AN EXAMINATION OF THE PERIOD OF V1828 SAGITTARII

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Abstract

V1828 Sgr, a 13-day Population I Cepheid, was re-examined to ascertain whether its period changes are gradual or abrupt. A parabolic, or gradual, representation of the period decrease is favored. The rate of change is -0.00309 cycle per century.

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In 1959, Andrea Kundsin of the Maria Mitchell Observatory (MMO) determined the elements of the Cepheid variable V1828 Sagittarii to be as follows (Hoffleit 1959):

$$JD_{max} = 2424402.000 + 12.985\ E. \qquad (1)$$

Equation (1) represents the data from JD 2424000 to 2433900. The star was studied again in 1975 by Deborah Carmichael (1975), who published new elements derived from data from JD 2435700 to 2442660:

$$JD_{max} = 2442275.000 + 12.972\ E. \qquad (2)$$

This study is an update and re-examination to determine whether the period decrease shown by the two sets of elements was gradual or abrupt.

Magnitude estimates of the variable were made from recent (post-1974) photographic plates in the MMO collection. The magnitudes of the sequence stars for V1828 Sgr were determined using iris photometry. These stars were compared to a known magnitude sequence, 1826-2728 (Warren et al. 1976). The two sequences are located in different parts of the Milky Way, one much brighter than the other. To decrease the effect of different amounts of background light, I used the photometric calibration process described by Querijero (1988).

A finding chart for V1828 Sgr and its sequence stars is shown in Figure 1, while the photographic magnitudes of the sequence stars are listed in the caption. The resulting range of apparent photographic magnitude for the variable, 12.8 to 14.5, compares fairly well to those first published (Hoffleit 1959), 12.6 to 14.9 photographic, as well as the published photoelectric blue range, 13.576 to 14.873 (Berdnikov 1986).

In determining (O-C)/P, or (Observed time of maximum - Computed time of maximum), divided by the Period, light curves were made for each year in the interval 1974-1988, plotting apparent photographic magnitude against phase. The phases were computed from the Julian dates, using the elements in equation (2). Carmichael's data and Kundsin's data were also plotted in the same way, as well as magnitude estimates made from older photographic plates at Harvard College Observatory, to broaden the range of dates available for analysis.

Several light curves (1981-1988), when averaged together, formed a mean light curve of photographic magnitude against phase from which the overall shape of the star's light curve was determined. This curve, whose phase of maximum falls at zero, was compared to individual light curves. Values for (O-C)/P were read from the graphs as deviations of observed maxima (on the light curves) from the maximum calculated by equation (2) (on the mean light curve), in units of the period. This comparison method of finding values of (O-C)/P was done both visually and by using a non-linear method of least squares analysis on the MMO computers (Belserene 1986).

Figure 2 shows an O-C diagram using both recent and older data. A parabola was fitted to the entire data set by the method of least squares, which minimizes the sums of the squares of the residuals. The elements implied by the parabola are:

$$JD_{max} = \underset{\pm 0.24}{2438228.74} + \underset{\pm 0.0003}{12.9752}\,E - \underset{\pm 0.0000006}{0.0000071}\,E^2. \qquad (3)$$

Two least-squares line segments that are representative of a more abrupt period change are also shown in Figure 2. The elements implied by both line segments agree nicely with those previously published for V1828 Sgr:

JD 2424288 to 2432729: $$JD_{max} = \underset{\pm 0.26}{2428934.42} + \underset{\pm 0.0012}{12.9846}\,E; \qquad (4)$$

JD 2436270 to 2447340: $$JD_{max} = \underset{\pm 0.16}{2443689.75} + \underset{\pm 0.0007}{12.9703}\,E. \qquad (5)$$

The parabola is subjectively favored over the two line segments. In addition, it matches well with the observed Cepheid period changes presented by Fernie (1984), who claims that these changes are indicative of stellar evolution.

It is interesting to see whether a line or curve fitted to only the more recent data can describe the entire set of data. The new parabolic elements implied by the recent data are as follow:

$$JD_{max} = \underset{\pm 0.20}{2443690.04} + \underset{\pm 0.0010}{12.9688}\,E - \underset{\pm 0.0000028}{0.0000062}\,E^2. \qquad (6)$$

The significance of the curvature implied by equation (6) was verified by a statistical F-test (Pringle 1975), which determined that the probability that the squared (parabolic) term is due to random scatter from the line fit to the data is only 4%. The parabola fitted only to the recent data, the central curve in Figure 3, represents the older data fairly well, although it is systematically higher. A confidence interval analysis was introduced (Barton 1986) to check whether this systematic deviation is merely due to the error associated with the parabola found from the recent data. The upper and lower curves in Figure 3 are the limits within which we have confidence in the parabola as a good fit. These confidence curves surround the parabola with plus or minus one standard deviation. Thus the probability that a real O-C value lies within this interval is 68% if the parabola is the correct representation. All of the early data fell within the one-sigma limit of the new curve with the exception of one point, which still remained within the expected error. This result demonstrates that the curvature of the new data can describe the entire data set, and a parabolic representation is therefore the best way to describe the period of V1828 Sgr. According to equation (5), the star's period is decreasing at the rapid rate of 0.00309 ± 0.00025 cycle/century.

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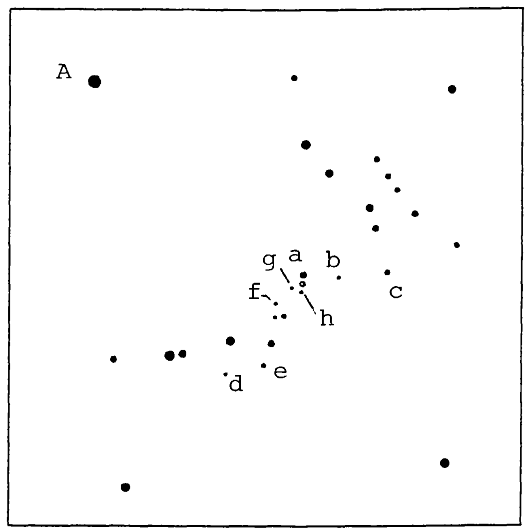

Figure 1. Finding chart for sequence stars used in making magnitude estimates of V1828 Sgr. The square measures roughly a degree on each side. North is at the top, and east is at the left. The photographic magnitudes are: a=12.7, b=14.0, c=13.8, d=14.1, f=14.3, g=14.5, h=14.6. A is SAO 186510; e is also used by Carmichael. The open circle represents V1828 Sgr.

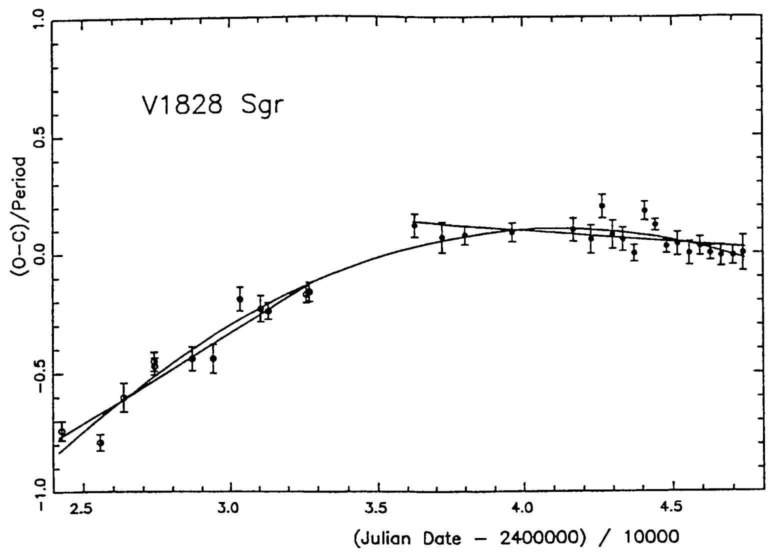

Figure 2. O-C diagram using visual estimates made by manually matching individual light curves to a mean light curve. The open circles indicate data taken from the Harvard plates, while the filled circles represent Maria Mitchell Observatory data.

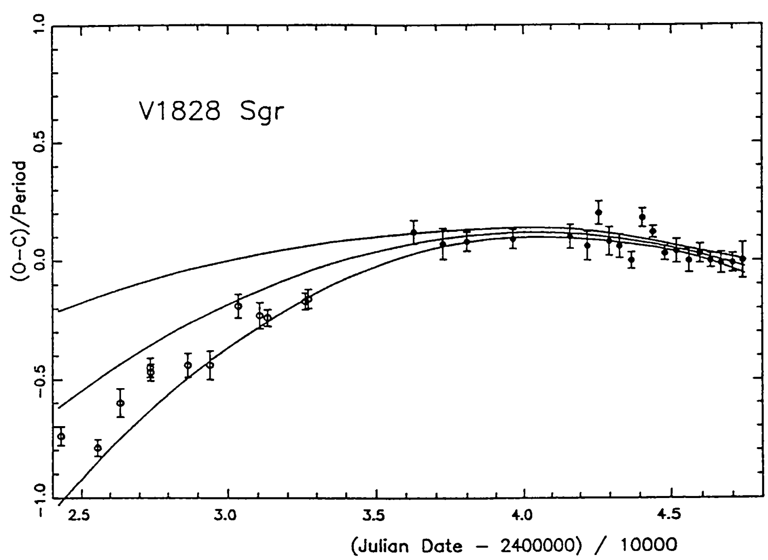

Figure 3. O-C diagram with confidence interval lines included. The middle curve is the parabola fitted to only the recent data. The upper and lower curves are the confidence limits described in the text. Symbols are as for Figure 2.