PERIOD CHANGES IN POPULATION II CEPHEIDS: TX DEL AND W VIR

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Abstract

We have used the Hipparcos database of epoch photometry to study the variability of two Population II Cepheids: TX Del and W Vir. We have constructed (O-C) diagrams for these stars, using the new data and data from the literature. The period of TX Del is decreasing, at a rate which is consistent with evolutionary predictions. The period change of W Vir is uncertain because of the many recent gaps in the data on this star. We urge AAVSO visual and photoelectric observers to monitor Population II Cepheids more systematically, since many of these stars have unstable periods, and at least one has an unstable amplitude.

1. Introduction

Population II Cepheids are periodic yellow supergiant pulsating variables with periods of 1 to 100 days which belong to Population II: the old, low-mass stars. These stars are believed to be undergoing "loops" in the Hertzsprung-Russell diagram (HRD) due to shell helium flashes, as they ascend the asymptotic giant branch (AGB) in the last phases of their lives (Wallerstein and Cox 1984; Vassiliadis and Wood 1993). The stars enter the Cepheid instability strip in the HRD, and begin to pulsate. They are, however, evolving on a time scale of a few x 10^4 years, so changes in period (and perhaps even amplitude) are to be expected.

Percy and Hale (1998) recently carried out a period study of RU Cam—a Population II Cepheid which, in 1965–66, abruptly decreased in amplitude. In this star, they detected random cycle-to-cycle fluctuations in period, evolutionary changes in period, and possible multiperiodicity.

The original purpose of the present study was to identify Population II Cepheids which had been observed by the Hipparcos satellite as part of its epoch photometry database (Perryman *et al.* 1997). We hoped to combine these data with archival data from the AAVSO and other sources, in order to study the period and (possible) amplitude changes in these stars. In the end, it turned out that only two stars appeared to have sufficient data for such a study: TX Del and W Vir. Other Population II Cepheids seem to have been observed only sporadically. It would be useful, however, to collect and analyze the data which *are* available.

2. Data and Analysis

The primary source of new data for this study is the Hipparcos database of epoch photometry (Perryman *et al.* 1997). The challenges of analyzing variable stars using this database have recently been discussed in this *Journal* by Marinova and

Percy (1999). Many measurements are made within a few hours. For the purpose of analyzing variable stars with periods of weeks to months, these "clusters" of measurements are effectively single measurements. These clusters tend to be distributed non-randomly, 20 to 30 days apart.

We have analyzed the data using light curves and phase diagrams, using the known periods and epochs of these stars (given below). To construct some phase diagrams, we have used the on-line software on the Hipparcos web site astro.estec.esa.nl/Hipparcos/hipparcos.html, which we recommend heartily for both research and educational purposes.

In addition, we have used data from the literature, as follows: for TX Del, Szabados (1980, 1991) and times of maxima therein; for W Vir, Abt (1954), Arp (1957), Eggen *et al.* (1957), Güssow (1932), Kwee (1967), Michalowska-Smak and Smak 1965), Nielson (1937), Raga *et al.* (1989), Schönfeld (1868–75), Sperra (1895, 1896, 1908), Yendell (1889–1904). One time of maximum in Schönfeld (1873) was not used because the date was ambiguous.

3. Results for Individual Stars

3.1. TX Del

Figure 1 shows the phase diagram for TX Del, using the Hipparcos epoch photometry, a period of 6.165907 days, and an epoch of JD 2442947.009 (Szabados 1980). This figure shows that the variability was quite stable during the three years of the Hipparcos mission.

This figure was used to derive one time of maximum brightness, for use in the (O-C) analysis.

The (O-C) diagram for TX Del, using the same period and epoch given above (Szabados 1980), and times of maximum from the sources mentioned, is shown in Figure 2. There is distinct curvature; the equation of the best-fit parabola, with (O-C) in days, is:

$$(O\text{-}C) = -4.945 \times 10^{-9} t^2 + 0.0001504\, t - 9.407 \qquad (1)$$

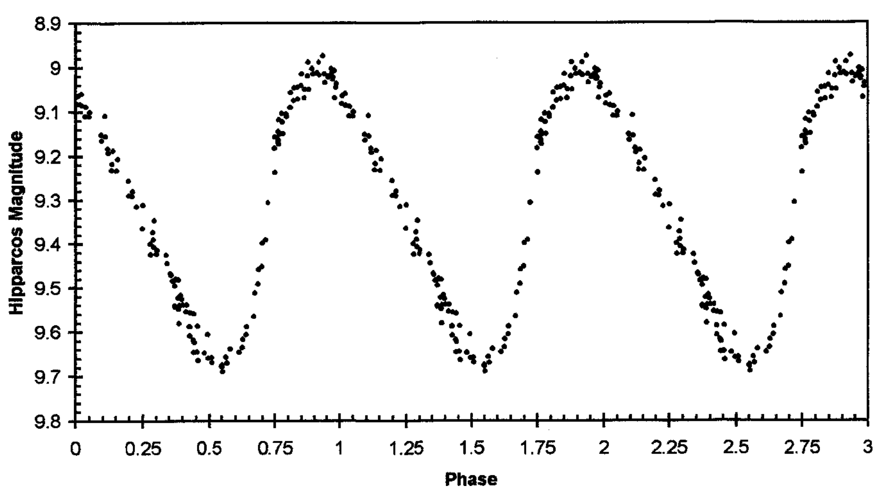

Figure 1. The phase curve for TX Del, using a period of 6.165907 days, an epoch of JD 2442947.009 (Szabados 1980), and Hipparcos epoch photometry.

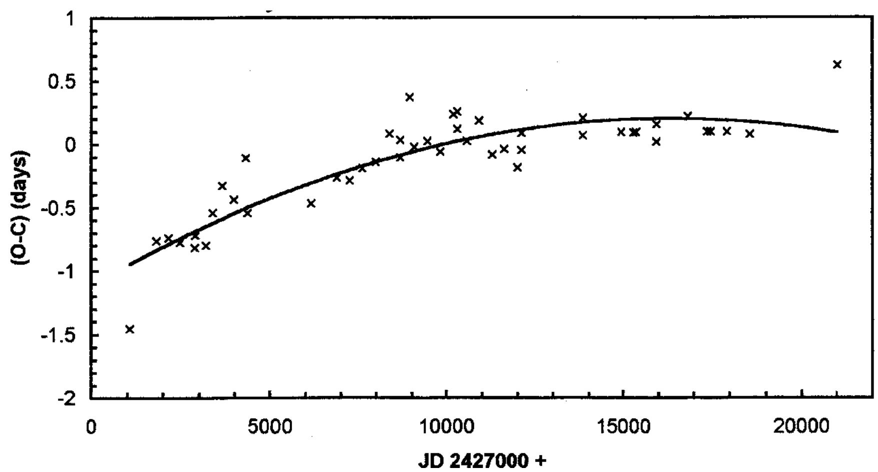

Figure 2. The (O-C) diagram for TX Del, using a period of 6.165907 days, an epoch of JD 2442947.009 (Szabados 1980), and the times of maximum given in the text.

The coefficient of t^2 corresponds to a rate of change of period of 6 x 10^{-8} d/d; at this rate, the period would change by a factor of two in 200,000 years. This is reasonably consistent with (though a bit longer than) the shell helium flash evolution time derived by Vassiliadis and Wood (1993) for solar-mass stars, namely about 100,000 years. Incidentally, there has been some suspicion that TX Del might be a Population I Cepheid, but Vinkó *et al.* (1998) found no evidence, one way or the other.

3.2. W Vir

The (O-C) diagram for W Vir, using a period of 17.2736 days, an epoch of JD 2432697.783 (*General Catalogue of Variable Stars* (GCVS), Kholopov *et al.* 1985), times of maximum from the sources mentioned, and times of minimum adjusted to times of maximum by subtracting 9.0 days, is shown in Figure 3. The relation "min = max - 9.0 days" was the one which produced the least scatter when all data were combined. Values greater than or less than 9.0 days gave significantly more scatter in the (O-C) diagram. The equation of the best-fit parabola, with (O-C) in days, is:

$$(O\text{-}C) = +3.832 \times 10^{-10} t^2 - 0.000256\, t - 0.252 \qquad (2)$$

If only times of maximum are used, then the equation of the best-fit parabola is:

$$(O\text{-}C) = -1.096 \times 10^{-10} t^2 - 0.000252\, t - 0.179 \qquad (3)$$

The fact that the sign of the quadratic term changes when (adjusted) times of minima are used, suggests that the curvature of the (O-C) diagram is not significant. In fact, a visual inspection of the diagram suggests that any curvature is marginal. The coefficients of t^2 in each case correspond to rates of period change of 1.4 x 10^{-8} and 3.8 x 10^{-9} d/d respectively; at these rates, the period would change by a factor of two in 4 million or 13 million years, respectively. This is one to two orders of magnitude longer than the shell helium flash evolution time derived by Vassiliadis and Wood (1993) for solar-mass stars.

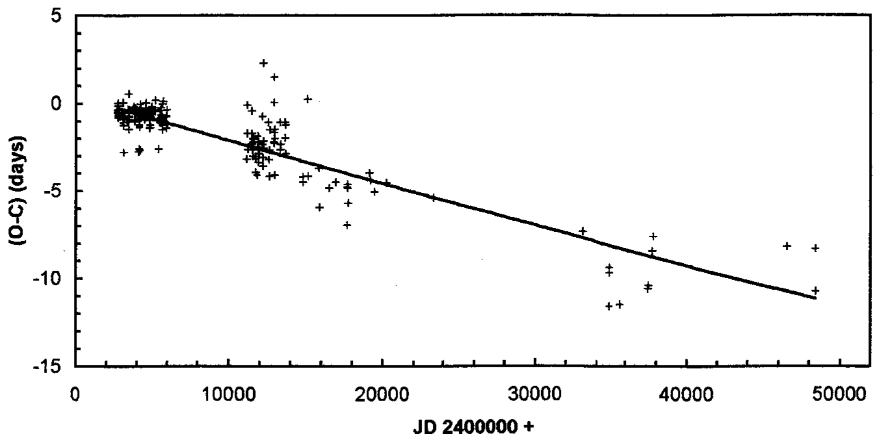

Figure 3. The (O-C) diagram for W Vir, using a period of 17.2736 days, an epoch of JD 2432697.783 (GCVS), and the times of maximum and minimum given in the text. Times of minimum have been adjusted to times of maximum by subtracting 9.0 days; see text for a discussion.

4. Discussion

There are very few Population II Cepheids which have been observed regularly and systematically over many decades. In particular, there are large gaps in the coverage of W Vir, which is considered to be the prototype of this class. Yet these are stars whose periods and amplitudes may change on a time scale of decades; RU Cam is a dramatic example. The period changes in these stars are expected to be rapid, given the transient phase of their evolution. According to the catalogue of Harris (1985), there are 10 Population II Cepheids brighter than magnitude 10 (namely: T Ant, V733 Aql, RU Cam, TX Del, SW Tau, AL Vir, V553 Cen, κ Pav, AU Peg, and RT TrA), and a further 14 between magnitude 10 and 11. Long-term monitoring of a carefully selected sample of Population II Cepheids would be an excellent project for AAVSO visual, photoelectric, or CCD observers. We strongly urge the AAVSO visual and photoelectric observers to begin monitoring a few Population II Cepheids in a systematic way.

In principle, long-term observations should be able to reveal period changes in some cases. The rate of change of period in Population II Cepheids is variable with time (Vassiliadis and Wood 1993). Stars are more likely to be found in slow phases of evolution, in which the rates of period change are slow; this appears to be the case with W Vir, in which the evolutionary changes are masked by random cycle-to-cycle changes. In TX Del, however, evolutionary changes seem to have been detected.

5. Conclusions

We have carried out a period study of two Population II Cepheids—TX Del and W Vir. The period of TX Del is changing at a significant rate, which is consistent with the expected rate of evolution of the star. The period change in W Vir is ambiguous, because of the limited observations of the star in recent times.

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