Discovering Discovery: Chich'en Itza, the Dresden Codex Venus Table and 10th Century Mayan Astronomical Innovation

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Abstract:
A new reading of Dresden Codex Page 24, the "Preface" to the Venus Table, is presented, demonstrating a much-improved overall coherence. This reading of hieroglyphic text, mathematical intervals, and calendric data specifically identifies the Mayan Long Count dates of the Venus Table's historical correction. The resulting Long Count placement of the manuscript's Venus Table suggests that it was an indigenous astronomical discovery made at Chich'en Itza, possibly under the patronage of K'ak' U Pakal K'awiil — one of the most prominent historical figures in the inscriptions of the city during its "epigraphic florescence." Revealing the logic underlying the construction of the page, the revised reading suggests a slightly less-accurate approximation to Venus's synodic period than the traditional interpretation allows, but introduces a justification for the graphical layout of Page 24 that is more straightforward than traditional interpretations.

Keywords: Maya, Astronomy, Calendars, Venus, Indigenous Knowledge

Introduction

After centuries of scant attention and eventual repose in the Dresden Library in Germany, a Postclassic manuscript written in Mayan hieroglyphs was brought to the attention of modern scholars during the nineteenth century. Six pages of this manuscript, the "Dresden Codex," have been recognized as relating to the planet Venus since Ernst Förstemann first began working through them in the 1880s. Förstemann suggested that across these pages, a table of dates[1] based on multiples of 584 days were used to track the observable period of Venus. Förstemann attempted a translation of the pages (almost a century before the decipherment of the script itself) by inferring the meaning from the calendric-astronomical patterns he recovered.

> [W]e find that the [Yucatec scribe] desires to say this:

[1] Dates in the Maya Calendar are made up of Long Count and Calendar Round components. The Long Count is a tally of days conceptually equivalent to the Julian Day Number. The differences are only that the Long Count is a modified vigesimal count (base-20) and the "zero date" is different in each case. The Calendar Round is a combination of the 260 Day Count and the 365 Day Count. The 260 Day Count is a combination of 13 numbers and 20 Day Signs, each advancing on a daily basis. The Day Signs are *Imix, Ik', Ak'bal, K'an, Chikchan, Kimi, Manik, Lamat, Muluk, Ok, Chuwen, Eb, Ben, Ix, Men, Kib, Kaban, Etz'nab, Kawak, Ajaw*. The 365 Day Count approximates the tropical year. Each of 18 months has 20 days; one final "month" is of only 5 days. The month names are *Pohp, Wo, Sip, Sots', Tsek, Xul, Yaxk'in, Mol, Ch'en, Yax, Sak, Keh, Mak, K'ank'in, Muwan, Pax, K'ayab, Kumk'u, Wayeb*. A full date would be written, for example, as *bolon pih bolon winikhaab ka haab kan winik waxak k'in ho lamat hun mol* and transcribed by modern scholars as 9.9.2.4.8 5 Lamat 1 Mol. Within hieroglyphic texts, dates (full or partial) are separated by time intervals or "distance numbers" given in Long Count format. A time interval of 4.8 represents 88 days. Three hundred sixty-five days would be represented 1.0.5 in Long Count notation.

> I am here treating especially the periods consisting of five successive Venus years, bringing them into harmony with the solar year and the [260 Day Count][2]. … [E]ach individual Venus year [is] divided into four unequal parts, which appertain to the east, north, west, and south and are ruled by certain deities, which I can mention only in part, owing to lack of space. Lastly, I would add that each of the five Venus years of a period is dominated as a whole by a deity, and the signs of these I give here (1894:443).

Förstemann's work of over a century ago goes a long way toward capturing the understanding still current in the contemporary literature (Aveni 2001; Bricker and Bricker 2007; Lounsbury 1983).

In the 1920s John Teeple, a chemical engineer turned Mayan calendar enthusiast, followed Förstemann and Eduard Seler's interpretive work to focus on the mathematical subtlety of the Venus Table. Teeple found that a sequence of four 'unconventional' time intervals on Page 24[3] of the manuscript—which confounded Förstemann (1894)— actually served as "corrected" multiples of the 584-day calendric period of Venus (Thompson 1978:224). These intervals suggested that Mayan astronomers kept track of the difference between their calendric progression based on a Venus Round of 584 days and the 583.9214-day synodic period of Venus. Teeple argued that these astronomers quantified the amount of error that would have accumulated, and that they developed a means for correcting their Table accordingly over very long spans of time. His interpretation was consolidated and extended by Eric Thompson at mid-century, who argued that Postclassic Mayan astronomers had access to an ephemeris for Venus accurate to "within one day in six thousand years" (1978:63).

This, I suggest, is where the historiography of the Dresden Codex Venus Table takes an interesting turn. Without an ability to read the hieroglyphic text in the Table, scholars were left at mid-century to make an argument for the Venus ephemeris mainly through its purported accuracy in predicting observable phenomena. This trope then dominated the academic consideration of the Venus Table: the better the accuracy it could attribute to the Table, the stronger the modern interpretation was considered to be (Thompson 1978; Lounsbury 1983, 1992; Bricker and Bricker 2007).

In particular, two forms of accuracy have controlled this discourse. The first has to do with the placement of one of the Calendar Round dates recorded in the Venus pages with respect to a historically reconstructed first morning visibility of Venus (fmv).[4] The second concerns how well the table could be re-cycled to minimize the accrued error between prediction and observation. In 1983, Floyd Lounsbury graphically depicted his and Thompson's approaches to both measures as shown in Figure 1.

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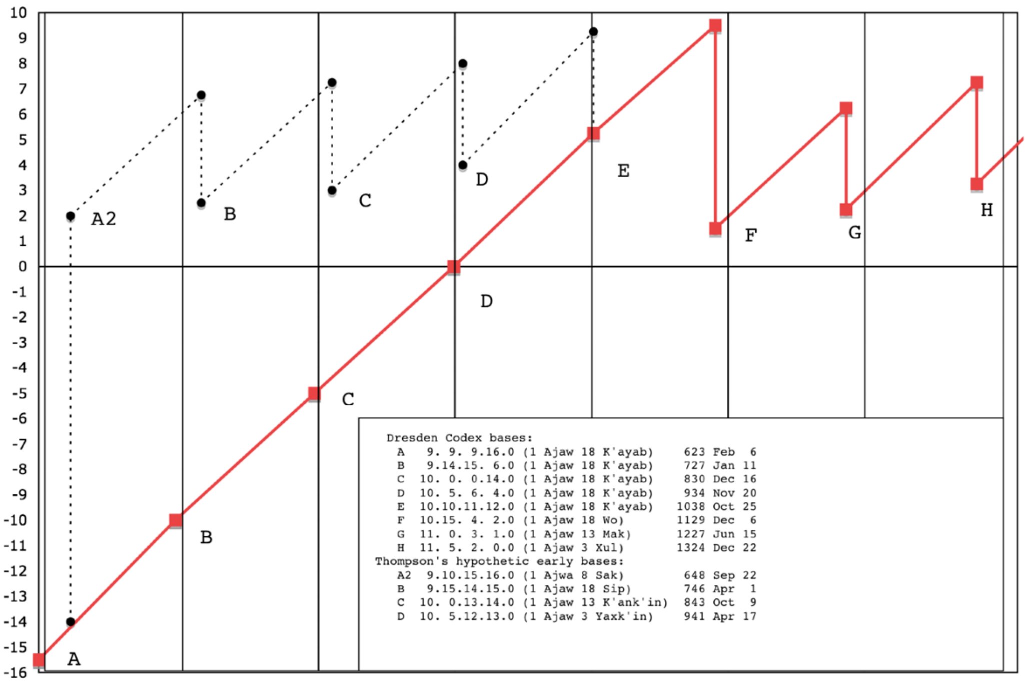
[2] Förstemann here used the term *tonalamatl*, which is the Nahuatl name for the 260 Day Count. See footnote 1.

[3] The apparent non-sequentiality of the Preface and the Table is accidental only. The manuscript had fragmented, and it was numbered out of order. In its original form, the Preface immediately preceded the Table.

[4] Scholars in the past turned to the Tuckerman Tables to look up idealized observations for the Mayan area (Lounsbury 1983:5); now it is common for archaeoastronomers to utilize software such as *EZCosmos* (Freidel, Schele, and Parker 1993) or *Planet's Visibility* (Bricker and Bricker 2007:116). Either way, a Calendar Correlation is necessary for these studies. See footnote 5.

Figure 1. Reconstruction of Lounsbury's "mean error" graph of Venus observations against hypothetical Dresden Codex predictions.



Lounsbury followed Thompson's approach to matching the long-term correction of the table, but changed the starting point; both models synchronize at 10.10.11.12.0 1 Ajaw 18 K'ayab, which they assigned to October 25, 1038 A.D. Lounsbury engaged the first aspect of the Venus Table's 'accuracy' by noting that his reconstruction placed the 1 Ajaw 18 K'ayab of 10.5.6.4.0 exactly on a (historically reconstructed) first morning visibility of Venus (mean error of '0'). He claimed that this fmv corresponded to a conjunction of Venus and Mars—in his view, a particularly noteworthy event (Lounsbury 1983:12).

Harvey Bricker and Victoria Bricker (2007) agreed with most of Lounsbury's work, modifying it slightly by changing the Calendar Correlation[5] by two days and arguing that the ephemeris was more strictly a warning table. This move slightly altered Bricker and Bricker's inherited notion of accuracy since now they want a table that strictly anticipates fmv; the constraint, of course, is that it cannot come so early that the prediction overlaps with last evening visibility—a rather small range of possibility over the long run, given that inferior conjunction varies and can be as short as half a day.

Nonetheless, the reconstructions by these scholars ascribe an impressive accuracy to Mayan Venusian astronomy and in its fundamentals create an interpretation

[5] The Calendar Correlation is an arithmetic constant used to link the Maya Long Count to the Julian Day Number. (See footnote 1) The GMT is the most commonly used Correlation Constant, where GMT = 584,283 and LC + GMT = JDN. The GMT includes "variants," however, that compensate for the prioritization of different data sets by the scholars utilizing it (cf. Aldana 2010, 2015).

that has been universally accepted by Mayanists since the early twentieth century (Morley 1975; Thompson 1972; Sharer 2006; Coe 1988). There are, however, complications with it. The first, as we shall see, is that the method they all propose for correcting the Table does not follow straightforwardly from the information actually recorded in the Preface. The correction interval which provides the greatest utility in maintaining accuracy, and which drives all current interpretations, is actually not even recorded on Page 24 or anywhere in the Venus Table. (See Figure 2) Instead, it is inferred from the two correction intervals that are written at the top of the Preface (Thompson 1978:226, 1972:63; Lounsbury 1992a:185; Bricker & Bricker 2007:103-104). Second, the standard interpretation requires that the anchor of the Table deviate from an historical fmv by some 16 days. In other words, the standard interpretation requires that a table designed to preserve first morning visibilities of Venus on dates 1 Ajaw was anchored to an historical date that did not.

In this essay, I suggest that if we set aside our expectations based on modern notions of accuracy, and look at the logic of Page 24 itself, not only does the currently accepted interpretation of it appear forced, we encounter a much more compelling explication of the Table. Through the new interpretation proposed here we find, for example, what we might expect: that the numbers recorded are the ones that are actually useful in correcting the Table, i.e. we do not have to rely on numbers that are simply implied by the ones explicitly recorded. Further, we find that there is a utilitarian purpose to the graphical layout of the intervals on Page 24. We also resolve the complications of the traditional model with respect to the anchor and the Correction Intervals.

In this essay, we incorporate a ritual utility and prioritize the internal logic of the table for the interpretation of how it interacts with observable Venus phenomena and the Venus Table of dates on Pages 46-50. In doing so, we encounter a much more robust reading of Page 24, reconstruct an hypothesis for the observed calendric-astronomical patterns that generated the Venus Table as recorded, and face a better fitting archaeological proposal for the origin of the Dresden Codex Venus Table at the "Observatory" of Terminal Classic Chich'en Itza.

Corrections

The Dresden Codex Venus pages are broken up into two parts. The first is often called the Preface as it contains preliminary descriptive information about the ensuing pages and it provides contextual data for the interpretation of the table itself. The second part is the Venus Table proper made up of calendric progressions through 65 Venus Rounds, each broken up into sub-periods marking first morning visibility (fmv), (something near) last morning visibility (lmv), first evening visibility (fev), and last evening visibility (lev).[6] Occupying the right hand side of each of the five pages of the Venus Table is an elaboration of the oracular meaning ascribed to first morning visibilities (Aldana 2008, 2015a).

If we focus on just the mathematical and calendric patterns, the ephemeris interpretation of the traditional approach seems reasonable. Recently, though, I have shown that the hieroglyphic textual narrative driving the Table is actually part

[6] The lack of symmetry and accord with regular observability of the individual sub-periods is still a matter of some debate (Aveni 1992).

Figure 3A. Visual representation of Thompson's method for applying the correction factors on Page 24 to the recorded base date of 9.9.9.16.0 1 Ajaw 18 K'ayab (cf. Bricker and Bricker 2007, Table 3.3).

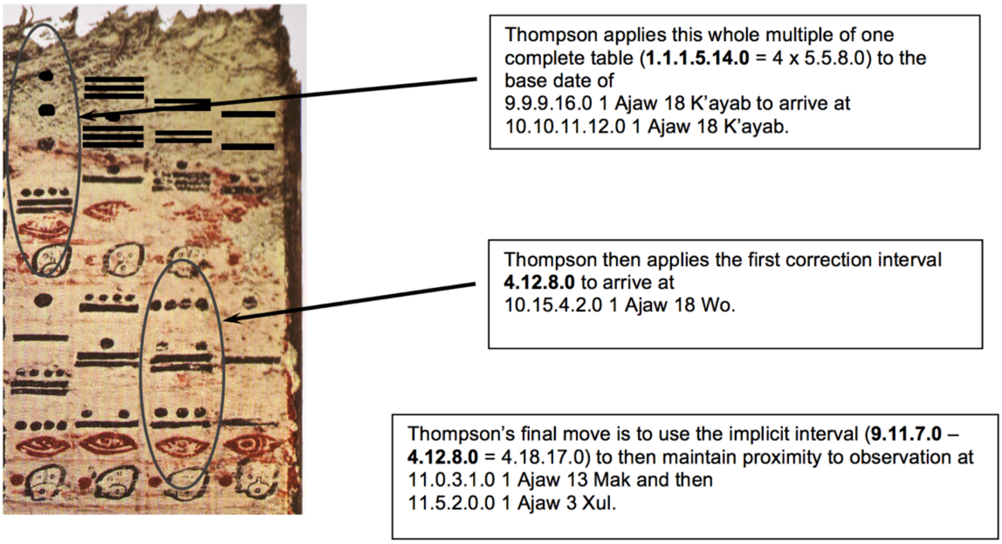


Figure 2B. Visual representation of Lounsbury's method for applying the correction factors on Page 24 to the recorded base date of 9.9.9.16.0 1 Ajaw 18 K'ayab (cf. Bricker and Bricker 2007, Table 3.3).

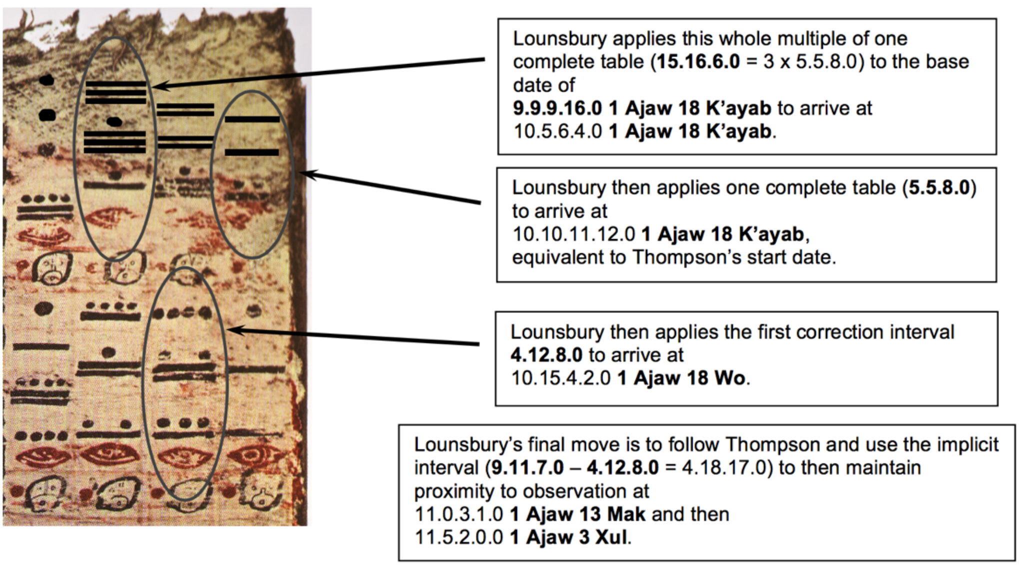


Figure 2C. Visual representation of Bricker and Bricker's method for applying the correction factors on Page 24 to the recorded base date of 9.9.9.16.0 1 Ajaw 18 K'ayab (cf. Bricker and Bricker 2007, Table 3.3).

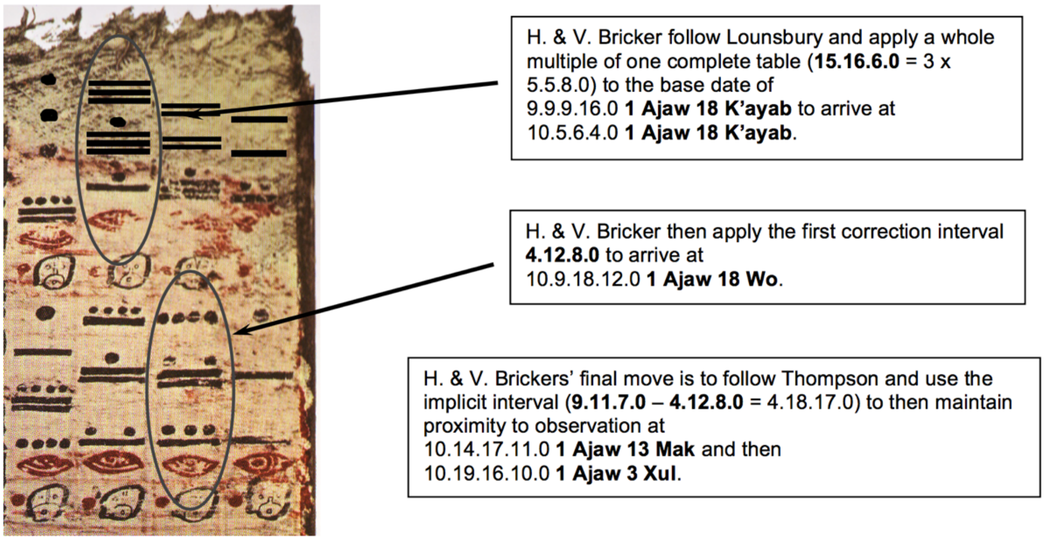
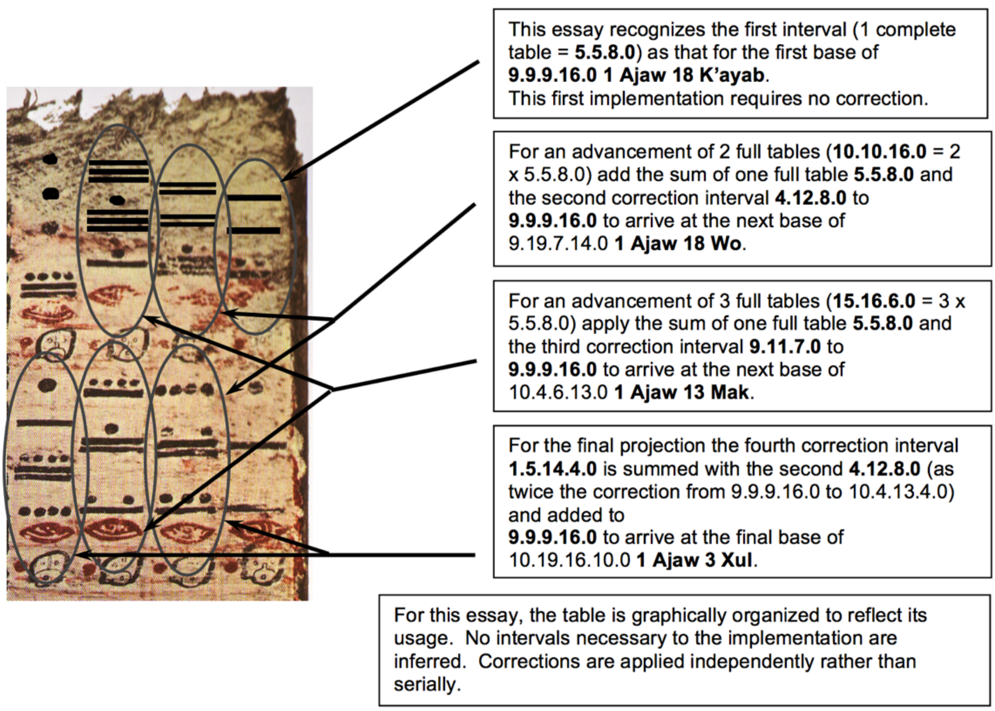


Figure 2D. Visual representation of Aldana's method for applying the correction factors on Page 24 to the recorded base date of 9.9.9.16.0 1 Ajaw 18 K'ayab.



of a larger ideological context.

My proposal for the reading of /k'al/—the operative verb throughout the Table—as 'to enclose,' means that a run through one row of the Table reads:

> On 3 Kib 4 Yaxk'in, the North is enclosed by Deity 1 and Chak Ek'. It is 236 days [since the previous first morning visibility of Venus]. On 2 Kimi 14 Sak, the West is enclosed by Deity 2 and Chak Ek'. It is 326 days. On 5 Kib 19 Tsek, the South is enclosed by Deity 3 and Chak Ek'. It is 576 days. On 13 K'an 7 Xul, the East is enclosed by Deity 4 and Chak Ek'. It is 584 days.

Whereas the traditional interpretation translates /k'al/ as 'to tie' or 'to bind' and leaves the meaning ambiguous (Aveni 2001), mine provides a straightforward narrative version of the graphic cosmogram illustrated on the frontispiece of the Central Mexican Féjérvary-Mayer Codex (Aldana 2011:56). (See Figure 3) The resulting equivalence between text and image suggests that accuracy of observation may not have been the Table's primary motivation—it is more likely that it guided ritual events according to Venus Rounds and sub-periods of them (Aldana 2011:64-5).

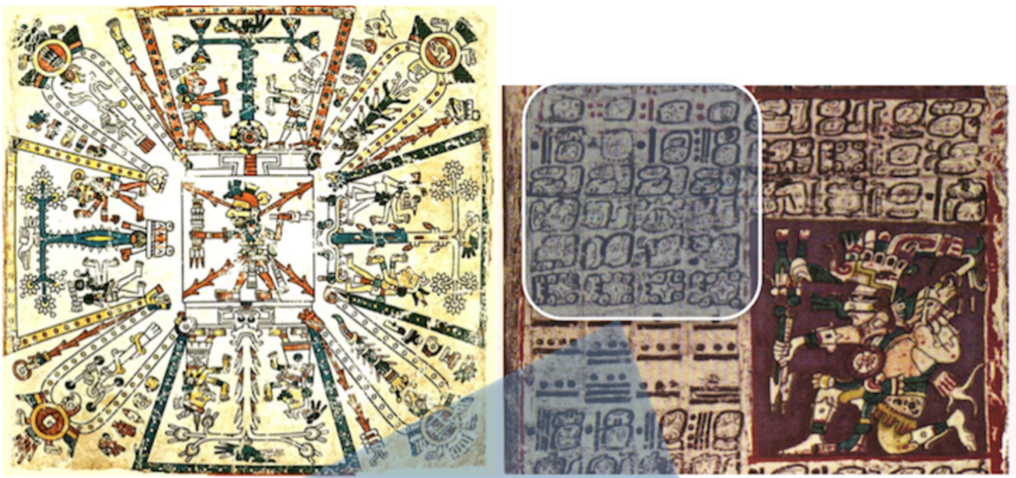
In other words, the short-term accuracy was probably not tremendously important—the vast majority of the population was probably not checking whether the ritual Venus calendar was off by a day or even a few.[7] Over the long-term, however, accuracy would certainly become significant—one could not be performing a ritual tied to first morning visibility when Venus was still visible as evening star. And when we turn to the corrections of the Venus Table on Page 24, we realize that we are looking at a concern with the long-term: the corrections are intended for periods of hundreds of years.

When we come to the determinations of long-term accuracy, then, two sets of Calendar Round dates are critical: two on Page 24; two on Page 50. These correspond to the placement of the table in historical time. Teeple's intervention was to show that a serial application of an inferred correction interval produces a progression through these four Calendar Round anchors. His 'inferred correction interval' comes from two time intervals written on Page 24. (See Figure 2) The second row of Long Count intervals from the top contains the only four intervals on the page that are not whole multiples of 2920 days (= 5 x 584 or one full row of the Venus Table): 185,120; 68,900; 33,280; and 9,100. The difference between the second and third intervals explicitly recorded in this row, 68,900 and 33,280, gives the inferred correction interval, 35,620 (9.11.7.0 − 4.12.8.0 = 4.18.17.0). It is this difference that Teeple uses (and Thompson and Lounsbury, and Bricker and Bricker) as the fundamental element in the reconstructed correction of the table (Bricker and Bricker 2007:102). As Teeple showed it:

1 Ajaw 18 K'ayab + 35,620
(1 Ajaw 8 Yax + 35,620)
1 Ajaw 18 Wo + 35,620
1 Ajaw 13 Mak + 35,620
1 Ajaw 3 Xul

[7] It probably was not even reasonable to expect that the vast majority of the population had access to a view of the horizon providing the capability of checking on the Table's accuracy. A view over the floral canopy was only available from the upper levels of the tallest structures, which certainly would have had restricted access.

Figure 3. The text in the Dresden Codex Venus Table can be understood as a written translation and adaptation to Venus cycles of the Central Mexican "cosmogram." The "St. Andrew's Cross" on (a) the Féjérvary-Mayer Codex frontispiece comprises dots and Day Signs, counting out a full 260 Day Count cycle. Each of the four main 'arms' of the cross represents a different cosmic region: East at the top, North on the left, West at the bottom and South on the right. Each direction sprouts a tree that is attended by two deities. The central image is dressed as a warrior who has vanquished a victim, whose body parts are connected by blood at the inter-cardinal vertices to the trace of time. Accordingly, each column of the text in (b) the Dresden Codex Venus Table excerpt begins with a date and then is anchored to the verb **K'AL-ja** (for *k'ahlaj* – 'to be enclosed'), followed by one of the cosmic directions, the name of a deity and the name for Venus. The fourth column, for example, can be read as: 'On 2 Kib 14 Wo, the East is enclosed by Jun Ajaw and Venus.' Ritual time, therefore, encloses each of the four cosmic regions facilitated by two celestial deities (the named one and Venus). Also, compare the central figure in the cosmogram, Xiuhtecuhtli, with the warrior figure in the Dresden Codex excerpt, who is named hieroglyphically as '*Chak Xiwite*' (**CHAK xi-wi-te**).



260DATE1	260DATE2	260DATE3	260DATE4
365DATE1	365DATE2	365DATE3	365DATE4
ENCLOSED IS	ENCLOSED IS	ENCLOSED IS	ENCLOSED IS
NORTH	WEST	SOUTH	EAST
DEITY 1	DEITY 2	DEITY 3	DEITY 4
VENUS	VENUS	VENUS	VENUS

The first, third, fourth, and fifth Calendar Rounds of this sequence are the two sets that show up on Page 24 and Page 50. Teeple's serial application of the inferred correction interval, though, produced one "extra" Calendar Round date: 1 Ajaw 8 Yax. This date does not show up in the Venus Pages at all. Teeple (1926:404) suggested that the omission corresponded to an actual implementation of the set of corrections to match a historically observed sequence of first morning visibilities.

Thompson, on the other hand, ignored the missing Calendar Round date and used the first correction interval, 4.12.8.0, to go directly from 1 Ajaw 18 K'ayab to 1 Ajaw 18 Wo. He then utilized the implied interval from there on. (See Figure 2) While his approach required that he accept an error of 16 days between the anchor of the Table and a historically reconstructed first morning visibility of Venus, Thompson explained that away by suggesting that the scribe was using it only for its numerological value (1972:63). Only slight modifications to Thompson's method have been used since (Bricker and Bricker 2007:102-104).

It turns out, however, that there is another method for producing the sequence of Calendar Rounds recorded in pages 46-50, and this one significantly more straightforward.

Mathematical Coherence

There is a viable alternative to Teeple's approach. As noted in my treatment of the operative verb within the Venus pages (Aldana 2011), the correction intervals explicitly written on Page 24 themselves take the Venus Table base date through each of the explicitly recorded anchors:

1 Ajaw 18 K'ayab	1 Ajaw 18 K'ayab
+ 4.12.8.0	+ 33,280
1 Ajaw 18 Wo	1 Ajaw 18 Wo
1 Ajaw 18 K'ayab	1 Ajaw 18 K'ayab
+ 9.11.7.0	+ 68,900
1 Ajaw 13 Mak	1 Ajaw 13 Mak
1 Ajaw 18 K'ayab	1 Ajaw 18 K'ayab
+ 1.5.14.4.0	+ 185,120
+ 4.12.8.0	+ 33,280
1 Ajaw 3 Xul	1 Ajaw 3 Xul

Notice that where Thompson's method applies the correction intervals *serially*, the sequence here shows that each interval applied *independently* more cleanly reproduces the Calendar Round dates. This alternate approach to the correction interval opens up a provocative mathematical coherence to the Table and generates a more robust interpretation overall. To see it, we first define a new term: the Corrected Venus Interval, which is that time interval used to move from one recorded Calendar Round date to a future Calendar Round date "corrected" for the slippage between the idealized 584-day period and the actual 583.92-day synodic period. We can then take VGC = Venus Great Cycle = 37,960; CI_n = n^{th} Correction Interval recorded on Page 24; and CVI_n = n^{th} corrected Venus interval. These produce the following relationships.

$1\ VGC + 1\ CI_1 = CVI_1$
5.5.8.0 + 4.12.8.0 = 9.17.16.0
37,960 + 33,280 = 71,240

This can be compared to the uncorrected interval it is meant to replace, which would be 2 Venus Great Cycles (2VGC):

2 x 5.5.8.0 = 10.10.16.0
2 * 37,960 = 75,920

So that:

$CVI_1/2VGC = 71{,}240/75{,}920$
$= 137/146$

Similarly, for the second Corrected Venus Interval:

$1\ VGC + 1\ CI_2 = CVI_2$
5.5.8.0 + 9.11.7.0 = 14.16.15.0
37,960 + 68,900 = 106,860

And for the 3 VGCs it is meant to correct:

3 x 5.5.8.0 = 15.16.6.0
3 * 37,960 = 113,880

So that:

$CVI_2/3VGC = 106{,}860/113{,}880$
$= 137/146$

The comparison yields:

$CVI_1/2VGC = CVI_2/3VGC$

Each corrected Venus interval (CVI_n) relative to its parallel, uncorrected interval produces the same ratio. The same ratio is used according to the same method for correcting projections for the periods of two Great Cycles into the future and that of three Great Cycles. Notice that with this approach, there is no skipping around and arbitrarily using inferred correction intervals or unscripted applications of one versus another. (See Figure 2) The method of correction is straightforwardly represented in the table of intervals.

The equivalence of these ratios suggests that they were constructed to be applied independently and not serially as Teeple originally proposed. It also allows us the hypothesis that they were intentionally constructed at least in part around this relationship. Moreover, we do not have to appeal to opaque origins for these intervals. The two correction intervals were created with very "Mayan numbers":

$$CVI_1 = 71{,}240 = 137 \times 520 = 137 \times 2 \times 260$$

$$2VGC = 75{,}920 = 146 \times 520 = 146 \times 2 \times 260 = 73 \times 2^2 \times 260 = 26 \times 2{,}920$$

While:

$$CVI_2 = 106{,}860 = 137 \times 780 = 137 \times 3 \times 260$$

$$3VGC = 113{,}880 = 146 \times 780 = 146 \times 3 \times 260 = 73 \times 2 \times 3 \times 260 = 39 \times 2{,}920$$

The prime number 73 is critical to Mayan calendric manipulations as shown by Lounsbury (1978) since it is a common factor of 365 (= 5 x 73) and 584 (= 8 x 73). Besides the denominators as whole number multiples of the arithmetic base of all intervals on Page 24, these are standard arithmetic relationships readily available to the Mayan calendric specialist (Aldana 2007; Lounsbury 1978; Thompson 1972). Nor are the numbers of a scope unattested within the Dresden Codex itself, as they are dwarfed by, for instance, the serpent numbers on Pages 61-73 of the same manuscript (Thompson 1972:80-88). Finally, the result is a very respectable 583.934 (= 71,240/122 = 106,860/183) average synodic period for Venus, which is not as accurate as the traditional model (583.92), but which we find is productive in other ways.

The mathematical coherence of Page 24 under the new interpretation is further corroborated by Lounsbury's 1992 essay on the mathematical structure of the Correction Intervals. Lounsbury showed that each correction interval takes the form of a Diophantine Equation (1992b:208) and he identified the term 2,340 as being fundamental to the construction of each. Here we define 2,340 as the Correction Factor, CF.

$$CI = x\text{VGC} - y\text{CF} \quad (x, y \in \text{I})$$

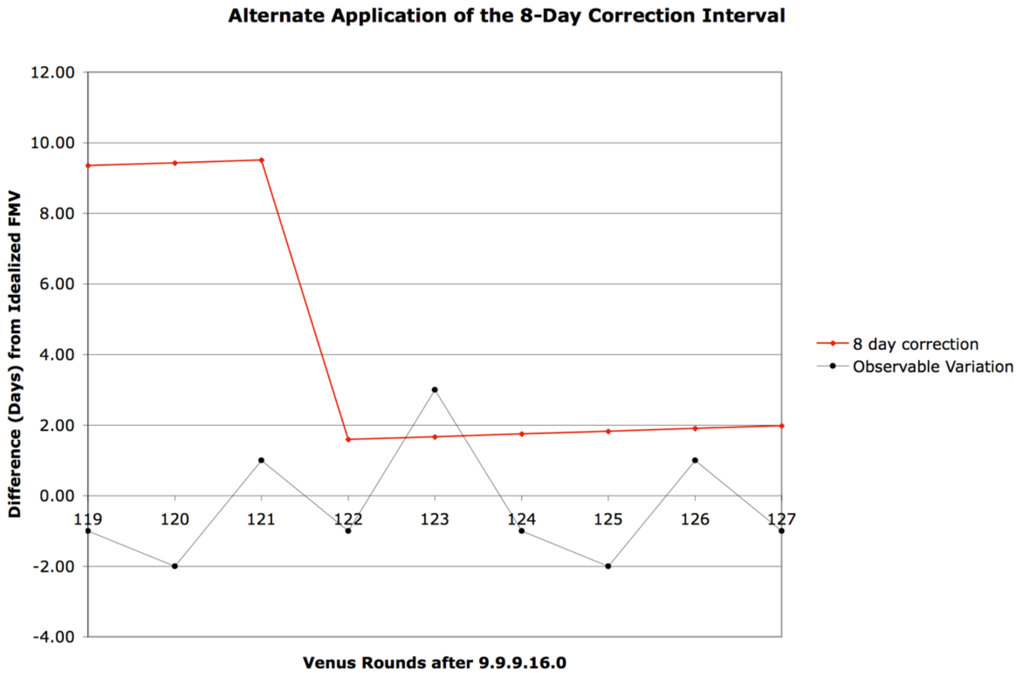
$$CI_1 = 4.12.8.0 = 1 \times 5.5.8.0 - 2 \times 6.9.0 = 1 \times 37{,}960 - 2 \times 2{,}340 = 33{,}280$$

$$CI_2 = 9.11.7.0 = 2 \times 5.5.8.0 - 3 \times 6.9.0 = 2 \times 37{,}960 - 3 \times 2{,}340 = 68{,}900$$

$$CI_3 = 1.5.14.4.0 = 5 \times 5.5.8.0 - 2 \times 6.9.0 = 3 \times 37{,}960 - 2 \times 2{,}340 = 185{,}120$$

even

Figure 4. Eight-day drop in the average error between the Venus Table prediction and an idealized projection forward of first morning visibilities from 9.9.9.16.0 1 Ajaw 18 K'ayab.



$$CI_4 = 1.5.5.0 = 4 \text{ x } 5.5.8.0 - 61 \text{ x } 6.9.0$$
$$= 4 \text{ x } 37{,}960 - 61 \text{ x } 2{,}340$$
$$= 9{,}100$$ [8]

The Correction Factor works as such because 2,340 is divisible by 260 (9 times), so it will preserve the same date in the 260 Day Count—in these cases it preserves the date 1 Ajaw. Also, 4 x 584 = 2,336, so subtracting intervals of 2,340 (or 4 x 584 + 4) compensates for the difference between the synodic period and the idealized Venus Round (Lounsbury 1992b).

The above equations also show that the coefficient *y* of the 2,340 Correction Factor corresponds to the number of 4-day corrections built into the correction interval (Lounsbury 1992b). The first, 4.12.8.0, would be used to invoke an 8-day correction. It follows that it would be useful for making up an accumulated error of around 8 days, which would occur after 60,736 days (= 8 x 13 x 584 (= 1.6 Great Cycles) since 13 x 584 produces 1 day of error). More straightforward, an interval of 2 full Great Cycles (75,920 = 2 x 37,960) would accumulate 10.2 days of error, so a correction of 8 days would bring predictions within observable tolerances.

In application, the correction interval actually truncates the progression and resets the anchor earlier than the completion of an integral number of full tables. That is, a complete Venus Great Cycle would

[8] This last interval has been considered enigmatic since Förstemann's time, and has even been dismissed by Thompson as an error, although recent work has resulted in proposals for its legitimate function (Aldana 2011; Lounsbury 1992b).

have ended at the 130th Venus Round; rather than wait for the accumulation of 10 days of error, the correction would have found that a 1 Ajaw date occurred eight VR earlier, on the 122nd. (See Figure 4) Shifting to this 1 Ajaw date as a new anchor brings the Table back into observational tolerances.

The pattern continues with the second correction interval. Here, the coefficient of CF (2,340) is 3, so we would expect this to correct an accumulated error of 12 days. Three uncorrected intervals would accumulate 15 days, so again, an application of this correction would bring three full uncorrected tables back into check with Venus's observability. Here again, the internal mathematical structure of the intervals suggests an independent applicability of the correction intervals, not a serial one.

One final observation favors the new interpretation presented here. When we look at the graphical layout of the Preface, the 2 CF (8-day) correction interval is placed underneath the interval for two uncorrected cycles, and the 3 CF (12-day) correction interval is placed directly below the interval for three uncorrected cycles. The first correction "fixes" a projection forward of two full tables, while the second correction "fixes" a projection of three full tables. This is a graphical relationship to Page 24 that has no parallel in the traditional interpretation.

An Observational Hypothesis

We do not have to appeal only to an elegant numerology here (though the Venus Table scribe included plenty of it); by applying the correction intervals to the dates on Page 24, we encounter a very practical source for the hypothetical *observational* origin of the Venus Table. To see this pattern, we shift back to the observational context of an astronomer of the Terminal Classic.

In 1980, Anthony Aveni noted that Chich'en Itza, located in the heart of the northern Yucatan Peninsula, would have been a strong candidate for the origin of the Venus Table. Aveni's extensive study of Terminal Classic Structure 3C-15, also known as the "Caracol" or the "Observatory" (Aveni, Gibbs and Hartung 1975; Aveni 1980), led him to suggest that the Dresden Codex Venus Table may have been constructed there. First, he pointed to the irregular orientation of the structure relative to the rest of the site as an indication of potential astronomical alignment (Aveni 2001:274); then he focused on the windows and niches in the circular structure that aligned with Venus events such as the planet's northern extreme. Establishing an architectural connection between the Caracol and Venus, Aveni then turned to the Dresden Codex.

> [As we have seen,] the Venus tables provide a means of relating ritual site function to observations of the planet at about the time the Caracol was erected. … [I]t is possible that the astronomical observations delineated in the Venus table in the Dresden Codex were collected by astronomers perched in the observation chamber of this tower and others like it in northern Yucatan. (2001:275)

We will see here that the revised interpretation proposed in this paper more strongly supports Aveni's assertion than the traditional approach.

If we take the Long Count anchor to the Table, 9.9.9.16.0 1 Ajaw 18 K'ayab, written on Page 24 as a historical anchor, then we can explore the application of the Corrected Venus Intervals in Long Count time. For the first corrected projection:

9.9.9.16.0 1 Ajaw 18 K'ayab + CVI_1

Figure 5. Structure 3C-15, or “the Observatory,” at Chich'en Itza, Yucatan.

= 9.9.9.16.0 + 5.5.8.0 + 4.12.8.0
= 9.19.7.14.0 1 Ajaw 18 Wo

This corrected anchor would have run for a full 37,960 days to end on:

9.19.7.14.0 1 Ajaw 18 Wo
+ 5.5.8.0
= 10.4.13.4.0 1 Ajaw 18 Wo

And for the second:

9.9.9.16.0 1 Ajaw 18 K’ayab + CVI_2
= 9.9.9.16.0 + 5.5.8.0 + 9.11.7.0
= 10.4.6.13.0 1 Ajaw 13 Mak

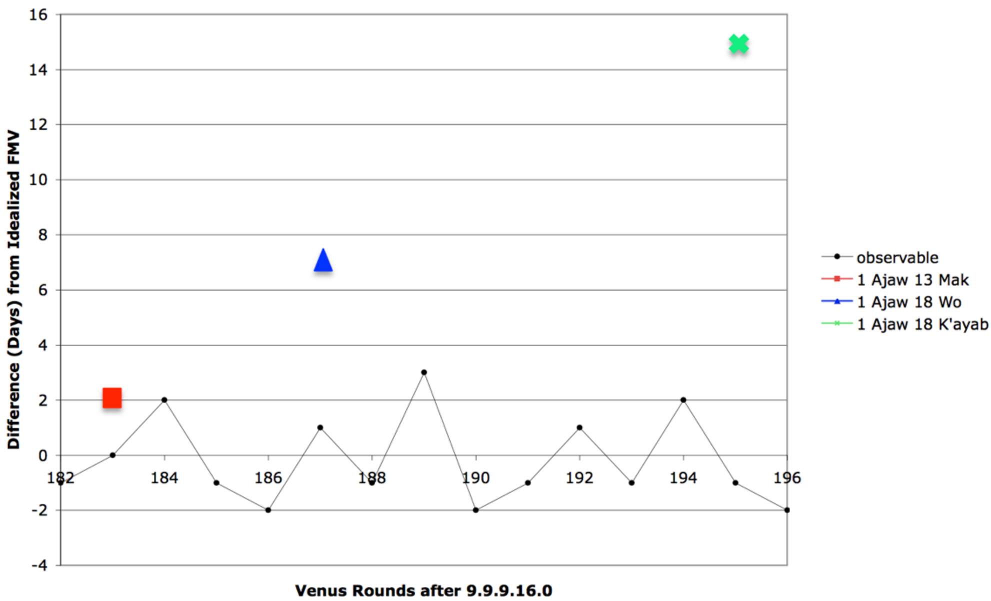
The latter 13 Mak date is the anchor for the table that we have running the full length of Pages 46 through 50 of the Dresden Codex. This table would have ended on 10.4.6.13.0 + 5.5.8.0 = 10.9.12.3.0 1 Ajaw 13 Mak. These Long Count dates easily fit within the use period of the Caracol at Chich’en Itza.

Specifically, there is evidence concerning the relationship between the manuscript and the building that went un-noticed in Aveni’s study. The Caracol itself contains hieroglyphic inscriptions that follow the Classic Mayan practice of recording historical and/or ritual events related to the dedication of ritual architecture. K’ak’ U Pakal K’awiil is named as the companion of several deities as well as mortal contemporaries in the inscriptions adorning the Monjas Structure, the Casa Colorada and the Caracol, all written during what Nikolai Grube and Ruth Krochok (2007:229) have called the “epigraphic florescence” at Chich’en Itza. In the Caracol Panel, K’ak’ U Pakal K’awiil is referred to as the protagonist of an event occurring ‘on the seventeenth *tuun* of *1 Ajaw*.’ Since we have both Long Count dates and Short Count dates at Chich’en Itza, K’ak’ U Pakal K’awiil’s event can be converted to 10.2.17.0.0 with confidence (Aldana 2011). This date is right in the middle of the dates implied by the Correction Intervals as we have recovered them.

Returning to the Long Count dates in the Venus Table, the difference between the end date of the first correction and the beginning date of the second correction are not far apart.

10.4.13.4.0 - 10.4.6.13.0 = 6.9.0

Figure 6. Three first morning visibility events occurring on 1 Ajaw dates, observable during the Terminal Classic.



It is not just that this interval is small and represents an overlap between one table and a subsequent one. This interval (6.9.0 = 2,340) is the Correction Factor that we saw above, utilized in all Diophantine Equations as Lounsbury showed in 1992. In other words, according to the revised interpretation presented here, the basic factor used to construct the Correction Intervals on Page 24 would have dropped out of the observations made by an astronomer during the Terminal Classic. Rather than propose this as some part of a proof for my interpretation, I suggest that this provides a window into the construction of the Venus Table itself.

Specifically, let us assume that the early Long Count anchor on Page 24 was preserved as an accurate historical record by a Postclassic astronomer and that s/he was viewing the night sky and recording first morning visibilities of Venus during the Terminal Classic at Chich'en Itza. If so, then most of what is written on Page 24 follows directly. That is, if we assume that 9.9.9.16.0 was a first morning appearance observed somewhere in the Mayan region and maintained in textual records, then we get the progression of Venus fmvs shown in Figure 6 based on a 583.9214 synodic period. (Notice that the variability is purely for illustrative purposes. Without a calendar correlation, and without meteorological data, actual visibility is purely hypothetical.)

The three single data points in Figure 6 are those 1 Ajaw dates falling near a first morning visibility event.[9] Notice in Figure 6 that the first fmv (at the 183rd VR after 9.9.9.16.0) occurred only 2 days from an idealized projection of a zero-error fmv event on 9.9.9.16.0. Two days of error

[9] One Ajaw dates are clearly central to the conceptualization of the Venus Table (Thompson 1972:63). Every interval on Page 24 is connected to or intended to retrieve a 1 Ajaw date.

over 292 years is certainly noteworthy. Given the variability of Venus fmv for any given Venus Round, it is indeed possible that this 1 Ajaw date fell precisely on an fmv event. Regardless, it would have been ideal for an interest in proximity to 1 Ajaw dates.

Whether it was exactly on, or even if it was off by a few days, the astronomers would have recognized an opportunity. If they witnessed and recorded this event, they would have found two 1 Ajaw fmv events separated by 106,860 days (= 10.4.6.13.0 – 9.9.9.16.0). Remaining vigilant for the next four Venus Rounds (or about 7 years) would have resulted in a tremendous payoff.

The fmv of the 187th Venus Round (after 9.9.9.16.0) would have fallen only 7 days (or as few as 4 days) from another 1 Ajaw date. When we consider this progression relative to Page 24, we recognize that these are not "just any" 1 Ajaw dates. The 183rd VR fell on 1 Ajaw 13 Mak; the 187th on 1 Ajaw 18 Wo. Both of these Calendar Rounds are highlighted within the Venus pages as we saw in the traditional interpretation of the correction mechanisms. More importantly, though, is the recognition that these two 1 Ajaw dates (13 Mak and 18 Wo) are separated by 2,340 days—the Correction Factor, noted above, built into all of the Correction Intervals as noted by Lounsbury (1992). Even more suggestive is that the 18 Wo date is two of these 2,340-day intervals from the next 1 Ajaw date near an fmv, which fell on 18 K'ayab.

This bears emphasis. The Correction Factor and two of the three Correction Intervals as well as three of the four Calendar Round dates all play roles in this one window of hypothetical observations during the early part of the eleventh baktun.

An attentive astronomer could have put this all together.

9.9.9.16.0 1 Ajaw 18 K'ayab
  + 3 x 5.5.8.0
  = 10.5.6.4.0 **1 Ajaw 18 K'ayab**

10.4.6.13.0 **1 Ajaw 13 Mak**
  = 9.9.9.16.0 1 Ajaw 18 K'ayab
    + 3 VGC – 3 CF
  = 9.9.9.16.0 1 Ajaw 18 K'ayab
    + 1 VGC + 1 CVI_2

10.4.13.4.0 **1 Ajaw 18 Wo**
  = 9.9.9.16.0 1 Ajaw 18 K'ayab
    + 3 VGC – 2 CF
  = 9.9.9.16.0 1 Ajaw 18 K'ayab
    + 2 VGC + 1 CVI_1

And so:

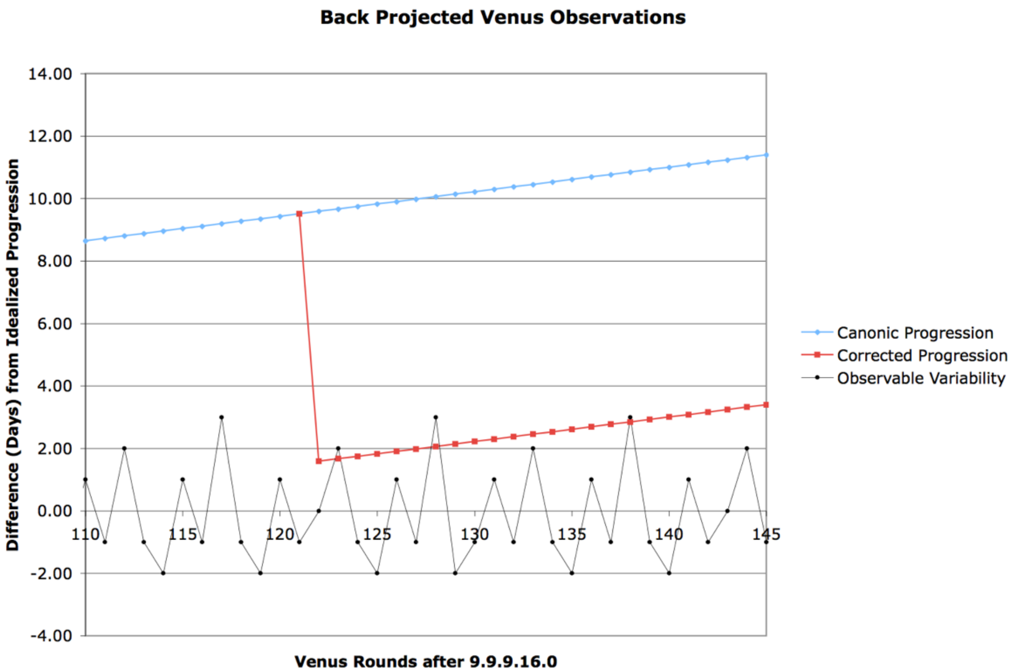
9.19.7.14.0 = 10.4.13.4.0 1 Ajaw 18 Wo
  – 5.5.8.0

9.19.7.14.0 **1 Ajaw 18 Wo**
  = 9.9.9.16.0 1 Ajaw 18 K'ayab
    + 2 VGC – 2 CF
  = 9.9.9.16.0 1 Ajaw 18 K'ayab
    + 1 VGC + 1 CVI_1

The derivation of all of the material on Page 24 would have dropped out of these two observations, seven years apart, along with one historical record. Furthermore, if s/he had access to other historical records of observed fmv (or fev), they would have fit within tolerance to the back-projected model this pattern produced, as shown in Figure 7. In this way, the derivation of the Correction Factor and the procedure for correcting the Venus Table over long spans of time in the Dresden Codex may reflect a cross-cultural analogue to Hipparchus's dependence on his Chaldean predecessors in his recognition of precession.

The 1 Ajaw 18 Wo date would then have been recognized as 2/3 of the way from 1 Ajaw 13 Mak to 1 Ajaw 18 K'ayab. It is again straightforward to have recog-

Figure 7. Reconstructed first morning visibilities of Venus for comparison against historical records.



nized this as a possible prior correction: 1 VGC – 2 CF should have corrected a projection forward of 2 VGCs. And herein lies the logic that reflects the pattern noted above. The two ratios of Correction Intervals to full Venus Great Cycle projections are equal.

1VGC – 2 CF to 2 VGC
= 2 VGC – 3 CF to 3VGC
= 137/146

With one historical record and direct observations of Venus over less than 10 years, the internal logic of Page 24 can be reconstructed. The implication is that the Venus Table captures and maintains an astronomical innovation – the discovery of the correction factors and their utility for Corrected Venus Intervals.

The traditional approach, however, takes the anchor not as a historical record, but as a numerological contrivance in error by 16 days (Thompson 1972:63; Lounsbury 1983:13). It also takes the correction intervals as serially applied. This paper takes the anchor as a historical record and the Correction Intervals as independently applied to the base date. The archaeological record corroborates the latter two suppositions.

The only explicit Venus record we have from the Classic period is that of Copan Structure 10L-11, which records a Venus /k'al/ event on 9.15.15.12.16 5 Kib 9 Pohp. As noted elsewhere (Aldana 2011; Fuls 2008) this event fits extremely well as an historical record of fev when we assume (against the traditional interpretation) that 9.9.9.16.0 was an accurate record of fmv. As such, it also suggests that the Venus Round was partitioned into the sub-periods reflected in the Dresden Codex Venus Table by the Late Classic at Copan. Moreover, the 9.15.15.12.16 Venus event was itself a historical record for the ruler who included it in his textual patronage. Yax Pahsaj Chan Yopat used this Venus event as an anchor to his own ritual event occurring 40 years later (Schele and Freidel 1990; Aldana 2011). By direct analogy, the 9.9.9.16.0 anchor to the Venus Table may have been a historical record.

Finally, the traditional interpretations put the effective use of the uncorrected tables up through anchors at 10.5.6.4.0 or 10.10.11.12.0. They then call for corrected tables starting at 10.9.18.12.0 (Lounsbury and Thompson) or 10.15.4.2.0 (Bricker and Bricker). And they place the 13 Mak anchor at 10.14.17.11.0 (Lounsbury and Thompson) or 11.0.3.1.0 (Bricker and Bricker). These traditional models, therefore, put the 13 Mak dates after 10.15.0.0.0, or up to 12 k'atun (~240 years) after the Caracol was dedicated and being used at Chich'en Itza. Even though Aveni suggests that the Table was developed at Chich'en Itza, the corrections were not utilized in the traditional interpretations until over a century after Chich'en Itza was abandoned. Here, though, I suggest that the 13 Mak table was derived and implemented between 10.4.6.13.0 and 10.4.13.4.0, within 20 years of Chich'en Itza's "epigraphic florescence," and that it was created to fit their own observations with historically recorded events.

The upshot is that rather than the ambiguous placement of the Dresden Codex Venus Table somewhere in the very late Postclassic, the interpretation of Page 24 presented in this essay puts its formulation within 25 years of the dedication of the Caracol. Twenty-five years of observations from the same building amounts to three full 8-year cycles of Venus, or three rows of the Venus Table on Pages 46-50. Notice also that, as opposed to the traditional approach, this reconstruction of fit is entirely independent of the Calendar Correlation Constant chosen. It requires only Long Count dates and the assumption of continuity between the Venus Table Long Count dates and the Long Count of the Classic period. These dates make a compelling case that the long-term correction of the Venus Table was derived at Chich'en Itza during the Terminal Classic at the Caracol, perhaps even under K'ak' U Pakal K'awiil's initiative.

The Third Correction Interval

The reconstruction proposed above is driven by the interpretation of the middle two correction intervals on Page 24. The third correction interval in that row differs significantly from these in size; it is almost 3 times the size of the 2nd correction interval (~506 years vs. ~188 years). In fact, this makes sense relative to another feature of the manuscript that has been long recognized. The Dresden Codex is clearly a copy (and probably a compilation) of earlier manuscripts (Thompson 1972:19). As all scholars studying the table have recognized, the 13 Mak version of the Venus Table—the one taking up pages 46-50—was not the one current when the manuscript was copied (Thompson 1972:15-16; Bricker and Bricker 2007:116). The reconstruction proposed here speaks to the *inherited* 13 Mak Venus Table's extension to a later time. In other words, the Correction Factor and the Corrected Venus Intervals had already been discovered hundreds of years before the scribe copied the table into the manuscript that we now call the Dresden Codex. Again, this re-copying was probably not a Postclassic innovation. The Copan record shows that Venus events were preserved for later reference at least since the Late Classic period.

As noted above, the third correction interval only produces a correction of 8 days, but it approaches 5 Great Cycles in scope. With each Great Cycle introducing 5 days of error, a correction much closer to 25 days would have been necessary. On the other hand:

9.9.9.16.0 1 Ajaw 18 K'ayab + CVI_3
= 9.9.9.16.0 + 1.5.14.4.0
= 10.15.4.2.0 1 Ajaw 18 Wo

The latter is a date that can also be derived directly from one of the observed fmvs at Chich'en Itza:

10.4.13.4.0 1 Ajaw 18 Wo + 2 x 5.5.8.0
= 10.15.4.2.0 1 Ajaw 18 Wo

If we assume a similar method for the 3 Xul base shift as that for the 13 Mak shift, then the utility of this relationship and that of the third interval fall out straightforwardly.

That is, if we assume that a late Postclassic astronomer observed an fmv near 10.19.16.10.0 1 Ajaw 3 Xul, s/he could have made sense of it in accord with the 13 Mak table s/he inherited. If the late Postclassic astronomer possessed a manuscript describing the observations from the Caracol at Chich'en Itza, s/he could have recognized that the interval from 9.9.9.16.0 to one of the recorded data points, 10.4.13.4.0 produced a difference of 15.3.6.0. This interval then added to 10.4.13.4.0 yielded the fmv that s/he observed:

9.9.9.16.0 1 Ajaw 18 K'ayab
+ 15.3.6.0
= 10.4.13.4.0 **1 Ajaw 18 Wo**
+ 15.3.6.0
= 10.19.16.10.0 **1 Ajaw 3 Xul**.

In other words, if the late Postclassic astronomer observed an fmv near 10.19.16.10.0 1 Ajaw 3 Xul, s/he could have consulted the manuscript in her/his possession to find that 10.4.13.4.0 1 Ajaw 18 Wo was also close to a historically observed fmv. The correction interval between the original anchor 9.9.9.16.0 and this historical date would then just have to be doubled to arrive at the 10.19.16.10.0 date directly observed. S/he could then have used the Table exactly as previously written with only a shift of the 365 Day Count to a base of 3 Xul.

Understood in this way, the scribe of the late Postclassic copied the necessary material from the Table's first correction, and then provided the interval necessary to make it useful for her/his contemporary times. Why did s/he not reconstruct the table entirely rather than copy the 13 Mak table for Pages 46-50? In fact, s/he did. The rows at the bottom of these five pages provide the haab' shift required to go from 13 Mak to 3 Xul. The 260-day Count dates do not have to change since the 1 Ajaw anchor is preserved regardless of shift. Furthermore, I have proposed elsewhere that the verb accompanying these lower 3 Xul rows is **tzekya'n* as 'to be corrected' (Aldana 2011:46). That proposal clearly gains currency given the reconstruction of the full table's implementation as presented here.

One complication with this proposal is that 10.19.16.10.0 1 Ajaw 3 Xul is 13 days from an idealized projection of synodic periods from 9.9.9.16.0 1 Ajaw 18 K'ayab. Thirteen days may test the credibility of the interpretation for some readers. Indeed, 13 days would almost certainly be excessive if the records came from observations at the same structure or even the same city. But here we are considering: an early Classic record at 9.9.9.16.0 that most likely came from observations at a southern lowland city; an early Postclassic record from Chich'en Itza in the northern Yucatan peninsula; and then a late Postclassic record from somewhere else in the Yucatan peninsula from an unknown structure. Given the tolerances on each of these observations, and given the emphasis on ritual events—not ephemeris accuracy—13 days of difference becomes reasonable for fmv events near 1 Ajaw dates separated by over 500 years.

Conclusion

I have argued elsewhere that the reconstruction of the correction procedure for the Dresden Codex Venus Table by modern scholarship has been unduly burdened by an interest in the correlation of the Mayan Long Count calendar with Christian chronologies (Aldana 2010, 2011). This essay adds to that study the complications that arise when we base our expectations for ancient science on modern conceptualizations of accuracy. From the perspective of matching up cross-Atlantic chronologies, these interests have been extremely useful. But it has also left some basic complications unconsidered.

In this essay we have prioritized the internal logic of the historical manuscript itself over its outside utility. In doing so, we have had to go against the traditional interpretation of Page 24 and the conventional wisdom supporting the currently accepted calendar correlation. By suspending the collective disbelief in the possibility of an alternative, this investigation has produced an interpretation of the correction mechanism for the Dresden Codex Venus Table that makes better use of what is actually written in the manuscript, and produces a much stronger chronological link to the manuscript's affiliation with the Caracol at Chich'en Itza. Although we must sacrifice the extreme accuracy for which the document (and Mayan culture) is known, we generate an interpretation that is more productive in interpreting the existing record and that provides new avenues for further research. Moreover, it argues for the recovery of an ancient Mayan astronomical discovery at Chich'en Itza.

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