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NEW APSIDAL MOTION DETERMINATION OF THE ECCENTRIC ECLIPSING BINARY V1143 CYGNI

The eclipsing binary V1143 Cyg (HR 7484; HD 185912; BD+54°2193; $V_{max} = +5.86$; B−V = +0.46) consists of a pair of F5 V stars moving in an eccentric orbit (e = 0.54) and having an orbital period of $P_{orb} = 7.64075$ days. The system is detached with both components residing well inside their respective Roche lobes. The orbital and stellar properties of V1143 Cyg are very well determined from the careful study of Andersen *et al.* (1987). One of the interesting aspects of this binary, that apparently has been overlooked, is that its U, V, W space velocity components, as given by Andersen *et al.* (1987) of +31, −16, −2 km/s, are very close those of the Hyades cluster (+40, −17, −3) km/s (Eggen 1960; Eggen 1970). (Note that the U, V, W velocity components are measured relative to the Sun and that the Eggen system is adopted in which a positive U-velocity is in the direction of the Galactic anti-center.) Although the similarity between the space motions of the binary and the Hyades Moving group could be a coincidence, it is more likely that V1143 Cyg is a member. If this is true, then the binary would be coeval with the Hyades, thus having an age of about 600 Myr. Knowing the age of a binary, vastly increases its importance for testing stellar structure, opacity laws, and evolution models (*e.g.* Guinan 1993).

Because of V1143 Cyg's eccentric orbit and deep, narrow eclipses, its apsidal motion can be accurately determined from an analysis of the timings of primary and secondary eclipses. The apsidal motion rate is determined from the change in the displacement of the secondary eclipse relative to the primary eclipse (*e.g.* Guinan and Maloney 1985). Independent determinations of the apsidal motion of V1143 Cyg have been made by Khaliullin (1983) and Gimenez and Margrave (1985); they are in good agreement, Khaliullin observing an apsidal motion rate of $\dot{\omega}_{obs} = 3\overset{\circ}{.}49/100\mathrm{yr} \pm 0\overset{\circ}{.}38/100\mathrm{yr}$ while Gimenez and Margrave observe $\dot{\omega}_{obs} = 3\overset{\circ}{.}36/100\mathrm{yr} \pm 0\overset{\circ}{.}19/100\mathrm{yr}$. However, Andersen *et al.* (1987) calculate a somewhat faster theoretical apsidal motion of $\dot{\omega} = 4\overset{\circ}{.}25/100\mathrm{yr} \pm 0\overset{\circ}{.}72/100\mathrm{yr}$ in which the expected relativistic and classical contributions to apsidal motion are $\dot{\omega}_{GR} = 1\overset{\circ}{.}86/100\mathrm{yr}$ and $\dot{\omega}_{cl} = 2\overset{\circ}{.}39/100\mathrm{yr}$, respectively. The apsidal motion due to classical mechanics results from the component stars' departures from spherical symmetry which arises from the tidal and rotational deformations of the stars. The classical term depends on the fractional stellar radii, stellar masses, rotation, and orbital period, as well as on the distribution of mass inside the stars. The masses, radii, and rotation velocities of the components are well known. The internal mass distribution of the stars is parameterized by the internal structure constants (k2) which are computed from stellar interior and evolution models (*e.g.* Claret and Gimenez 1992). The relativistic apsidal term arises as a consequence of General Relativity as in the case of Mercury's 43"/100yr relativistic apsidal motion.

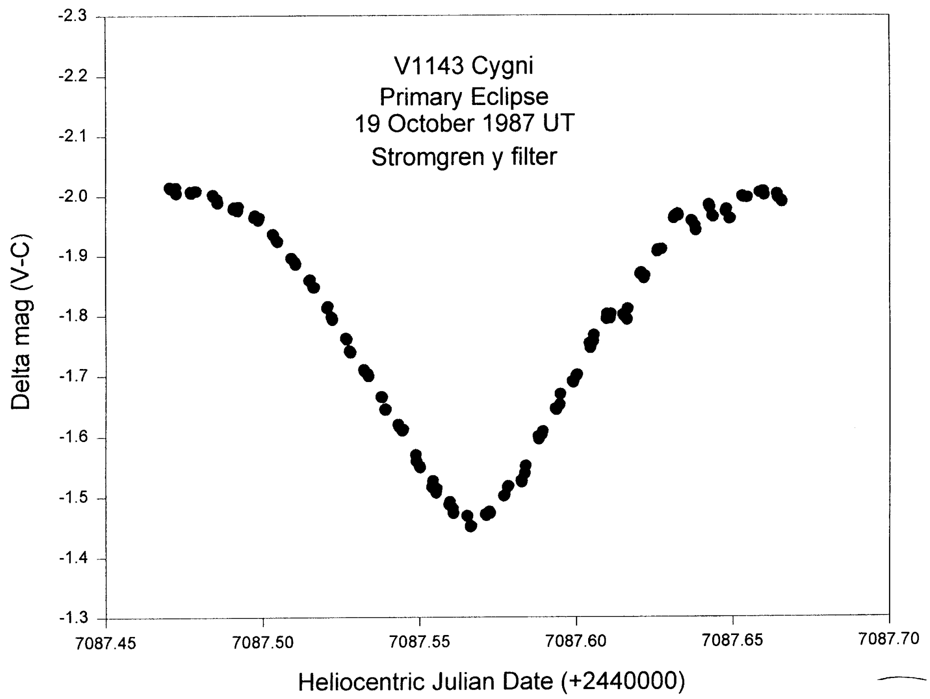

Figure 1. A plot of the primary eclipse of 19 October 1987 taken with the Strömgren "y" filter

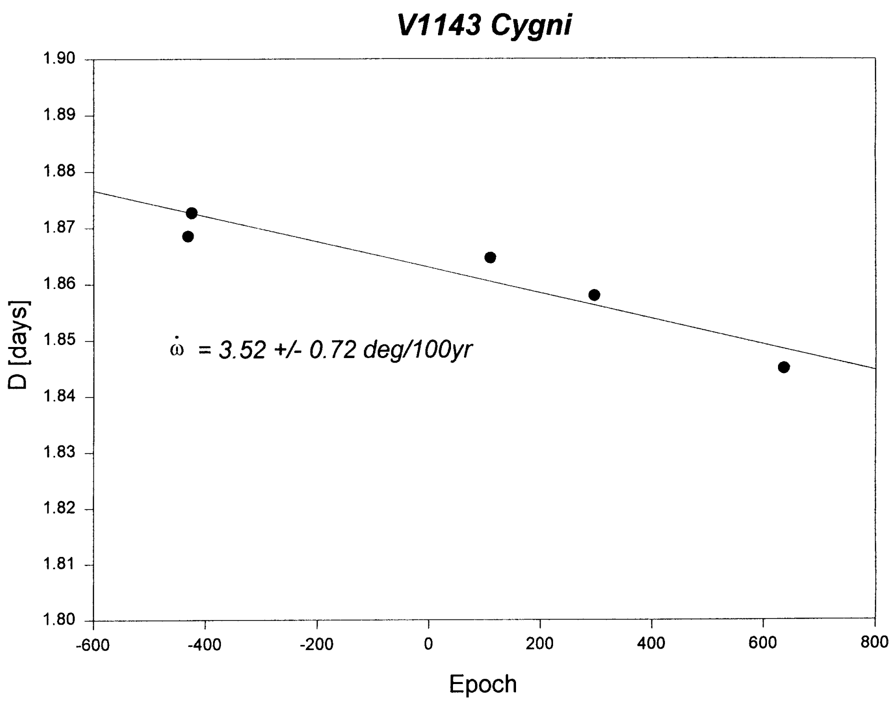

Figure 2. A plot of the displacement of secondary minimum from the half period point vs. epoch showing the observed apsidal motion rate

Photoelectric photometry of V1143 Cyg was conducted with the Jenkins 38-cm reflector at Villanova University Observatory. The observations reported here were made on the nights of 17 and 19 October 1987 UT, using intermediate-bandpass blue ($\lambda_{max} = 4530$Å) and yellow ($\lambda_{max} = 5500$Å) interference filters. These were nights on which the secondary and primary minima occur, respectively. The yellow filter has characteristics closely matched to the Strömgren "y" filter. Differential photometry was carried out in the usual manner using HD 185978 (F8; $m_V = +7.^{m}8$). This star had been used in previous photometric studies of the system and appears constant in light. The observations were corrected for differential extinction and the times were converted to Heliocentric Julian Day Number (HJD). The photometry was reduced using a program developed by G. P. McCook.

For illustration, the observations of the primary minimum is presented in Figure 1 in which the differential magnitudes, in the sense variable minus comparison star (V−C), are plotted against HJD for the yellow observations. The mid-times of the secondary and primary eclipses were determined by least squares fits of the minima with parabolas and also by bisecting cords (see Guinan *et al.* 1994). The two methods yield similar results for the blue and yellow data sets of each eclipse. The measured eclipse timings are:

$$\mathrm{T\ (Min\,I)} = \mathrm{HJD}\ 2447087.5669 \pm 0.^{d}0001$$
$$\mathrm{T\ (Min\,II)} = \mathrm{HJD}\ 2447085.5910 \pm 0.^{d}0001$$

These eclipse timings are very close to the times predicted using the light elements of Gimenez and Margrave (1985). Thus indicating that the ephemerides given by them are essentially correct.

We added these timings to the photoelectric eclipse timings already available (see Koch 1977; Khaliullin 1983; Gimenez and Margrave 1985; Guinan *et al.* 1987; Caton and Burns 1993; Lacy and Fox 1994). However, the last two timings were only of primary eclipse. We then recomputed the rate of apsidal motion for the system. This was done following the procedure of Guinan and Maloney (1985). Independent linear least squares solutions were made of the primary and secondary eclipses, respectively, yielding periods of P (min I) = 7.64075095 ± 0.00000082 days and P (min II) = 7.64072932 ± 0.00000359 days. The period determination from the primary eclipses is better determined than secondary eclipses because the primary eclipse has twice as many timings. A plot of the change of the displacement of secondary minimum from the half period point (D = $t_1 + t_2 - 0.5P$) is shown in Figure 2. This slow variation in the displacement of secondary minimum is due to advance of the line of apsides of the orbit and the data yields an apsidal motion rate of $\dot{\omega}_{obs} = 3.^{\circ}52$/100yr $\pm 0.^{\circ}72$/100yr. This value is nearly identical to those determined previously. The reason for the relatively large error is explained in two ways. First, there are only five independent timings of secondary minima and therefore the apsidal motion rate is still not well defined. Also, in calculating the errors, we took the uncertainties in both of the periods determined from the analysis of primary and secondary eclipses and propagated them through the equations to calculate the total uncertainty in the apsidal motion rate. More timings, in particular of secondary eclipses, are necessary to help define the apsidal motion rate more precisely, so we plan to obtain additional photometry of V1143 Cyg. In particular, we hope to obtain additional timings of the secondary minimum.

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Joseph F. BURNS
Edward F. GUINAN
James J. MARSHALL
Dept. of Astronomy and Astrophysics
Villanova University
Villanova, PA 19085
USA

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