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PHOTOMETRIC VARIABILITY OF THE ELLIPSOIDAL STAR AND SPECTROSCOPIC BINARY 7 CAMELOPARDALIS

For several years we have used 7 Cam (= BS 1568, HD 31278, ADS 3536; Sp = A1V, but see below; V = 4.47) as our principal check star for differential photometry of 9 Aurigae, with BS 1561 (Sp = A2V; V = 5.78) as the comparison star. Recently, over the course of a seven-night photometric run at Mauna Kea we noticed that the nightly means of 7 Cam vs. BS 1561 were the same only every other night. So we added a second check star, BS 1668 (Sp = F5V, V = 5.68), to the observing sequence. Photometry of the second check star, with respect to BS 1561, showed it to be constant to within the observational errors. A power spectrum of the recent 7 Cam vs. BS 1561 data indicated a period just under two days, but we suspected that it was just an alias of data taken primarily at a single site. However, a footnote in the *Bright Star Catalogue* indicated that 7 Cam is a known spectroscopic binary with a period of 3.88 days. It occurred to us that 7 Cam could be an ellipsoidal variable star with a photometric period equal to half the orbital period.

A SIMBAD search pointed us to a paper in which Lucy and Sweeney (1971) recomputed, under the assumption that the orbit is exactly circular, the orbit determined by Harper (1911) on the basis of Ottawa and Lick radial velocities. It is not clear from their paper whether Lucy and Sweeney took into account the additional velocities measured at the Dominion Astrophysical Observatory and used by Harper (1934) to refine the orbital period. The exact period, and its uncertainty (which Lucy and Sweeney did not give), are of particular interest to us, as they enable us to extrapolate to the present day the spectroscopic phase of the system for comparison with the photometric phase. We therefore recomputed the orbit ourselves from the Lick, Ottawa, and Dominion Astrophysical Observatory radial velocities. We know of no others of comparable precision. An empirical adjustment was made to the zero-point of the Lick data, and the three sources were weighted so as to equalize the variances of their residuals. The solution is:

$P = 3.884505 \pm 0.000033$ days
$T_0 = $ JD 2418636.210 ± 0.011
$V_0 = -9.2 \pm 0.5$ km sec^{-1} (γ velocity)
$K = 35.4 \pm 0.7$ km sec^{-1}
$e = 0$
$a_1 \sin i = 1.89 \pm 0.04 \times 10^9$ m
$f(m) = 0.0179 \pm 0.010\ M_\odot$

Here T_0 is the epoch of maximum velocity (when the component we see is receding from us). $a_1 \sin i$ is the true radius of the orbit of the primary about the center of mass, projected in the line of sight. f(m) is the mass function.

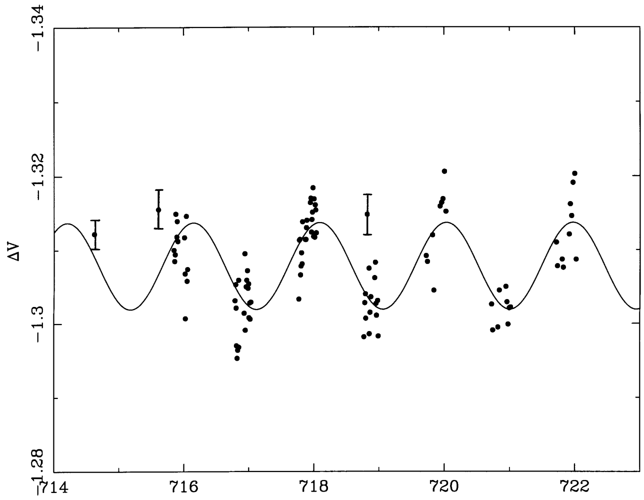

Figure 1 – Differential photometry of 7 Cam (BS 1568) vs. BS 1561. The three points with error bars are nightly means of data by Luedeke. The rest are individual differential magnitudes obtained at Mauna Kea.

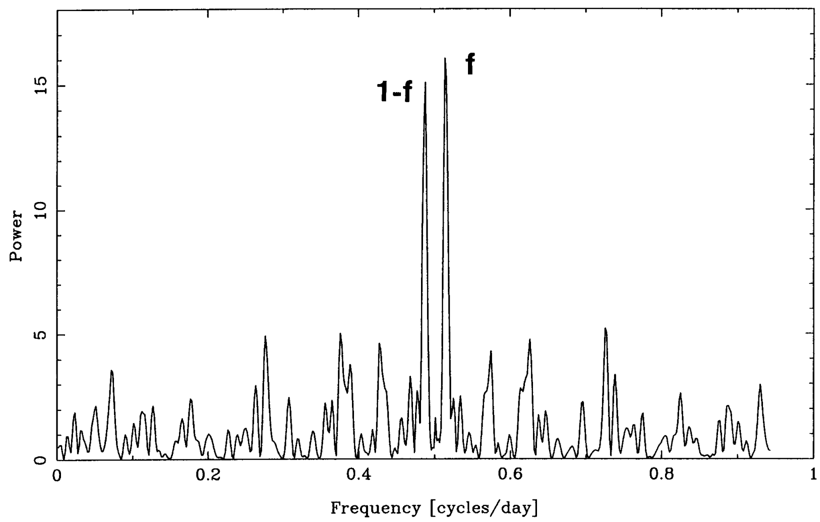

Figure 2 – Power Spectrum of data obtained by Guinan and McCook in 1989/90. The frequency $f = 0.51487$ and its one-day alias are indicated.

In Figure 1 we give the data recently obtained, also showing the least-squares sinusoid fit to the data obtained at Mauna Kea, with a period equal to half of the spectroscopic period. The derived photometric amplitude is 5.9 ± 0.9 mmag. If we adopt an epoch of HJD 2449000, the derived phase of minimum light is $-.2238 \pm 0.0263$, where the negative phase means that the photometric minimum occurs slightly *after* the given epoch. The goodness of fit is $\pm$ 3.8 mmag for a single observation.

Do previous data confirm the variability? The best set to use was obtained over a 136-day period in 1989/90 by Guinan and McCook with the Phoenix-10 APT at Mt. Hopkins, Arizona. These data can be obtained from Archives of IAU Commission 27 as file 218 of unpublished photometry (see Krisciunas and Guinan 1990). In Figure 2 we show the power spectrum of the V-band data from five years ago. The least-squares phase of the

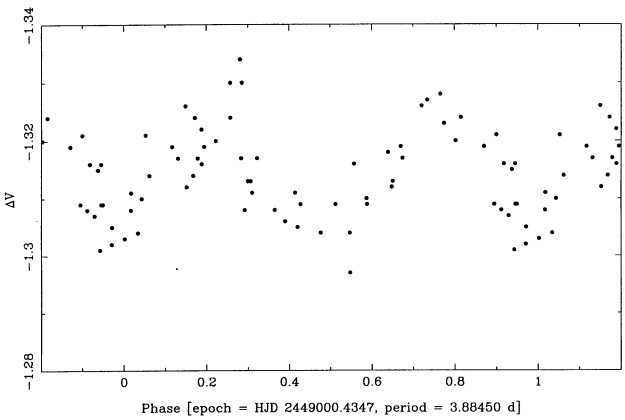

Figure 3 – Data by Guinan and McCook from 1989/90, phased with ephemeris derived from the 1994/5 data. The mean value of $\Delta V = -1.3145 \pm 0.0010$ is slightly brighter than the mean value obtained from the more recent photometry obtained at Mauna Kea, $\Delta V = -1.3078 \pm 0.0006$.

1989/90 data, from an epoch of 2449000, is $-.2010 \pm 0.0204$, within the errors equal to the phase of the 1994/5 data. In Figure 3 we show the 1989/90 data phased with the ephemeris derived from the most recent data, but folded with the full orbital period, just in case one side of the primary appears differently than the other. One can see graphically that the ephemeris has not changed. The photometric amplitude derived from the 1989/90 V-band data is 7.8 ± 1.0 mmag, with a goodness of fit of $\pm$ 5.6 mmag for a single observation. B-band and U-band data taken in 1989/90 yield amplitudes of 6.6 ± 1.3 and 7.6 ± 1.2 mmag, respectively.

A tentative piece of confirming evidence, that we are seeing the larger projected area of an ellipsoidal star every half orbit, comes from the orbital determination. We should see the minimum light, when either of the visible star's smaller sides is facing us, when the orbital phase is .25 or .75. Between the spectroscopically derived epoch of maximum velocity, and an epoch of minimum light of HJD 2449000.4347, the difference in time divided by Griffin's orbital period gives 7816.755 ± 0.068 orbits. Since the fractional part of this number is close to .75, it is entirely consistent with the notion that the visible component of 7 Cam is tidally distorted by a less massive, unseen component. This could be greatly reinforced by a new spectroscopic determination of the orbital phase.

It is likely that the published luminosity class of 7 Cam is wrong. It may be a subgiant, not a main sequence star. Given the mass function, an assumed mass of 2.2 $M_\odot$ for the primary and a range of masses for the secondary, we attempted to model the ellipsoidal nature of the primary and found that there is no solution if the primary is the size of a main sequence early A-type star ($R \approx 1.8 R_\odot$). However, if the primary has $R > 3.0 R_\odot$, a photometric range of $\pm$ 6–7 mmag can be obtained. Given the primary's projected rotational rate of 45 km sec^{-1}, if $R > 3.45 R_\odot$ the rotational period could equal the orbital period. This tidal locking is not unexpected. If $\sin i \approx 1$ (expected for a photometrically variable ellipsoidal star), the mass of the secondary is ≈ 0.5 $M_\odot$.

Roman (1949) includes 7 Cam in her list of probable members of the Ursa Major stream. There is a problem with this. The age of the UMa cluster is about $2\text{–}3 \times 10^8$ years (Wielen 1978; Soderblom 1990). A 2.2 $M_\odot$ star such as 7 Cam would have a main sequence lifetime an order of magnitude longer than this. If 7 Cam is indeed a subgiant, it is much too old to be a member of the UMa stream.

We note that the secondary we have been discussing is *not* the $m_v = 7.9$ companion discovered by Dembowski, listed by Aitken (1932), and more recently observed at $\rho = 0\farcs483$ by McAlister *et al.* (1989) via speckle observations. 7 Cam also has an $m_v = 11.3$ companion at $\rho = 26''$.

The HIPPARCOS parallax, when it becomes available, will allow many of parameters of this system to be more accurately determined.

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