

A Double-lined Spectroscopic Binary in the Open Cluster Trumpler 14

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ABSTRACT. We present the results of a determination of the preliminary orbital elements of the spectroscopic binary FMM 3 in the field of the open cluster Trumpler 14. The spectrum of this binary shows two sets of lines that are roughly similar. The period found was around 5 days ($P = 5.0339 \pm 0.0003$), and the orbit is eccentric ($e = 0.51 \pm 0.02$). These values were adopted from the combined solution for both components. The mass ratio of the system is 0.76 ± 0.06 .

1. INTRODUCTION

Establishing the existence of short-period binaries in compact and dense open clusters is important. Dynamical considerations indicate that the compact and dense nature of these clusters is due to the lack of hard binaries. The open cluster Trumpler 14 in the η Carinae complex contains a large number of massive O-type stars. It is compact and seems to be a bound cluster. It is important to know if there is a lack of primordial binaries among its members. It may be argued that, in the case of Tr 14, from the three different processes that make a subgroup in an OB association expand, only the dynamical interactions with binaries remain as the possible source of expansion (see Penny et al. 1993).

Two studies, namely, Levato et al. (1991) and Penny et al. (1993), presented discrepant results about the binary nature

of some of the brightest members of the cluster: for seven stars in common, three of them are spectroscopic binaries according to Levato et al. (1991), while the same stars show no clear radial velocity variations in the work of Penny et al. (1993). García et al. (1998) reobserved the stars in Tr 14 in an effort to resolve the discrepancies. They found that the systematic effect pointed out by Penny et al. (1993) affecting Levato et al.'s data exists, but they also found evidence indicative of binarity in some of the stars observed. In particular, two sets of lines seemed to be present in the spectra of star FMM 3, as designated by Feinstein, Marraco, & Muzzio (1973).

The present paper is a straightforward effort for determining the preliminary orbital parameters for this star.

2. OBSERVATIONS

FMM 3 has been classified as B0.5 IV–V (Morrell, García, & Levato 1988). Its visual magnitude is 10.80, and the observed $B - V$ is 0.26 as measured by Feinstein et al. (1973). The quoted $V \sin i$, 111 km s^{-1} , should be taken with caution because of blended spectral lines even at the resolving power used in this paper.

A total of 23 new spectra of FMM 3 were obtained at CASLEO in the blue region of the spectrum using the Jorge Sahade 2.1 m telescope and the REOSC echelle spectro-

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graph.⁵ The spectra were recorded on a Tek CCD of 1024×1024 pixels. We used a grating of 400 grooves mm^{-1} as a cross-disperser. This instrumental configuration gives a 2 pixel resolution of 0.30 Å, with a useful wavelength range of 2000 Å (from 3700 to 5700 Å). We have also obtained the usual series of bias and flat-field frames. The signal-to-noise ratio of the spectra of the program stars is never larger than 70. A Th-Ar lamp provided the wavelength calibration. During the observations, the spectrograph was conveniently rotated to avoid contamination by HD 93128, a nearby companion at less than 3" separation. The new 23 spectra observed were added to two spectra whose radial velocities were published by García et al. (1998).

To establish the zero-point correction for our radial velocity determinations, we have obtained spectra for a set of standard stars selected from Feckel (1985) and for HR 1996 and HR 2806, which were used as standards by Penny et al. (1993). No corrections were applied to our data.

All the observations were processed and analyzed using IRAF⁶ routines.

3. RESULTS

Heliocentric radial velocities were derived for each observation by measuring the positions of several H and He I lines (when not seriously affected by nebular emission), He II $\lambda 4686$, Mg II $\lambda 4481$, and Si IV $\lambda 4088$. Only average radial velocities are presented in Table 1, but extensive tables showing line-by-line measurements are also available on request. The position of the spectral lines selected for radial velocity measurements were measured using a Gaussian fitting and deblending routines included in the SPLLOT task of IRAF.

Rest wavelengths were taken from Bolton & Rogers (1978), Moore (1923), and Striganov & Sventitskii (1968). Table 1 shows the average heliocentric radial velocity for each spectrum of FMM 3 jointly with the Julian date, the probable error of the average, and the number of lines included in the average.

We have looked for possible periods of variation of the radial velocity. With this purpose, we used the code written by Morbey (1978). The best period found is $P = 5.033$ days. This period and preliminary orbital elements determined graphically were used as input in Bertiau's (Bertiau & Grobbon 1969) code to compute the final period and the remaining orbital elements. The adopted values are listed in

TABLE 1

HELIOCENTRIC RADIAL VELOCITIES OF FMM 3 IN TRUMPLER 14

HJD (+2,400,000)	Radial Velocity (km s^{-1})	Number of Lines	Probable Error (km s^{-1})
49,765.719.....	-18.40	10	3.6
50,110.788.....	+79.5 (P)	12	4.0
	-106.2 (S)	4	3.7
50,111.778.....	+37.6	7	4.3
50,444.807.....	+54.1	9	3.9
50,446.817.....	-140.0 (P)	11	8.0
	+200 (S)	10	8.0
50,447.814.....	+72.6	10	3.2
	-106		
50,480.848.....	-7.0 (P)	16	3.9
50,584.496.....	+80.0	12	7.5
	-121.0		
50,585.487.....	+21 (P)	17	3.2
50,617.482.....	-117 (P)	8	3.0
	+85 (S)	8	7.1
50,618.460.....	+34 (P)	12	7.0
50,821.818.....	+23 (P)	17	3.0
50,822.819.....	-64 (P)	16	4.7
	+30 (S)	17	3.0
51,207.816.....	+72.0 (P)	8	1.3
	-90 (S)	4	1.9
51,208.831.....	+69 (P)	8	2.3
	-87 (S)	3	10.0
51,209.775.....	+14 (P)	11	1.7
51,210.674.....	-34 (P)	8	1.0
51,211.662.....	-131 (P)	11	1.5
	+170 (S)	3	7.2
51,215.783.....	-36 (P)	8	1.8
51,216.778.....	-127 (P)	5	2.7
51,217.746.....	+70 (P)	11	2.1
	-106 (S)	3	5.7
51,218.770.....	+70 (P)	8	3.3
	-86 (S)	2	6.1
51,275.61.....	+60.5 (P)	14	3.9
	-75.6 (S)	8	3
51,276.570.....	+23	13	3
51,279.547.....	+66.9 (P)	11	5.6
	-120.5 (S)	4	4.2

NOTE.—(P) = primary, (S) = secondary.

Table 2. We have deleted from the computation six spectra with both sets of lines very much blended around phase 0.6.

Figure 1 shows the computed radial velocity curves for the primary and secondary components with the elements of Table 2, as well as the observations in both cases. The probable error of the fit is 10 km s^{-1} .

As a check of the uncertainties of the orbital solution, we have also computed the radial velocity solution for the primary alone. With 20 observations of the primary we have obtained the orbital elements shown in Table 3, which are not very different from those in Table 2, but the probable error of the fit in this case is 5 km s^{-1} .

We have located component A in the theoretical H-R diagram. For this purpose we considered its spectral type as

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TABLE 2
ORBITAL ELEMENTS FOR TR 14-3

Element	Primary	Error	Secondary	Error
$a \sin i$ (km).....	0.693E+07	$\pm 0.447E+06$	0.908E+07	$\pm 0.491E+06$
e	0.51	0.02		
K (km s ⁻¹).....	117	4	153	5
ω (deg).....	236	5		
T_0 (JD).....	2,450,582.94	0.04		
P (days).....	5.0339	0.0003		
V_0 (km s ⁻¹).....	-5.7	3		
$M_1 \sin^3 i$ (M_\odot).....	3.66	0.77		
$M_2 \sin^3 i$ (M_\odot).....	2.79	0.69		
$Q(M_2/M_1)$	0.76	0.06		

B0.5 IV–V, and we have used the available photometry, the distance modulus for the cluster, and the bolometric correction derived from the calibration provided by Chlebowski & Garmany (1991). Comparing the position of component A in the theoretical H-R diagram with the evolutionary tracks computed by Schaller et al. (1992), we find that the mass for the primary is around 20 solar masses while that of component B is 15 solar masses according to the mass ratio

of the system. An inclination of the system of around 35° results from the above numbers, with no chances of observing eclipses.

4. DISCUSSION

One of the points that is not clear yet is the presence of “bound” OB clusters within OB associations, as is the case of Trumpler 14. As Penny et al. (1993) have pointed out, there are only three ways to explain the expansion of the subgroups in an OB association: (a) dispersal of the original gas by the photoionizing flux of the massive stars, (b) mass loss by stellar winds and supernovae, and (c) dynamical exchange involving binaries. In the case of Tr 14 the two first processes can be rejected, and only the dynamical exchange involving binaries remains as responsible for the expansion (see Penny et al. 1993).

Morrell et al. (1988) suggested that the compact appearance of Tr 14 would also be explained if the distance to Tr 14 is larger than the distance to Tr 16, which appears less compact. They suggested two possible distances to Tr 14: 2.8 and 3.45 kpc. Using the results by Morrell et al. (1988), Penny et al. (1993) derived for Trumpler 14 (a) the cluster radius, 1.0–1.2 pc; (b) the crossing time for the cluster, $(1.1\text{--}1.4) \times 10^5$ yr; and (c) from theoretical evolutionary tracks an age of about 5.5×10^5 yr. On the other hand, Massey & Johnson (1993) found from extensive CCD photometry that (a) the clusters Tr 14 and Tr 16 are at the same distance and (b) this distance is 3.2 kpc (close to the larger value proposed by Morrell et al. 1988). If their results are correct, then the compactness of Tr 14 could be explained by the anomalously low binary frequency. Hence, it is very important to know this frequency among the members of Tr 14. The results presented in this paper are not in the correct trend in order to support the explanation suggested above for the compact appearance of Trumpler 14. However, detailed observations of the other main-sequence stars in Trumpler 14 are necessary to arrive at a safe conclusion about the level of the binary content of this young cluster. Consider-

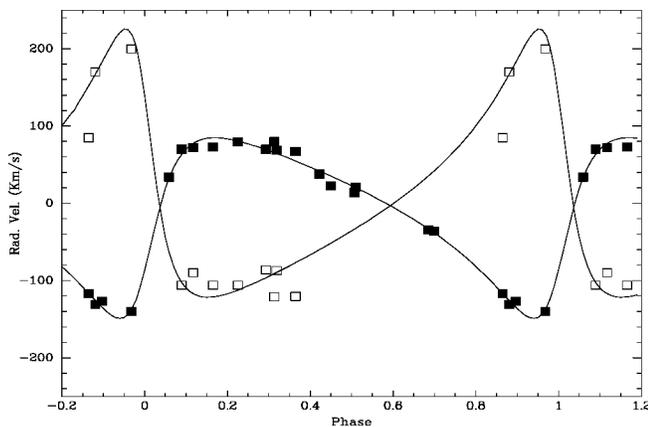


FIG. 1.—Radial velocity curve for FMM 3 in Trumpler 14. Black squares represent the observations of the primary while open squares are for the secondary. The size of the symbols roughly corresponds to the 2σ error for the radial velocity measurements.

TABLE 3
ORBITAL ELEMENTS FOR TR 14-3A

Element	Primary	Error
$a \sin i$ (km).....	0.693E+07	$\pm 0.226E+06$
e	0.48	0.015
K (km s ⁻¹).....	115	3
ω (deg).....	239	2.5
T_0 (JD).....	2,450,582.91	0.03
P (days).....	5.0343	0.0002
V_0 (km s ⁻¹).....	-3.8	1.5
$f(m)$	0.52	0.05

ing the youth of Tr 14, it seems safe to conclude that FMM 3 is a primordial binary. This assumption is also supported by the large eccentricity of the orbit computed in this paper. The barycentric velocity of FMM 3 is around -5 km s^{-1} , not very different than the barycentric velocity for the cluster derived by García et al. (1998) (6 km s^{-1}) or by Penny et al. (1993) (4.7 km s^{-1}). Finally, it is worth mentioning that the mass ratio for FMM 3 is high compared with that one should expect for a young cluster, if binary forma-

tion was due to stellar encounters. See Abt & Willmarth (1996).

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