Performance analysis of the large space debris tracking telescope in the North Caucasus after the second first light

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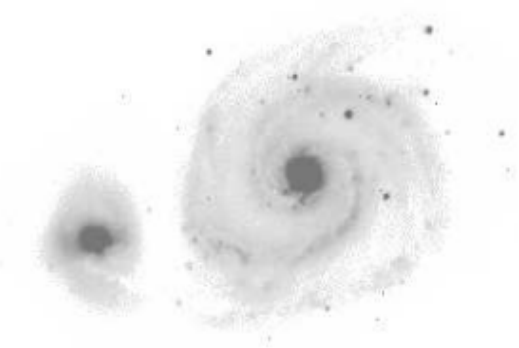


Introduction. Telescope

- A relatively large 80-cm telescope has just started to work in the International Scientific Optical Network (ISON) at a good observing site in the North Caucasus.
- The instrument probation in observation of GEO and HEO space debris objects is currently going.

ISON overview

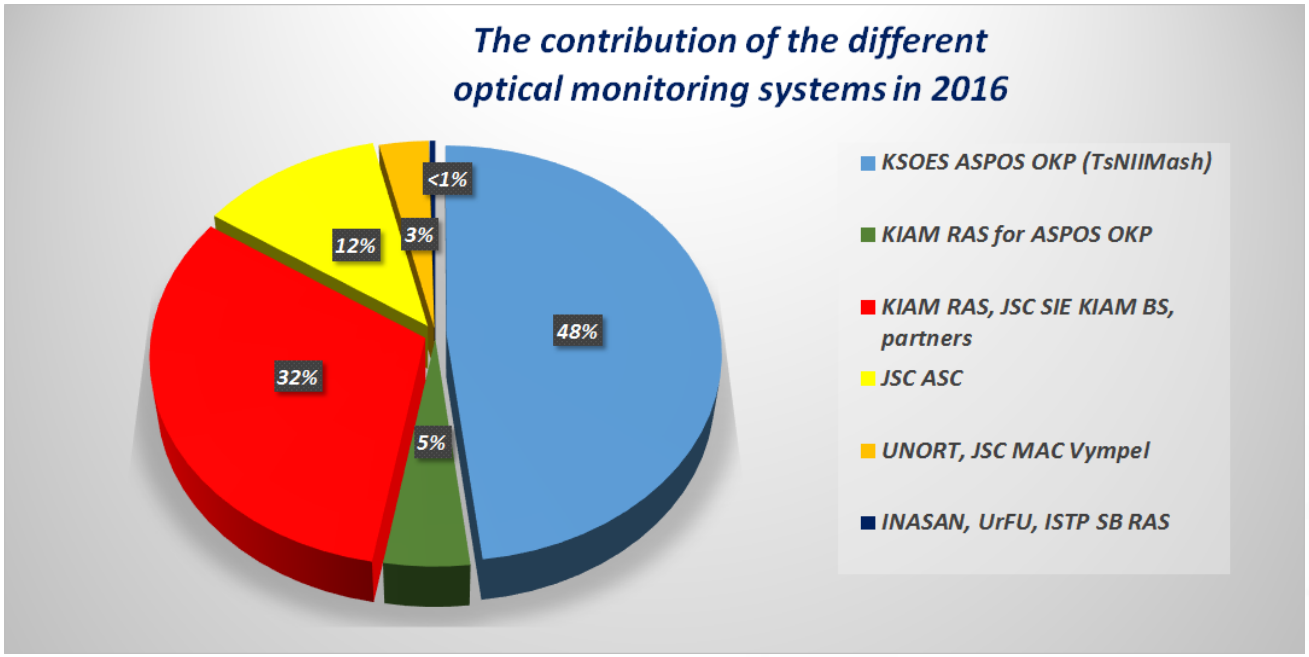
- ISON is an open international project developed to be an independent source of data about natural and artificial space objects for scientific and applied purposes.
- Main observation topics: space debris, asteroids, gamma-ray burst afterglows.
- ISON is one of the top near-Earth technogenic object surveillance systems in the world, whose database is regularly updated with the globally distributed network of optical tracking systems.
- Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM) coordinates the ISON project. KIAM maintains space objects database of the Russian Academy of Sciences/Federal Agency for Scientific Organisations and provides conjunction analysis for Russian satellites in high orbits under the order of Roscosmos.

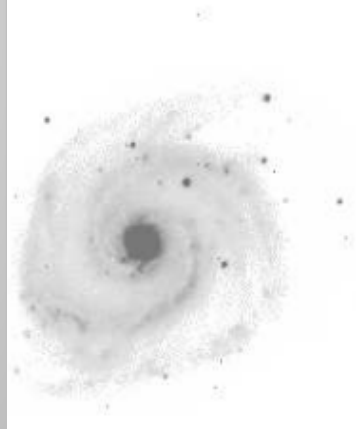
ISON overview

- ISON provides continuous monitoring of the GEO object population, tracking and surveying of objects in GEO, LEO, and in Molniya and other HEOs.
- ISON cooperates with 38 observation facilities in 16 countries with 90 telescopes from 12.5 cm up to 2.6 m aperture. Additionally, the number of preparatory works on new observational sites in 8 countries is being implemented at the moment.
- ISON now represents an interagency association that includes the 4 main segments—scientific cooperation, Roscosmos, industry organisations and a new one for commercial activities.

ISON overview. Segments of involved telescopes

- 26 telescopes of the KIAM international scientific cooperation.
- 24 telescopes of the small innovative enterprise KIAM Ballistics-Service for usage in commercial aspects.
- 22 telescopes of Roscosmos/TsNIIMash (6 observatories EOP-1, EOP-2 + 4 single telescopes) for the conjunction analysis support.
- 18 telescopes data is sharing with the Vimpel corporation for the pursuit of space situation analysis.





ISON overview

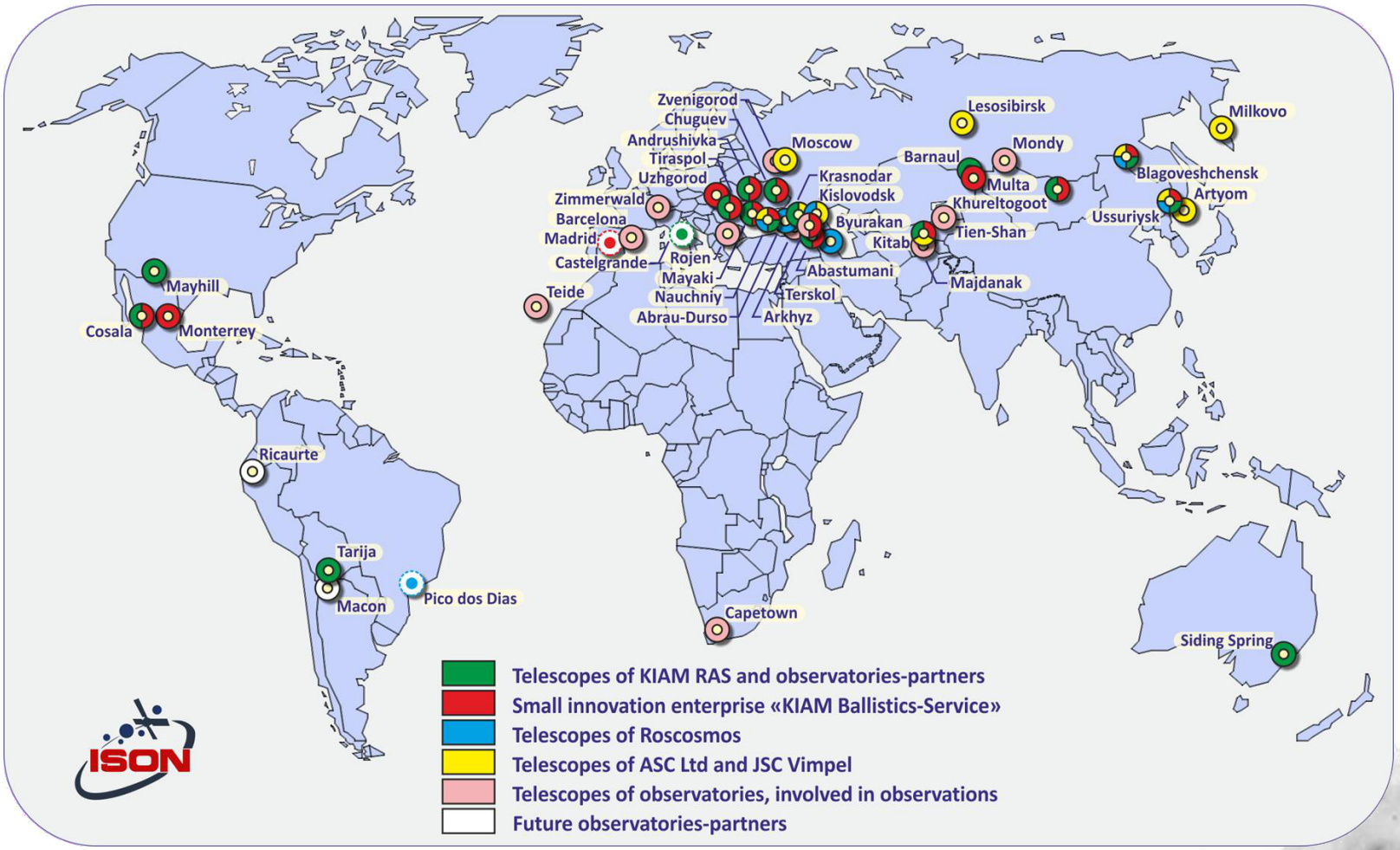


Fig. 1. ISON facilities location map

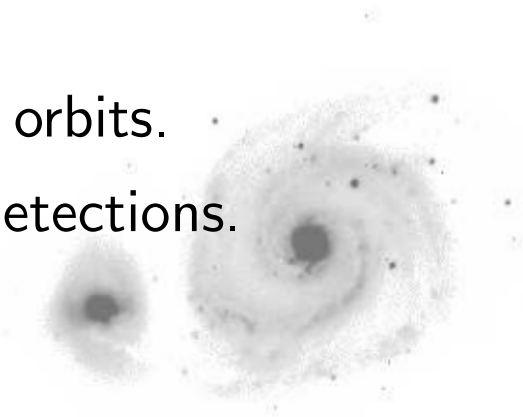
ISON overview. Structure

7 telescope subsets:

- global GEO survey (down to 15.5 mag)
- extended GEO survey (down to 14 mag)
- deep local GEO survey (down to 17 mag)
- tracking the faint (fainter than 15.5 mag) space debris in GEO and GTO
- tracking the bright GEO and GTO objects
- tracking the bright LEO and HEO objects
- for observation of asteroids

▷ One telescope provides survey of the Molniya-type orbits.

▷ Extended GEO surveys also produce HEO object detections.



ISON overview. Recent developments

- Generally, 19 million measurements of 2.4 million tracklets for approx 6150 objects in high orbits obtained by the KIAM data centre in 2016: 2040 objects in GEO, 4110—in HEO. Orbital elements of these objects are regularly updated at the moment.
- 550 new objects have been discovered and 480 previously lost objects have been rediscovered in 2016—corresponding values increased by about half compare with 2015.
- The ISON (KIAM) orbit list of technogenic NEOs, some of which are non-TLE and unique high area-to-mass ratio (HAMR) objects in GEO and HEO, has conditionally free access within the diverse forms of cooperation.
- To sum up, knowledge on HEO objects has been significantly extended (4110 objects).

ISON overview. Recent developments

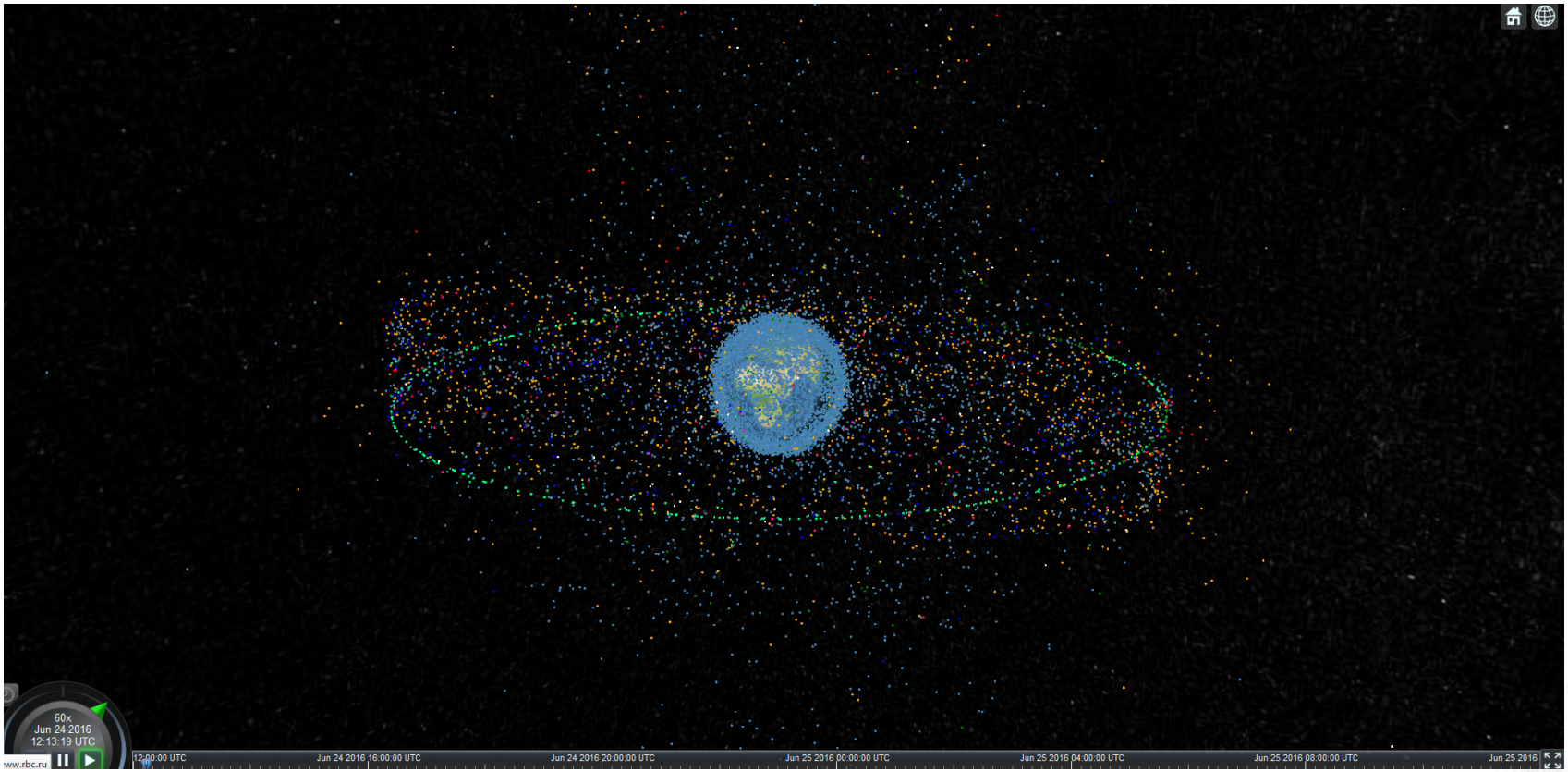


Fig. 2. The snapshot of the KIAM space debris database on 24 June 2016, 12:13:19 UTC

ISON overview. Discovery statistics

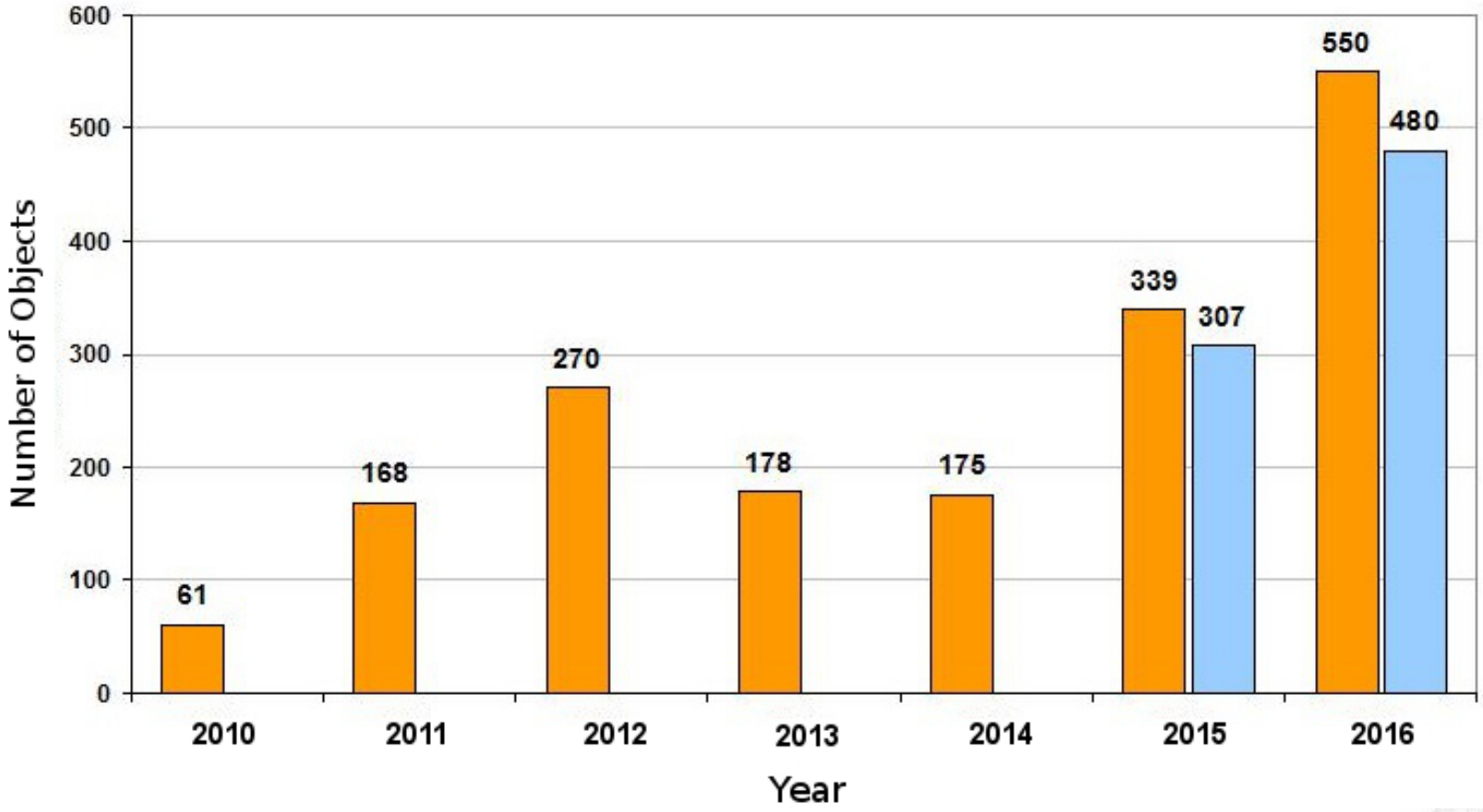


Fig. 3. A number of object discoveries shown by year of follow-up: orange colour assigned for discovered objects, blue for rediscovered objects.

ISON overview. Progress in 2016

- 80-cm K-800 in the North Caucasus and 60-cm Zeiss-600 in Bolivia have been commissioned for technogenic NEOs tracking.
- The first measurements were made using a new 1.6-m telescope AZT-33VM at Mondy (The Sayan Mountains, Siberia, Russia) under contract with Roscosmos.
- Second Mexican observatory (at Monterrey) joined to ISON.
- Subsystem for deep local GEO surveys has been arranged.
- The technique of new space objects quick identification and follow-up recently has been improved in the number of the ISON observatories, that has increased the GEO and HEO space debris discovery rate significantly.
- Regular optical observations of LEO objects have been started.

ISON overview

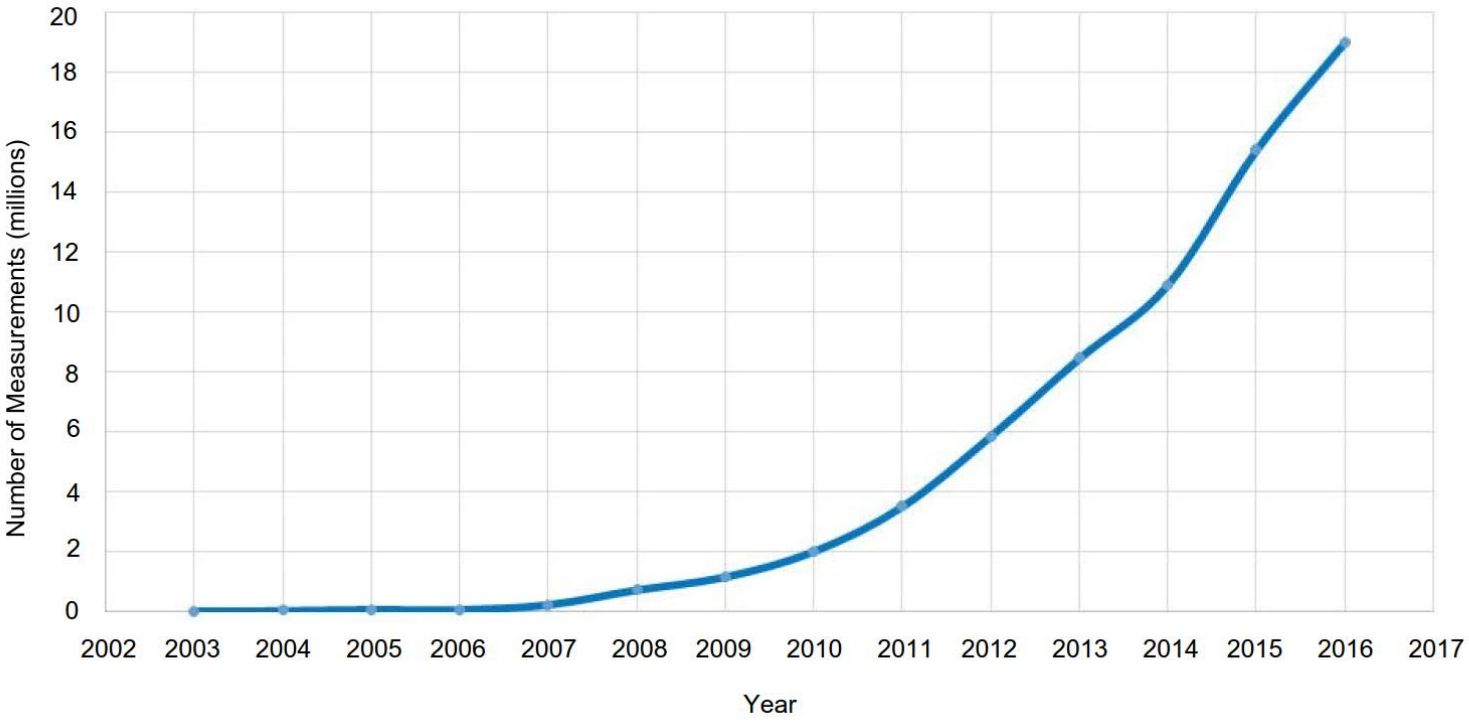


Fig. 4. The number of optical measurements obtained by ISON telescopes

ISON overview. GEO coverage

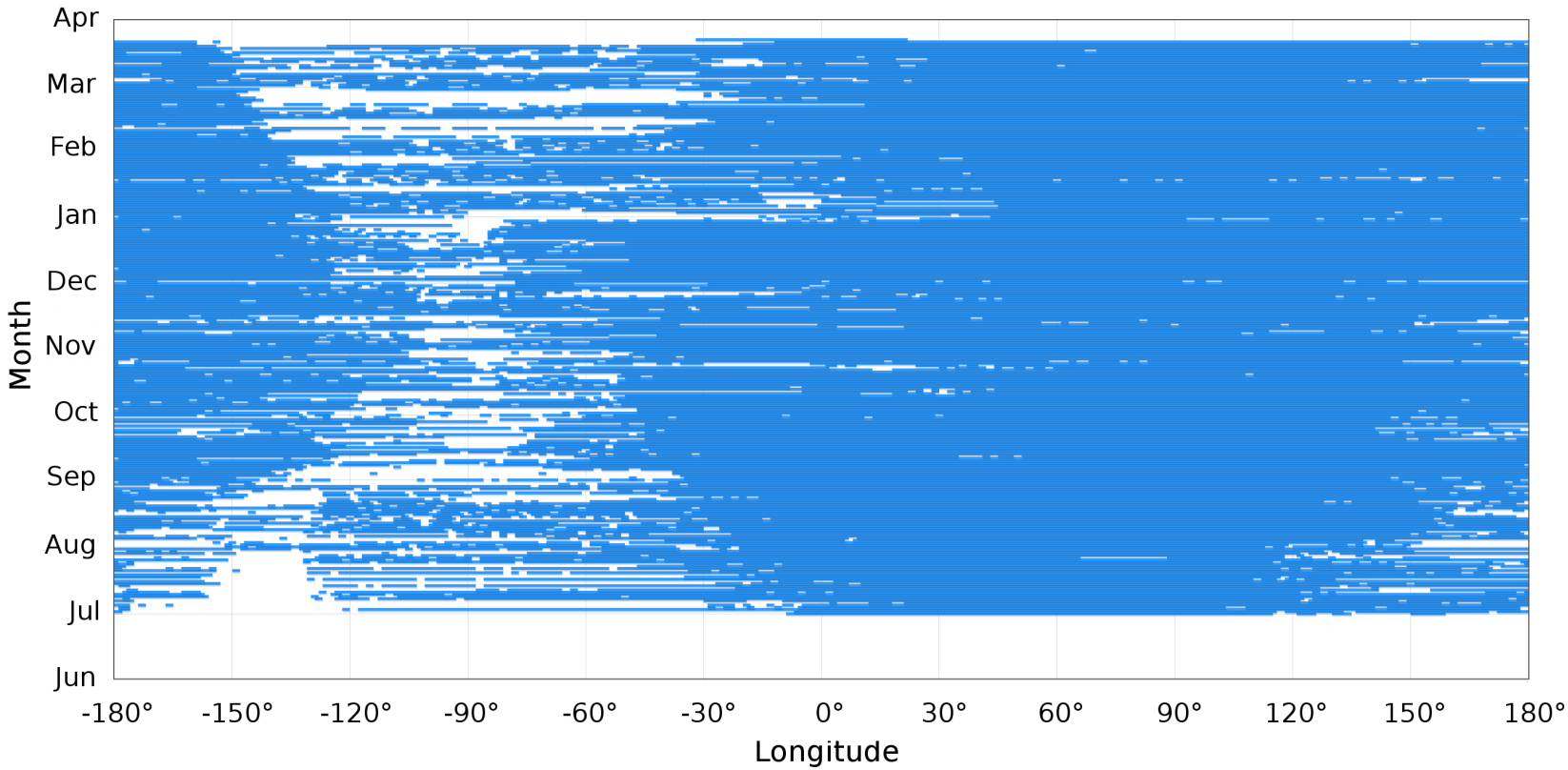


Fig. 5. The sweep of the GEO area at different longitudes by ISON for July 2015–March 2016

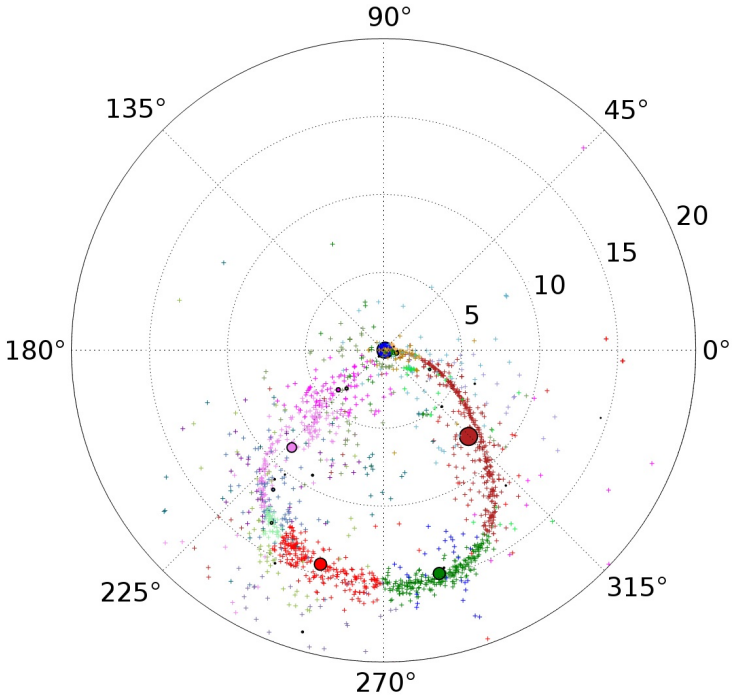


Fig. 6. A new representation for the GEO object distribution in the polar coordinate system within the debris model elaboration. Radius indicates the orbital inclination of an object in degrees. Polar angle is azimuth of the orbit's normal at the intersection with the zero-inclination plane, measured from the X axis of the inertial coordinate system. The figure, based on the KIAM database objects (+), divided into groups that correspond to different colours, each group has point of thickening (o), which magnitude is proportional to the number of objects

The K-800 telescope

- The instrument placement at the Peak Terskol Observatory at an altitude of 3100 meters provides pristine seeing conditions during on an average 1000 hours per year.
- This 80-cm telescope K-800, initially Cassegrain, was rebuilt for the observations in the prime focus with CCD technique due to the joint efforts of the ISON project and the Astronomical Observatory of Odessa I. I. Mechnikov National University.
- K-800 is the largest telescope whose observing time is fully used for ISON's tasks at present.
- During the 2016 fall one-month probation term feasibility of using the instrument for monitoring space debris in GEO was evaluated, almost one thousand proper object follow-ups involved in the statistics, the object distribution has maximum about magnitude 17.

K-800. Specifications

- Presently, the instrument with a 228 cm focal length, provided by the large-format 3k×3k CCD camera with 12μm pixel pitch, has enlarged 55 arc minutes field of view.
- K-800 is able to detect up to magnitude 19 GEO and HEO objects using few second exposures in binning readout mode.
- The K-800 telescope is still under rebuilding, thus further enhancement is expected: installation of new 2k×2k CCD camera having 24μm pixels for the dimmer object registration, using a photometric filter wheel for space junk models development, the telescope complete control system renewal, and stepper motors replacement by DC motors with encoders for better object pinpointing also.
- The primary mirror re-aluminization is envisaged in 2017.
- About one thousand measurements of tracklets for a single good night of observations is post-processed in-situ in less than an hour using the APEX software toolkit. This data is promptly sent to the KIAM data centre for orbital determination and conjunction analysis.

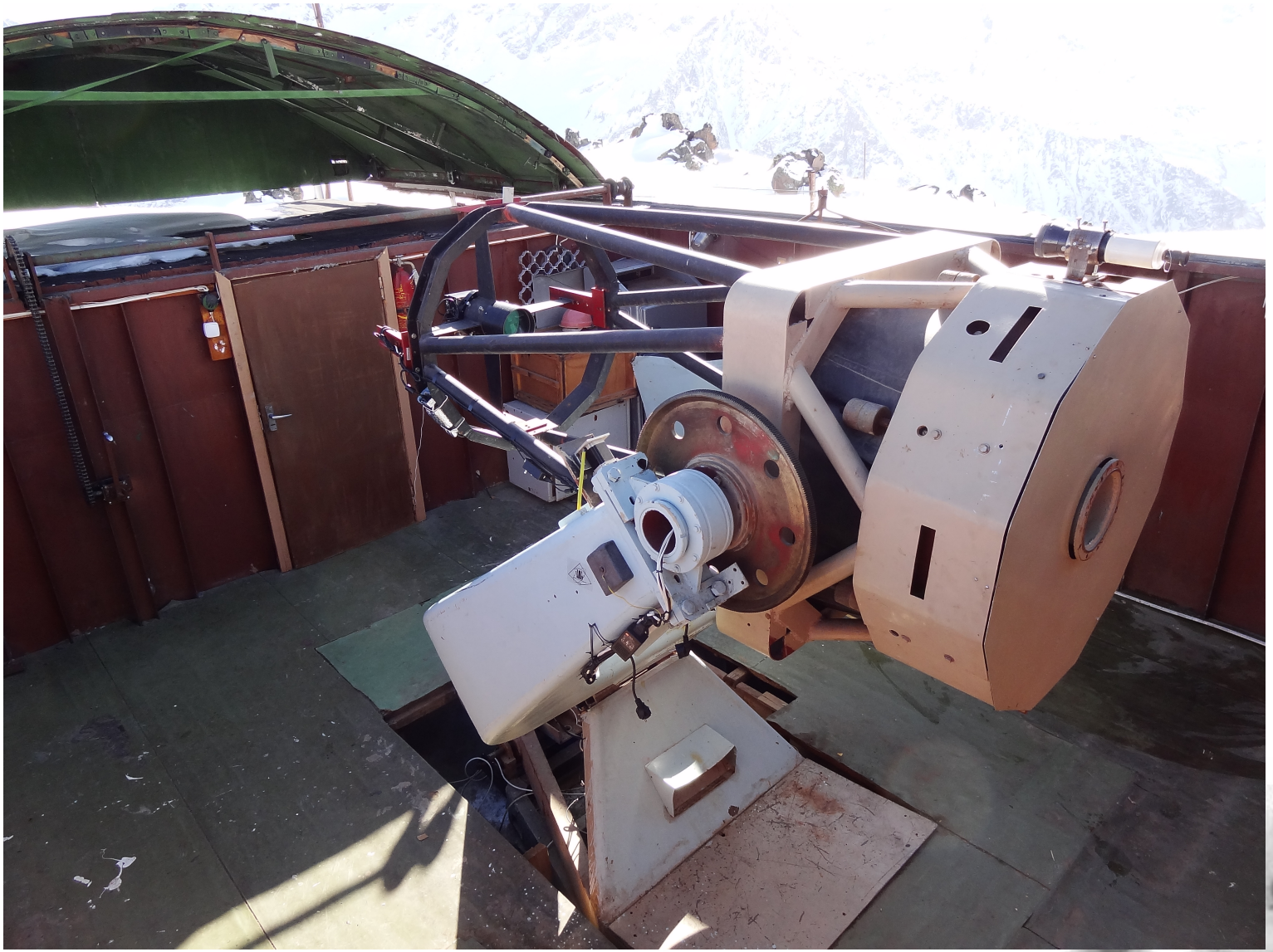


Fig. 7. The K-800 telescope in earlier 2017

K-800. Observation statistics

Month	Observing Nights	Tracklets	Meas	New and Re-found Objects
July	5	86	929	0
August	20	812	9580	19
September	11	806	7579	13
October	4	498	4336	4
November	7	676	5784	2
December	12	739	6628	2
Total	**59**	**3617**	**34836**	**40**

K-800. Observation statistics

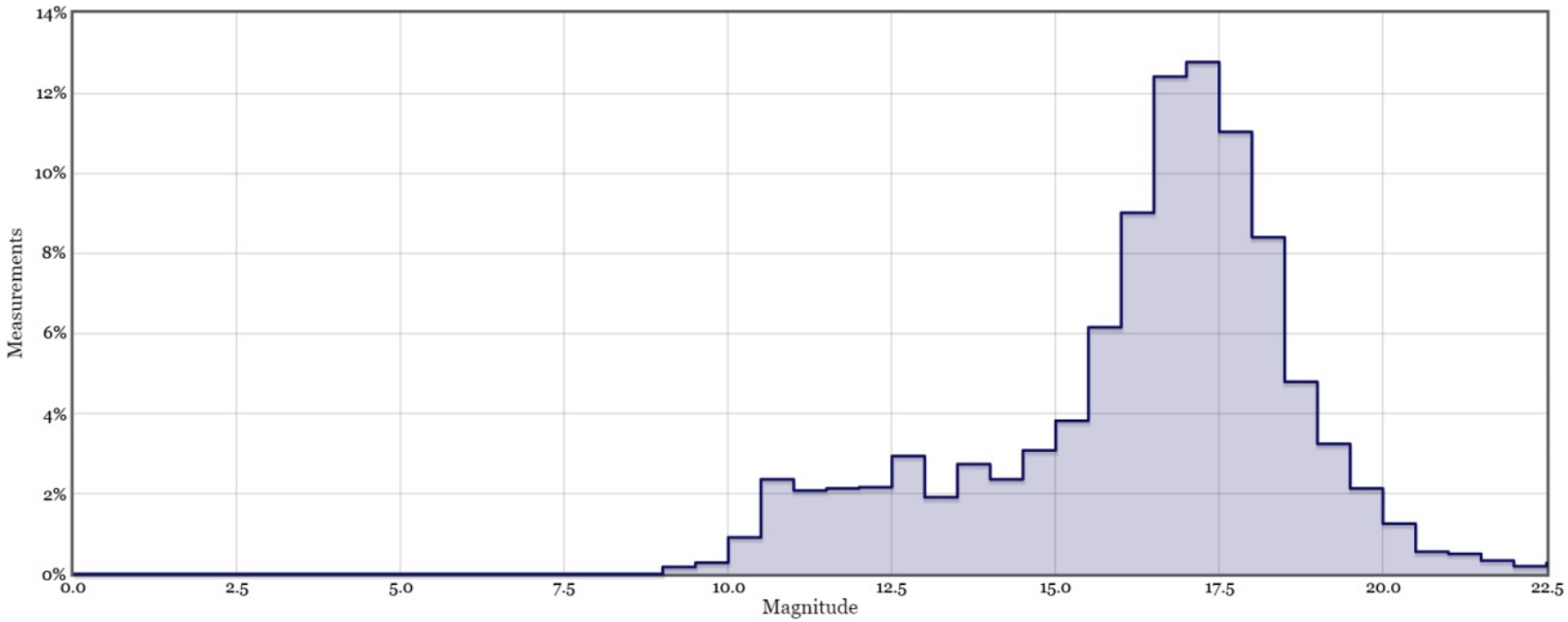


Fig. 8. Percentage distribution of magnitude of GEO and HEO objects that have been observed using the K-800 telescope in the second half of 2016

Summary

- It is possible to use medium and large-sized telescopes within scientific and technical cooperation, in particular through the substantial modernization of previously out-of-use and outmoded instruments.
- Commissioned 80-cm telescope will retain the leading position among ISON's fully operated telescopes for a considerable time in virtue of its limiting magnitude.
- Promising results have been shown already by K-800, moreover, further enhancement of capacity, values of limiting magnitude and field of view is expected as well.
- Nevertheless, corresponding telescopes have obvious limitations in the field of space debris research. Thus, analogous instruments having a field of view more than 15 square degrees are needed to provide catalogue completeness and stability in case of faint objects in the GEO region.
- KIAM catalogue of GEOs maintains now reliable tracking for object down to 15.5–16 m. Besides, KIAM implements a new cluster telescope for the improvement down to 16.5–17 m.

Thank you for your attention!

The Whirlpool Galaxy, September 2016
The Peak Terskol Observatory, Russia