Spectroscopic Subcomponents in Visual Double Stars: the Most Probable Values of their Physical and Orbital Parameters. Application to the System WDS 14404+2159

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Summary. Double stars with spectroscopic subcomponents are very interesting objects from many points of view. In this way, determination of their orbits and masses has become a key step in its study. We show a method that allows to calculate, both from orbits and Hipparcos parallax, the most probable values of all stellar masses, spectroscopic binary inclination, angular separation between their components and even a spectral types' estimate. We apply this method to triple system WDS 14404+2159 (a double star with a single-lined spectroscopic subcomponent) and compare our results with other estimations.

1 Methodology

1.1 Notation

We will use 1, 2 and 3 subscripts to refer to Aa, Ab and B components, respectively. M_j will be the absolute magnitude of the component j; m_j, the apparent visual magnitude and $\mathcal{M}_j$, its mass. The subscript 12 is used to refer to the spectroscopic subsystem. Moreover, ΔM will be the difference between absolute magnitudes of the components of the spectroscopic subsystem.

Once we have calculated the masses, the semi-major axis and the inclination of the spectroscopic orbit can be computed. New apparent visual magnitudes are also given, as well as spectral types of all components.

The semi-major axis and inclination can be added to the known spectroscopic orbital elements. Therefore, the angle of node will be the only orbital element that remains unknown.

1.2 Jaschek's criterion

If the subsystem is a single-lined spectroscopic binary, we can suppose from [1] that $\Delta M = M_2 - M_1 \geq 1$.

1.3 Basic Steps

Compatible Parallax Values

We compute the parallax by means of:

$$\log \pi = \frac{M_1 - m_{12} - 5}{5} - \frac{1}{2}\log(1 + 10^{-0.4\Delta M}). \tag{1}$$

Eq. 1 provides the parallax values depending on M_1 and ΔM, which are compatible with the margin of error given by Hipparcos.

For each value of M_1 and π, we calculate the corresponding value of M_2 (obtained from ΔM) and M_3 (inferred from m_3 and π).

From now on, we will work with mean values of the three absolute magnitudes and the mean parallax.

Estimation of Spectral Types and Masses

The spectral types will be estimated from the calibration given in [2], and the individual masses will be calculated from a statistical fit given in [3] and reproduced here in Table 1. These equations, valid only for a certain range of spectral types, Table 1, give functional relations between the mass and the spectral type for components of a binary system, where the coefficients a and b take several values depending on the luminosity class. On the other hand, s is a continuous variable defined in [4] that represents the spectral class.

Table 1. Estimation of masses $\mathcal{M}$ from the spectral type s

$\mathcal{M}$	a	b	Spectral range
$(a + b\,e^{-s})^2$	1.34 ± 0.17	20.8 ± 2.5	$B4 - K4$
$a\,s^b$	19.29 ± 0.86	-1.660 ± 0.065	$B0.5 - K3.5$
$a + \frac{b}{s^2}$	-0.117 ± 0.090	27.47 ± 0.61	$B0.5 - M6$

Note: Here e is the number e.

Moreover, the mass function for the spectroscopic binary is:

$$\frac{(\mathcal{M}_2 \sin i)^3}{(\mathcal{M}_1 + \mathcal{M}_2)^2} = 3.985 \cdot 10^{-20} k_1^3 P (1 - e^2)^{\frac{3}{2}}, \tag{2}$$

with $\mathcal{M}_1$ and $\mathcal{M}_2$ the masses of components 1 and 2, respectively; i, the inclination; k_1, the radial velocity amplitude; P, the period; and e, the eccentricity. In this way, we can estimate the minimum mass and the latest spectral type of the secondary spectroscopic component.

2 Application to WDS 14404+2159

2.1 Data

HD 129132 is known as a triple system, see [5]. Its Hipparcos parallax is $\pi_{\rm Hip} = 9.47 \pm 0.71$ mas.

The combined apparent magnitude of the spectroscopic subsystem is $m_{12} = 6.05$, while the magnitude of the visual component B is $m_3 = 7.1$.

The visual binary orbit was calculated by Barlow and Scarfe [6], who obtained a period of $9.^y268 \pm 0.^y019$ and a semi-major axis of $0.''074 \pm 0.''001$. From the same reference we take the following orbital elements of the close pair: $P = 101.^d606 \pm 0.^d008$, $e = 0.117 \pm 0.007$, $\omega_1 = 140.^\circ7 \pm 2.^\circ9$ and $K_1 = 19.0 \pm 0.1$ km s^{-1}.

2.2 Results

Table 2. The final results for WDS 14404+2159

$\mathcal{M}_1$ ($\mathcal{M}_\odot$)	2.66 ± 0.24	Sp_1	A3IV
$\mathcal{M}_2$ ($\mathcal{M}_\odot$)	1.44 ± 0.10	Sp_2	F2V
$\mathcal{M}_3$ ($\mathcal{M}_\odot$)	2.13 ± 0.10	Sp_3	A5V
$\mathcal{M}$ ($\mathcal{M}_\odot$)	6.23 ± 0.28		
π (mas)	9.48 ± 0.30	M_1	1.14 ± 0.05
a (AU)	7.81 ± 0.27	M_2	2.98 ± 0.07
a_{12} (AU)	0.656 ± 0.023	M_3	1.99 ± 0.17
a_{12} (mas)	6.22 ± 0.29	m_1	6.26 ± 0.05
a_1 (AU)	0.231 ± 0.019	m_2	8.09 ± 0.07
i (°)	$49.8(130.2) \pm 5.5$	m_3	7.11 ± 0.17

The results are shown in Table 2 and the orbit is drawn in Fig. 1. We have also calculated the maximum separation of the spectroscopic subsystem $\rho_{\rm max} = 6.78$ mas.

A plausible model for this system is given in [6], with $\mathcal{M}_1 = 1.97\ \mathcal{M}_\odot$, $\mathcal{M}_2 = 1.29\ \mathcal{M}_\odot$ and $\mathcal{M}_3 = 1.82\ \mathcal{M}_\odot$. Later, different values were calculated by [7] with the total mass ($6.633 \pm 1.694\ \mathcal{M}_\odot$) about 30% larger than the previous estimate by [6] ($5.08\ \mathcal{M}_\odot$) and about 6.6% larger than the mass obtained by us ($6.22 \pm 0.28\ \mathcal{M}_\odot$). The estimation given in [6] for the inclination ($i = 45^\circ$) is in good agreement with our result, $i = 49.^\circ8 \pm 5.^\circ5$.

3 Remarks

Although in this work we are dealing with single-lined spectroscopic binaries, we know that this method can also be applied to double-lined spectroscopic binaries. Usually, in this case, we can expect even more accurate results.

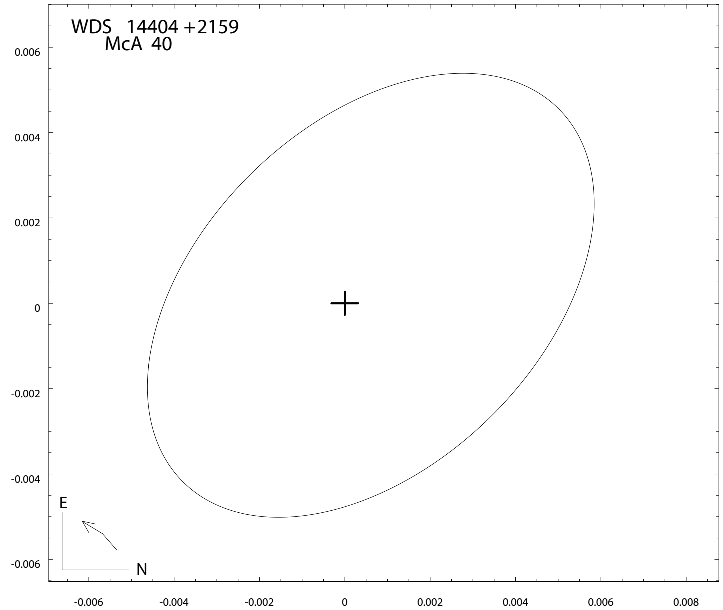

Fig. 1. Apparent orbit of the spectroscopic sub-component in WDS 14404+2159. Axis scale in arcseconds.

With regard to the possibility of optically resolving these systems, it can be noted that angular separations will never be larger than a few miliarcseconds.

Theoretically, it would be possible to determine the direction of the motion in the spectroscopic orbit by studying the perturbations due to the visual component B. A secular increase of the argument of periastron will suggest retrograde motion ($i > 90°$), while its decrease will correspond to a direct motion ($i < 90°$).

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