Morocco's Contribution to the Dark and Quiet Sky Initiative for Peaceful Space Uses

Presented to the Committee on the Peaceful Uses of Outer Space (COPUOS)

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Presentation Outline:

Space Weather at the Oukaimeden Observatory and dedicated instrumentation

Space Debris and Satellite Tracking: Instrumentation

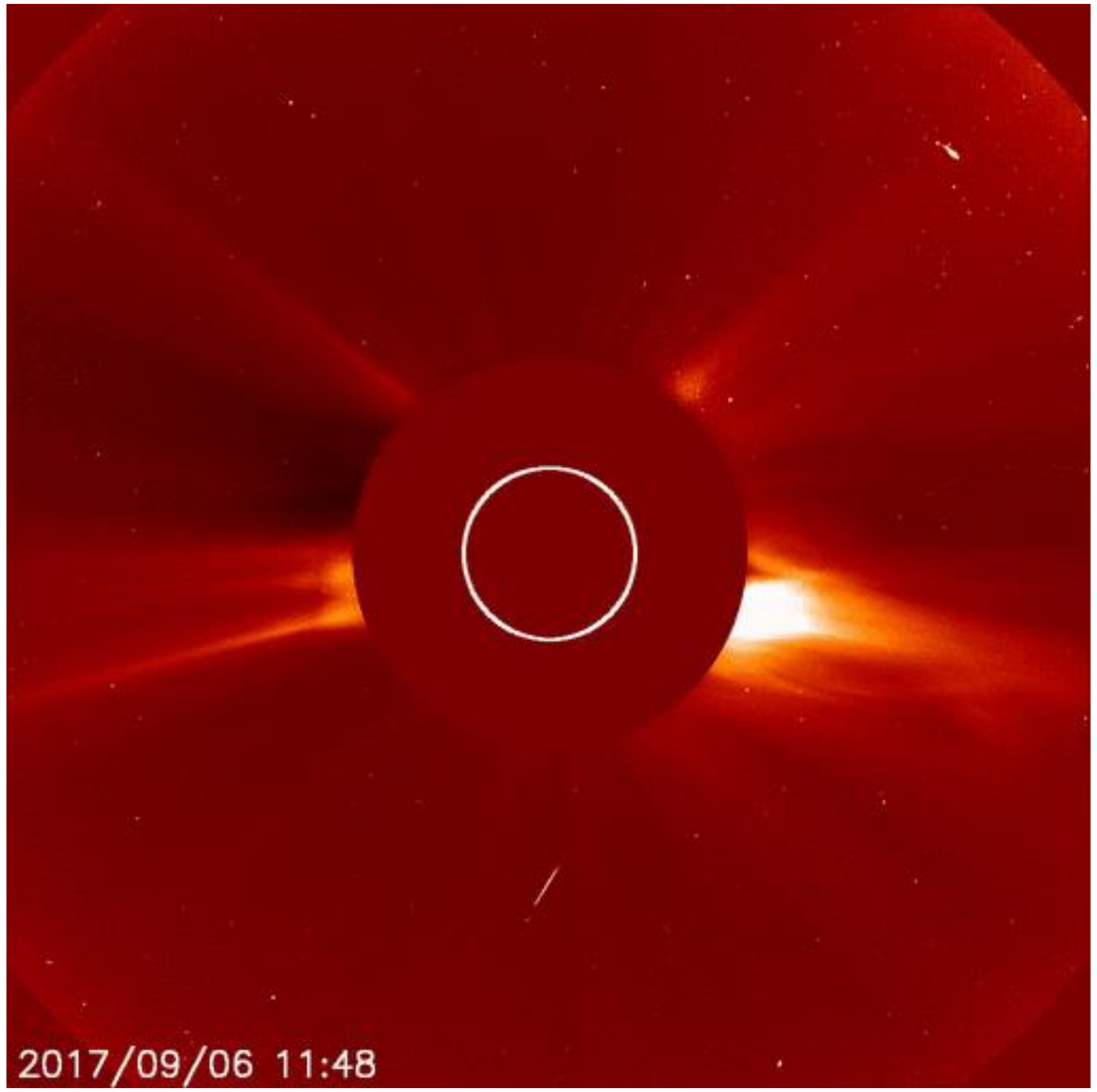
Space Debris and Satellite Tracking: Tool development and research fields

Cooperation and Networking

Recommandations

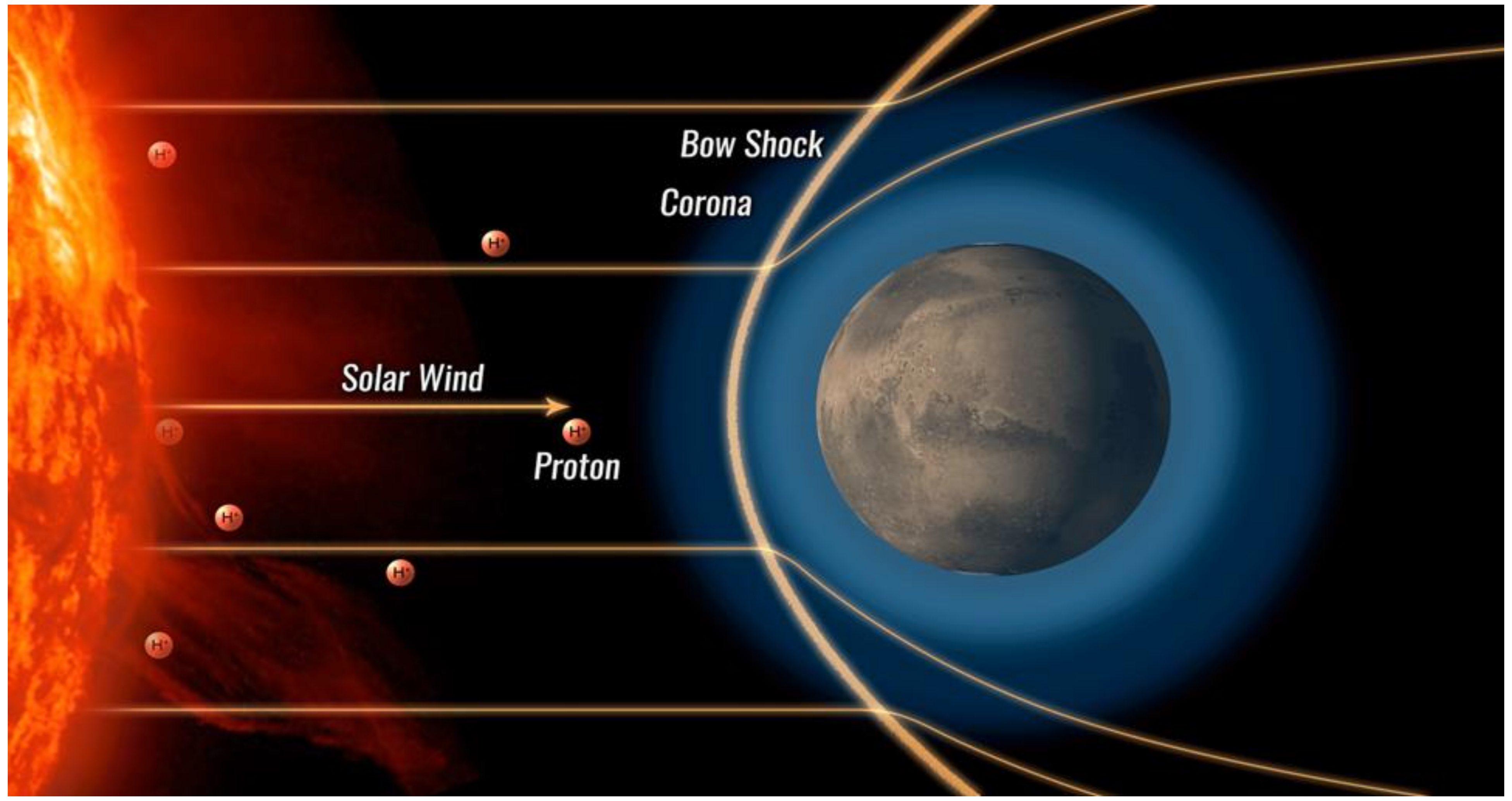
Conclusion

1 - Why is the study of SW so important?

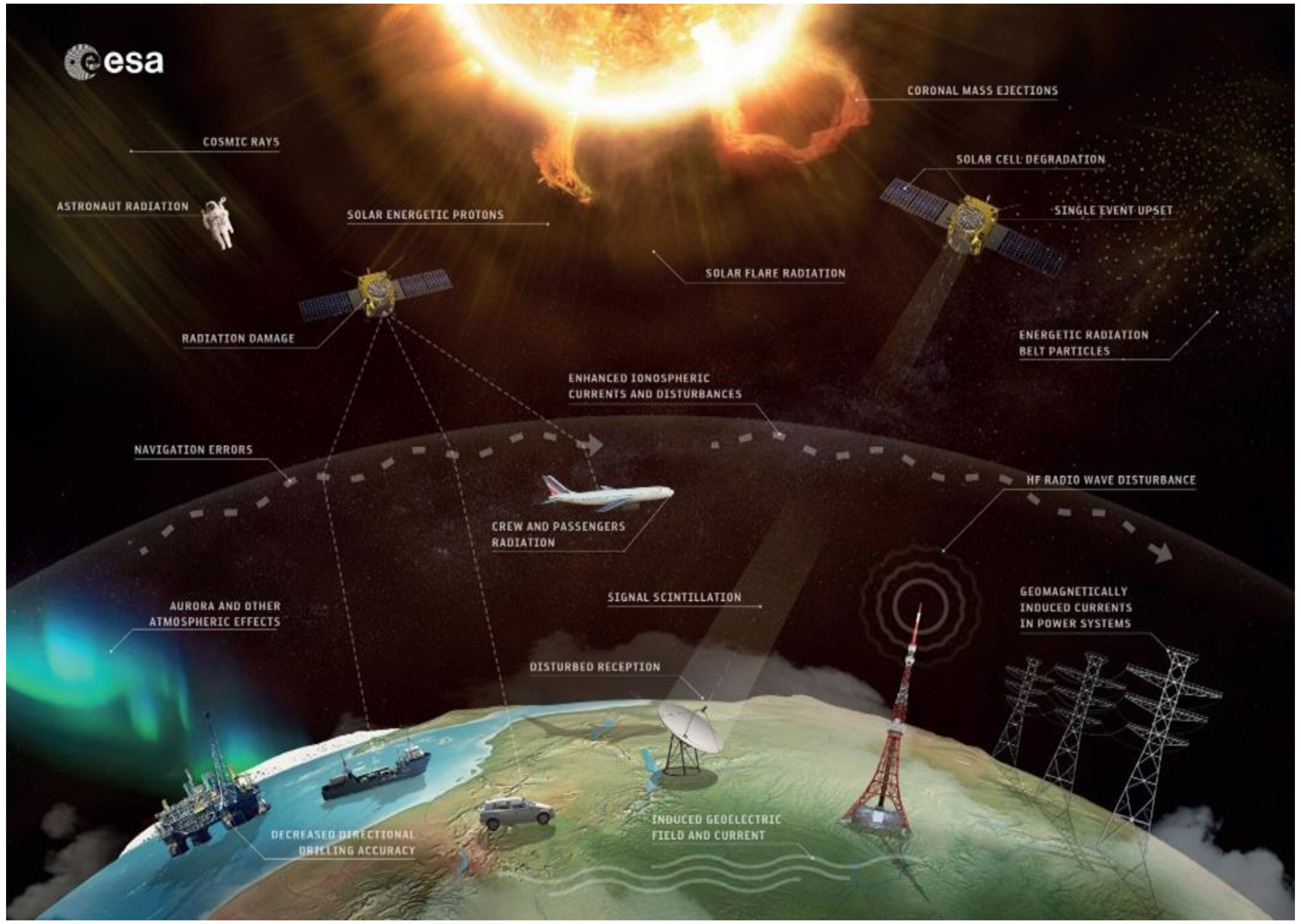


Space Weather (SW) refers to the **conditions** and **disturbances** in the space environment that are primarily caused by the **Sun's activity**

- **SW Encompasses various phenomena, including:**
  - **Solar flares,**
  - **Coronal Mass Ejections CMEs,**
  - **Solar Winds …etc**



1 - Why is the study of SW so important?



- A lot of sectors can be affected by Space Weather
  - Space-based telecommunications,
  - Broadcasting,
  - Weather services and navigation
  - Global Navigation Satellite Systems (GNSS)
  - Electric power distribution and HF…etc

- Increased radiation leads to greater health risks for astronauts,
- High energy particles causes operational anomalies and Damage to aircraft electronics,
- Disruption to power distribution networks

What about Earth's Upper Atmosphere?

1 - Why is the study of SW so important?

The ionosphere: The ionized part of the Earth's atmosphere (beyond ~90km), it is a partially ionized **magnetized** plasma

The primary source of plasma and energy for the ionosphere is:

- Solar EUV, UV, and X-ray radiation;
- also magnetospheric electric fields and particle precipitation
- as well as wave forcing from the lower atmosphere

The main effects of the SW on the ionosphere and the thermosphere:

- Changing of the plasma number density: wave propagation in radio HF range,
- GNSS: Ionospheric delay
- Ionospheric scintillation
- Ion drag…etc

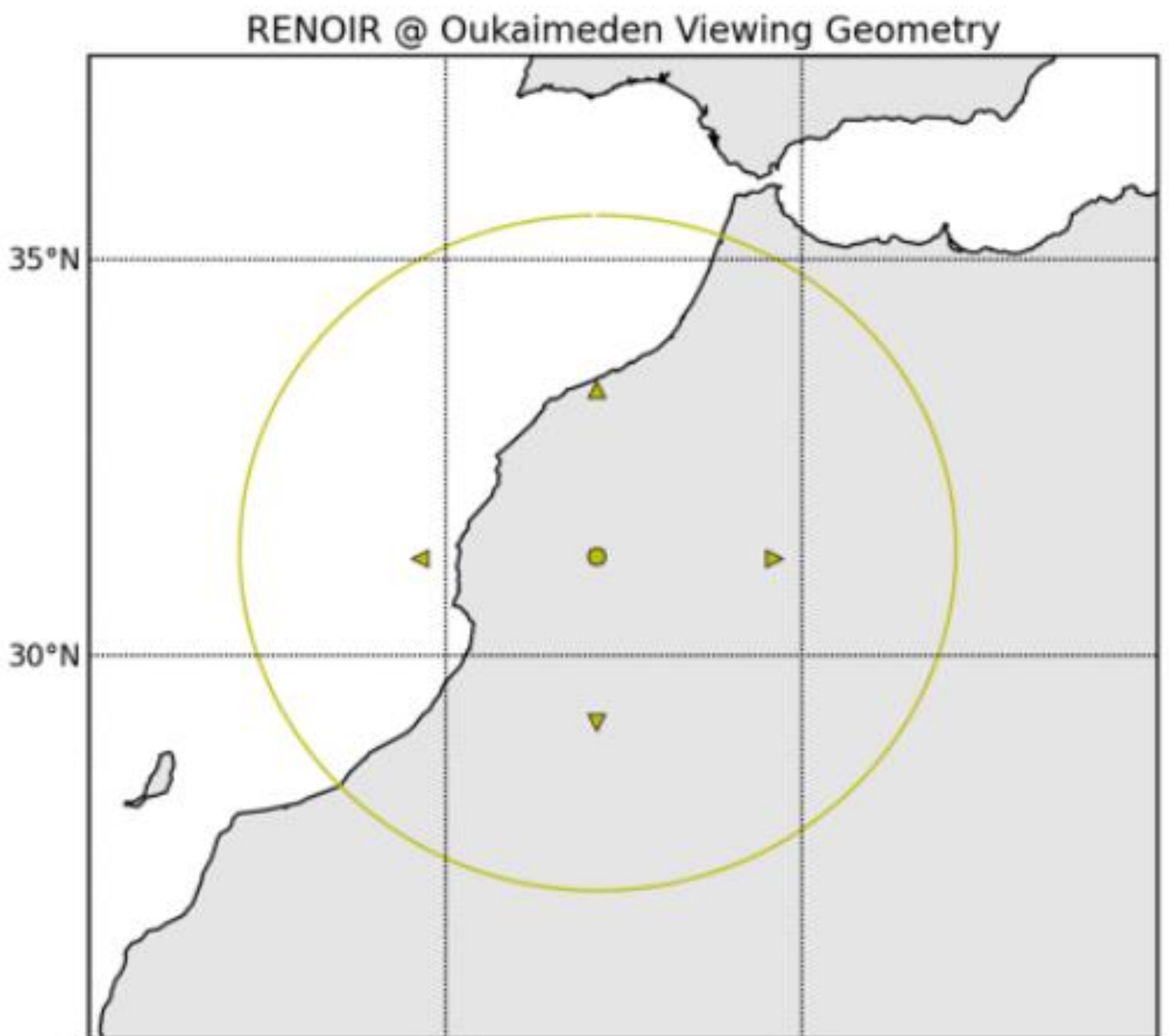
Hence the crucial need for monitoring, studying and predicting the effects of space weather

2 - To explore the thermospheric-ionospheric coupling:

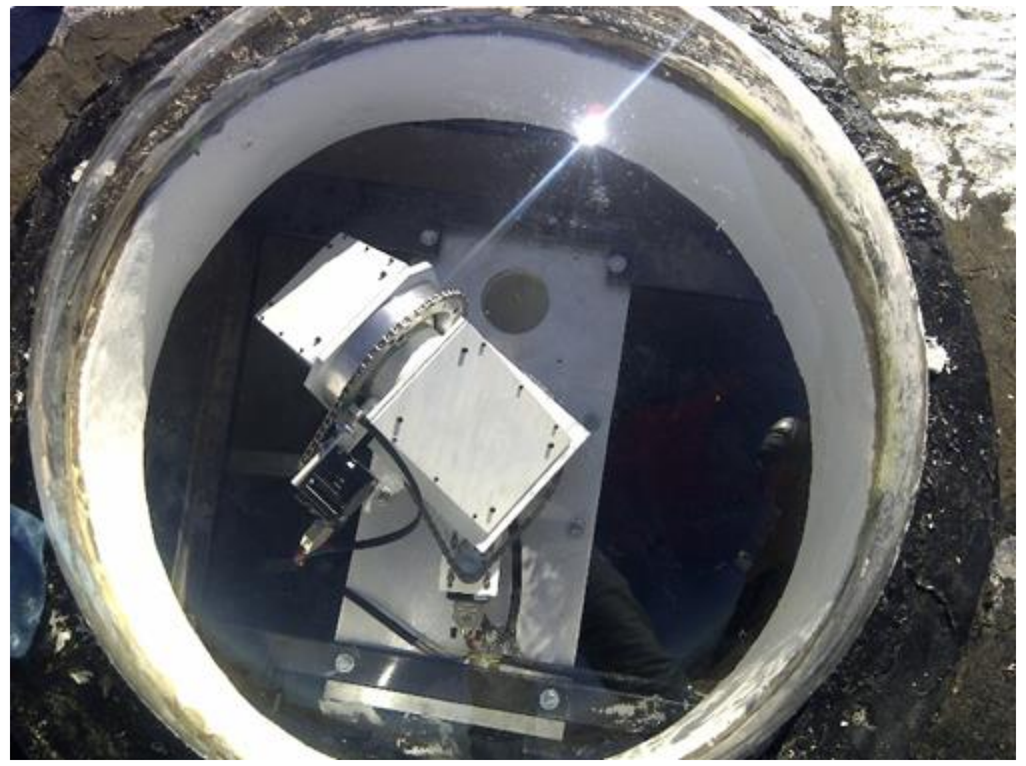
RENOIR experiment installed at Oukaimeden Observatory since November 2013:

A FPI interferometer accurately measures:

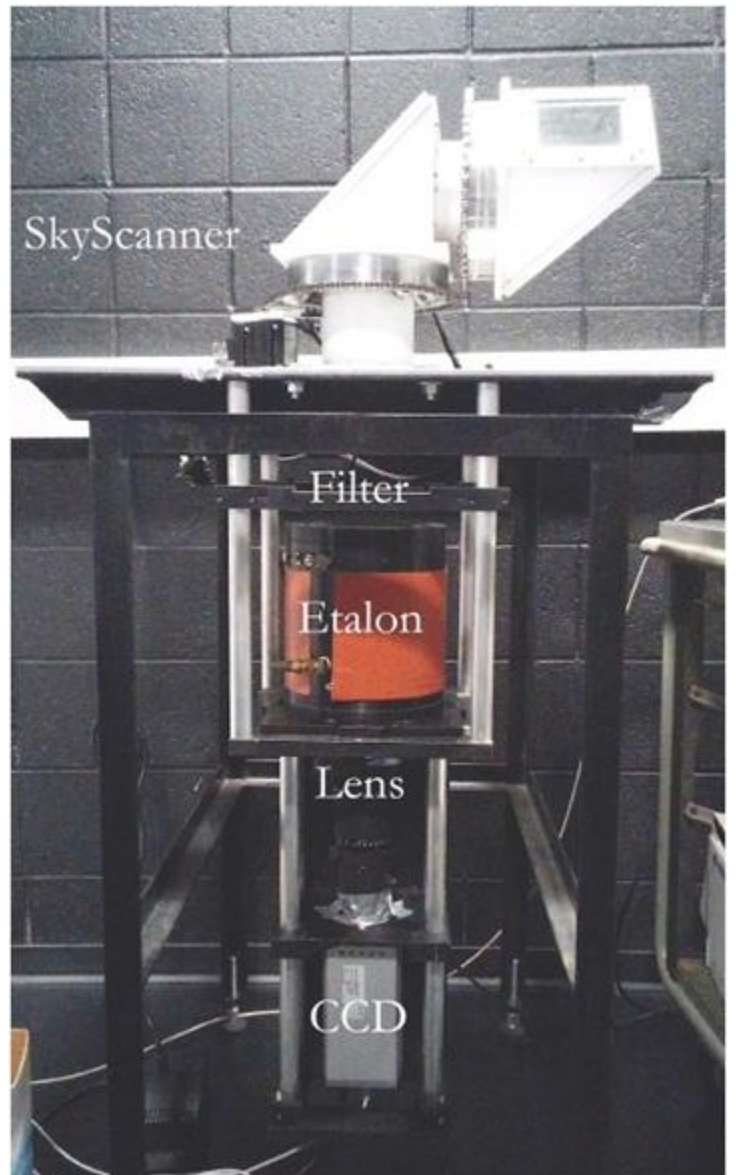
- Neutral wind velocity,
- Neutral temperature and
- Airglow intensity.



View over the dome

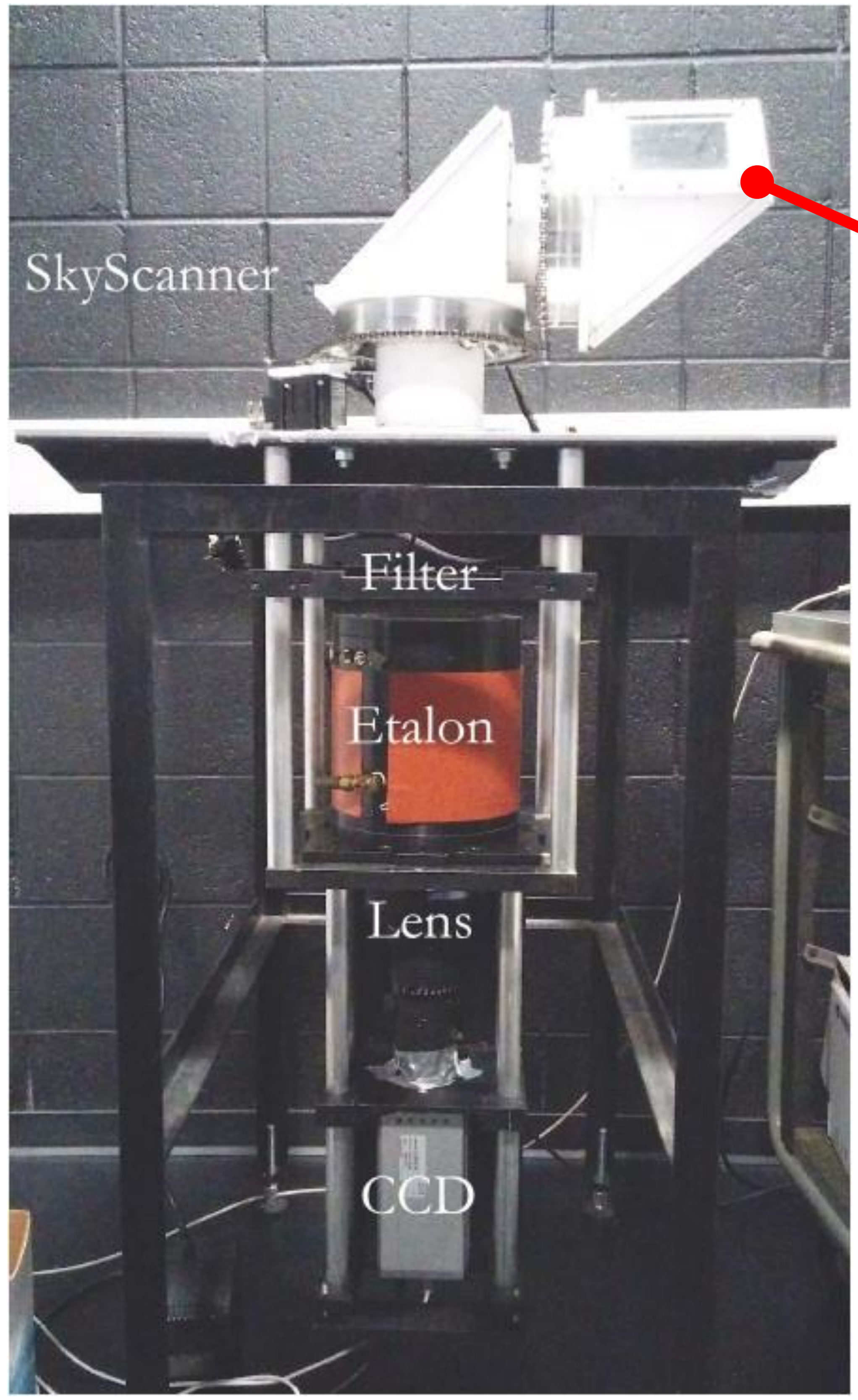


View of the whole instrument

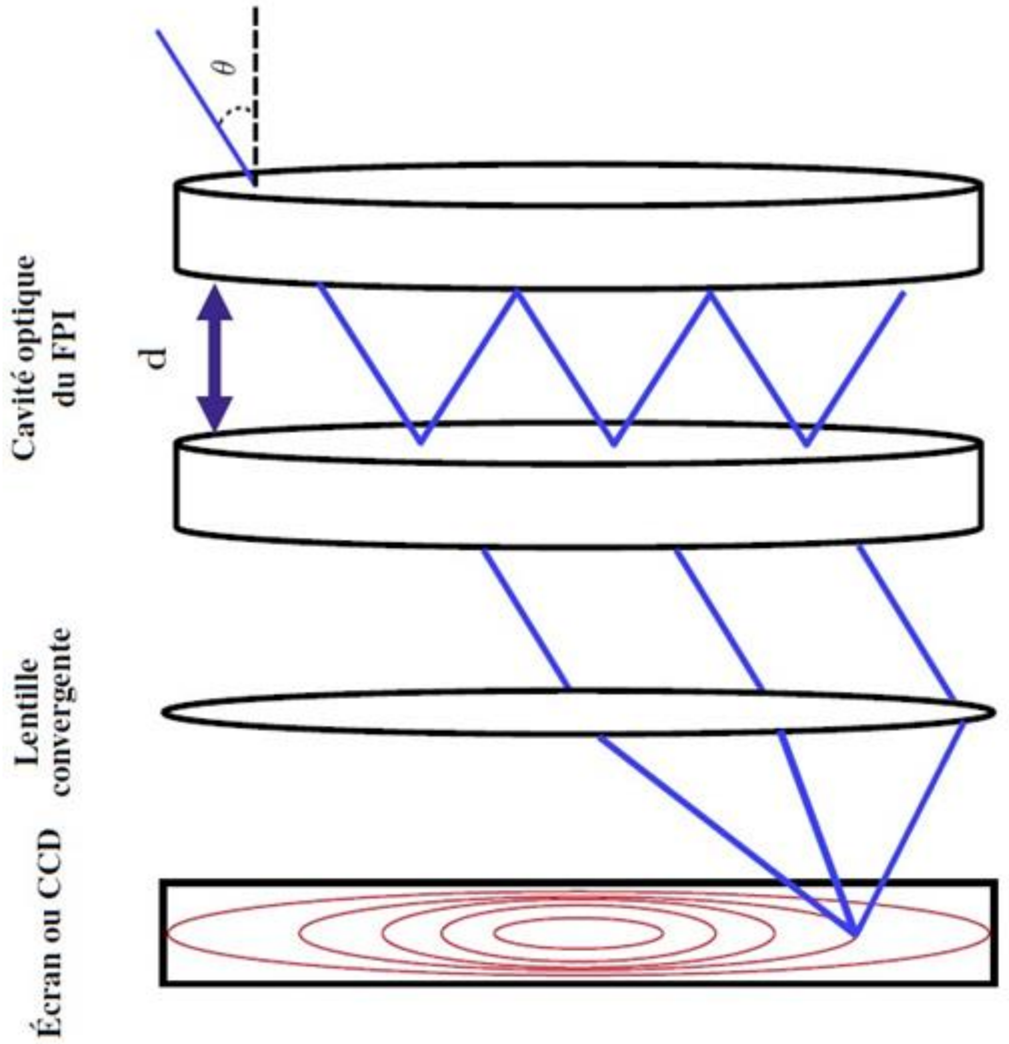


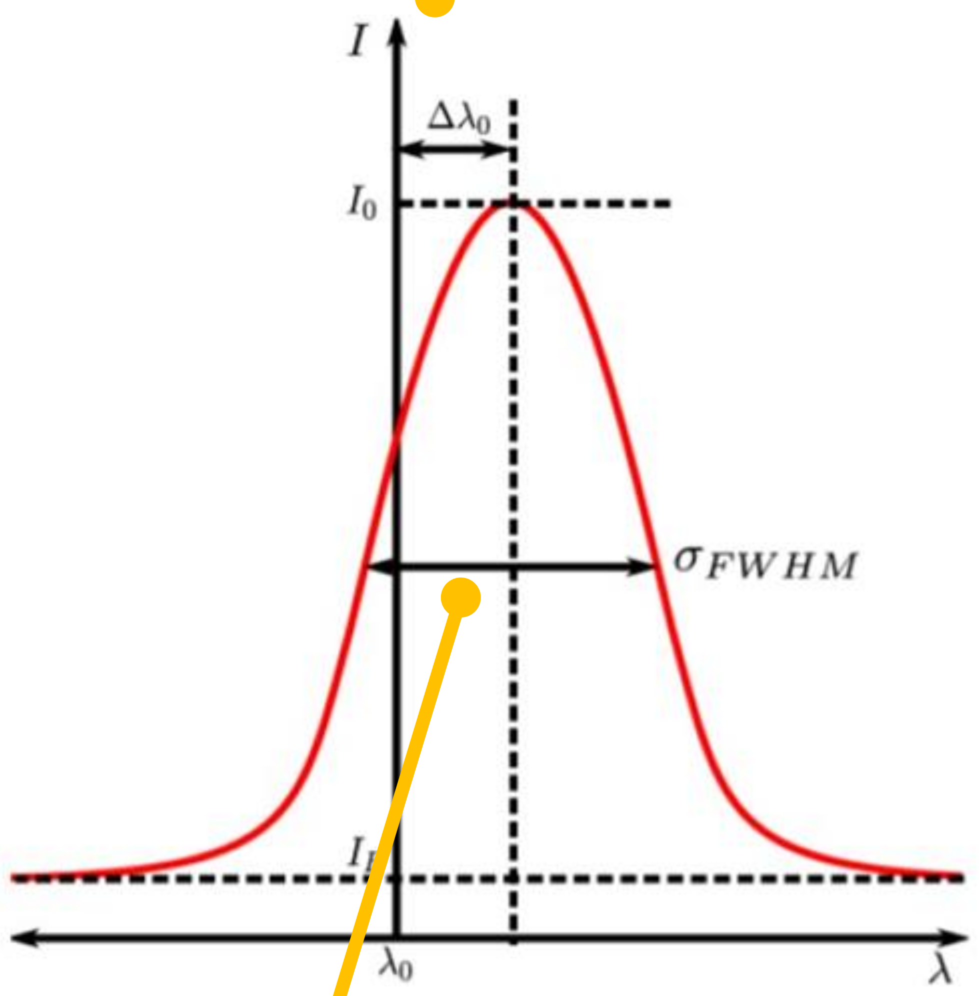
2 - To explore the thermospheric-ionospheric coupling:

Doppler shift : $\lambda_c = \lambda_0 \left[1 + \frac{U}{c}\right]$



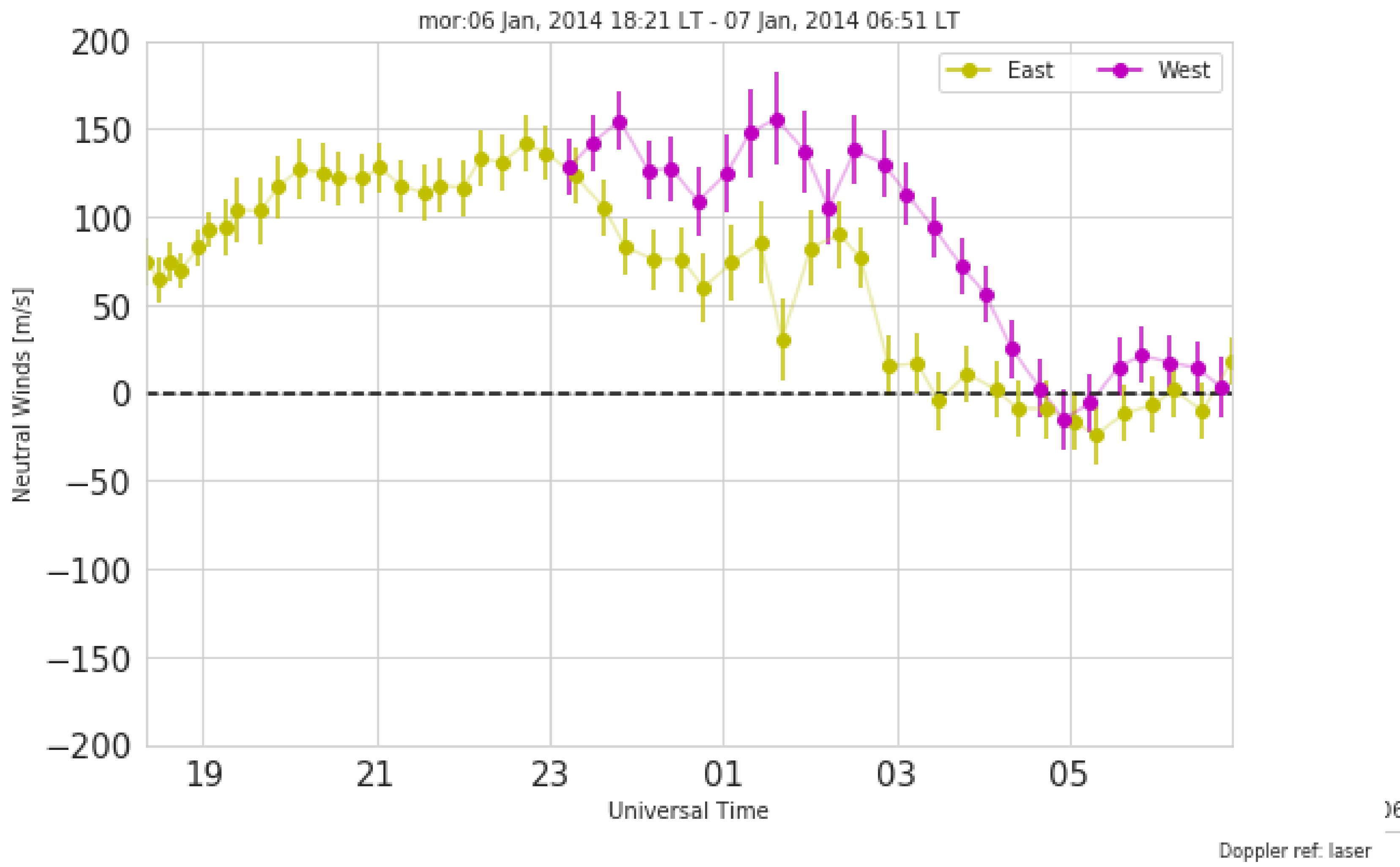
- Collects light from any direction in the sky
- FOV ~1,8°
- Cycle lasts on average about thirty minutes

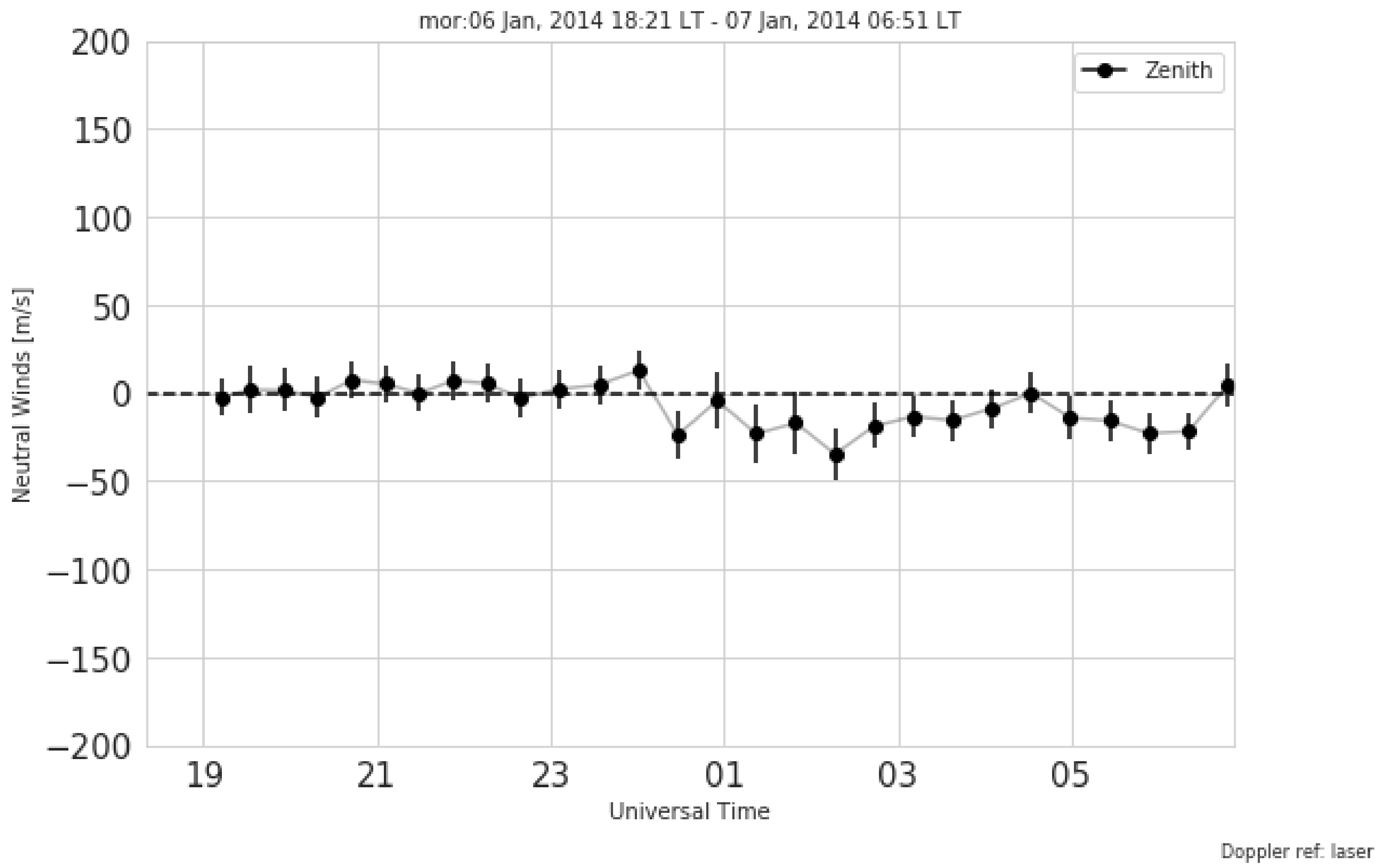


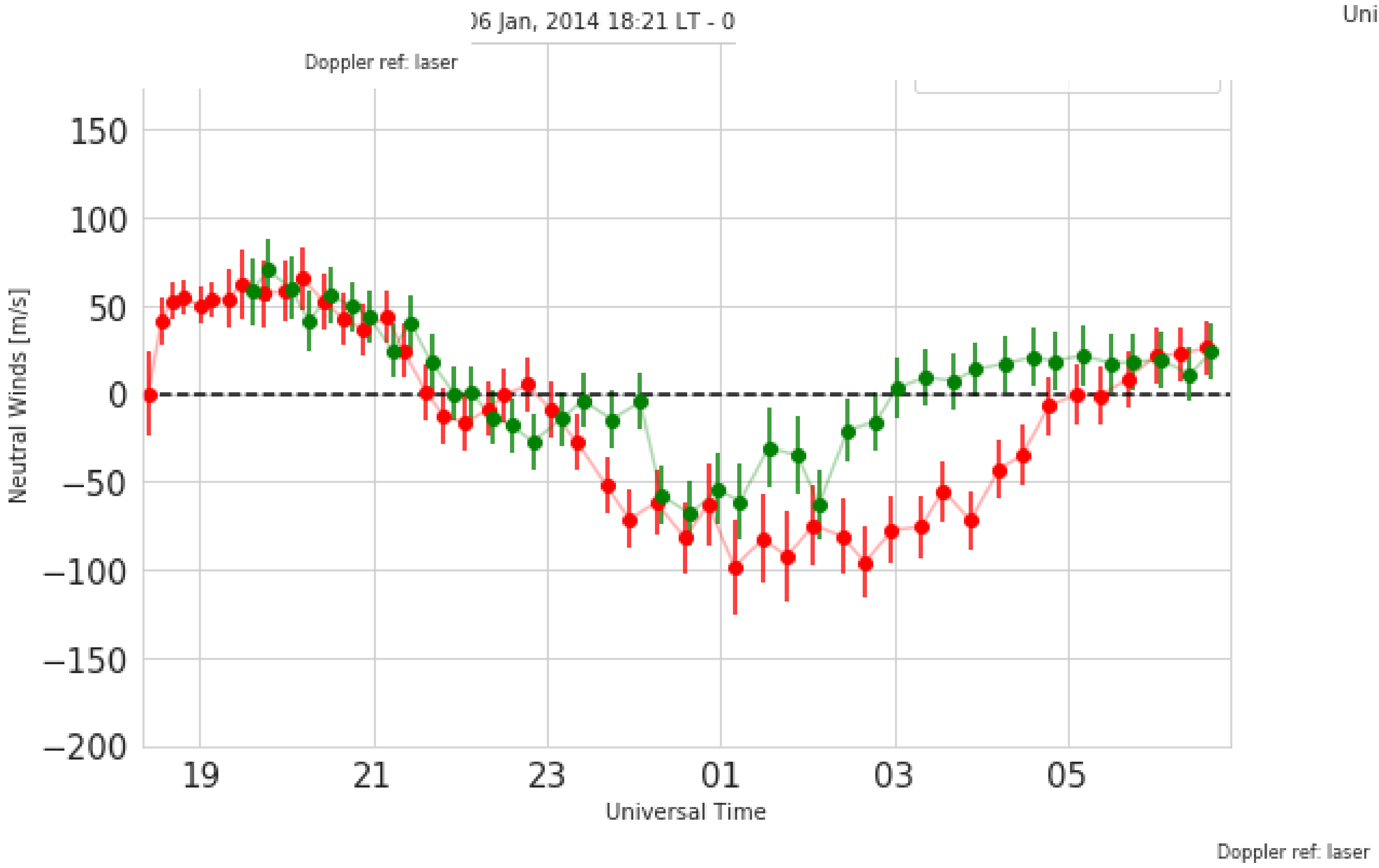


Doppler Broadening : $\Delta\lambda_{FWHM} = \frac{\lambda_0}{c}\sqrt{\frac{kT}{m}}$

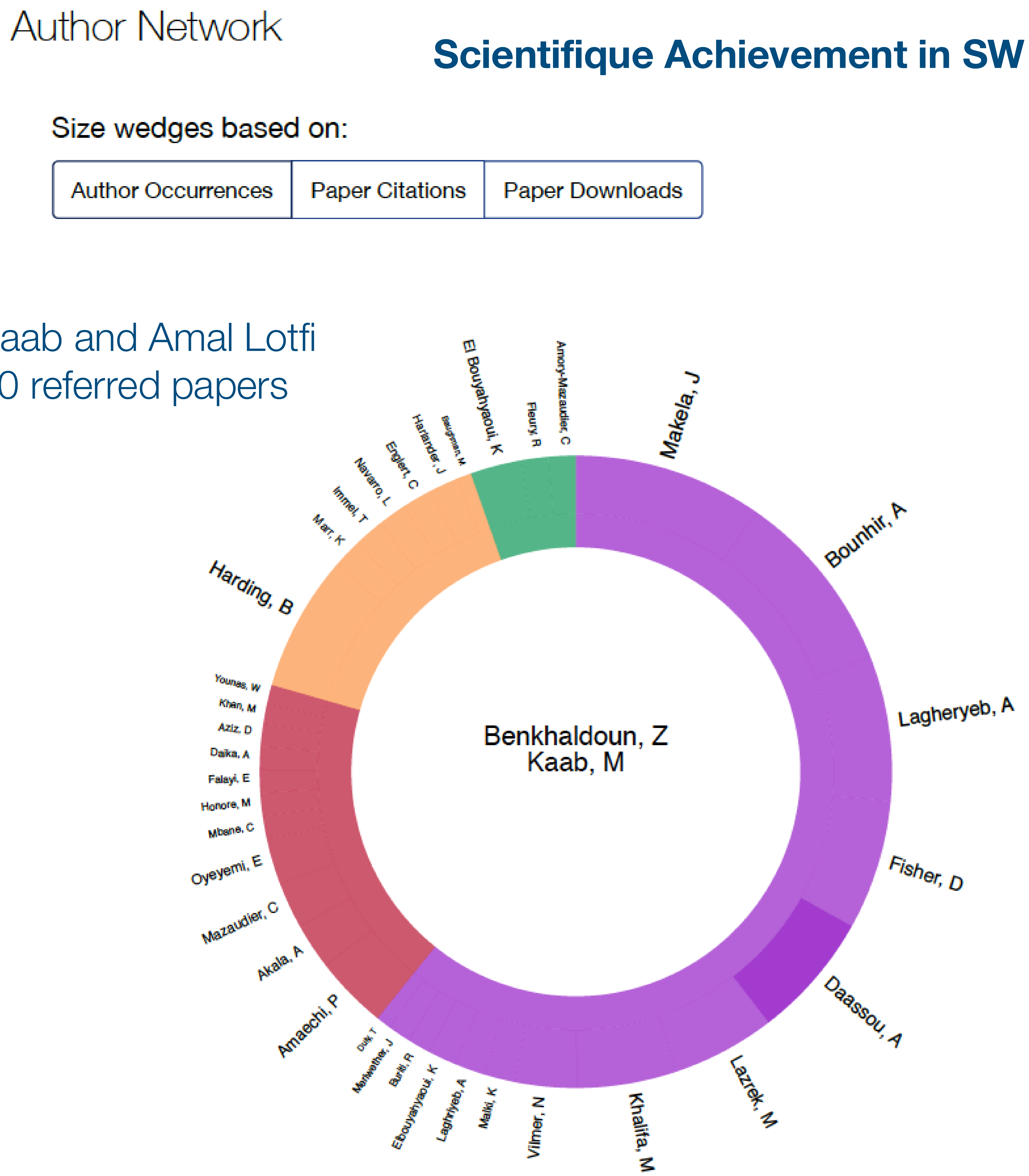
2 - To explore the thermospheric-ionospheric coupling:







Scientifique Achievement in SW @LPHEA/OUKA

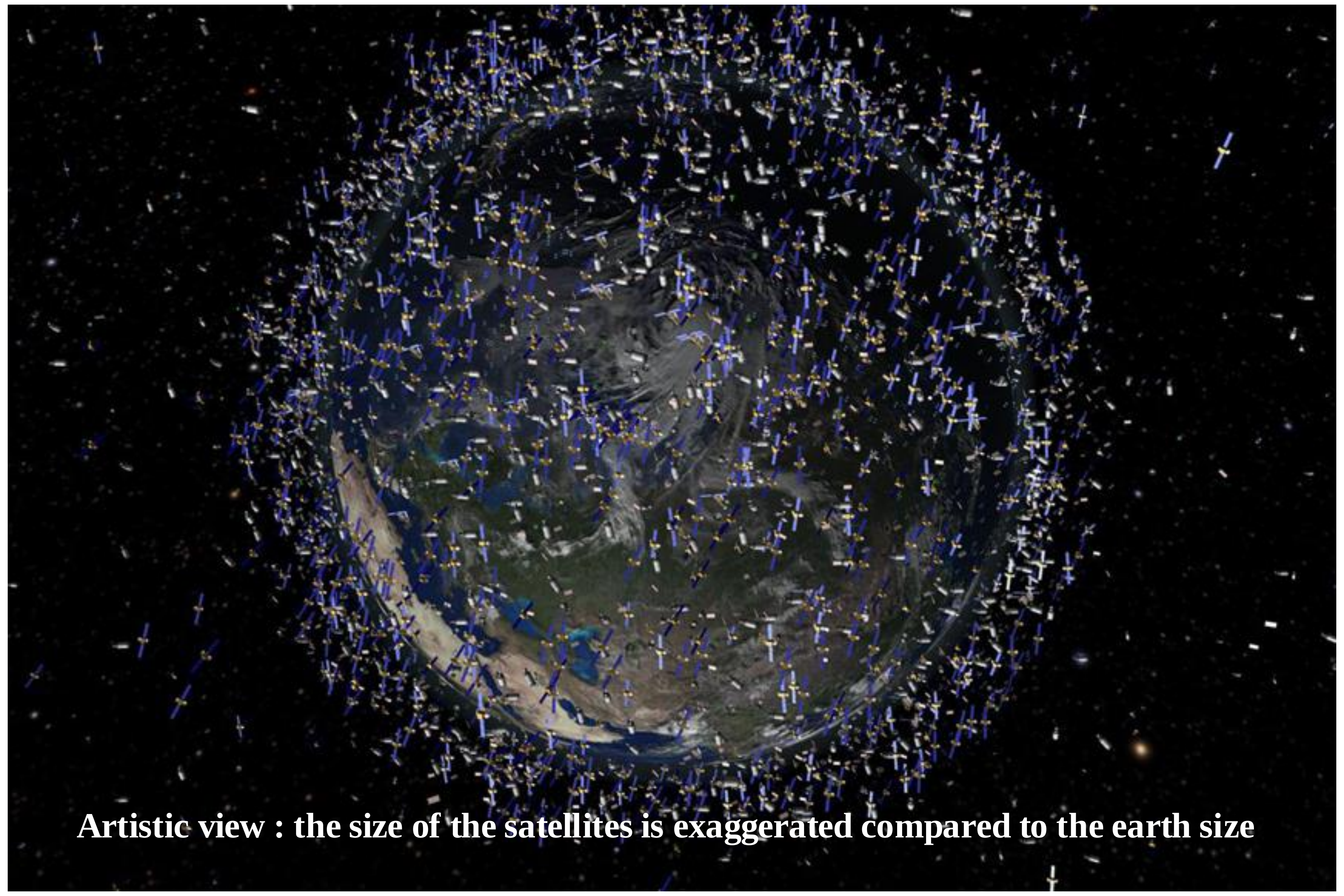


2 PHD:

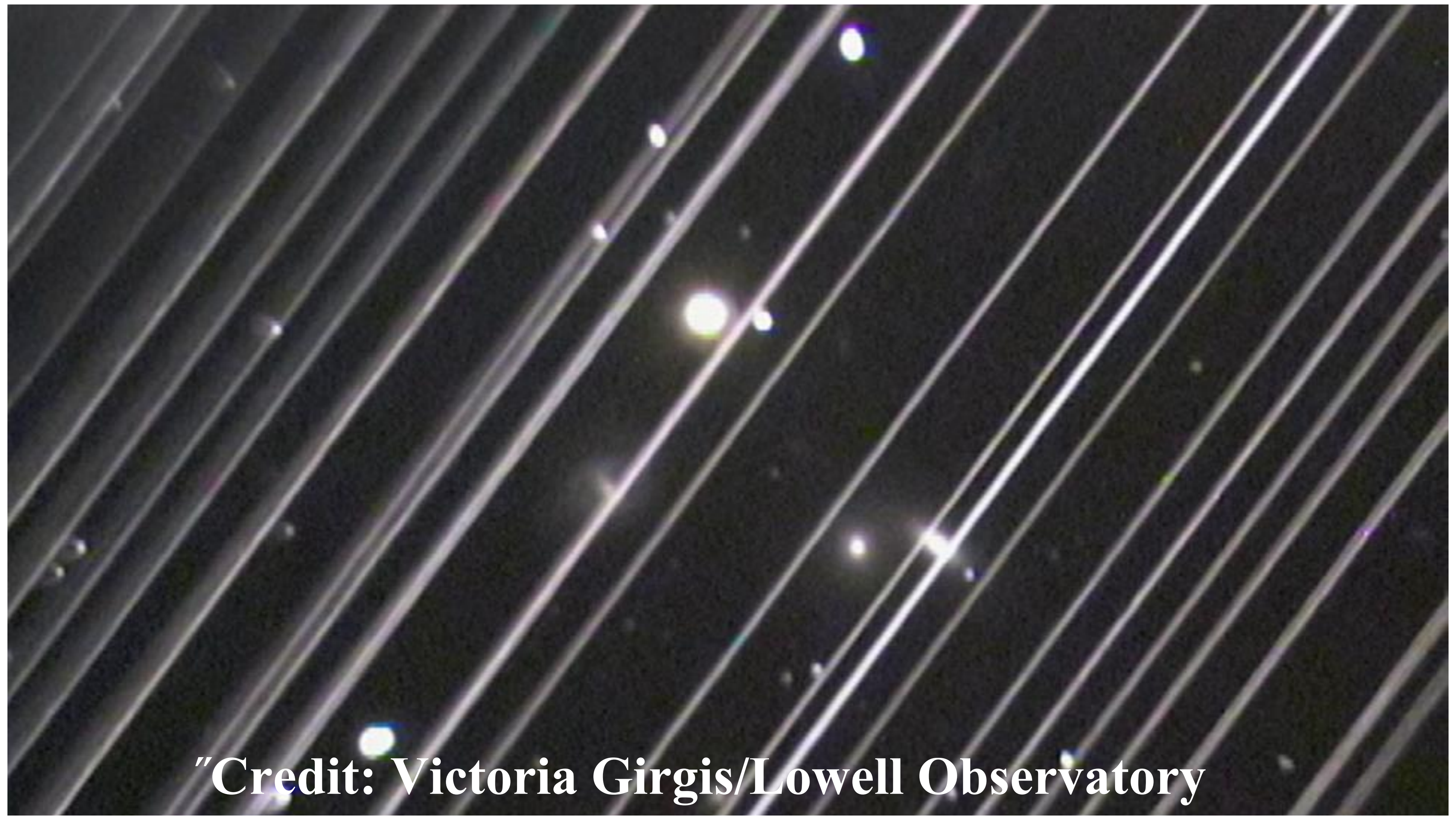
- Mohamed Kaab and Amal Lotfi
- More than 10 referred papers

Space Debris and Satellite: Contexte

- **The surge in mega-constellations poses a major threat to astronomy, causing increased light pollution and disrupting vital observations.**
- **Balancing technological progress with preserving the purity of the night sky has become an urgent challenge for researchers.**
- **Also, the challenges of space traffic management and navigation in Earth's orbit become important and very challenging.**

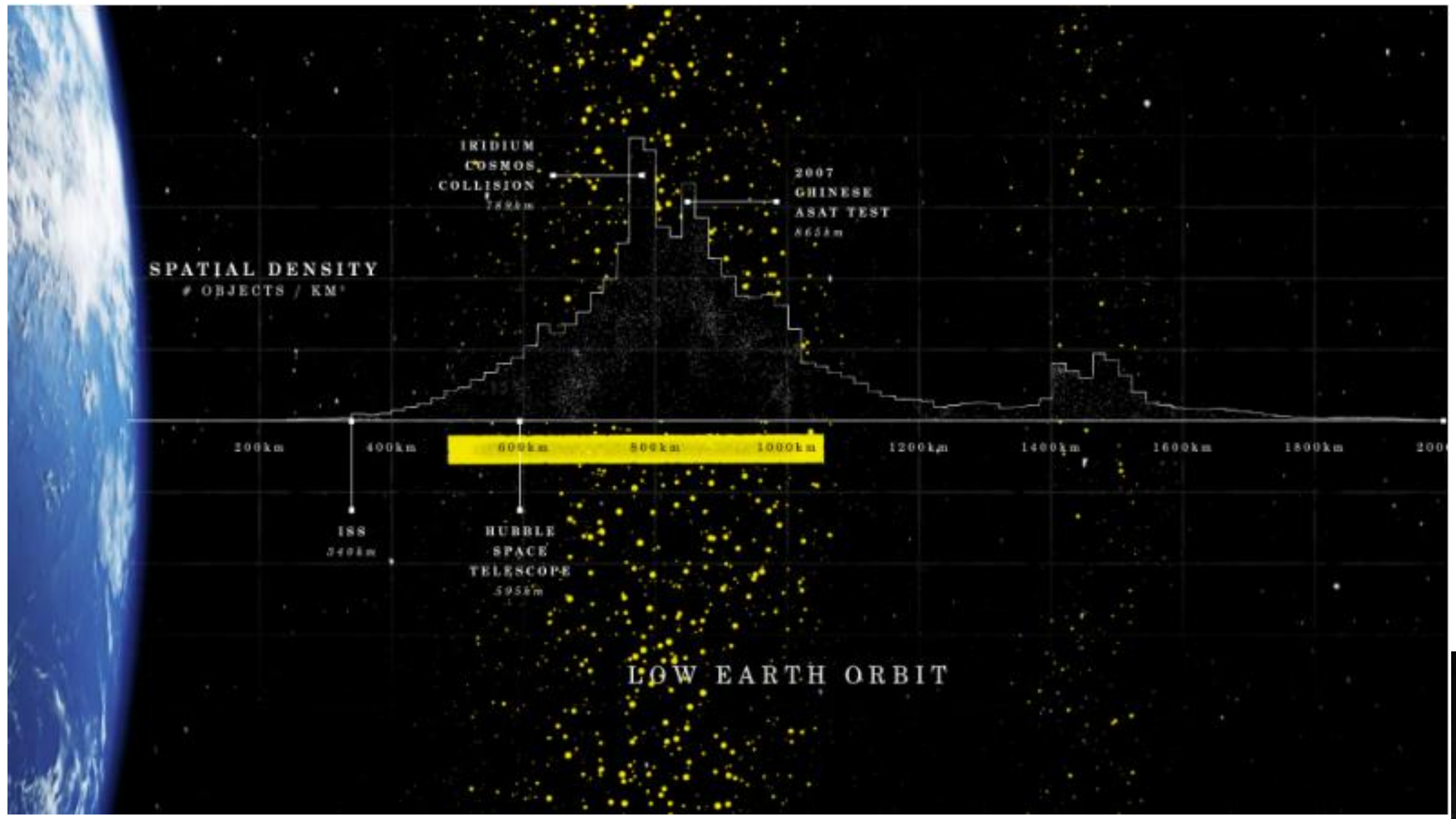


Space traffic is becoming very difficult to manage



Problem for astronomy observation : Megaconstellations becoming the new light pollution

What’s happening in low-Earth orbit?



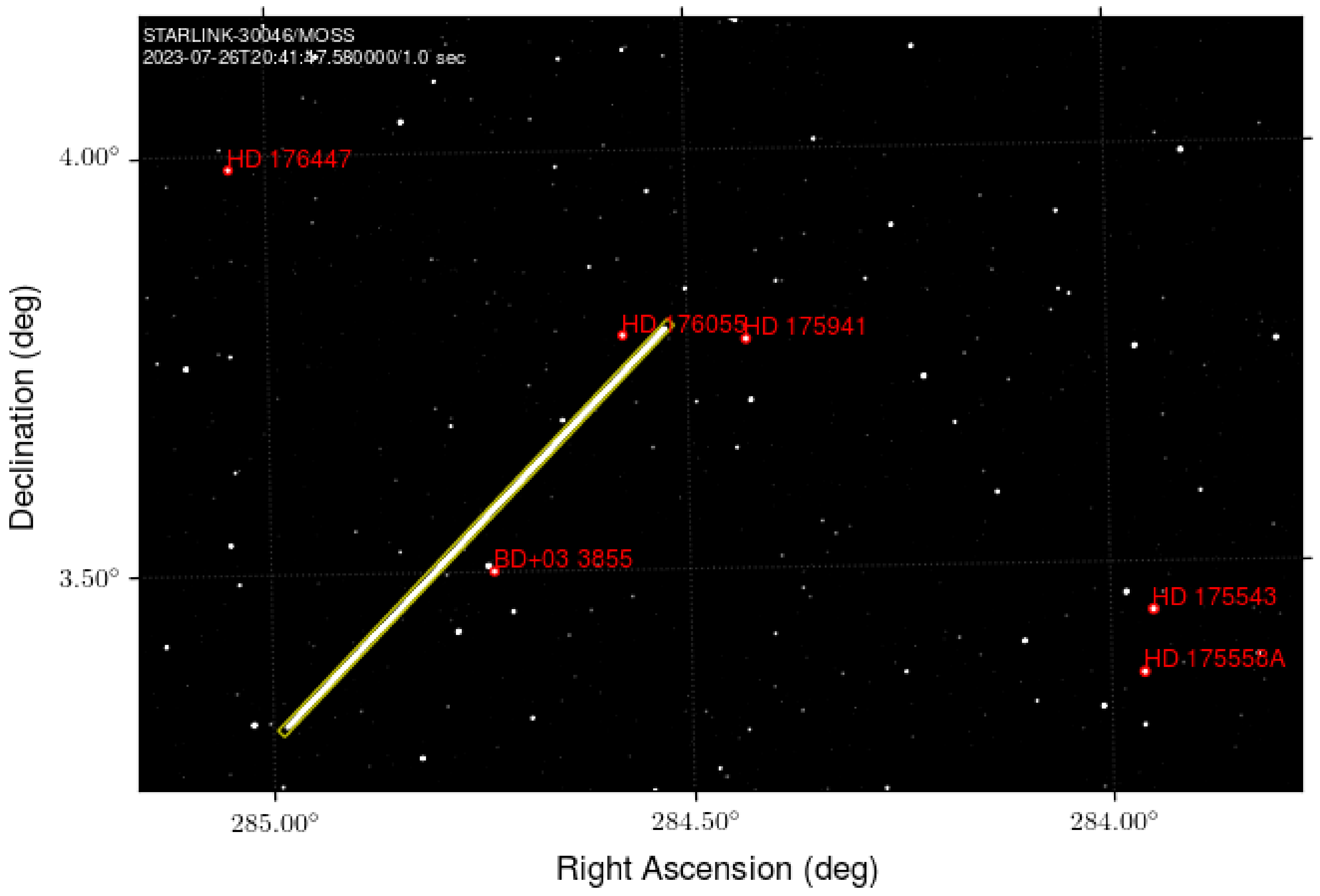
- Thousands at < 2000 km altitude
- Satellite are reflection sun light when are not in earth's shadow

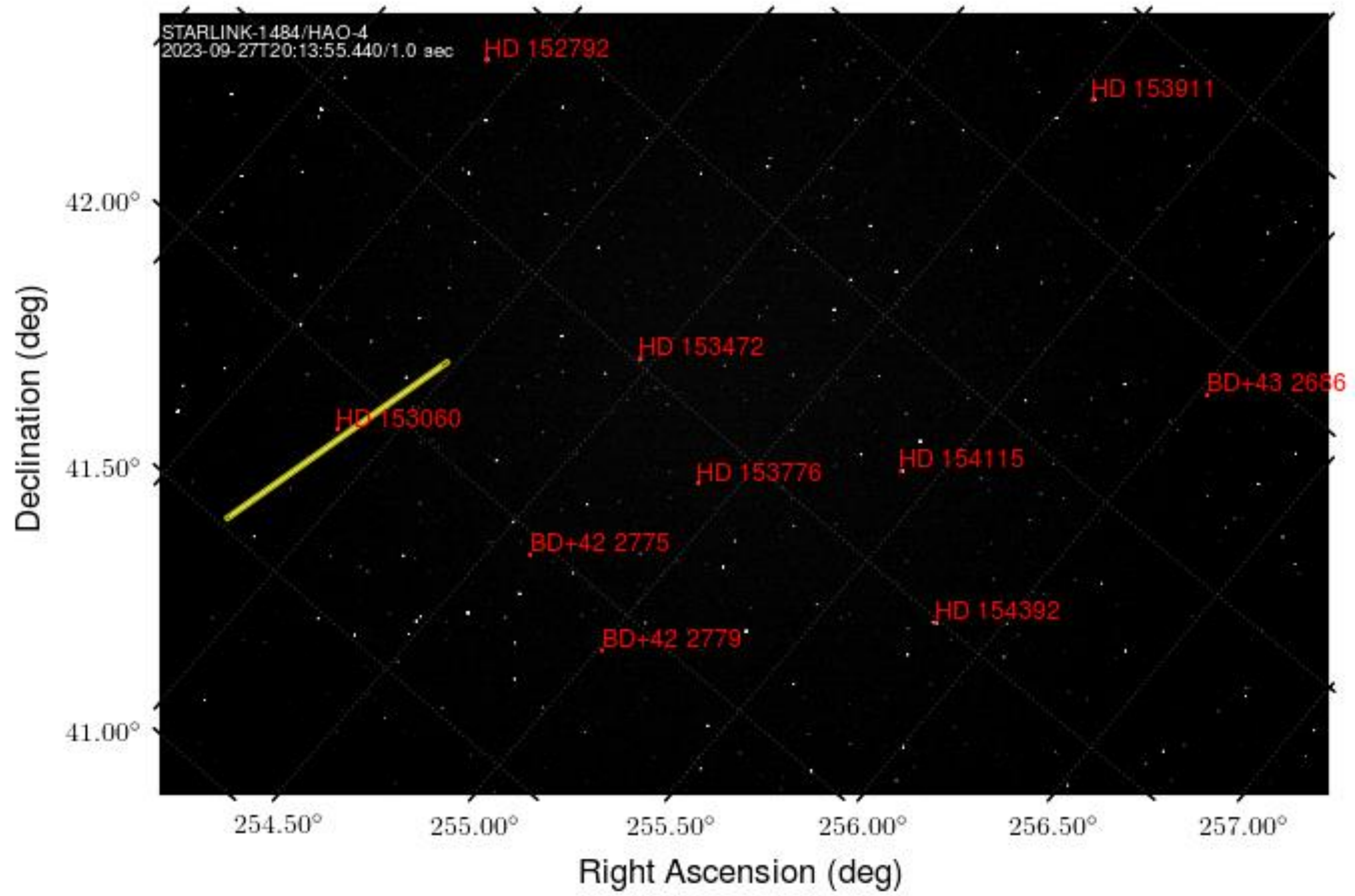
Bright streak left in an astronomical image of a group of galaxies with the Hubble Space Telescope.

Why we should care about this?

- Astronomical Data Interference (unwanted artifacts into observations)
- Space Debris Concerns (More Increasing number of satellites in LEO also adds to the growing issue of space debris)

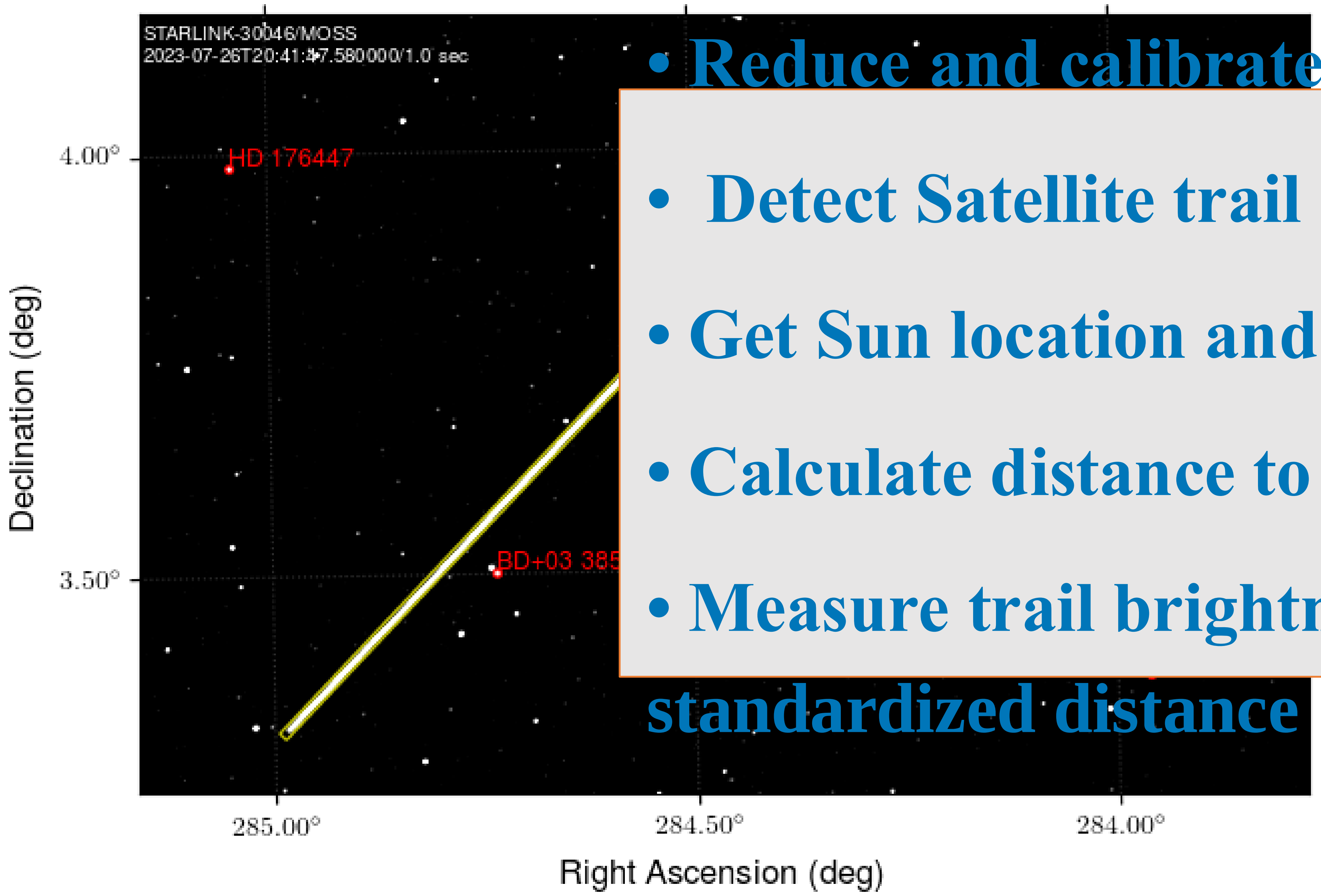
Analysis of LEO satellite observations





*Two example of satellite observations reduced and analysed :**STARLINK-30046** taken with the [O.5m MOSS telescope] at the Oukaimeden Observatory, and observation of Starlink-1484 from the [HAO Observatory]. Used comparison stars are marked with red circles.*

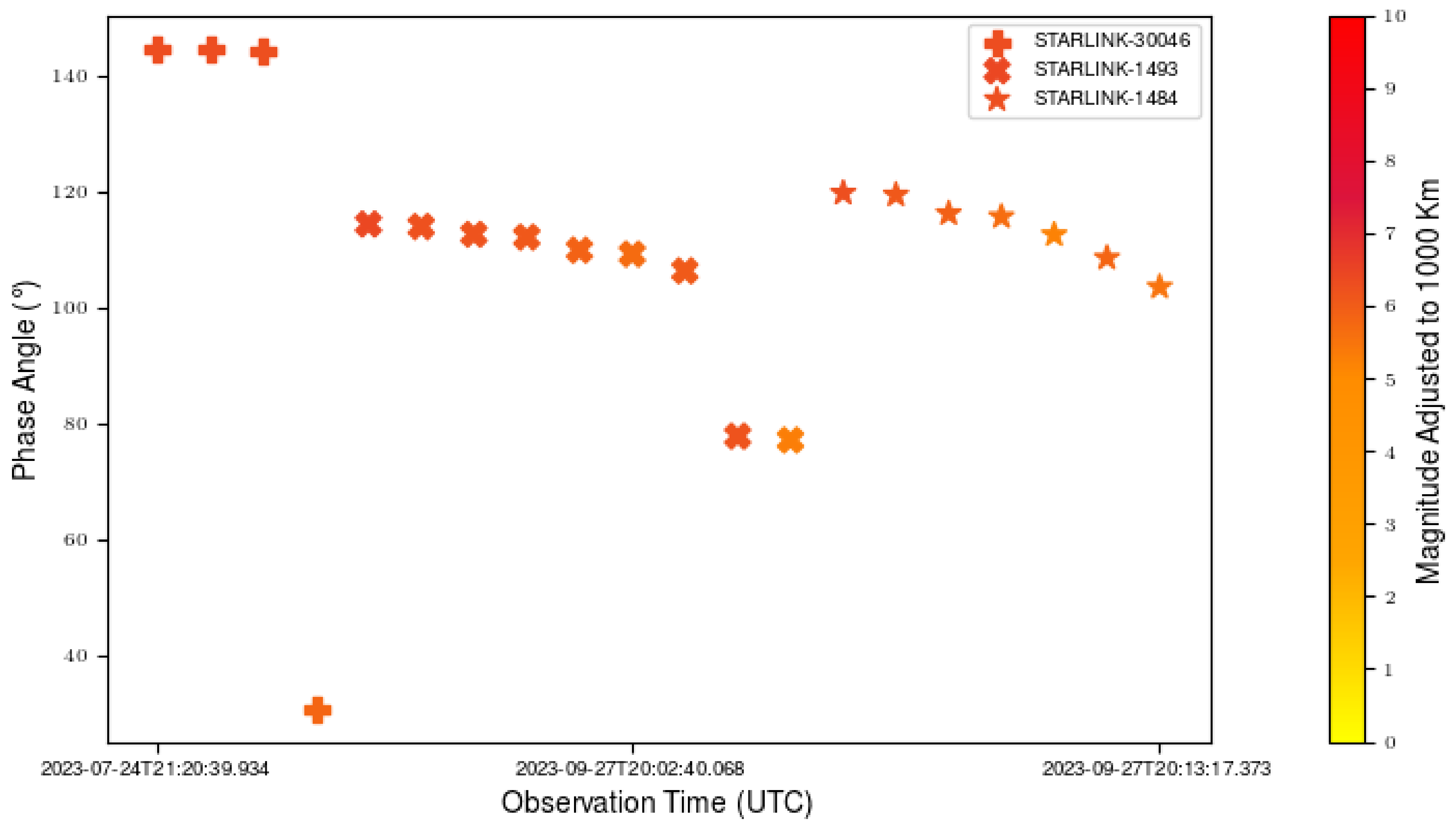
Analysis of LEO satellite observations

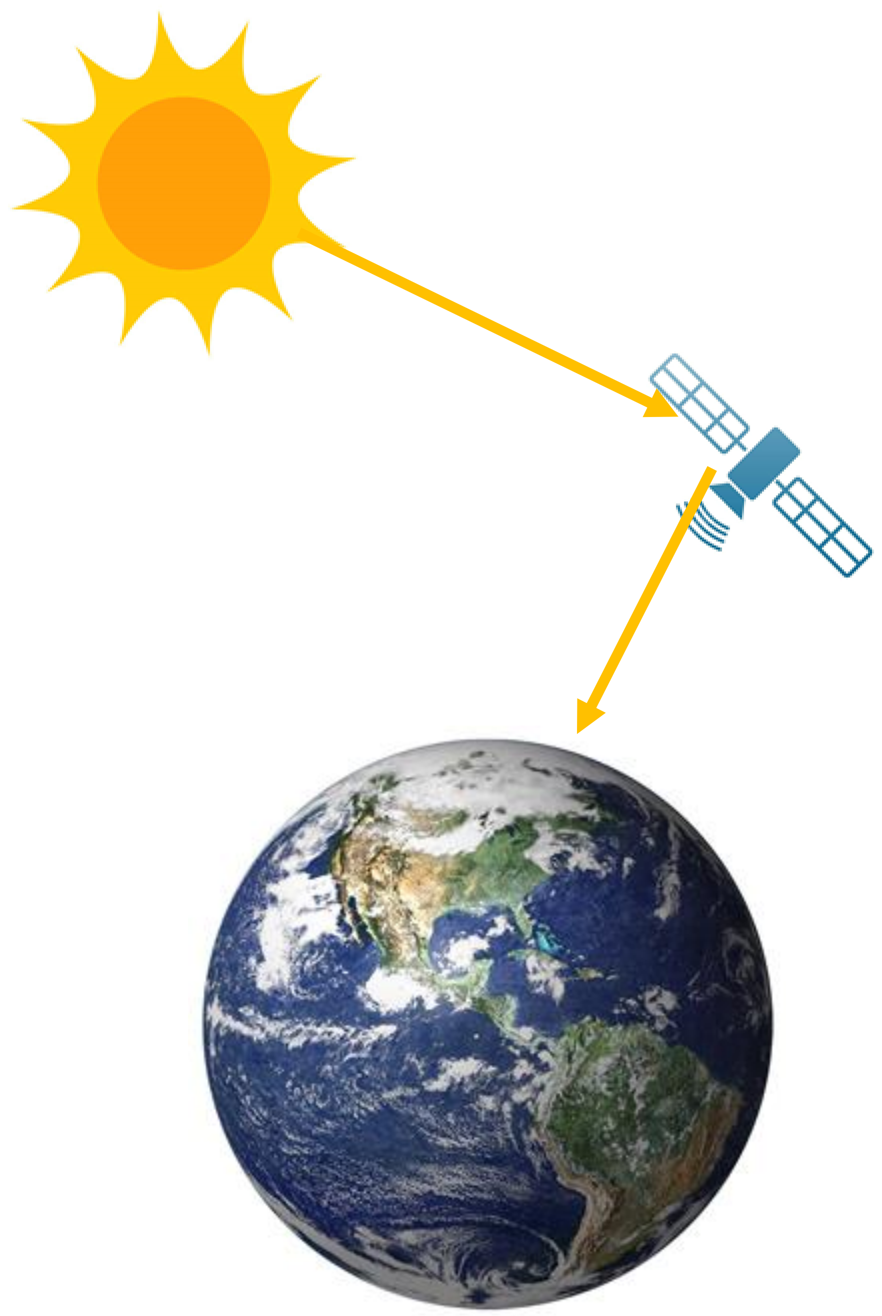


- Reduce and calibrate raw images
- Detect Satellite trail and comparison stars
- Get Sun location and phase angle
- Calculate distance to satellite from TLE
- Measure trail brightness and Normalize to standardized distance

*Two example of satellite observations reduced and analysed :**STARLINK-30046** taken with the [O.5m MOSS telescope]() at the Oukaimeden Observatory, and observation of Starlink-1484 from the [HAO Observatory](). Used comparison stars are marked with red circles.*

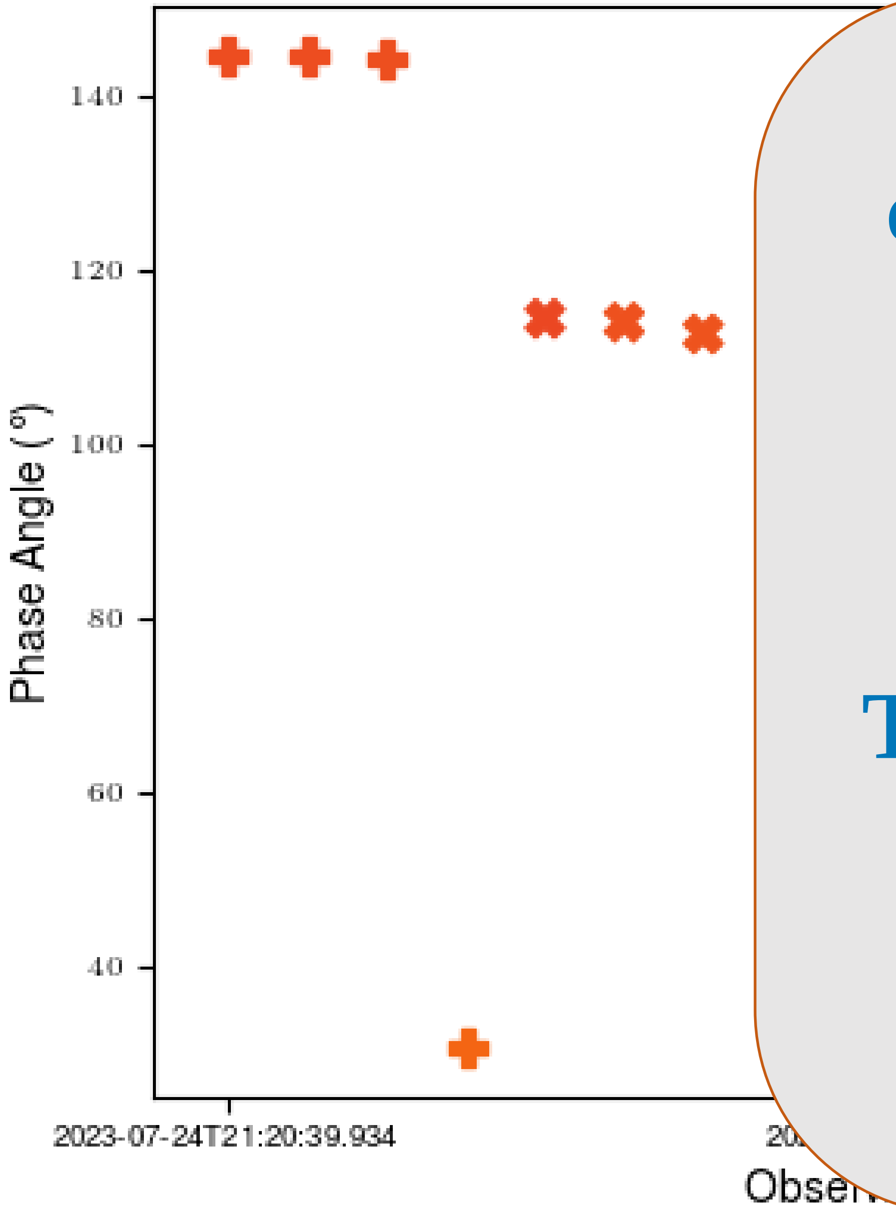
Brightness Measurement





The brightness as a function of Time and phase angle for Starlink satellite observation. Data points in the plot represent the range-normalized magnitudes.

Brightness Measurement



Magnitudes brighter than 7 are generally considered problematic for research (Tyson et al. 2020).

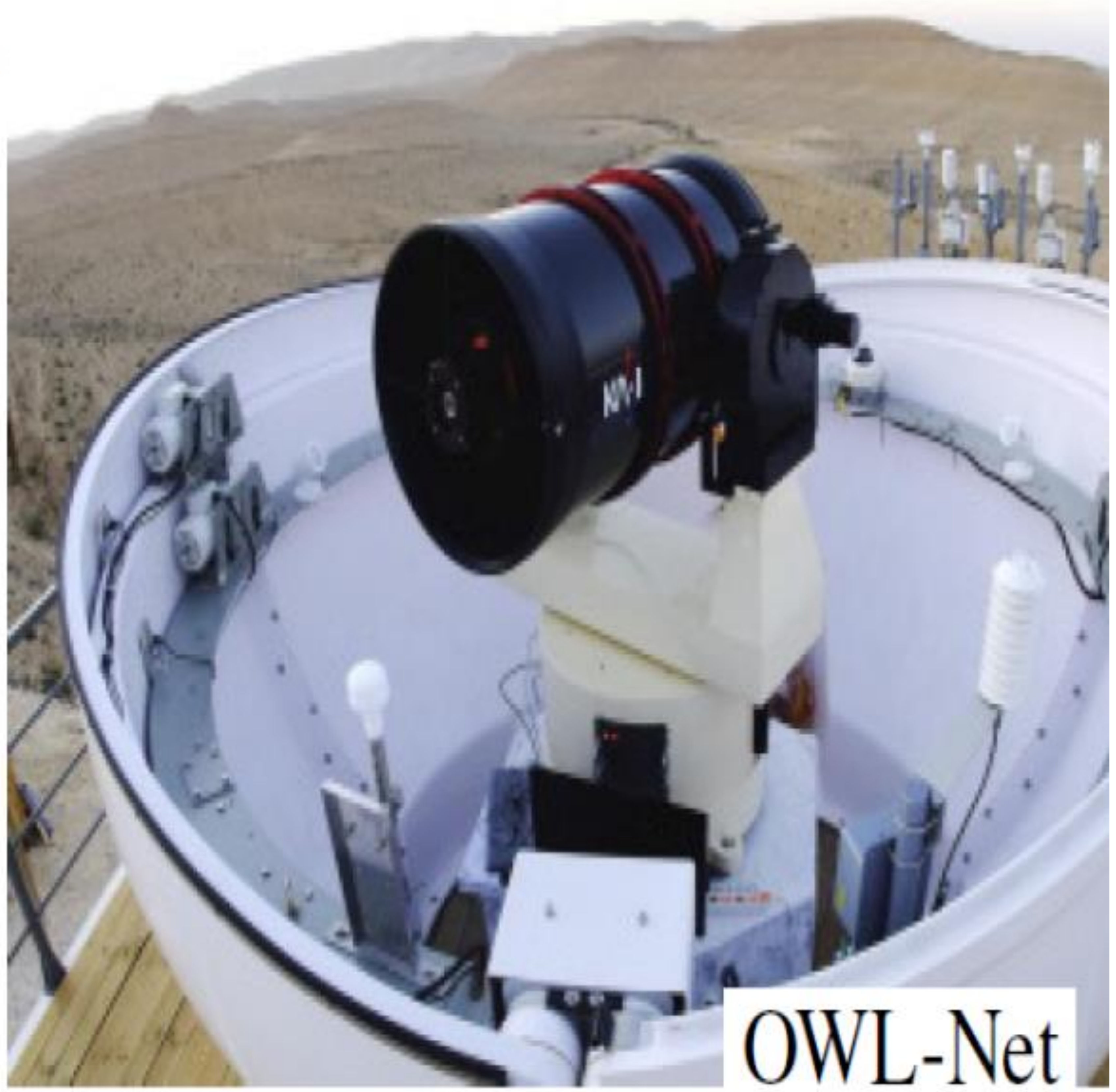
The apparent and adjusted Magnitude values indicate that Starlink Gen 2 Mini satellites can be very bright and are a concern for astronomers !

The brightness as a function of Time and phase angle for Starlink satellite observation. Data points in the plot represent the range-normalized magnitudes.

Observations Facilities: Telescopes

OWL telescope :

- OWL-Net: Optical Wide-field Patrol Network
- Rapid tracking of near earth and space objects
- The aperture size of the mirror is 0.5m in ritchey chretien configuration and its field of view is 1.1deg x 1.1deg on the CCD sensor
- It is renowned for its ability to track near-Earth and space objects quickly.
- They use an Alt-Az type telescope mount
- The telescope has a maximum slewing speed of 20 deg/sec



Observations Facilities: Telescopes

MOSS telescope :

- MOSS: MOROCCO OUKAIMEDEN SKY SURVEY
- T500 with a fork mount on an equatorial table.
- The field of view is 2.1 square degrees with the focal of 1493mm, F/D=3.0.
- They use CMOSS Camera ASI6200MM Pro IMX 455, ZWO.
- Rapid tracking of near earth and space objects
- The aperture size of the mirror is 0.5m in ritchey chretien configuration and its field of view is 1.1deg x 1.1deg on the CCD sensor

Observations Facilities: Telescopes

HAOs Telescope :

- HAO : High Atlas Observatory,
- Specializes in wide-field deep-sky observations, capturing expansive nebulae and cosmic formations. Also capable of researching and detecting asteroids, Near-Earth Objects (NEOs), and satellites.
- Equipped with the Takahashi FSQ 85 refractor, featuring an 85mm aperture and an F/5.3 configuration resulting in a focal length of 455mm. Paired with the ZWO ASI 2600 MM Pro camera.

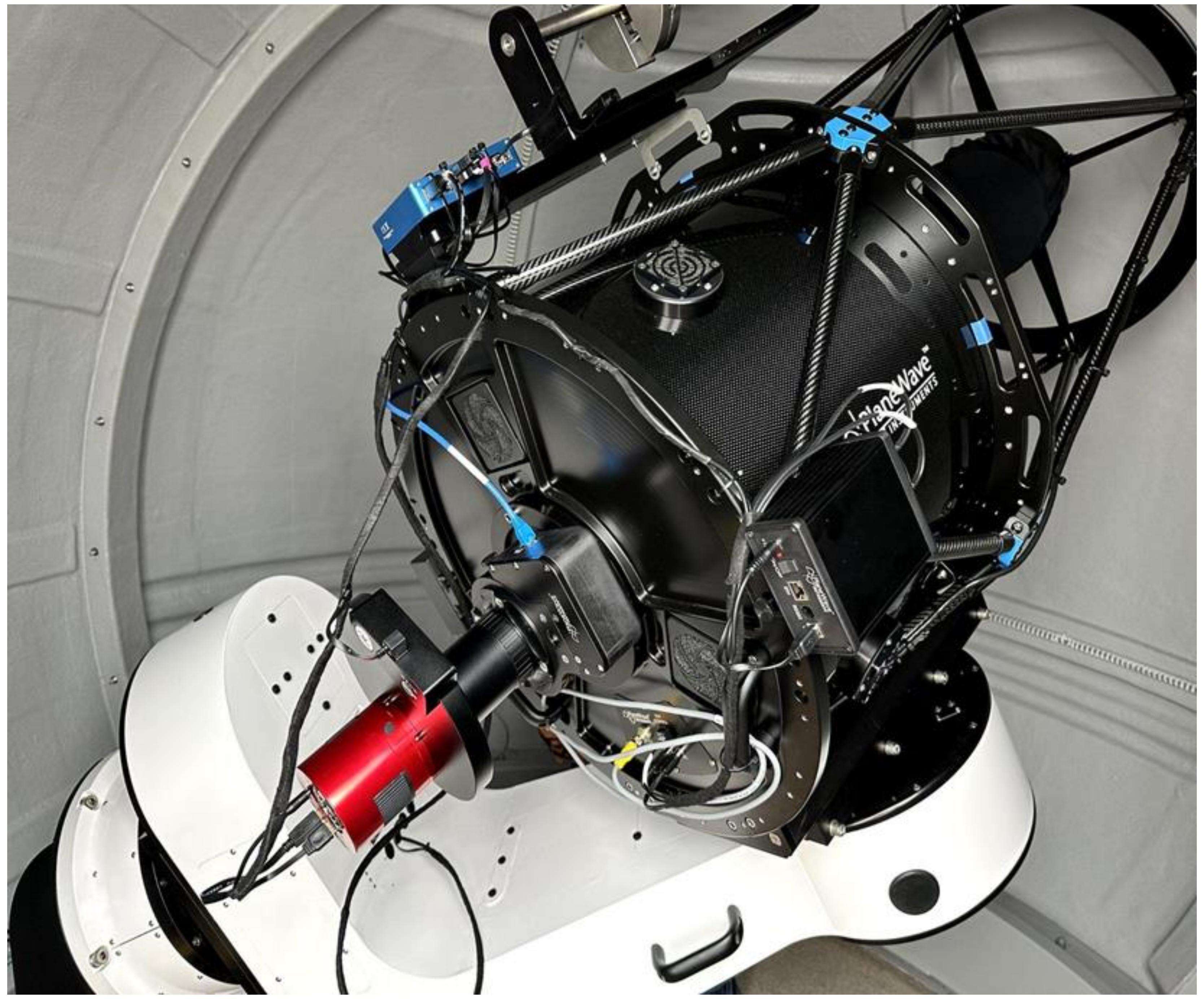
Observations Facilities: Telescopes

ASO telescope

The new Atlas Sky Observatory (ASO) features a PlaneWave Telescope with a CDK 20 Camera diameter of 508mm,, and a Planewave mount.

It has a wide field of view measuring:

35’ 52.9” x 23’ 57.3”.



Observations Facilities: Telescopes

SpaceFlux Telescope :

- Mount: L-350 Direct Drive Mount, Speed: 30 degrees per second and Weight Capacity: 45 kilograms
- Installation: Telescope: PlaneWave L350 mm, Alt/Az configuration, Optical Design: Corrected Cassegrain
- Aperture: 350 mm, Focal Length: 1050 mm, Focal Ratio: f/3 and Image Circle: 60 mm, covering over 3 degrees of the night sky
- Objective: Observing satellites in tracking mode to determine their position at a given moment.

Observations Facilities: Telescopes

Telescopes installed at Oukaimeden observatory by Astronomical Scientific Center

Binocular 2 x 19.4 cm

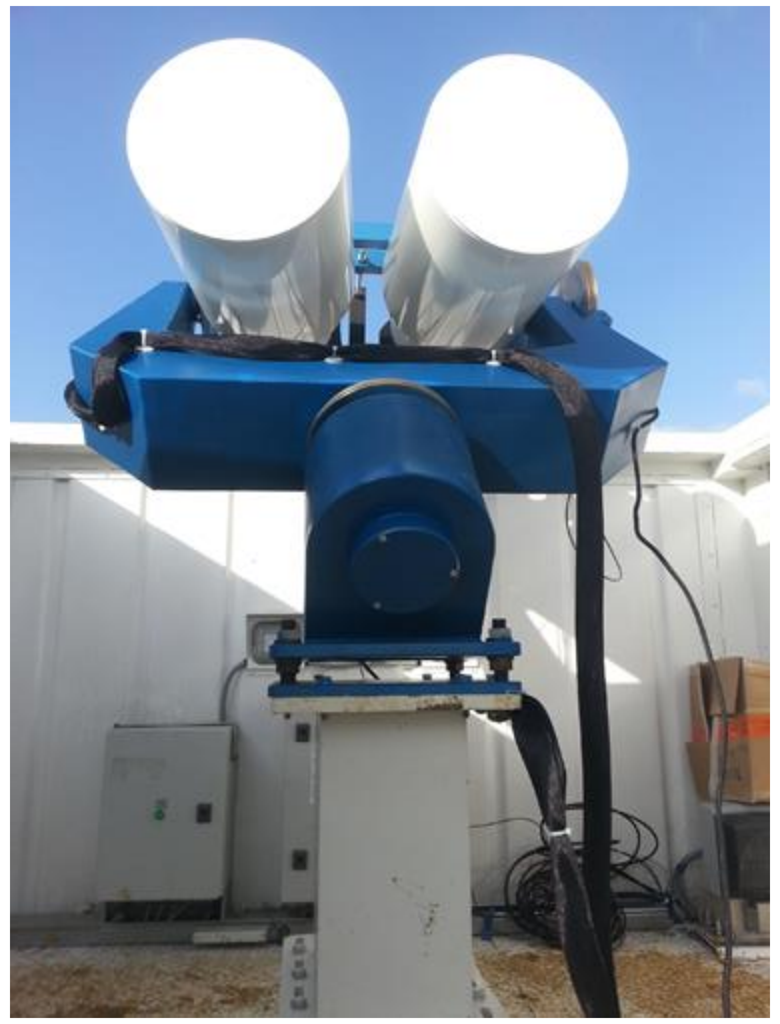
Mode of observations – large fields survey

Field of view – 7,1°x 7,1° (each channel)

Sensor – Gpixel-4040 (each channel)

Image scale – 6.3 arcsec per pixel

Limiting magnitude – 16.7m (for reference observation conditions and stellar-like object)



Telescope 50 cm

Mode of observations – targeting (individual objects) and local fields survey

Field of view: 2,26°x 2,26°

Sensor: Gpixel-4040

Image scale: 1.99 arcsec per pixel

Limiting magnitude: 19.1m (for reference observation conditions and stellar-like object)

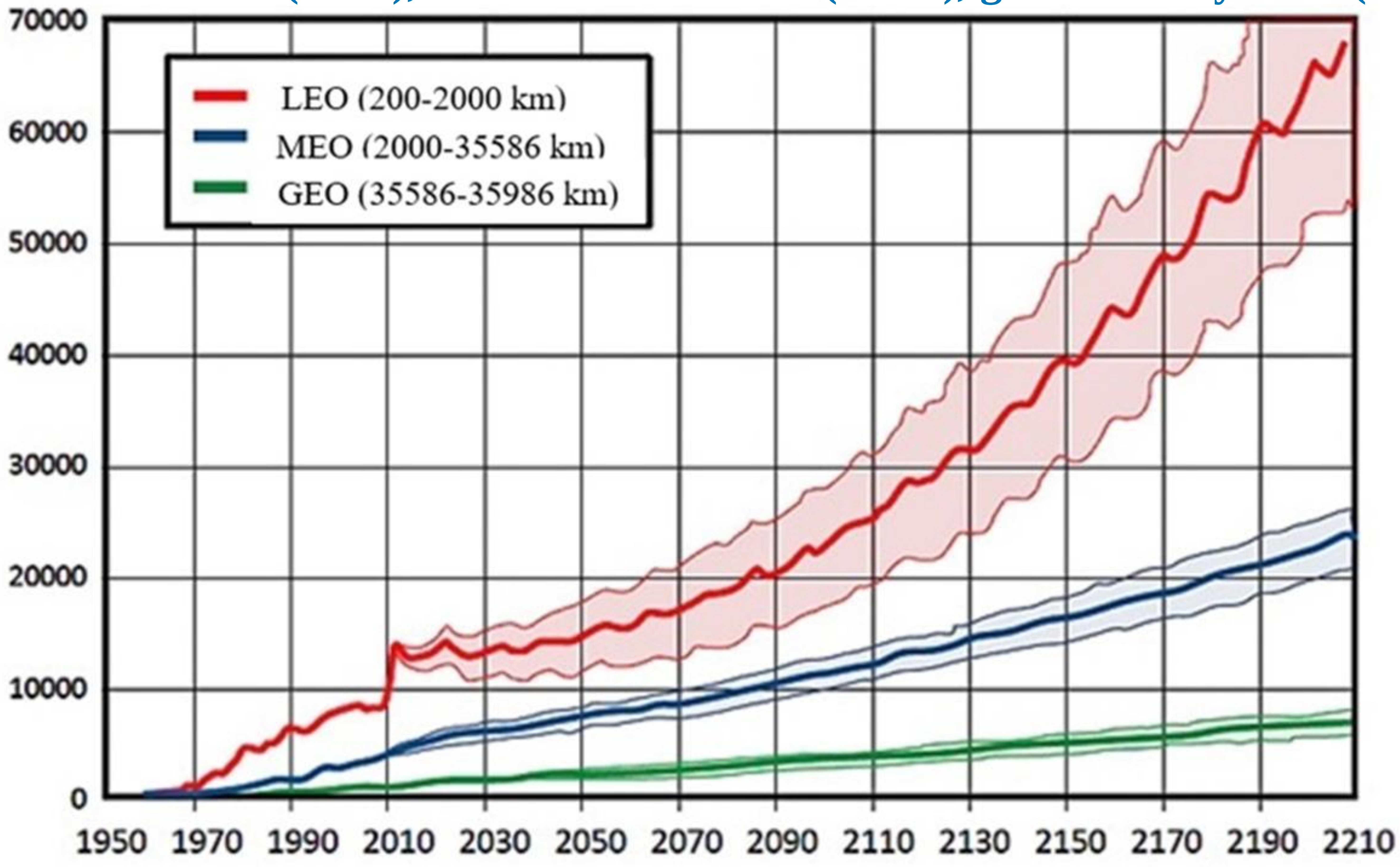
Observations Facilities: Observational tools

Website of planification : https://ouca.uca.ma/Satellites/

Big Data!

The forecast of space debris increase (NASA):

low Earth orbit (LEO), medium Earth orbit (MEO), geostationary orbit (GEO)



from: E. N. Abramova, S. V. Reznik; Small spacecraft's inflatable aerodynamic decelerator design issues analysis. *AIP Conf. Proc.* 15 November 2019; 2171 (1): 040002.

https://doi.org/10.1063/1.5133188

New Area of investigation @ LPHEA:

Machine Learning for Satellite and space debris

We face to the vast amounts of satellite data and space debris,

The utilization of machine learning techniques is crucial for efficient data processing and analysis.

Machine learning algorithms can sift through massive datasets to identify patterns, anomalies, and trends, enabling timely and accurate decision-making in space operations.

Additionally, machine learning can enhance predictive modeling for collision avoidance and space traffic management, mitigating the risks associated with orbital debris.

Embracing machine learning technologies is essential for ensuring the safety and sustainability of space activities amidst the growing complexity of the space environment.

Machine Learning Approaches: The deployed Model

Random Forest :

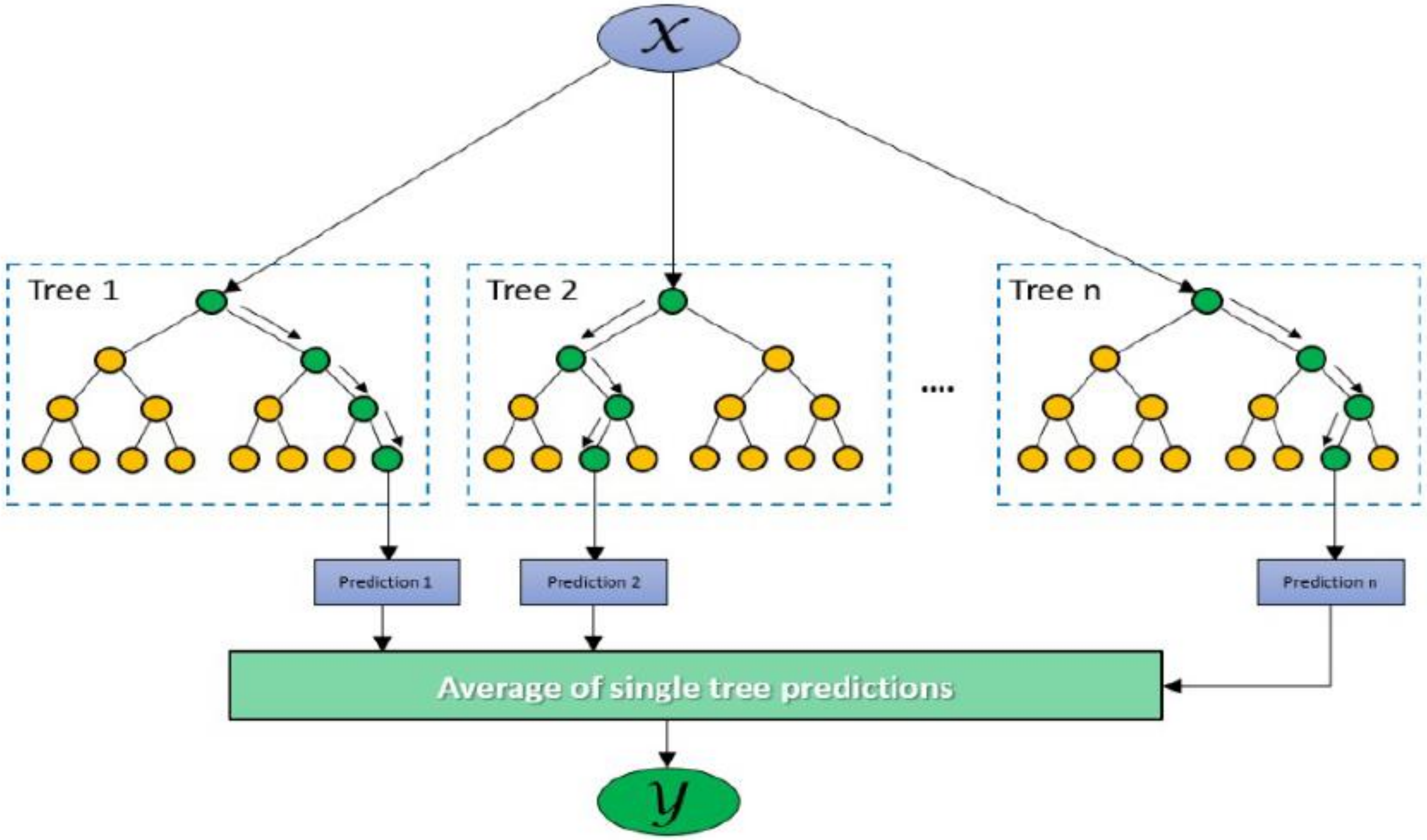


Figure 2: Random Forest illustration

Machine Learning Approaches: results

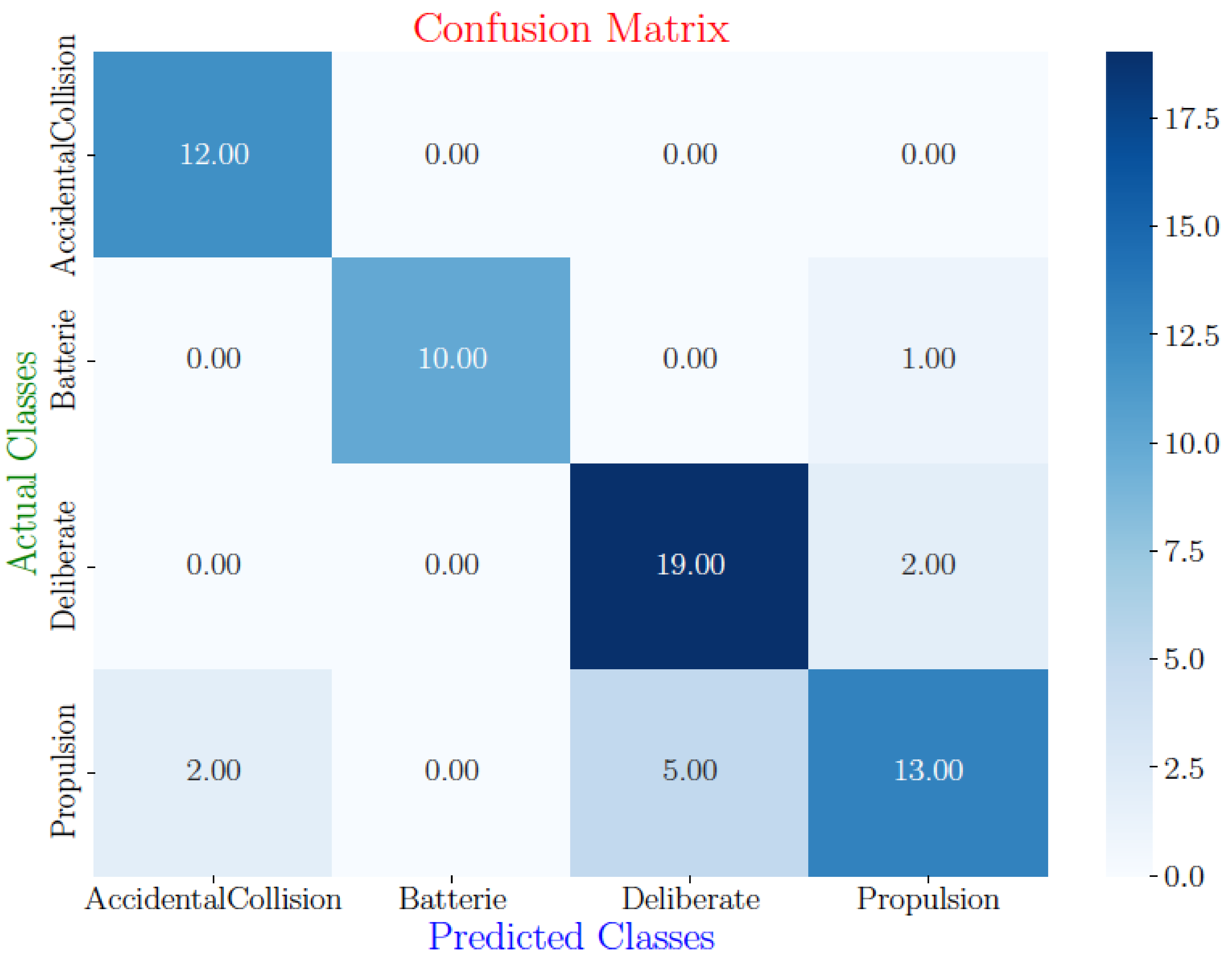


Figure 4: Confusion matrix using the Multi-Layer Perceptron CLassifier method

Networking and International cooperation

- **Collaboration and networking are essential for global space weather surveys, satellite monitoring, and tracking space debris.**
- **By combining resources, expertise, and data across nations and organizations, we can significantly improve our ability to manage and track objects in space.**
- **This united effort is critical to:**
- **Ensuring the safety of space operations.**
- **Reducing the risk of collisions.**
- **Preserving the long-term sustainability of space activities.**
- **International cooperation enables a deeper, more comprehensive understanding of the dynamic space environment, fostering global progress in space safety.**

Looking Forward: Recommendations for COPUOS

1. **Policy Development**
   - Regulate satellite mega-constellations to minimize light pollution.
   - International guidelines for radio frequency management.
2. **Capacity Building**
   - Support for training programs in developing countries.
   - Strengthen African networks for space research.
3. **Enhanced Collaboration**
   - Promote data-sharing platforms for global satellite monitoring.
   - Joint initiatives for mitigating space traffic risks.

Conclusion

- **Morocco’s contributions exemplify the importance of regional leadership in the Dark and Quiet Sky initiative.**
- **Collaborative efforts at Oukaimeden Observatory demonstrate the potential for global partnerships.**
- **Together, we can safeguard the sustainability of space activities for future generations.**

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Thank you for your attention.