Capabilities of ISON observatories for GAIA-FUN-SSO support

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ABSTRACT

Since 2009 the International Scientific Optical Network (ISON), coordinated by the Keldysh Institute of Applied Mathematics (KIAM RAS), is consistently implementing a research program called ASPIN (Asteroid Search and Photometry Initiative). The ASPIN goals are to search of small bodies in the Solar system: study of orbital and physical parameters of NEAs; discovery and follow-up of new objects; creation of new telescopes and sophisticated software to search for asteroids. In frame of this Initiative is planned to involve several 0.4 - 2.6 m telescopes to confirm the observations of Solar system objects which will be discovered by Gaia. Among which the telescopes are included the 2.6 m Shain Telescope at the Crimean Astrophysical Observatory, the 1 m Zeiss Telescope (the Eastern one) at the Tien-Shan Observatory of the Fesenkov Astrophysical Institute and the other. In the report capabilities of ISON observatories will be presented to be used for Gaia observations support.

The main interest for ISON network (that now comprises more than eighty telescopes on five continents) is the optical observations of space debris and artificial satellites. The observing objects in frame of ISON include also the space observatories in high apogee orbits like for Spektr-R mission (Radioastron), to provide the ballistic optimizing control.

We also describe main ballistic aspects for a spacecraft orbiting near the L2 Lagrange point of the Sun-Earth system. A libration point of mission design always assumes a certain orbital accuracy, which is required for motion prediction and planning maneuvers to maintain station. While standard slant range and Doppler observations are used to measure only radial parameters, fairly easy accessible optical observations of right ascension and declination provide the missing data of direction to the spacecraft. The report contains assessments of how the utilization of angles observations impacts on the accuracy of orbit determination of a spacecraft near L2 point.

ISON observatories can be equipped with a robotic telescope control software - KDS, which can observe Gaia alerts in near-realtime mode. This system already testing at ISON-NM Observatory (MPC code: H15) for gamma-ray bursts alerts. KDS system works with VOEvent sockets - receiving and processing alerts in XML format and can be shortly upgraded for the Gaia alerts.

ISON-NM Observatory already joined to Gaia-FUN observing campaigns, including observations of two NEAs (1996 FG3 and 2013 TV135). ISON-NM doing our survey work since July 2010. For this time, observatory already made 492,000 astrometric observations, which was sent to MPC. Obtained 1469 provisional designations of asteroids, discovered 4 NEAs, 2 Centaurs, 21 Jovian Trojans and 2 comets.

ISON PARTICIPANTS IN GAIA-FUN-SSO

MPC Code	Observatory	Telescope m	FOV arcmin	Scale arcsec/pix	Coordinates	Altitude m
K99	ISON-Uzhgorod	0.4	72	1.4	E22.453, N48.563	235
A50	Andrushivka	0.5	150	4.4	E28.997, N50.001	240
585	Lisnyky	0.7 0.48	16.9 x16.4 6x4	0.96 0.24	E30.524, N50.298	156
095	Crimea-Nauchnij	2.6 0.64	9.3 140.8	0.27 2.06	E34.016, N44.728	596
121	Chuguev	0.7	16.9 x16.4	0.96	E36.934, N49.641	151
C40	Kuban	0.5	92	1.35	E39.030, N45.020	60
119	Abastumani	0.7 1.25	45 x 30 10. 5	0.9 0.3	E42.820, N41.754	1595
D00	ISON-Kislovodsk	0.4	100	2.0	E42.654, N43.740	2107
188	Maidanak	1.5 0.6	18.3 11.7	0.27 0.69	E66.896, N38.673	2593
190 193	Gissar Sanglok	0.7 0.6	30 60	1.8 1.2	E68.68, N38.49 E69.218, N38.261	730 2286
N42	Tien-Shan	1.0	20	0.3	E76.971, N	2040
O75	ISON-Hureltogoot	0.4	138	2.7	E107.051, N47.865	1604
D54	Blagoveschensk	0.5	74	1.45	E127.482, N50.318	226
C15	ISON-Ussuriysk	0.65 0.5	132 72	3.9 4.2	E132.166, N43.698	277
-	Cosala, Sinaloa	0.4	78	1.5	W106,609, N24,401	631
H15	ISON-NM	0.4	100	1.5	E254.472, N32.744	2225

CAPABILITIES OF ISON

ISON telescopes with aperture from 0.4 to 2.6 m are involved in two sub-sets (1) to make observations for searching asteroids and (2) for photometric observations of asteroids. All of these telescopes are also used to observe gamma-ray bursts from alerts, which receive from cosmic gamma-ray telescopes.

Five survey telescopes with an aperture from 0.4 to 0.65 m perform regularly searching new asteroids and comets. These telescopes have large fields of view - more than one and a half degrees. Some of the other telescopes of the network carry out occasional observations of newly discovered NEAs to determine their positions and measure the magnitudes (follow-up observations).

Among ISON participants in Gaia support observations there are more than 10 telescopes with apertures ranging from 0.4 to 0.6 meters, 6 telescopes within 0.64-0.7m and 4 telescopes of 1m and up to 2.6 m. All telescopes equipped with modern CCD cameras and filter-wheels with standard BVRI filters.

Also it is expected that in the next 1-2 years the ISON network will replenish in several new telescopes with diameters of mirrors of 40-65 cm, which is also be able to take part in supporting the observation Gaia mission.

SEARCHING ASTEROIDS




40-cm H15, ISON-NM Observatory (left)

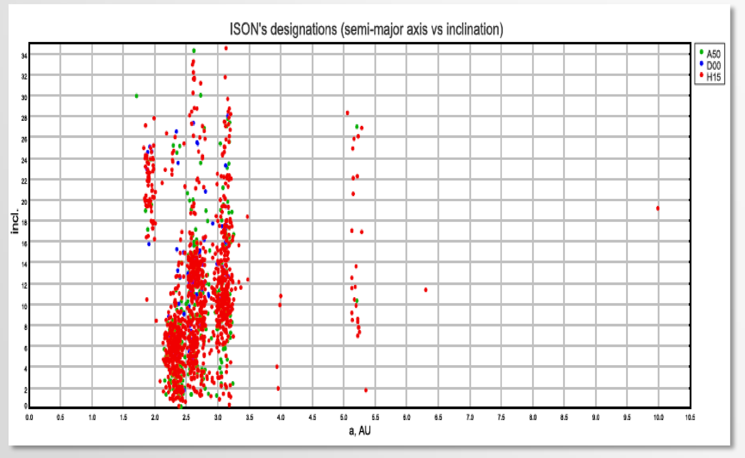
60-cm A50, Andrushivka Observatory (right)

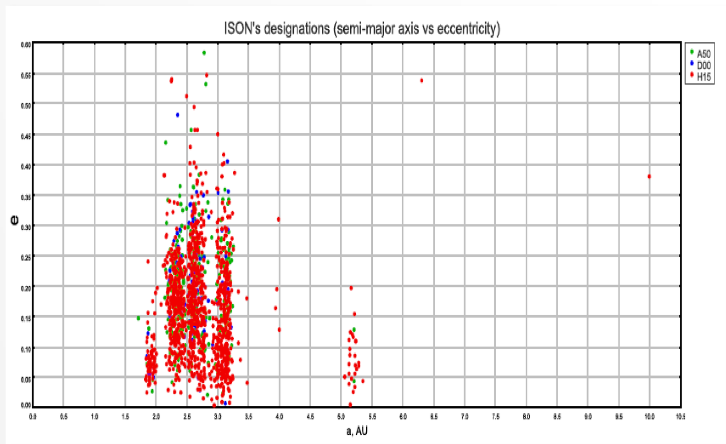
40-cm D00, ISON-Kislovodsk (lower right)

40-cm O75, ISON-Hureltogot

65-cm C15, ISON-Ussurijsk (middle)

Orbital elements of more 1500 asteroids, discovered by ISON





Example of GAIA astrometry from the 2.6 m Shain Telescope at the Crimean Astrophysical Observatory

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10531 39479
261014 21051163 02393877 +17395050 001211
261014 21071995 02393885 +17395220 001212
261014 21092824 02393887 +17395390 001212
261014 21113816 02393896 +17395480 001210
261014 21145843 02393906 +17395720 001207
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261014 21191769 02393917 +17395920 001207
261014 21212559 02393922 +17400000 001206
261014 21233535 02393931 +17400120 001206
END

10531 39479
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261014 23354244 02394309 +17404390 001203
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END
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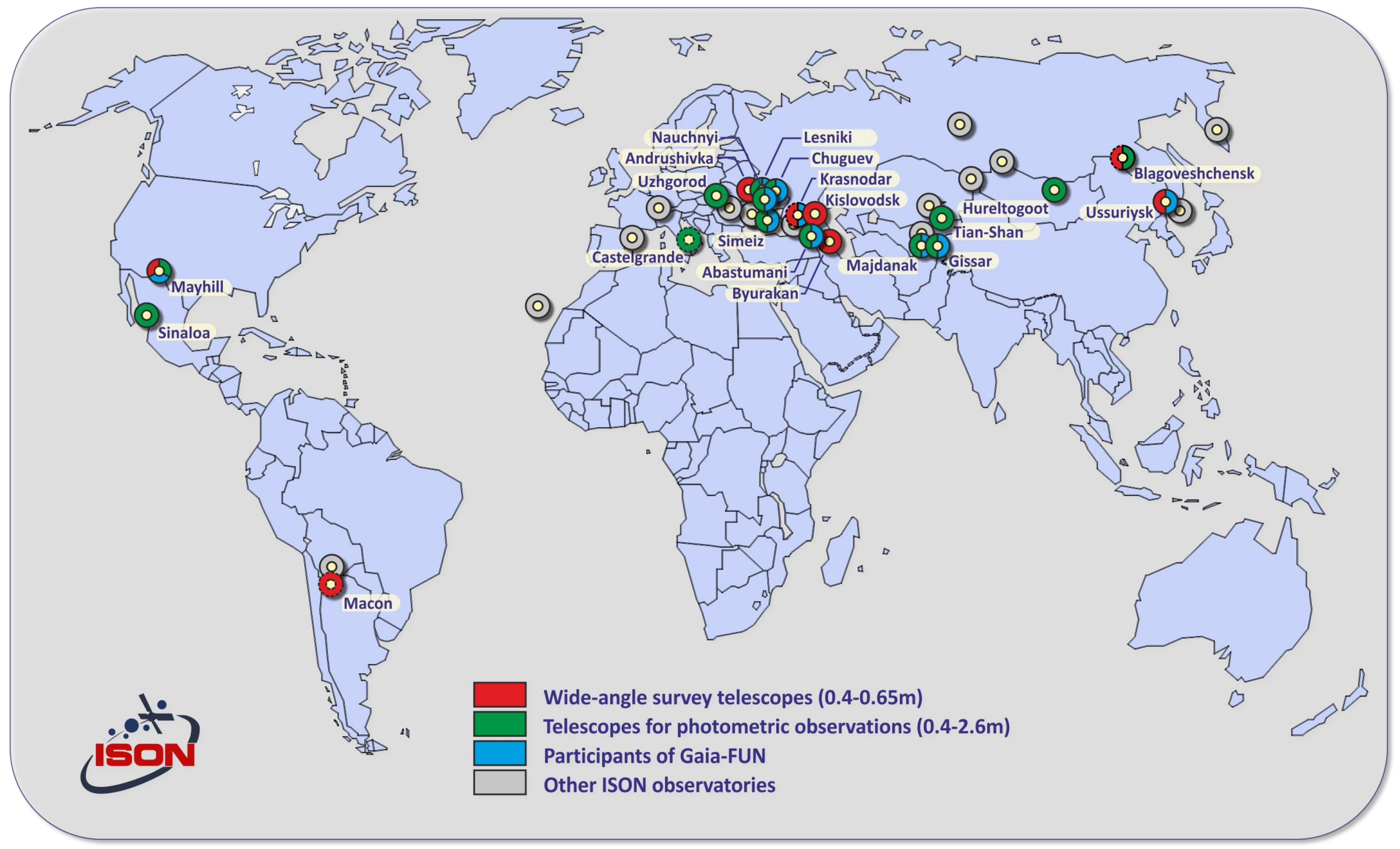
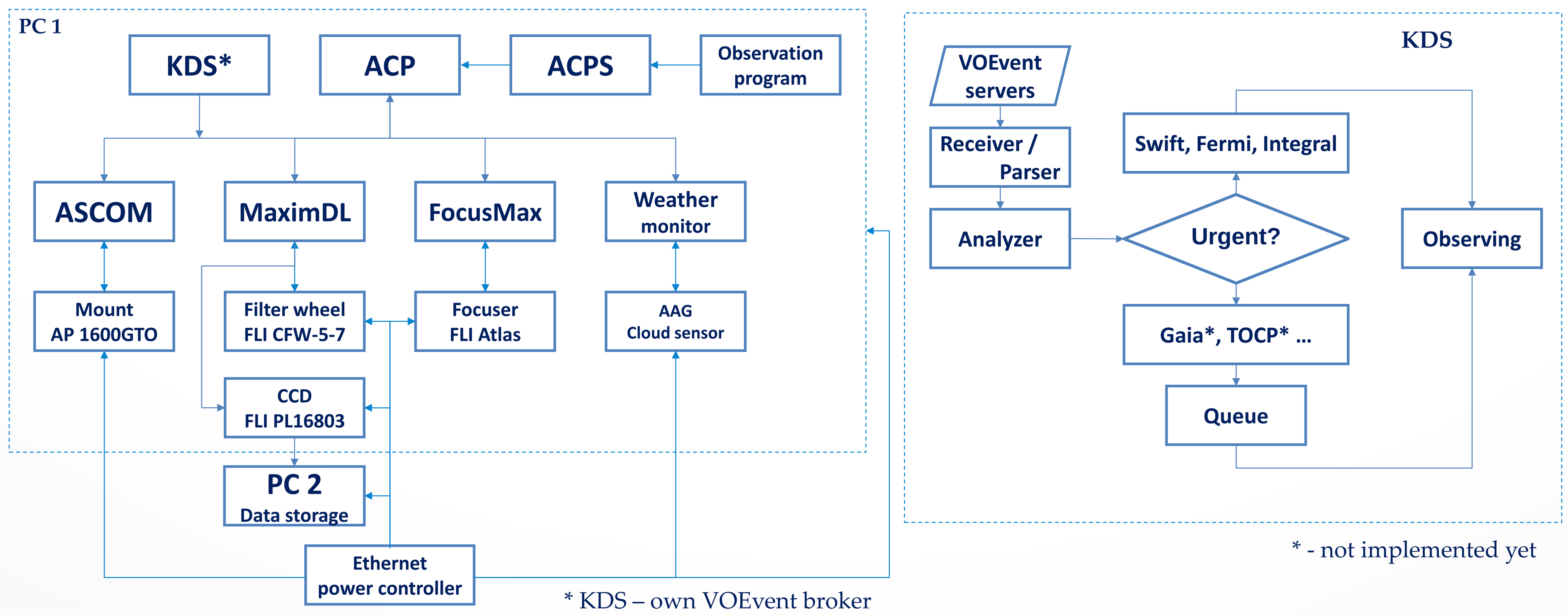
Map of ISON observatories



ISON-NM Observatory already worked with GAIA-FUN observation campaigns of near-Earth asteroids 1996 FG3 and 2013 TV135

ISON-NM observatory control system



* - not implemented yet

* KDS – own VOEvent broker

Optical angles measurements impact on the orbit determination accuracy of the spacecraft near the L2 point of the Sun-Earth system

Traditional slant range and Doppler measurements do not always provide good estimate of spacecraft state vector, especially if the spacecraft moves far from gravitating bodies, e.g. on cruise trajectory or near libration points. During important phases of a mission, when orbital accuracy plays crucial role, additional support of VLBI observation is generally used. However such accurate angular observations are very resource-intensive and hard to be conducted regularly. In contrast optical angular observations are rather cheap, can be carried out solely by larger number of observatories and do not require special onboard transmitter. Though lower accuracy limits the distances at which these observations are viable. We studied how use of optical angular observations along with standard radio tracking improves orbit determination (OD) accuracy of a spacecraft on quasi-periodic orbit near L2 point of the Sun-Earth system.

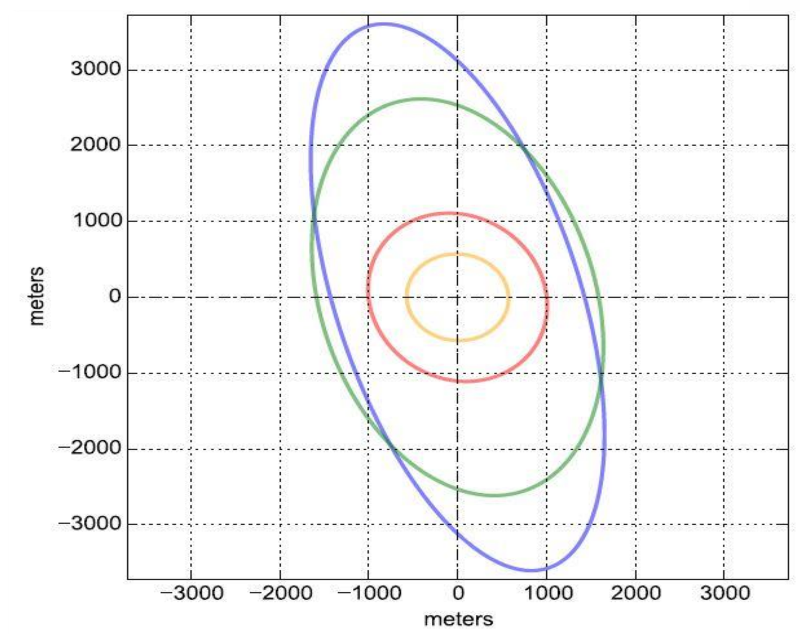
OD errors assessments were made assuming certain observation schedule: radio tracking is performed on daily basis alternately from three distant tracking stations (Baikonur, Bear Lakes and Ussuriysk), optical observations are conducted daily or every two days by a number of observatories (one observatory at a night). Accuracy of Doppler measurements has been set at 0.1 mm/s level, range measurements per pass bias – to 5 meters (m), range noise level – to 3 m. Accuracy of optical observations has been set to 0.4 arcsec for both right ascension and declination. In addition stochastic parameters have been added into the OD process in order to compensate errors of the motion model. New set of constant unmodeled accelerations has been used every 18 hours. A priori estimate of the state noise was m/s^2. All error estimates above are given at 1σ-level.

Table. 1. *Estimated errors of spacecraft position and velocity determination using different tracking scenarios*

No	Arc, days	Optical observations	Max. position error (3σ), m	Max. velocity error (3σ), mm/s
1	8	Every day	582	1.79
2	8	Every 2 days	1134	2.41
3	8	Radio tracking only	3724	6.14
4	14	Radio tracking only	2676	3.08

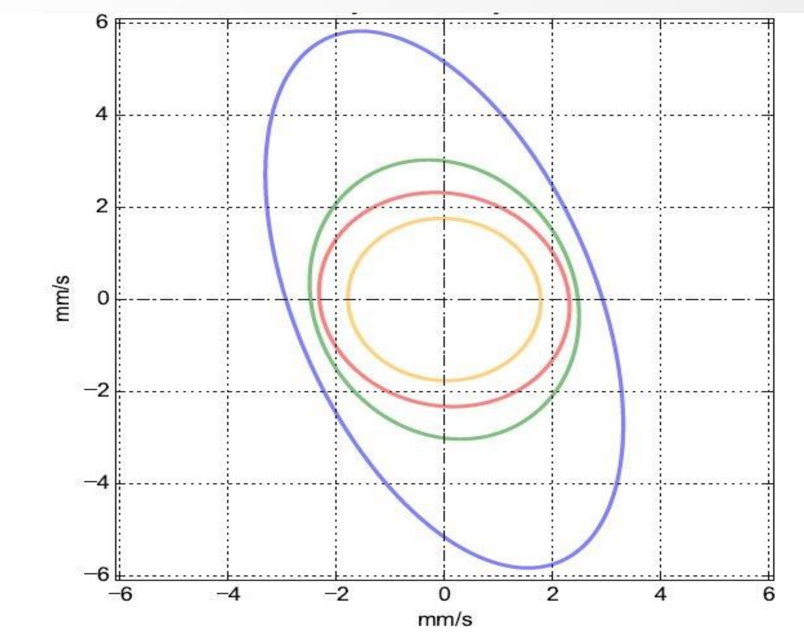
Four OD scenarios with different arc lengths and observational data structure were considered. They are briefly described in Table 1. The estimate of spacecraft state vector uncertainty was obtained for each scenario. Maximum errors of position and velocity determinations also described in Table. 1. Projections of corresponding ellipsoids on the target plane orthogonal to geocentric position vector of the spacecraft are shown in Figures 1 and 2. Since radial parameters are well known due to accurate range and Doppler observations, this plane contains the major part of the uncertainty. As it shows introduction of optical angular observations drastically improves knowledge of spacecraft position even using shorter arcs and sparse optical data. It also reduces uncertainty of velocity determination crucial for calculation of station-keeping maneuvers. All this including more confident orbit determination on shorter arcs makes optical angular observations valuable and at the same moment relatively easy obtainable source of orbital data.

Position uncertainty, 3-σ level



Scattering ellipses of geocentric position of the spacecraft on the target plane (3σ uncertainty) obtained within different observation scenarios from Table 1. (1 – orange, 2 – red, 3 – blue, 4 – green)

Velocity uncertainty 3-σ level



Scattering ellipses of geocentric velocity of the spacecraft on the target plane (3σ uncertainty) obtained within different observation scenarios from Table 1. (1 – orange, 2 – red, 3 – blue, 4 – green)