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The nearby triple star HIP 101955

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Abstract. The nearby triple star HIP 101955 with strongly inclined orbit still remains. Thus the long-term dynamical stability deserves to be discussed based on the new dynamical state parameters (component masses and kinematic parameters) derived from fitting the accurate three-body model to the radial velocity, the Hipparcos Intermediate Astrometric Data (HIAD), and the accumulated speckle and visual data. It is found that the three-body system remains integrated and most likely undergoes Kozai cycles. With the already accumulated high-precision data, the three-body effects cannot always be neglected in the determination of the dynamical state. And it is expected that this will be the general case under the available Gaia data.

Keywords. binaries: close, stars: kinematics and dynamics, stars: individual (HIP 101955)

1. Introduction

According to the Multiple Star Catalog Tokovinin (1997), the nearby triple star HIP 101955 with low orbit hierarchy and strongly inclined orbit still remains. Thus the stability of this system deserves to be studied with improved dynamical state parameters. The three components were optically resolved for the first time by Balega *et al.* (2002) and Malogolovets *et al.* (2007). Detailed study of this triple system were presented in these papers and Tokovinin & Latham (2017). However, these results are not satisfactory.

In fact, the main factors that decide the quality of dynamical state determination are the time span, the precision of observations, and the accuracy of the dynamical model. All these factors are taken into consideration in our redetermination. First, in the previous orbital determinations, only relative position data (RPD) from speckle interferometric observations made in 1998 $\sim$ 2004 are used. In our redetermination, apart from spectroscopic and visual RPD accumulated since 1934, the HIAD, and radial velocities are used jointly. Therefore, both the time span and precision of the observational data are significantly increased. Second, the accuracy is increased by using the three-body model, which turns out to be necessary for us to obtain a better result.

2. Observational Data and fitting results

With three kinds of observational data, the maximum likelihood estimate of model parameters is usually obtained by minimizing the following objective function

$$\chi^2 = \sum_{i=1}^{N} \left(\frac{y_i - y(x_i; a_1 \cdots a_M)}{\sigma_i}\right)^2, \qquad (2.1)$$

where y_i is the observed value with standard error σ_i, and $y(x_i; a_1 \cdots a_M)$ is the calculated value depending on the model parameters $a_1 \cdots a_M$.

Taking into consideration the two-body effect on the motion of A_m (the center of mass of A_a, A_b), which is previously ignored when the inner and outer orbits are determined separately, we simultaneously fit the double two-body model to all observational data. There are 21 model parameters, including the 7 inner orbital elements, 7 outer orbital elements and the mass ratio q. The other parameters are 5 motion state parameters $(\alpha_c, \delta_c, \varpi_c, \dot{\alpha}_c, \dot{\delta}_c)$ describes the constant motion of Cm_3 (the mass center of the 3-body

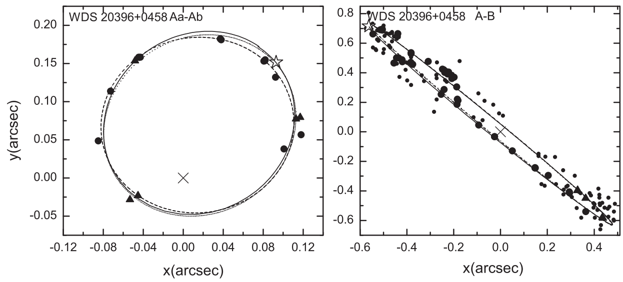

Figure 1. Inner and outer orbital motions of HIP 101955. The filled circles are the RPD used in our fitting and triangle points are RPD from Tokovinin & Latham (2017).

system) in the ICRS , and ρ which is related to the magnitude difference (Δm) and the mass ratio (q) by $\rho = \frac{r}{1+r} - q$ ($r = 10^{-0.4\Delta m}, q = M_{Ab}/(M_{Aa} + M_{Ab})$). Here, as well as in the following, the Bounded Variable Least Squares (BVLS) algorithm Lawson & Hanson (1995) is used to give the least-square solution.

The fitted inner and outer orbits are plotted in Figure 1 as dotted curves, while the orbits provided by Tokovinin & Latham (2017) are plotted as dashed curves.

Using the three-body model, we have again 21 parameters to fit. The parameter set $(\alpha_c, \delta_c, \varpi_c, \dot{\alpha}_c, \dot{\delta}_c)$, and ρ are the same as in the double two-body model. The other parameters are component masses (M_{Aa}, M_{Ab}, M_B), the initial (1991.25) position and velocity $(r_x, r_y, r_z, v_x, v_y, v_z)_{Ab}$ of Ab relative to Aa, the initial position and velocity $(r_x, r_y, r_z, v_x, v_y, v_z)_B$ of B relative to Aa.

The preliminary fitting results are plotted in Figure 1. The open stars represent the best-fit position at the epoch 1991.25 and the solid curves are the trajectories. The χ^2 of this result is much reduced in comparison with the result using double two-body model.

3. Summary

The dynamical state parameters of HIP 101955 modeled as a three-body system are determined. Based on this result, the long-term dynamical stability is explored for 10^3 of the outer period. The instantaneous two-body orbital elements, e.g., a_{in}, a_{out}, e_{out}, are found to be constant. Other parameters vary significantly. In comparison with the result by our simultaneous fit using the double two-body model, the maximum positional deviation reaches ~50 mas within the time interval [1891.25, 2091.25]. Therefore, with the already accumulated high-precision data, the three-body effects cannot always be neglected in the determination of the dynamical state of a triple star. This should be the general case as the Gaia data are available.

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