Arrangement and results of ISON observations

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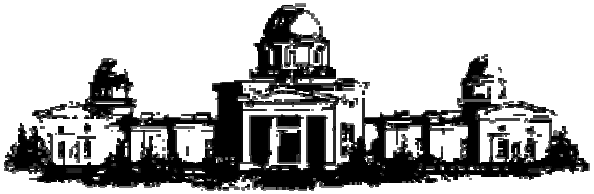
8th US/Russian Space Surveillance Workshop
18-23 April 2010, Wailea, Maui



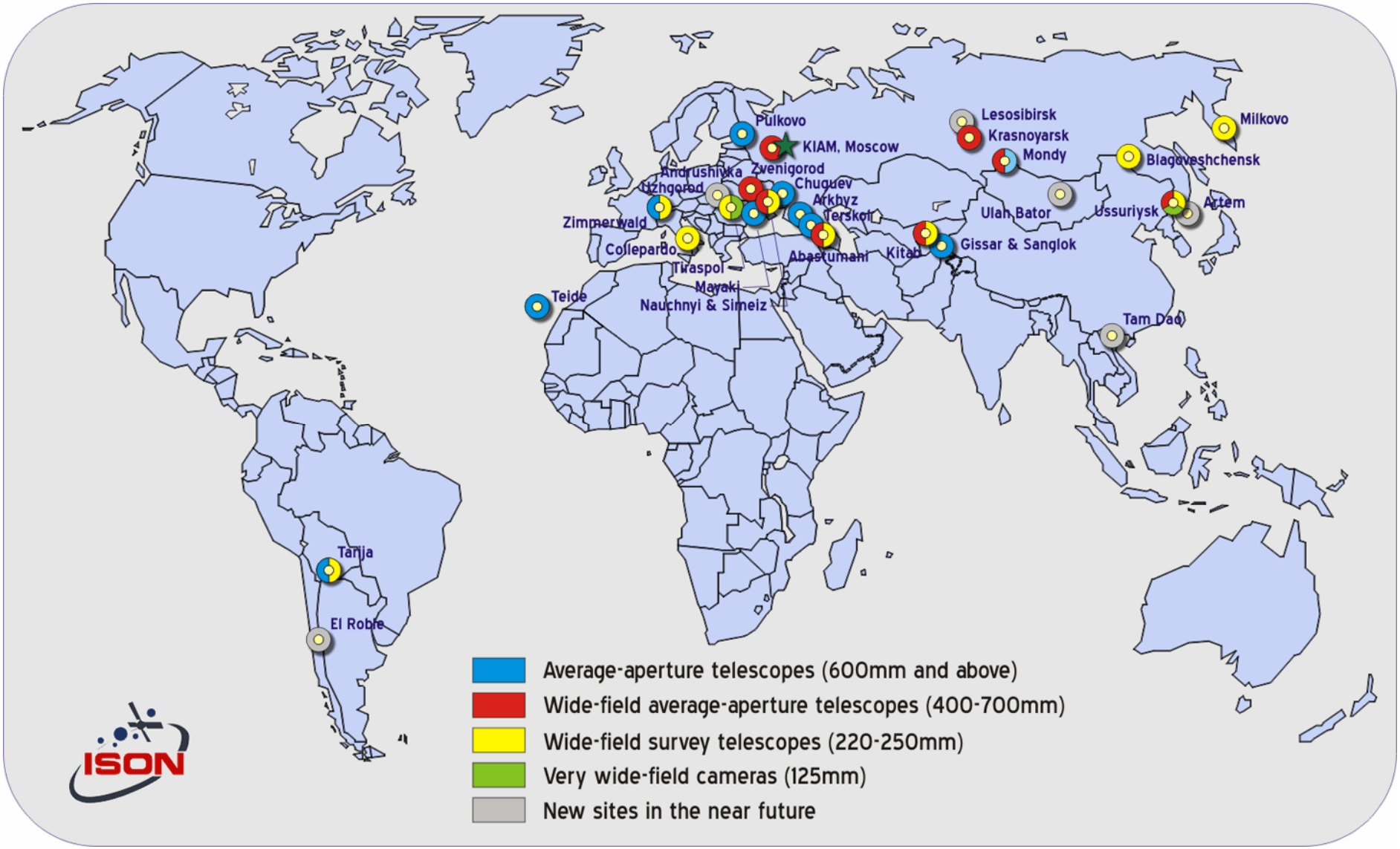
International Scientific Optical Network (ISON)

- ISON is an open international completely civilian project mainly aimed at being a source of information on space objects for scientific analysis and space situation awareness
- ISON is an inexpensive solution of very complicated goal of space surveillance for high orbits
- From one side, ISON is a non-government project, and therefore do not have special state budget support, from the other side ISON is a voluntary union of astronomical observatories and scientific institutions, and therefore the financial expenses on support of observers and other staff are not as large as in case of dedicated military installations working in on-duty mode
- There are more than 3 millions of measurements collected by KIAM to April 2010

First meeting of future ISON in Pulkovo

SIXTH US/RUSSIAN SPACE SURVEILLANCE WORKSHOP

ISON: International scientific optical network



ISON observation arrangement

- telescopes with large FOV of the search and survey subsystem provide regular surveying of the GEO region in 20° width in inclination
- results obtained are analyzed by the observation planning&data processing group using algorithm which allows to find correlation between uncorrelated short tracks in order to discover new objects and to establish their preliminary orbits
- ephemerides for new detected objects are sent to group of telescopes for confirmation follow-up observations
- confirmed objects are classified as “bright” and “faint” based on their brightness - the border between these two groups corresponds to 16.0-16.5 magnitude in average at some fixed conditions (phase angle, elevation, range)
- they are added to the orbital archive which is used for ephemerides distributed weekly to telescopes of 2 subsystems – for faint and bright space object tracking

Telescopes for GEO Surveys

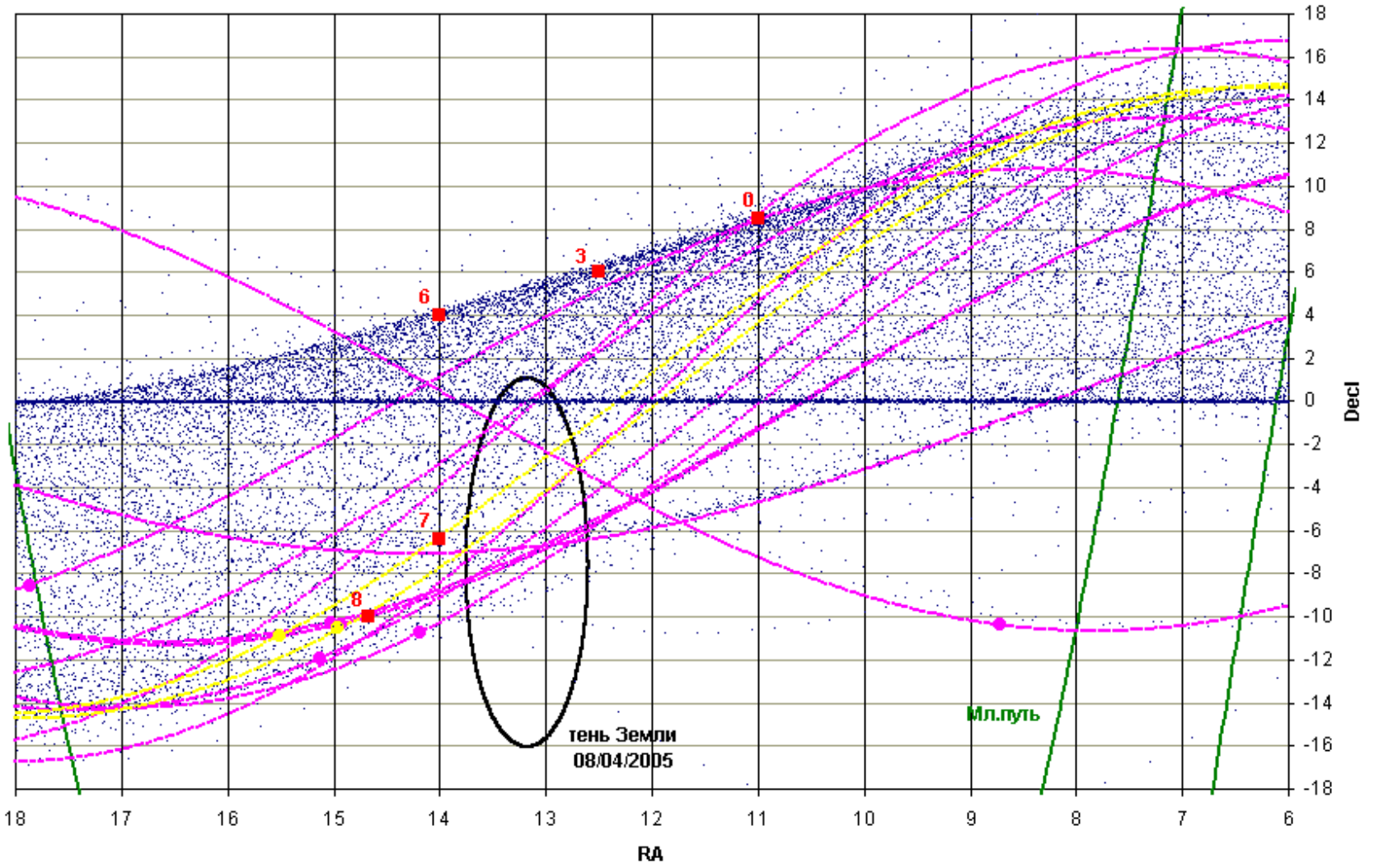
22-cm SRT-220 (PH-1) in **Nauchny-1** with FOV of **4,12°** started surveys in *May 2007*
60-cm S-600 in Andrushivka with FOV of **2°** started surveys in *March 2009*
22-cm ORI-22 in **Ussuriysk** with FOV of **5.5°** started surveys in *September 2009*
22-cm ORI-22 in **Blagoveschensk** with FOV of **4°** started surveys in *March 2010*
22-cm ORI-22 in **Collepardo** with FOV of **4°** started surveys in *April 2010*
22-cm ORI-22 in **Kitab** with FOV of **5.5°** will start surveys in *May 2010*

Different survey strategies tested

Telescopes for confirmation follow up

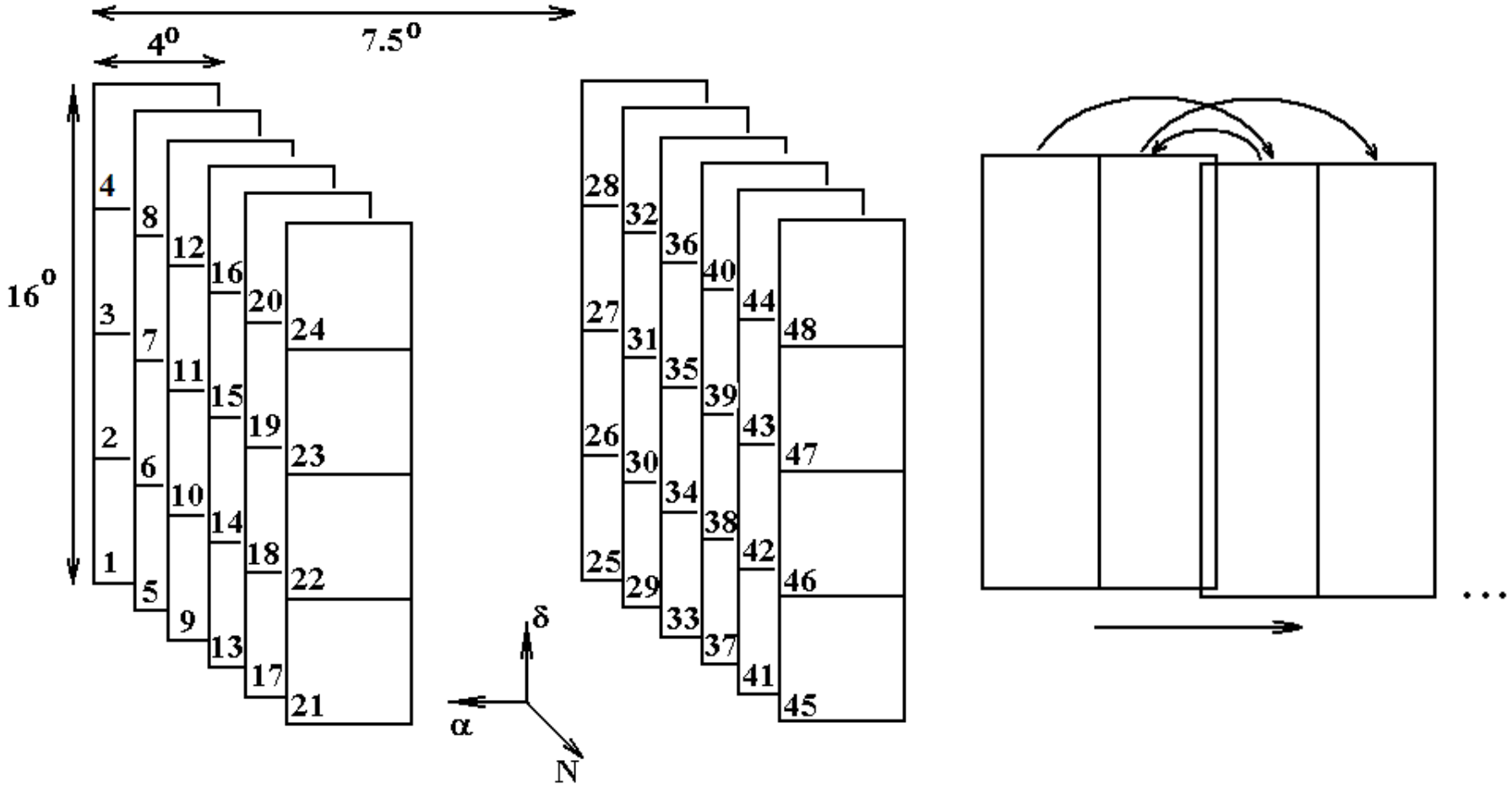
- 64-cm AT-64 in Nauchny-1 with FOV of 2.3°
- 48-cm AZT-14 in Mondy with FOV of 1.3°
- 60-cm Zeiss-600 in Arkhyz with FOV of 10’
- 1-m ZIMLAT in Zimmerwald with FOV of 23’
- 22-cm ORI-22 in Kitab with FOV of 5.5°
- 25-cm GAS-250 in Ussuriysk with FOV of 2.8°

Distribution of the catalogued GEO objects in right ascension – declination plane, trajectories of fragments of presumably exploded objects are crossing yellow lines – Ekrans, magenta lines – Transtages

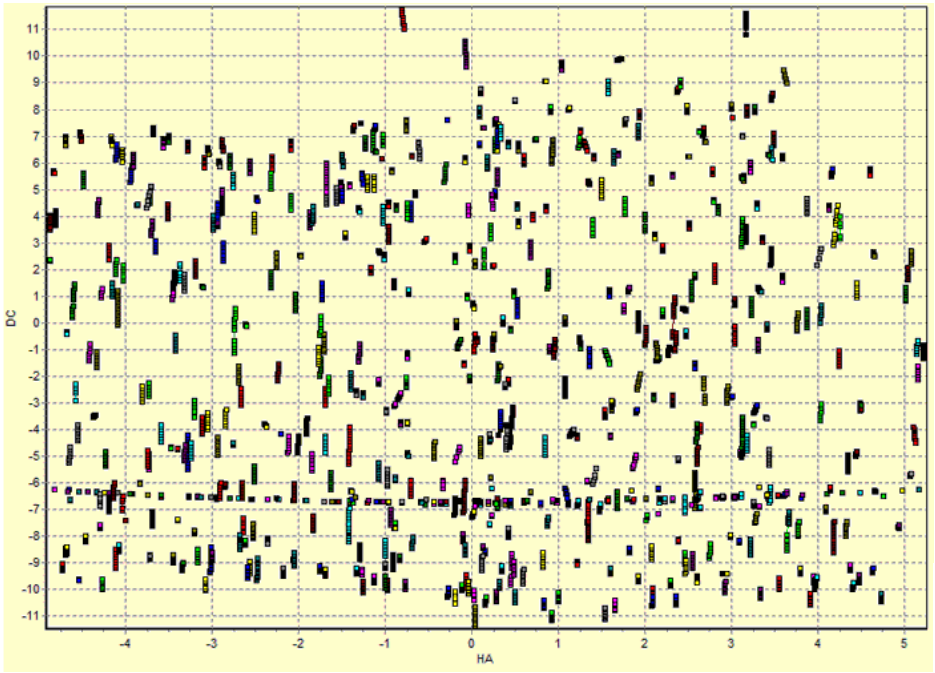


Survey strategy

12 frames with 10 s exposure (6+6);
64 sq.degr. – 7.2 min., 100 s interval;
~30 min. tracks



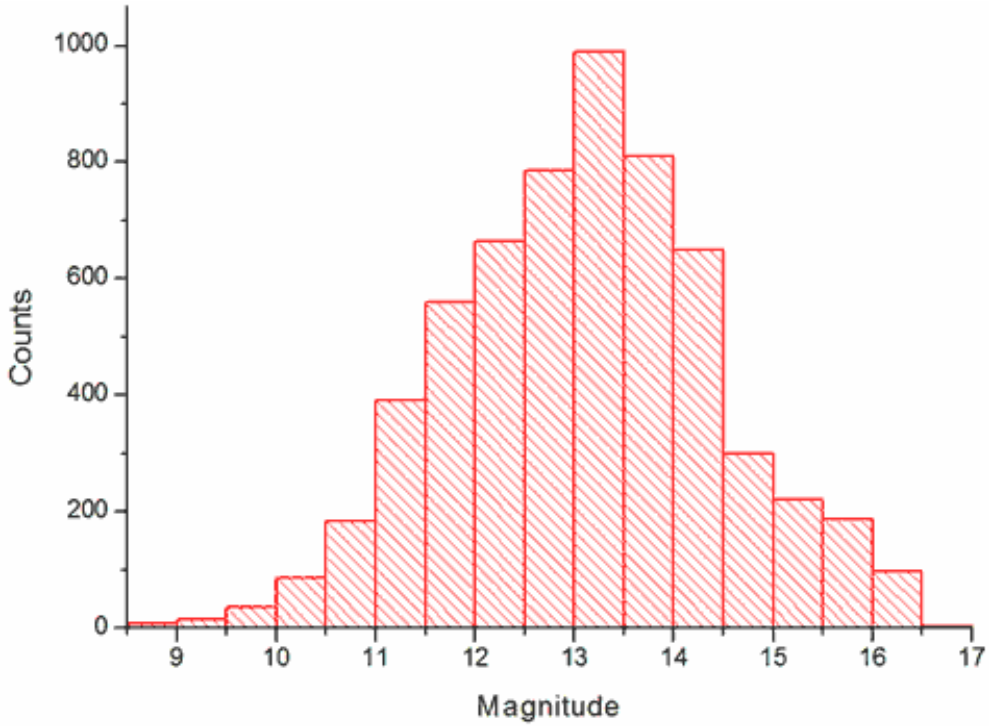
Survey sample



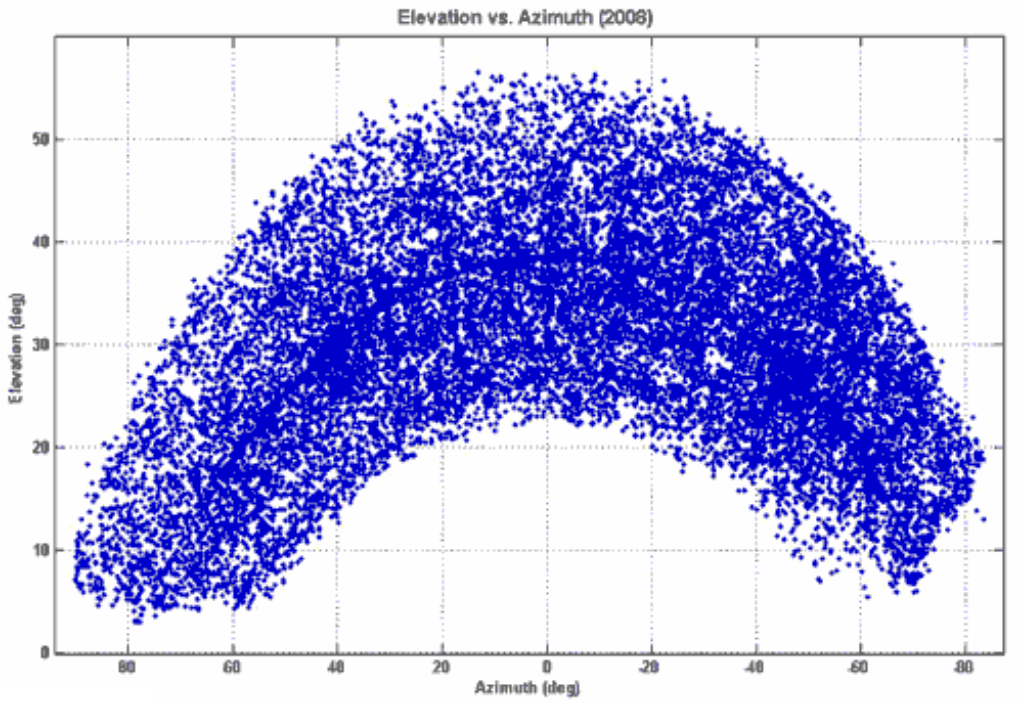
S081203 survey on RST-220
in Nauchny-1
2008, 12 03, 15:41 – 03:55 UT
survey area: 14.1°E - 90.0°E

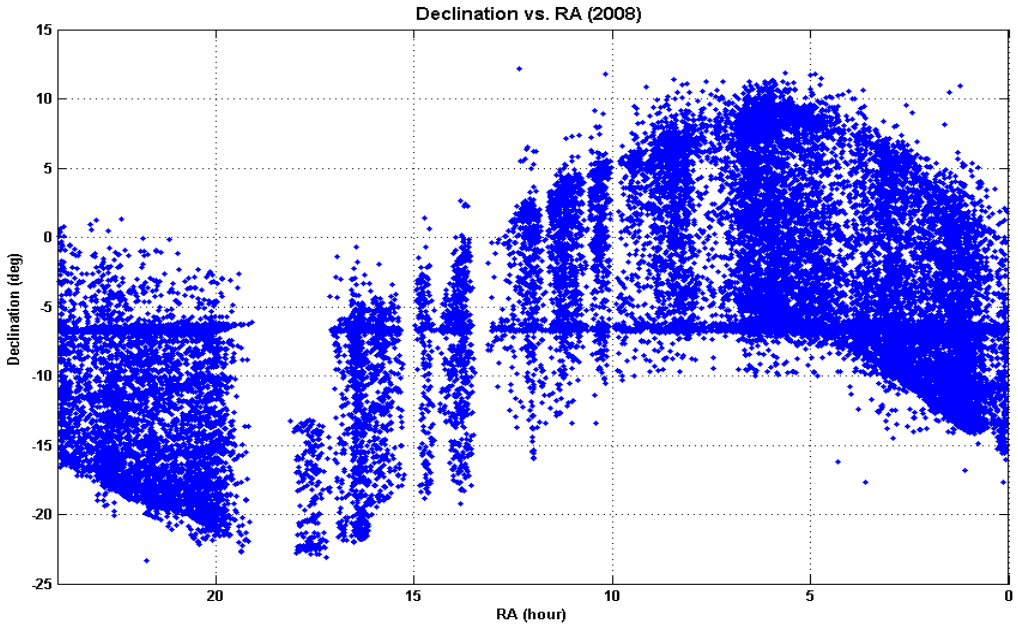
421 tracks of catalogued objects,
89 uncorrelated tracks

up to 16,5 magnitude



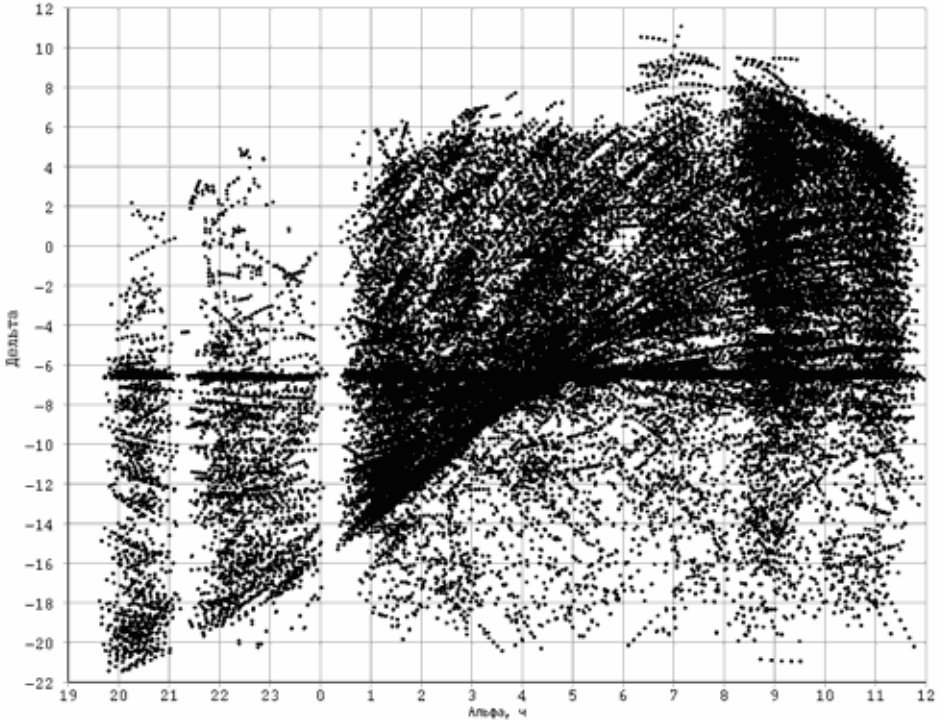
Nauchny-1 RST-220 coverage during GEO surveys in 2008

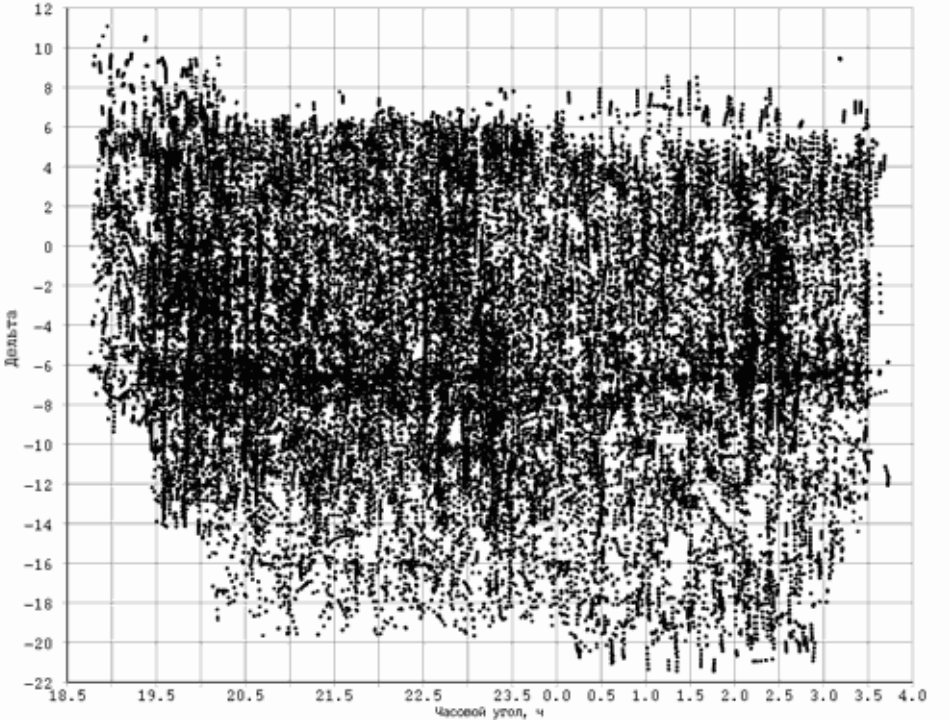




Survey nights – 104
Measurements – 203384
Tracks – 28299
Correlated objects – 1243
Uncorrelated tracks - 646

Coverage in GEO surveys.
Ussuriysk ORI-22, 2009/09/01-2010/03/01

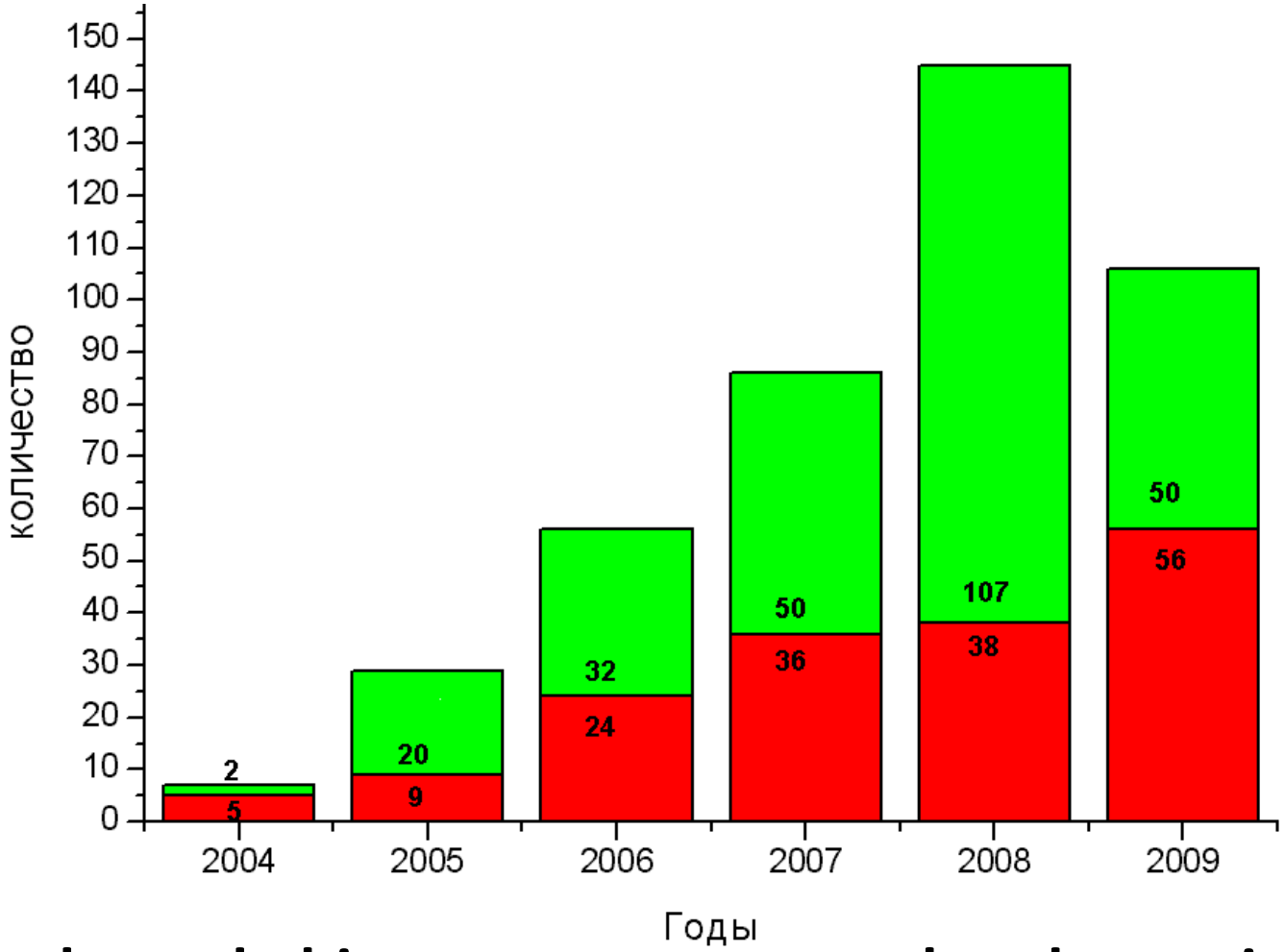




Right Ascension - Declination

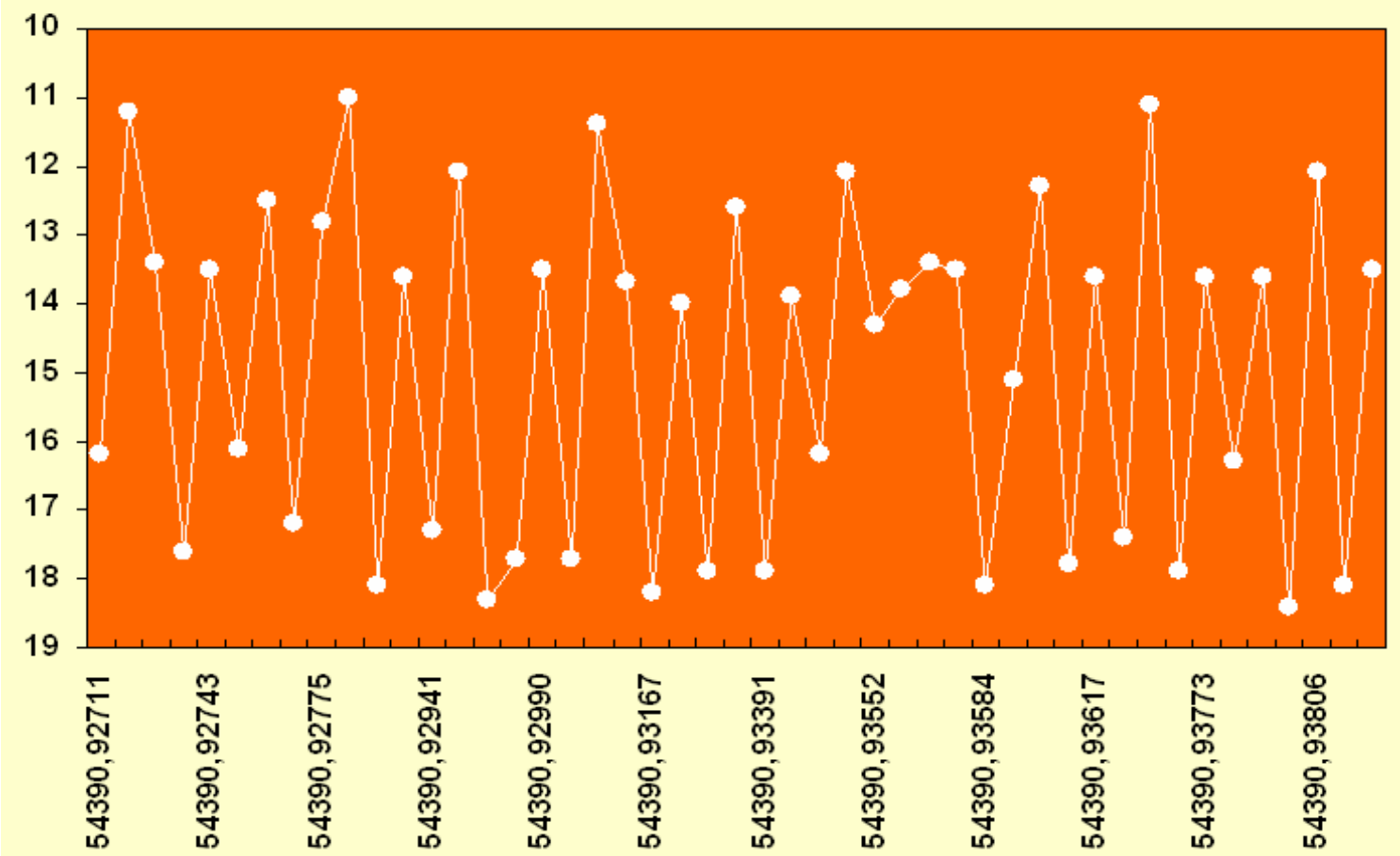
Hour Angle - Declination

Distribution by year of quantity of discovered and confirmed objects

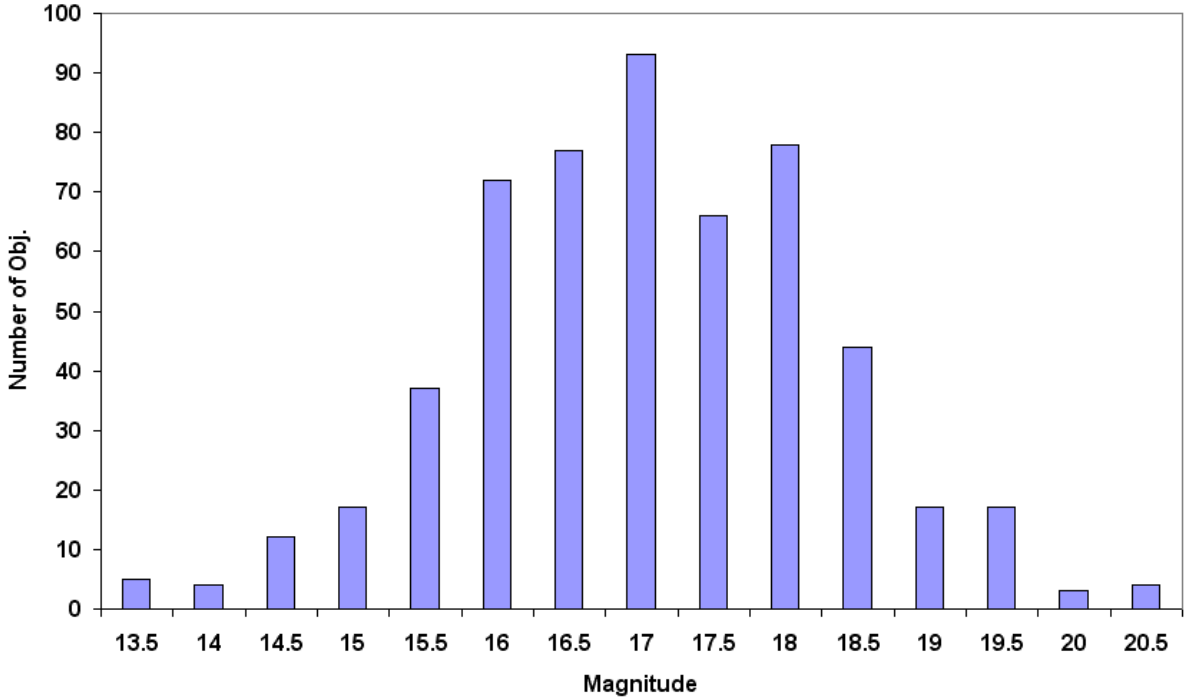


Red – catalogued objects, green - uncorrelated one-night tracks

Many faint fragments with high AMR display ultra-high brightness variability

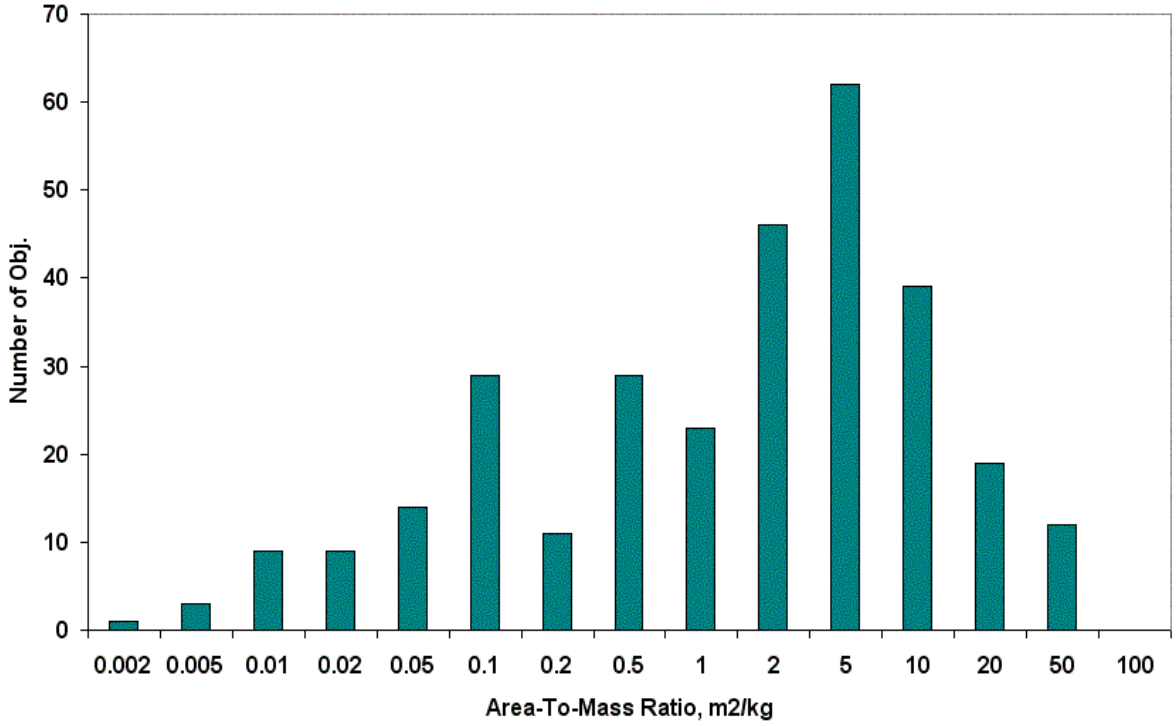


Light Curve (magnitudes vs. modified Julian dates) of 90022 fragment measured with 70-cm AZT-8 in Gissar

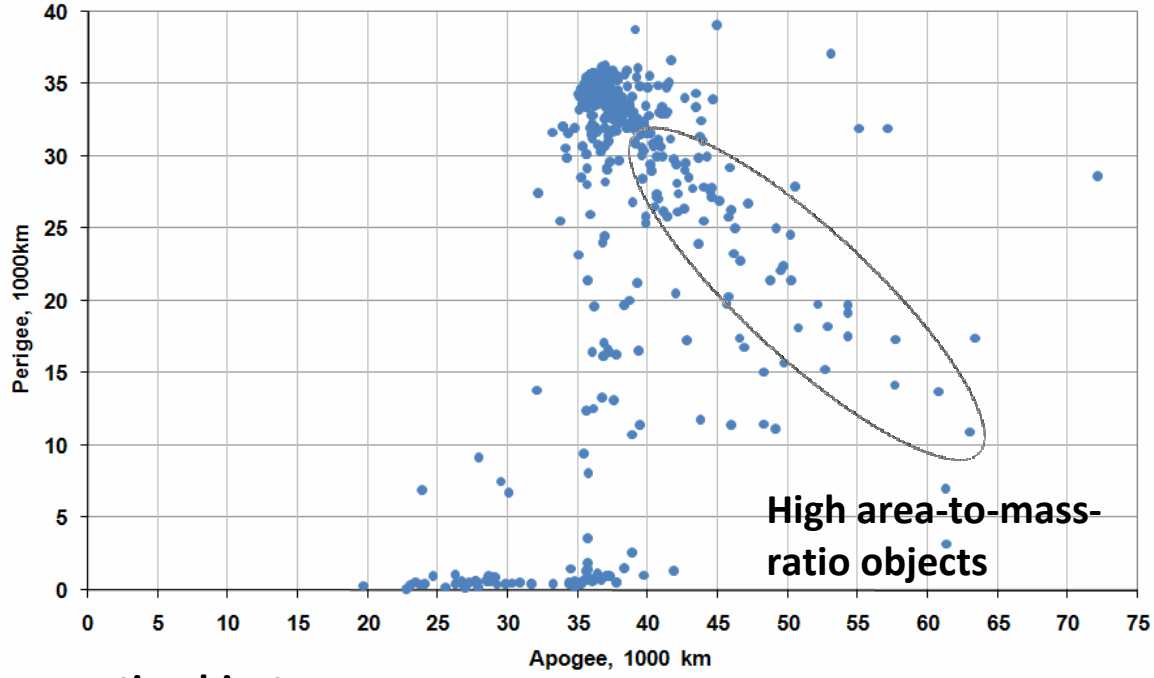


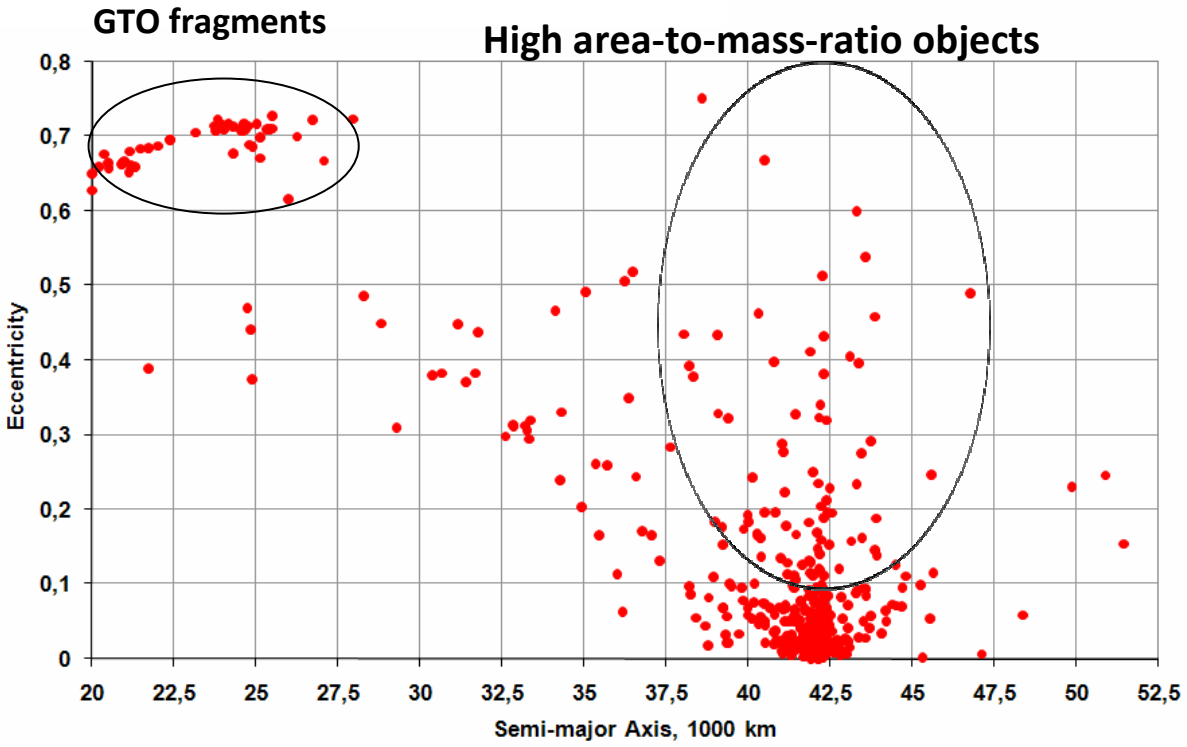
Distribution of average brightness for 546 fragments (including 341 object and 205 uncorrelated one-night tracks)

Distribution of average AMR value for 306 fragments



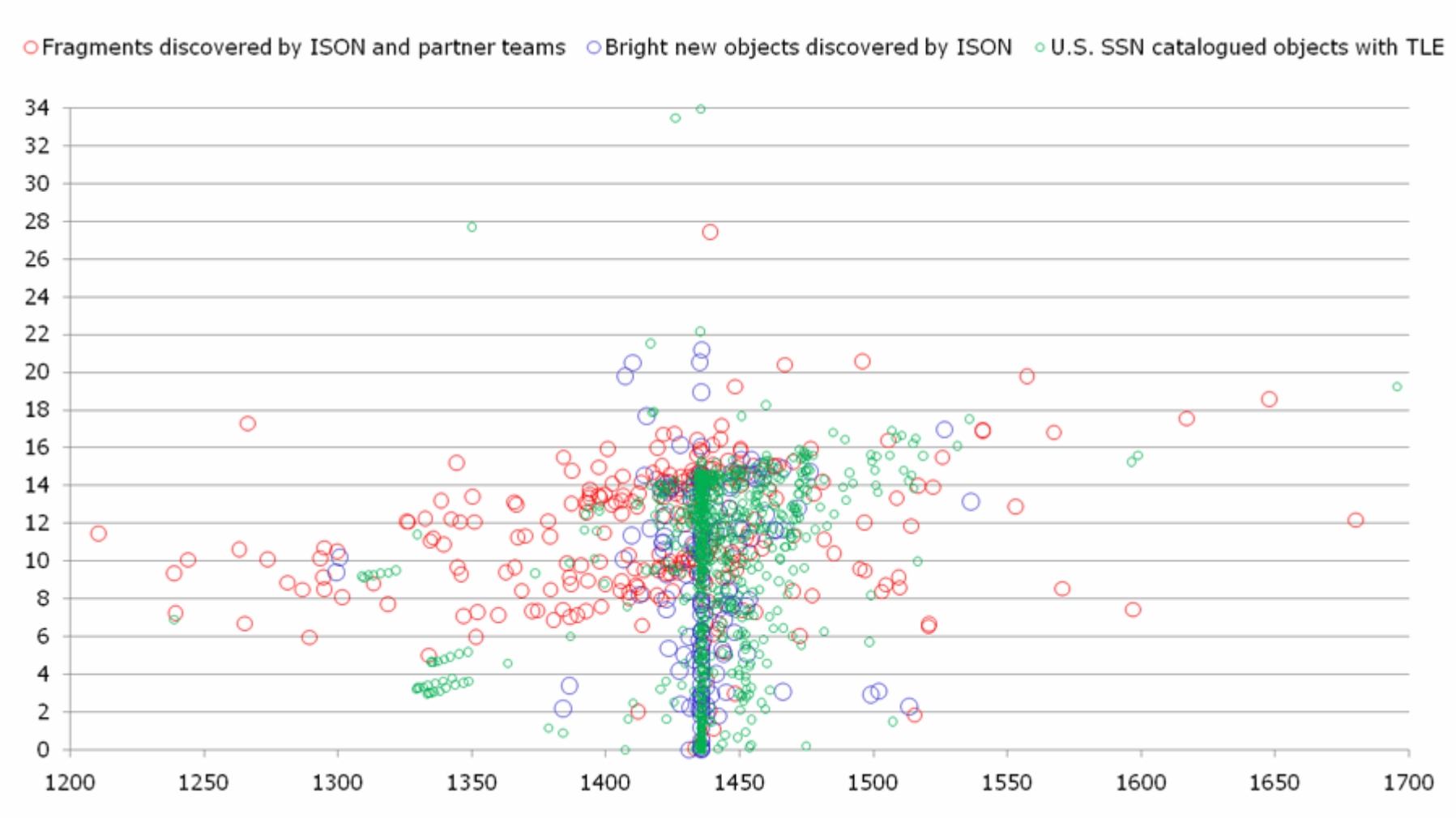
Distribution of apogee and perigee for 439 fragments (including 341 object and 98 uncorrelated one-night tracks)



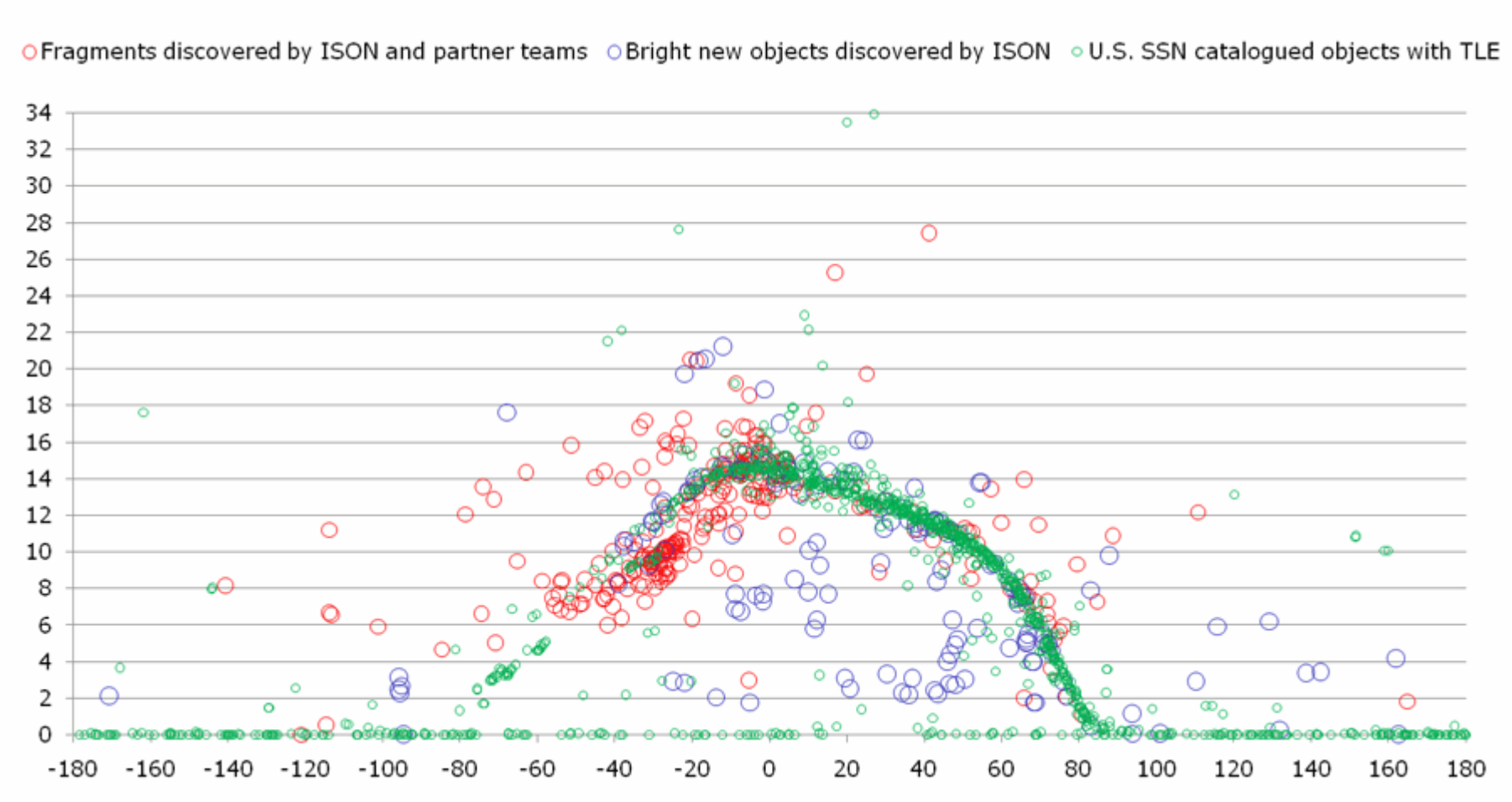


Distribution of eccentricity and semi-major axis for 439 fragments (including 341 object and 98 uncorrelated one-night tracks).

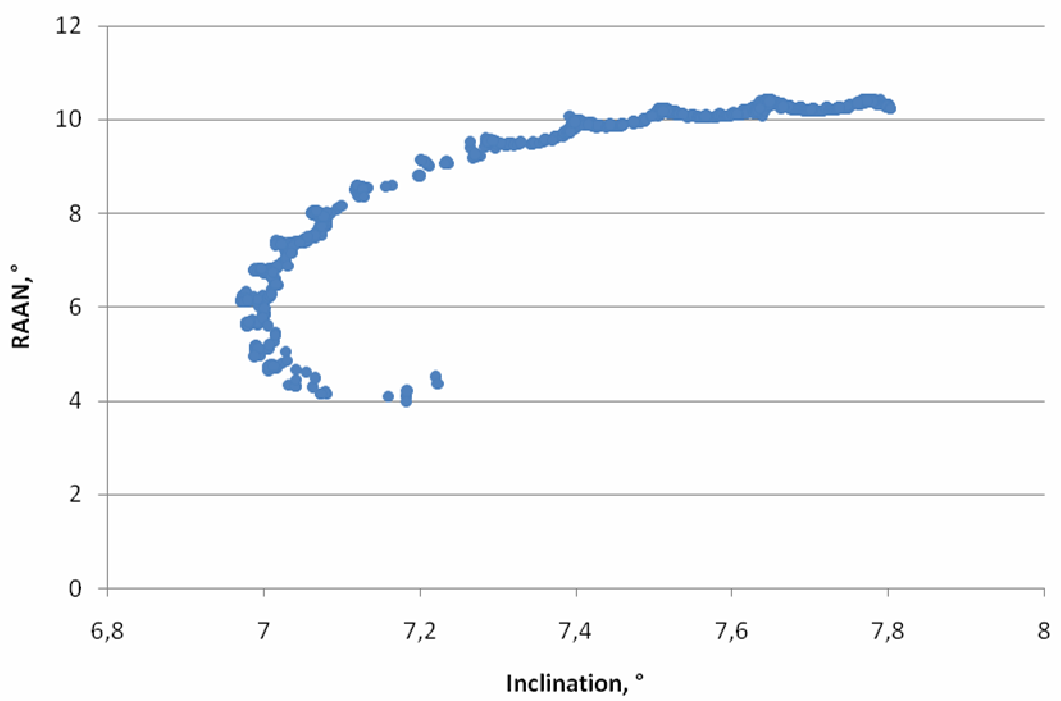
Distribution of 1441 GEO objects by period and inclination

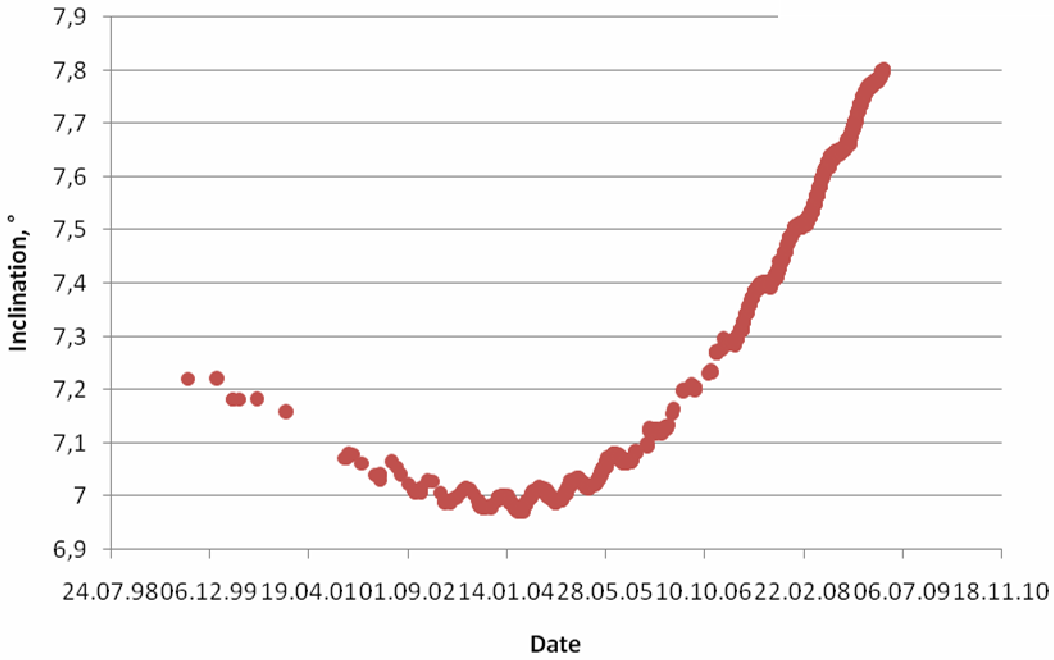


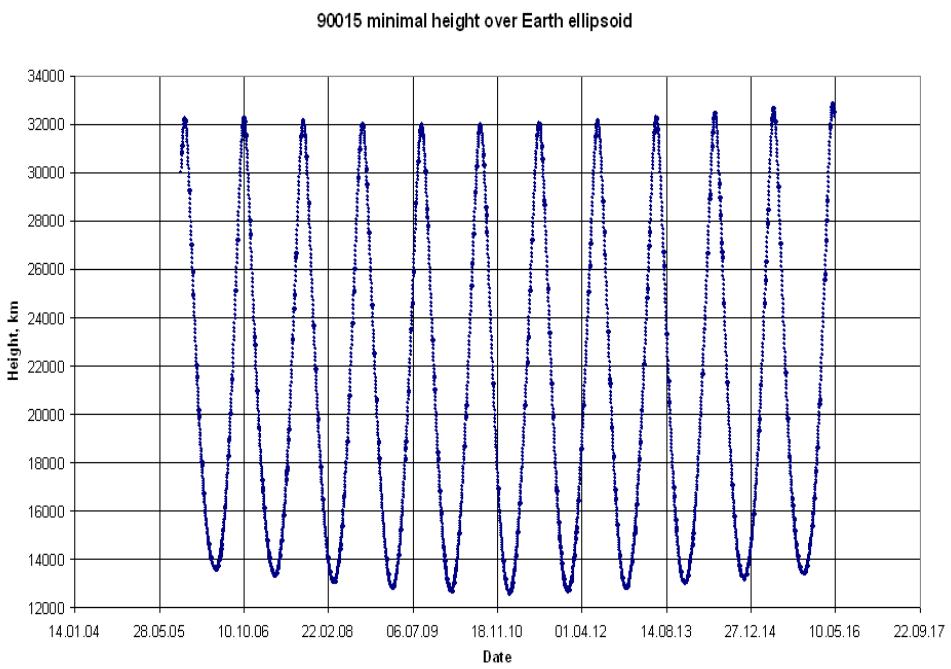
Distribution of 1441 GEO objects by RAAN and inclination

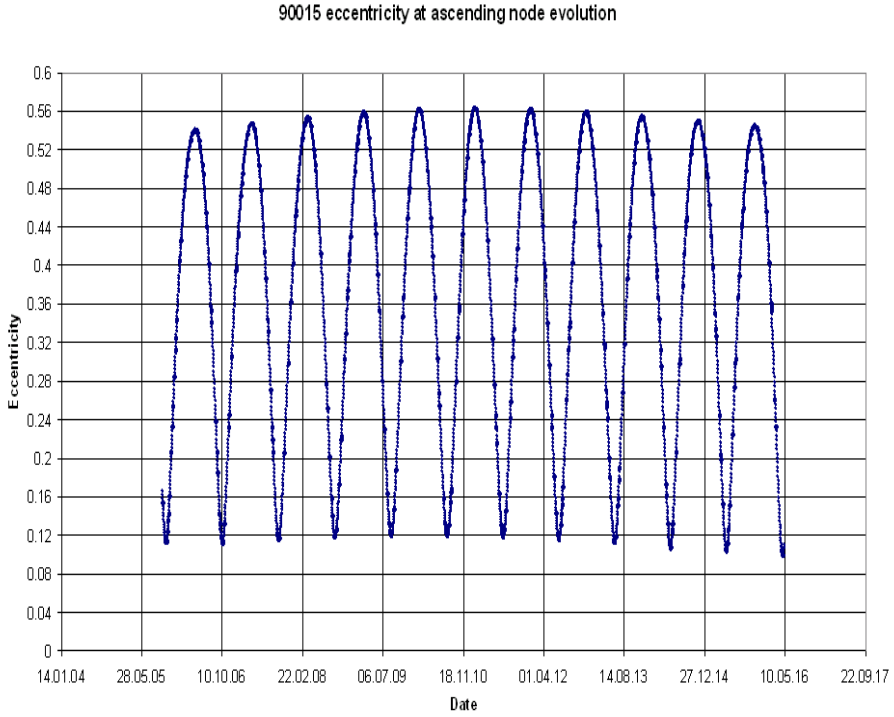


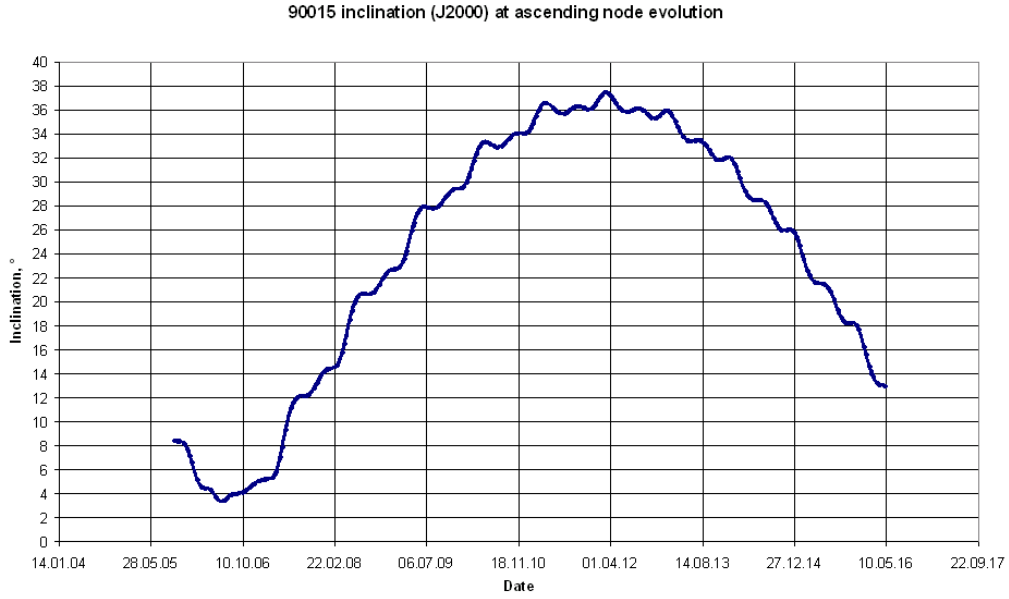
10 years of orbital plane evolution for object 95177











Orbital evolution of the 90015 object (AMR>1m2/kg) over 11 years

ISON

GEO space debris population

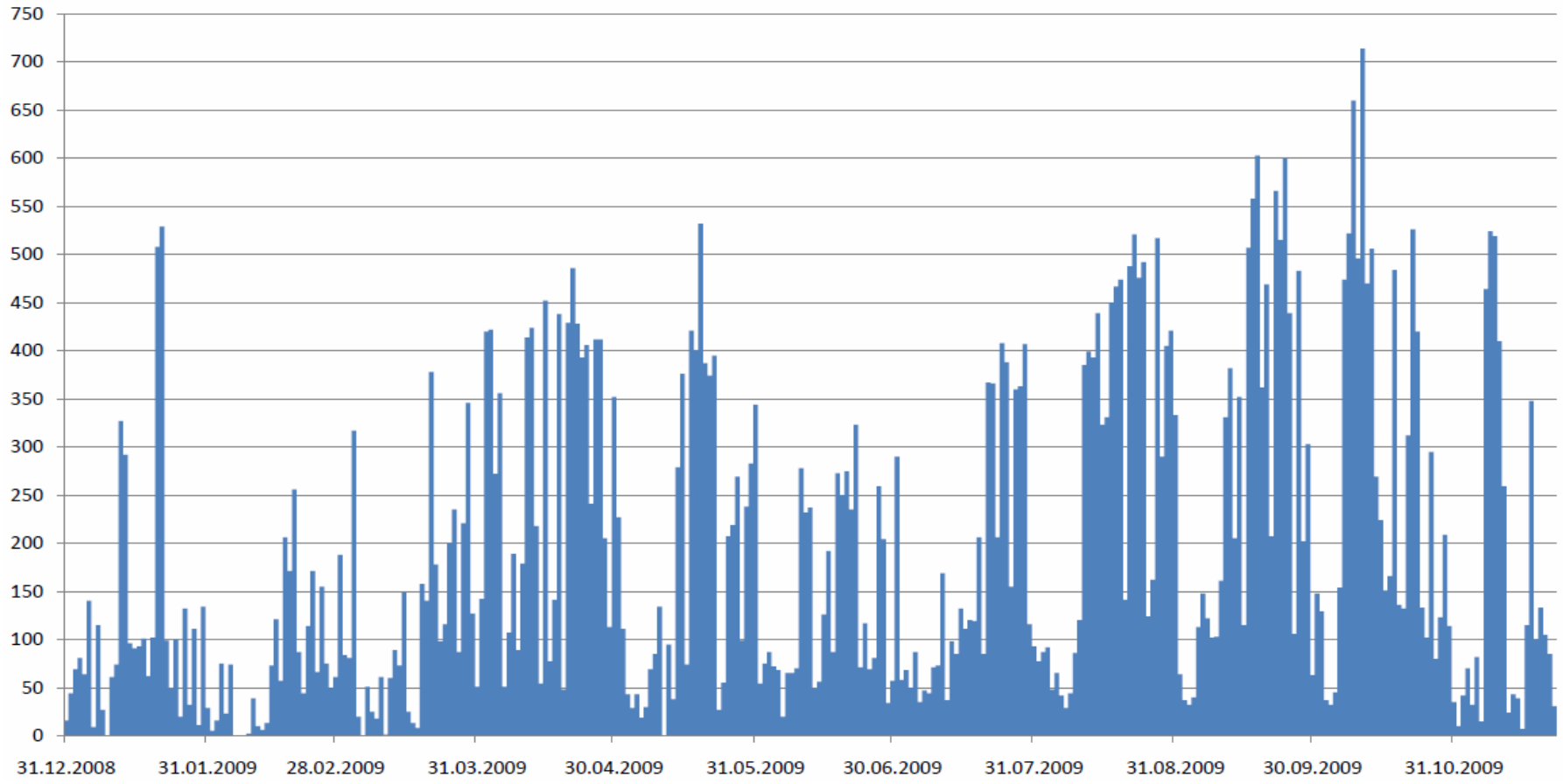
- Surprisingly, number of discoveries of relatively bright GEO debris objects (brighter than 16 magnitude) continues to grow. Every month, about 10 such new debris objects are being discovered
- Many of newly discovered GEO space debris are crossing or permanently staying in the GEO protected region and increase threat to operational spacecrafts. It is important to discover as many such debris as possible and understand the sources from which they are originating
- It is expected that at least several hundreds more of GEO space debris brighter than 18^{th} magnitude (which corresponds to 30-40 cm size and larger, assuming standard reflectivity characteristics) exist in the GEO region. Number of fainter (and thus smaller) objects is not yet estimated correctly

Known GEO Population (KIAM database, Dec 31, 2009)

- Total tracking by ISON – **1467** objects in the GEO region (**compare to 1016 objects for which data are provided by the U.S. SSN via SpaceTrack Web-service**), **including:**

- *Spacecrafts* – **892**
  391 under control, 501 non-functional
- *Upper stages* – **250**
  of more than 15 different types
- *Fragments and objects of undetermined type* – **325**
  only 20 GEO fragments are officially catalogued by the U.S. SSN

Observed GEO Objects Number (by night, Jan-Nov 2009)

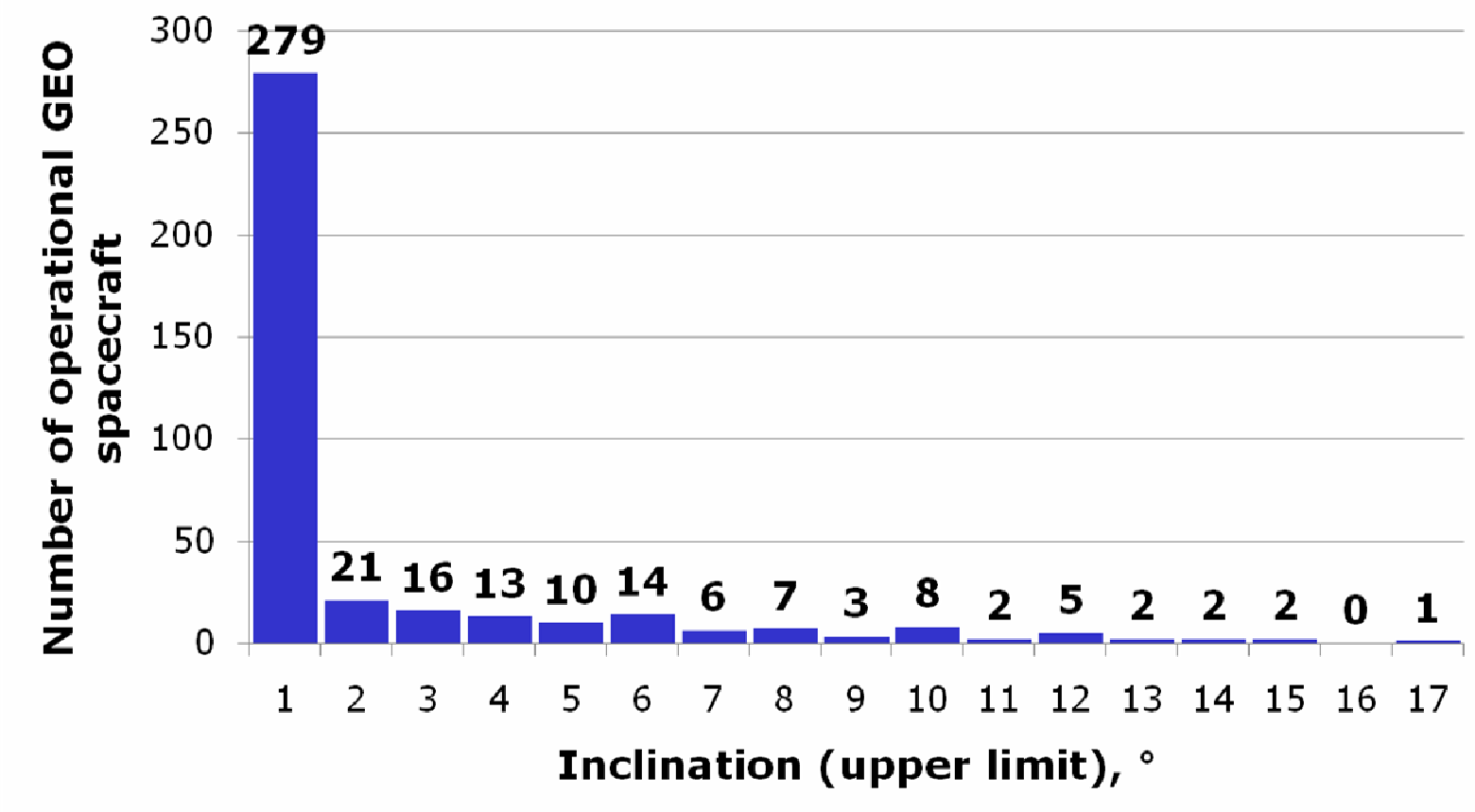


GEO protected region population

Object type	Overall number	Inclination range, °	Eccentricity range	Period range, min
Operational spacecraft	391	0.0-16.3	0.0000-0.1067	1435.52-1436.14
Non-operational spacecraft	282	0.3-21.1	0.0000-0.1804	1197.7-1458.2
including permanently staying in GEO protected region	*212*	*0.8-15.3*	*0.0000-0.0039*	*1430.4-1445.2*
Spent upper stages and AKMs	174	0.2-23.1	0.0003-0.1784	1197.6-1766.0
including permanently staying in GEO protected region	*67*	*1.2-15.3*	*0.0003-0.0044*	*1428.9-1444.1*
Fragments and objects of unknown type	250	0.2-20.6	0.0009-0.2045	1161.2-1617.3
including permanently staying in GEO protected region	*13*	*10.9-14.4*	*0.0009-0.0042*	*1433.1-1439.7*
Total	**1097**	**0.0-23.1**	**0.0000-0.1784**	**1161.2-1766.0**
including permanently staying in GEO protected region	***683***	***0.0-15.3***	***0.0000-0.1067***	***1428.9-1445.2***

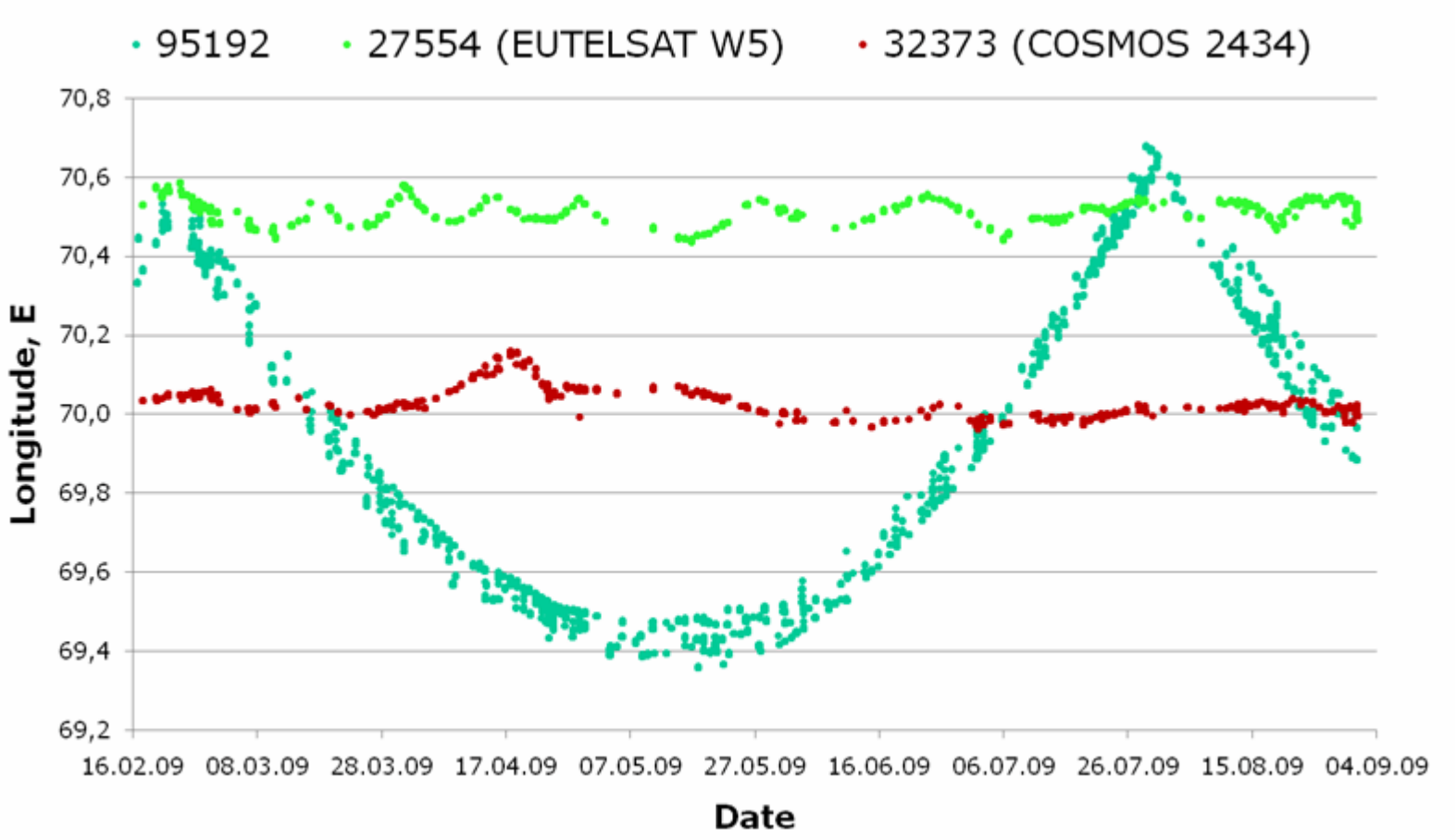
Operational spacecrafts represent 35.6% of the overall GEO protected region population (57.2% of objects permanently staying in this region)

Distribution of GEO operational spacecrafts by inclination

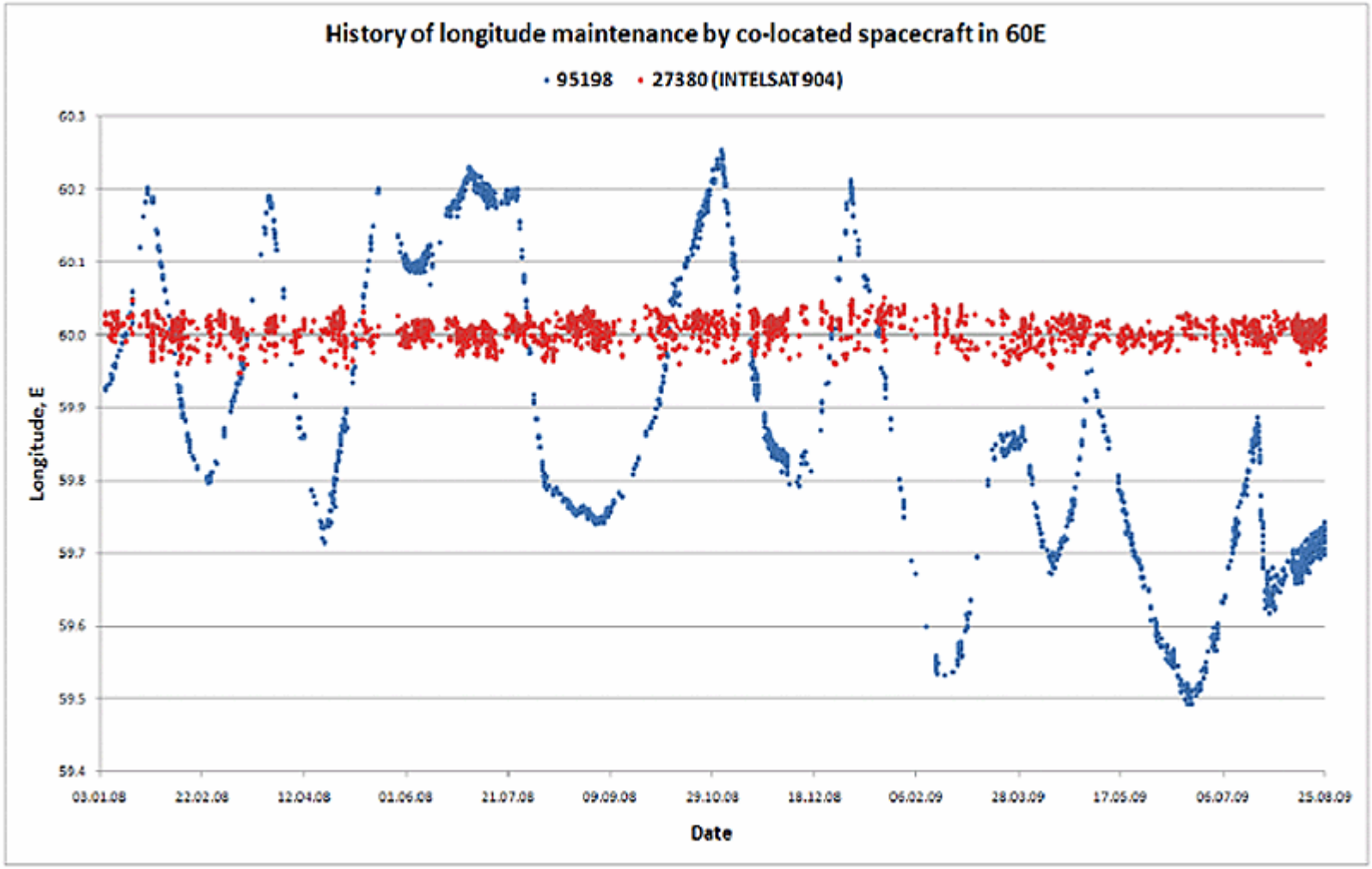


112 spacecrafts (almost 29% of all operational GEO satellites) are located in inclined orbits

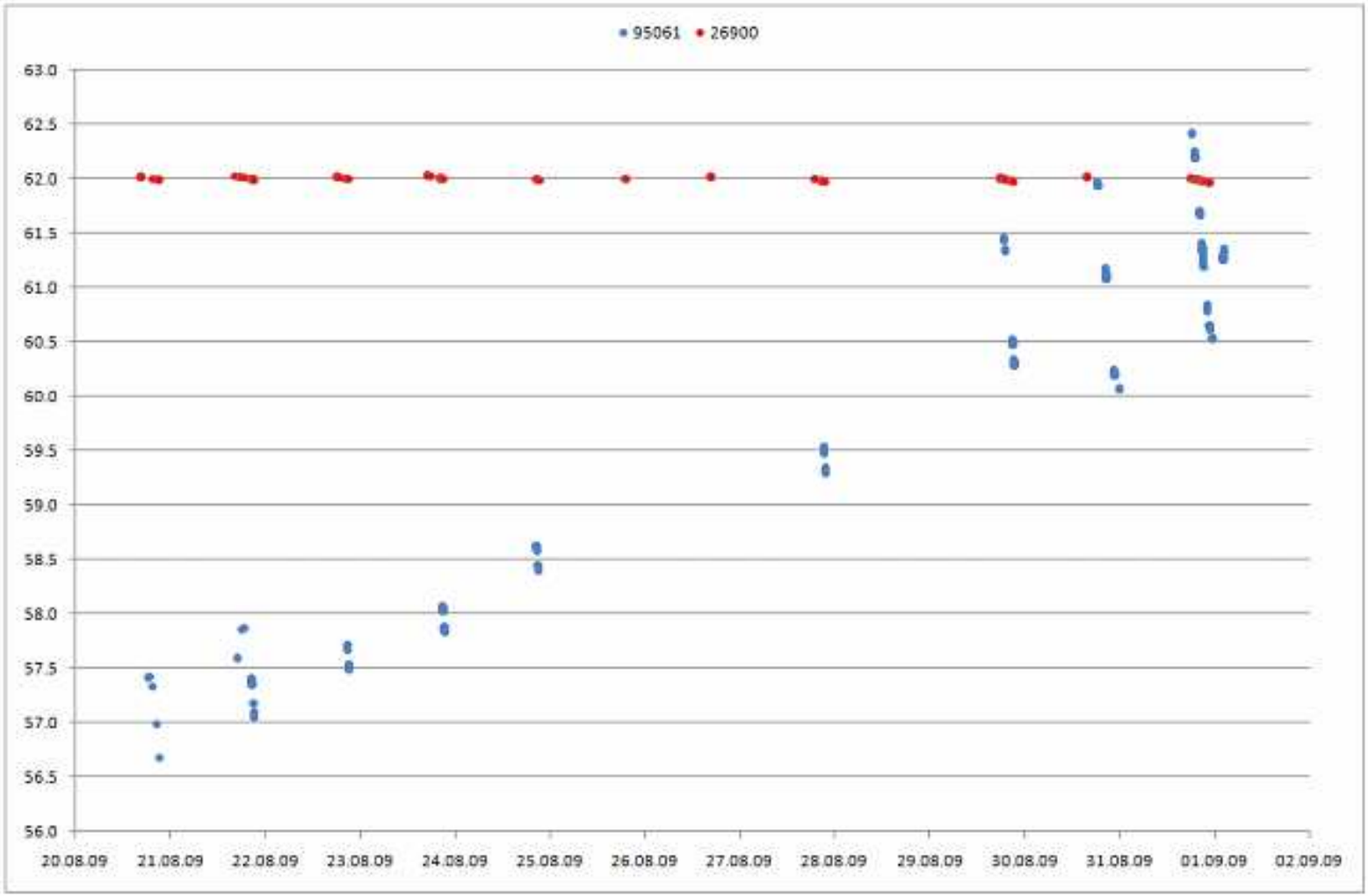
Co-located spacecrafts around 70E



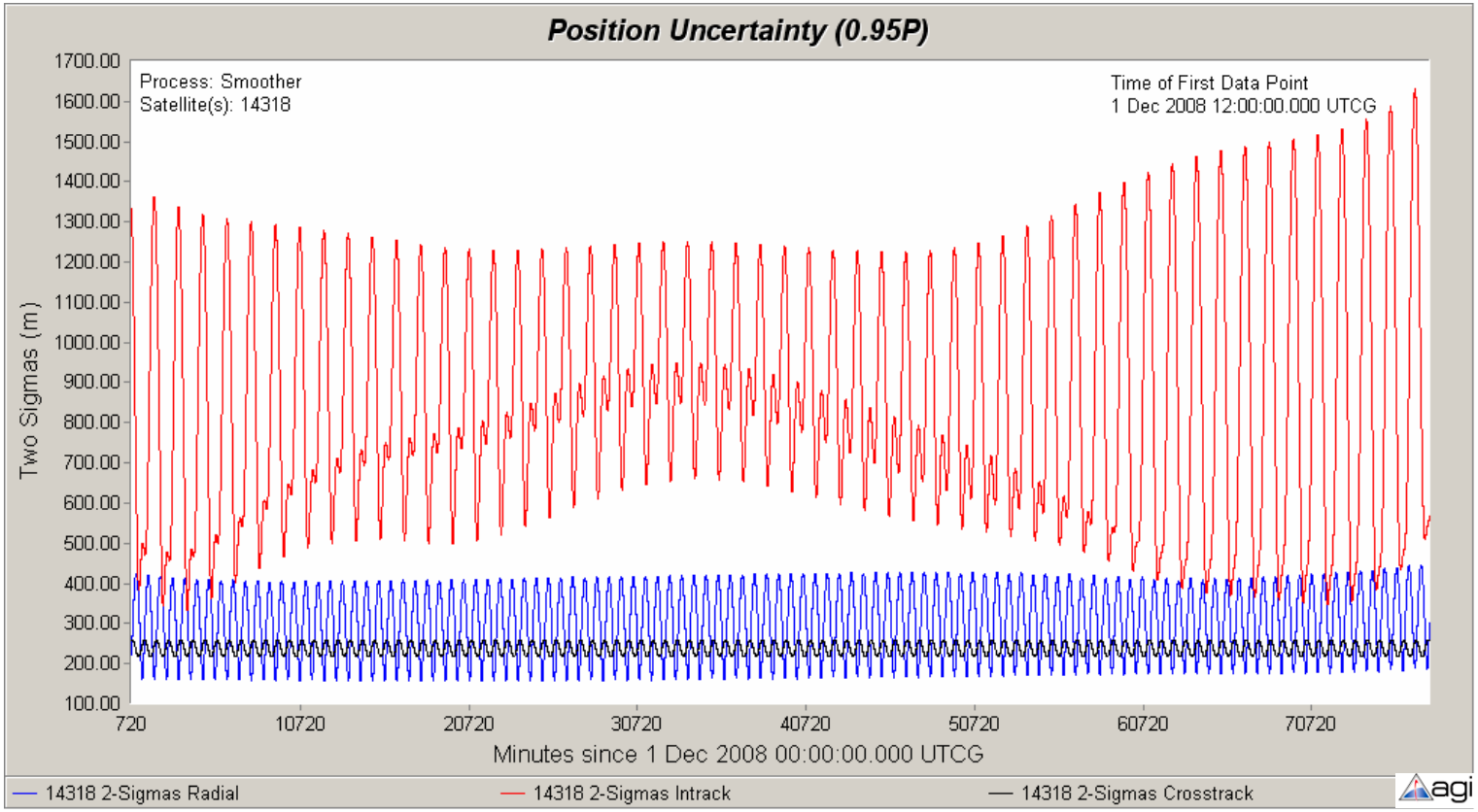
Co-located spacecrafts around 60E



Positions of objects 95061 and 29600 (INTELSAT 902) during Aug 20-31

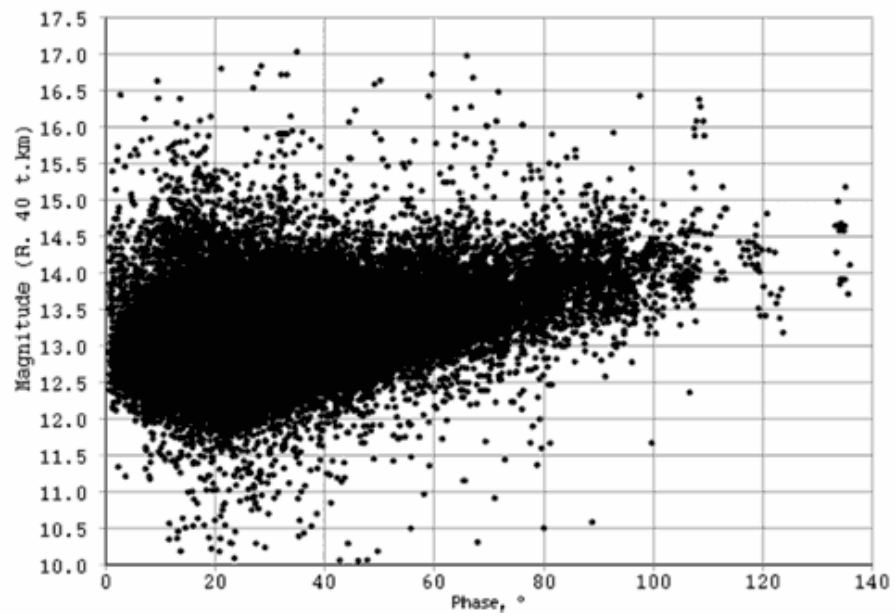


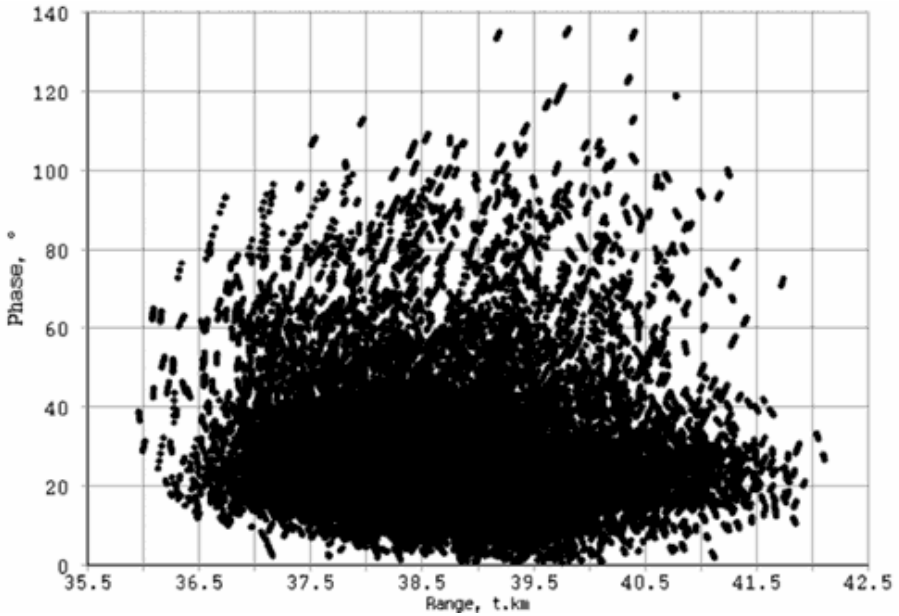
Accuracy of orbital data produced by ISON (object 14318, INSAT-1B)



One of the commercial communication satellites operated by SES performed collision-avoidance maneuver based on orbital data produced by ISON for 14318

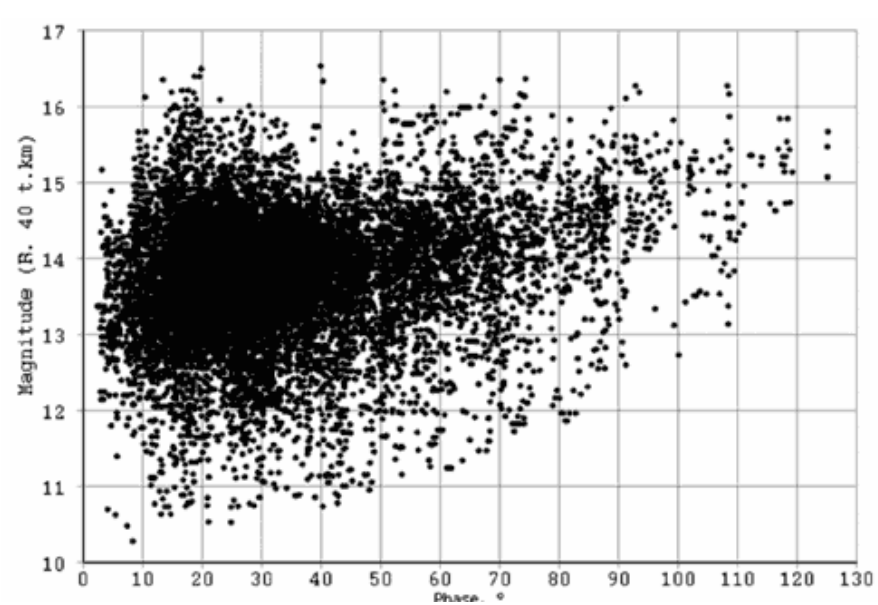
Brightness of typical objects. Block DM (GEO only)

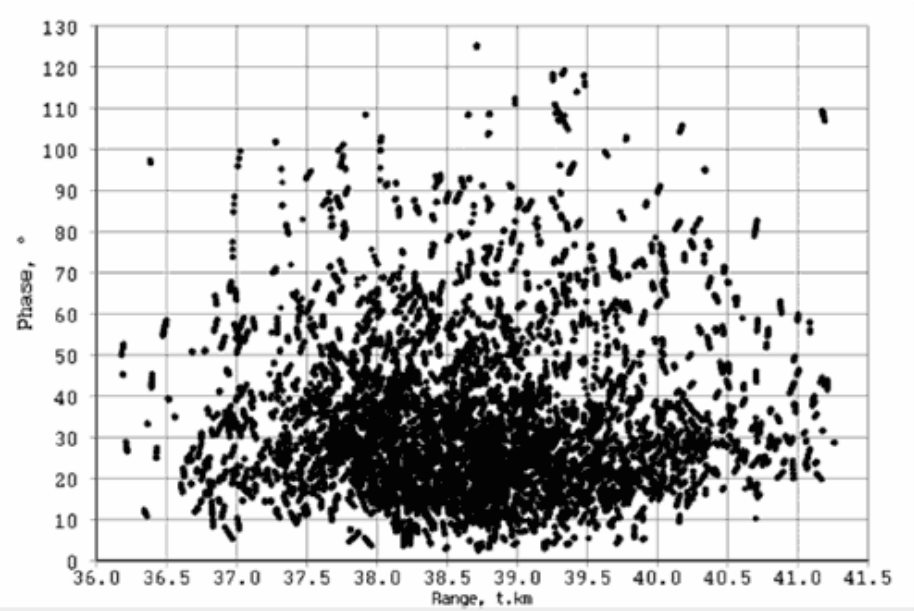




Number of objects:101, Number of measurements: 70143, Number of telescopes: 26

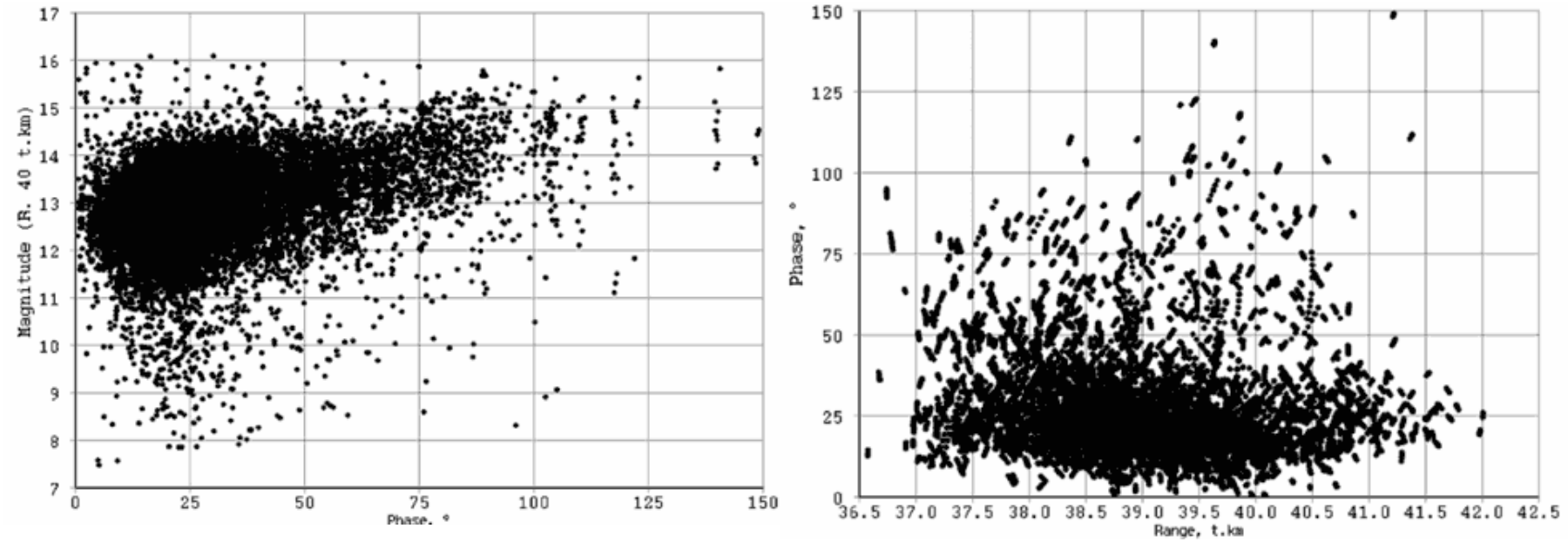
Brightness of typical objects.
IUS 2nd Stage





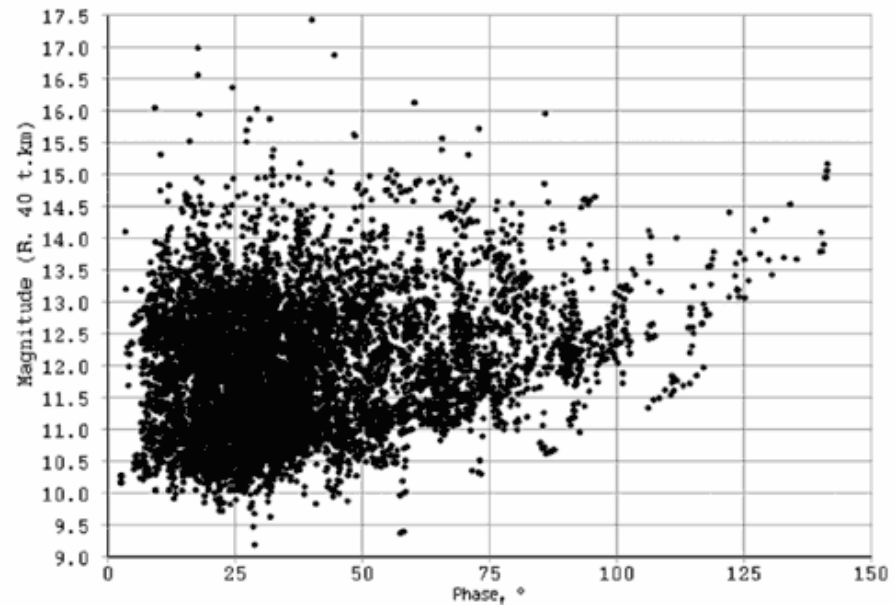
Number of objects:17, Number of measurements: 14433, Number of telescopes: 26

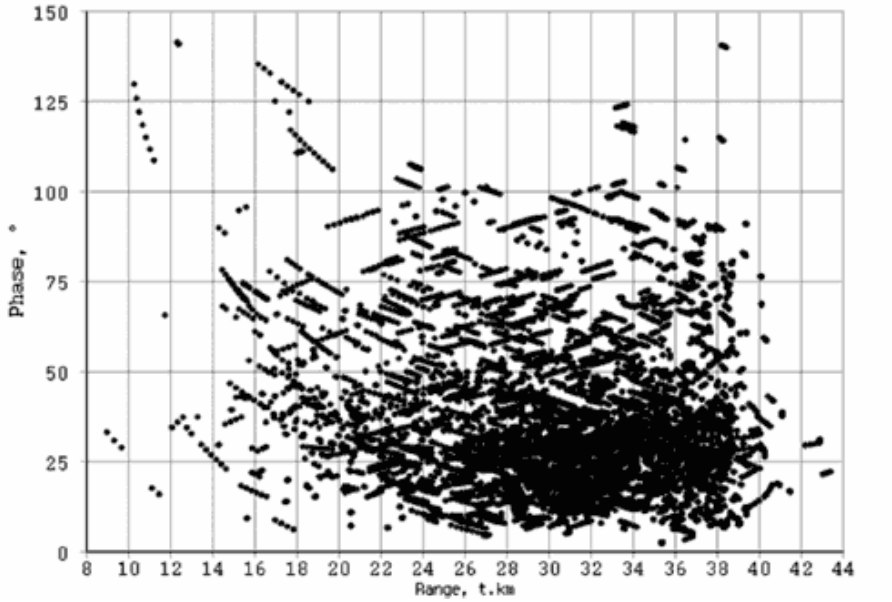
Brightness of typical objects.
Gorizont type spacecraft (non active)



Number of objects:26, Number of measurements: 19757, Number of telescopes: 18

Brightness of typical objects.
Ariane 5 2nd Stage





Number of objects:36, Number of measurements: 10329, Number of telescopes: 20

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^m is complete and presented to the public.
- Several hundreds of previously unknown objects discovered in GEO region present a clear indication of lack of our knowledge of true high orbit 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 spacecrafts.
- The information obtained can be used for spaceflight safety and traffic management tasks in GEO thanks to more complete set of objects covered (35%), much higher accuracy and overall reliability, compared to other existing public sources

Late of March we have discovered 3 new objects with high AMR. In addition, another one was discovered earlier by Thomas Schildknecht team and confirmed by our even more earlier measurements. All four are very interesting. First, their orbital evolution is more or less good predictable without involvement of newly developing sophisticated software for high AMR case. Second, they are bright enough in order to be tracked even with 22-25 cm aperture instruments. Third, estimated AMR values are impressive:

KIAM object No.	AMR, sq.m/kg	Tracking since
90200	49-50	17.03.2010
95300	20	15.03.2010
95317	20-23	21.03.2010
43216	30-31	10.11.2009

And finally, all these objects are at their evolution stage when eccentricity is growing and perigee is decreasing. 90200 and 43216 already have perigee less than 10000 km and it continues to go down.

I think this is a case when we can try to establish a joint observation campaign in order to keep good orbits for all 4. When perigee of any of them will decrease to LEO altitudes (for 90200 and 43216 this will happen very soon) there will be a rare opportunity to try to study them with radars.

Current orbits we have are following:

ObjN	Date/time, UT	Period,min	Incl,deg	Eccentr	ArgOfPerig,deg
90200	18.04 14:10:00	1110.6	2.88	0.49908	278
95300	16.04 15:16:38	1236.5	4.30	0.18053	356
95317	18.04 18:27:19	1277.5	9.07	0.31425	22
43216	19.04 15:27:08	1208.4	8.96	0.62326	36

If you agree then I will send you our optical measurements in GEOS-C format compatible with AGI's ODTK software (this variant of GEOS-C is slightly different of the original one). It would be also desirable to support the experiment with optical observations to study spectrum and variability.