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On statistical distributions of wide binary stars

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The semi-major axis is a key parameter of binary stellar systems. In order to obtain current semi-major axis distribution we investigated a volume-limited sample of the binaries in solar neighbourhood. Obtained distribution shows unsatisfactory agreement with the canonical Opik's law.

Key words: binaries: general - binaries: visual

INTRODUCTION

The majority of stars in our galaxy are in binary or multiple systems. While the physical properties and evolution of a single star is determined mainly by its mass, binary systems possess at least 4 fundamental parameters: component masses, orbital separation and eccentricity. These parameters generally remain conserved throughout evolution in wide systems.

The semi-major axis a is a key parameter of binary system. The a values vary over a huge range of several orders of magnitude. The exact form of semi-major axis distribution is still unknown. The brief review of modern models is presented in [2]. Generally accepted log-flat distribution (Opik's law [4]) implies the equal number of close and wide systems, e. g. the number of stars with $1 < a < 10$ a. u. roughly equals the number of stars with $10 < a < 100$ a. u.

Wide and close binaries are expected to form via two different ways. While fragmentation during initial free-fall protostar collapse is the main mechanism for wide binaries, close binaries are believed to originate via fragmentation in the protostellar accretion disk of a primary star [3]. Consequent orbital evolution caused by interaction with circumbinary disc and gravitational field of surrounding stars alters the initial semi-major axis and eccentricity distributions. Hence, checking the statistical distributions of binaries gives insight into stellar formation and evolution process.

RETRIEVING SEMI-MAJOR AXIS DISTRIBUTION

If both stars are observed as distinct sources of light, it is possible to measure the current angular separation and the positional angle of secondary component. In some cases we can track the motion of stars around centre of mass over time. Then, after sufficient number of observations, the apparent orbit is fitted. Since the plane of orbital revolution is not usually perpendicular to our line of sight, we observe the projection of true elliptical orbit on celestial sphere. The sufficiently long set of observations of stars' positions together with recorded time is enough to determine the tilt angle of a given binary and, therefore semi-major axis expressed in angular units can be calculated. Unless the distance to the binary is known, we cannot determine actual semi-major axis expressed in linear units (e.g., km, a. u.).

The determined orbital elements (including angular semi-major axis) of visual binary stars are assembled in the Sixth Catalogue of Orbits of Visual Binary Stars (ORB6) [1]. No mention on binary star distance is given. The derived orbits are of different reliability due to various factors, such as accuracy of initial observations, number of revolutions from first to last observation, total number of observations, etc. In order to estimate the quality of calculated orbit, grades are assigned to each entry in the catalogue. The grade is natural number varying from '1' for definitive orbits to '5' for orbits of indeterminate quality. Few interferometric binaries orbits (which generally have good quality) have '8' grade, '9' is given for astrometric orbits. Due to large inaccuracy, orbits with grades '5' and '9' are excluded from posterior analysis.

The relationship between angular, a'', and linear, a, semi-major axis for a star with known parallax, π, is trivial:

$$a'' = \frac{a}{d} = a\pi, \qquad (1)$$

Since ORB6 does not contain reference on parallax, we made cross-identification with another cat-

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alogue. To study the statistical properties of binaries we should minimize selection effects. Confident parallax estimates were executed by Hipparcos mission and they are available only for nearest bright ($m < 7.3$) stars. Therefore we have selected Raghavan survey [5] for analysis. This survey comprises 454 solar-type primary stars within 25 pc from the Sun with parallax errors less than 5%. The larger distance limit would make the sample magnitude-limited and hence incomplete. Note that binaries in the solar neighbourhood are less biased due to comprehensive monitoring of nearby Sun-like stars.

Values of parallax from the new Hipparcos astrometric catalogue [6] were used. For comparison of Raghavan and ORB6 data sets we have used Tool for OPerations on Catalogues And Tables (`TOPCAT`). 48 pairs from Raghavan survey were found in ORB6 after cross-matching. Multiple systems were manually checked to prevent incorrect identification. Fig. 1 shows observed distribution of binaries by semi-major axis in angular units, Fig. 2 represents resulting distribution in linear units.

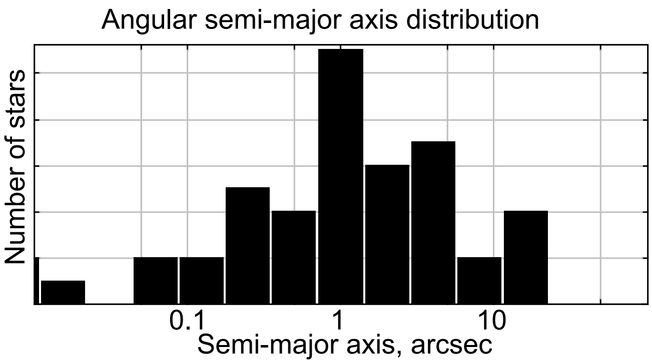

Fig. 1: The observed angular semi-major axis distribution in Raghavan sample.

RESULTS

The obtained distribution shows unsatisfactory agreement with the canonical Opik's law. Certainly the number of systems with large a is underestimated. Time span from the first to the last observation is still insufficient to accomplish the full orbit coverage for wide systems with long orbital periods. Nevertheless the distribution form in separation range $a < 10$ a. u. does not fit log-flat law. It remains an issue, since the examined sample comprises of nearby well-studied stars and pretends to be complete.

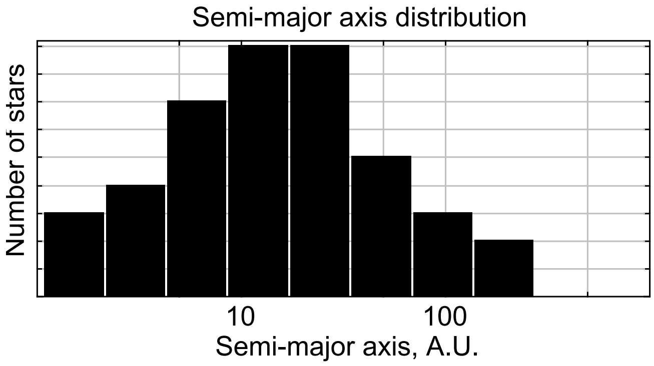

Fig. 2: The observed linear semi-major axis distribution in Raghavan sample.

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REFERENCES

[1] Hartkopf W. I., Mason B. D. & Worley C. E. 2001, AJ, 122, 3472

[2] Kouwenhoven M. B. N., Goodwin S. P., Parker R. J. et al. 2010, MNRAS, 404, 1835

[3] Kraus A. L., Ireland M. J., Martinache F. & Hillenbrand L. A. 2011, ApJ, 731, article id. 8

[4] Öpik E. 1924, Publ. of the Tartu Astrofizica Observatory, 25, 1

[5] Raghavan D., McAlister H. A., Henry T. J. et al. 2010, ApJS, 190, 1

[6] van Leeuwen F. 2007, A&A, 474, 653