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A new method for orbit determination on the Gaia SB1s

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Abstract. An iterative method to determine the self-consistent orbital solutions of single-lined spectroscopic binaries (SB1s) along with compatible physical properties of component stars via a simultaneous fit including both the Hipparcos Intermediate Astrometric Data (HIAD) and radial velocity data is introduced in this work. For the method, a stellar evolutionary model is used to distribute the total mass and luminosity to the primary and the secondary and update the ratio of the semimajor axes of the photocenter to the primary orbits. Once the Gaia Intermediate Astrometric Data (GIAD) are released, the method can be applied to study the Gaia SB1s and give self-consistent orbital solutions and compatible physical properties of component stars.

Keywords. single-lined spectroscopic binaries, orbital determination, fundamental parameters.

1. Introduction

Since the Hipparcos catalogue has been published in 1997 (ESA (ed.) (1997)), the photocentric orbital solution of some spectroscopic binaries have already been determined by HIAD (Van Leeuwen& Evans(1998); Jancart *et al.* (2005); Ren & Fu(2010), Ren & Fu(2013)). In these work, they treated the semimajor axis of the photocenter orbit as a free fitting parameter which couldn't make full use of spectroscopic parameters or considered the the primary orbit is consistent with the photocenter orbits which neglected the influence of the secondary. Therefore, we have developed an appropriate method that makes full use of the HIAD and the radial velocity data, and gives a self-consistent orbit as well as the compatible physical properties of the component stars (Wang *et al.* (2015)).

Comparing with Hipparcos mission, the precision of Gaia is much higher at order of magnitude (Lindegren *et al.* (2016)). Then, our new method can be used to determine the orbits of the SB1s in combination of the GIAD and radial velocity data in the future, and the preliminary physical properties of the known SB1s can be derived.

Although the orbital solutions of SB1s mentioned above rely on stellar evolutionary model, it is helpful for developing binary statistical study. Meanwhile, these results can guide follow-up observation and derive physical parameters of component stars independent of stellar evolutionary model. Then, these physical parameters can be used to test stellar evolutionary model.

2. The new method

For an SB1, the semimajor axis (a_0) of the photocenter orbit can be expressed as

$$a_0 = \lambda a_1 = \lambda \varpi \frac{K_1 P \sqrt{1-e^2}}{2\pi \sin i}, \qquad (2.1)$$

where a_1, ϖ, K_1, P, e, and i are the semi-major axis of the primary orbit, the system parallax, the semi-amplitude of the radial velocity curve of the primary, the orbital period, the orbital eccentricity, and the orbital inclination, respectively. The parameter λ can be expressed as

$$\lambda = [1 - \frac{10^{0.4H_p}(1+q^{-1})}{1+10^{0.4H_{p2}}}]. \tag{2.2}$$

The value of λ is between 0 and 1. The parameters q, H_p, H_{p2} in Equation (2.2) represent the mass ratio $\frac{M_2}{M_1}$, and the Hipparcos magnitude of a binary system and the secondary, respectively. H_{p2} can be calculated from the mass-absolute Hipparcos magnitude (Arenou *et al.* (2000)).

$$H_{p2} = -13.5 \log M_2 + 5.07. \tag{2.3}$$

A simultaneous fit to the revised HIAD(Van Leeuwen(2007)) and Radial velocity data is used to derive the orbital solution. The iterative fitting process begins with $\lambda = 1$. The modified grid method developed by (Ren & Fu(2010)) is used to search for the global optimization solution. Based on this solution, the value of λ is updated in combination with the stellar evolutionary model, more information refer to Wang *et al.* (2015).

With the method mentioned above, we have study eight SB1s and found that HIP 7143 and HIP 45333 have relative large luminosity ratio of the secondary and primary which may be resolved by the latest observation, and this have already been proved by Halbwachs *et al.* (2014) and Fekel *et al.* (2015).

3. Conclusions

In combination of spectroscopic orbital parameters and Hipparcos parallax, we found that the minimum angular semi-major axes of more than 1200 SB1s in the 9th Catalogue of Spectroscopic Binary Orbits (Pourbaix *et al.* (2004)) is bigger than 0.3mas. This means that the method mentioned above can be used to study these systems, and give the self-consistent orbital solutions along with compatible physical properties of component stars. And the secondaries of these systems which can be observed by the latest observation can be picked out for further observation and analysis.

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