Observations with survey instruments of the ISON network

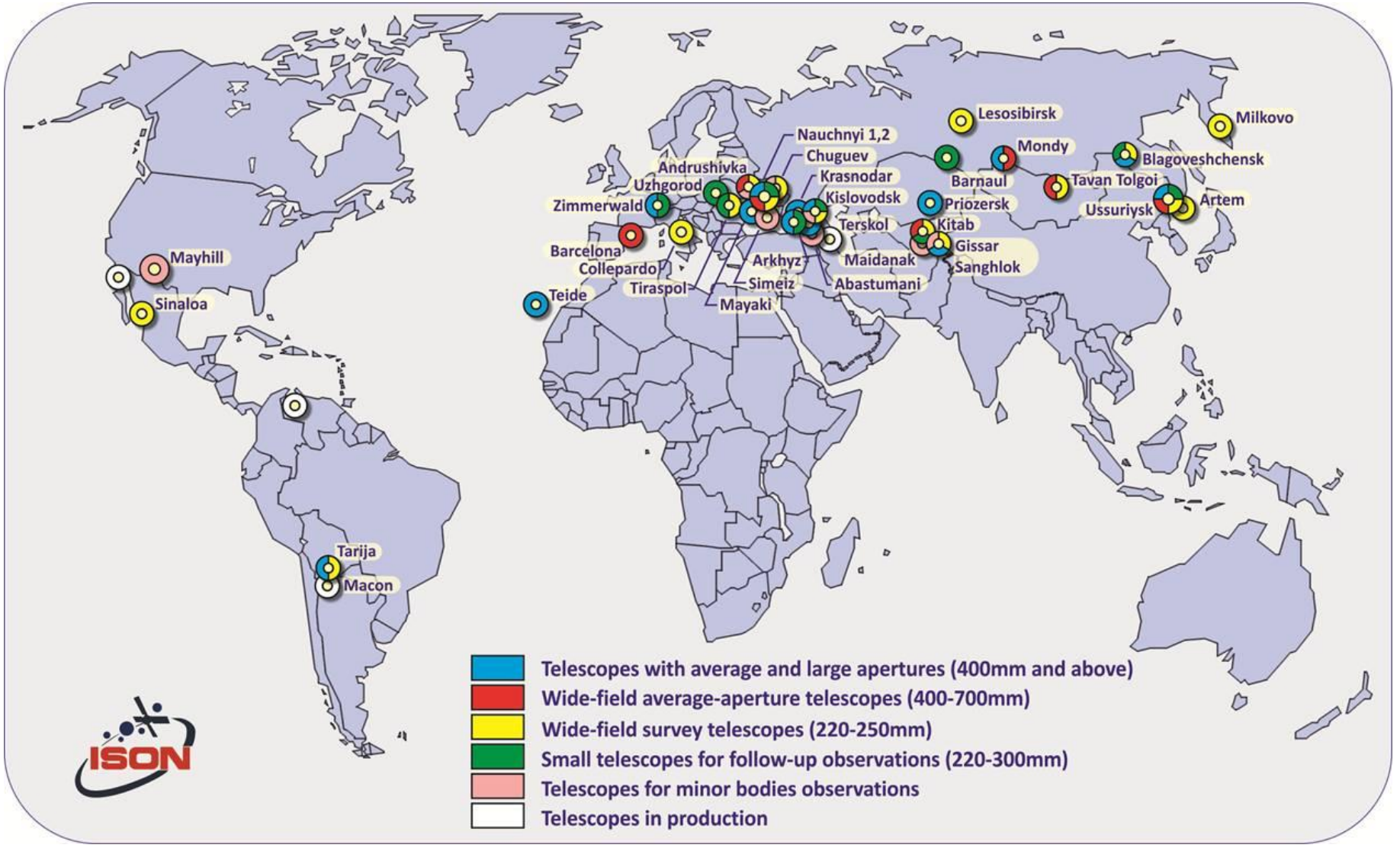
Igor Molotov, Vladimir Agapov
Keldysh Institute of Applied Mathematics RAS
Alexey Matkin, Alexander Lapshin, Dmitriy Chestnov
Astronomical Scientific Centre Project-technics, JSC

39th COSPAR Scientific Assembly 2012
July 14-22, Mysore, India

International Scientific Optical Network

- ISON is an open international non-government project developed to be an independent source of data about space objects for scientific analysis and S/C operators
- Additional scientific goals – asteroids and GRB afterglows
- ISON optical network represents one of largest systems specializing in observation of space objects
- Cooperation already joins 33 observation facilities of various affiliation in 14 countries and is coordinated by the Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences (KIAM) and maintained with assistance of ASC “Project-technics”, JSC
- Main concept of ISON network - development of survey instruments (telescopes with large field of view)

Map of ISON observatories



ISON structure

Instrument subsystems:

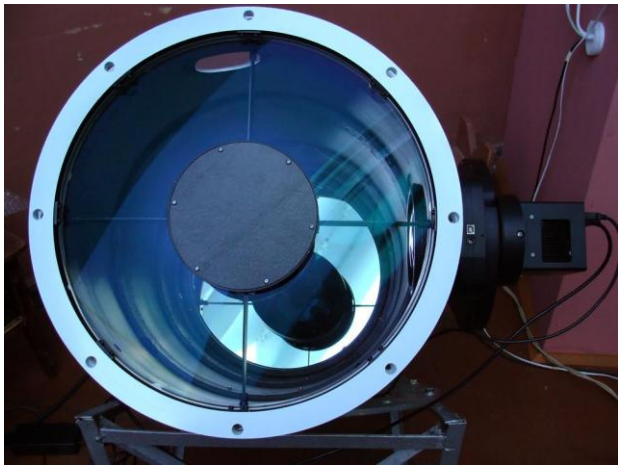
- subsystem for surveys of the GEO region (to 15.5^{m})
- subsystem for tracking of the high orbit faint (fainter than 15.5^{m}) space debris at GEO and GTO
- subsystem for tracking of bright GEO and HEO objects
- subsystem for HEO objects surveys (in development)
- subsystem for LEO objects tracking (in development)

Four network operation support groups:

- electric and software engineering
- optical and mount engineering
- observation planning and data processing
- new observation technique elaboration

ISON survey telescopes

56 units of 8 types (29 are already installed)

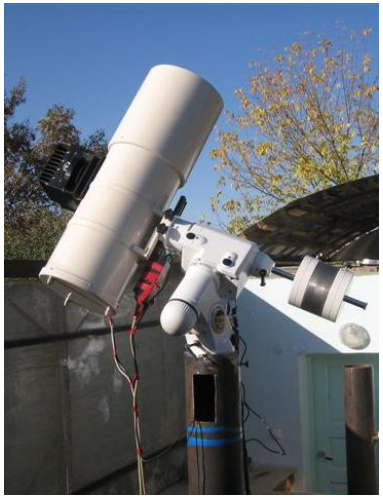
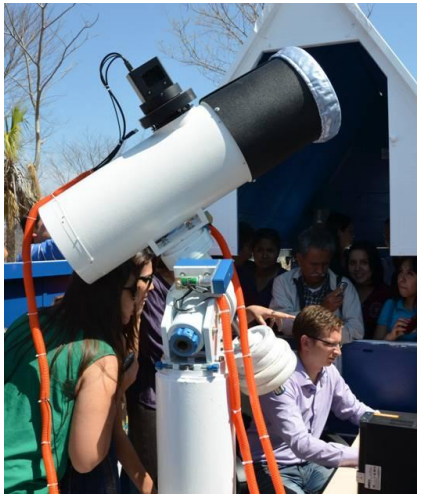





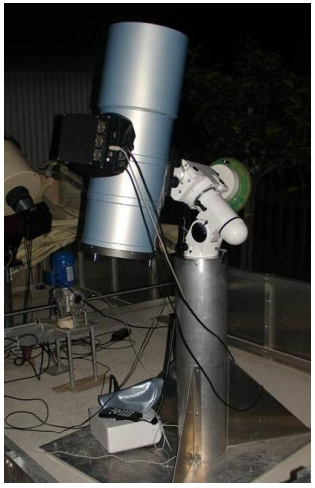

ISON survey telescopes

- 12.5-cm, FOV 12x10 degree – 4 (1)
- 19.2-cm, FOV 7x7 degree – 9 (2)
- 2x19.2-cm, FOV 14x5 degree – 4 (1)
- 4x19.2-cm, FOV 14x10 degree – 2 (0)
- 22-cm, FOV 4x4 (5.5x5.5) degree – 12 (12)
- 25-cm, FOV 3.4x3.4 degree – 15 (8)
- 40-cm, FOV 2.3x2.3 degree – 8 (3)
- 50-cm, FOV 1.8x1.8 (2.5x2.5) degree – 2 (2)
- 65-cm, FOV 2.6x2.6 degree – 5 in production

Global search and survey subsystem for the GEO region: *14 of 22-25 cm telescopes with FOV of 3.5- 5.5 degree*

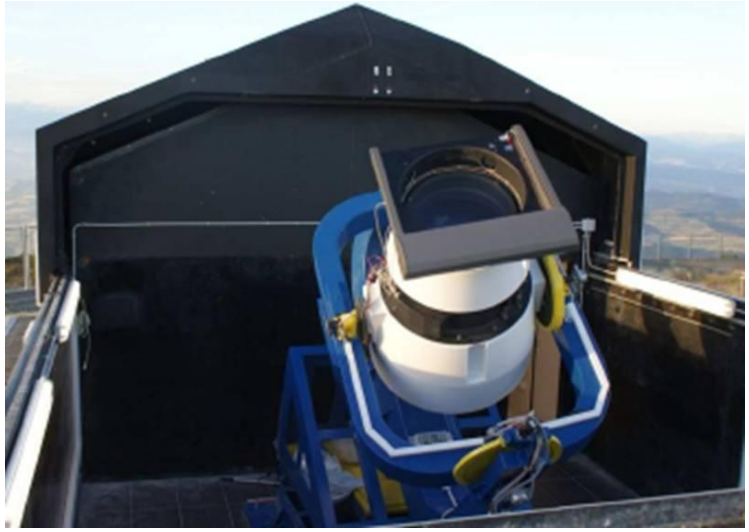


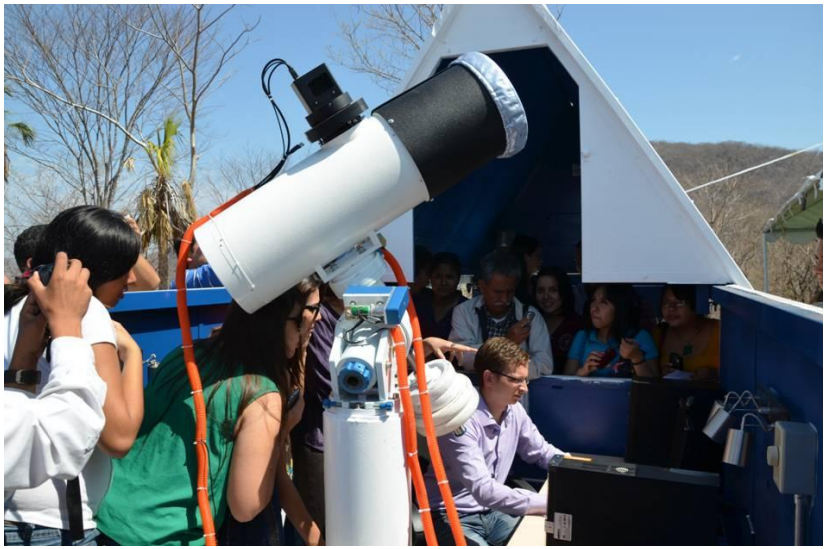



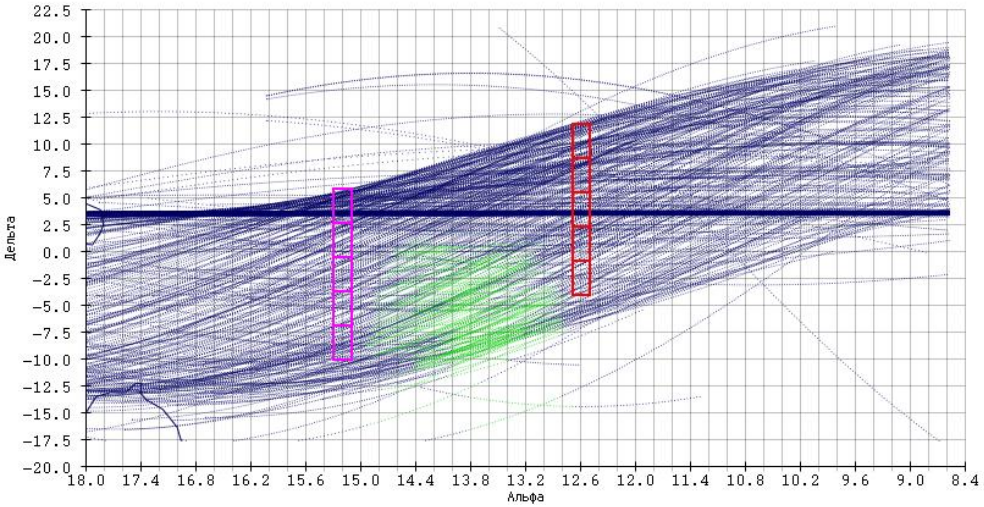
Global GEO-survey subsystem completion

- Two more 25-cm survey telescopes are installed (**Chuguev** near Kharkov, Ukraine and **Cosala,** Sinaloa state, Mexico)
- 50-cm telescope TFRM near **Barselona** started observations within the framework of ISON
- Standard strategy of GEO survey scheduling is implemented for all survey telescopes - productivity of ISON network is increased 1.5 times (1,155,446 measurements in 150570 tracks in 1st quarter 2012)
- Thus, global GEO-survey subsystem of 14 automated telescopes is completed

Global GEO-survey subsystem completion – Barselona, Cosala and Chuguev

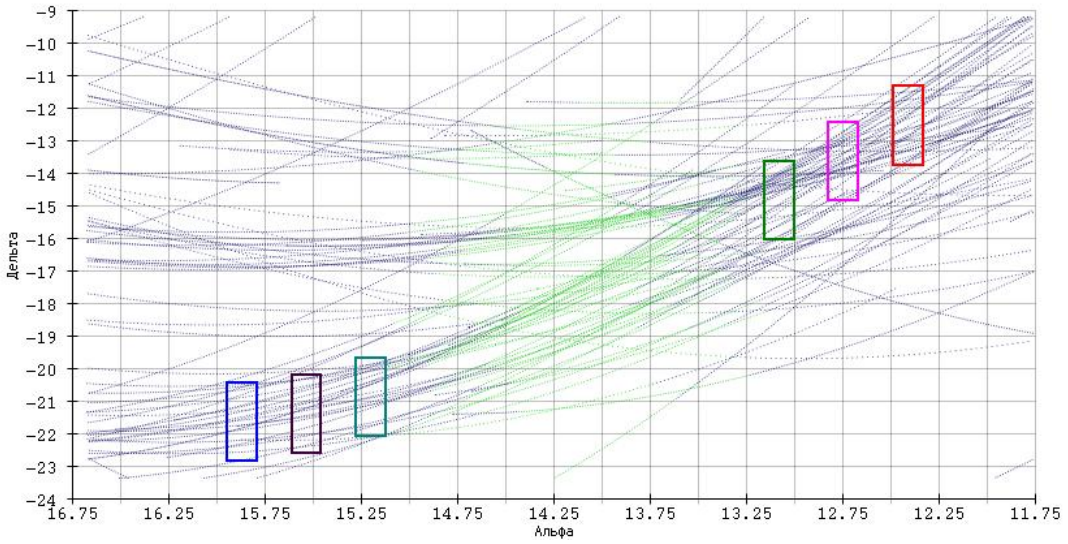






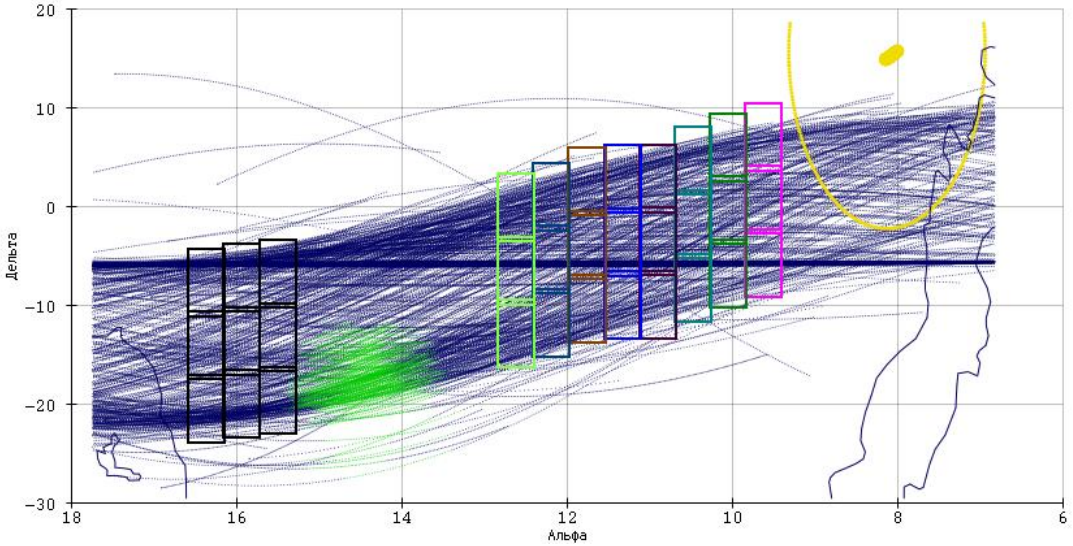
Adjustment of faint fragment survey

- Installation of CCD camera with 50-mm chip at 50-cm ORI-50 telescope resulted in 2.5x2.5 deg FOV and provided ability to cover fields with the highest density of known fragment trajectories
- Ussuriysk ORI-50 participated in discovering of about 100 new faint objects during 2011



Start of HEO surveys, extended GEO surveys

- 19.2 cm VT-78e and 18 cm VT-52c telescopes with 7x7 degree FOV are installed in Sanglok and Nauchnyi-1
- **Sanglok** carries out extended GEO survey (14000 measurements in 2000 tracks for 500-600 objects per a survey, including up to 150 HEO objects)
- **Nauchniy-1** – both extended GEO survey and targeted survey of HEO objects



Start of HEO surveys, extended GEO surveys (examples)

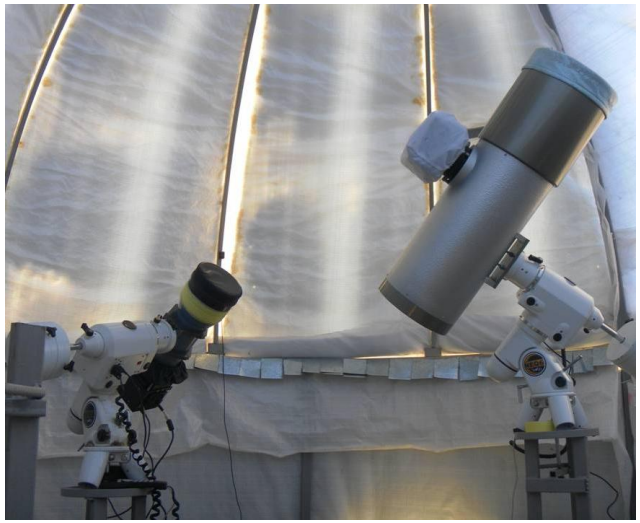
Sanglok VT-78e first extended GEO surveys, Jan 2012

Date	Duration, hh:mm	Tracks	Measurements	Objects
14.01.2012	11:47	2297	16006	577
18.01.2012	12:33	2413	16910	609
19.01.2012	11:08	2265	16063	597
20.01.2012	12:28	2428	17030	637
28.01.2012	12:14	2383	16822	606
31.01.2012	11:44	2184	15553	580

Nauchniy-1 VT-52c first extended GEO surveys, Apr 2012

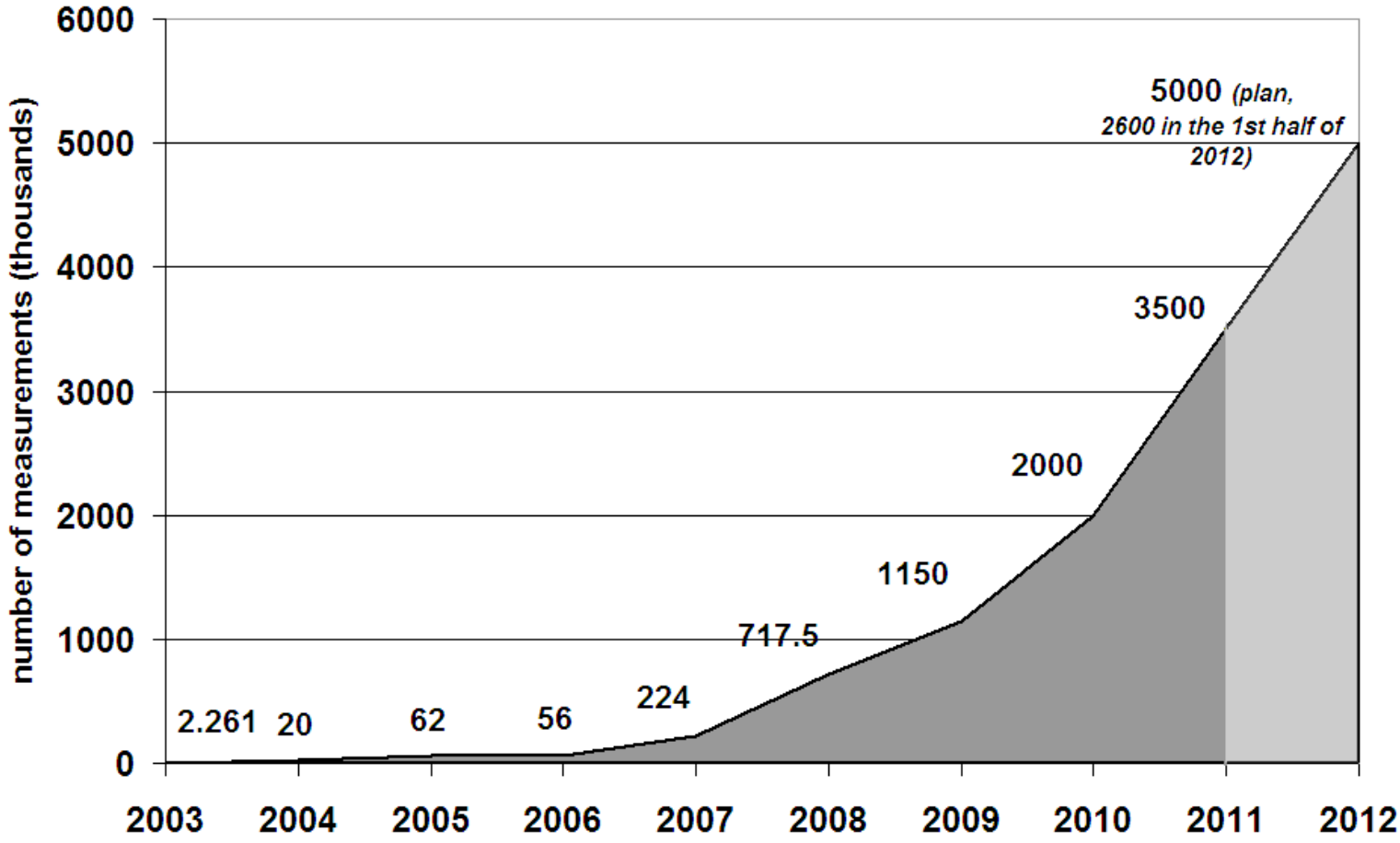
Date	Duration, hh:mm	Tracks	Measurements	Objects
12.04.2012	2:05	471	3607	459
13.04.2012	2:42	355	2626	330
16.04.2012	4:13	742	5175	405
25.04.2012	7:43	1341	10190	601
27.04.2012	8:01	1255	9533	584

Subsystem for LEO objects tracking from telescopes with FOV of 12x10 degree

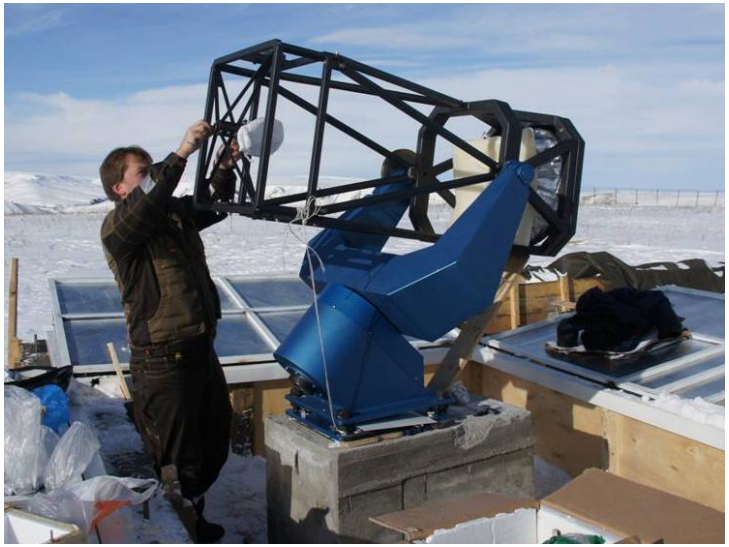


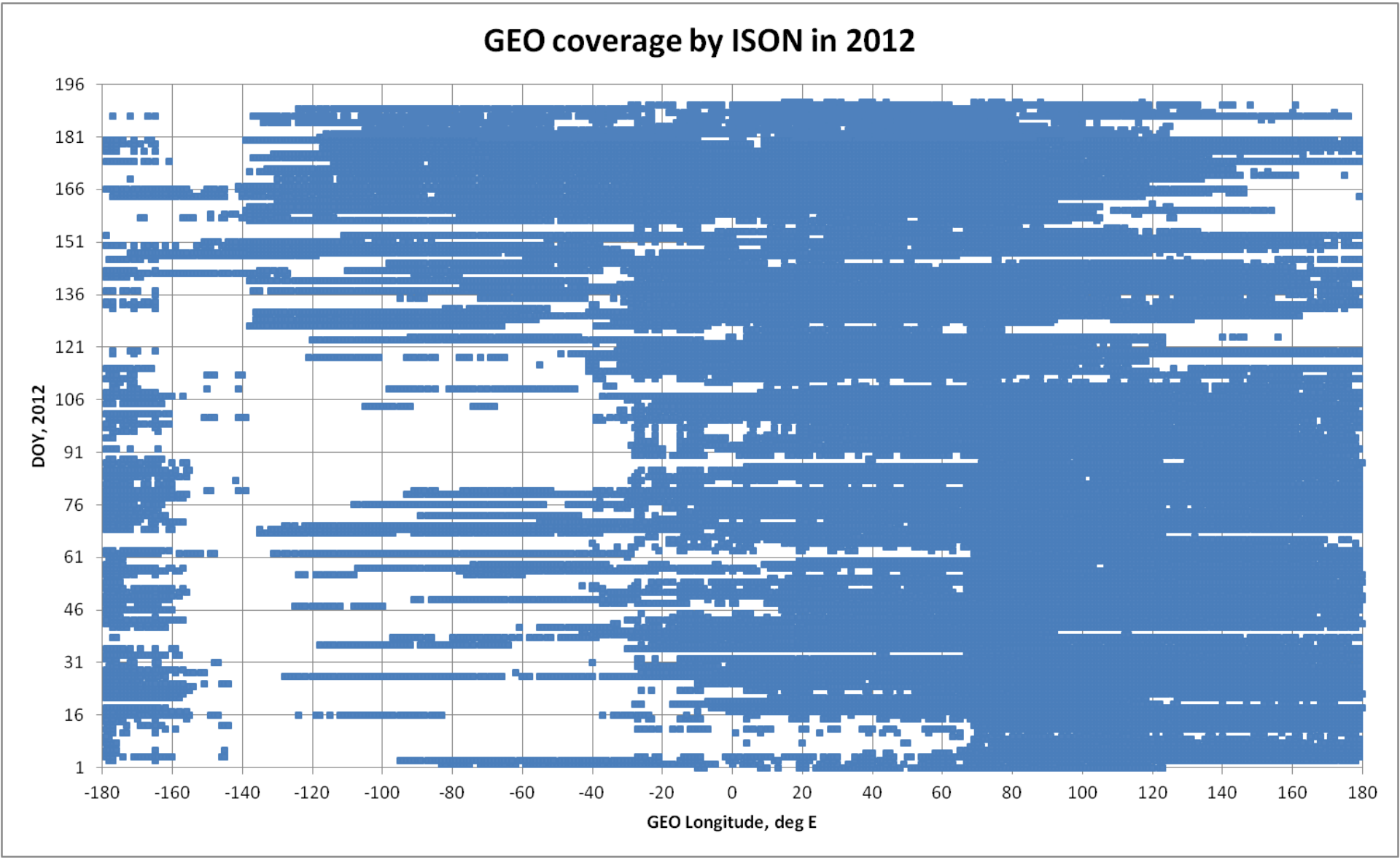
Quantity of measurements accumulated by ISON instruments (by year)

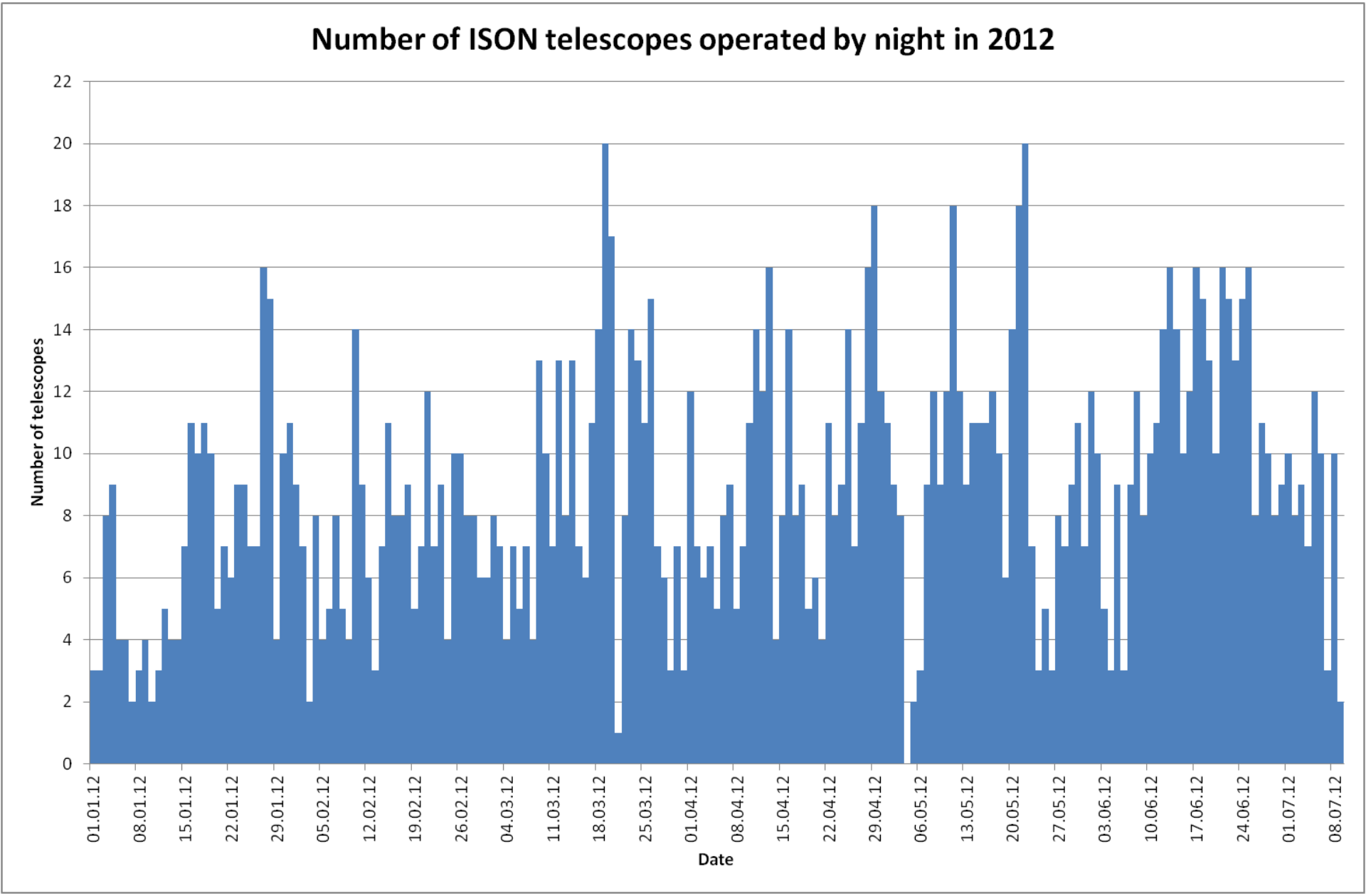
>10 millions measurements to the date

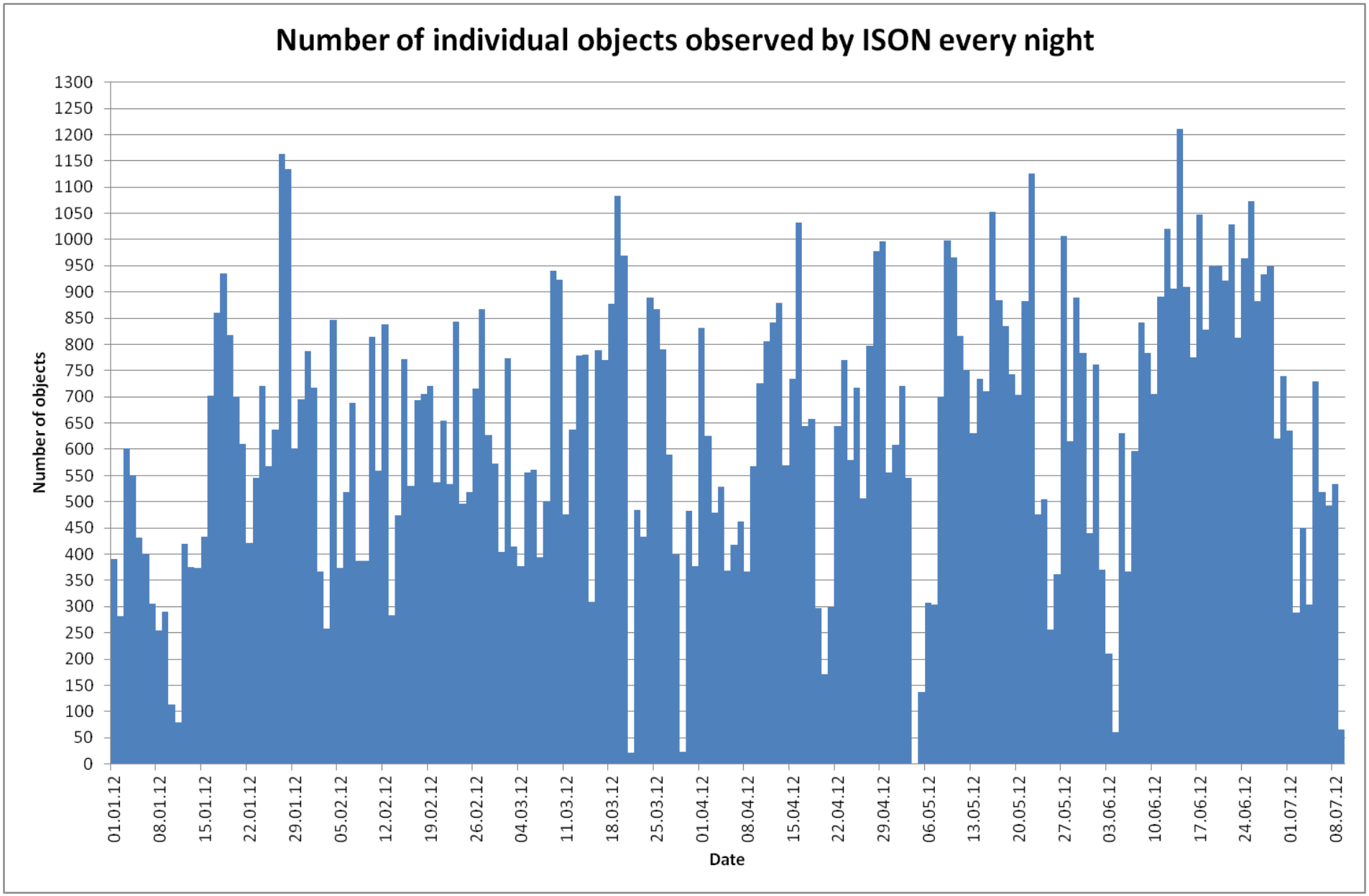


First of 6 dedicated mini-observatories (EOP-1 near Kislovodsk: 40-cm, 25-cm and 2x19.2 cm telescopes, and 50-cm telescope)




GEO coverage by ISON in 2012
DOY, 2012
196
181
166
151
136
121
106
91
76
61
46
31
16
1
-180
-160
-140
-120
-100
-80
-60
-40
-20
0
20
40
60
80
100
120
140
160
180
GEO Longitude, deg E


Number of ISON telescopes operated by night in 2012
Number of telescopes
0
2
4
6
8
10
12
14
16
18
20
22
01.01.12
08.01.12
15.01.12
22.01.12
29.01.12
05.02.12
12.02.12
19.02.12
26.02.12
04.03.12
11.03.12
18.03.12
25.03.12
01.04.12
08.04.12
15.04.12
22.04.12
29.04.12
06.05.12
13.05.12
20.05.12
27.05.12
03.06.12
10.06.12
17.06.12
24.06.12
01.07.12
08.07.12
Date


Number of individual objects observed by ISON every night
Number of objects
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
01.01.12
08.01.12
15.01.12
22.01.12
29.01.12
05.02.12
12.02.12
19.02.12
26.02.12
04.03.12
11.03.12
18.03.12
25.03.12
01.04.12
08.04.12
15.04.12
22.04.12
29.04.12
06.05.12
13.05.12
20.05.12
27.05.12
03.06.12
10.06.12
17.06.12
24.06.12
01.07.12
08.07.12
Date

ISON Research Goals in Space Debris Area

- Estimation of real population of space debris at higher geocentric orbits
- Determination of physical properties of discovered space debris objects
- Determination of probable sources of newly discovering space debris fragments
- Verification of existing models of space debris distribution and evolution at higher orbits
- Higher orbit space debris risk assessment
- Improvement of technologies of studying of space debris population using optical instruments
- Improvement of motion models for space debris objects with complex physical properties

ISON Monitored GEO Region Objects

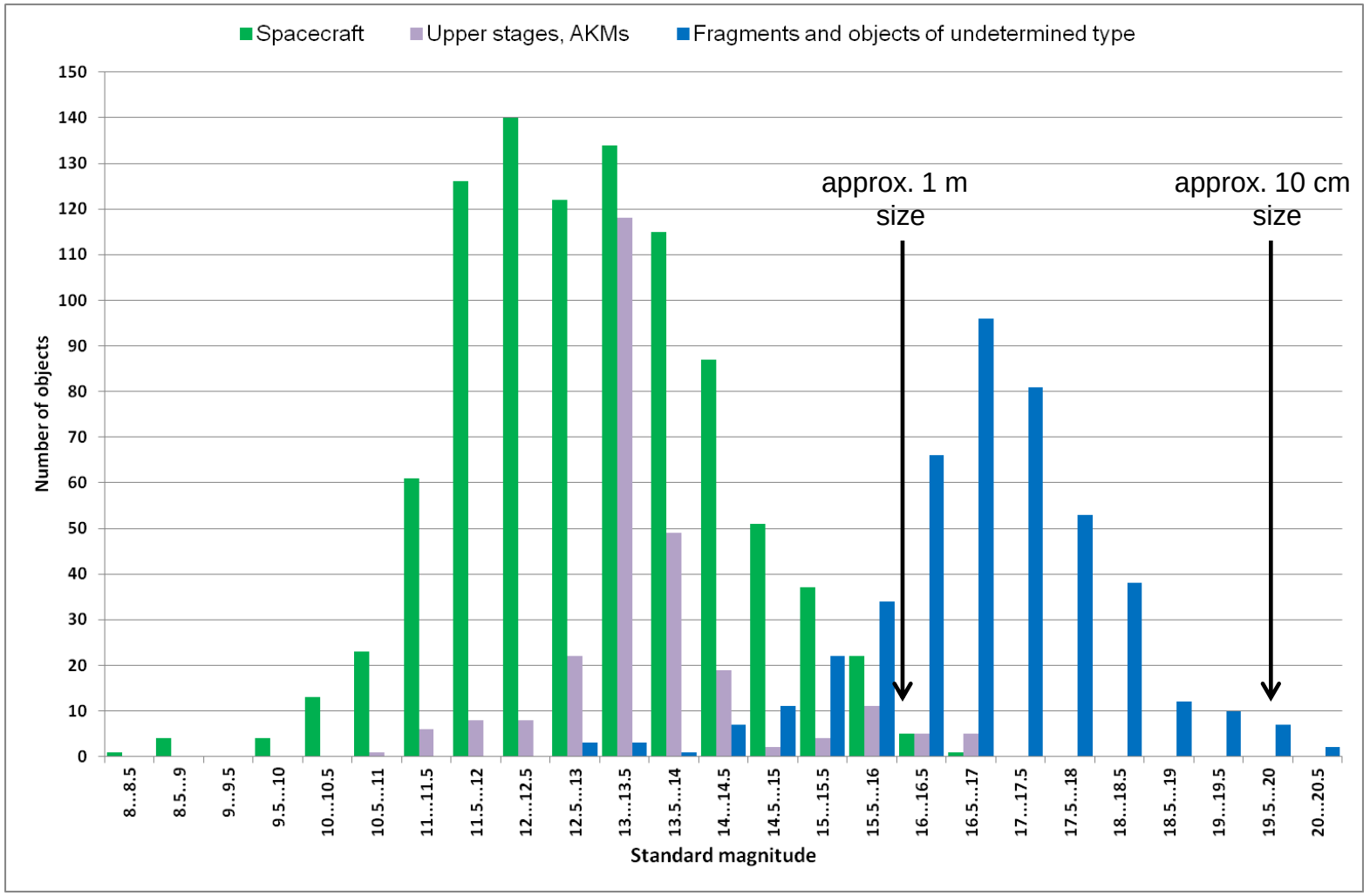
	01.01.2011	01.01.2012
Total objects in GEO, *including:*	**1557**	**1704**
spacecraft	922	954
active	404	422
non-active	518	532
upper stages and AKMs	257	260
fragments and undetermined type objects	378	490

- 66 new GEO region previously unknown fragments are already discovered and added to the ISON database in 2012

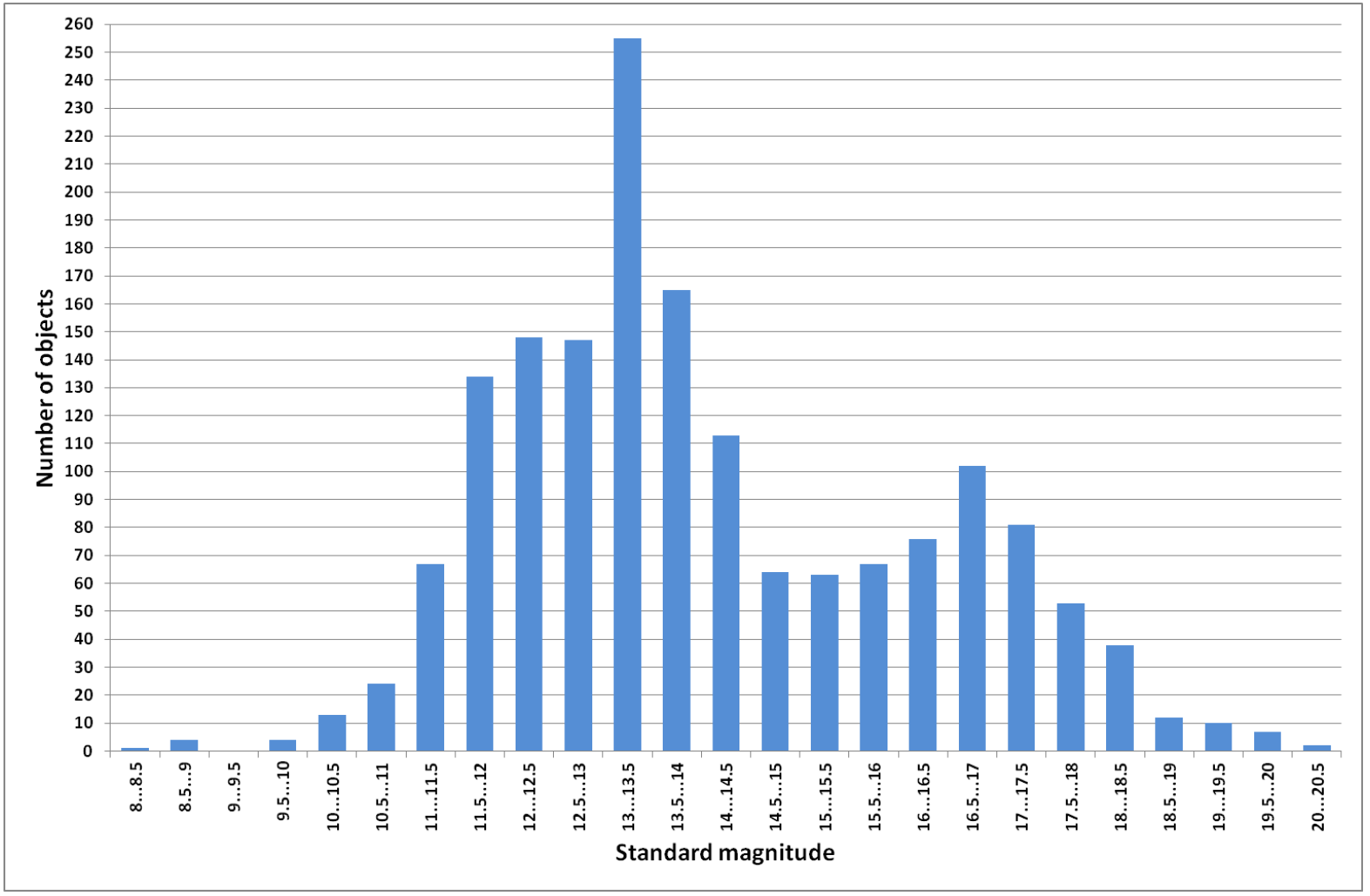
Brightness distribution of observing GEO objects

- Each object is assumed as a diffuse sphere with albedo of 0.15
- Differences between diffuse sphere phase function and real phase function for particular object are ignored
- Standard brightness (referring to a zero phase angle and 40000 km distance) is calculated for each object based on all collected measurements to the date
- Objects are split into 3 groups:
  - spacecraft,
  - rocket bodies (upper stages, AKMs),
  - fragments and objects of undetermined type

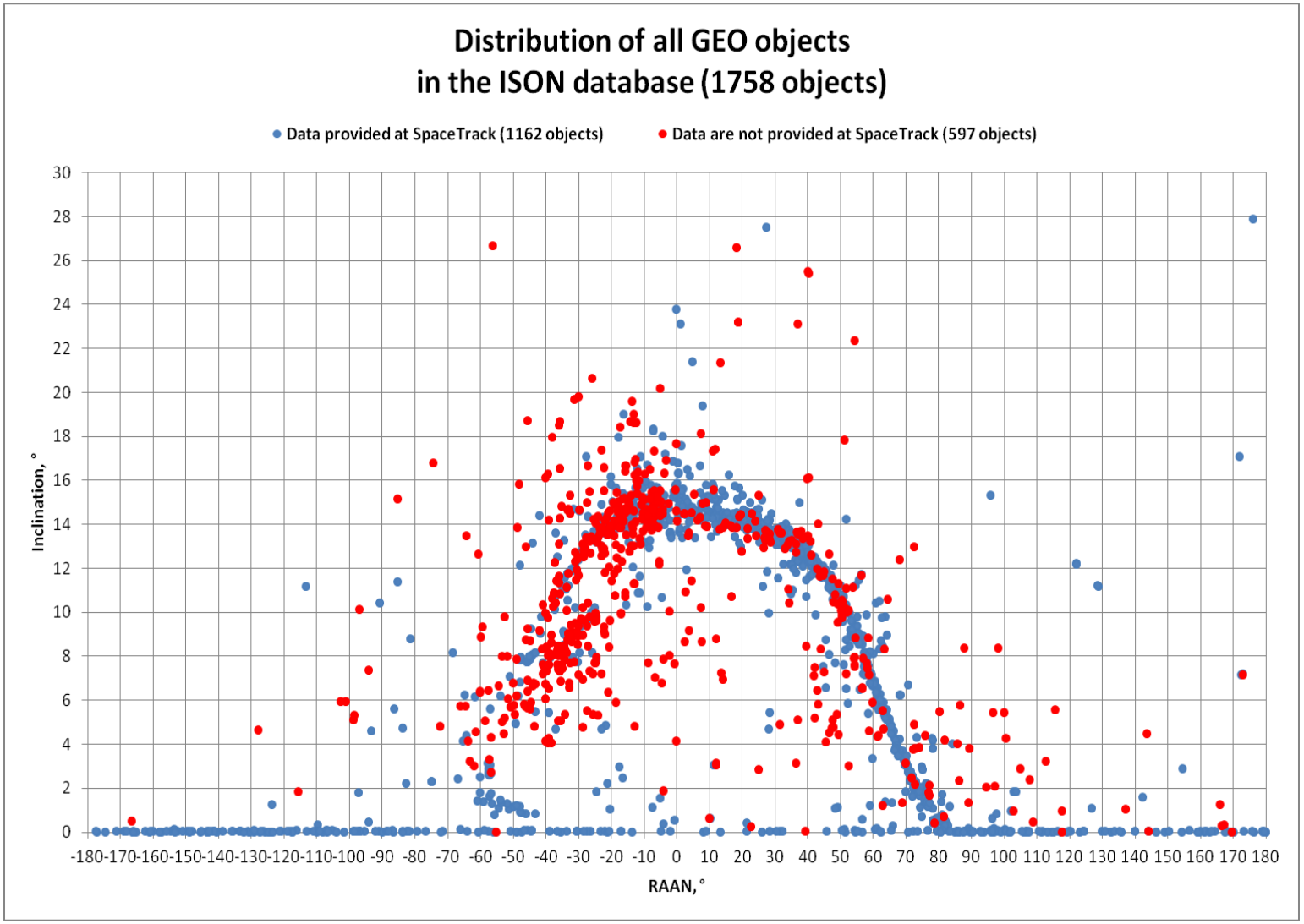
ISON Tracked GEO Objects Distribution by Standard Magnitude – 1704 objects



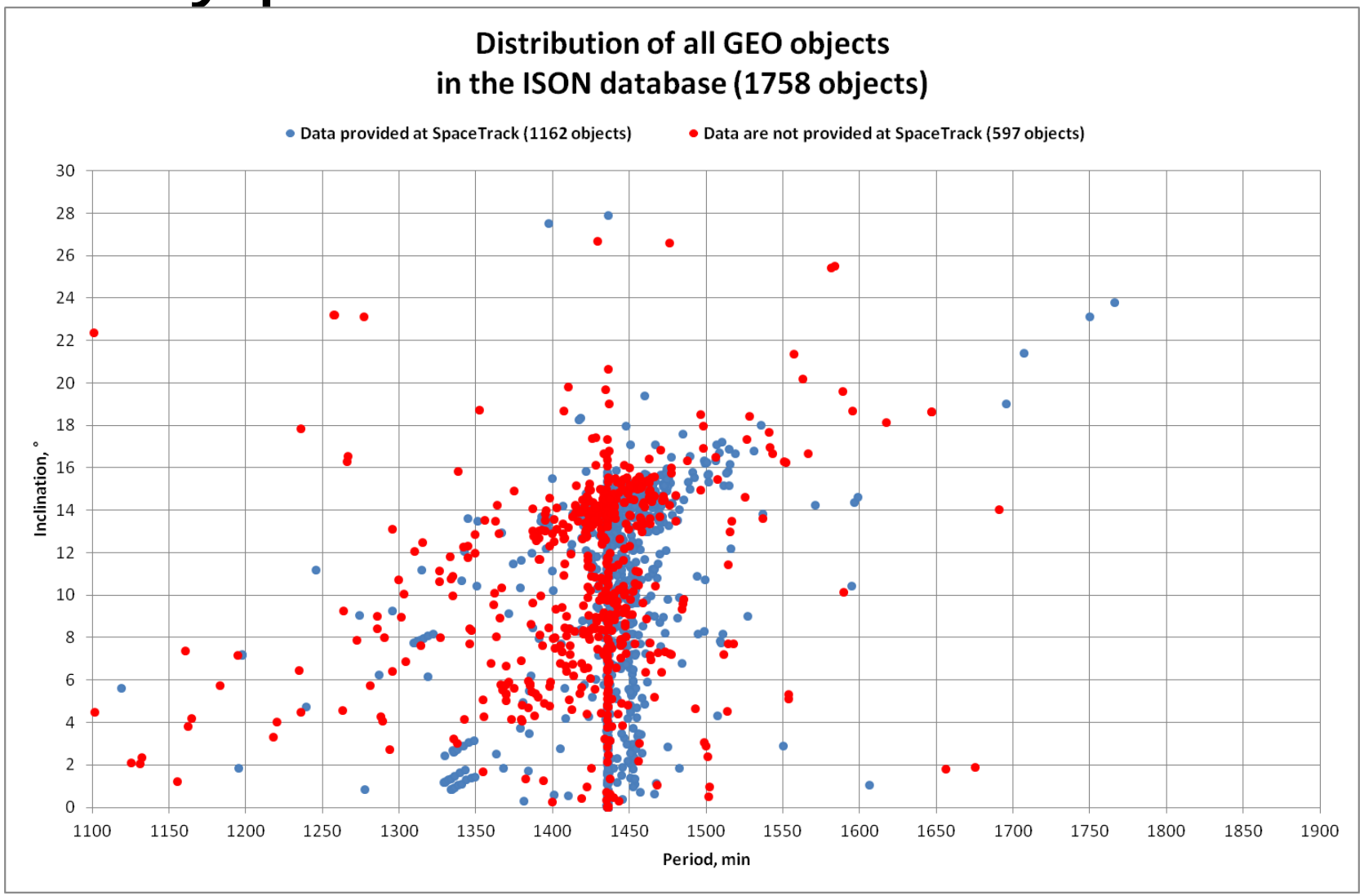
ISON Tracked GEO Objects Distribution by Standard Magnitude – 1704 objects



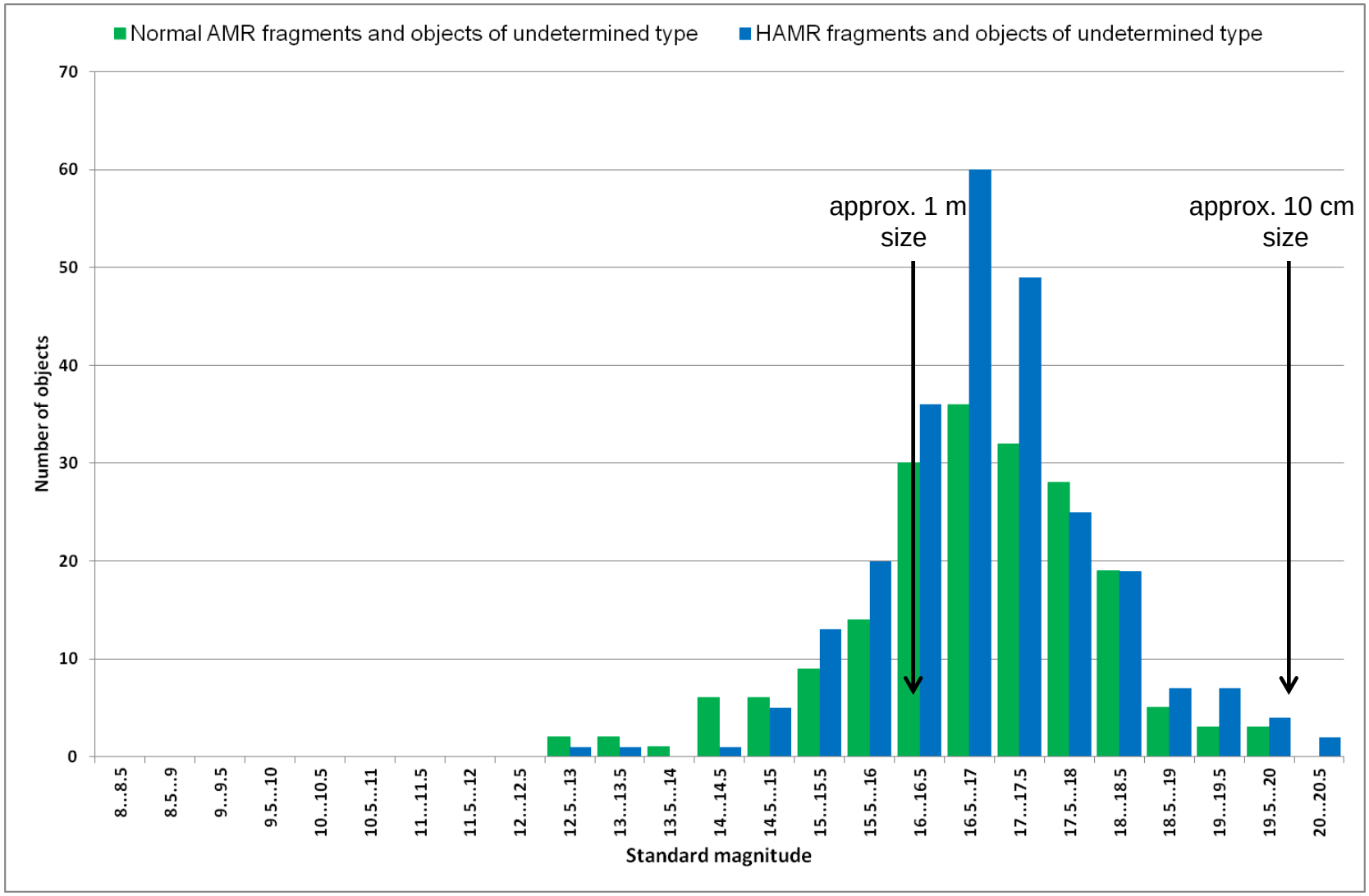
Distribution of observing GEO objects by RAAN and inclination



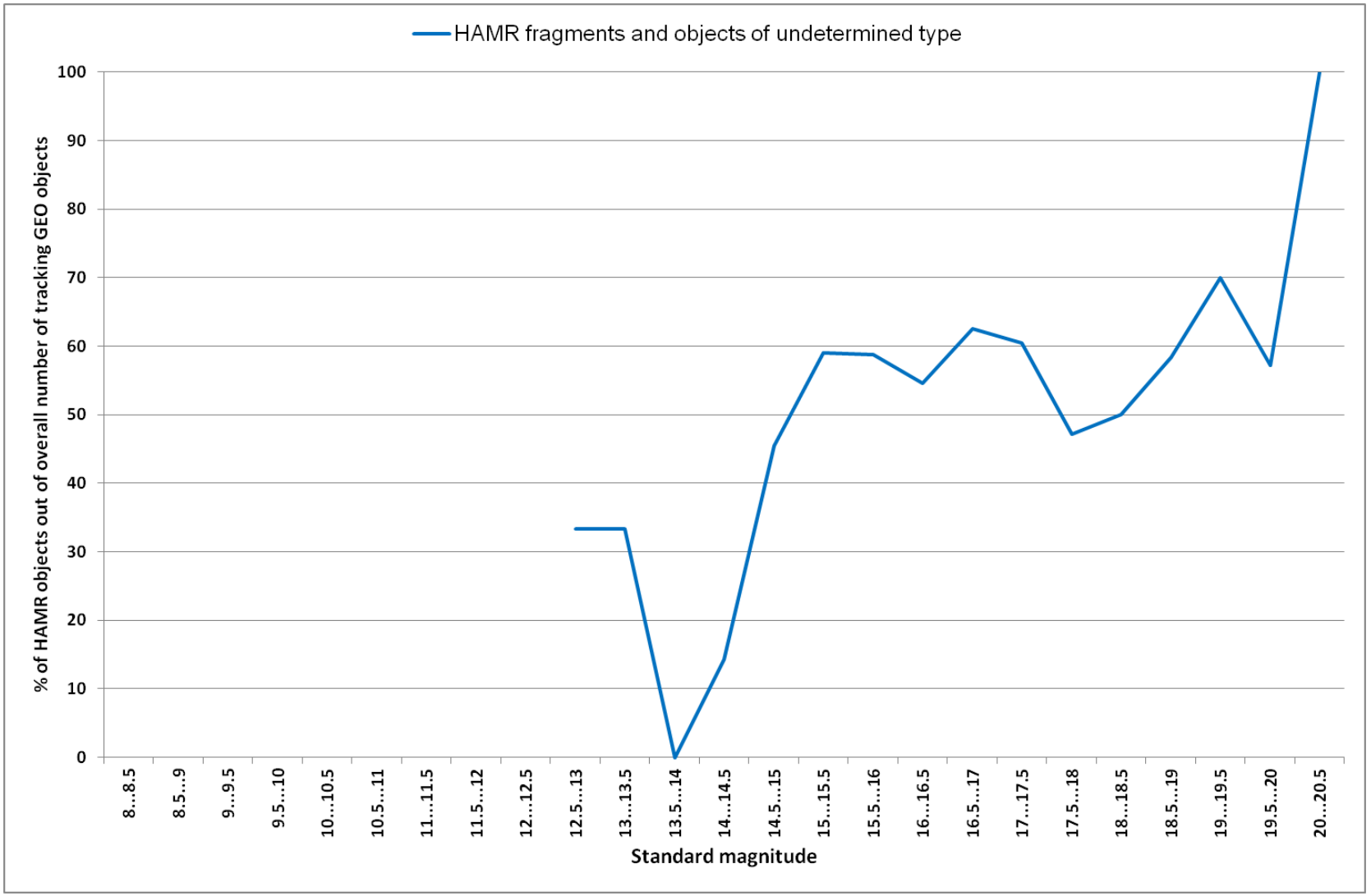
Distribution of observing GEO objects by period and inclination



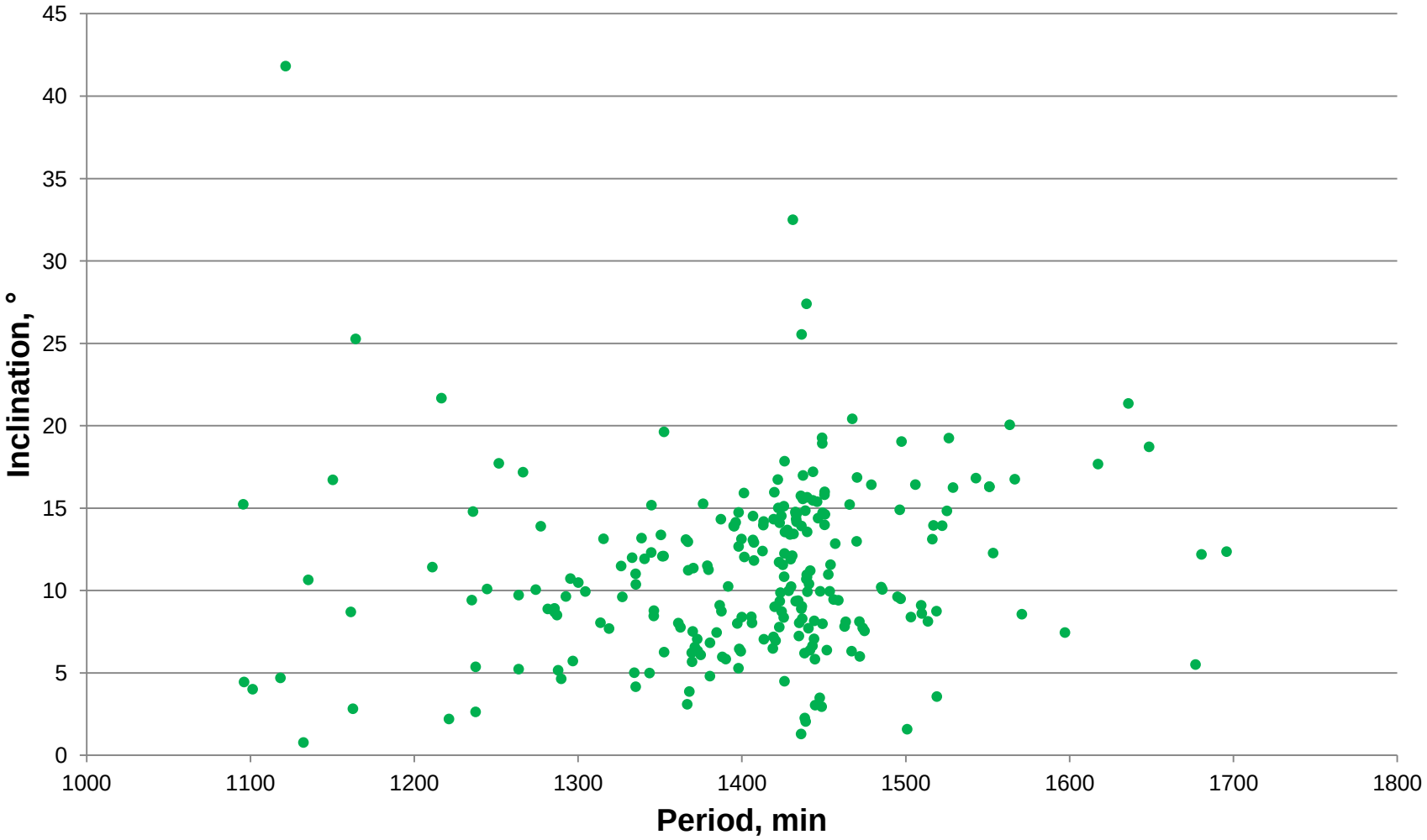
ISON Tracked GEO Fragments and Objects of Undetermined Type

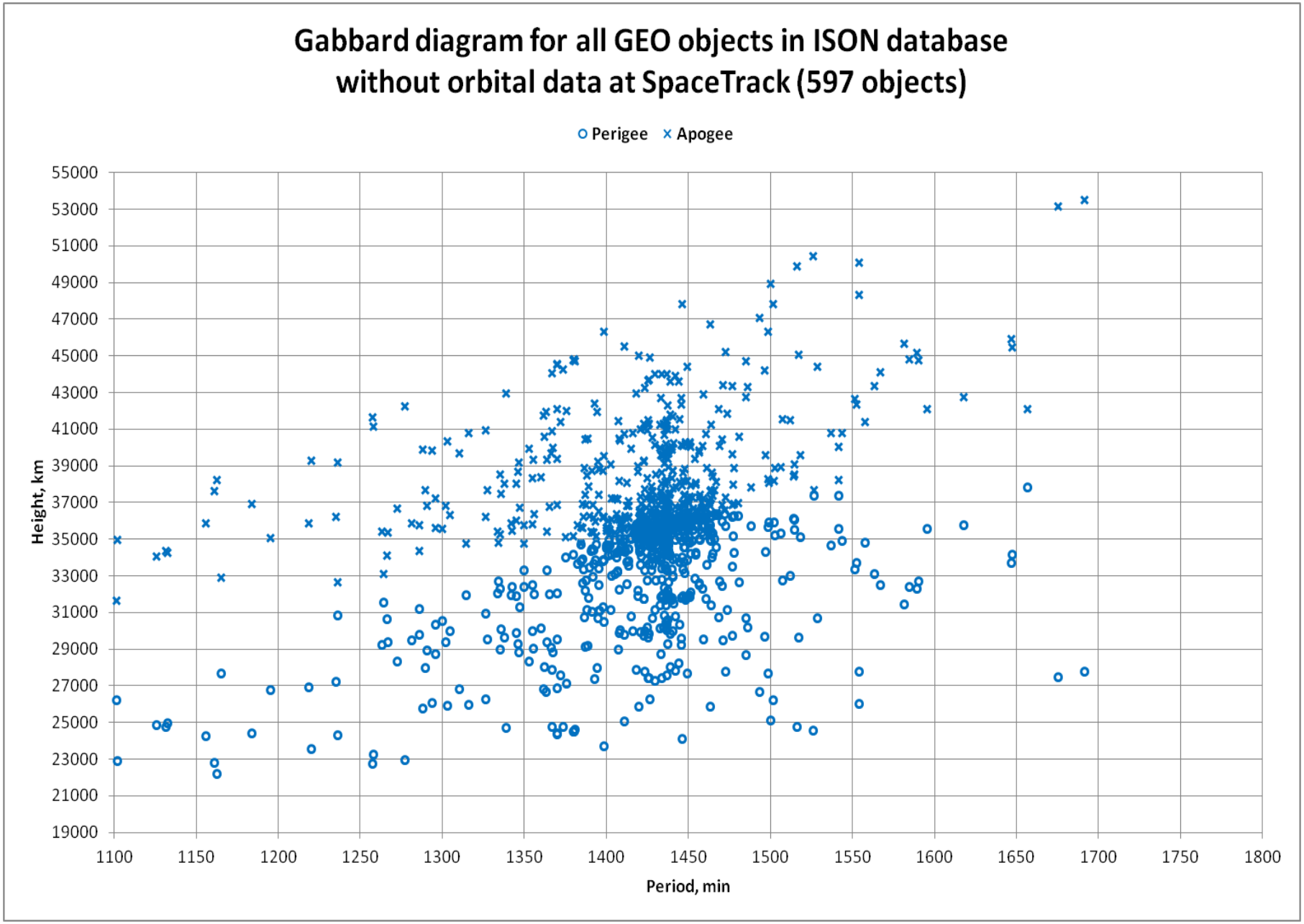


GEO HAMR Objects. How many?

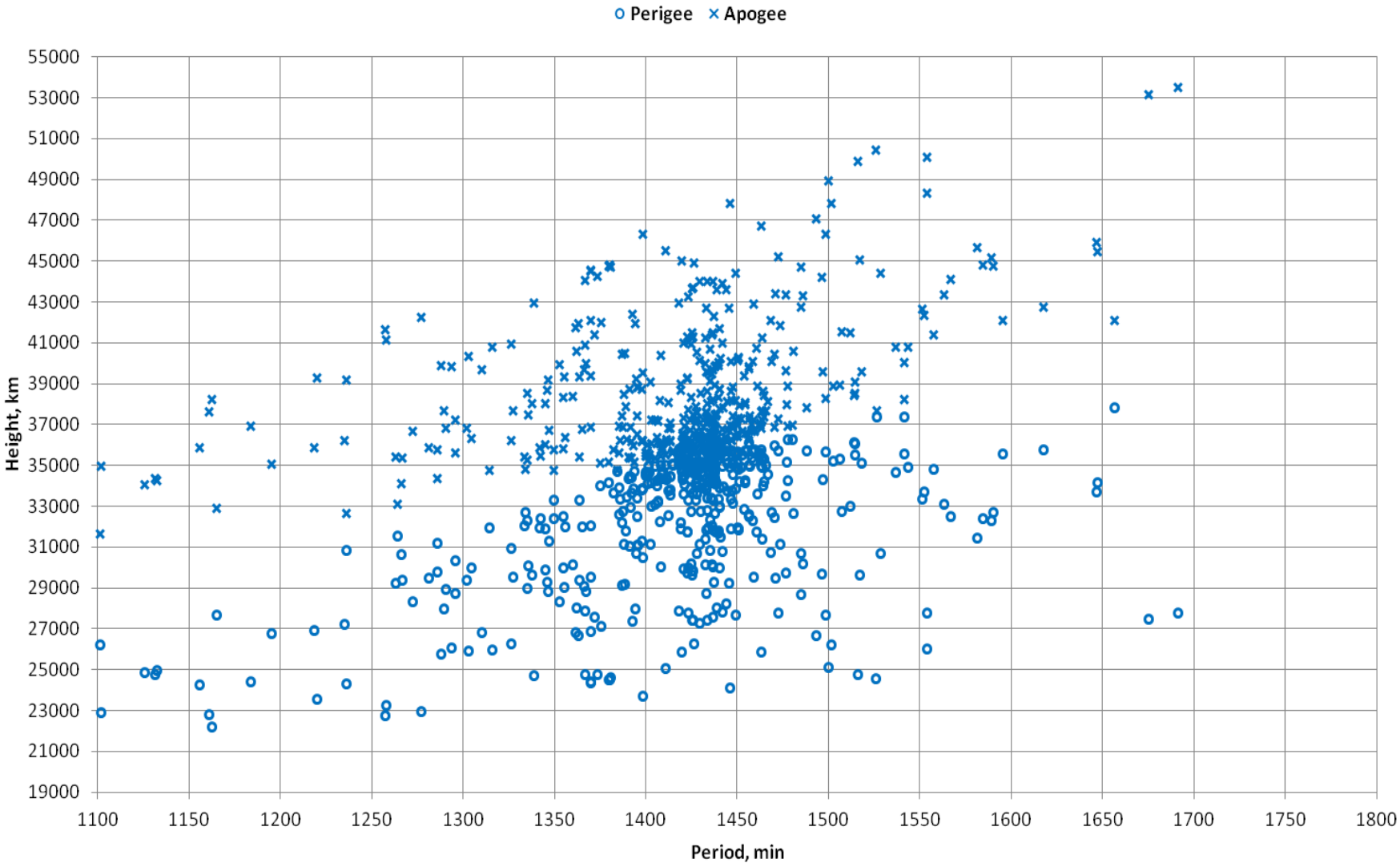


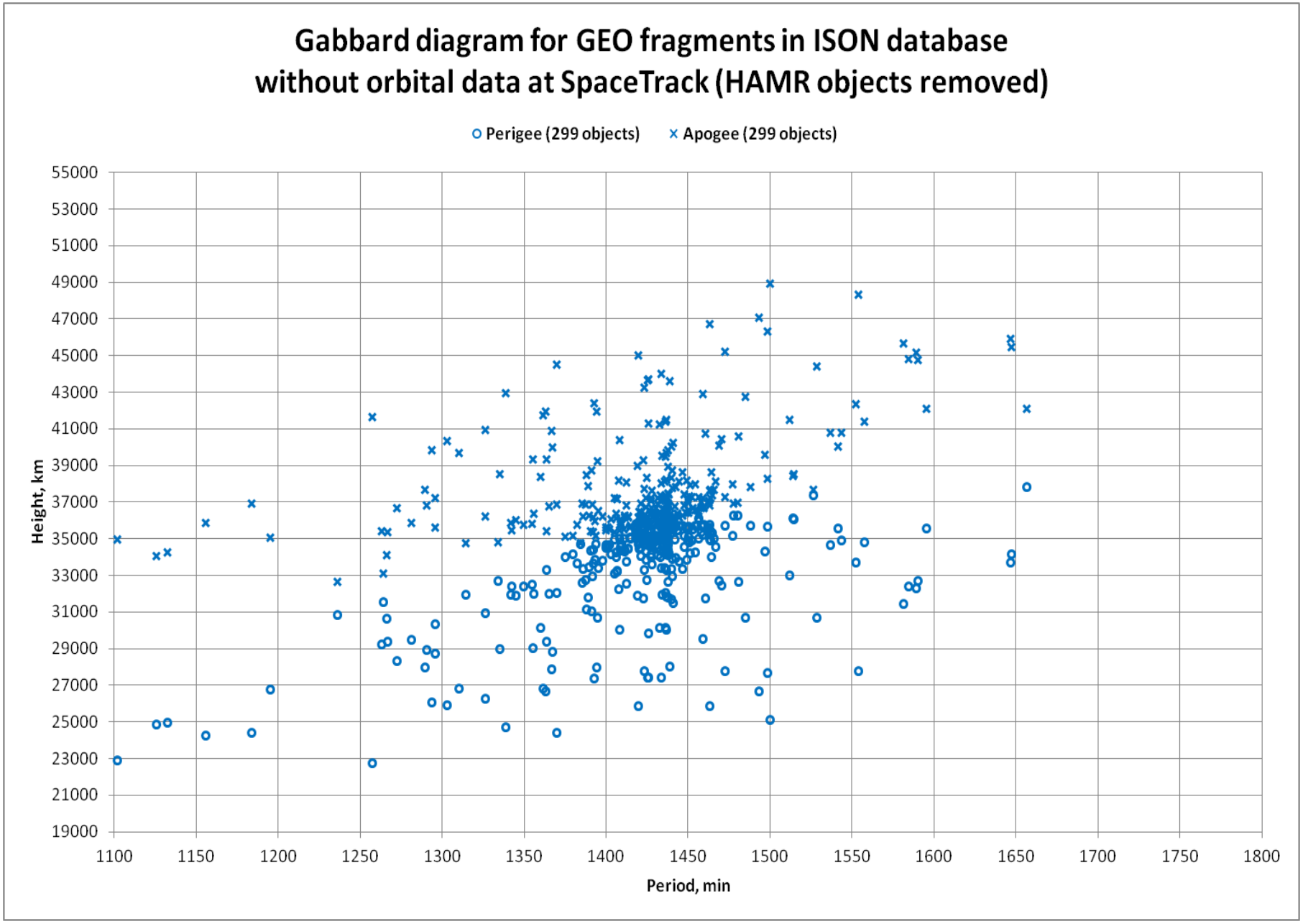
Distribution of High AMR objects by period and inclination




Gabbard diagram for all GEO objects in ISON database
without orbital data at SpaceTrack (597 objects)
Perigee
Apogee
Height, km
55000
53000
51000
49000
47000
45000
43000
41000
39000
37000
35000
33000
31000
29000
27000
25000
23000
21000
19000
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
Period, min

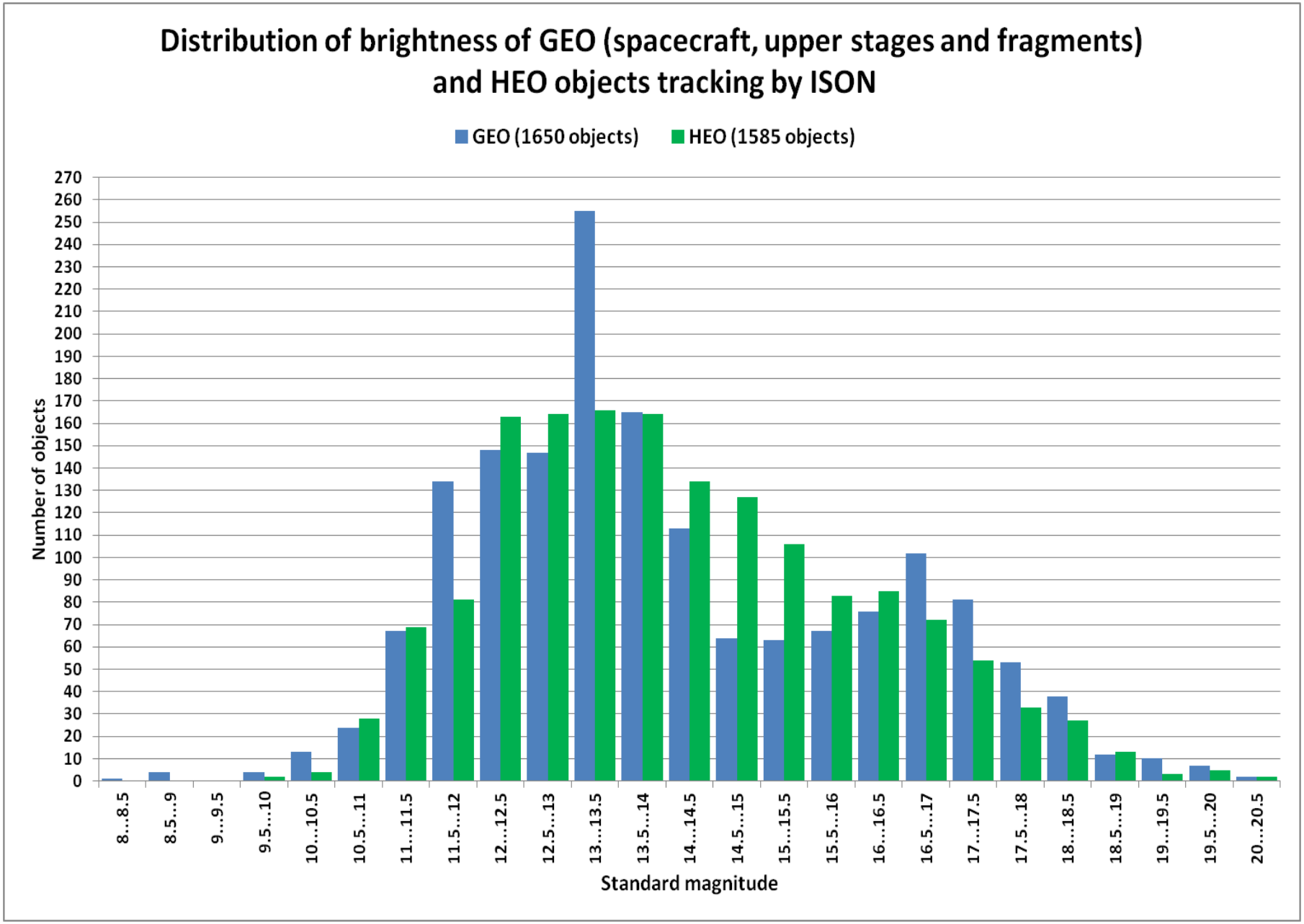
Gabbard diagram for GEO fragments in ISON database without orbital data at SpaceTrack (450 objects)



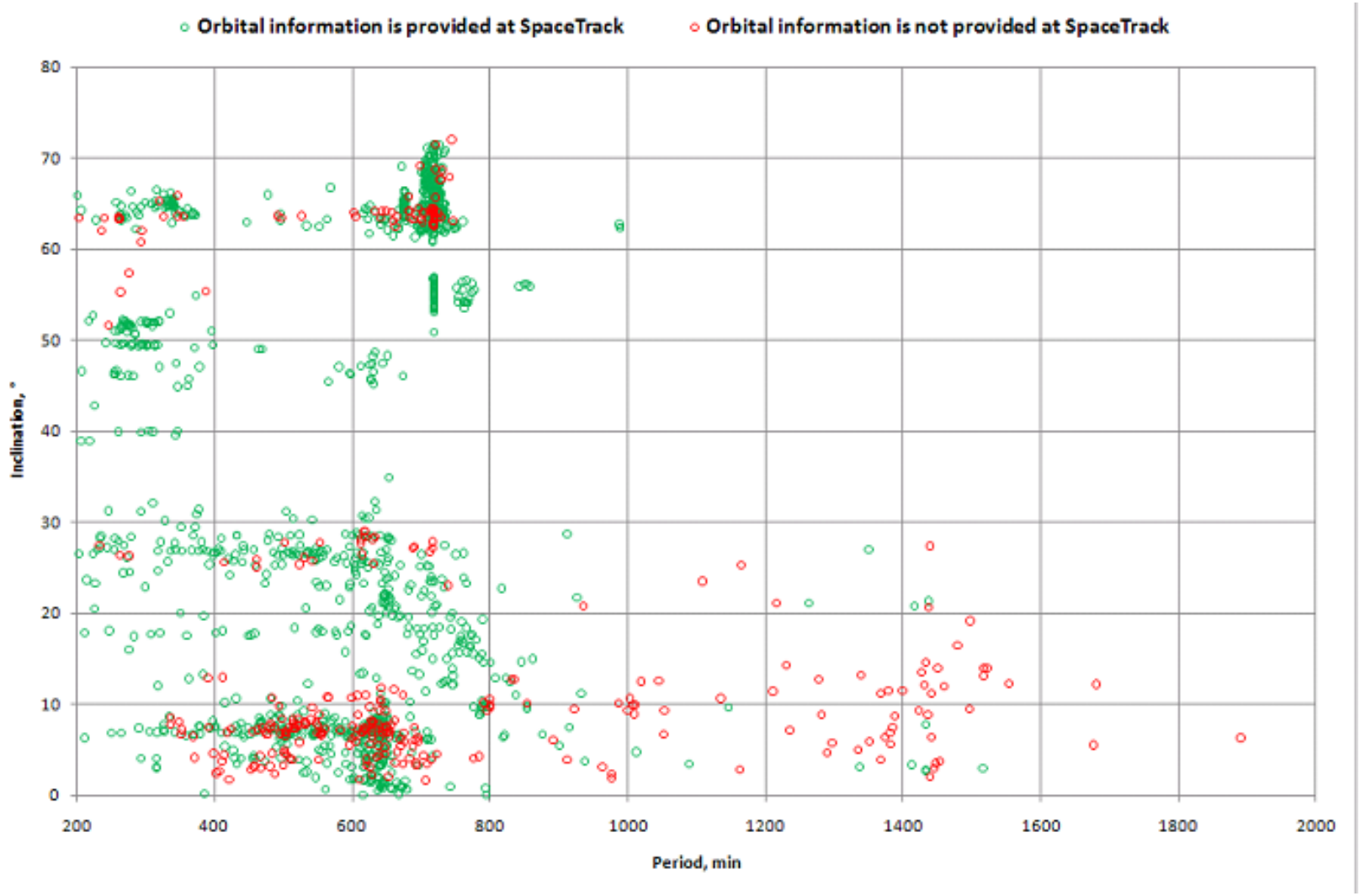

Gabbard diagram for GEO fragments in ISON database
without orbital data at SpaceTrack (HAMR objects removed)
Perigee (299 objects)
Apogee (299 objects)
Height, km
55000
53000
51000
49000
47000
45000
43000
41000
39000
37000
35000
33000
31000
29000
27000
25000
23000
21000
19000
1100
1150
1200
1250
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
Period, min

HEO and MEO Objects Measured (KIAM database, Sep 1, 2010)

- **Total – 1699 objects on HEO and MEO with orbits updated occasionally or by tasking, including**
- **Spacecraft – 394**
- **Upper stages and AKMs – 560**
- **Fragments and objects of undetermined type – 744**


Distribution of brightness of GEO (spacecraft, upper stages and fragments) and HEO objects tracking by ISON
GEO (1650 objects)
HEO (1585 objects)
Number of objects
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
250
260
270
8...8.5
8.5...9
9...9.5
9.5...10
10...10.5
10.5...11
11...11.5
11.5...12
12...12.5
12.5...13
13...13.5
13.5...14
14...14.5
14.5...15
15...15.5
15.5...16
16...16.5
16.5...17
17...17.5
17.5...18
18...18.5
18.5...19
19...19.5
19.5...20
20...20.5
Standard magnitude

Distribution of 1699 HEO and MEO objects by Period and Inclination



Conclusions (1)

- 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 18th 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

Conclusions (2)

- ISON network collects on a routine basis astrometric and brightness measurements for more than 1700 objects in GEO region and more than 600 objects at HEO orbits
- Obtained measurement data are processing to improve orbits and to find various events (appearance of a new object due to launches, fragments separation etc., possible close encounter, manoeuvres of different purpose)
- Accumulated information is using to support spaceflight safety tasks, including those ones solving within the framework of ASPOS OKP system by Roscosmos jointly with RAS
- Development of ISON – the first international network for monitoring near-Earth space – continues and all nations are welcome to join us

Acknowledgements

Great thanks to all ISON observers and engineers

Special thanks to the AIUB team for support of continuing multiyear cooperative GEO and HEO debris research especially HAMR ones