# Determination of star-catalog biases from positional observations of numbered minor planets

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Systematic errors of star catalogs have been determined by the O-C ("observed-calculated") residuals for the asteroid positional observations. The O-C values were obtained by improving the orbits of 356968 numbered asteroids.

The improvement of asteroid orbits was carried out by a differential method which was conducted in two steps. At the first step, the orbital elements of Ceres, Pallas, and Vesta were improved, taking into account the perturbations from the major planets, the Moon, Pluto using DE405 and their mutual perturbations. Then we calculated the ephemerides of these three planets. To calculate the orbital elements of other numbered asteroids, we used the ephemerides obtained and all available positional observations. 70,234,284 values of O-C were obtained for the observations after 2001.

The greatest number of observations after 2001 refer to the following catalogs: USNO A2.0 (34,610,829 observations), UCAC-2 and 3 (25,541,657 observations), and USNO B1.0 (9,744,401 observations). The mean value of O-C was calculated for each of the 10,212 equal areas on the celestial sphere and interpreted as a star catalog systematic bias for the corresponding area. The error of this value depends on the number of O-C values and the number of planets from which observations were used for the calculation in the corresponding area.

The comparison of biases obtained with the results in [1] are given in the Table: $\alpha$, $\delta$ (in hours and degrees) are the coordinates of an area center; $\Delta\alpha_1$,$\Delta\delta_1$ (in arcseconds) are the systematic errors of right ascensions and declinations of the USNO A2.0 catalog given in [1] and $\Delta\alpha$,$\Delta\delta$ (in arcseconds) are errors obtained by us; N is the number of O-C values used to calculate $\Delta\alpha$,$\Delta\delta$, and $N_{pl}$ is the number of minor planets from which observations were used for the calculation in the specific area. The differences between the systematic errors can be explained by the different number of observations and procedures used for the calculation of the systematic errors. It should be noted that the jumps of the systematic errors of the USNO A2.0 catalog for certain areas in [1] are revealed. In particular, for the area with coordinates $(0^h.753, 3^o.21)$, the bias of declination obtained in [1] differs from that in the neighboring areas. The systematic errors that are determined by us vary more smoothly from area to area.

| $\alpha$ | $\delta$ | $\Delta\alpha_1$ | $\Delta\delta_1$ | $\Delta\alpha$ | $\Delta\delta$ | $N$ | $N_{pl}$ | $\Delta\dot{\alpha}$ | $\Delta\dot{\delta}$ |
|---|---|---|---|---|---|---|---|---|---|
| 23.91 | 4.82 | − 0.08 | 0.33 | − 0.04 | 0.32 | 11768 | 1632 | $15 \pm 0$ | $17 \pm 0$ |
| 0.082 | 4.82 | − 0.02 | 0.27 | − 0.19 | 0.46 | 12131 | 1759 | $07 \pm 1$ | $19 \pm 5$ |
| 0.250 | 3.21 | − 0.05 | 0.35 | − 0.22 | 0.48 | 20699 | 2363 | $01 \pm 2$ | $25 \pm 2$ |
| 0.418 | 3.21 | − 0.03 | 0.46 | − 0.13 | 0.43 | 21871 | 2787 | $03 \pm 1$ | $27 \pm 3$ |
| 0.586 | 3.21 | − 0.01 | 0.47 | − 0.12 | 0.47 | 22614 | 2850 | $03 \pm 2$ | $28 \pm 4$ |
| 0.753 | 3.21 | − 0.09 | 0.01 | − 0.10 | 0.42 | 23086 | 2823 | $10 \pm 0$ | $22 \pm 0$ |
| 0.921 | 3.21 | − 0.12 | 0.24 | − 0.07 | 0.25 | 23506 | 2919 | $10 \pm 1$ | $20 \pm 0$ |
| 1.089 | 3.21 | − 0.02 | 0.44 | − 0.07 | 0.39 | 23634 | 2923 | $11 \pm 1$ | $22 \pm 4$ |

Using the same O-C values and the same partition of the celestial sphere, the estimation of variation of the systematic errors $\Delta\dot{\alpha}$,$\Delta\dot{\delta}$ (in *mas* per year) for the USNO A2.0 catalog are given in the last two columns of the Table. The analysis of these values shows considerable variation of the systematic errors, especially, in declination. This allows us to conclude that the values of the systematic errors for this catalog vary not only from area to area, but also with time. It means that the observations based on this catalog must be corrected not only depending on the differing areas, but differing epochs as well.

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**References:** Chesley S.R., Baer J., Monet D.G. Treatment of star catalog biases in asteroid astrometric observations. Icarus, 2010. V. 210. P. 158–181.