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TIME OF MINIMUM DETERMINATION OF THE ECLIPSING BINARY V541 CYGNI

The study of apsidal motion in eclipsing binaries has become more interesting with the recent discovery that at least two well-defined systems, DI Her and AS Cam, have observed apsidal motions significantly less than those predicted from general relativity and standard classical theory (Guinan and Maloney, 1985, 1987; Maloney et al., 1986). V541 Cygni (=BD+30°3704; $m_V = +10^m6$) is an eclipsing binary consisting of two massive ($M_1 = M_2 \simeq 2.5M_\odot$) B9 V stars moving in a highly eccentric orbit (e = 0.474) with an orbital period of 15.34 days. This system has been identified by Khaliullin (1983, 1985) and Guinan and Maloney (1987) as an important test case for studying general-relativistic apsidal motion. The recent study by Khaliullin (1985) has determined that the contribution to apsidal motion due to general relativity ($\dot{\omega}_{GR} = 0.82 \pm 0.08$ deg/100yr) is over five times larger than the classical contribution ($\dot{\omega}_{CL} = 0.15 \pm 0.03$ deg/100yr) which arises from tidal and rotational distortion of the stars. The dominance of the relativistic contribution to the apsidal motion is unusual, since the apsidal motion from classical effects overwhelms the relativistic contribution in all but a handful of systems. The classical contribution is small in the case of V541 Cyg because of the small fractional radii of the components ($r_1 = 0.044$; $r_2 = 0.043$) so that the tidal deformations of the stars are very small (Khaliullin 1985). Thus, V541 Cyg serves as an excellent test case for post-Newtonian theories of gravity because the classical apsidal motion is small and the general-relativistic contribution is nearly 70 times larger than the relativistic contribution of $\dot{\omega}_{GR}$=43"/100yr for the orbit of Mercury.

The apsidal motion of an eclipsing binary is measured from the times of primary and secondary eclipse. Khaliullin (1985) has measured the apsidal motion of V541 Cyg from two light curves of the system obtained about 23 years apart, and finds $\dot{\omega}_{obs}=0.90 \pm 0.13$ deg/100yr. This value agrees very well with the combined theoretical classical and relativistic contributions to apsidal motion given above of $\dot{\omega}_{GR+CL}=0.97\pm0.09$ deg/100yr. Because Khaliullin's determination is based only on two light curves, we are attempting to secure additional photoelectric timings to determine more accurately the apsidal motion of this important system. We report here a new time of primary minimum determined at Lines Observatory.

Photoelectric photometry of V541 Cyg was carried out on 21 July 1987 using a photoelectric photometer attached to the 20-inch Lines Reflector. The observations were made differentially with respect to a nearby comparison star using blue (B) and yellow (V) filters of the UBV system. BD+30^{o}3702 (listed as star 3 by Karpowicz (1961)) served as the comparison star for which we estimate $\underline{V}$ = +9.9 and $\underline{B-V}$ = +0.36. Extinction corrections were applied to the data and the times were converted to heliocentric Julian day (HJD) in the ususal way. Details of the instrumentation and data reduction are given by Lines et al. (1986).

The differential $\underline{V}$-magnitudes of primary eclipse are plotted against HJD in the figure. A determination of the time of mid-eclipse was made for both the yellow and blue observations using a computer code described by Guinan et al. (1987). The composite result for time of primary eclipse is:

$$T(\text{min I}) = \text{HJD } 2446998.8424 \pm 0.0010.$$

Using the light elements of Khaliullin for primary minimum of

$$T(\text{min I}) = \text{HJD } 2444882.2127 + 15^{d}.337873E,$$

the (O-C) of this determination is +0.0032 day. This timing as well as earlier eclipse timings have been used to determine the apsidal motion of V541 Cyg of $\dot{\omega}_{obs} = 0.95 \pm 0.06$ deg/100 yr. This value is close to that found previously by Khaliullin and agrees very well with the theoretically expected apsidal motion. However, in these calculations the masses of the stars were assumed to be $M_1 = M_2 = 2.5M_\odot$ from their B9 V spectral types. A radial velocity study of this system is badly needed before we can claim complete agreement between theory and observational data. Due to the crucial role that gravity plays in our understanding of the physical universe, it is critical that we

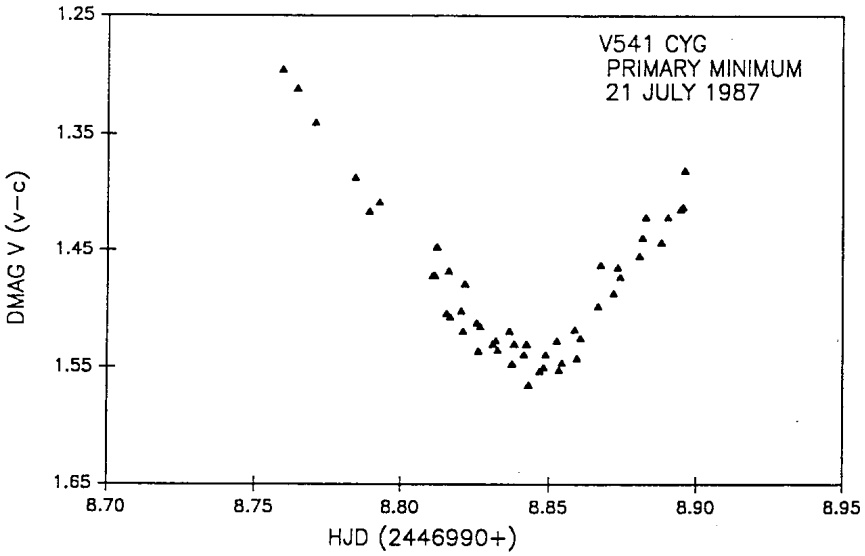

Figure 1. The differential V-magnitudes of V541 Cyg plotted against heliocentric Julian Day number.

make every effort to comprehend the apsidal motion of V541 Cyg and other massive binary systems.

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