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V772 Cas: AN INTRINSICALLY VARIABLE BpSi STAR IN AN ECLIPSING BINARY?

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V772 Cas (HD 10260, HR 481) was discovered to be variable by the *Hipparcos* team (ESA, 1997), who determined the amplitude to be 0.039 magnitudes (*Hp*). Kazarovets *et al.* (1999) classified it as an ACV: star and assigned the *GCVS* designation of V772 Cas. Hube (1970) announced the radial velocity (RV) to be variable, based on eleven spectra. An ongoing study, by the present author, of late–B stars whose RVs have been discovered to vary (e.g. by Hube, 1970), but which lack published orbits, has so far yielded orbital periods, P_{orb}, for several of them, including V772 Cas. Combining the RVs of Hube (1970) with the *Hipparcos* photometry of V772 Cas, we find that $P_{orb} = 5.0138$ days and confirm that it is an eclipsing binary, perhaps an Algol-type. We present a preliminary spectroscopic orbit and evidence for a possible modulation of the light curve, which may arise in intrinsic variability of the primary star, perhaps of the α^2 CVn type. The purpose of this note is to alert observers to the possibility of intrinsic variability of this chemically peculiar, slowly rotating, B8IIIpSi eclipsing binary star, in order that observations may be made as early as the coming observing season (2008–2009).

Otero (2007) announced that V772 Cas is an eclipsing binary, with an eccentric orbit and a period of 10.7269 days. At the same time, he cautioned that the star 'might be a small amplitude ACV ($V = 6.68 - 6.69$) star with a period of 3.5473 d'. We attempted to resolve this uncertainty in the period and to determine the type of variability by requiring that the photometric and RV data meet, as closely as possible, these conditions: the correct period must result in the maximum coherence in the phased velocity and light curves; the least squares solution for the spectroscopic orbital elements converges to a Keplerian one; the final orbit yields the minimum standard error (S.E.) of one RV observation, and that it predicts a naive proxy time of primary minimum. It should be emphasized that *Hipparcos* did not observe any eclipse throughout its entire length, so that there is no directly observed time of minimum for V772 Cas. As a simple proxy for it, we adopted T_{min} to be the JD of the faintest magnitude observed by *Hipparcos*.

Candidate periods were initially chosen from amongst those with the strongest signals in a period search of the *Hipparcos* data using various standard periodogram techniques. The resulting power spectra differed amongst themselves. However, the strongest peaks in the spectral window, between 0.9 and 12 days, are at 5.08, 5.67, 8.23, 9.08, 10.84 days, with a very weak one at 3.55 days, and there are no peaks at aliases of one year. Phase plots of the RV and *Hipparcos* photometry data for periods corresponding to the strongest peaks in the power spectra between 0.9 days and 12 days, focusing on the interval between 3 and 12 days, were ultimately relied upon to eliminate those candidate periods that gave clearly incoherent or extremely noisy light curves.

No coherent phased light curves were found for periods between 10.1 and 12.5 days, although somewhat coherent and noisy light curves for periods of 3.461 and 10.026 days must be mentioned, as the former provides some support for the shorter period proposed by Otero (2007) and the latter is twice the period ultimately settled upon as being the correct one. The candidate period of 10.026 days yields a light curve with two clear minima separated by very nearly $0.5P$, but it was eliminated because the resulting RV curve is double-waved, inconsistent with duplicity and evidence that this candidate period is twice the true period. While the 3.461-day period light curve is very noisy, it produces a very clean RV curve, which is nonetheless neither Keplerian nor convergent in the orbit solution.

As might be expected from such a small number of observations, the periodogram search of the RVs was not very helpful. However, none of the spectral window peaks in the RV data correspond to any of the candidate periods described above, nor do any of the strongest RV power spectrum peaks yield a coherent and Keplerian RV curve.

Combining the results from the periodogram and phase-plot period searches of the *Hipparcos* and RV data, it was found that light *and* RV curves that met the requirements described above could only be obtained by periods between about 5.012 and 5.014 days. Applying those criteria, we found that $P_{orb} = 5.0138$ days produces the minimum scatter in the light curve, a spectroscopic orbit solution that both converges to a Keplerian orbit and very closely predicts a simple proxy for T_{min} (see below).

However, the orbit solution converged to $P_{orb} = 5.01253$ days when all orbital elements were allowed to vary as unknowns. Eclipses will occur, assuming $i = 90°$, at phases corresponding to $\nu + \omega = 90°$ and $270°$, where ν is the true anomaly and ω is the longitude of periastron in the orbit. $P_{orb} = 5.01253$ was rejected because T_{min}, as predicted from the orbit solution, is nearly one day different from our proxy T_{min}. Furthermore, $P_{orb} = 5.0138$ is only slightly more than 1σ longer while producing a more coherent light curve. We thus fixed the period in the orbit solution at 5.0138 days, and the resulting orbital elements are listed in Table 1, which also provides their standard errors. Orbital elements from the $P_{orb} = 5.01253$ solution differ from the one adopted here by no more than expected from the standard errors of each solution. We also emphasize that none of the other candidate periods resulted in both coherent light *and* velocity curves, and that the correctness of $P_{orb} = 5.0138$ days can be supported entirely by the photometry, without appeal to the RVs, as discussed below. Moreover, these combined results appear to exclude any period near 3.5 days, or between 10.0-12.0 days, from being the correct one. The RVs and *Hipparcos* data cover 387 and 233 cycles of the orbit, respectively.

Table 1. Spectroscopic orbital elements of V772 Cas.

Element Value	S.E.
P=5.0138	±(fixed) days
T=JD 2439799.53	±0.61 days
e=0.17	±0.10
ω=305°	±45°
V_0=−3.1	±2.9 km sec^{-1}
K=38.4	±4.7 km sec^{-1}

Figure 1 shows the eleven RVs of Hube (1970), phased on $P_{orb} = 5.0138$ days and referred to the time of periastron in Table 1. The small grey dots indicate the RV curve using those orbital elements. In view of the small number of RV measures of V772 Cas, this orbit must be considered preliminary.

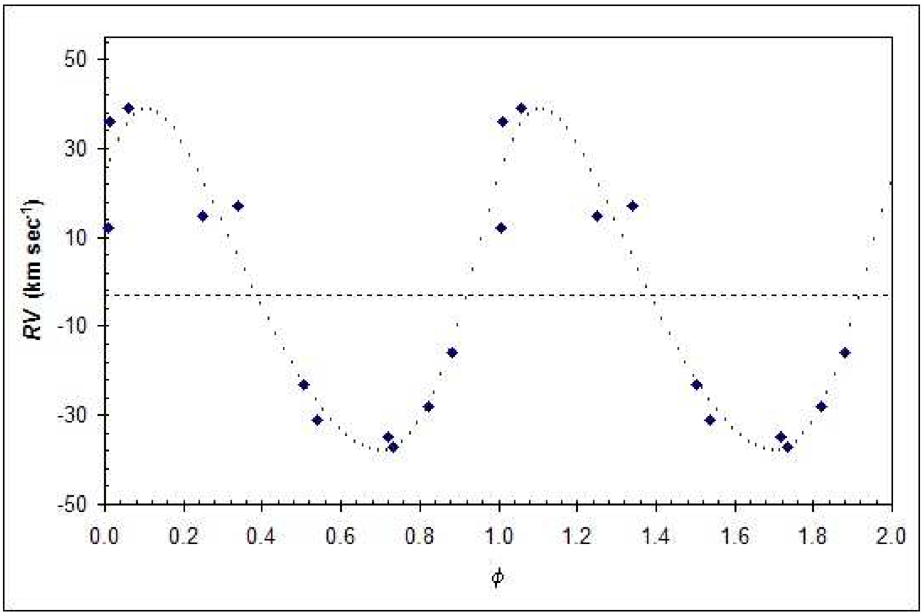

Figure 1. Radial velocity curve of V772 Cas, $P_{orb} = 5.0138$ days, observations by Hube (1970). $\phi = 0.0$ is the time of periastron passage given in Table 1. The theoretical velocity curve is that from the orbital elements in Table 1.

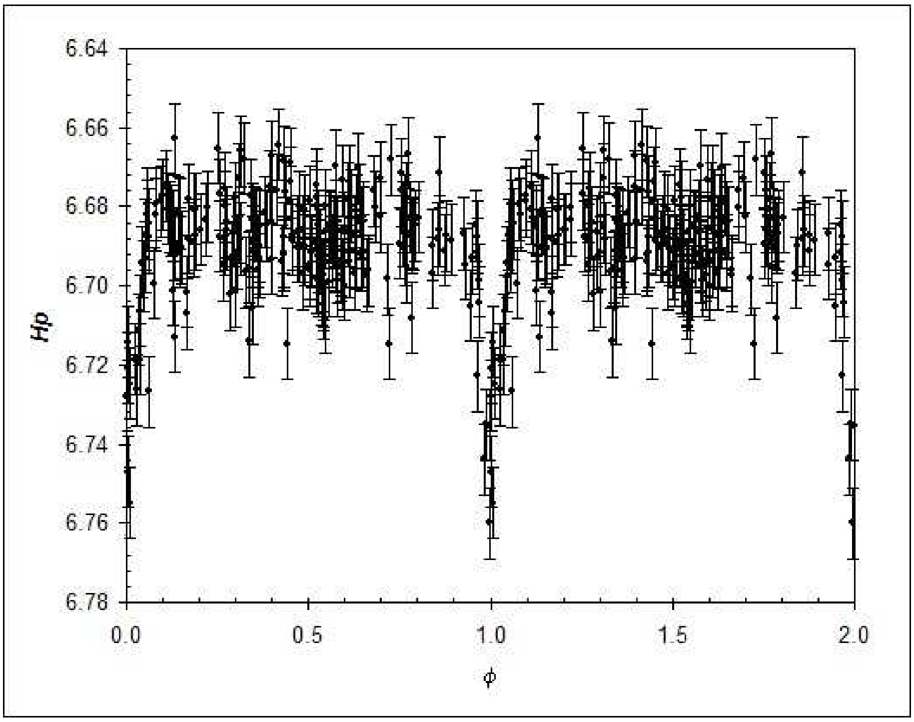

Figure 2. Light curve of V772 Cas light curve (*Hipparcos* observations). The observations are phased on $P_{orb} = 5.0138$ days and T_{min} = JD 2448099.08.

Figure 2 shows the full light curve of the *Hipparcos* data, phased on P_{orb}=5.0138 days and the proxy T_{min}=JD 2448099.08; the light curves in Figures 3 and 4 also are phased this way. Largely owing to the distortion of the light curve evident in Figure 2, we do not offer an estimate of the uncertainty of T_{min}, but point out that T_{min}=JD 2448099.19 would be appropriate if the eclipse were total and the egress portion of the light curve were as short as the ingress portion. However, P_{orb} and the time of periastron passage given in Table 1 predicts T_{min} to occur only 0.002 day later than the proxy T_{min} given above. Notice that the time of periastron and time of minimum were determined by virtually independent methods, the period being fixed entirely from the photometry while the time of periastron is entirely from the orbit solution.

Figures 3 and 4 show detail from Figure 2 near primary eclipse, at ϕ=0.0, and at ϕ=0.5, respectively. The offset by $\sim$0.06 in phase of the shallow 'secondary minimum', seen in Figure 3, is merely consistent with the poorly-determined eccentricity given in Table 1. It may, instead, be accounted for by a short-period modulation of the system's light that appears to be present throughout the entire orbit, and this putative modulation may also be responsible for the marked asymmetry of the light curve during primary eclipse ($0.10< \phi <0.25$), visible in Figure 3, and for the 'third' minimum at $\phi\sim$0.35 seen in Figure 4. If it is accepted that the supposed minimum at $\phi\sim$0.56 is real and not merely an observational artifact, then it seems difficult to dismiss the minima at $\phi\sim$0.35 as occurring entirely by chance. It was not found possible to artificially force light minima to occur at precisely ϕ=0.0 and 0.5 and to have both a convincingly coherent light curve and a convergent orbit solution. Since v sin i is only 20 km sec^{-1} (Abt *et al.* 2002), variations owing to an ellipsoidal-shaped primary star do not seem likely.

This short-period modulation apparently persisted during the 233 orbital cycles covered by the *Hipparcos* observations, and its period must therefore be equal to an integer fraction of P_{orb} to have maintained coherence. A value for it very close to one day may be gleaned from the light curve, and we note, in passing, that $P_{orb}/5$ = 1.00276 days. (A referee, more alert than the present author, pointed out that this is very close to the length of the sidereal day in units of mean solar days. It is worth mentioning that the spectral window of the out-of-eclipse *Hipparcos* data set shows no signatures, above the noise level, between periods of 0.5-1.7 days.) An attempt to determine a more accurate value for this periodicity was made by removing from consideration all observations made during primary eclipse, construed narrowly, and then performing periodogram searches of the remaining data. None of the strongest peaks in the power spectrum of this out-of-eclipse data are very close to an integer fraction of P_{orb}, in the interval 0.5-7.0 days, and none of them produce a convincingly coherent light curve. A period of 1.609 days produces a convincing light curve, and $P_{orb}/3$=1.671. But this result is complicated by the choice of observations that are presumed to fall outside of eclipse. It is hoped that future observations will sort out this situation.

Because the modulation apparently remained coherent, it may be attributed to either intrinsic variability with a constant period, or to duplicity of one of the components. The primary star's spectral type, B8IIIpSi (Cowley 1972), and the distortion of the light curve at primary minimum suggest that intrinsic variability of the primary star is the more likely source of the modulation and that it is of the α^2 CVn type (ACV). That it is the primary star to which the variability should be assigned is indicated by the large Δm between the two components, which is inferred by the failure, so far, to detect the secondary's spectrum and by the shallow, 'secondary', minimum near $\phi\sim$0.56.

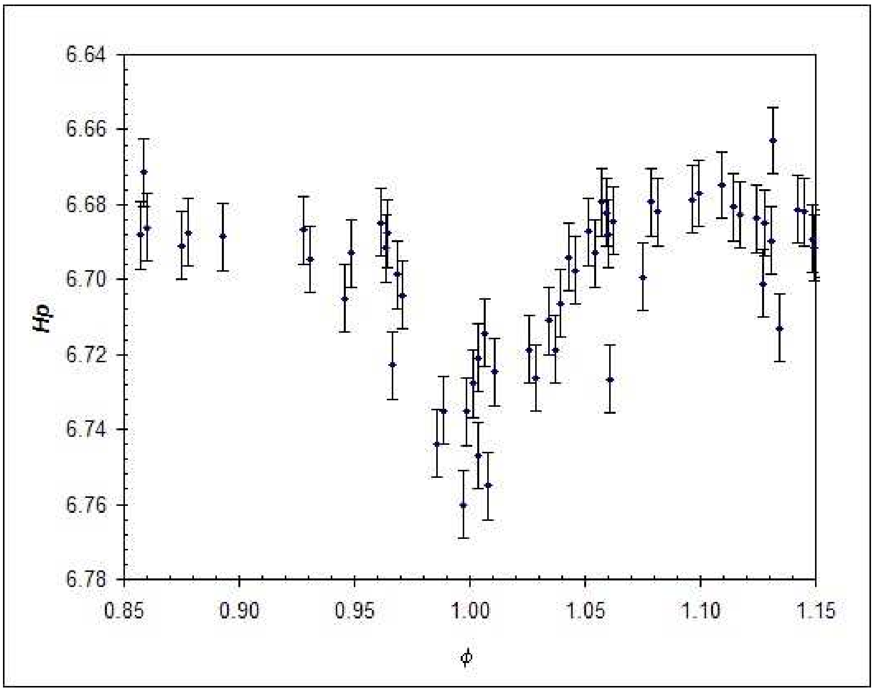

Figure 3. Light curve of V772 Cas light curve (*Hipparcos* observations) showing detail near primary eclipse. Notice the light curve asymmetry during primary eclipse. The observations are phased on P_{orb}=5.0138 days and T_{min}=JD 2448099.08.

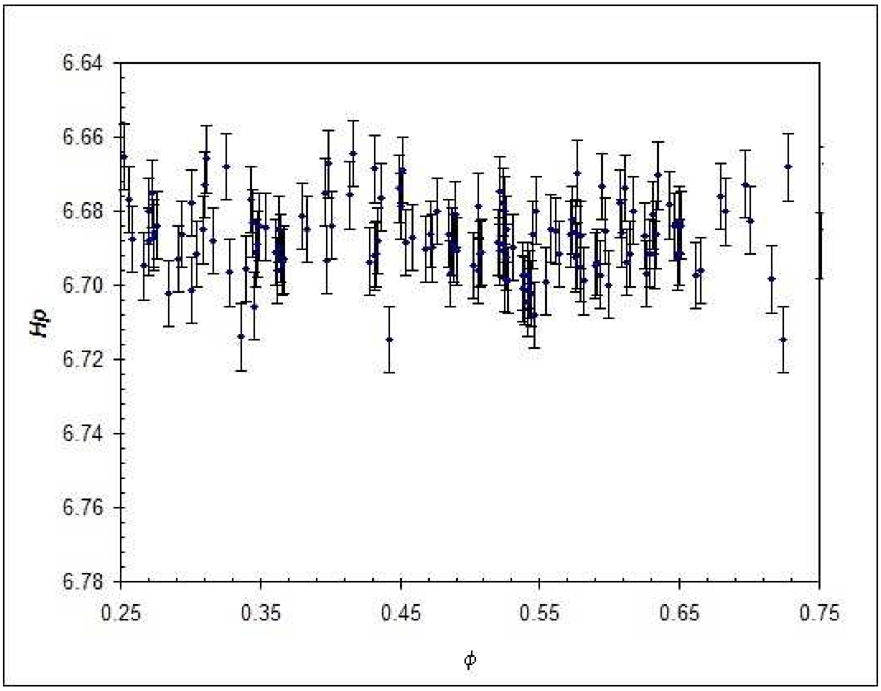

Figure 4. Light curve of V772 Cas (*Hipparcos* observations) showing detail near ϕ=0.5. A shallow minimum may occur at $\phi\sim$0.56. Another minimum, of about the same depth, is possible at $\phi\sim$0.35. The observations are phased on P_{orb}=5.0138 days and T_{min}=JD 2448099.08.

This note proposes an orbital period of 5.0138 days for V772 Cas and that the light curve may be modulated by intrinsic light variations of the primary star with a period near 1 day. High-resolution spectra and time-series photometry of V772 Cas are highly desirable to determine the character of the putative modulation, especially of its period, and to clarify the nature of the eclipsing-spectroscopic binary system. Observations at sites separated by some distance in terrestrial longitude would be valuable.

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