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# ORBITAL ELEMENTS AND OPTICAL SPECTROSCOPY OF THE ENIGMATIC cF + B BINARY SYSTEM HD 207739

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## ABSTRACT

The orbit of the peculiar interacting F8 + B binary system is established on the basis of 93 radial-velocity measurements mostly made photoelectrically. The period is 140.78 days, the velocity amplitude is 70 km $s^{-1}$, and the orbit has a small but nevertheless significant eccentricity. The mass function of 5 $\mathfrak{M}_{\odot}$ is extraordinarily large and probably indicates that the F-type component (the one whose radial velocity is measured) is the secondary in terms of mass. Optical spectroscopy in the red region reveals strong and variable Hα emission, [N II] emission at the γ-velocity of the system (presumably arising in a hot circumstellar shell), and N I and Na I absorption also of circumstellar origin. The He I D3 line is sometimes present in absorption, at a velocity that is not constant but always negative. A coherent model of the system has not yet been achieved.

*Key words:* spectroscopic binary–radial velocities–orbit–HD 207739

## 1. Introduction

HD 207739 is an eighth-magnitude star on the eastern border of Cygnus, about 3° south-following ρ Cygni. It is listed in the *Henry Draper Catalogue* (Cannon and Pickering 1924) as having spectral type G5. Attention was first drawn to its unusual nature by Merrill (1942), who discovered from an objective-prism plate exposed on 1939 July 22 that the Hα line was in emission; he subsequently took a slit spectrogram which disclosed P Cygni profiles in the Balmer lines from Hβ to Hε and enabled him to classify the object as cF8e and to measure a radial velocity from the metallic lines. The discovery was made in the course of a program aimed at finding emission-line stars of types A and B; although HD 207739 was given a discovery number (318) (Merrill, Burwell, and Miller 1942) it did not feature in the successive versions of the catalog of such stars (Merrill 1943, 1949), presumably because its spectral type was too late—the early-type component had not then been recognized. However, it does appear in Bidelman's (1954) *Catalogue and Bibliography of Emission-Line Stars of Types Later than B*, with the information that "On a McDonald spectrogram the spectrum of the component of later type is veiled but is probably of type F8 II, while the other component appears to be a B-type star".

A great deal of interest has arisen in HD 207739 in recent years, following the discovery by one of us and his colleagues (Parsons, Holm, and Kondo 1983) with IUE of the peculiar nature of the ultraviolet spectrum. The system shows evidence of an optically thick high-temperature plasma, and its ultraviolet spectrum varies substantially from week to week; there is especially intense emission in the Mg II λ 2800 doublet.

An initial interpretation of fragmentary, and in one instance erroneous, radial-velocity data led to the publication (Kondo, McCluskey, and Parsons 1984) of a preliminary orbital period of 18.6 days. However, in response to a call addressed by S.B.P. to a number of radial-velocity observers for data on HD 207739, R.F.G. sent a series of 23 measurements made systematically between July 1983 and January 1984, mostly with

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the original photoelectric radial-velocity spectrometer (Griffin 1967) in Cambridge. They showed, without any doubt, that the period is just over 140 days, as has been reported in the literature already (Parsons, Bopp, and Kondo 1984; Kondo, McCluskey, and Parsons 1985) but without the benefit of the supporting data. Among the reasons for not publishing the material immediately were (a) the period determined at that time was not quite accurate enough to allow Merrill's (1942) observation to be assigned with certainty to its correct cycle and phase, and (b) (more importantly) there was an indication that the orbit was not quite circular, and R.F.G. wished to be sure whether or not the eccentricity was significantly different from zero. The system has consequently remained under observation, albeit less frequently than at first, up till the end of 1988.

At the same time as the orbital period was being established from radial velocities, the system was also being intensively observed photometrically, notably by Bloomer (1984). The 140-day period was apparent in the light curve, which showed two minima in each cycle; they were at first interpreted in terms of eclipses (Bloomer 1984) and then as ellipsoidal variation with a probable eclipse (Parsons and Bopp 1986); but it now seems likely that there is no eclipse and that all the light variations arise from the ellipsoidal distortion of the F star together with some small-amplitude "flickering" (Parsons, Dempsey, and Bopp 1988). The system has been given the variable-star designation V1914 Cygni by Kholopov *et al.* (1987), who have listed its type as ellipsoidal. The amplitude of photometric variation, between *V* magnitudes 8.39 and 8.59, is large for an ellipsoidal variable; Parsons *et al.* (1988) have noted that the necessary great distortion of the F star implies that that star is larger and more luminous than the spectral type of F8 II suggests. It must be remembered that the type was assigned (Bidelman 1954) long before the current interest in HD 207739 arose and that it is very difficult to classify individual components in a composite spectrum (Bidelman 1984; Griffin 1986); no effort seems to have been made in recent years to classify the stars involved in the HD 207739 system, and it would not be surprising if, in light of all that is known now about the system, an upward revision of the luminosity were found necessary.

## 2. Radial Velocities

In addition to the single radial-velocity measurement published by Merrill (1942) there is one attributed to Bopp (Parsons *et al.* 1983), nine by Parsons (1983), two by Beavers and Eitter (1986), and three by Fouts (1987). We now present 87 new velocities to enable the orbit to be determined. They include 70 measurements obtained photoelectrically by R.F.G., principally at Cambridge, but including six measures made with the spectrometer on the Palomar 200-inch (5-m) telescope (Griffin and Gunn 1974), ten with the "Coravel" of Geneva Observatory at Haute-Provence (Baranne, Mayor, and Poncet 1979), and two with the system at the 48-inch (1.2-m) telescope of the Dominion Astrophysical Observatory (Fletcher *et al.* 1982). There are, in addition, 17 new velocities obtained at the auxiliary telescope associated with the coudé spectrograph of the 84-inch (2-m) reflector at Kitt Peak National Observatory with various of the "CF" systems (cf. Dempsey, Parsons, and Bopp 1988). All the velocities are listed in Table 1. Two pairs of measurements made within an hour of one another by Parsons (1983) have been averaged in the table. The photoelectric observations are on the zero point that has always been used at Cambridge and is believed (Griffin and Herbig 1981) to need a correction of about $-0.8$ km s$^{-1}$ for conversion to the IAU system, although the IAU system itself has an uncertainty comparable with the difference. The other velocities are supposedly already on the IAU zero point. However, when a relative adjustment of 0.8 km s$^{-1}$ was made to the different sets of velocities in an effort to improve their homogeneity, the effect was to produce a systematic discrepancy between them, of much the same magnitude as the adjustment that had been made! We have, therefore, refrained from doctoring any of the velocities in the table—the published ones are listed as published and the photoelectric ones have not been corrected for any anomaly of the photoelectric zero point.

The photoelectric measurements (and no doubt the others) were made more difficult and less accurate than usual because of the considerable line broadening in HD 207739, which presumably arises from the axial rotation of the F star which is the one whose velocity is being measured. The broadening is not constant; apparent $v \sin i$ values obtained from the six Palomar traces range from 16 to 30 km s$^{-1}$—a spread that is far greater than can be attributed to any observational uncertainty. Cambridge traces are not good enough to give additional $v \sin i$ values. Of course, a tidally distorted star must be expected to appear to rotate faster when it is viewed "broadside" than when it is seen "end-on", so one might naively suppose that the observed rotational broadening should be greatest when the radial velocity is near to an extremum and least when it is close to the $\gamma$-velocity. Unfortunately, the Palomar observations are not nearly numerous enough to provide either a proper coverage of orbital phases or an impression as to whether the broadening is a unique function of phase; but certainly the behavior of HD 207739 is not well represented by the simple model of a rotating ellipsoidal star. The largest values of apparent rotation were indeed seen near a nodal passage, on 1982 November 24 and 26, but so was the smallest value, on 1986 November 25, though near the opposite node. Another extraordinary feature of radial-velocity traces of HD 207739, unique in our experience, is a tendency for the "continuum" to lie higher on the red side of the "dip" than on the blue side (see Fig. 1). Again, the effect is too marked to be an artifact of observational error; in fact the trace shown in Figure 1 represents the summation of two virtually identical traces, because the observers had such difficulty in believing the first one that they promptly took another—which showed exactly the same thing. The effect seems to indicate either that there is emission extending for a long way on the red sides of at least some of the metallic lines on which the radial-velocity spectrometer operates, or else that there is absorption extending a long way on the blue sides. It cannot be interpreted simply by appeal to radial-velocity traces: the high efficiency of the photoelectric method of measuring radial velocities arises from the averaging, over hundreds of lines, of profiles which in normal stars are sufficiently represented by the average but which in an object as bizarre as HD 207739 need to be studied individually. Satisfactory understanding of the processes responsible for the peculiarities adumbrated by the radial-velocity traces will require (and probably repay) a systematic and probably lengthy program of proper spectroscopy. Clearly, however, the asymmetry of the line profile seen in Figure 1 creates an uncertainty as to just where the center of the dip is and must limit the accuracy with which radial velocities can be assigned to HD 207739.

## 3. Orbit

In the orbit solution all the data have been given equal weight and exhibit mutually comparable residuals, with the following exceptions. Merrill's (1942) single velocity is of unknown, probably not very high, accuracy, so it has not been included in the solution. Among Fouts' three velocities, obtained with an intensified Reticon system at Mount Wilson, two give enormous residuals, so all three have been rejected. Four measurements made in one observing run at Kitt Peak give large systematic residuals, and we have been obliged to reject them. Radial velocities obtained at Palomar are usually particularly reliable, especially on difficult objects such as HD 207739; a weighting of 4 in comparison with Cambridge data has often been found appropriate (e.g., Griffin *et al.* 1985) and has been used in this case and is justified by the residuals. We have not given extra weight to the radial velocities published by Parsons (1983), despite their uniformly small residuals, because they are closely spaced in time and refer to only two distinct epochs. The orbit is illustrated in Figure 2 and the elements are set out in Table 2.

## 4. Spectroscopic Observations

Optical spectroscopic observations of HD 207739 have been obtained from time to time since 1979 with the coudé feed telescope at Kitt Peak National Observatory and with the Ritter 1-m telescope at the University of Toledo. Photographic plates, Reticons, and CCDs have been used to record spectra of the Hα, Na I D line, and Ca II infrared-triplet wavelength regions, with spectral resolution ranging from 0.3 Å to 0.9 Å. Information on the detectors, spectral resolutions, and data-reduction procedures is given in Dempsey *et al.* (1990).

In the red, metallic absorption lines from the F component are seen along with a strong Hα emission line having an equivalent width of the order of 23 Å (Fig. 3). The Hα line is variable in profile and equivalent width on a time scale of weeks or months, but observations made a few days apart show no significant differences. The changes of equivalent width exceed 20% but show no apparent correlation with phase. The emission is divided by a deep absorption line, and the ratio of the intensities of the violet and red components (~ 0.5) shows erratic variations of 20%–30%.

Radial-velocity measures of the Hα central absorption and emission peaks do not permit us unambiguously to identify the origin of the emission, although in the comparable F5 II + B system HD 37453 (Parsons *et al.* 1988) the Hα emission appears to originate in a wind from the F star.

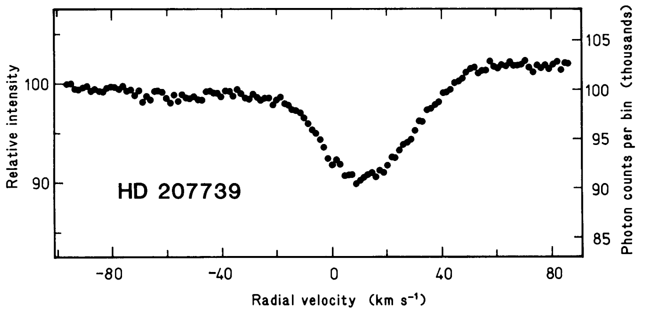


FIG. 1–Palomar radial-velocity trace of HD 207739, taken on 1984 December 3. Notice that the red (positive-velocity) side of the trace lies systematically higher than the blue side.

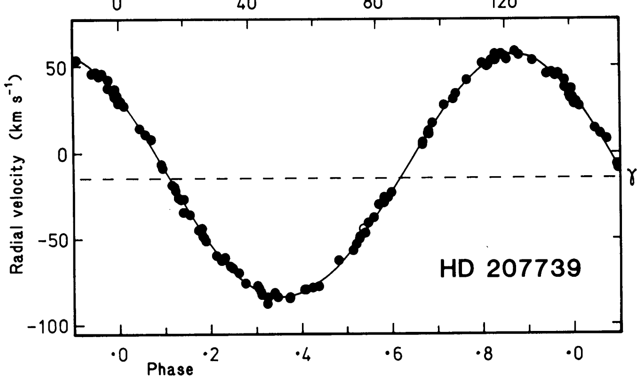


FIG. 2–The computed orbit of HD 207739, with the measured radial velocities plotted. The observation by Merrill (1942), which is several times as old as any of the others but is of unknown reliability and was omitted from the orbit computation, is shown as the open circle. Seven other velocities which were rejected from the solution (see text and Table 1) have been omitted from the figure in the interest of clarity.

TABLE 1
Radial-Velocity Measurements of HD 207739

| Date | MJD | Velocity km s$^{-1}$ | Phase | (O - C) km s$^{-1}$ | Source[a] |
|---|---|---|---|---|---|
| 1940 July 17.00[b] | 29827.00 | -44.0 | $\overline{107}$.537 | +2.6 | Merrill |
| 1981 Sept 25.22 | 44872.22 | -79.0 | 0.406 | +1.5 | CF5 |
| 1982 July 24.31[b] | 45174.31 | -39.7 | 2.552 | +1.2 | Fouts |
| 24.32[b] | 174.32 | -22.0 | .552 | +18.9 | Fouts |
| Sept 19.25 | 231.25 | +44.6 | .956 | -0.8 | CF3 |
| 24.19 | 236.19 | +34.6 | .992 | -0.5 | Parsons |
| 25.20 | 237.20 | +33.2 | .999 | +0.6 | Parsons |
| 26.20 | 238.20 | +29.9 | 3.006 | -0.2 | Parsons |
| 27.23 | 239.23 | +27.0 | .013 | -0.4 | Parsons |
| Oct 22.08 | 264.08 | -51.3 | .190 | -2.1 | Beavers |
| Nov 7.04 | 280.04 | -77.0 | .303 | +3.0 | Beavers |
| 24.18 | 297.18 | -77.8 | .425 | 0.0 | Palomar |
| 26.12 | 299.12 | -77.3 | .439 | -2.0 | Palomar |
| Dec 8.74 | 311.74 | -49.1: | .528 | +0.7 | Cambridge |
| 1983 Apr 26.43 | 45450.43 | -56.2 | 4.513 | -1.3 | Parsons |
| 27.43 | 451.43 | -53.0 | .520 | -0.5 | Parsons |
| 28.44 | 452.44 | -49.9 | .528 | +0.1 | Parsons |
| July 1.02 | 516.02 | +42.2 | .979 | +3.2 | Cambridge |
| 3.09 | 518.09 | +37.0 | .994 | +2.7 | Cambridge |
| 4.04 | 519.04 | +28.6 | 5.001 | -3.3 | Cambridge |
| 5.08 | 520.08 | +28.3 | .008 | -1.0 | Cambridge |
| 22.08 | 537.08 | -26.0 | .129 | -2.7 | Cambridge |
| 30.04 | 545.04 | -49.4 | .185 | -1.9 | Cambridge |
| Aug 3.06 | 549.06 | -59.7 | .214 | -1.6 | Cambridge |
| 7.03 | 553.03 | -66.0 | .242 | +1.0 | Cambridge |
| 11.93 | 557.93 | -75.7: | .277 | -0.2 | Cambridge |
| 16.06 | 562.06 | -78.6 | .306 | +1.8 | Cambridge |
| 20.96 | 566.96 | -80.9 | .341 | +2.5 | Cambridge |
| Sept 18.95 | 595.95 | -40.6 | .547 | +2.3 | Cambridge |
| 22.21 | 599.21 | -30.0 | .570 | +3.8 | CF1 |
| 25.25 | 602.25 | -25.5 | .592 | -0.5 | CF4 |
| 26.22 | 603.22 | -23.1 | .599 | -1.0 | CF4 |
| Oct 5.96 | 612.96 | +6.2 | .668 | -0.7 | Cambridge |
| 16.20 | 623.20 | +34.1 | .741 | +0.1 | Palomar |
| 24.29 | 631.29 | +51.4 | .798 | +2.2 | DAO |
| 28.31 | 635.31 | +56.5 | .827 | +2.7 | DAO |
| Nov 14.80 | 652.80 | +46.7 | .951 | -0.1 | Cambridge |
| 21.76 | 659.76 | +31.1 | 6.000 | -1.0 | Cambridge |
| Dec 1.78 | 669.78 | +7.6 | .071 | +4.7 | Cambridge |
| 10.74 | 678.74 | -27.2 | .135 | -1.1 | Cambridge |
| 26.73 | 694.73 | -66.8 | .249 | +2.0 | Cambridge |
| 1984 Jan 4.75 | 45703.75 | -80.3 | 6.313 | +0.9 | Cambridge |
| 18.76 | 717.76 | -79.0: | .412 | +0.7 | Cambridge |
| Mar 29.49[b] | 788.49 | +43.2 | .915 | -10.3 | CF4 |
| 31.50[b] | 790.50 | +42.7 | .929 | -8.6 | CF4 |
| Apr 2.49[b] | 792.49 | +44.7 | .943 | -3.9 | CF4 |
| 3.49[b] | 793.49 | +38.3 | .950 | -8.7 | CF4 |
| 28.11 | 818.11 | -22.2: | 7.125 | -0.6 | Cambridge |
| May 13.10 | 833.10 | -60.7 | .232 | +3.1 | Cambridge |
| Aug 20.95 | 932.95 | +45.5 | .941 | -3.5 | Cambridge |
| 26.24[b] | 938.24 | +24.9 | .978 | -14.4 | Fouts |
| 30.98 | 942.98 | +27.8 | 8.012 | 0.0 | Cambridge |
| Sept 4.97 | 947.97 | +14.0 | .047 | +0.5 | Cambridge |
| 22.91 | 965.91 | -45.1 | .175 | -1.8 | Cambridge |
| 29.91 | 972.91 | -62.6 | .225 | -1.0 | Cambridge |
| Oct 14.15 | 987.15 | -83.6 | .326 | -1.1 | CF1 |
| 17.17 | 990.17 | -83.6 | .347 | 0.0 | CF1 |
| 20.85 | 993.85 | -84.4 | .373 | -1.1 | Cambridge |
| Nov 19.17 | 46023.17 | -26.0 | .582 | +3.1 | CF1 |

TABLE 1 (Continued)

| Date | | | MJD | Velocity km s$^{-1}$ | Phase | (O - C) km s$^{-1}$ | Source[a] |
|---|---|---|---|---|---|---|---|
| 1984 | Dec | 1.16 | 46035.16 | +4.6 | 8.667 | -1.9 | Palomar |
| | | 3.14 | 037.14 | +11.4 | .681 | -0.8 | Palomar |
| | | 7.74 | 041.74 | +27.9 | .714 | +3.2 | Cambridge |
| | | 10.74 | 044.74 | +31.6 | .735 | -0.6 | Cambridge |
| | | 14.75 | 048.75 | +41.6 | .763 | +0.7 | Cambridge |
| | | 26.72 | 060.72 | +56.4 | .848 | +0.5 | Cambridge |
| 1985 | July | 21.09 | 46267.09 | -82.4 | 10.314 | -1.0 | Cambridge |
| | Sept | 28.95 | 336.95 | +51.3 | .810 | -0.2 | Cambridge |
| | | 30.22 | 338.22 | +53.1 | .820 | +0.2 | CF1 |
| | Oct | 1.15 | 339.15 | +54.0 | .826 | +0.2 | CF1 |
| | | 3.25 | 341.25 | +57.2 | .841 | +1.9 | CF1 |
| | | 4.13 | 342.13 | +55.4 | .847 | -0.4 | CF1 |
| | | 4.91 | 342.91 | +53.7 | .853 | -2.4 | Cambridge |
| | | 12.88 | 350.88 | +53.4 | .909 | -0.8 | Cambridge |
| | | 20.88 | 358.88 | +46.0 | .966 | +3.2 | Cambridge |
| | | 22.86 | 360.86 | +37.8 | .980 | -0.9 | Cambridge |
| | | 24.87 | 362.87 | +31.9 | .995 | -2.2 | Cambridge |
| | Nov | 2.83 | 371.83 | +10.7 | 11.058 | +1.9 | Cambridge |
| | | 11.83 | 380.83 | -18.8 | .122 | +1.5 | Cambridge |
| 1986 | Aug | 23.12 | 46665.12 | -34.5: | 13.142 | -5.5 | Coravel |
| | | 25.08 | 667.08 | -36.0 | .155 | -0.9 | Coravel |
| | | 29.02 | 671.02 | -48.3 | .183 | -1.6 | Coravel |
| | Sept | 9.04 | 682.04 | -69.6 | .262 | +2.5 | Cambridge |
| | | 17.97 | 690.97 | -87.5 | .325 | -5.1 | Cambridge |
| | | 24.98 | 697.98 | -83.4 | .375 | -0.2 | Cambridge |
| | Oct | 18.29 | 721.29 | -46.4 | .541 | -1.1 | CF1 |
| | | 20.88 | 723.88 | -37.7 | .559 | +0.6 | Cambridge |
| | | 23.89 | 726.89 | -29.2 | .580 | +0.5 | Cambridge |
| | Nov | 6.81 | 740.81 | +11.8 | .679 | +0.3 | Cambridge |
| | | 8.11 | 742.11 | +17.2 | .688 | +2.0 | CF1 |
| | | 25.09 | 759.09 | +50.4 | .809 | -0.8 | Palomar |
| 1987 | Oct | 12.95 | 47080.95 | -6.5 | 16.095 | +1.4 | Coravel |
| | | 24.90 | 092.90 | -44.1 | .180 | +1.3 | Cambridge |
| 1988 | July | 27.06 | 47369.06 | -27.0 | 18.142 | +2.1 | Cambridge |
| | Sept | 12.97 | 416.97 | -62.4 | .482 | +2.3 | Cambridge |
| | Oct | 10.91 | 444.91 | +13.2 | .681 | +1.1 | Cambridge |
| | Nov | 2.90 | 467.90 | +56.4 | .844 | +0.8 | Coravel |
| | | 6.91 | 471.91 | +58.3 | .872 | +1.8 | Coravel |
| 1989 | Mar | 29.17 | 47614.17 | +56.3 | 19.883 | 0.0 | Coravel |
| | Apr | 28.13 | 644.13 | -9.0 | 20.096 | -0.9 | Coravel |
| | May | 1.15 | 647.15 | -17.1 | .117 | +0.9 | Coravel |
| | | 3.12 | 649.12 | -24.0 | .131 | +0.3 | Coravel |

[a]Sources:

| | |
|---|---|
| Merrill | (1942) |
| CF5 | KPNO photography, 15 Å mm$^{-1}$ |
| Fouts | (1987) |
| CF3 | KPNO RCA CCD, 15 Å mm$^{-1}$ |
| Parsons | (1983) |
| Beavers | and Eitter (1986) |
| Palomar | Photoelectric (cf. Griffin and Gunn 1974) |
| Cambridge | Photoelectric (cf. Griffin 1967) |
| CF1 | KPNO TI3 CCD, 8 Å mm$^{-1}$ |
| CF4 | KPNO RCA CCD, 8 Å mm$^{-1}$ |
| DAO | Photoelectric (cf. Fletcher et al. 1982) |
| Coravel | Photoelectric (cf. Baranne at al. 1979) |

[b]Not used in orbital solution

TABLE 2

Orbital elements for HD 207739

| | | |
|---|---|---|
| P | = | 140.782 ± 0.018 days |
| $\gamma$ | = | -14.82 ± 0.19 km $s^{-1}$ |
| K | = | 70.1 ± 0.3 km $s^{-1}$ |
| e | = | 0.027 ± 0.004 |
| $\omega$ | = | 49 ± 8 degrees |
| T | = | MJD 46082 ± 3 |
| $T_0$ | = | MJD 46062.80 ± 0.09 |
| $a_1 \sin i$ | = | 135.7 ± 0.5 Gm |
| f(m) | = | 5.03 ± 0.06 $M_\odot$ |
| R.m.s. residual (unit weight) | = | 1.9 km $s^{-1}$ |

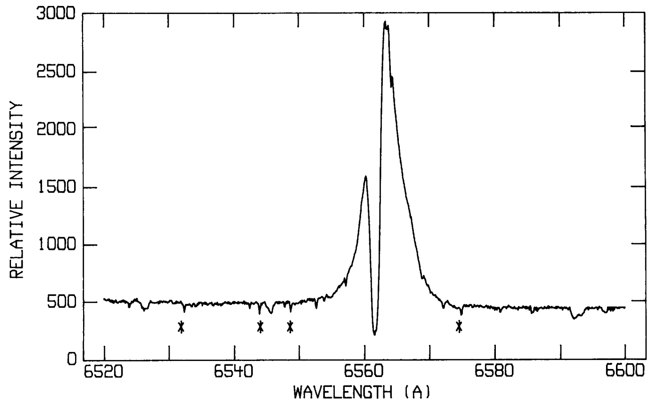


FIG. 3–The red region of the spectrum of HD 207739, showing the extremely strong Hα emission line. The broad metallic features originate in the photosphere of the F star while the narrow, weak absorption lines marked with an asterisk are due to telluric water vapor.

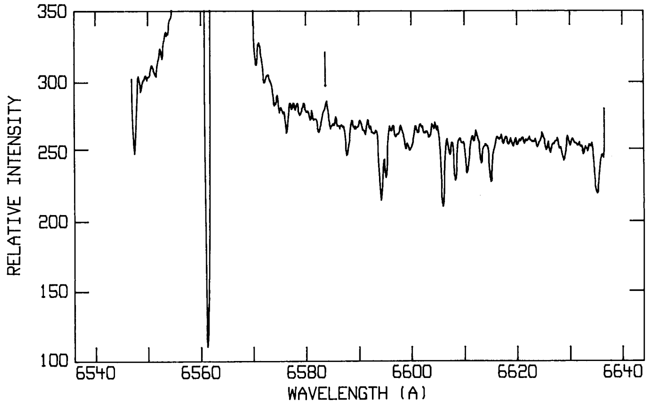


FIG. 4–The red spectrum of HD 207739. The λ6584 [N II] emission line is marked by the vertical line.

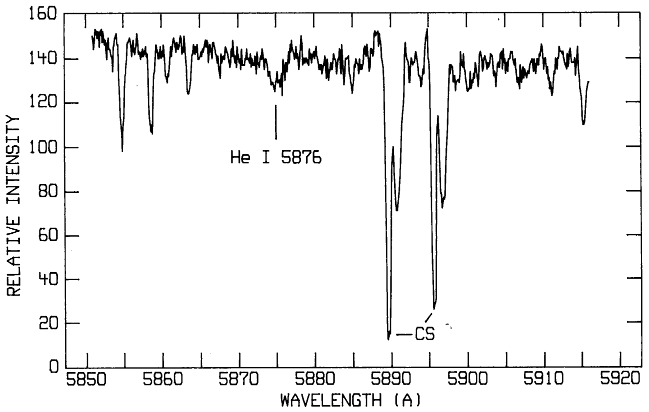


FIG. 5–The region of the Na I D lines in the spectrum of HD 207739. The components of the D lines arising from the photosphere of the F star are redshifted at this phase. The stronger absorption components, marked CS, arise in a circumstellar shell. The D lines appear to show blueshifted emission wings, and a broad He I D3 line is present at λ5876.

There is spectroscopic evidence for an extended circumstellar cloud around the HD 207739 system. A large ionized shell is indicated by the presence of the λλ6548 and 6584 emission features of [N II] (Fig. 4). Those lines are much weaker in HD 207739 than in the hypergiant HR 8752 (Lambert and Luck 1978), and usually only the stronger λ6584 feature can be detected with certainty. The line has a radial velocity of −10 km $s^{-1}$, very close to the γ-velocity of the system. Additional evidence for circumstellar material around HD 207739 is the existence of multiple components in the D lines (Fig. 5). The D lines consist of broad, shallow absorptions which arise in the photosphere of the F star along with narrow, deep absorption lines with a constant radial velocity of −23 km $s^{-1}$. The narrow components are not mainly of interstellar origin, since they vary in equivalent width and residual intensity by at least 30%. Some observations, including the one reproduced as Figure 5, show what appear to be emission wings on the shortward sides of the lines—the wrong side to correlate with the extraordinary asymmetry seen in Figure 1. There does not appear to be any correlation between changes in the D line strengths and Hα profile variations.

There is a broad, variable absorption feature (visible in Fig. 5) at the wavelength of the He I λ5875.8 D3 line. On some of our spectra the feature is very weak or nonexistent, but on others it reaches an equivalent width of 600 mÅ. Since He I absorption is completely unexpected in an F-type spectrum, it was initially supposed to originate from the B star or possibly a surrounding accretion disk. However, velocity data seem to rule out the B star as the source of the absorption: the velocity of the line is always negative, with values ranging from −31 to −144 km $s^{-1}$, and is not correlated with orbital phase. The fact that the velocity is always more negative than the systemic velocity suggests that the absorption arises in an expanding atmosphere of some sort, but the location of the absorbing material is left undetermined.

One observation of HD 207739 was obtained of the Ca II infrared triplet lines and is shown as Figure 6. The

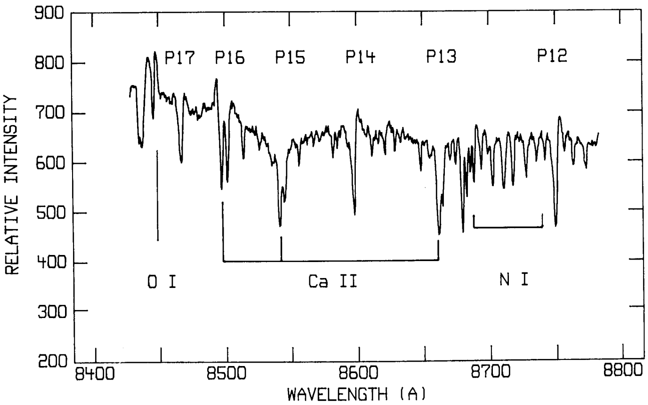


FIG. 6–The Ca II infrared-triplet region in the spectrum of HD 207739. The various spectral features are discussed in the text.

Ca lines appear as narrow absorption features, blended with the Paschen series. Ca II λ8498 shows a blueshifted emission component. The O I line at λ8446 is in emission, a characteristic shared by many Be stars owing to fluorescence with Lyman-β (Bowen 1947). The Paschen lines P12–P18 are visible as narrow absorption lines with redward emission components. To the red of P13 there are several absorptions whch we identify as transitions of N I, including the triplet at λ8680. We measure a mean velocity of $-14.6 \pm 1.5$ km $s^{-1}$ for the N I lines (compared to the orbital velocity of $-1$ km $s^{-1}$ for the F star at that phase) and suggest that they arise in the circumstellar shell which produces the narrow D lines and [N II] emission. N I features of similar intensity and velocity behavior are also present in spectra we have obtained of other systems, including β Lyrae, which is known to have circumstellar material and which is too early in spectral type to produce such features in its atmosphere.

### 5. Discussion

A noteworthy feature of the results shown in Table 2 is the very large mass function, 5 $\mathfrak{M}_\odot$. In the usual case, where the observed component of a binary may be expected to be the more massive one, the elementary interpretation is that both components must have masses more than four times the mass function. The a priori likelihood that both components of HD 207739 have masses in excess of 20 $\mathfrak{M}_\odot$ is small; it seems more probable that the usual assumption is invalid in this instance and that the F star is the less massive component. For it to be less massive but at the same time more evolved than its B-type companion, it must, by implication, have lost a lot of mass since it left the main sequence. The hot, optically thick plasma which is indicated by IUE spectra gives grounds for thinking that the star is losing mass quite rapidly right now, although no quantitative estimate of the rate has yet been attempted. However, the fact that even the largest observed value of the projected rotational velocity is less than half the semiamplitude of the orbital velocity variation demonstrates that the radius of the F star is less than half the radius of its orbit around the center of gravity of the binary system—always provided that it is rotating in synchronism with its orbital motion, as seems very likely. In other words, the F star is far from filling its Roche lobe. That conclusion is perhaps rather surprising in view of the gross tidal distortion that must exist to account for the large photometric variability, and it leaves unexplained the cause of the mass loss that is implied by the IUE observations.

Another interesting feature of the orbital elements is the existence of a small but significant eccentricity. The fact that the eccentricity is seven times its own standard deviation should be sufficient evidence of its significance, but if additional reassurance were needed it is available in the form of Bassett's (1978) tests for circularity. The sum of the squares of the (weighted) residuals of the 93 observations utilized in the orbital solution is 331 $km^2$ $s^{-2}$, whereas when zero eccentricity is forced on the solution the sum rises to 533 $km^2$ $s^{-2}$. Thus, the 87 degrees of freedom left after the 93 observations are used to determine six orbital elements (including $e$ and $\omega$) account for 331 $km^2$ $s^{-2}$ of the total variance, whereas the two degrees of freedom represented by $e$ and $\omega$ account for the rest, 202 $km^2$ $s^{-2}$. If we make the assumption that the orbit is really circular, then the two estimates of variance per degree of freedom, of 331/87 and 202/2, should be the same; the likelihood that they will differ by the factor (26.5) which they actually do may be assessed by entering tables of the $F$ distribution (e.g., Lindley and Miller 1953) with 2 and 87 degrees of freedom. The 1% point of $F_{2,87}$ is about 4.9 and the 0.1% level is reached at about 7.6, so it may be seen that the value of 26.5 is very significant indeed. However, statistical significance is one thing and physical significance is another: the spectral peculiarity implied by the radial-velocity trace shown in Figure 1, and the fact that the star is known to be far from spherical, and the probability that it has (to say the very least) asymmetrically distributed surface brightness all suggest that it would be unwise to be too dogmatic concerning the circularity or otherwise of the orbital path followed by the center of mass of the star as distinct from the centroid of luminosity of the observed spectrum.

In this paper we have determined the orbit of HD 207739 and described some aspects of the spectrum. The very large mass function of 5 $\mathfrak{M}_\odot$ is intriguing; spectroscopy in the near-ultraviolet, which we have not yet obtained, might enable the velocity amplitude of the B-type component, and thereby the mass ratio, to be measured. There are an extraordinary number of unusual features among our data on HD 207739, and we have not been able to propose for the system a comprehensive model that accounts for them all. Among the noteworthy features is the indifference to orbital phase of so many of the variable parameters that we have studied. Even the linewidths derived from radial-velocity traces, which necessarily refer to the F-type star whose velocity has been measured, do not show a clear phase correlation; while the variations of positions, strengths, and profiles of the Hα and D3 lines, whose origins are less certain, seem also to be independent of phase. In fact, the only phase-related quantity (apart from the radial velocity) appears to be the optical brightness of the system, which varies at twice the orbital frequency and is therefore pretty certainly ascribable to rotation of the ellipsoidal F star. IUE observations (Parsons *et al.* 1983) show that there is a large amount of high-temperature plasma in the system; we have found evidence for an ionized circumstellar shell emitting [N II] radiation, and cooler (perhaps more distant) material in which Na I and N I absorption lines are formed. The radial velocities of the shell lines give no indication of outflow, except in the case of the Na I D lines whose modest negative offset from the systemic velocity may well arise from an unresolved interstellar component.

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