

HD 170200: THE SPECTROGRAPHIC ORBIT AND EVIDENCE FOR MASS LOSS

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Spectrograms obtained between 1924 and 1975 have been used to derive orbital elements for HD 170200. No completely convincing evidence has been found for any change in these elements during the past 51 years, although the most recent velocities appear to lie systematically below the average velocity curve. On several plates sharp, weak absorption lines are found in the violet wings of the primary-star lines. These cannot be identified with the secondary star and are interpreted as evidence for discontinuous mass loss from the primary.

Key words: HD 170200 — spectrographic orbit — mass loss

I. Introduction

The star HD 170200 (= HR 6928, $V = 5.7$, MK Sp. = B8 III, $\alpha = 18^{\text{h}}25^{\text{m}}5$, $\delta = +6^{\circ}10'$ (1950)) was originally found to have a variable radial velocity on the basis of the measurement of three plates from the Dominion Astrophysical Observatory (DAO) and ten plates from the David Dunlap Observatory (DDO; Hube 1970). The velocity variation has been independently confirmed by T. Gandet (private communication) using eleven Kitt Peak (KPNO) plates taken in 1970. These plates are all of relatively low dispersion. One additional low-dispersion plate has subsequently been found in the DAO files, and another in the DDO plate files. From 1970 to 1972, 26 $12 \text{ \AA mm}^{-1}$ plates were obtained at the DDO, and in 1975 three $15 \text{ \AA mm}^{-1}$ plates were obtained at the DAO. Observations up to, and including, 1962 were made with prism spectrographs; those from 1966 to 1975 with grating spectrographs. The DDO spectrograms were all measured on a Grant comparator, and some were re-measured on a Zeiss-Abbé comparator; the DAO plates have been measured on the oscilloscopic-setting comparator ARCTURUS.

II. The Spectrographic Orbit

The orbital period was found by employing a computer program which seeks to minimize the sum of the absolute differences between successive phased velocities. Periods were sought in the range one to five days — inspection of the table of observations immediately reveals that a longer period is not possible. The period was found using all available observations except those from Kitt Peak (which were used only to check the finally derived elements) and the first and last three observations from the DAO. These latter four velocities were not available until after a preliminary orbital solution had been found, but they are satisfied to within its formal uncertainty by the

adopted period of 3.494064 days.

Velocities phased with this period define a nearly sinusoidal curve from which a preliminary set of circular orbital elements was derived. Differential least squares corrections to these elements were computed using the method of Sterne (1941), thereby providing noncircular elements. This set of elements and the mean errors are listed in Table II. Finally, least squares differential corrections to these elements were calculated using the Lehmann-Filhés equation of condition. In this last step, the period was a variable and was computed to have the value which appears above. The elements so derived and their mean errors are listed in Table II. The observational data are listed in Table I along with the phase measured from T , and the plate residuals.

The final stage in the solution, as outlined above, was repeated twice more: First, incorporating the earliest DAO plate and the three plates from 1975; second, using only the DDO $12 \text{ \AA mm}^{-1}$ plates and holding the period fixed at 3.494064 days. In the first instance, the semiamplitude (K), and the systemic velocity (γ) were changed significantly. This result is due almost entirely to the fact that the velocities from the $15 \text{ \AA mm}^{-1}$ plates fall systematically below the curve which best fits the earlier velocities. At all stages in the observational program, standard velocity stars were observed and measured, and gave no reason for believing that any systematic errors are present in the velocities. It is difficult to avoid concluding that between May 1972 and August 1975 there occurred a real change in the orbital elements, or some other change in the system, which resulted in a measured difference of about 15 km sec^{-1} , between the final set of radial velocities and the earlier ones.

The 26 DDO $12 \text{ \AA mm}^{-1}$ plates provided the most concentrated series of consistently high-quality radial velocities. The elements derived from these velocities

TABLE I
OBSERVATIONAL DATA FOR HD 170200

JD $\oplus$ 2420000 +	Source	Disp. (Å mm ⁻¹)	V ₀ (km sec ⁻¹)	n	p.e. (km sec ⁻¹)	Phase (from T)	O - C (km sec ⁻¹)
1924							
4009.691	DAO	30	+ 4.2	3	6.0	0.650	+19.0
1925							
4964.019	DAO	30	- 9.2	3	3.9	0.778	-21.4
4965.978	DAO	30	-43.4	6	5.0	0.339	+ 4.3
5043.894	DAO	30	- 9.7	5	0.8	0.638	+ 6.0
1939-40							
9486.588	DDO	66	-29.8	7	5.9	0.136	-12.8
9735.885	DDO	66	-38.9	4	8.9	0.485	+ 2.2
1962							
17857.696	DDO	33	+14.1	5	5.7	0.945	- 8.6
17860.669	DDO	33	+16.1	4	7.9	0.795	+ 1.0
17862.683	DDO	33	-38.2	7	2.7	0.372	+10.0
1966							
19199.928	DDO	40	+ 9.7	10	1.1	0.091	+15.1
19285.800	DDO	40	- 3.7	7	7.3	0.667	+ 6.0
19289.799	DDO	40	+26.7	5	7.2	0.812	+ 9.2
19307.733	DDO	40	+18.9	7	3.9	0.945	- 3.8
19308.701	DDO	40	-39.9	6	4.0	0.222	-4.3
19312.693	DDO	40	-43.9	11	3.1	0.364	+ 4.3
1970-72							
20801.610	DDO	12	-46.5	15	1.7	0.492	- 6.3
20802.708	DDO	12	+16.6	14	2.2	0.806	- 0.1
20803.622	DDO	12	+ 0.4	13	1.2	0.068	- 0.1
20803.700	DDO	12	- 2.2	11	0.9	0.090	+ 3.0
20808.566	DDO	12	-42.0	11	1.6	0.483	- 0.7
20809.697	DDO	12	+27.5	4	2.9	0.806	+10.8
21140.597	DDO	12	-37.5	11	1.3	0.510	0.0
21141.608	DDO	12	+13.2	4	5.2	0.799	- 2.5
21141.752	DDO	12	+18.0	14	2.8	0.840	- 3.0
21147.582	DDO	12	-41.0	15	1.8	0.509	- 3.0
21147.780	DDO	12	-32.7	15	1.6	0.565	- 3.4
21148.586	DDO	12	+19.7	8	3.0	0.796	+ 4.5
21148.742	DDO	12	+25.4	7	2.3	0.841	+ 4.3
21159.597	DDO	12	+21.5	14	2.8	0.947	- 0.9
21159.778	DDO	12	+15.9	9	1.8	0.999	+ 0.4
21160.579	DDO	12	-37.1	18	1.2	0.229	- 0.3
21160.783	DDO	12	-51.8	13	1.6	0.287	- 7.3
21193.667	DDO	12	- 6.9	8	1.3	0.698	- 3.7
21457.733	DDO	12	-38.8	18	1.7	0.274	+ 4.3
21457.824	DDO	12	-49.7	16	1.7	0.300	- 4.1
21458.665	DDO	12	-36.5	13	2.2	0.541	- 3.1
21458.788	DDO	12	-27.6	18	1.0	0.576	- 0.1
21462.733	DDO	12	- 1.1	19	1.0	0.705	+ 0.8
21462.805	DDO	12	+ 2.9	13	1.5	0.726	+ 0.6
21463.716	DDO	12	+20.7	10	0.9	0.986	+ 3.0
21463.851	DDO	12	+10.2	16	1.0	0.025	- 0.3
1975							
22644.751	DAO	15	- 6.1	10	2.3	0.999	-21.6
22648.816	DAO	15	-32.5	13	1.3	0.162	- 9.4
22649.777	DAO	15	-59.3	6	5.6	0.437	-13.4

TABLE II
ORBITAL ELEMENTS FOR HD 170200

Element	All plates 1925 to 1972 (Sterne's Method)	All plates 1925 to 1972 (L-F Solution)	DDO 12 Å mm ⁻¹ 1970 to 1972 (L-F Solution)
γ (km sec ⁻¹)	-14.3 ± 1.1	-14.2 ± 1.1	-14.7 ± 0.7
K (km sec ⁻¹)	35.9 ± 1.6	36.3 ± 1.5	38.5 ± 1.0
e	0.086 ± 0.008	0.084 ± 0.045	0.063 ± 0.031
ω	$37^{\circ}2 \pm 4.7$	$41^{\circ}3 \pm 2.5$	$36^{\circ}1 \pm 1.5$
$T(\text{JD}_{\oplus})$	2440806.844 ± 0.026	2440806.880 ± 0.024	2440806.838 ± 0.014
$P(\text{days})$	3.494074 ± 0.000017	3.494064 ± 0.000016	3.494064 adopted
$a_1 \sin i (\times 10^6 \text{ km})$	1.72 ± 0.08	1.74 ± 0.07	1.85 ± 0.05
Mass function ($\odot$)	0.017 ± 0.002	0.017 ± 0.002	0.021 ± 0.002

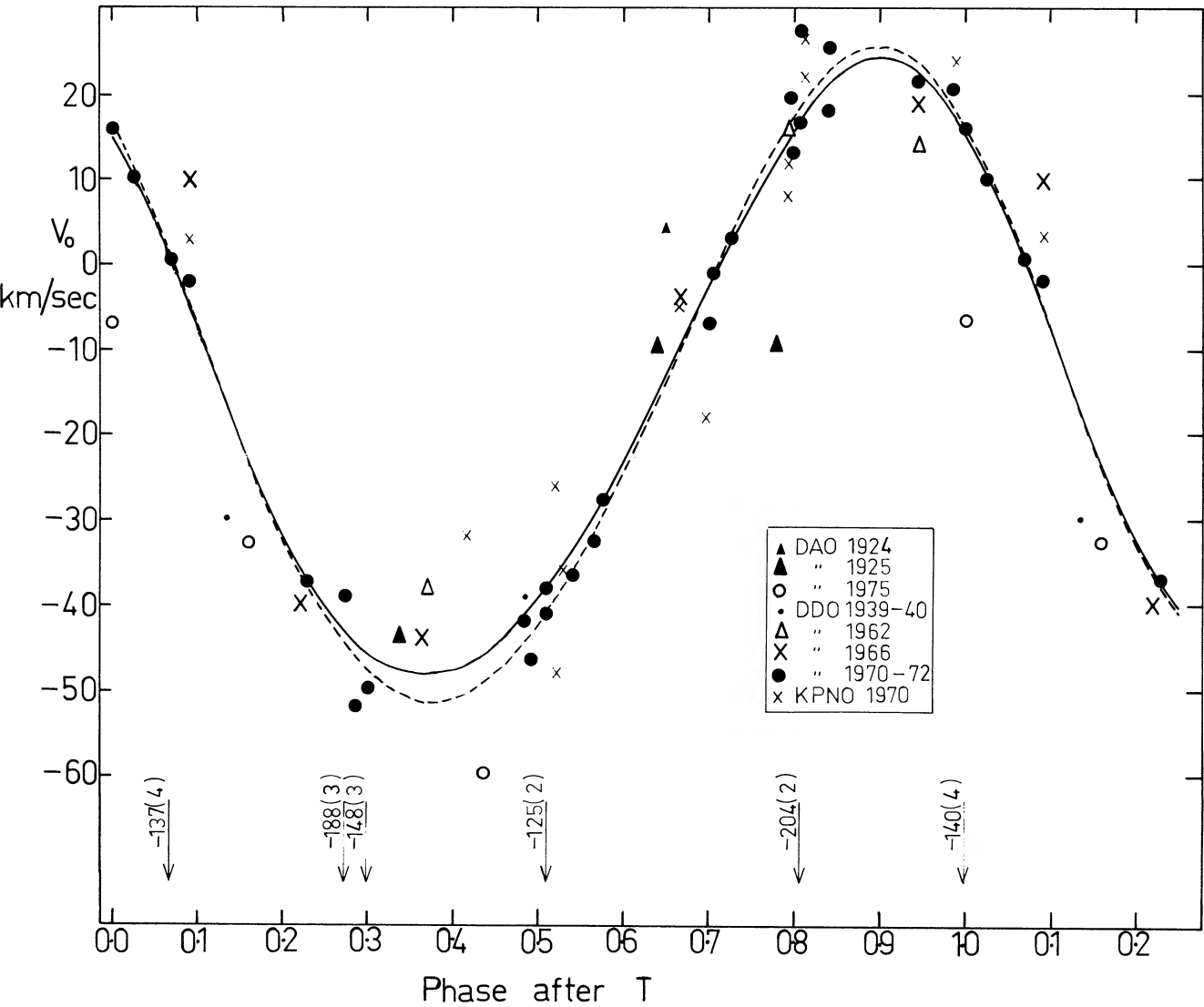


FIG. 1 — The radial velocity curve for HD 170200. Solid curve based on all available data from 1925 to 1972, KPNO, data excluded; broken curve from DDO 12 Å mm⁻¹ plates alone. For the satellite lines, the average velocities and numbers of lines measured are shown at the bottom.

could be considered the ones of highest precision and, therefore, are listed separately in Table II.

The observations and velocity curves based on each of the last two sets of elements are plotted in Figure 1.

III. Evidence for Mass Loss

The observational program and data analysis for HD 170200 would have been terminated in 1972 had it not been noticed that on several of the $12 \text{ \AA mm}^{-1}$ plates there are sharp, weak, absorption lines in the violet wings of some stellar lines. These satellite lines occur over a wide range of phase and always with measured radial velocities more negative than the minimum radial velocity for the primary star. Hence, these lines *cannot* be identified with the secondary star, but presumably are associated with gas streaming away from the primary. Satellite lines have been found at $\lambda 4481$ (Mg II), $\lambda 4471$ and 4026 (He I), $\lambda 4340$ and 4101 (H I), $\lambda 4130$ and 4128 (Si II), and at $\lambda 3933$ (Ca II), although never simultaneously at all these positions. In addition, on a few plates red components to the hydrogen and helium lines may be present and possibly are to be identified with the secondary, but these lines were always so weak that their reality is questionable. On the basis of its shape and radial velocity, the principal component of the K-line is of stellar and not interstellar origin.

Rectified intensity tracings were obtained for a small selection of the $12 \text{ \AA mm}^{-1}$ plates using the new Perkin-Elmer PDS Microdensitometer at the DDO. All of these spectra were exposed on Kodak IIA-O emulsion and were more often underexposed than overexposed. As a result the traces tend to be relatively noisy. Nevertheless, for those plates on which the satellite lines are most easily seen visually, the same lines can be identified on the traces. The best example is plate no. 36039 taken on JD 2441457.824. Traces at $\lambda 4026$, H δ and H γ are shown in Figure 2 where the approximate centers of the stellar and satellite components are marked. On this plate, and others, the satellite lines are seen visually to extend the full width of the spectrum; they are definitely not features of the noise and their reality is unquestionable.

Not surprisingly, these features are not seen on any of the early, low-dispersion plates. No emission features are visible on the $12 \text{ \AA mm}^{-1}$ plates which cover the spectral range $3700 \text{ \AA}$ to the H β line. The star was observed at $15 \text{ \AA mm}^{-1}$ in Victoria during August 1975, in the hope of confirming the phenomenon. On the first of these three plates the satellite lines can be seen at $\lambda 4026$, 4101 , 4340 , and 4471 . In addition, there may be a central emission feature at H β , although this is somewhat uncertain because the plate is underexposed in that region.

The fact that absorption occurs in the helium lines

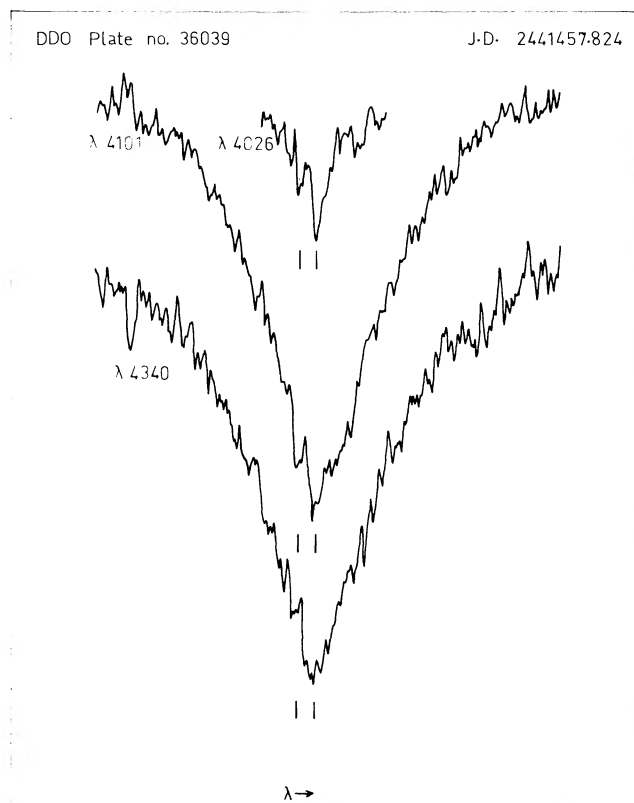


FIG. 2—Rectified intensity profiles of helium and hydrogen lines.

means that the gas is hot and is detected only while still very close to the primary. The absence of a correlation between the occurrence of the satellite lines and phase implies a discontinuously expanding disk or shell of material rather than, say, a stream passing between the two stars. The observations of the satellite lines are summarized in Table III and on Figure 1.

A feature common to most shell stars and related objects with circumstellar material is rotationally broadened stellar absorption lines. However, the hydrogen lines and other lines in the spectrum of HD 170200 are relatively sharp. The full width at half intensity of $\lambda 4481$ is $0.9 \text{ \AA}$ which corresponds to a projected rotational velocity of approximately 30 km sec^{-1} (Slettebak et al. 1975). Either the star is a slow rotator or it is viewed from a high stellar latitude. In either case, a simple model of a rapidly rotating star with a ring of circumstellar matter confined to the equatorial zone does not apply.

This writer has been unable to find any references in the literature to other stars with the same spectral features as have been found in HD 170200. This may not be too surprising since, as has been pointed out many times in the past, every shell-type star is probably unique in some way. The velocities of 100 to 200 km sec^{-1} are consistent with measured expansion

TABLE III
OBSERVATIONS OF SATELLITE LINES

Plate No. JD2440000 + Phase after <i>T</i>	Line	Radial Velocity	
		Star	Sat.
DDO 33475	$\lambda 3933$ Ca II	- 7	- 137
803.622	$\lambda 4101$ H I	- 9	- 154
0.068	$\lambda 4128$ Si II	+ 7	- 183
	$\lambda 4130$ Si II	+ 7	- 73
DDO 33527	$\lambda 4471$ He I	+ 36	- 181
809.697	$\lambda 4481$ Mg II	+ 29	- 246
0.806			
DDO 34760	$\lambda 4471$ He I	- 40	- 121
1140.597	$\lambda 4481$ Mg II	- 43	- 129
0.510			
DDO 36034	$\lambda 4026$ He I	- 27	- 179
1457.733	$\lambda 4101$ H I	- 23	- 176
0.274	$\lambda 4340$ H I	- 13	- 210
DDO 36039	$\lambda 4026$ He I	- 53	- 153
1457.824	$\lambda 4101$ H I	- 55	- 144
0.300	$\lambda 4340$ H I	- 53	- 146
DAO 78368	$\lambda 4026$ He I	+ 9	- 124
2644.755	$\lambda 4101$ H I	- 8	- 125
0.999	$\lambda 4340$ H I	- 8	- 186
	$\lambda 4471$ He I	- 1	- 128

velocities for circumstellar material around other early-type stars, and the irregular appearance of shell absorption features without the appearance of emission is also not uncommon among such stars.

The unusual features of the star suggest the possibility of photometric variability. At the writer's request, J. E. Winzer made a few observations in the Strömgren four-color system at Kitt Peak in March 1975, but without finding any evidence for light variations. If, as appears to be the case, mass ejection occurs discontinuously and at infrequent intervals, one might expect the system to maintain constant brightness most of the time.

What is now required is a long series of well-exposed, high-dispersion spectra on a fine-grain emulsion to independently confirm the observations and conclusions presented here. In addition, a program of photometry ought to be carried out. The writer proposes to do both, and invites other observers to do the same.

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REFERENCES

- Hube, D. P. 1970, *Mem. R.A.S.* **72**, 233.
 Slettebak, A., Collins II, G. W., Boyce, P. B., White, N. M., and Parkinson, T. D. 1975, *Ap. J. Suppl.* **29**, 137.
 Sterne, T. E. 1941, *Proc. Nat. Acad. Sci.* **27**, 175.