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Increasing of new GEO/HEO space debris discovery rate with ISON optical network

Igor Molotov [a,b]*, Thomas Schildknecht[c], Francisco Javier Montojo[d], Vasiliy Rumyantsev[e], Vadim Biryukov[e], Vladimir Zolotov[a], Takhir Fakhrutdinov[a], Mikhail Zakhvatkin[a], Viktor Voropaev[a], Gennadiy Borovin[a], Leonid Elenin[a], Dmitriy Chestnov[a], Tatiana Kokina[f], Tungalag Namkhai[g], Rodolfo Zalles[h], Raguli Inasaridze[i], Alexander Vikhristenko[j], Sergey Buyko[k], Andrey Smirnov[k], Gennadiy Kornienko[l], Anna Erofeeva[l], Alexander Wolf[m], Alexander Kaplinskiy[m], Oleg Rusakov[n], Artem Mokhnatkin[n]

[a] *Keldysh Institute of Applied Mathematic RAS, Miusskaya sq., 4, Moscow, Russia 125047,* molotov@kiam1.rssi.ru
[b] *Small innovation enterprise «KIAM Ballistics-Service», Miusskaya sq., 4, Moscow, Russia 125047,* im62@mail.ru
[c] *Astronomical Institute UB, Sidlerstrasse 5, Bern, Switzerland 3012,* thomas.schildknecht@aiub.unibe.ch
[d] *Real Instituto y Observatorio de la Armada,Plaza de las Marinas, San Fernando, Spain 11110, fjmontojo@roa.es*
[e] *Crimean Astrophysical Observatory, RAS, Nauchny, Crimea, Russia 298409,* rum14@list.ru
[f] *Universidad Autonomia de Sinaloa, Ciudad Universitaria, Culiacan, Mexico 80000,* anisili@rambler.ru
[g] *Research Center of Astronomy and Geophysics MAS, 7th building of MAS, Bayanzurkh district, Ulaanbaatar, Mongolia MNG 210351,* namkhai_tungalag@yahoo.com
[h] *Observatorio Astronomico Nacional UAJMS, Casilla 51, Tarija, Bolivia E-0149,* rozalles@cosett.com.bo
[i] *Kharadze Abastumani Astrophysical Observatory ISU, Kakutsa Cholokashvili Ave 3/5, Tbilisi, Georgia 0162,* innasaridze@yahoo.com
[j] *Pridnestrovskiy State University, 25 October str., 128, Tiraspol, Moldova 734042,* astrovam1@rambler.ru
[k] *All-Russian Research Institute of Experimental Physics, Mira Ave 37, Sarov, Nizhny Novgorod region, Russia 607188,* starbizon56@yandex.ru
[l] *Ussuriysk Astrophysical Observatory RAS, Solnechnaya str.21, Ussurijsk, Russia 92533,* g_kornienko@mail.ru
[m] *Altay State Pedagogical University, Molodejnaya str. 55, Barnaul, Russia 656031,* alekap@mail.ru
[n] *Pulkovo Astronomical Observatory, Pulkovskoe chaussee 65/1, St.-Petersburg, Russia 196140,* artspace3@mail.ru
* Corresponding Author

Abstract

International Scientific Optical Network (ISON) represents one of largest systems specializing in observation of space objects. ISON provides permanent monitoring of the whole GEO region, regular surveying of Molniya type orbits, and tracking of objects at GEO, GTO, HEO and LEO. ISON project is continuously developing and is joining now the 37 observation facilities in 16 countries with 86 telescopes of different class (aperture from 12.5 cm to 2.6 m). 15.4 millions measurements in 2.1 millions of tracklets for about 5000 objects are collected by KIAM in 2015. 339 new space objects have been discovered, 307 previously lost objects have been rediscovered. For comparison, 160 new objects have been discovered in 2014, and 250 in 2013. 2014 was devoted to putting into operation of small survey and follow up telescopes (including new subsystem for extended GEO surveys to determine more precise orbits for conjunction analysis). This caused some decreasing of new space debris discovery rate in 2014. During 2015 and 2016 a lot of the telescopes of 40 cm ï 80 cm apertures has been putted into operation. In addition, the methodology of quick identification and follow up of new space objects has been adjusted in part of ISON observatories. This resulted significant increasing of GEO/HEO space debris discovery rate. Achieved parameters of the above mentioned telescopes and obtained results will be presented and discussed. It is planned to start the printing of KIAM monthly bulletin with orbits of new discovered space debris.
Keywords: space debris, optical telescope, astrometry measurements, orbit, catalogue

Acronyms/Abbreviations

International Scientific Optical Network (ISON), Central Research Institute of Machine Building (TsNIIMash), Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM), experimental optical point (EOP), optical-electronic tool (OET), Facility for Operating Robotic Telescope Equipment (FORTE).

1. Introduction

International Scientific Optical Network (ISON) [1] is an open international project developed to be an independent source of data about space objects for scientific analysis and space situation awareness. Main areas of monitoring are the Geostationary (GEO) and highly-elliptical (HEO) orbits. Observations of the MEO and LEO objects are started. Also ISON provides the observations of the asteroids [2] and gamma-ray bursts afterglows [3]. Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences

(KIAM), which coordinates the ISON project and processes ISON measurements, maintains 40% more complete GEO-object catalogue than public TLE data, and comparable database in part of HEO and MEO objects. Currently ISON collaborates with the 37 observation facilities in 16 countries with 86 telescopes of different class (aperture from 12.5 cm to 2.6 m). 74 telescopes in 33 observation points are participating in the space debris observations. Core of the ISON network is the 33 telescopes of KIAM RAS, KIAM Ballistics-Service Ltd and NCT Ltd. Moreover KIAM/ISON interacts with many university, academician, commercial and private observatories in Switzerland, Spain, Bulgaria, Kazakhstan, Georgia, Ukraine and Russia, and with the growing network of dedicated space debris observatories of the Roscosmos/TSNIIimash [4].

Most part of the observatories collaborated with KIAM/ISON uses the standard software package elaborated within ISON project - AccuTime module (GPS receiver), CameraControl module (CCD camera), CHAOS module (telescope mount), Apex II module (astrometric and photometric reduction of the CCD frames), or new integrated telescope control system and data acquisition software package FORTE [5].

All telescopes are arranging in six main subsets of telescopes: (i) global GEO survey, (ii) extended GEO survey, (iii) deep GEO survey, (iv) tracking of bright (brighter than 15.5 star magnitude) GEO and HEO objects, (v) tracking of the faint (fainter than 15.5 star magnitude) space debris at GEO and GTO, (vi) asteroids researches. Additionally one telescope provides the regular surveys of the Molniya-type HEO objects. So, the ISON optical network now represents one of largest and powerful ground systems specializing in observation of space objects (geographical location of the observatories collaborating with ISON is in [6]). Survey telescopes provide a main stream of the measurements for the catalogue maintenance and the new object detections. New bright objects then are tracked with subset (iv), new faint objects - with subset (v). The GEO surveys provide also many detections of the HEO/GTO objects. These HEO/GTO objects then are tracked with subsets (iv) and (v).

Using ISON data KIAM carries out the researches in following fields: (i) estimation of real population of space debris at high geocentric orbits, (ii) determination of physical properties of discovered space debris objects, (iii) determination of probable sources of newly discovering space debris fragments, (iv) verification of existing evolution models of space debris distribution, (v) high orbit space debris risk assessment, (vi) improvement of technologies of studying of space debris population using optical instruments, (vi) improvement of motion models for space debris objects with complex physical properties.

2. Recent developments within the ISON project

Deployment of the six Roscosmos mini-observatories and three telescopes (21 telescope total of the 19.2 cm ï 65 cm apertures) has been completed. Four mini-observatories EOP-1 with 3 telescopes in each: 40 cm, 25 cm and double 19.2 cm apertures are installed in Kislovodsk (North Caucasus), Buyrakan (Armenia) and Nauchniy-3 (Crimea). Two mini-observatories EOP-2 with 3 telescopes in each: 65 cm, 40 cm, 4x19.2 cm apertures are installed in Kislovodsk and Blagoveschensk. Three separate telescopes ï OET-65 (65 cm), OET-50 (50 cm) and OET-25 (25 cm) are installed in Ussuriysk, Kislovodsk and Abrau-Durso.

Two 50-cm telescopes ORI-50ML (see Fig. 1) with field of view 2 degrees were installed in Kislovodsk (North Caucasus) and Nauchniy-3 (Crimea) and incorporated in subset (iii) for deep GEO surveys.

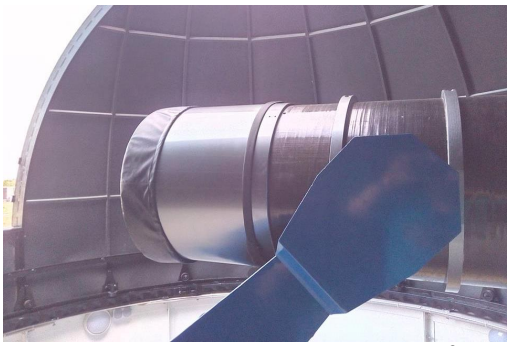

Fig. 1. New 50-cm telescopes ORI-50ML with field of view 2 degrees in Naucnniy-3, Crimea

So, new telescope subset (iii) is formed in the ISON network. It includes three 65 cm telescopes of the Roscosmos/TSNIIimash and three 50 cm telescopes (third telescopes in Andrushivka, Ukraine). The goal of this subset for deep GEO surveys is a detection of unknown faint space objects. It is planned to install two more similar 50 cm telescopes in Multa, Russia and Assy-Turgen, Kazakhstan.

Two telescopes ï 60 cm Ceiss-600 in Tarija, Bolivia and 80 cm K-800 in Terskol (see Fig. 2), North Caucasus supplement the subset (v) for tracking of the faint GEO and HEO objects. Both telescopes were automated and upgraded with lens corrector to enlarge field of view up to 55 minutes. K-800 telescope is able to track the space objects fainter 19 star magnitude. ISON can track the faint objects along all GEO after restoring of operations of 40 cm CHV-400 telescope in Cosala, Mexico.

Also, the methodology of quick identification and follow up of new space objects has been adjusted in the

Fig. 2. Upgraded 80 cm telescope K-800 with field of view 55 minutes in Terskol, North Caucasus

observatories of Roscosmos/TSNIIimash where there are the powerful computers. Received CCD images are processed in near real-time and then obtained measurements are compared with the list of orbits from local catalogue. And new detections immediately transferred to other working telescopes of the ISON. These works resulted significant increasing of GEO/HEO space debris discovery rate.

Other direction of the ISON development is starting of the exchange of the telescopes from subset (i) for global GEO survey. First 22 cm telescope with field of view 4.1 degrees in Nauchniy-1, Crimea is changed on 30 cm telescope GenonMax (see Fig. 3) with field of view 4.7 degrees. Second telescope will be changed in Kitab, Uzbekistan in first half of 2017, third ï in Blagoveschensk in second half of 2017.

Fig. 3. New 30 cm telescope GenonMax with field of view 4.7 degrees in Nauchniy-1, Crimea

This is also will improve the detection of the faint GEO objects, because of the faint objects periodically have the flashes due to variability of their brightness and in these cases are detected even with small survey telescopes. GenonMax telescopes provide a better limiting sensitivity (on 1 ï 1.5 star magnitude) and thus more detections of new objects.

3. Obtained results

Number of the measurements that is producing by the ISON is steadily growing each year (see Fig. 4). 15.4 millions measurements in 2.1 millions of tracklets for 4373 objects at high orbits are collected by KIAM data centre in 2015 ï 2069 at GEO, 1966 at HEO and 338 at MEO. Statistics on observed GEO, HEO and LEO objects is given on Fig. 5 ï Fig. 7 and in Table 1.

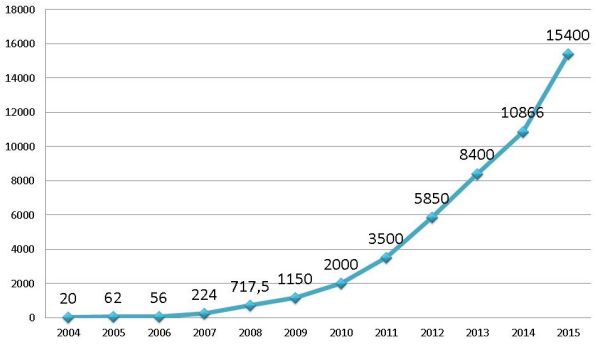

Fig. 4. Number of measurements (in thousands) collected by ISON annually for the 2004 ï 2015 period.

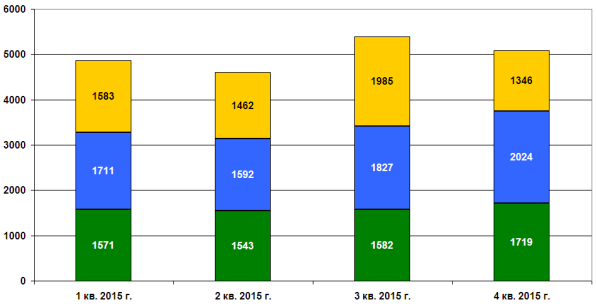

Fig. 5. Types and quantity of ISON observed objects in 2015 quarterly (1 ï 4 from left to right) . Green colour ï GEO, blue colourï HEO, yellow colourï LEO

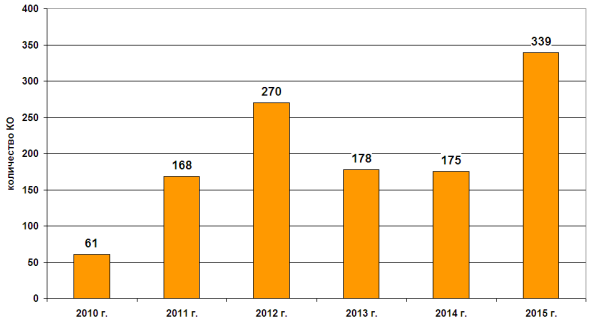

Fig. 6. New objects discovery statistic annually

Fig. 6 shows that in 2015 it were discovered 339 new objects that almost in 2 times more than in 2014.

Table 1. Quantity of high orbit objects observed by ISON cooperation quarterly

Quarter	GEO bright	GEO faint	HEO bright	HEO faint
1 ï 2016	1380	410	1430	370
4 ï 2015	1340	380	1520	510
3 ï 2015	1310	270	1390	440
2 ï 2015	1320	220	1230	360
1 ï 2015	1300	240	1470	370
4 ï 2014	1280	260	1100	340

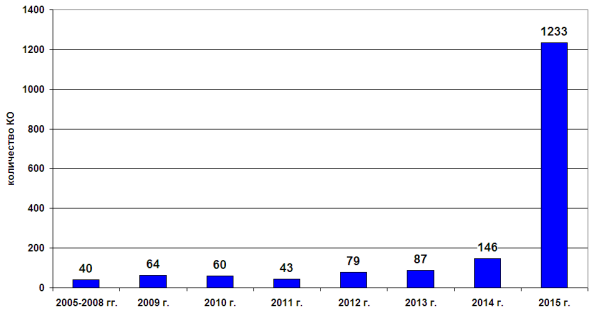

Fig. 7. Distribution of 1742 non-TLE objects in KIAM database on year of last measurements.

Fig. 7 demonstrates that many faint objects are lost. These are mostly the objects with high are to mass ratio due to difficulty of their tracking.

So, number of discoveries of relatively bright GEO debris objects (brighter than 16-17 star magnitudes) continues to grow in spite of already few year meticulous surveys of all GEO ring. This may demonstrate that there is some source of permanent generation of new GEO objects. Many of newly discovered GEO space debris are crossing or permanently staying in the GEO protected region and increase threat to operational spacecrafts. It is expected that at least several hundreds more of GEO space debris exist in the GEO region.

6. Conclusions

The annual plans for the development of the ISON project were fulfilled. It was arranged new telescope subset (iii) for deep GEO surveys from five telescopes of 50 cm and 65 cm aperture with field of view of 2 ï 2.5 degrees. Also subset (v) for tracking of the faint space debris at GEO and GTO was added with 6 telescopes of 40 cm, 60 cm and 80 cm aperture. It was started upgrade of the subset (i) with new 30 cm telescopes with field of view 4.7 degrees. This resulted significant increasing of the GEO/HEO space debris discovery rate (in two times in comparison with previous year). 339 new objects at high orbits were catalogued by KIAM data centre. 307 previously lost objects have been rediscovered. In common 15.4 millions measurements in 2.1 millions of tracklets for 4373 objects at high orbits are collected by KIAM data centre in 2015 ï 2069 at GEO, 1966 at HEO and 338 at MEO.

It is expected that the ISON project will continue the development. These are the 10 existing telescopes which may putted in operation during next year. Production of new series of 40-cm telescopes with field of views 4 degrees is started. The places for these telescopes installation are searched. ISON project is open for cooperation and invites new partners to collaborate in field of the space debris and asteroids investigations.

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