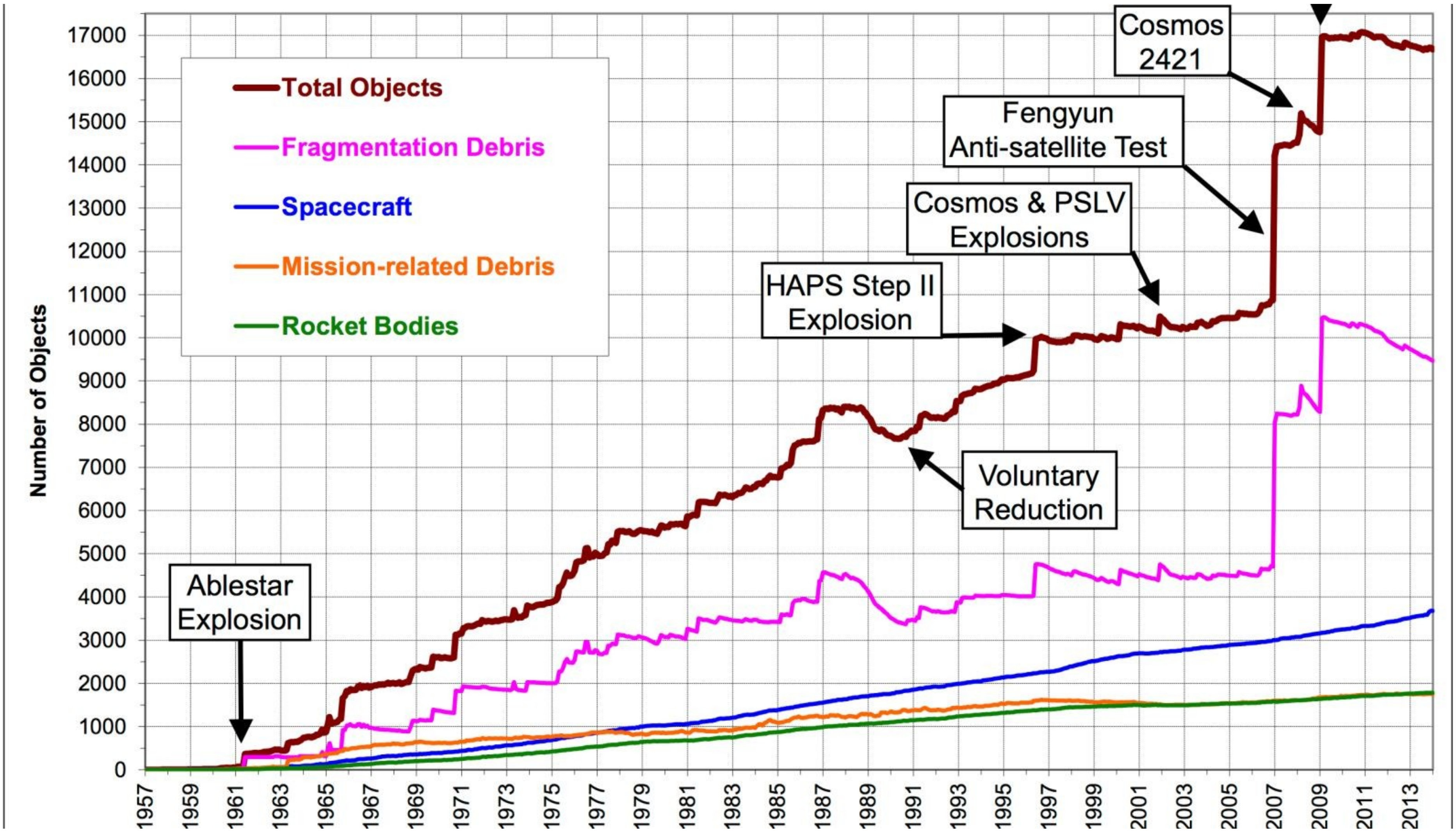
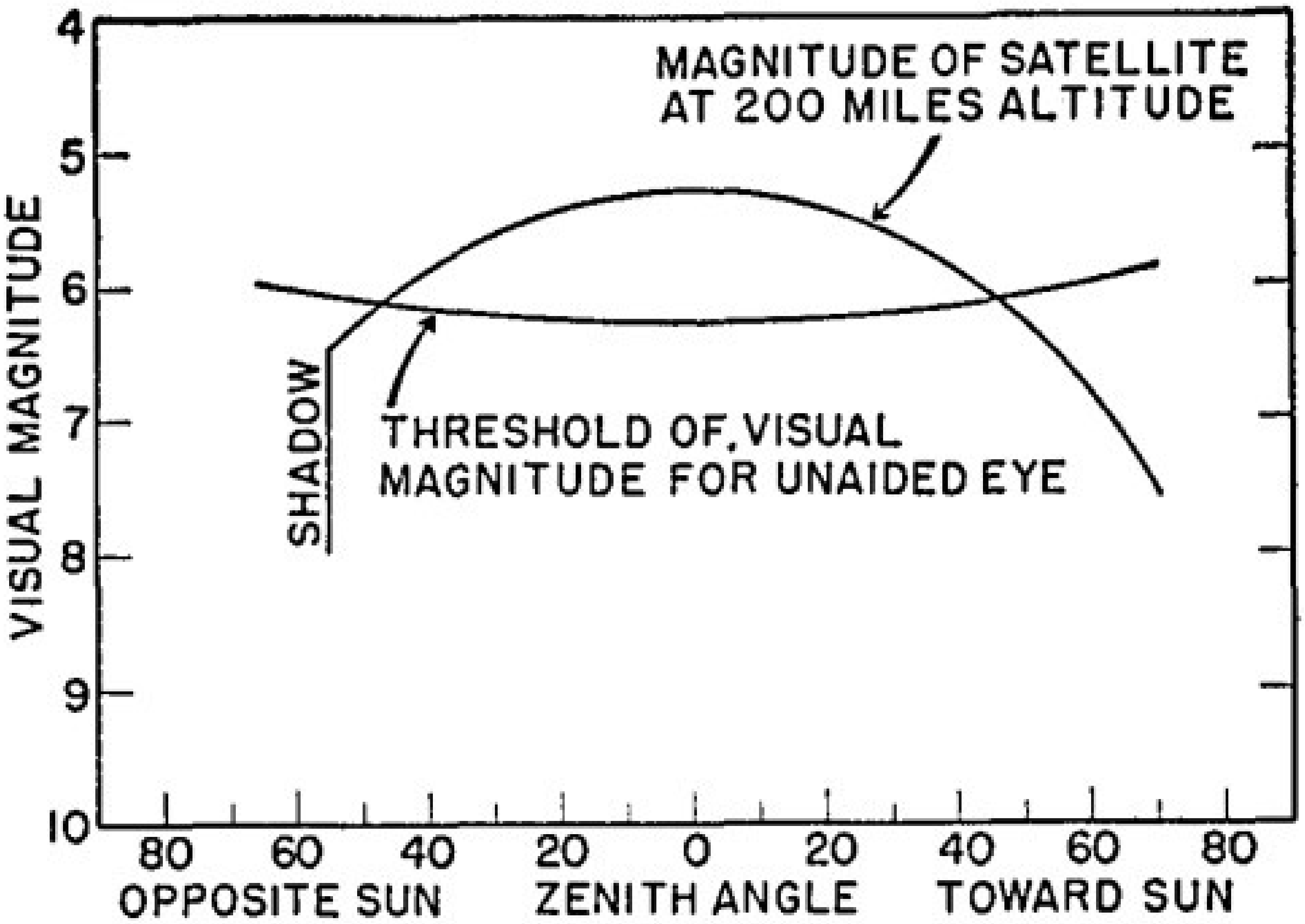
Determination of non-orbital parameters

Andrey Yudaev
MIPT, Space Informatics lab.

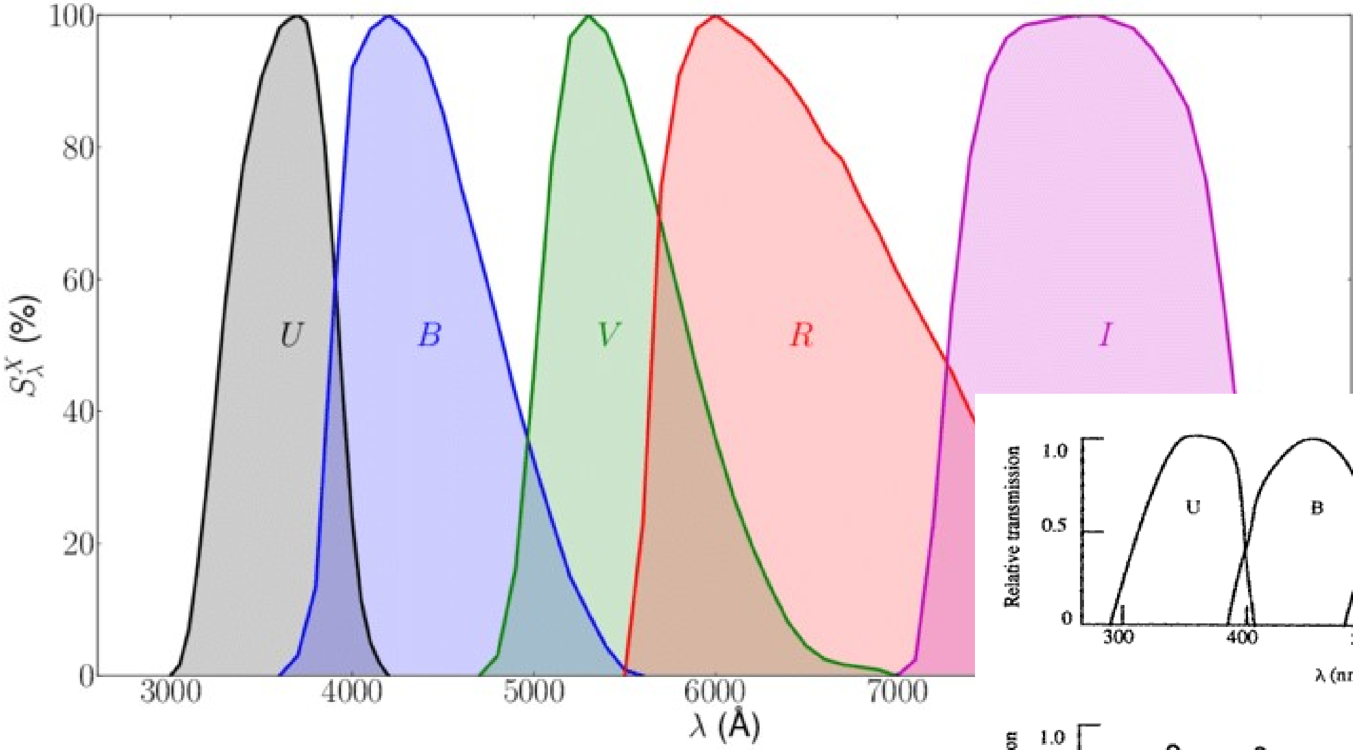
The problem of space debris



Observable parameters



Observable parameters



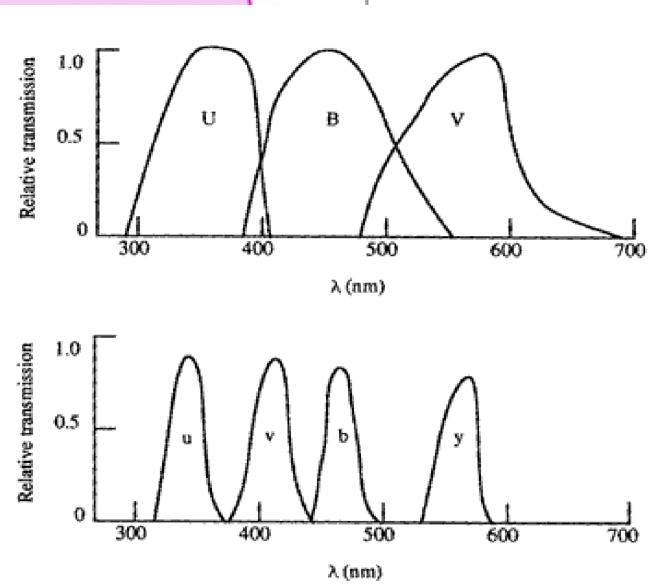
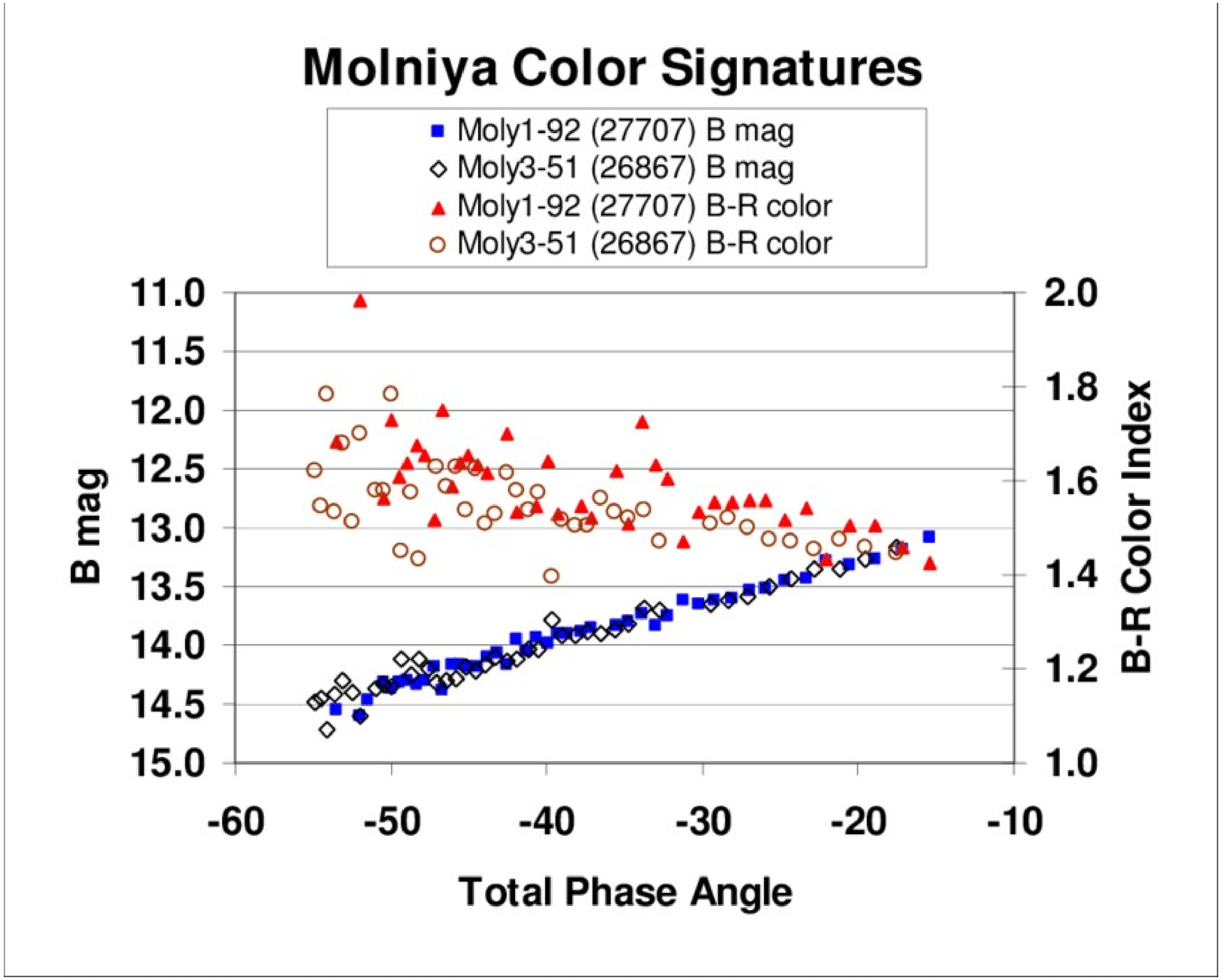


Fig. 10.7. The bandpasses for the broad band UBV system compared to those of the uvby intermediate band system.

Color indexes



Error contributors

- **Atmosphere**
  - Scintillation
  - Extinction
  - Color dependency
- **CCDs, variance, etc.**

Thanks for your attention!

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Track detection using convolutional neural network

Shemenev Alexander

Shevchenko Anton

MIPT
2018

Structure

- Problem statement
- Existing solutions
- Convolutional Neural Networks
- Validation

The problem and its relevance

- Processing frames from telescopes.
- Detection of NEO.
- Objects require a model.
- Search for objects with no model.

Existing methods

Hardware

- Tracking
- Time-delay integration

Software

- Removal of stars, corrupted pixels, etc.
- Hough or Radon transform
- Statistical algorithms with different models

Convolutional Neural Networks (CNN)

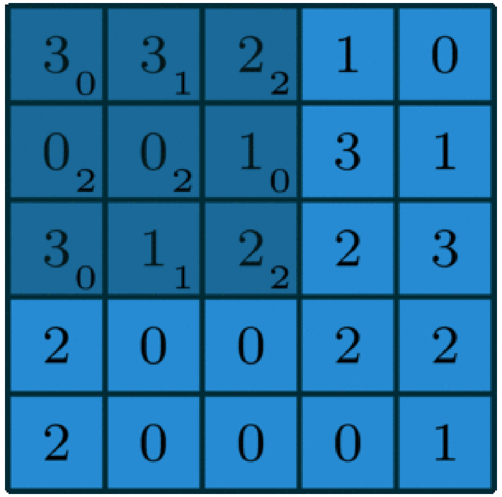
Advantages

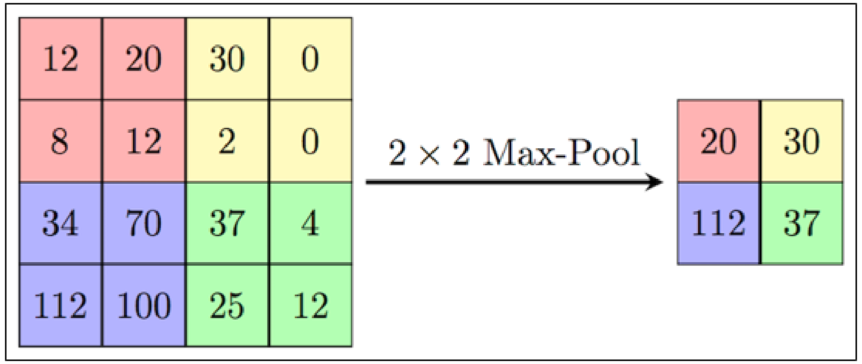
- No need in object’s model
- Resistance to noise in the input data
- Potentially fast performance
- Ability to process multidimensional data

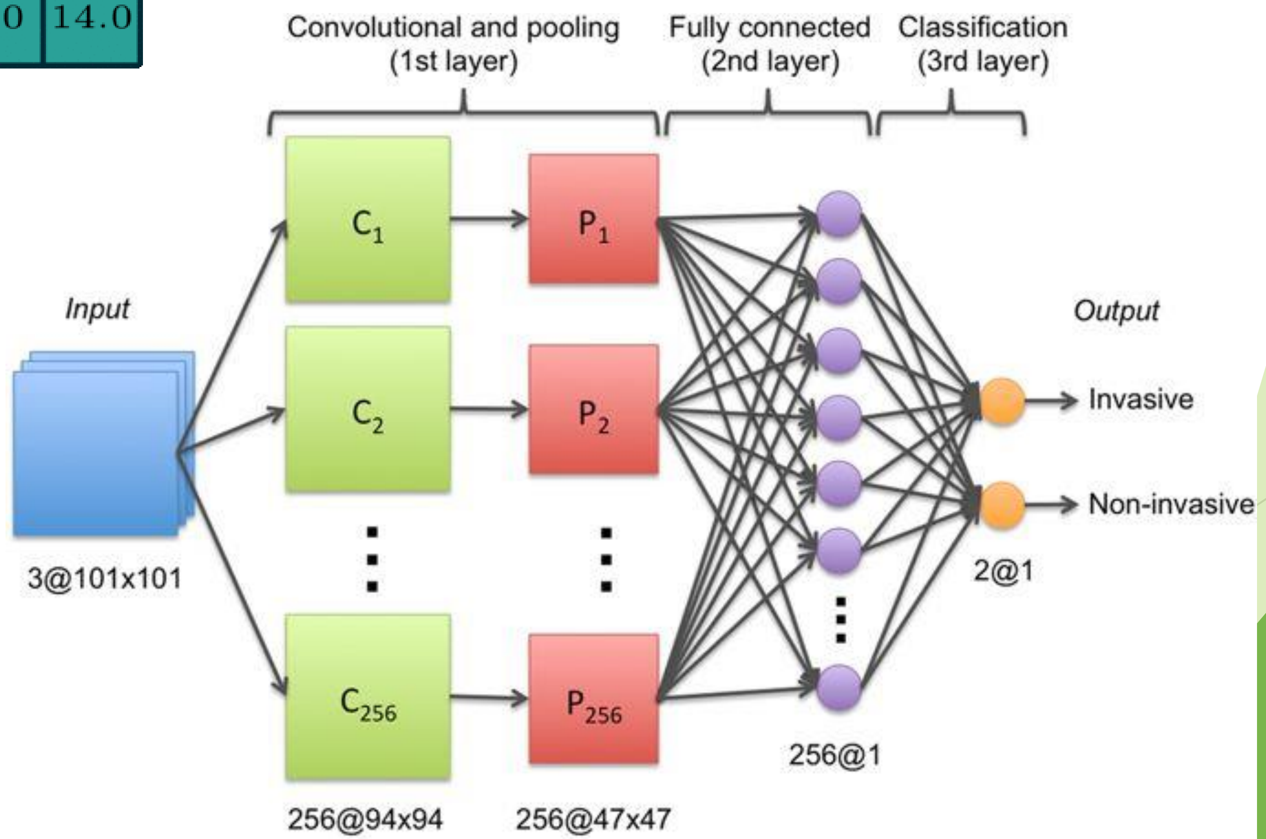
Disadvantages

- Uncertain results
- Requires a large set of data
- Huge learning time

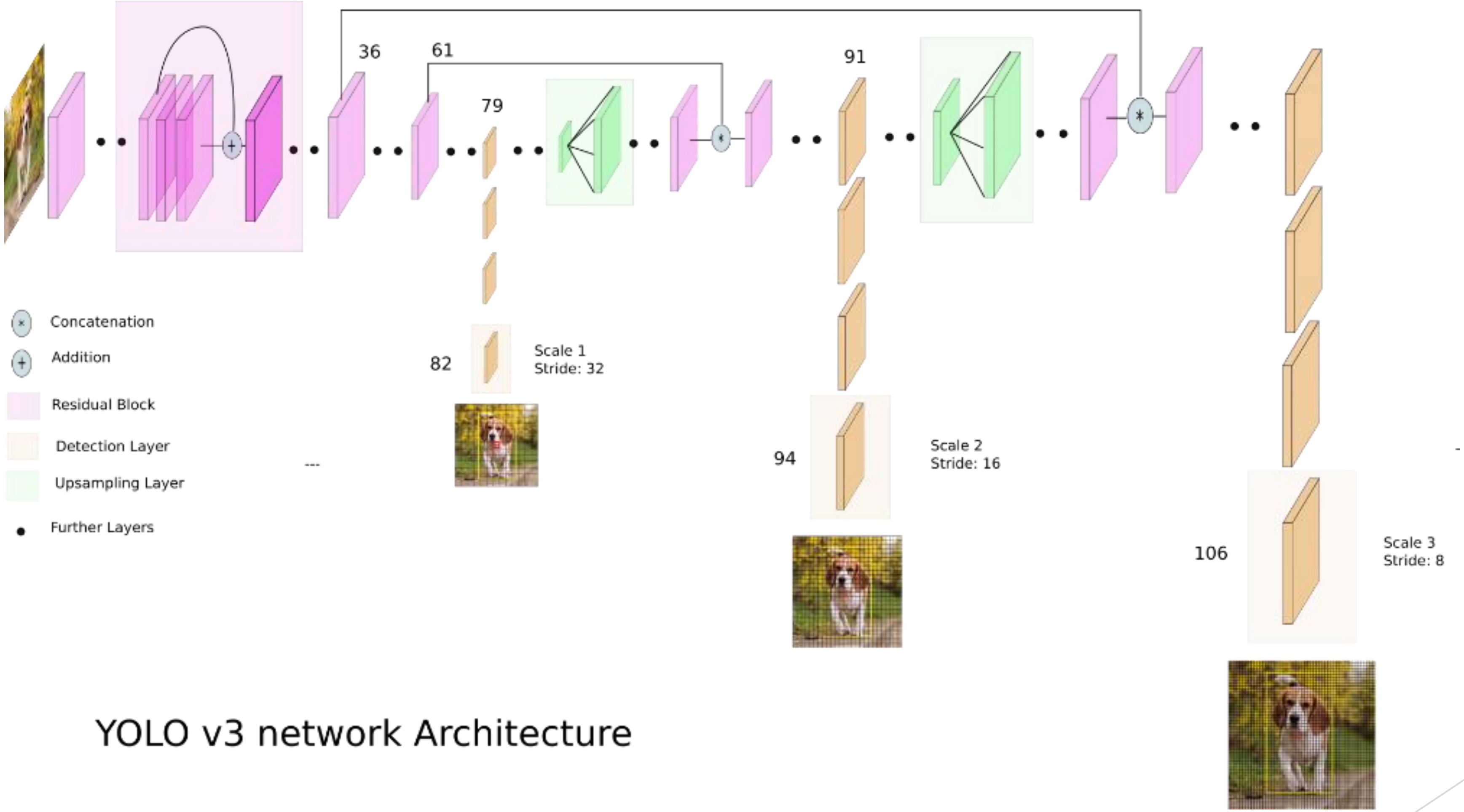
Convolutional neural network (CNN)





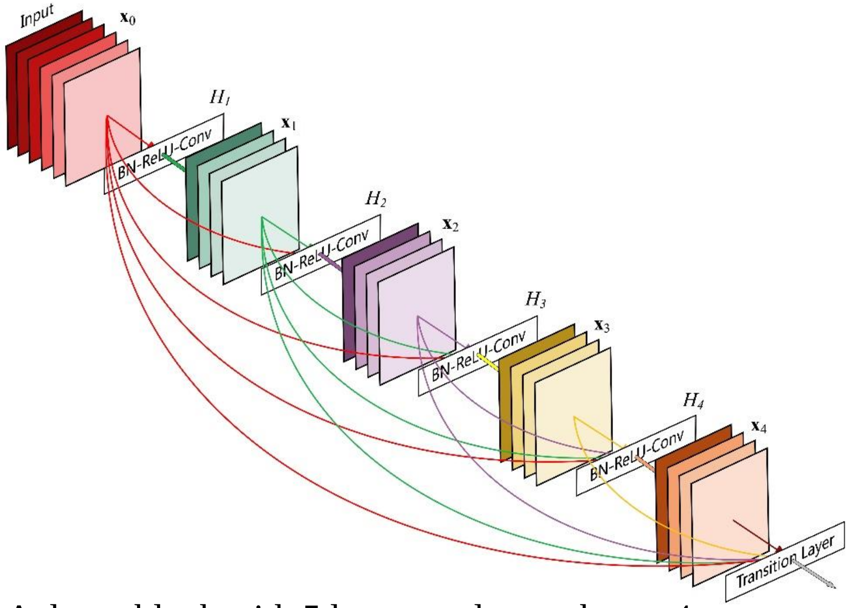


YOLOv3

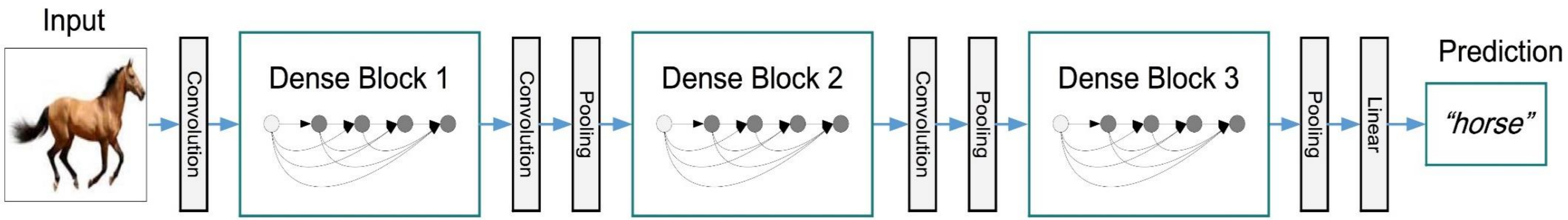


YOLO v3 network Architecture

DenseNet



A dense block with 5 layers and growth rate 4



A deep DenseNet with three dense blocks.

Toolkit

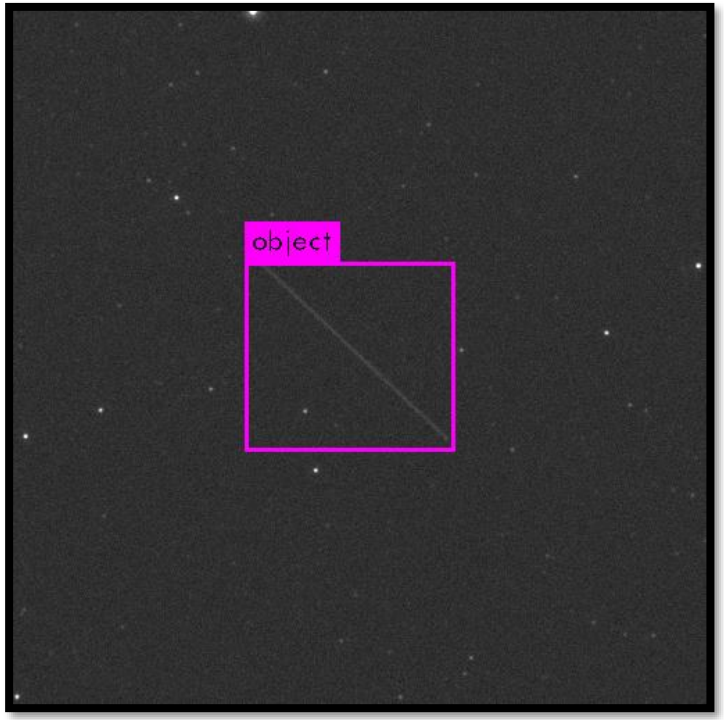
Hardware

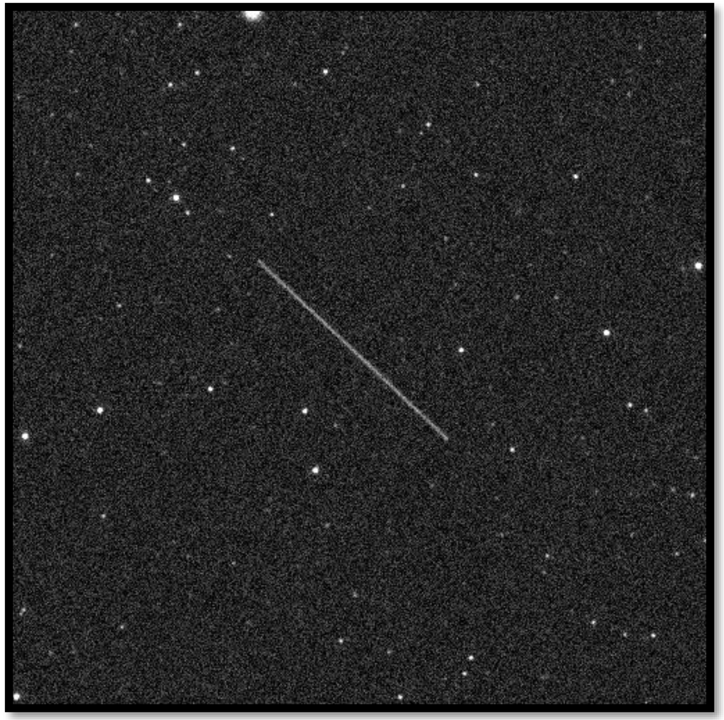
- Intel i7-8700 3,2GHz
- 16 GB RAM
- Nvidia GTX 1060 (6GB)/1080 Ti (11GB)

Software

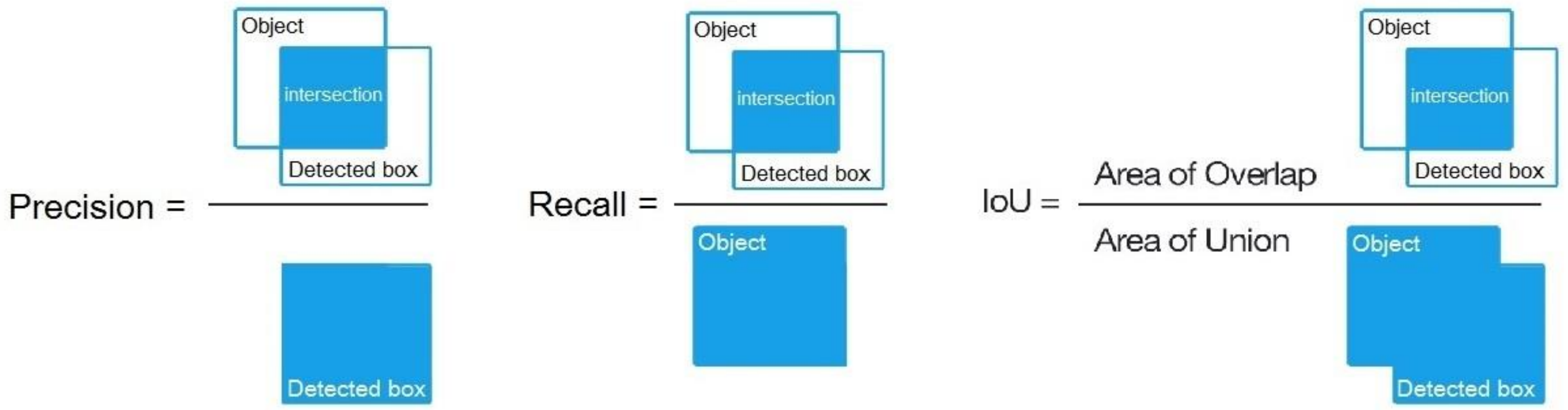
- CUDA 10
- CuDNN
- DarkNet

Detected tracks



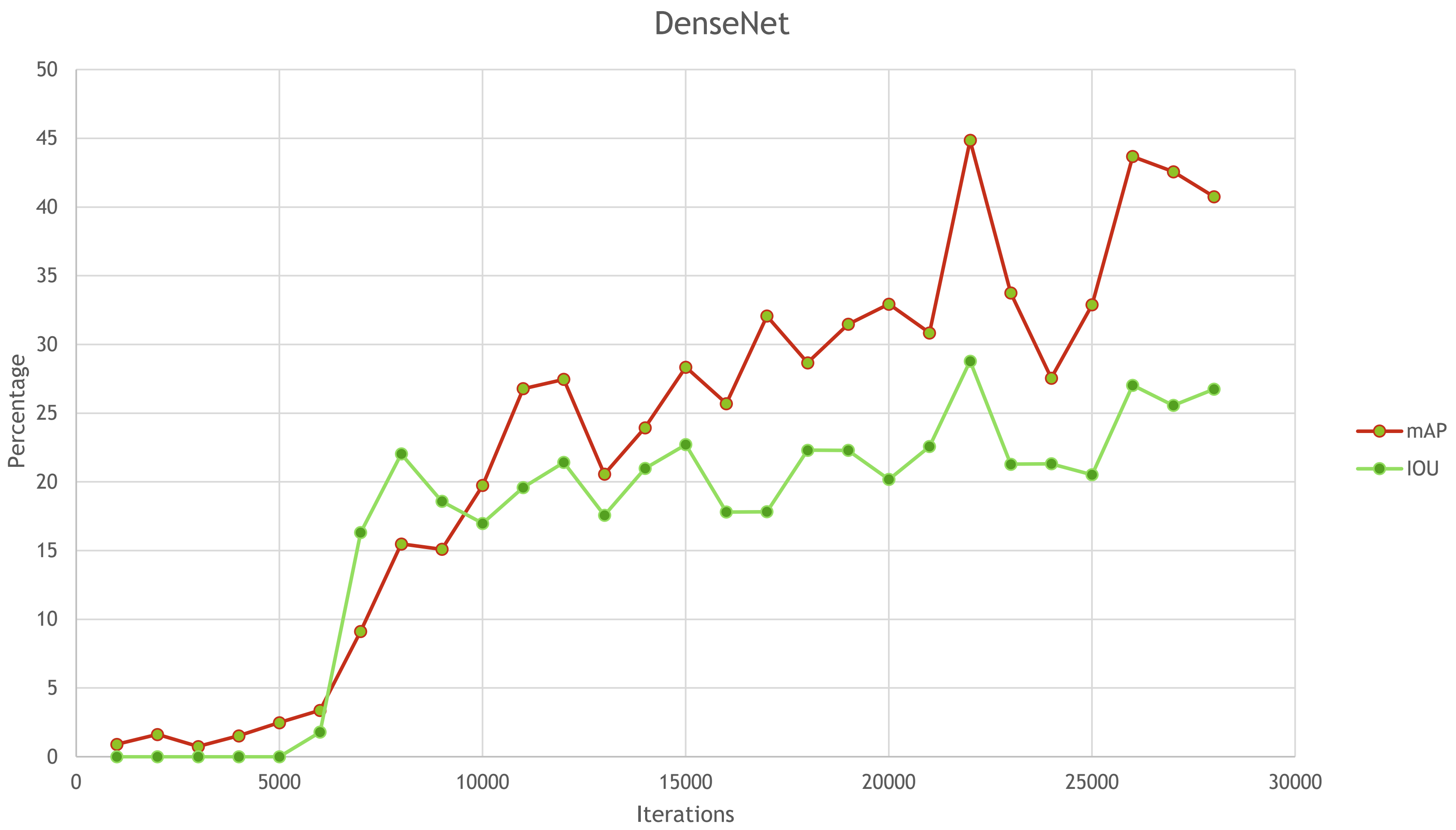


Validation



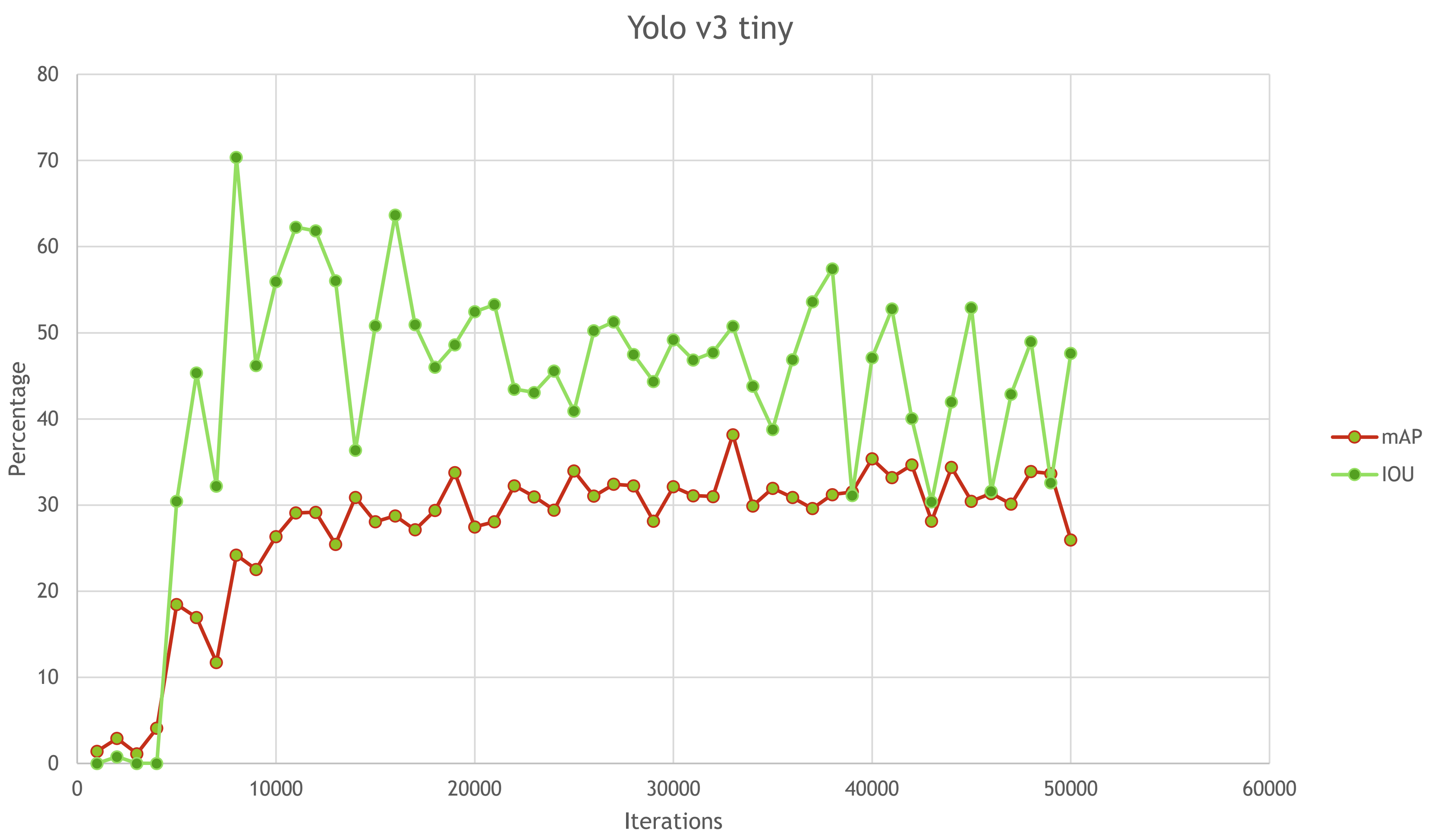
Object
intersection
Detected box
Precision =
Detected box
Object
intersection
Detected box
Recall =
Object
IoU =
Area of Overlap
Area of Union
Object
intersection
Detected box
Object
Detected box

Validation



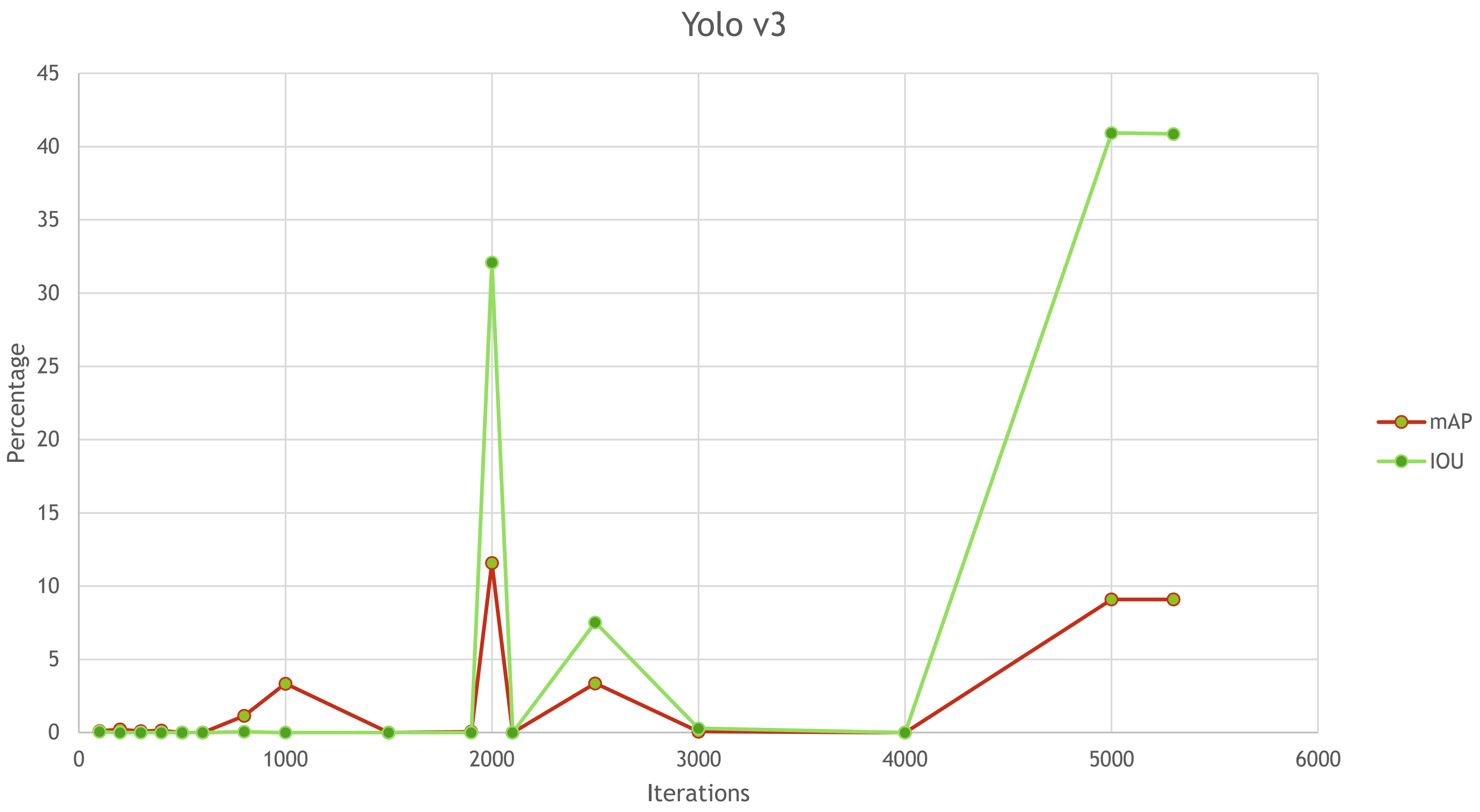
DenseNet
Percentage
Iterations
mAP
IOU
50
45
40
35
30
25
20
15
10
5
0
0
5000
10000
15000
20000
25000
30000

Validation



Yolo v3 tiny
80
70
60
50
40
30
20
10
0
Percentage
0
10000
20000
30000
40000
50000
60000
Iterations
mAP
IOU

Validation



Yolo v3
Percentage
45
40
35
30
25
20
15
10
5
0
0
1000
2000
3000
4000
5000
6000
Iterations
mAP
IOU

Conclusion

- Several CNN architectures have been tested
- New requirements for datasets have been estimated
- New insights on further progress have been achieved

Thank you for attention

САМАРСКИЙ УНИВЕРСИТЕТ
SAMARA UNIVERSITY

PROJECT OF SPACE-ROCKET SYSTEM INTENDED FOR DISPOSAL OF SPACE DEBRIS AT GEOSTATIONARY ORBIT

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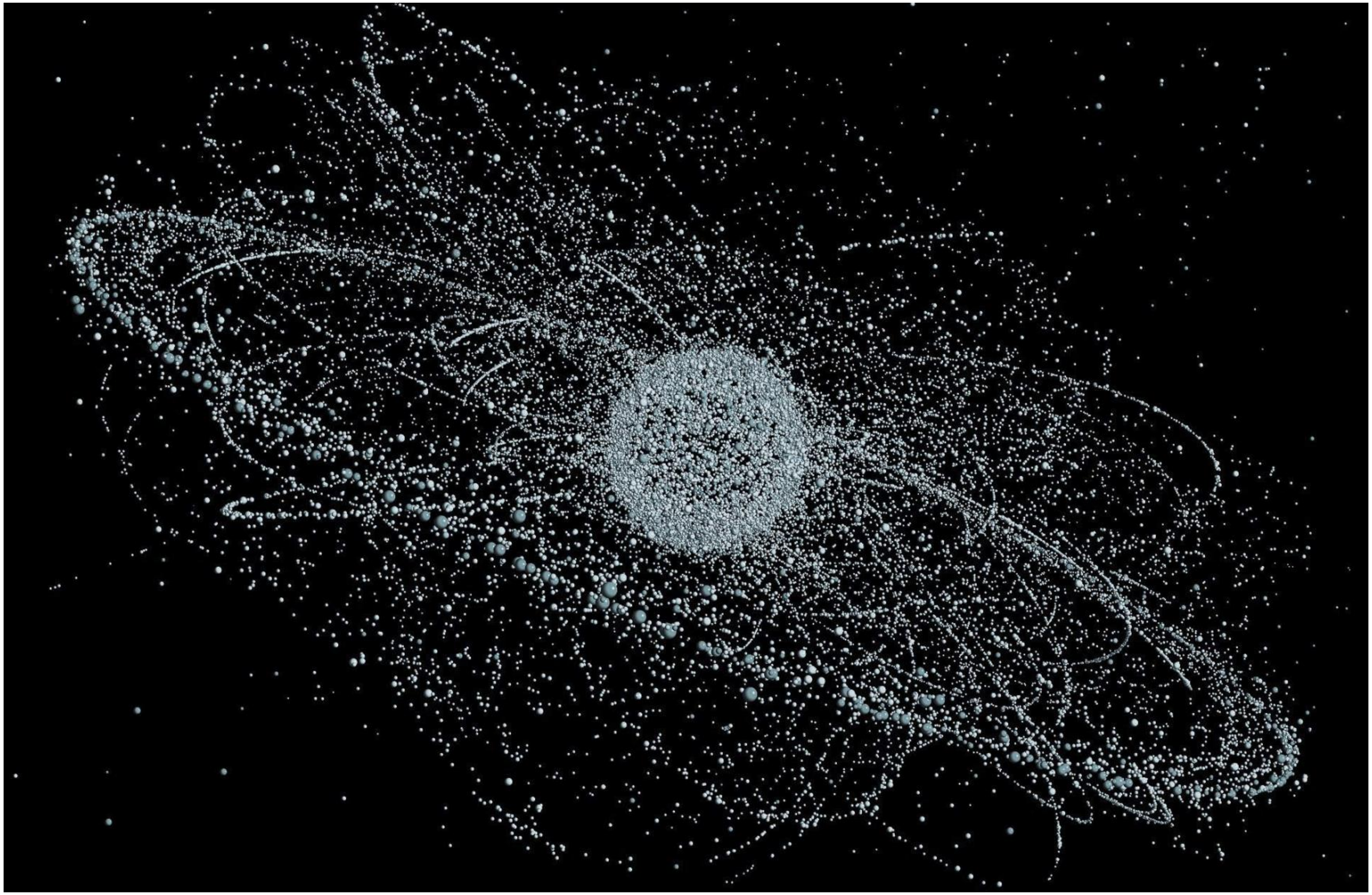
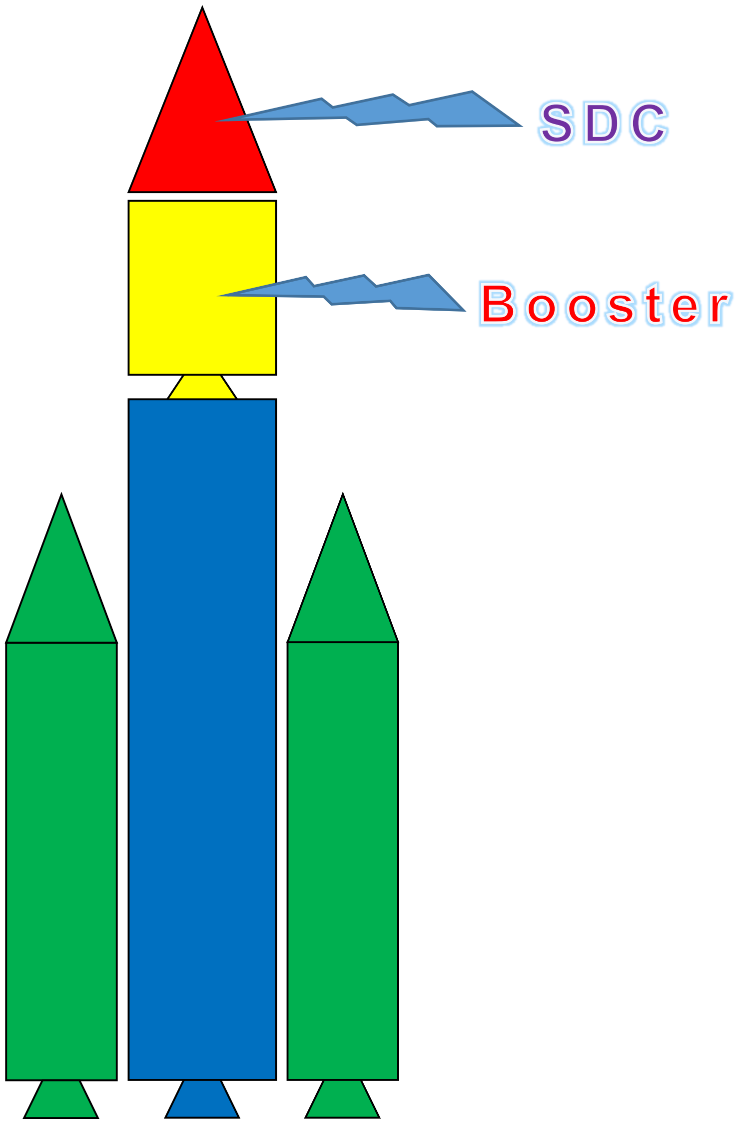
Pavel V. Fadeenkov, PhD, associate professor

Gregory A. Filippov, post-graduate student

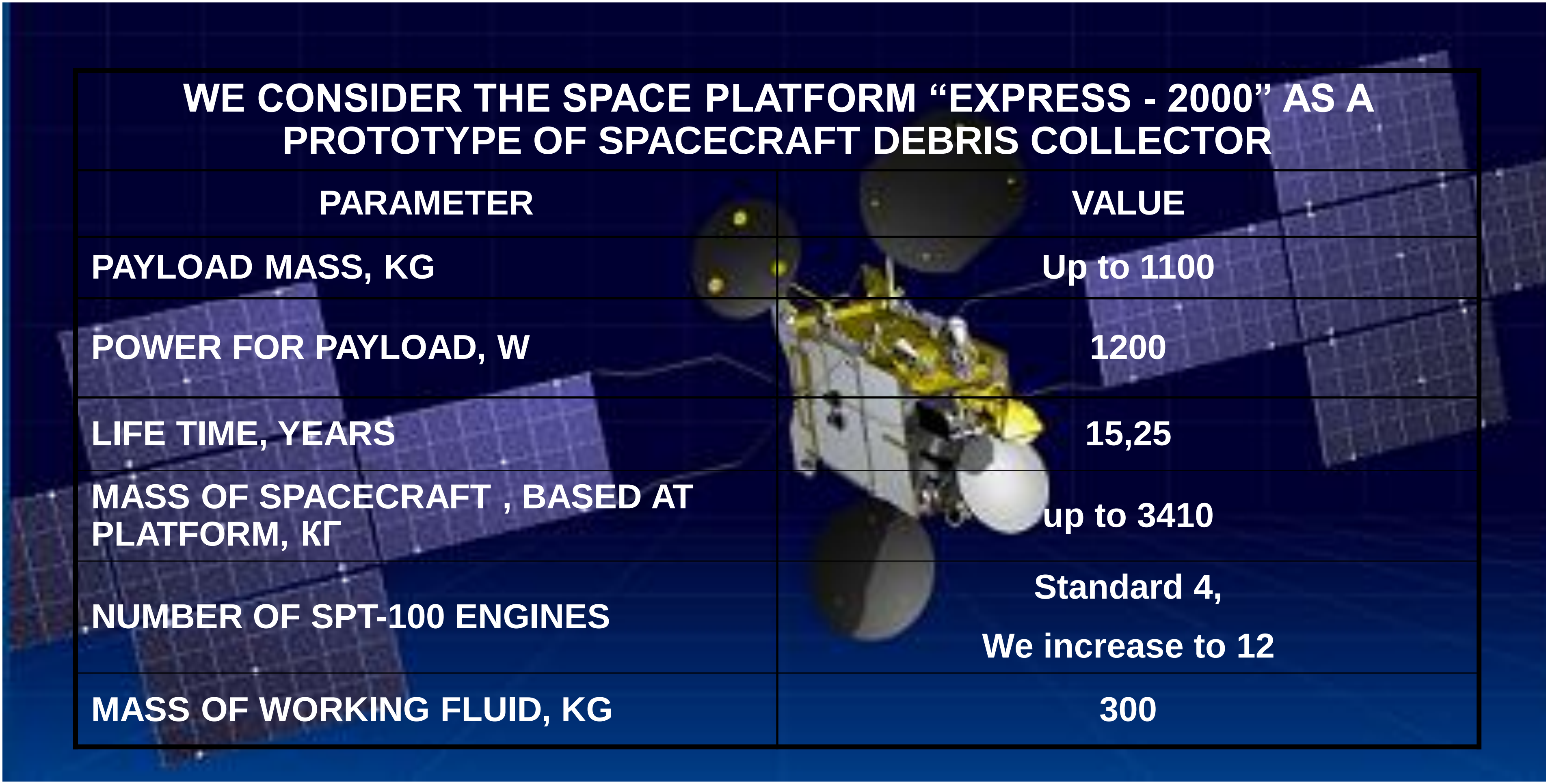
MIPT, Dolgopruny, December, 6-8th , 2018 y.

ABOUT SPACE DEBRIS





1. Rocket “Soyuz 2.1b” inject booster and SDC to reference orbit;
2. Booster transfer SDC to geostationary transfer orbit via impulse engines;
3. SDC, using its engines of low-thrust, move to area of first FSD at GSO;
4. SDC carry out series of operations with FSD – closing with it, fixed on-board, transferring to disposal orbit and return to GSO to next fragment of FSD.



WE CONSIDER THE SPACE PLATFORM “EXPRESS - 2000” AS A PROTOTYPE OF SPACECRAFT DEBRIS COLLECTOR	
PARAMETER	VALUE
PAYLOAD MASS, KG	Up to 1100
POWER FOR PAYLOAD, W	1200
LIFE TIME, YEARS	15,25
MASS OF SPACECRAFT , BASED AT PLATFORM, КГ	up to 3410
NUMBER OF SPT-100 ENGINES	Standard 4, We increase to 12
MASS OF WORKING FLUID, KG	300

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Characteristics of “Soyuz” missile	
Parameter	**Value**
Height of injection orbit, km	200
Inclination of injection orbit, deg	51,8
Payload mass, kg	8200
Characteristics of “Fregat” booster	
Dry mass, kg	940
Propellant mass, kg	5300
Thrust, kgf	2024
Specific impulse, s	331

1. Due to impulse chemical engine booster “Fregat” transfer SDC to geostationary transfer orbit with parameters:

A = 16500 км, e = 0,6, i = 51,8°

2. Next SDC move to GSO along optimal trajectory with next characteristics:

V_x = 4,58 km/s, m_{WF} = 850 kg, T = 160 days, m_{PL} = 500 kg

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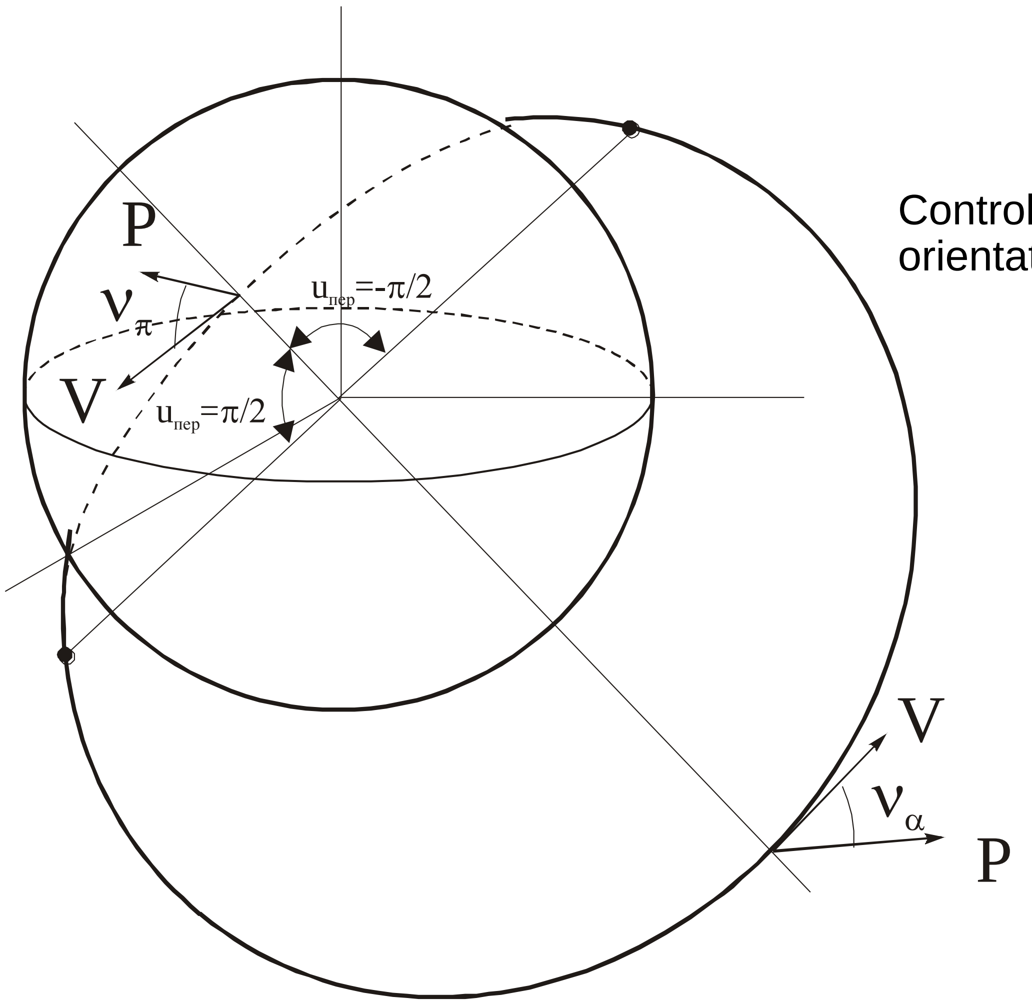

Control program for acceleration from thrust orientation

$$\nu = \begin{cases} \nu_{\pi}, & -\dfrac{\pi}{2} \le u \le \dfrac{\pi}{2}, \\ \nu_{\alpha}, & \dfrac{\pi}{2} \le u \le \dfrac{3\pi}{2}. \end{cases}$$

Averaged equations

$$\frac{dA}{dV_x} = \frac{1}{\pi}\cdot\sqrt{\frac{A^3}{\mu}}\cdot\sqrt{1-e^2}\cdot\left(2\cdot\arccos(e)\cdot(\cos\nu_1-\cos\nu_2)+2\cdot\pi\cdot\cos\nu_2\right),$$

$$\frac{de}{dV_x} = \frac{1}{2\pi}\cdot\sqrt{\frac{A}{\mu}}\cdot\sqrt{1-e^2}\cdot\left(\begin{aligned}&[\cos\nu_1-\cos\nu_2]\cdot\left[4\sqrt{1-e^2}-e\cdot\left(e\cdot\sqrt{1-e^2}+3\cdot\arccos(e)\right)\right]-\\&+3\cdot\pi\cdot e\cdot\cos\nu_2\end{aligned}\right),$$

$$\frac{di}{dV_x} = \frac{-1}{2\pi}\cdot\sqrt{\frac{A}{\mu\cdot(1-e^2)}}\cdot\left(\begin{aligned}&[\sin\nu_1+\sin\nu_2]\cdot\left[(2+e^2)\sqrt{1-e^2}-3\cdot e\cdot\arccos(e)\right]+\\&+3\cdot\pi\cdot e\cdot\sin\nu_2\end{aligned}\right).$$

Hamiltonian function:

$$H = H_1\cdot\cos(\nu_\pi)+H_2\cdot\cos(\nu_\alpha)+H_3\cdot\sin(\nu_\pi)+H_4\cdot\sin(\nu_\alpha)-1=0$$

Optimal control program

$$\tan(\nu_1)=\frac{H_3}{H_1},\quad \tan(\nu_2)=\frac{H_4}{H_2}$$

$$\psi_i = \frac{1}{\dfrac{H_3(A_0, e_0)}{\sin(\nu_{\pi_0})} + \dfrac{H_4(A_0, e_0)}{\sin(\nu_{\alpha_0})}} = \mathrm{const}.$$

ψ_{A0} and ψ_{e0} determine from system of equation

$$\begin{cases} k_1(A_0, e_0)\cdot\psi_{A_0} + k_2(A_0, e_0)\cdot\psi_{e_0} = H_3(A_0, e_0)\cdot\cot(\nu_{\pi_0}) \\ k_3(A_0, e_0)\cdot\psi_{A_0} + k_4(A_0, e_0)\cdot\psi_{e_0} = H_4(A_0, e_0)\cdot\cot(\nu_{\alpha_0}) \end{cases}$$

Obtain:

$\nu_{\pi 0} = 69{,}2°$

$\nu_{\alpha 0} = 5{,}6°$

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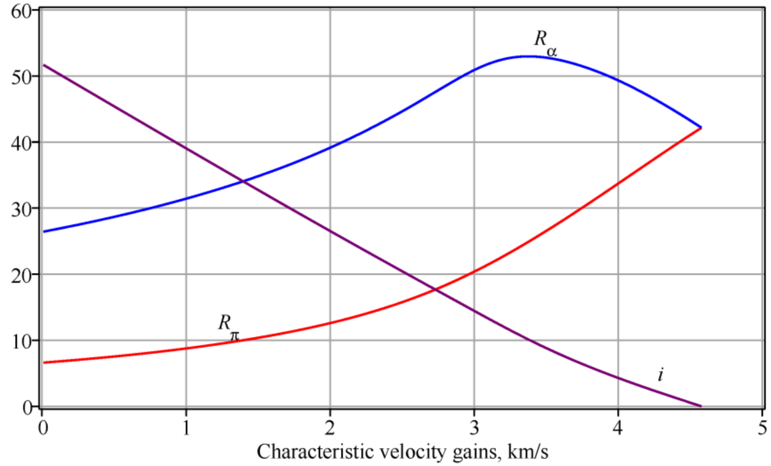
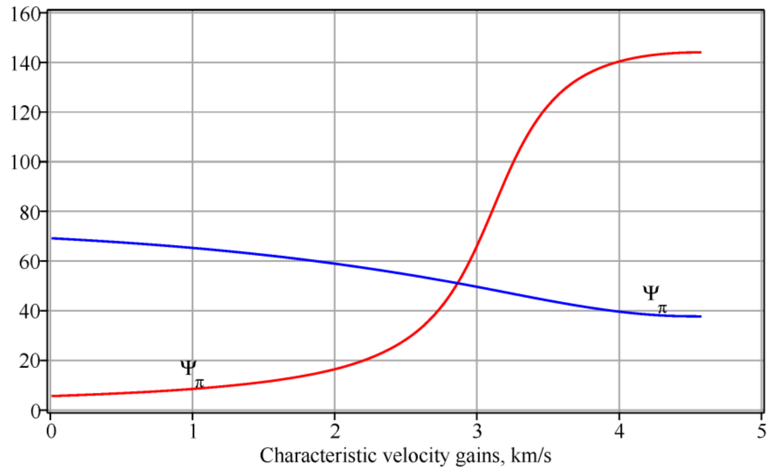
TRANSFER OF SDC TO GSO WITH LOW-THRUST TRAJECTORIES OF MOTION



Time history of orbit perigee R_π, apogee R_α and inclination i.

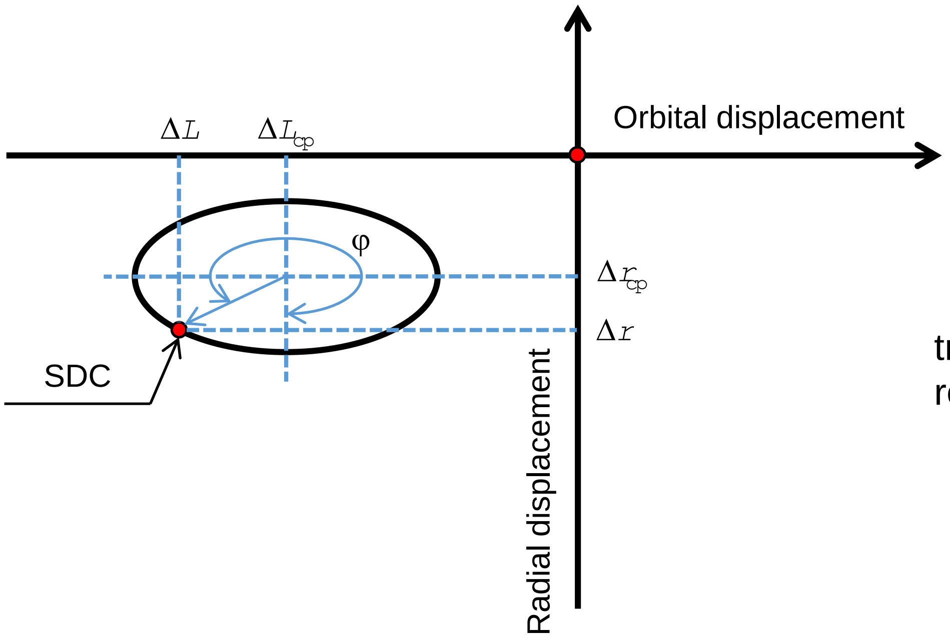
As time we consider gains of characteristic velocity



Time history of control program – thrust angle in perigee Ψ_π and apogee Ψ_α.

As time we consider gains of characteristic velocity

MATH MODEL



$$\Delta \dot{r}_{av} = \frac{2}{\lambda} \cdot a_T,$$

$$\Delta \dot{L}_{av} = -1{,}5 \cdot \lambda \cdot \Delta r_{av} - \frac{2}{\lambda} \cdot a_S,$$

$$\dot{l} = \frac{1}{\lambda} \cdot \left(a_S \cdot \sin\varphi + 2 \cdot a_T \cdot \cos\varphi\right),$$

$$\dot{\varphi} = \lambda + \frac{1}{\lambda \cdot l} \cdot \left(a_S \cdot \cos\varphi - 2 \cdot a_T \cdot \sin\varphi\right).$$

Motion control of SDC is carrying out via transversal acceleration of thrust component reversing:

$$a_S = 0,$$

$$a_T = \begin{cases} a, & 0 < t < t_1, \\ 0, & t_1 < t < t_\pi, \\ -a, & t_\pi < t < t_2. \end{cases}$$

Boundary conditions

$$t = 0: \quad \Delta r_{av} = \Delta r_{av_0}, \quad \Delta L_{av} = \Delta L_{av_0}, \quad l = l_0;$$

$$t = t_f: \quad \Delta r_{av} = \Delta r_{av_f}, \quad \Delta L_{av} = \Delta L_{av_f}, \quad l = l_f.$$

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MOTION OF SDC AT GSO BETWEEN FRAGMENTS OF SPACE DEBRIS CONTROL PROGRAM

$$\Delta r_{ср}(\theta) = \Delta r_{ср_0} + K \cdot C,$$

$$\Delta L_{ср}(\theta) = \Delta L_{ср_0} - \frac{3}{2} \cdot \Delta r_{ср_0} \cdot \theta - \frac{3}{2} \cdot K \cdot D,$$

$$r^2(\theta) = r_0^2 + 2 \cdot K \cdot \delta \cdot r_0 \cdot \sqrt{A^2 + B^2} \cdot \sin(\theta + \varphi_0 + \xi) + K^2 \cdot \left(A^2 + B^2\right),$$

$$K = 2 \cdot \frac{a}{\lambda^2}, \xi = \arctan\frac{B}{A}, \theta = \lambda \cdot (t_1 + t_п + t_2)$$

	Control program with reversed signum of acceleration from thrust at active areas	Control program with constant signum of acceleration from thrust at active areas
A	$\cos(\theta-\theta_1)-\cos\theta+\cos\theta_2-1$	$\cos(\theta-\theta_1)-\cos\theta-\cos\theta_2+1$
B	$-\sin(\theta-\theta_1)+\sin\theta-\sin\theta_2$	$-\sin(\theta-\theta_1)+\sin\theta+\sin\theta_2$
C	$\theta_1-\theta_2$	$\theta_1+\theta_2$
D	$\frac{\theta_1^2-\theta_2^2}{2}+\theta_1\cdot(\theta_2+\theta_п)$	$\frac{\theta_1^2+\theta_2^2}{2}+\theta_1\cdot(\theta_2+\theta_п)$

Control program with reversed signum of acceleration from thrust at active areas:

$$t_1 = \frac{-12\cdot a\cdot\delta\cdot\lambda\cdot\Delta r_{ср_0}\cdot t_\pi + 3\cdot\lambda^2\cdot\mathbf{R} + 8\cdot a\cdot\delta\cdot\mathbf{L}}{24\cdot a^2\cdot t_\pi},$$

$$t_2 = \frac{-12\cdot a\cdot\delta\cdot\lambda\cdot\Delta r_{ср_к}\cdot t_\pi + 3\cdot\lambda^2\cdot\mathbf{R} + 8\cdot a\cdot\delta\cdot\mathbf{L}}{24\cdot a^2\cdot t_\pi}$$

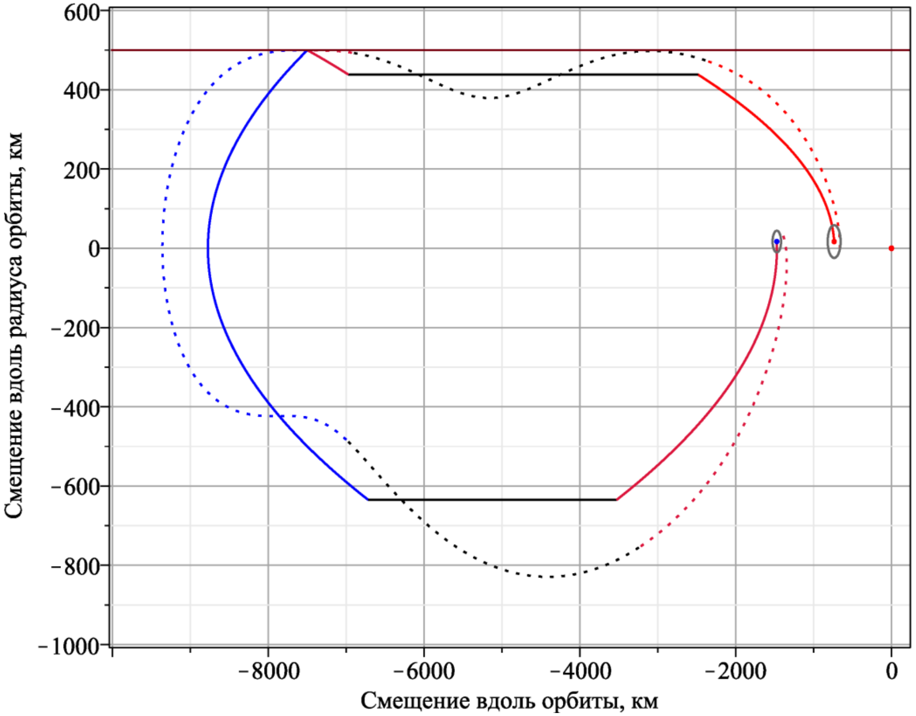
Control program with constant signum of acceleration from thrust at active areas:

$$t_1 = \frac{\frac{\delta}{6}\cdot\sqrt{36\cdot a^2\cdot t_\pi^2 + 18\cdot\lambda^2\cdot\mathbf{R} + 48\cdot a\cdot\delta\cdot\mathbf{L}} - \Delta r_{ср_0}\cdot\lambda - a\cdot\delta\cdot t_\pi}{2\cdot a\cdot\delta},$$

$$t_2 = \frac{\frac{\delta}{6}\cdot\sqrt{36\cdot a^2\cdot t_\pi^2 + 18\cdot\lambda^2\cdot\mathbf{R} + 48\cdot a\cdot\delta\cdot\mathbf{L}} - \Delta r_{ср_к}\cdot\lambda - a\cdot\delta\cdot t_\pi}{2\cdot a\cdot\delta}.$$

where $\mathbf{R} = \Delta r_{av_0}^2 + \Delta r_{av_f}^2, \mathbf{L} = \Delta L_{av_0} - \Delta L_{av_f}$

MOTION OF SDC AT GSO BETWEEN FRAGMENTS OF SPACE DEBRIS TRAJECTORIES



After transferring SDC to GSO, it carries out series operations of FSD disposal. One operation contains two stages. At first stage SDC closing with FSD, fixed it on-board and transfer it to disposal orbit. At second stage SDC return to GSO to next fragment of FSD.

We solve "model" problem:

1. FSD stay at GSO, distance between them is constant and equal to one degree or 736 km;
2. Disposal orbit is circular and upper GSO to 500 km.

Boundary conditions of transfers:

Transfer to disposal orbit

$t=0:\ \Delta r_{av}=0$ км, $\Delta L_{av}=-736$ км, $l=40$ км;

$t=t_f:\ \Delta r_{av}=500$ км, $\Delta L_{av}=-7500$ км, $l=1$ км.

Rendezvous with next FSD

$t=0:\ \Delta r_{av}=500$ км, $\Delta L_{av}=-7500$ км, $l=1$ км;

$t=t^{К}:\ \Delta r_{av}=0$ км, $\Delta L_{av}=-1472$ км, $l=1$ км.

$V_x = 82{,}75$ m/s, $m_t = 15$ kg, $T = 10$ days

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$$n = \frac{M_0 - M_{\text{РТ}_1} - M_{\text{к}} + \frac{V_{x_2}}{C} \cdot \left(M_0 - M_{\text{РТ}_1}\right)}{\frac{V_{x_1}}{C} \cdot \left(M_0 - M_{\text{РТ}_1} + M_{\text{ФКМ}}\right) + \frac{V_{x_2}}{C} \cdot \left(M_0 - M_{\text{РТ}_1}\right)} = 18\ \text{FSD}.$$

$$T = T_1 + \left(t_{M_1} + t_{n_1}\right) \cdot n + \left(t_{M_2} + t_{n_2}\right) \cdot (n-1) = 2\ \text{years}.$$

САМАРСКИЙ УНИВЕРСИТЕТ
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THANK YOU FOR ATTENSION

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Analysis of the ISON network contribution to the solution of near-Earth space monitoring tasks

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Keldysh Institute of Applied Mathematics, RAS

Small innovation enterprise «KIAM Ballistics-Service» Ltd.

im62@mail.ru, www.astronomer.ru

I[ST] INTERNATIONAL AEROSPACE SYMPOSIUM
THE SILK ROAD

International Scientific Optical Network (ISON)

- ISON have been started in 2004 and have been maintained under contracts with Roscosmos (based on RAS-Roscosmos agreement)
- Keldysh Institute of Applied Mathematics (KIAM), RAS supervises the ISON project, maintain database of space objects, develops the space debris population model, and provides conjunction analysis for Russian satellites at high orbits
- ISON is involved in informal association from 43 observatories of various affiliation with 100 telescopes in 18 countries that are sent their measurements to the KIAM database
- ISON consists of 53 telescopes, produces 28% of measurements in KIAM database.
- Roscosmos has own network of optical facilities now and plan to stop an interaction with ISON since 2019, therefore search of new consumers is topical

ISON/KIAM structure for space debris research

- **4 telescope subsets:**

- global GEO survey (down to 15.5^m) with 4 additional telescopes for extended GEO survey (down to 14^m)
- tracking the faint (fainter than 15.5^m) space debris at GEO and GTO
- tracking the bright GEO, GTO and HEO objects
- for observation of asteroids (survey and phjtometry)

- **Group for engineering&software support**
- **Two centers of observation planning and data processing** (RAS for scientific researches and SIE "BS" for customers including private and foreign)
- **Conjunction analysis centre** of ASPOS OKP system
- **Space debris population model** at high orbits.

Global GEO survey subset: 12 telescopes of 20 – 50 cm with FOV of 3.3-5.5 degrees

Ussuriysk ORI-22, Urumqi ORI-25, Kitab ORI-22, Abastumani ORI-22, Chuguev ORI-25, Andrushivka ORI-22, Castelgrande ORI-22, Zimmerwald ASA-20, Barcelona TFRM, Tarija ORI-25, Monterrey ORI-25, Cosala ORI-25

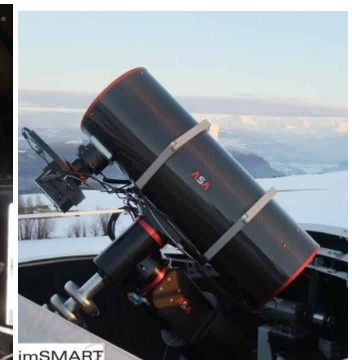








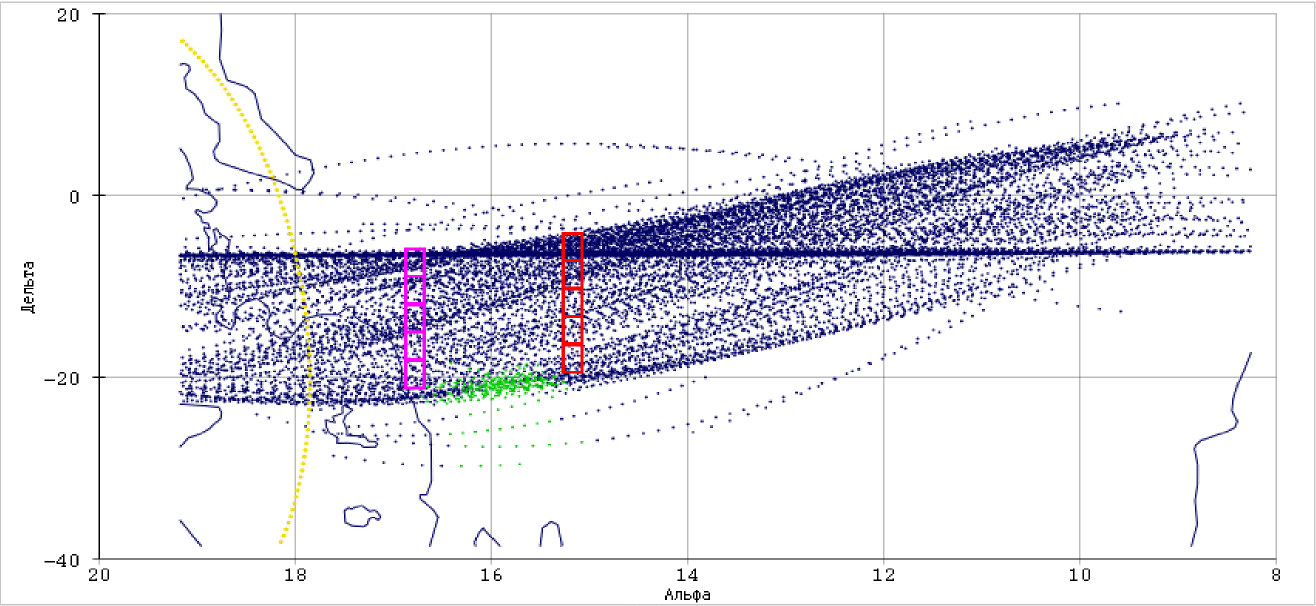




Extended GEO surveys – 4 of 19.2 cm telescopes with FOV 7 degrees

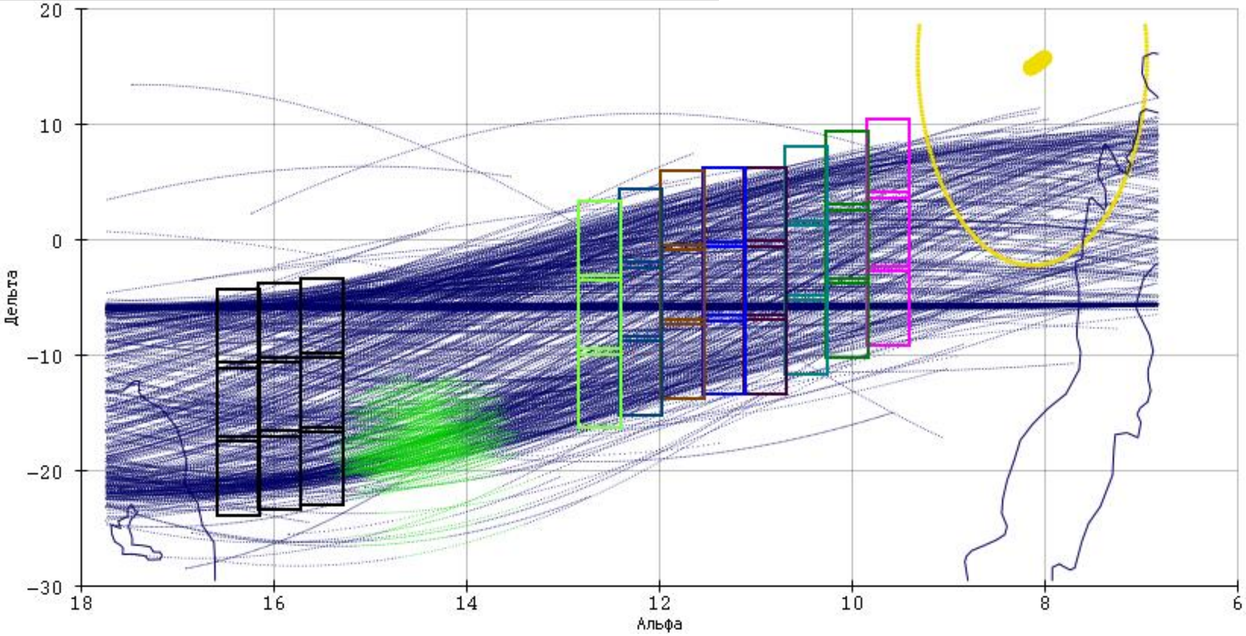
Ussuriysk VT-78a (Far East), Khureltogoot VT-78a (Mongolia), Multa VT-78a (Altay region), Tiraspol VT-78a (Moldova)

Comparison of plans for standard and extended GEO surveys



Barriers selects before and after Earth shadow position providing long measuring arc

Distribution of the catalogued GEO objects in right ascension – declination plane



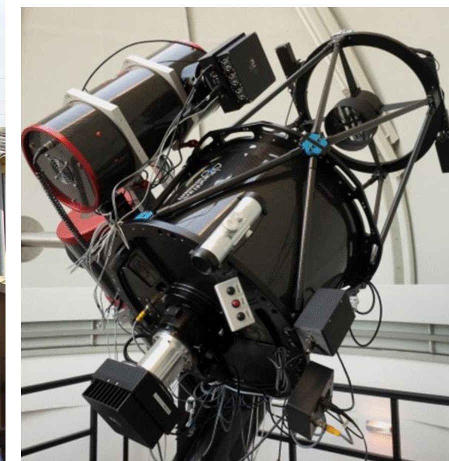
Global GEO survey subsystem:

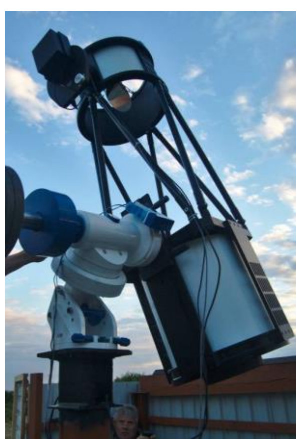
- Each telescope for standard survey is twice surveying visible part of GEO in 18 degree width and provides per night a few thousands measurements for a few hundreds objects of 15.5 m and average lengths of measuring arcs up to 30 minutes
- Each telescope for extended survey is multiple surveying visible part of GEO and provides up to 15 thousands measurements for 500 - 700 objects of 14 m and average lengths of measuring arcs up to a few hours
- These surveys produce measurements for all bright GEO-objects along GEO in the whole and allow to the KIAM to maintain database on bright objects and to quickly detect the objects of new GEO launches
- Additionally extended surveys allow KIAM to determine more precise GEO orbits for conjunction analysis, to detect maneuvers of active satellites and to help maintain the orbits of GEO objects in clusters

Telescope subset for tracking the faint (fainter than 15.5^{m}) space debris

80-cm K-800 Terskol, 64-cm AT-64 Nauchny, 50-cm ORI-50 Andrushivka, 50-cm RC-500 Zimmerwald, 40-cm CHV-400 Cosala, 40-cm CHV-400 Uzghorod, 40-cm ORI-40 Khureltogoot, 40-cm New Mexico, 36-cm Kitab



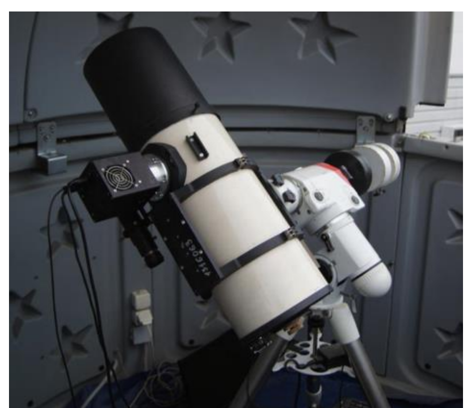



Telescope subset for tracking the bright (brighter than 15.5^m) space debris

25-cm GAS-250 Ussuriysk, 25-cm BRC-250 Uzghorod, 25-cm ORI-25 Tiraspol, 18-cm GAM-180 Krasnodar, 25-cm TAL-250K in Tarija

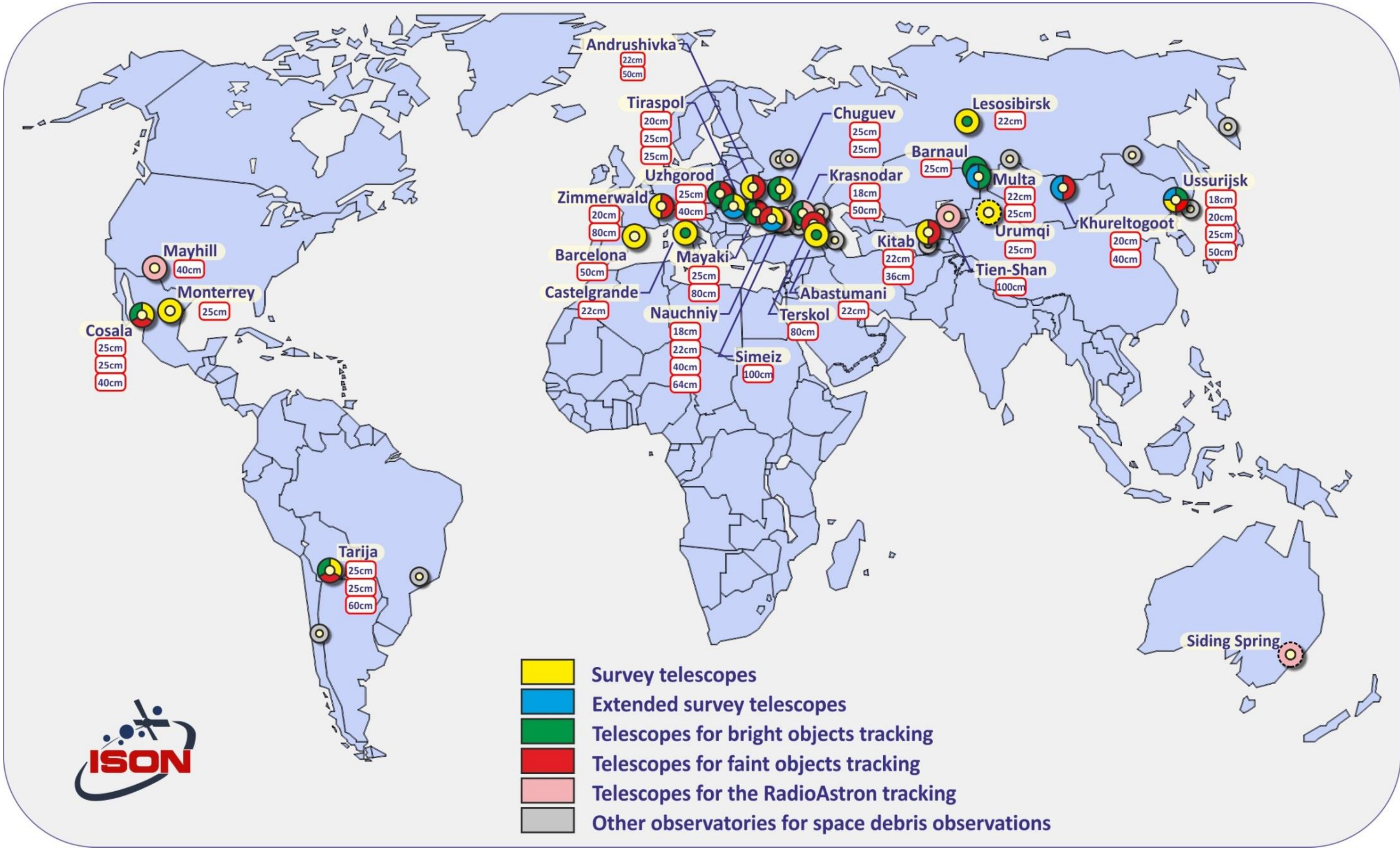




Map of ISON telescopes&observatories

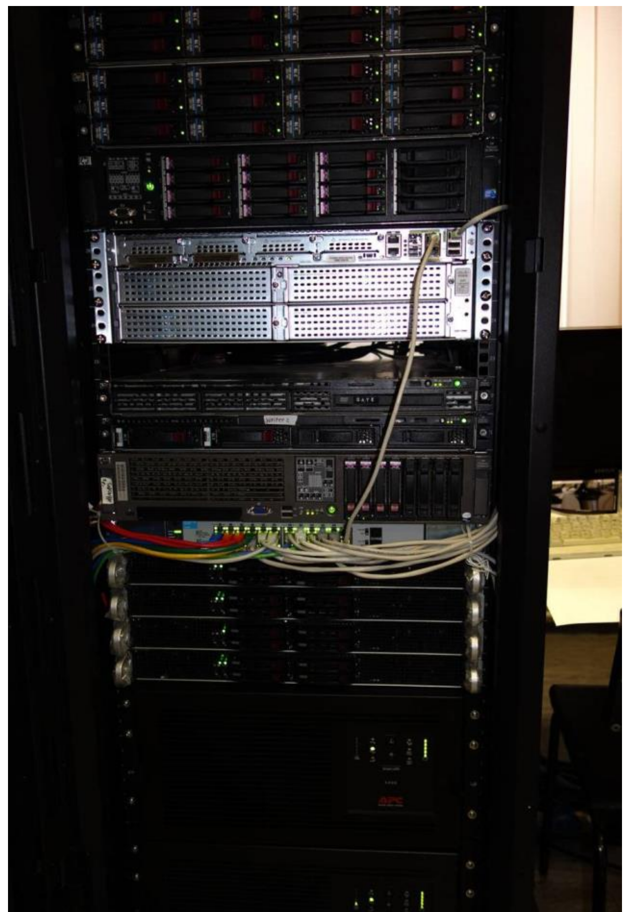
including close plans



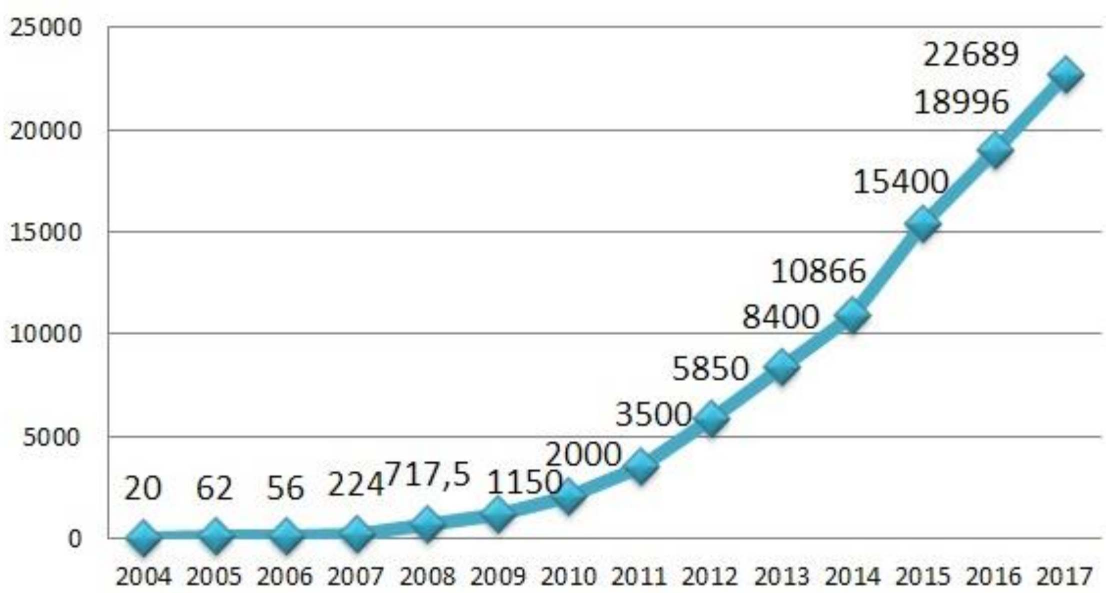
Hardware of conjunction analysis segment (Roscosmos) and KIAM database

6 servers of 48 cores ~ 10 TFLOPS

2438 GEO-objects, 2925 HEO-objects 361 MEO-objects on 01.01.2018



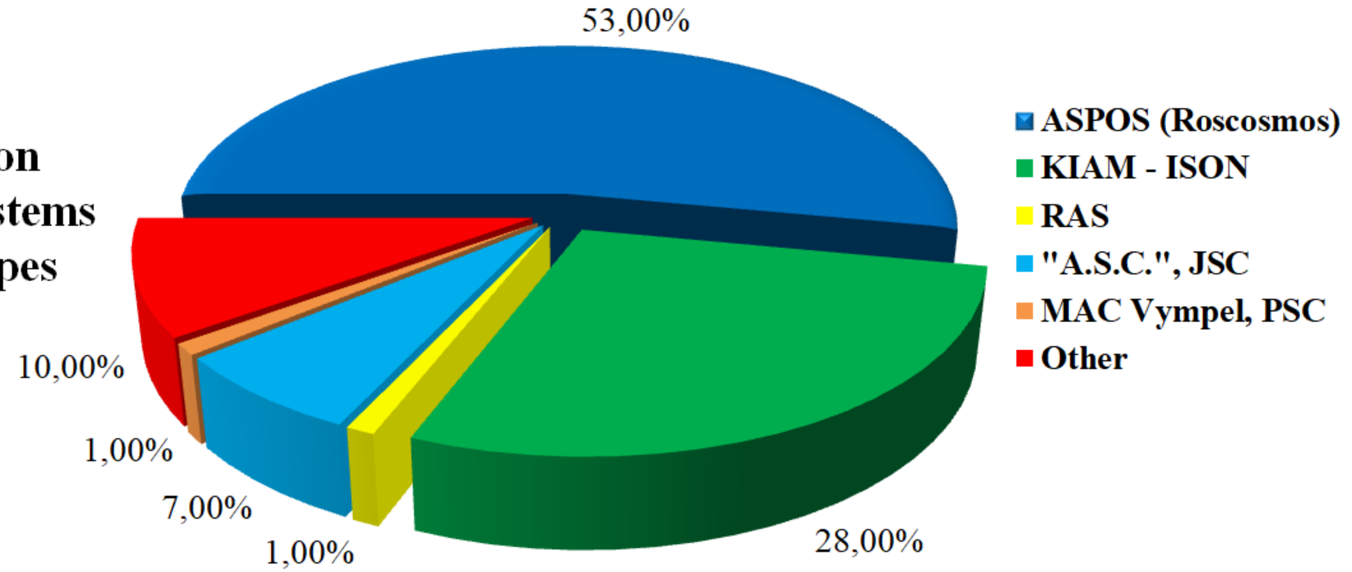
Measurements statistics of different observing collaborators that send the data to KIAM



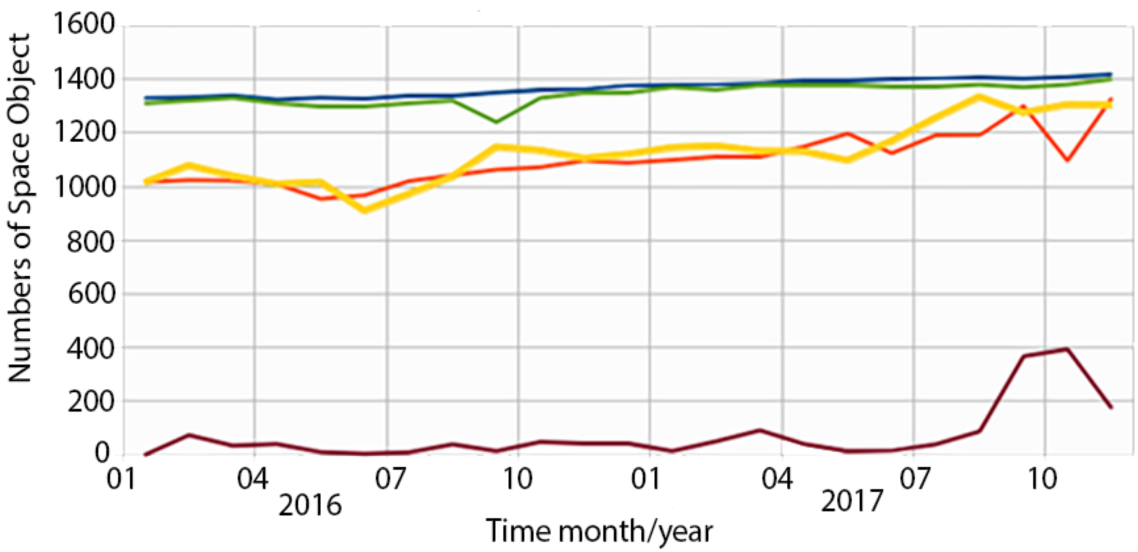
ISON portion is 6,353 millions measurements in 2017

Number of measurements 2003-2017, thousands

Gross contribution of various subsystems of optical telescopes in 2017

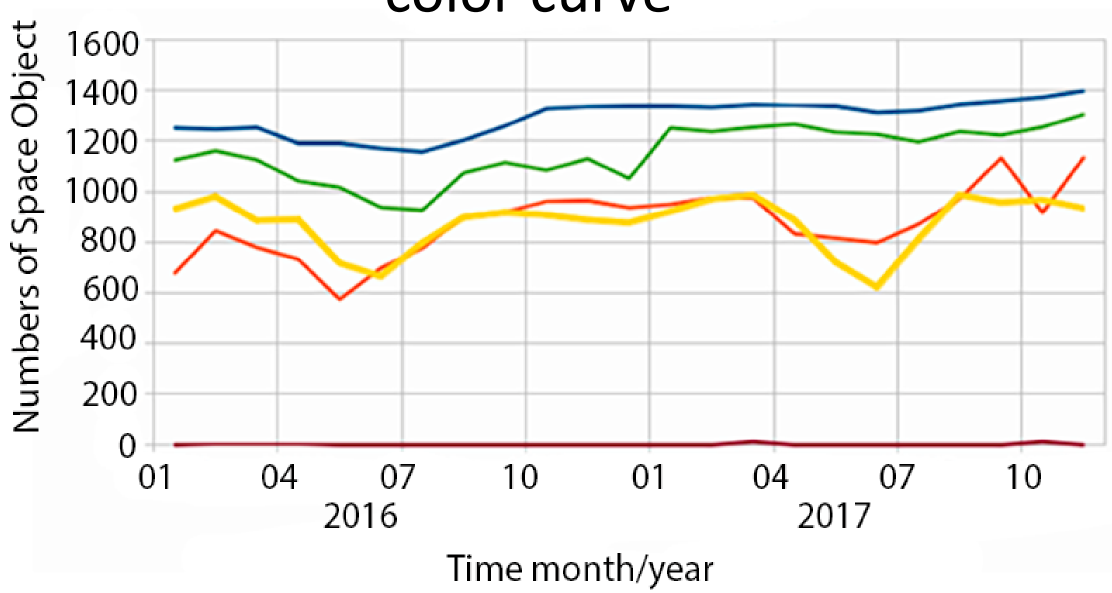


Catalogue in part of bright GEO-objects has precise orbits for CA due to ISON contribution

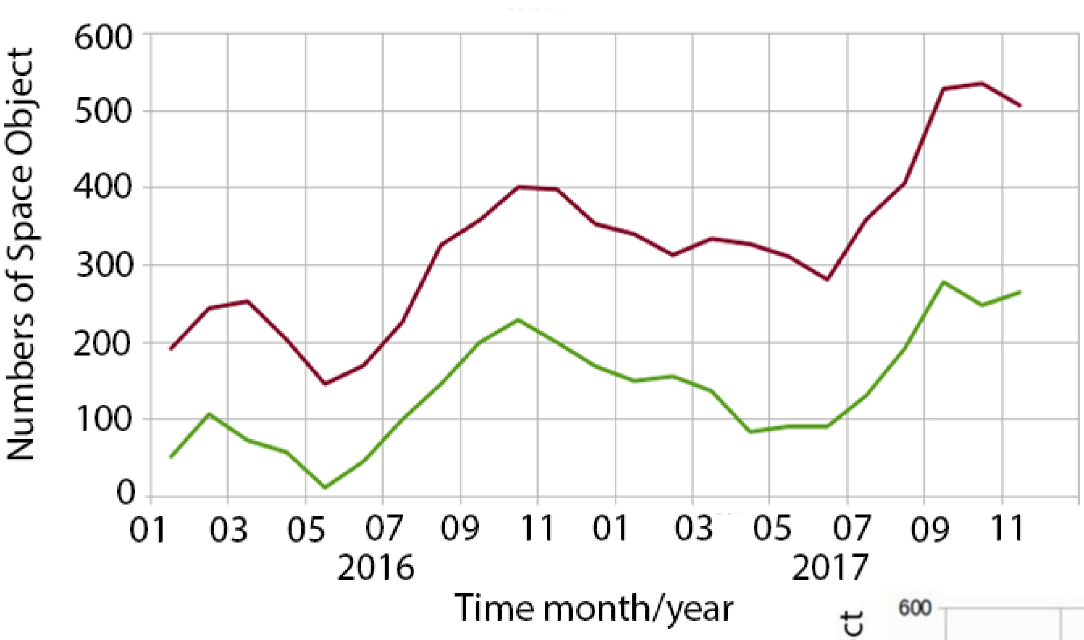


Quantity of observed bright GEO objects by months of 2016-2017. ISON (**green**), ASPOS OKP (**red**), industry organizations (**yellow** and **brown**). Total data – **blue** color curve

Quantity of tracked bright GEO objects by months of 2016-2017. ISON (**green**), ASPOS OKP (**red**), industry organizations (**yellow** and **brown**). Total data – **blue** color curve



Catalogue in part of faint GEO-objects is poor suitable for conjunction analysis



Comparing the number of all observed (**brown curve**) and tracked faint GEO-objects with good orbits (**green curve**) by months of 2016-2017. quantity of faint objects with good orbits is too little. Many faint objects regularly lost – catalogue is "breathing".

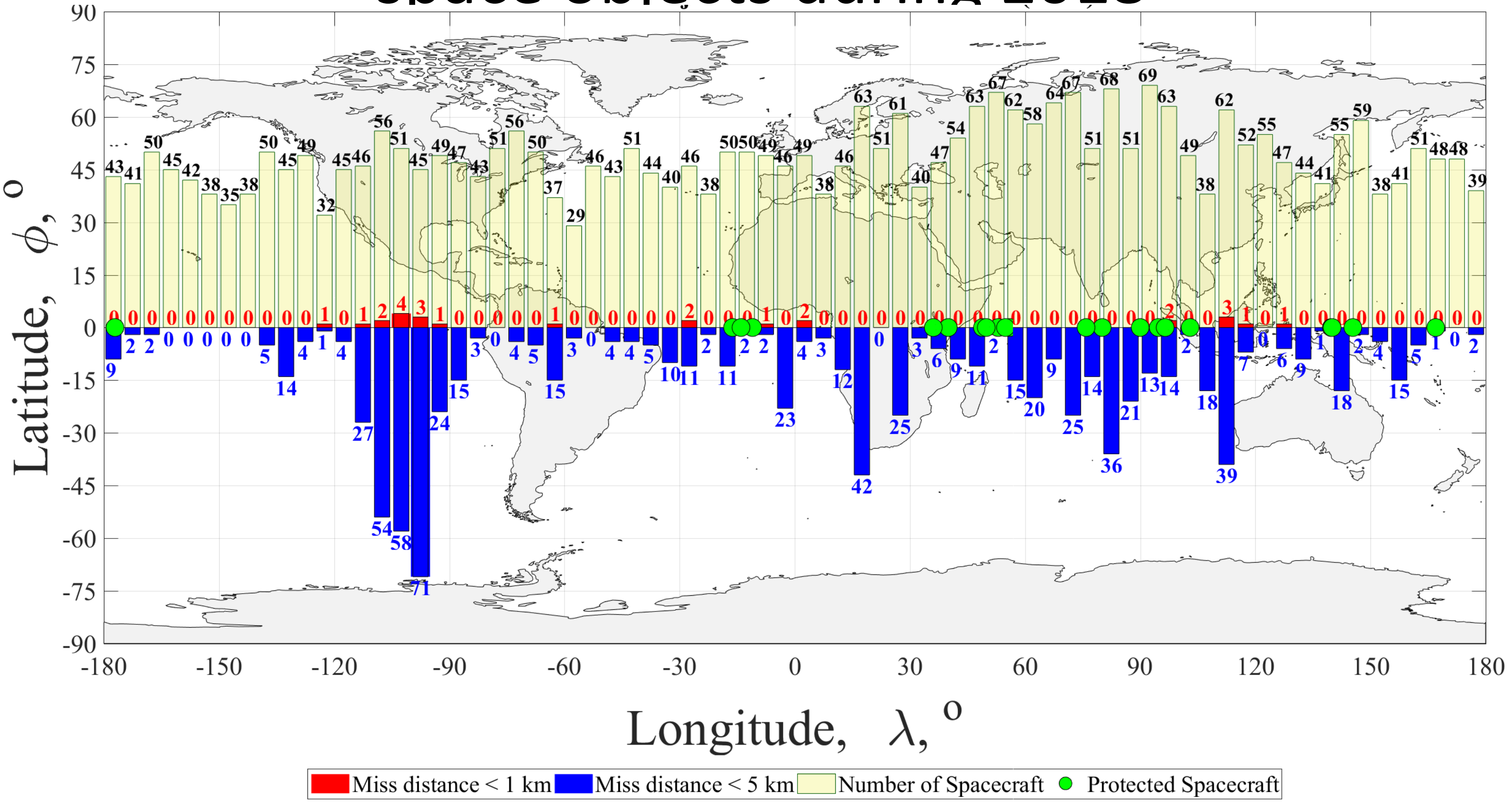
Quantity of observed faint GEO objects by months of 2016-2017. ISON (**green**), ASPOS OKP (**red**), industry organizations (**yellow** and **brown**). Total data– **blue** color curve

Conjunction analysis statistics for Roscosmos satellites in 2017/2018

Under ASPOS OKP project KIAM fulfills the daily conjunction analysis for 21 GEO and 30 MEO satellites.
Since 2017 the calculations are including the conjunctions of GEO and MEO objects with HEO objects

Objects	< 1 km	< 5 km
GEO	3/0	29/20
MEO	0/1	25/26
GEO fainter 16 m	0/0	2/1
MEO fainter 16 m	0/0	0/2
GEO having no TLE	1	6
MEO having no TLE	0	0
GEO with ARM> 1 m2	0/0	1/0
MEO with ARM> 1 m2	0/0	0/0

Statistics of rapprochements between all active GEO satellites and all catalogued GEO and HEO space objects during 2018

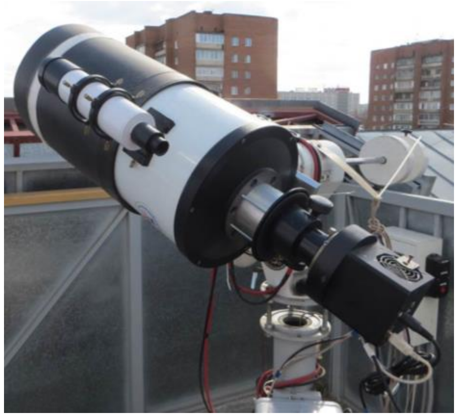


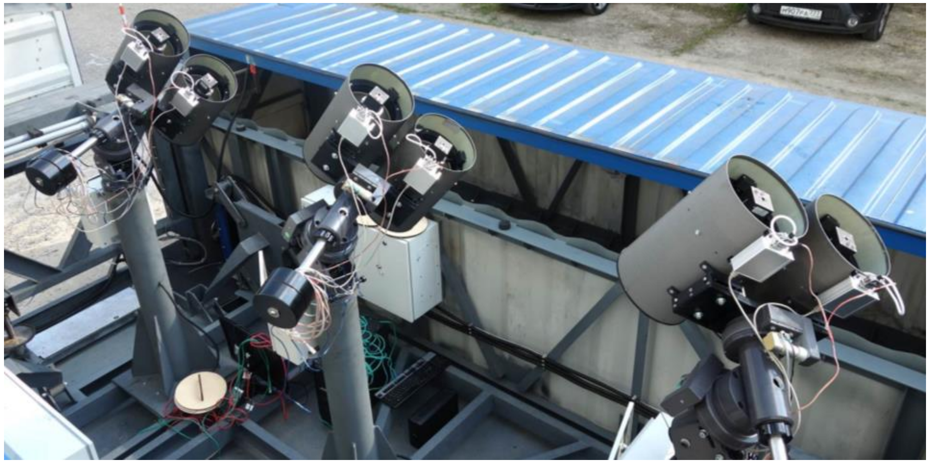
Current directions of ISON development

- Creation of new ISON subsystem for accuracy tracking that is important for observations of pairs of approaching objects to improve its orbits for conjunction analysis (almost all Russian telescopes have the large field of view and the average accuracy of measurements)
- Elaboration of new software for telescope control (KDS that automatically provides alert observation) and observation scheduling
- Adjusting of observation techniques of GEO objects with long exposure times and LEO object detection and tracking
- Minimization of the expenses on the ISON operations:

- Enlarging of the KIAM scientific cooperation (we are ready to install ISON telescopes on the terms of free operation and sharing the data)
- Redirection of part of more large aperture telescopes from space debris to astronomy observations to obtain scientific results for grants
- Searching of foreign contracts (i.e. few GMV/ISON observing campaigns)

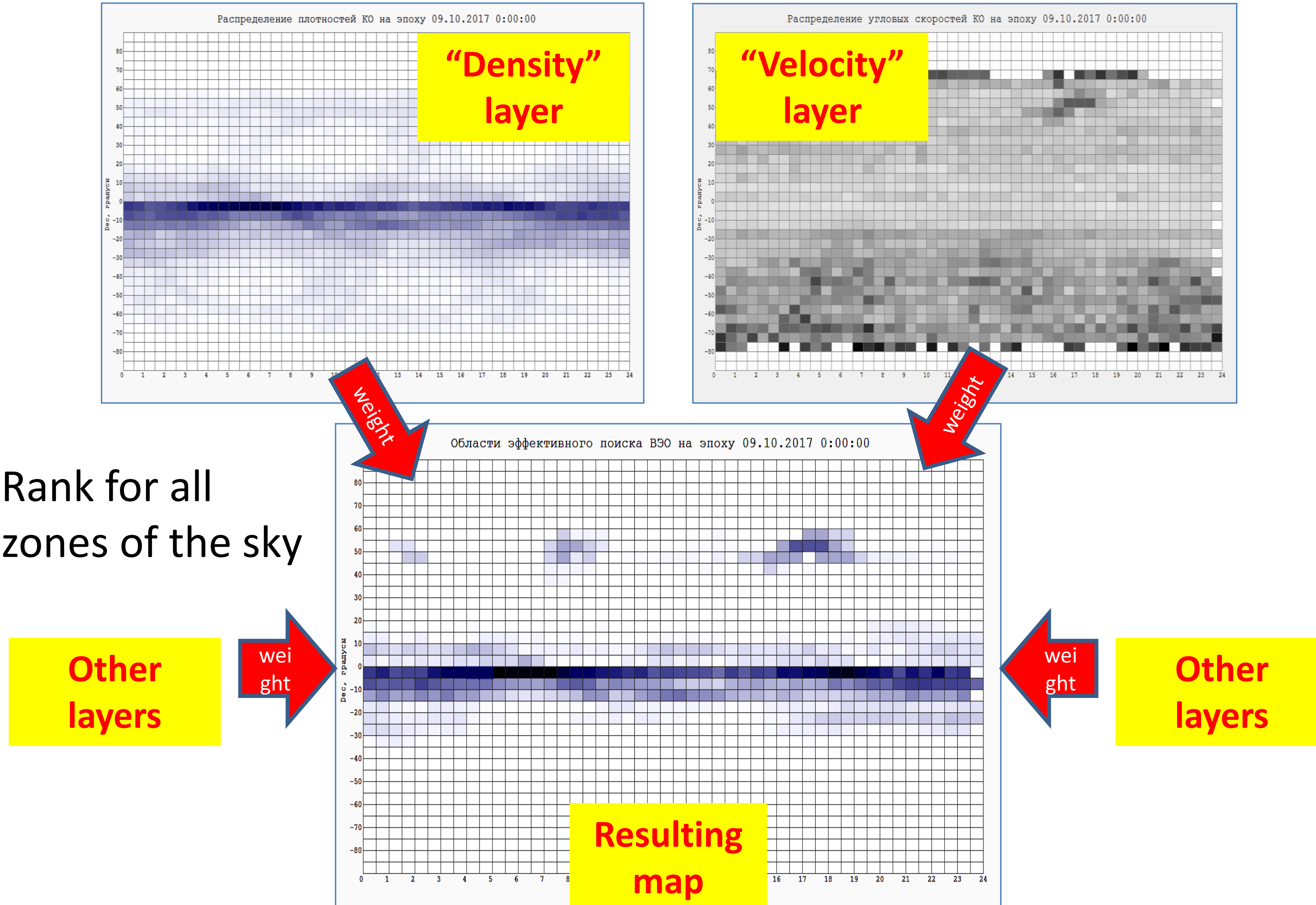
Creation of new ISON subsystem for accuracy tracking (< 1”) 25 cm TAL-250K and 40 cm DIN-400, and prototype of 6x20-cm cluster for LEO and HEO detections



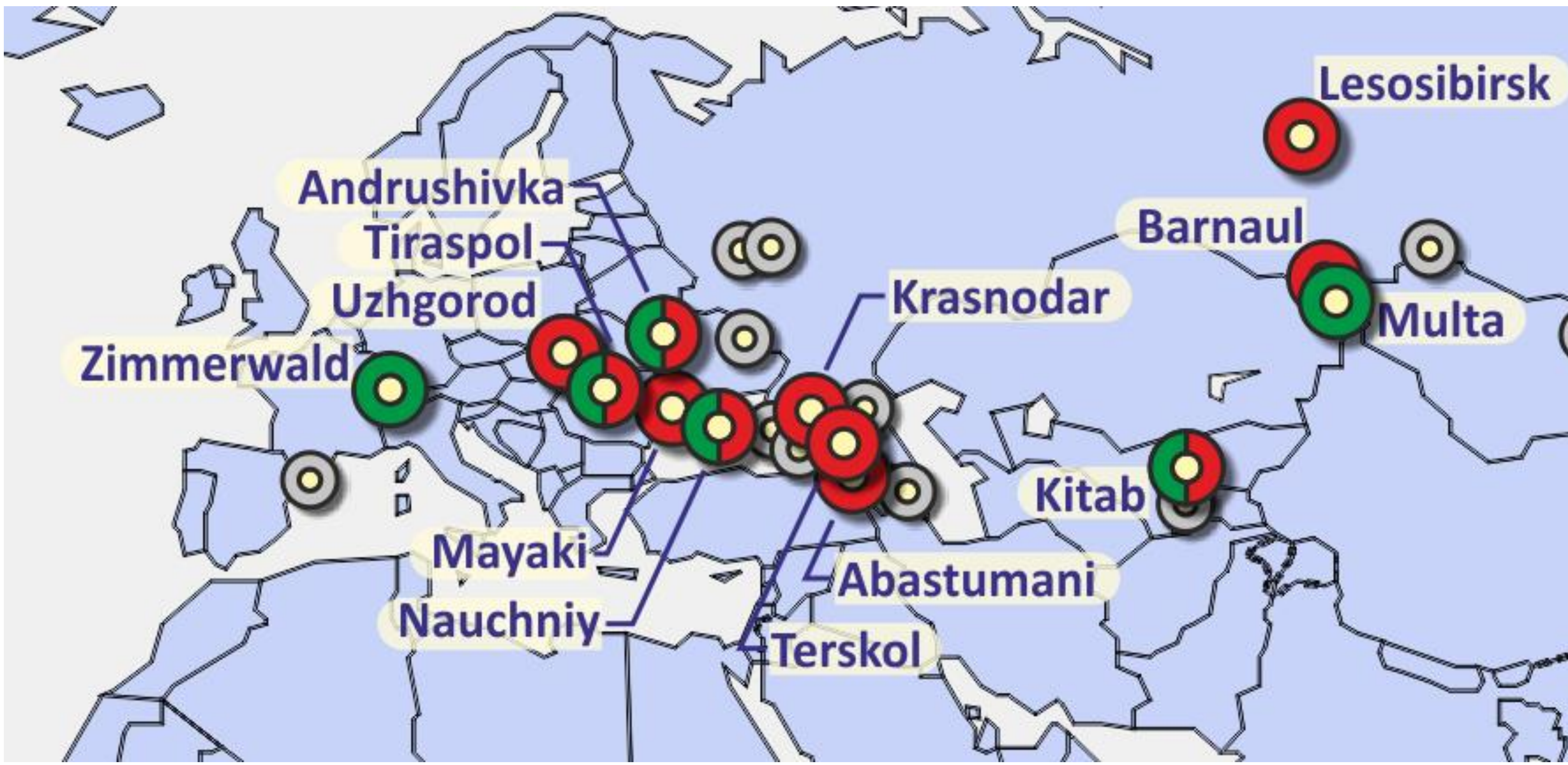

New observations scheduling for HEO-objects survey

Rank for all zones of the sky



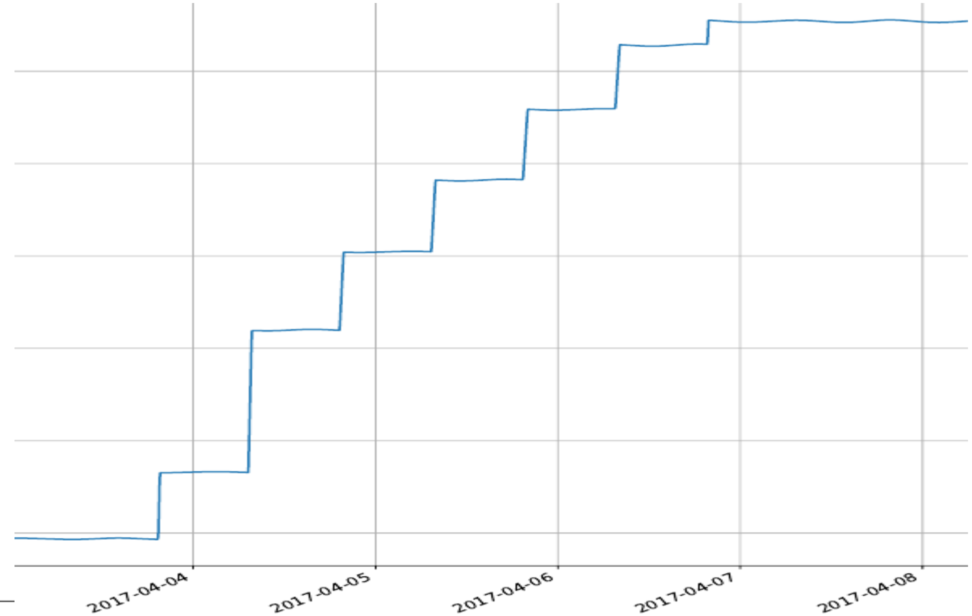
Example of SIE “BS” work for foreign customer:

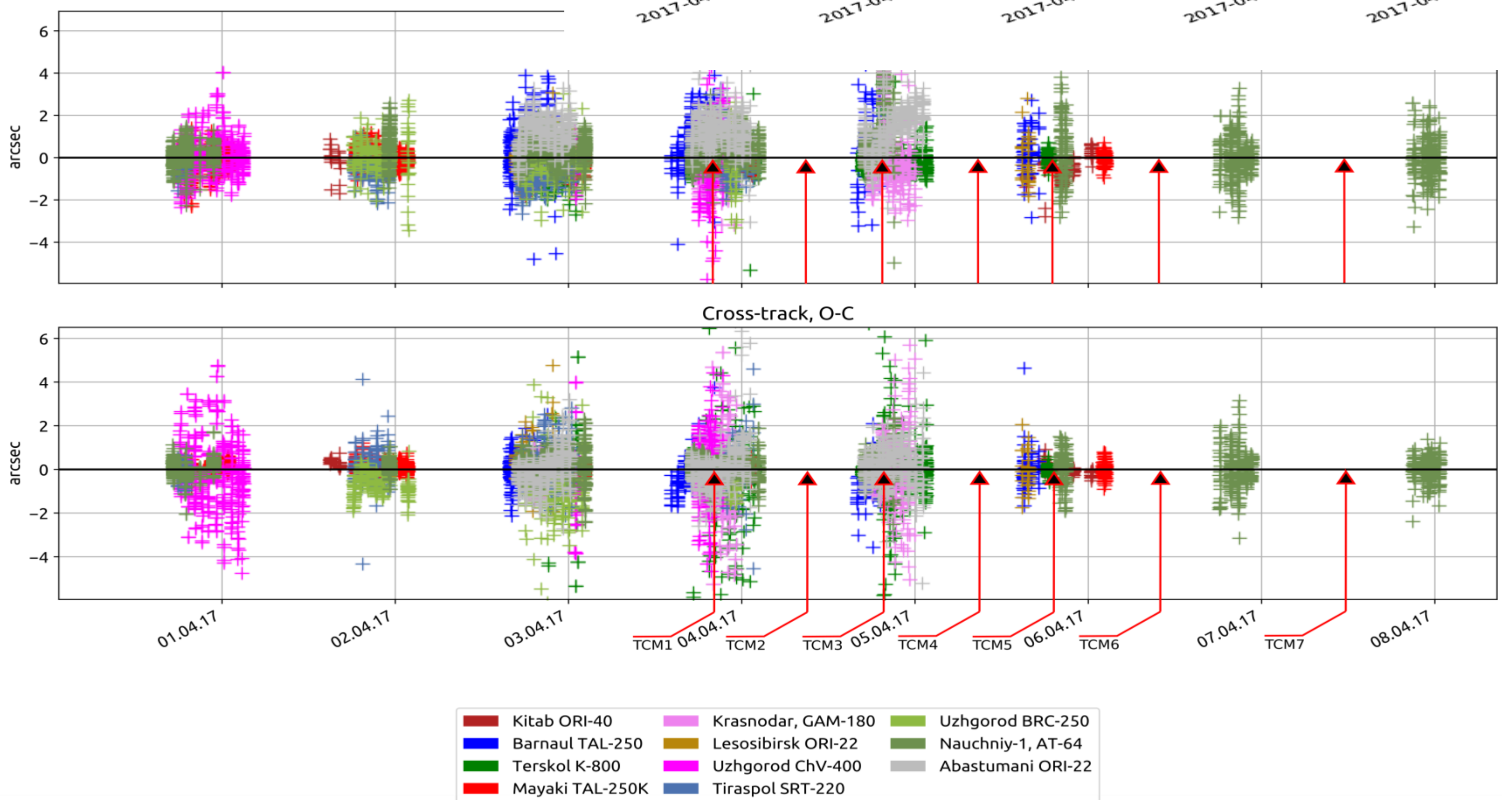
17 telescopes in 13 observatories collected 11000 measurements during support of METEOSAT-7 end-of-life operations under GMV/ISON observation campaign



Red – tracking observations, green – survey observations

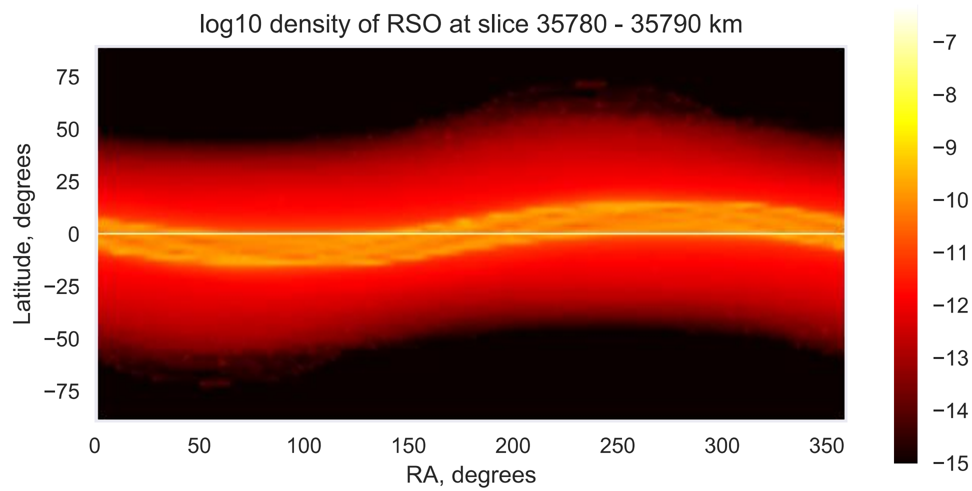
Support of METEOSAT-7 end-of-life operations: two maneuvers per day

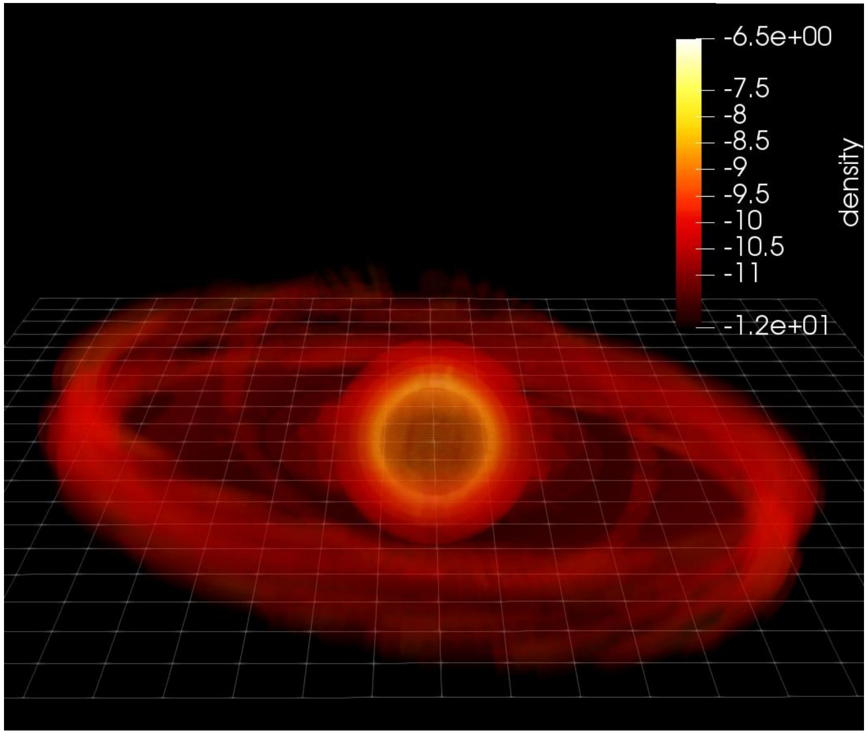


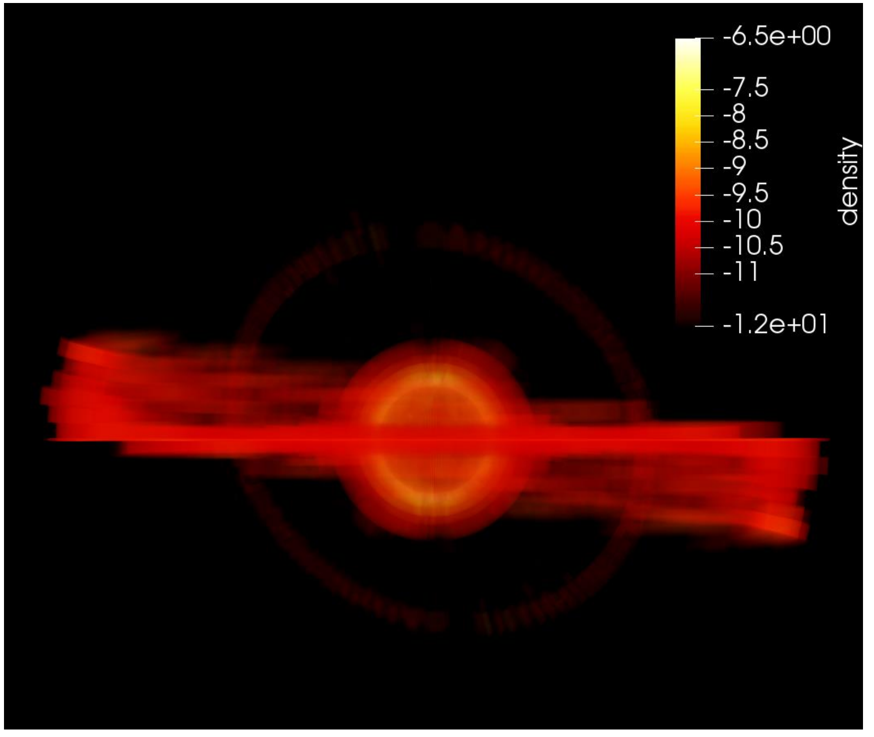


Statistical model derived from cat. objects

- 306 normal local centers were generated out of 18177 RSO (2017-05).
- Naturally describes high density areas (e.g. intact GSO) by means of covariance matrix







Summary

- ISON consist of 53 telescopes and continues to provide the important contribution to space surveillance at high orbits. During 2017, 6,353 millions of ISON measurements compile 28% of common data
- ISON makes a decisive contribution in maintenance of catalogue of precise orbits of the bright GEO-objects thank to multiple surveys that is very important for conjunction analysis, because of 94% (46 from 49) of rapprochements for last 18 months were exactly with bright objects
- ISON develops subset for accuracy tracking (<1”)
- There are 10 telescopes of 19.2 cm to 50 cm class that may be installed in good places for sharing the data. **Proposals are welcome**.
- 80 cm K-800 telescope data is used for verification of space debris population model
- Catalogue of faint GEO objects (fainter 16 m) is practically does not exist - every 5 months the catalog is updated and reduced by 250-300 objects (up to 50-60%). It is necessary to elaborate new methods of scheduling and observations of faint objects

Astrometry and photometry of satellites and space debris at the ISON-Castelgrande Observatory

S. Schmalz, I. Molotov, F. Graziani, V. Kouprianov,
R. Di Roberto, M. Truglio, V. Voropaev –
1st International Aerospace Symposium: The Silk Road (06 – 08 December 2018)
– MIPT, Dolgoprudny, Russia (07.12.2018)

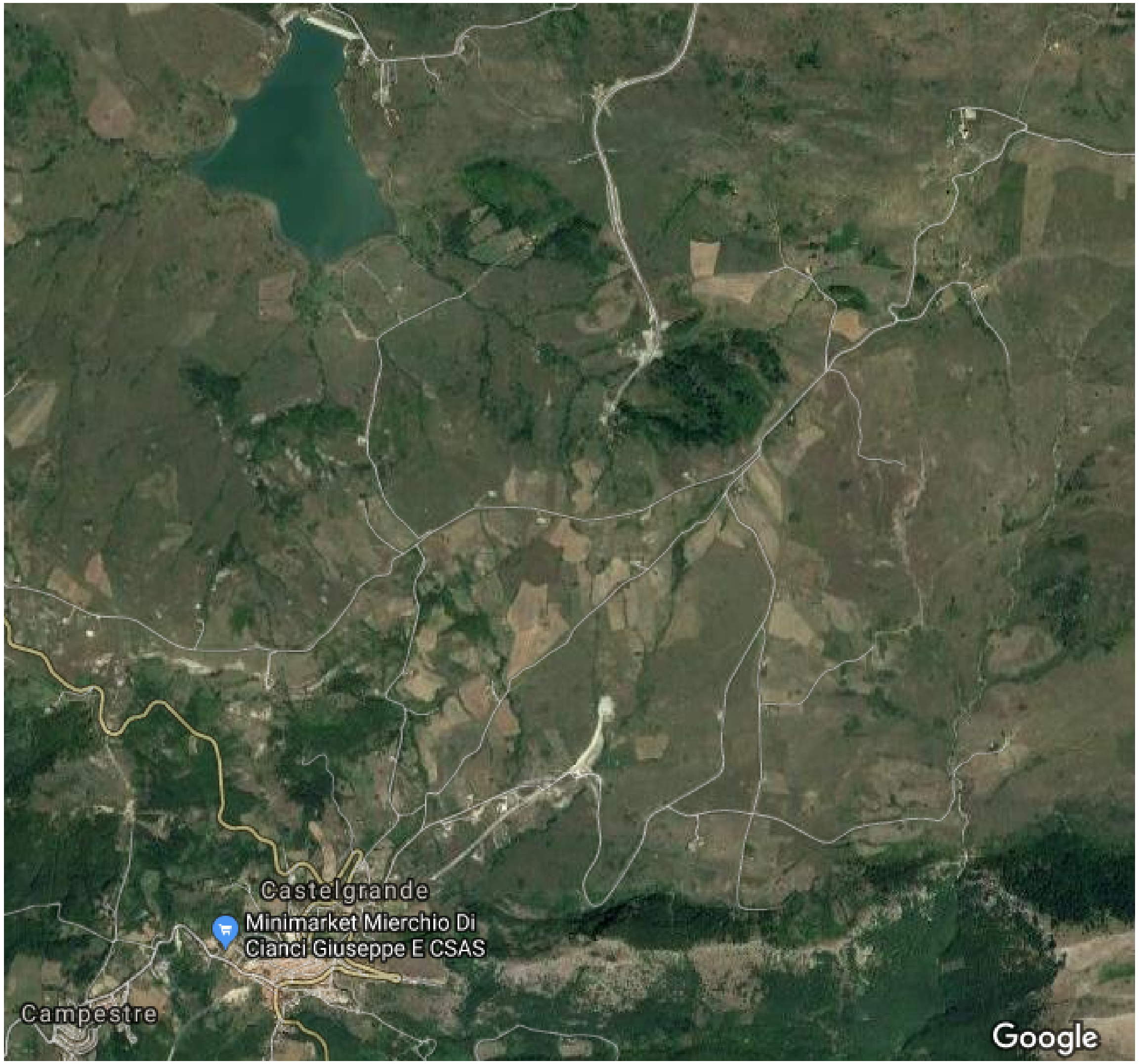
Group of Astrodynamics for the Use of Space Systems

Area

- Where:
  - 15.463387 E, 40.817566 N, 1250 m a.s.l., CET
  - South Italy, region Basilicata, province Potenza, comune Castelgrande, ~7 km northwards from Castelgrande, on Toppo di Castelgrande mountain
  - Climate type: Mediterranean hot/cool dry-summer (Csa/Csb)


Area

- Where:


Castelgrande
Minimarket Mierchio Di
Cianci Giuseppe E CSAS
Campestre
Google

Area

- Osservatorio Astronomico di Castelgrande
  - TT1 (154-cm, INAF-OAC)
  - ISON-Castelgrande Observatory

    (KIAM + GAUSS + Castelgrande comune = CastelGAUSS Project)
    - YouTube:

      www.youtube.com/watch?v=neAc2aSgd44

Facilities

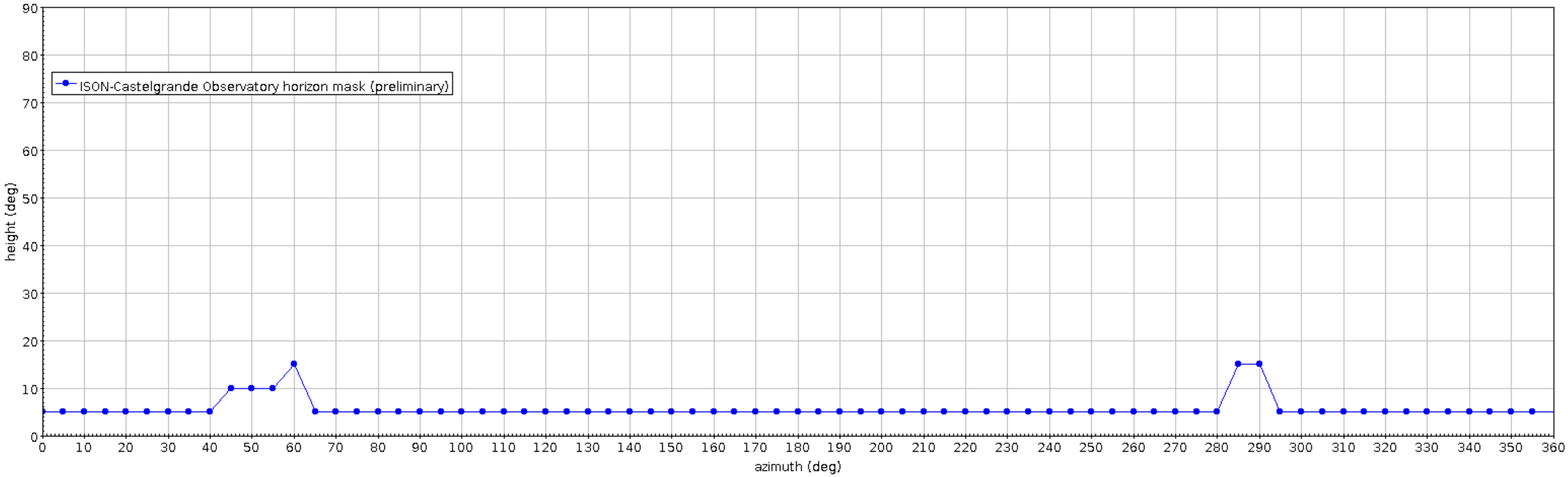
- Inside TT1 Building:
  - guesthouse: kitchen, two bedrooms, WC, shower, TV room
  - lecture hall (70-80 seats)
  - mechanical / electrical workshop
  - storage area, other rooms

Sky & Site Quality

- AAG Cloudwatcher:
  - rain / cloud / windspeed / air temperature sensors
- SQM-L:
  - best value so far 21.47 mag/arcsec²
  - usually 21.0 – 21.3 mag/arcsec²
    with clear moonless sky
  - class 3 sky on the Bortle scale
- Seeing:
  - 1.2 arcsec (average)

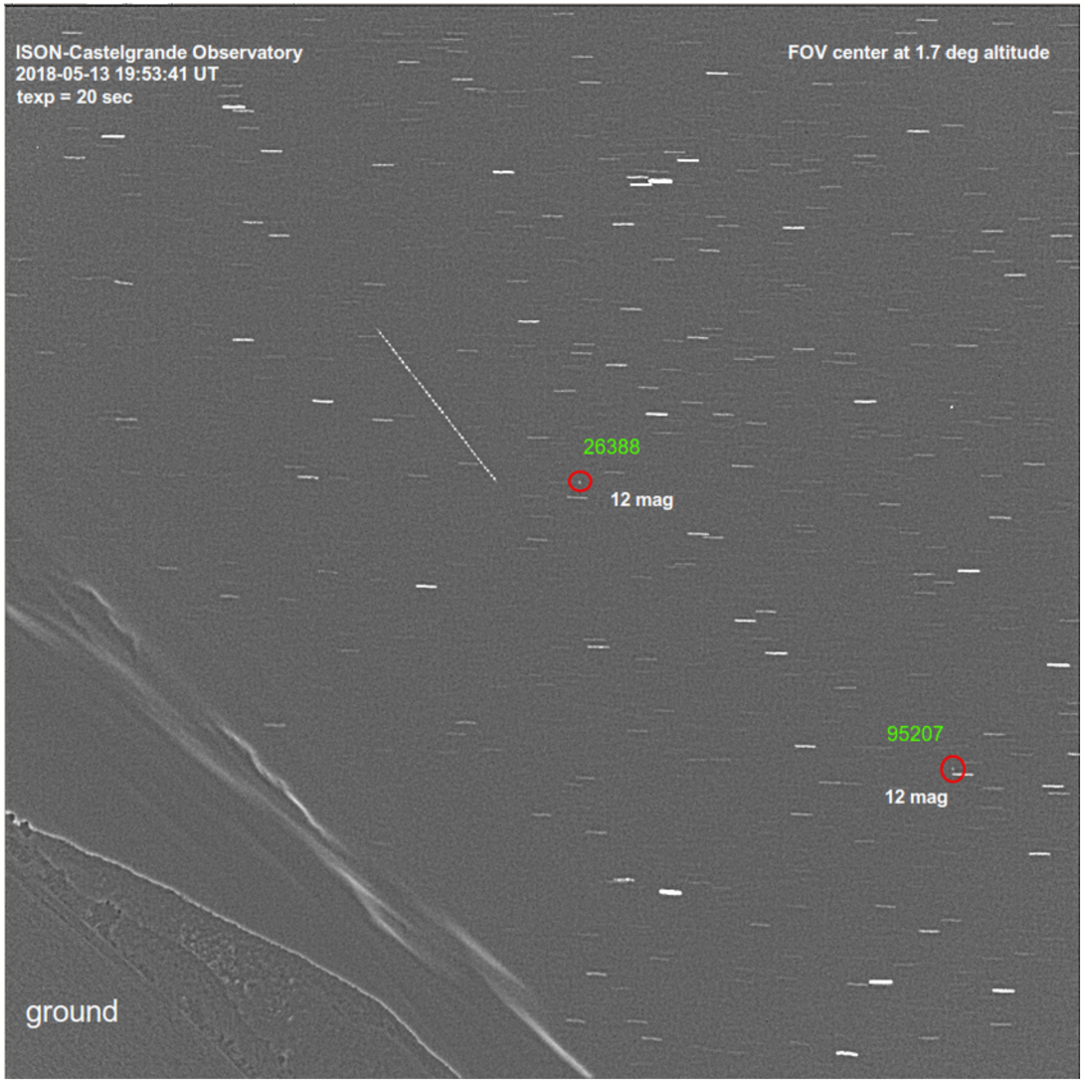
Sky & Site Quality

- Open Horizon:
  – horizon mask



Sky & Site Quality

- Open Horizon:
  - practical example:
    - FOV center at 1.7 deg altitude,
    - 12 mag objects visible at 20 sec exposure time

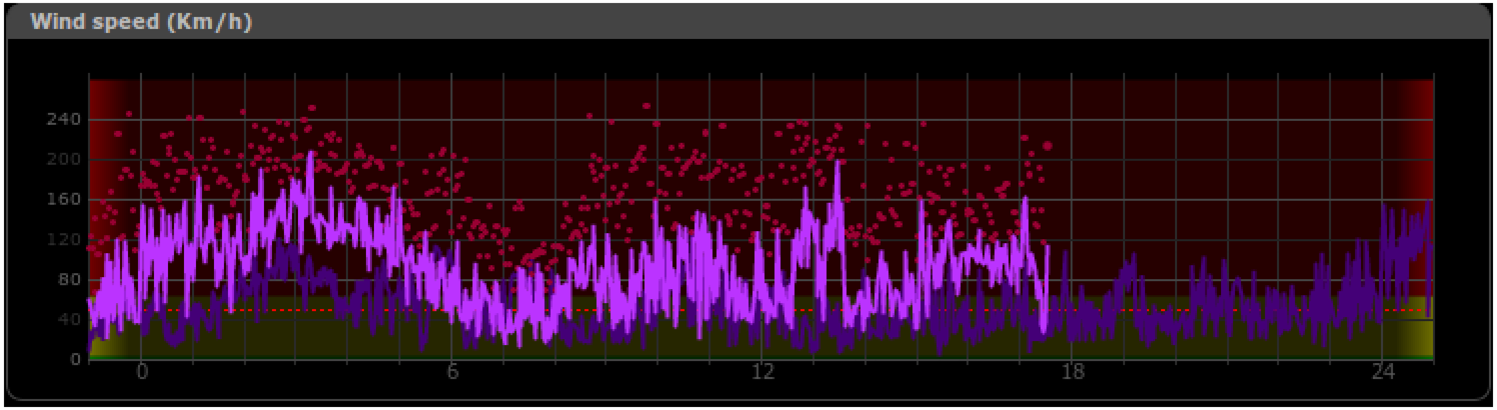


Sky & Site Quality

- Open Horizon:
  - another example:
    - sun still visible below the horizon (refraction)

Sky & Site Quality

- Problems:
  - wind:
    - sometimes above 100 km/h



  - humidity:
    - sometimes at 90 – 92% during several consequent clear nights
  - insects (ladybugs)

Sky & Site Quality

- Problems:
  - snow / frost in December – March:

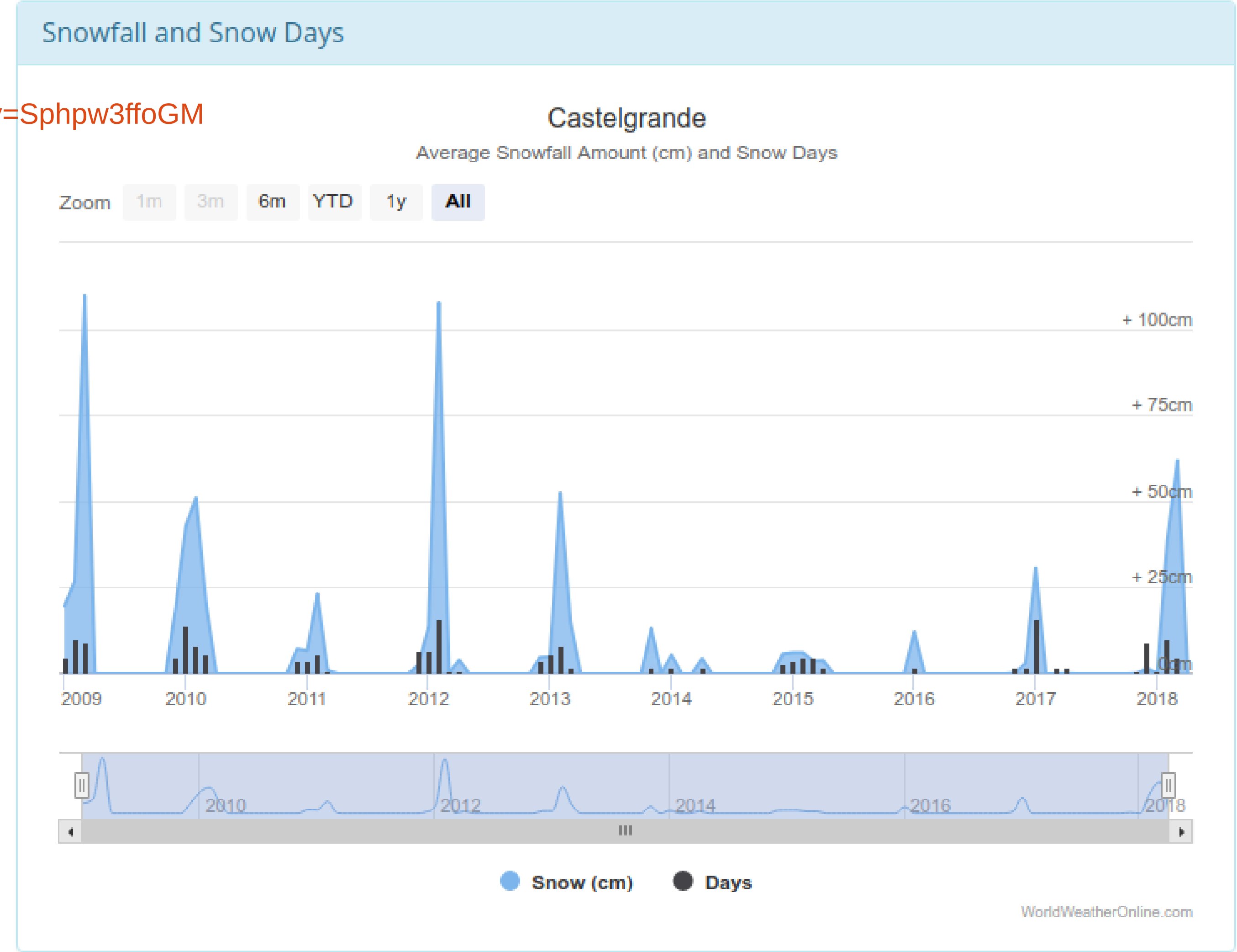


Sky & Site Quality

- Snowfall and Snow Days:

Youtube:

www.youtube.com/watch?v=Sphpw3ffoGM



Sky & Site Quality

- Starlight Xpress Oculus 180 All-Sky Camera
  - 1.55 mm 180° fish-eye lens
  - Sony SuperHAD CCD

Sky & Site Quality

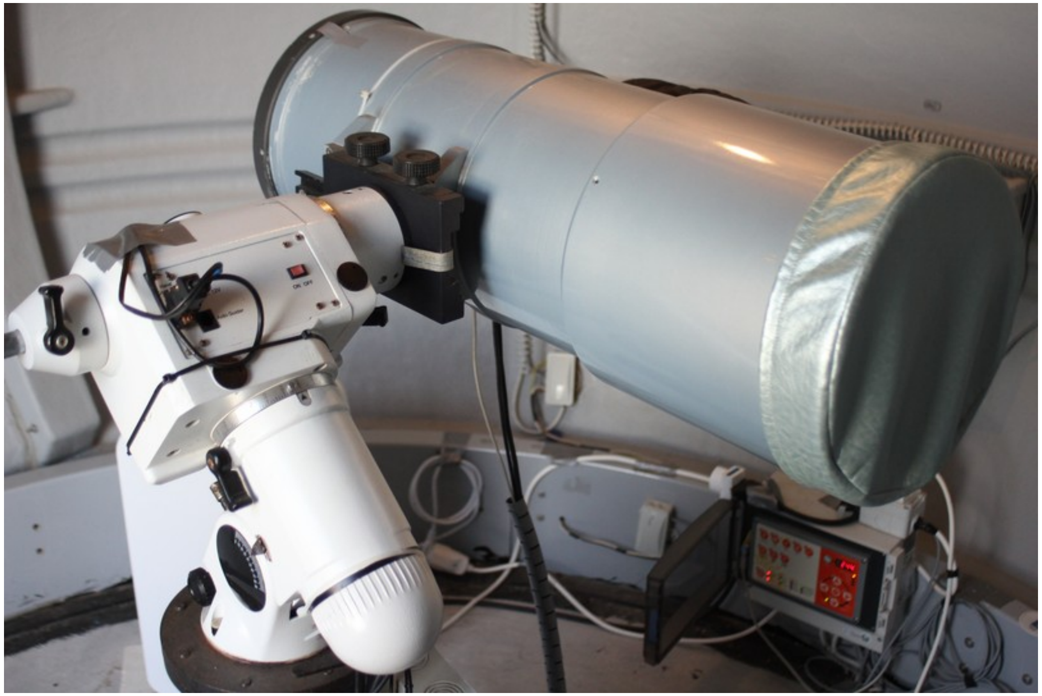
- Number of Observational Nights:
  - best run so far: 20 nights in April, July, August 2018
  - surprise: 17 nights in January 2018
  - minimum of 150 – 180 nights per year

Observatory Setup

- **Currently:**

Observatory Setup

- Currently:
  - installed in 2014
  - inside a 3-m Scopedome cupola
  - custom-built Hamilton-Newton telescope with a blend and an aperture coma corrector, 22 cm aperture, 510 mm focal length
  - on a Skywatcher EQ-6 Pro SynScan mount
  - with a FLI MicroLine 9000 CCD camera, 3056×3056 px CCD size, 12 micron pixel size
  - FOV 4.1°×4.1°
  - timed by a Trimble GPS-reciever
  - manually focused
  - taken care of by an Ariston air-dehumidifier
  - visually controlled through a FosCam IR surveillance camera
  - controlled from a barebone in-box computer
  - operatable remotely



Observatory Software

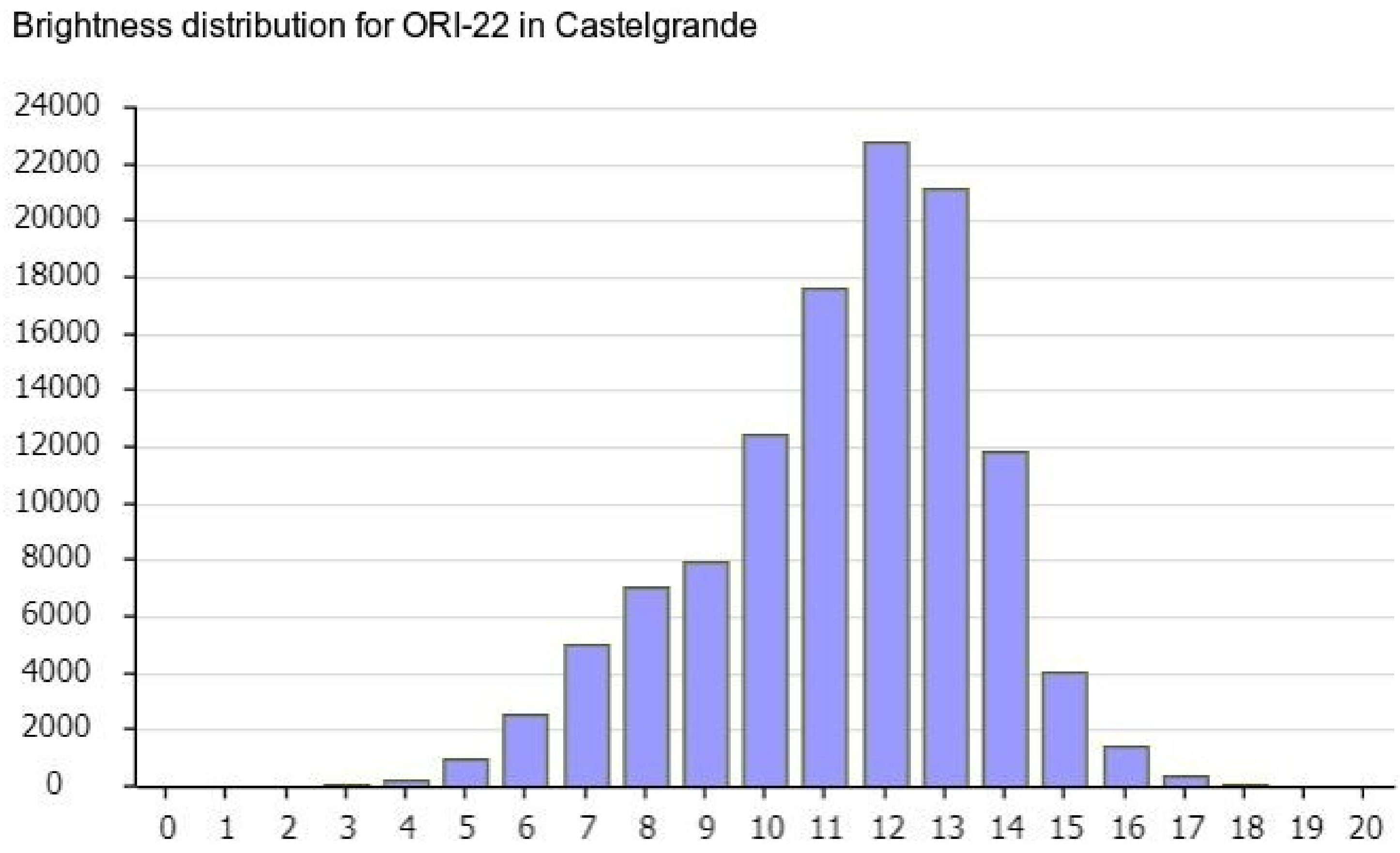
- Telescope Control System PC:
  - Ubuntu LTS 16.04 → Ubuntu LTS 18.04
  - **FORTE 0.17.0**
- Image Processing PC:
  - Ubuntu LTS 14.04 → Ubuntu LTS 18.04
  - **APEX 2.4.1 (dependencies: AstroPy, NumPy, SciPy)**
  - IRAF / SAOImage DS9
  - **HeavenSat**
  - Stellarium
  - AstroImageJ / Fitswork
  - VO Tools (Aladin / TOPCAT)
- Web Tools:
  - astrometry.net → local
  - Trello board
  - GitHub Pages
- Access:
  - Teamviewer / AnyDesk

Observations

- Astrometry:
  - satellites and space debris:
    - first oservation on October 26/27, 2017
    - tracking mode / tracking search mode
    - survey mode
    - up to 300 objects in GEO, MEO & HEO per night
    - down to 17th magnitude (in tracking mode at not too high angular velocities)
    - down to 15th magnitude (in survey mode)
    - precision ~ 1 – 2 arcsec

Observations

- Astrometry:
  - satellites and space debris:



Observations

- Chinese Space Station Tiangong-1:
  - captured on 4 subsequent images on March 31, 2018, 03:50 – 03:52 UT
  - t_{exp} = 0.5 sec
  - Saturn (above), Mars (right), globular cluster M22

Observations

- Photometry:
  - optical GRB afterglows:
    - lim_{mag} ~ 19 mag on stacked images ($texp_{int}$ ~ 1 – 2 hours) → PyGCN socket client (a FORTE GCN client script for automated telescope slew and unattended observation)
    - (new old) idea: a space object alert observation and follow-up system
    - VO-compliant SAMP (?)

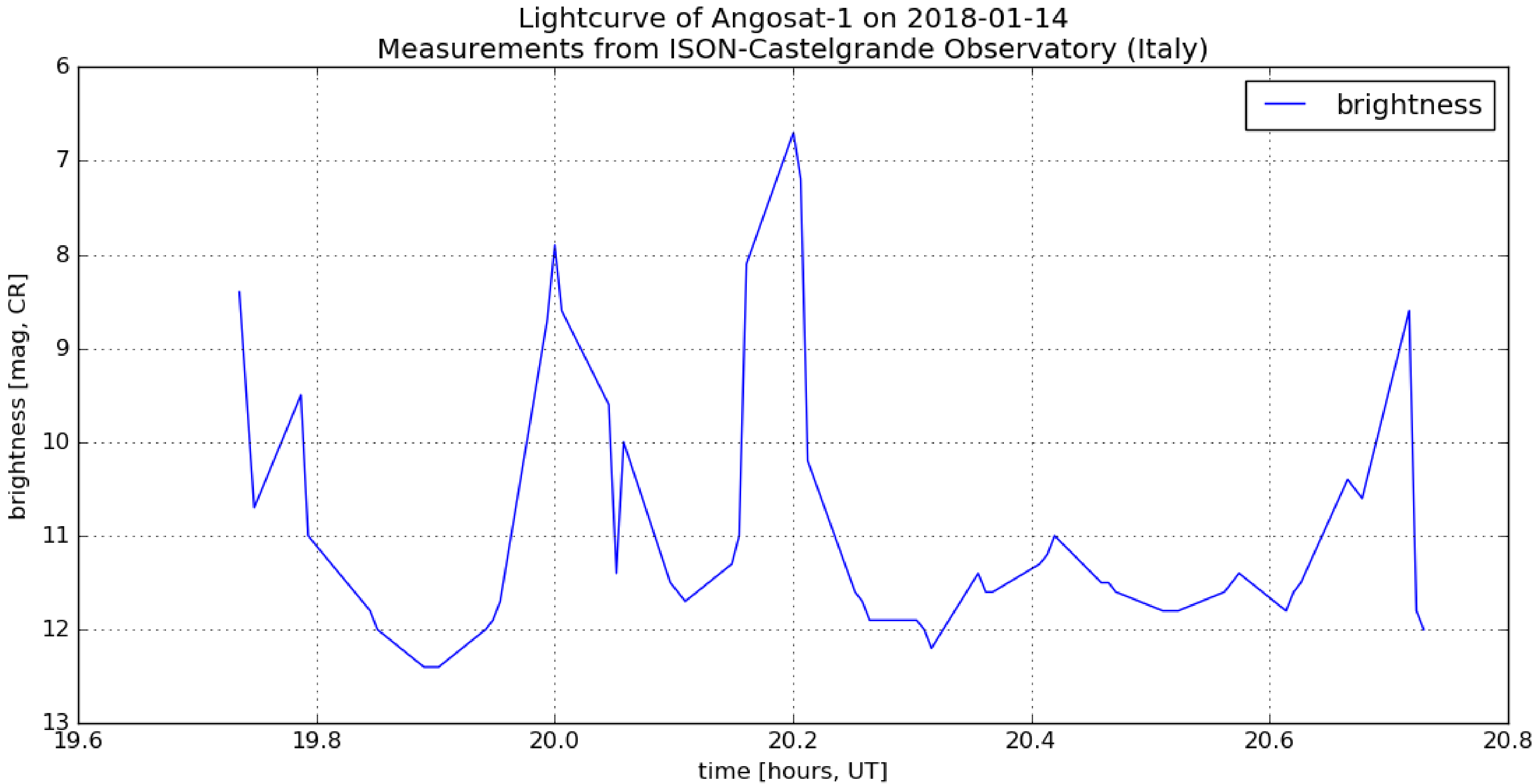
    “The future’s not set. There’s no fate but what we make for ourselves.” © “The Terminator” movie.

Observations

- Photometry:
  - satellites and space debris:
    - Angosat-1 (NORAD: 43087) campaign Jan-Apr 2018
    - amplitude resolution: above ~ 0.20 – 0.30 mag
    - best sampling with t_{exp} ~ 5 – 10 sec
    - limiting magnitude at good quality: ~ 14 – 15 mag

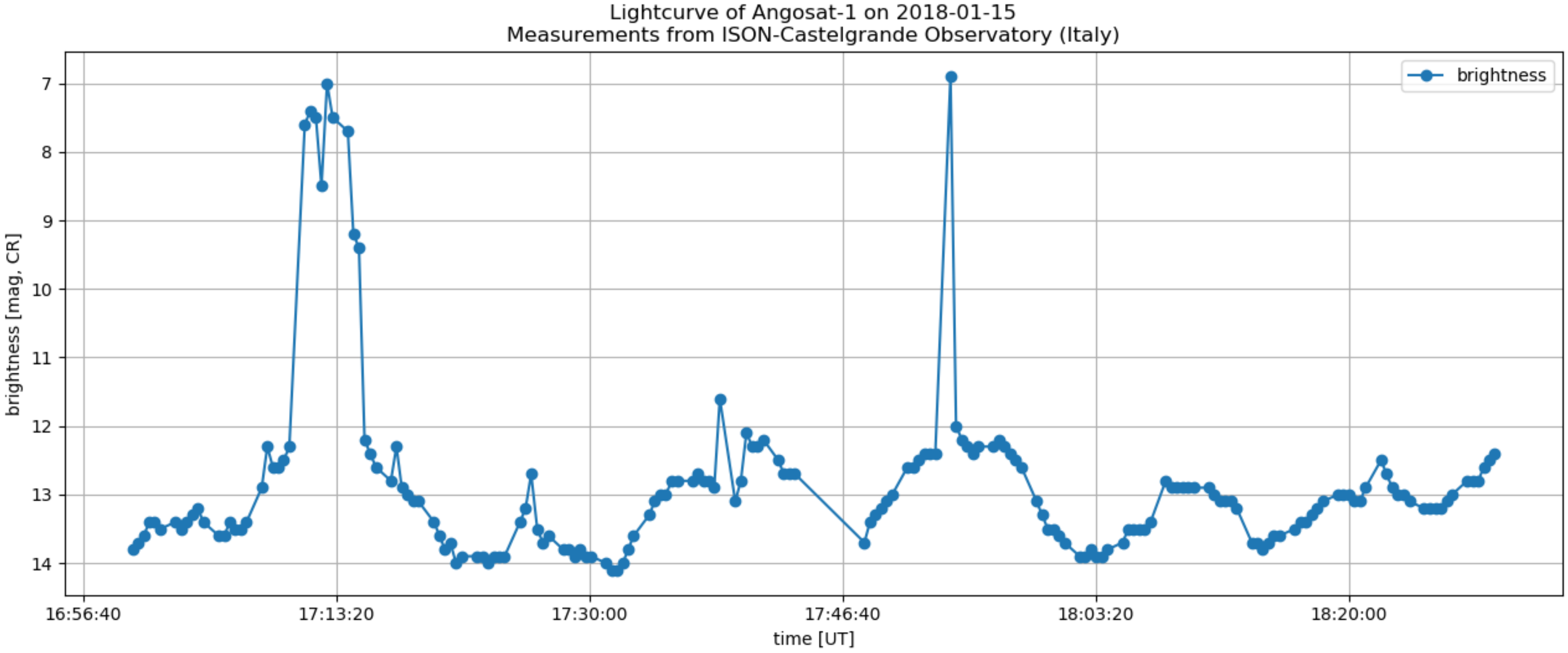
Observations

- Photometry (Angosat-1):



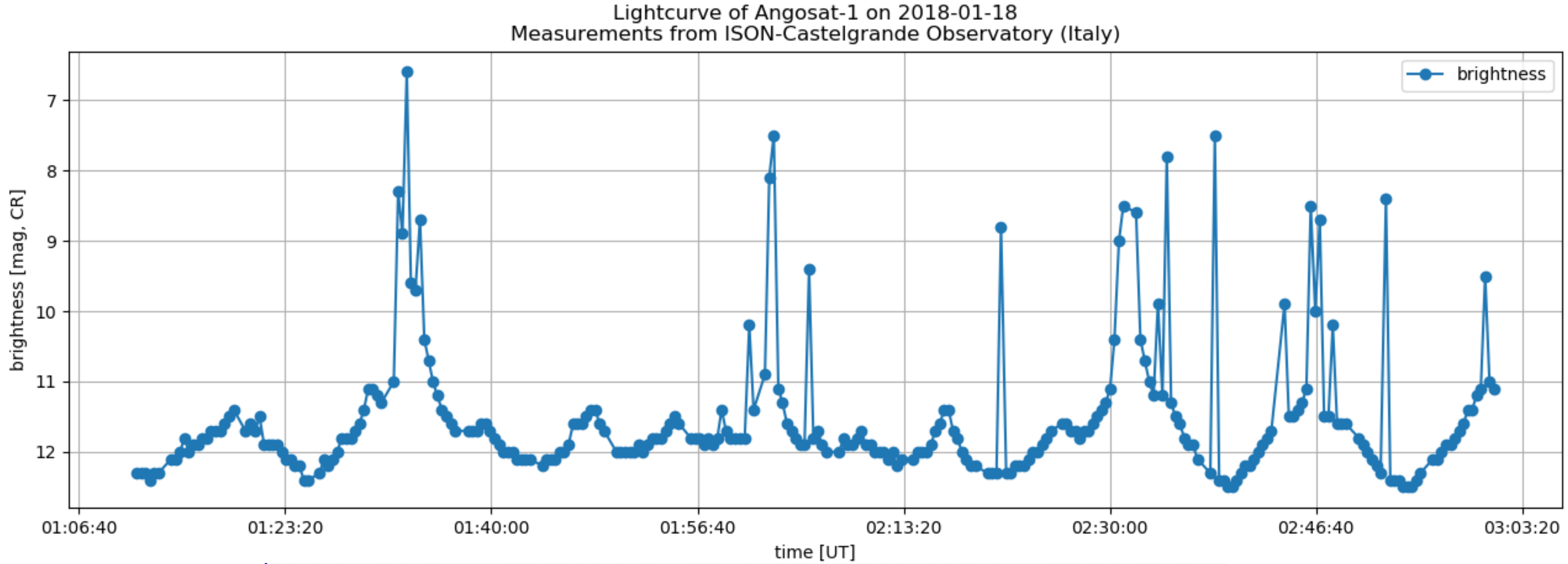
Observations

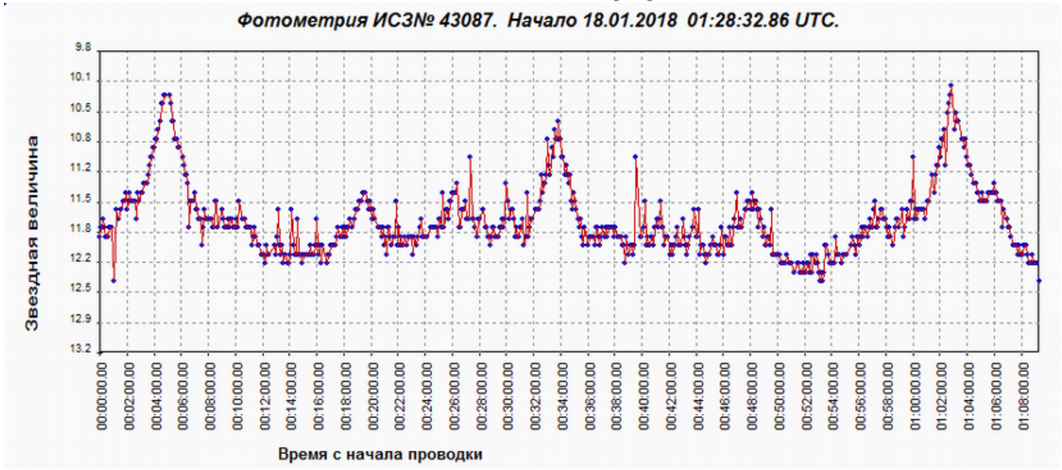
- Photometry (Angosat-1):



Observations

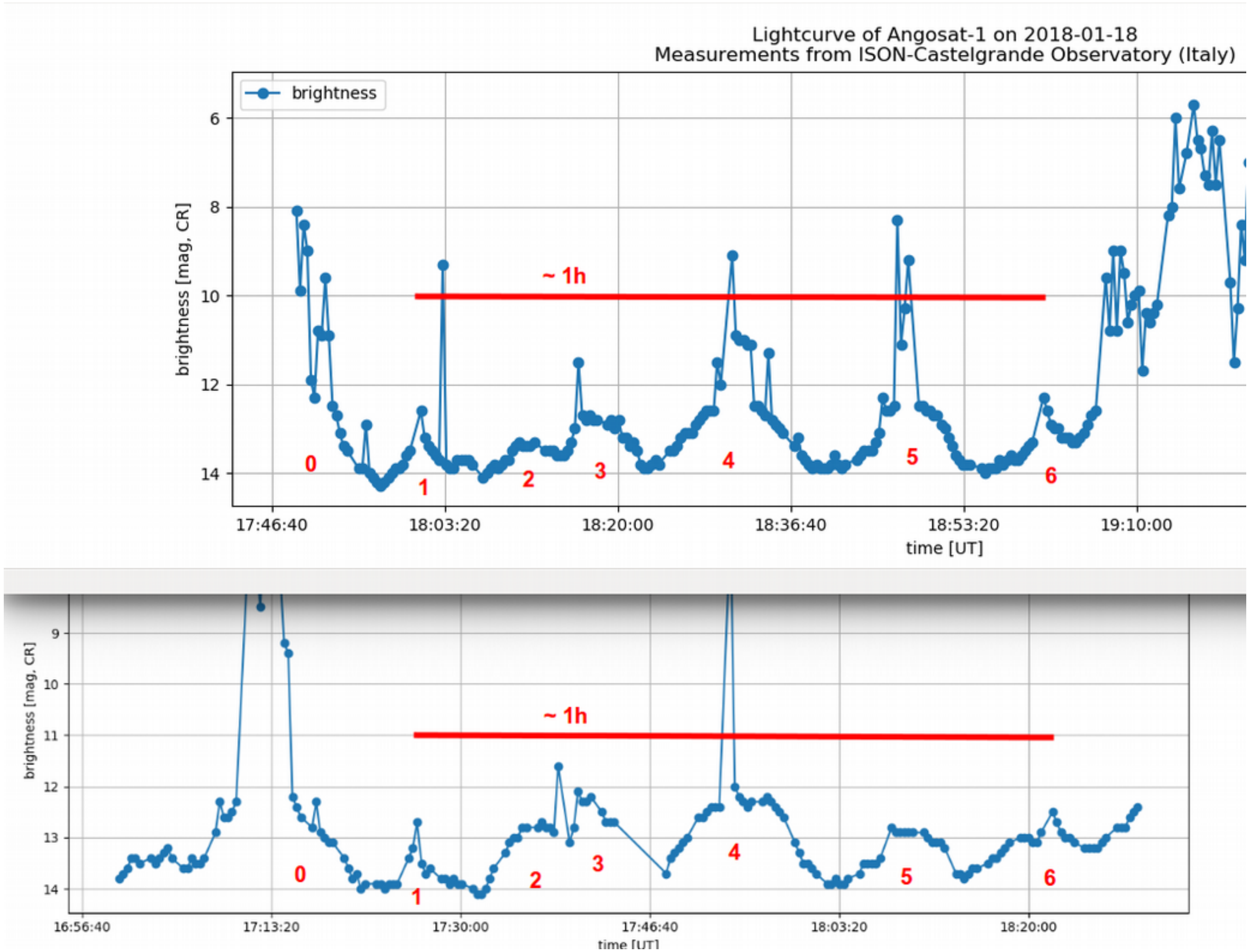
- Photometry (Angosat-1): compared to Arkhyz





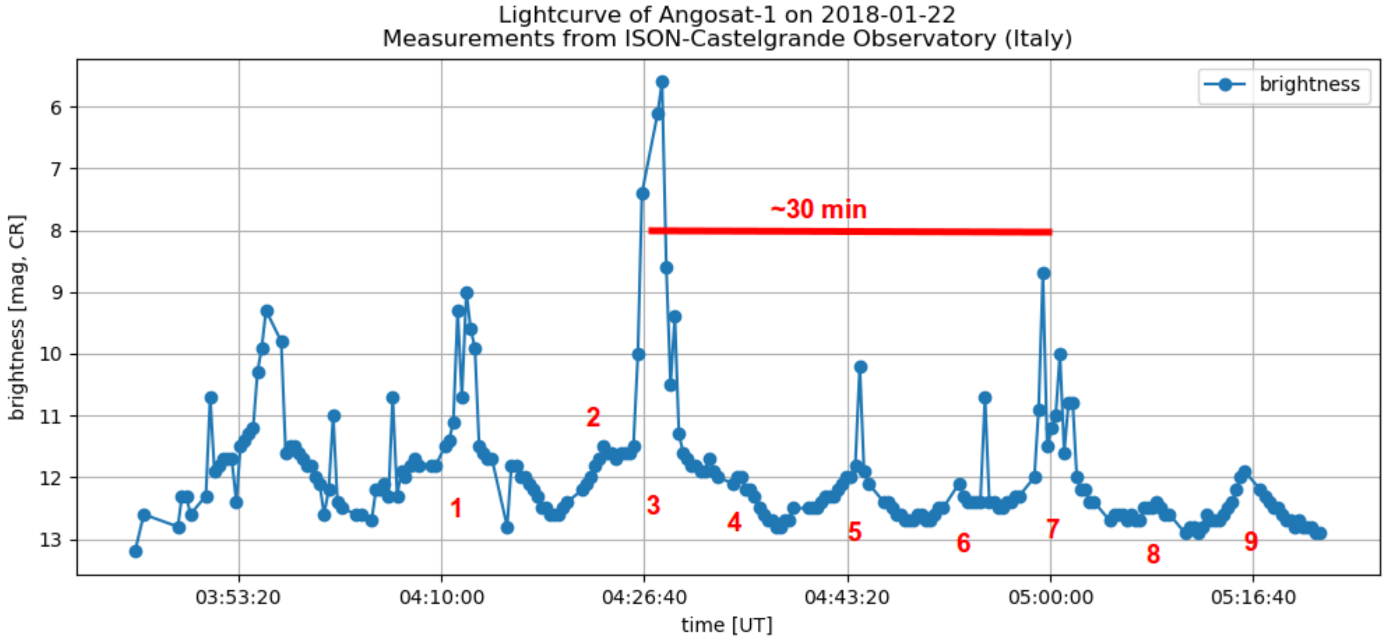
Observations

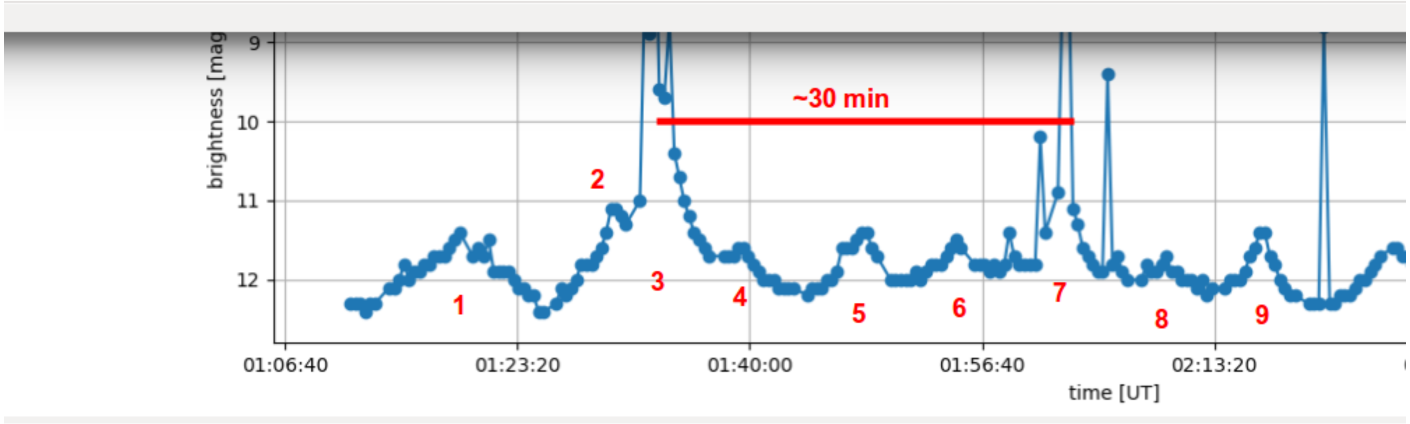
- Photometry (Angosat-1):



Observations

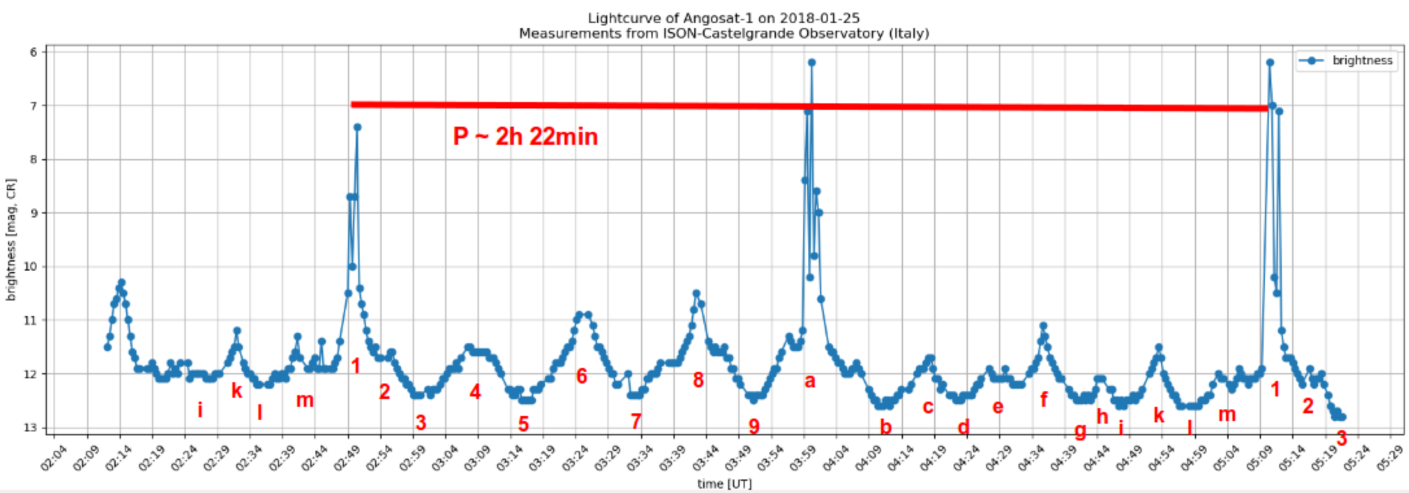
- Photometry (Angosat-1):

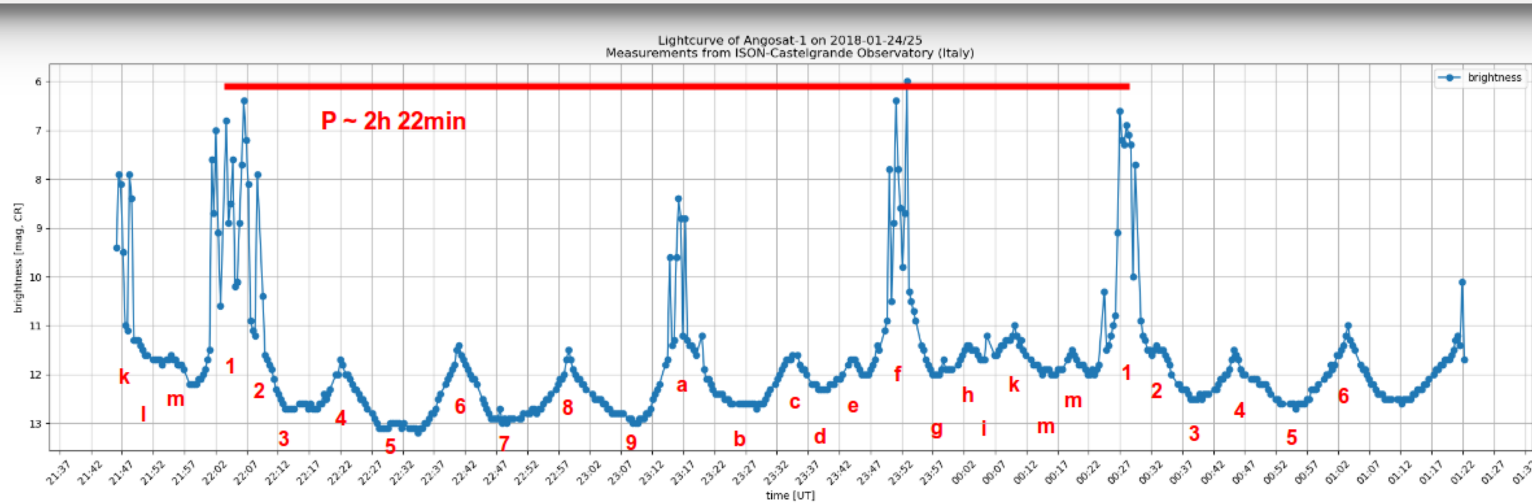




Observations

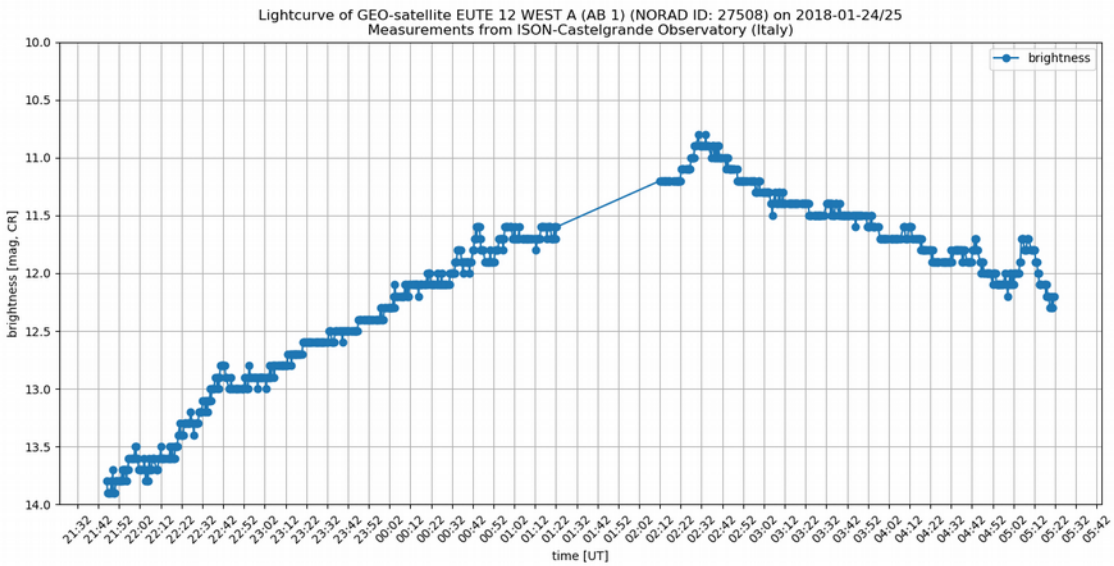
- Photometry (Angosat-1):

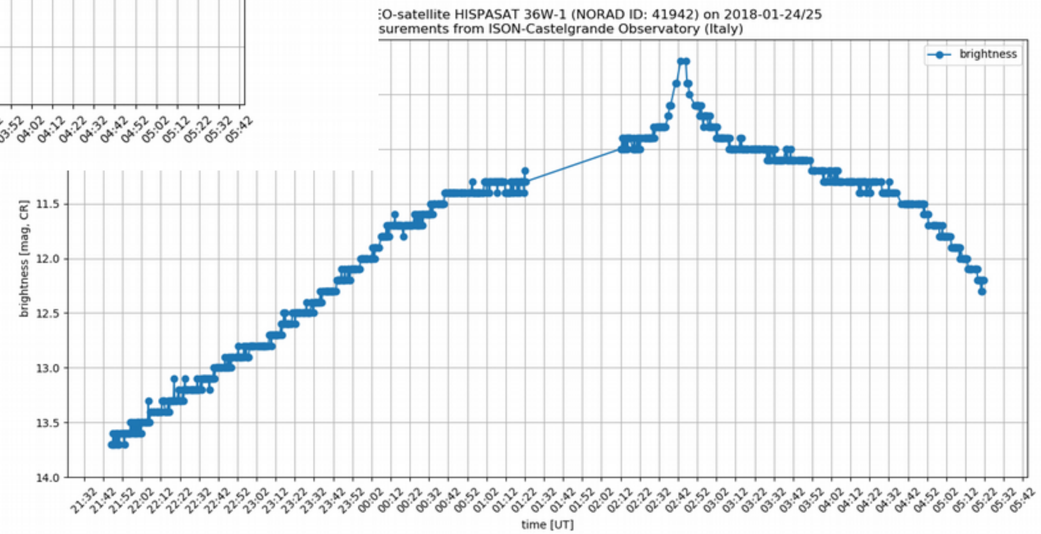




Observations

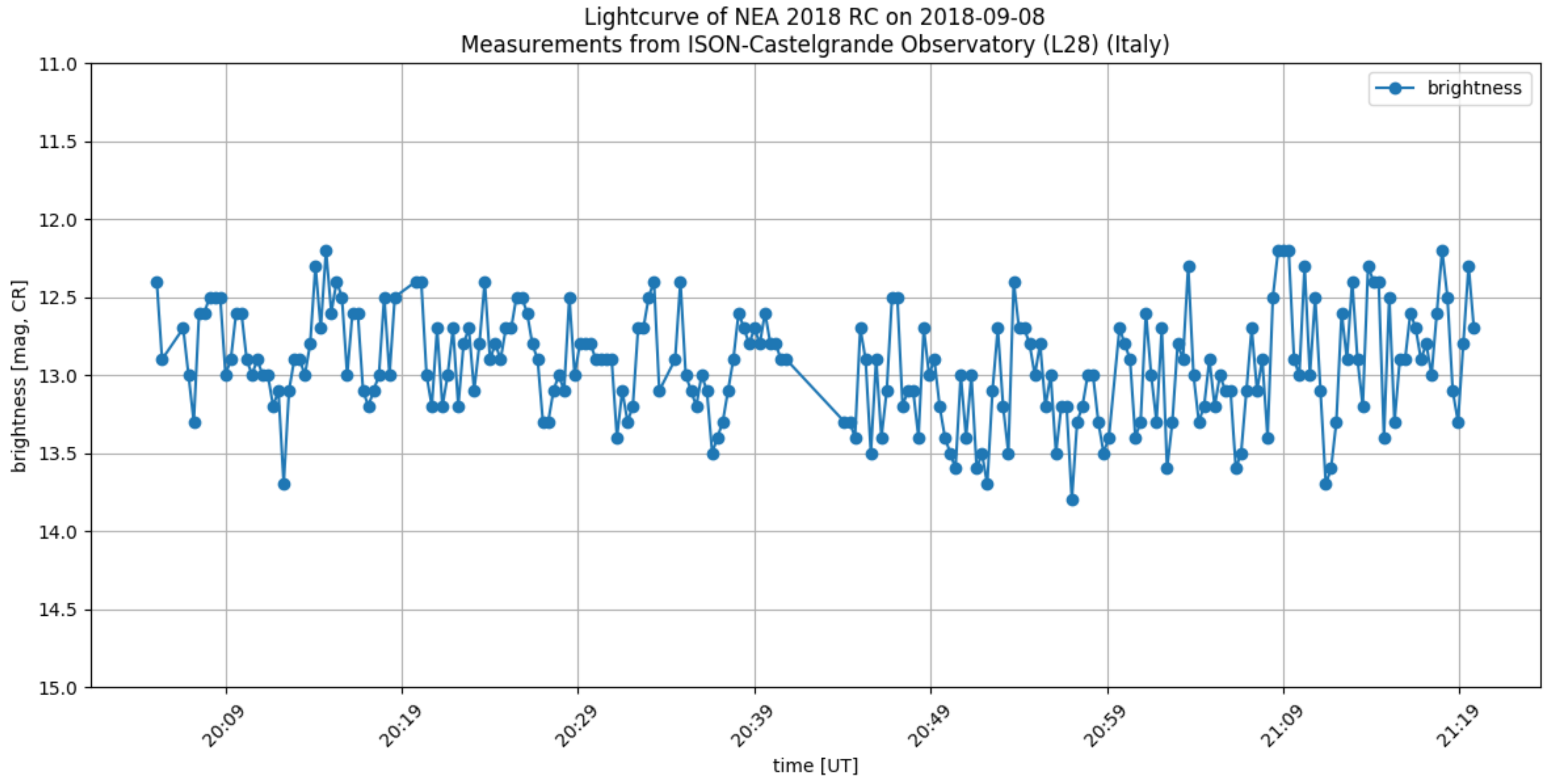
- Photometry (typical intact GEO sats):





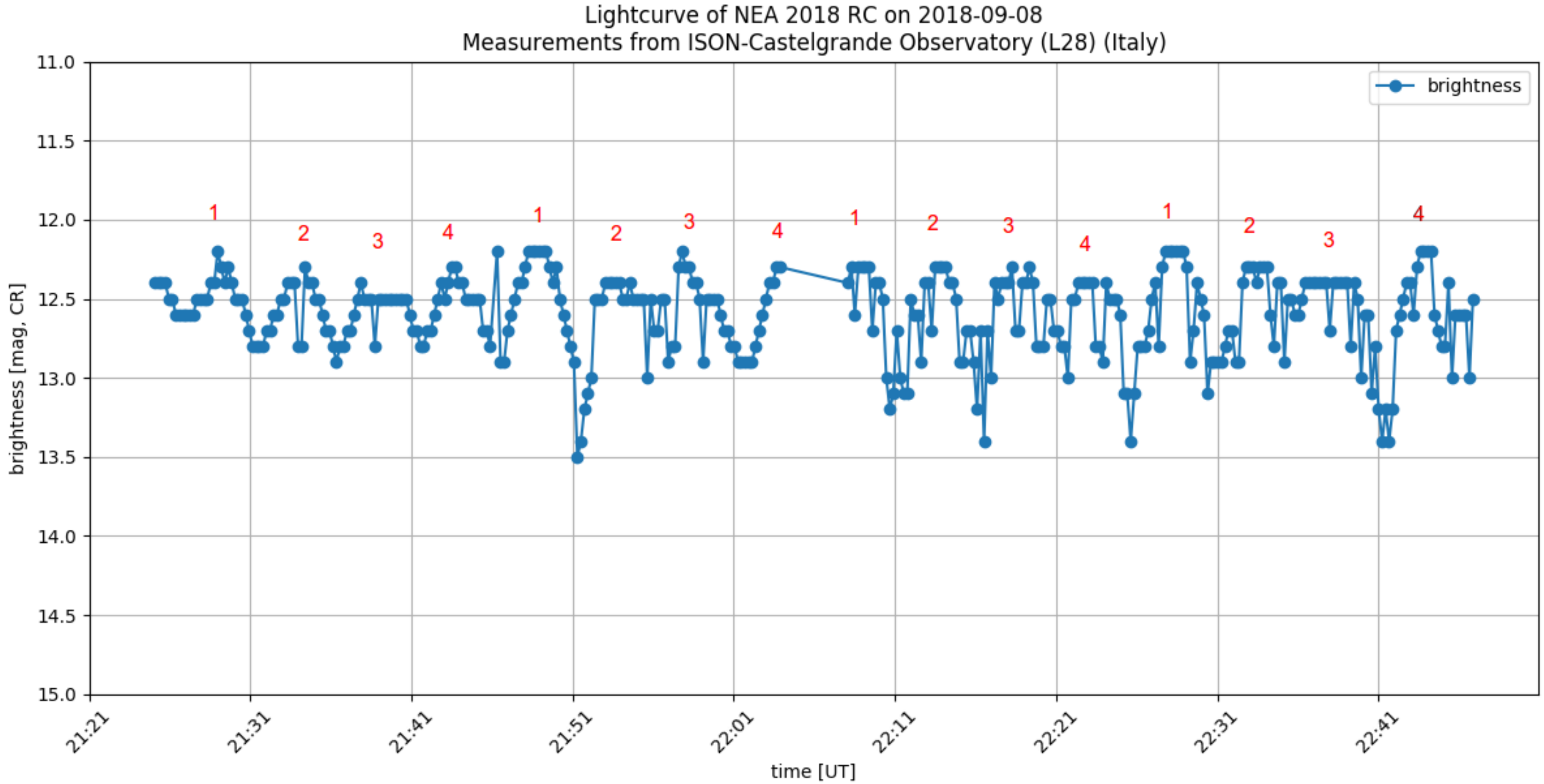
Observations

- Photometry:
  - Near-Earth Asteroids:



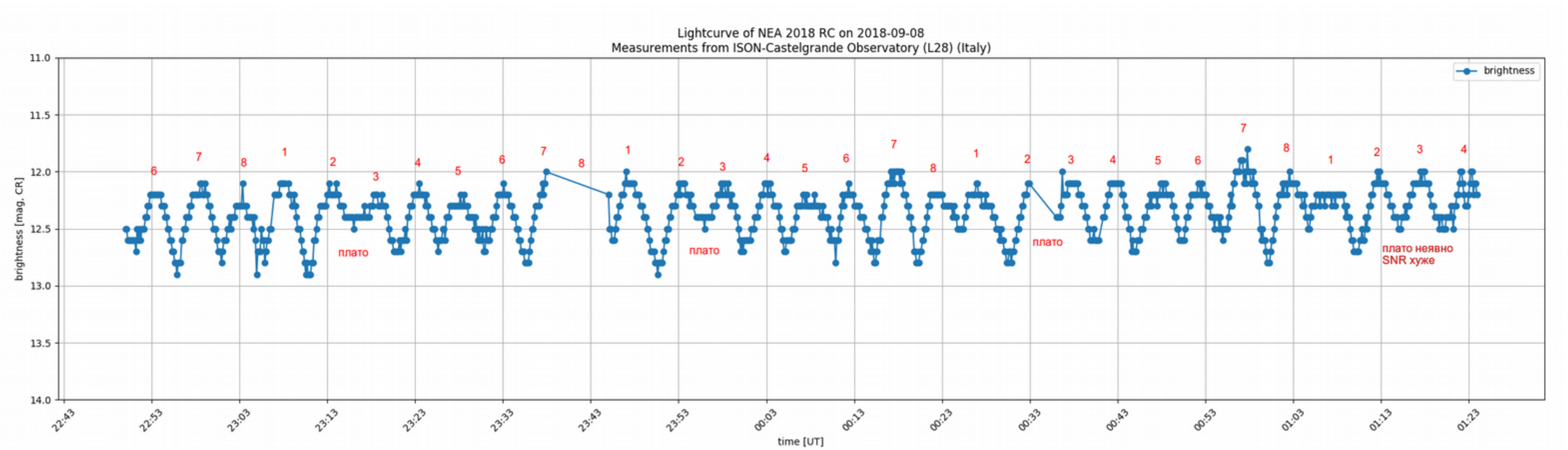
Observations

- Photometry:
  - Near-Earth Asteroids:



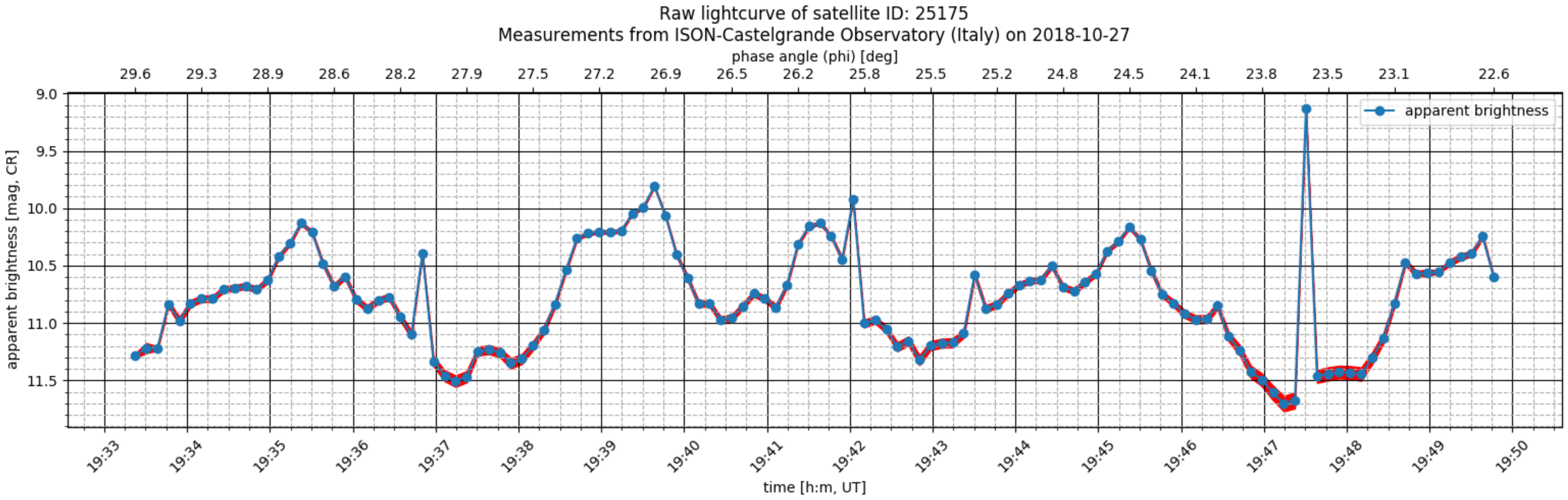
Observations

- Photometry:
  - Near-Earth Asteroids:



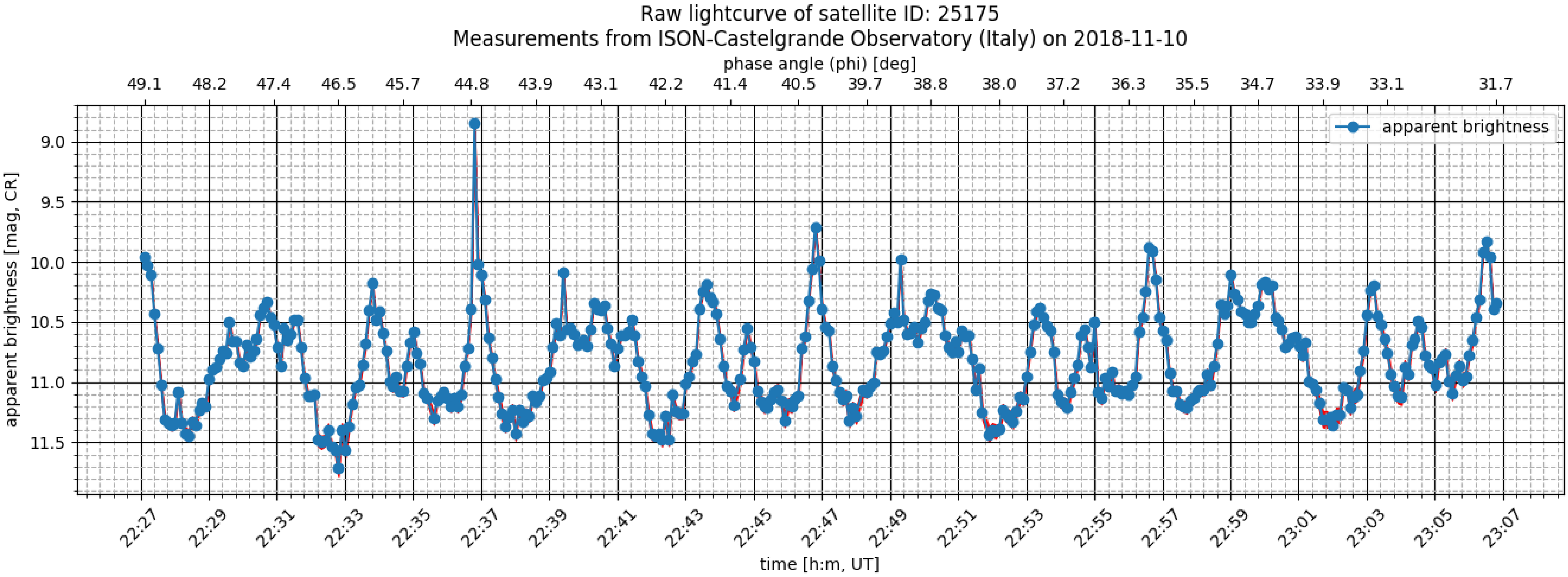
Observations

- Photometry:
  - COMETS (1998-011A), a failed GEO satellite in HEO:



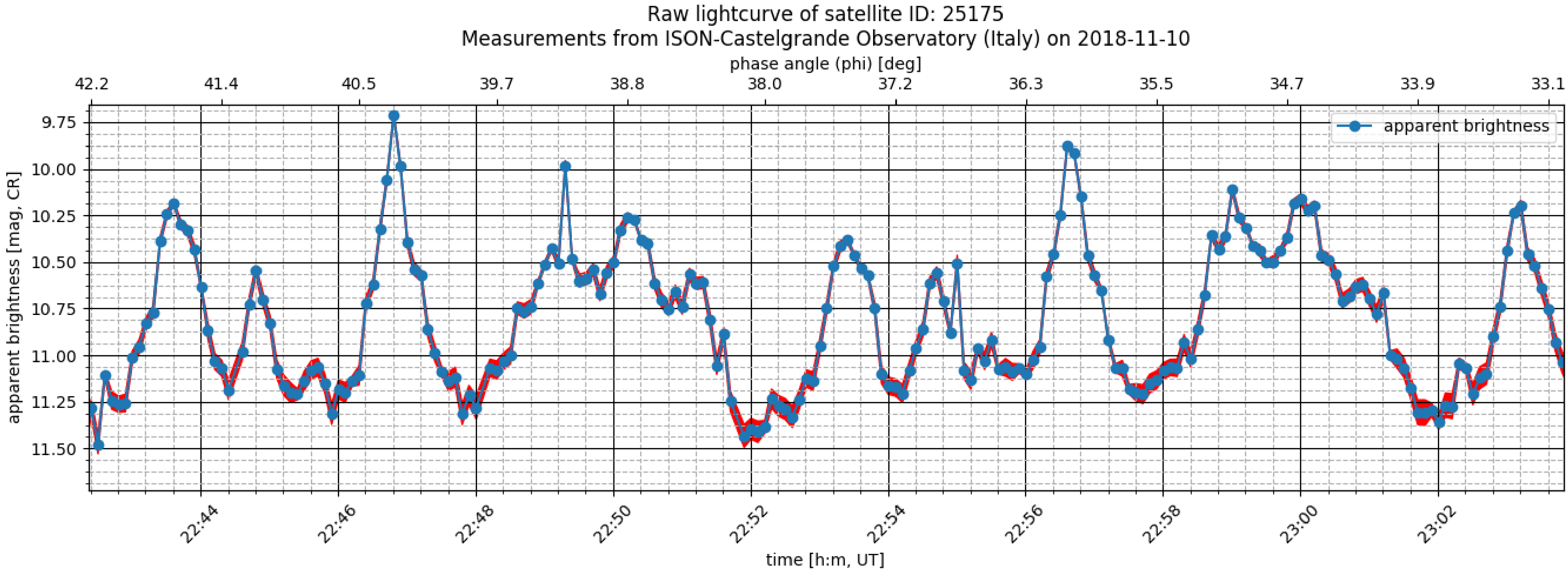
Observations

- Photometry:
  - COMETS (1998-011A), a failed GEO satellite in HEO:



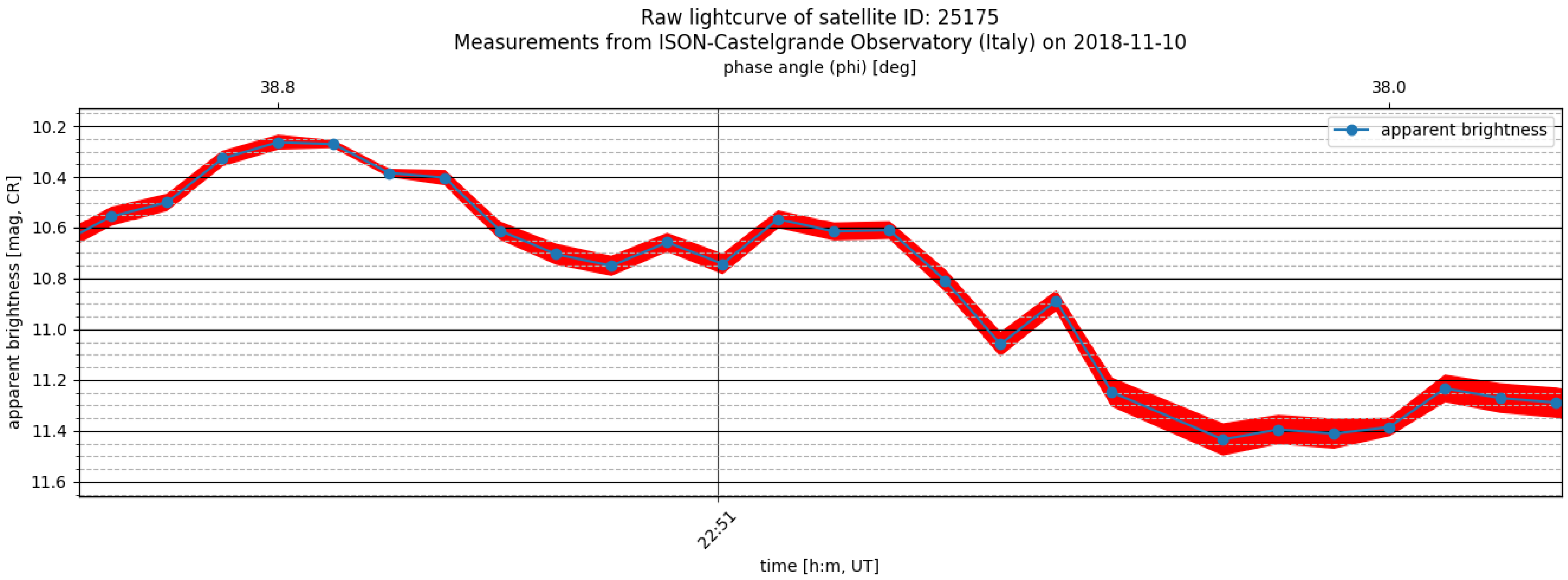
Observations

- Photometry:
  - COMETS (1998-011A), a failed GEO satellite in HEO:



Observations

- Photometry:
  - COMETS (1998-011A), a failed GEO satellite in HEO:



Observations

- Photometry:
  - based on XML data output by APEX:

<data>
<meas>
<id>25175</id>
<utc>2018-10-27T19:33:22.500000</utc>
<ra_j2000>0.769910169652</ra_j2000>
<dec_j2000>-8.82323289288</dec_j2000>
...
<snr>53.7844287515</snr>
<mag>11.2831033147</mag>
<mag_error>0.0201868129859</mag_error>
</meas>
...
</data>

Outlook

- 35-cm Ritchey-Chrètien:
  - 3-m Scopedome cupola
  - Skywatcher EQ-8 Pro SynScan mount

Outlook

Outlook

- **Online:** observatory website; **hardware:** SQM-LE, all-sky camera
- **Interaction with:**
  - INAF-OAC, Italy (154-cm)
  - ISON-Khureltogoot Observatory, Mongolia, MPC code O75 (19-cm & 40-cm)
  - ISON-Urumci Observatory, China (25-cm)
  - AIUB, Switzerland (80-cm)
- **Observations:**
  - refinement: minor bodies of the Solar System (MPC observatory code L28 received on 24.06.2018)
  - refinement: optical GRB afterglows
  - new: variable stars (VaST software) / SN & optical transients (a new APEX module)
  - new: exoplanet transits (APEX) / asteroid occultations
  - new: meteors (video + radio)
- **Software:**
  - (FORTE) schedule script format for planning of survey mode satellite observations
  - (APEX) orbit catalog based Python script for planning of tracking mode satellite observations
  - (APEX) satellite photometry pipe-line, analysis tools, database, 3D object modelling
  - (FORTE & KDS) new space object alert observation and follow-up system

Grazie!