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DISCOVERY OF A BRIGHT ECLIPSING BINARY IN THE PLEIADES CLUSTER

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The bright ($V = 6.83$) Pleiades cluster member HD 23642 (Hertzsprung designation H III-1431, HIP 17704, $03^{\rm h}47^{\rm m}29\overset{\rm s}{.}45$ / $+24^\circ 17' 18\overset{''}{.}0$, J2000,SpT A0V) was the first double-lined spectroscopic binary to be discovered in that cluster, by Pearce (1957) and Abt (1958). The period is 2.46 days and the orbit is essentially circular. Abt considered eclipses possible, but this was never confirmed. The availability of 66 accurate photometric measurements (typical error 0.008 mag) from the Hipparcos mission (ESA, 1997) over a 3-year interval prompted us to investigate this suggestion, and we indeed found strong indications of a dip in brightness at about the expected phase for a secondary eclipse.

Because of the time elapsed since the spectroscopic measurements by Pearce (interval 1943-1949) and Abt (Nov-Dec 1957), and the limited precision of the orbital periods derived independently by the two investigators, we combined the measurements to obtain a more accurate ephemeris suitable for predicting eclipses some 35 years into the future, at the mean epoch of the Hipparcos observations. Weights were assigned to the photographic radial velocities according to the information in the original sources, and a velocity offset was allowed for (but was found to be insignificant). The result, Min I (HJD) = 2,434,127.6203(80) + 2.4611240(90) $\times E$, leads to the folded plot of the Hipparcos data seen in Figure 1a. The 5 faintest measurements cluster very close to the predicted time of secondary eclipse, and are essentially within the uncertainty in that prediction indicated by the horizontal error bars.

In order to improve the period further, we obtained additional high-resolution echelle spectra of HD 23642 with the 1.5-m Wyeth reflector at the Oak Ridge Observatory (Harvard, Massachusetts). The four single-order spectra cover 45 Å centered at 5187 Å, and have a resolving power of $\lambda/\Delta\lambda = 35{,}000$. We derived radial velocities for both components using the two-dimensional cross-correlation technique TODCOR (Zucker & Mazeh 1994). Typical uncertainties are 1–1.5 km s^{-1}, far superior to the velocities from the older sources. Merging these velocities (weighted appropriately) with those of Pearce and Abt yields a period that is more than an order of magnitude more precise: Min I (HJD) = 2,436,096.5204(44)+2.46113329(66)$\times E$. The spectroscopic orbit is shown in Figure 2, and the elements are given in Table 1. The preliminary light ratio we obtain, at the mean wavelength of our observations, is $l_B/l_A = 0.31 \pm 0.03$, or $\Delta m = 1.3$ mag.

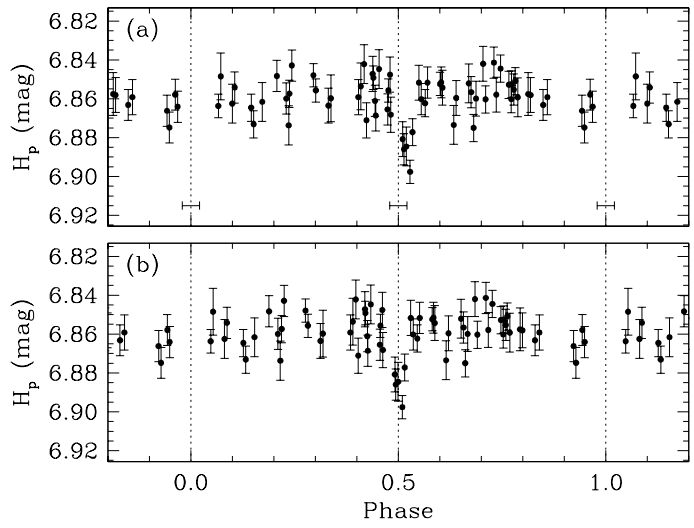

Figure 1. Hipparcos epoch photometry for HD 23642. (a) Data folded with the ephemeris derived from the radial velocities of Pearce (1957) and Abt (1958). The eclipse phases are indicated with dotted lines. The formal uncertainty in the phases is indicated by the horizontal error bars. (b) Data folded with the improved ephemeris derived by adding our new velocities. The phase uncertainty is negligible on the scale of this figure.

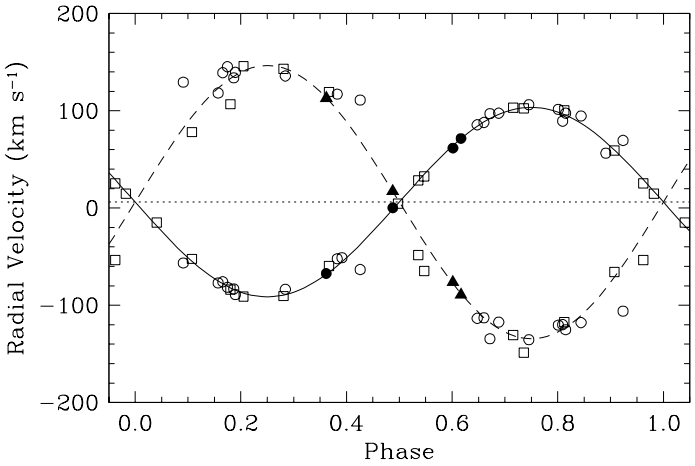

Figure 2. Radial velocity curve of HD 23642, with the observations by Pearce (1957; open circles), Abt (1958; open squares), and our new observations (filled symbols). The solid line is for the primary, and the dashed line for the secondary. The center-of-mass velocity is indicated by the dotted line.

The Hipparcos data folded with this new period are shown in Figure 1b. The apparent dip in brightness is seen to shift even closer to phase 0.5, which is unlikely to be a coincidence. The eclipsing nature of the binary is thus confirmed. Further support for this is given by the large minimum masses (Table 1), in particular for the primary, which is consistent with the values expected from the A0V spectral type.

Table 1. Combined spectroscopic solution for HD 23642.

Parameter	Value
P (days)	2.46113329 ± 0.00000066
γ (km s^{-1})	+6.1 ± 1.7
K_A (km s^{-1})	97.40 ± 0.84
K_B (km s^{-1})	140.47 ± 0.85
e	0 (adopted)
$T_{\rm max}$ (HJD)	2,436,095.9051 ± 0.0040
$a_A \sin i$ (10^6 km)	3.296 ± 0.030
$a_B \sin i$ (10^6 km)	4.754 ± 0.030
$a \sin i$ ($R_\odot$)	11.566 ± 0.061
$M_A \sin^3 i$ ($M_\odot$)	2.027 ± 0.032
$M_B \sin^3 i$ ($M_\odot$)	1.405 ± 0.026
$q \equiv M_B/M_A$	0.6934 ± 0.0077
ΔRV (Pearce − Abt) (km s^{-1})	+1.9 ± 1.9
ΔRV (Pearce − new) (km s^{-1})	+0.8 ± 1.8
N_A, N_B (Pearce)	21, 19
N_A, N_B (Abt)	15, 12
N_A, N_B (new)	4, 4
σ_A, σ_B (Pearce) (km s^{-1})	8.9, 20.8
σ_A, σ_B (Abt) (km s^{-1})	3.1, 17.8
σ_A, σ_B (new) (km s^{-1})	1.68, 1.01

As seen in Figure 1b, there are no Hipparcos observations near phase 0.0, and thus the primary eclipse was missed. A very tentative fit to the secondary eclipse performed with the light curve program EBOP along with estimates of the components' properties is shown in Figure 3. While the secondary eclipse has a depth of ∼0.03 mag, the primary is expected to be approximately 0.07 mag deep. The eclipses are thus grazing ($i \approx 78°$), and the system is well detached.

HD 23642 appears to be the first eclipsing binary to be confirmed in the Pleiades cluster[1], and it is quite remarkable that such a bright star has not been inspected carefully before, particularly since it is known to be chemically peculiar (spectral classification A0Vp(Si)+Am; Abt & Levato 1978). Further spectroscopic and photometric observations of HD 23642 are underway to improve the orbits. Eventually this system may well yield the first dynamically determined stellar masses in the Pleiades, and may even have a bearing on the issue of its distance.

[1]A report by Prosser & Stauffer (1993) about an anomalous dimming in the light of the Pleiades member H III-263, possibly due to eclipses, has yet to be confirmed.

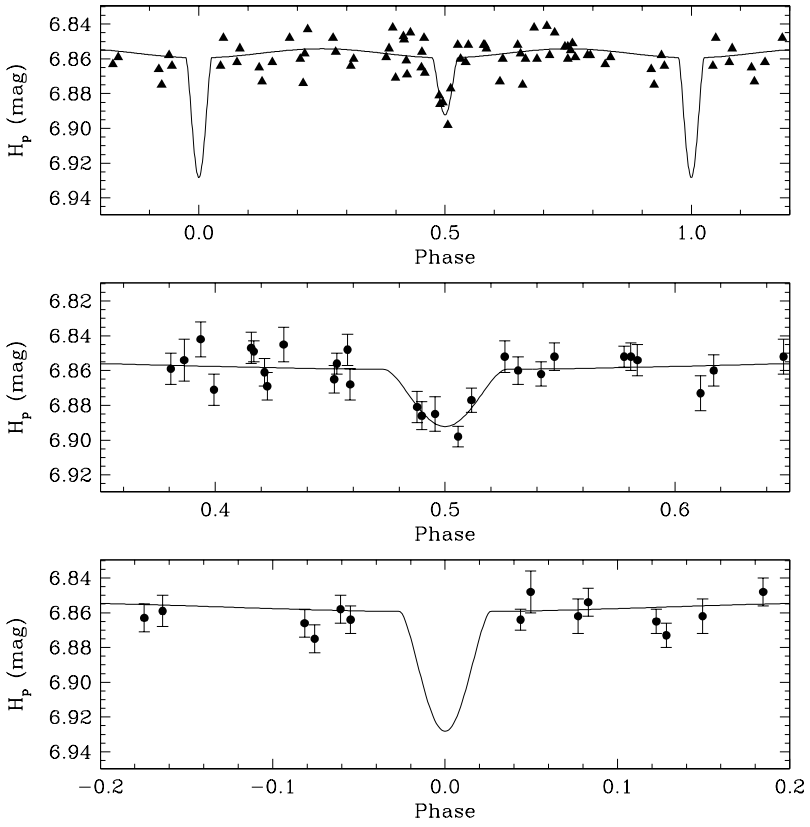

Figure 3. Tentative EBOP light curve superimposed on the Hipparcos epoch photometry of HD 23642.

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