Inter-Agency Space Debris Coordination Committee

IT 34.1

Feasible options to study Molniya population of space debris

Coordinators: Lorenzo Mariani (ASI), Pascal Richard (CNES)

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Description

The internal task aims to promote a coordinated precursor observing campaign:

- Joint observation of calibration target, in order to improve observation strategies, analysis methods and results refinement and to foster findings exchange among participants.
- Statistical search for uncatalogued Molniya objects.
- Accurate orbital determination of some Molniya-like target objects to investigate long term orbital evolution.
- Statistical survey for some target Molniya-like objects aiming to investigate coupling between attitude dynamics and orbit evolution.
- Support forensics of events in Molniya.

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Statistical survey

Coordinators: Lorenzo Mariani (ASI), Pascal Richard (CNES)

Statistical survey

Planning

To perform **orbit determination** on these 10 targets, it is necessary to acquire **measurements both when they are at apogee and at perigee**. To observe as **many objects as possible** during a single night, instead of continuously observing the object for an extended period while it is at apogee, it is preferable to **observe it twice during the same pass**, leaving a temporal interval between observations. This also **extend the observed arc of the orbit**.

The details for this campaign were:

- **Targets**: 10 objects in TLE tracking
- **Observation period**: Jul. 2023 – Apr. 2024
- **Analysis**: astrometric and photometric
- **Apogee observation**: one series with minimum 200 frame or two series with minimum 100 frame each one
- **Perigee observation**: one series with as high number of frames as possible
- **Output for each observation**: the observatory coordinates and one TDM with topocentric RA, Dec and one TDM with observed luminous flux

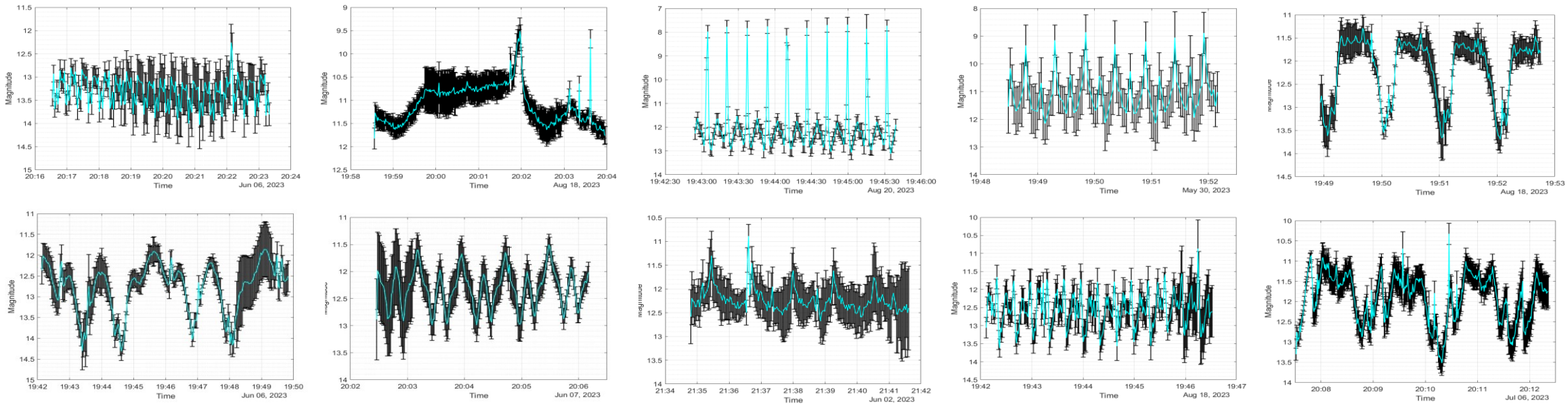
Statistical survey

Participation of ASI

92 Molniya satellites belonging to recent or past constellations were selected. **About 50% of these objects were observed** by ASI and **10 objects** with interesting light curves **were selected** among them.

ASI acquired approximately **2500 astrometric and photometric measurements for the 10 targets between July and August 2023**.

Of these targets **12376 and 14790 have the perigee in the north hemisphere**. It can be interesting to understand if and how the attitude motion has affected this change.



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Statistical survey

COEs trends

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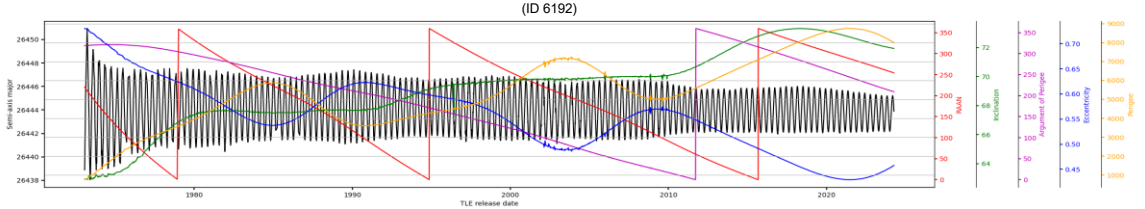

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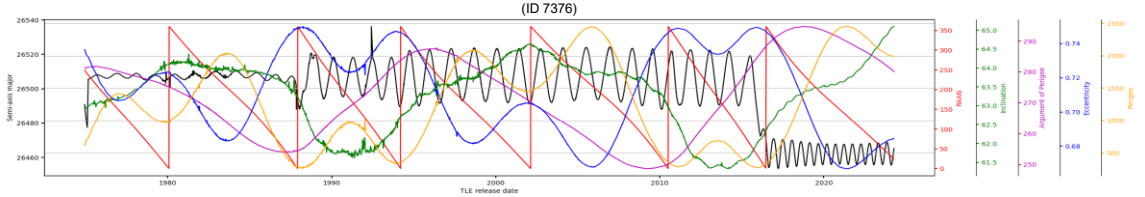

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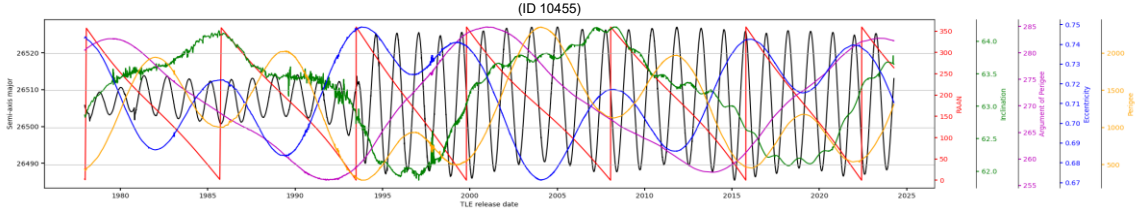

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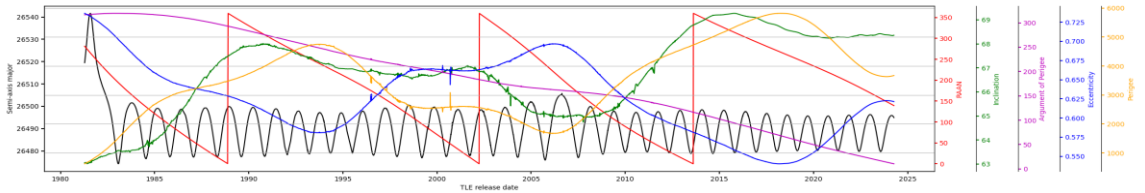

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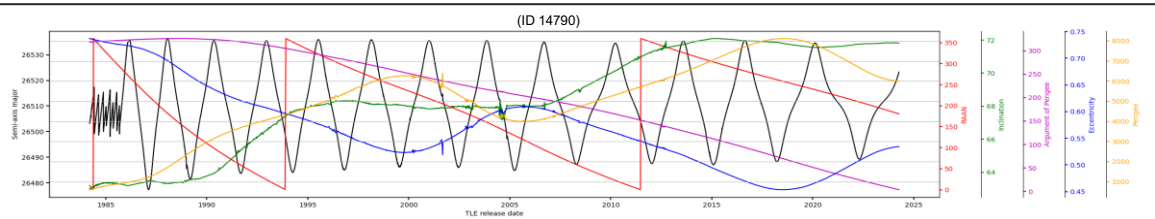

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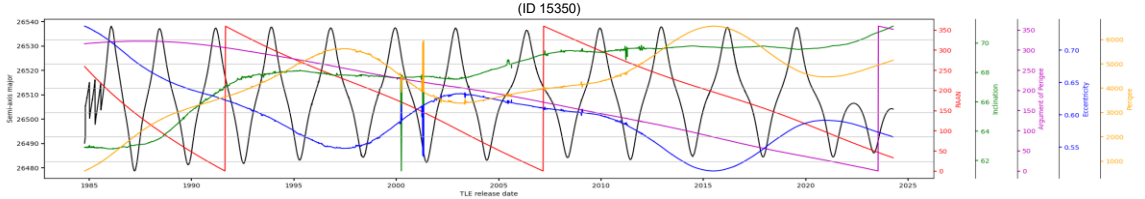

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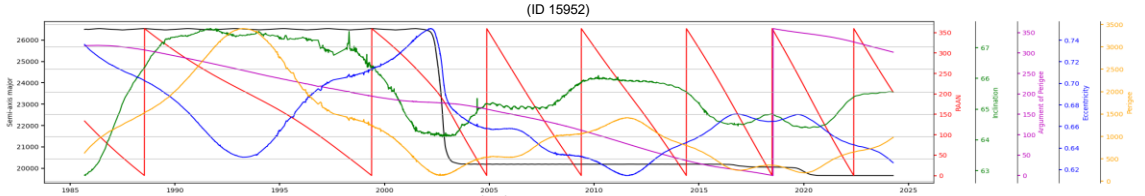

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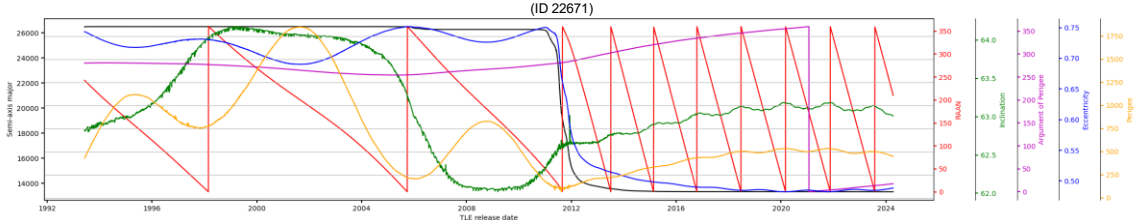

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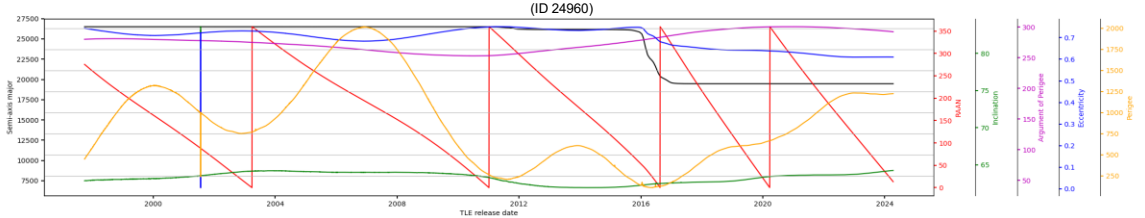

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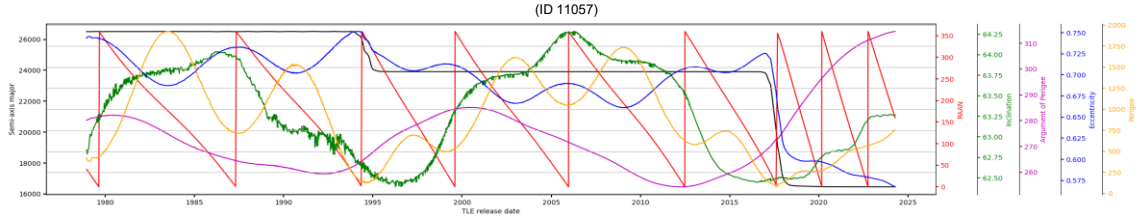

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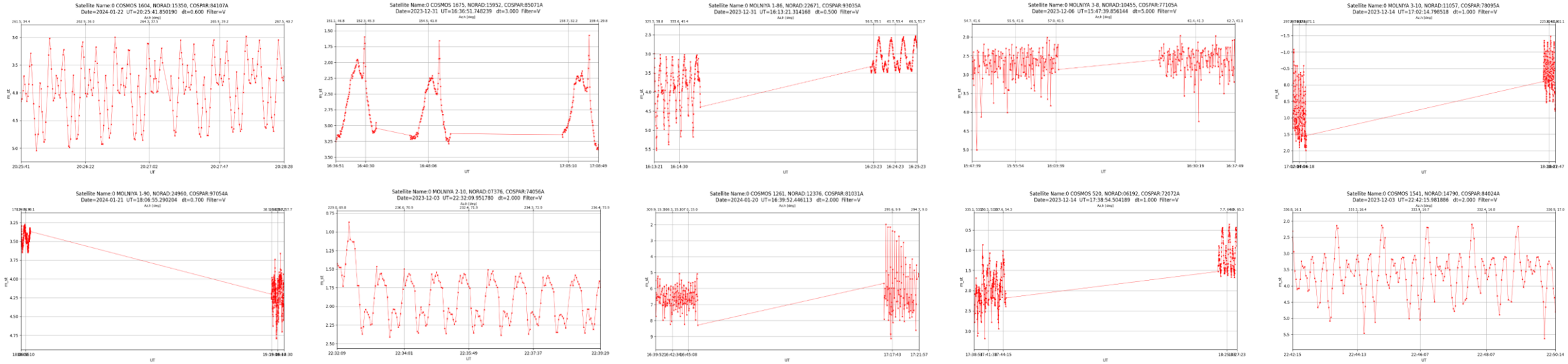
Statistical survey

Participation of SSAU

Up to April 2024, measurements have been obtained from **6 telescopes over 73 nights**, with some nights **involving observations from multiple telescopes**. These observations yielded a total of **411 astrometry tracks** and produced **more than 200 light curves from 4 telescopes**.

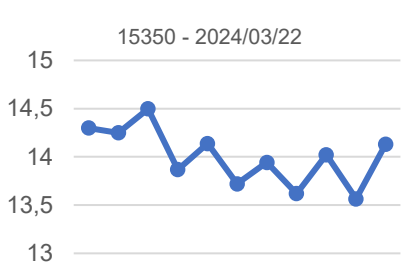
On March 20th, for **12376**, despite the unfavourable weather conditions and a limited number of observations, SSAU managed to capture **the transition from brightness fluctuations with a relatively small amplitude to fluctuations** with a significantly greater amplitude (about 2 magnitudes higher for observations corrected per 1000 km). SSAU had previously observed **similar transitions for the LEO satellites 13552 and 18340**, but it was the first time such a moment had been observed for HEO satellites.

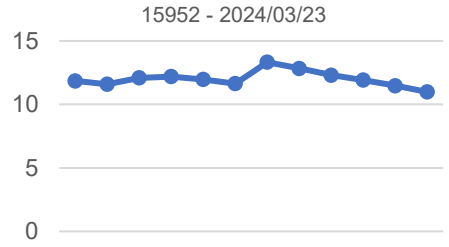


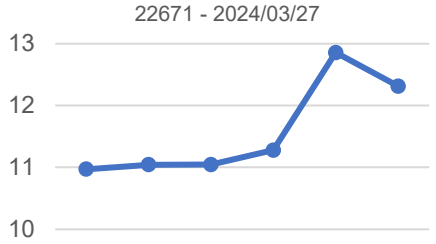
Statistical survey

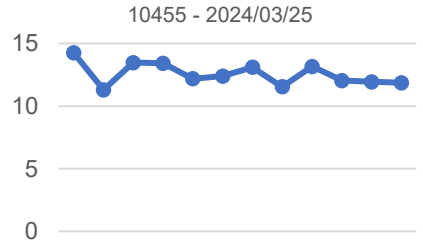
Participation of CSA

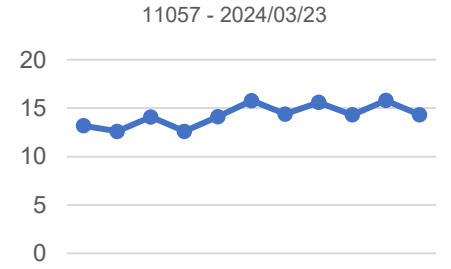
In March 2024, **space-based measurements** were obtained from **NEOSSat**. The CSA successfully collected approximately **300 photometric and astrometric measurements** over the course of **six consecutive days**, covering **9 of the 10 designated targets**.

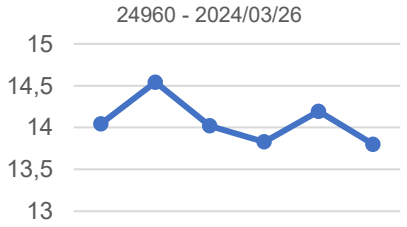


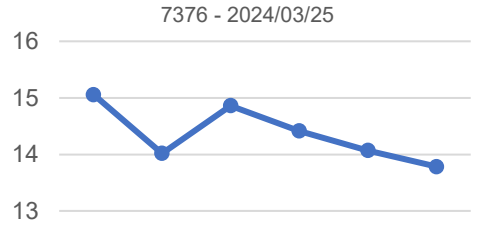


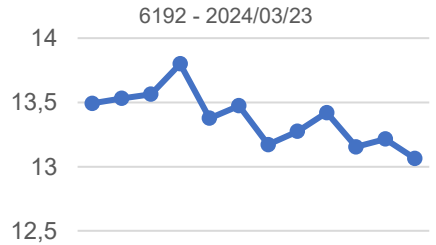


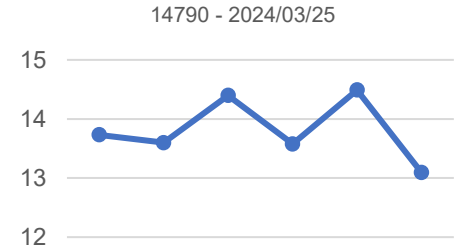












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IT 34.1

Statistical search

Coordinators: Lorenzo Mariani (ASI), Pascal Richard (CNES)

Statistical search

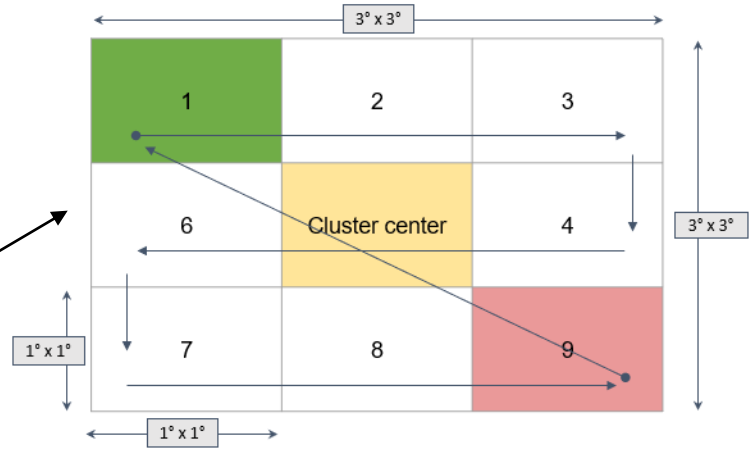
Planning

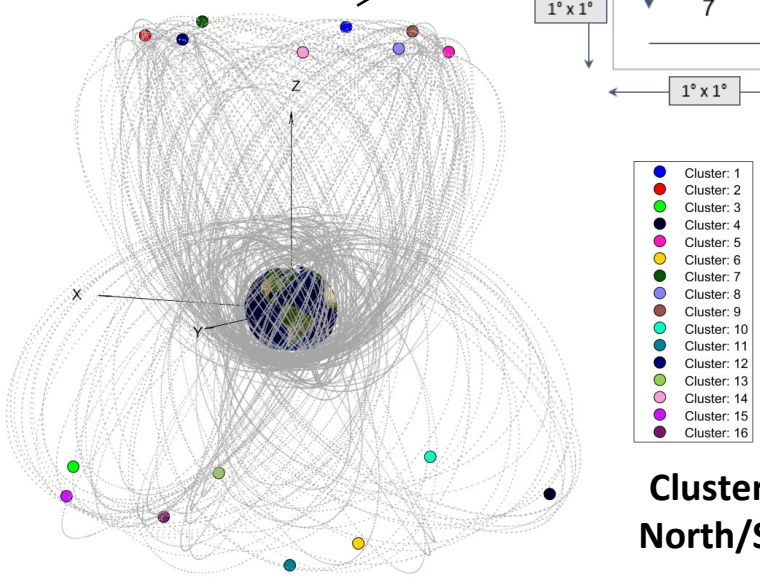
The method presented to identify new objects is based on observe regions in which the current catalogued Molniya apogee density is maximum. The strategy tries to guarantees the acquisition of **more than one frame for the observation of an object**.

The details for this campaign were:

- **Observation mode:** sidereal tracking
- **Observation period:** from March 18th, 2024, to March 24th, 2024
- **Observation duration:** 7 days
- **Suggested consecutive nights:** 3 nights (minimum 2 nights)
- **Suggested observation duration:** 6 hours/night (minimum 4 hours/night)
- **Analysis:** astrometric
- **ROI acquisition strategy:** scanning at least two time the chosen cluster
- **Cluster acquisition strategy:** at least two consecutive frames for each sub region inside the chosen cluster

Cluster observation strategy





Clusters centroids in the North/South Hemisphere

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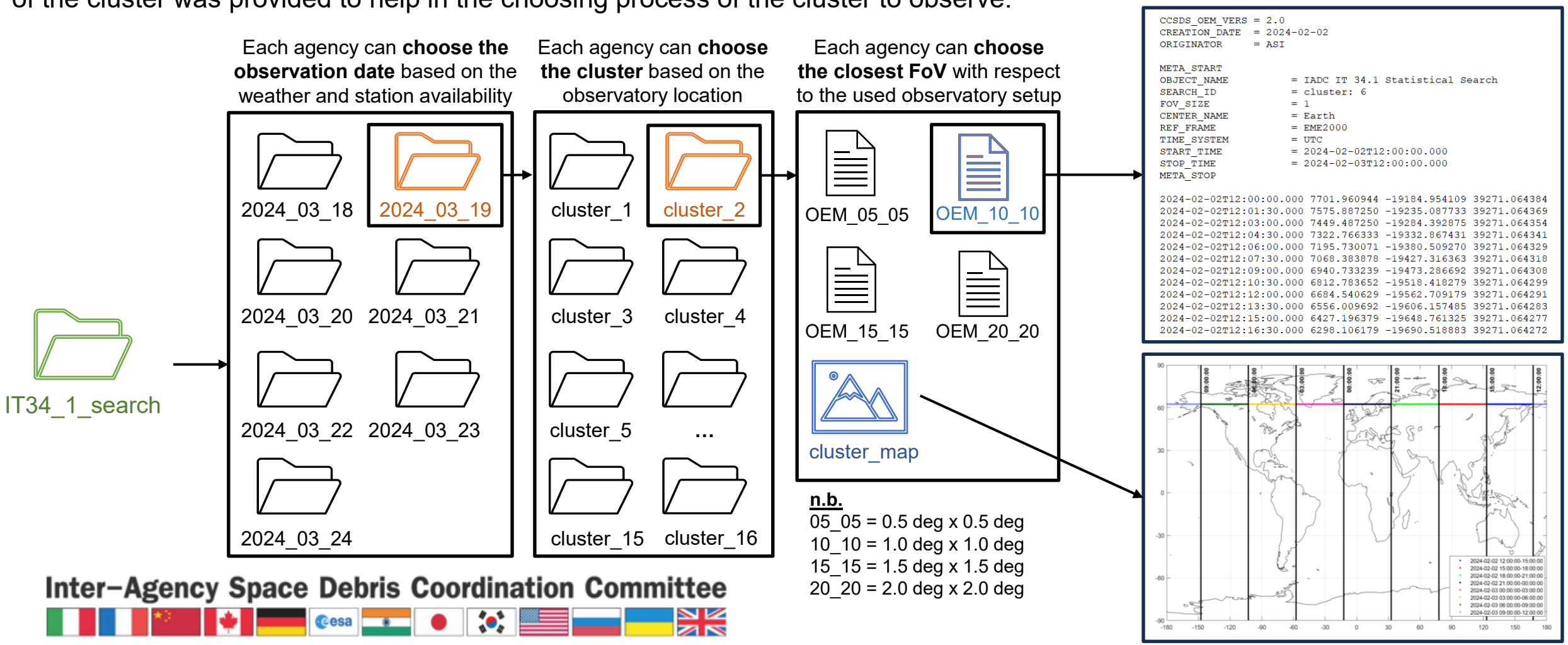
Statistical search

Input from ASI

ASI provided a folder containing OEM format text files, with X, Y, Z coordinates in ECEF for each cluster (north and south hemispheres) and for four typical FoV. For each day and for each cluster, a map in geographic coordinates with the ground tracks of the cluster was provided to help in the choosing process of the cluster to observe.



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Statistical search

Participation

- **ASI**

Three nights of observation were conducted to verify the strategy, focusing on one cluster. Then, **six more nights** of observation were conducted, but with both cameras of the SCUDO observatory, and different clusters was observed. ASI was only able to observe **for two consecutive days**, **March 19th and 20th**, during the planned week due to unfavourable weather conditions.

- **SSAU**

During the survey phase, SSAU conducted observations over **three consecutive nights using a single telescope**. Each night, a varying number of fields of view were captured, with **five frames for each field**. On **March 18th, cluster 3** was targeted with **225 fields** acquired, followed by **227 fields** acquired for **cluster 5 on March 19th**. On **March 20th**, another observation of **cluster 3** was conducted, capturing **251 fields**, **totalling 3515 images**. During this period, **a total of 12 objects were detected, including 2 UTCs, 1 in LEO, and 3 in MEO**.

- **DLR**

DLR conducted observations **from Chile** over the course of **three nights**, specifically **on March 19th, 21st, and 24th**, during which they acquired over **2000 images in total**. The analysis of these images is currently underway, and as such, the exact number of tracklets and objects acquired is not yet known.

- **CNSA**

5 night of observation was carried out by CNSA from March 18th to March 24th and the data reduction is in progress.

Statistical search

Results from ASI

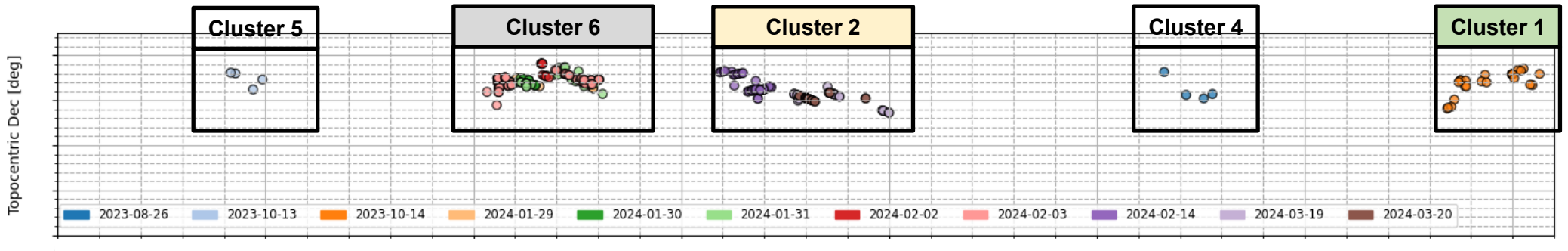
Observation date	Cluster	Observation duration	Total Frames		Tracklets number		Catalogued detected		UTCs	
			CAM1	CAM2	CAM1	CAM2	CAM1	CAM2	CAM1	CAM2
2023-08-26	4	7.5 h	1440	N/A	18	N/A	14	N/A	4	N/A
2023-10-13	5	7.5 h	840	N/A	12	N/A	8	N/A	4	N/A
2023-10-14	1	8.5 h	1020	N/A	38	N/A	15	N/A	23	N/A
2024-01-29	6	8.5 h	1000	1050	19	14	12	5	7	9
2024-01-30	6	6.5 h	736	750	15	12	8	6	7	6
2024-01-31	6	10.5 h	1269	1290	42	30	21	20	21	10
2024-02-02	6	10.0 h	872	1835	43	81	39	71	4	10
2024-02-03	6	10.5 h	964	1928	38	139	24	90	14	49
2024-02-14	2	10.0 h	848	1711	34	108	31	69	3	39
2024-03-19	2	8.5 h	N/A	1434	N/A	38	N/A	7	N/A	31
2024-03-20	2	5.5 h	N/A	916	N/A	30	N/A	11	N/A	19

Comparison with NORAD public catalogue in spacetrack.org
To be compared with vimpel.ru

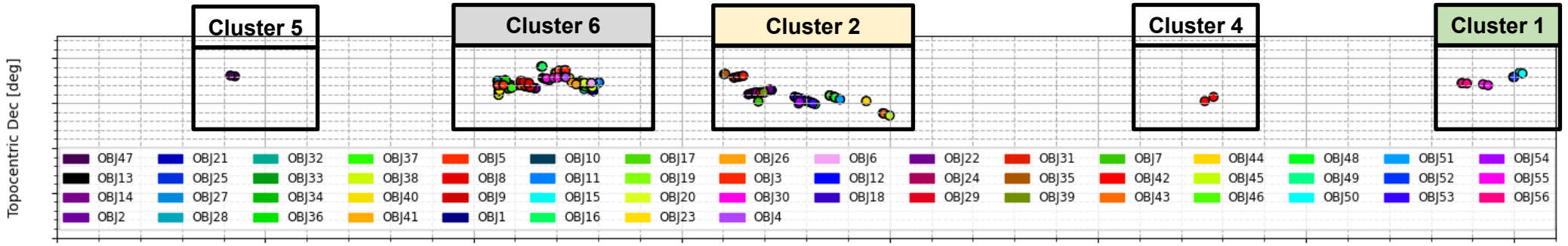
Statistical search

UTCs from ASI

UTCs
Nº tracklets = 260

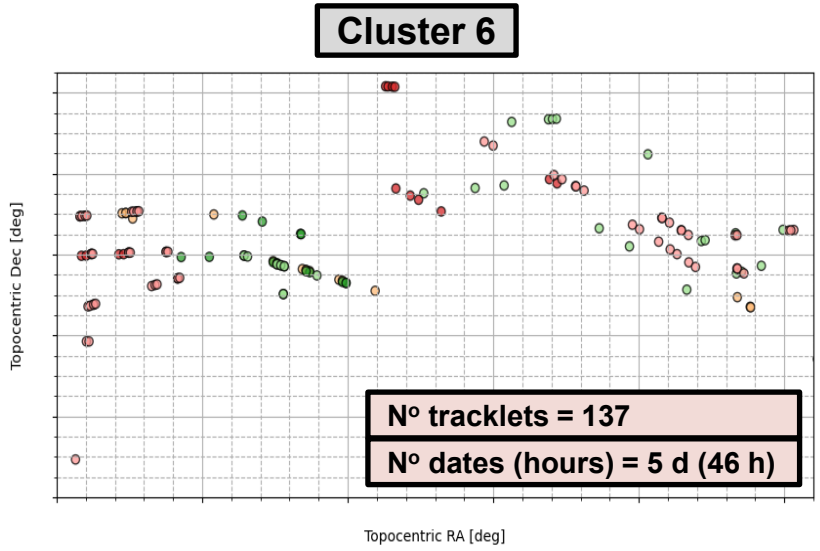


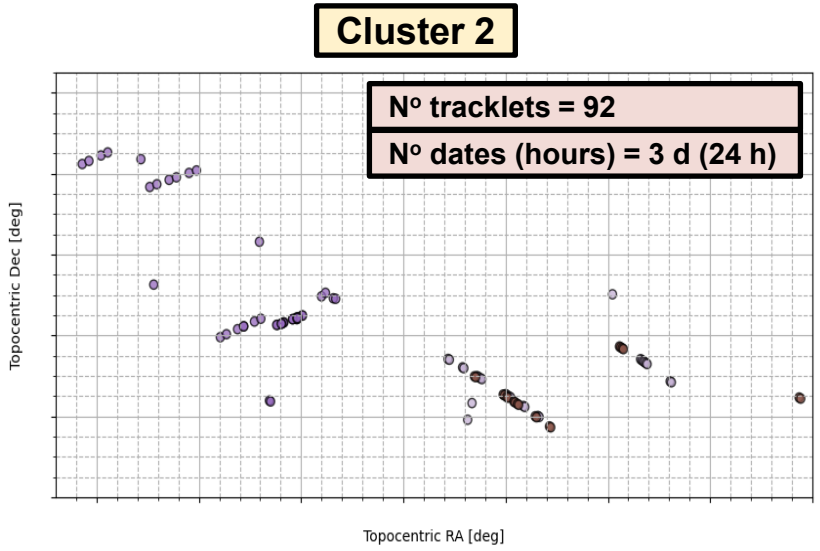
Associations
Nº objects = 56

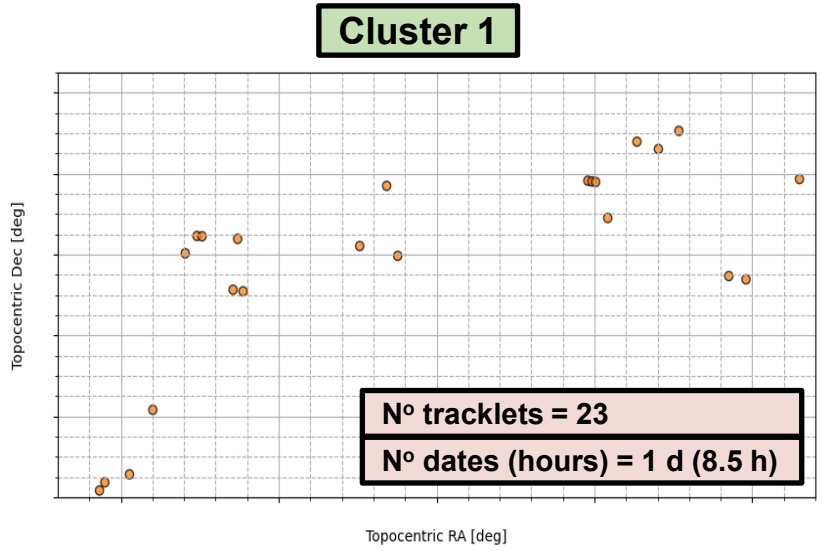


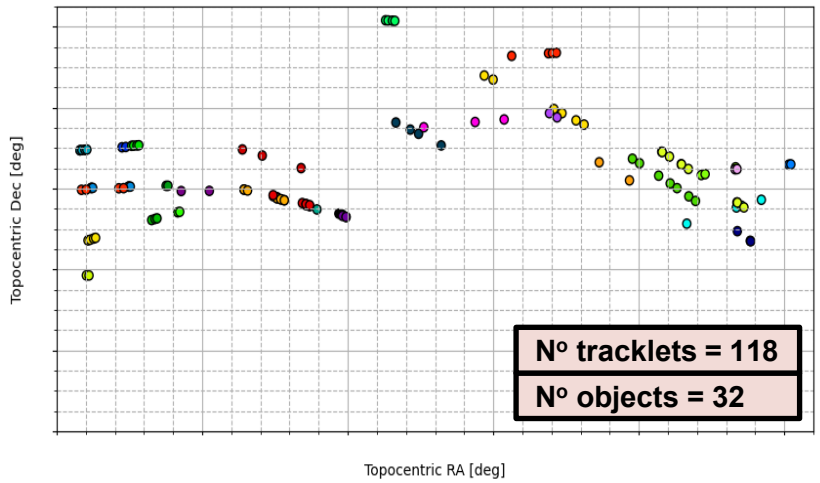
Statistical search

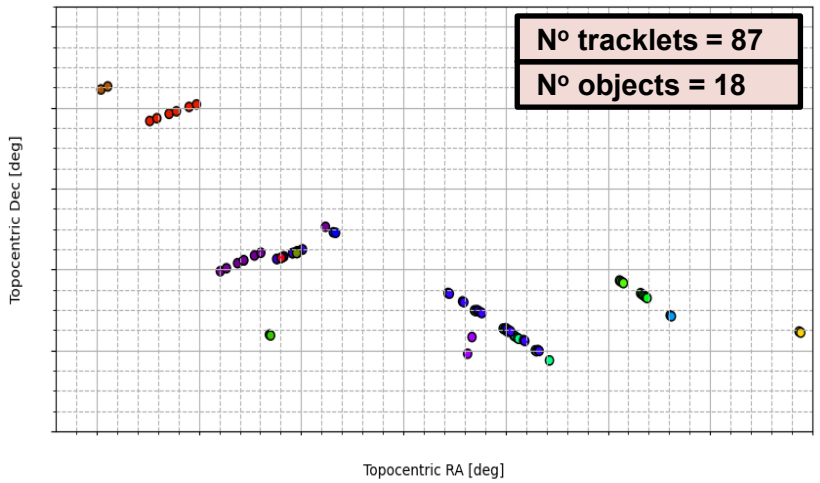
Associations

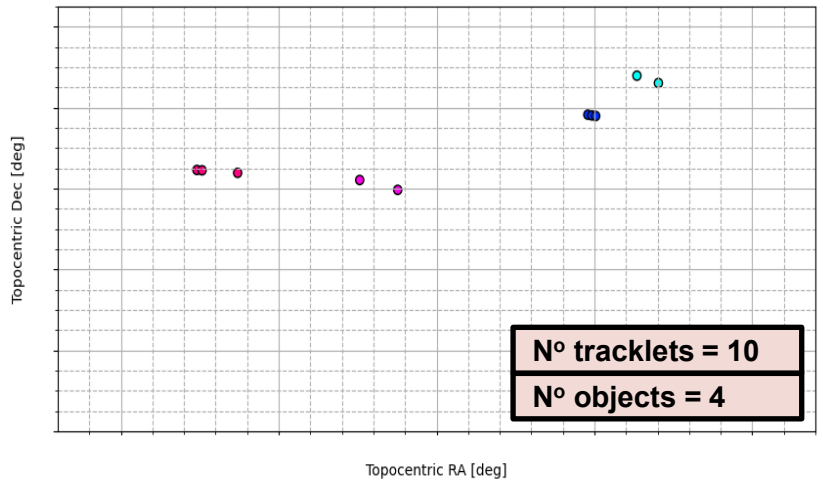










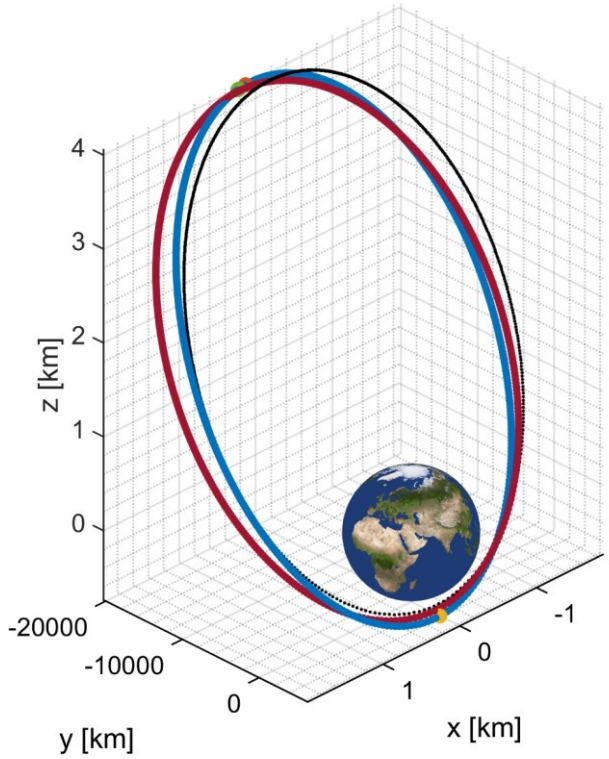


Statistical survey

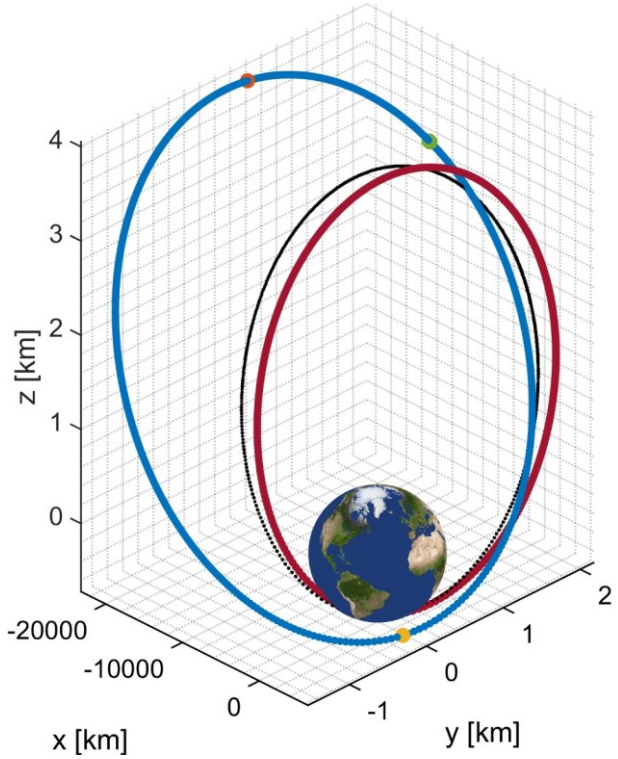
IOD / OD for catalogued

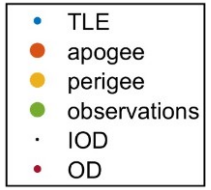
To test the IOD method was performed a comparison between the orbit generated by propagating the TLE of the observed object and the orbits generated using two-point IOD and OD based on all available measurements (10 for NORAD ID 47719 and 4 for NORAD ID 23645).

Apogee observation



Near apogee observation





Angular Errors in Perigee observation

	IOD	OD
Apogee	7.194 deg	39.897 deg
Near apogee	139.435 deg	134.339 deg

Considerations:

The IOD method imposes the apogee near to the acquired measurements, so:

- If the measurements are not taken at the apogee, both IOD and OD orbits presents large error.
- If the **measurements** are taken **at apogee**, **both IOD and OD yield consistent orbits**.

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IT 34.1 – Statistical survey

Conclusions

- ASI, SSAU and CSA have collected measurements for the 10 targets. In particular, ASI collected 2500 astrometric and photometric measurements from 10 targets, while SSAU collected around 200 light curves over 73 nights and CSA collected space-based measurements of these targets.
  - Can be interesting to **examine the light curves of these objects** and, if possible, **compare them with the ones of satellites launched during the same period that have not changed their period** (if available).

- The list with the 10 targets was passed by ASI to the **WG2** to **simulate the behaviour of fragmentation in Molniya** for objects that have different orbits. This simulation aims to elucidate how these objects, subjected to distinct orbital perturbations over time, respond to such influences.
  - Can be interesting to examine the light curves of all those simulated by WG2 **to understand if they differ from each other or exhibit similarities**.

- No accurate orbital determination of the 10 target objects was performed.
  - Can be interesting to propagate the initial condition at the beginning of the operational **orbit to see what happened from that moment until the perigee flipped**, and hopefully conduct a dynamic analysis.

IT 34.1 – Statistical search

Conclusions

- **ASI, SSAU, DLR and CNSA conducted observation for the statistical search** in the week that starts from March 18th, 2024, to March 24th, 2024. In particular, ASI observed for 11 night of which 2 in the joint campaign, while SSAU and DLR observed for three nights in that week and CNSA for five days.
  - Can be interesting to conduct an analysis on the UTCs using the measurements of all the agencies.

- **ASI performed IOD with Väisälä method suggested by ESA** to understand if it makes sense and could be possible **to schedule a perigee observation** after initial detection during apogee pass (IOD, scheduling, re-observation from another observatory) for objects with subsequent observations in multiple frames.
  - The results shown that **if the observation of the object is close to the apogee it can be possible to retrieve a reasonable orbit**. The problem is that **is not possible to know a-priori if** the measurement of a not catalogue object is retrieved when **the object is at the apogee**.
- It is planned to collect the lesson learnt until the IADC43