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# International scientific optical network for space debris research

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**Abstract**

A joint team of researchers under the auspices of the Center for Space Debris Information Collection, Processing and Analysis of the Russian Academy of Sciences collaborates with 15 observatories around the world to perform observations of space debris. For this purpose, 14 telescopes were equipped with charge-coupled device (CCD) cameras, Global Positioning System (GPS) receivers, CCD frame processing and ephemeris computation software, with the support of the European and Russian grants. Many of the observation campaigns were carried out in collaboration with the Astronomical Institute of the University of Bern (AIUB) team operating at the Zimmerwald observatory and conducting research for the European Space Agency (ESA), using the Tenerife/Teide telescope for searching and tracking of unknown objects in the geostationary region (GEO). More than 130,000 measurements of space objects along a GEO arc of 340.9°, collected and processed at Space Debris Data Base in the Ballistic Center of the Keldysh Institute of Applied Mathematics (KIAM) in 2005–2006, allowed us to find 288 GEO objects that are absent in the public orbital databases and to determine their orbital elements. Methods of discovering and tracking small space debris fragments at high orbits were developed and tested. About 40 of 150 detected unknown objects of magnitudes 15–20.5 were tracked during many months. A series of dedicated 22-cm telescopes with large field of view for GEO survey tasks is in process of construction. 7 60-cm telescopes will be modernized in 2007.


*Keywords:* Space debris; Faint fragment; Unknown object; Geostationary orbit; Data base; Optical telescope; Optical network

## 1. Introduction

The problem of studying the real population of space debris objects in the GEO region is extremely important.

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On the one hand, geostationary orbit represents a unique area of the near space from the point of view of solving various tasks (television and communication services, weather monitoring, data relay, etc.), and, on the other hand, it is a limited natural resource which requires preservation for future use. There is no natural mechanism of self-cleaning here, similar to the low Earth orbit (LEO) region (decay of space debris fragments in the Earth atmosphere). Most of the GEO objects will live eternally, moving along their orbits. Therefore, the program of GEO objects investigation using a 70-m dish antenna radar facility in Evpatoria, Crimea of Ukraine, was established in 2001 (Molotov et al., 2004). At the same time, the work of arranging a scientific optical telescope network was initiated for the purpose of improving the ephemerides of radar targets (Agapov et al., 2004), as the 70-m antenna in Evpatoria (RT-70) had a 3.6 arcmin beam width and the available orbital data precision was not enough for pointing RT-70 to space objects. Since 2003, a scientific optical network carries out the observations of GEO objects under the auspices of the Ballistic Center of the Keldysh Institute of Applied Mathematics (KIAM), Russian Academy of Science. In 2004, the first attempts to detect and track small GEO fragments of space debris were made using the AT-64 telescope in Nauchnij, Crimea (Volvach et al., 2006), and a collaboration with European observatories was established (Agapov et al., 2005). Since 2005, the observations of the International Scientific Optical Network (ISON) were carried out on a regular basis (Molotov, 2005). The list of participating observatories, with the characteristics of each telescope involved, obtained results statistics and future plans, is presented below.

## 2. Scientific cooperation of the former Soviet Union observatories

The first GEO object observations within this project were carried out in April 2001 at the Pulkovo observatory, which has a long history of astrometric satellite observations. It was the 10-cm AKD telescope that obtained the first photographic frame of the “Sputnik” rocket body on October 10, 1957. In the following years, the Nauchnij, Mayaki and Goloseevo observatories joined this activity. Then, in 2002–2003, the work on identifying the present condition of all optical observatories of the former Soviet Union (FSU) and negotiations for their possible participation in the project of scientific network was performed. This allowed us to elaborate the program of refurbishing and modernization of the telescopes involved, that was accomplished, step by step, with the support of the Grant No. 03-70-567 of the International Association for the Promotion of Co-operation with Scientists from the New Independent States of the FSU and the Grant No. 09.255.52/053 of the Ministry of Education and Science of the Russian Federation, during 2004–2006. Fourteen optical telescopes were equipped with CCD cameras and GPS receivers to arrange the ISON for space debris research: 2.6-m ZTSh, 64-cm AT-64 and 22-cm SR-220 in Nauchnij, 65-cm refractor and 22-cm SR-220 in Pulkovo, 60-cm Zeiss-600 in Maidanak, 40-cm double Zeiss astrograph in Kitab, 40-cm double Zeiss astrograph in Ussuriysk, 40-cm double Zeiss astrograph in Abastumani, 60-cm RC-600 in Mayaki, 23-cm expedition astrograph in Tarija, 70-cm AZT-8 in Chuguev, 70-cm AZT-8 in Gissar, and 22-cm SR-220 in Tiraspol. The operational group for planning and scheduling ISON observations and the technical group providing a necessary support for ISON observatories, developing the dedicated software and technical solutions, and arranging the training courses, were created. Apex II, a universal software platform for astronomical image processing, being developed at the Pulkovo observatory, was distributed among the observers. One of the peculiarities of this software is the ability to process images with trailed reference stars which appear during 5–10 s exposures taken without sidereal tracking, using the point spread function fitting technique (Kouprianov, in press).

The geographic positions of the FSU observatories collaborating with ISON are presented in Fig. 1, while the characteristics of the telescopes involved are given in Table 1. This table also displays the development plans for the year 2007.

It is planned to divide the ISON telescopes into a number of dedicated subsystems. The first subset for regular GEO region surveillance, between 130°W and 210°E, will consist of 7 automated 22-cm telescopes SR-220 (see Fig. 2) with large field of view (FOV), up to 20 square degrees (Terebizh, 2001). Two test surveys, arranged with the SR-220 in Nauchnij, displayed the high performance of the proposed solution. 100% of the catalogued GEO objects down to magnitude 15 and, partially, high Earth orbit (HEO) objects, were detected in sky areas of $20° \times 20°$ and $30° \times 30°$ in a few hours of observation. Four SR-220 will be put into operation in the first half of 2007 in Nauchnij, Pulkovo, Ussuriysk and Tiraspol. The astrographs of 23 and 40 cm will be used to track the unknown objects detected in the surveys on a long measurement arc, and also for geostationary transfer orbit (GTO) objects observations.

The second subset is intended for more efficient searching and tracking of GEO objects with magnitudes 15–18. The basis for this subsystem will comprise the AT-64 in Nauchnij, and the RC-600 and SR-500 in Ussuriysk, with a FOV of about $2° \times 2°$. In addition, correctors will be installed on the Zeiss-600 in Simeiz, Zelenchuk, Maidanak and Tarija to obtain a FOV of about 1°. These Ziess-600 telescopes will be provided with CCD cameras in 2007. The telescopes of 2.6-m ZTSh in Nauchnij, Zeiss-1000 in Simeiz and Zelenchuk, 1.5-m AZT-22 in Maidanak, Zeiss-2000 in Terskol and 1.6-m AZT-33IK in Mondy will be used for investigation of GEO fragments with magnitudes 19–21. The ISON news are regularly published in a dedicated web site: www.lfvn.astronomer.ru.