



Dark and Quiet Skies and Satellite Constellations

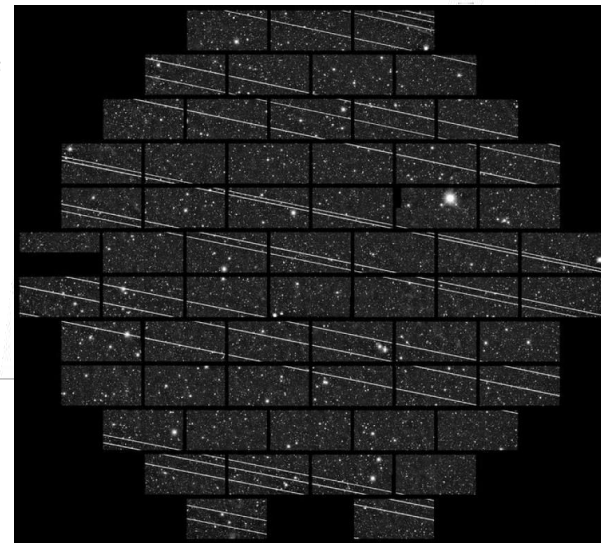
Mike Peel

Postdoc in Physics/Aeronautics
Imperial College London
CPS SatHub co-lead

RAS A&G Highlights
9 October 2026

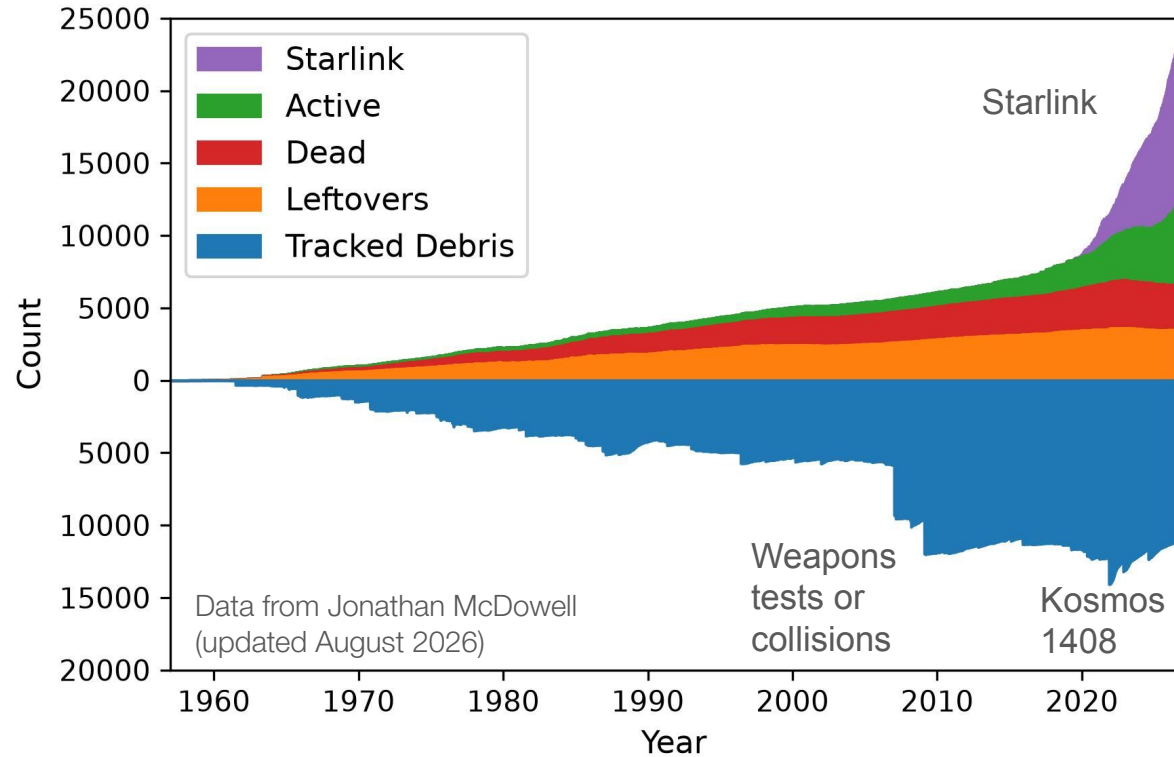
RAS Specialist Discussion Meeting - PREVIEW!

- Dark and Quiet Skies and Satellite Constellations
- Friday 16 October 2026, 10-17h
- Burlington House + online (fully hybrid)
- £15 (in-person) / £5 (online) / £0 (RAS Fellows)
- Organisers: Mike Peel, Marieta Valdivia Lefort, Robert Massey, Paul Daniels, Davide Amato, Dave Clements
- Packed agenda + time for discussions!
- <https://www.ras.ac.uk/events-and-meetings/ras-meetings/dark-and-quiet-skies-and-satellite-constellations>



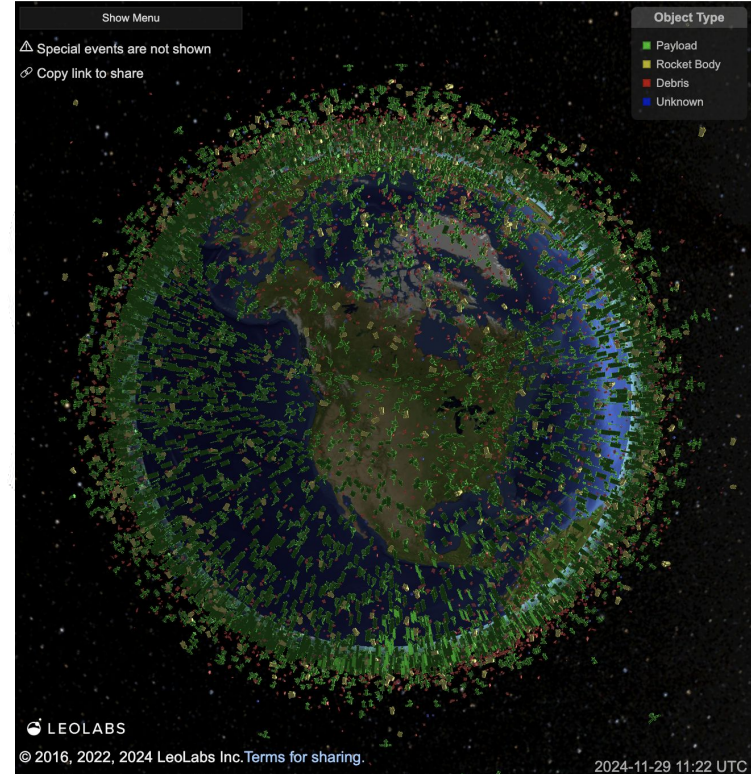
Credit: CTIO/NOIRLab/NSF/AURA/DECam DELVE Survey

Rapidly increasing numbers of satellites



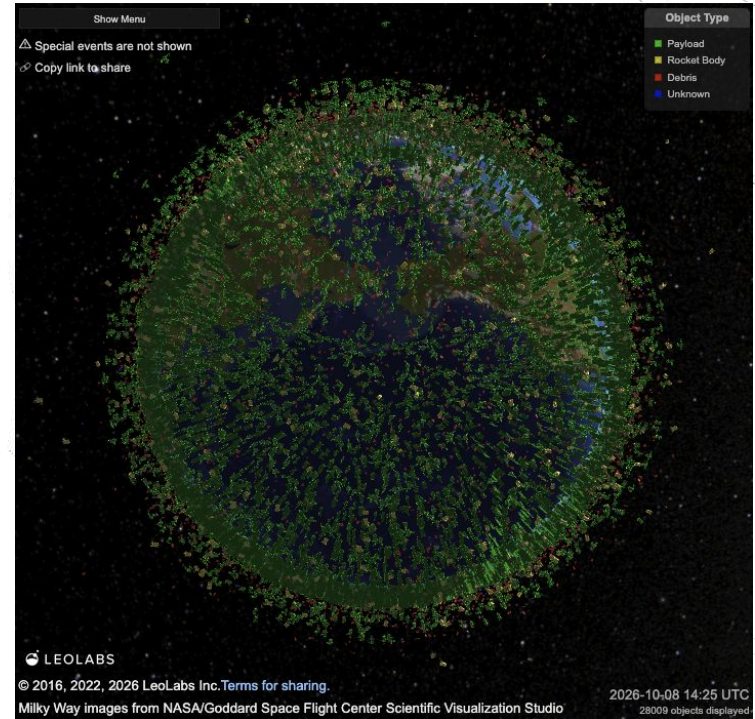
Space is changing rapidly

- 18,000+ satellites in Low Earth Orbit
- ~3 million proposed!
- Driven by drastically reduced launch costs via commercial reusable rockets
- Satellites are important for:
 - Space telescopes
 - Communications
 - Earth observations
 - Weather forecasting
 - Military applications
 - Sovereign capacity



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How do satellites affect astronomy?

*Not to scale - for illustration purposes only

Reflecting sunlight

Because of their altitude, satellites can reflect sunlight down to locations on Earth where the Sun has already set – when optical telescopes are observing. How bright these reflections are depends on the satellites' orientation, size, material and reflectivity.

Changing the night sky

Casual stargazers, astrophotographers, and Indigenous communities that have observed the night sky for generations are seeing increasing numbers of satellites, altering their view of pristine night skies.

Radio emissions

Even during the day, satellites can interfere with radio telescopes on Earth due to the very bright signals they emit to transmit information, but also due to unintended electromagnetic radiation leaking from their onboard electronics.

+ thermal emission



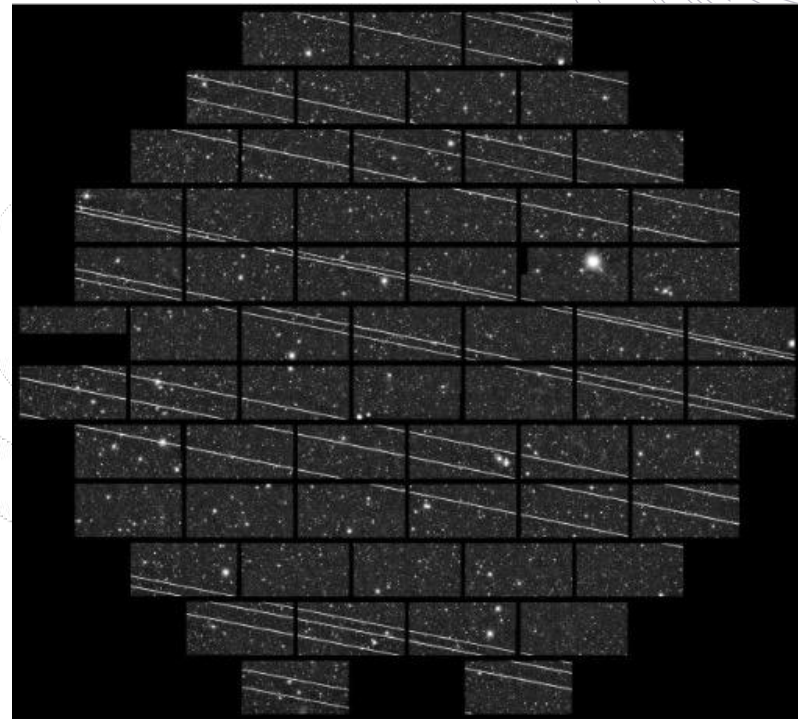
Impact on the night sky



Pentre Ifan burial chamber, Pembrokeshire, Wales - Max Alexander "Our Fragile Space"

Effects on optical astronomy

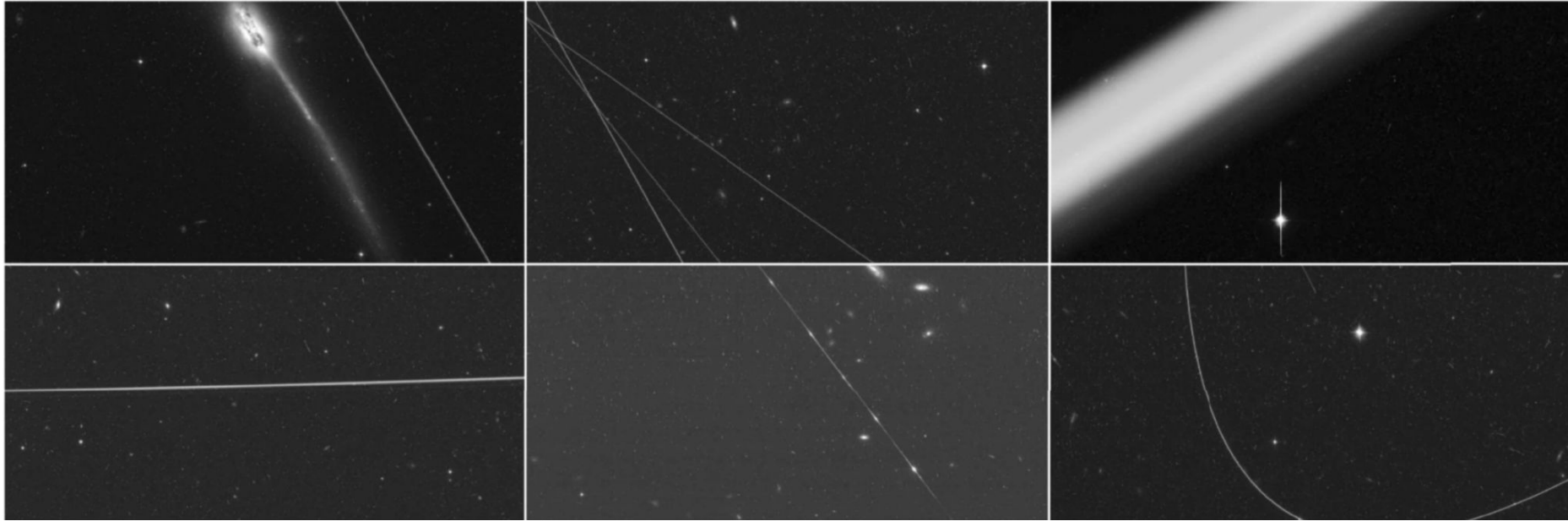
- Satellite streaks can cause unusable data
- Want fainter than 7th mag (not visible by eye, don't overwhelm Rubin LSSTCam)
- Can also increase average sky brightness!
- Impacts to science include:
 - Asteroids: need twilight observations
 - Variable stars: lost time series
 - Dark matter weak lensing: subtle distortions to the shapes of galaxies
 - Spectroscopy: unknowingly contaminated
 - Extreme brightness may damage detectors



Credit: CTIO/NOIRLab/NSF/AURA/Decam DELVE Survey

Impact on Space-based Astronomy

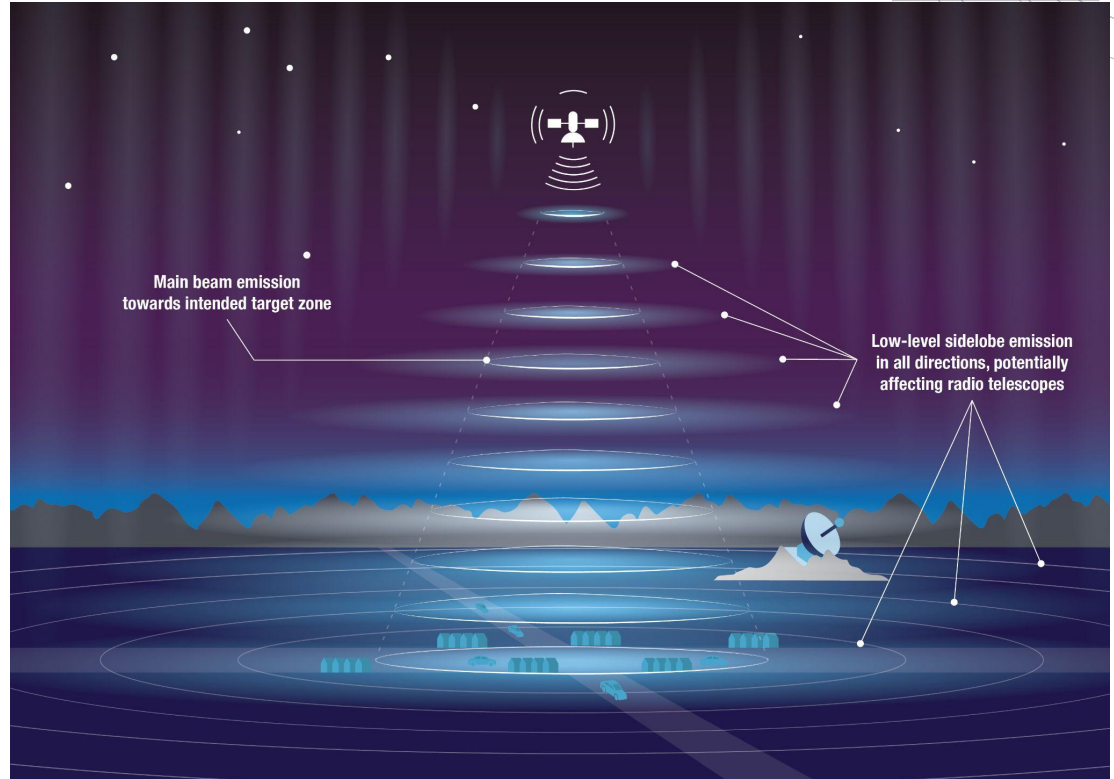
Satellite trails in HST individual exposures - Kruk et al. (2023); also see Borlaff et al. (2025)



Also see Project SPARKLES: <https://sparkles.readthedocs.io/en/latest/>

Effects on radio astronomy

- Intentional emissions (downlinks)
- Unintentional out-of-band emission (harmonics/leakage)
- Unintentional electromagnetic radiation (UEMR)
- Reflection of strong terrestrial radio signals off satellite bodies



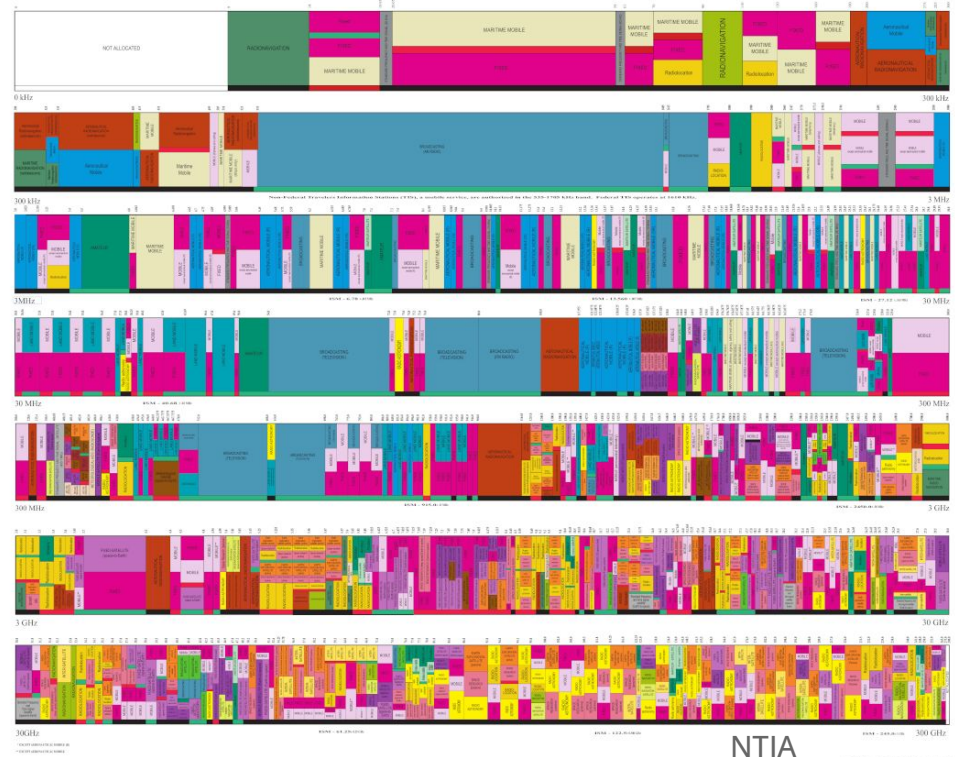
Radio spectrum is regulated and very crowded

Bright yellow boxes on this chart are frequencies reserved for radio astronomy (often shared).

Radio astronomy observes at all frequencies - has to work around active transmissions (often called 'radio frequency interference' - but not legally interference)

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

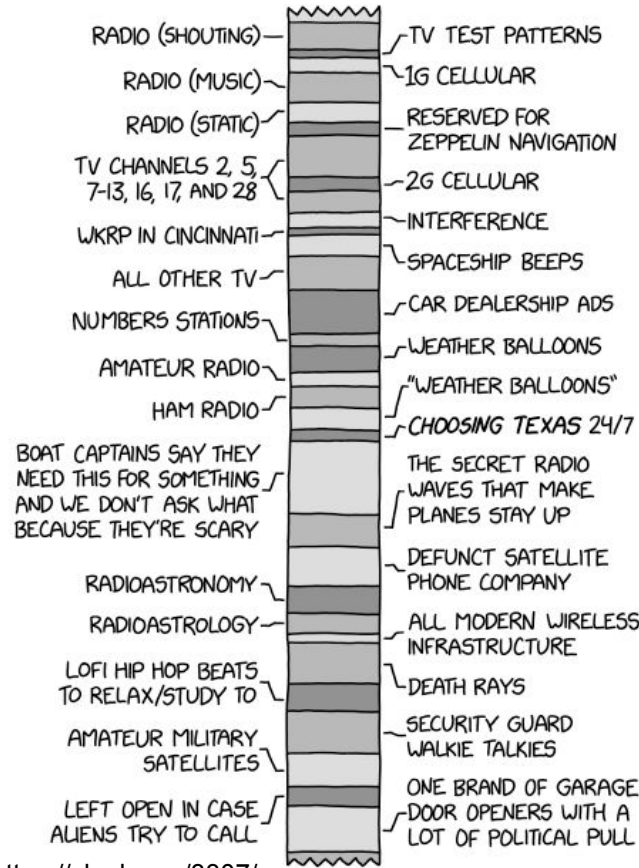


Radio spectrum

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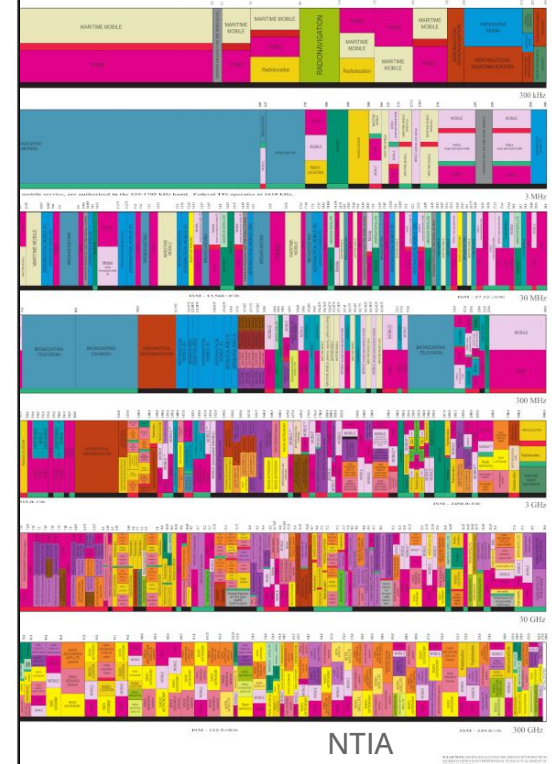
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MODERN SPECTRUM ALLOCATION CHART



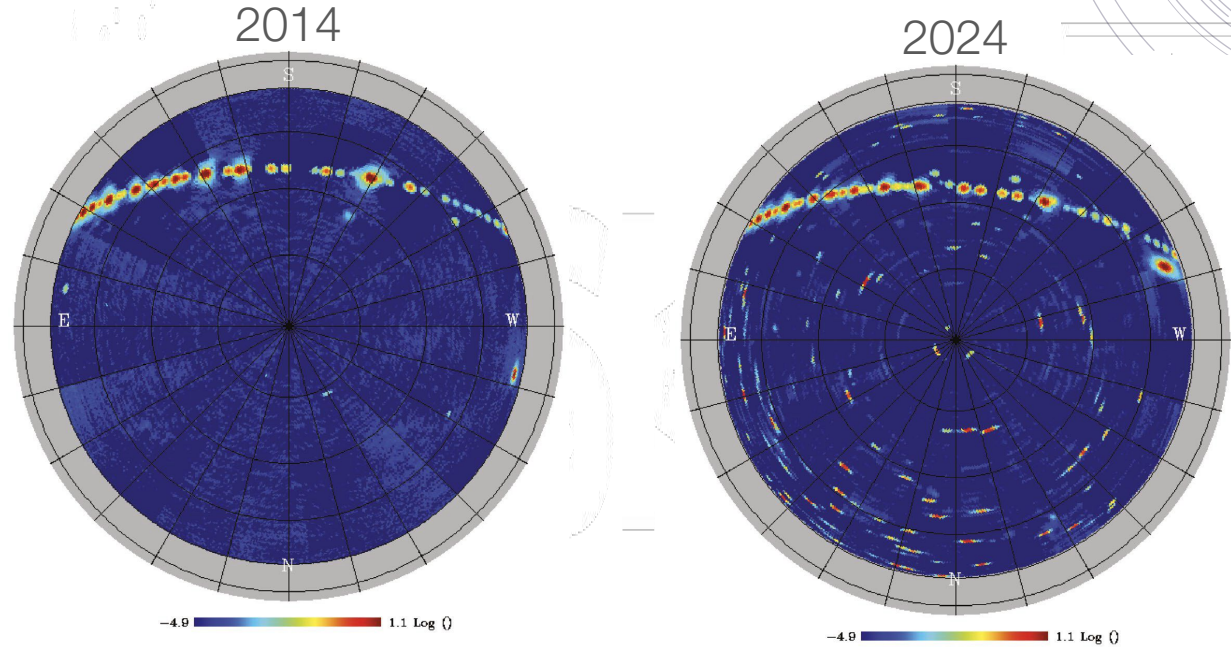
<https://xkcd.com/3307/>

crowded



Impact on radio observations

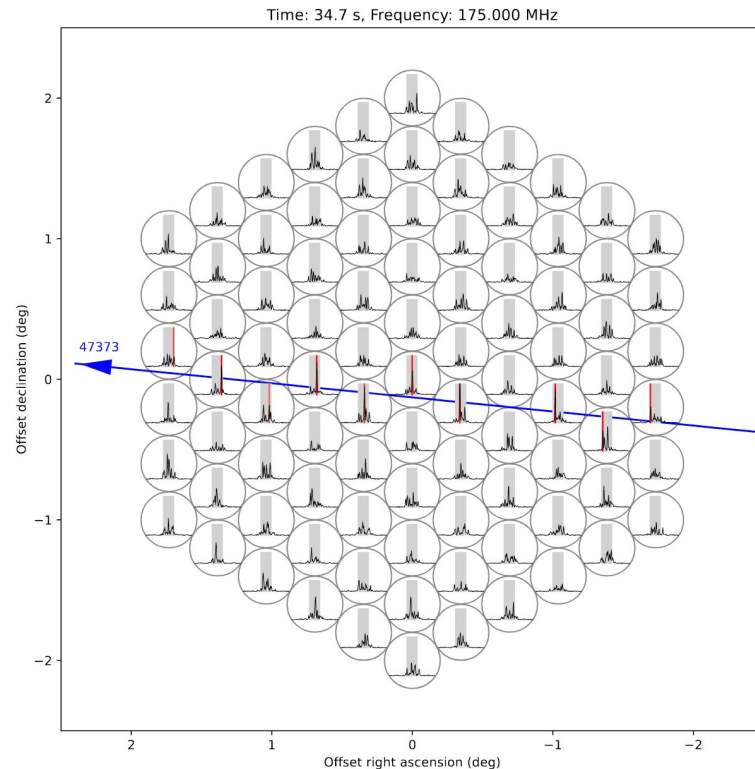
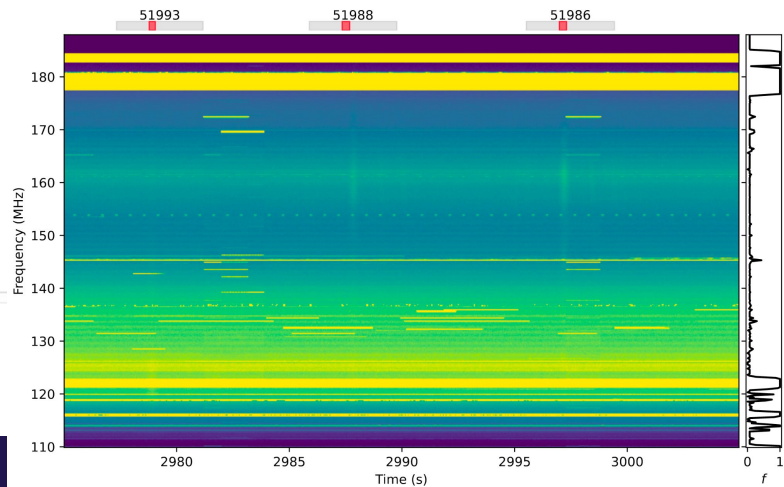
Observations from
QUIJOTE
telescopes from
Teide Observatory
(Tenerife)
10-14GHz



2014 vs. 2024: The increase in satellite signals at 10-20GHz is clearly visible between the geostationary band and the new satellite constellation signals.

Unintended emission at low frequencies

- LOFAR sees Starlink passing overhead!
- Unintended emission from back-end electronics seen at ~ 150 - 180 MHz
- Not permitted bands for transmitting...
- Di Vruno et al. (2023), A&A (published), arXiv:2307.02316
- (Also Grigg et al., 2023, 2309.15672)

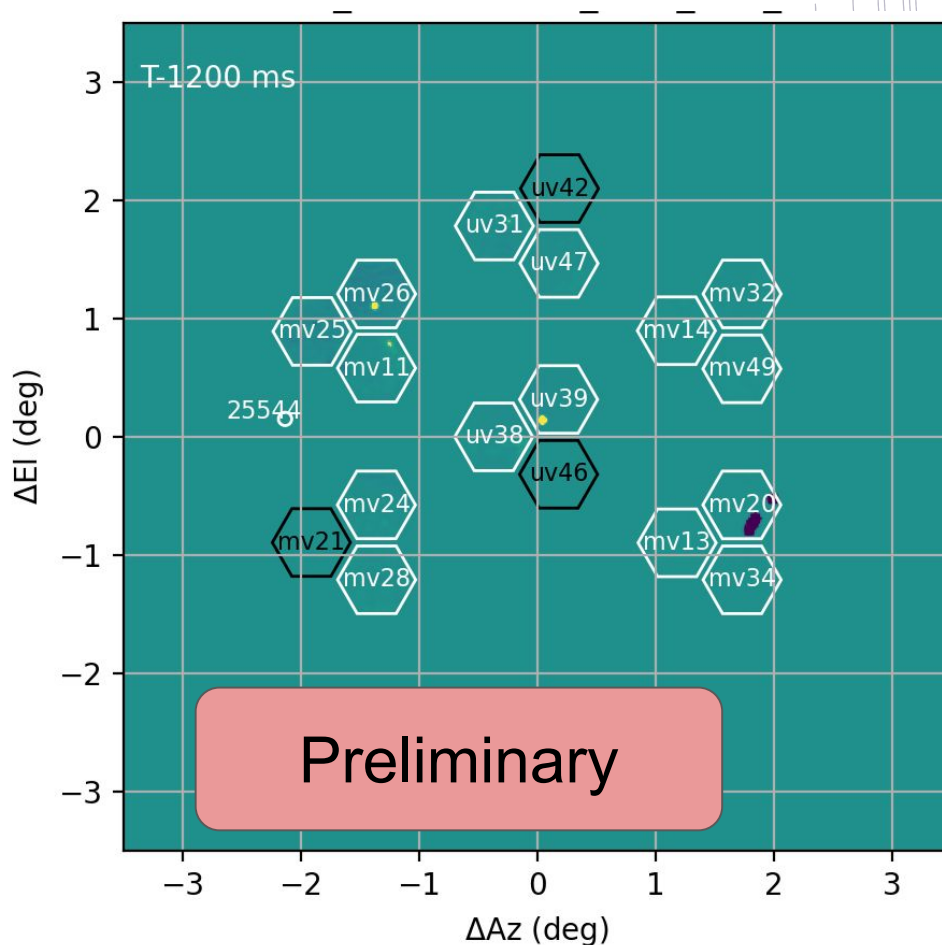
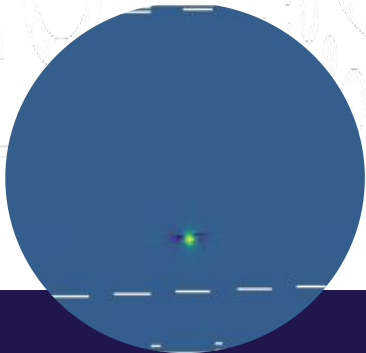


Thermal emission

Simons Observatory detects thermal emission from e.g., the International Space Station!

Estimated to be on the order of 100 Jy at 100 GHz!

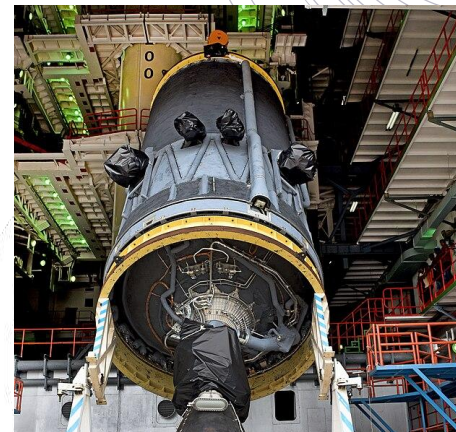
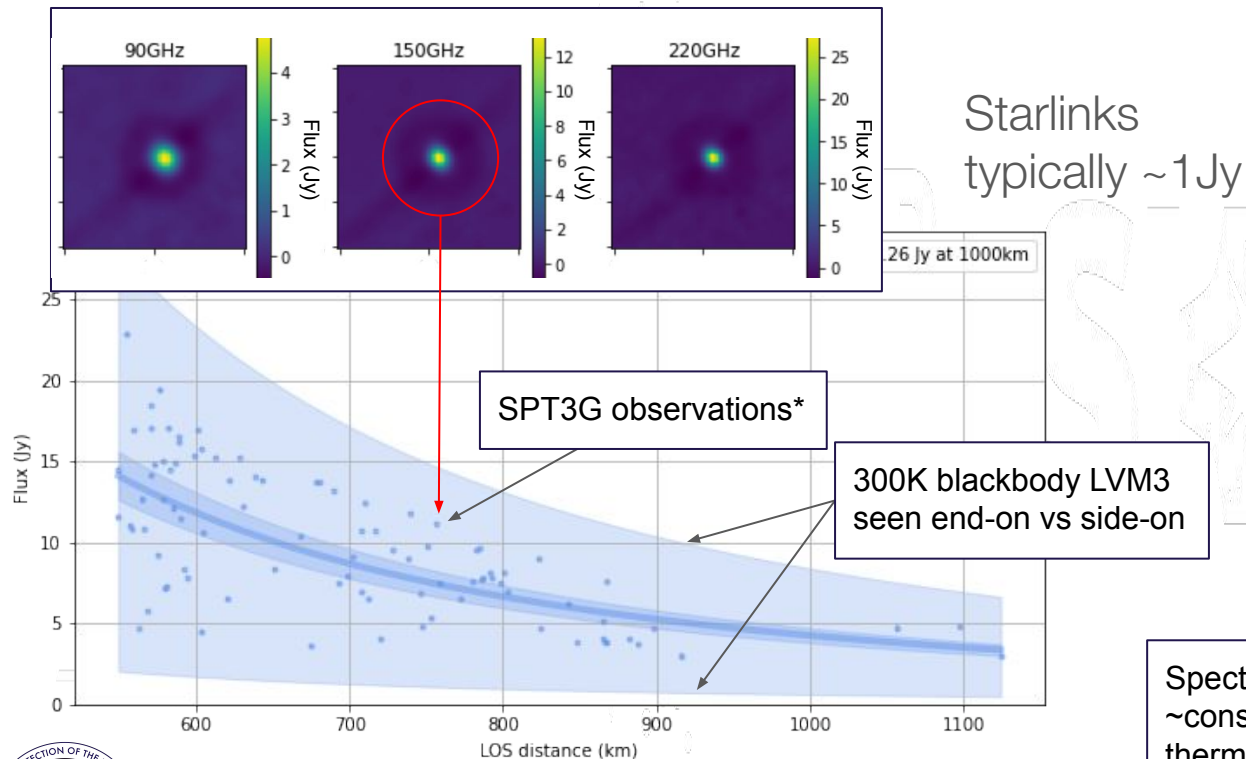
Thermal amplitude depends on temperature, size, and distance.



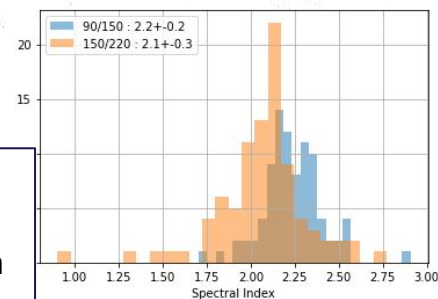
Example from South Pole Telescope

Even if not actively emitting RF signal, satellites can be millimeter bright!

(Foster et al.,
arXiv:2411.03374)



LVM3 Upper stage : 4m diam. x 13.5m long



Spectral index
 $\sim$ consistent with
thermal emission

* observed both in direct sunlight and in Earth's shadow

What can the satellite industry do to lessen the impact on astronomy?



Divert signals

Operate in frequencies allocated for satellites and use technology that allows to divert beams or stop transmission momentarily while transiting radio telescope beams.

Quiet onboard electronics

Reduce radio noise from electronic components of satellites from design phase. Develop and adopt standards for radio emissions and test electronics before launch.

Darker satellites

Use less reflective material or a non-reflective coating to make satellites less bright or divert light reflection away from Earth.

Smaller and fewer satellites

Keep satellites small to reduce their footprint and reflections, and minimise overall numbers.

Repositioning

Alter the orientation of satellites where possible so that solar arrays point away from Earth, reducing flares and glints. Mitigate increased impact during orbit-raising and de-orbiting, and minimise the time satellites spend in orbit when not in service.

Lower Earth orbit

Put satellites in orbits below 600 km so they stay longer in Earth's shadow, cross the sky then disappear faster when viewed from low latitudes, and appear fainter to large telescopes due to being out of focus.



Did you know?

Astronomers have recommended a limit of magnitude 7 on reflected sunlight from satellites so they are invisible to the unaided eye.

*Not to scale - for illustration purposes only

What can **astronomers** and **policy makers** do to help astronomy?

Information sharing

Astronomers can avoid passing satellites by planning observations around satellite orbits – when location information is shared in advance by satellite operators and is publicly available. They can also share observation schedules with satellite operators to help them avoid telescopes.

Radio telescope registration

Astronomers can register radio astronomy telescopes through their national administrations with the UN specialised agency - ITU, which is crucial to obtain international protections.



See the map of ITU-registered radio telescopes.

Post processing

Post-processing of data can remove streaks from images but some information is inevitably lost.

Diplomacy

International bodies like the United Nations and its committees can pass resolutions or produce guidelines encouraging member states to adopt recommendations.

Regulations

Regulatory bodies can build on good practice and guidelines to develop new regulations, requiring stakeholders to follow them.

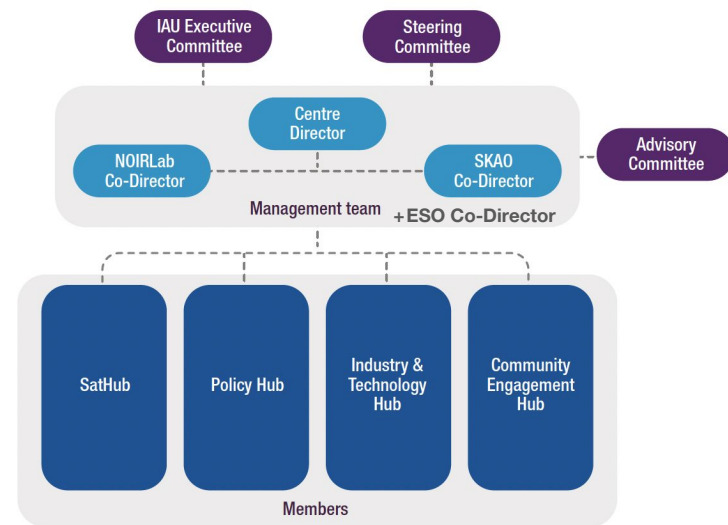
Good practice

Astronomers and industry are developing recommendations, which policy makers can turn into guidelines to encourage industry to follow good practice.



Centre for the Protection of Dark and Quiet Sky

- Centre of expertise of the International Astronomical Union, hosted by the SKAO; NSF NOIRLab; and ESO
- International cooperation among software engineers, observers, astronomers, satellite industry folk, policy experts, space lawyers, government officials
- Our mission:
coordinate efforts and unify voices across the global astronomical community to protect the dark and quiet sky from satellite constellation interference.



Four hubs

- **SatHub**

- Satellite observations and data analysis to understand problem + find mitigations during data processing. Developing **SatChecker** and **SCORE** (amongst other software).

- **Industry & Technology Hub**

- Fosters collaboration between the astronomy and satellite operator communities

- **Policy Hub**

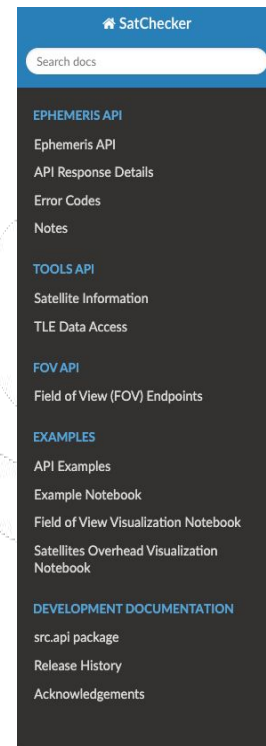
- Studies national and international policies and regulations related to the use of space

- **Community & Engagement Hub**

- Builds bridges between all involved stakeholders and affected communities

SatChecker

- API for predicting satellite positions (single satellite) and transits (field of view (FOV) predictions)
- Best predictions of satellite positions based on public and more precise operator provided data
- Define RA/Dec center, radius, and time window; get all satellites overhead at a given time/location
- Access to all archival TLE data (back to 1959)
- Regular updates with latest TLEs (every ~8 hours) (LEO satellites regularly manoeuvre etc.)
- Satellite metadata: NORAD ID, COSPAR ID, launch/decay dates, etc.
- API docs: <https://satchecker.readthedocs.io/en/latest/>
<https://satchecker.cps.iau.org/api/docs/>



🏠 / SatChecker Ephemeris API Documentation [View page source](#)

SatChecker Ephemeris API Documentation

Overview

SatChecker is a satellite position prediction tool from the IAU CPS (IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference) SatHub group. It uses TLEs (two-line element sets) from Celestrak and Space-Track to provide predictions of satellite positions at a given time and location. It also provides additional information like range, on-sky velocity, and an "illuminated" flag for each prediction point.

SatChecker uses the TLE with the closest epoch date available to the date specified in the API parameters - currently available TLEs go back to July 2019. General TLE data is updated daily, and supplemental TLEs from Celestrak are updated every 8 hours.

The SatChecker Tools API provides additional functionality for satellite name and ID lookup, as well as the ability to retrieve all available TLE data for a given satellite over a given date range. Satellites can be assigned temporary IDs after launch, and names are subject to change, so the Tools API can be used to keep track of these changes.

Support



For assistance with SatChecker, please open an issue on the [GitHub](#)



Forecast positions in FOV

← → ↻ satchecker.readthedocs.io/en/latest/fov.html

SatChecker

Search docs

EPHEMERIS API

Ephemeris API

API Response Details

Error Codes

Notes

TOOLS API

Satellite Information

TLE Data Access

FOV API

Field of View (FOV) Endpoints

Satellite passes Through FOV

Satellites above the horizon

EXAMPLES

API Examples

Example Notebook

Field of View Visualization Notebook

Satellites Overhead Visualization Notebook

DEVELOPMENT DOCUMENTATION

src.api package

Release History

Acknowledgements

Field of View (FOV) Endpoints

The FOV API provides two main endpoints for checking satellite positions relative to a or horizon.

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Satellite passes Through FOV

The FOV API provides two main endpoints for checking satellite positions relative to a or horizon.

Query Parameters:

- latitude - (required) - Observer's latitude in degrees
- longitude - (required) - Observer's longitude in degree
- elevation - (required) - Observer's elevation in meters
- site - (optional) - Site name (e.g. 'greenwich') - if provide longitude, and elevation can't be used; see [astropy site](#) list of valid site names
- start_time_jd - (optional) - Julian Date for start of obs window
- mid_obs_time_jd - (optional) - Julian Date for middle of obs window
- duration - (required) - Duration to check in seconds
- ra - (required) - Right Ascension of FOV center in deg
- dec - (required) - Declination of FOV center in degrees
- fov_radius - (required) - Radius of circular FOV in deg
- group_by - (optional) - How to group results ("satellite" Default is "time" for chronological order)

Example Request

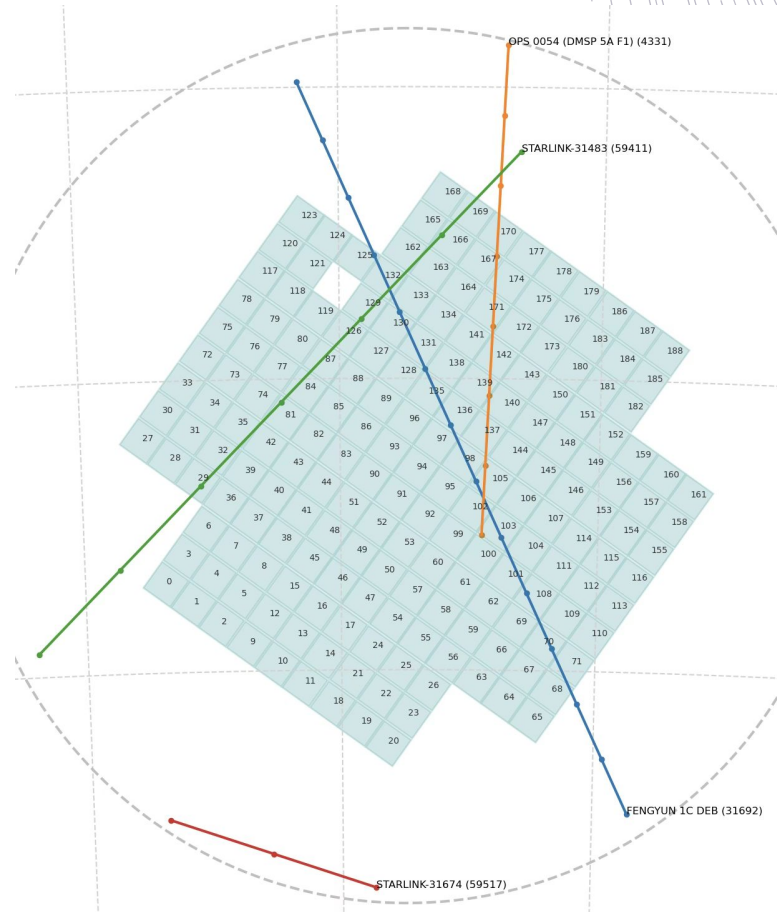
Browser

Python

Bash

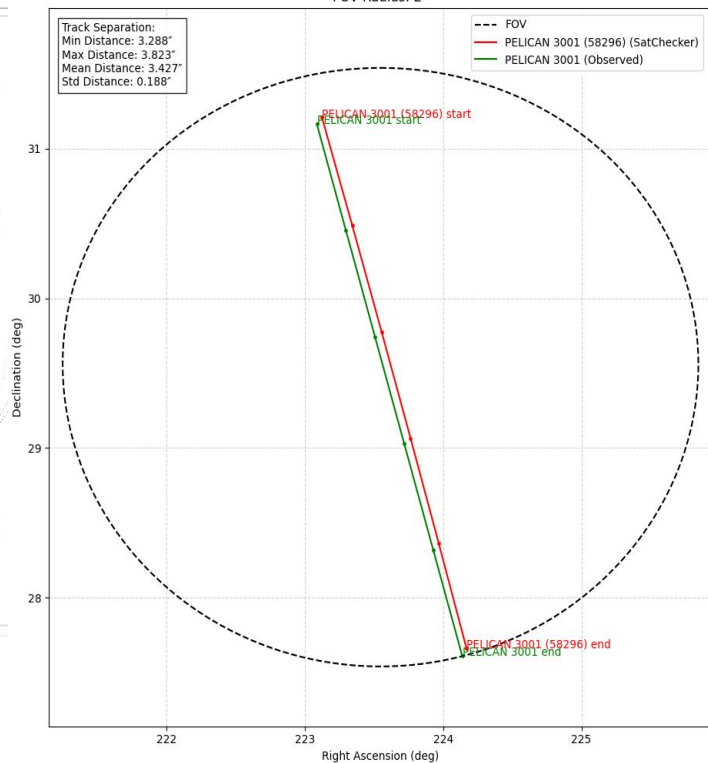
Powershell

```
https://satchecker.cps.iau.org/fov/satellite-passes/?latitude=33&longitude=-117&elevation=100&start_time_jd=2460623.394780&ra=157.56&dec=20&fov_radius=3&group_by=satellite
```

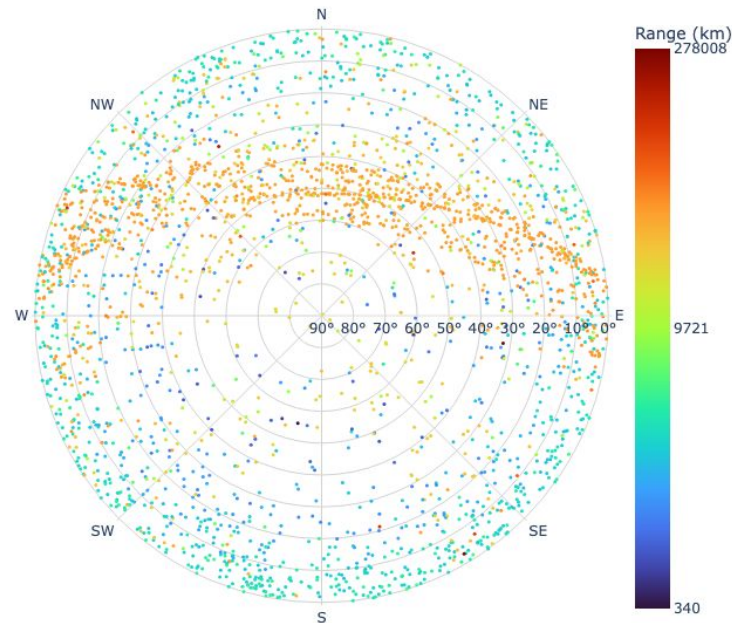


SatChecker Field of View service

Satellite Passes on 2024-06-05
Green: Observed, Red: PELICAN-3001, Blue: Other Satellites
FOV Radius: 2°

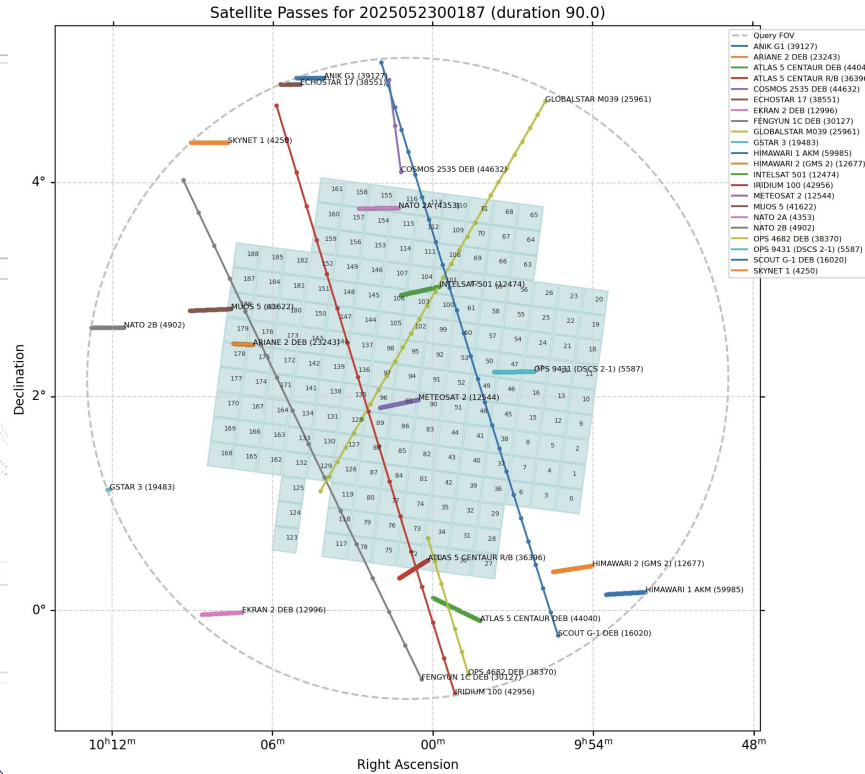


All-Sky View with Alt/Az Grid

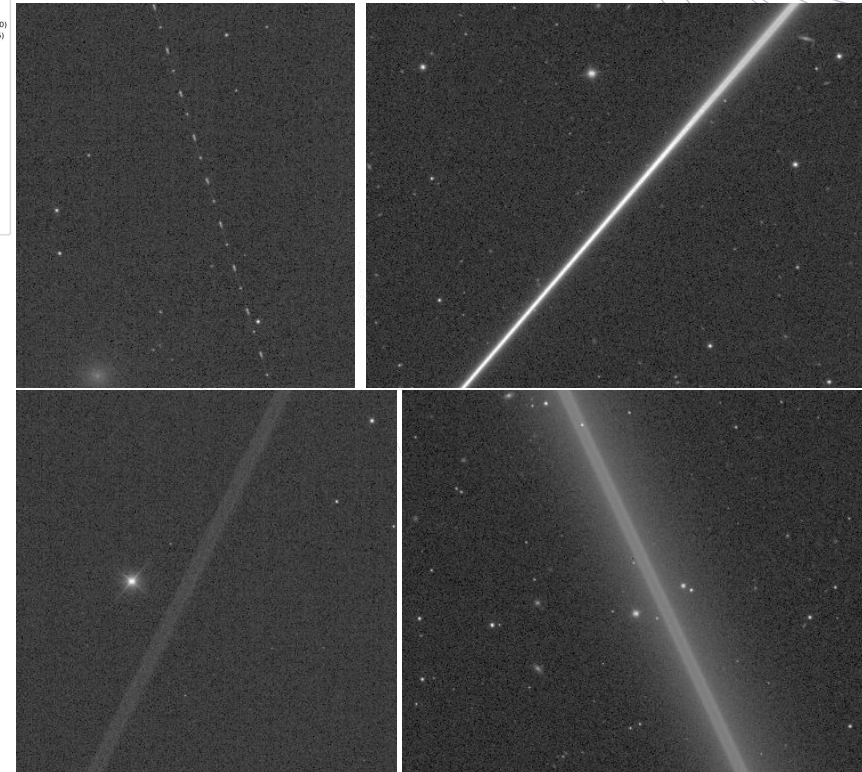


Example: Satellite streaks seen by Rubin Observatory

From Jangid et al. poster at
2025 Rubin Community Workshop

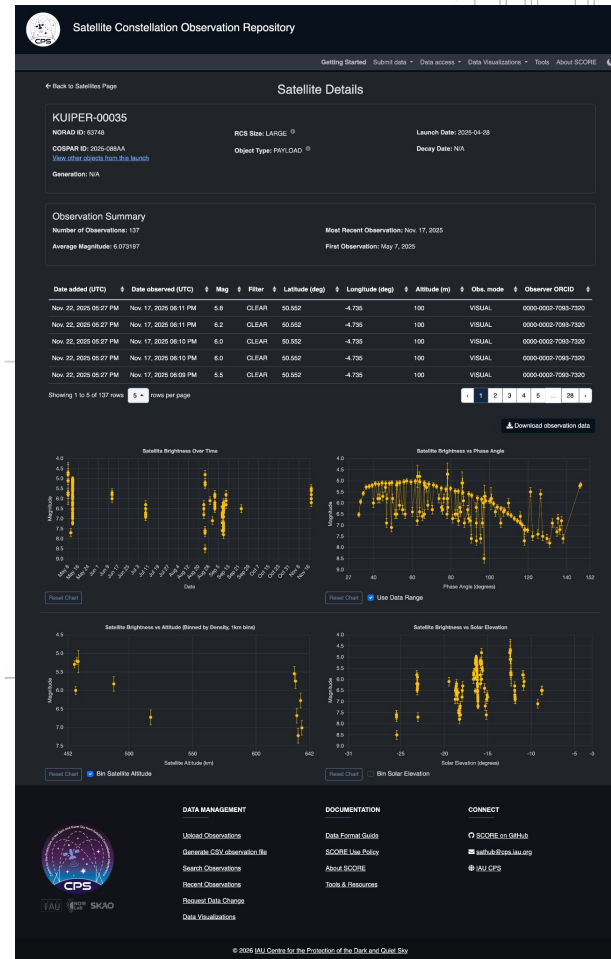


<https://community.lsst.org/r/rb-satellite-constellations-and-lsst-new-tools-and-impact-assessments/10729>



Satellite Constellation Observation Repository (SCORE)

- Open data set to collect brightness and position observations of satellites
- Can be used to characterize satellites as actually observed or validate position/brightness predictions
- APIs to upload / download data
- Attribution using ORCID
- Cross referenced with SatChecker
- <https://score.cps.iau.org/>



SCORE statistics

Starlink

1994 satellites •

9143 obs •

Avg: 5.98 mag

Amazon LEO

102 satellites •

2484 obs •

Avg: 6.17 mag

AST SpaceMobile

12 satellites •

1199 obs •

Avg: 3.46 mag

Qianfan

73 satellites •

1169 obs •

Avg: 5.72 mag

Planet Labs

1 satellites • 338 obs

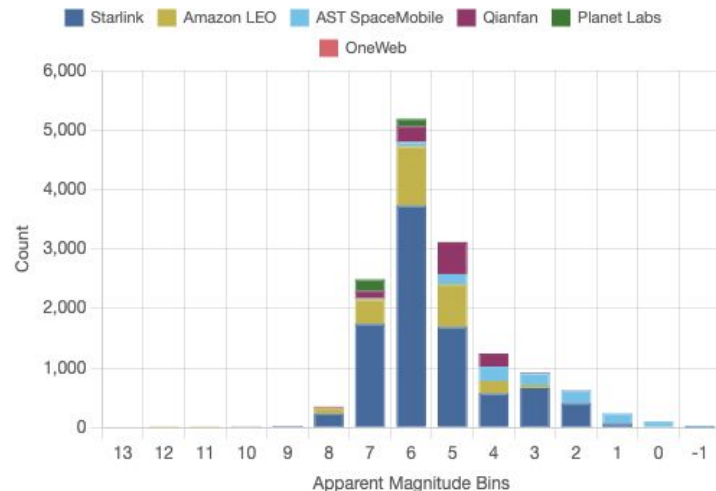
• Avg: 7.03 mag

OneWeb

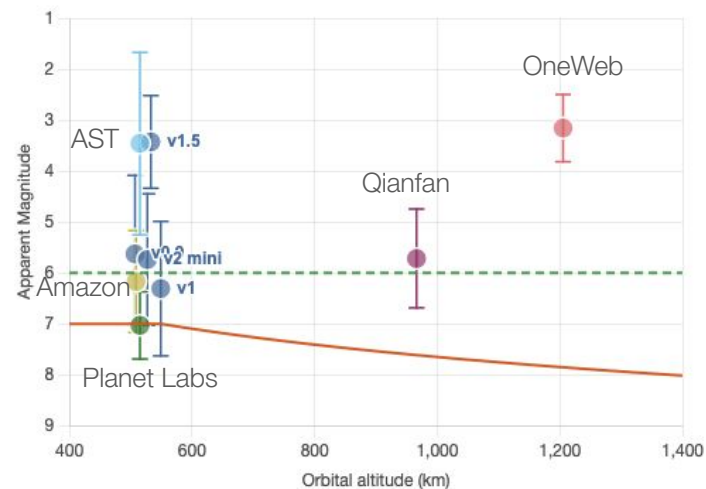
9 satellites • 12 obs •

Avg: 3.16 mag

Observations by Apparent Magnitude



Observed Brightness vs Orbital Altitude



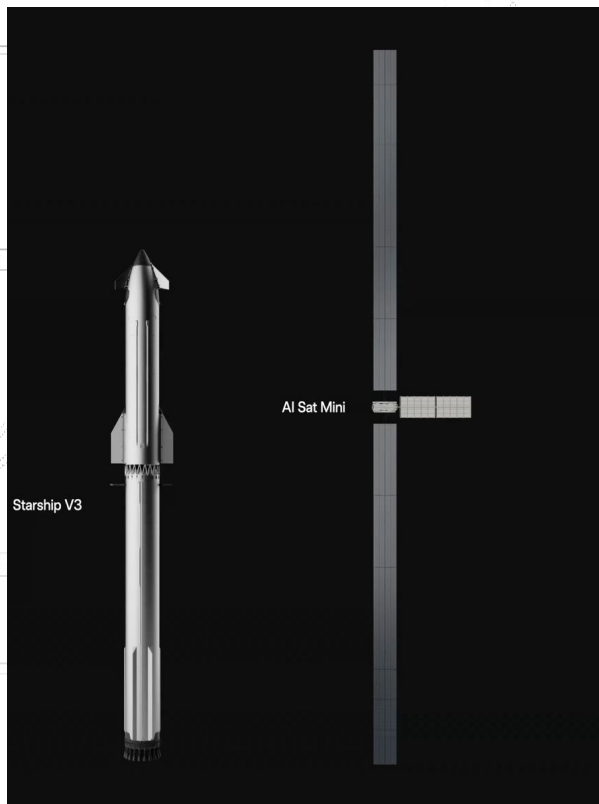
Policy approaches

- UN Committee on the Peaceful Uses of Outer Space
 - Dark and Quiet Skies agenda item in the Scientific and Technical Subcommittee (STSC)
 - Group of Friends for the Dark and Quiet Skies for Science and Society
- CRAF and SKAO interfacing with ITU
 - With RAS involvement via Marieta & Megaconstellations Working Group
- EU Space Act, national policies, etc.



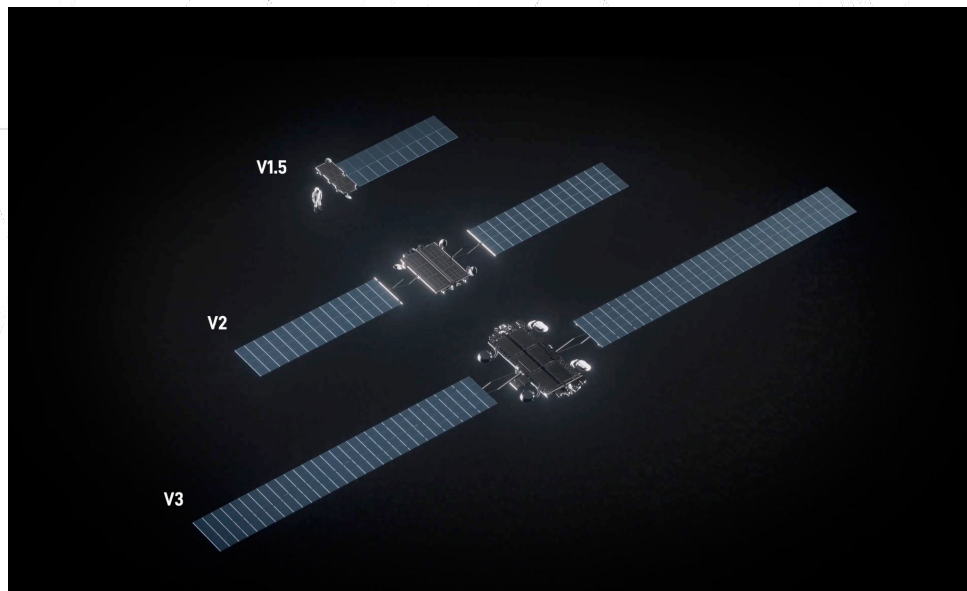
There's more coming...

SpaceX: 1 million AI data centres in space



Huge numbers of even larger satellites (solar panel span comparable to plane wingspans)
Others also now planning orbital data centres...!

(<https://spacenews.com/spacex-files-plans-for-million-satellite-orbital-data-center-constellation/>)



Reflect Orbital wants to provide 'daylight as a service'

Sunlight after dark



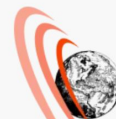
2 satellites
2026



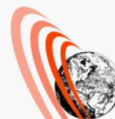
36 satellites
2027



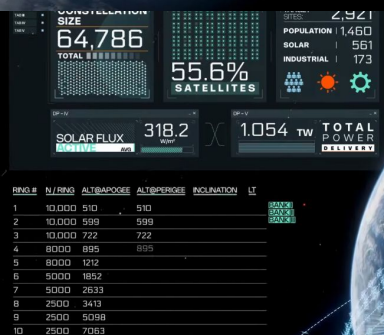
1k+ satellites
2028



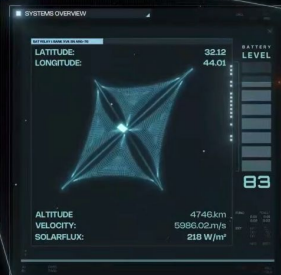
5k+ satellites
2030



50k+ satellites
2035



Sunlight after dark



2028

Up to 100 lux for 2 hours
comparable to indoor
work areas.

2 lux 24/7 comparable to
streetlighting.

2030

Up to 5,000 lux for
minutes comparable to
daylight.

Up to 100 lux for 2 hours
comparable to indoor
work areas.

2035

Up to 36,000 lux for
hours comparable to
daylight.

Up to 100 lux 24/7
comparable to indoor
work areas

2 lux 24/7 comparable to
street lighting.

Test satellite to launch soon - observations
needed to assess potential impact

IMPERIAL

TAU

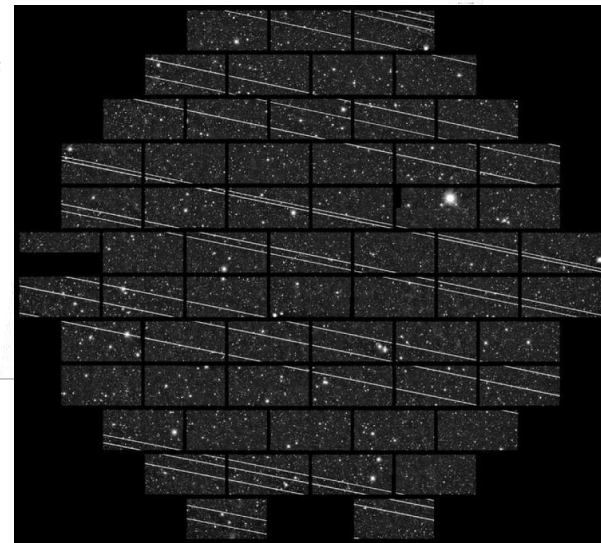
NOIR Lab

SKAO

ESO

RAS Specialist Discussion Meeting

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Credit: CTIO/NOIRLab/NSF/AURA/DECam DELVE Survey

Conclusions

- Dramatically increasing numbers of satellites...
- New types of satellite uses constantly appearing...!
- Significant impact on optical, submm, radio astronomy
- CPS working to quantify their impact - please help!
- Please also join RAS's Megaconstellation Working Group!
- Is this an existential crisis for astronomy?
- SDM next Friday - please participate!
- Please join CPS ...! <https://cps.iau.org/> -->

