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BINARY 15 MONOCEROTIS AND STAR CLUSTER NGC 2264

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Abstract. The orbit of 15 Mon (close pair CHR 168 Aa-Ab) was recently calculated on the basis of speckle measurements only. Four new measurements, performed after the orbit calculation, satisfy this orbit very well. The orbital elements and the mass values expected for the components, as well as their distance moduli, result in a distance of 15 Mon in a very good agreement with the distance to NGC 2264, but disagrees with the trigonometric distance of the binary. On the basis of the orbital elements and mass ratio the line-of-sight velocity of the binary mass centre is determined. It is found that the value of this velocity is within the limits expected for stars belonging to NGC 2264. Its difference from the expected mean in the field of NGC 2264 agrees well with the value mentioned in the literature.

1. INTRODUCTION

According to WDS catalog (Mason et al. 2008) 15 Mon is a multiple star containing more than 10 components. It is still uncertain if these stars form a bound group. The only case with known orbital motion concerns the close pair CHR 168 Aa-Ab (separations measured by now less than 110 mas). It consists of two O (spectral type) stars at a position: $\alpha = 6^h41^m$, $\delta = 9°54'$. Both components are very bright stars with apparent magnitudes equal to 4.66 and 5.90. The fact that it is bound was firstly established from spectroscopic measurements, to be confirmed afterwards on the basis of speckle measurements. The binary is in the field of open cluster NGC 2264.

The examinations of NGC 2264 suggest that its distance is more than 600 pc (e.g. Pérez et al. 1987, Mason et al. 1998, Dahm et al. 2007). On the other hand the trigonometric parallax (ESA 1997, van Leeuwen 2007) of the bright star 15 Mon results in a distance of about 300 pc. Studies of different kind (orbit, photometry and spectroscopy) offer possibilities to find the cause of this discrepancy.

Vasilevskis et al. (1965) determined the relative proper motions for 245 stars in the field of NGC 2264. Based on them they calculated the membership probability for each star. One of the stars was also 15 Mon for which they found a membership probability of 0.96. Afterwards line-of-sight velocities in the field of NGC 2264 were also determined (Liu et al. 1989, Fürész et al. 2006). It is of interest to compare the line-of-sight velocity of the mass centre of 15 Mon with these data because in this way a new possibility arises to establish the relationship between the binary and the cluster.

Table 1: Orbital elements for 15 Mon = CHR 168 Aa-Ab

P[yr]	T	$a['']$	e	$i[^\circ]$	$\Omega[^\circ]$	$\omega[^\circ]$
74.28	1996.06	0.0956	0.716	51.2	52.6	69.2
±4.06	±4.16	±0.0149	±0.098	±3.1	±5.2	±11.1

Table 2: Observations and residuals: asterisk denotes observation where we changed the quadrant of the position angle, diamond referes to an observation performed after the orbit calculation.

Epoch	θ $[^\circ]$	ρ $['']$	(O-C)$_\theta$ $[^\circ]$	(O-C)$_\rho$ $['']$	Reference
1988.1704	12.9	0.057	5.2	–0.005	McAlister et al. (1993)
1993.0925	35.4	0.039	–6.4	–0.004	McAlister et al. (1993)
1993.1967	36.7	0.041	–6.2	–0.002	McAlister et al. (1993)
1996.0742	116.9	0.0237	4.6	0.005	Gies et al. (1997)
2001.0197	231.1	0.061	–0.4	0.000	Mason et al. (2009)
2005.8635	242.2	0.104	–6.0	0.015	Mason et al. (2009)
2005.9422 *	66.1	0.089	–2.3	0.000	Horch et al. (2008)
2005.9422	246.2	0.091	–2.2	0.002	Horch et al. (2008)
2006.1909	251.9	0.089	2.9	–0.001	Mason et al. (2009)
2007.0125 $^\diamond$	250.8	0.094	–0.1	0.000	Horch et al. (2010)
2008.7705 *$^\diamond$	74.6	0.1004	0.0	0.001	Tokovinin et al. (2010)
2009.2622 *$^\diamond$	75.6	0.1034	0.1	0.003	Tokovinin et al. (2010)
2009.2622 *$^\diamond$	74.9	0.1032	–0.6	0.002	Tokovinin et al. (2010)

2. ORBIT OF 15 MON

The first orbit for 15 Mon (close pair CHR 168 Aa-Ab) was calculated by Gies et al. (1993, 1997). They used both the spectroscopic and speckle measurements. Recently Cvetković (2009) calculated the orbit for this pair using the speckle measurements only. The full account on the subject can be found in (Cvetković et al. 2010). Table 1 contains the elements of this orbit with their errors.

In the meantime, after the orbit publication, four new speckle measurements have taken place. Therefore, it becomes possible to examine their fit to the orbit by Cvetković (2009). Table 2 contains the measured values for the position angle θ and separation ρ, the measurement epoch, the corresponding residuals of the orbit and the references. As can be seen from Table 2., the new measurements (indicated by sign $^\diamond$) result in very low (O-C) values.

3. DISTANCE PROBLEM

According to the Hipparcos trigonometric parallax (ESA 1997) and the new parallax (van Leeuwen 2007) the distance to the binary should be 313 pc, i.e. 282 pc, respectively. On the other hand, the period and semi-major axis found by Cvetković

(2009) combined with the mass values expected for the components on the basis of their spectral types and luminosity classes suggest a distance between 700 and 750 pc. Such a distance is confirmed from the distance modulus (Cvetković et al. 2010).

However, as said in Introduction, it is very likely that binary 15 Mon belongs to star cluster NGC 2264. Independent distance determinations for this cluster (e.g. Pérez et al. 1987) suggest that it is at 735 pc from the Sun. Therefore, the result of Cvetković et al. (2010) concerning the distance of the binary is in accordance with the distance of the cluster.

The parallaxes and proper motions for 20 open clusters among which is NGC 2264 were derived by van Leeuwen (2009). His conclusion is that NGC 2264 can not be included as a cluster closer than 500 pc. At such large distances it is very difficult to obtain reliable trigonometric parallaxes. For this reason the big discrepancy in the case of the distance for 15 Mon (found trigonometrically and by using alternative methods) is not surprising.

4. 15 MON AND NGC 2264 ON THE BASIS OF LINE-OF-SIGHT VELOCITY

On the basis of what has been said above it is very likely that binary 15 Mon or close pair CHR 168 Aa-Ab (together with the whole star group) is a member of open cluster NGC 2264.

With the orbital elements obtained by Cvetković (2009) assuming a mass ratio of 0.50 we have calculated the line-of-sight velocity of the primary as function of time. This dependence is compared with the measurements and the best fit corresponds to the value of $+33.6 \pm 1.0$ km s^{-1} for the line-of-sight velocity of the binary mass centre. The mean line-of-sight velocity in the field of NGC 2264 is +24 km s^{-1} (Liu et al. 1989), i.e. +22 km s^{-1} (Fürész et al. 2006). In the latter paper much more stars were measured. According to them the velocity dispersion (σ) in the field of NGC 2264 is 3.5 km s^{-1} and also the velocity field contains a north-south gradient (see Fig. 4 in their paper). The meaning of the gradient is that the mean velocity slightly varies with declination. With regard to the declination of 15 Mon the mean to be compared with the motion of the binary exceeds 25 km s^{-1}. In addition Fürész et al. (2006) admit the stars with residual line-of-sight velocities within 4σ to be still members of star cluster NGC 2264. The difference between the line-of-sight velocities of the binary mass centre and the mean value corresponding to its declination is about 8 km s^{-1} which is within the limit of 4σ. On the other hand Fürész et al. (2006) report about a bubble-like feature (Fig. 6 in their paper) at 7 km s^{-1} connected to 15 Mon. This is a very good agreement. Additionally, NGC 2264 is known to contain very young stars. The components of the binary being very massive O type stars, which means that they are very young, naturally belong to this cluster.

5. CONCLUSION

The distance of binary 15 Mon found on the basis of the orbital elements and total mass, as well as, on the photometry, indicates that the trigonometric distance is very unreliable. This is not surprising because low parallaxes, as is the case with our star, are near the limits achieved by Hipparcos. The line-of-sight velocity for the mass centre of 15 Mon found by us is within the limits for the field of NGC 2264 as found

by Fürész et al. (2006). In addition, the age of the binary components is similar to the typical age of NGC 2264 stars. Therefore, on the basis of our results concerning the orbital motion of the binary we can conclude that 15 Mon is physically related to star cluster NGC 2264.

New measurements both speckle and spectroscopic will improve the determination of the orbital elements and new space missions (GAIA) will make available more accurate parallaxes which will contribute to the interpretation of the space motion of 15 Mon with respect to NGC 2264.

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