THE POSSIBILITY OF A CHANGING PERIOD FOR V1288 SAGITTARII

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Abstract

V1288 Sagittarii was studied using data from the Maria Mitchell Observatory and earlier published data in order to determine the accuracy and constancy of its published period. The Maria Mitchell data indicated nothing definitive about the constancy of the period, but the earlier data were open to two interpretations, one of which strongly suggested a constant period while the other pointed to a changing period.

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V1288 Sgr is an RR Lyrae variable of subtype ab, with a published period of 0.520510 day and photographic magnitude range 12.6 to 14.0 (Fokker 1951).

Magnitudes of this variable were estimated from 795 plates taken at the Maria Mitchell Observatory between 1924 and 1984. The magnitudes were estimated relative to the four sequence stars used by Fokker and one additional brighter star. I recalibrated the sequence by using a sequence in Sagittarius for which magnitudes have been found by Warren *et al*. (1976). I then used the fly-spanker technique described by Nygard (1973) to give the photographic magnitudes listed in Table I along with Fokker's values for the sequence star magnitudes. This recalibration provided a new estimate of the magnitude range of V1288 Sgr, resulting in values of 13.5 and 15.1 at maximum and minimum, respectively.

The phases of the estimates were computed using the elements

$$JD_{(max)} = 2428077.371 + 0.520510\ n \qquad (1)$$

(Fokker 1951). Twelve graphs of magnitude vs. phase were plotted, each containing data from a 1-3 year interval. (The data collected between 1924 and 1956 were sufficiently sparse to be included in the 1957 graph.) A curve was fitted to each plot, and from these curves a mean light curve was drawn, on which a nominal maximum was marked. The mean light curve was then fitted to each graph and the observed phase of maximum was compared to the computed phase. These data were plotted against Julian Date in an O-C diagram. The method of least squares was used to fit both a straight line and a parabola to the diagram, as shown in Figure 1.

The slope of the straight line was negative, meaning that the period used was too large and implying a new period of 0.5205067 day. The mean error of a full weight value of O-C based on residuals from the line was ± 0.0067 cycle.

The parabola proved to be only a slightly better fit (mean error = ± 0.0065 cycle), implying a rate of change in cycles per million years of -0.229 ± 0.176. However, it is not necessarily justifiable to assume from this that the period is in fact changing. A comparison of the rate of change with its mean error shows that the uncertainty of this value is almost as large as the value itself. In addition, a statistical test outlined by Pringle (1974) can be applied to determine the "confidence level" of the parabola, i.e., the probability that the quadratic term is truly significant. The confidence level for this parabola is p = 0.78, well below the desired confidence level of 0.90 - 0.95. In other words, there is a 23% probability that the seemingly parabolic shape of the curve is due to a Gaussian distribution of data points around the curve. Thus there is a strong possibility that the period of V1288 Sgr is indeed constant. The new elements derived from the straight line and the parabola, respectively, are as follows:

$$JD(max) = 2440515.389 + 0.5205067\ n \qquad (2)$$
$$\pm\ 0.002 \quad \pm\ 0.0000004$$

and

$$JD_{(max)} = 2440515.392 + 0.5205066\ n - 8.50 \times 10^{-11}\ n^2. \qquad (3)$$
$$\pm\ 0.003 \quad \pm\ 0.0000004 \quad \pm\ 6.51 \times 10^{-11}$$

This ambiguity could be resolved by studying plates from earlier years, which would probably provide enough data to give a definite indication of the shape of the least-squares curve. Unfortunately, there are very few pre-1957 Sagittarius plates in the Maria Mitchell collection. I therefore attempted to obtain some data from Fokker's results, which were based on his study of plates taken at the Union Observatory between 1934 and 1944 (Fokker 1951). He provided two data tables which were especially useful: Table II, containing points on the ascending branch, and Table III, containing the normal points he used to plot the mean light curve (phase vs. magnitude). The phases given in Table III were computed using the formula

$$n + phi = (JD - 2420000) \times \text{reciprocal period}, \qquad (4)$$

where n refers to the cycle number and phi to phase. It should be noted that the reciprocal period given (1.921213/d) is not the same as the reciprocal of the published period 0.520510 day, which is 1.921193/d. Where "reciprocal period" is used here, it refers to the former number.

I used these normal points to plot a light curve, converting the phases to Julian Date by representing all the phases as having occurred in the same cycle. This cycle was chosen to be the one corresponding to the mean Julian Date of Fokker's observations, JD = 2428195. The above formula gives n = 15744 at phase zero on that date. Thus the equivalent Julian Date for each mean point is given by

$$JD = 2420000 + \frac{(15744 + phi)}{1.921213}. \qquad (5)$$

These dates and magnitudes were then used to plot a light curve by the method described above, using the published elements given in Equation (1). Fitting the mean light curve to this plot gave an O-C of 0.87 cycle at the mean JD 2428195.

If this analysis is correct, it would strongly support the hypothesis that the period is changing, since the least-squares parabola fitted to the O-C diagram as shown in Figure 2 has a confidence level of over 99%. Hence the parabolic shape of the curve is now almost certainly genuine. It implies a new period of 0.5205067 day, with a rate of change in cycles per million years of -0.291 ±0.056.

Unfortunately, the second method of analyzing these data produces contradictory results. The Julian Dates given in Fokker's Table II are of a point on the ascending branch where the width of maximum equals 0.3 cycle. On Fokker's mean light curve maximum occurs 0.109 cycle after this point; on the mean light curve that I drew the phase difference is 0.09 cycle. (This minor discrepancy can be ascribed to uncertainty of the position of the nomimal maximum.) The Julian Dates of Table II were then increased by 0.0468 day, the equivalent in days of 0.09 cycle, to give the times of maximum. Values of O-C for these dates were then found by applying Equation (1).

These values were found to range from 0.96 to 1.02 cycles, surprisingly different from the figure of 0.87 cycle that was found for the O-C of the data in Table III. As a result, the combination of the data in Table II and the Maria Mitchell data does not strongly support a changing period over a constant one, since a parabola is not a significantly better fit to these data than the straight line shown in Figure 2. In fact, the mean error based on residuals from the line is ±0.0103 cycle, while that based on residuals from the parabola is ±0.0104 cycle. In addition, the confidence level p for the parabola is only 0.51.

The difference in the values of O-C given by two different calculations using the same observations appears to be due to an inconsistency between Fokker's Tables II and III. Fokker states that the dates in Table II refer to the point on the ascending branch of the mean light curve mentioned above. Yet when Equation (2) is applied to these dates, the resulting phases range from 0.211 to 0.285 cycle. Both Fokker's mean light curve and his Table III indicate that this phase range refers to times of maximum brightness. Until this discrepancy is resolved, these results remain ambiguous, with one interpretation yielding evidence for a changing period and the other strongly suggesting a constant period for V1288 Sgr. The new elements indicated by these data for a constant period and a changing period, respectively, are as follows:

$$JD_{(max)} = \underset{\pm\ 0.003}{2440515.390} + \underset{\pm\ 0.00000014}{0.52050670}\ n \qquad (6)$$

and

$$JD(max) = \underset{\pm\ 0.002}{2440515.392} + \underset{\pm\ 0.00000034}{0.52050665}\ n - \underset{\pm\ 0.21\ \times\ 10^{-10}}{1.08 \times 10^{-10}}\ n^2. \qquad (7)$$

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TABLE I

Comparison Star Sequence for V1288 Sagittarii

Star	Photographic Magnitudes (Fokker 1951)	Recalibrated
aa	----	13.2
a	12.6	13.5
b	13.1	14.0
c	13.4	14.3
d	14.2	15.2

Note: The new sequence star aa is located 1.0 arcmin north and 0.5 arcmin east of the sequence star b on the published finding chart (Fokker 1951).

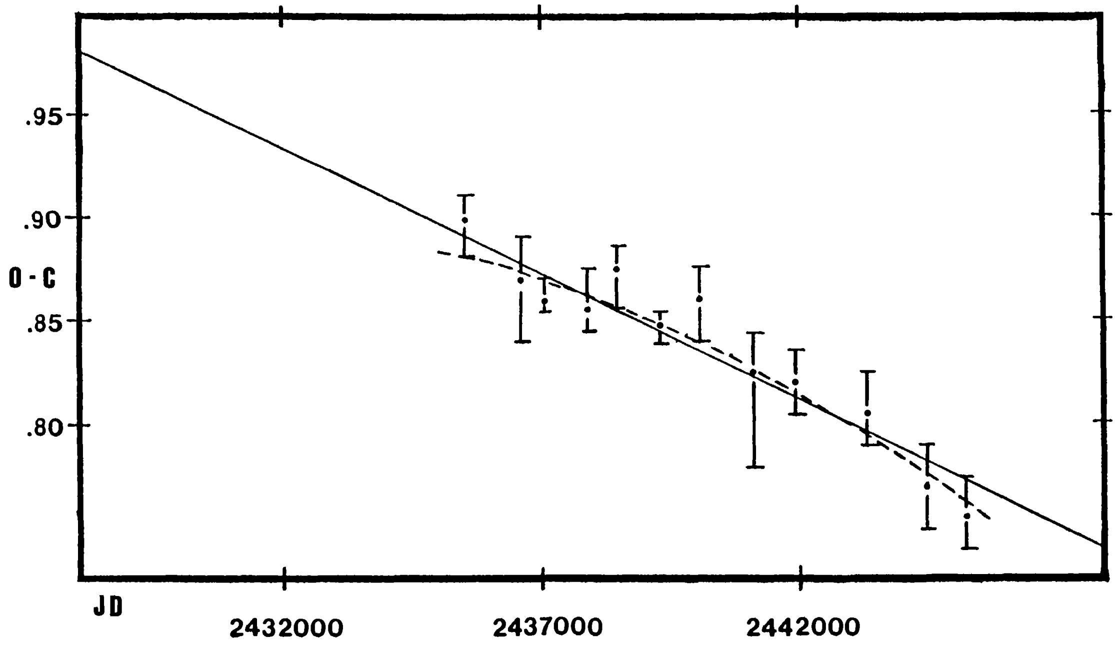

Figure 1. Julian Date vs. O-C for the Maria Mitchell data on V1288 Sgr. The least-squares parabolic fit and straight line fit are shown.

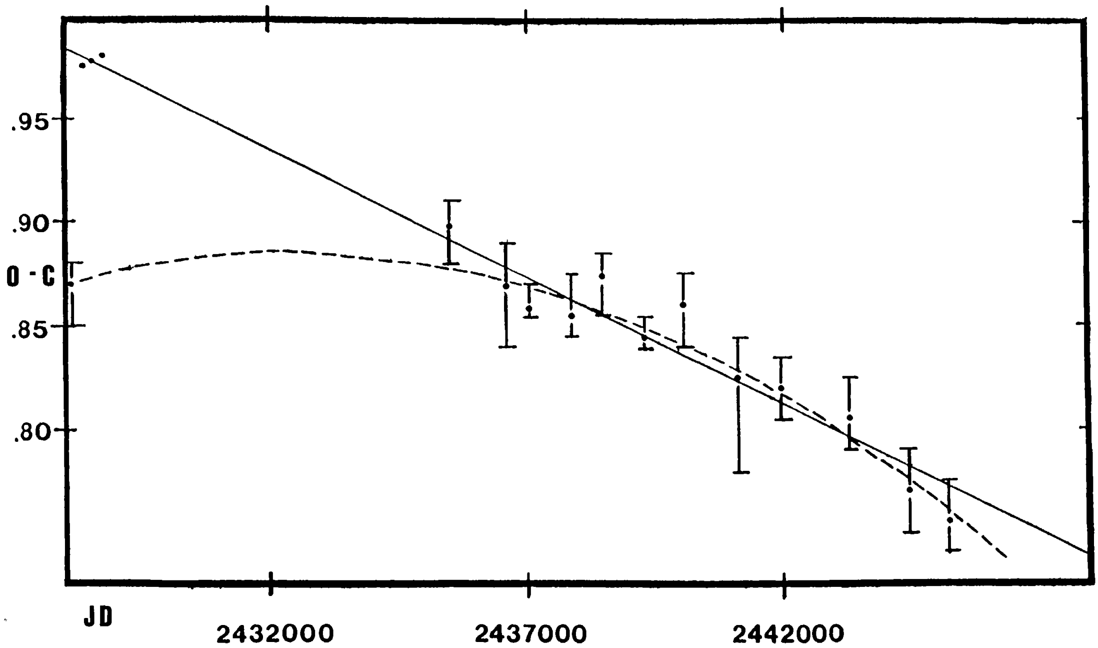

Figure 2. Julian Date vs. O-C for the Maria Mitchell data on V1288 Sgr as well as data from Table III (far left) and Table II (upper left) of Fokker (1951). The least-squares parabola is fitted to include the Table III data, while the straight line includes the Table II data.