NEW ELEMENTS FOR CM SCUTI

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Received 25 November 1987

Abstract

Linear elements are updated for the Cepheid star CM Scuti, and possible parabolic elements imply a period increase of 1.6 ±0.9 days per million years.

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There are 1320 plates in the Maria Mitchell Observatory (MMO) Scutum collection with good images of CM Scuti, a Cepheid variable. The date range is JD 2421427 to 2446972 (1931 to 1987). The elements were updated by means of magnitude estimates from these plates with the addition of published photoelectric data (Walraven *et al*. 1958).

The magnitudes of the sequence stars were determined by comparison to stars in a nearby field with known magnitudes using the flyspanker method (Stock and Williams 1964). With this calibration, the shape of the curve from the MMO data matched the shape of the curve from the published data well, implying that the assigned differences in magnitudes between comparison stars were correct. There was, however, a difference in zero-point of about 0.48 magnitude. MMO data had magnitudes ranging from 12.45 to 13.25 photographic, while the published data ranged from 12.0 to 12.8. The difference in zero-points was most likely due to the distance between the field with the stars of known magnitudes and the field with the comparison stars on the plate. Figure 1 shows the adopted comparison sequence.

The MMO data were used to check the constancy and correctness of the light curve. First data from 1950 to 1987 were used to make an O-C diagram using the published elements (Walraven *et al*. 1958):

$$JD_{(max)} = 2431476.290 + 3.91697\ E. \quad (1)$$

The least squares line through the data points produced improved elements:

$$JD_{(max)} = 2431476.437 + 3.916966\ E. \quad (2)$$

Figure 2 shows all the data from 1931 to 1987 plotted with these elements. A mean light curve was then formed by averaging the magnitudes on this curve at the same phase as shown in Figure 3.

The intermediate elements in equation (2) were used to determine new O-C values for subsets of the data. The method adopted is a non-linear least-squares method to compare the curve in Figure 3 to the observed points in each subset (Belserene 1986). The FORTRAN program finds two estimates of O-C. For the first, it "moves" the calculated curve along just the x-axis (phase) until the calculated curve appears to be "right on top of" the observed curve as judged by the sum of the squares of the residuals of the data points from the calculated curve. For the second, it adjusts two parameters; it "moves" the calculated curve along both the x-axis (phase) and the y-axis (magnitude) until the curves appear to coincide. The program also finds the way the sum of the squares of the residuals increases for poorer trials on either side of the best O-C value. The rate of this increase gives the standard error of the derived O-C value. There is about a 68% probability that the true value lies within this confidence region (Belserene 1986) marked by error bars on Figure 4, the final O-C graph. The O-C values and their error bars came from the results of moving MMO data along just the x-axis and the result of moving the published data along both axes to correct for the difference in magnitude between their data and ours.

The JD's, O-C values, and error bars from the program described above were fed into a least squares program which produced the new heliocentric elements:

(Linear) $$JD_{(max)} = \underset{\pm 0.012}{2431476.405} + \underset{\pm 0.0000065}{3.9169642}\,E \qquad (3)$$

(Parabolic) $$JD_{(max)} = \underset{\pm 0.017}{2431476.382} + \underset{\pm 0.000012}{3.916947}\,E + \underset{\pm 0.48 \times 10^{-8}}{0.86 \times 10^{-8}}\,E^2. \qquad (4)$$

The parabolic elements imply that the period is increasing at a rate of 1.6 ±0.9 days per million years. Along with the squared term, the least squares program gives a value for the confidence level with which we can say the squared term was not due to chance deviations (Pringle 1975). The confidence level for this squared term came out to be 0.91. That means there is a 91% chance that the squared term was not due to chance deviations.

I conclude that CM Sct had a nearly constant period during 1918-1987, and while more observations are needed to verify the parabolic elements, the probability is only 9% that the indicated period increase is due to random errors in the O-C values.

This research was conducted under the guidance of Dr. Emilia P. Belserene, whom I would like to thank for all her time and support. This work was funded by National Science Foundation grants AST-8320491 and AST-8619885.

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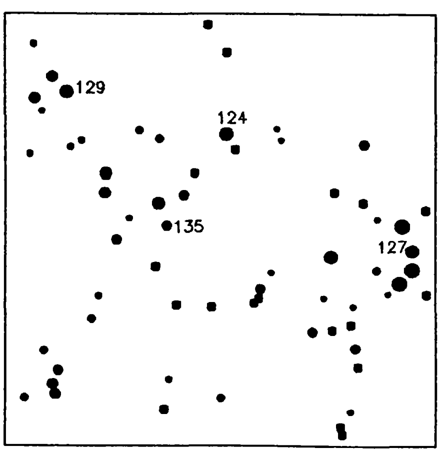

Figure 1. CM Sct and its comparison sequence. Comparison stars are labeled with their assigned photographic magnitudes (decimal omitted). The square is 22 arc minutes across.

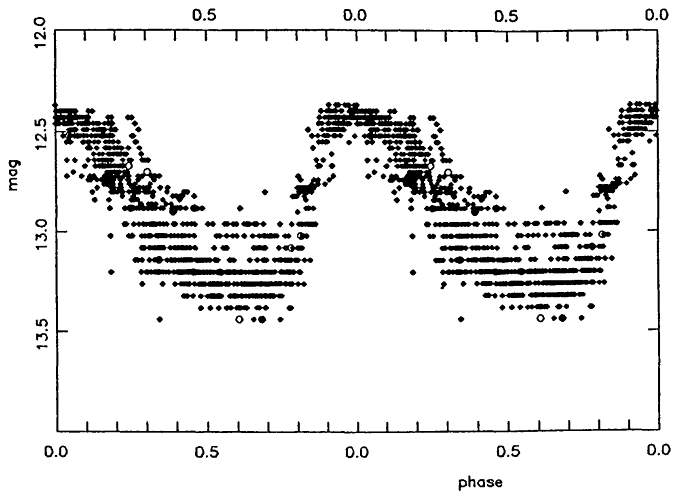

Figure 2. Photographic magnitudes of CM Sct from 1931 to 1987 plotted against phase using elements in equation (2).

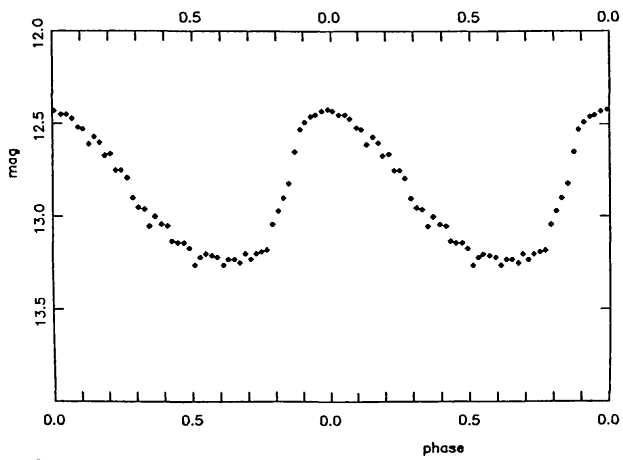

Figure 3. Phase averaged light curve from the observations in Figure 2.

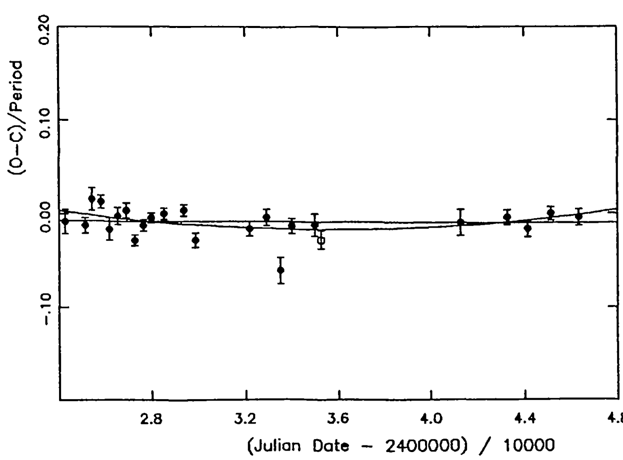

Figure 4. Final O-C graph for CM Sct, based on elements in equation (2). Filled circles are Maria Mitchell Observatory data; open circle is published data (Walraven et al. 1958). Elements derived from the line and parabola are given in equations (3) and (4).