The Moment Approach for Resolving the Orbital Elements of Astrometric Binaries: Possible Application to Cygnus X-1

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Resolving the orbital elements of astrometric binaries has been the important issue for measuring the masses of stars. The masses of main sequence stars are important to clarify the stellar population and evolution. The masses of compact objects, i.e., white dwarfs, neutron stars, and black holes, are important to clear the nature of these objects.

“A moment approach” is one of methods for resolving the orbital elements, which is developed by Iwama et al [1]. The future astrometric observations such as Gaia and Small-JASMINE enable us to measure the stellar positions at a precision of the 10-microarcsecond level. This means that we may be able to measure the orbital elements of close binaries such as high mass X-ray binaries with the period of a few days, i.e., Cygnus X-1, whose period is about 6 days. Here, we should note that the observational data are numerous, for example, about 100 data points for Gaia and about 10^5 data points for Small-JASMINE. If these data points are isochronous, they are expected to show a spacial bias due to the difference of the velocity of the star on the celestial sphere. Therefore the spacial moments due to the bias allow us to measure the orbital elements of astrometric binaries. This moment approach would be useful for obtaining recovered values as trial values of the steepest descent method for reaching the best-fitting parameter values.

The previous study [1] have room for improvement. Temporal information is not incorporated in the previous approach, where only the spacial bias is considered and the time of each data is neglected. The stellar position is determined by the orbital phase which is directly related to the time, so that the information of the time is important to constrain the orbital parameter. To incorporate temporal information, of N observed points we average the coordinate of n_a observed points which are neighboring positions. Using averaged data points, which show better accuracies, we apply the moment approach to calculate the orbital elements.

Figure 1 shows the apparent orbits for the mean values of the recovered parameters using the approach in the paper [1] and the present one. Here, σ represents the observational error for each position measurement in unit of the semi-major axis of the trial binary. In Figure 1, we set $(\sigma, N, n_a) = (5, 10000, 100)$. We see that the present approach significantly improves the previous one for the orbit shape.

Let us consider a possible application to Cyg X-1, whose angular radius is ~0.03 mas. The required precision of the Small-JASMINE is 0.01 mas, so that we expect that the orbit of Cyg X-1 will be detected by Small-JASMINE. The calculational results show that the semi-major axis is expected to be recovered with an accuracy comparable to the true value from astrometric observations alone. Therefore, it is more convenient to start with the values that are recovered from the present moment approach and next to use the steepest descent method for finally reaching the best-fitting parameter values. This manuscript is a review of the paper [2].

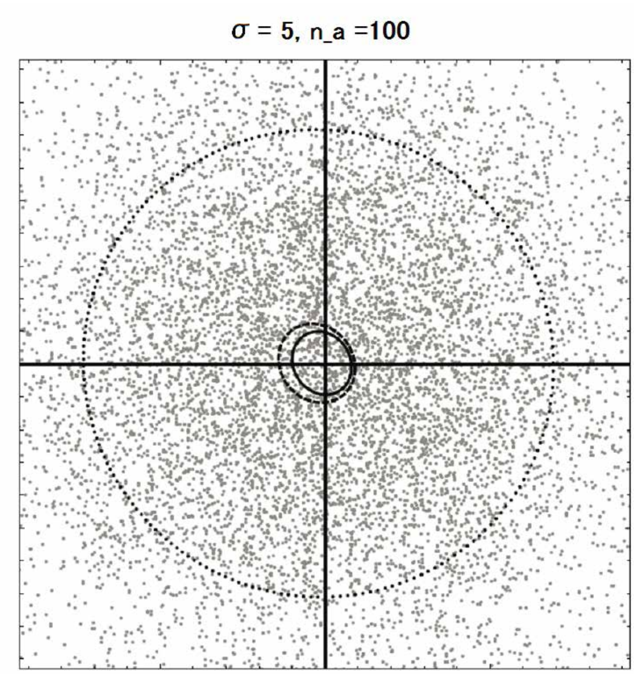

Figure 1: The apparent orbits for the mean values of the recovered parameters. The solid curve is the apparent ellipse for the true parabeters, and the dotted and dashed curves denote orbits for the mean value of the recovered parameters from the approach in [1] and the present one, respectively.

References

[1] Iwama, H., Asada, H., Yamada, K.: 2013, *PASJ*, **65**, 2.
[2] Yamada, K., Yamaguchi, M. S., Asada, H., Gouda, N.: 2014, *PASJ*, **66**, 5.