Digitization of the Pulkovo collection of astronegatives: current status and scientific results

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Pulkovo Observatory

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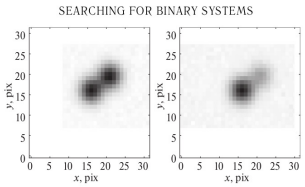
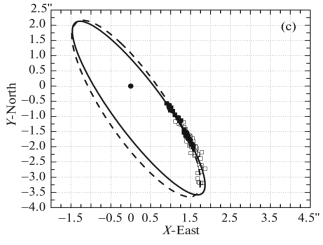
LASA = Lab of Astrometry and Stellar Astronomy

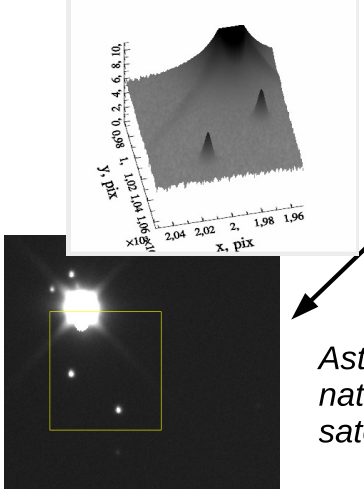


Kinematics and duplicity of dwarf stars in the solar neighborhood

LASA

Visual Double stars. Orbits and invisible satellites.





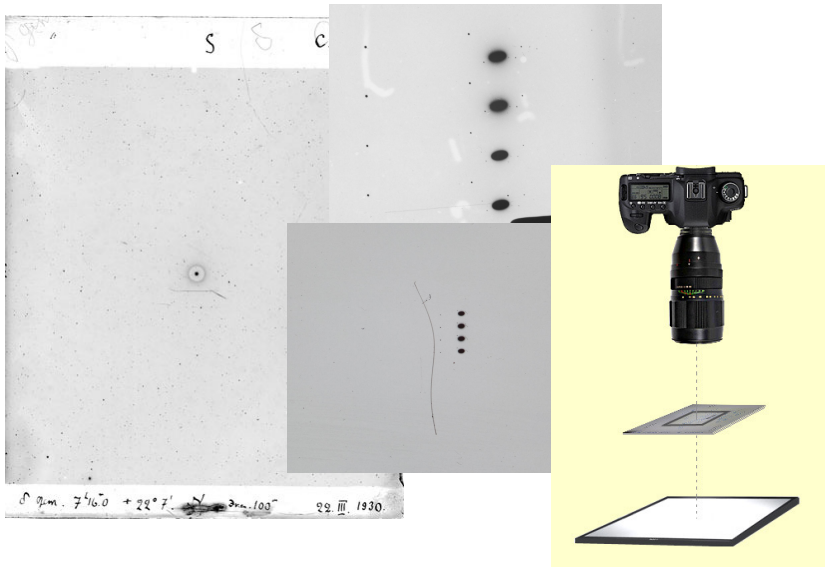
Astrometry of the natural planetary satellites

Scientific goals of Pulkovo photographic observations in the 20th century

- Determination of mutual positions of the visual binary stars components in order to derive the orbits and masses.
- Improvements of ephemerides of Solar system bodies via their equatorial coordinates (mainly planetary satellites).
- Sky surveys for constructing astrometric catalogues in order to extend the reference frame at a large number of faint stars.
- Proper motion surveys (stellar kinematics and open stellar clusters investigations).

Properties of the archive

To this day the plates archive has more than 50,000 astronegatives



26-inch refractor - 22,222 pl. (1956 - 2007)
Normal Astrograph - 16,353 pl. (1894 - 2004)

Expeditionary Astrograph
Ordubad, Azerbaijan - 2255 pl. (1974-1994)
Tarija, Bolivia - 5486 pl. (1982-1994)
... and a lot of small sets of astronegatives.

The 26-inch refractor and Normal astrograph are basic telescopes of the collection...

The 26-inch refractor

D=0.65 m, F=10.5m, FOV=30 $\times$ 30 arcmins, scale=19.81 arcsec/mm

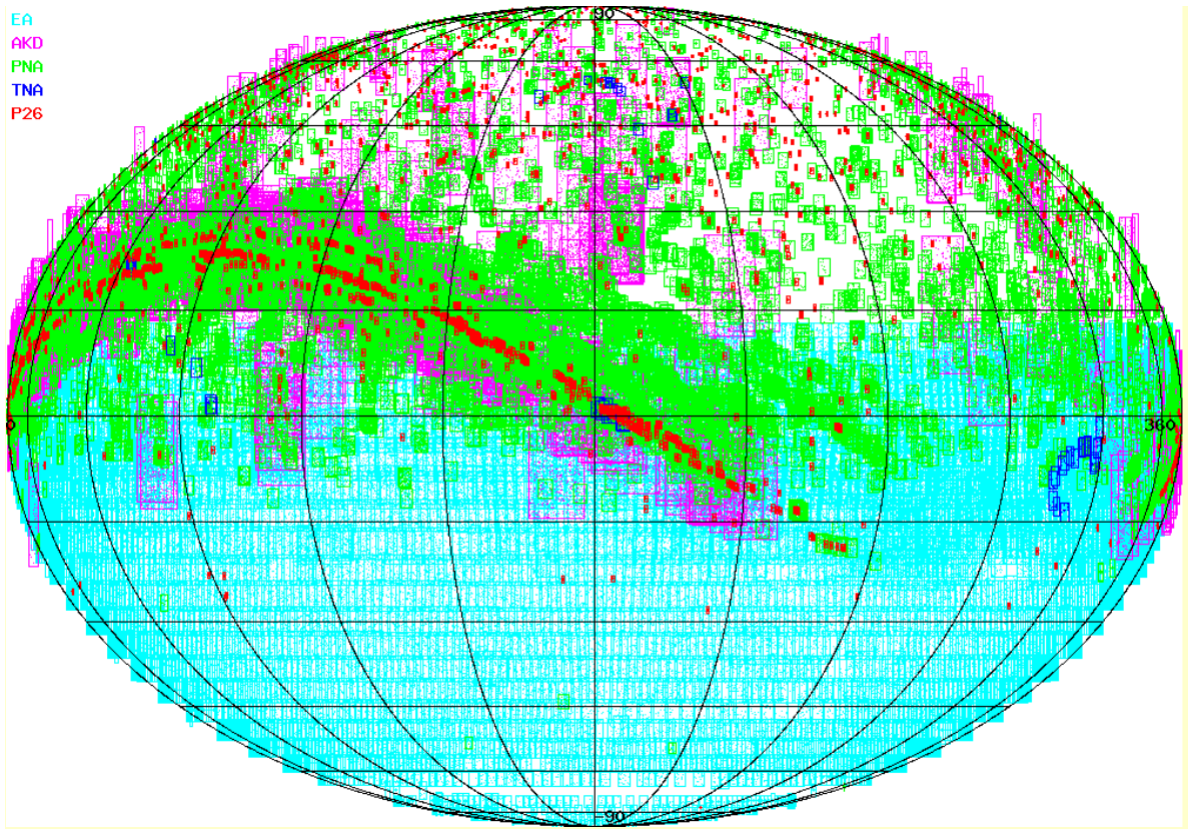
The 26-inch refractor web cam

The Normal astrograph

D=0.33 m, F=3.5m, FOV=2 $\times$ 2 deg, scale=60.0 arcsec/mm

The Normal astrograph web cam

Distribution of the plates over the celestial sphere



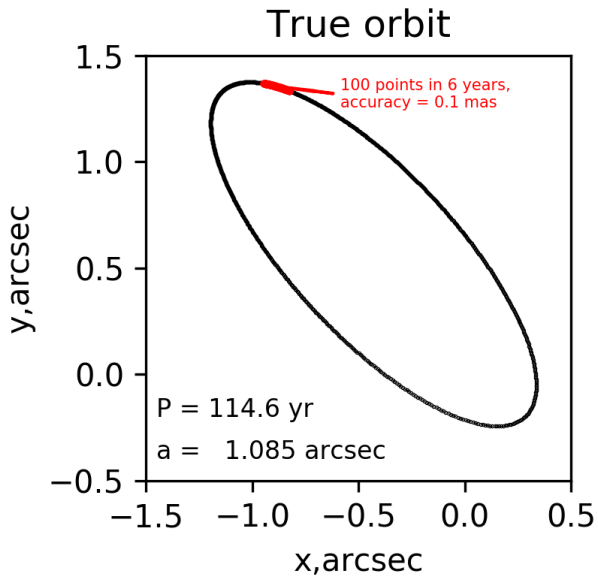
PNA - Normal Astrograph, P26 - 26-inch refractor, EA - Expeditionary Astrograph, TNA - Normal Astrograph at the Tashkent (Uzbekistan), AKD - short focal length astroghraph of the Pulkovo Observatory

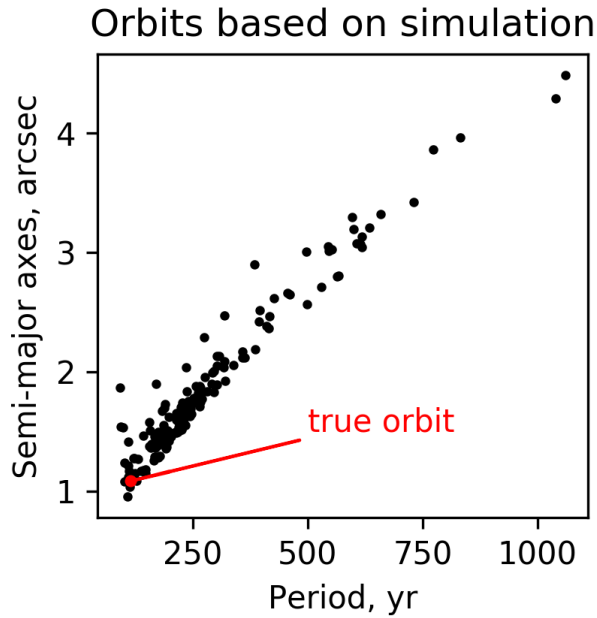
What are the modern goals?

- So,... what is it about wide binaries? The statistical parameters of binaries population reflect formation history and dynamical evolution. And now only about 3000 orbits of 150.000 binaries are available.

What are the modern goals?

Wide binaries in the Gaia epoch

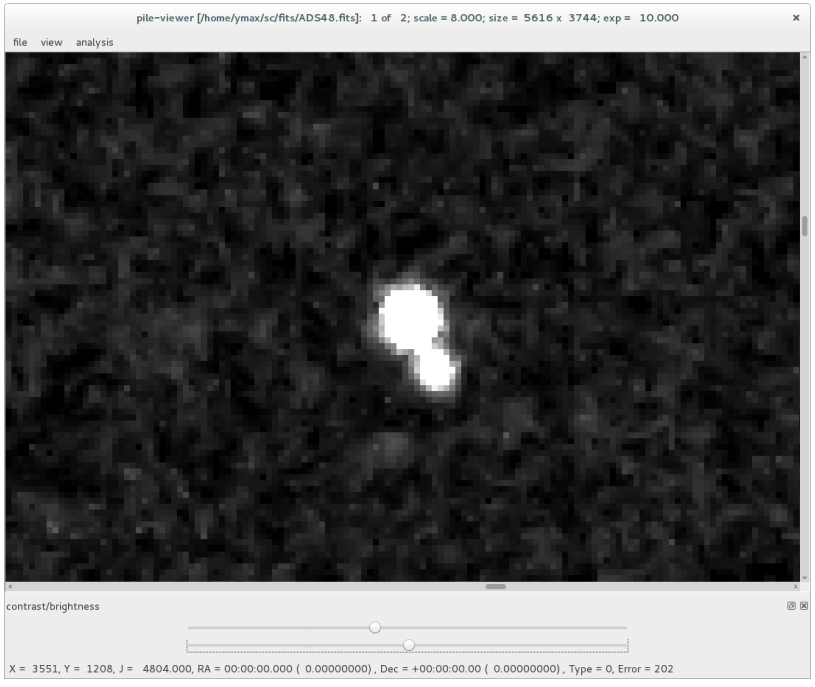


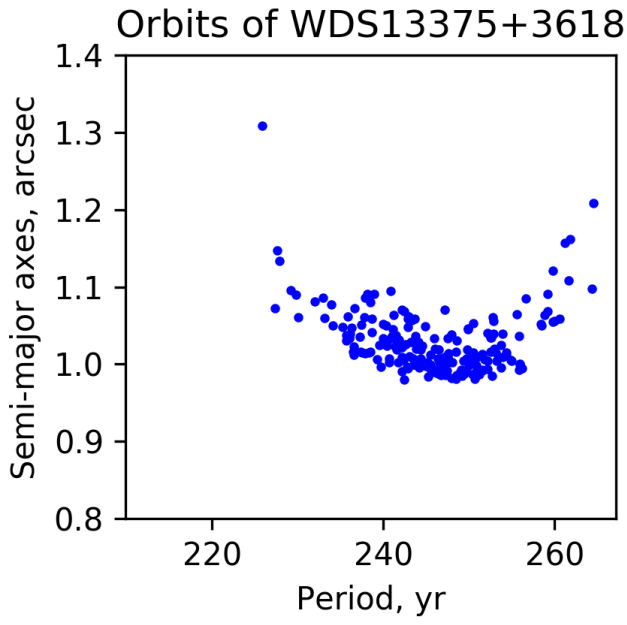


Lets imagine typical orbit and simulate 200 sets of observations with Gaia mean accuracy and mission duration.

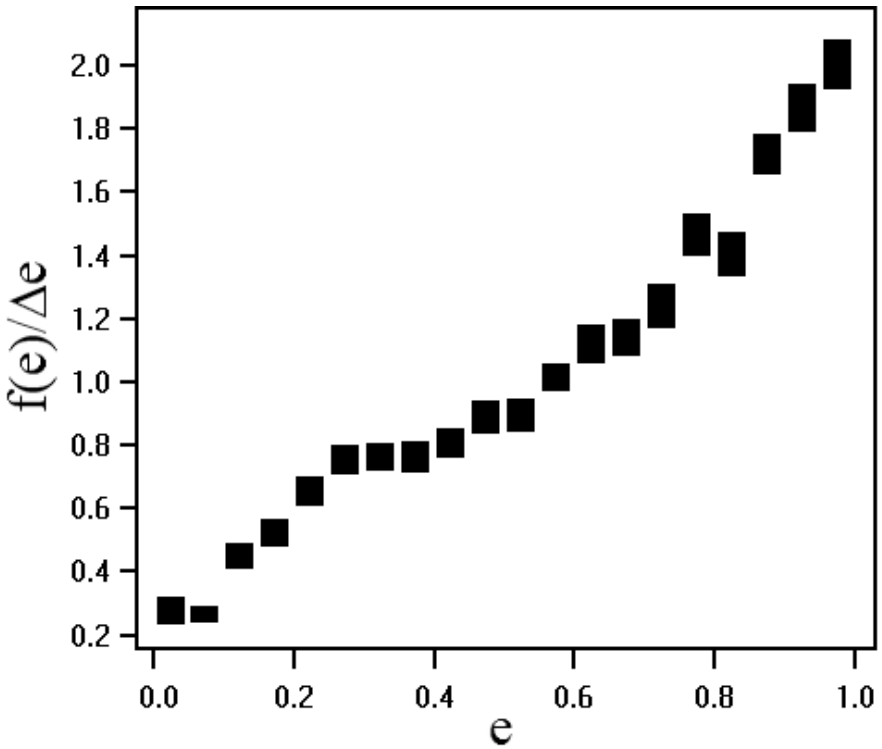
Right panel of figure above contains 200 points for appropriate orbits. As we see, Gaia provides incomplete data set for accurate orbit determinations of relatively wide pairs. As a result, we should use old ground based observations and/or conduct new of ones.

An example of ‘good’ set of orbits (wds13375+3618) resulted from digitization of the Pulkovo photographic observations





The binary stars. The first results of digitization

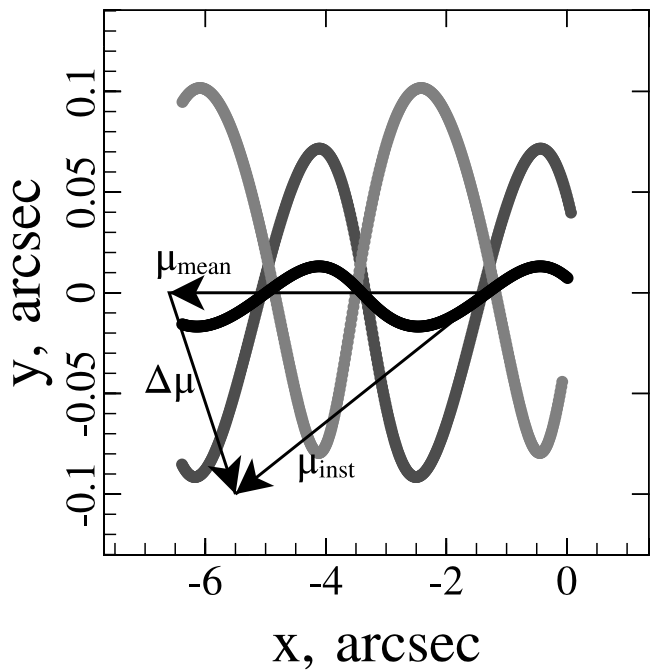


About 9000 of plates with binaries have been digitized. The results of the measurements have been combined with the data of CCD-observations performed using the 26-inch refractor. Finally, the orbital parameters of 451 binaries have been determined. The relative positions and proper motions calculated with these orbital parameters are in good agreement with the Gaia data (differences are less than 5 mas and 0.5 mas/yr correspondingly). Relatively large values of differences might be caused by the presence of previously unknown components. The eccentricity distribution supports the 'thermal distribution hypothesis' ($f = 2e$).

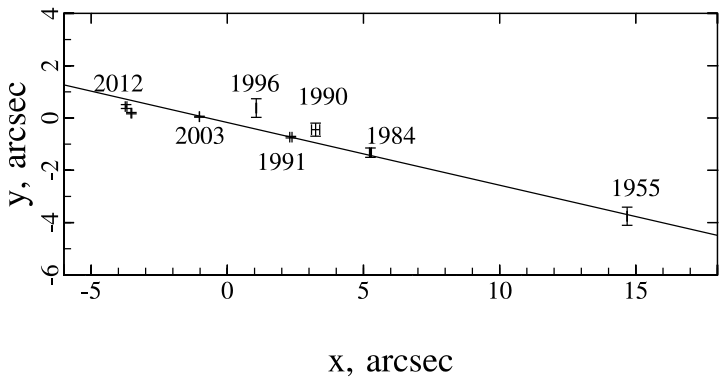
What are the modern goals?

- Finding unrevealed astrometric binaries.

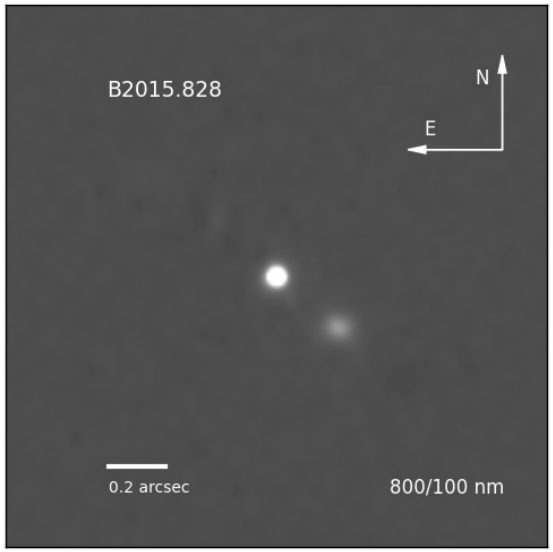
$\mu_{mean} = (Gaia - OldPhotographicpositions)/\Delta T$, $\mu_{inst} = Gaia\ proper\ motions$



Discovering of the binary nature of the high proper motion star J1158+4239



Photographic and 'traditional' CCD observations



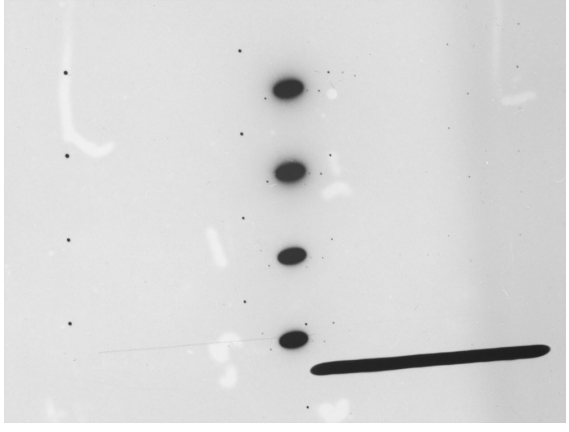
Speckle-interferometry with 6 m BTA telescope (SAO RAS)

What are the modern goals?

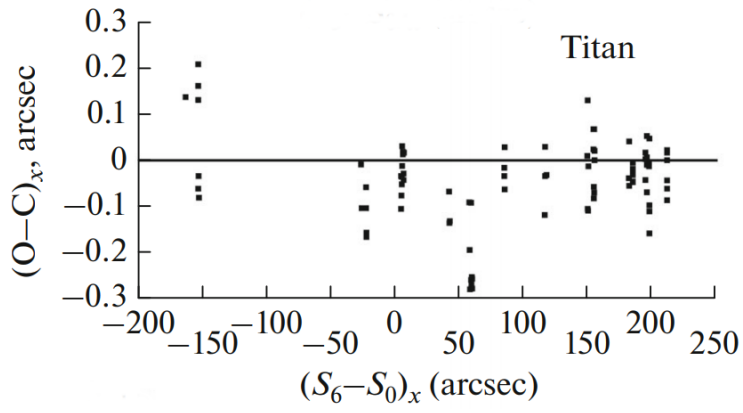
- Long-term evolution of the orbital parameters of the Solar system bodies.
- Connection between the GaiaCRF2 and the dynamical ephemerids reference frames.

The Pulkovo plates contain a lot of the images of the asteroids and planetary satellites. Our goal is redetermination of their position in the Gaia reference frame.

An example of new reduction of the saturnian satellites based on the digitized Pulkovo plates



An example of the Pulkovo astronegative with saturnian system



A behavior of Titan's (O-C) as a function of the Saturn centered positions

Digitization process

MDD = Mobile Digitizing Device

Digital camera Canon EOS 5D Mark II

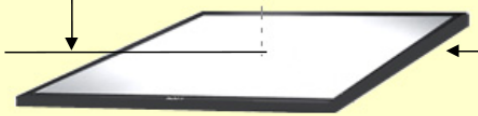
21.1-megapixel
sensor type - **CMOS**
size - **36 x 24 мм**
maximum resolution – **5616 x 3744**
ISO **50 - 3200**

focal length **200 мм**
aperture **1:4.0 ÷ 1:22**
field of view **12°**
resolution (center/edge) **40/30 lines/mm**

~1200 mm

Photographic plate,
digitized area is ~ **80x120 mm**

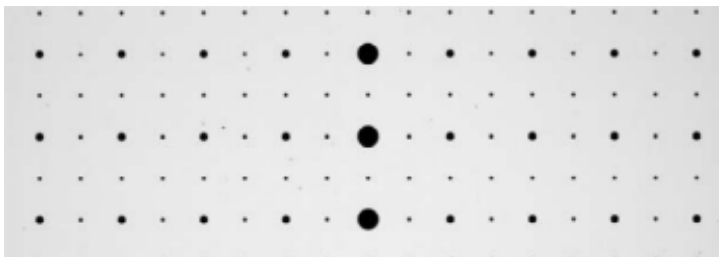
~1200 mm



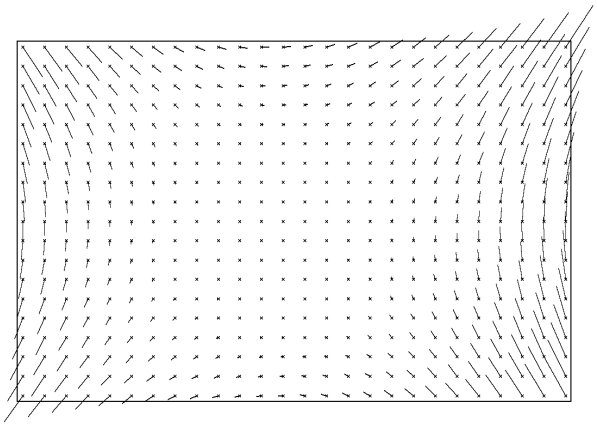
LCD as a backlight
(out of focus depth)

Digitization process

A combination of high accuracy machine measurements (the ROB-digitizer), fast imaging with full format camera is used to extract new astronomical results from Pulkovo astronegatives.



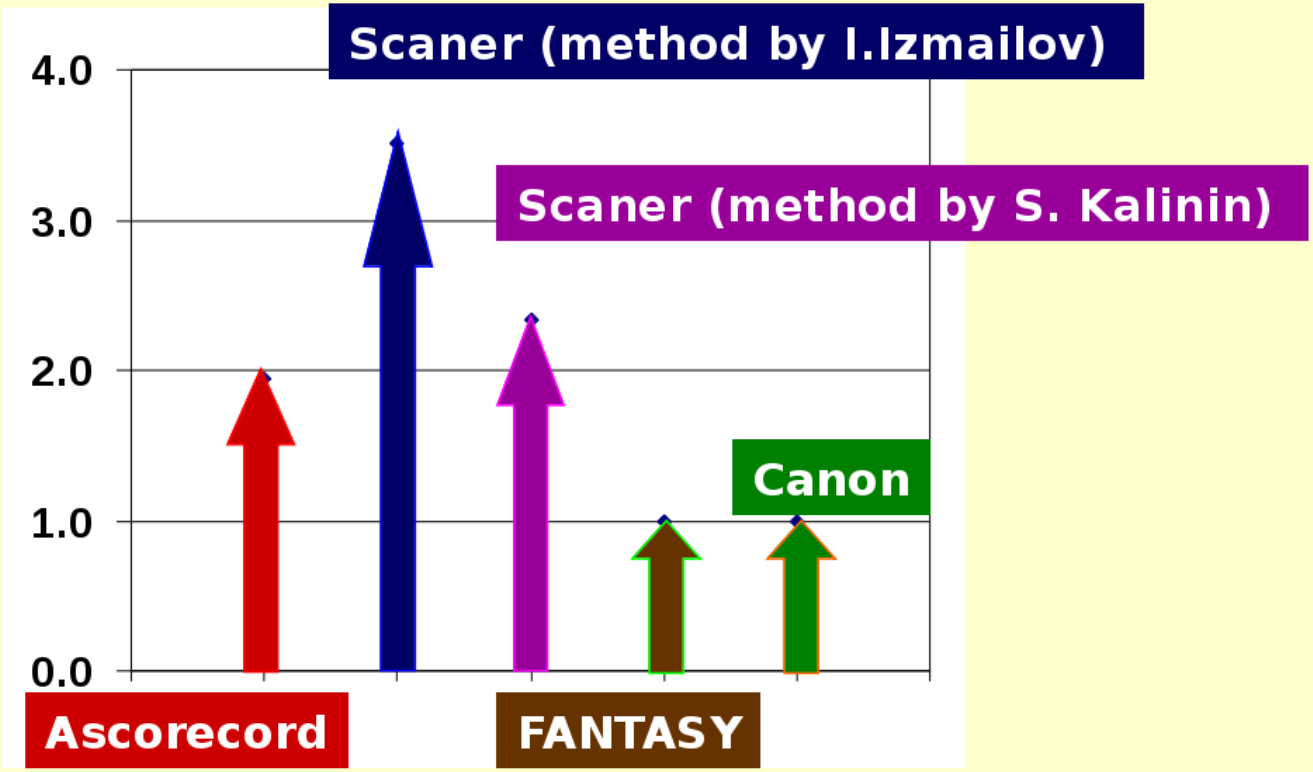
An example of the template scanned with the ROB-digitizer



A field distortion pattern calculated with the template

The accuracy...

As a result, the accuracy of the plate x,y is about 1 mkm. Equatorial coordinates and proper motions from the Gaia catalogue are used to make astrometric calibration. The final astrometric accuracy has been improved up to 10 – 30 mas for binaries and to 50 – 100 mas for planetary satellites.



Canon = MDD

Conclusions

- The Pulkovo astronegatives archive is a rich source of astronomical data for wide epoch differences.
- A combination of high accuracy machine measurements and simple camera imaging allows us to obtain high precision positions in small FOV (e.g. for binaries).
- Digitization of the templates with new generation machines (like NAROO) is required.
- Only fifth part of the Pulkovo photographic archive has been digitized.
- Significant progress has been made with the Pulkovo astronegatives in the field of investigations of the binary stars.

Thank you!

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