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On the selection effects in catalogues of binary stars

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Investigation of physical properties of different kinds of binary stars can provide us with an invaluable information about star formation and evolution. To obtain present-day distributions of binaries along various parameters from catalogues, selection effects should be taken into account. In this paper some catalogues of visual binaries were investigated with respect to selection effects. The distributions of catalogue binaries with respect to components separation, limiting magnitude and magnitude difference were studied and corrected for selection effects.

Key words: catalogues; (stars:) binaries: visual; stars: statistics

INTRODUCTION

The star formation history (in particularly, the initial mass function) is a fundamental aspect defining all consequent stellar evolution and observational properties of stars and stellar systems. Binary stars serve as invaluable source of our knowledge of stellar parameters, however, the their observed distributions should be corrected for selection effects.

The aim of our study is to find the distributions of binaries with respect to angular separation and magnitude difference of components.

CATALOGUES AND SKY DISTRIBUTION

We have performed an analysis of visual binaries from three catalogues, namely:

1. Catalogue of Components of Double & Multiple stars (CCDM [1]),

2. the Washington Visual Double Star Catalogue (WDS[1]),

3. Tycho Double Star Catalogue (TDSC [2]).

Firstly, we studied the distribution of binary stars over the sky. The observed star distributions reflect spatial concentration toward the Milky Way (for CCDM see Fig. 1, left panel) and some irregularities over the declination. These irregularities can be explained by the fact that the observations were made in relatively narrow declination strips (see Table 1). They can bias the final distributions. Moreover, some of these observations contain many optical double stars [3]. Authors of some observations e. g. Smart W. M., who observed the whole sky) discovered many optical double stars. These stars were found in WDS and CCDM catalogues. The optical pairs bias final distributions, that is why they were removed from the statistics. We removed pairs observed by Ali, Smart, Baillaud, Scheiner, Stein, Pourteau, Aravamudan.

Table 1: Observations in declination strips.

dec, deg	designation	author
+38	ALI Ali1949	Ali A.
+38	ES Es 1901	Espin T. E.
+38	SEI Sei1908	Scheiner J.
+24	POU Pou1933	Pourteau M.
+2	BAL Bal1924	Baillaud R.
+56	STI Sti1932	Stein J.
-20	ARA Ara1961	Aravamudan S.
-62	JSP Jsp1935	Jessup M. K.

Initially we considered TDSC as a homogeneous catalogue, however, according to one of its authors (C. Fabricius, 2011, private communication), a cross match of Tycho binary stars was made with WDS, and the authors have 1,220 systems from Tycho-2, 18,160 other systems already in WDS, 13,251 systems not in WDS.

The TDCS sky distribution, corrected for WDS stars, is shown in Fig. 1, right panel. A concentration towards ecliptic latitude $\pm 47°$, produced due to the Hipparcos scanning technique, is also visible as two weak wave-like structures.

CORRECTION FOR SELECTION EFFECTS

The magnitude and angular separation distributions of catalogued binaries are subjects to selection

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[1] `http://ad.usno.navy.mil/wds/`

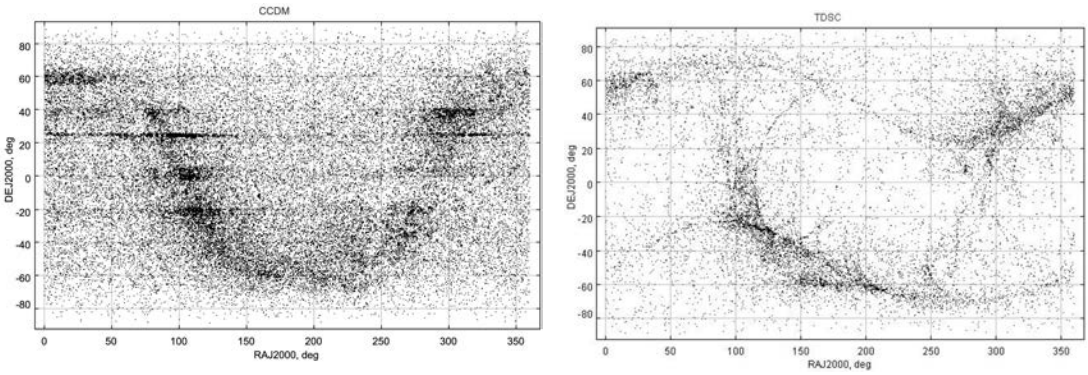

Fig. 1: The distributions of binary stars in CCDM (left) and TDSC (right).

effects. To correct the first one, a limiting stellar magnitude should be known for a given catalogue. The distributions of primary and secondary components for catalogues CCDM, WDS and TDSC (see Fig. 2) were used to determine completeness limit. The data may be considered as statistically complete up to $m_{v1} = 10.25^m$ for WDS, $m_{v1} = 11^m$ for TDSC and $m_{v1} = 9^m$ for CCDM.

To correct an upper limit of the angular separation distribution optical pairs were removed from the sets. For a lower limit a value of $0.1''$ was taken. It is a typical value for 1-m aperture telescope, used by observers of visual binaries.

RESULTS AND CONCLUSIONS

The resulting distributions of angular separation and the components magnitude difference, corrected for the selection effects discussed above, are shown in Fig. 3. One can see that the distributions of ρ and Δm (for $0.25 < \rho < 10^3$ and $0 < \Delta m < 7$) show a good agreement for WDS and CCDM, and can be approximated by the expression:

$$y_1 = A_1 + A_2\rho + A_3\rho^2 + A_4\rho^3,$$

$$A_2 = -0.40 \pm 0.09,$$
$$A_3 = 0.56 \pm 0.09, \quad A_4 = -0.19 \pm 0.02.$$

$$y_2 = B_1 + B_2\Delta m,$$
$$B_2 = -0.38 \pm 0.01.$$

For TDSC (for $0 < \Delta m < 2.5$):

$$y_3 = C_1 + C_2\Delta m$$
$$C_1 = 2.76 \pm 0.18, C_2 = -1.29 \pm 0.14.$$

Coefficients A and B depend on catalogue completeness. According to Fisher test at a significance level of 0.05 a 3rd order polynomial is statistically optimal for the distribution of ρ. The distributions for TDSC stars slightly differs from the other catalogues. This is a subject of our further study.

ACKNOWLEDGEMENT

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[3] Poveda A., Allen C. & Parrao L. 1982, ApJ, 258, 589

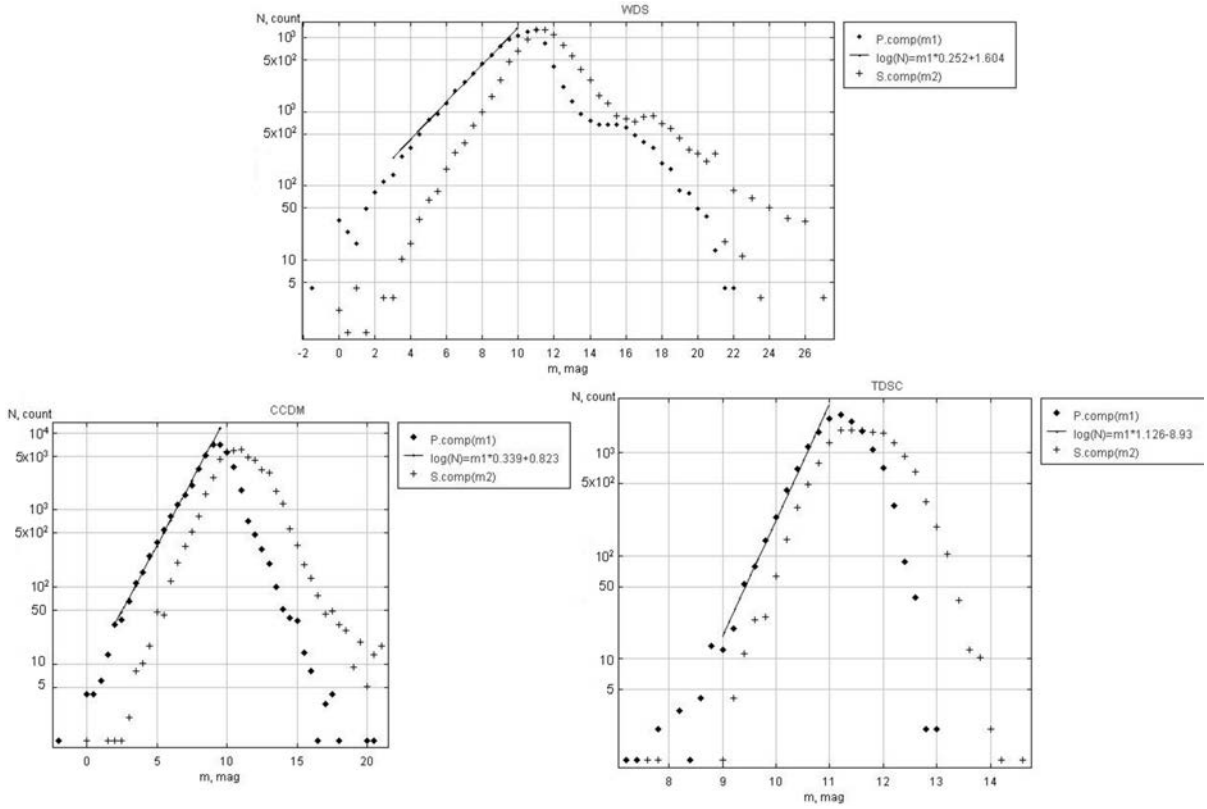

Fig. 2: The distribution of primary and secondary components for catalogues CCDM, TDSC and WDS.

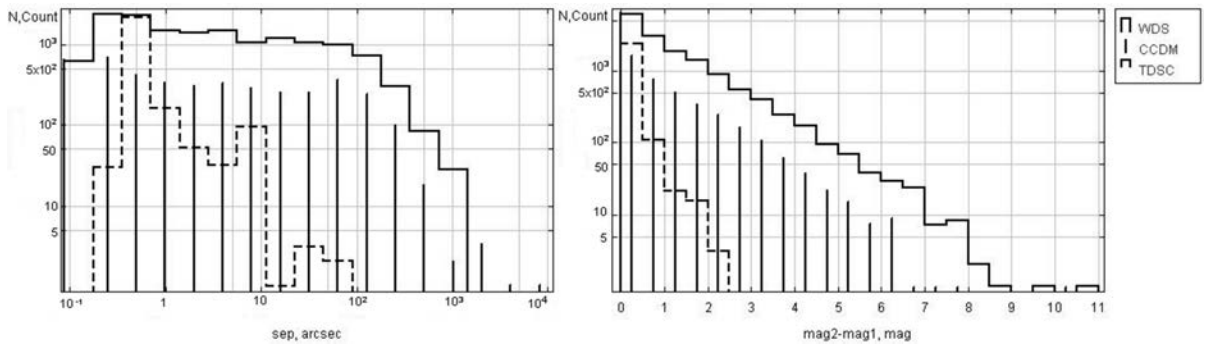

Fig. 3: The resulting distributions of angular separation and the components magnitude difference, corrected for the selection effects.