



Russian Academy of Science  
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# International scientific optical observation network (ISON) for the near-Earth space surveillance – results of the first years of work and plans for the future

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Presentation for the 45th session of the COPUOS STSC  
19 February 2008, Vienna

# The ISON network

The International Scientific Optical Network (ISON) presented last year at the 44<sup>th</sup> session of the STSC is continued to develop.

In 2007 the network was gradually improved both in the number of facilities and the quality of it's output. New tasks have been added.

As of the beginning of 2008 the ISON network joins:

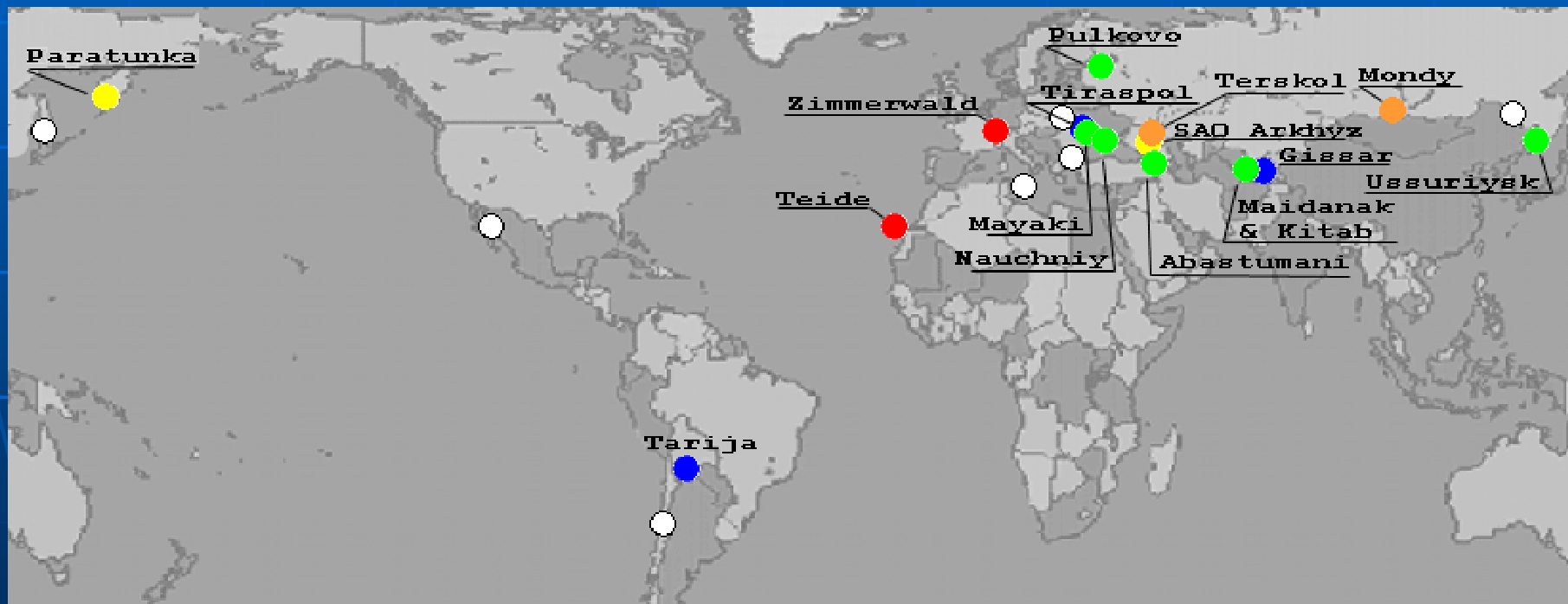
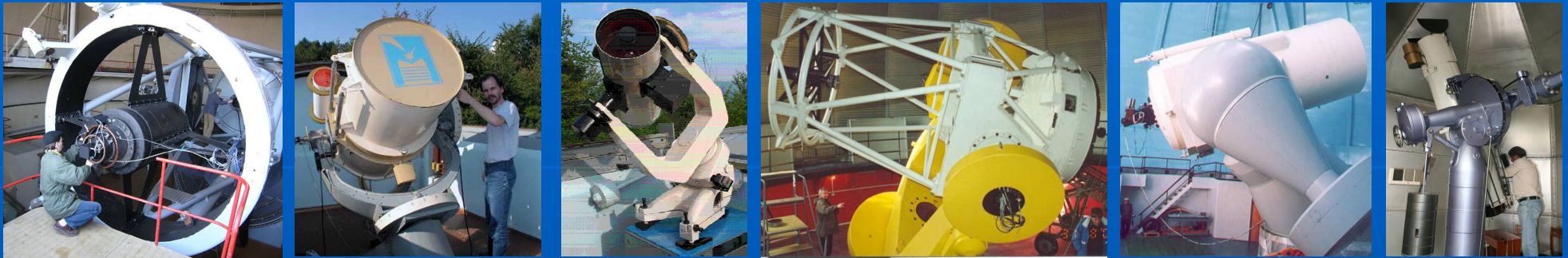
- 18 scientific institutions in 9 states
- 18 observatories and observation facilities
- 25 optical instruments
- more than 50 observers and researchers

Project principal coordinator responsible for the formulation of the solving tasks, observation planning, collecting and analysis of the results is Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM RAS).

# The ISON structure

- **network of optical facilities:**
  - search and survey subsystem for studying of the bright (not fainter than 16<sup>th</sup> magnitude) objects in GEO region (**initial operations stage**)
  - subsystem for high altitude faint space debris detection and tracking (**operational**)
  - search and survey subsystem for studying of the bright (not fainter than 16<sup>th</sup> magnitude) objects on HEO, MEO and LEO orbits (**in development**)
- **center for observation planning and data processing including maintenance of the database on space objects**
- **group of technical and programming support**
- **group of the network development**

# The ISON facilities and instruments

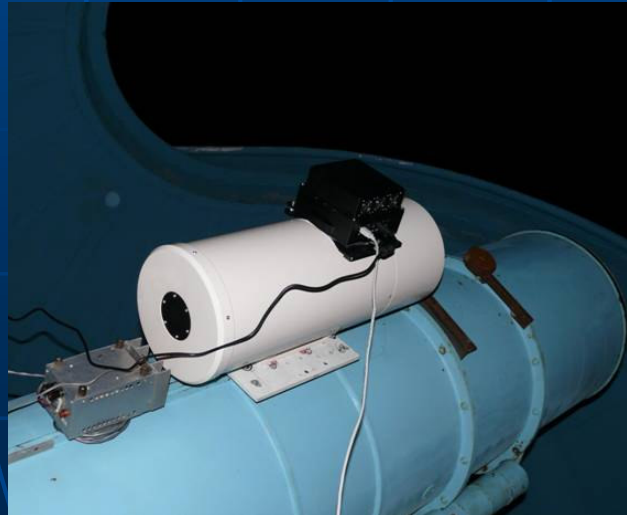




# Search and survey subsystem for the bright objects in GEO region

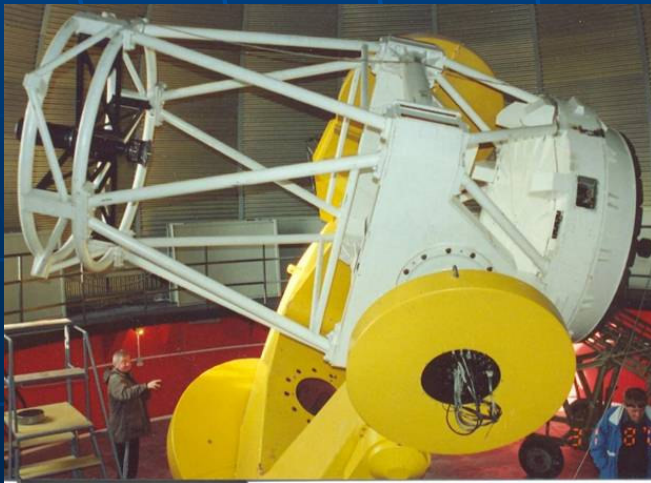
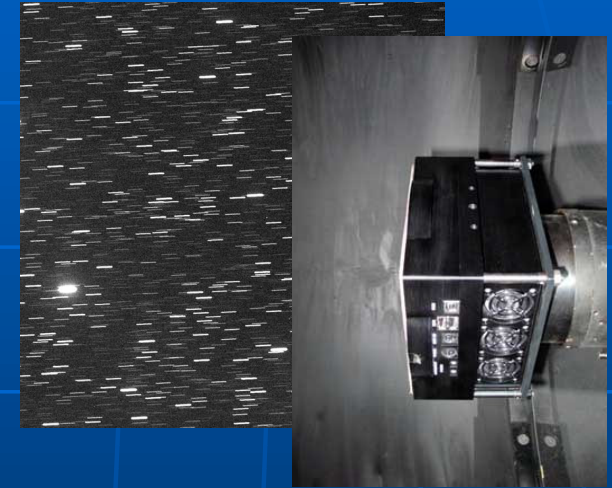


The subsystem is based on 22-cm class instruments with FOV up to  $4.8^\circ$





# Subsystem for high altitude faint space debris detection and tracking

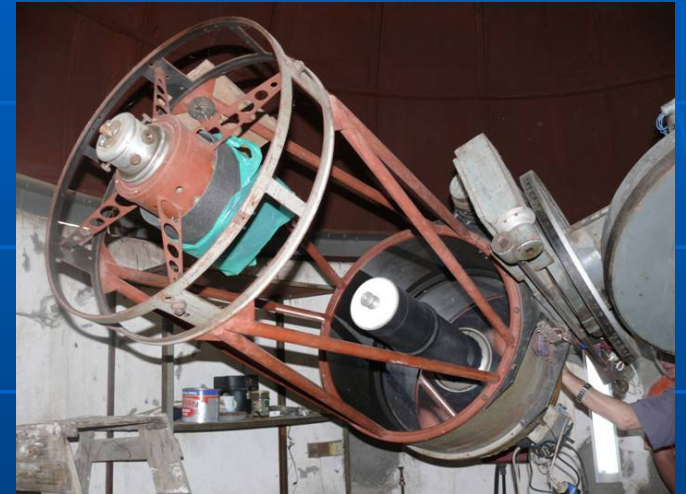
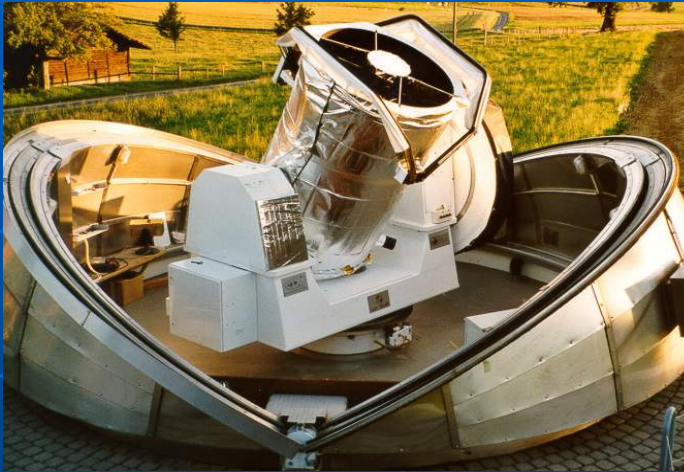


The subsystem includes instruments of 0.6, 0.8, 1.0, 1.5, 2.0 and 2.6 m class  
New instruments of 0.5 and 0.35 m class will be added





# Subsystem for high altitude faint space debris detection and tracking (cont.)



# Research goals

- estimation of real population of artificial objects on high geocentric orbits
- determining of possible origin of the discovered objects
- verification of existed space debris distribution and evolution models for high orbits (GEO, HEO, MEO)
- estimation of the real level of danger caused by space debris fragments for operational spacecrafts on high orbits at present and in the future
- testing and improvement of the technology of space debris studies using optical instruments
- improvement of the motion models for measurements processing and orbit propagation of specific space debris objects with high AMR



# Solving tasks

- detection and continuous tracking of as large number of unknown high altitude faint (and thus as the first estimation – small) objects as possible
- development and maintenance of “continuous” orbital archive for observed objects accessible as a public domain resource
- studying of the real orbital evolution of discovered objects and improvement of orbital motion models used
- studying of the physical properties of observed objects
- prediction and analysis of possible dangerous situation that may caused by discovered objects
- analysis of possible origin of discovered objects, modeling of circumstances under which they could to appear on orbit
- deterministic analysis of distribution of controlled and uncontrolled objects in GEO region and it's change in time
- studying the peculiarities of controlled motion of the spacecraft belonging to different owners but located in the vicinity of the same GEO position
- development of standard approaches of representation and dissemination of data on orbital situation

# The ISON network capabilities

At the beginning of 2008 the ISON network have following capabilities:

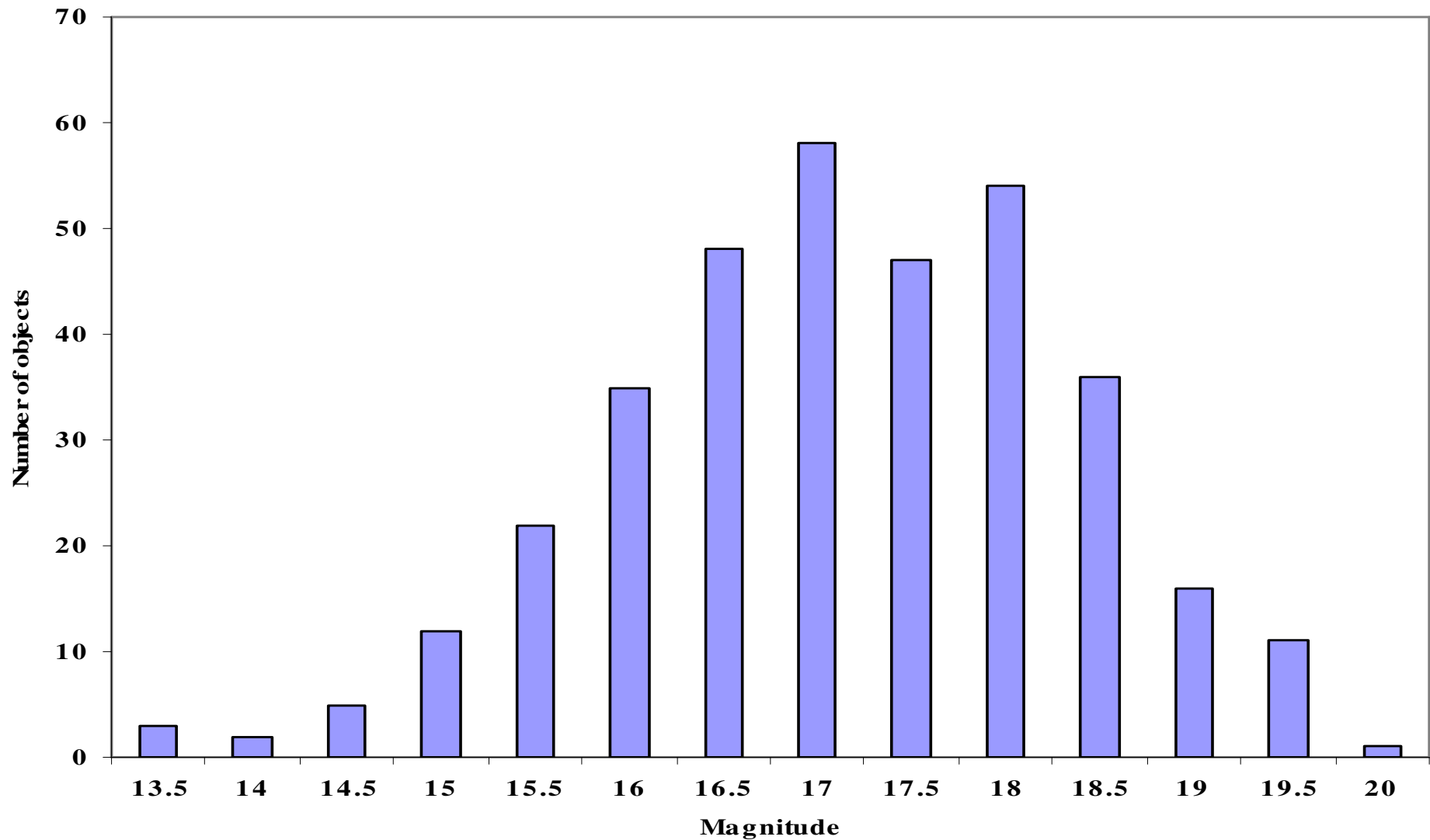
- Global surveying of the GEO region by longitude ( $0^{\circ}$ - $360^{\circ}$ ) and inclination ( $0^{\circ}$ - $20^{\circ}$ )
- Selective monitoring of objects on HEO orbits of the "Molniya"-type and GTO
- Autonomous detection and tracking of 0.2-1 m size GEO and HEO objects having brightness down to 20<sup>th</sup> magnitude
- Production of highly accurate measurements for GEO and HEO objects (at the level of 0.4-1 arcsec)
- Processing of all obtained measurements, construction of precise orbits and maintenance of the dynamical orbital archive
- Prediction and analysis of possible dangerous situation on GEO and HEO
- Conducting of experimental observations of LEO and HEO objects including debris of recent fragmentations



# GEO region study results obtained in 2007

- Global GEO coverage capability is achieved that is important for continuous studying of space debris situation in that region
- Since Jun 2007 wide GEO survey mode is implemented for longitudes 31.5W to 90E in a zone  $\pm 16^\circ$  with respect to the "true" GEO ring. Partial GEO survey mode is implemented for other longitudes
- Overall number of obtained measurements exceeded 230000
- Number of continuously tracked objects in GEO and HEO - 1690, including 143 unknown bright GEO objects (brighter than  $15^m$ ) orbital data for which publishes annually in «ESOC Classification of Geosynchronous Objects» (the last one – Issue 10, Feb 2008)
- 353 faint (fainter than  $15^m$ ) objects are discovered in GEO region surveys during the last 3 years, including objects with high AMR. Thus population of tracked objects in GEO region is increased more than 30 per cent. Results are publishing monthly by KIAM in High Geocentric Orbit Space Debris Circular . New discoveries continues to happen in every survey.
- Unexpected changes in orbital motion of old GEO objects are reveled in 2007 («KUPON» 1997-070A, «RADUGA» 1993-013A and other). Cause of those changes is not yet understood but in any case they can not be explained by natural forces like gravity or solar radiation pressure
- Large amount of observation is collected that makes possible accurate analysis of the peculiarities of controlled motion of the spacecraft belonging to different owners but located in the vicinity of the same GEO position

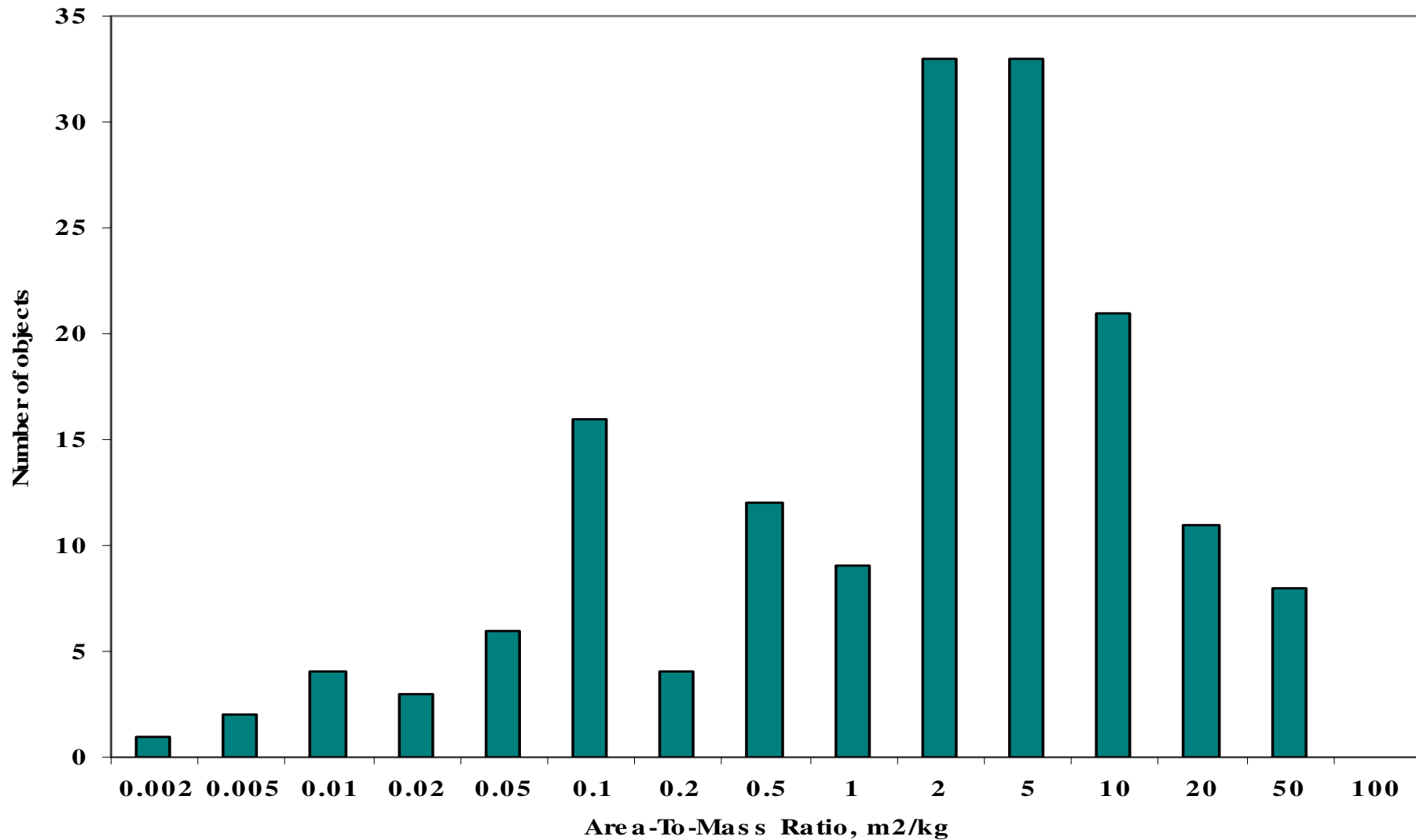
# GEO and GEO-like fragments



Brightness distribution for 350 fragments

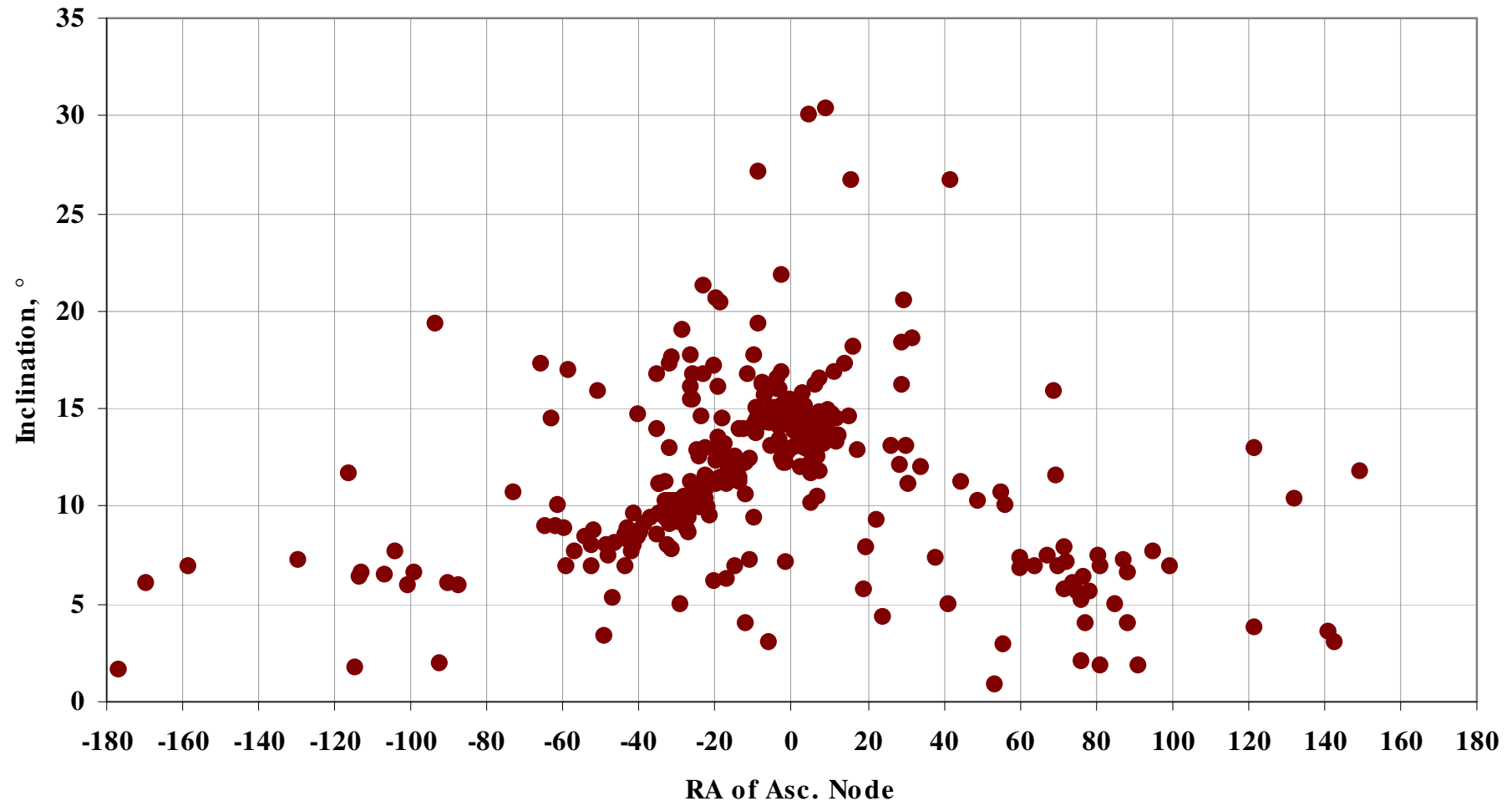


# GEO and GEO-like fragments



Distribution of AMR value for 163 fragments

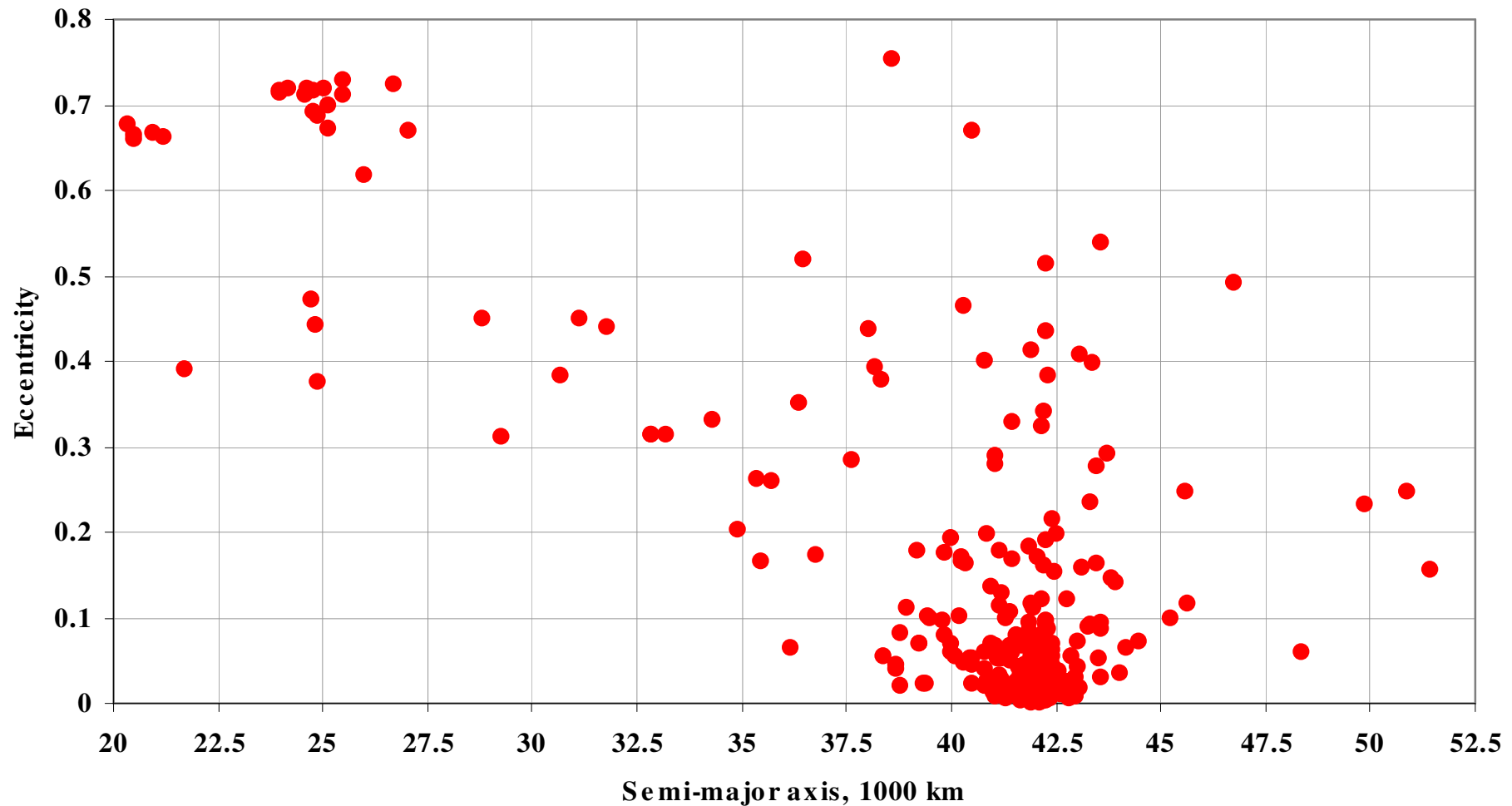
# GEO and GEO-like fragments



Distribution of inclination and RAAN for 353 fragments



# GEO and GEO-like fragments



Distribution of semimajor axis and eccentricity  
for 272 fragments

# Different mechanisms are involved into GEO debris creation

Fragments in GEO region are discovered on different types of orbits both drifting and librating. That means there are different GEO debris creation processes:

- for debris on libration orbits → separation with small relative velocity from the “parent” object (possible scenario – low velocity collision, deterioration of outer surface under influence of the environment or low velocity operational fragment separation)
- for debris on drifting orbits → high velocity separation from any object in GEO region (possible scenario – fragmentation in explosion) or low velocity separation from objects moved to the graveyard orbit (possible scenario – low velocity collision or deterioration of outer surface under influence of the environment)

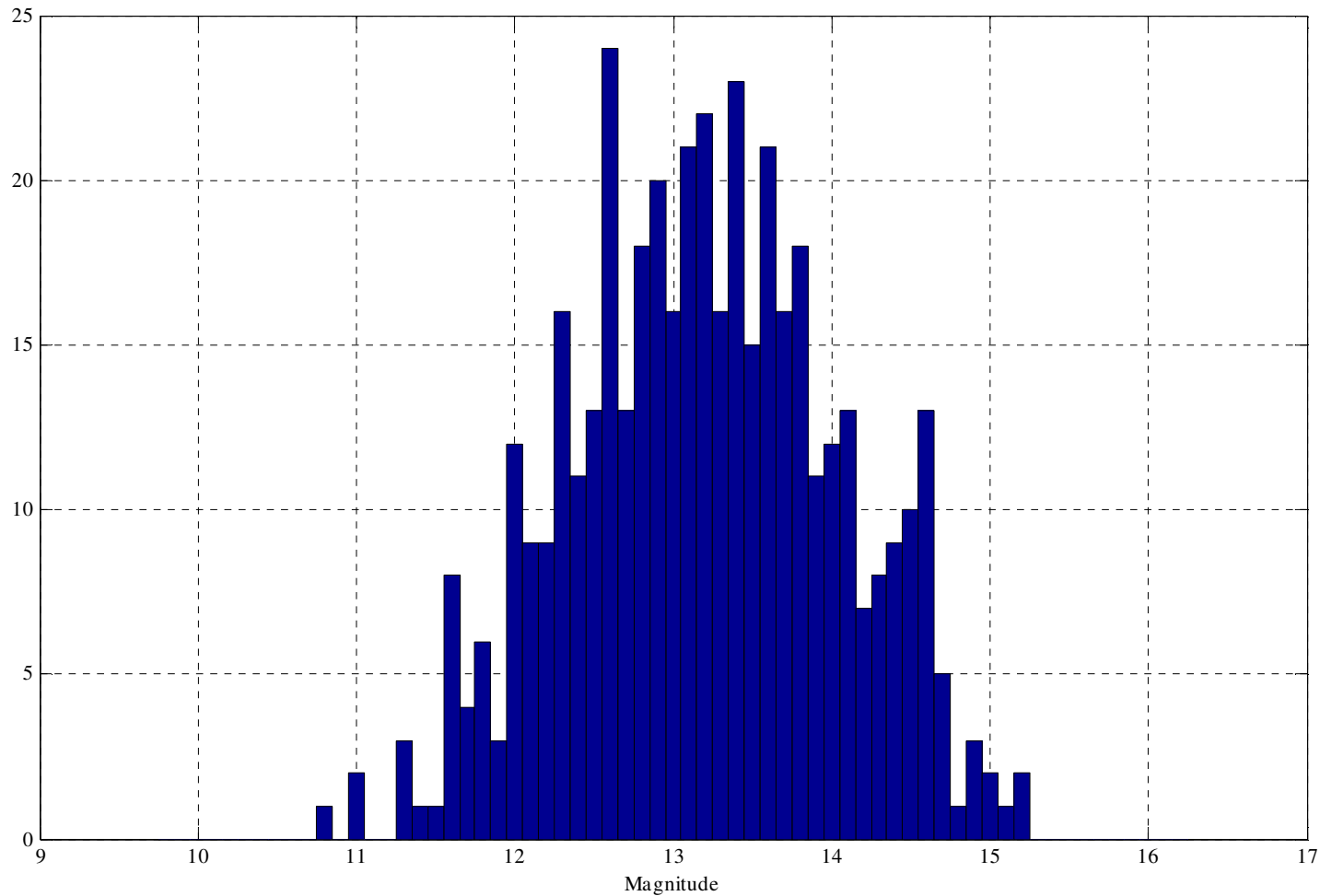
Additional studies are required to understand the most probable scenario of GEO fragments creation and to develop recommendations how to avoid (if possible) new fragments generation in the future.

# LEO and HEO experimental observation results obtained in 2007

- Successful experiments on independent discovery and tracking of debris created in fragmentations of Briz-M upper stage (object #28944), Block of ullage motor (#25054) and Fengyun 1C (#25730) are carried out. Small aperture (22 cm) optical instrument is used.
- Near 100 earlier unknown bright and more than 150 faint objects are observed on HEO (mostly GTO) orbits. All discovered bright objects are continuously tracking by now.

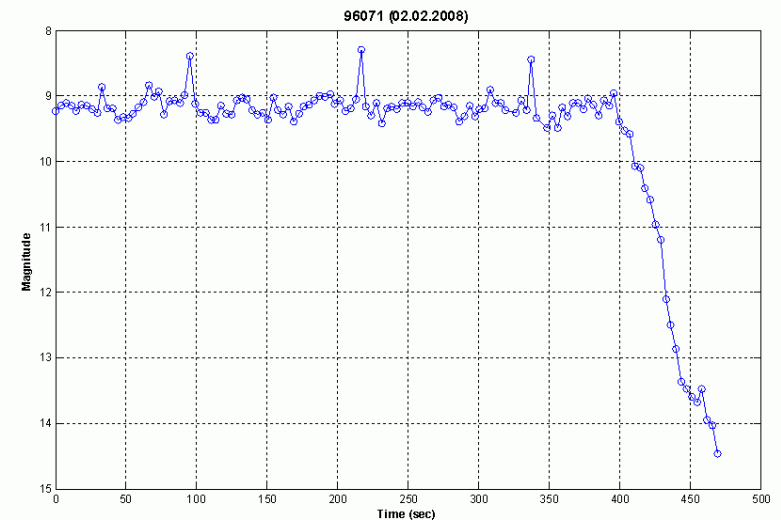
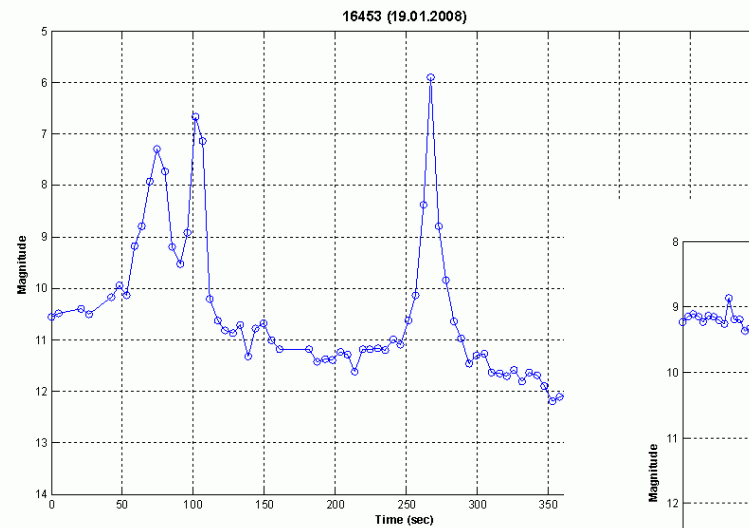
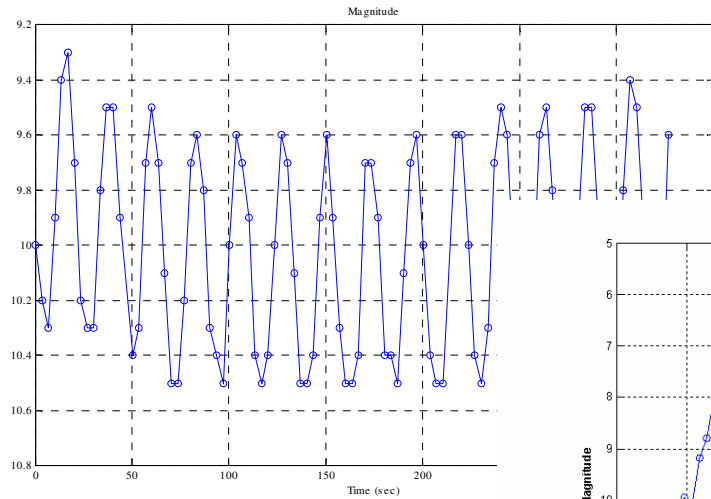


# LEO objects observations with small aperture optics



Brightness distribution for object #30457 (average size 26 cm)

# LEO and HEO objects observation



Typical brightness patterns for two newly discovered HEO objects and LEO object #16453

# The ISON perspectives for 2009

- > 30 telescopes with aperture from 15 cm to 2,6 m
- Independent continuous tracking of all objects larger than 1 m in size and more than 90% of objects larger than 0.5 m in size along all GEO arc
- Improved capability to detect and to track faint GEO and HEO objects with magnitude down to 21<sup>m</sup>
- Monitoring of GTO, Molniya and other types of HEO and continuous tracking of more than 80% HEO objects larger than 1 m in size
- Capability to carry out regular optical surveys of LEO
- Publication of special information bulletin
- Maintenance of the special public Internet-resource with updated orbital information on all tracked high altitude objects



# Conclusions

- New level of quality of GEO region research is achieved: full GEO arc coverage is established, regular wide surveys are carried out, for the first time our knowledge of true GEO population of objects brighter than 15<sup>m</sup> is complete and presented for public
- Several hundreds of earlier unknown objects discovered in GEO region and on HEO orbits are presented a clear indication of lack of our knowledge of true high orbits population. Number of discovered new high altitude fragments continues to grow so the research should be expanded in order to obtain as complete information as possible on potentially dangerous objects crossing orbits of operational GEO and HEO spacecrafts.
- The regular process of discovering and continuous tracking of high orbit fragments is established (to the date more than 100000 obtained for nearly 450 such fragments)
- Obtained information is publishing on a regular basis
- The ISON network is developing intensively and will be capable soon to independently track all GEO and HEO objects brighter than 15<sup>th</sup>-16<sup>th</sup> magnitude as well as to accurately monitor LEO dangerous objects
- The ISON is an open scientific structure and all nations are welcome to participate