MICHELSON AND METON

LYNN E. ROSE

This paper is a review of a column by Professor Irving Michelson ("Scientifically Speaking . . .", subtitled "19-Year Lunar Calendar Cycle: Accurate Adjustment to 365¼-Day Civil Calendar", *Pensee,* Winter, 1974-1975, pages 50-52); it will also serve as an introduction to the paper by Professor Alfred de Grazia and to the paper by Professor Livio Stecchini that immediately follow in this issue of KRONOS.

In his column, Professor Michelson discusses the considerable precision with which such quantities as the mean synodic month of 29.530589 days can be measured. He says that this eight-digit precision "stands as an elegant tribute to the 'hard sciences' at their best" (page 50). He repeatedly offers the suggestion — but never presents any evidence or arguments — that such precision is incompatible with any radical changes of planetary or lunar orbits within historical times.

Why he offers this suggestion is never explained, and many readers may find the suggestion inherently implausible. For when an orbiting body has been drastically perturbed, and when the perturbing force is no longer operative or no longer in range, we would then expect the body in question to be on a new orbit, and to remain on that new orbit (except for minor, long-distance perturbations of the sort that are occurring even today) until such time as it is drastically perturbed again. It is puzzling that Michelson believes that even "a thousand years" (page 52) would not be long enough for a perturbed body to emerge on a new orbit. (It might be noted that after a space vehicle has fired its engines for a short time, it is *immediately* on a new orbit.)

Most of Michelson's column is focused on calendar cycles that give procedures for adding extra or intercalary months to certain years in such a way that at the completion of the cycle the lunar month (29.530589 days) and the seasonal or tropical year (365.2421988 days) will come out fairly even. He is particularly interested in a 19-year cycle that is attributed to Meton, who lived in fifth-century Athens. Michelson notes, however, that *many* sorts of cycles are found in calendars. In the Gregorian calendar, for example, any two occurrences of the same calendar date that are separated by 28 years will occur on the same day of the week, "provided only that the exceptional end-of-century non-leap-years are avoided"; thus "a 1947 pretty-girl calendar can be dusted off and used again in 1975" (page 51).

For purposes of simplification, Michelson assumes (see page 51) that the ancient calendar-makers would be using a lunar calendar of twelve lunar months of about 29½ days, and that they would also recognize "a

civil year of 365¼ days". As we shall see, these simplifications do not provide an adequate basis for Michelson's inferences about how long it would take for various lunar calendars to fall out of step with the seasons. Thus he suggests that a lunar year based on "12 New Moons" would last about 354 days, and would fall short of the civil year by up to 11¼ days, with the result that "New Year day would slide around the entire cycle of seasons in roughly 32 years". This would be true if the mean lunar month were exactly 29½ days, but it should be noted that if our calendar-makers based their months on the *observed* phases of the Moon (which cycle is in fact slightly *greater* than 29½ days), then new year's day would actually move through the seasons in well over 33 years, not "32 years".

The same point should be stressed when Michelson considers intercalating one extra lunar month every three years: he claims that 37 lunar months of 29.53 days ("37 x 29.53 = 1,091.61 days") would fall short of three civil years ("3 x 365.25 = 1,095.75 days") by 4.14 days, and he then says that "each new year would regress in season and travel around the whole four seasons in about 266 years". Notice, first, that Michelson's arithmetic is wrong: the product of 37 and 29.53 is actually 1092.61, not 1091.61; and thus the shortfall would be 3.14, not 4.14. Notice also that 29.53 is still not the actual length of the lunar month. If actual new moons determine the months, then the shortfall with respect to the civil year would be only 3.1182 days. And the shortfall with respect to the tropical year would be only 3.0948 days, so that the passage of new year's day through the seasons would require just over 354 years, not "266 years". Even if the months did average exactly 29.53 days, a shortfall of 4.14 days would imply a passage through the seasons in less than 265 years, rather than in 266 years. (A shortfall of 3.14 days would imply nearly 349 years.) But I suggest that Michelson did not even use his own figure of 4.14 days in arriving at his answer of 266 years. Instead he probably miscalculated that 37 "months" (37 x 29.53 = 1,091.61 [sic] days") falls short of three tropical years (3 x 365.2421988 = 1095.7265964 days) by 4.1165964 days, and then divided the 1095.7265964 by 4.1165964 to get just over 266 years. He may have used fewer decimal places than this, but the 4.14 was not used at all. If Michelson's arithmetic had not been wrong, his answer would have been well over 351 years, rather than "about 266 years". And with real lunar months of 29.530589 days, instead of the simplified "months" of only 29.53 days, the answer would have been just over 354 years.

The main calendar cycle that Michelson treats is the Metonic cycle of 19 years, which contained seven intercalary months placed in years 3, 6, 8, 11, 14, 17, and 19. He says that these results were "announced at the Olympic Games in Athens" (page 52), and engraved in gold (hence the expression "golden numbers"). Michelson stresses the fact that 235

lunar months comes very close to 19 civil years of 365¼ days. (More importantly, it is also a fact that 235 lunar months comes almost as close to 19 *tropical* years, but Michelson does not point this out.) Michelson does correctly note that the difference between 235 lunar months and 19 years of 365¼ days is 0.0616 day; but his remark that this "accumulates to one day only in 303 years" (page 51) is either an error or a misprint, since 19 divided by 0.0616 is actually over 308.

Michelson claims that Meton's "discovery of the 19-year cycle presupposes *precise* knowledge of the length of the lunar month as well as of the solar (tropical) year of 365.2421988 days, to second-decimal accuracy at least" (page 51). But this is by no means correct. The 19-year cycle could have been discovered simply by *counting* both the months and the years until they once again came out even. One could *count* the 235 months and the 19 years, *without* having precise values for either quantity. This would not even need to take the discoverer 19 years: if records were available going back a number of years, the necessary data could have been found in those empirical records. And no "second-decimal accuracy" need have been involved. Meton *may* very well have had "such second-decimal accuracy", but the point is that Michelson has not *shown* that the discovery of the 19-year cycle *presupposed* such accuracy. The question of what Meton was really doing will be explored by de Grazia and by Stecchini in the papers that follow.

Two closing points: (1) I am unaware that Velikovsky or his supporters have ever said (as Michelson implies on page 50 and again on page 52) that Earth's orbital period was ever 354 days long. (2) It is false that the "year 2000 will thus be the first turn-of-the-century leap year of the Gregorian calendar" (page 50): the Gregorian calendar was instituted by Pope Gregory XIII in 1582, and its first turn-of-the-century leap year was in the year 1600.

MAKING MOONSHINE WITH HARD SCIENCE

ALFRED DE GRAZIA

A comment on Irving Michelson's column "Scientifically Speaking . . ."

With all due respect for Professor Michelson, I cannot understand the rationale behind *Pensee's* having allowed him (or anyone else for that matter) to pretend to be "Scientifically Speaking . . ." It is a usurpation of authority, and an implication that other contributors to *Pensee* have written *un*scientifically. "Science" is exhibited in a work itself or in a judgement rendered afterwards upon it; it is also a propagandistic term when employed in Professor Michelson's usage. The phrase "*hard* science" adds insult to injury.

But rather than continue along this vein, I should like to turn to the substance of Professor Michelson's arguments. They are misleading and moreover incorrect. They are also irrelevant to Dr. Velikovsky's theories, which they strain to affect.

Michelson says that "hard science" comes into being when the moon's revolution is measured to the accuracy of an eight-digit number. But eight digits can be attached to an IQ score, an automobile license, the average height of Americans, the temperature of a frying pan, a tonal harmony in music, a rhythmic sequence in Indian dance, and so on. And if we proceeded to an accuracy of ten digits, or twelve, we might find the moon revolving a bit irregularly, which a genial mechanician such as Professor Michelson might trace back to an old disaster.

The important questions are what the number means and what purpose it serves. In the present case, we are led to believe that this eight-digit number will be shown to (a) have been used or discovered by a Greek named Meton about 432 B.C., or (b) have been known to the ancients at a time when catastrophes are alleged to have involved the moon in changed behaviors. Neither of these is demonstrated, and indeed, Michelson indicates later on that both implications are unnecessary to his story of Meton. Michelson further presumes that 250 years are not long enough for a changed lunar month to be noticed or calculated, but offers no argument on the point.

What Michelson *does* utimately argue is that by 432 B.C. (255 years after the presumed last Mars disaster), a *four*-digit lunar cycle calculation would have been sufficiently accurate to permit the design of a 19-year calendar involving an intercalation of moon and sun, granted of course, the sun's 365.25 figure was known (as he takes for granted and I would not oppose) and provided that anyone cared about the matter.

This is a useful line of inquiry, no matter how deviously pursued. It can help us understand what was going on in those days.

What *was* going on? I hope that I may be forgiven for presenting some fictional excerpts from the recently recovered journal of Kakrates, research assistant to the astronomer Meton, the Hero of the Golden Letters of 432 B.C. (Incidentally, I doubt that any Olympic games of that year were held in Athens, as Michelson says, unless some athlete hurled a discus awfully far.)

Excerpts from The Spurious Journal of Kakrates

Tablet A. My friend Mikelson and I were drinking a bit heavily last night and I bet him that I could produce a good all-purpose calendar without the resources of a holy temple at my disposal. From a window of my house, I can see a skinny tree on the eastern horizon that I can use for orientation.

Tablet B. I have observed the sunrise every day. I noted that after 365.25 days (or was it 365.24 or 365.26?)* the rim of the sun peeks up at the edge of the tree again from the left or north side. I was cheered because I caught the cycle so closely (I didn't touch a drop of wine the night before). Hence I continued.

Tablet ⌐. I watched for another cycle, and then another. It does appear to be 365.25 alright. Meanwhile, I have learned that various watchtowers and astrologers in Thebes, Syracuse, Memphis, etc. are getting the same effect. Some of them take this game seriously. If 365.25 is not observed perfectly, it can certainly be inferred from the statistical averaging. I haven't told Meton what I'm doing yet, but when I told him of my concept of averaging, he smiled and patted me on the shoulder. He is busy with city planning. I could bring his associate, Euktemon, into the picture, but why complicate matters?

Tablet △. I have also been observing the moon-days from the opposite window of my house, as it sets in the bay. The new moon turned out to repeat its appearance 12 times plus a tenth less than 11 sun-days in the time it took the sun to touch back upon the tree. I subtracted the 10.9 days from 365.25, and got 354.35. To get an average month, I divided this by 12 and got 29.53 days. Suppose I distribute the 11 days among the months, giving half-days to seven and one and a half days to 5 months. I'd have a workable calendar! I shall do something later with that little lost time, maybe spread it out over the years. Some of my politician friends have become excited by the game and chipped in funds to hire a diligent research assistant to help with the sightings. The watchtower and astrological societies from here and there confirm that their instruments give the same readings. (I am glad that I entertained several

* Editor's note: for convenience, the fractional numbers that Kakrates used have been converted to the modern decimal system wherever they occur in the journal.

of these chaps at Selena's tavern during the last Olympics.) Anyhow, it averages out. One phenomenal Chaldean with sophisticated equipment (I hear he foretold the death of the king's mother-in-law) reported that he got 29.5306 with averaging. Wow! Six digits! But who needs it. It's just pedantic overkill.

Tablet E. (I wish I could afford papyrus.) Now I added up three solar years of moon-cycles and discovered that 37 cycles came within a little over four days of matching perfectly. Carrying out the arithmetical calculations further, I got rid of practically all of the four-day fraction in 19 years. Much more refined observations would be needed to improve this cycle. As it stands, even though I have not based it upon observations for a full cycle, I can see that it will give enough accuracy for centuries. The days will not perceptibly march ahead of each other over a person's lifetime, or even over the lifetime of a kingdom.

Tablet Z. I mentioned that I can match the sun and moon cycles almost exactly on a 19-year base to the politicians in Selena's tavern, and they are going to make a political issue of the Calendar. Others said, though, that the idea is politically impractical; a 19-year "year" that means nothing will bring only ridicule. I said, however, that maybe I could please the priests and cultists by getting the artist Petty to draw illustrations for each month using the Roman vestal virgins as models. This must have been what Mikelson meant when he mumbled something about "pretty-girl calendars," no doubt a Socratic slip of tongue.* It won't work, they said; these soft-heads want a year for the sun, a year for the moon, a year for the seasons, a year to begin with the bacchanalia, or the saturnalia, solstices, or what-not. And, of course, the archons like to have the years named after their period in office.

Tablet H. I must find a way to appease the priests and cultists. They don't like the idea of automatic calendars (the damned humanists). Maybe I'll intercalate days by the magic number of seven. I'll figure out a common denominator and then decide what to do with the extra time. Just as the festival and political calendars do nowadays, I'll take care of the half-day problem by alternating 29-day and 30-day months. Then, to take care of the surplus of days, I'll put in an extra thirteenth month of 29 days (the cultists will like that 13-business); placing it in the years 3, 6, 8, 11, 14, 17, and 19 will give us a magic number 7, the number of moving celestial bodies (I'll call them "eternal" since everyone likes the word). It also sets well with the 7-stringed lyre. Mikelson has left town and I can't collect on the bet.

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* Editor's note: the mistake was not Mikelson's. A tablet has come to light disclosing that the slip was made by another **taverna habitue'**.

Papyrus ⊖. I'm in trouble. The priests won't buy my 19-year calendar. All this talk of late about "an emerging power elite of secular science and politics" doesn't stand up when the fortune-tellers start demonstrating on the street. They are pressuring Meton to stop my moonlighting. He pointed out to them that an issue of academic freedom was involved. Privately, he gave me to understand that the results of my work have to be published, of course, in his name. He also insited that I begin the year on the summer solstice and that I count months by *full* moons. Moreover, we must wait for a full 19-year cycle to prove my contentions. Mere prediction is not enough. Fortunately, some far-sighted statesmen have given Meton a research grant sufficient to set up an observation post with a panel of three assistants (with myself in charge), and a few other amenities, including a site-visit to Jerusalem. I put a brass stake by the tree and bought a donkey, but now visit the research station mostly to pay the assistants and check out the tree (fortunately, it scarcely grows at all and one of the assistants keeps the dogs away).

. . . *Here occurs a long time-gap in the journal* . . .

Papyrus I. I wonder why other Greeks haven't climbed aboard the wagon? Everyone still acts as if they didn't need an automatic and standard calendar and now we're moving into the 19th year. The other day I actually saw a priest of some kind or another taste the soil to see whether spring had begun — with a crowd around him. At least they don't sacrifice humans anymore to get the crops going. Are scholars afraid to tackle the problem? Haven't the times been ripe for invention? The priests are always yapping against "taking the human element out" of calendars (*their* human element!).

I suppose that I should have confessed in the beginning that the Chaldeans and Egyptians knew all of this. But it was pure patriotism that motivated me to suppress the information. The Greeks have to invent everything. Especially the Athenians. They would have killed the project if they thought foreigners had beaten us to the results. Anyhow, this is all a problem for the psychologists and political scientists — the soft science guys.

Papyrus K. Finally! After 20 years. Everyone professes to be amazed. Our party is in power. The Athenians are ablaze with patriotism. They praise Meton all over town. They are certifying my formula in gold letters on a prime wall location! In Meton's name, of course. That will impress the watchtowers and astrological societies — their President in Gold Letters! He has authorized me to give them all free tickets to the Olympic Games. But not to that barbarian who had the gall to write him, "Meton, stop reinventing

the wheel. The Chinese have used your cycle for 100 years, and even the seven intercalations." Not to mention that anonymity from Egypt who sent him a tablet with just the obscenity " Φ " inscribed on it.

Tablet Λ. The gold letters are staying up, but the opposition is too strong. Meton's calendar will not be adopted after all. They claim that they will check things by the formula from time to time. Why do they do this? For as long as anyone can recollect, the skies have been perfectly regular and before that, well, forever. Yet these unscientific idiots pretend that they have to take their measure every day and every month to be sure things are the same — as if the skies would fall if these nitpickers turned to more important problems — like better housing, exclusion of aliens, etc.

. . . *end of Kakrates' journal* . . .

Since I was dubious of Kakrates' work, I asked a living historian of science about the matter. This was Professor Livio Stecchini, who is an historian of science and has done much work with ancient calendars and measurements. Professor Stecchini believes (as, in fact, do I) that Meton knew all the while that the solar year was 365.25 and the lunar month about 29.5 days and Stecchini shows, in the following paper, how readily Meton might have concocted the Metonic cycle, getting the .03 by chance, and then how Callippus and Hipparchus improved upon it.

Meton was probably offering a simple formula from his stock of astronomical knowledge to some people who were interested in routinizing and mechanizing the calendar. It was ordinary applied scientific research and consultation. To demonstrate his formula (or, better, to replicate the foreign experience for Greek eyes) one would need only "poorboy" techniques. The Athenians, agree Meritt, Pritchett, and Neugebauer, did not follow the Metonic cycle, and Meritt says that the Athenians did not tie their months to lunar observations but followed a rule of convenience with alternate 29 and 30 day months and an occasional check upon the moon and Meton to prevent the calendar from wandering too far astray. Moreover, the four-digit stability of the moon's revolution, which had been in effect for a couple of centuries, could have been proven out in a few years, and had nothing to do with when the last destabilizing encounter involving the moon had taken place. Finally, I leave it to others to make fact out of my fable in the Meton case, that is, to show how politics determines practical sciences in calendar-making as in other areas.

RECOMMENDED ADDITIONAL READING

Encyclopedia Britannica (1973 edition), "Calendar," Vol. III.
Benjamin D. Meritt, **The Athenian Calendar in the Fifth Century** (Cambridge: Harvard Univ. Press, 1928).
Benjamin D. Meritt, **The Athenian Year** (Berkeley) Univ. of California Press, 1961).
William K. Pritchett and Otto Neugebauer, **The Calendars of Athens** (Cambridge: Harvard Univ. Press, 1947).

GREEK ESTIMATES OF THE SYNODIC MONTH

LIVIO STECCHINI

The problem that Meton intended to solve was — which is the smallest number of solar years than can be divided exactly into a series of more or less alternating months of 30 and 29 days?

He knew that solar years are about 365.25 days and that a lunar month is about 29.5 days. He counted that 19 solar years are 19 x 365.25 = 6939.75 days. He assumed that 19 solar years are 6940 days, either because he did not take 365.25 as an exact figure or because he chose to disregard a difference of 0.25 days. By dividing he found that in 6940 days there are 235 lunar months of 29.5 days, with a remainder of 7.5 days. If there had been no remainder he would have divided the 6940 days into 117½ months of 30 days and 117½ months of 29 days; but since there was a remainder of 7.5 days, he increased the number of months of 30 days to 117.5 + 7.5= 125. The number of months of 29 days had to be reduced to 117.5 - 7.5 = 110.

One hundred years later, Callippus objected to the system of Meton on the ground that the solar year should be calculated as exactly 365.25 days. Since, according to this reckoning, the 19 years of the Metonic cycle are 6939.75 days, he quadrupled the years of this cycle to 76 years, in order to obtain a round figure of 27,759 days. According to the Metonic cycle this period would contain:

4 x 125 = 500 months of 30 days
4 x 110 = 440 months of 29 days

Since Callippus had found an excess of one day in 76 years, he changed the pattern to:

499 months of 30 days
441 months of 29 days

Hipparchus (around 150 B.C.), since he knew that a solar year is somewhat shorter than 365.25 days, proposed that the cycle of Callippus be quadrupled to 304 years, but deducting one day. He assumed that 304 solar years are (304 x 365.25) -1 = 111,035 days, which makes a solar year equal to 365.24671 days. Calculating correctly, 304 years are 111,033.6 days. As to the lunar months Hipparchus limited himself to quadrupling the figures of the cycle of Callippus:

4 x 499 months of 30 days
4 x 441 months of 29 days

If we average the length of the months according to the three cycles, we have:

Meton	29.531915 solar days
Callippus	29.530851
Hipparchus	29.530581
(correct figure —	29.530588)

Meton was correct to the second decimal figure, Callippus to the third, and Hipparchus to the fifth. The datum of Hipparchus is breath-taking, since it differs by a second from the correct one, whereas he was off by about 7 minutes in calculating the length of the solar year.

The precision achieved in calculating the duration of the synodic month is not difficult to explain. The basic problem was simple: it was a matter of counting how many new moons occur in a period of solar years. The observations could have been made simply by recording at each summer solstice how much sooner was the preceding new moon and how much later was the following new moon. In a few years one could arrive at a good datum for the length of lunar month. It is true that in marking the date of new moons there was a constant danger of erring by a day, but in the long run these errors would even out and the very development of luni-solar calendars would call the errors to attention. Several cultures adopted independently the Metonic calendar, because calendars were used not only to regulate political and economic activities, but also to record the occurrence of eclipses. The date of eclipses was not a matter of mere scientific interest and the ability to predict them had great social value. With the Metonic calendar, the good recording of eclipses and their prediction became an elementary operation. Eclipses repeat themselves according to the same pattern after 223 lunar months, that is, about 18 solar years and 11 days. They occur in the same part of the sky in three cycles of 223 months. If the lunar month were to be calculated with an accuracy of less than 29.53 days, in less than 6 years one would notice that eclipses occur not only at the wrong time, but also on the wrong solar day. Because the Metonic cycle was used to calculate the date of eclipses, the Greeks were driven to introduce refinements into it. Hipparchus proposed that for the sake of predicting eclipses there be adopted a cycle of 19 x 223 lunar months. According to him, this was the shortest period in which a series of lunar months equals a whole number of solar days. He assumed that 19 x 223 lunar months are exactly 125,121 solar days or 342 solar years and 208 days. Modern figures give 342 years and 208.17 days. Textbooks repeat that Hipparchus reckoned the solar year as 365.24666 days, but, although he mentioned this figure, he must have known better ones, since in the case before us he reckoned the solar year as 365.24 days (correct datum 365.242199). All this proves that the calculation of the ratio between lunar month and solar year did not involve elaborate observational procedures, so that it could result in the gathering of extremely accurate data.