Research Article

Artem Mokhnatkin*, Igor Molotov, Eduardo Gerardo Perez Tijerina, José Enrique Perez Leon, Tatiana Kokina, and Thomas Schildknecht

Implementing of the ISON project in Northern Mexico

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Abstract: ISON, being an open international project that collects and interprets data about space objects for scientific analysis and spacecraft operators, includes about 40 observational sites. An involvement of two Mexican sites participating in optical observations of geostationary and highly elliptical objects as a part of the ISON project is considered. A brief description of the facilities and their observation statistics are given. Prospects for the further development of sites for monitoring near-Earth objects in Mexico are presented, including data of astronomical observing conditions from field stations.

Keywords: telescope, high elliptical orbit, geosynchronous orbit, space debris, satellite, tracking

1 Introduction

High Earth orbits are of great interest both for applied purposes of communication and navigation systems, and scientific researchers as well. Monitoring of this region is a very topical goal due to the significantly increased number of the catalogued space objects there, including works on providing for the safety of satellites and the development of the proper model of space debris population. The International Scientific Optical Network (ISON or NSOI AFN in Russian) is an open international non-government project developed to be an independent source of data about space objects for scientific analysis and spacecraft operators.

At the moment, ISON collaborates with two Mexican institutions: the Autonomous University of Sinaloa since October 2010 and the Autonomous University of Nuevo León (UANL in Spanish) since October 2016. Both organisations have proper observation sites in Northen Mexico, which are characterised by a low level of humidity and a sufficient number of clear hours, moreover, developing new sites with a higher transparency of atmosphere already has been planned. Mexican sites have unique longitude location for survey and tracking of geosynchronous (GEO) and high elliptical orbit (HEO) objects, especially in the interest of orbital determination and conjunction analyses for Russian and Mexican satellites.

2 The ISON project overview

ISON is one of the headmost near-Earth technogenic object surveillance systems in the world, whose catalogue is regularly updated with observations from the globally distributed network of optical tracking systems.

Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM RAS) is the host organisation of ISON, that maintains space objects database and also provides conjunction analysis for GEO satellites. ISON project is continuously developing—new observatories are joining, new telescope subsystems are forming, and KIAM database is upgrading: 38 observation facilities in 16 countries comprising 90 telescopes from 12,5 cm up to 2,6 m aperture are involved in the ISON project, including two in Mexico (shown in Figure 3). ISON provides continuous monitoring of the GEO object population, tracking and sur-

Corresponding Author: Artem Mokhnatkin: Central Astronomical Observatory of the Russian Academy at Pulkovo;
Email: artspace3@mail.ru
Igor Molotov: Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences; Email: im62@mail.ru
Eduardo Gerardo Perez Tijerina: Autonomous University of Nuevo León; Email: eduardo.pereztj@gmail.com
José Enrique Perez Leon: Autonomous University of Nuevo León; Email: enrique584@hotmail.com
Tatiana Kokina: Autonomous University of Sinaloa;
Email: anisili@rambler.ru
Thomas Schildknecht: University of Bern;
Email: thomas.schildknecht@aiub.unibe.ch

veying of objects in GEO, LEO, and in Molniya and other HEO orbits (Molotov *et al.* 2008, 2009).

As a result of the recent developments, 2.4 million tracklets comprising 19 million measurements obtained by ISON in 2016 (Molotov *et al.* 2016), the general trend from 2003 presented in Figure 4. Orbit determination and conjunction analysis for GEO and HEO are performing on a routine daily basis. Thus, orbital elements of approximately 6150 objects (2040 GEO and 4110 HEO) in the KIAM database are regularly updated at the moment.

Moreover, 550 new objects have been discovered and 480 previously lost objects have been rediscovered in 2016—corresponding quantities increased by about half compare with 2015.

3 Cosala site

The Cosala observation facility of the Autonomous University of Sinaloa (AUS) was commissioned and began its work in May 2012. The astronomical observatory is located in the territory of the ecological reserve of AUS, at an altitude of 600 m, in the vicinity of Cosala town (State of Sinaloa). There was built a pavilion with a sliding roof and installed the 25-cm ORI-25 telescope (Figure 1) which provided by the ISON project, since then, the observatory regularly holds geosynchronous objects observations. Almost 800 thousand measurements of space debris objects and satellites in high orbits were made during approx 600 observation nights in 5 years. Observatory Cosala took an active part in the discovery of 16 uncataloged objects and rediscovery of 15 of previously lost objects. Observations at the ORI-25 are carried out in an automatic mode. Obtained data are promptly sent to the database of KIAM RAS, where are used for the prediction of dangerous approaches, including Russian and Mexican satellites.

One-year operation statistics of ORI-25 at Cosala is presented in Figure 8 and Figure 11.

4 Nuevo León sites

The telescope has been installed at UANL Monterrey City Campus (25° 41’ N 100° 18’ W, 560 m altitude) in October 2016, commissioning works were carried out by engineers of KIAM RAS. The ORI-25 telescope follows a Hamilton optical design, similar to that for the ISON branch in Tarija, Bolivia (Zalles Barrera *et al.* 2014), with a 25 cm diameter mirror and a 625,0 cm focal length, giving a wide field-of-

Figure 1. ORI-25 at the Cosala site in early 2012.

view of 3° × 3°. Mounted FLI Microline ML09000 camera acquires images of 3056 × 3056 μm pixels.

Since observations began, the survey of geosynchronous objects has covered a belt-shaped region of the celestial sphere with a range of $-49° < \delta < 10°$.

About 4TB of data have been obtained by ORI-25 at the moment, whereas during the observation period about one year 62% of nights were operational. Gathered data are collecting and sending to KIAM RAS for further analysis. Clear conditions in Monterrey (the capital of Nuevo León) had been limited by climate events related with the last two hurricane seasons (July 1st–December 1st) and the last season of cold fronts (November–March). Our work at UANL is aimed to determine basic kinematic parameters of geosynchronous objects by using a pattern recognition algorithm, to distinguish a target source from a background of motion-blurred stars, that is common task for obtained ISON images in given case.

One-year operation statistics of ORI-25 at Monterrey is presented in Figure 9 and Figure 10. Notably, that the magnitude distribution of the ORI-25 at Monterrey includes slightly more weak objects comparing with the same instrument at Cosala (Figure 10 and Figure 11) in spite of relatively large light pollution at Monterrey.

ISON has motivated the recent study of complementary sites, which will increase the current performance of the ORI-25 and other equipment which will be devoted to asteroids observations. We are focused by now on weather, seeing and mean sky brightness measurements, for a cou-

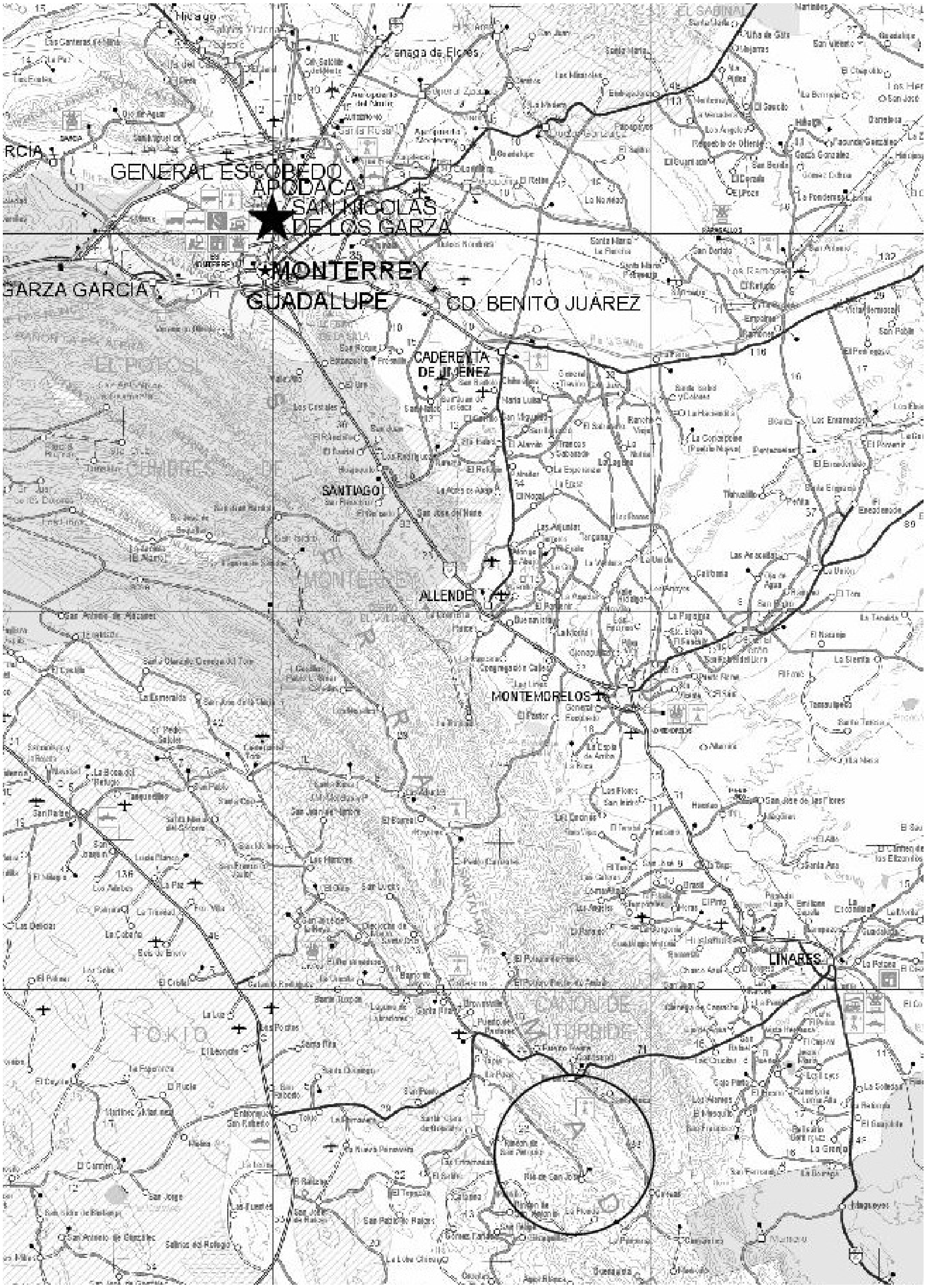

Figure 2. Shown the present ISON observatory position at Monterrey, marked by a star, and the prospect zone for its future southward movement, enclosed by a circle. One grid approx corresponds to 50 km.

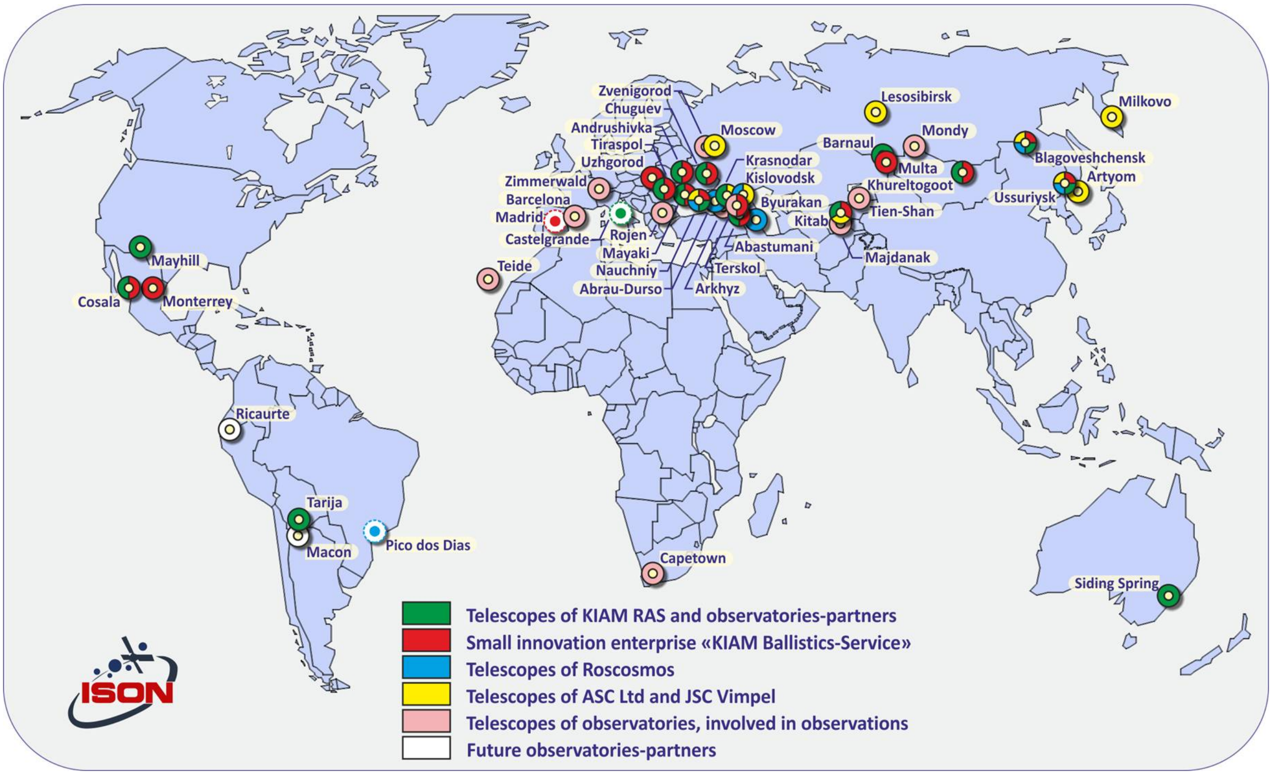

Figure 3. Location map of facilities affiliated with the ISON project.

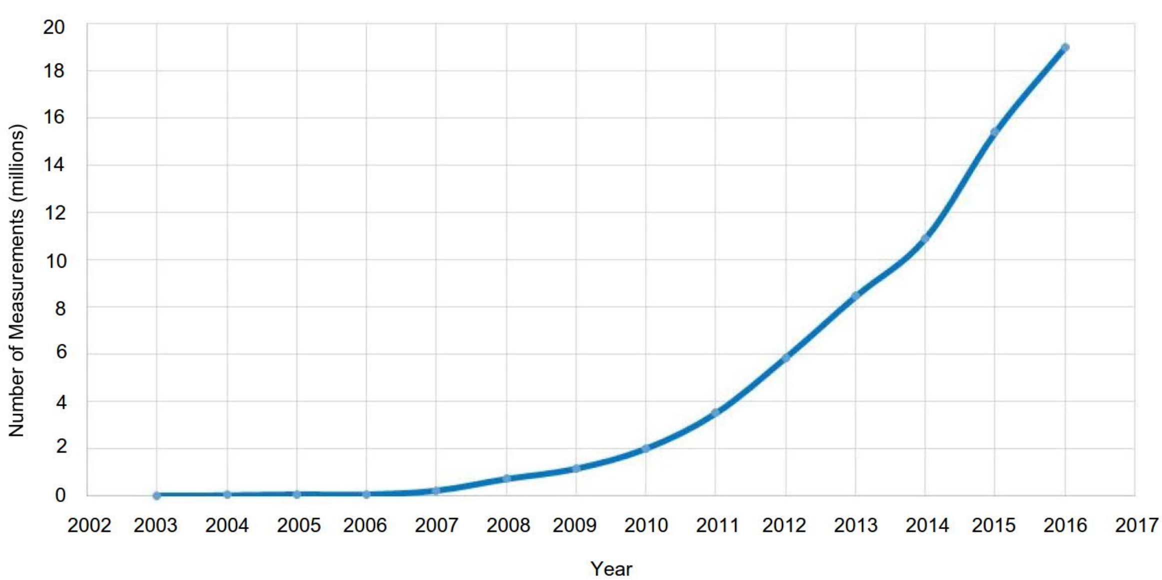

Figure 4. The number of optical measurements obtained by ISON telescopes.

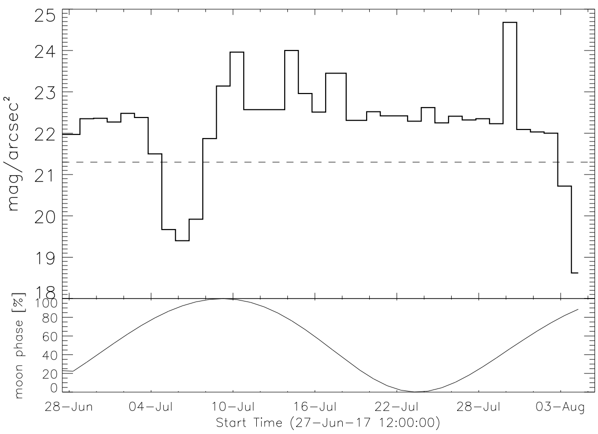

Figure 5. *Top panel:* Plot for Infiernillo (3,140 meters altitude) sky darkness measurements. This graph shows the maximum mag/arcsec^2 reached every night during the beginning of the summer season. *Bottom panel:* The correspondent moon phase evolution for this time.

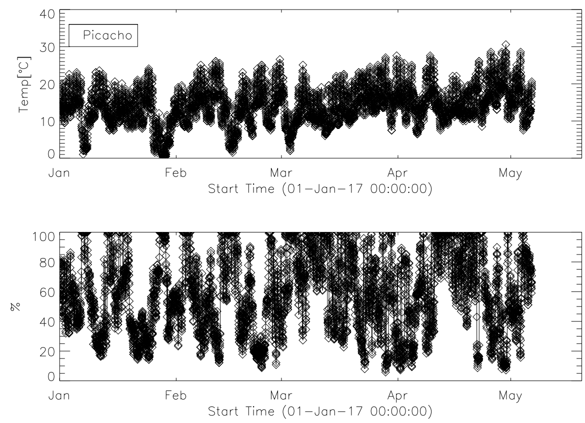

Figure 6. The plot for Picacho (2,730 meters altitude) meteorological measurements from January to May 2017. *Top panel:* Temperature. *Bottom panel:* Humidity, whose modulations are due mainly by a couple of seasonal events, the cold fronts which occur during the first 3–4 months of the year and the Mexican monsoon from the end of spring to the end of summer.

ple of sites at altitudes greater than 1000 m over mean sea level.

Figure 2 shows the current position of ORI-25 at Monterrey, marked by a black star. The test sites being located in the southern region, enclosed by a circle.

The majority of light from Monterrey and other large northern cities is quite well blocked by the Sierra Madre Ridge. There are two sites which we are working on since May 2017, Picacho (2,700 m) and Infiernillo (3,140 m) inside enclosed circle area.

Sky darkness measurements were carried by employing an Unihedron Sky Quality Meter (Pun *et al.* 2014). Such device measures the spatially integrated sky brightness (mag/arcsec^2) through a factory-calibrated sensor and stores data to a PC via USB. Following the device specifications, its accuracy is ±10% (± 0.10 mag/arcsec^2). The graph in Figure 5 shows the maximum sky darkness values at Infiernillo site during the last summer observation campaign. The total sky darkness modulation is caused by moon phases, reaching an average value of 22,7 mag/arcsec^2 out from 90% of phase. This value is quite above the reference value of 21,3 mag/arcsec^2 (dashed line) of the observed surface brightness of the Milky Way.

Panels from Figure 6 shows temperature (*top*) and relative humidity (*bottom*) from Picacho site for the first five months of the present year. Dispersion in humidity accounts for weather conditions during the occurrence of cold fronts during the first three months of the year and the Mexican monsoon activity by the end of April.

We will implement sky darkness measurements and meteorological observations at both sites by the end of the year. Such measurements will be complemented by data from clouds counting through a whole-sky camera and seeing measurements through a Differential Image Motion Monitor (DIMM) camera (see Figure 7). Both instruments are already in the testing phase at the UANL Solar Observatory. This site is in enclosed circle region in Figure 10 as well.

Figure 7. DIMM camera device for seeing measurements, currently installed at the UANL Solar Observatory.

Month	Nights	Measurements	Tracklets	Measured Objects	Processed Images
09 2017	7	6355	737	430	2730
08 2017	4	4030	431	345	1398
07 2017	0	0	0	0	0
06 2017	15	14565	1250	663	6315
05 2017	20	37710	3628	928	13476
04 2017	14	24068	2416	791	8304
03 2017	20	44088	4455	899	16207
02 2017	18	40635	4183	878	14855
01 2017	16	25607	2597	730	9946
12 2016	17	36785	3625	764	14504
11 2016	18	33376	3154	788	12437
10 2016	17	36310	3397	834	13475
09 2016	9	9350	888	470	3562
Total	175	312879	30761	8520	117209

Figure 8. Statistics of ORI-25 optical measurements at Cosala, September 2016–September 2017.

Month	Nights	Measurements	Tracklets	Measured Objects	Processed Images
09 2017	3	6418	918	400	2705
08 2017	3	4830	695	262	2459
07 2017	6	5878	945	403	2900
06 2017	8	6579	1070	391	2851
05 2017	3	4556	682	330	2022
04 2017	13	27182	4062	619	9703
03 2017	13	25265	3785	527	10931
02 2017	1	233	41	39	120
01 2017	14	36905	5153	659	15272
12 2016	7	21046	3004	614	8576
11 2016	12	31687	4546	612	13736
10 2016	7	20301	2895	629	8564
09 2016	1	80	10	10	26
Total	91	190960	27806	5495	79865

Figure 9. Statistics of ORI-25 optical measurements at Monterrey, September 2016–September 2017.

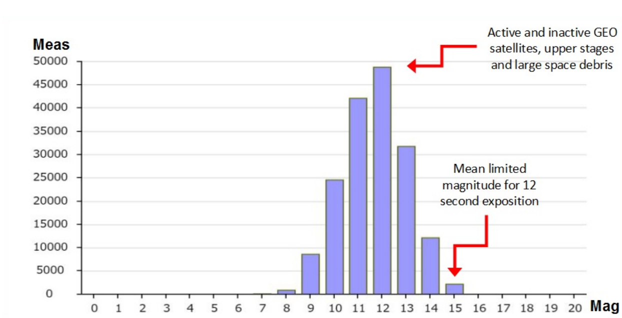

Figure 10. Magnitude distribution of ORI-25 measurements at Monterrey, September 2016–September 2017.

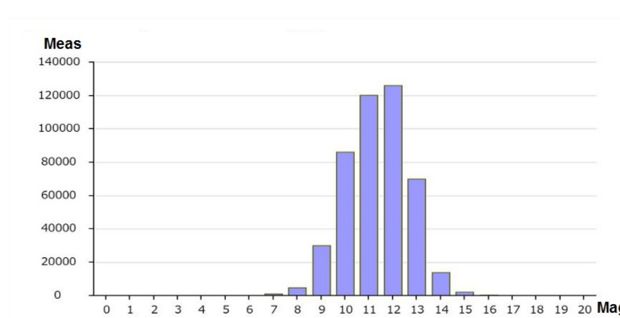

Figure 11. Magnitude distribution of ORI-25 measurements at Cosala, January 2016–September 2017.

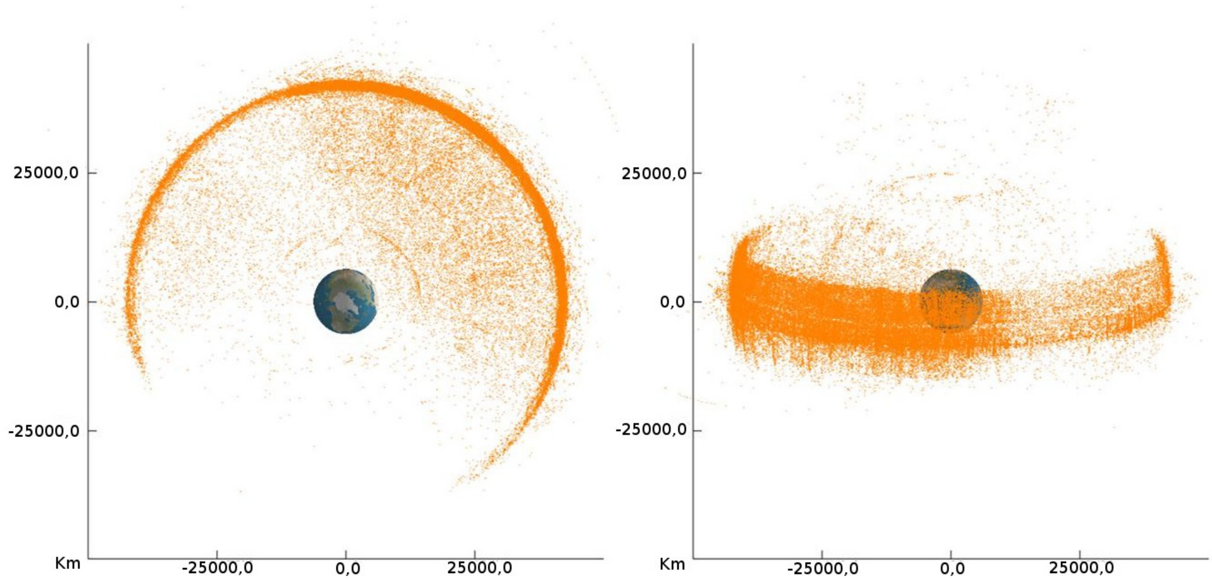

Figure 12. A sample of distribution of space debris objects measured by ISON in Jan–Feb 2017.

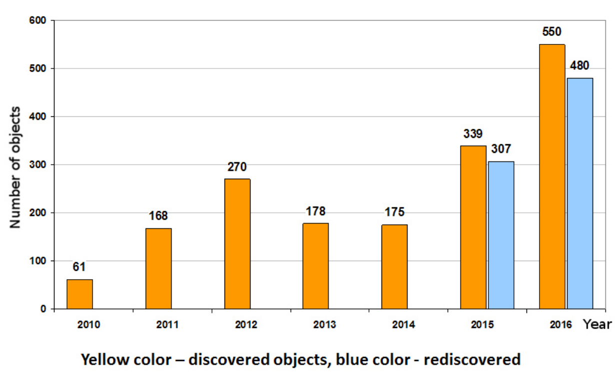

Figure 13. Statistics of discoveries and re-discoveries of ISON per year

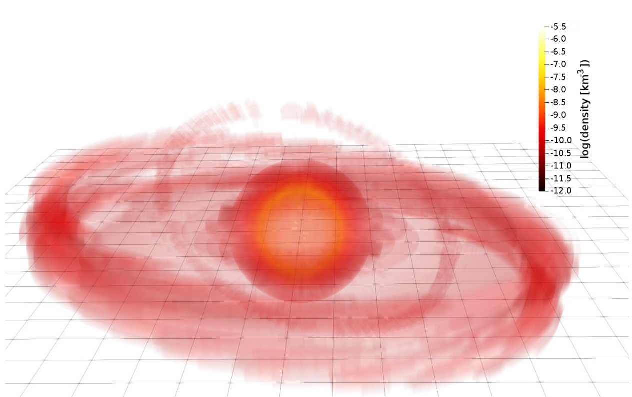

Figure 14. Space debris model elaborated by ISON in KIAM RAS, the outer ring corresponds to the geostationary region.

5 Results

Two small-aperture telescopes for HEO and GEO objects tracking and surveying in Mexico have shown appropriate results within the ISON project. The observation facility at Cosala confirms the status of the reliable site with the high efficiency of observations.

The one-year test observation campaign, held at Monterrey, reveals remarkable results due to the well-coordinated work of the observer team. Furthermore, surveys and astroclimate analysis were carried out in several prospective locations in the State of Nuevo León with more suitable dark and transparent sky conditions.

Present work is a liaison in the Russian-Mexican space situational awareness.

Data gathered by Mexican stations from the Western Hemisphere play an essential role in maintenance and growth of the ISON catalogue. An example of space debris objects, observed by the whole ISON network in Jan-Feb 2017, shown in Figure 12. More than 1,5 thousand GEO and HEO space debris objects have been discovered with the participation of ISON in total, more detailed in Figure 13. Gathered data were also used by ISON for the development of space debris models, an example of realisation that includes the HEO population is presented in Figure 14.

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