Beyond the "Dresden Codex": New Insights into the Evolution of Maya Eclipse Prediction

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Background of the Study

In 1973 the author published a paper in Science in which he traced the origin of the Mesoamerican 260-day sacred almanac to Izapa, a large Pre-Classic ceremonial center located on the Pacific coastal plain of southernmost Mexico. Although he had not visited the site, through a combination of clues derived both from the literature then available as well as from observations he had made on his first field trip to highland Mexico and the Yucatan earlier the same year, he deduced that Izapa was the only place that met the almanac's necessary prerequisites of astronomy, history, and geography. These were (1) location along a parallel of latitude at which a 260-day interval can be measured between zenithal sun passages, (2) a site that predated the known usage of the almanac, and (3) a place situated in a lowland tropical niche where fauna such as alligators, monkeys, and iguanas were to be found, for animals such as these served as day-names in the almanac. His solution to the long-running controversy over whether the Mesoamerican calendar was the product of the Mayas or the "Olmecs" obviously tipped the balance decisively in favor of the latter, a misnamed people who he now identified as the Zoques, the original inhabitants of the region of Soconusco where Izapa is located. His research also revealed that the correlation coefficient of 584,285 proposed by John Eric Sydney Thompson in 1927 was the only one that yielded a starting date of August 13th for the sacred almanac, thus according precisely with the southward zenithal passage of the sun over Izapa.

During the author's first field trip to Izapa in 1974, he discovered that the Mesoamerican 365-day secular calendar had also been devised there. Once again, the site's geographic location proved to be of critical importance, for it had been chosen with such care that from Izapa, at the summer solstice, the sun would appear to rise out of Volcán Tajumulco, the highest mountain in Central America. Thus, by counting the days between successive sunrises over the most prominent topographic feature within sight, the Zoques had found a means of calibrating the length of the tropical year with much greater precision. This discovery not only confirmed that each of the time-counts had been developed independently but also that the second was almost certainly intended as a refinement to the first.

In 1976, an observation of Bishop Landa turned the author's attention toward the Yucatan. In his volume Relación de Las Cosas de Yucatán, Landa reported that the Maya "always begin their New Year on the 16th day of *our* month of July". Of course, when he was writing, the Christian world used the Julian calendar, so the equivalent date in our present Gregorian calendar would have been July 26th. Although Landa couldn't account for why the Maya used this date to start their New Year, the present author realized that they had merely exchanged the day of the southward zenithal passage of the sun over Izapa to a place in the Yucatan where this event would have more meaning to the local populace. By examining a solar ephemeris, he found that this event took place on July 26th at latitude 19.5º N., and because the ceremonial center of Edzná is the only site of importance along this parallel, the author concluded that Landa had made his observation there, in the Puuc district of western Yucatan.

To date the key events in the evolution of the Mesoamerican time-counts, the author devised a computer program to run both the Maya and Christian calendars back from a known date of their correspondence to the times when the following innovations took place: (1) the Maya shift of the start of their New Year from August 13th to July 26th; (2) the combination of the 260-day sacred almanac and the 365-day secular calendar to form the so-called "Long Count"; (3) the origin of 365-day secular calendar; and (4) the origin of the 260-day sacred almanac. The results of his computer analysis were published in the Journal for the History of Astronomy in 1978 and are abstracted in the table below.

Table 1 – Dates of Key Events in the Calendrical History of Mesoamerica

EVENT	DATE
Maya New Year Shifted from 8/13 to 7/26	July 26, 48
Combination of Sacred Almanac and Secular Calendar into the "Long Count"	September 18, -235 *
Beginning of the Secular Calendar	June 22, -1324 **
Beginning of the Sacred Almanac	August 13, -1358

* Confirms the calculation of Teeple made in 1931 but discounted by Thompson.
** Reinforced by the appearance of the "solsticial orientation principle" at the "Olmec" site of San Lorenzo as early as 1200 BCE and its subsequent diffusion to sites including La Venta, Tres Zapotes, and Monte Alban by 800 BCE.

Source: "A Reconstruction of the Chronology of Mesoamerican Calendrical Systems", *Journal for the History of Astronomy*, Vol. 9, pp.105-116. Cambridge: 1978.

The fact that we now know that Landa had visited Edzná gives new poignancy to his remarks near the end of Chapter 41 of his volume where he says "We collected a great number of their books, and because they deal with nothing but superstition and the lies of the devil, we burned them all, which caused the people shock and gave them much pain." As the place where the calendar had become "Mayan", Edzná had no doubt served as the intellectual keystone of their civilization, and what had most likely been its largest single repository of written knowledge, Landa had completely reduced to ashes. Indirect evidence for such a conclusion comes from John Eric Sydney Thompson who found that a one-day correction had been made to the calendar in the year 672. Although he noted that this correction first showed up in the Puuc region, he also observed that it was adopted throughout the Maya realm soon thereafter. Thus, without realizing the geographic significance of Edzná, Thompson had inadvertently stumbled across a highly suggestive clue to the astronomical and calendrical "clout" that it wielded.

When the present author made his first visit to Edzná in 1978, he identified three of its structures as having served astronomical functions. At the base of the site's most commanding building, a five-story pyramid called "Cinco Pisos", was an ingenious

Figure 1. The gnomon at the base of Edzná's principal pyramid,"Cinco Pisos". It consists of a tapered shaft of stone surmounted by a stone disk having the same diameter as the base of the shaft. At noon on the days of the zenithal sun passage, the entire shaft is in the shadow of the disk; at other times, the shaft itself casts a shadow, as in the photograph above. (Photo by author.)

gnomon that allowed the Maya to calibrate the zenithal passage of the sun with remarkable precision. Located at an azimuth of 285.5º from Cinco Pisos is a small pyramid that marks the sunset position on August 13th, toward which the entire ceremonial center had been oriented. Finally, intersecting the horizon at an azimuth of 300º (again measured from Cinco Pisos) is a second small pyramid that the author recognized as a marker for the northernmost setting point of the moon. It was the latter structure that he found especially intriguing because the only function it could have conceivably served was as a tool for the prediction of eclipses.

Unknown to the author, Ray Matheny of Brigham Young University had carried out extensive excavations at the site in 1973, and had named the latter pyramid “La Vieja” (“The Ancient One”), due both to its age and its dilapidated condition. Matheny’s work proved that Edzná was not only one of the earliest ceremonial centers founded by the Maya – dating to 150 BCE -- but one of their largest urban nodes as well, probably boasting a population of more than 20,000 in its heyday. Although he had not recognized the astronomical function of “La Vieja”, from his dating of the structure we can, nevertheless, confidently conclude that the Maya had been preoccupied with the prediction of eclipses since the very dawn of their civilization.

Figure 2. “Cinco Pisos”, Edzná’s most commanding structure, is over 30 meters (100 feet) in height and can se seen across the low limestone peninsula of Yucatan for a distance of nearly 50 kilometers (30 miles). It is oriented through the portal (seen above) to a notch in an elongated mound that serves as an artificial horizon on the west to the top of a smaller pyramid that marks the position of the setting sun of August 13, the day the Maya believed the present world was created. (Photo by author.)

The Maya’s Struggle to Comprehend the Moon

As practitioners of naked-eye, horizon-based astronomy, it is obvious that the Maya never recognized the existence of “nodes”, or points where the moon’s orbit intersected that of the sun; the simple reason was that they had no means of defining any celestial position other than the zenith. At least by marking the northernmost setting point of the moon against the horizon -- as they did in constructing “La Vieja” -- they obtained a fixed point from which they could count the number of days that elapsed between two lunar events. Even though the Maya had advanced to the very cusp of literacy, like most preliterate peoples, the easiest way to record spatial observations -- other than by framing them against a prominent topographic feature such as Tajumulco -- was by erecting durable markers of their own in the landscape to calibrate the rising or setting azimuths of the sun, moon, planets and stars. And, if Mesoamerican sky-watchers had any advantage over those of mid-latitude cultures, it was only because their location in the Tropics enabled them to use the zenith to mark the vertical passage of the sun by day, whereas for the nighttime observation of fainter objects, such as the Pleiades, they frequently opted to construct a zenith tube within a building rather than erecting a gnomon outside of it.

Figure 3. The western horizon as seen from the summit of “Cinco Pisos” at Edzná in 1978. The portal of the pyramid is near the bottom of the photograph, aligned to the notch in the ridge that serves as an artificial horizon, behind which the small pyramid that marks the August 13th sunset rises out of the jungle scrub. Near the right-hand edge of the photograph a second pyramid, called “La Vieja” by Matheny, marks the northernmost setting point of the moon. (Photo by author.)

When it came to eclipses, the mysterious darkenings of the moon obviously were less frequent than solar eclipses, but when they occurred, they were visible over a far wider area. To early peoples like the Maya, they were probably more ominous as well. This is because their cause was never really understood, for whereas the disk of the moon is often visible at the time of a solar eclipse, the shadow that moved across the moon was not easily comprehended; that it was the shadow of the earth itself that caused the darkening they could scarcely have imagined.

Inasmuch as lunar eclipses occur only when the moon is full, for the Maya to have used "La Vieja" as an eclipse-warning device it was necessary to count the number of lunations, or full moons, that took place between the time of the moon's northernmost setting and the times it was darkened by the earth's shadow. This in itself may have proved something of a challenge for the Maya, for they also never grasped the concept of fractions. (Indeed, the problem of defining a "lunation" may have been the reason that the Maya began recording the age of the moon in their inscriptions in AD 357, as Coe reports.) Although they were fully aware that the time between full moons was not 29 days, but neither was it 30, so it was not until they had counted 149 lunations that they reached an even number of 4400 days. To be sure, this was a roundabout means of solving their problem, but had they been able to express this relationship as a fraction, it would have equaled 29.5302 days, which is almost exactly the value that modern astronomers employ.

As they counted the days between two consecutive settings of the moon at its northernmost extreme, the Maya were in effect rediscovering for themselves the interval known to the Babylonians as the saros. Although the Maya were wont to think in terms of cyclical measures of time, they may well have been surprised at the length of this particular interval, for it took no less than 6585.3 days to complete, or 18 years and –-- depending on the number of intervening leap years -- either 10 or 11 and one-third days.)   Of course, eclipses recur after an interval of the same duration, although this may not have been readily apparent to the Maya because several saros cycles are normally in progress at any given time and thus could be easily confused with one another. If the Maya had used the Long Count to define the length of a saros, they would have found that it equaled 18 tuns (each of 360 days), 5 uinals (each of 20 days), and 5 kin (of 1 day each). On the other hand, had they counted solely by using the sacred 260-day almanac, they would quickly have realized that the time between two eclipses in the same saros series equaled 25 calendar rounds, i.e. 25 times 260, plus 85 days, and they could have predicted well in advance the very day on which it would take place.

On the other hand, for the Maya, the fact that the length of a saros contains a fraction again posed a problem, for three-tenths of a day corresponds to just over 8 hours in time.   This meant that each succeeding eclipse took place 120º farther to the west around the globe, so that although they might observe two eclipses in a saros cycle from a given place, the third would always be invisible to them.

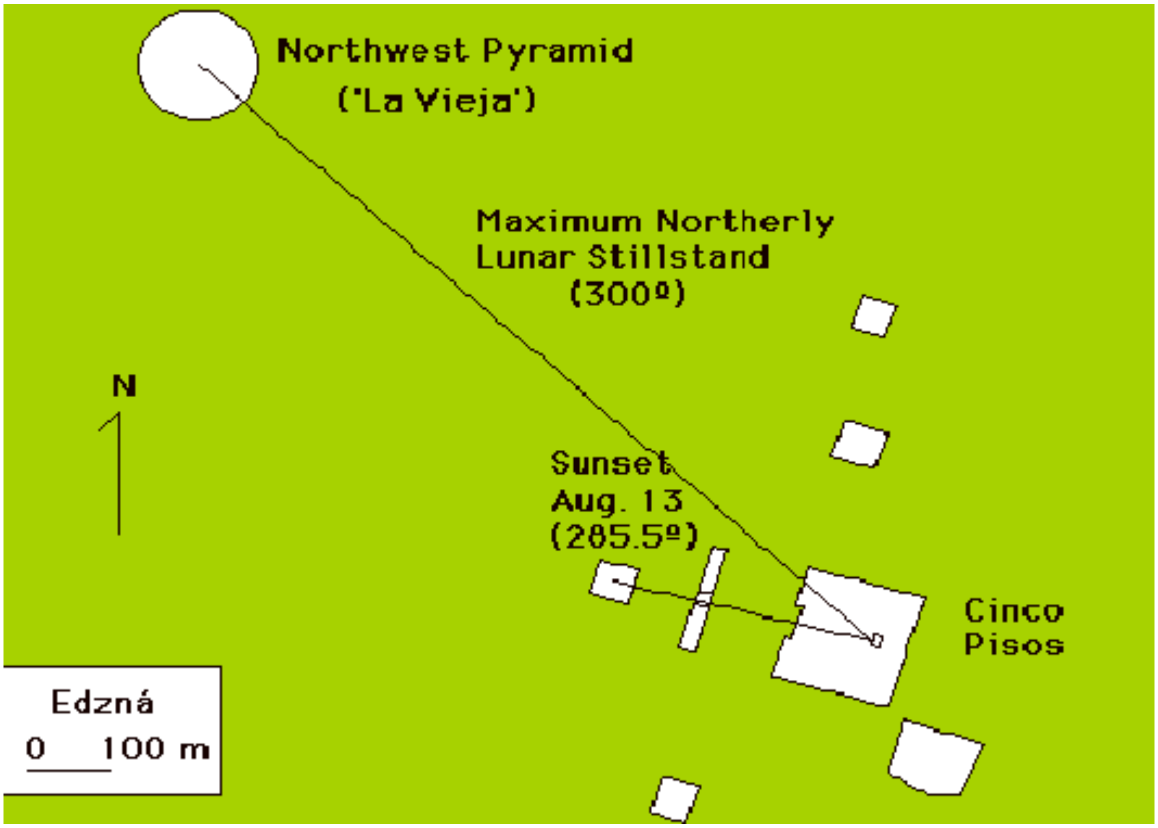

Figure 4. The site plan of Edzná showing its orientation to the small pyramid marking the August 13th sunset and the sight-line from "Cinco Pisos" to "La Vieja" which marks the northernmost setting point of the moon.

The Enigma of the Dresden Codex

One of the few Maya books that escaped the bonfires of Bishop Landa was the so-called "Dresden Codex". This lavishly illustrated document contains a section that has been identified as an "eclipse warning table", and it is to that part of the manuscript that we will limit the following discussion.

The table begins with the description of what seem to have been three eclipses, the first of which has been dated to November 8, 755 (using the original Thompson correlation coefficient of 584,285), the second to November 23, 755, and the third which fell on December 8, 755. Maud Makemson, an astronomer at Vassar, interpreted this equally spaced sequence as representing a lunar eclipse bracketed by two solar eclipses – a pattern that occurs with a fair degree of frequency as the moon passes its nodes. Floyd Lounsbury, an anthropologist at Yale, observed that if Makemson was correct, then the author of the Dresden Codex must have arrived at these dates by computation rather than by observation, for no such sequence of events was visible on those dates anywhere in the Yucatan. Lounsbury's source for this conclusion was none other than Oppolzer, the Austrian count who had published a compendium of global eclipses as early as 1887 and whose authority has gone unsullied to this day. Indeed, when Jean Meuss, the Belgian astronomer updated Oppolzer's seminal work in 1979, he could not but marvel at the detailed precision that his predecessor had achieved without the benefit of so much as a calculator.

However, when Eric Thompson examined the Codex in the early 1970's, he had already discounted the likelihood of Maya dates *ever* coinciding with real astronomical events, so as far as he was concerned, that was not the issue. (The reason was that in 1935 Thompson had altered his correlation constant to 584,283 and thereby rendered it inaccurate by two days. He insisted, moreover, that the Maya were not "astronomers", but "astrologers", and that there was no reason to expect their inscriptions to accord with celestial events – an injunction that most archaeologists summarily followed.) As he proceeded with his analysis, Thompson claims to have identified no fewer than ninety-two errors in the text, most of which he attributed to "mistakes in transcription", but he resisted dismissing the book's importance simply on that account. He did, however, conclude that the "Dresden Codex" was a late 12th century copy of an earlier manuscript and that it was most likely written in Chichen Itza.

In 1983, Harvey and Virginia Bricker published one of the first in-depth investigations of the "eclipse warning table". Ironically, after having tested several calendar correlations for "goodness of fit", they opted to use the revised formula of Thompson for their analysis, in the process either overlooking or ignoring the latter's injunction against expecting Maya dates to accord with astronomical events. The Brickers, moreover, limited their study to solar eclipses, which, though more numerous than lunar eclipses are also more erratic in their geographic distribution and far more limited in terms of their visibility. Thus, in commenting on their paper, Aveni noted that a single observer could easily have devised such a table simply through witnessing the lunar eclipses that occurred within a span of about thirty years, whereas to develop a similar historical sequence by using solar eclipses would have taken several centuries instead. In his comments on their paper, Lounsbury pointed out that two of the basic assumptions made about the table directly contradicted one another; on the one hand, if the Maya dates were correct but no eclipses were visible, then the correlation coefficient must by wrong. Otherwise, he concluded, the dates must have been transcribed incorrectly and that they most likely described events from the 11th century instead. In response, the Brickers argued that they had successfully tested the Codex's eclipse warning table not only for 12th century eclipses but for the prediction of a 1991 eclipse as well, to which Lounsbury replied by noting that when he evaluated their results statistically, he found the odds of their being correct were scarcely better than "50-50".

More recently the Böhm brothers from the Czech Republic have taken quite a different approach to the "contradictions" posed by the Codex. They contend that the reason the first of the eclipses mentioned did not coincide with a real event is because the original Thompson correlation was itself wrong. To remedy the matter they have established a "more accurate correlation" of their own that commences some 104 years later in time. Unfortunately, the fact that their correlation does not coincide with other events that we can verify having been recorded by the Maya – such as the total solar eclipse of July 16, 790 -- renders their "explanation" of the Dresden Codex even less convincing.

In the meantime, however, a variety of new sources, chiefly compiled with the aid of computers, have become available and have served to finally unravel the mystery. The most helpful of these is the NASA Eclipse Home Page on the World Wide Web, authored by Fred Espenak. It not only updates the works of both Oppolzer and Meuss but greatly augments them as well. Hence, it is primarily to this source that the author has turned for the discussion that follows.

Returning to the "problem" of the Dresden Codex, it is quite clear from the NASA data cited above that the supposed solar eclipse of November 8, 755 did not in fact occur. The Maya author of the Codex may have thought it did, but on that morning the sun and the moon rose over the Yucatan just eight minutes and 2.5 degrees apart -- *close* to an eclipse, yes, but definitely *not* an eclipse. (The latter values are derived from the "Voyager" computer program published by Carina Software of San Leandro, California.) The Maya author must likewise have postulated that a lunar eclipse occurred fifteen days later, because he certainly didn't observe that event either, for it was centered over the Indian subcontinent in southern Asia. Then, in what appears to have been another bold leap of imagination on the priest's part, he postulated a second solar eclipse, fifteen days later still. Ironically, while this event did indeed take place, it occurred between the southern tip of Africa and Antarctica where probably not a single human being in the world witnessed it.

Thus, Lounsbury had been quite correct in his assessment: the Codex' author couldn't have observed any of these events because the first didn't happen and the other two weren't visible from the Yucatan. On the other hand, the fact that the latter two of the eclipses *did* occur, and on the dates that the Maya recorded for them in the Codex, proves once again the validity of the original Thompson correlation coefficient. Thus, although Lounsbury was mistaken about the eclipses having taken place in the 11th century, he was nevertheless correct in noting that whenever two solar eclipses occur within a month of each other, they are never visible from the same vantage point. This fact alone would explain why the Maya scribe who penned this document could only have deduced that such a pattern had occurred because he certainly could never have witnessed it. On the other hand, if Thompson's reconstruction of the dating and the provenance of the Dresden Codex is accurate, then we have good reason to ask why a late 12th century scribe would have bothered to copy an eclipse warning table from the middle of the 8th century, faulty as it was, and expect it to be of much use four hundred years later?

In any event, now that we know for certain that the "original" Codex was a product of the middle of the 8th century, what does it really tell us about the state of Maya eclipse knowledge at that point in time? Why did its author begin his treatise with an event that *did not occur*, and follow it up with two other events he *couldn't have observed*? More puzzling yet was how he had been able to "theorize" the existence of solar eclipses that both preceded and followed the lunar eclipse by fifteen days, if he had never witnessed such a sequence himself? Obviously we must first address some of the intriguing questions raised by this enigmatic document before we can attempt to look "beyond the Dresden Codex".

The Unseen Lunar Eclipse of November 23, 755

From the NASA eclipse site we learn that the lunar eclipse that the author of the Dresden Codex was describing was one in a saros series numbered 86 by Espenak. The series had begun on July 13, -74 with annular eclipses that continued until March 31, 359, when its first partial eclipse took place. These, in turn, went on until June 25, 503 when its first total eclipse occurred. At Edzná, and hence throughout the Yucatan, the latter was visible, but only as a partial eclipse, as was its next eclipse on July 27, 557. At Edzná the first total eclipse of saros #86 that was visible was that of August 29, 611, which likewise happened to be the longest of its entire series, with a total phase that lasted 232 minutes and a partial phase that reached 106 minutes. However, from this time forward, a normal saros pattern of two visible eclipses followed by one invisible event persisted up until the date that the original version of the Dresden Codex was committed to writing, so its author(s) would have had nearly a century and a half to accustom themselves to this reality. After we examine how they could have foreseen the solar eclipses that supposedly both preceded and followed the lunar eclipse by fifteen days, we shall discuss why they chose to make an "invisible" event the centerpiece of their eclipse table.

Solar Saros #74: The 15-Day "Forerunner"

Despite the 1150-year history of lunar saros #86, it was only from June 28, -74 until March 25, 377 that each of its eclipses was preceded fifteen days earlier by a solar eclipse that was visible from the Yucatan. The latter were the product of solar saros #74, whose annular eclipses continued until January 19, 269 and were followed by one hybrid eclipse on February 21, 323 and one total eclipse in 377. Solar saros #74 continued producing total eclipses until June 10, 503, and its final partial eclipse took place on October 17, 729. Thus, for more than three hundred and seventy years (i.e., from AD 377 to AD 755) the Maya had not witnessed a single solar eclipse which preceded the lunar eclipse series described in the Dresden Codex by fifteen days, and, unknown to them, the entire sequence of such eclipses had ended some twenty-six years before the original Dresden Codex was even written. This latter point, of course, explains why no solar eclipse occurred on November 8, 755, but it still doesn't tell us how such a notion could have continued to form a part of the Maya's "astronomic knowledge" for so long a time.

In the discussion that follows, all the measurements cited were made by using the "Voyager" computer program and Edzná as the vantage point, although the results would have been little different if they had been made at Chichen Itza, which Thompson favors as the Dresden Codex' place of origin. For example, the azimuths of sun and moonrise at Chichen Itza varied by only 9 to 10 arc minutes from those measured at Edzná on the days of the solar eclipses that both preceded and followed the lunar eclipse of November 23, 755, in other words, by merely 1/6 of a degree.

Using the “Voyager” program to ”turn back the clock” and re-create the heavens at the time of the first solar eclipse of saros # 74 that the Maya could have observed on June 28, -74, we find that a heliacal rising of the planet Venus had taken place at 2:56 AM that morning. From the research of Thompson and others, we know that the early Mesoamericans not only anticipated the heliacal risings of Venus with fear and trepidation but they also appear to have believed that Venus itself was somehow involved in the eclipse phenomenon. When we discover that such heliacal risings of Venus occurred no fewer than fourteen out of the twenty-six times that the Maya observed the eclipses of solar saros #74, we can perhaps understand their propensity for thinking such a thing.

Continuing our analysis, we also discover that on the morning of June 28, -74 the moon rose at 5:15 AM at an azimuth of +22º 59’, followed by the sun at 5:19 AM at an azimuth +23º25’. Thus, both the sun and moon rose within 4 minutes of each other, only 26’ apart. Although the Maya had no means of precisely calibrating such differences in rising times and azimuths, they certainly would have been impressed by the fact that the sun and moon rose “so close together”, both in time and space. That this happened on a day on which a solar eclipse later took place would surely have become a “warning sign” or a “clue” they would watch for. Indeed, as it turned out, this naked eye, horizon-based observation was probably as close as they ever came to the recognition of a lunar node.

Eighteen years and eleven days later, they looked for the next eclipse in the saros #74 series to occur, and, as the morning of July 7, -56 dawned, the moon rose at 5:03 AM at an azimuth of +23º10’, followed twelve minutes later by the sun at azimuth +22º50. On this occasion the temporal difference in timing between them had lengthened to 12 minutes but the spatial difference had been reduced to 20’. Venus, however, was tardy this morning, rising fifteen minutes after the sun, and hence was probably not observed at all.

A basically similar pattern was repeated on each of the following two dozen occasions that a saros #74 eclipse was observed by the Maya. During this entire span of time -- measuring more than 450 years in all -- on mornings of solar eclipses in the saros #74 series, the average difference in sun- and moon-rises was 13.6 minutes in time and just 51.4 minutes of arc (i.e., less than 1º) in azimuth. Thus, the “clue” the Maya had found to confirm the arrival of a solar eclipse was about as “sure-fire” as any preliterate people had ever devised, although it didn’t give the priests much “lead-time” to inform the general populace. Indeed, on three occasions near the end of the series that was visible to the Maya, the eclipse was already in progress as the sun and moon rose, and two of these events were likewise preceded by a heliacal rising of Venus.

The reason that the saros #74 eclipses disappeared from the Maya’s view was that the track they were following gradually shifted from 7.5º N. latitude in the year -74 to 17.4º N. in the year -2. Thereafter, it shifted southward again, passing the Equator about the year 130 and continued to latitude 7.4º S. in the year 214. There it turned northward once more, this time passing the Equator about the year 285. Continuing northward, it had reached 30.6º N.latitude by the time of the final eclipse that the Maya observed in the year 377. Thereafter its further progress into the high latitudes of the Arctic made it invisible from the Yucatan, and, as already noted, saros #74 ended in the year 729.

Although the Maya had no notion of what caused this sequence of solar eclipses to disappear, at least they had learned a valuable lesson from their early observation of it, namely that whenever the sun and moon rose "close together" in time and in space, an eclipse of the sun was about to take place somewhere, even if it wouldn't be visible to them. Perhaps if they had been able to calibrate rising times and azimuths more closely, they may have realized that by the end of saros #74 the temporal difference between sun- and moonrise had increased to 38 minutes and the spatial difference had risen to 3º41', so the clue that they had employed so successfully for so long had gradually ceased to be of value. Through the entire period that the Maya were aware of saros # 74, the standard deviation of the time difference between sun- and moon-rises on the days it produced eclipses was 9.45 minutes, while the standard deviation of the difference in their rising azimuths was 67.54 arc-minutes, or 1º08'. Thus, on the morning of November 8, 755, when the sun and moon rose just eight minutes and 2.5º apart, they were well within the parameters that the Maya had come to utilize in predicting solar eclipses. Understandably, the Maya had every expectation that such an event would occur "somewhere" that day, even if they didn't see it.

Solar Saros #112: The 15-Day "Follower"

Another, and perhaps more baffling question, surrounds the series of solar eclipses that supposedly followed each of the saros #86 lunar eclipses by fifteen days. Again, by consulting the NASA eclipse site, we find that they could only have been produced by solar saros # 112. However, this saros did not even begin until July 31, 539, and throughout the entire time of the Mayas' existence, it produced only partial eclipses. Even more surprising is the fact that at no time were the Maya able to observe any of its eclipses, for their paths all lay in the high latitudes of the southern hemisphere. Thus, because the Maya lacked any first-hand proof that saros #112 even existed, the only way they could have concluded that these events were occurring was, once again, through observing the "closeness" of the rising times and locations of the sun and moon against the eastern horizon. Crude though this method might seem, when we tally up what their experience would have yielded, we find that the standard deviation of the difference between the times of sun- and moon-rises on the days of anticipated eclipses of solar saros #112 was no greater than 10.83 minutes, while the standard deviation of the difference in their rising azimuths amounted to only 91.24 arc minutes, or 1º31'. To be sure, the Maya never enjoyed the satisfaction of knowing if they were correct or not, and even after a saros had terminated they had every reason to believe that as long as the sun and the moon continued to rise "close together", the unseen solar eclipses were continuing to occur. (The full documentation of the analyses of solar saroses #74 and #112 is found in Table 2 below.)

Thus, what the Dresden Codex reveals about the state of eclipse knowledge prevailing in Chichen Itza at the middle of the 8^{th} century can only be described as "a mixed bag". On the one hand, the careful observation of sun- and moon rises against the dawn horizon had most likely provided the local sky watchers with a clue for anticipating solar eclipses, unseen though they were. On the other hand, if the Maya still hadn't recognized that every third lunar eclipse in a series would be invisible, perhaps the realization that a lunar eclipse was *scheduled* to occur was all that mattered to them. After all, if they couldn't see the solar eclipses whose existence they "theorized", then why should it be any different with the lunar eclipse whose occurrence they had "calculated"? Thus, impressive though the computations of the author(s) of the Codex were, they could only have served to warn that an eclipse was about to occur *somewhere* but they certainly could never have resulted in the dependable prediction of eclipses that would either allay the common people's fears or strengthen the latter's faith in the omniscience of the priests.

Table 2. Separation in Time and Space of Sun- and Moon Rises on Days When Solar Eclipses Produced by Saroses #74 and #112 Took Place (as Measured from Edzná).

SAROS #74	MINUTES	DISTANCE	SAROS #112	MINUTES	DISTANCE
377	14	86			
395	17	81			
413	2	10			
431	13	50			
449	22	70			
467	5	30			
485	12	12			
503	31	17			
521	12	25			
539	8	66	539	33	247
557	22	78	557	14	214
575	17	10	575	6	40
593	3	85	593	34	295
611	23	204	611	14	165
629	20	69	629	6	112
647	1	93	647	34	288
665	22	239	665	14	148
683	19	38	683	8	14
701	7	139	701	31	228
719	38	221	719	11	114
	9.45	67.54	737	13	26
			755	29	139
				10.83	91.24

(The years in which eclipses took place are listed in each of the left-hand columns. Spatial distances between the azimuths of sun- and moonrise are given in arc-minutes, of which there are 60 to each degree. At the bottom of the columns listing times and distances, the standard deviations are given.)

Source: Compiled by the author using the "Voyager" program from Carina Software, San Leandro, California.

Indeed, without the calibration afforded by “La Vieja”, it would have been unreasonable to expect that the local priests in any of the outlying areas of Yucatan would ever have been able to match their knowledge of the moon’s behavior with those working at Edzná. Therefore, rather than representing “state of the art” Maya astronomy in the year 755, the Dresden Codex was more likely an outdated parochial document even at the time it was written. The justification for such a belief is that just eight years after the series of “unseen events” described in the original version of the Dresden Codex, the priests at Edzná appear to have made their first and only successful prediction of a lunar eclipse. The evidence is admittedly circumstantial, but if it isn’t accurate, then we are left with an unexplained “coincidence” that is even more difficult to account for.

How “La Vieja” Could Have Functioned in the Prediction of Eclipses

To illustrate the challenge that confronted the Maya priests in trying to find some pattern in the moon’s behavior, let us make reference to Table 3 where all of the 28 lunar eclipses visible in Edzná from AD 686 to 763 are listed according to (1) their Julian Day Number, (2) the Christian date on which they occurred, (3) the number of days which had elapsed since the latest extreme moonset over “La Vieja”, (4) the number of days since the previous eclipse, (5) the number of lunations that equaled this value, (6) the total number of lunations that had passed since the latest extreme moonset, (7) the saros number of the eclipse and whether it was total (T) or partial (P) according to the NASA Eclipse Home Page, and finally (8) the Maya Date on which the event occurred – first in their 260-day sacred almanac, and then in their 365-day secular calendar. Thus, Table 2 summarizes the kind of information that may have enabled them to make a successful prediction of the lunar eclipse of June 29, 763.

When we examine the data from this seventy-seven year period, we can easily deduce how it might have encouraged the Maya to venture such a prediction. It appears that one of the recurring eclipse patterns that the Maya may have unwittingly “tracked” was a saros series labeled # 90 by Espenak. It had begun in the year -134 (i.e., 135 BCE) and continued until CE 1345, so the Maya happen to have been witnesses to the most central and longest lasting phase of its eclipse series. Indeed, saros series #90 made its first appearance at Edzná as a partial eclipse lasting 102 minutes in the middle of the night of April 26, 655, after which it did not reappear again until May 28, 709. However, the fact that it was not total at the time of its first appearance probably accounted for the fact that the Maya took no special notice of it. Moreover, because neither of the next two eclipses in saros cycle #90 was visible at Edzná, the Maya may also have simply lost track of it.

In Table 3 we begin our analysis with the extreme moonset of the year CE 686 (LM = Lunar Maximum). During the 6585-day interval that followed, we find that the first eclipse occurred at 3 lunations, a second at 9 lunations, and a third at 50 lunations, followed by three more eclipses at 138 lunations, 144 lunations, and at 179 lunations. As we check the numbers of the saros series that were involved in each of these eclipses, we find that number 90 was not among them; hence, this was one of the intervals when this particular saros series was not visible at Edzná. The important point to remember, however, is that while modern astronomers assign numbers to saros series to keep track of eclipses, the Maya would have to have done so by cataloguing them according to the number of "lunations" or " moons" that accrued. Thus, without even knowing that saroses existed, the Maya learned to look for repetitive eclipses at, for example, every third, ninth, or fiftieth full moon instead.

In the 6585-day interval that followed the extreme moonset of November 17, 704, we note that a very different pattern of eclipses set in. This time the first eclipse did not occur until the 44th lunation, but the second followed just 12 full moons later at the 56th lunation. Here, we find saros #90 involved for the first time, giving rise to a total eclipse whose partial phase lasted 112 minutes and its total phase extended for 45 minutes. Surely, a total eclipse of this duration must have made a fairly strong impression on the Maya. Although five further lunar eclipses took place before the next extreme moonset -- two of them partial and three total – the Maya would have recognized only two of them as being companion series to saros #90. These were saros #86 at 185 lunations (with a total eclipse on November 2, 719) and saros #96 at 197 lunations (with a partial eclipse on October 21, 720).

Following the next extreme moonset in the year 722, the Maya had to count a full 56 lunations before any eclipse occurred, but when it did, it was again total and of even longer duration – the partial phase had lengthened to 113 minutes and the total phase to 49 minutes. By now the Maya had realized that when an eclipse occurred at the 56th lunation, it was indeed a "major" event. And, although they didn't know it, it was once again a member of the saros #90 series. At the 185th lunation they once again catalogued a total eclipse in the saros #86 series on November 12, 737, and they likewise had the satisfaction of recording another partial eclipse in the saros #96 series on November 1, 738. By this time it would appear that they were becoming confident enough of their grasp of eclipse behavior to venture making a long-range prediction.

Rather than expecting to see such a lunar eclipse recur a third time (in the saros #90 sequence) on June 18, 745 -- when their calculations would have told them it was due -- the Maya now knew better than to look for it. This was because, just 3 lunations after the extreme moonset of December 8, 740, an eclipse had taken place which told them that they were again beginning to witness the same kind of pattern of eclipse occurrences they had experienced after the extreme moonset of 686. In other words, they knew there would be no eclipse when the time of the 56th lunation arrived – at least none that they could see. Although they couldn't have known where the moon would be on this occasion, it turned out that it was directly overhead in western Australia at that time. By the same token, they realized that there would be no eclipse when the 185th lunation arrived either, so the priests at Edzná would not have anticipated the return of saros #86 in 755 the way the author(s) of the Dresden Codex had done in Chichen Itza.

Now, at least the pattern had become clear, even if the understanding of how it happened had not; as far as the priests of Edzná were concerned, an eclipse only occurred two times after the same number of lunations had passed. Then, it "took a rest" -- probably somewhere in the "underworld" -- before returning two more times, then “rested” again. Naturally this meant that, following the next extreme moonset, the Maya could confidently expect that a major eclipse *would* occur at the 56th lunation, which may have emboldened them to make the first, and as it turns out, perhaps the *only* successful eclipse prediction they ever made.

After the next extreme moon-set occurred on December 19, 758, the priests at Edzná had only to wait another 88 days before they could confirm whether the moon was back on its 56th lunation schedule. Thus, when a lunar eclipse failed to take place before the middle of March, 759, they would have known they were safe to make such a prediction. And, as it turned out, this meant that they had no less than four years and three months “lead time” to spread the word across the Maya realm. However, what we don’t know is whether anyone was any longer paying attention to Edzná regarding matters of celestial importance, as Thompson implied had been the case just a century earlier.

More recent research has revealed that many of the lowland Maya sites in the Yucatan and Peten regions were already undergoing a crescendo of internecine warfare in the late 8th century so military activities had probably already taken precedence over intellectual inquiry in many of these areas. Therefore, it is hardly surprising that up until the present time only one possible reference to this eclipse has been found in Maya inscriptions, and this was not in Edzná, near the heart of the Maya realm, but rather in Copan, Honduras near its southernmost extremity.

As early as the 1920’s, Herbert Spinden had postulated that an “astronomical congress” had taken place in Copan sometime about the middle of the 8th century. He based his conclusion on a series of glyphs he found at the site showing persons who he identified as astronomer-priests seated on pillows with their cross-staffs raised before them surveying the night sky. He offered, however, no explanation for what purpose the congress may have been convened, but one of the glyphs he translated as “Sun Near the Horizon”, for whatever merit that may have. A more recent scholar, David Stuart, has dismissed Spinden’s thesis, and argues that from his reading of the glyphs, the conclave (if there even was one) involved the accession to the throne of a new local king instead. In other words, what Spinden had seen as astronomer-priests, Stuart sees instead as the sixteen earlier kings of Copan. Although we may never know which of the two interpretations is the correct one, we do know for certain that a total lunar eclipse took place in the early evening twilight of June 28, 763, local time, coinciding precisely with the 56th lunation that the priests of Edzná had anticipated. (Occurring just after sunset, this eclipse might well have been depicted by a glyph entitled “Sun Near the Horizon”. Note also that, inasmuch as a new Julian Day had begun in London little more than an hour earlier, this eclipse was recorded by Western science as having taken place on June 29th instead.) In any case, according to Espenak, this event was the longest and most complete total lunar eclipse of the entire 8th century (its partial phase lasted 114 minutes and its total, 52 minutes). At Copan, the notation of this date appears on no fewer than eight different altars and pyramids, making it the most repeatedly recorded event in all of Maya history. It is obvious that whatever happened on this date must have been an occasion of paramount importance to the Maya. One can only wonder if, after more than eight centuries of observation and record keeping, this exuberant outburst was really the celebration of the Maya's first successful eclipse prediction, or if the accession of a new local king at Copan would have been sufficient cause to warrant such a flurry of glyph carving? If it had been the latter, then was it because the Maya knew the eclipse was on its way and they consciously chose to install their new ruler on this auspicious occasion? Or was it merely a fortuitous coincidence that Copan's last king *happened* to ascend the throne on the very eve of the century's most spectacular astronomical event? I must leave it up to the reader to decide.

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In spite of the Maya's ignorance of nodes, orbits, and even fractions, it would appear that they had managed to find a way of using the behavior of the moon itself to chart the advent of both solar and lunar eclipses. One can only marvel at the patience and perseverance of their priests who, generation by generation, assembled and recorded the observations that would have made this triumph of the human intellect possible. Yet, at the same time, one cannot but associate a great sense of irony with what, for them, must have been a bittersweet accomplishment, for it never again was replicated, or even could be. We know that, in just a matter of a few decades, the Maya world had slipped into a decline from which it did not recover. Indeed, perhaps the very fact that so little notice was taken of this triumph at sites in the Yucatan meant that the "collapse" was already in progress there and that nobody was "listening" to the priests any longer. In any case, during the next couple of centuries, the jungle reclaimed most of their cities and cornfields, and the Maya civilization itself disappeared like an ephemeral shadow crossing the moon. Sic transit gloria mundi.

Table 3. Lunar Eclipses visible from Edzná, AD 686-763.

Julian Day #	Christian Date	Event	Total Days	Days Elapsed	Lunations	Total Lunations	Saros #	Maya Date	
1971931	11/08/686	LM–299°14'	0	0	0	0		4 Cimi	4 Kankin
1972018	2/3/687	Lunar Eclipse	87	87	3	3	83–T	13 Ben	11 Cumku
1972195	7/30/687	Lunar Eclipse	264	177	6	9	88–T	8 Oc	3 Chen
1973406	11/22/690	Lunar Eclipse	1475	1211	41	50	85–T	10 Imix	19 Kankin
1974617	3/17/694	Lunar Eclipse	2686	1211	41	91	82–T	12 Eb	10 Uo
1974793	9/9/694	Lunar Eclipse	2862	176	6	97	87–T	6 Lamat	6 Zac
1976004	1/2/698	Lunar Eclipse	4073	1211	41	138	84–T	8 Cauac	2 Kayab
1976182	6/29/698	Lunar Eclipse	4251	178	6	144	89–T	4 Caban	15 Yaxkin
1977215	4/27/701	Lunar Eclipse	5284	1033	35	179	81–T	10 Oc	13 Zodz
1978515	11/17/704	LM–299°03'	0	0	0	0		10 Oc	18 Kankin
1979814	6/8/708	Lunar Eclipse	1299	1299	44	44	80–P	9 Muluc	17 Xul
1980168	5/28/709	Lunar Eclipse	1653	354	12	56	90–T	12 Akbal	6 Xul
1981733	9/9/713	Lunar Eclipse	3218	1565	53	109	97–T	4 Lamat	11 Zac
1982767	7/9/716	Lunar Eclipse	4252	1034	35	144	89–T	11 Ik	10 Mol
1983978	11/2/719	Lunar Eclipse	5463	1211	41	185	86–T	13 Ben	6 Kankin
1984155	4/27/720	Lunar Eclipse	5640	177	6	191	91–T	8 Oc	18 Zodz
1984332	10/21/720	Lunar Eclipse	5817	177	6	197	96–P	3 Manik	15 Mac
1985100	11/28/722	LM–299°49'	0	0	0	0		4 Men	13 Muan
1986753	6/8/727	Lunar Eclipse	1653	354	12	56	90–T	6 Lamat	1 Yaxkin
1987964	10/1/730	Lunar Eclipse	2863	531	18	97	87–T	8 Cauac	17 Ceh
1989175	1/24/734	Lunar Eclipse	4075	177	6	138	84–T	10 Oc	13 Cumku
1990563	11/12/737	Lunar Eclipse	5463	354	12	185	86–T	7 Eznab	1 Muan
1990917	11/1/738	Lunar Eclipse	5817	354	12	197	96–P	10 Eb	10 Kankin

1991685	12/8/740	LM– 300°10'	0	0	0	0		11 Ahau	8 Pax
1991773	3/7/741	Lunar Eclipse	88	88	3	3	83-T	8 Lamat	11 Uo
1991950	8/31/741	Lunar Eclipse	265	177	6	9	88-T	3 Chicchan	8 Zac
1993161	12/24/744	Lunar Eclipse	1476	1033	35	50	85-T	5 Cib	4 Kayab
1994372	4/18/748	Lunar Eclipse	2687	176	6	91	82-T	7 Manik	15 Zodz
1994548	10/11/748	Lunar Eclipse	2863	176	6	97	87-T	1 Akbal	11 Mac
1995759	2/4/752	Lunar Eclipse	4074	353	12	138	84-T	3 Ix	2 Pop
1995937	7/31/752	Lunar Eclipse	4252	178	6	144	89-T	12 Eb	0 Yax
1998270	12/19/758	LM– 300°11'	0	0	0	0		5 Chicchan	3 Kayab
1999922	**6/29/763**	**Lunar Eclipse**	**1652**	**1652**	**56**	**56**	**90-T**	**6 Caban**	**10 Mol**
2004855	12/29/776	LM– 299°46'	0	0	0	0		12 Oc	18 Kayab
2006509	7/10/781	Lunar Eclipse	1654	1654	56	56	90-T	2 Kan	7 Chen
2009802	**7/16/790**	**Solar Eclipse**	**4947**	**3293**	**111.5**			**5 Cib**	**14 Chen**

(Note that the lunar eclipse recorded on numerous monuments at Copan is shown in boldface type, as is the solar eclipse of 790 that the Maya recorded at Santa Elena Poco Uinic, Chiapas. However, the intervening total lunar eclipse of 781, that was also in the saros # 90 series, apparently went unrecorded by the Maya, as did seven other lunar eclipses leading up to it. Although the "Maya collapse" had probably already begun in the lowlands of the Yucatan, it appears that in the more remote mountain areas of their realm the recording of celestial events persisted for several more decades; indeed, the last recorded Long Count date that has been found (equivalent to January 18, 909) comes from Tonina in the highlands of Chiapas state.)

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