Maya Astronomy

J. E. S. Thompson

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By J. E. S. Thompson, F.B.A.
Centre of Maya Studies, National University of Mexico

[Plates 19 and 20]

The Maya had three concurrent counts: 365-day years; 360-day 'years' (*tuns*), with named vigesimal multiples to 3200000 *tuns*, for calculations; and a 260-day sacred almanac (13 numbers and 20 concurrent names) covering all mundane and astronomical activities.

Solar eclipse and Venus synodical revolutions are tabulated in one hieroglyphic book to reach the lowest common multiple with 260: for Venus 37960 days (584 × 65 = 260 × 146 also 365 × 104); for the Moon 11960 days (405 lunations = 260 × 46). The Maya successfully predicted eclipses, but were unaware of which would be visible to them. Means were astronomical; ends, astrological.

Ingenious corrections, also retaining the 260-day connexion, occur. The corrected error in Venus revolutions is one day in 6000 years. Lunar corrections similarly had to conform to the sacred almanac. Other planetary tables are very dubiously identified.

Solar data are challengeable. Dates are recorded 5 million, possibly 90 and 400 million years ago.

The Maya occupied the whole peninsula of Yucatan and the area south of it including eastern Chiapas, the highlands of Guatemala and the western fringes of Honduras and El Salvador. The area extends from about 13 to 21° north of the equator. The most advanced centres were in the heart of this territory, the rain-forest lowlands of the Peten and Usumacinta drainage. The highlands in the south, although endowed with products, such as jade, obsidian, quetzal feathers of great value to the Maya economy, lagged behind the lowlands in art, architecture, and science. Maya culture, an outgrowth of earlier cultures, notably the Olmec, with greatest development in the Isthmus of Tehuantepec, southern Veracruz and the Pacific coast of Chiapas and Guatemala, was late, with its greatest period approximately A.D. 200 to 900. I see no evidence that Maya successes in astronomy and calendrics owe anything to Old World influences except perhaps for a basic stratum introduced, one may suppose, by hunter-gatherers crossing from the Old World via the Bering Strait from 10000 B.C. onward.

By A.D. 950 the great ceremonial centres had been abandoned to the forest, but Maya culture continued in peripheral regions, particularly on the western, northern and northeastern parts of the peninsula. This continuing culture, affected by outside influences, was marked by a rising importance of warfare and a concomitant loss of influence by religion. Deterioration of the arts is very obvious and Maya interest in time was no longer obsessive. The period of decline ended with the Spanish conquest (A.D. 1540).

No people in history has shown such interest in time as the Maya. Records of its passage were inscribed on practically every stela, on lintels of wood and stone, on stairways, cornices, friezes and panels.

Time was pictured as an endless relay march to eternity with the number of each time period from the day up carrying the period as a load on its back. Each sunset the marchers halted. Were it, for example, the fifteenth day, the bearer, the god of number 15, handed over his load to the god of number 16 to carry next day. On the last day of the year, the divine numerical carriers for year, month and day would similarly hand over to a new series (Thompson 1950, pp. 59–61).

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The Maya calendar

The extremely complex Maya calendar comprised three separate but concurrent counts. There was a year of 365 days formed of 18 'months' of 20 days each and an additional and extremely unlucky period of 5 days at its end. An approximate year of 360 days, composed of eighteen 20-day months, called *tun* was used in long-distance calculations. Multiples of this were in the vigesimal system used by the Maya for all forms of counting. There are hieroglyphs and names for the tun itself as well as for 20, 400, 8000, 160000, and 3200000 tuns.

The third count, and to the Maya the most important, was their sacred almanac of 260 days. This was formed of the numbers 1 to 13 and 20 named days which ran concurrently, more or less as though we had 1 Sunday, 2 Monday, etc., and then 8 Sunday, 9 Monday, etc., until the cycle closed with the thirteenth Saturday and went back to 1 Sunday at the end of 91 days. The Maya cycle was 260 days, the lowest common multiple of 13 and 20.

Each of the 20 names and 13 numbers was a god or goddess, not merely influenced by some god, and each day was looked on as a living being. Every activity on earth and in the skies was related to this sacred almanac, with certain days and numbers propitious or otherwise for such activities as planting crops, hunting, marriage, collecting honey, curing disease, making war, or the outgoings and incomings of planets.

Maya dates were recorded in terms of both the 260 and 365 day counts. As the highest common factor of those two numbers is five, a combination of the two counts could not recur until 52 years had passed. In addition, time was fixed by a count of tuns and their multiples from an epoch far in the past, which was not historical, but possibly marked a recreation of the world (the Maya believed the world had been created and destroyed four times and that we are now in the fifth creation). This epoch corresponded, according to the most widely accepted correlation of the two calendars, to 3113 B.C. – 10 August to be precise. It lay 3000 years in the past, when Maya culture, Maya glyphs and distant reckonings began. There are Maya dates far earlier than that, and such was the complexity of the Maya machine, that a date could be fixed in such a way that it would not repeat for 3000000000 million years, give or take a million years. There is some uncertainty about the numbering of the very high periods, but according to one arrangement, dates 90000000 and 400000000 years in the past are recorded. Even should the suggested arrangement be incorrect, there is no doubt that dates 300000000 years apart are inscribed on stelae (Thompson 1950, pp. 314–16).

Correlation of Maya and European calendars

The Maya calendar can be correlated with our own with considerable certainty. The 260-day almanac survives to the present day among some remote Maya communities. All those almanacs agree to the day. Projected back to the sixteenth century, they fail by only one day to synchronize with a Maya year and a European year (for 1553) correlated by a Franciscan missionary. The one-day break arose probably because the friar may have collected his information on the start of the Maya year (16 July o.s.) in 1551 and failed to allow for the intervening leap day of 1552.

The modern Maya almanacs, furthermore, agree to the day with Aztec-European double dates. Clearly, all Middle America had a synchronized 260-day almanac, and as this has not lost a day in the face of Spanish attempts to suppress it during the past four and a half centuries, one must conclude that there was no loss when the priest astronomers were dominant at an earlier period. Moon-age records from then bear out that conclusion.

Other data, notably records of Moon ages and heliacal risings of Venus in Maya sources, events of the Spanish conquest expressed also in terms of Maya new year days or of the katun (20-tun) count which formed yet another cycle of 260 tuns, the findings of Maya archaeology and their relationships to the archaeological sequences in the Valley of Mexico and other parts of highland Mexico, and, finally, carbon-14 readings of wooden lintels and beams dated in terms of the Maya calendar come very close to leaving the exact correlation of the two calendars beyond doubt. It does, however, depend on the assumption that there was never any break in the Maya calendar. Reasons for making that assumption are, as we have seen, very strong. To those one may add that the sacredness of the 260-day almanac was such that any tampering with it would have been unthinkable to the Maya priesthood; in addition, it would have set awry all the interlocking cycles of the moon and Venus and other counts, the importance of which is noted below. Discussions of all factors are in Morley (1920, appendix II), L. Roys (1935), Spinden (1924), Thompson (1935, 1950), and Satterthwaite & Ralph (1960).

The correlation, known as Goodman–Martínez–Thompson, which meets those conditions, calls for the addition to any Maya date, first reduced to days, of the number 584283, to give the Julian equivalent. Thus, as we have seen, the Maya epoch, written 13.0.0.0.0 4 Ahau 8 Cumku, becomes the equivalent of 10 August 3113 B.C., and 9.15.0.0.0 4 Ahau 13 Yax, at the height of the Classic period, corresponds to 20 August A.D. 731.

This correlation has won wide acceptance, but it has been rejected by a few who, with one exception, depend solely on astronomical data as interpreted, often very dubiously, by themselves. They pay little or no attention to the non-astronomical lines of evidence listed above and give no reasons for ignoring them, an attitude which hardly elicits one's respect. Each proclaims his own correlation – one student within a few years has announced six different correlations – based solely on differing and speculative interpretations of Maya astronomical data. None has persuaded any rival that the true light has been vouchsafed him.

Needless to say, an unchallengeable correlation of the two calendars would be immensely helpful in identifying astronomical data in the texts, although I myself am far from convinced that planetary observations were recorded on the stone monuments, unless favourable phenomena perhaps governed a ruler's accession date. Stelae recorded past events whereas Maya astronomers aimed at prediction. Planetary matters would have been noted on work sheets, not on stelae, so sacred in Maya eyes.

Scores of dates with records of contemporary Moon age and the position of the current moon in a group of six (sometimes five?) lunations, as well as a few Moon ages calculated for dates then far in the past, are carved on stone monuments, but the most striking astronomical data are in the Dresden codex, one of only three surviving hieroglyphic books of the Maya (Thompson 1972). This is an edition of around A.D. 1250 of a lost earlier version of perhaps about A.D. 750. Dresden codex, so-named for the city in which it now reposes, contains, in addition to a great number of 260-day almanacs of divination in connexion with all forms of mundane activities, tables for synodical revolutions of Venus and for solar eclipses, each preceded by multiplication tables of the periods involved and entries giving corrections which must be applied.

Synodical revolutions of Venus

It is necessary to emphasize what has already been said, namely that every astronomical mechanism, just like everything else in Maya life, had to be related to the 260-day sacred almanac. In the case of Venus, the position 1 Ahau was *the* day. On that day the cycle of revolutions of Venus started and ended. As it was more important for the Maya to keep that contact with 1 Ahau than to record exactly the calculated day of heliacal rising of the planet, corrections had to be made with that end in view.

The Venus table, occupying six pages of Dresden codex, covers 65 synodical revolutions of the planet (more precisely from one heliacal rising after inferior conjunction to another) averaged at 584 days. The first page, an introduction, gives religious and divinatory data and multiplications of 584, as well as needed corrections. Each revolution has four divisions or stations 230, 90, 250 and 8 days apart, marking roughly disappearance and reappearance before and after superior conjunction, then Venus as evening star, and finally 8 days of invisibility from disappearance to reappearance at heliacal rising after inferior conjunction. Note that no attention was paid to invisible phenomena – inferior and superior conjunctions, an important point in assessing claims regarding other planets.

The total of 65 synodical revolutions was chosen because 584 × 65 (37960 days) equal 146 of the 260-day sacred almanacs, that being the lowest common multiple of the two. It is incidentally 104 years of 365 days, which gave the number extra importance, but was not a deciding factor in the choice of the over-all period. The Maya knew very well that the length of the average revolution – it can vary from about 580 to 587 days – was not 584 days, but their equivalent of about 583.92 days (they did not use decimals), and that therefore their table was too long. However, should they make, say, a 1-day deduction when needed, the start of the table would no longer fall on the all-important day 1 Ahau; such a correction would have broken contact with the 260-day almanac, a disastrous happening in Maya eyes. A correction had to be made in such a way that it involved a multiple of 260 days.

At the bottom of the page prefacing the table are given multiples of 5, 10, 15, 20 and similar intervals of 5 up to 60 synodical revolutions of 584 days. The table continues at the top of the page with 65, 130, 195 and 260 multiples of 584, these last representing the length of the table and twice, thrice and four times its length. The last figure equals 365 × 416. It was not put there for ornament but was utilized in computations (figure 1, plate 19, left page).

The Maya were well aware that their table of 584 × 65 was slightly over 5 days too long. They corrected the error by formulae given in the centre of the prefatory page. The Maya priest-astronomer knew from his tables that the 61st revolution of Venus ended on the day called 5 Kan, which was precisely 4 days after 1 Ahau. The accumulated error then was between 4 and 5 days. Accordingly, he subtracted 4 days, and, recovering the all-important 1 Ahau, started the count again. The equation is

$$\begin{aligned}
584 \times 61 \ (35624 \text{ days}) - 4 \text{ days} &= 35620 \text{ days}\\
260 \times 137 &= 35620 \text{ days}\\
583.92 \times 61 \ (\text{true syn. revs.}) &= 35619.12 \text{ days}
\end{aligned}$$

The correction was good, but still 0.88 day short in just under a century, and that was not good enough for the Maya. They learned to make that 4-day correction, and then, when the error in their first correction had amounted to 4 days, they made an 8-day correction at the end

Figure 1. Two pages of Venus data, Dresden codex. Left page: top left, gods and prognostications for heliacal risings; right, multiples of synodical revolutions with corrections to them in space below first line of glyphs. A bar represents 5, a dot, 1, a flat oval, 0. Place numeration top to bottom: 400 tuns (each of 360 days), 20 tuns, single tuns, 20-day months, and days. Bars and dots serve as multipliers of suppressed periods. Accordingly, 8.2.0 in bottom right corner represents $8 \times 360 + 2 \times 20 + 0$ days $=$ 2920 days, 5 Venus revolutions of 584 days. Columns to left of this are multiples thereof, 10 Venus revolutions, etc. Right page: phases of synodical revolution. Bottom of page records intervals between stations. Left to right: 11.16 (236 days), to disappearance, 4.10 (90 days), to reappearance after superior conjunction, 12.10 (250 days) to disappearance before inferior conjunction, and 8 days to heliacal rising. Total 584 days. On right, patron deity, Venus deity who has hurled spear earthward, and, at bottom, victim with spear driven through him. Also augural glyphs for heliacal rising.

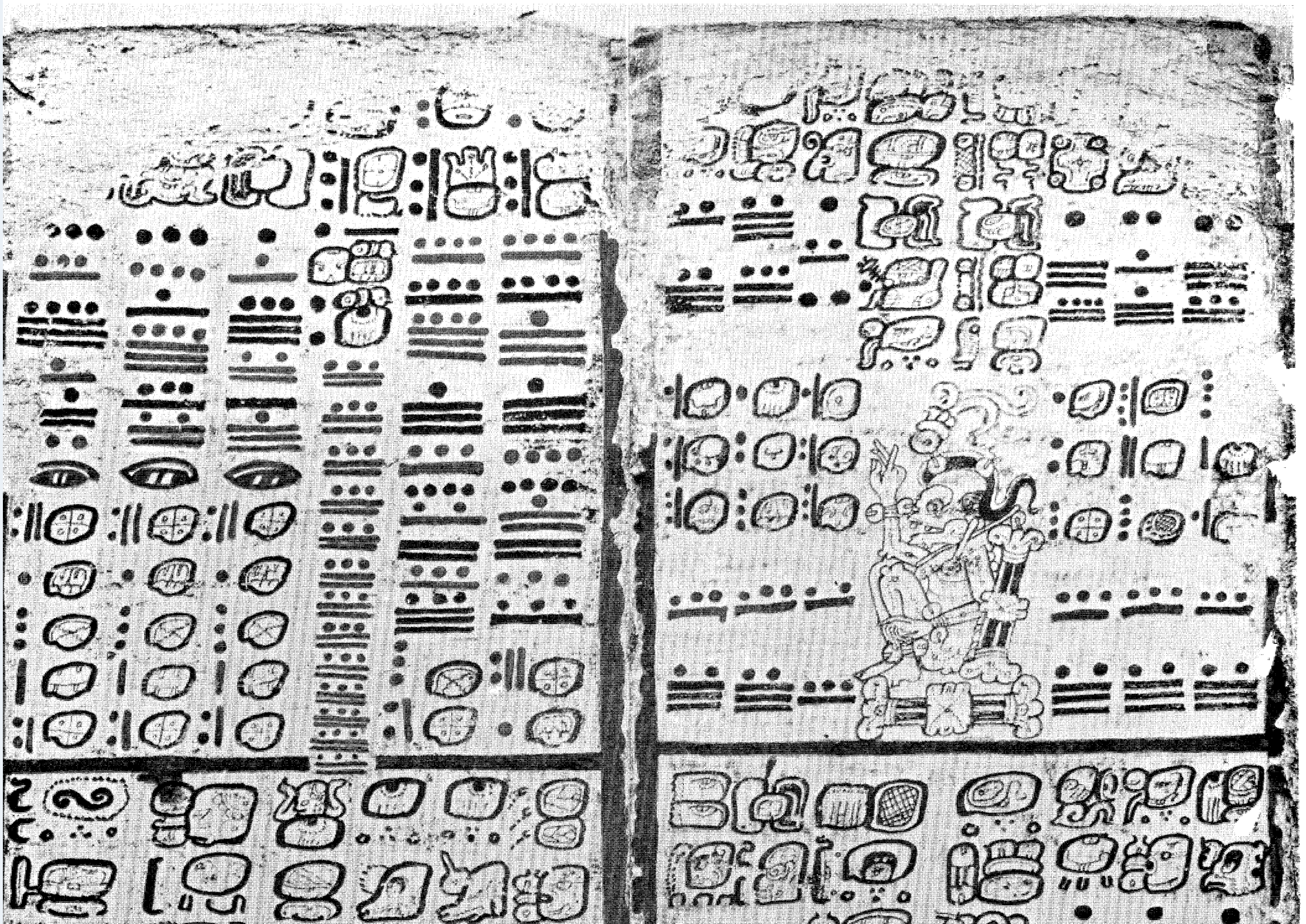

FIGURE 2. Two pages of eclipse tables, Dresden codex. Left page: top left, multiples of 1.13.4.0 (405 lunations). Right page: top, upper sets of bars and dots are accumulated totals of groups of 6 and 5 lunations: 177, 354, 502, picture, 679 (mistakenly written 674), 856, 1033 days (35 lunations). Lower set of bars and dots: 177, 177, 148, picture, 177, 177, 177 (6 and 5 Moon groups). Picture with prognostications only after 5-lunation group. Bottom halves of pages: continuation of lunation count as above six lunations (117 days) and five lunations (148 days). The latter only immediately before pictures.

of the 57th revolution of the planet, which terminated on the day 9 Muluc, 8 days after 1 Ahau, thus again recovering the vital position 1 Ahau by producing a total divisible by 260. In the line of corrections in the centre of the introductory page to the table appears the number 33 280, which is exactly 584 × 57 – 8 days, and beside it the number 68 900, which is 584 × 61 – 4 days and 584 × 57 – 8 days.

From the correctional entries it can be deduced that the second correction was made after the first had been applied four times in the following arrangement:

$$\begin{aligned} 4(584\times 61-4 \text{ days})+584\times 57-8 \text{ days} &= 175\,760 \text{ days}\\ 260\times 676 &= 175\,760 \text{ days}\\ 583.92\times 301 &= 175\,759.92 \text{ days}\end{aligned}$$

After 301 synodical revolutions of Venus have passed and the Maya corrections totalling 24 days have been made, the Maya calculation was still in error, but that error was only 0.08 day in a span of over 481 years. Bearing in mind the variability of the planet's synodical revolution and the hindrances to accurate observation caused by cloudy weather in the rainy season and morning mists in the dry season, the accuracy attained is almost unbelievable. It was based on boundless patience and undoubted cooperation of astronomers of different places and different generations. Students may differ as to the exact times when those corrections were to be made, but there can be no doubt as to how the system operated.

These pages had been identified as a table of Venus revolutions in the early days of Maya research; the credit for recognizing the all-important system of corrections goes to Teeple (1930), a chemical engineer, who took up the study of Maya astronomy to wile away long train journeys across the U.S.A.

From Mexican sources it is known that Venus was much feared at heliacal rising after inferior conjunction; its rays then slew various categories of persons or personified manifestations of nature. Illustrations in the Maya table (figure 1, plate 19) show Venus gods hurling spears earthward, and, below the slain victims. The accompanying glyphs, with very few exceptions are direful: 'Woe to the maize, woe to the corn fields, drought, misery, affliction of war' and so on (Thompson 1972, p. 70). By predicting the day of heliacal rising, the priests were able to warn the threatened group, so that it could take protective measures. For instance, we know from Mexican sources that 'when it [Venus] emerged much fear came over them; all were frightened. Everywhere the outlets and openings [of houses] were closed up. It was said that perchance [the light] might bring a cause of sickness, something evil when it came to emerge' (Sahagún 1950–70, book 7, ch. 3). The spear represents the 'death ray'.

This last brings out a most important point: we must try not to look at Maya astronomy through European eyes. Maya emphasis was almost wholly on heliacal rising after inferior conjunction because of the astrological importance of that position as listed above. The Maya astronomer – astrologer, if you will – completely ignored phenomena which seem important to us – greatest elongation, retrogade motion, greatest brilliance, and conjunction with the Sun – presumably because those phenomena had no affect on mundane affairs. Modern astronomers who have delved into the mathematics of Maya astronomy assume almost without exception that the Maya would have been extremely interested in planetary conjunction with the Sun. Yet, the evidence in this Venus table – and the Maya were certainly more interested in Venus than in any other planet – is that that phenomenon was completely ignored. Indeed, since solar conjunction of any planet is unobservable, there seems no valid reason why we should credit the Maya with such an interest still less in the case of other planets of far less importance to them. We know neither names nor glyphs of any planet other than Venus.

The famous astrologer Dr John Dee used an Aztec obsidian mirror to see into the future. We may look down our noses at his ideas, but one may be sure that in outlook he was far closer to a Maya priest astronomer than is an astronomer of our century.

Eclipses and lunar calculations

The eclipse table, occupying eight pages, follows immediately the Venus table in Dresden codex, and, indeed, is of the same pattern. It, too, has an introduction with dates leading back to the epoch, and multiples of 11 960 days, the length of the table, a number which is also a multiple of the 260-day sacred almanac. It also has corrections, again like those of the Venus introduction in that they are applied before the whole cycle of 11 960 days has run its course, and, again, are made so that 12 Lamat, the day of the lunar table is recovered. These parallels are, in my opinion highly important, for they establish a pattern, to which other planetary tables, if they exist, should be expected to conform. The lunar equation is:

$$\begin{aligned} &\text{405 moons} &&= 11\,960 \text{ days}\\ &260 \times 46 &&= 11\,960 \text{ days}\\ &\text{405 astronomical moons} &&= 11\,959.89 \text{ days} \end{aligned}$$

The table consists principally of totals of 177 days, very occasionally of 178 days, representing six-moon groups. There are also nine five-moon groups, amounting to 148 days, each being followed by a picture and additional glyphs (figure 2, plate 20).

As early as 1910 the astronomer Robert Willson (1924), observing the number 6585 among the figures, concluded that the pages dealt with the saros or at least a series of eclipses. He also noted that the intervals between the pictures were 1742, 1033 and 1211, thrice repeated. He was, naturally, aware from Schram's tables that if there is a central solar eclipse somewhere on Earth on a given date, there will be the same phenomenon after 1033, 1211, 1388 and 1565 days and perhaps after 1742 days. Clearly, then, one function of the table was solar eclipse prediction. Another function, as we know, was long-distance lunar calculation. However, the Maya, not knowing anything of the nature of the world or the Copernican system, could not predict whether any particular eclipse would be visible in the Maya area. It is hard to see how, with their lack of knowledge of the mechanics of eclipses, they could have gone beyond that; they could not know that when an eclipse failed to materialize for them on one of the dates in their table, it had, in fact been visible in Tibet, Timbuctoo or Australia.

Astronomers, who have not been able to steep themselves in Maya attitudes and Maya colonial literature, have supposed that this is a table of observed eclipses and have tried to match the numbers accompanied by pictures with solar eclipses visible to the Maya. However, the multiples of the period (one would carry the original date of the table over 1200 years into the future) and the various introductory dates given at the start of these pages as well as the Maya obsession with divination, particularly in terms of the 260-day almanac, make it clear that this was a table for predictions to be used time after time. Solar eclipses were occasions of dire peril. It was believed the world might end during a solar eclipse – a belief still held by the present-day Maya, and, at the very least, dreaded creatures then descended to earth to cause great havoc. The Maya sought to predict eclipses so that the threatened disaster could be averted by prior ceremonies. Hence the association of the lunar table, like other handling of phenomena, with their sort of 'Old Moore's almanac' of 260-days. The use of the table as a prediction apparatus is supported by accompanying glyphs of death, crop failure and of sky-supporting deities apparently thought to descend to Earth during eclipses; all are prophetic.

John Teeple, whose contributions to understanding of the Venus tables have been mentioned, not only discovered how lunar data were recorded on the monuments, but with equal genius reconstructed the method the Maya almost certainly used in constructing this table and its predecessors, finding how they solved the problem of where to insert each 5-lunation group (Teeple 1930). Because of the retrogression of the node day, the table could not be used indefinitely, so it can be inferred that the present table had various predecessors, in which the positions of the 5-lunation groups would have been different. He found that choice of locations for those 5-lunation groups involved the use of a double 260-day almanac. He discovered that if observed eclipses were plotted on a circle or strip with 520 teeth or gradations corresponding to the day names and numbers of a double sacred almanac, they would be found to cluster in three segments of the circle or sections of the strip, each segment comprising up to 34 days. The clustering and the size of the segment are so because a solar eclipse must fall within approximately 18 days either side of the node. As the paths of Sun and Moon cross every 173.31 days, three of those eclipses half years equal 519.93 days, which by a remarkable coincidence are less than a tenth of a day short of 520 days, the doubled 260-day Maya almanac. Observed eclipses, when plotted on that wheel, would be seen to occur within 18 or 19 days either side of the main spokes or radii 173, 173 and 174 days apart.

As the eclipse interval is 177.18 days, each eclipse advances nearly 4 days, or nearly 12 days at each return to one of the three segments. Observation would show that if, by the addition of the normal moons, 177 days, a position was reached beyond the limits of the segment, it would be necessary to use instead a five-moon grouping of 148 days to keep within the segment which alone would insure that an eclipse might be observable. Thus, with no knowledge of node crossing, the Maya constructed this very accurate table of solar eclipse predictions, but, as remarked, without being able to forecast whether any given eclipse would be visible to them.

This same formula of 405 moons equal 46 sacred 260-day almanacs was used for long-distance lunar calculations at least as early as the seventh century A.D. and probably earlier still. At the important site of Palenque a date then 3812 years in the past and two others, a few days apart, 3051 years in the past, were recorded on stone wall panels, each accompanied by a statement of the age of the Moon and the number of the lunation in a group of six. The above 405-moon formula connects then current lunar observations to those calculated Moon ages in the far past to within a day. However, the formula not being quite accurate, an error of 13 days had accumulated. The earliest date informs us that the Moon was then 5 days old and the Moon was the second in the group of six. The real Moon age would have been 18 days.

There is good evidence that the Maya realized that their formula was too long, and at about the time those Palenque dates were carved, they began to apply a correction of the same kind as they made in the Venus count. That is, they stopped at a point in the 405-moon formula where they could make a correction (of 1 day, not 4 or 8 days as in the Venus formulae) yet still retain the essential link with the 260-day almanac by recovering the day 12 Lamat.

The point for correction was at the end of the 361st moon:

361 Maya moons – 1 day = 10660 days
260 × 41 = 10660 days
361 astronomical moons = 10660.54 days

The correction was slightly over a half day short of the mark, whereas the 405 moons = 11960 days was 0.11 day too long.

One backward reckoning at Copan of just over 1000 years comprises 19 405-moon groups and 13 361-moon groups. The long distance from the 12 Lamat nearest the epoch of the calendar to the 12 Lamat which marked the start – A.D. 755 – of (the long-disused) lunar table comprises 111 405-moon groups plus eight 361-moon groups. Among the multiples of 405 moons on the introductory page of the lunar table appears the number 371020 which resolves itself into twenty-three 405-moon groups and nine 361-moon groups. This number added to 101 405-moon groups and reduced to days (1578980) is the distance of over 4300 years from the 12 Lamat nearest the start of the calendar to the base in Maya notation 10.19.6.1.8 12 Lamat 6 Cumku (A.D. 1210), which is written in the introduction to the eclipse tables, and which was the current base without much doubt when the present edition of this hieroglyphic book was made. At that late date 12 Lamat was still *the* Moon day; the essential link with the 260-day almanac was unbroken.

There are other computations which involve a mixture of 405-moon groups and 361-moon groups (Thompson 1972, p. 74). Most probably the Maya never learnt which ratio of one group to the other was most accurate. As the 405-moon cycle accumulates an error of one day only after three centuries, the Maya failure to achieve a perfect solution is understandable. The ideal ratio would have been 5:1:

405 Maya moons × 5 = 260 × 46 × 5 = 59800 days
361 Maya moons – 1 day = 260 × 41 = 10660 days
total 2386 Maya moons – 1 day = 260 × 271 = 70460 days
2386 astronomical moons = 70459.98 days

One such interval of 2386 moons is recorded, but as there is no specific indication that this is a lunar count, it could be a coincidence, for which one must always be prepared in Maya arithmetic. If it was intended to mark that 5:1 ratio, it shows an accuracy in measuring the length of a lunation of a brilliance never approached by any other people on the same level of civilization.

Observations of other planets

The Maya surely were interested in the synodical revolutions of other planets, and numbers occur which are multiples or near multiples of such cycles, but there are hundreds of intervals recorded on the stone monuments and in the books. In cases of long intervals, perhaps running into hundreds of thousands of days, anyone can get plenty of planetary data if one allows oneself sufficient latitude in deciding what length the Maya accepted for the synodical revolution of a planet. That of Jupiter is 398.867 days. If one postulates the Maya calculated it as 399 days or 398.7 or 398.85, one may get ‘striking results’, but even the very close approximation of 398.85 days accumulates a huge error in the 3500 years between the calendrical epoch and the start of the Classic period. The astronomer Ludendorff (1937, p. 19) used 398.883, 398.8842 and 398.8844 for Jupiter's synodical revolution in discussing three related intervals of around 34000 years. Not unexpectedly, with such leeway he could show that the intervals were divisible by revolutions of the planet without remainder. One of the intervals, incidentally, was wrongly written by the Maya without any doubt, yet produced equally notable phenomena. Yet another warning against 'playing with numbers'.

As noted, planetary data are unlikely to have been recorded on stone monuments except possibly for astrological reasons in connexion with choosing accession dates for rulers; the Venus and lunar tables in Dresden codex have led to the search for other planetary tables in that book.

Claims have been made (Escalona Ramos 1940; Makemson 1943; Smiley 1961, 1967; Spinden 1942; Willson 1924) that pages of that book treat of synodical revolutions of Jupiter, Mars, Saturn and Mercury, of equinoxes and possibly periodicity of hurricanes, and even of sidereal revolutions. No two investigators agree as to which pages cover which planet.

In the absence of introductory multiples of the synodical revolutions and necessary corrections, as on the Venus and lunar pages, of any convincing planetary phases, and of any evidence of relating synodical revolutions to the 260-day almanac, the cases for such tables of Jupiter, Saturn and Mercury are extremely weak.

The associated almanacs show no relationship to the planets either in length or subject-matter. For instance, it has been claimed that dates on pp. 61 and 62 deal with revolutions of Jupiter. They introduce a 7 × 260-day almanac (1820 days), far from a multiple of the Jupiter revolution. The subject-matter is equally at variance. It comprises thirteen pictures of the rain gods and accompanying glyphs of the deities' activities and food offerings made to them. There are a large number of dates which would have to be planetary stations if the almanac is astronomical, varying from 1 to 13 days apart, but such intervals as stations are quite meaningless. Clearly, there is no connexion with Jupiter or any other planet.

A possible exception to what has been written above is a table of 780 days (3 × 260), one of several in Dresden codex which is a multiple of 260 days. The number is a very close approximation to the synodical revolution of Mars (779.936 days), and this is preceded by a table of multiples of 78 and 780 days, but with no correctional numbers. Willson (1924) believed this covered revolutions of Mars. The arrangement of the triple almanac is like the general run of divinatory almanacs; it does not resemble the Venus record, and a number of the associated glyphs cover agriculture. It consists of ten sections of 78 days, each in turn made up of intervals of 19, 19, 19 and 21 days. If this is a Mars revolution, it has no less than forty stations compared with Venus's four stations at obvious points – appearance and reappearance of the planet. One cannot conceive of a planet having forty stations at those repeating, short intervals. Other students have rejected the Mars interpretation and suggested the table deals with other planets. It is surely far more likely to be mere chance that this triple almanac so nearly equals in length a revolution of Mars. The 78-day subdivisions, prominent in both the almanac and the table of multiples, have no obvious connexion with Mars or with any other planet for that matter.

I am confident that the only ephemeris in Dresden codex is that of Venus. The failure of students to agree on which pages are to be assigned to other planets strongly supports that view. The question of sidereal revolutions of planets is discussed below.

The Maya zodiac

The Maya had a sort of zodiac, the best example being in the hieroglyphic book called Codex Paris (Spinden 1916, 1924, pp. 55–56, 1941). It comprises thirteen animal signs. Rattlesnake, turtle, scorpion, bat, two birds and frog (?) are identifiable; others are fantastic creatures or are obliterated. Each, suspended upright from the sky, has a sun glyph in its jaws or beak. Intervals of 28 days between the 13 associated day signs form a 364-day year, which is repeated five times to achieve the vital relationship with the 260-day sacred almanac: $364 \times 5 = 260 \times 7$. Unlike most glyphic texts, the sequence reads right to left. It has been suggested that that was because the star groups 'feed into the path of the sun'. How this 364-day count could have been related to a sidereal year is not clear. The concept may have been brought to the New World by hunter-gatherers at a very early date (p. 97).

Stars and constellations

Information on Maya ideas concerning stars and constellations is scarce and few Maya names for the latter have survived. That is surely because no European showed any interest in Maya astronomy before Maya culture collapsed; our knowledge of the wonderful achievements in the matters of eclipses and Venus movements come entirely from pre-Spanish sources. Glyphs of stars or constellations may be drawn in the Venus table, and conjunctions of the Moon with stars may be recorded in the same Dresden codex. That stars affected human life is made clear by two passages in a book of the colonial period, written in the Maya language but using the European alphabet, which recounts much Maya history and mythology: 'In due measure they sought the lucky days until they saw the good stars enter into their reign; then they kept watch while the reign of the good stars began. Then everything was good' and, in contrast, 'ill-omened is the star adorning the night. Frightful is its house' (R. L. Roys 1933, pp. 83, 91).

The Aztec are said to have held their great ceremony of rekindling fire at the end of the 52-year cycle when the Pleiades reached the zenith at midnight, but as the ceremony receded 13 days each time it recurred because of the absence of bissextile years, the ceremony could not have been related to the movement of the Pleaiades indefinitely. In fact, the last time the ceremony was held, in 1507, it would have occurred in or near February, so it is probable that on that occasion it happened to coincide with an overhead position of the Pleiades at midnight. The point is that this is evidence that the peoples of Middle America did pay attention to positions of constellations.

The not too reliable Tezozomoc (1878, ch. 82), writing at the age of 78 – he was born just before Cortés conquered Mexico – tells of how his grandfather Moctezuma was admonished at his induction specially to rise at midnight to observe the firesticks constellation, as they call the Keys of St Peter [perhaps in Gemini], the Ball Court constellation, the Pleiades and the Scorpion [Great Bear] which mark the four celestial cardinal points. Toward dawn he must also observe carefully Xonecuilli, 'the Cross of St. James, which appears in the southern sky in the direction of China and India'. According to Sahagun's Spanish text (1938, book 7, ch. 8), a far more reliable source, this last was the Little Bear. This confused account makes clear the importance of stellar observation among the Aztec and, we may be sure, the same was true of the Maya. It also reveals confusion about identifications, a matter to which I shall return.

The only reference I know, early or modern, to constellations as time markers among the

Maya is that the present-day Lacandon say that the corn fields should be burned preparatory to sowing when the Pleiades have reached tree-top level at dawn. One may conjecture that such practices were once widespread, but modified by choice of a nearby favourable day; the Lacandon have lost the 260-day almanac.

I had intended to list in an appendix names in various Maya linguistic groups for individual stars and constellations. Unfortunately, utter confusion – uncertainties of identification and the same name given by different informants to distinct constellations – makes that impossible.

One reason for the confusion is that since lines joining stars to form constellations are imaginary, there is no reason to suppose that the peoples of Middle America saw the same figures in the night sky (unless they were introduced from Asia and remained unchanged) as we do. Secondly, communication between informant and interrogator is often bad. The latter, conditioned to our names, might point to Taurus, for instance, and ask the Maya name for the constellation, but for the informant, parts of Taurus and Orion may form a single constellation, with resulting misunderstandings. Thirdly, the interrogator may point to a constellation, but the informant mistakes the direction of his interrogator's finger or misunderstands his description in a language which is not shared by both. A drawing, probably seldom employed, may not be of much help, for the Maya peasant is not used to that form of representation. Finally, the old priest-astronomer group, who could have supplied the information, ceased to exist as such a generation after the Spanish conquest – sons of the aristocracy were removed to centres in which they were given a European education.

I would suppose that imagining star groups as pictures is a very ancient introduction from the Old World to the New, probably on the hunter–gatherer horizon, but the old names have been lost. Of well-known constellation names only Scorpio is found also in Middle America, but it is highly doubtful that the same constellation is involved.

Native terms (*xok* and *tzec*), meaning scorpion, are given by the Kekchi Maya and the Chaneabal Maya to the Great Bear, although the latter is queried by the interrogator, perhaps because he was surprised by the reply. Moreover, the great sixteenth-century ethnologist, Bernardino de Sahagún (1938, book 7, ch. 4), wrote that the Aztec called the Great Bear (*el carro*) scorpion. In his Nahuatl writings he illustrates the scorpion (*colotl*) constellation with a perfect drawing of the Great Bear.

The earliest (sixteenth century) Yucatec–Maya dictionary has the entry: '*zinaan*, scorpion (alacrán o escorpión) and also it is escorpio, celestial sign'. *Signo*, sign, as in English, is used in reference to the zodiac. It is possible that the author of the dictionary misunderstood the location of the Maya constellation Scorpion, and assumed it coincided with the Old World Scorpion.

On the other hand, in the Maya 'zodiac' the scorpion is in the fourth position. The first sign is obliterated; the second is *tzab*, rattle of the rattlesnake in Yucatec, Lacandon and Manche Chol Maya (but sandal or heap in other Maya languages). The creature's body, in the fashion of Maya snakes, probably loops down through Aldebaran and the left arm and lion skin pendent from it of Orion, and then up to Bellatrix, then a right-angle turn with Betelgeuze the eye or tip of snout. The third sign is turtle, which the Yucatec Maya placed in Gemini according to more than one source, but, again, one cannot be sure that the two constellations coincided.

With roughly equal spacing – the thirteen signs should be 28° apart (p. 92), the fourth sign should lie between Cancer and Leo; our Scorpio is much too far west. One could hazard a guess that it is in fact Leo. The Maya depicted the scorpion head down with outspread and thrust-forward claws. Regulus would be the tip of the left claw; northern stars the raised tail. Naturally, this is mere speculation.

I have discussed the elusive Middle American constellation of the scorpion in detail to warn of pitfalls awaiting those without knowledge of the native cultures, and to urge caution in identifying Maya star groups and, far worse, theorizing from the positions those shakily identified stars held far in the past. That way one quickly finishes up in a nebula.

Alinements and measures

Orientation of buildings presents difficulties; the Maya seldom alined walls correctly and seem to have been incapable of making a true right angle. For instance, the walls of the Castillo, most prominent temple at Chichen Itza, read 18°, 20°, 22°, and 24° (Rivard 1970). The nearby Warriors complex has 17° 35′, 16° 20′ and 15° 15′ for the main structure, the northwest and north colonnades respectively; the underlying Chac Mool temple is 13° 30′ (Morris, Charlot & Morris 1931). One wonders whether the 4° difference between the under and upper and later temple was deliberate.

At Tikal, greatest Maya site, orientations of front walls of the five great pyramid temples (rear-wall readings differ by up to 1° 37′) read 7° 1′, 9° 3′, 9° 51′, 10° 46′ and 18° 16′ (Tozzer 1911, p. 115). One suspects that in the first four cases the Maya sought uniform orientation, and so variation arises from sloppiness, for such variability occurs all over the Maya area and is a warning against crediting the Maya with intention and precision for every significant orientation noted. Divergence of one wall from another presumably resulted from the inability of the Maya to lay out true right angles. Satterthwaite (1935, p. 1, 1944, p. 21), who excavated the site for several seasons, noted that his plans and sections 'are based on the assumption that intended right angles really are such and that intended straight lines are straight lines. Nowhere at Piedras Negras does such an assumption agree with the facts. If there are true right angles in the buildings of the city (we have found one or two) they are probably the result of chance'. He has noted, for example, a difference of 6° between the long and short axes of one ball court at the site.

The reluctance of archaeologists to give the orientation of Maya buildings probably stems from the affect of those factors on complete accuracy.

It has been thought that a round tower at Chichen Itza served as an observatory. Three longish window shafts survive. It would seem most logical to have sighted down the middle of each shaft with the aid of sticks or cords, but such lines produced nothing of obvious import. Diagonal sights from one inner to the opposite outer jamb were more promising. The readings are: N 60° 15′ W, and due west (window 1); S 61° 15′ W and S 48° 0′ W (window 2); S 18° 0′ W and S 2° 45′ W (window 3). Only the due west line seems significant. That shaft is considerably wider (68 cm) compared with 21 cm for the other two (Ruppert 1935, pp. 189, 233–37). Unless the other lines of sight have values not at present obvious, one is reluctant to accept the observatory explanation.

Carnegie Institution of Washington carefully checked an apparent line of sight joining two stelae set on ridges, 6.5 km apart, at the ruins of Copan. It has been claimed that sunset behind one stela on 12 April (81° 09′) informed the Maya when to burn the felled timber on their cornfields (Morley 1926, pp. 277–282). In fact, the Maya know when to burn: just before the rains, heralded by increasingly humid heat. Were any special date chosen for that activity – a day of changing winds is required – it would have been a lucky day in the 260-day almanac (the modern Lacandon who, as noted, observe the Pleiades no longer have a calendar), and present-day 260-day almanacs have days regarded as favourable for maize.

The present-day Ixil Maya of the Guatemalan highlands have a double line of sight comprising stone markers from the town cemetery of Nebaj west [*sic*] to an indentation at the top of a high hill. The account by Lincoln quoted by Long (1948) is very brief and confused. Sunrise was observed 'on March 19, 1940, two days before the equinox. Sun rose this day at 6° 31.5′. Direction observed with simple adjustable compass. Observations of the Sun are made at the stone today by zahorins [shamans] for planting and harvesting'. Long was not sure that he had correctly deciphered the figure given for the line of sight or the word adjustable. Lincoln was an ethnologist and probably had a simple hand compass, quite probably with its own error, but surely not readable to the third decimal point of the minutes. Presumably one must add that the reading was south of east. The reading was presumably magnetic, a matter of around 7°. *Today* in the context seems to mean *nowadays*. Certainly, the spring equinox marks neither planting nor sowing, and is 20 or more days before the time for burning off the corn fields. One may suppose that this is a line of sight on the sun at the spring equinox, but how it bore on agricultural activities remains in doubt.

Groups comprising a temple on the west side of a court, facing a line of three temples on a single platform on the opposite side, are fairly common in Maya ruins (Ruppert 1940). A bearing from the centre of the west structure to the centre of the middle east structure varies from under 1° S to 10° 15′. The group at the site of Uaxactun shows most promise. A bearing from a stela at the base of the stairway leading to the west temple to the middle of the doorway of the centre temple of the three on the east platform is S 89° 03′ E (true east bearing touches the face of the north jamb of the doorway). To the centres of the doorways of the north and south temples of the east platform, bearings are respectively N 68° 00′ E and S 65° 18′ E. The latter is a good approximation to the winter solsticial line; the former 2° 40′ S of the summer solsticial line (Ricketson & Ricketson 1937, pp. 105–108). It must be noted that the lines of sight are quite short – just over 60 m for the solsticial lines, so a small change in the observer's position – and there is no evidence that it was from in front of the stela – would produce widely different bearings, although the true east bearing would remain unchanged. For the Maya, Sun overhead may have been more important than solstices, of far greater interest to dwellers in northern climes.

There is, however, documentary evidence that the lay-out of buildings in some parts, at least, of Middle America, was related to the equinoxes. In a very early source (Motilinía 1971, pt. 1, ch. 16, para. 89) we read: 'This feast [the 20-day month Tlacaxipeualistli] used to fall when the sun was in the middle of the [temple of] Huitzilopochtli, which was the equinox, and because it was a little twisted, Montezuma wished to tear it down and straighten it.' Names have been modernized. In similar passages *the* Huitzilopochtli makes sense only if read as temple or pyramid. Huitzilopochtli was the tribal god of the Aztec. His temple shared a pyramid with that (on the north) dedicated to the rain god, Tlaloc. They faced west. Huitzilopochtli was intimately connected with the Sun and in many respects may be regarded as a solar deity. Whether the Sun passed over the centre of the roof of the temple of Huitzilopochtli, or whether it was visible in the narrow passage between the temples of the two gods, which is more probable, is not of major importance. The point we must bear in mind is that Montezuma was prepared to tear down the temple to get a correct equinoctial alinement. As there were no tall buildings on the west side of the great court, no view of the Sun at rising would have been possible. Nor would such a view have been possible at Uaxactun.

No standard measurement in Maya architecture has yet been recognized.

The Maya did not use a bissextile system, but they were obviously aware of the inadequacy of their 365-day year. There are a number of dates on stelae which can be interpreted as correcting the loss accumulated since the epoch, over 3500 years in the past, at the height of the Classic period. If these are corrections, they rival our Gregorian calendar in accuracy. Some have now proved to record civil events, such as accessions of rulers, but since astrology plays a world-wide part in choice of dates for such occasions, their function of bissextile corrections is not necessarily negatived. I once accepted them as such (Thompson 1950, pp. 317–20), but now, like most students in the field, I am sceptical. No glyph indicative of correction has been isolated and, with so many dates recorded, one must beware of coincidence.

Coincidence is, indeed, a very serious problem in Maya astronomy because of the huge quantities of numbers to 'play with'. Many years ago the German astronomer Hans Ludendorff published astronomical phenomena associated with Maya dates and using what was in all probability a wrong correlation of calendars. Some of the dates he used had, unfortunately, been wrongly read. I was able to demonstrate that the incorrectly read dates produced a higher percentage of astronomical phenomena than those correctly read (Thompson 1935, pp. 83–87).

More recently, another astronomer (Smiley 1968), misled by a poor grasp of the mechanics of the Maya calendar, read two non-existent dates (Satterthwaite 1964, pp. 51–53) which, in his correlation, fall respectively 2–3 days before conjunction of Jupiter and Saturn with the Sun and 1 day after a conjunction of Saturn with the Sun. He cites these as evidence of the outstanding mastery of astronomy and mathematics which enabled the Maya to predict invisible conjunctions, and as support for his correlation. These incorrectly read dates would have fallen at the start of the Maya Classic period, only eighty years after the earliest known Maya text and some four centuries before the peak of Maya astronomy. Why the Maya should have wished to record invisible conjunctions, granting they had the ability to calculate them, is hard to say. Certainly, the Venus tables, to the Maya a far more important planet, pay no attention to either inferior or superior conjunction; they display interest only in heliacal risings and disappearances before conjunction.

Smiley (1961, p. 241), using the same method of reading Maya dates unacceptable for the past 50 years to all students of the Maya calendar, produces five consequently wrongly read dates which in his correlation fall near – they range from 2 days before to 22 days after – conjunctions of Jupiter with the Sun. He concludes that the chance of coincidence is less than one in ten million. Since the dates were never recorded, we are made doubly aware of the dangers of coincidence. Incidentally, four of the dates are very early; one is very late, but that is the one which is farthest off conjunction, so, had the dates existed, one would have to conclude that, after some seven centuries, the Maya ability to calculate this invisible configuration had become considerably less.

SIDEREAL REVOLUTIONS OF PLANETS

Several persons interested in the subject have assumed that the Maya were able to measure sidereal revolutions of the planets, citing lengthy Maya intervals which they claim to be multiples of these. Such intervals, amounting often to some 4000 years can produce all sorts of exciting 'results' when one allows oneself a variation of the second or third decimal point in the length of the sidereal revolution of a planet (p. 90).

Lawrence Roys (1935, p. 92) in a planet-by-planet discussion of the problem, wrote: 'It seems very improbable that they [the Maya] knew those sidereal periods, but a general denial is hardly in order where there is no direct Maya evidence on the subject. However, the difficulties of obtaining the astronomical records necessary for these determinations are so great, and the mathematical logic so advanced, that they appear too difficult for a people in the Maya stage of civilization, and the burden of showing a reasonably simple way of finding sidereal periods lies on anyone who suggests that they were known to the Maya.'

Roys goes on to cite as an example of difficulties subsequent observations of conjunctions of Jupiter with Aldebaran with variations from the true sidereal period of 35, 198 and 24 days. Even averaged out, they are 46 days short. He adds that conjunctions with other stars produce markedly different results. Retrograde motion and proximity of the Sun denying observation increase the difficulties. He concludes 'For the Maya to have discovered the true sidereal period seems very far from likely'.

One must not attribute to the Maya knowledge which is unattainable with the sole aid of the naked eye. In that connexion, it is worth bearing in mind that the Maya had no knowledge of algebra or even fractions (Maya 'hours' were based merely on the approximate position of the Sun), and, as we have seen, they were incapable of measuring a right angle.

One must beware of coincidence, an alarming feature when one 'plays with numbers'.

Surely, to comprehend the aims, attitudes and achievements of Maya astronomers who were first and last priests, an understanding of Maya mentality and outlook is essential. One must appreciate the impact of the divinatory aspects of the 260-day sacred almanac, and never lose sight of the fact that the ends of Maya astronomy were not scientific, but astrological. The Maya were interested in heliacal rising of Venus because then the world was in danger, and carefully recorded that happening; invisible conjunctions of planets with the Sun had no bearing on man's future, and therefore there was no call to try and calculate them. One must try and get in the skin of the Maya priest-astronomer. Also some knowledge of Maya culture and history is essential. The findings of archaeology cannot be ignored.

Had astronomers interested in Maya astronomy such a background, we would be spared assertions that the Maya calendar was in full swing before 3500 B.C., when in fact, agriculture in the New World had hardly got under way, and the Maya were still over 3000 years short of developing an identity. We would also be saved from consequent wild deductions that because the Pleiades were on the celestial equator at that date, the Maya were then probably living in or near Peru (Smiley 1960). Needless to say, there is not the slightest evidence that the Maya or anyone else in Middle America had then any sort of reliable time reckoning, or that the ancestors of the Maya were then living south of the equator. In the light of such deductions, which one can only designate as highly intemperate, and of other material discussed above, one is inclined to say that Maya astronomy is too important to be left to the astronomers.

In conclusion, I believe that Maya calendrical and astronomical achievements were made independently of the Old World, except that giving animal names to constellations in the Maya 'zodiac' and in other parts of the heavens, as well as of some days in Middle American calendars, may have been a custom surviving from very simple systems of counting of hunter-gatherers brought by immigrants to the New World by way of the Bering Strait, perhaps as early as 10000 B.C. They savour of a pre-agricultural horizon. Later immigrants, one may suppose, should be credited with the introduction to the New World of such concepts as dragon-like beings, each with its associated colour and world direction. This is surely too complex an aggregation to have developed independently in two areas.

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FIGURE 1. Two pages of Venus data, Dresden codex. Left page: top left, gods and prognostications for heliacal risings; right, multiples of synodical revolutions with corrections to them in space below first line of glyphs. A bar represents 5, a dot, 1, a flat oval, 0. Place numeration top to bottom: 400 tuns (each of 360 days), 20 tuns, single tuns, 20-day months, and days. Bars and dots serve as multipliers of suppressed periods. Accordingly, 8.2.0 in bottom right corner represents 8 × 360 + 2 × 20 + 0 days = 2920 days, 5 Venus revolutions of 584 days. Columns to left of this are multiples thereof, 10 Venus revolutions, etc. Right page: phases of synodical revolution. Bottom of page records intervals between stations. Left to right: 11.16 (236 days), to disappearance, 4.10 (90 days), to reappearance after superior conjunction, 12.10 (250 days) to disappearance before inferior conjunction, and 8 days to heliacal rising. Total 584 days. On right, patron deity, Venus deity who has hurled spear earthward, and, at bottom, victim with spear driven through him. Also augural glyphs for heliacal rising.

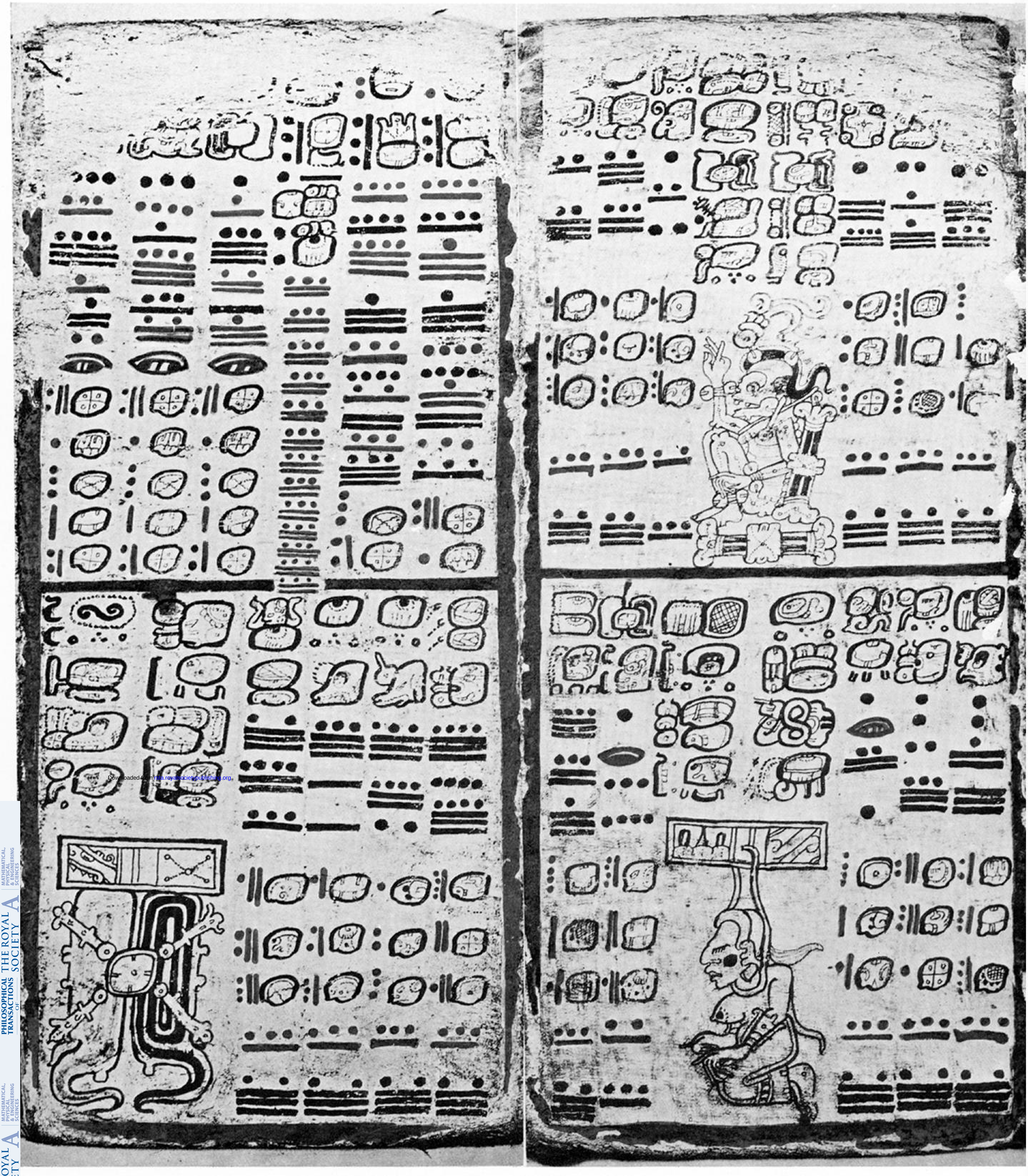

FIGURE 2. Two pages of eclipse tables, Dresden codex. Left page: top left, multiples of 1.13.4.0 (405 lunations). Right page: top, upper sets of bars and dots are accumulated totals of groups of 6 and 5 lunations: 177, 354, 502, picture, 679 (mistakenly written 674), 856, 1033 days (35 lunations). Lower set of bars and dots: 177, 177, 148, picture, 177, 177, 177 (6 and 5 Moon groups). Picture with prognostications only after 5-lunation group. Bottom halves of pages: continuation of lunation count as above six lunations (117 days) and five lunations (148 days). The latter only immediately before pictures.