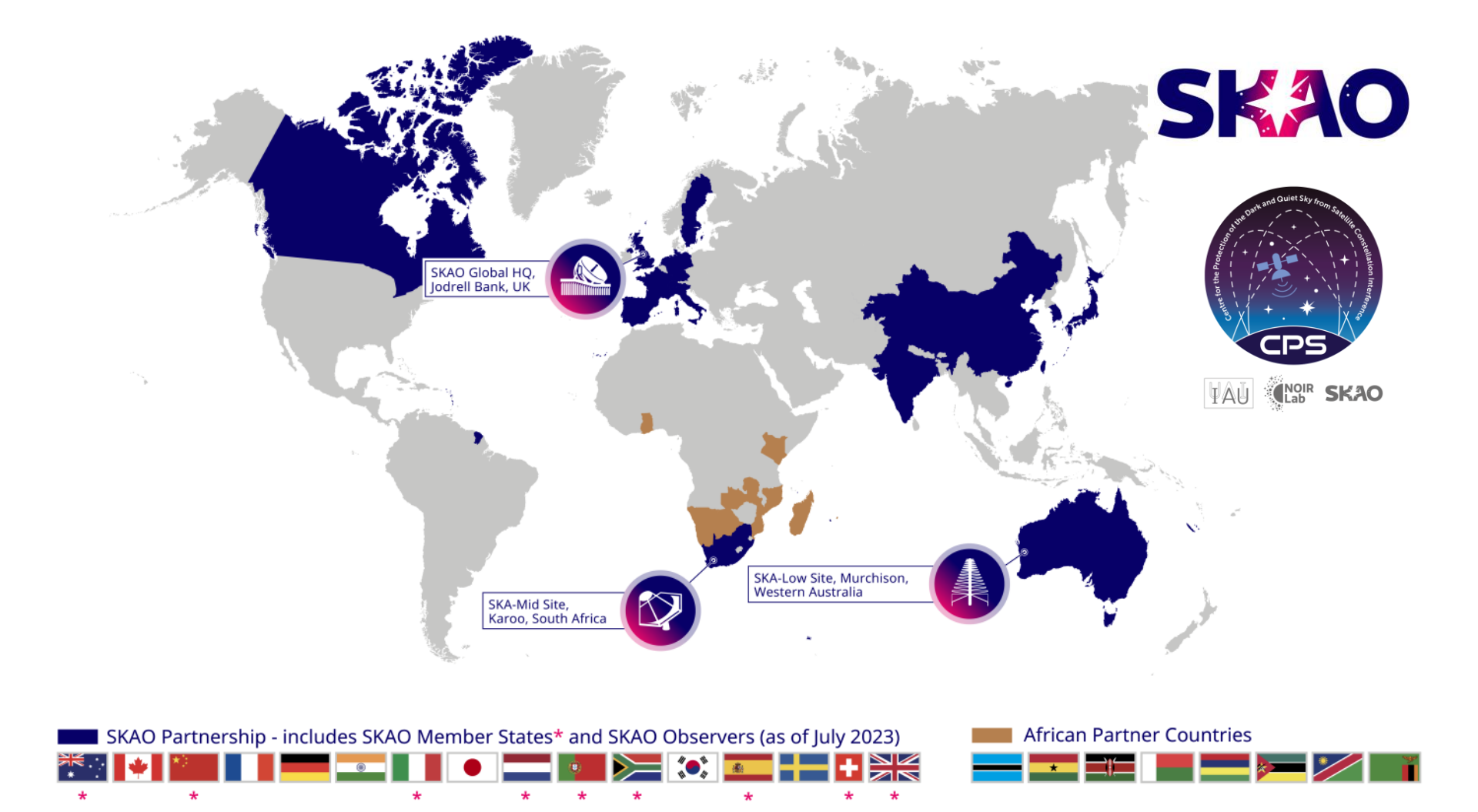
DARK & QUIET SKIES

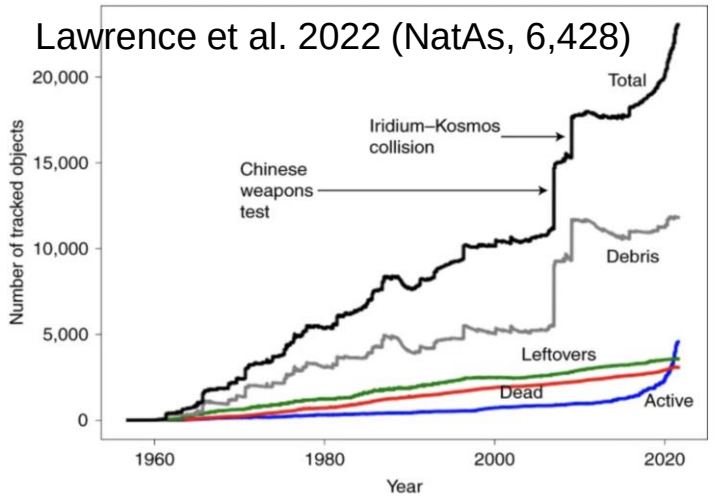
Federico Di Vruno
Spectrum Manager
IAU CPS Co-Director


SKAO
SKAO Global HQ,
Jodrell Bank, UK
SKA-Mid Site,
Karoo, South Africa
SKA-Low Site, Murchison,
Western Australia
Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference
CPS
IAU
NOIR Lab
SKAO
SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of July 2023)
African Partner Countries

Activity in Low Earth Orbit

Number of active satellites (1957-2023)

Lawrence et al. 2022 (NatAs, 6,428)



Updated version of the plot from ref. [3]. Here 'dead' refers to entire derelict satellites, 'leftovers' refers to parts such as rocket stages and so on, and 'debris' refers to material resulting from fragmentations, explosions and collisions. Data extracted from the General Catalog of Artificial Space Objects[12].

Active satellites in LEO (200 – 2000 km)

1957 October 4: 1

2019 : ~2,200

Mega-constellations

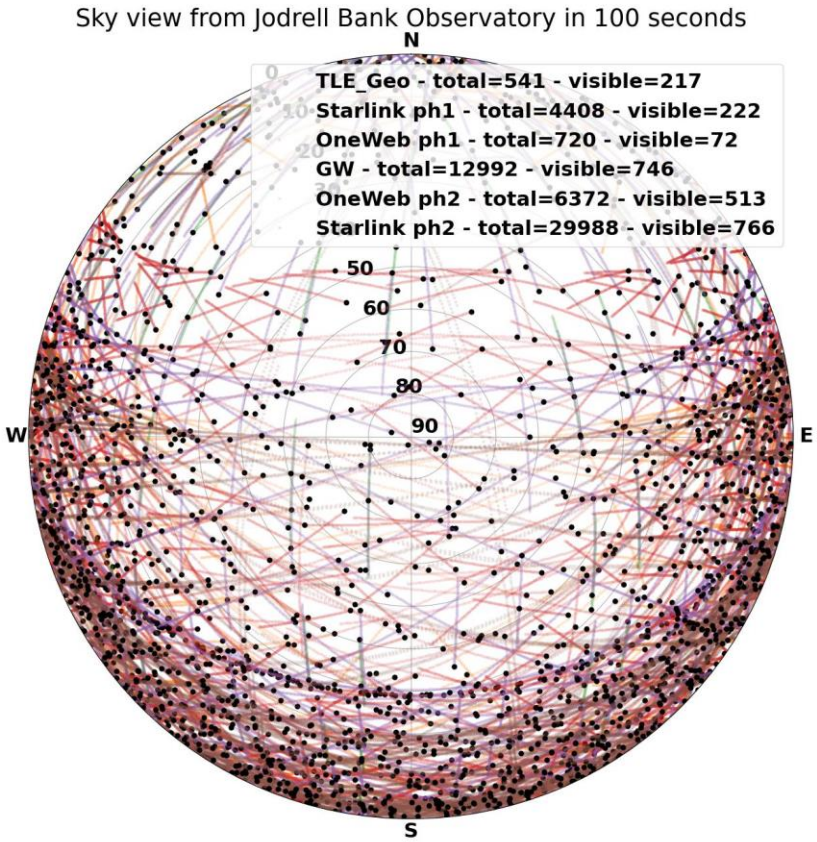
2022 : ~4,000

2023 : >7,700 (Celestrak)

2030+ : >400,000 (based on filings)

Sky view from Jodrell Bank Observatory
Lat = 53 deg
100 seconds

- **Geostationary orbit**
- **Starlink phase 1**
- **OneWeb phase 1**
- **Guo Wang (p)**
- **OneWeb phase 2 (p)**
- **Starlink phase 2 (p)**

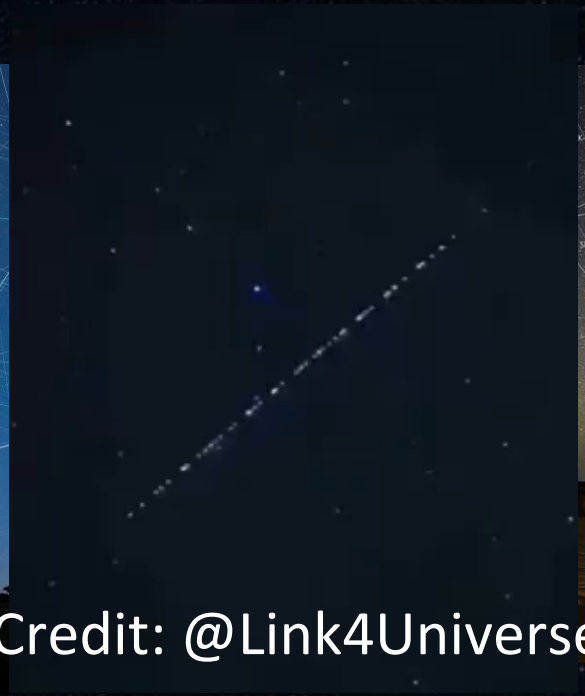


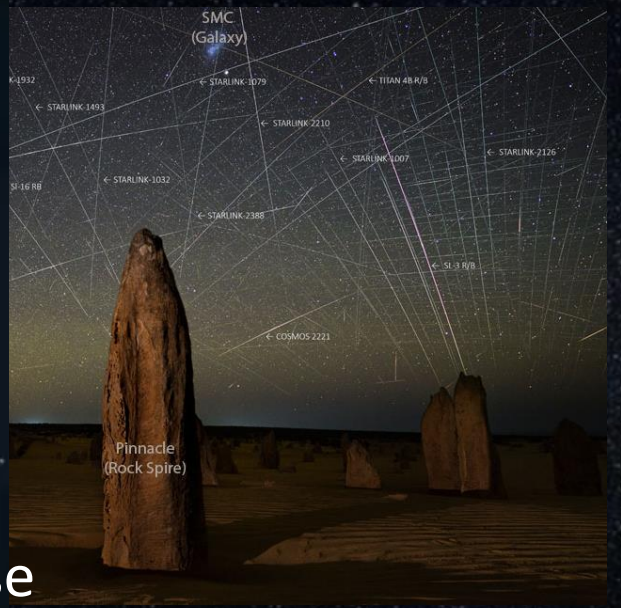
Satellites above horizon = 2319

Source: Federico Di Vruno

Effects on the Dark and (radio)Quiet Sky

View of the night sky



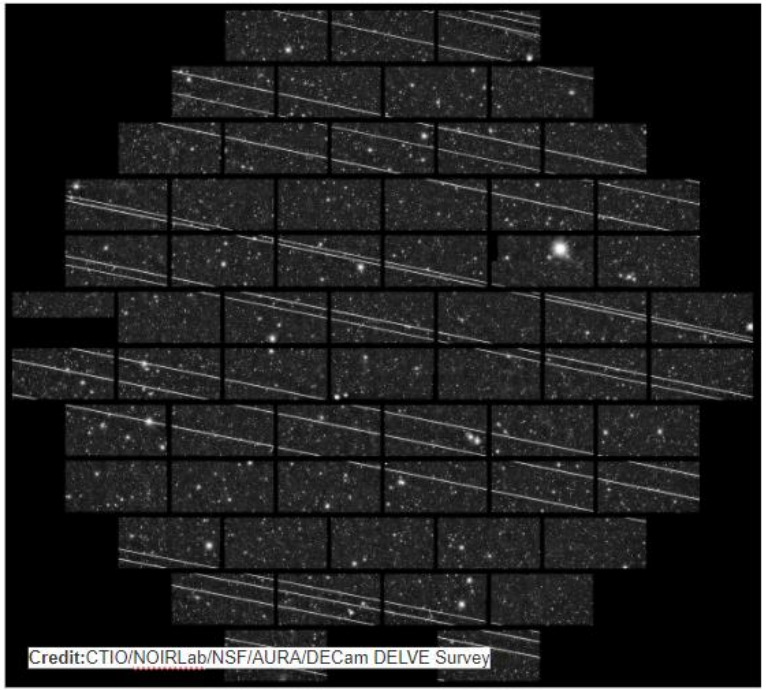


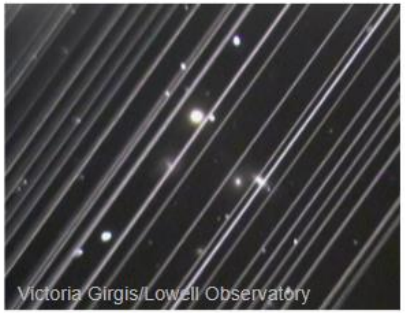
Credit: @Link4Universe

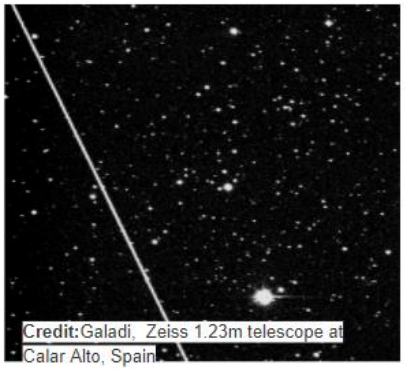
Source: Max Alexander “Our Fragile Space”

Source: Joshua Rozells

Threats to optical astronomy (Earth and space)



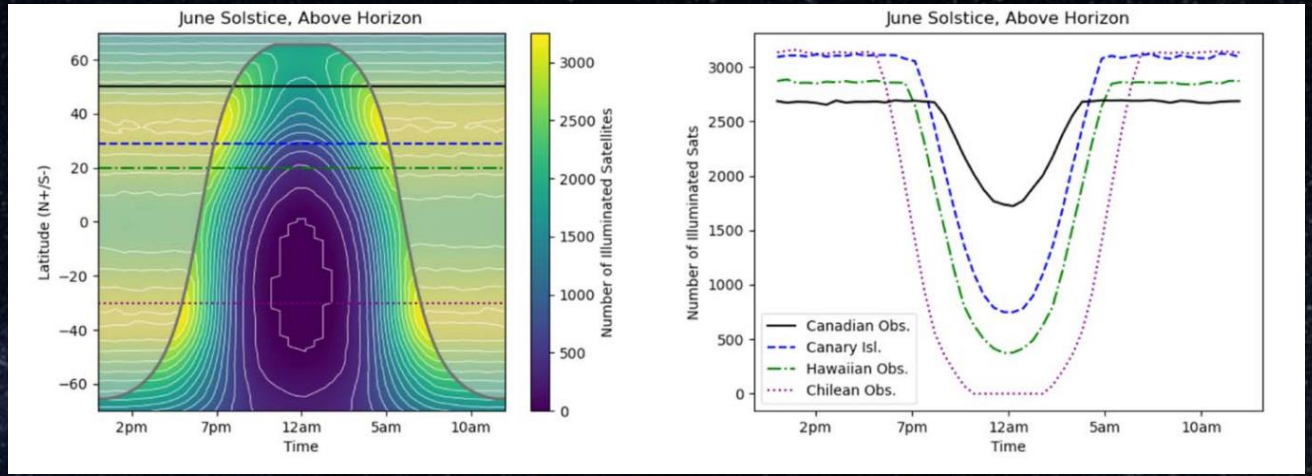


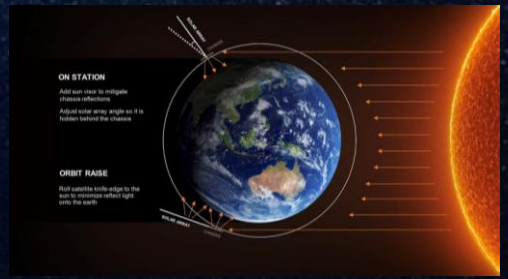


Satellite brightness and visibility

Function of :

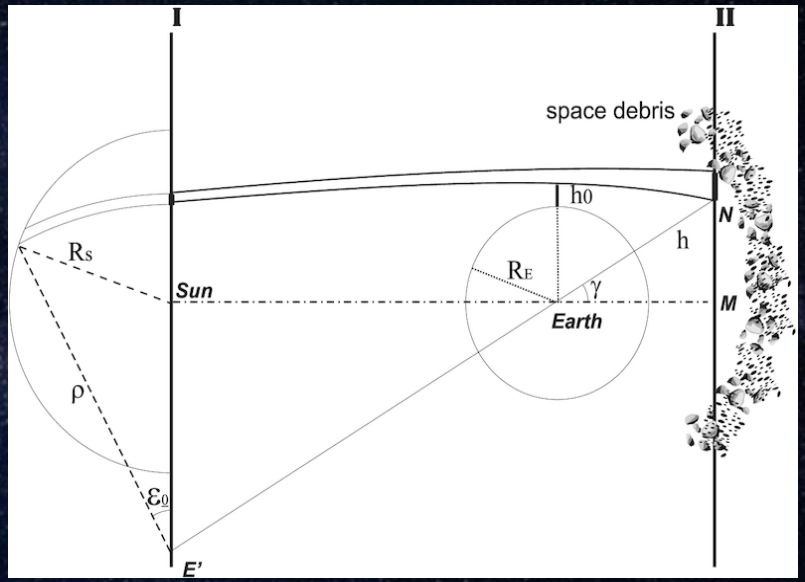
- Satellite design
- Materials
- Orbital altitude
- Observatory location
- Time of year





Visibility of satellites of different constellations (deployed and planned) N = 65000
S. Lawler, A. Boley, H. Rein
https://doi.org/10.3847/1538-3881/ac341b

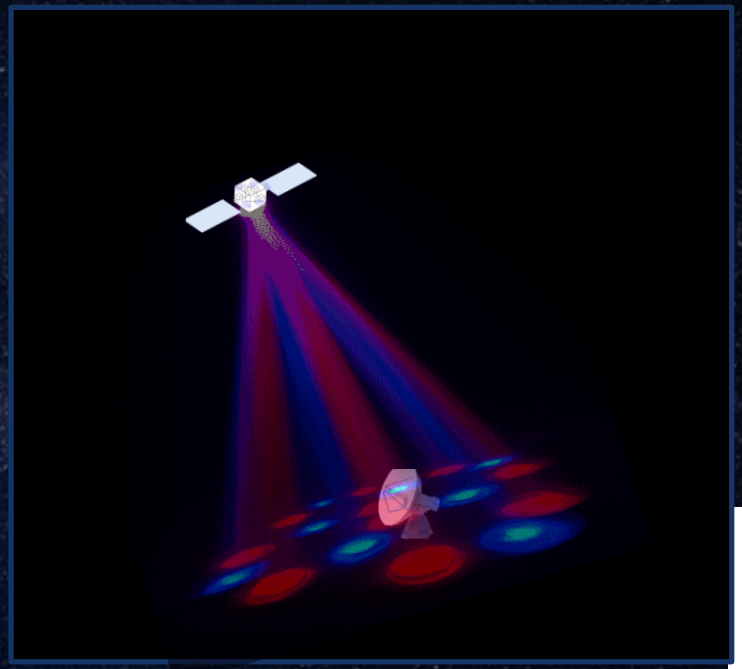
Increase of sky brightness due to space debris



M Kocifaj, F. Kundracik, J. C. Barentine, S. Bara

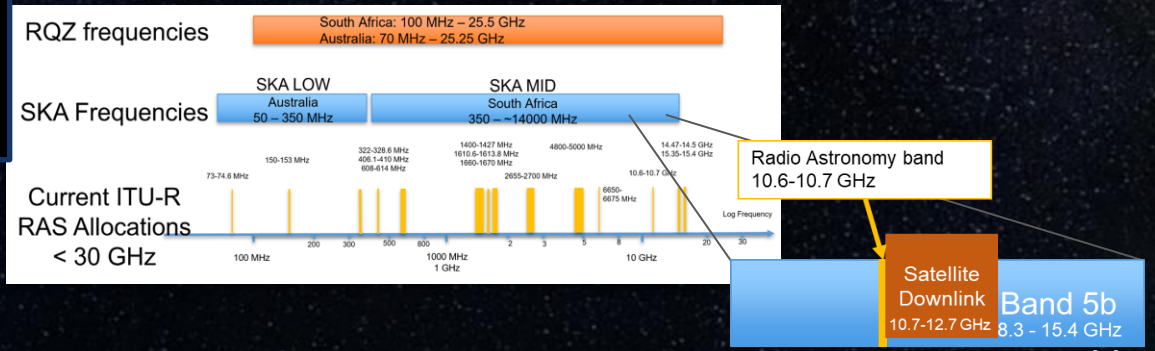
Mon Not R Astron Soc Lett, Volume 504, Issue 1, June 2021, Pages L40–L44, https://doi.org/10.1093/mnrasl/slab030

Threats to radio astronomy



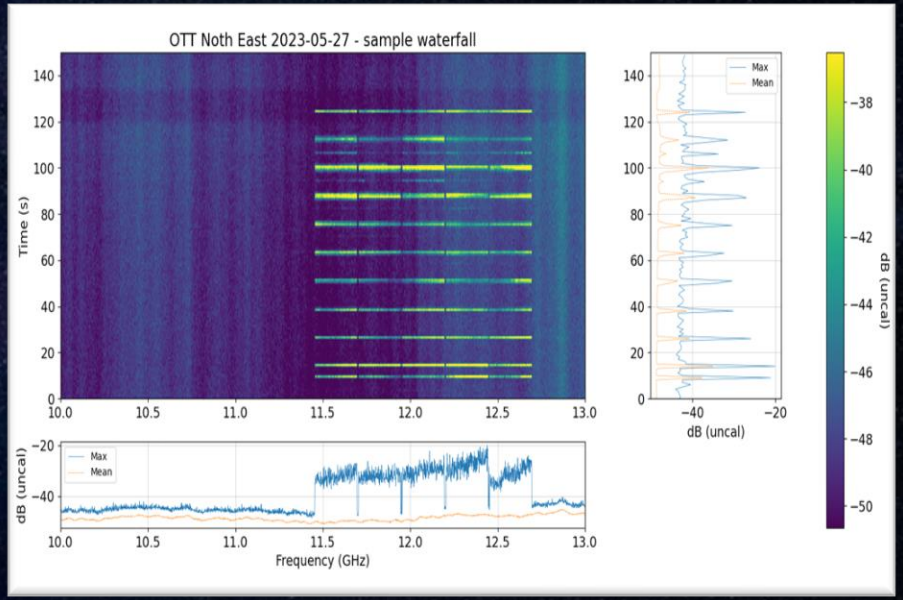
- Satellite visible 24/7
- Main transmissions close to protected bands
- Steerable beams, fixed beams
- Radio Quiet Zones affected
- Many planned frequencies close to protected bands:

Frequency	Band	Use	Protected RAS bands (primary)
10.7 – 12.75 GHz	Ku	Users	(p) 10.6-10.7 GHz
19.7 – 20.2 GHz	Ka	Users/GW	(p) 22.21 – 22.5 GHz
37.5 – 42.5 GHz	V	Gateways	(p) 42.5 – 43.5 GHz
71.0 – 76.0 GHZ	E	Gateways	(p) 76 – 77.5 GHz



Threats to radio astronomy

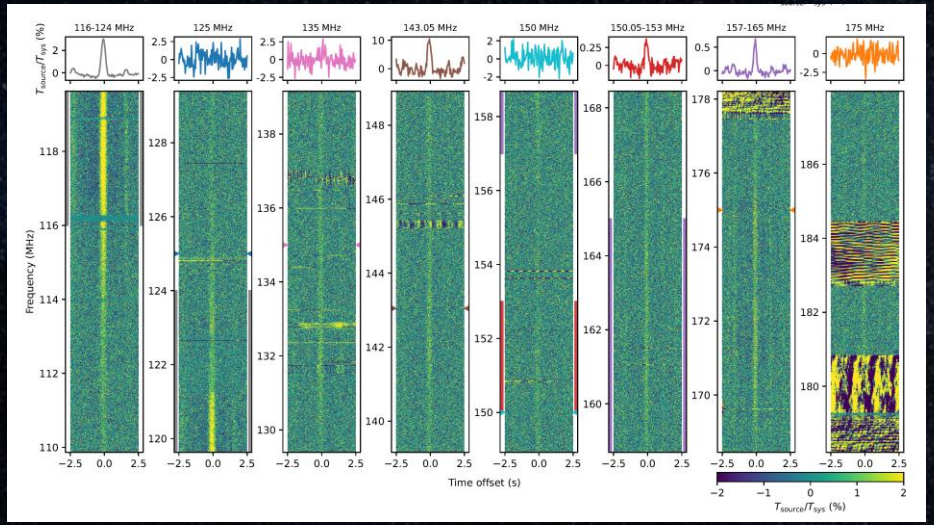
Very strong signals in downlink bands (10e6 Jy)



Satellite downlinks in Ku band (10.7 – 12.7 GHz)

F. Di Vruno, G. Hovey, Onsala Space Observatory

Weak signals in unintended radiation (~10s Jy)



Unintended Electromagnetic Radiation (110 – 180 MHz)

https://www.aanda.org/articles/aa/full_html/2023/08/aa46374-23/aa46374-23.html

The International Astronomical Union's response

The IAU response

Protection of radio astronomy at the ITU-R:

- SKAO
- CRAF
- IUCAF
- IAU

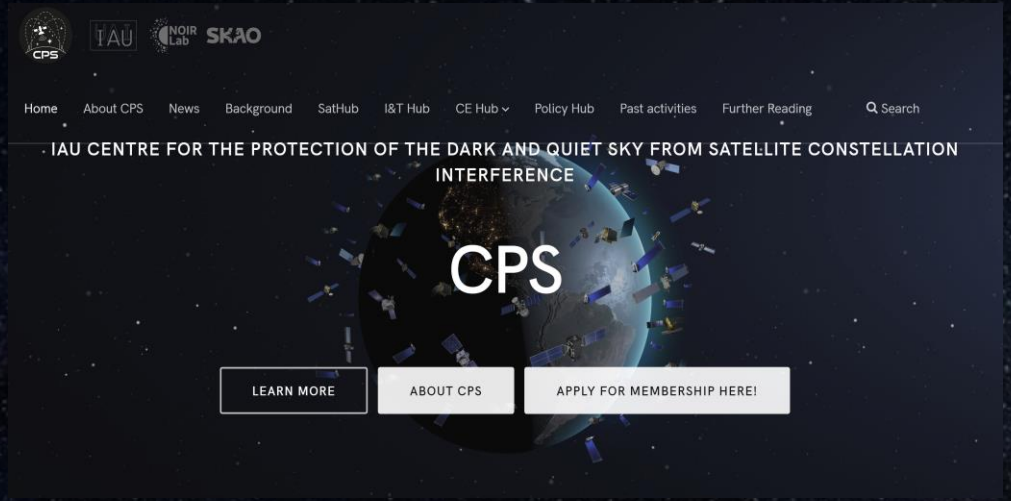
Promoting international guidelines at the UN COPUOS:

- IAU
- SKAO
- ESO
- EAS

Creation of the “IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference”

IAU CPS - a brief summary

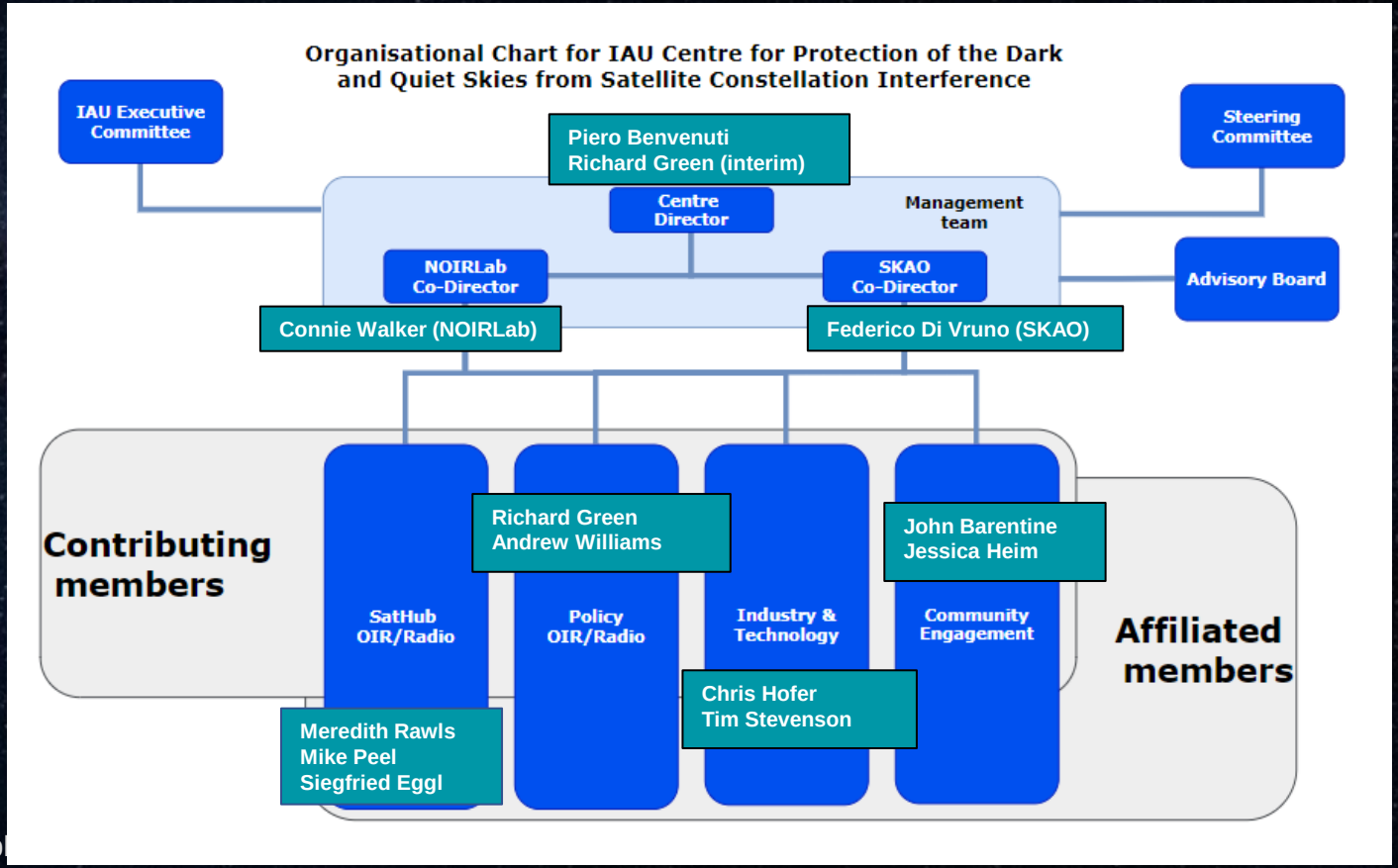
https://cps.iau.org



- **Coordinate efforts and unify voices**
- **Bringing together different communities**
- **Collect, produce and disseminate information and resources**
- **Open and free products**

- **4 Hubs**
- **> 200 members (astronomers, amateur astro, Astro-photography, communications, policy, etc)**

IAU CPS Hubs Activities



Policy Hub

Co-leads: Richard Green and Andy Williams

policy@cps.iau.org

- *Raise awareness in policy forums*
- *Study Space policy*
- *Coordinate national societies*
- *COPUOS*
- *Liaise with ITU groups*

WP1 Position Document

WP2 National Space Law and Policy

WP3 Space Sustainability Rating (Astronomy module)

WP4 COPUOS coordination (IAU, ESO, SKAO, EAS)

.

..

WP11 Recommendations compilation and distilling

Ad Hoc responses to consultations on Space Law

Community Engagement Hub

Co-leads: John Barentine and Jessica Heim ✉ community-engage@cps.iau.org

CE Hub is CPS' bridge to the community of night sky users beyond professional astronomers. It ensures their voices are part of the broader discussion.

Awareness

Informative videos "SATCONS 101":
https://cps.iau.org/community-engagement-hub/satcons-101/

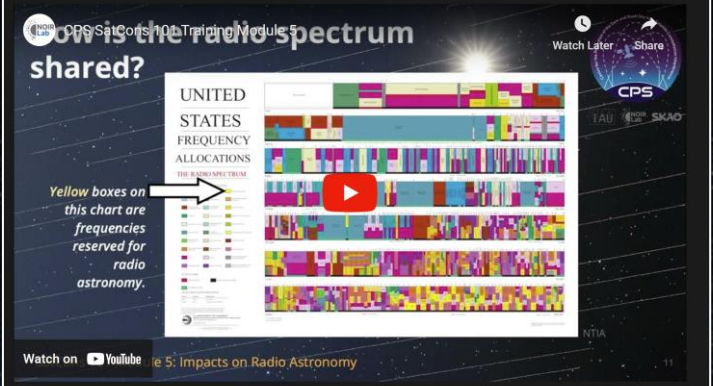
Foundations for IAU Community Engagement:
https://arxiv.org/pdf/2311.02184.pdf

- *Underrepresented communities*
- *Communications*
- *Engagement*

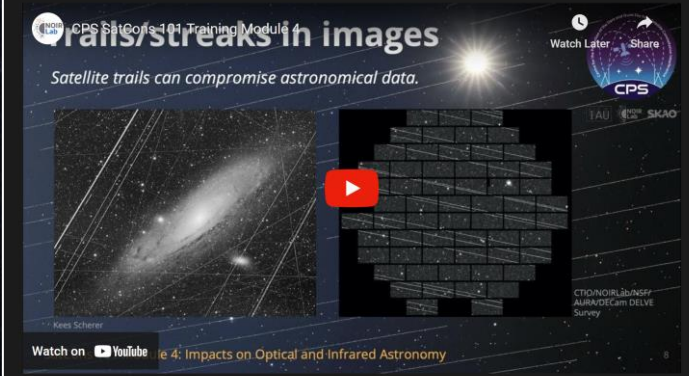
Satellite Basics

Satellite Constellation Design and Operation

Impacts on Radio Astronomy



Impacts to Optical/IR Astronomy

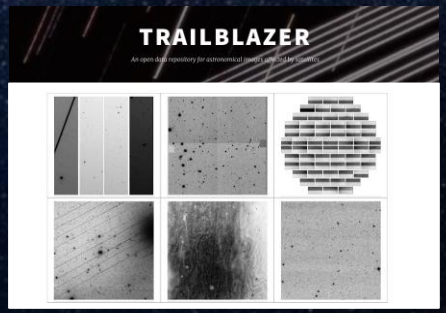


Satellites Hub (SatHub)

Co-leads: Siegfried Eggl, Mike Peel and Meredith Rawls

sathub@cps.iau.org

- *Observations*
- *Data storage*
- *Orbital predictions*
- *Software*



http://trailblazer.dirac.dev

WP01 Observations & Data Repositories

Coordination of professional and amateur optical & radio observations of satellites (brightness, positions, etc.) Data collection and repositories, including TrailBlazer.

WP02 Orbital solutions

Very accurate satellite positions for astronomical observations; to be used for things like avoidance.

WP03 Software Tools

Artifact removal, Simulations. Position Prediction, Citizen-science platform

WP04 Training

Online (or in person) training activities for observing artificial satellites.

Industry & Technology Hub

Co-leads: Chris Hofer and Tim Stevenson; Advisor: Patricia Cooper

industry@cps.iau.org

- *Outreach to industry*
- *Resources to bridge the gap*
- *Promote exchange of information*

SpaceX, Amazon Kuiper and OneWeb + 4 new members

- Awareness raising in industry
- Technical Advisory Committee (TAC)
- Astronomy Guides programme
- Resources for Industry

What have we been up to?

Updates on Dark and Quiet Skies

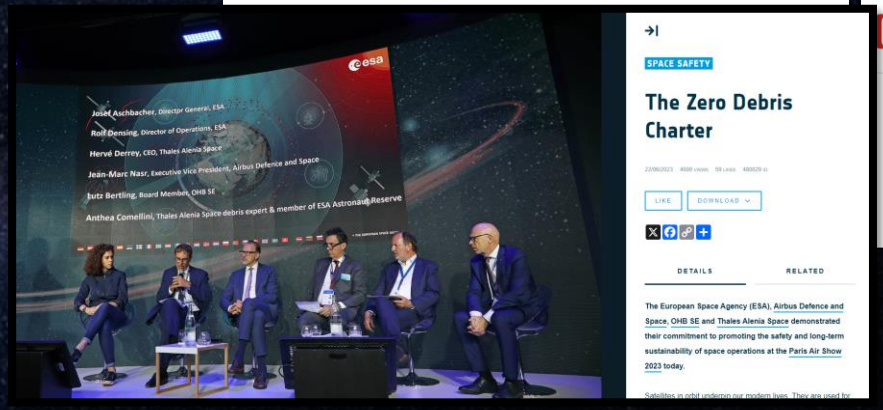
Awareness and supporting national groups

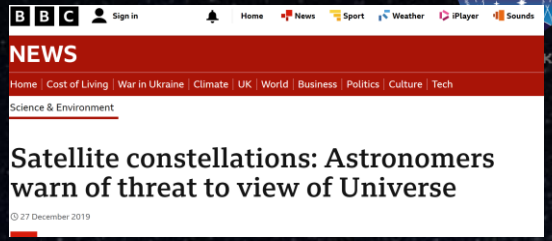
IAU CPS Welcomes Support from G7 Science Ministers on Dark and Quiet Skies

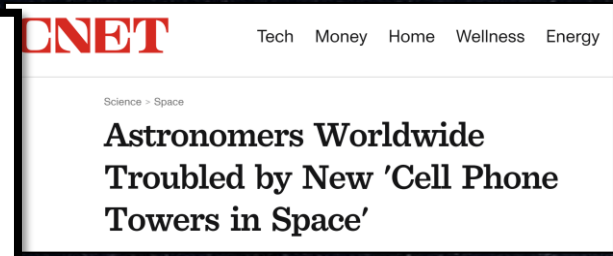
18 May 2023

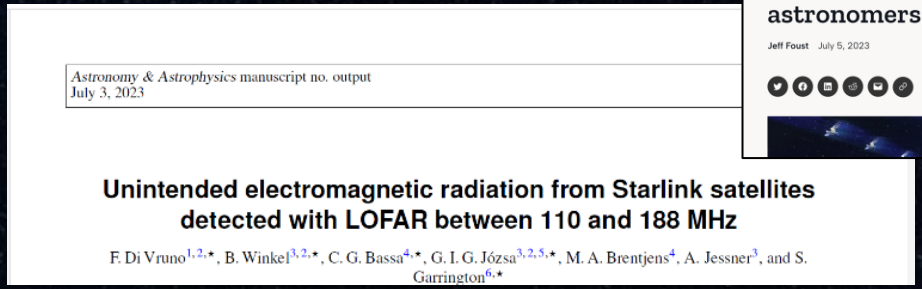
Science and technology ministers of the G7 forum have for the first time stressed the importance of continuing to discuss the impact of large satellite constellations on astronomy

READ MORE









Updates on Dark and Quiet Skies

Observations

Optical observations of Blue Walker 3 (published in Nature)

Unintended Electromagnetic Radiation of Satellites with LOFAR (published A&A)

More observations and modelling ongoing:

- ***BW3 + ISS (sub mm)***
- ***Starlink gen 2 (optical)***
- ***OneWeb reflectivity models***
- ***Amazon Kuiper demo sats***

Radio observations coordinated with CRAF and SKAO (ongoing)

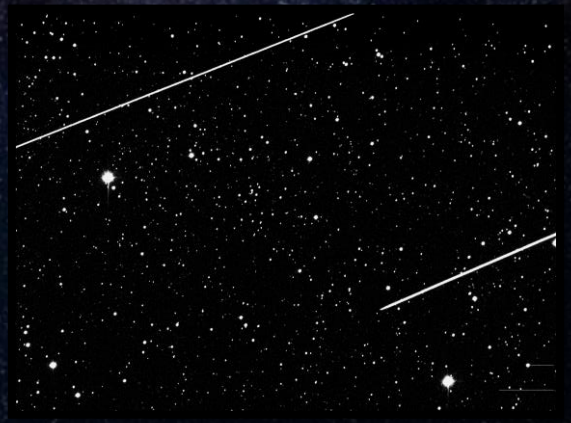
Updates on Dark and Quiet Skies

Software development

Orbital solutions portal:
Public, standardized access to orbital solutions of artificial satellites

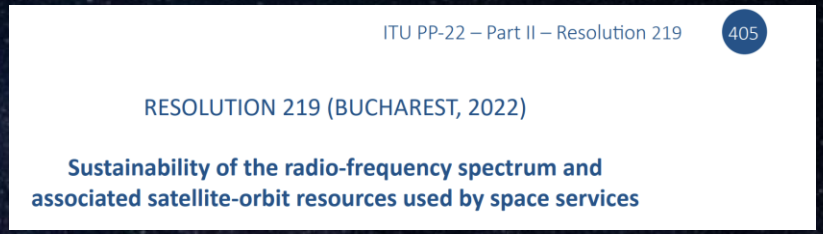
Mark Handley

Data Repository & Exchange
Publicly available, easily accessible, user-friendly, well documented



Updates on Dark and Quiet Skies

International Telecommunication Union



ITU PP-22 – Part II – Resolution 219 405

RESOLUTION 219 (BUCHAREST, 2022)

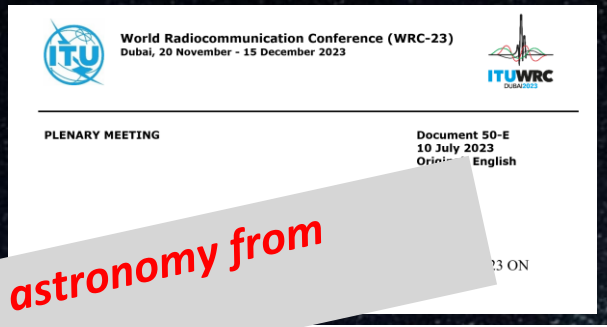
Sustainability of the radio-frequency spectrum and associated satellite-orbit resources used by space services

resolves

1 to instruct the Radiocommunication Assembly, as a matter of ... necessary studies through relevant ITU Radiocommunicati... issue of the increasing use of radio-frequen... GSO orbits and the long-term... to, and rational and con... resources, consistent with the objec...

2 that the results of ...ied studies should be submitted by the Director of BR to the subsequent wor... radiocommunication conference (WRC) for its consideration and any necessary action, as appropriate,

Working on WRC-27 proposals to protect radio astronomy from satellite constellations



World Radiocommunication Conference (WRC-23)
Dubai, 20 November - 15 December 2023

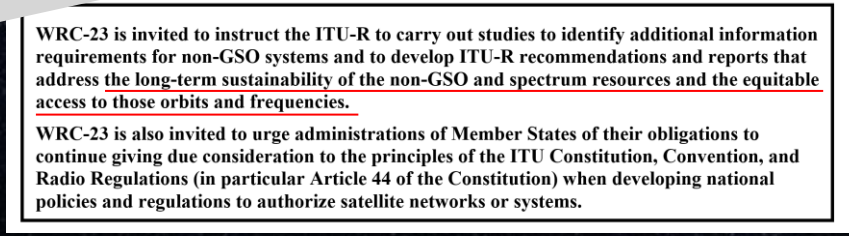
ITUWRC DUBAI2023

PLENARY MEETING

Document 50-E
10 July 2023
Original: English

...23 ON

...y and equitable access and rational use of the non-GSO ...um resources



WRC-23 is invited to instruct the ITU-R to carry out studies to identify additional information requirements for non-GSO systems and to develop ITU-R recommendations and reports that address the long-term sustainability of the non-GSO and spectrum resources and the equitable access to those orbits and frequencies.

WRC-23 is also invited to urge administrations of Member States of their obligations to continue giving due consideration to the principles of the ITU Constitution, Convention, and Radio Regulations (in particular Article 44 of the Constitution) when developing national policies and regulations to authorize satellite networks or systems.

ITU Council resolution on Space Sustainability

Radio Regulations Board on Long Term Sustainability on Non-GSO

Updates on Dark and Quiet Skies

UN COPUOS

- *Intense debate at the 60th Scientific and Technical Subcommittee (STSC) 2023 and the 66th UN COPUOS 2023*
- *Spain and Chile established a "Group of Friends" on D&QS (IAU CPS is secretariat)*
- *Next STSC in Feb 2024: definition of name and scope of an agenda item on D&QS*

IAU CPS briefs delegations as United Nations meeting kicks off

30 May 2023

Ahead of the start of the 66th session of the United Nations' Committee on the Peaceful Uses of Outer Space (UN COPUOS), the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Con...

READ MORE

Dark and Quiet Skies Feature Prominently at UN Meeting

20 Jun 2023

The issue of the protection of dark and quiet skies from large satellite constellation interference featured prominently at the 66th meeting of the United Nations Committee on the Peaceful Uses of Ou...

READ MORE

Updates on Dark and Quiet Skies

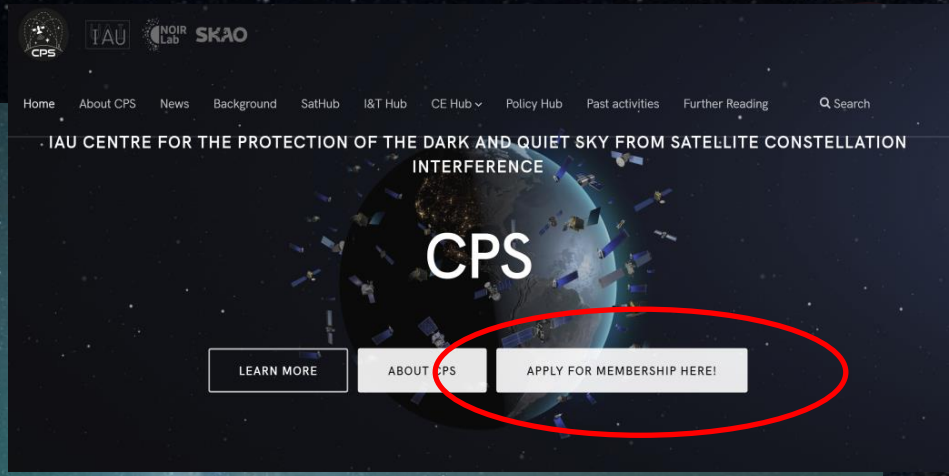
Industry - Constellations

- *Amazon Kuiper to launch two satellites and discussing coordination of optical observations with SatHub*
- *SpaceX developed dielectric film and offers it at cost*
- *FCC included conditions in Satellite constellations licenses*
- *IRIS^2 (EU constellation) advancing, IAU CPS in contact with the European Commission through the European Astronomical Society*
- *UK "Astra Carta" launched, with the Earth Space Sustainability Initiative. IAU and SKAO signed Memorandum*
- *First Technical Advisory Committee (TAC) held*

IAUS385 Symposium held in La Palma, Canary Islands (Oct 2023)

Thank you for your kind attention!

QUESTIONS?



Contact:
federico.divruno@cps.iau.org

Info CPS:
info@cps.iau.org