ORBIT DETERMINATION OF THE SINGLE-LINED SPECTROSCOPIC BINARIES BY USING THE REVISED HIPPARCOS INTERMEDIATE ASTROMETRIC DATA

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Abstract. By fitting the revised Hipparcos intermediate astrometric data (HIAD), we obtain the photocentric orbital solutions of some single-lined spectroscopic binaries (SB1s) in the 9th Catalogue of Orbits of Spectroscopic Binaries (SB9). For SB1s with relatively small magnitude difference between the two components, we find that the primary orbit is not a good approximation of the photocentric orbit in their orbit determination and suggest that future spectroscopic observations and advanced spectral separation techniques should be applied to these systems. In order to facilitate these future observations, we also estimate the full orbital solutions and provide the observational ephemerides. As an example, we give the result for HIP 113860.

1 Introduction

The ultimate goal of binary orbit determination is to obtain the full orbital solution and the component masses. For a double-lined spectroscopic binary (SB2) with period smaller than 5 years and with known spectroscopic orbital elements and the component mass ratio, this goal can be achieved with very high precision by fitting the coming Gaia astrometric data. But this does not apply to a single-lined spectroscopic binary (SB1), because the mass ratio is not known.

Recently, the high resolution infrared spectroscopy is applied to some SB1s (Mazeh et al. 2003) and some advanced spectral separation techniques are developed, e.g., Doppler tomography, spectral disentangling and two-dimensional correlation techniques (e.g., Gies 2004). And so, it is expected that more and more SB1s, even those with rather low mass ratio, will be turned into SB2.
Jancart et al. (2005) have already determined the orbital solutions of 70 SB1s in the 9th Catalogue of Orbits of Spectroscopic Binaries (SB9, Pourbaix, et al. 2004) by fitting the Hipparcos intermediate astrometric data (HIAD). But in their fitting processing, they assumed that the angular semi major axis of the photocentric orbit \( a_0 \) is equal to the angular semi major axis of the primary orbit \( a_1 \). This assumption might bring large deviation to \( a_0 \) and make the orbital solution unreliable especially for those SB1s with relatively small Hipparcos magnitude difference \( \Delta H_p \) between the two components. On the other hand, the HIAD have been revised recently and the accuracy of the new data is improved by a factor of 2.2 in the total weight (van Leeuwen 2007). For some SB1s, this makes it necessary to determine the orbital solutions without the above assumption.

\[ \frac{\Delta H_p}{\kappa - \beta} \]

\[ \kappa = \frac{M_2}{M_1 + M_2} \] and \[ \beta = \frac{1}{1 + 10^{\Delta H_p}} \]. For SB1s composed of main sequence stars, the relation between \( \frac{\beta}{\kappa - \beta} \) and \( \Delta H_p \) is shown in the Figure 1.

From this figure, we can see that the relative difference is \( \sim 20\% \) when \( \Delta H_p < 3 \).

The other is that the number of nonlinear model parameters is reduced by replacing the inclination \( i \) (\( i \in (0^\circ, 180^\circ) \)) by the linear parameter \( \psi = \cos i (\psi \in (-1, 1)) \). In this way, fitting efficiency is significantly improved.

More details of the fitting method can be found in Ren & Fu (2010).
Fig. 2. The left panel shows the relative orbit of HIP 113860. The dash and the dotted circles indicate the V band Rayleigh limits of the 4 meter and 6 meter telescopes, respectively. The right panel shows the radial velocity curves of the primary and the secondary of HIP 113860.

3 Result

HIP 113860 is an SB1 with the spectroscopic orbital solution as follows: the period $P = 178.3177$ days, the eccentricity $e = 0.53$, the time of passage at periastron $T = 2435319.73$, the argument of the periastron $\omega = 2^\circ 6$, and the mass function $f = 0.10929 \, M_\odot$.

By fitting the revised HIAD, photocentric orbital solution of HIP 113860 is obtained as follows: $a_0 = 5.9 \pm 0.2 \, \text{mas}$, $i = 49^\circ 3 \pm 4^\circ 1$, the latitude of the ascending node $\Omega = 269^\circ 7 \pm 3^\circ 7$. Because the primary is a main sequence star, we can estimate the mass of the primary by using the colour - magnitude relation and the mass - luminosity relation of main sequence stars (Arenou et al. 2000; Henry et al. 1997). The estimated result is $M_1 = 1.56 \, M_\odot$, which implies that $M_2 = 1.26 \, M_\odot$.

If the secondary of HIP 113860 is assumed to be a main sequence star, the magnitude differences are estimated by virtue of the mass - luminosity relations: $\Delta H_p \sim 1.25$, and the visual magnitude difference $\Delta V \sim 1.16$.

Then, there are two ways to estimate the $\frac{\beta}{\kappa - \beta}$:

One is

$$\frac{\beta}{\kappa - \beta} = \frac{1}{M_1 + M_2} \frac{1}{1 + 10^{0.4 \Delta H_p}} = 0.53,$$

(3.1)

and the other is

$$\frac{\beta}{\kappa - \beta} = \frac{a_1 - a_0}{a_0} = 0.56.$$

(3.2)

Obviously, these two results are in accordance with each other and imply that assuming $a_0 = a_1$ would bring over 50% relative error for $a_0$.

Taylor et al. (2003) pointed out that SB1s with magnitude difference less than 3 can easily be turned into SB2. HIP 113860 is such an SB1. In order to facilitate its future observations, we give the relative orbit (see the left panel of Fig. 2) and
Table 1. Ephemerides of HIP 113860.

<table>
<thead>
<tr>
<th>Orbital phase</th>
<th>$\rho$ (mas)</th>
<th>$\theta$ (deg)</th>
<th>$RV_1$ (km s$^{-1}$)</th>
<th>$RV_2$ (km s$^{-1}$)</th>
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<tr>
<td>0.0</td>
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<td>45.4</td>
<td>-6.6</td>
<td>-5.3</td>
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<tr>
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<td>96.8</td>
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</tr>
<tr>
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<tr>
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</tr>
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</tr>
<tr>
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<tr>
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<td>12.8</td>
<td>336.1</td>
<td>11.1</td>
<td>-27.1</td>
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</table>

the radial velocity curves (see the right panel of Fig. 2). The relevant ephemerides is given in Table 1. From the results, we can see that this system may be easily turned into SB2 by the spectroscopy and resolved by the speckle interferometry.

Supported by the National Natural Science Foundation of China (grant No. 10703014, 10833001 and 11073059).

References


