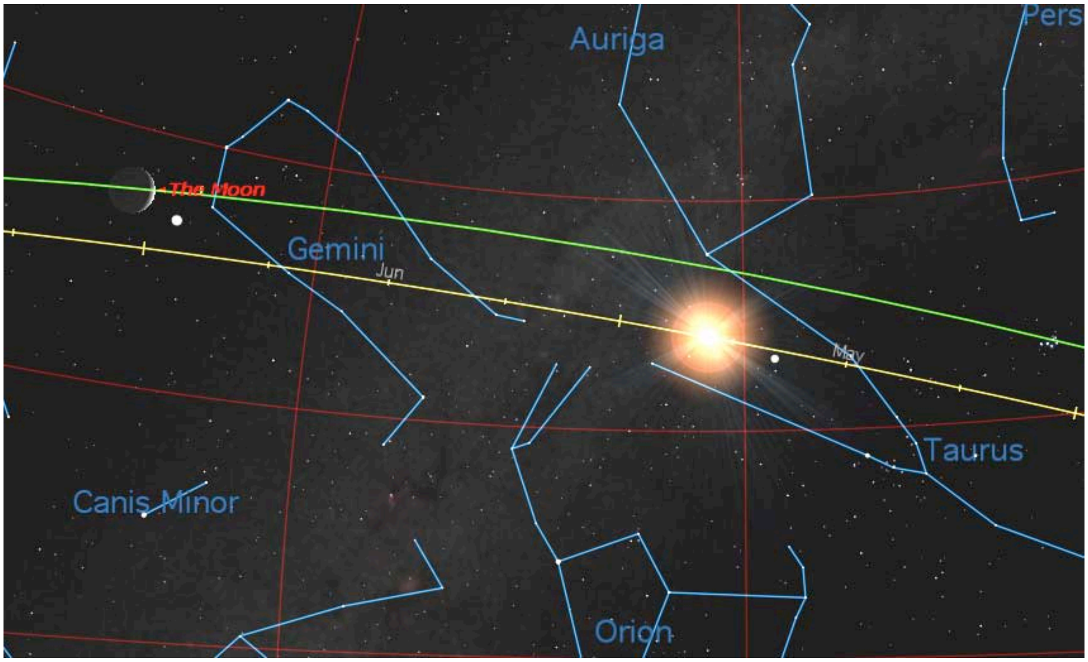


Figure 5.17: Serpent Number 1a on 3 Chikchan 18 Xul, May 27, 779 CE (May 23 Julian). Sun and moon are on either side of the Milky Way

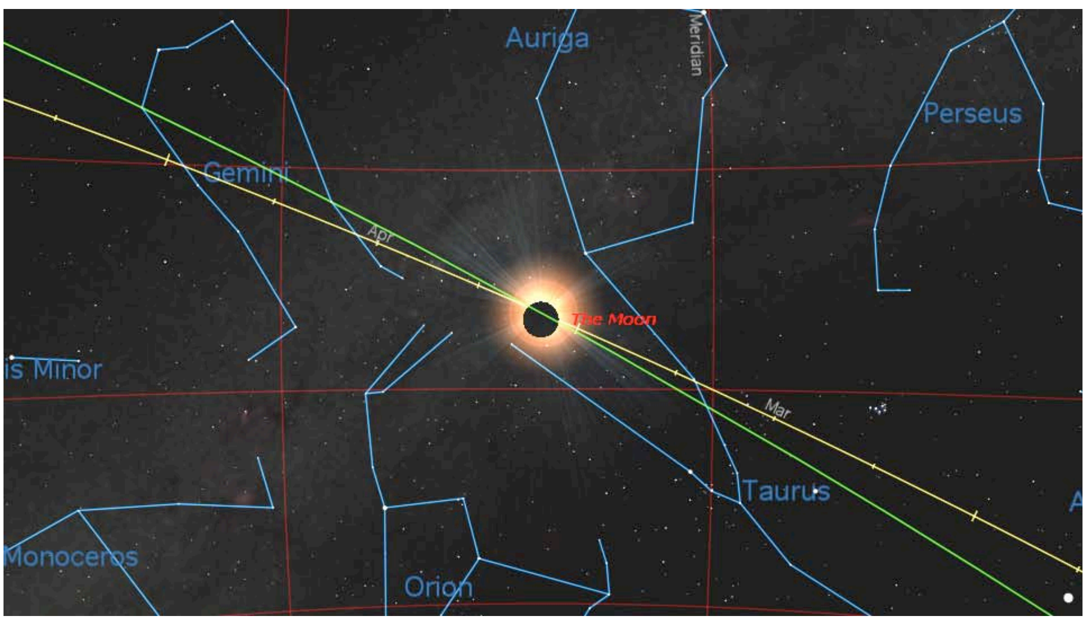


Figure 5.18: Partial solar eclipse on April 3, 3114 BCE (April 23 Julian), exactly 131 days earlier than the Creation date. Same sidereal position of the sun as in Serpent Number 1a above.

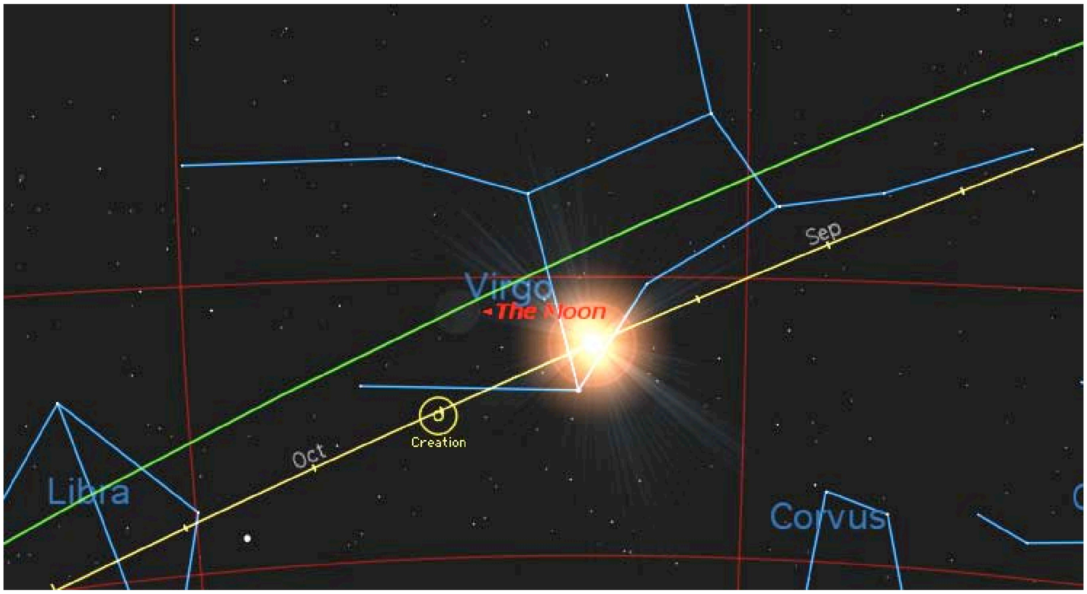


Figure 5.19: Serpent Number 1b on 3 Chikchan 13 Pax, October 2, 1052 CE (Sept. 26 Julian). New moon in Virgo.

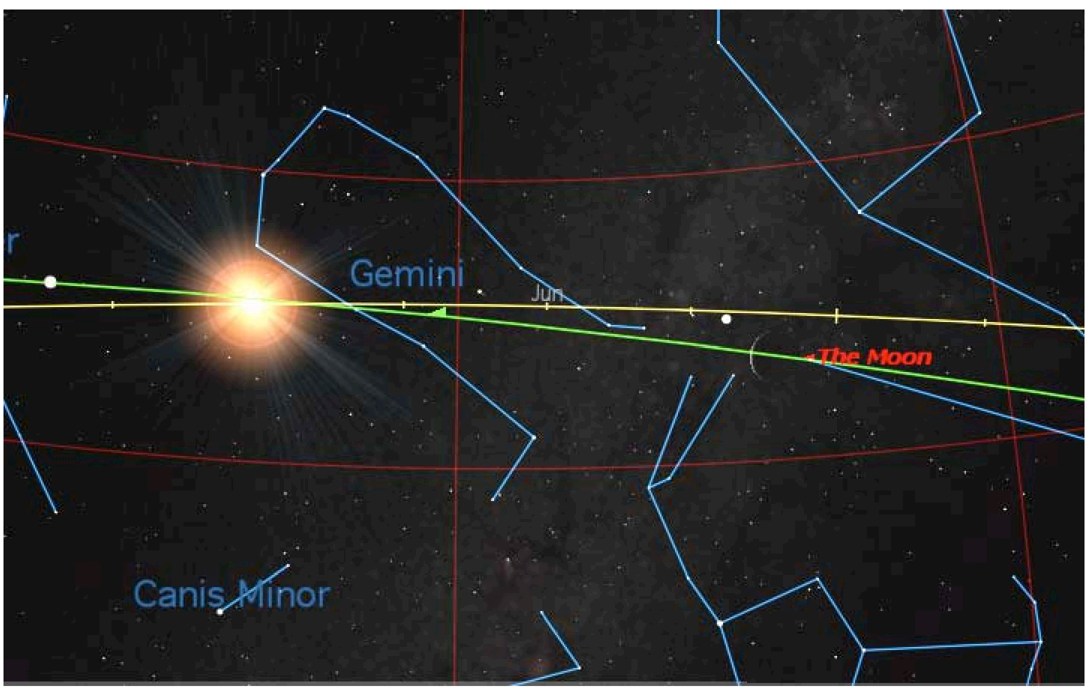


Figure 5.20: 3 Ix date prior to Serpent Number 1b , on 3 Ix 2 Keh, July 3, 1052 CE (June 27 Julian). The sun is at the ascending node, but here the sun and moon have both switched places with their sidereal positions in Serpent Number 1a

Figure 5.22: Serpent Number 3
Dresden page 62A–B
(above and right)

Figure 5.21: Serpent Number 2
Dresden page 62C–D
(left)

Figure 5.23: (below)
a) **XIB'-OK-ki** written at bottom right.
b) **mu-XIB'b'i** from page 63. C5

a)

b)

Figure 5.24: Serpent Number 4
Dresden 62 C–D
(above and right)

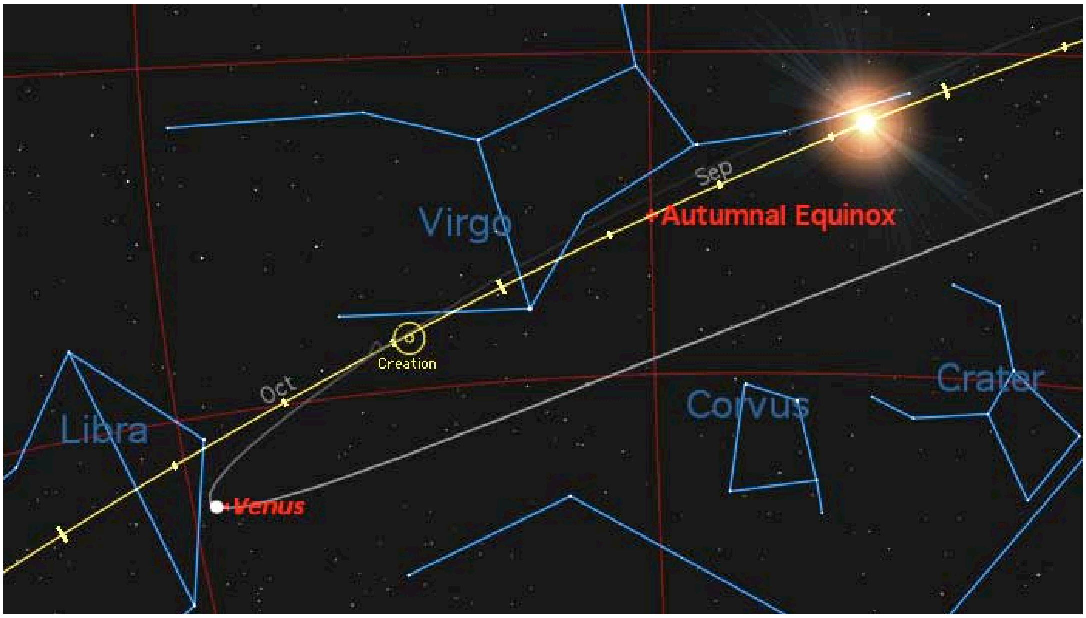


Figure 5.25: Serpent Number 4a on13 Ak'b'al 1 K'ank'in, September 3, 958 CE (Aug. 29 Julian). Venus is at the exact point of its greatest evening elongation, very close to the nadir at14.8º N latitude.

Figure 5.25: Serpent Number 4a on13 Ak'b'al 1 K'ank'in, September 3, 958 CE (Aug. 29 Julian). Venus is at the exact point of its greatest evening elongation, very close to the nadir at14.8º N latitude.

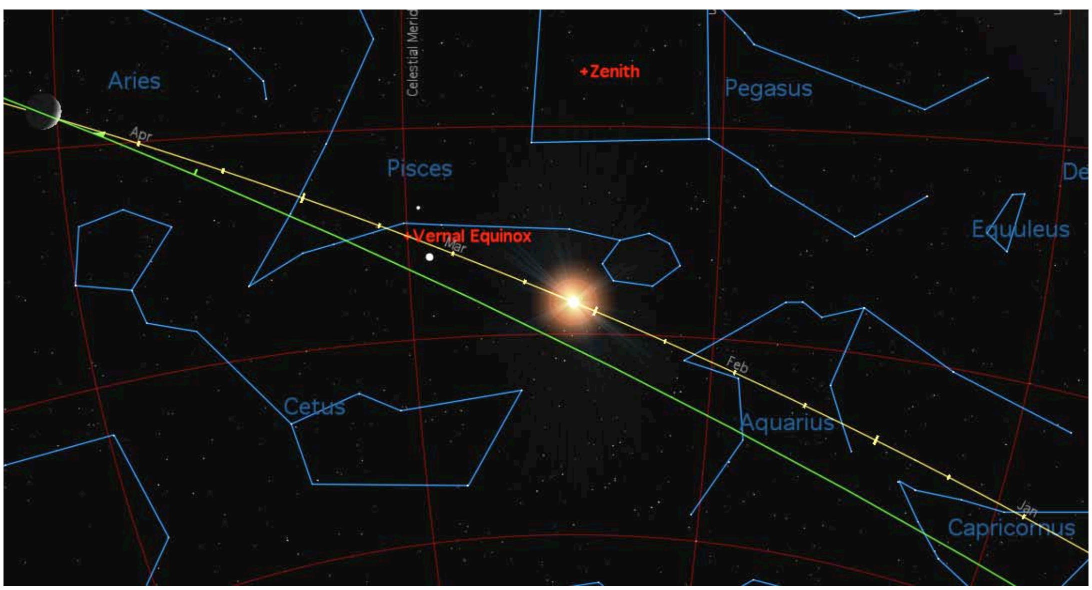


Figure 5.26: Serpent Number 4b 3 K'an 17 Wo, March 3, 795 CE (Feb. 27 Julian). The sun is in Pisces, exactly 219 days prior to the sidereal position of the Creation in Virgo. This sidereal position in Pisces represents the position of the second solar zenith when the introductory distance number is added forward from the Creation date to reach the year 11,896 CE.

a b

Figure 5.27:
Dresden 62 E–F
a) Ring Number 62E
b) Ring Number 62F

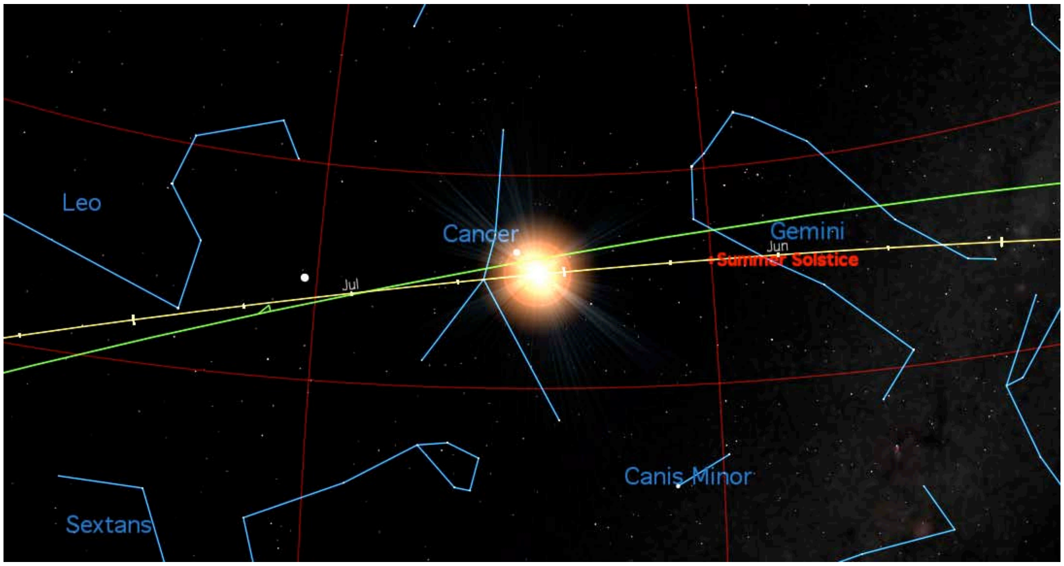


Figure 5.28a: Ring Number 62E, 3 Chikchan 18 Sip, July 5, 371 CE (July 4 Julian).

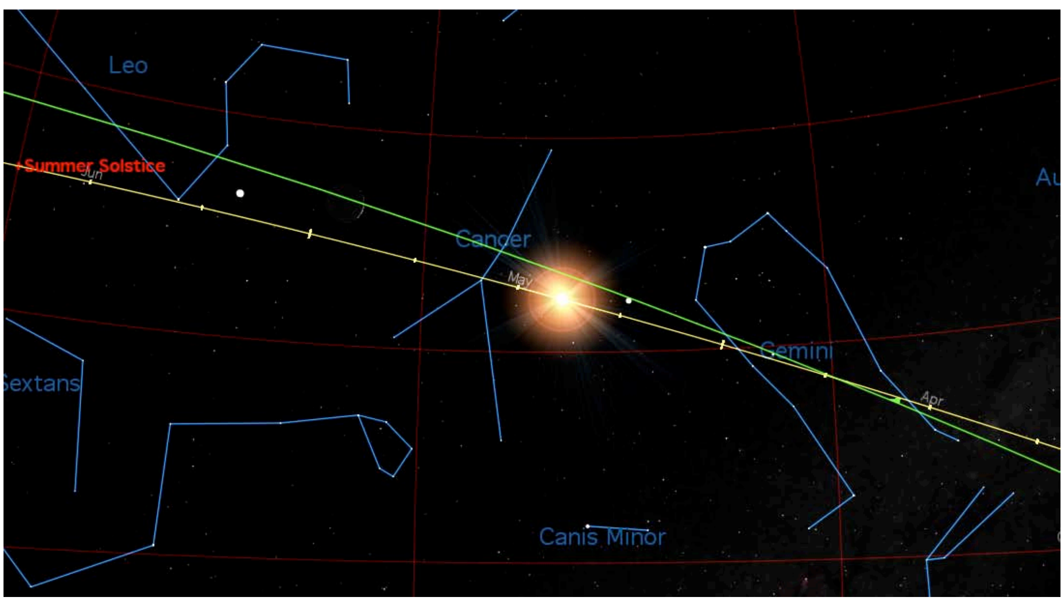


Figure 5.28b: Ring Base from 62 E on May 14, 3115 BCE (June 9 Julian). Same sidereal position as above.

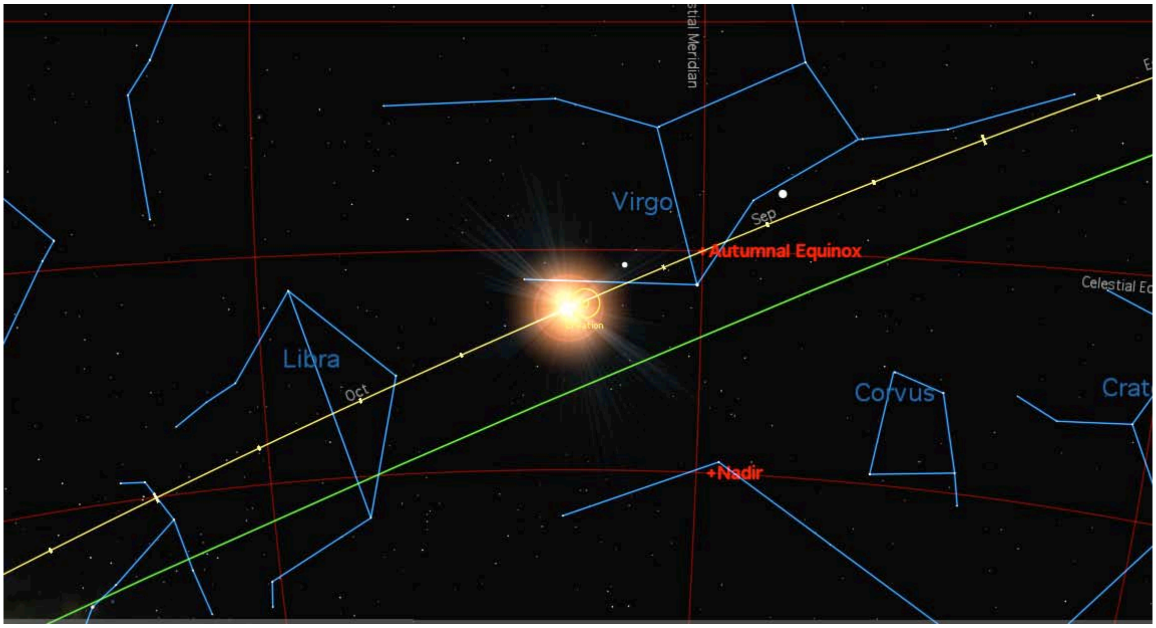


Figure 5.29: Long Round date for 62E. Adding the Ring Number 1.04.16 to 3 Chikchan 18 Sip on July 5, 371 CE, we reach a date 4 Imix 9 Mol, October 3, 372 CE (Oct. 2 Julian) with the sun is in the sidereal position in Virgo where it appeared on the Creation date 4 Ajaw 8 Kumk'u

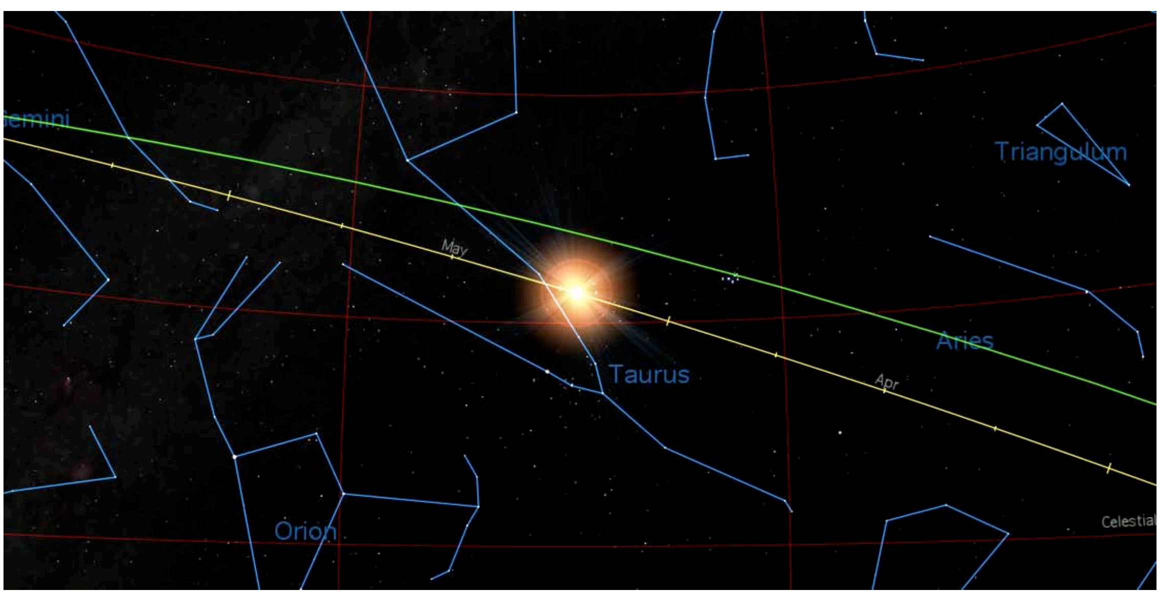


Figure 5.30: New Year posirtion after 62E. 1 P'op on May 8, 371 CE (May 7 Julian). 219 days after the sun was in the sidereal position of Creation on 8 Mol.

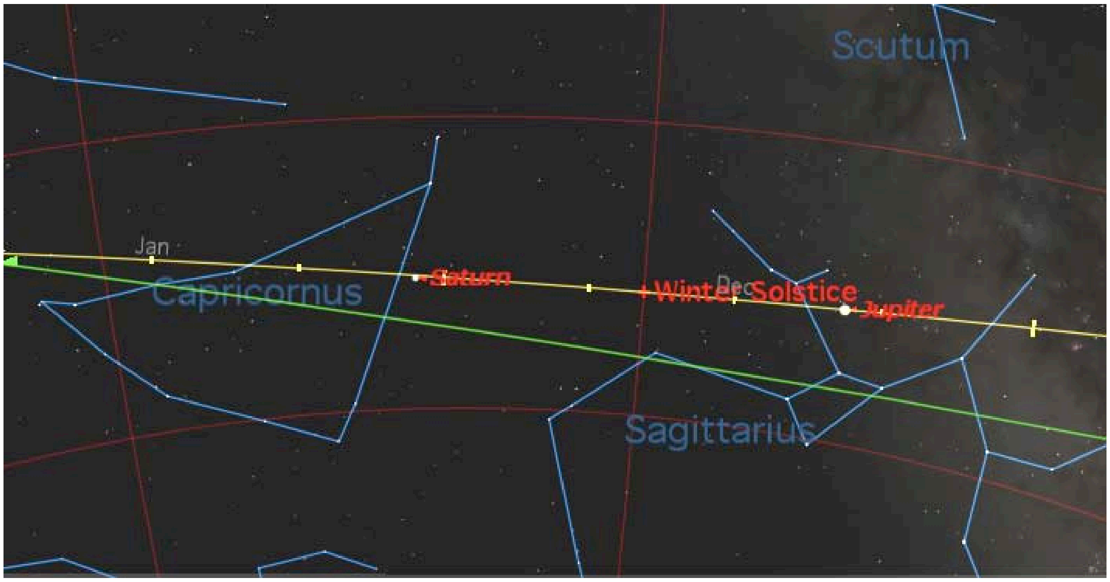


Figure 5.31a: Ring Number 62E. 3 Chikchan 18 Sip, July 5, 371 CE (July 4 Julian), Saturn is directly at opposition to the sun in Capricorn, exactly in the middle of its retrograde period.

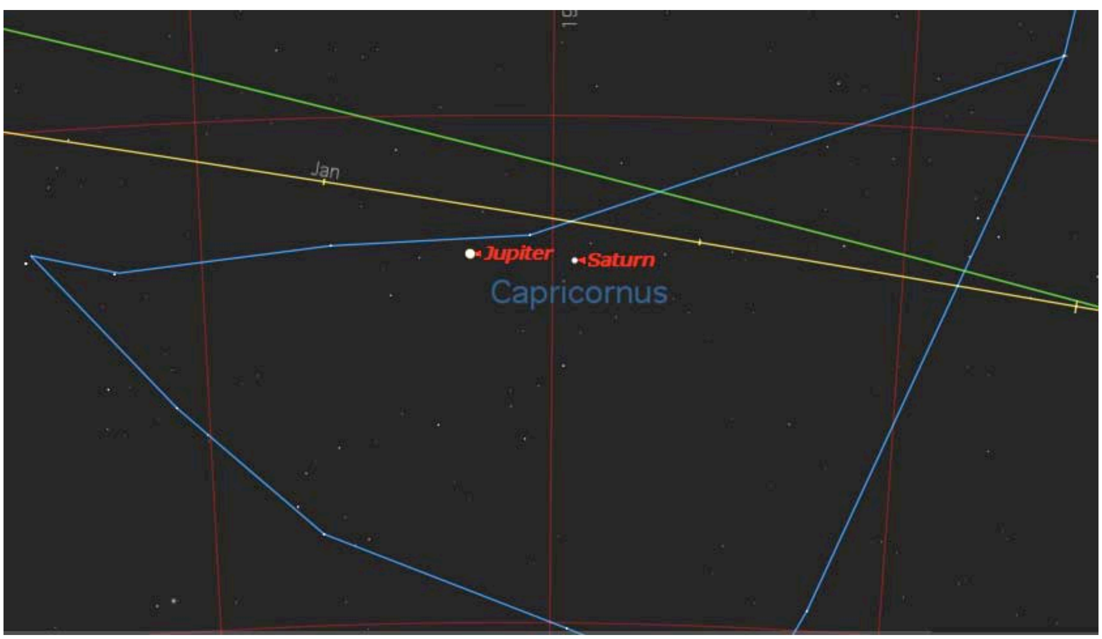


Figure 5.31b: Long Round date from 62E. October 3, 372 CE (Oct. 2 Julian), Saturn and Jupiter are in a close conjunction in Capricorn

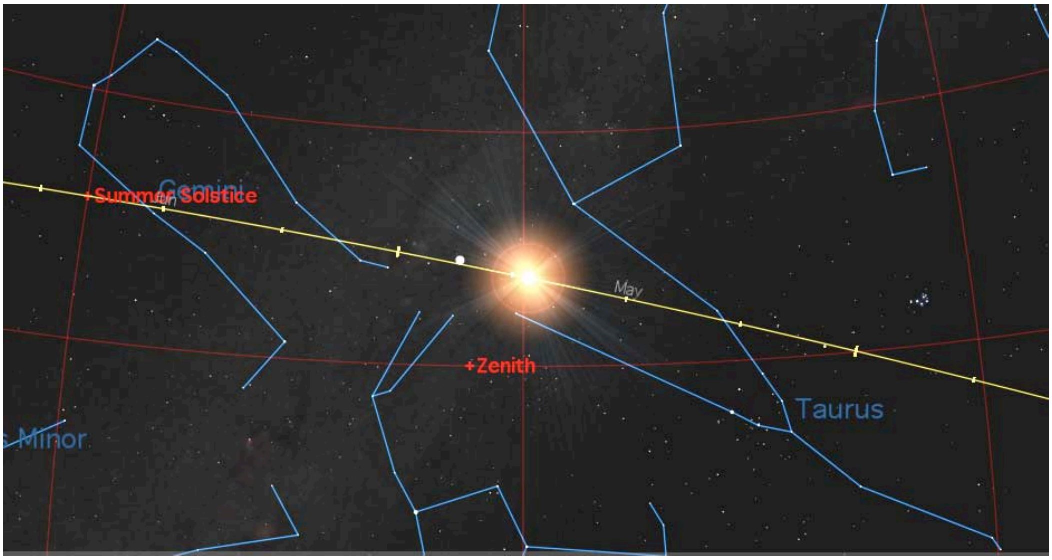


Figure 5.32: Ring Number 62F. 13 Ak'b'al 16 P'op, May 24, 371 CE (May 23 Julian). This is the exact sidereal position in which a solar eclipse takes place 132 days prior to the Creation date on April 3, 3114 BCE

Figure 5.33:
Dresden 63A–C
a) Ring Number 63A
b) Ring Number 63B
c) Ring Number 63C

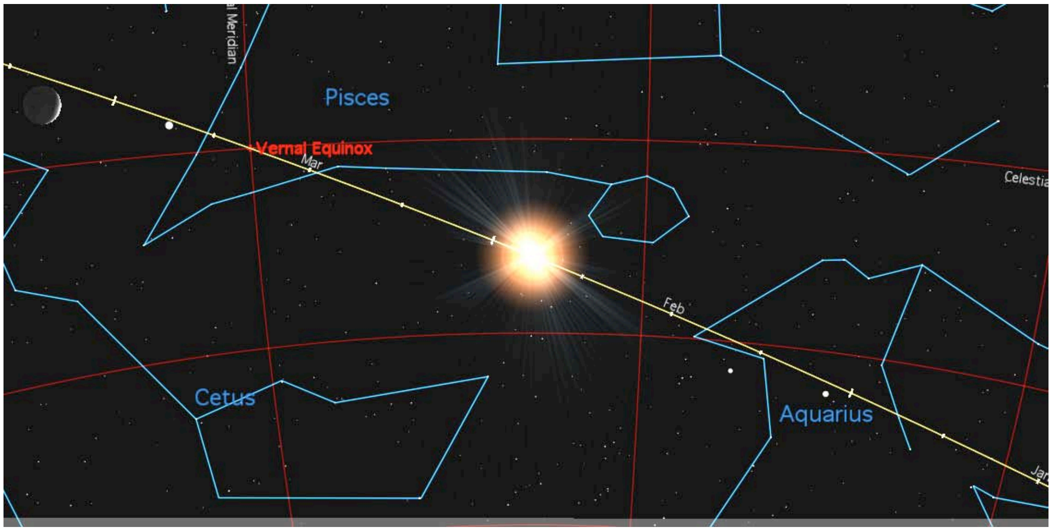


Figure 5.34a: Ring Number 63A. 3 Chikchan 8 K'ank'in, on February 25, 266 CE (also February 25 Julian). 218 days prior to Era Base sidereal position. This position in Pisces is the future position of the second solar zenith after adding the Serpent Series introductory distance number to reach the year 11,897 CE.

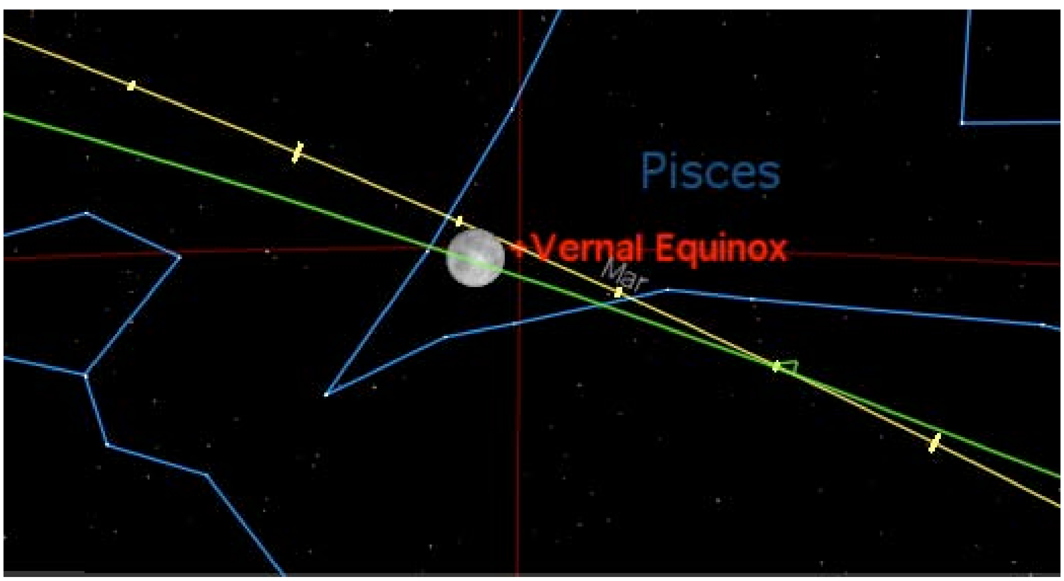


Figure 5.34b: Ring Number 63A + 218 days to full moon at 0° azimuth, close to sidereal position of vernal equinox.

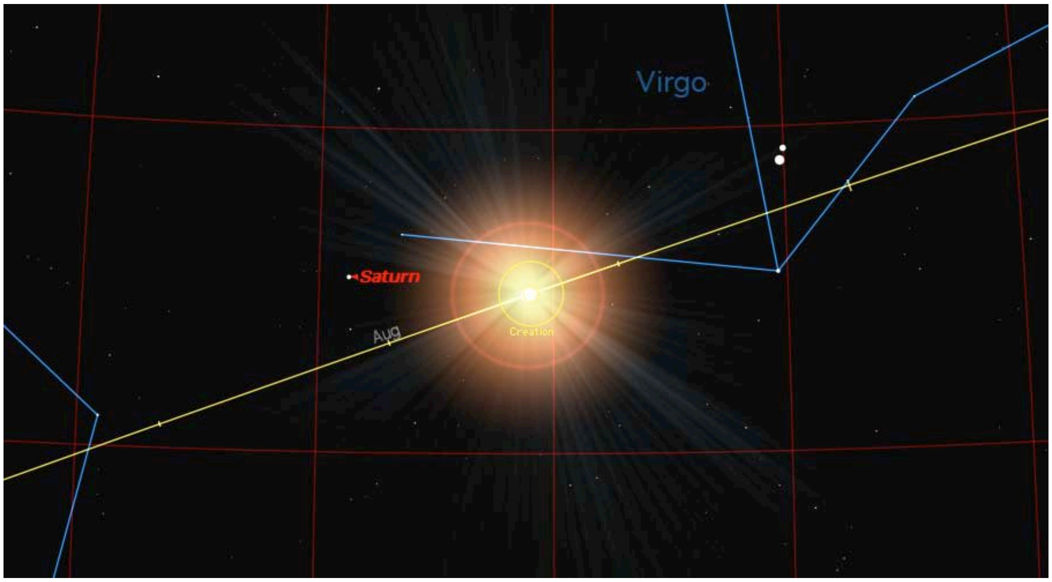


Figure 5.35a: Era Base. 4 Ajaw 8 Kumk'u August 13, 3114 BCE. Saturn is just 6 days from conjunction with the sun, and it is at the azimuth of the second zenith

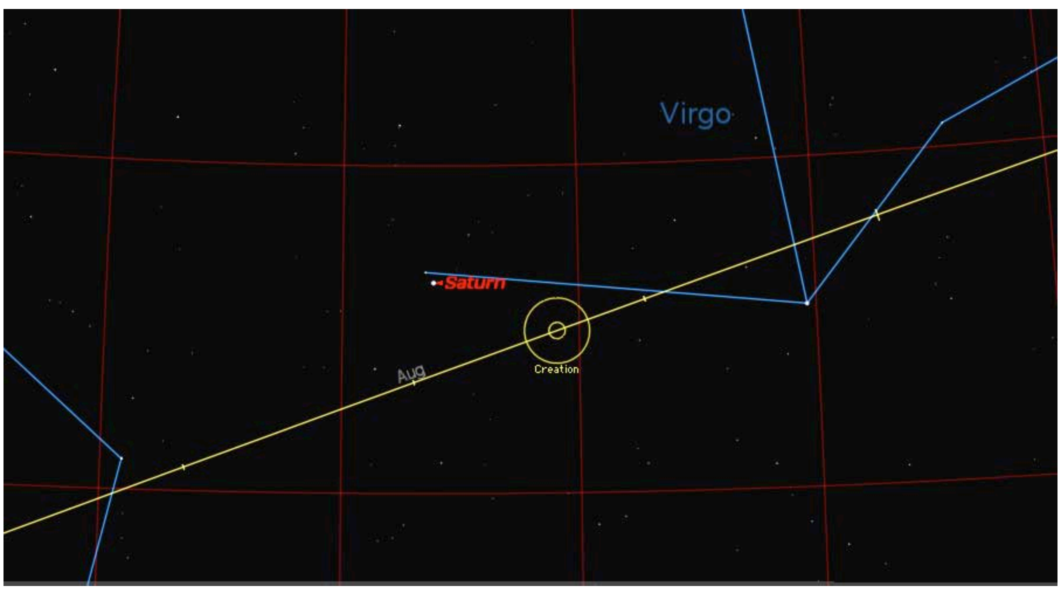


Figure 5.35a: Ring Base for Ring Number 63A, 235 days prior to Era Base. 3 Chikchan 13 Xul, on December 21, 3115 BCE. Saturn at first stationary point, near the same sidereal position as above.

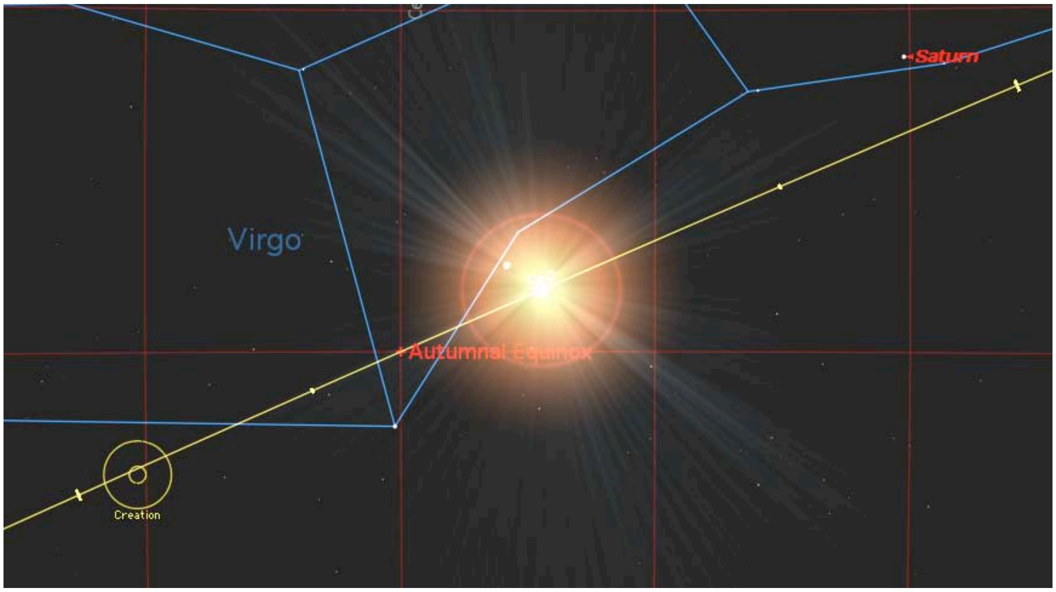


Figure 5.36a: Ring Number 63B. 13 Ak'b'al 11 Yaxk'in on September 18, 360 CE (September 17 Julian).

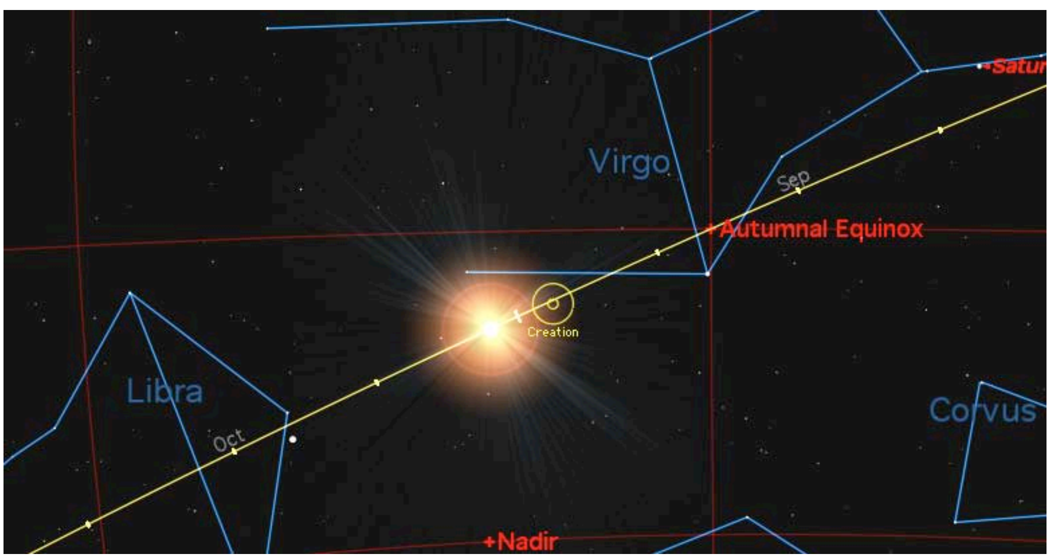


Figure 5.36b: Long Round for 63B. 13 Ak'b'al 11 Yaxk'in + 17 to October 5, 360 CE (October 4 Julian). The sun is exactly three days beyond the sidereal position of the Creation in Virgo

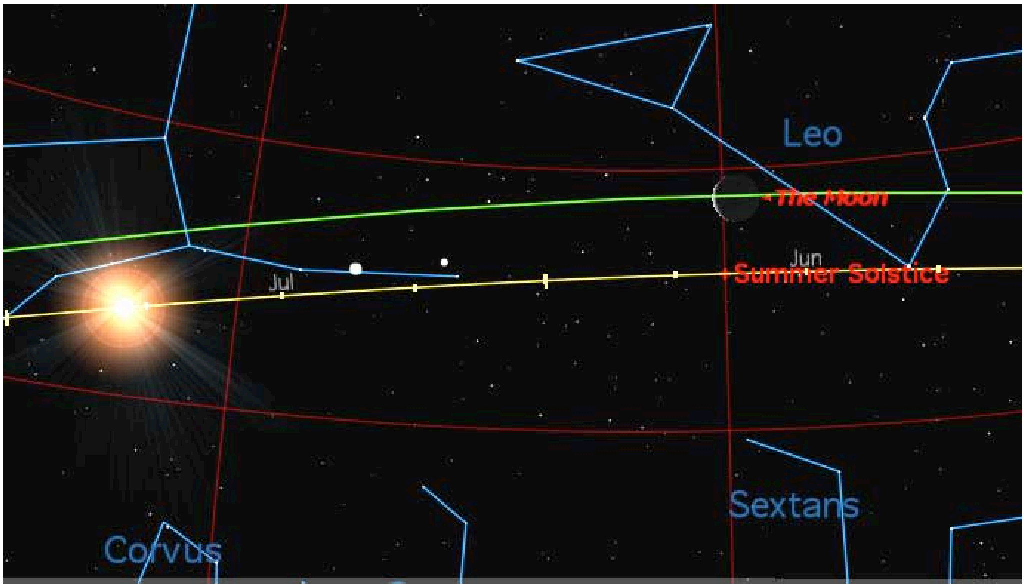


Figure 5.37: Ring Base for 63B. Subtract 17 days from Era Base to reach July 27, 3114 BCE

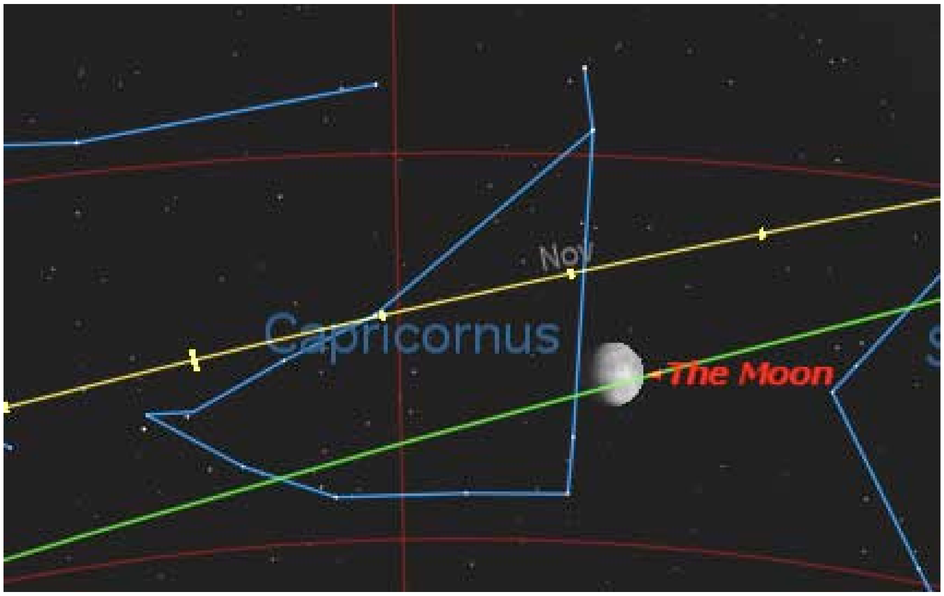


Figure 5.38a: Subtracting another 17 days from the **Ring Base for 63B** to reach July 10, 3114 BCE. This is the sidereal position and phase of the moon on the winter solstice on December 21, 18,124 BCE

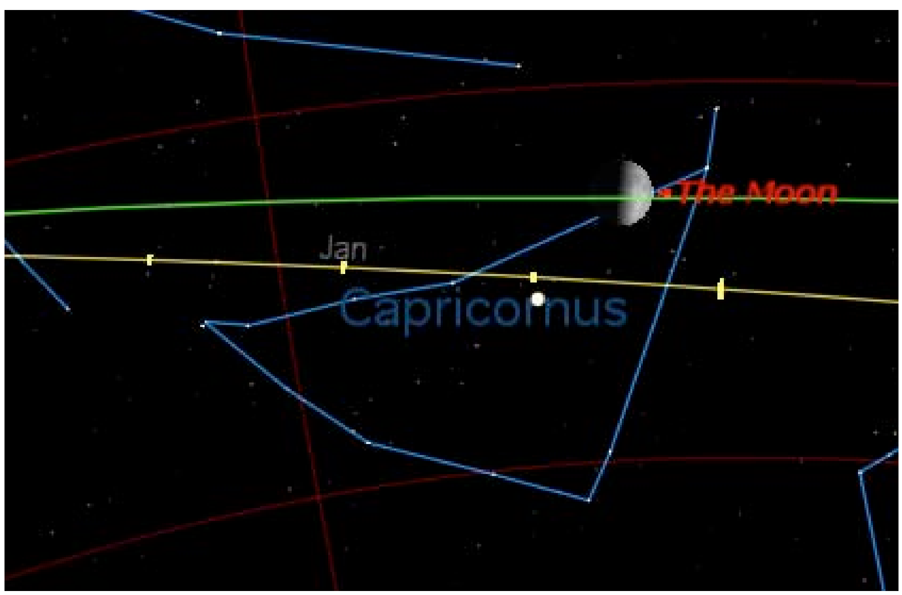


Figure 5.38b: Long Round for 63B. October 5, 360 CE (October 4 Julian). The moon is in the same sidereal position as above on July 10, 3114 BCE, 17 days before the Ring Base. This also represents the sidereal position of the moon on the winter solstice in 18,124 BCE

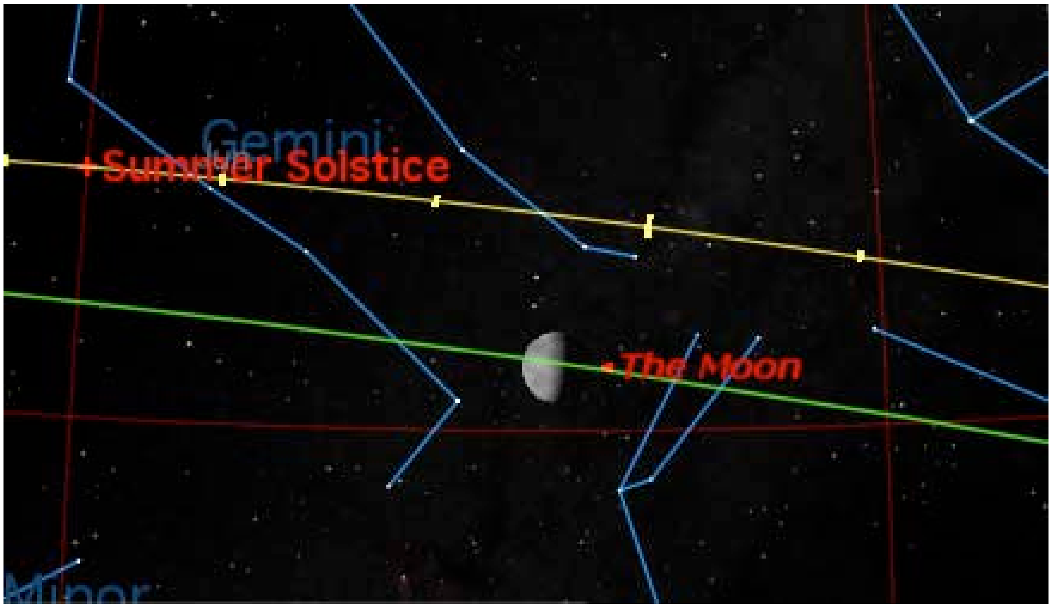


Figure 5.39: Ring Number 63B. September 18, 360 CE, The moon is exactly at the third quarter, and six days past the ascending node . This is identical to the phase of the moon on the 9 K'an 12 K'ayab' base date.

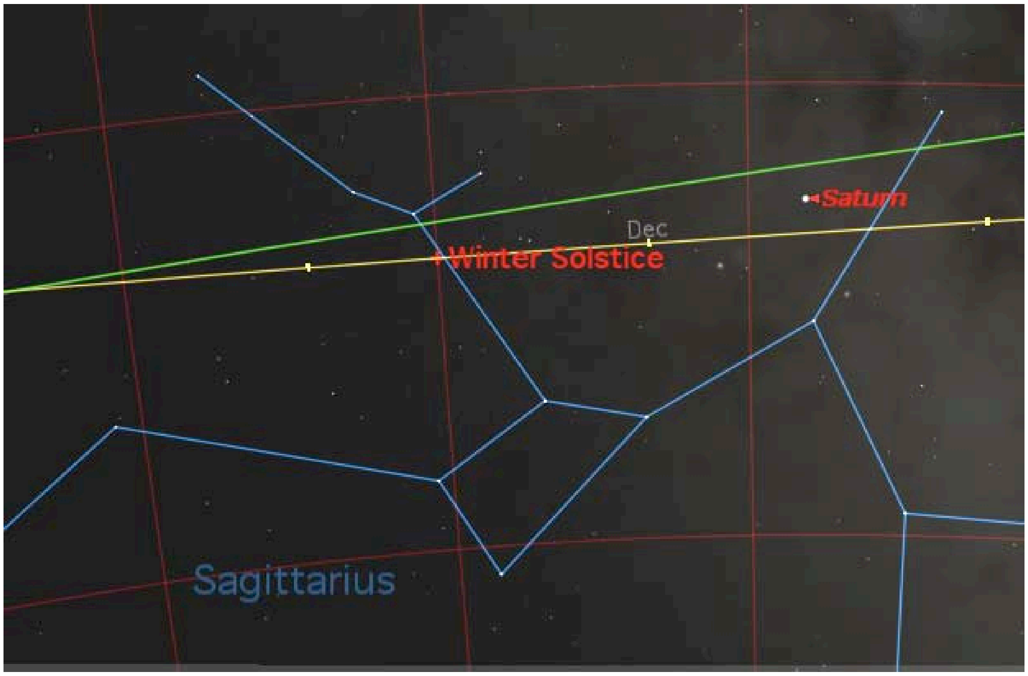


Figure 5.40a: Ring Number 63C red. 13 Ak'b'al 1 K'ank'in on September 3, 958 CE (August 29 Julian). Saturn is exactly at its second stationary point in Sagittarius, near the sidereal position of the winter solstice in the Milky Way.

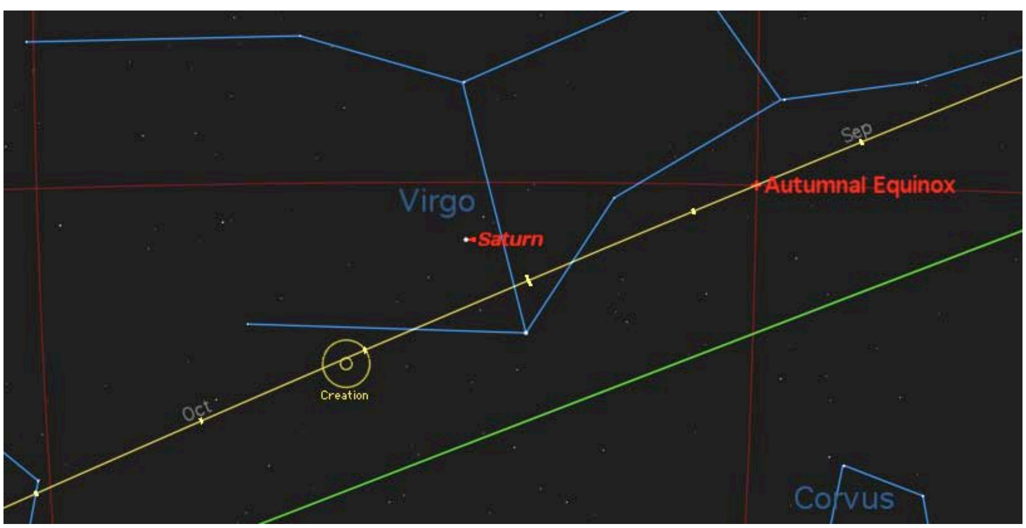


Figure 5.40b: Long Round date for 63C red. 4 Ik 15 Sak, June 15,1099 CE (June 9 Julian). Saturn is at the exact point of its second stationary point, here in Virgo near the sidereal position of the Era Base date.

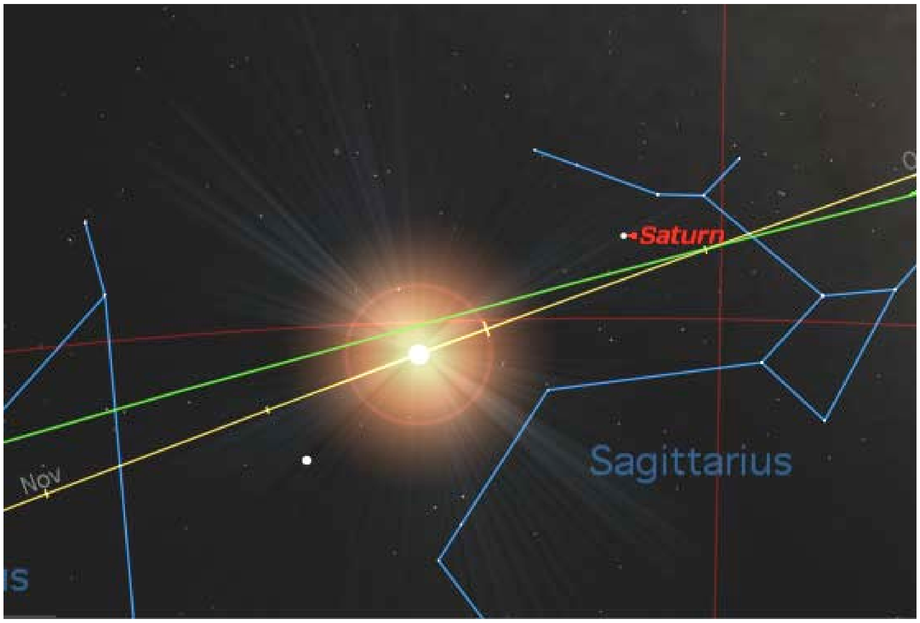


Figure 5.41a: Ring Base for 63C red. November 3, 3255 BCE (November 28 Julian). Saturn is near conjunction with the sun, very close to day of the first solar nadir at 14.8º N

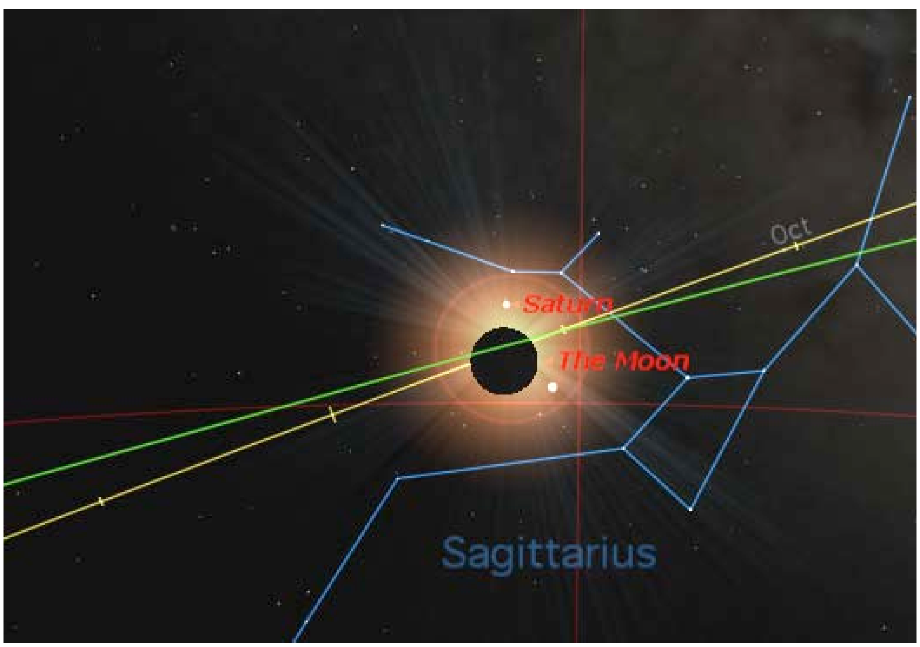


Figure 5.41b: Eight days prior to **Ring Base for 63C red**, there is a partial solar eclipse at the ascending node near midnight, in conjunction with the sun near the first solar nadir at 14.8º N.

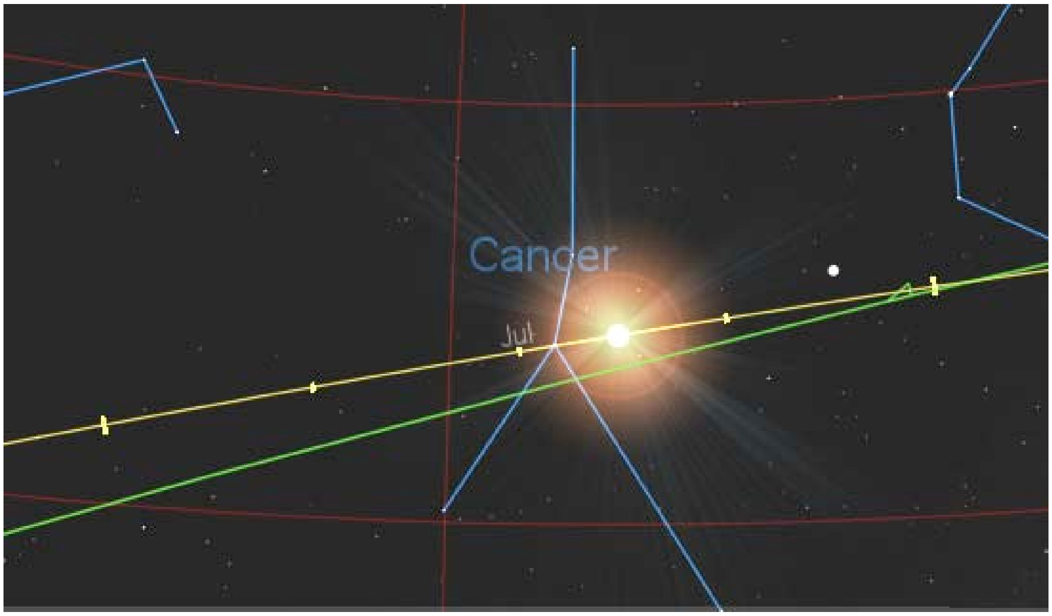


Figure 5.42: Ring Number 63C black. 3 Chikchan 8 Sak, July 14, 949 CE (July 9 Julian). The sun is in the familiar sidereal position of the first solar zenith at 19.5° N in 3114 BCE.

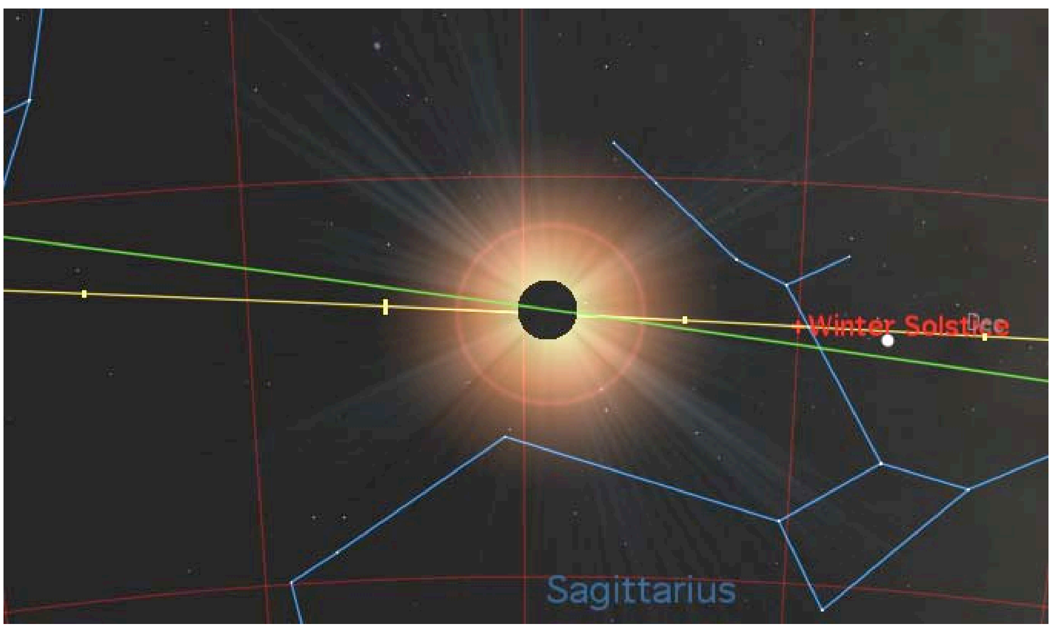


Figure 5.43: Six days after 3 Pop winter solstice on December 21, 949 CE (December 16 Julian), in year of **Ring Number 63C black**, there is an invisible total solar eclipse in the same sidereal position of the sun on the Ring Base for this calculation on 13 Imix 9 Wo, November 3, 3255 BCE.

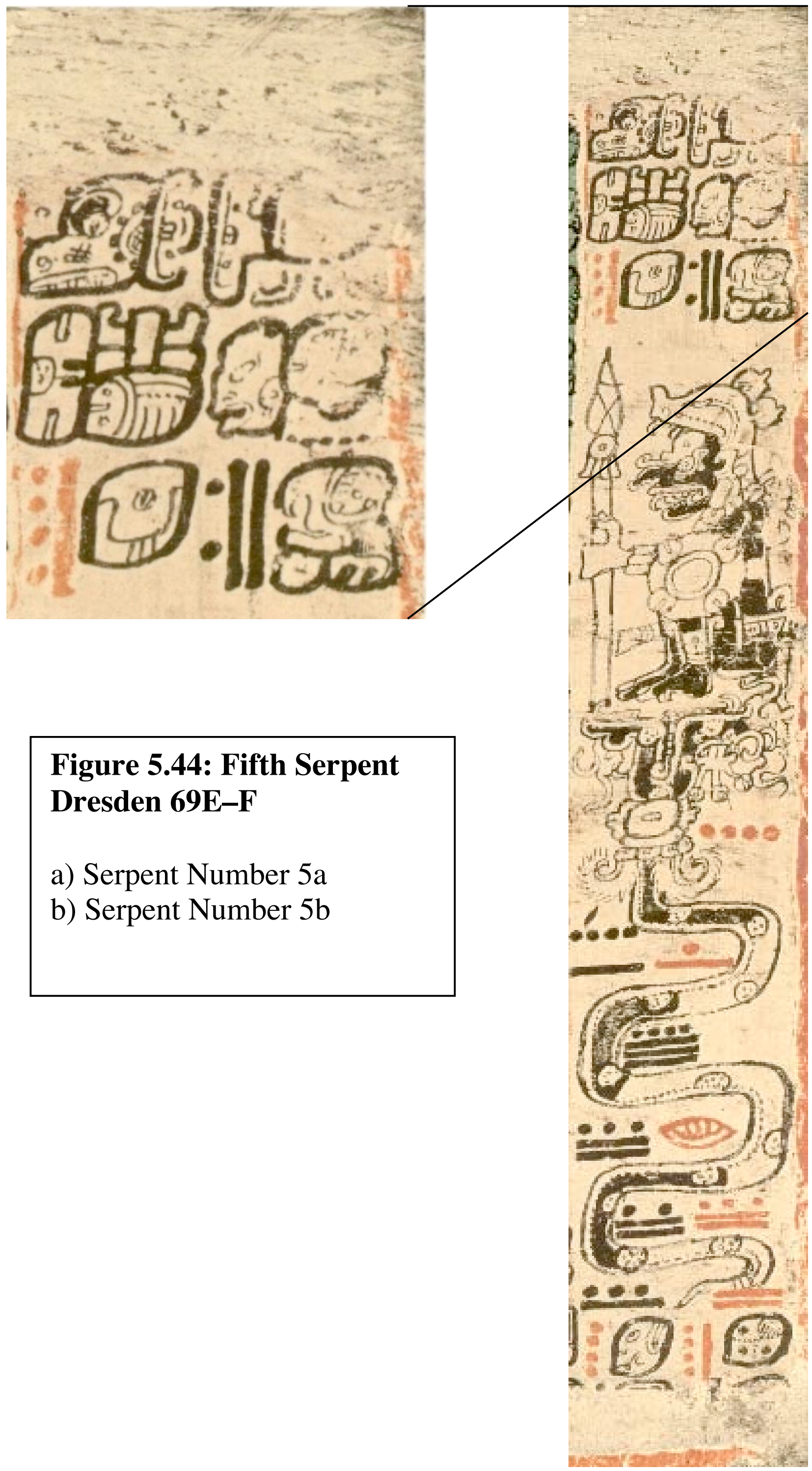


Figure 5.44: Fifth Serpent Dresden 69E–F

a) Serpent Number 5a
b) Serpent Number 5b

a **b**

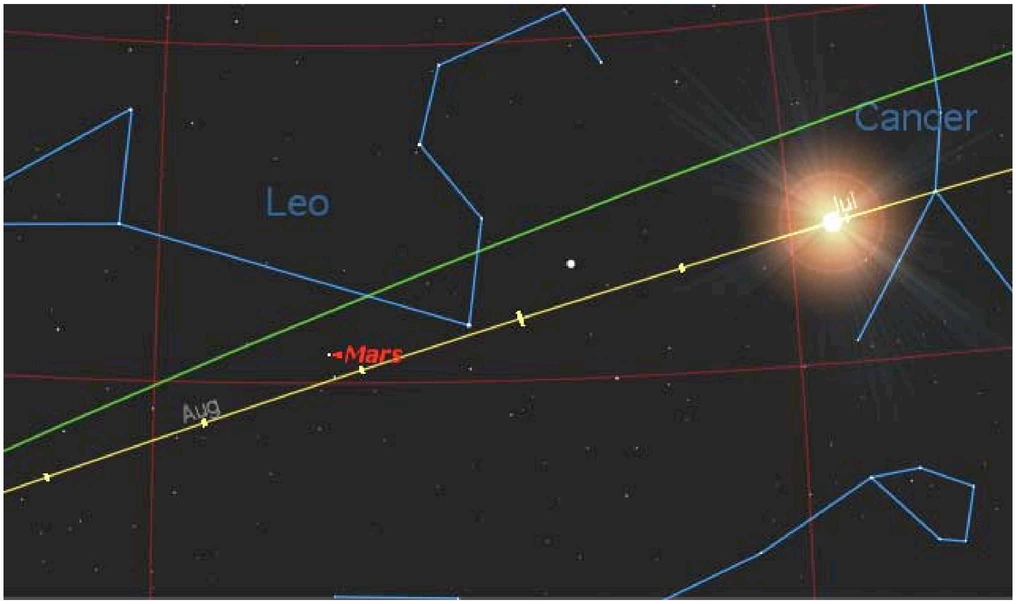


Figure 5.45: Serpent Number 5a. 4 Eb' 5 Ch'en, July 18, 759 CE (July 16 Julian). Mars is in the sidereal position of the second solar zenith at14.8° N latitude in Leo

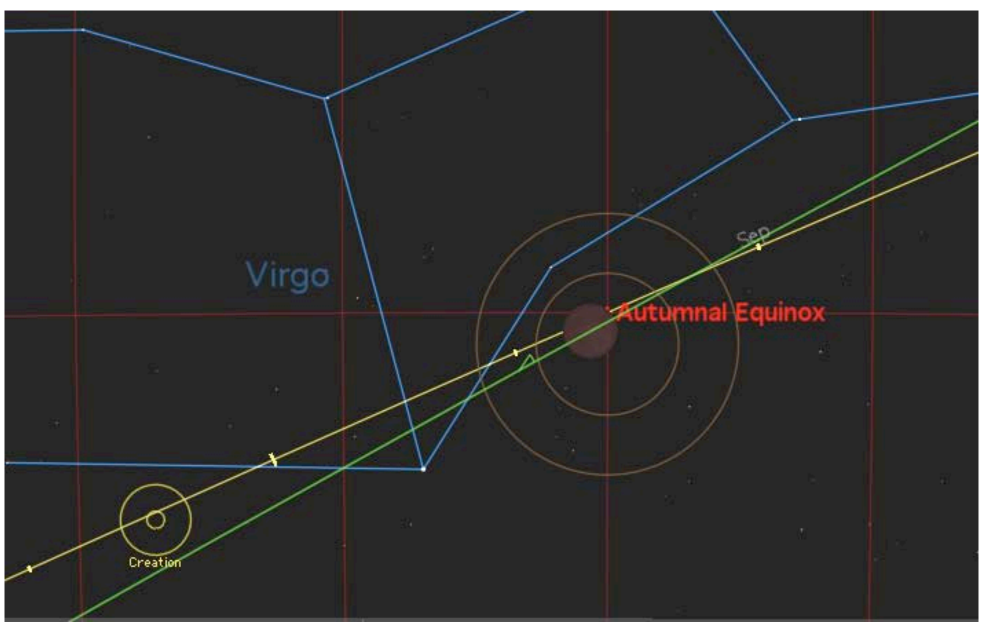


Figure 5.46: Serpent Number 5a – 118 days to nodal passage on 3 Ix 7 Sip on March 22, 759 CE (March 20 Julian) – 2 days to a total lunar eclipse on March 20, only one day after the vernal equinox.

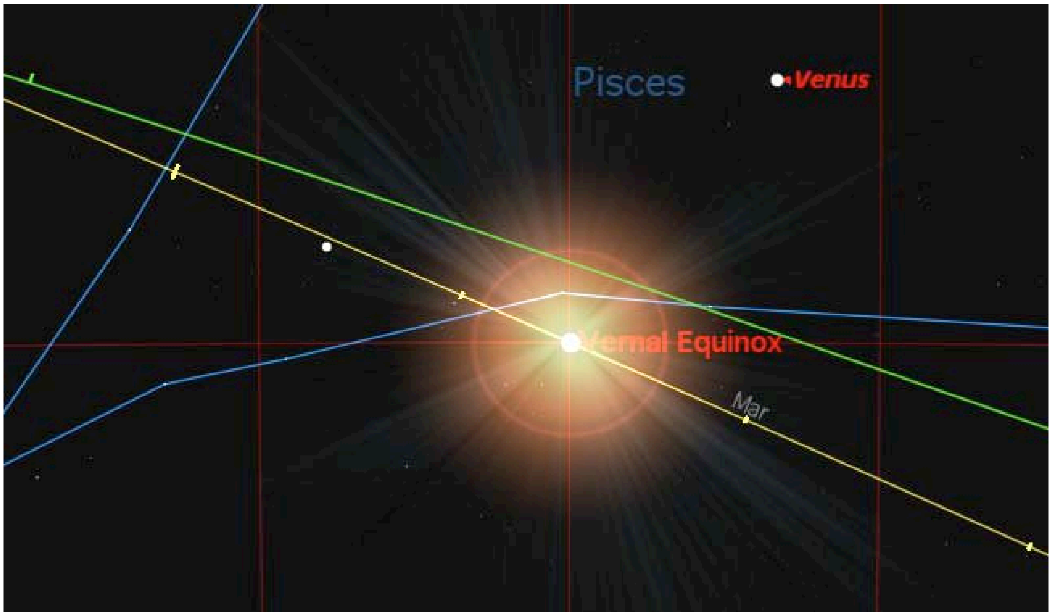


Figure 5.47: Serpent Number 5b. 9 Ix 12 Sip, March 20, 786 CE (March 16 Julian). The sun is exactly at the vernal equinox in Pisces. First appearance of Venus as morning star after inferior conjunction.

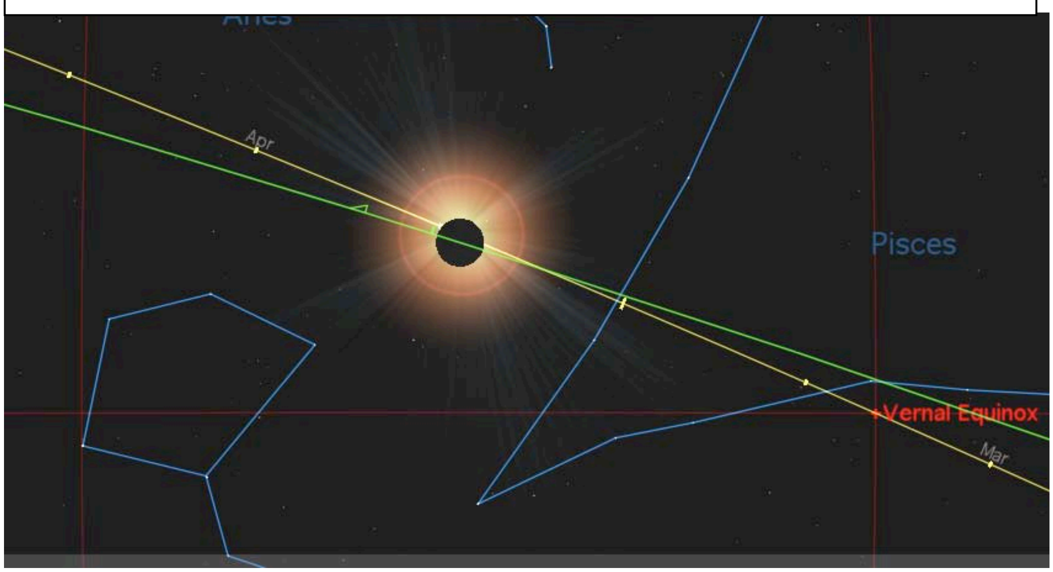


Figure 5.48a: Serpent Number 5b + 20 days to nodal passage on 3 Ix 12 Sotz' on April 9, 786 (April 5 Julian) – 2 days to partial visible solar eclipse in Pisces, just after sunrise on April 7 (April 3 Julian).

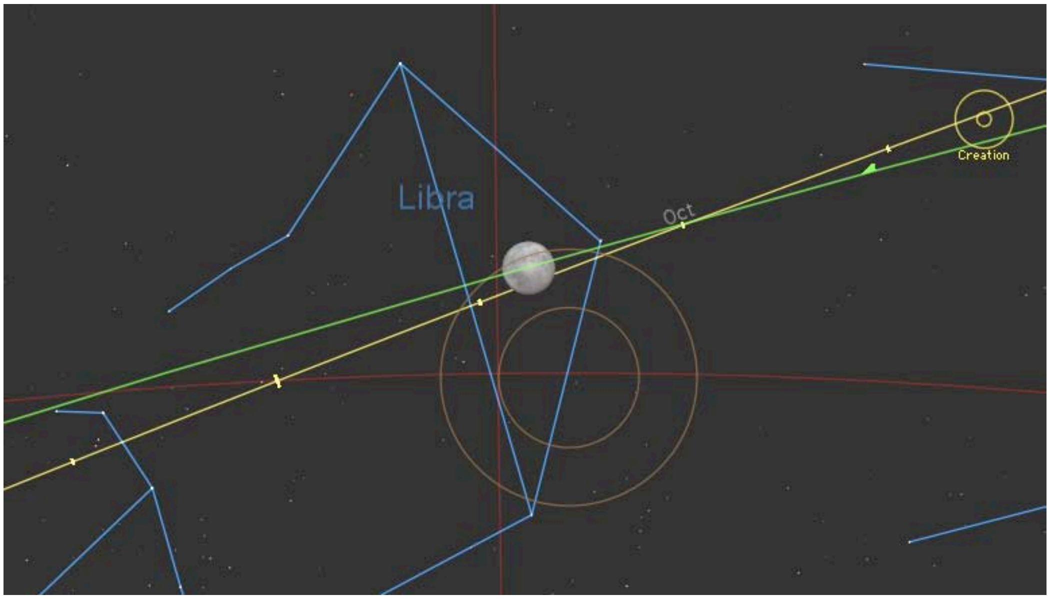


Figure 5.48b: Partial, visible lunar eclipse in Libra on April 22 (April 17 Julian), after 3 Ix nodal passage following **Serpent Number 5b**.

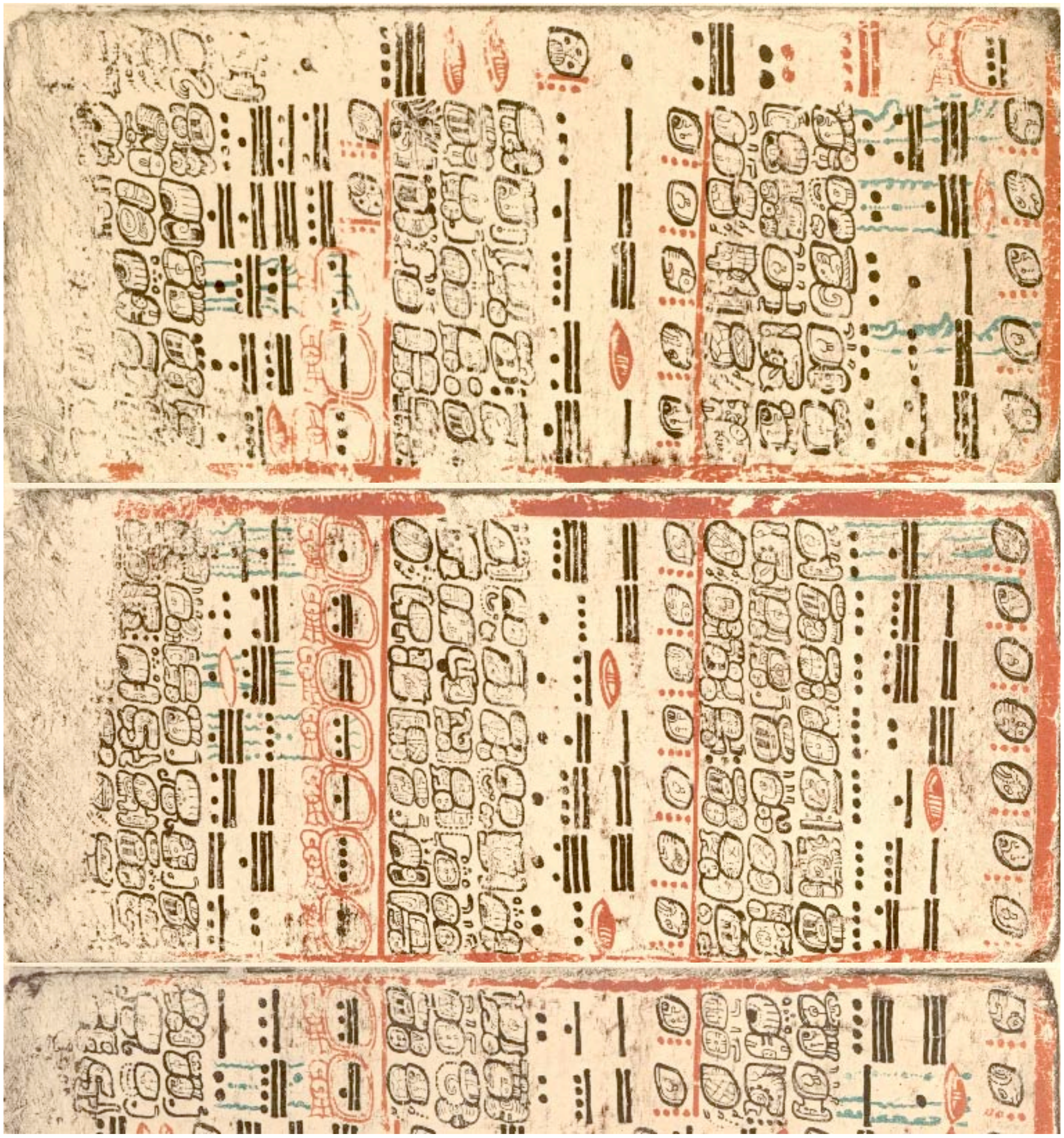


Figure 5.49: Dresden 71(E–F), 72, 73
The Upper and Lower Water Tables

Figure 5.50: Dresden 74
The Flood Scene

Figure 5.51: Dresden 70A-D

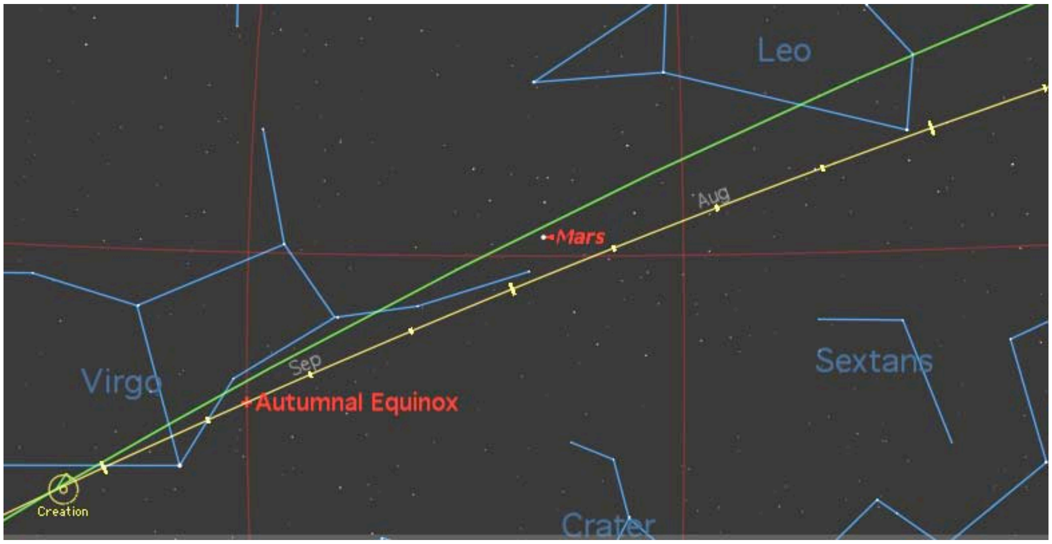


Figure 5.52a: Ring Number 70A top. 9 Ix 12 Muwan, December 6, 702 CE (December 2 Julian). The sidereal position of Mars is at the head of Virgo near Leo, about 40 days prior to its first stationary point.

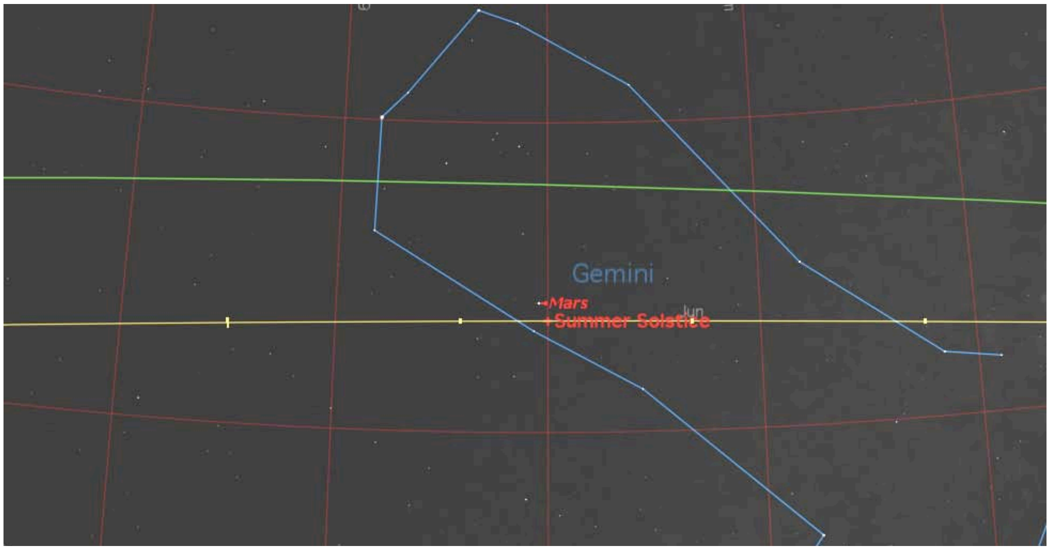


Figure 5.52b: Ring Number 70A top –122 days to 4 Eb' on August 6, 702 CE (August 2 Julian). Mars is in the exact sidereal position of the summer solstice in Gemini.

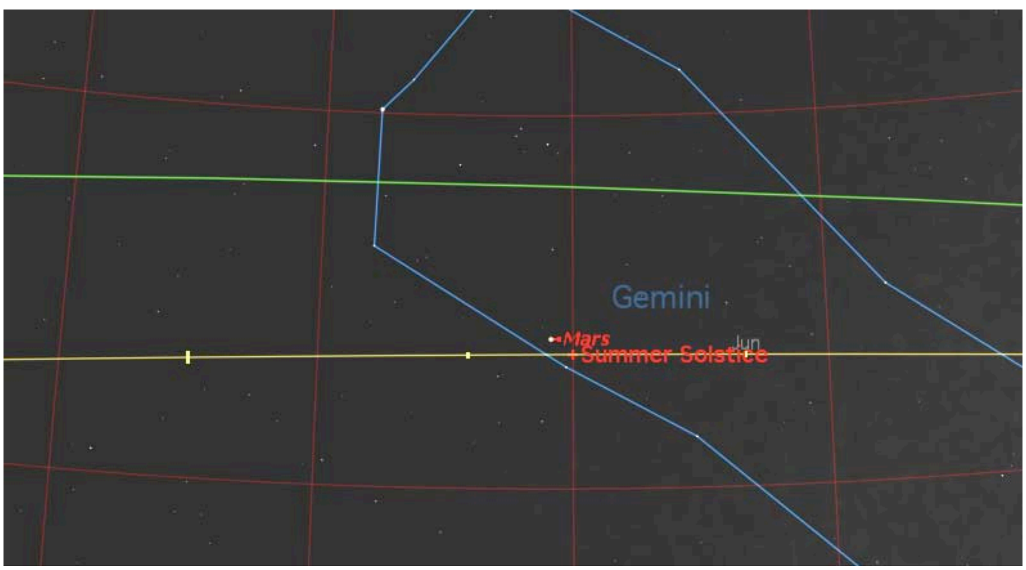


Figure 5.52c: Ring Number 70A top – 10 x 702 days to September 16, 683 CE (September 13 Julian). Mars is in exactly the same sidereal position of the summer solstice in Gemini as on 4 Eb' (Figure 5.52b), while it is in the same synodic phase as it was on the terminal date 9 Ix 12 Muwan, December 6, 702 CE.

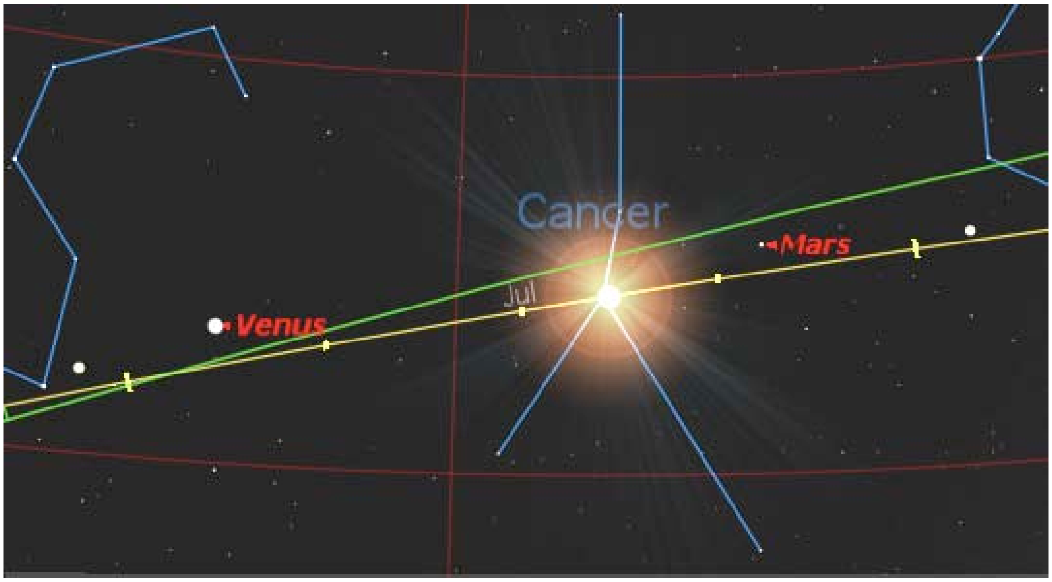


Figure 5.53a: Ring Number 70B top. 9 Ix 17 Ch'en, July 15, 817 CE (July 11 Julian). The sun is in the familiar sidereal position of Cancer that seems to represent the first solar zenith at 19.5º N in the year of the Era Base date.

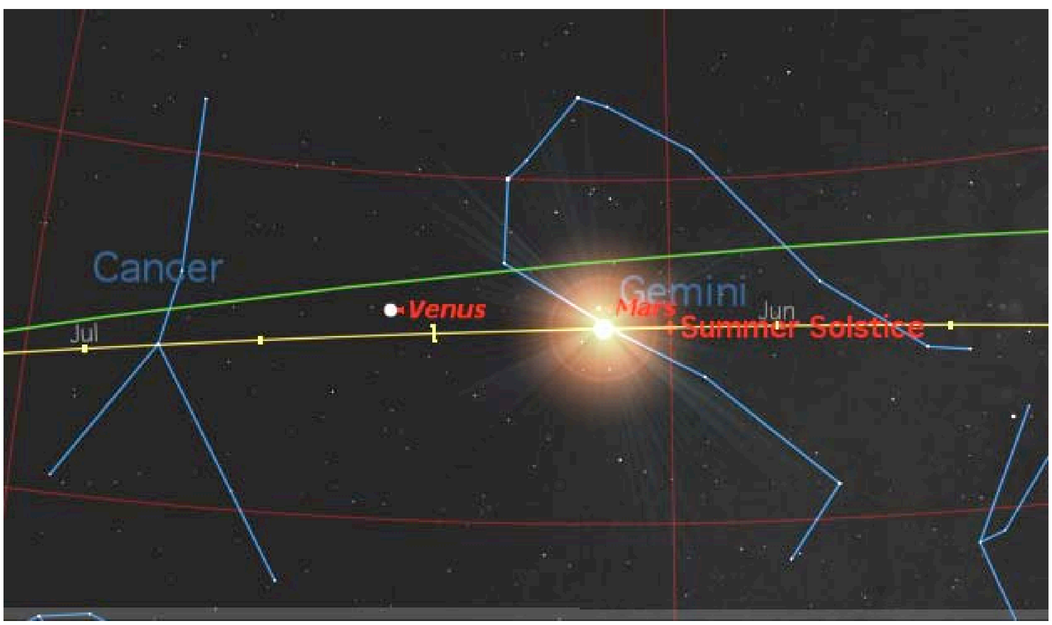


Figure 5.53b: Ring Number 70B top – 20 days to June 24 (June 20 Julian) Sun conjuncts Mars in the exact same sidereal position in Gemini as where Mars appears on 4 Eb', 122 days before the previous terminal date in 70A (Figure 5.52b), the sidereal position of the summer solstice in 702 CE.

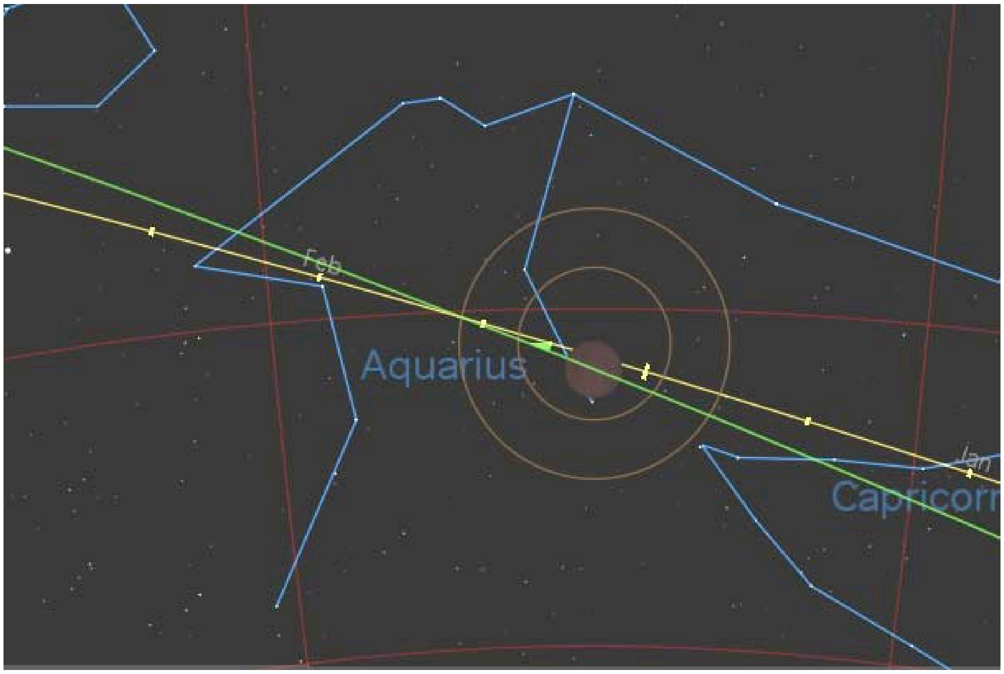


Figure 5.54: Ring Number 70B top + 20 days to 3 Ix 17 Yax on August 4, 817 CE (July 31 Julian) brings us to a total lunar eclipse in Aquarius.

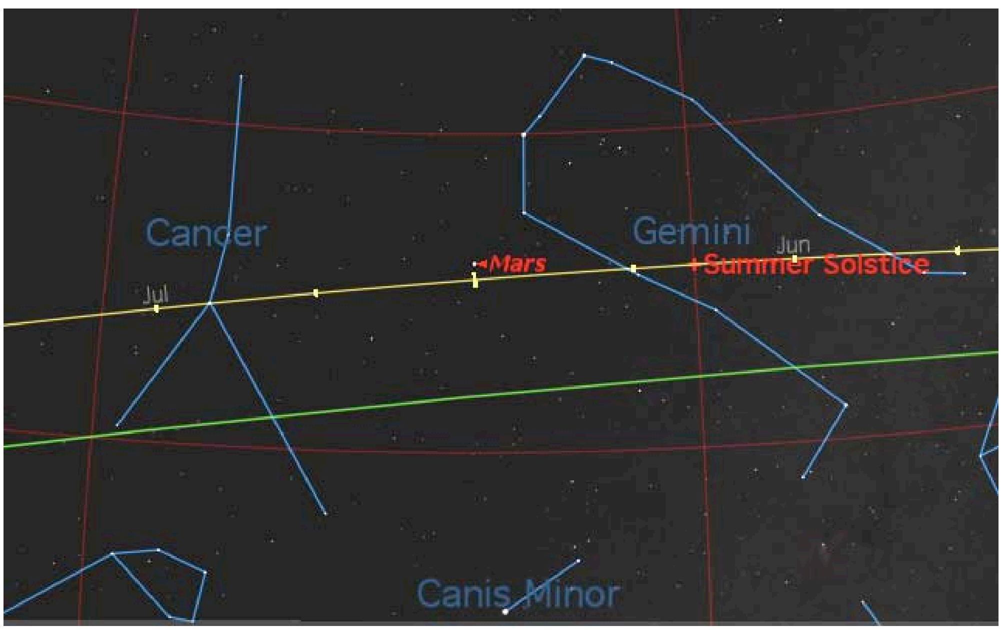


Figure 5.55: Ring Number 70B top + 14,040 days – 122 days to a day 4 Eb' + 1,820 days from the lower water table reaches August 16, 860 CE (August 12 Julian), returning Mars to the same sidereal position as it appears on the terminal date for 70B top (Figure 5.53a).

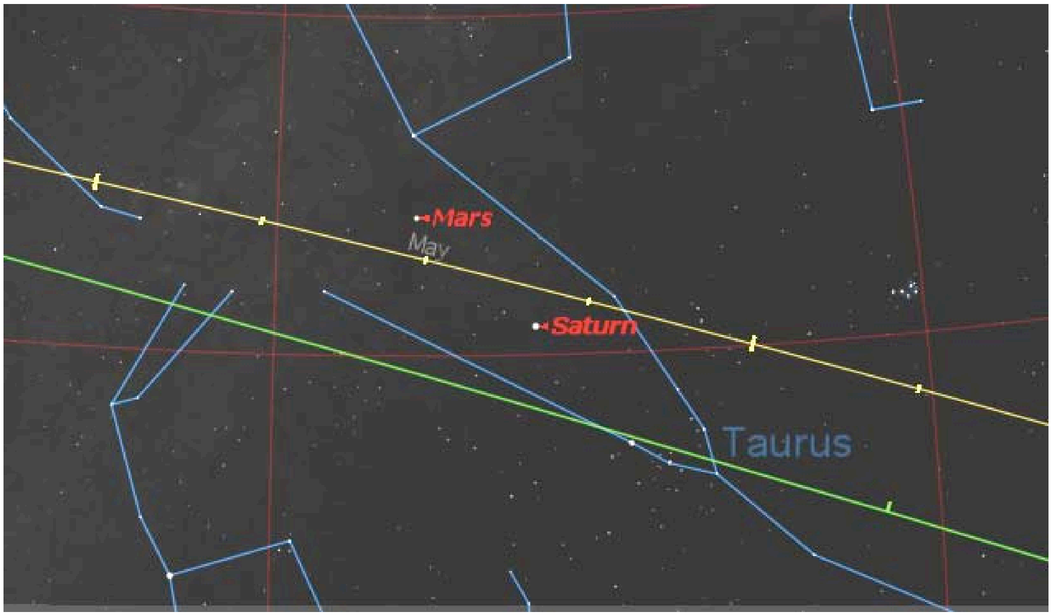


Figure 5.56a: Ring number 70A bottom. 9 Ix 7 Mak, February 27, 176 CE (February 26 Julian). On this day, Mars is in Taurus near the first zenith at 19.5° N

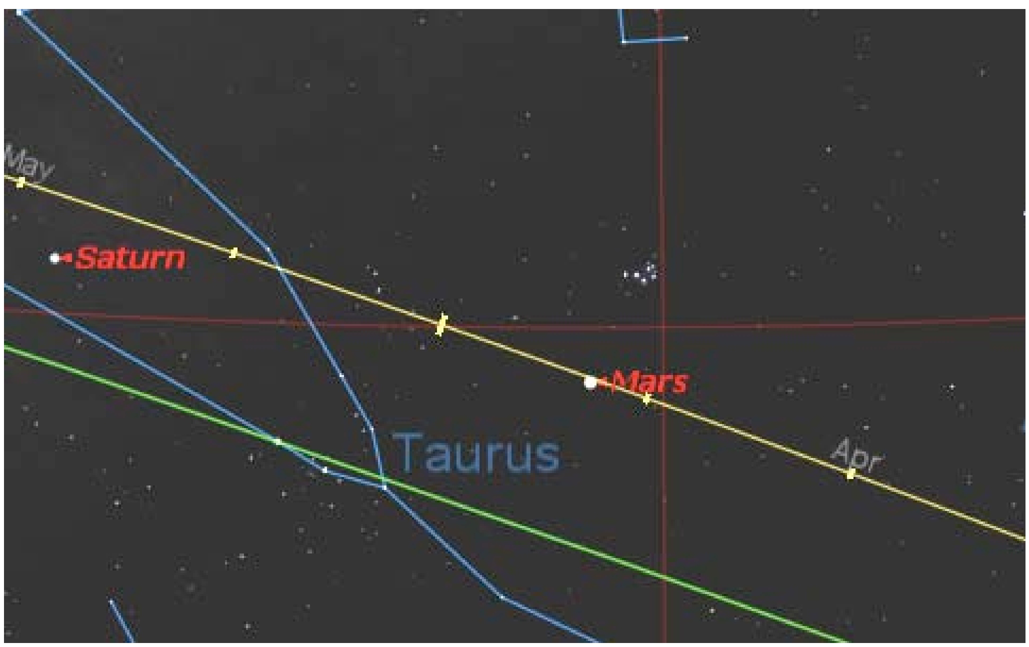


Figure 5.56b: Ring number 70A bottom – 122 days to 4 Eb' 5 Yaxk'in, October 29, 175 CE (October 28 Julian), Mars is in Taurus at the first zenith at 14.8° N, directly at opposition to the sun at the first nadir.

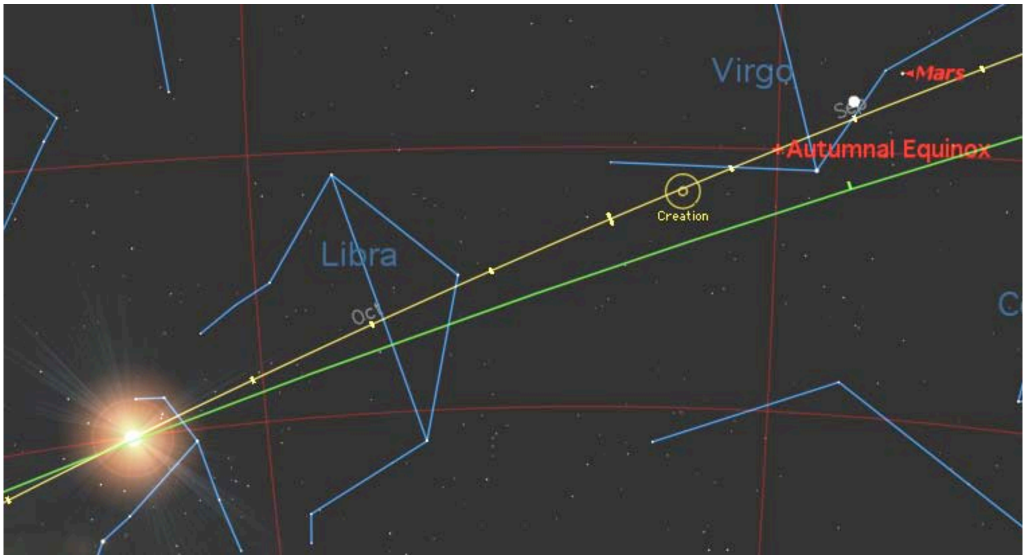


Figure 5.57: Ring Number 70A bottom – 122 days – 1,820 days to November 4, 170 CE (November 3 Julian). The sun is at the ascending node, while Mars appears near 0º in Virgo. 8 days prior to lunar eclipse in Taurus.

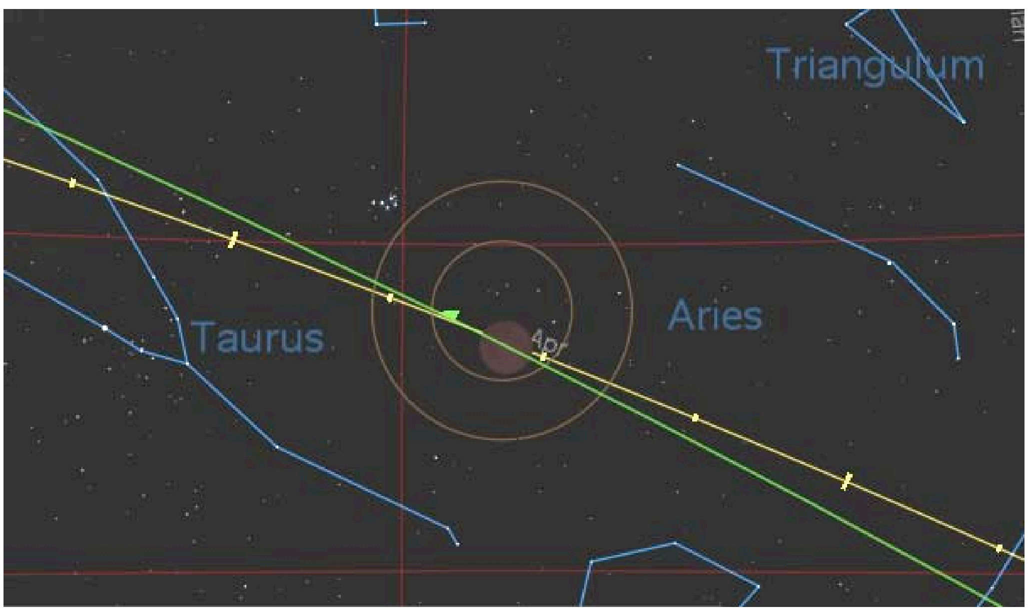


Figure 5.58: Ring Number 70A bottom + 1,820 days – 122 days to 4 Eb' 0 Yaxk'in, October 22, 180 CE. Total lunar eclipse in Taurus, similar to 9 K'an 12 K'ayab' base date.

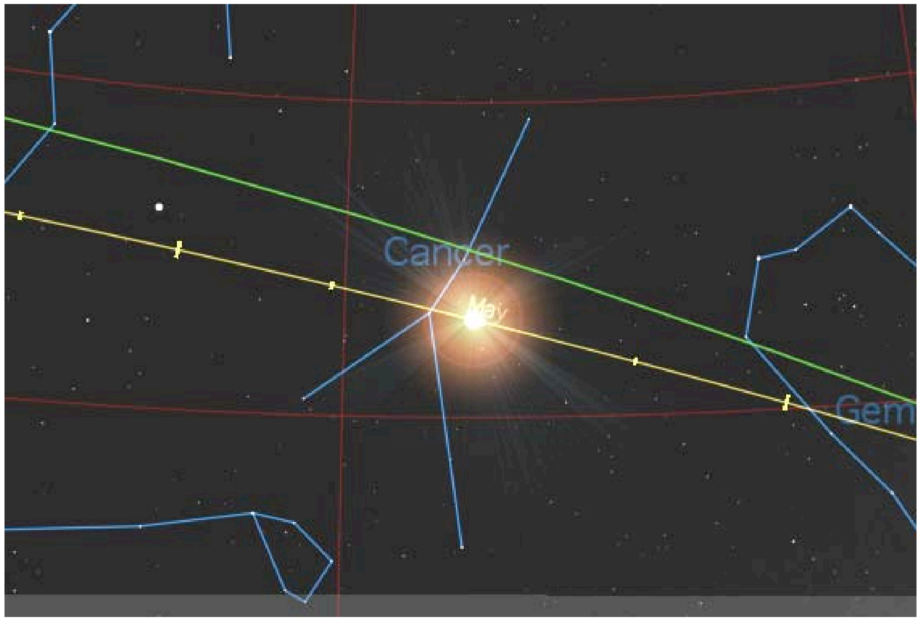


Figure 5.59: Ring Base for 70A bottom. 9 Ix 2 Yaxk'in, 86 days prior to the Era Base on May 19, 3114 BCE (June 14 Julian). This sun is in the exact position of the second solar zenith at 19.5º N in Cancer, the sidereal position often repeated throughout the Serpent Series.

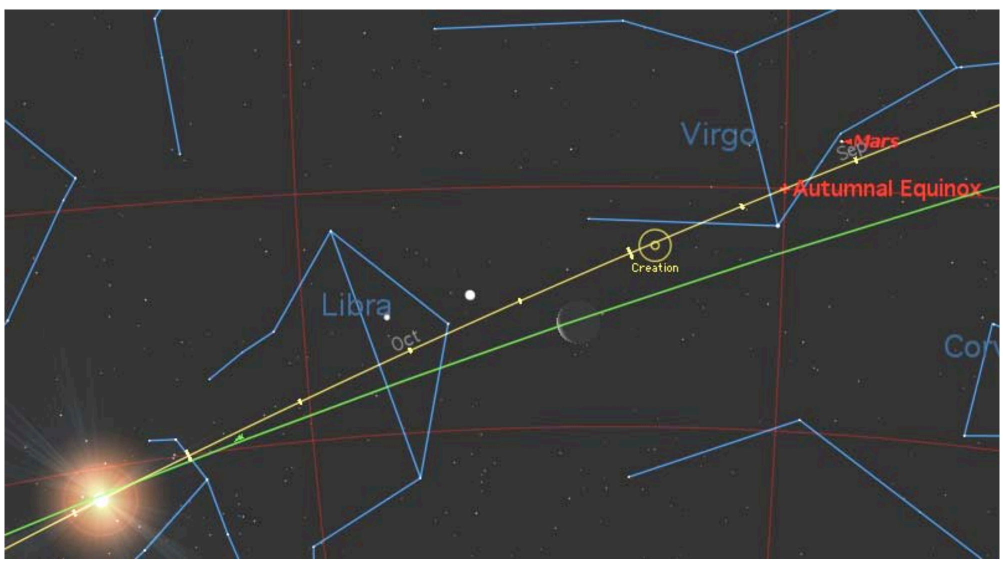


Figure 5.60: Ring Number 70B bottom. 4 Eb' 5 Yax on November 8, 375 CE (November 7 Julian). Solar nodal passage in Scorpius, Mars appears in the same sidereal position in Virgo near 0º in which it appeared in one of the dates from the previous Ring Number on November 4, 170 CE (November 3 Julian) (Figure 5.57).

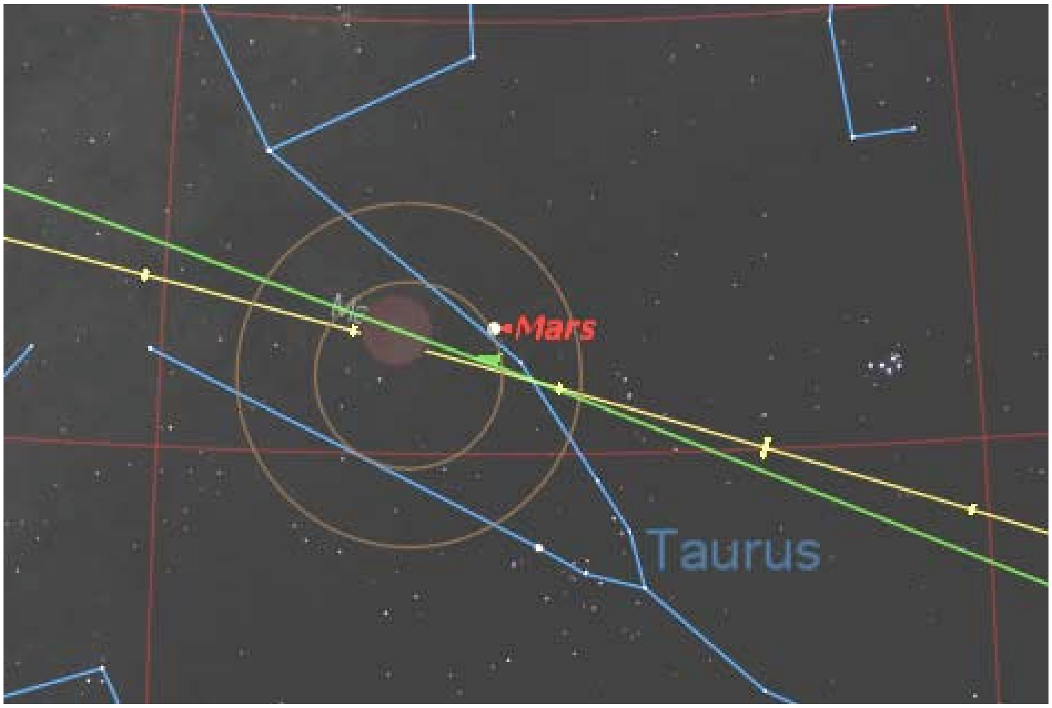


Figure 5.61: Ring Number 70B bottom – 13 days to a total lunar eclipse at the first zenith in Taurus on October 26, 375 CE (October 25 Julian).

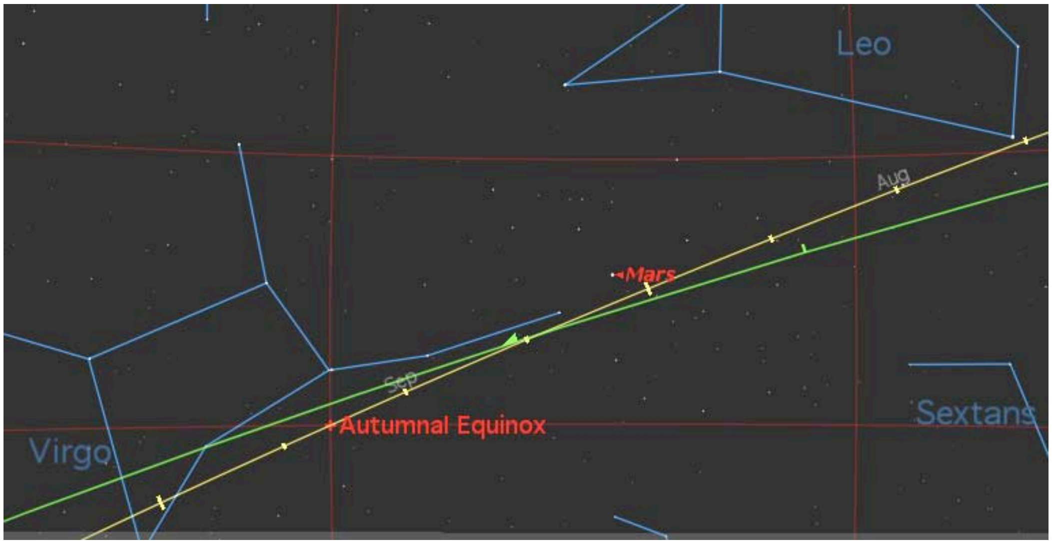


Figure 5.62a: Long Count 70C. 4 Eb' 5 Pop, October 29, 1178 CE (October 22 Julian). The sidereal position of Mars repeats that in 70A top (Figure 5.52a), at the head of Virgo,

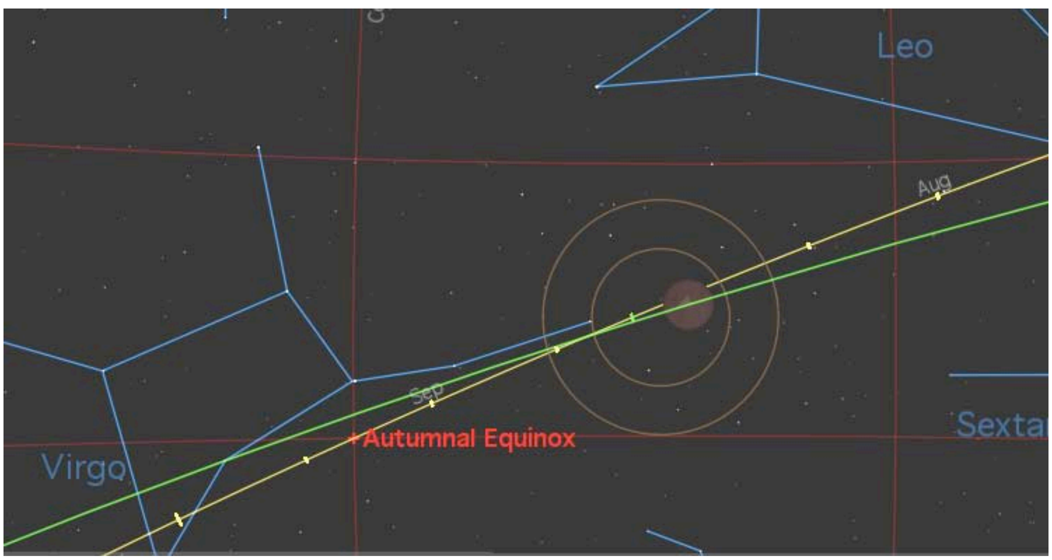


Figure 5.62b: Long count 70C + 122 days to 9 Ix + 2 days to March 2, 1179 CE (February 23 Julian). Total lunar eclipse exactly in the same sidereal position by the head of Virgo where Mars appears on the terminal date.

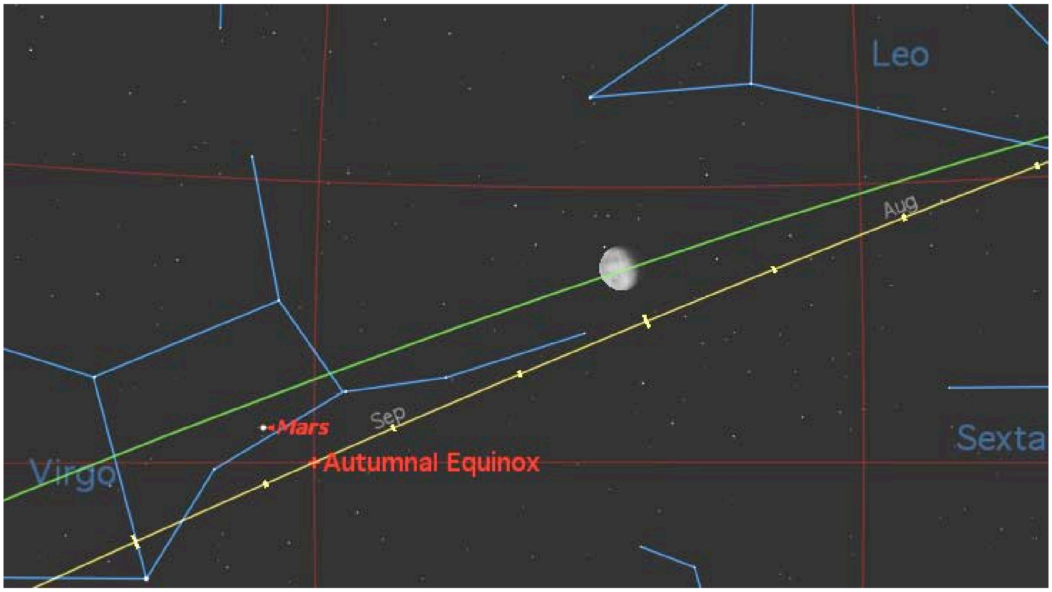


Figure 5.63: Long Count 70D. 9 Ix 7 Sip, on January 10, 1051 CE (January 4 Julian). The moon again appears in the same sidereal position by the head of Virgo where it appears in a total lunar eclipse on Long Count 70C + 122 days (Figure 5.62b).

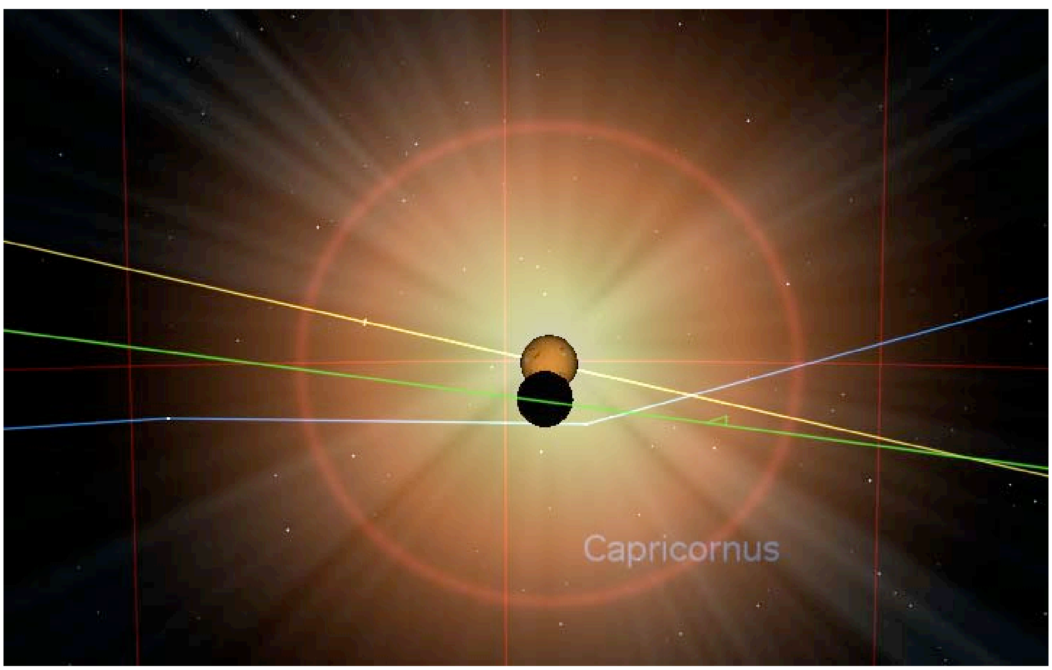


Figure 5.64: Long Count 70D + 11 days to January 21, 1051 CE. Invisible, partial solar eclipse before sunrise when the sun is very close to the second solar nadir at 19.5º N in Capricorn.

Chapter VI

Conclusion

The Serpent Series in the Dresden Codex is an unparalleled surviving example of Maya theoretical astronomy. The original research in this dissertation project demonstrates that the Serpent Series were used to calculate the sidereal year, the Copán tropical year, the 365-day Haab’, the eclipse year, the synodic and sidereal lunar cycles, and the cycles of Venus, Mars, Saturn, and possibly Jupiter. The Serpent Series incorporates and extends the astronomical information found elsewhere in the Dresden Codex in the lunar table, the Venus almanac, and the Mars tables. Covering intervals of tens of thousands of years, the Serpent Series contains the only recorded evidence that the Maya were not only aware of the precession of the equinoxes, but they were capable of accurately calculating precession and the sidereal year over vast periods of time. Because the intervals of time within the Serpent Series are so large, they demonstrate that the Maya had values for solar, lunar, and planetary cycles that are remarkably comparable to current measurements.

The Serpent Series introductory distance number can be used to accurately calculate the sidereal year over 15,009 years. The Maya multiplied this interval five times to calculate the same theoretical position of the tropical year and the same sidereal position of the sun over an interval of 75,000 years, nearly equivalent to three whole cycles of precession. Furthermore, this distance number, and the 9 K’an 12 K’ayab’ base date within the Serpent Series, confirm the use of the Copán tropical year of 365.2419355 days within the Dresden Codex. The 219-day remainder in the Serpent Series introductory distance number serves as an ideal interval between the second solar zenith at 14.8º N latitude on August 13, and the vernal equinox, while the 9 K'an 12 K'ayab' base date falls precisely on the summer solstice over 30,000 years prior to the Long Count Era Base date 4 Ajaw 8 Kumk'u, on August 13, 3114 BCE. These intervals, and those found throughout the Serpent Series, directly support the 584285 GMT correlation constant, as well as highlighting the latitude of 14.8º N as the location at which the two idealized zenith passages of the sun occur 260 days apart.

The Serpent Series base date 9 K'an 12 K'ayab' appears as a uniquely conceived point in time. It's position on the summer solstice in 33,142 BCE serves as a more universal base date that is independent of latitude, unlike the Long Count Era Base date that implies the August 13 solar zenith at 14.8º N. However, the Haab' New Year 1 Pop falls 34 days after the 9 K'an 12 K'ayab' base date, and this occurs on July 26, 33,142 BCE, the second solar zenith passage at 19.5 º N in the Yucatan. In this way, the 9 K'an 12 K'ayab' base date implies a local latitude that corresponds to the likely origin of these segments of the Dresden Codex.

The 9 K'an 12 K'ayab' base date positions the sun directly at a node, and nodal positions of the sun are found throughout the Serpent Numbers, using the nearest base day 3 Ix. Thus, as Victoria and Harvey Bricker (1988) first proposed, the Serpent Series can be used to commensurate the tropical year with the Haab' and the eclipse seasons. However, it is evident that the Serpent Series additionally includes a commensuration with the sidereal year and precession. Future analyses of the seasonal table may provide further insight into how this table was used for these multiple purposes, and how the present study may modify the Bricker's initial model.

The 9 K’an 12 K’ayab’ base date is twice the Serpent Series introductory distance number, plus less than nine years before the Long Count Era Base date 4 Ajaw 8 Kumk’u. In this way, the sidereal position of the 9 K’an 12 K’ayab’ base date can be determined. The resulting position of this summer solstice in Libra is unexpected, but highly significant, in that it occurs directly opposite a sidereal position near the Pleiades. When the sun occurs in the sidereal position of Libra on the 9 K’an 12 K’ayab’ base date, the Pleiades make their last visible appearance on the eastern horizon, rising at opposition after sunset. Thereafter, the Pleiades first appear higher above the horizon.

Serpent Number 3a directly repeats the sidereal position of the sun on the base date 9 K’an 12 K’ayab’, including the position of the sun at the same lunar node. In addition, this Serpent Number, the only one whose base day is 3 Ix, occurs exactly on the evening of a total lunar eclipse near the Pleiades, and the full moon passes exactly through the first zenith at 14.8º N, while the sun is at the nadir. Such repeated events coordinated with sidereal observations of the Pleiades and exact positions in the tropical year could have been used to calculate precession, much as Hipparchus used repeating lunar eclipses occurring near the vernal equinox. In particular, the use of zenith and nadir passages provided precise means by which to measure the tropical year in Mesoamerica.

The Dresden Codex was certainly copied from many earlier versions, and it contains the accumulated data of centuries of previous observations. Given the primacy of the zenith and nadir passages at 14.8º N cited within the Serpent Series, it is possible that some of the observations from the Classic period were performed at this latitude in Copán. At the same time, it appears that the date of the second solar zenith at 14.8º on August 13 was observed throughout Mesoamerica at various latitudes, as far north as Teotihuacan in the Central Valley of Mexico, and Edzná in the Yucatan, though the second solar zeniths occur on different dates at these sites (Malmström 1997:104, 179). The importance of this ideal latitude is reinforced by the occurrence of the Long Count Era Base date on August 13, exactly 260 days before the first solar zenith at 14.8º N. While it would be possible to observe azimuth rising and setting positions of the sun or moon on these two days at any latitude, it would only be possible to directly observe zenith passages on these days from 14.8º N.

The secondary inscriptions in the Serpent Series demonstrate highly accurate values for both the synodic and sidereal lunar cycles over tens of thousands of years. These are coordinated with both the solar zenith at 14.8º N, and the solstices, demonstrating once again the utility of zenith passages at this latitude, along with the solstices, as important positions within the tropical year. The accuracy of these lunar measurements surpasses those Teeple (1931) found for the Classic period. Thus, by the time of the Postclassic, the authors of the Dresden Codex had apparently accumulated enough data to refine their calculations beyond those from the Classic period. Therefore, the lunar table from the Dresden Codex, which utilizes the Palenque lunar values in one run of the table, was certainly recycled using specific corrections. Various authors have proposed different ways in which this may have taken place.

I offer a new interpretation of the inscription on page 52 of the lunar table as an interval of 47,489 days, which can be used to calculate eclipses in the same sidereal position and the same time of year over a period of 130 years. Furthermore, with adjustments, this interval provides an excellent means to calculate the sidereal year, the tropical year, the Haab', the lunar cycles, and the eclipse year. I have highlighted the importance of the 1,820-day interval used within the Serpent Series as a shifting of the sidereal position of the lunar nodes by a quarter of year from the position of the solstices to that of the equinoxes, or vice versa. Twice this interval, 3,640 days, returns the nodes to roughly the same position in the tropical year, and this forms the basis of the 47,489-day calculation from the lunar table.

Earlier evidence for the 1,820-day interval can be seen in Glyph Y from the Classic period Supplementary Series. Glyph Y has been shown to represent a cycle of seven. Commensurated with the Tzolk'in cycle of 260 days, this cycle of seven gives the cycle of 1,820 days, which can be used to track the sidereal position of eclipses. Given its relationship with the deity K'awil and the 819-day count, Glyph Y may indicate that both K'awil and the 819-day count could be associated with tracking the sidereal position of eclipses over long periods of time, along with calculating the tropical year, the Haab', and the sidereal year, as in the Serpent Series. Further investigation of these proposals is necessary to determine the uses of Glyph Y and the 819-day count in the Classic period.

I have similarly proposed that Glyph G from the Classic period arose as a means to predict eclipses using the position of the moon relative to the lunar nodes. Glyph G thus uses the 260-day Tzolk'in and the cycle of nine, and the coefficients of some of the examples of Glyph G appear to correspond to intervals associated with the draconian month. Thus, Glyph G and Glyph Y appear to be components of the larger Lunar Series that follows them, and the entirety of the Supplementary Series may be labeled a true Lunar Series.

I have examined each of the dates given in the Serpent Series, and several of these dates indicate accurate planetary cycles for Venus, Mars, and Saturn, in association with vast periods of time, sidereal positions and precessional drift. Further analyses of these dates and their associated texts will be necessary in the future to determine precisely why each date was chosen, and what adjustments may have been used in their calculations.

The evidence from the Serpent Series presented in this dissertation project strongly suggests that the ancient Maya astronomers were capable of observing and recording multiple astronomical cycles, including the precession of the equinoxes. No previous research has demonstrated the latter with any degree of certainty. While it may be impossible to prove that the Maya used the Serpent Series for this purpose, I find no other explanation satisfactory for the use of such precise and accurate intervals over periods of tens of thousands of years. To suggest that the Maya had a more accurate calculation of the sidereal year than any prior observers in human history is a large claim, but it is one for which I believe there is now ample evidence.

Interestingly, there is no mention within the Serpent Series of the 13 B'ak'tun end date in 2012 CE, which Jenkins claims to be of primary importance. This is not to discount the possibility that it was previously relevant, but in the inauguration of the new 9 K'an 12 K'ayab' base date in the Serpent Series, we see calculations that extend some 30,000 years into the past, and some 70,000 years into the future, none of which include any mention of the 2012 end date. However, the Long Count Era Base date from 3114 BCE is repeatedly mentioned.

Aveni suggests that archaeoastronomy is now equally concerned with questions of both "how" and "why" astronomical observations took place. I have suggested that we have yet to exhaust questions of how, some of which have been partially answered by my research. Regarding questions of why, we may never know exactly why the Maya were concerned with the sidereal year and precession. To suggest that these calculations of theoretical astronomy represent something astrological begs the question of what purpose such distant calculations held for the lives of those who conceived them. Given the presence of the world-ending flood imagery on the final page of the Serpent Series, it is tempting to suggest that these astronomical calculations of distant eclipses were used to determine various world-ending events. However, it is difficult to understand exactly how such mythological representations may have been understood by astronomers on the one hand, and by other segments of Maya society on the other. Were these metaphorical stories used to refer to repeating astronomical observations, or were these astronomical observations used to represent literal interpretations of world-ending periods? Further exploration of these ideas within a mythological and astronomical context is necessary to begin to try to understand some of these core issues.

As Ulansey proposes, the Mithraic mysteries may have arisen as a mythological system of multiple world ages, based on the discoveries of Hipparchus concerning the precession of the equinoxes. Likewise, it is possible that the Maya knowledge of precession led to a similar conception of world ages, as Jenkins and Brotherson suggest. If the Long Count itself arose as a codified form of five world ages, covering one cycle of precession, this knowledge was later modified in the Serpent Series to include far longer periods of time, in association with precise measurements of multiple cycles. Did these new calculations then inspire a new mythology? How were these extremely refined astronomical calculations disseminated and interpreted by the larger population? Were the contents of the Dresden Codex only understood by the initiated, in this case the astronomer-priests? This is quite possible. But such an expansive awareness of time, and a concern with tens of thousands of years in the past and future appears to have been deeply interwoven in Mesoamerican cosmology, and this may derive from a tradition of accurate astronomical observations.

We may never fully understand the multiple reasons why the Maya astronomers were concerned with precession. What we can say is that they were almost certainly observing it, and recording these observations over hundreds of years of their history, at least until the traumatic invasion of the Europeans.

While it may be ethnocentric to assert that the Maya were observing astronomical phenomena in the same way as their counterparts in the West, it is equally ethnocentric to insist that they were incapable of such observations, particularly when their observations and their unique system of tropical zenith astronomy appear to have led them to far more accurate calculations than those of any of their contemporaries elsewhere in the world. Perhaps it is sufficient to say that the Maya were observing precession because it was there to be observed, and because they were uniquely capable of observing it with remarkable accuracy.

The Maya tradition of astronomical science sits within the larger traditions of Mesoamerica, and the question remains whether other Mesoamerican cultures were similarly recording and observing precession, or sharing their data with the Maya. Certainly, if the Long Count system itself arose in part because of precessional calculations, this system descends from usage outside the Maya area. Furthermore, conceptions of multiple world-ages can be found throughout

Mesoamerica, and it is possible that a knowledge of precession existed in many places throughout the region. Future research may provide examples of precessional knowledge from other times and places within Mesoamerica, but they may require explicit numerical calculations like those found in the Serpent Series. In my own future research, I plan to discuss the cosmological texts from Palenque, as these texts from the Cross Group are the clearest example of precessional knowledge from the Classic period.

I am both humbled and, like Aveni, in awe of the sophistication of astronomical observations in the Serpent Series. Indeed, the Dresden Codex is a very special document. Out of the three confirmed Maya codices that survived the Spanish invasion, this one document contains just enough information to reconstruct some of the most spectacular astronomical knowledge of the ancient Maya. In this ongoing conversation across time, the ancient Maya are giving us one remarkable example of their capabilities as astronomers, mathematicians, and scholars. These achievements deserve our full recognition and their rightful place in the history of humankind, particularly in the face of their near destruction at the hands of European invaders who were, and perhaps still are, incapable of fully understanding them.

James Evans (1998:443) concludes his treatise on ancient astronomy with a quotation from Strabo's *Geography* I, 2, I:

> To engage in philosophical discussion with everyone is unseemly,
> but with Eratosthenes, Hipparchus, Posidonius, Polybius and others of such kind, it is a beautiful thing.

In this list of others, we must now include the multitudes of Maya and Mesoamerican astronomers, who shall forever remain nameless, but whose unparalleled accomplishments continue to inspire us. It has been the greatest honor and privilege to witness and to discuss their work.

References

Aldana, Gerardo V.
2001 *Oracular Science: Uncertainty in the History of Maya Astronomy 500–1600*. Ph.D. dissertation. Cambridge: Harvard University.

2002 Solar Stelae and a Venus Window: Science and Royal Personality in Late Classic Copán. In *Archaeoastronomy*, Supplement to Volume 33 of the Journal for the History of Astronomy, Number 27, pp. S29-S50. Cambridge: Science History Publications, Ltd.

2006 *The Apotheosis of Janahb Pakal: Science, History, and Religion at Classic Maya Palenque.* Boulder: University Press of Colorado.

2006b Creation Mythology and Oracular Science: Maya Hieroglyphic Windows into Indigenous Thought. Presentation at the University of California at Davis, October 12th, 2006.

Anderson, Arthur J.O., and Charles E. Dibble, tr.
1953 *Florentine Codex, General history of the things of New Spain. Book 7: The Sun, Moon, and stars, and the binding of the years*, by Bernardino de Sahagún. Monograph 14, part 8, book 7. Santa Fe: School of American Research, Archaeological Institute of America.

Andrews, E. Wyllis
1938 The phonetic value of Glyph C of the Maya supplementary series. *American Anthropologist*, 40:755–58. Menasha.

Apenes, Ola
1936 Possible Derivation of the 260 Day Period of the Maya Calendar. *Ethnos* (Stockholm), vol. 1, pp. 5–8.

Ardren, Traci, ed.
2002 *Ancient Maya Women*. Walnut Creek: Alta Mira Press.

Attinasi, John J.
1973 *Lak t'an - a grammar of the Chol (Mayan) word*. Ph.D. dissertation. Chicago: University of Chicago, Department of Anthropology. In John M. Dienhart1997.

Aulie, H. Wilbur, and Evelyn W. de Aulie, with Cesar Menéses Díaz, and Cristóbal López Vázquez
1978 *Diccionario Ch'ol-Espanol, Espanol-Ch'ol.* Serie de vocabularios y diccionarios indegenas, Mariano Silva y Aceves, ed., No. 21. México, D.F.: Instituto Lingüístico de Verano.

Aveni, Anthony F.
1989 *World Archaeoastronomy*, A. F. Aveni, ed. New York: Cambridge University Press.

1992 *The Sky in Mayan Literature*. A. F. Aveni, ed. New York: Oxford University Press.

1992 The Moon and the Venus Table: An Example of Commensuration in the Maya calendar. In *The Sky in Mayan Literature*. A. F. Aveni, ed., pp. 87-101. New York: Oxford University Press.

1996 Review of *Maya Cosmos: Three Thousand Years on the Shaman's Path* by David Freidel, Linda Schele, Joy Parker. In *American Anthropologist*, New Series, Vol. 98, No. 1, 197-198. March, 1996.

2001 *Skywatchers*. Austin: University of Texas Press.

Aveni, Anthony F., Harvey M. Bricker, and Victoria R. Bricker
2003 Seeking the Sidereal: Observable Planetary Stations and the Ancient Maya Record. *Journal for the History of Astronomy* 34: 145–161.

Barrera Vásquez, Alfredo, Juan Ramón Bastarrachea Manzano, William Brito Sansores, Refugio Vermont Salas, David Dzul Góngora, Domingo Dzul Poot
1980 *Diccionario Maya Cordemex. Maya-Español.* Español-Maya. Mérida: Ediciones Cordemex.

Barthel, Thomas
1952 Der Morgensternkult in den Darstellungen der Dresdener Mayahandschrift. *Ethnos* 17: 73-112.

Roger Beck
2006 *The Religion of the Mithras Cult in the Roman Empire: Mysteries of the Unconquered Sun*. Oxford: Oxford University Press.

Benson, Elizabeth, ed.
1985 Fourth Palenque Round Table, 1980, Palenque Round Table Series, Volume 6. Merle Greene Robertson, gen. ed. San Francisco: Pre-Columbian Art Research Institute.

Benson, Elizabeth, and Gillett G. Griffin, eds
1988 *Maya Iconongraphy*. Princeton: Princeton University Press.

Berger, A.L.
1976 Obliquity and precession for the last 5 million years. *Astronomy and Astrophysics* 51:127.

Berlin, Heinrich
1963 The Palenque Triad. *Journal de la Société des Américanistes*, n.s., 52:91-99. Paris.

Beyer, Hermann
1933 Emendations of the 'Serpent Numbers' of the Dresden Maya Codex. *Anthropos* (St. Gabriel Mödling bei Wien) 28: pp.1–7.

1943 The Long Count Position of the Serpent Number Dates. *Proc. 27th Int. Cong. Of Amer., Mexico, 1939* (Mexico) I: pp. 401–405.

Bolles, David
1997 Combined Dictionary–Concordance of the Yucatecan Mayan Language. *Reports Submitted to FAMSI*. 1997
URL: < http://www.famsi.org/reports/96072/udic.htm>

Boot, Erik
2004 The Nominal *YAXHA'(AL) CHAK* on Classic Maya Ceramics and a Possible cephalomorphic Variant for *YAX*. Article posted on www.mayavase.com. February 5, 2004.
URL: <http://www.mayavase.com/YaxhaalChak.pdf>

Bowditch, Charles P.
1903 Notes on the report of Teobert Maler in *Memoirs of the Peabody Museum*, Vol. II, no. II. Cambridge.

1910 *The Numeration, Calendar Systems and Astronomical Knowledge of the Mayas*. Cambridge.

Brasseur de Bourbourg, Charles Étienne
1864 *Relation des choses de Yucatán de Diego de Landa*. Paris.

Bricker, Harvey M., Anthony F. Aveni, and Victoria R. Bricker
2001 Ancient Maya Documents Concerning the Movement of Mars. *Proceedings of the National Academy of Sciences of the United States of America* 98, pp. 2107–2110.

Bricker, Harvey M., and Victoria R. Bricker
1983 Classic Maya Prediction of Solar Eclipses. *Current Anthropology* 24:1-23.

1997 More on the Mars Table in the Dresden Codex. *Latin American Antiquity* 8:384–397.

Bricker, Victoria R.
1986 *A Grammar of Mayan Hieroglyphs*. Middle American Research Institute, Tulane University, Pub. No. 56. New Orleans: Middle American Research Institute, Tulane University.

Bricker, Victoria R., and Harvey M. Bricker
1986 The Mars Table in the Dresden Codex. In R*esearch and Reflections in Archaeology and History, Essays in Honor of Doris Stone*, E.W. Andrews, ed., pp. 51-80, Middle American Research Institute, Publication 57. New Orleans: Middle American Research Institute, Tulane University.

1988 The Seasonal Table in the Dresden Codex and Related Almanacs. In *Archaeoastronomy*, Supplement to Volume 19 of the Journal for the History of Astronomy, Number 12, pp. S1-S62. Cambridge: Science History Publications, Ltd.

1992 Zodiacal References in the Maya Codices. In *The Sky in Mayan Literature*, Anthony F. Aveni, ed., pp. 148–183. New York: Oxford University Press.

2005 Astronomical References in the Water Tables on Pages 69 to 74 of the Dresden Codex. In *Painted books and indigenous knowledge in Mesoamerica: manuscript studies in honor of Mary Elizabeth Smith*, Elizabeth Hill Boone, ed., pp. 213–229. Pub. 69. New Orleans: Middle American Research Institute, Tulane University

Bricker, Victoria R., Eleuterio Po'ot Yah, and Ofelia Dzul de Po'ot
1998 *A Dictionary of The Maya Language As Spoken in Hocaba, Yucatan*. Salt Lake City: The University of Utah Press.

Brotherson, Gordon
1992 *The Book of the Fourth World*. Bloomington: Indiana University Press.

Callaway, Carl
2006 "The Birth of the Number Twenty in the Dresden Codex." Preliminary draft of an unpublished manuscript distributed at the 2006 Texas Maya Meetings in Austin.

Campion, Nicholas
1994 *The Great Year : astrology, millenarianism and history in the western tradition*. New York : Arkana.

1999 The Age of Aquarius: A Modern Constellation Myth. Paper presented to the Oxford VI Conference on Archaeoastronomy and Astronomy in Culture, June 1999.

2000 *Astrology, History and Apocalypse.* London: Center for Psychological Astrology Press.

Closs, Michael P.
1983 Were the Ancient Maya Aware of the Precession of the Equinoxes? Review of "The Paris Codex: Decoding an Astronomical Ephemeris." By Gregory Severin. *Archaeoastronomy* VI (1–4):164–171. College Park: The Journal of the Center for Archaeoastronomy.

Coe, Michael D.
1973 *The Maya Scribe and His World*. New York: Grolier Club.

1989 The Hero Twins: Myth and Image. In *The Maya Vase Book, Volume 1*, pp. 161–184. New York: Kerr Associates.

1989b The Royal Fifth: earliest notices of Maya writing. *Research Reports on Ancient Maya Writing 28*. Washington D.C.: Center for Maya Research.

1992 *Breaking the Maya Code.* New York: Thames and Hudson.

1994 *Mexico: From the Olmecs to the Aztecs*. New York: Thames and Hudson.

Coe, Michael D., and Justin Kerr
1997 *The Art of the Maya Scribe*. New York: Harry N. Abrams, Inc.

Cook, Suzanne
2005 *Lacandon Color Terms*. University of Victoria. May 2004 URL:<web.uvic.ca/lacandon/media/Lacandon_Colour_Terms.pdf>

Davoust, Michel
1995 *L'Ecriture Maya et son dechiffrement*. Paris: Centre National de la Recherche Scientifique.

1997 *Un Nouveau Commentaire du Codex du Dresde*. Paris: Centre National de la Recherche Scientifique.

Delgaty, Colin
1964 *Vocabulario tzotzil de San Andrés, Chiapas.* México: Summer Institute of Linguistics (Serie de vocabularios indígenas No. 10). In Dienhart 1997.

Dienhart, John M.
1997 *The Mayan Languages- A Comparative Vocabulary*, electronic version. Odense University.

Edmonson, Munro S.
1988 *The Book of the Year: Middle American Calendrical Systems.* Salt Lake City: University of Utah Press.

Evans, James
1998 *The History and Practice of Ancient Astronomy*. New York: Oxford University Press.

Fields, Virginia M., ed., Merle Greene Robertson, gen. ed.
1991 *Sixth Palenque Round Table, 1986*, Palenque Round Table Series, Volume 8. Norman: University of Oklahoma Press.

Flores Gutiérrez, Daniel
1995 En el problema del inicio del año y el origen del calendario mesoamericano: Un punto de vista astronómico. *Coloquio Cantos de Mesoamérica: Metodologías cientificas en la búsqueda del conocimiento prehispánico*, Daniel Flores, ed., pp. 119–132. Mexico City: Instituto de Astronomía, Facultad de Ciencias, Universidad Autónoma de México.

Förstemann, Ernst W.
1895 *Zur Entzifferung der Mayahandschriften.* V. Zu Dresd. 71–73 und 51–58. Druck von C. Heinrich, Dresden.

1897 *Zur Entzifferung der Mayahandschriften.* VI. Dresden.

1901 *Commentar zur Mayahandschrift der Königlichen öffentlichen Bibliotek zu Dresden.* Verlag von Richard Bertling, Dresden.

1905 Die Schlangenzahlen der Dresdener Mayahandschrift. *Das Weltall* 5:200. Berlin.

1906 Commentary on the Maya Manuscript in the Royal Public Library of Dresden. *Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University,* 4(2): 182-215. Cambridge, Massachusetts: Peabody Museum of Archaeology and Ethnology, Harvard University:

Foundation for the Advancement of Mesomerican Studies, Inc.
2007 *The complete Förstemann version of the Dresden Codex in PDF format.* URL: < http://www.famsi.org/mayawriting/codices/dresden.html>

Fountain, John W., and Rolf M. Sinclair, eds.
2005 *Current Studies in Archaeoastronomy: Conversations Across Time and Space. Selected Papers from the Fifth Oxford International Conference at Santa Fe, 1996*. Edited by John W. Fountain and Rolf M. Sinclair. Durham: Carolina Academic Press.

Frazer, James G.
1911 *The Golden Bough. A Study in Magic and Religion*, Part I, vol, I. *The Magic Art and the Evolution of Kings*. London: Macmillan 3rd edn.

Freidel, David, Linda Schele and Joy Parker
1993 *Maya Cosmos, Three Thousand Years on the Shaman's Path*. New York: William Morrow and Company.

Frobenius, Leo
1904 *Das zeitalter des sonnengottes.* Berlin:G. Reimer.

Girard, Rafael
1948 *El Calendario Maya-Mexica: Origen, Función, Desarrollo y Lugar de Procedencia*. Mexico City: Editorial Stylo.

Goodman, Joseph T.
1897 The Archaic Maya Inscriptions. Appendix to Vol. VI of *Biologia Centrali-americana (Archaeology)*, A. P. Maudslay, ed. London: Porter.

1905 Maya Dates. *American Anthropologist* 7:642-647.

Graham, Ian
1967 Archaeological Explorations in El Peten, Guatemala. *Middle American Research Institute, Tulane University, Pub. 33.* New Orleans: Middle American Research Institute, Tulane University.

1978 *Corpus of Maya Hieroglyphic Inscriptions, Volume II, Part 2*. Cambridge, Massachusetts: Peabody Museum of Archaeology and Ethnology, Harvard University.

1979 *Corpus of Maya Hieroglyphic Inscriptions, Volume III, Part 2.* Cambridge, Massachusetts: Peabody Museum of Archaeology and Ethnology, Harvard University.

Greene Robertson, Merle, ed.
1976 *The Art, Iconography & Dynastic History of Palenque Part 3: Proceedings of the Segunda Mesa Redonda de Palenque, December 14-21, 1974, Palenque, Chiapas, Mexico*. Pebble Beach: Robert Louis Stevenson School.

1980 *Third Palenque Round Table, 1978 Part 2, Palenque Round Table Series, Volume 5*. Austin: University of Texas Press.

Gressmann, Hugo
1906 Winckler's altorientalisches Phantasiebild. *Zeitschrift für Wissenschaftliche Theologie*, Band 49, pp. 289-309.

Grimm, Jacob
1835 *Deutsche Mythologie.* Göttingen : In der Dieterichschen Buchhandlung.

Grofe, Michael J.
2006 "Glyph Y and GII: The Mirror and the Child" Glyph Dwellers, no. 21, February 2006. URL: <http://cougar.ucdavis.edu/NAS/Maya/R21.pdf>

Gronemeyer, Sven
2006 Glyphs G and F identified as aspects of the Maize God. *Wayeb' Notes*. No. 22. URL: < http://www.wayeb.org/notes/wayeb_notes0022.pdf>

Grube, Nikolai, and Werner Nahm
1994 A Census of Xibalba: A Complete Inventory of "Way" Characters on Maya Ceramics. In Kerr and Kerr 1994:686-715.

Grube, Nikolai, and Linda Schele
1991 Tzuk in Classic Maya Inscriptions. *Texas Notes on Precolumbian Art, Writing, and Culture*, No. 14.

Hartner, Willy
1970 Al-Battani. *Dictionary of Scientific Biography*. Charles C. Gillispie, ed., Vol. 1:507–516. New York: Charles Scribner's Sons.

Hilton, J.L., ed.
2006 Report of the International Astronomical Union Division I Working Group on Precession and the Ecliptic. *Celestial Mechanics and Dynamical Astronomy* 94:351–367.

Hofling, Charles A., with Félix Fernando Tesucún
1997 *Itzaj Maya-Spanish-English Dictionary*. Salt Lake City: University of Utah Press.

Houston, Stephen D.
1993 *Hieroglyphs and History at Dos Pilas: Dynastic Politics of the Classic Maya.* Austin: University of Texas Press.

Houston, Stephen D., and David Stuart
1996 Gods, Glyphs, and Kings: Divinity and Rulership among the Classic Maya. *Antiquity* 70:289-312.

Ilía Nájera Colorado, Martha
1995 El temor a los eclipses entre comunidades mayas contemporáneas. In *Religión y sociedad en el area maya*, edited by Carmen Varela Torrecilla, Juan Luis Bonor Villajero, and Yolanda Fernández Marquínez, pp. 319–27. Sociedad Española de Estudios Mayas, pub. 3. Madrid: Instituto de Cooperación Iberoamericana.

Imaginova Canada, Ltd.
2006 Starry Night Pro, Version 6.0.0 pcEM. Astronomy Software. URL: < http://www.starrynight.com>

Jenkins, John Major
1998 *Maya Cosmogenesis 2012: The True Meaning of the Maya Calendar End-Date*. Santa Fe: Bear and Comapany.

Jeremias, Alfred
1903 *Im Kampfe um Babel und Bibel : ein Wort zur Verständigung und Abwehr*. Leipzig: Hinrichs.

Justeson, John S.
1984 Appendix B: Interpretations of Mayan Hieroglyphs. In Justeson and Campbell 1984: 315-362.

1989 Ancient Maya Ethnoastronomy: An Overview of Hieroglyphic Sources. In *World Archaeoastronomy*, A. F. Aveni, ed., pp. 76-129. New York: Cambridge University Press.

Justeson, John S., and Lyle Campbell, eds.
1984 *Phoneticism in Mayan Hieroglyphic Writing*. Institute for Mesoamerican Studies, State University of New York Publication 9. Albany: Institute for Mesoamerican Studies, State University of New York at Albany.

Kaufman, Terrence S., and William M. Norman
1984 An Outline of Proto-Cholan Phonology, Morphology, and Vocabulary. In Justeson and Campbell 1984:77-166.

Kelley, David H.
1962 Glyphic Evidence for a Dynastic Sequence at Quirigua, Guatemala. *American Antiquity* 27:323–335.

1965 The Birth of the Gods at Palenque. *Estudios de Cultura Maya* 5:93-134. México, D.F.: Seminario de Cultura Maya.

1972 The Nine Lords of the Night. In *Studies in the Archaeology of Mexico and Guatemala*, edited by John A. Graham, pp. 53-68. Contributions of the University of California Archaeological Research Facility, No. 16. University of California, Berkeley.

1989 Mesoamerican Astronomy and the Maya Calendar Correlation Problem. In *Memorias del Segundo Coloquio Internacional de Mayistas* 1:65–95. Mexico: Univesidad Nacional Autónomia de México.

Kerr, Justin, and Barbara Kerr, eds.
1994 *The Maya Vase Book: A Corpus of Rollout Photographs of Maya Vases, Volume 4*. New York: Kerr Associates.

Knorosov, Yuri V.
1955 La escritura de los antiguos Mayas (ensayo de descifrado) [Spanish translation of Sistema Pis'ma Drevnikh Maiia]. *Instituto de Etnografia N. N. Miklujo-Maklai*. Moscow: Editorial de la Academia de Ciencias de la URSS.

1958 The Problem of the Study of the Maya Hieroglyphic Writing. *American Antiquity* 23:284-291.

1967 *Selected Chapters from The Writing of the Maya Indians*. Translated by Sophie Coe; Tatiana Proskouriakoff, collaborating editor. Russian Translation Series, Vol. 6. Cambridge, Massachusetts: Peabody Museum of Archaeology and Ethnology, Harvard University:

Kuhn, Thomas
1970 Logic of Discovery and Psychology of Research. In Imre Lakatos and Alan Musgrove, Eds., *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.

Kugler, Franz
1909 Auf den Trümmern des Panbabylonismus. *Anthropos*, Band IV, pp. 477–499).

1910 *Im Bannkreis Babels: Panbabylonistische Konstruktionen und Religionsgeschichtliche Tatsachen.* Münster: Aschendorff.

Lacadena, Alfonso
1994 Propuesta para la lectura del signo T158. *Mayab* 9:62-65.

1997 Cha'/ka', Yax and Wi'il: Three Examples of Adverbial use Adjectives in Classic Maya Inscriptions. *Texas Notes on Precolumbian Art, Writing, and Culture*, Number 78, 1997. Austin: Center of the History and Art of Ancient American Culture, Art Department, University of Texas at Austin.

Laughlin, Robert M.
1975 *The Great Tzotzil Dictionary of San Lorenzo Zinacantán.* Smithsonian Contributions to Anthropology, Number 19. Washington, D.C.: Smithsonian Institution Press.

1977 *Of Cabbages and Kings: Tales from Zinacantán*. Smithsonian Contributions to Anthropology, no. 23. Washington, D.C.: Smithsonian Institution Press.

Laughlin, Robert M., and Carol Karasik
1988 *The People of the Bat*. Washington, D.C.: Smithsonian Institution Press.

Leach, Edmund
1970 Review of *Hamlet's Mill*. In *The New York Review of Books*, February 12, 1970, p. 36.

Lévy-Bruhl, Lucien
1918 *Les Fonctions mentales dans les sociétés inférieures.* Paris: F. Alcan.

1966 *How Natives Think*. Translation of *Les Fonctions mentales dans les sociétés inférieures*, by Lilian Clare. New York: Washington Square Press.

Looper, Matthew G.
1995 *The Sculpture Programs of Butz'-Tiliw, an Eighth-Century Maya King of Quirigua, Guatemala*. Ph.D. dissertation, University of Texas at Austin.

2002 Women-Men (and Men-Women): Classic Maya Rulers and the Third Gender, in *Ancient Maya Women* ed. by Traci Arden Walnut Creek CA: Altamira Press

2003 *Lightning Warrior: Maya Art and Kingship at Quirigua*. Austin: University of Texas Press.

Lounsbury, Floyd G.
1976 A Rationale for the Initial Date of the Temple of the Cross at Palenque. In Greene Robertson 1976:211-224.

1978 Maya Numeration, Computation, and Calendrical Astronomy. In *Dictionary of Scientific Biography*, Charles Couldson Gillespie, ed. Vol XV, Charles Scribner's Sons, New York, pp. 759–818.

1980 Some Problems in the Interpretation of the Mythological Portion of the Hieroglyphic Text of the Temple of the Cross at Palenque. In Greene Robertson 1980:99-115.

1983 The Base of the Venus Tables of the Dresden Codex, and Its Significance for the Calendar-correlation Problem. In *The Proceedings of the 44th International Congress of Americanists*, Anthony F. Aveni and Gordon Brotherston, BAR International Series 174, Eds., pp. 1-26. London: Oxford University Press.

1985 The Identities of the Mythological Figures in the Cross Group Inscriptions of Palenque. In Benson 1985:45-58.

1992 A Solution for the Number 1.5.5.0 of the Mayan Venus Table. In *The Sky in Mayan Literature*. Anthony F. Aveni, ed., pp. 207-215. New York: Oxford University Press.

Love, Bruce
1991 A Text from the Dresden New Year Pages. In Fields 1991:293-302.

1994 *The Paris Codex: Handbook for a Maya Priest.* Austin: University of Texas Press.

Macri, Martha J.
2005 A Lunar Origin for the Mesoamerican Calendars of 20, 13, 9, and 7 Days. In *Current Studies in Archaeoastronomy: Conversations Across Time and Space. Selected Papers from the Fifth Oxford International Conference at Santa Fe, 1996*. Edited by John W. Fountain and Rolf M. Sinclair. Durham: Carolina Academic Press.

Macri, Martha J., and Matthew G. Looper
2003 *The New Catalog of Maya Hieroglyphs, Volume One: The Classic Period Inscriptions.* Norman: University of Oklahoma Press.

Macri, Martha J., and Jan McHargue, Eds.
1996 *Eighth Palenque Round Table, 1993.* Merle Greene Robertson, general ed. San Francisco; Pre-Columbian Art Research Institute.

MacLeod, Barbara
1990 *Deciphering the Primary Standard Sequence.* Ph.D. dissertation, University of Texas, Austin.

1991 The Classic Name for Cumku. *North Austin Hieroglyphic Hunches*, Number 8, February 22, 1991.

1995 T128: The Next Generation (and Hopefully, a Resolution)!! *North Austin Hieroglyphic Hunches 11*.

Malmström, Vincent H.
1973 Origin of the Mesoamerican 260-day Calendar. *Science*, vol. 181, no. 4103, pp. 939–941.

1978 A Reconstruction of the Chronology of Mesoamerican Calendrical Systems. Journal for the History of Astronomy, vol. 9, pp.105-116.

1997 *Cycles of the Sun, Mysteries of the Moon: The Calendar in Mesoamerican Civilization*. Austin: University of Texas Press.

2003 The Astronomical Insignificance of Maya Date 13.0.0.0.0. URL:< http://www.dartmouth.edu/~izapa/M-32.pdf>

Martínez Hernandez, Juan
1926 *Paralelismo entre los calendarios maya y azteca. Su correlación con el calendario juliano.* Merida: Compañía Tipográfica Yucateca.

1929 *Diccionario de Motul, Maya Español. Atribuido a Fray Antonio de Cuidad Real y Arte de Lengua Maya por Fray Juan Coronel*. Mérida: Compañía Tipográfica Yucateca.

Mathews, Peter
1980 Notes on the Dynastic Sequence of Bonampak, Part 1. In Greene Robertson 1980:60-73.

Mayer, Karl Herbert
1980 *Maya Monuments of Unknown Provenance in the United States*. Ramona, California: Acoma Books.

Meeus, Jean, and Denis Savoie
1992 The History of the Tropical Year. *Journal of the British Astronomical Association*. 102, 1:40–42.

Mendez, Alonso Mendez, Edwin L. Barnhart, Christopher Powell, and Carol Karasik
2005 Astronomical Observations from the Temple of the Sun. *Archaeoastronomy: The Journal of Astronomy in Culture.* Vol. XIX, 2005.

Merrill, Robert H.
1945 Maya Sun Calendar Dictum Disproved. *American Antiquity*, vol. 10, pp. 307–311.

Milbrath, Susan
1996 Postclassic Maya Metaphors for Lunar Motion. In *Eighth Palenque Round Table, 1993.* Martha J. Macri and Jan McHargue, Eds.; Merle Greene Robertson, general ed.; pp. 379–392. San Francisco; Pre-Columbian Art Research Institute.

1999 *Star Gods of the Maya: Astronomy in Art, Folklore, and Calendars.* Austin: University of Texas Press

Miles, A.C., and Rush Rhees
1971 Ludwig Wittgenstein's 'Remarks on Frazer's *Golden Bough*'. In *The Human World*, no. 3, May 1971, pp. 28–41. [Translated from the original German version in Synthèse, no. 17, 1967]

Montejo, Victor D.
1993 In the Name of the Pot, the Sun, the Broken Spear, the Rock, the Stick, the Idol, Ad Infinitum and Ad Nauseum: An Expose of Anglo Anthropologists Obsessions with and Invention of Maya Gods. In *Wicazo SA, Review*, Spring 1993, Vol. IX, No. 1, Native American Studies, UCD.

1999 Becoming Maya?: Appropriation of the White Shaman. In *Native Americas.* Spring 1999. pp. 58-61

2001 The Road to Heaven: Jakaltek Maya Beliefs, Religion, and the Ecology. In *Indigenous Traditions and Ecology: The Interbeing of Cosmology and Community*. J.A. Grim, ed. Cambridge: Harvard University Press.

Montgomery, John
1990 A Note on the date of Piedras Negras Lintel 3. In *U Mut Maya III*, Tom & Carolyn Jones eds. pp. 139-141. Arcata: Tom Jones & Carolyn Young.

1992 Drawings of Maya Monuments and Inscriptions. In *U Mut Maya IV*, Tom & Carolyn Jones eds. pp. 283-290.

Morley, Sylvanus Griswold
1915 *An Introduction to the Study of the Maya Hieroglyphs*. Smithsonian Institution: Bureau of American Ethnology Bulletin 57. Washington, D. C.: Government Printing Office.

1916 The Supplementary Series in the Maya inscriptions. In *Holmes Anniv. Vol.*, pp. 366–96. Washington, D.C.

Neugebauer, Otto von
1950 The Alleged Babylonian Discovery of the Precession of the Equinoxes. *Journal of the American Oriental Society*, Volume 70, Number 1, pp.1-8.

Nuttall, Zelia
1928 Nouvelles lumières sur les civilizations americaines et le système du calendrier. *Proceedings of the Twenty-second International Congress of Americanists* (Rome), pp. 119–148.

Pagden, A.R., ed.
1975 *The Maya: Diego de Landa's Account of the Affairs of Yucatán.* Edited and translated by A.R. Pagden. Chicago: J. Philip O'Hara, Inc.

Payne-Gaposchkin Cecilia
1973 Review of Hamlet's Mill. In *Journal for the History of Astronomy*, Volume 3, 1972, Pages 206-211.

Pío-Pérez, Juan
1864 Cronologia Antigua de Yucatán y Examen del Método con que los Indios Contaba el Tiempo; Sacada de Varios Documentos Antiguos. In *Collection de documents dans les langues indigénes pour servir à l'étude de l'histoire de la philology de l'Amerique ancienne*, by C.E. Brasseur de Bourbourg, pp. 366–429. Paris.

Popper, Karl R.
1959 *The Logic of Scientific Discovery*. New York: Harper Torchbooks.

Powell, Christopher
1997 *A New View on Maya Astronomy*. M.A. Thesis, University of Texas, Austin, 1997.

Proskouriakoff, Tatiana
1960 Historical Implications of a Pattern of Dates at Piedras Negras. *American Antiquity* 25:454-475.

Rätsch, Christian, and K'ayum Ma'ax
1984 *Ein Kosmos im Regenwald*. Cologne: Eugen Diederichs Verlaag.

Ridington, Robin
2000 Voice, Representation and Dialogue: The Poetics of Native American Spiritual Traditions. In *Native American Spirituality: A Critical Reader*, Lee Irwin, Ed, pp. 97–120. Lincoln: University of Nebraska Press.

Rosny, Léon de
1876 Essai sur le dechiffrement de l'écriture hiératique de l'Amerique Centrale, la pierre de Baude-Leemans. *Revue Orientale et Americaine*, 2nd series, I:225-261. Paris.

Santillana, Giorgio de, and Hertha von Dechend
1969 *Hamlet's mill: an essay on myth and the frame of time*. Boston: Gambit.

Satterthwaite, Linton
1965 Calendrics of the Maya Lowlands. In *Archaeology of Southern Mesoamerica*, part 2, Gordon Willey, ed., pp. 603–631. *Handbook of Middle American Indians*, vol. 3, Robert Wauchope, general Editor. Austin: University of Texas Press.

Schele, Linda
1979 The Palenque Traid: A Visual and Glyphic Approach. *Actes du XLIIe Congres de Americanistes* 7:401–23.

1991 *Workbook for the XVth Maya Hieroglyphic Workshop at Texas, March 9-10, 1991; Yaxchilan*. Austin: Department of Art and Art History and the Institute of Latin American Studies, University of Texas at Austin.

1992 Notebook for the XVIth Maya Hieroglyphic Workshop at Texas, March 14-15, 1992; Palenque: the Group of the Cross. Austin: Department of Art and Art History and the Institute of Latin American Studies, University of Texas at Austin.

Schele, Linda and Nikolai Grube
1997 *Notebook for the XXIst Maya Hieroglyphic Forum at Texas*, *March, 1997*. Austin: Department of Art and Art History, the College of Fine Arts and the Institute of Latin American Studies, University of Texas at Austin.

Schele, Linda, Nikolai Grube, and Federico Fahsen
1992 The Lunar Series in Classic Maya Inscriptions: New Observations and Interpretations. *Texas Notes on Precolumbian Art, Writing, and Culture*, Number 29, 1992. Austin: Center of the History and Art of Ancient American Culture, Art Department, University of Texas at Austin.

Schele, Linda, and Peter Mathews
1993 *Notebook for the XVIIth Maya Hieroglyphic Workshop at Texas*, *March 13-14, 1993; Palenque: Dynastic History*. Austin: Department of Art and Art History, the College of Fine Arts, the College of Liberal Arts and the Institute of Latin American Studies, University of Texas at Austin.

Schele, Linda, and Mary Ellen Miller
1986 *The Blood of Kings: Dynasty and Ritual in Maya Art*. Fort Worth: Kimball Art Museum.

Schele, Linda, and Elizabeth Newsome
1991 Taking the Headband at Copán. *Copán Not*e, No. 49.

Schellhas, Paul
1904 Representation of Deities of the Maya Manuscripts. *Papers of the Peabody Museum of Archaeology and Ethnology, Harvard University, Vol 4, no. 1*. Cambridge, Massachusetts: Peabody Museum of Archaeology and Ethnology, Harvard University.

Schnabel Paul
1923 *Berossos und die babylonisch-hellenistische Lieratur.* Leipzig: B. G. Teubner.

1927 Kidenas, Hipparch und die Entdeckung der Präzession. *Zeitschrift für Assyriologie und Verwandte Gebiete*, Neue Folge, Band 3 (Band 37), pp. 1-60.

Severin, Gregory
1981 The Paris Codex: Decoding an Astronomical Ephemeris. *Transactions of the American Philosophical Society*, Vol. 71, part 5. Philadelphia.

Siecke, Ernst
1892 *Die Liebesgeschichte des Himmels Untersuchungen zur indogermanischen Sagenkunde.* Strassburg : Karl J. Trübner.

Spinden, Herbert J.
1942 Time scale for the New World. *Proc. Eighth Amer. Scientific Cong.*, 2: 39–44. Washington D.C.

Stuart, David
1988 Blood Symbolism in Maya Iconography. In *Maya Iconongraphy*. Elizabeth P. Benson & Gillett G. Griffin, eds. pp. 175-221. Princeton: Princeton University Press.

1989 The "First Ruler" on Stela 24. *Copan Note 7*. Honduras: Copán Mosaics Project and the Instituto Hondureño de Anthropología e Historia.

1998 "The Fire Enters His House:" Architecture and Ritual in Classic Maya Texts. In *Function and Meaning in Classic Maya Architecture: A Symposium at Dumbarton Oaks*, 7th and 8th October 1994, Stephen D. Houston ed., pp. 373-425. Washington, D. C.: Dumbarton Oaks Research Library and Collection.

2005 *The Inscriptions from Temple XIX at Palenque*. San Francisco: The Pre-Columbian Art Research Institute.

2006 *Sourcebook for the 30th Maya Meetings, March 14–19, 2006*. Austin: The Mesoamerican Center, Department of Art and Art History, The University of Texas at Austin.

Stuart, David, and Stephen Houston
1991 Classic Maya Place Names. *Studies in Pre-Columbian Art and Archaeology 33*. Washington, D. C.: Dumbarton Oaks Research Library and Collection.

Stuart, David, Stephen D. Houston, and John Robertson
1999 *Recovering the Past: Classic Maya Language and Classic Maya Gods. Notebook for the XXIIIrd Maya Hieroglyphic Forum at Texas*. Austin: Department of Art and Art History, the College of Fine Arts, and the Institute of Latin American Studies, University of Texas at Austin.

Stucken, Eduard
1907 *Astralmythen: Religionsgeschichtliche untersuchungen.* Leipzig: E. Pfeiffer

Swerdlow, N.M.
1991 On the cosmical mysteries of Mithras (review article of Ulansey 1989), *Classical Philology*, 86: 48-63

Tambiah, Stanley Jeyeraja
1990 *Magic, Science, Religion, and the Scope of Rationality*. The Lewis Henry Morgan Lectures: 1981. Cambridge: Cambridge University Press.

Tate, Carolyn E.
1992 *Yaxchilan: The Design of a Maya Ceremonial City*. Austin: University of Texas Press.

Taube, Karl A.
1992 *The Major Gods of Ancient Yucatan.* Studies in pre-Columbian Art and Archaeology 32. Washington, D. C.: Dumbarton Oaks Research Library and Collection.

Tedlock, Barbara
1982 *Time and the Highland Maya.* Albuquerque: University of New Mexico Press.

Tedlock, Dennis
1992 Myth, Man and the Problem of Correlation in Mayan Books. In *The Sky in Mayan Literature*, A. F. Aveni, Ed., pp. 247-273.New York: Oxford University Press.

1996 *Popol Vuh: The Definitive Edition of the Mayan Book of the Dawn of Life and the Glories of Gods and Kings.* New York: Simon and Schuster.

Teeple, John E.
1931 *Maya Astronomy.* Contributions to American Archaeology, Vol. I, No. 2, pp. 29-116, Carnegie Publication No. 403. Washington, D. C.: Carnegie Institution of Washington.

Thompson, Gary D.
2006 The Myth of Babylonian Knowledge of Precession. In *Essays Relating To The History Of Occidental Constellations and Star Names to the Classical Period*. URL:< http://members.optusnet.com.au/gtosiris/page9f.html>

2007 The Development, Heyday, and Demise of Panbabylonism. In *Essays Relating To The History Of Occidental Constellations and Star Names to the Classical Period*. URL:<http://members.optusnet.com.au/gtosiris/page9e.html>

2007b Critics and Criticisms of Hamlet's Mill. In *Essays Relating To The History Of Occidental Constellations and Star Names to the Classical Period*. URL:<http://members.optusnet.com.au/gtosiris/page9j.html>

Thompson, J. Eric S.
1927 A correlation of the Mayan and European calendars. *Field Museum of Natural History Publication* 241, Anthropology Series 27 (1):3–22.

1929 Maya Chronology: Glyph G of the Lunar Series. *American Anthropologist*, 31:223–31. Menasha.

1935 Maya chronology: the correlation question. *Carnegie Inst. Wash*., pub. 456, Contrib. 14, Washington D.C.

1943 Maya epigraphy: a cycle of 819 days. *Notes on Middle American Archaeology and Ethnology*, Vol. I, No. 22, pp. 137-151. .Washington, D.C.: Carnegie Institution of Washington.

1962 *A Catalog of Maya Hieroglyphs.* Norman: University of Oklahoma Press.

1967 Maya Creation Myths (Part 2). *Estudios de Cultura Maya* 6: 15–44.

1971 *Maya Hieroglyphic Writing: An Introduction*. Norman: University of Oklahoma Press.

1972 *A Commentary on the Dresden Codex A Maya Heiroglyphic Book.* Philadelphia: American Philosophical Society.

Toomer, G. J.
1978 Hipparchus. *Dictionary of Scientific Biography*. Charles C. Gillispie, ed., Vol. 15:207-224. New York: Charles Scribner's Sons.

Tuhiwai-Smith, Linda.
1999 *Decolonizing Methodologies*. New York: St Martin's Press.

Ulansey, David
1989 *The Origins of the Mithraic Mysteries : cosmology and salvation in the ancient world.* New York : Oxford University Press.

United States Government Printing Office.
2000 *The Astronomical Almanac for the Year 2000.* Washington, DC: Navy Dept., Naval Observatory, Nautical Almanac Office, p. C1.

Vail, Gabrielle
2002 *The Madrid Codex: A Maya Hieroglyphic Book.* A website and database available on-line at www.doaks.org/codex. Washington, D. C.: Dumbarton Oaks Research Library and Collection:

Vail, Gabrielle, and Andrea Stone
2002 Representations of Women in Postclassic and Colonial Maya Literature and Art. *Ancient Maya Women*, Traci Ardren, ed., pp. 203-228. Walnut Creek: Alta Mira Press.

Willson, Robert W.
1924 Astronomical Notes on the Maya Codices. *Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University*, 6(3). Cambridge, Massachusetts: Peabody Museum of Archaeology and Ethnology, Harvard University.

Winckler, Hugo
1903 *Himmels- und Weltenbild der Babylonier als Grundlage der Weltanschauung und Mythologie aller Völker*. Leipzig: Hinrichs.

Wisdom, Charles
1950 *Materials on the Chortí Language*. Microfilm Collection of Manuscripts on Cultural Anthropology, 28. Chicago: University of Chicago Library.

Yasugi, Yoshiho, and Kenji Saito
1991 Glyph Y of the Maya Supplementary Series. *Research Reports on Ancient Maya Writing*, No. 34 and 35, April 1991, pp. 1-12. Washington, D.C.: Center for Maya Research.