A CONTRIBUTION TO THE CONTROVERSY REGARDING THE PERIOD OF EG SAGITTARII

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Abstract

We give reasons to prefer the period near 2.5 days, favored by some authors, to the double period for EG Sagittarii. The near commensurability with the day has caused alternate eclipses to go unobserved for long stretches of time. When they are observed, they are too deep to be secondary minima.

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EG Sagittarii, at $\alpha = 19^h\ 08^m\ 44^s$, $\delta = -14°\ 21'.5$ (1900), is an eclipsing system whose period is either just under 2.5 days or just under 5 days. The most recent elements are by Berthold (1981), who gives the period to 8 significant figures:

$$JD_{min} = 2441830.517 + 4.9723590\ n. \qquad (1)$$

He notes that the choice between the shorter and longer periods has yet to be made.

In the hope of resolving the question, we looked for minima in the Maria Mitchell plate collection, and we searched the journals for clues.

Twelve of our plates show EG Sgr in minimum. Five of these are near phase 0.0 according to equation (1); the others are near phase 0.5. It seems clear that the shorter period is to be preferred, unless we are seeing both a secondary and a primary minimum.

Uitterdijk (1949) had also seen eclipses at both phases. Out of 17 epochs in his Table 9, 13 would be "primary" (phase zero) according to the above interpretation and 4 "secondary." He is one of the authors who favored the shorter alternative, giving the duration of minimum as grounds for this choice. We do not understand what his reasoning might have been, but it is true that the duration he gives for the eclipse, 0.13 of the suggested short period, fits in well with the durations in his list of 29 Algol systems in the study. The only ones with durations under 0.10 are those with periods over 9 days. Perhaps this was his reason.

We offer a more compelling argument, based on the depth of the minima. The Maria Mitchell Observatory photographic data demonstrate that the "secondary" minimum is at least 1.1 magnitudes deep, and the "primary" at least 0.9 magnitude deep. We see, by converting to intensities, that at least 63% of the light of the system is hidden at phase 0.5 and at least 56% at phase 0.0. These calculations assume that our magnitudes are on the Pogson scale. Our sequence-star magnitudes come from iris photometry calibrated by a photoelectric sequence near NGC 6712 ($\alpha = 18^h\ 47^m.6$, $\delta = -08°\ 50'$, 1900). While the two fields are not ideally placed on the plates available for the transfer, we doubt that the deviation from the Pogson scale can be as large as 10%. The quoted percentages imply that each star contributes more than half of the light of the system, a clear impossibility.

We argue, then, for the shorter period, and present the following elements, based on our minima and a search of the literature:

$$JD_{min} = 2443732.442 + 2.486160\ E. \qquad (2)$$

Equation (2) is valid after JD 2430000. This epoch is by Locher (1978). It is the one adopted for the 1981 ephemeris in the International Supplement to the Cracow Annuario (Flin 1980), with, however, P = 4.9724742 days.

Between JD 2422000 and 2430000 the minima are better represented by:

$$JD_{min} = 2427393.285 + 2.486235\ E. \qquad (3)$$

This epoch is Uitterdijk's (1949).

There can be no doubt that the change in period is real. By giving the two sets of linear elements, (2) and (3), we do not mean to imply, however, that the period must have remained constant during the corresponding time intervals, but only that the linear elements are satisfactory.

The photographic range by our calibration is magnitude 11.3 to fainter than magnitude 12.4. Duration of the minimum is poorly known. Values from magnitude 7.2 to magnitude 15.6 appear in the literature. A finding chart, Figure 1, is given to encourage observations.

What remains to be explained is why the 2.5 day period had not already been universally favored. It seems that most workers were seeing only what we have called "primary" eclipses, phase zero according to equation (1) or odd values of E in equations (2) and (3). The question as to whether or not eclipses at phase 0.5 were secondary did not arise. They were not even seen.

All of Soloviev's (1946) 17 observations in minima correspond to odd values of E. These include 10 separate minima in 4 years. All of Tsesevich's (1954) 36 observations are also of the odd-E kind (7 separate minima within 65 days). Gaposchkin's (1953) 670 observations produce a mean light curve, at the 5 day period, with a dip of only 0.05 magnitude near the expected "secondary," which he does, in fact, interpret as a secondary minimum. There must have been very few observations during even-E minima among the 670 observations.

It seems likely that the problem originates in the near commensurability with the length of the day. If an odd-E eclipse occurs near midnight, the following even-E eclipse occurs near noon two and a half days later. If the period were exactly 2.5 days, the existence of the even-E eclipse would never become known, barring information from other longitudes. The deviation from 2.5 days is significant, however, and every five days the visible, odd-E eclipse comes almost 40 minutes earlier. After 87 and 92 days there are even-E eclipses near midnight. It is interesting to note Tsesevich's 65 days of observations. If he had continued into the next lunation he might have picked up an even-E eclipse. Perhaps by then the star was setting too early.

At least three cycles influence when a minimum can be seen: the solar day, the sidereal day, and the orbital period. We programmed our TRS-80 computer to count how many even-E and odd-E eclipses would be observed in successive years if observations were made frequently, but only within 2.4 hours of the meridian and within 3.6 hours of midnight. The results were dramatic. Odd-E eclipses dominated for years on end, gradually to be replaced by years in which both kinds of eclipses were common. These were the years when eclipses came at dawn and dusk at the time of year when Sagittarius was near opposition and, therefore, near the meridian at midnight. Then even-E eclipses would dominate and eventually the starting situation would recur. The length of this long cycle depends in a very sensitive way on the exact orbital period. It turns out that there are critical periods for which the alternation would never take place! These are the values of P_n found by substituting integers for n in the expression:

$$2.5/P_n = 1 + n/365.25. \quad (4)$$

Setting n = 2 we find P_2 = 2.486385 days, close to the period of EG Sgr. The same kind of eclipse, even-E or odd-E, would come at the same time of night near all oppositions if the period were exactly equal to this or any of the other critical values.

The length of the long cycle in a real, non-critical case can be calculated in two steps. First find:

$$X = 365.25\ (2.5/P - 1). \quad (5)$$

It will be very near 2 if P is near the critical value P_2, or, in general, near n if P is near the critical value P_n. The cycle length, in years, is the absolute value of:

$$T = 1/(X-n). \quad (6)$$

Before JD 2430000, when the period of EG Sgr was 2.486235 days, T was 45 years. It is now down to 30 years. When the computer was allowed to simulate 50 years of observations, a process which took over 24 hours of computer time, it found cycle lengths in agreement with the formulae.

A feeling for the critical case, P = 2.486385 days, may be had from the consideration that two cycles amount to 39.2 minutes less than 5 days. In a year there are 73.45 of these nearly-five-day intervals. Eclipses that occur 39.2 minutes earlier 73.45 times per year will be found exactly 2 days early in a whole year, thus coming at the same time of night again in the same season every year. (For the critical value with n = 1, the lag is one day.)

These numerical manipulations, while fun, interesting, and enlightening, do not completely explain why observers at several longitudes, looking at EG Sgr on and off since 1902 have seen such an overwhelmingly high percentage of odd-E eclipses. The computer analysis did not take into account a fourth cycle which influences when one might catch an eclipse: the phase of the moon. One would not expect the phase of the moon to have a systematic effect for EG Sgr. Its observable even-E and odd-E eclipses are separated by 87 and 92 days, as noted above. If moonlight interferes with one it will interfere with the other. These must have been an element of chance, too.

Projects for the future include settling the question regarding the duration of the minimum and monitoring the system for period changes. It would be helpful if photoelectric observers would look for a real secondary eclipse near phase 0.5 according to the elements of equation (3).

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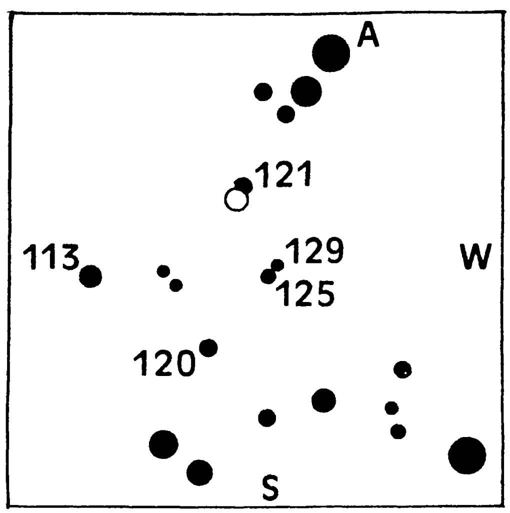

Figure 1. Finding chart for EG Sgr, which is shown as an open circle. The area shown is about 30 arcmin square. The star marked A is SAO162344, $\alpha = 19^h\ 11^m.2$, $\delta = -14°\ 7'.5$ (1950), visual magnitude 7.3. Adopted photographic magnitudes of comparison stars are indicated, with the decimal point omitted.