

THE M DWARF DOUBLE-LINED SPECTROSCOPIC BINARY GLIESE 268

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ABSTRACT

High-resolution Digicon observations in the neighborhood of $H\alpha$ reveal Gliese 268 as a double-lined spectroscopic binary with components of similar brightness. Separate orbital solutions of the primary and secondary velocities yield mutually consistent orbital elements; we find an orbital period of 10^d4 , a moderately eccentric orbit ($e = 0.34$), and a mass ratio $M_1/M_2 = 1.20$. The primary and secondary minimum masses of 0.191 and $0.159 M_\odot$, respectively, must be very close to the actual masses of the primary and secondary, which are both dM5e stars. No observational search for possible eclipses has been carried out. In view of the lack of M dwarf eclipsing binaries—only two are known—the system would be of great interest if it proved to be an eclipsing binary, but the large separation between the components makes this unlikely.

I. INTRODUCTION

Although the M dwarfs are the most common type of star in the neighborhood of the Sun, very few M dwarf eclipsing, or spectroscopic, binaries are known.

This is due to a combination of strong observational selection effects, which operate against the discovery of eclipsing, or spectroscopic, binaries among such faint objects, and a real lack of these types of binary in the M dwarfs. The evidence of a real absence of detached M dwarf binaries with periods of a few days, or less, which extends, also, to the same class of G, and K, dwarf binaries, has been recently discussed by Patterson (1984). Huang (1966) proposed the reason for their absence. The stellar wind of a cool main-sequence star carries away an enormous amount of angular momentum thanks to the star's magnetic field, which gives the wind a rigid-body rotation. This magnetic braking acts to slow the rotation of all lower-main-sequence stars, single or binary, that have convective envelopes. If the star is a binary in which the components are close enough for tidal effects to synchronize the rotational and orbital periods, then magnetic braking cannot slow the rotation of the components to less than the synchronous rate; instead angular momentum leaks away from the system as the rotational angular momentum of the components drained away by magnetic braking is replaced by transferred orbital angular momentum. The two stars spiral in towards each other, and what had been a detached binary is destroyed in a surprisingly short time ($\sim 10^8$ yr; Patterson 1984); the outcome is probably a W UMa system.

As a result of this situation, only two M dwarf eclipsing binaries (YY Gem and CM Dra) are known. Clearly, the discovery of a new M dwarf eclipsing binary would cause a significant increase in the population of known M dwarf eclipsing binaries and would therefore be worthwhile.

As a known spectroscopic binary (Joy 1947), the dM5e star Gliese 268 offers some promise of being a new M dwarf eclipsing binary. Although neither the orbital period, nor the orbit, nor the nature of the companion is known, the 110 km s^{-1} range of velocity variation (Gliese 1969; notes to the main table) suggests an interestingly short period. The dM5e spectral type (Joy 1947; Joy and Abt 1974) of the primary means that the hydrogen lines are in emission; the

spectrum of the secondary has not been seen. Flare activity on Gliese 268 was discovered independently by Chugainov (1974) and Pettersen (1975). Table I gives basic data for Gliese 268.

In this paper we report the results of high-resolution Digicon observations of Gliese 268 in the neighborhood of $H\alpha$. They show that the spectrum is double lined and that the secondary is also a dM5e star. Analysis of the primary and secondary radial velocities reveals a 10^d4 orbit of moderate eccentricity ($e = 0.34$). Although the derived primary and secondary minimum masses of 0.191 and $0.159 M_\odot$ must be close to their actual masses, the separation between the primary and secondary is so large that the prospects for eclipses are not very good.

II. OBSERVATIONS

All observations were made with the McDonald Observatory 2.7 m telescope, coudé spectrograph, and a 936 diode Digicon detector (Tull, Choisser, and Snow 1975). They were centered at 6570 \AA and covered 120 \AA at a resolution of 0.39 \AA . The observations had a typical signal-to-noise ratio—in the peak of the $H\alpha$ emission—of approximately 30, which was usually achieved in an observing time of about 30^m .

Each observation was accompanied by an observation of a FeNe comparison source for use in the radial-velocity measurement procedure. Barnard's star (M3.8 V) was also observed once for use as a radial-velocity standard.

The first observation revealed two separate $H\alpha$ emission lines, each capped with a small central reversal, surrounded by a busy, double-lined absorption spectrum. Figure 1 shows a 35 \AA stretch of spectrum that includes $H\alpha$ in two observations, one double lined and one single lined, and compares it with the same stretch of spectrum in Barnard's star.

TABLE I. Basic data for Gliese 268.

RA (1950)	$7^h06^m39^s$
Dec. (1950)	$+ 38^\circ 37'5$
Sp. T.	dM5e
π	$0''.169 \pm 0.007$
V	11.48
M_V	12.62 ± 0.12

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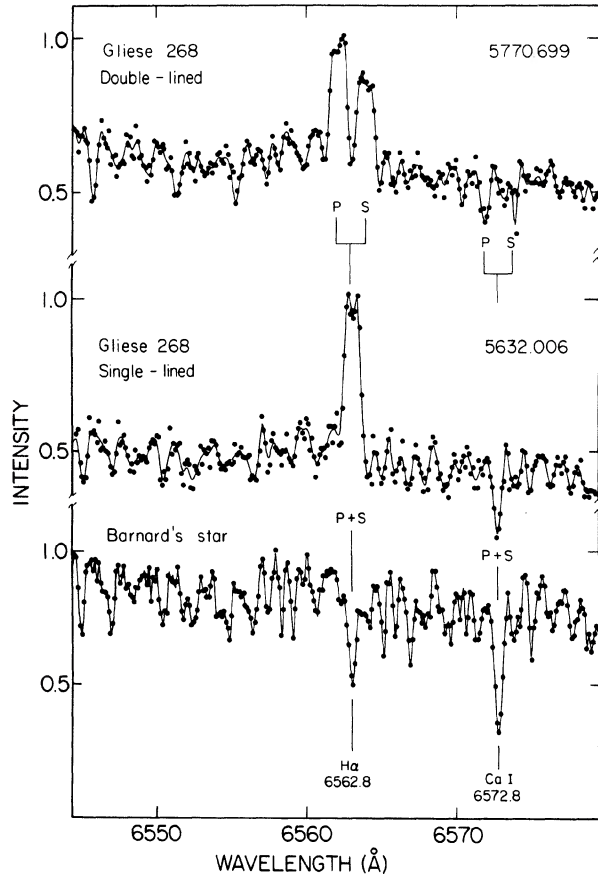


FIG. 1. Two observations of Gliese 268—one double lined and one single lined—in the neighborhood of H α compared with the same piece of spectrum in Barnard's star.

The absorption spectrum is almost entirely due to TiO; the only other identifiable atomic line, besides H α , is the 6572 Å Ca I line (see Fig. 1). Although the TiO absorption is prevalent, low-resolution spectra of M dwarfs (Turnshek *et al.* 1985) show that in the neighborhood of H α , it is much less intense than in other parts of the visible spectrum, so, from the point of view of available photons, this is much the most favorable part of the visible spectrum in which to observe.

Table II lists all the observations, which were made between February 1983 and March 1984.

III. MEASUREMENT AND ANALYSIS OF THE RADIAL VELOCITIES

Inspection of the spectra showed that the wavelengths of the two H α emission lines corresponded exactly with the wavelengths of H α in the two absorption-line spectra. In other words, the two H α emission lines clearly originate from the two components of the binary. Furthermore, in general, the stronger and weaker H α emission lines belonged with the stronger and weaker absorption-line spectra, respectively. For most observations, therefore, the identification of the primary and secondary spectra was unambiguous, in spite of the great similarity of the two spectra.

However, because of the extremely crowded nature of the absorption-line spectra, and because of the very modest signal-to-noise ratios of a few of the observations, the identification of the primary and secondary spectra was not always obvious. Therefore, for the initial assignment of the primary and secondary spectra for each observation, prior to measurement of the radial velocities, we made the identifications of the primary and secondary absorption spectra on the basis of the stronger and weaker H α emission lines, respectively. After measurement of the primary and secondary velocities, when it became clear that the period is 10^d4, it was necessary to interchange this initial assignment of the primary and sec-

TABLE II. Radial velocities of Gliese 268.

JD - 2445000	Phase	Primary		Secondary	
		RV (km s ⁻¹)	O - C (km s ⁻¹)	RV (km s ⁻¹)	O - C (km s ⁻¹)
393.873	0.8558	6.0	-2.8	75.4	2.5
394.876	0.9520	-5.3	-1.3	86.8	-1.6
395.804	0.0410	14.9	-2.0	64.2	0.9
632.006	0.6907	39.3	2.4	—	—
664.019	0.7605	26.7	0.1	—	—
666.906	0.0373	16.3	0.9	63.9	-1.1
667.019	0.0482	18.4	-1.2	60.8	0.9
690.847	0.3331	59.6	-2.5	6.8	-2.1
714.867	0.6364	38.2	-5.3	—	—
714.888	0.6384	38.1	-5.1	—	—
714.905	0.6400	36.7	-6.4	—	—
714.978	0.6470	33.5	-8.8	—	—
715.860	0.7316	35.6	4.5	—	—
716.977	0.8387	11.9	-0.3	70.9	2.1
717.684	0.9065	1.8	2.2	87.7	3.7
717.802	0.9178	-1.7	0.2	85.7	-0.1
718.750	0.0087	3.2	-2.1	79.1	2.0
720.854	0.2105	58.0	-0.3	17.1	3.6
720.948	0.2195	59.0	0.0	—	—
721.711	0.2927	62.6	0.6	11.2	2.2
721.932	0.3139	57.5	-4.7	14.0	5.2
722.840	0.4009	60.7	0.2	8.4	-2.4
722.953	0.4118	64.7	4.6	13.9	2.6
752.610	0.2556	61.4	0.3	15.0	4.9
754.728	0.4587	60.2	2.4	13.9	-0.1
770.699	0.9902	0.5	0.1	84.1	1.0

TABLE III. Radial-velocity orbits of Gliese 268.

	Solution		
	Primary	Secondary	Combined
P (days)	10.428 ± 0.003	10.430 ± 0.001	10.428 ± 0.002
V_0 (km s $^{-1}$)	37.0 ± 0.5	39.1 ± 0.5	37.9 ± 0.5
K_1 (km s $^{-1}$)	32.5 ± 0.7	—	33.1 ± 0.9
K_2 (km s $^{-1}$)	—	39.3 ± 0.5	39.8 ± 1.8
e	0.32 ± 0.03	0.31 ± 0.01	0.34 ± 0.02
ω	223.7 ± 3.6	28.7 ± 4.1	217.5 ± 3.9
T (— 2445000)	770.9 ± 0.1	770.65 ± 0.08	770.80 ± 0.09
$a_1 \sin i$ (10^6 km)	4.36 ± 0.04	—	4.47 ± 0.13
$a_2 \sin i$ (10^6 km)	—	5.36 ± 0.03	5.37 ± 0.25
$M_1 \sin^3 i$ (M_\odot)	0.186 ± 0.007	—	0.191 ± 0.015
$M_2 \sin^3 i$ (M_\odot)	—	0.154 ± 0.006	0.159 ± 0.011

ondary spectra for one observation—the second—in order for all the velocities to make sense.

The primary and secondary radial velocities were measured from the absorption spectra by cross correlation with the spectrum of Barnard's star; see Tomkin (1983) for details of the method. The adopted radial velocity of Barnard's star was -108 km s $^{-1}$ (Gliese 1969).

Separate orbital solutions of the primary and secondary velocities are given in Table III. The elements P (period), V_0 (systemic velocity), e (eccentricity), and T (epoch of periastron passage), which should in principle be identical for the primary and secondary, are in reasonable agreement, while the primary and secondary ω (longitude of periastron), which should differ by 180° , differ by 195° , which is acceptable. We also made a simultaneous solution of the primary and secondary velocities together; it is the third solution in Table III. The adopted orbital elements and the phases and O — C in Table II are for this solution. Figure 2 plots the primary and secondary velocities and the calculated primary and secondary velocity curves for the simultaneous solution.

IV. RESULTS

The results (Table III) of our high-resolution Digicon observations reveal Gliese 268 as a double-lined spectroscopic binary composed of a pair of dM5e stars in a moderately eccentric 10^4 orbit. From the relative strengths of the absorption spectra, we estimate that the secondary-to-primary brightness ratio in the continuum is ~ 0.7 .

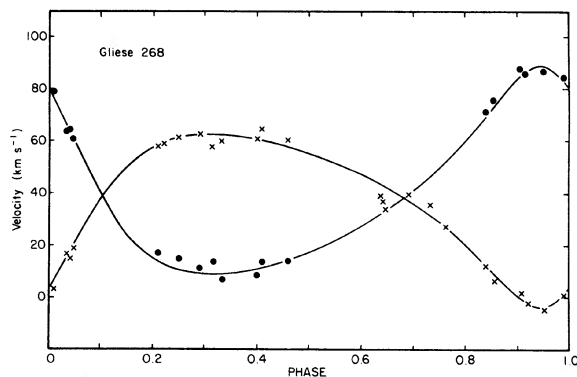


FIG. 2. Primary and secondary velocities fitted with the calculated primary and secondary velocity curves for the combined solution.

The average $H\alpha$ emission intensities, in units of the combined continuum-level intensity, are 1.65 ± 0.12 and 1.44 ± 0.12 for the primary and secondary, respectively. The variation of the relative intensities of the $H\alpha$ emission is sufficiently small that the primary emission is usually, but not always, stronger than the secondary emission. Plots of the intensity of primary and secondary $H\alpha$ emission versus orbital phase show no sign of modulation with orbital phase.

The minimum masses, $M \sin^3 i$, are 0.191 and $0.159 M_\odot$. These minimum masses put Gliese 268 on the relationship between M_V and mass for eclipsing and visual M dwarf binaries with reliable masses (Popper 1980; Table 2), so they must be close to the actual masses. This indicates that the inclination cannot be too far from 90° ; for example, if $i < 70^\circ$, then the actual masses of the components would be significantly larger than expected on the basis of their luminosities.

It is possible that the components of Gliese 268 eclipse each other, but, thanks to their pint-sized nature, it is not very likely. Estimated radii for the components of $\sim 0.2R_\odot$, obtained from the empirical mass-radius relation $R/R_\odot = (M/M_\odot)^{0.88}$ for low-mass ZAMS stars (Patterson 1984), combined with the separation $(a_1 + a_2) \sin i = 9.84 \times 10^6$ km mean that the inclination must be within $\sim 1.5^\circ$ of 90° for the occurrence of eclipses. We have seen that the inclination probably lies in the range $70^\circ \leq i \leq 90^\circ$, so the probability that Gliese 268 is an eclipsing binary is less than one in ten. A search for rotational modulation of the brightness of Gliese 268 was done in December 1983 and January 1984. No variability larger than 0.01 mag was seen. None of the photometric observations were made at times of conjunction, so an observational search for eclipses remains to be done.

DeCampli and Baliunas' (1979) relationship for the synchronization time scale in stars with convective envelopes applied to Gliese 268 gives a time scale of $\sim 10^{12}$ yr. Thus, although magnetic braking has probably slowed the rotation of the components, their rotation and orbital periods are not expected to be synchronized. This time scale of $\sim 10^{12}$ yr is comparable to the estimated entire main-sequence lifetime of a $0.2M_\odot$ M dwarf so it seems unlikely that Gliese 268 will fall into the maw of the tidal-interaction magnetic-braking mechanism.

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