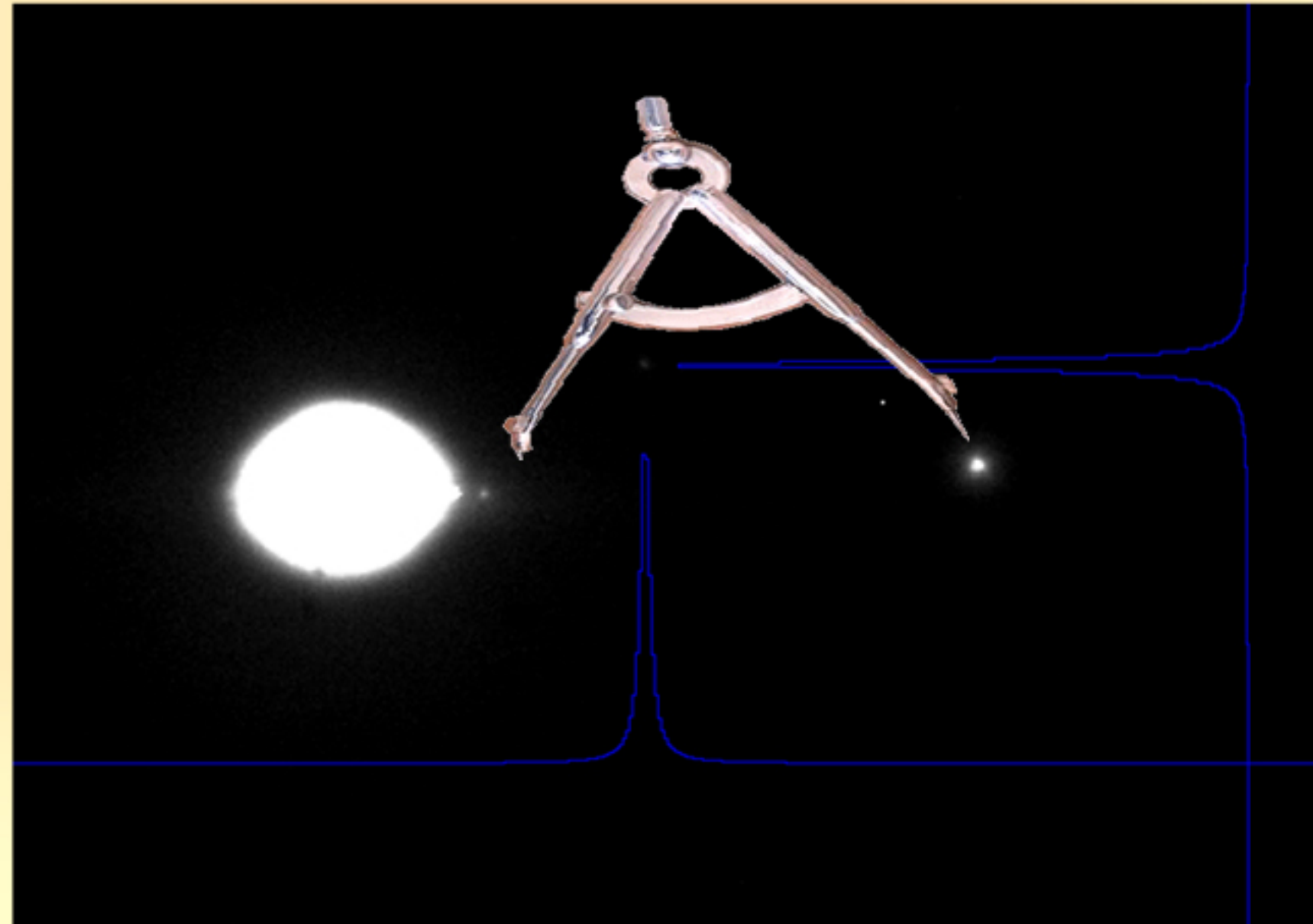


The analysis of accuracy of ephemerides of the Saturnian satellites with Pulkovo Normal Astrograph CCD-observations.

Khrutskaya E.V., **Khovritchev M.Yu.**,
Berezhnoy A.A., Narizhnaya N.V.,
Dement'eva A.A.

Pulkovo Observatory



Pulkovo Normal Astrograph:

Normal Astrograph ($D/F=0.33\text{m}/3.5\text{m}$),
CCD camera: S2C,
FOV = 18×16 arcmin,
Pixel size 900×900 mas



Data reduction

Main stages of reduction procedure...

1. Planetary halo (background gradient) was fitted and subtracted.
2. Determination of pixels positions of satellites (x,y) by PSF fitting.
3. Astrometric reduction....

Standard six constants model was applied. UCAC2 was used as a reference catalogue.

4. Types of the results.

Equatorial coordinates of the satellites referred to UCAC2 system. Relative positions "satellite - satellite" as differences of $RA_{S1} - RA_{S2}$ and $Dec_{S1} - Dec_{S2}$.



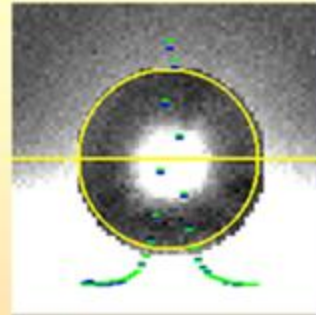
Data reduction.

Planetary halo and smear effects.

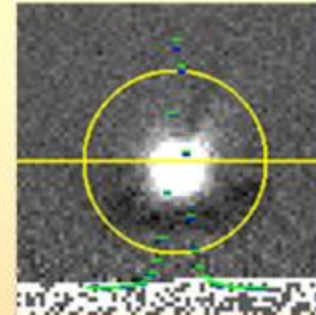
Median filtering.

NA CCD images

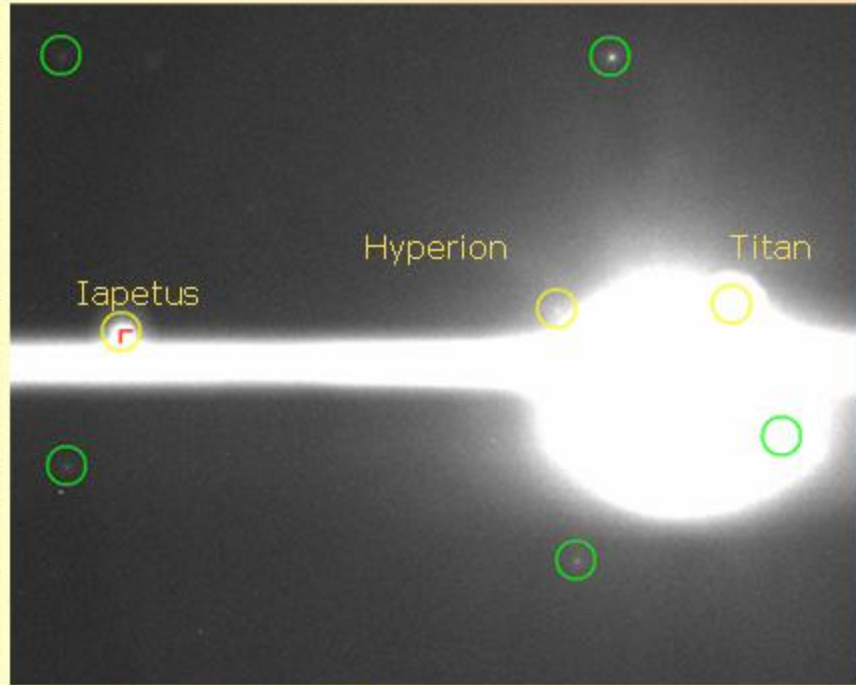
PSF fitting



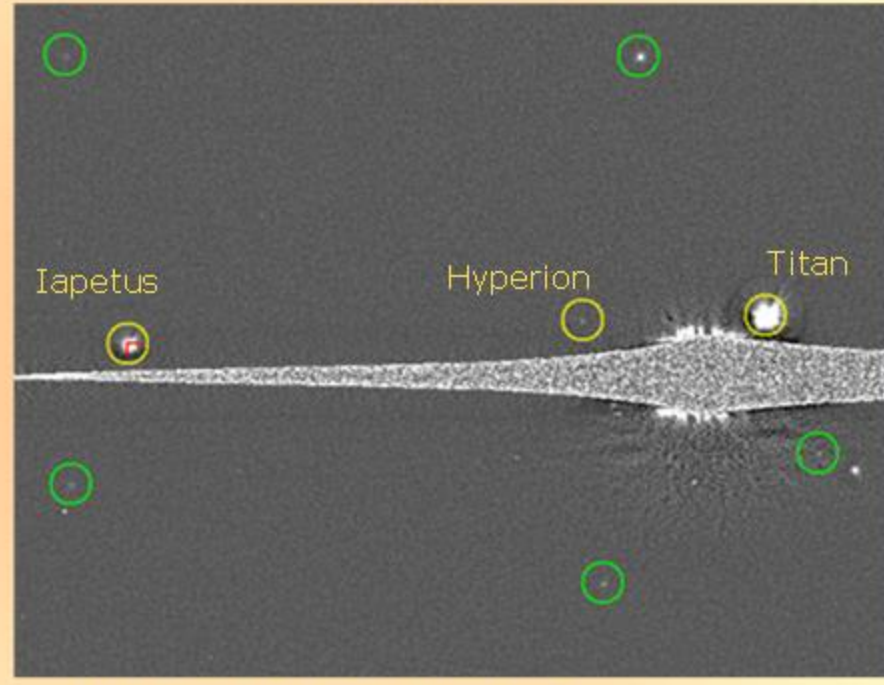
Local approximation.



Median filtering.



Before halo correction.



After median filtering.

Astrometric differences between results of these methods are within 10 mas.

Ephemerides of the satellites were calculated with MULTI-SAT system

The screenshot shows a Mozilla Firefox browser window displaying the website 'IMCCE-SAI: Natural Satellites Service. Ephemerides'. The address bar shows the URL 'http://lnfm1.sai.msu.ru/neb/nss/nssephmr.htm'. The page header includes the logos and names of the Sternberg Astronomical Institute and Moscow University. The main content area features a navigation menu with links for 'Наблюдения', 'Эфемериды', 'Библиография', 'Параметры', and 'Ссылки в интернете'. Below the menu, there is a section titled 'Служба естественных спутников планет. Эфемериды MULTI-SAT.' with language options for 'Français' and 'English'. There are two sections for selecting planets: 'Эфемериды с постоянным шагом по времени' and 'Эфемериды для таблицы моментов и (O-C) для наблюдений', both with buttons for Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto. A footer note indicates 'beagle is indexing http://lnfm1.sai.msu.ru/neb/nss/nssephmr.htm'.

Emel'yanov N.V., Arlot J.-E. The natural satellites ephemerides facility MULTI-SAT. // Astron. and Astrophys. 2008. V. 487. P. 759–765.

Mean values of the (O-C) and standard errors of satellites' coordinates.

Sat.	mean (O-C) RA	(O-C) Dec.	st.err. mas	n

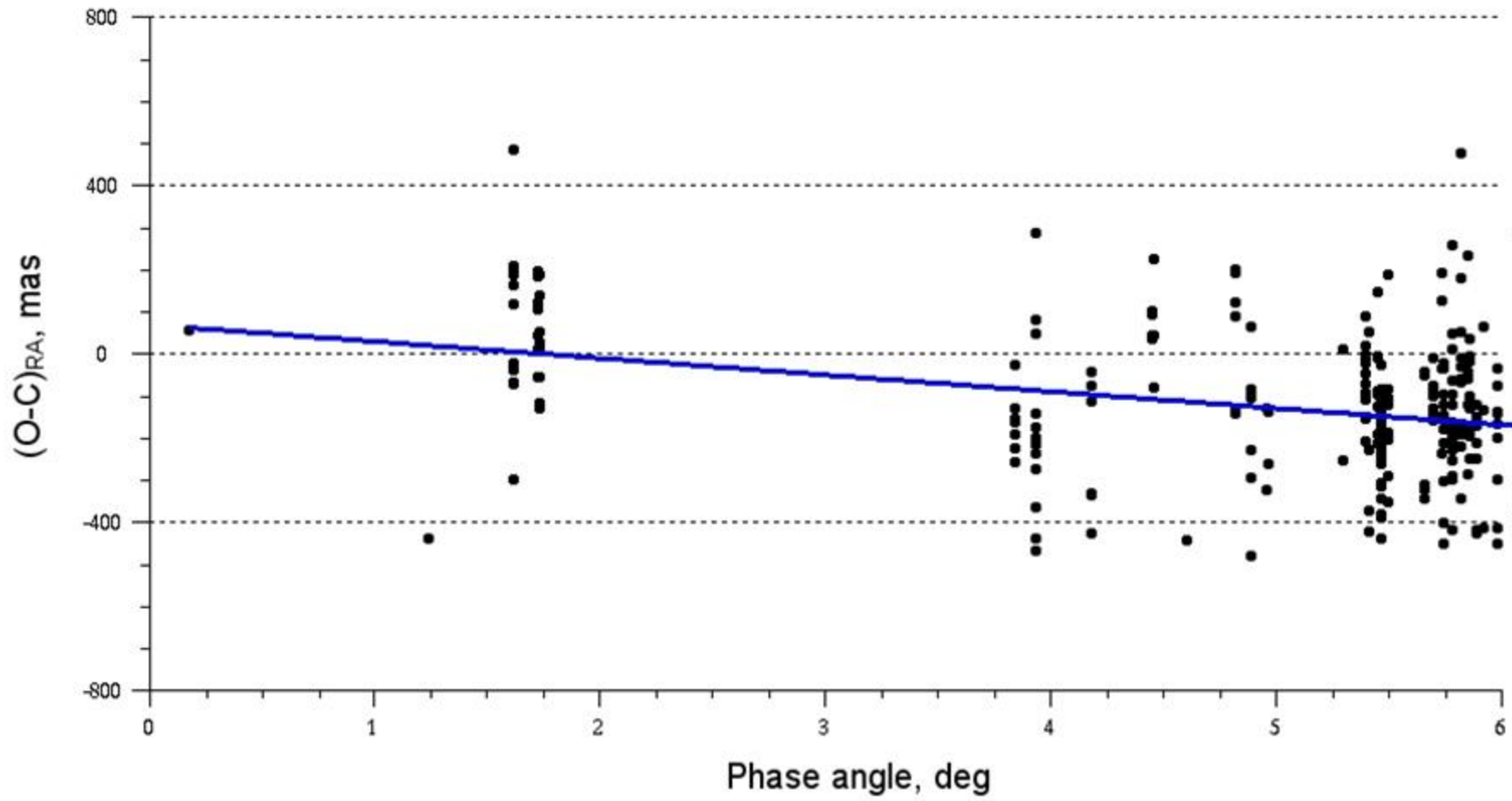
Equatorial coordinates referred to UCAC2				
S5	-79	45	35-80	10
S6	-131	103	20-50	28
S7	17	-9	30-90	21
S8	-47	84	20-80	23

Relative coordinates 'satellites-satellites'				
S6-S5	-77	27	10-80	9
S7-S5	23	-98	60-150	6
S8-S5	231	-122	30-80	6
S7-S6	160	-134	50-90	14
S8-S6	140	-57	30-70	18
S8-S7	-177	81	50-100	11

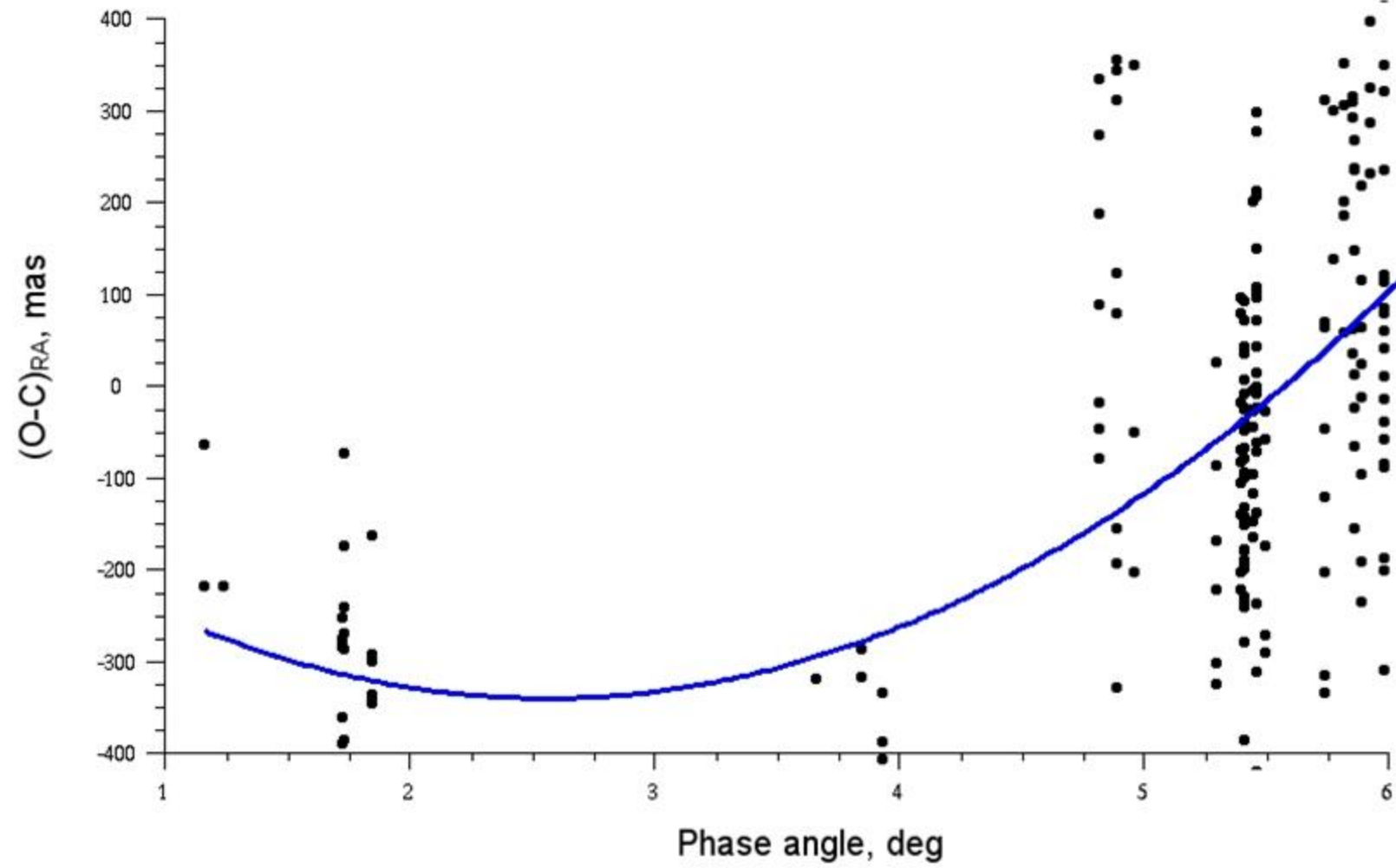
n is number of observations

Satellites' ephemerides = INPOP06+TASS1.7

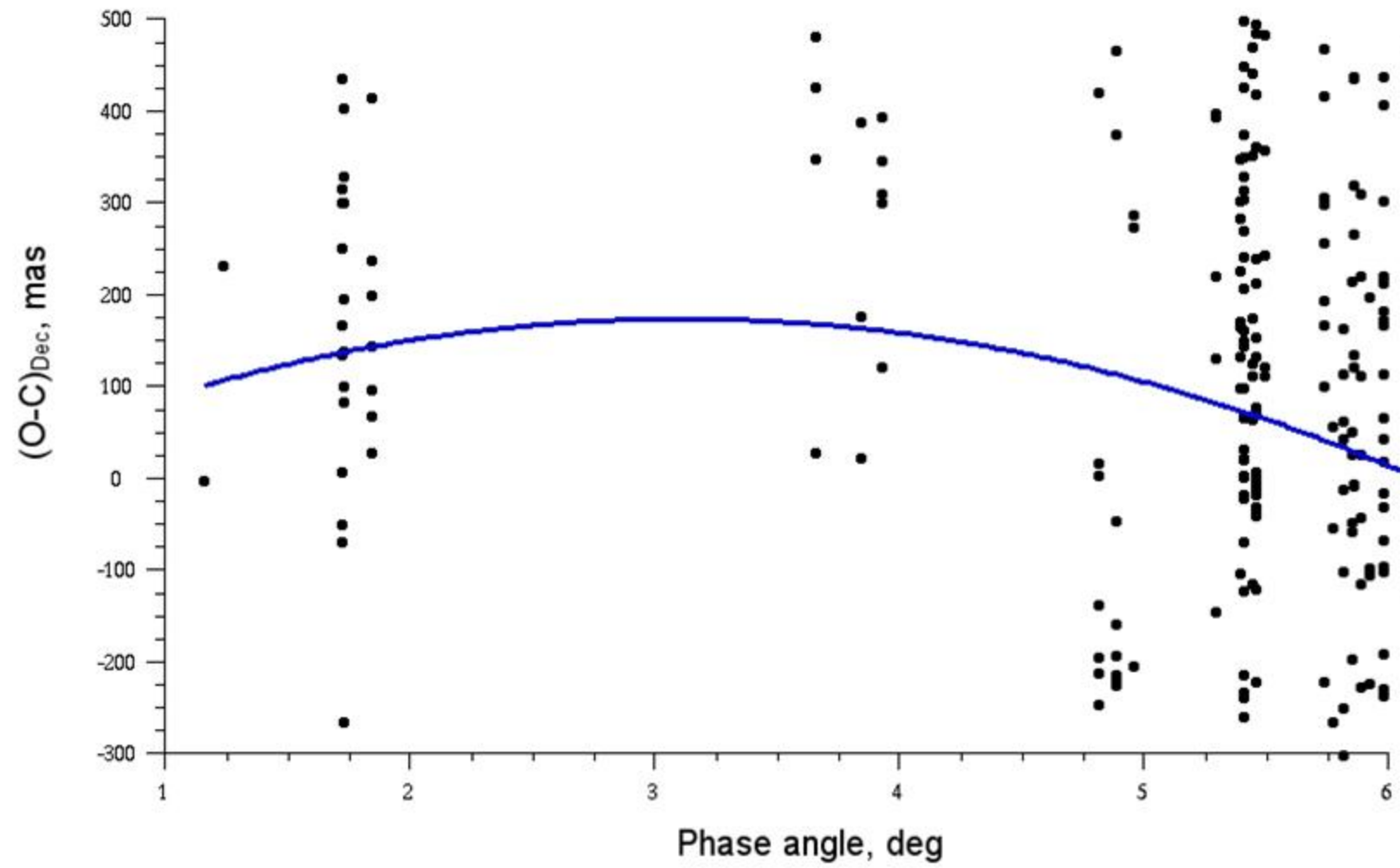
Titan (O-C)_{RA} vs Phase angle



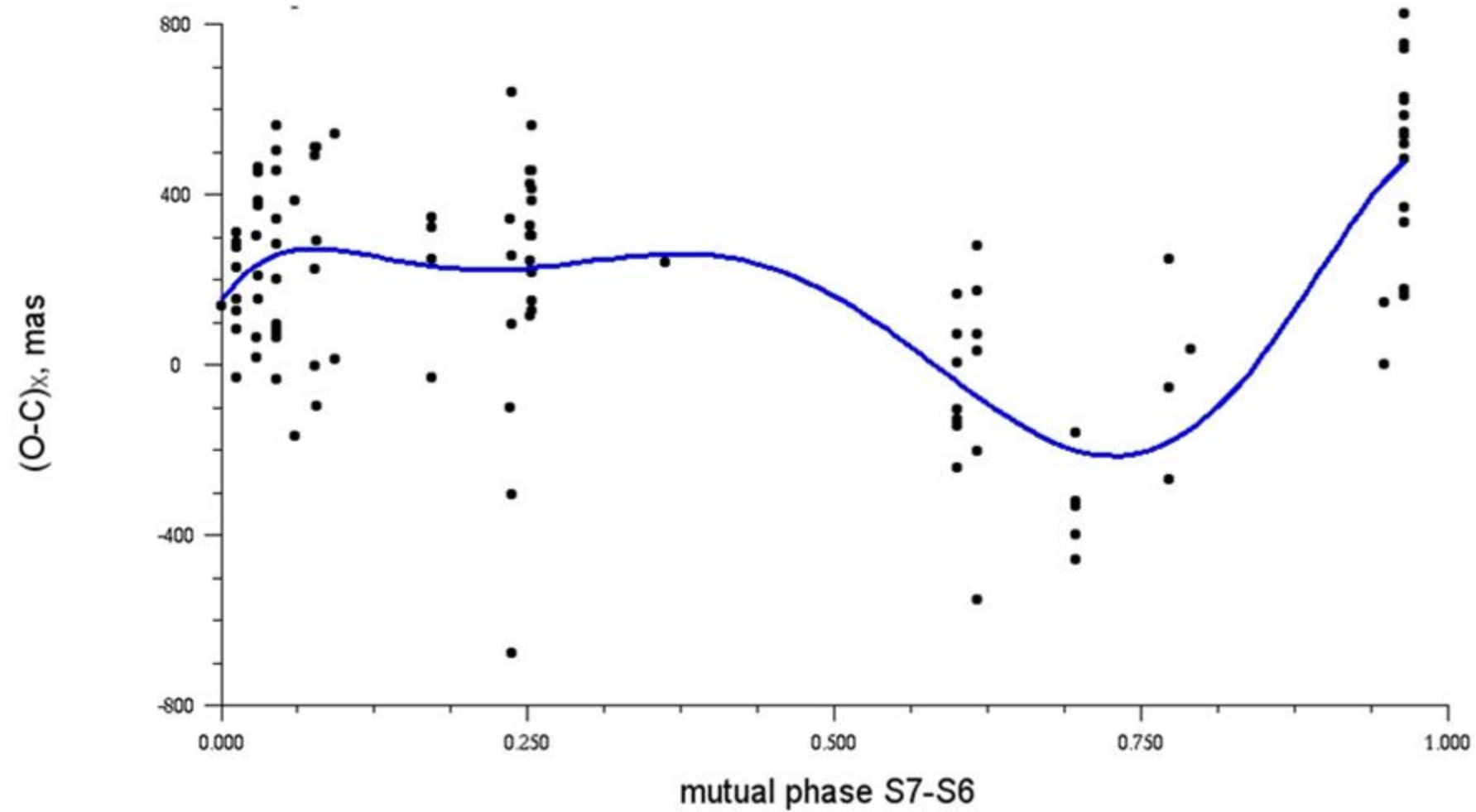
Iapetus $(O-C)_{RA}$ vs Phase angle



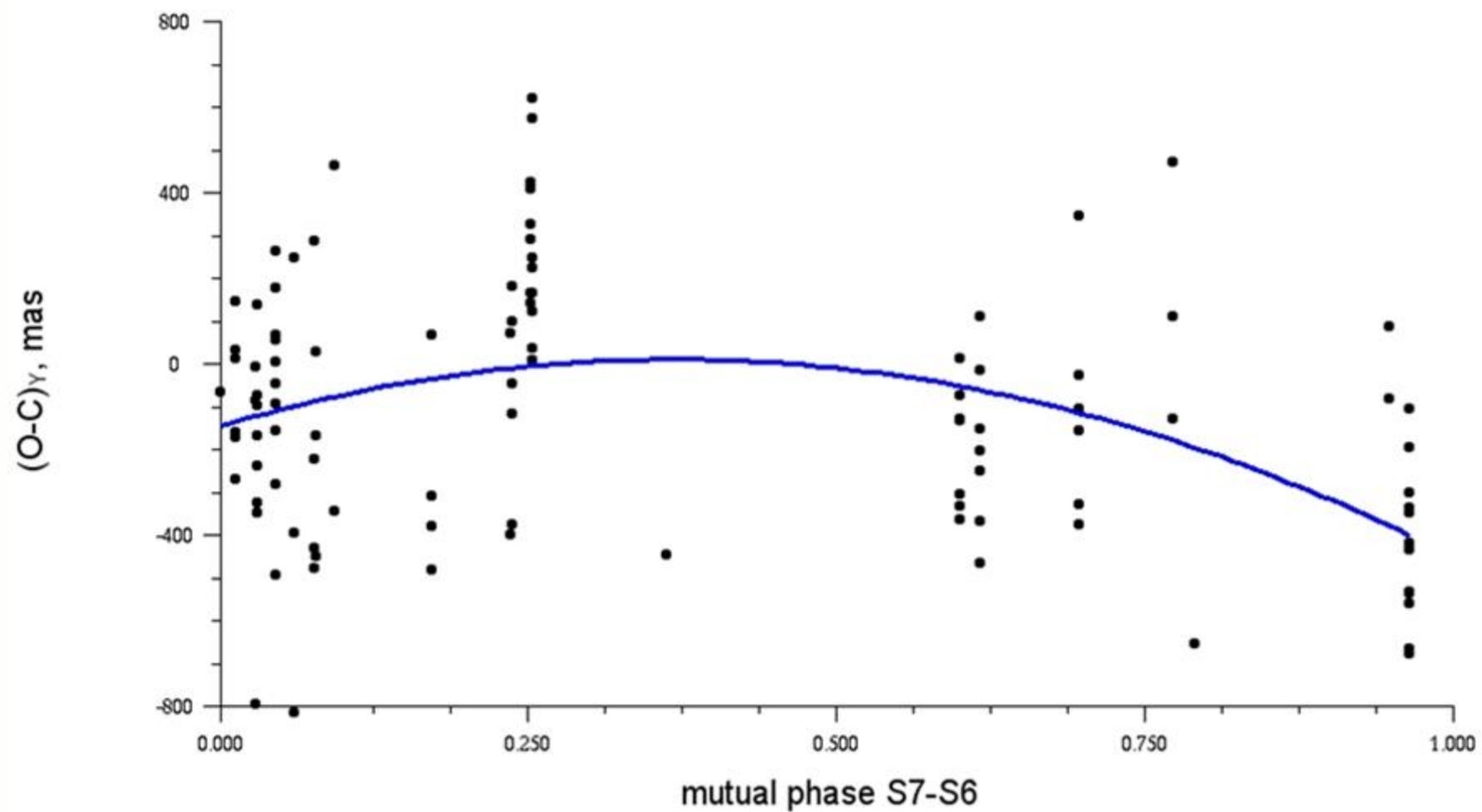
Iapetus $(O-C)_{Dec}$ vs Phase angle



S7-S6 (O-C)_x vs mutual phase

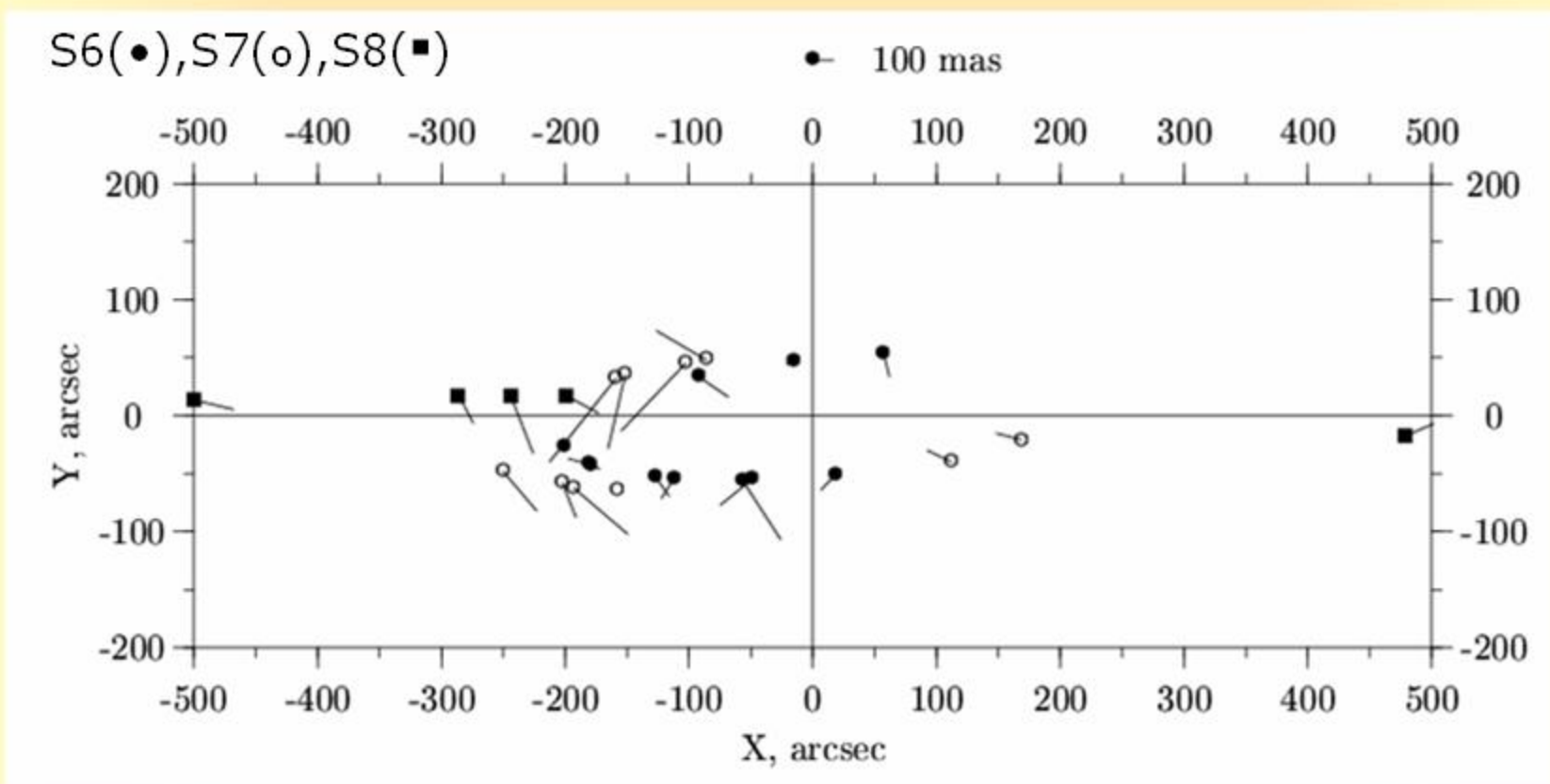


S7-S6 (O-C) γ vs mutual phase

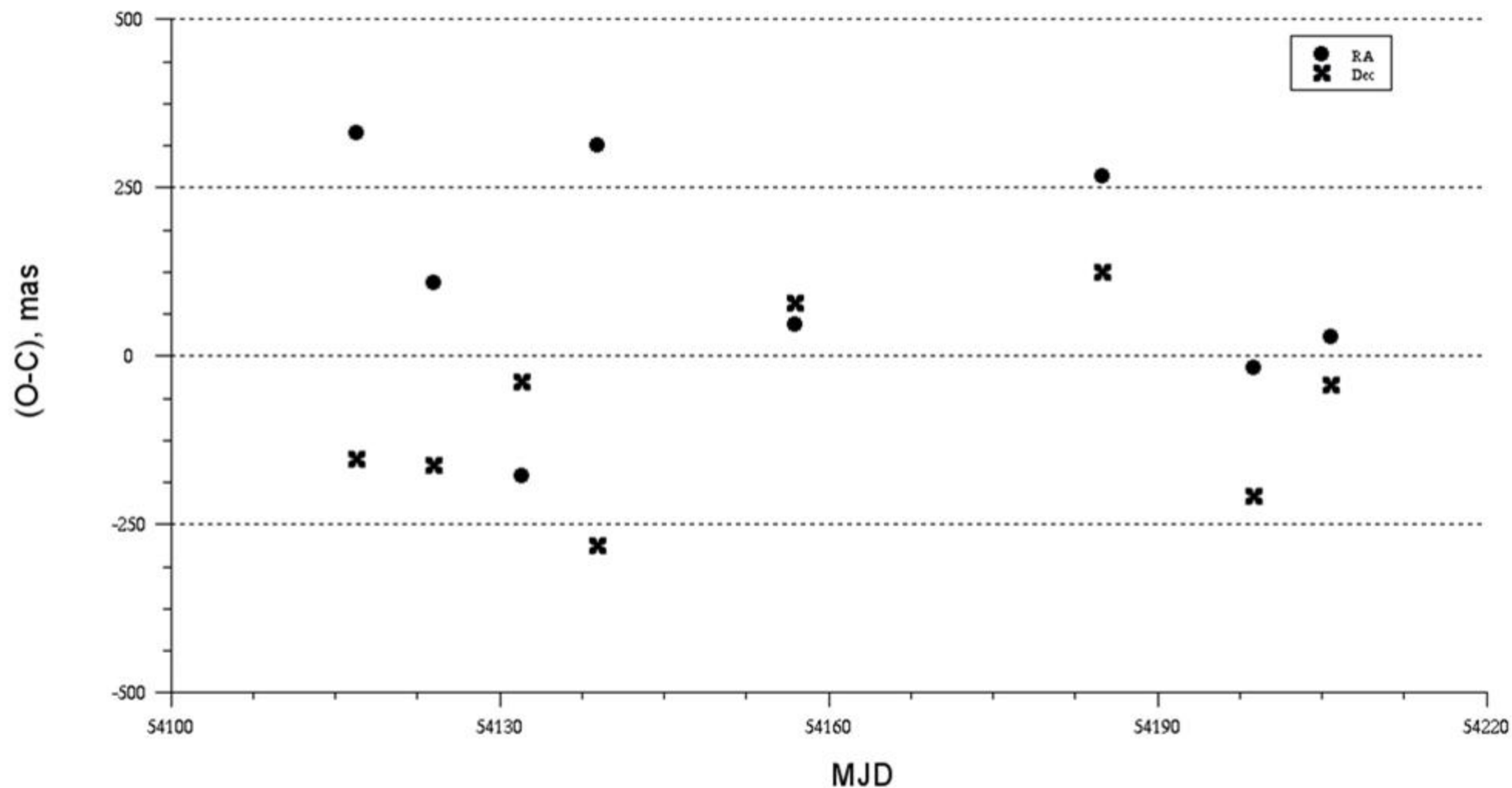


Motions of Titan, Hyperion and Iapetus and their (O-C) vectors.

X,Y - positions referred to Saturn.

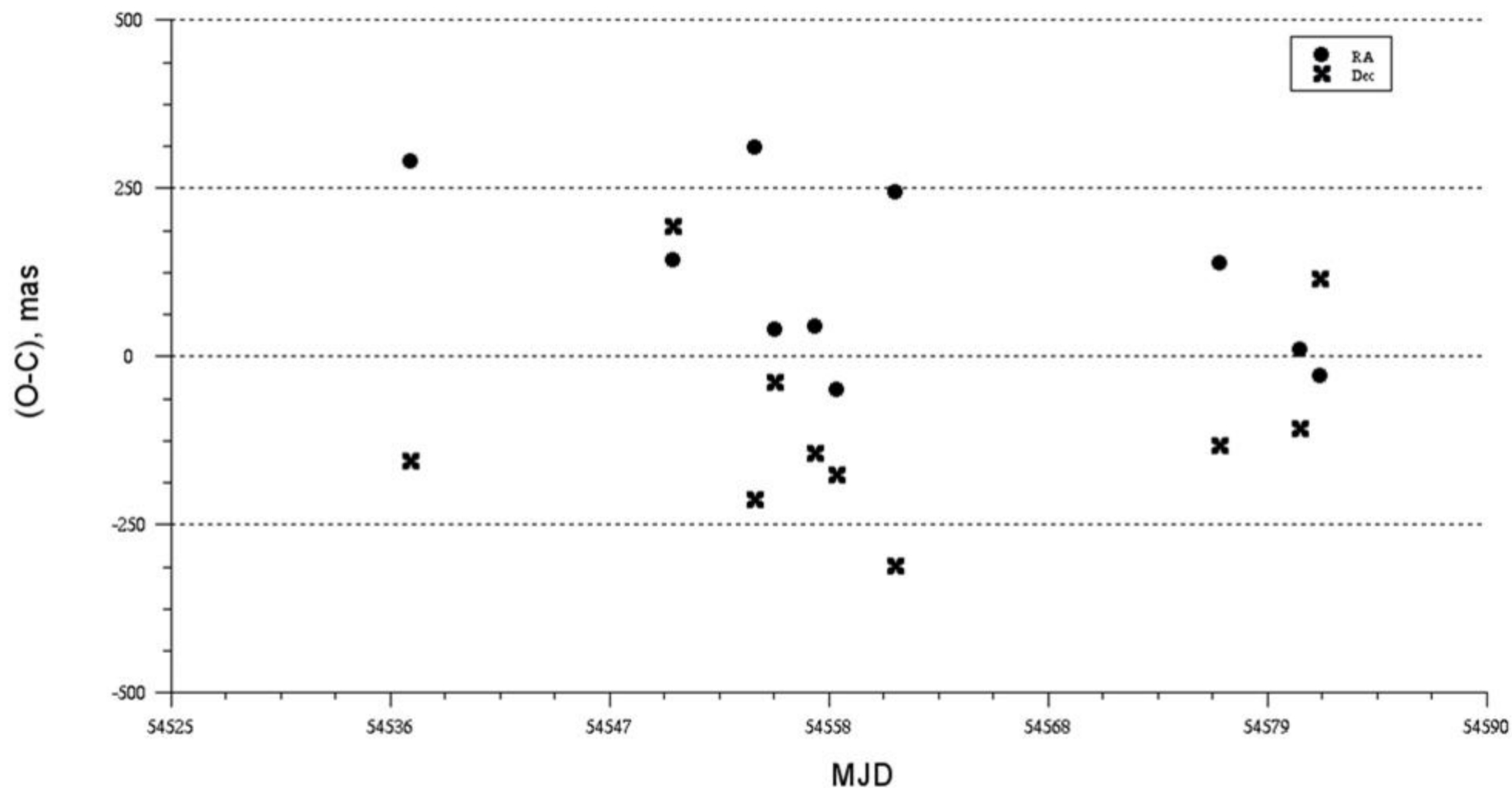


(O-C) values of Phoebe (S9), 2007



Mean values: $(O-C)_{RA} = 110$ mas, $(O-C)_{Dec} = -93$ mas.
Standard errors are within 45 to 100 mas.

(O-C) values of Phoebe (S9), 2008



Mean values: $(O-C)_{RA} = 110 \text{ mas}$, $(O-C)_{Dec} = -93 \text{ mas}$.
Standard errors are within 45 to 100 mas.

Conclusions

1. A set of accurate astrometric observations of Saturnian satellites have been collected with Pulkovo **Normal Astrograph**.
2. **Internal accuracy** of astrometric observations of the satellites of Saturn is **30 to 100** mas.
3. (O-C) values are less than **100 to 200** mas in the most cases. The theory-dependent systematic effects cause the positional differences of the same order.
4. The systematic effects are seen in (O-C) as functions of phase angle or phase of mutual orbital motion. Hence presented data set may be used to improve the theories of motions of Saturnian satellites.

Acknowledgments: Authors want to thank Organizing Committees of the conference and RFBR (projects: 07-02-00235-a and 07-02-92169).