Astrometry and photometry of asteroids from the UkrVO database of astroplates

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***Abstract*. We present the developed methods of digitization, image processing, reduction, and scientific data mining with the latest reference catalogs, which allowed us to obtain a good positional and photometric accuracy in B-band of 6,500 asteroids down to 17.5^m from database of old photographic astroplates.**
These values, distribution, and types of asteroids from the published two catalogs related to the FON-Kyiv and Fon-Kitab sky surveys are compared with current estimates for the FON-Dushanbe survey and astroplate archives of the Baldone and Tautenburg observatories.
For some of asteroids, observations are either completely absent or not enough over the certain time interval to the moments of their official discoveries (about 300 such objects were found).
Positional observations for this long-term period are highly useful for a more detailed study of the dynamics and orbital parameters of asteroids as well as the obtained photometric parameters are very complementary with present-day data for studying changes in brightness and light curves.

The **Ukrainian Virtual Observatory** (UkrVO, http://ukr-vo.org) database is compiled from photographic observations conducted in 1898-2018 at observational sites of 8 Ukrainian observatories with about 50 instruments. Now the UkrVO archive covers the data of about **40,000 astroplates**, from which **15,000 are digitized.**
The most of these digitized ones is related to the FON project (Northern Sky Photographic Survey), 1981-1996 yrs.
But these images have produced a large number of faint asteroids down to 17.5^m.

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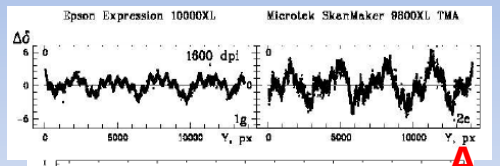
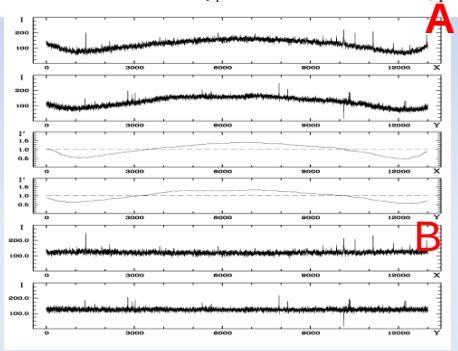
MIDAS/ROMAFOT based calibration software

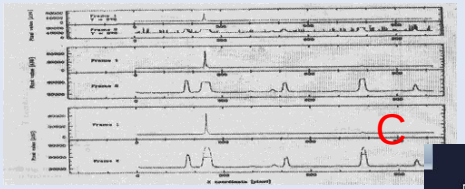
The initial processiing of digitized images with calibrating software includes finding and eliminating of own flat field of the plate (**B**), finding and selection of objects, removing of «hot»pixels, restoration of overexposed images (**C**), removing of scaner mechanics errors (**A**).
(**D**) - photometric characteristics for two exposures
(**E**) - positional systematic differences over the field of plate
(**F**) - internal positional accuracy for 2 scanners



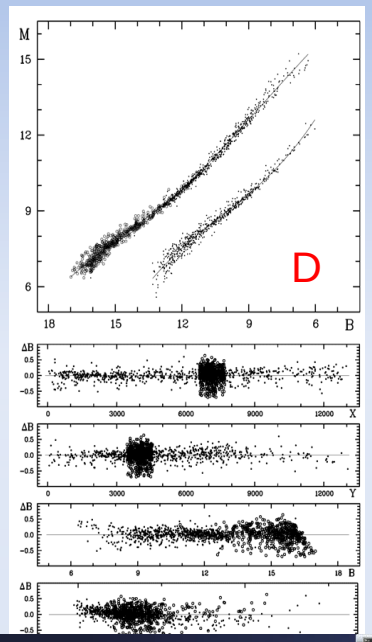
A



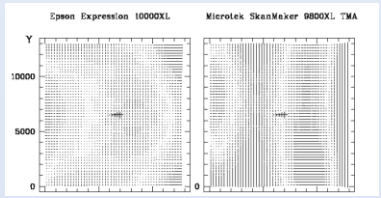
B



C



D



E

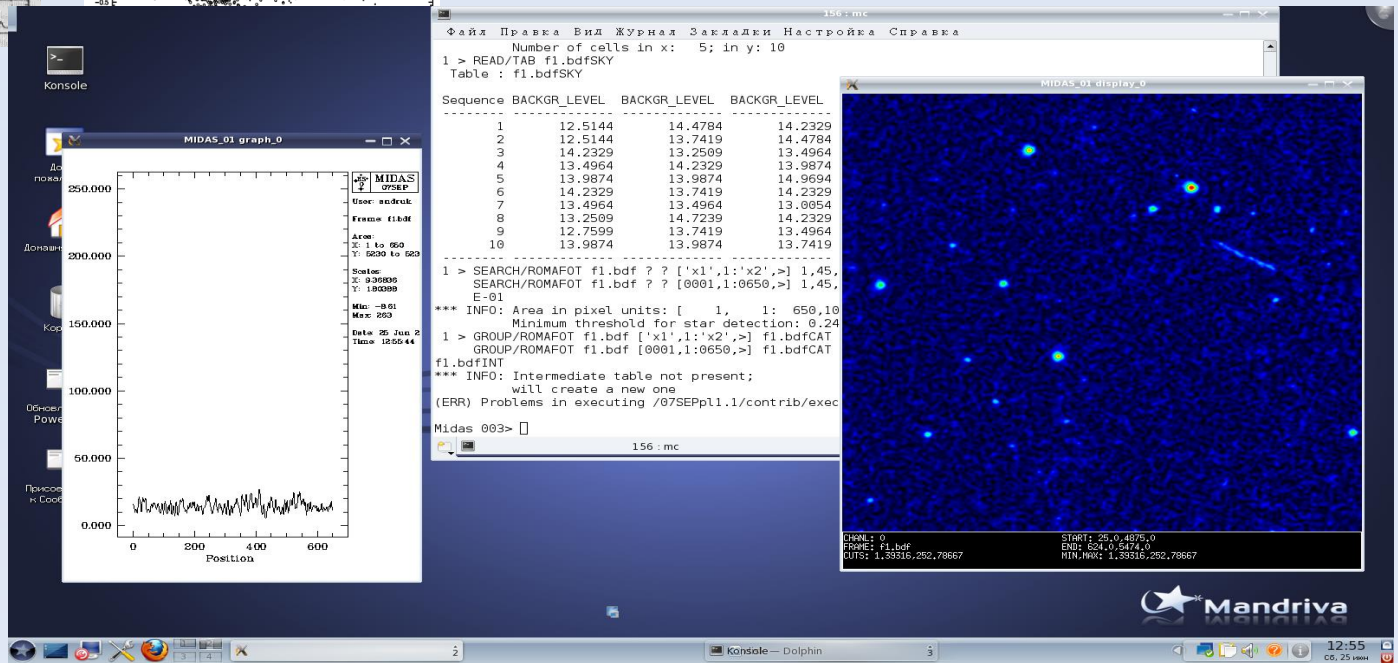
Epson Expression 10000XL

n	B	σ_α	σ_δ	N
1	6.55	0.123	0.099	17
2	7.64	0.092	0.098	30
3	8.59	0.113	0.095	95
4	9.58	0.087	0.087	275
5	10.56	0.081	0.088	659
6	11.59	0.080	0.084	1851
7	12.44	0.089	0.091	2099
8	13.29	0.090	0.103	386
9	14.21	0.110	0.108	13
	11.73	0.085	0.089	5425

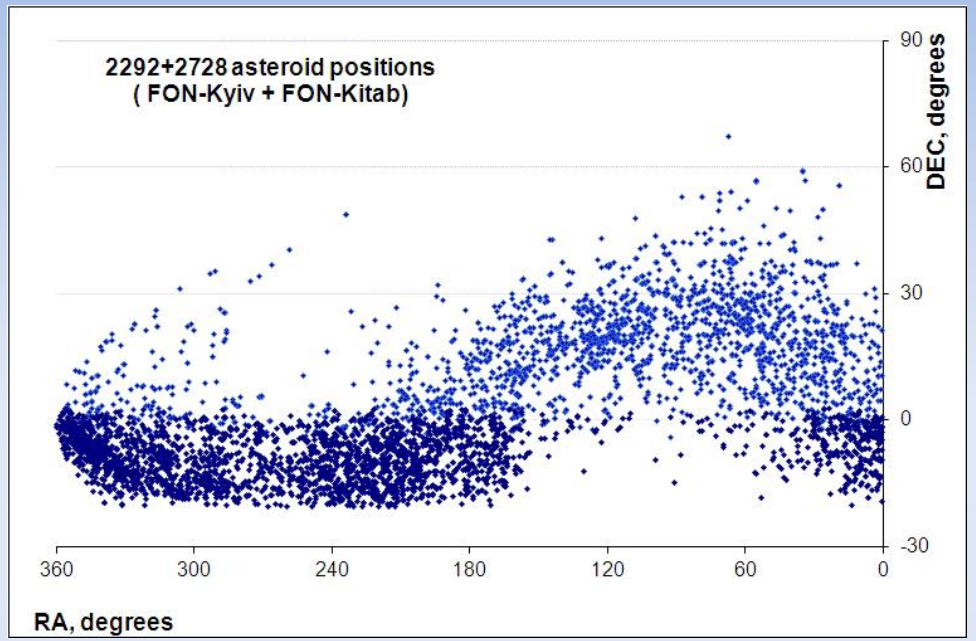
Microtek SkanMaker 9800XL TMA

n	B	σ_α	σ_δ	N
1	6.81	0.395	0.435	4
2	7.66	0.369	0.383	25
3	8.59	0.263	0.239	100
4	9.60	0.159	0.145	281
5	10.59	0.128	0.127	721
6	11.58	0.117	0.117	2024
7	12.45	0.128	0.128	2416
8	13.31	0.137	0.136	512
9	14.22	0.129	0.200	19
	11.80	0.130	0.129	6103

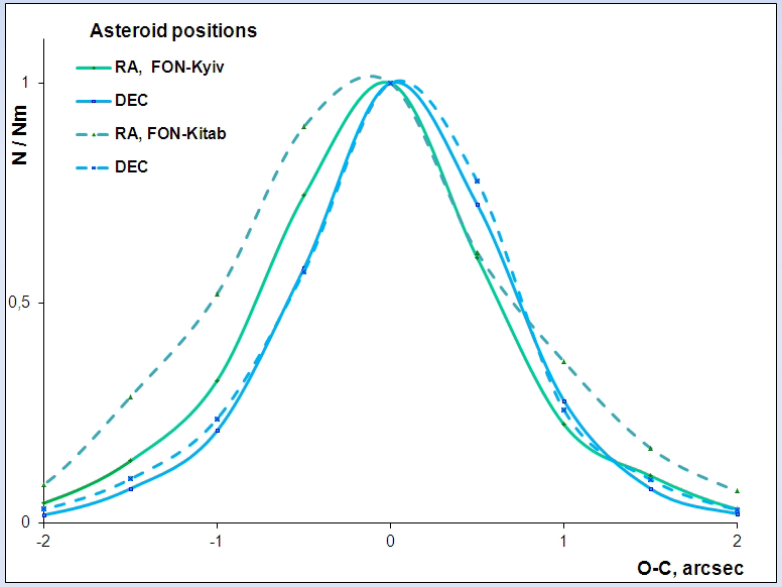
F

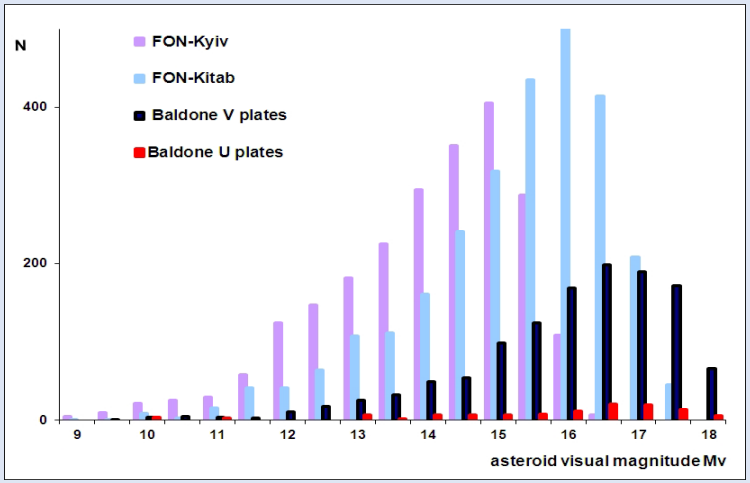


FON-Kyiv + FON-Kitab : 2292+2728 asteroid positions and magnitudes



(http://gua.db.ukr-vo.org/starcatalogs.php)
VizieR On-line Data Catalogs:
2019yCatp003003401S
2021yCatp063003101S

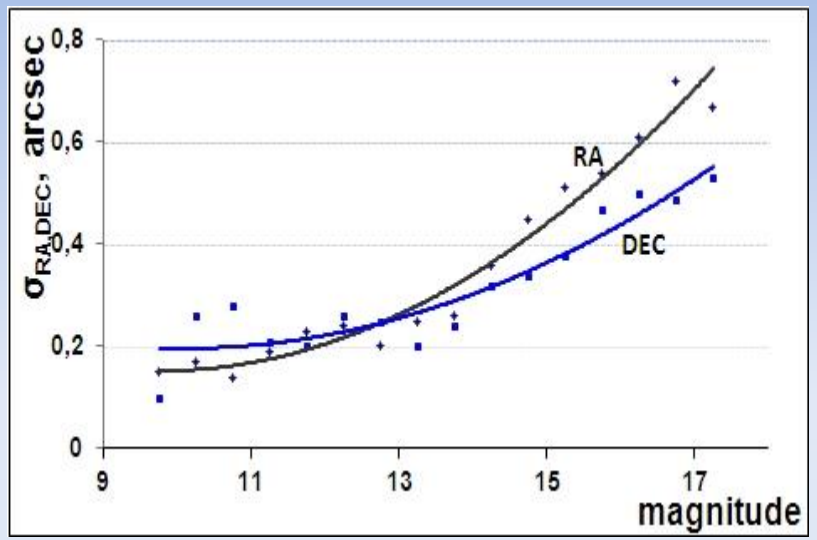


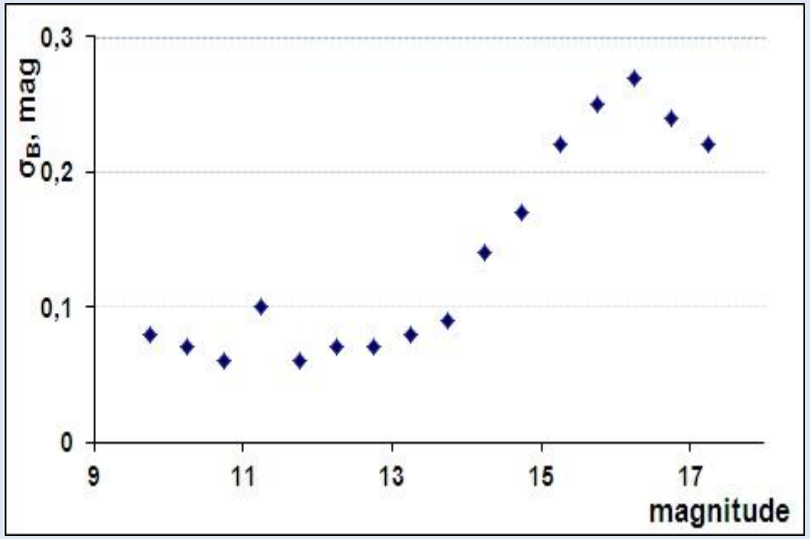


Comparison of all asteroid positions with ephemeris demonstrates a **good agreement** between the results obtained from the FON-KYIV and FON-KITAB digitized images.

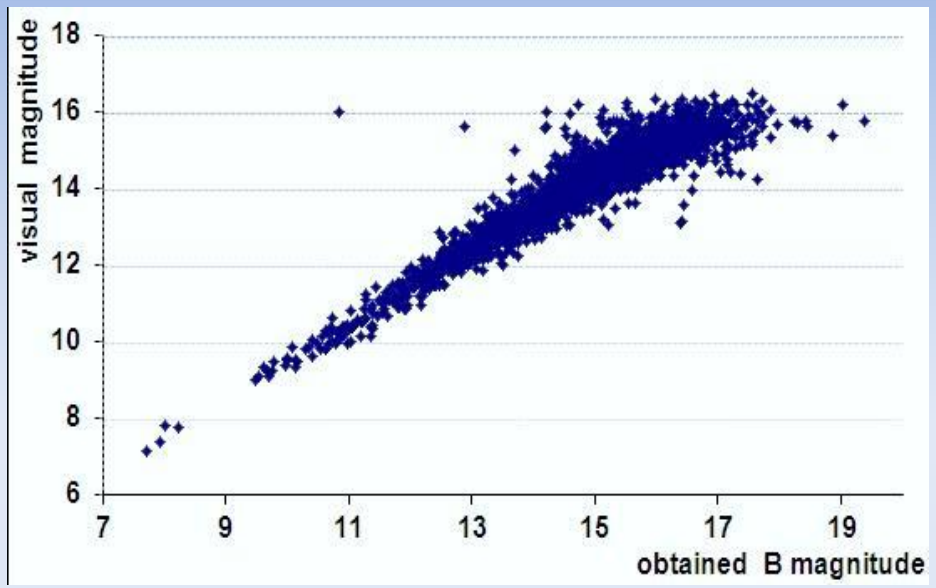
Asteroids down **to 16^{m}** stellar magnitude, which were identified from the FON-KYIV part, down **to 17 – 17.5^{m}** from the FON-KITAB, and down **to 18^{m}** from the Baldone archive

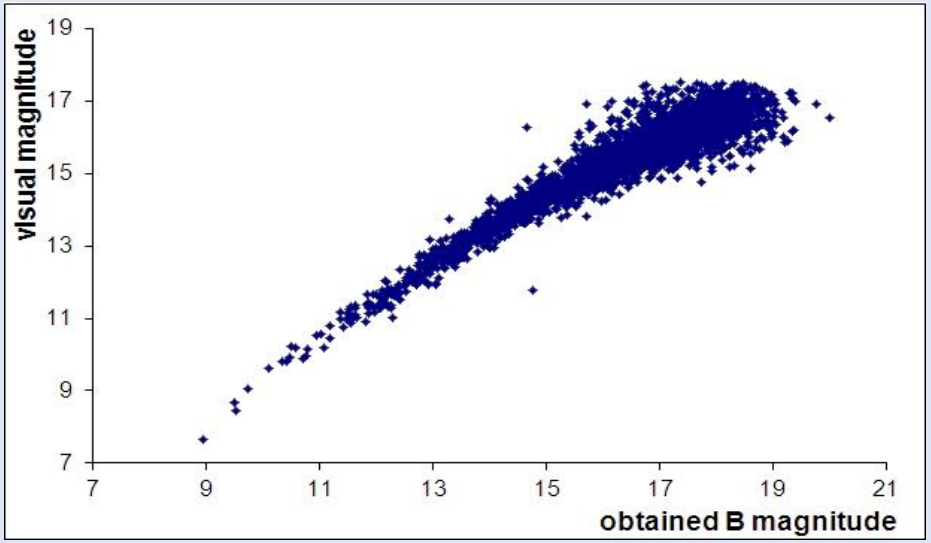
FON-Kyiv + FON-Kitab :





RMS errors of asteroid coordinates (top) and magnitudes (bottom) in FON-Kitab sky survey

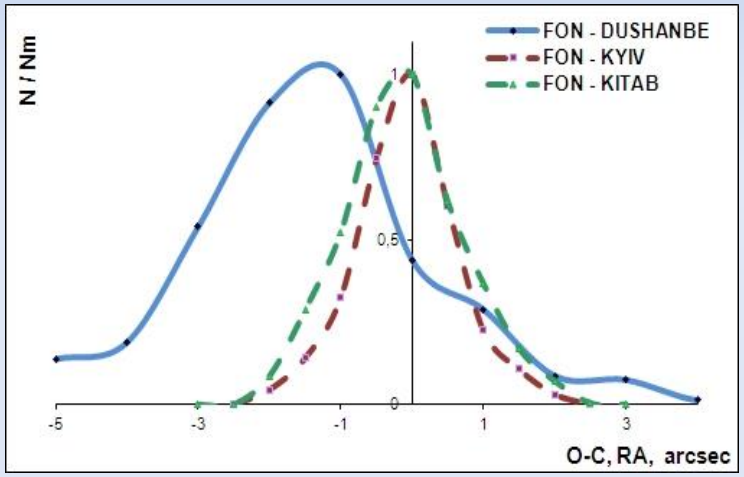


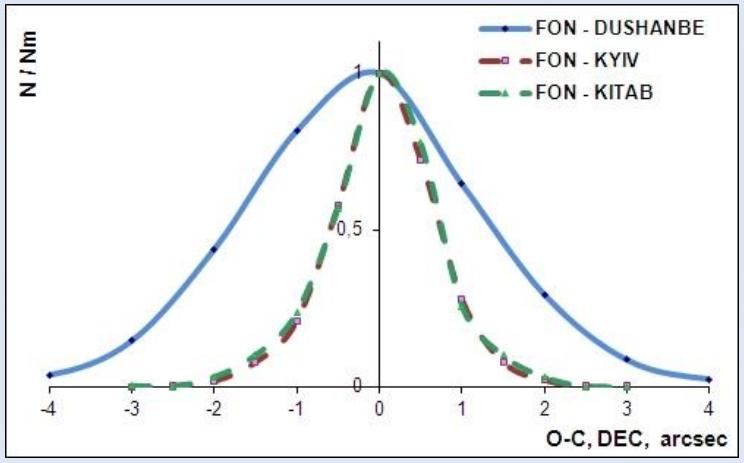


Distribution of B-magnitudes of asteroids for FON-Kyiv (top) and FON-Kitab (bottom) surveys

FON-Dushanbe – third part of the Northern Sky Survey project in 1985-1992 on the Zeiss-400 astrograph at the Hissar Astronomical Observatory of the Institute of Astrophysics of the NAS of Tajikistan

First results - about 300 positions and magnitudes of asteroids.





The O-C differences in both coordinates for all asteroids are presented in comparison with similar data for FON-Kyiv and FON-Kitab.

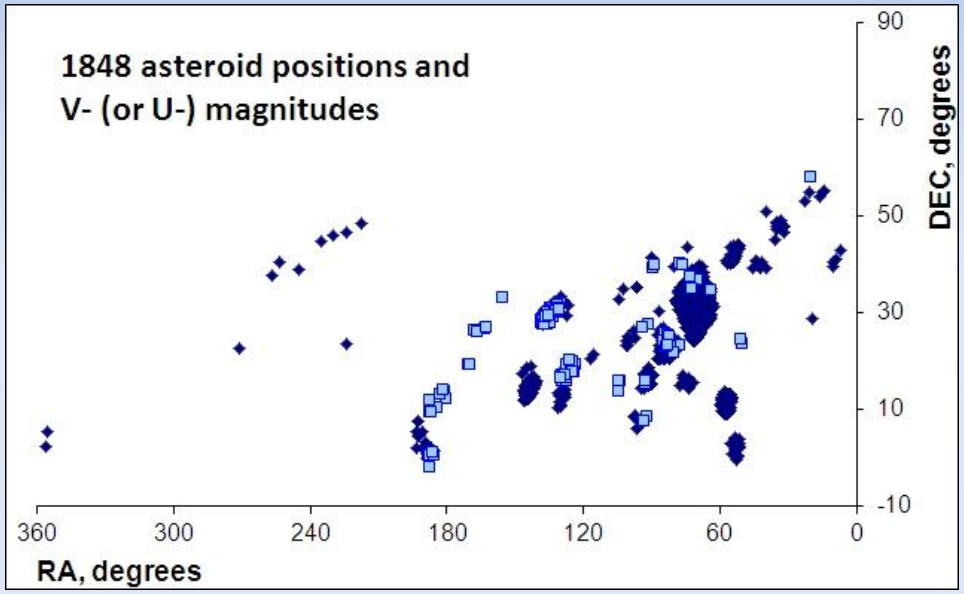
A systematic O-C shift is noticeable in the RA coordinate for all asteroid positions from the two FON-Dushanbe zones.

The further analysis using data of orbital velocities of asteroids near the observational moments shows a clear correlation of the O-C with the value of their orbital velocities. The last could be the result of systematic underestimation of time in positions of asteroids.

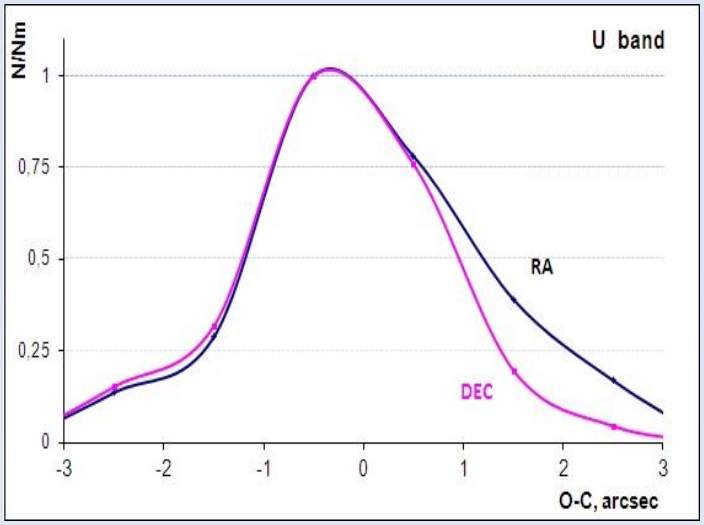
In the future, this systematic component should be clarified and excluded.

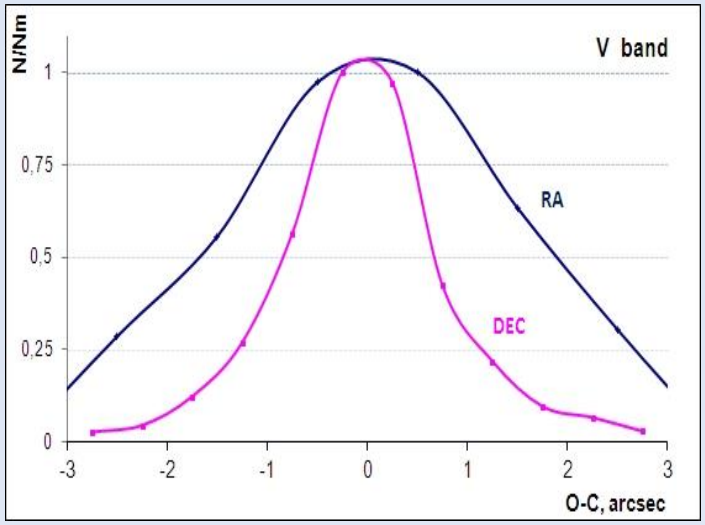
The Baldone astroplates with U- and V- filters :

Result - 1848 positions and magnitudes of asteroids from **1967-1995** observational period (http://gua.db.ukr-vo.org/starcatalogs.php)



The catalog includes 1678 and 170 asteroid positions and magnitudes from observations in the V and U bands, respectively. It also contains seven positions and magnitudes of comets.

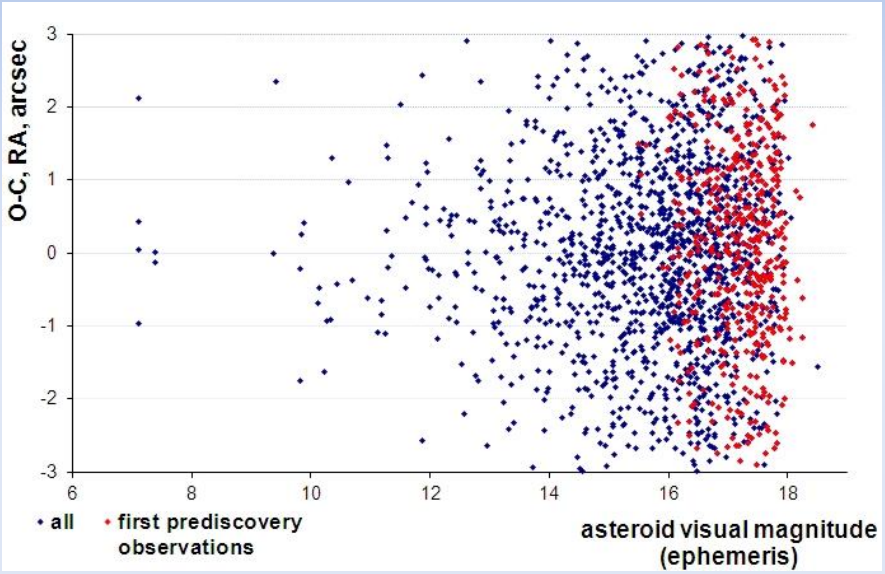


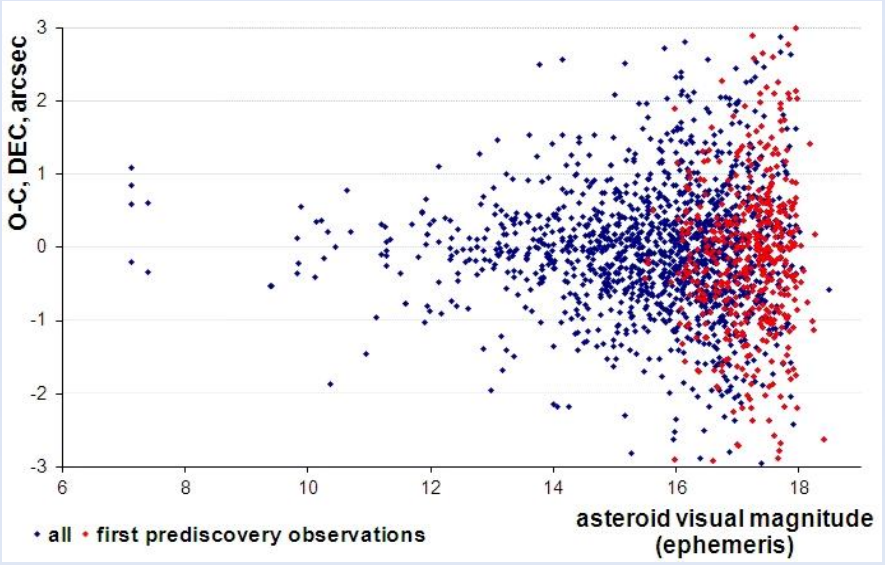


Histograms of O-C differences after comparing all positions of asteroids with JPL ephemeris

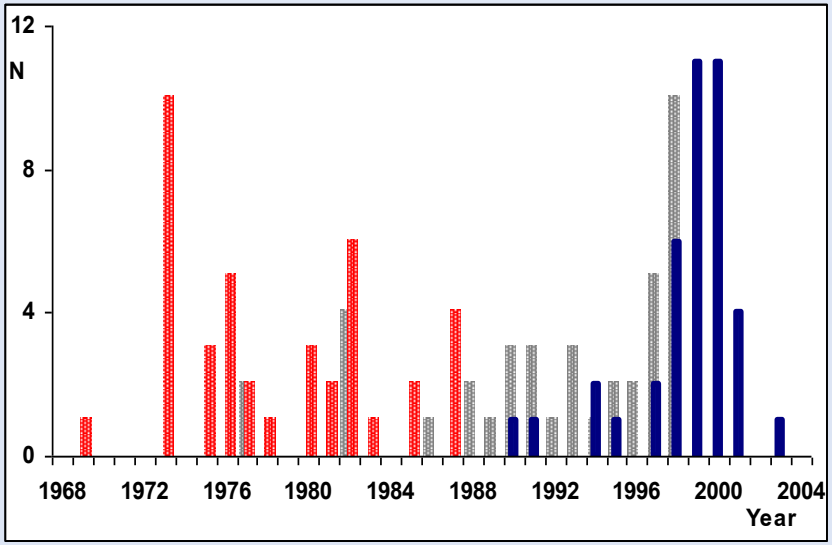
Precovery asteroid positions from the Baldone astroplate archive

Distribution of O-C differences along both coordinates for all and precovery asteroid positions





Among the objects in this catalog are asteroids of particular interest. It was found that **490 faint asteroids** have the first prediscovery observations with the Baldone Schmidt telescope. The discovery of these objects took place only 20-40 years later.



For example, 40 Baldone observations of asteroids (red markers) chronologically precede the first similar asteroid observations of the MPC database

The Tautenburg Schmidt telescope archive

Our another upcoming project on the catalog of asteroids is based on the Karl Schwarzschild Tautenburg Observatory database of asteroids (Boerngen (1991)).

Based on the data of processing the plates, a test search for images of asteroids and other objects of the Solar System registered on the plates in moments of their exposition was conducted.

Plate	Date, UTC	asteroid	RA	DEC	V mag
1232	1963 09 16.986806	2145	01 36 57.172	+29 25 40.93	15.91
2127	1965 10 24.169792	383	07 39 28.793	+21 20 29.77	13.98
2127	1965 10 24.169792	1181	07 39 24.304	+20 54 14.29	15.08
2134	1965 10 30.069792	383	07 43 45.547	+21 14 42.30	14.41
2134	1965 10 30.069792	1181	07 45 08.344	+20 24 30.08	14.85
2134	1965 10 30.069792	2525	07 32 26.256	+22 00 35.29	15.90
2135	1965 10 30.104514	383	07 43 46.364	+21 14 41.42	14.26
2135	1965 10 30.104514	1181	07 45 09.503	+20 24 23.31	14.76
2135	1965 10 30.104514	2525	07 32 26.777	+22 00 34.86	15.84

Positions and V-magnitudes of asteroids identified on the plates of Tautenburg Schmidt telescope (the preliminary results).

Conclusions

We present results of past (FON-Kyiv, FON-Kitab archive) as compare with our current (FON-Dushanbe, Baldone observatory archive) projects related to the processing of old photographic astroplates with aim to find backward observations of moving objects such as asteroids and comets. Some of them could occur the earliest observations of the objects long before their official discovery. The obtained (O-C) differences evident about good accuracy, so these catalogs are highly useful for studying dynamical and orbital parameter's changes.

Our another upcoming project on the catalog of asteroids is based on the Karl Schwarzschild Tautenburg Observatory database of asteroids (Boerngen 1991). The common statistics on their type: the most asteroids are objects of main belt, 53 objects are Mars crossers, 110 double/triple asteroids, 1 NEO, 19 comets.

All the published catalogs are displayed in VizieR as well as current databases of digitized astroplates are available through http://ukr-vo.org/digarchives/index.php?b1&1.