SatHub: Satellite software tools for the community

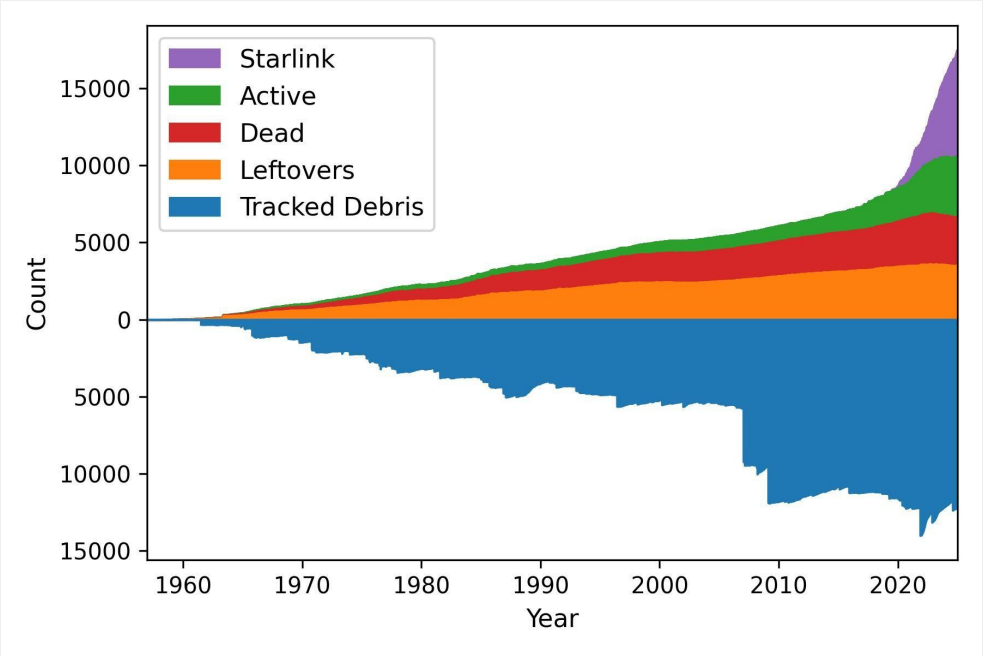
Mike Peel on behalf of IAU CPS SatHub
Meredith Rawls, Siegfried Eggl, Michelle Dadighat

(Postdoc, Imperial College London)

Swiss SKA Days, 26 August 2025

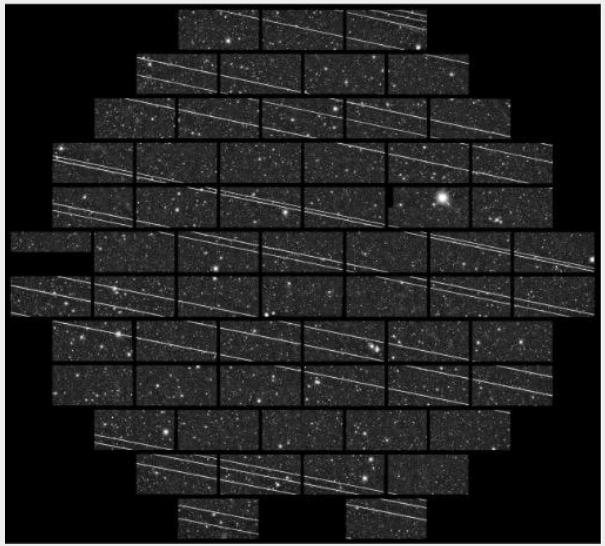
Space is changing rapidly

- 8500+ satellites in Low Earth Orbit
- ITU filings for >1,000,000 satellites
- Major concerns:
  - Effects on optical astronomy
  - Effects on radio astronomy
  - Effects on the night sky
  - Space traffic management
  - Space debris



Effects on astronomy

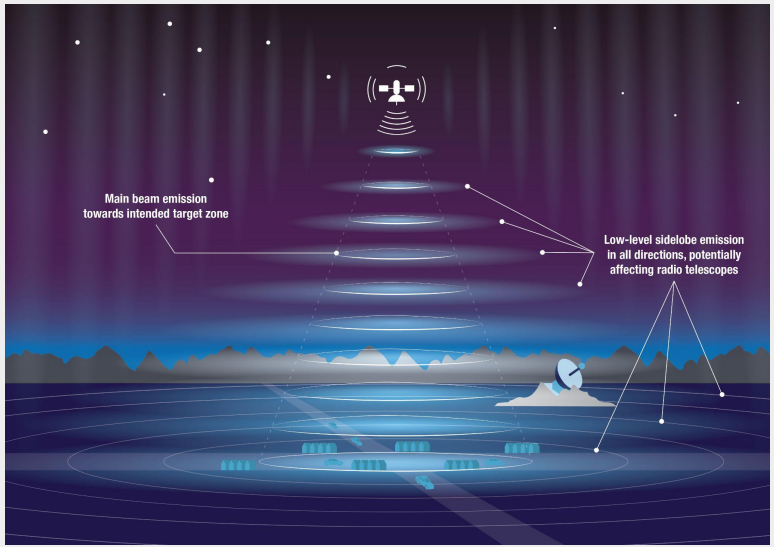
Optical astronomy: Satellite streaks can cause unusable data



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

Radio astronomy:

- Intentional emissions (i.e. strong downlinks)
- UEMR (unintentional electromagnetic radiation)



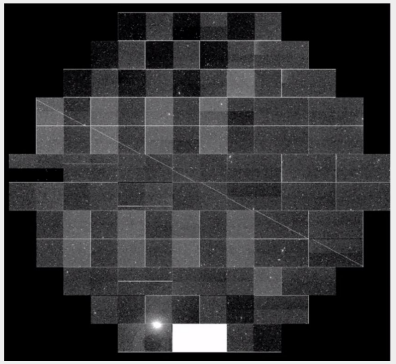
Credit: SKAO

Four hubs

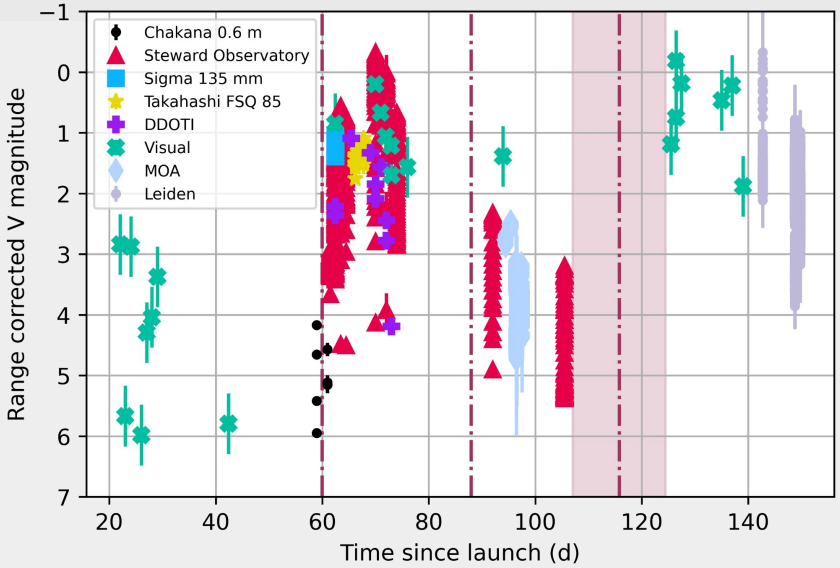
- **SatHub**
  - Satellite observation and data analysis to understand problem + find mitigations during data processing
- **Industry & Technology Hub**
  - Foster collaboration between the astronomy and satellite operator communities
- **Policy Hub**
  - Studies national and international policies and regulations related to the use of space
- **Community & Engagement Hub**
  - Bridge between all involved stakeholders and affected communities

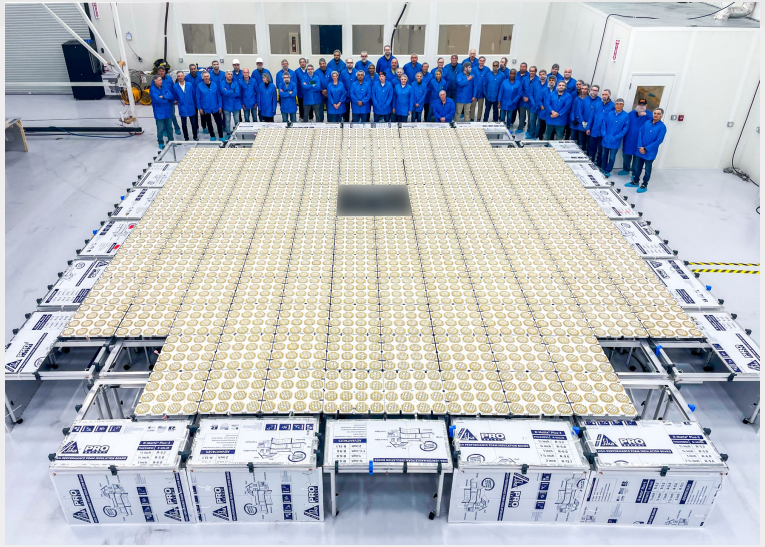
IAU CPS SatHub Aims (see Connie's talk)

- **Assess constellation impact on optical and radio astronomy** via independent observation campaigns and peer reviewed publications
- **Strengthen relations** with key players:
  Privateer, The Exclosure, Slingshot Aerospace, European Centre for Space Safety, The Aerospace Corporation, AST SpaceMobile, SpaceX, Amazon Kuiper, Planet Labs, and more
- **Develop mitigation tools for astronomers**/observatories
  - SatChecker satellite position prediction service (also connections with Satellite Orbit Prediction Processor/SOPP under development)
  - Satellite Constellation Observation REpository (SCORE)
  - NSF SWIFT-Sat: Field-Of-View / active satellite avoidance service
  - Radio astronomy impact modeling (SCEPTER)
- **Coordinate mitigation efforts** with all stakeholders



AST SpaceMobile Bluewalker 3 observations

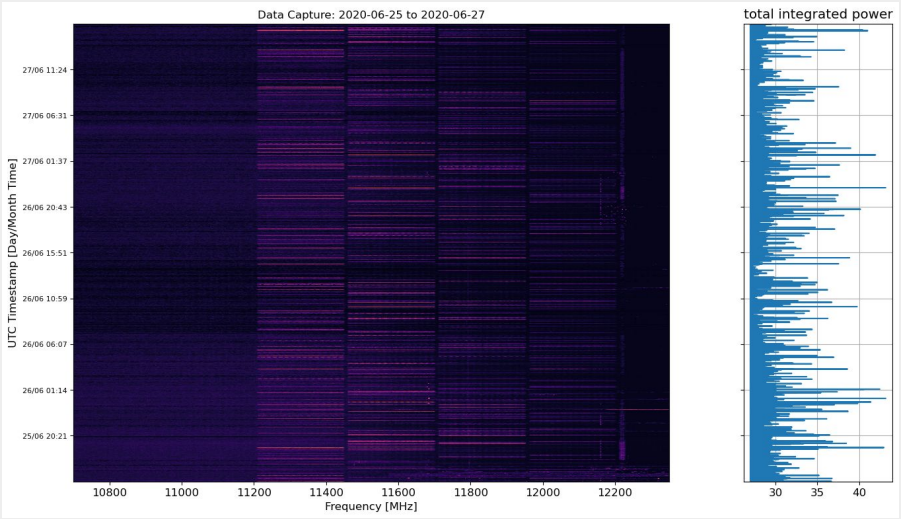


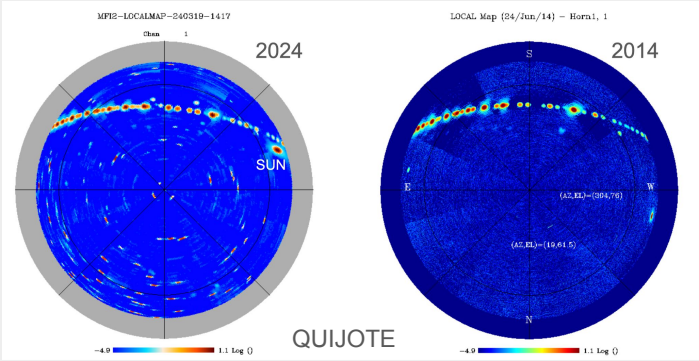


- 64m² phased array, prototype for mobile phone connections using standard phones + satellite
- Observing campaign to observe with multiple telescopes + visual observers
- Optical measurements show it to be brighter than all except top 10 stars (Nandakumar et al., Nature, 2023)
- + launch vehicle adapter bright & untracked for first few days
- + position predictions degrade over time
- 5 BlueBirds since, more (and larger) expected soon...

Potential impact at radio frequencies

- Active 10-20GHz transmissions - plus 40GHz, 120-180GHz soon? (and octaves!)
  - Each satellite constellation using different frequencies? Important to minimise frequency use...
- Sidelobe coupling also a concern, particularly for CMB experiments
- Difficult to filter out with broadband detectors, unless using FPGAs
- Satellites highly variable - need to accurately know positions, or see as transients?
- Protected radio bands v. narrow - observations normally use broader unprotected bandwidths



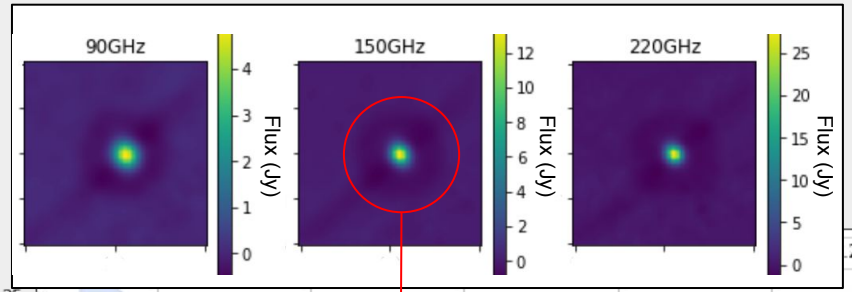


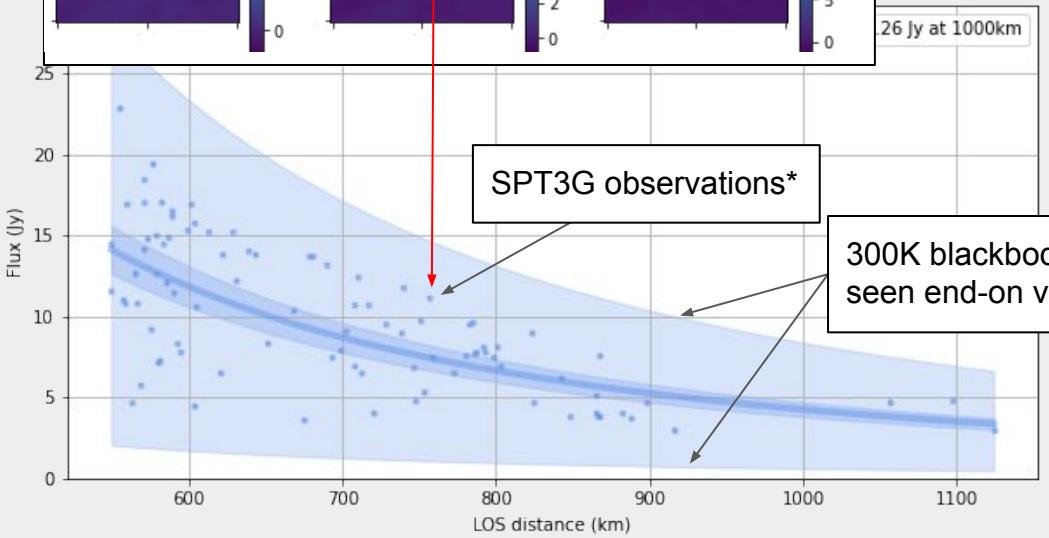
Above: QUIJOTE 10-14GHz observations from Tenerife in 2014 and 2024
Left: satellite dish observations, F. Di Vruno

Thermal Emission

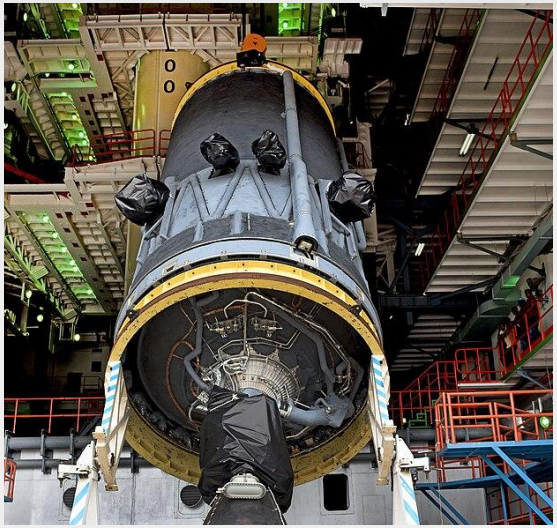
(Foster et al. 2025)

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

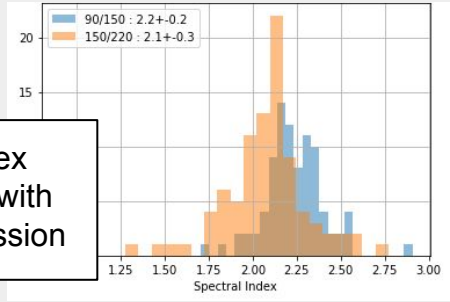




* observed both in direct sunlight and in Earth's shadow



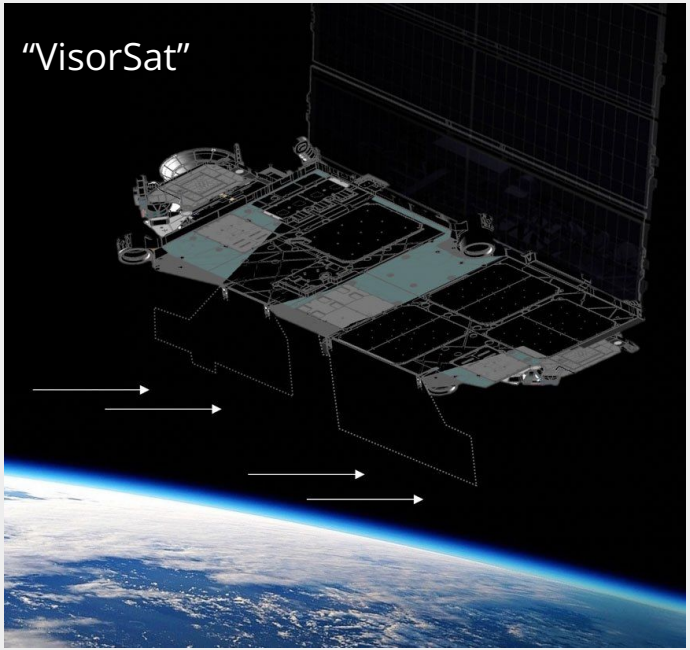
LVM3 Upper stage : 4m diam. x 13.5m long



Spectral index ~consistent with thermal emission

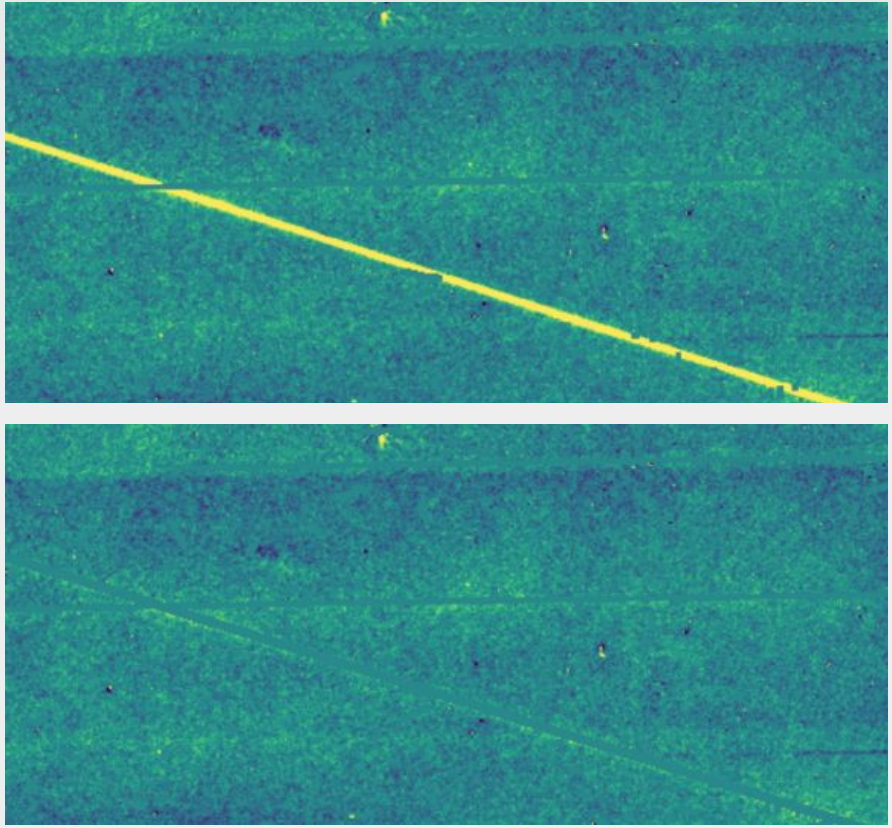
Mitigations: Satellites

- Fewer satellites
- Materials engineering: coatings (specular reflectivity)
- Attitude control (minimise reflections)
- Reflectivity simulation and testing labs (growing need)
- Steerable radio beams (enable direct illumination avoidance)
- Minimise sidelobe emission
- Control of unintended electromagnetic radiation



Mitigations: Telescopes

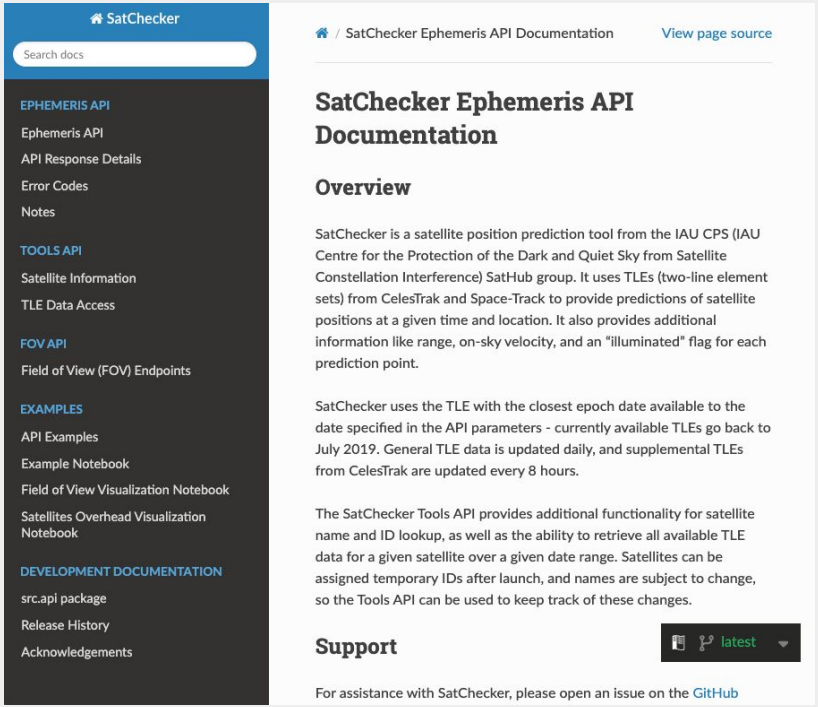
- Observations planning
- Software to avoid satellites
- Closing telescope shutter when satellite overhead
- More resilient receivers
- Observations to verify mitigations
- Redoing observations
- Modelling / Simulations
- Post processing of data (masking)



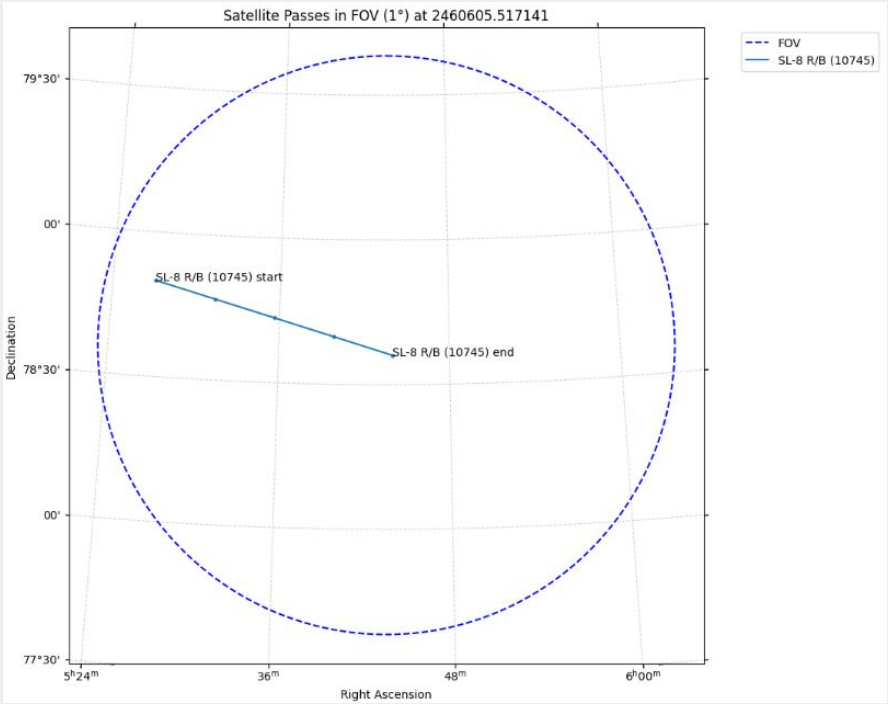
Hasan et al. (2022)

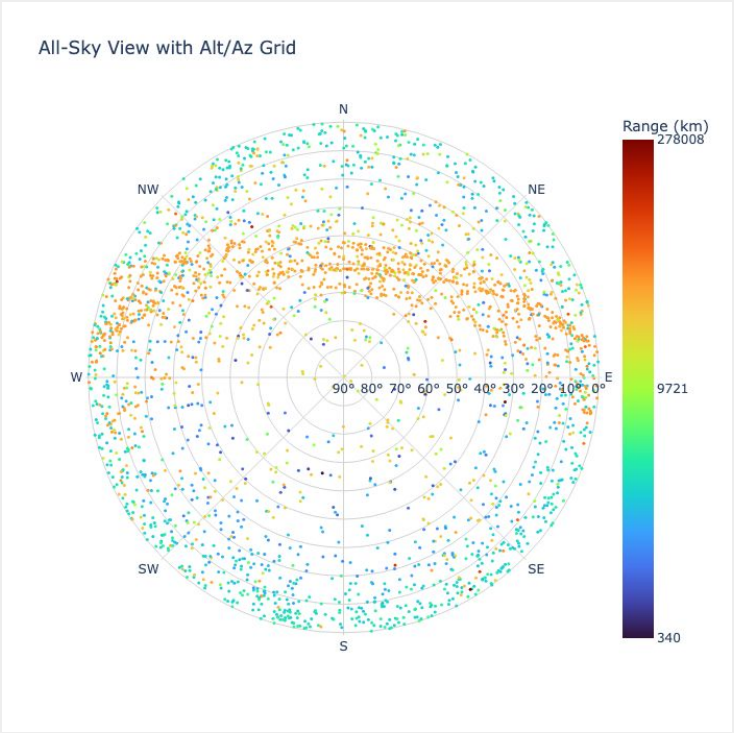
SatChecker

- API for predicting satellite positions and transits
- Single satellite or field of view (FOV) predictions
- Define RA/Dec center, radius, and time window, get all satellites overhead at a given time/location
- Access to archival TLE data
  - Current: 69,437,098 TLEs, satellites back to April 2019, rocket bodies back to September 2023
  - Archive: 208,651,537 TLEs, all Celestrak TLEs back to 1959
- Provides 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/



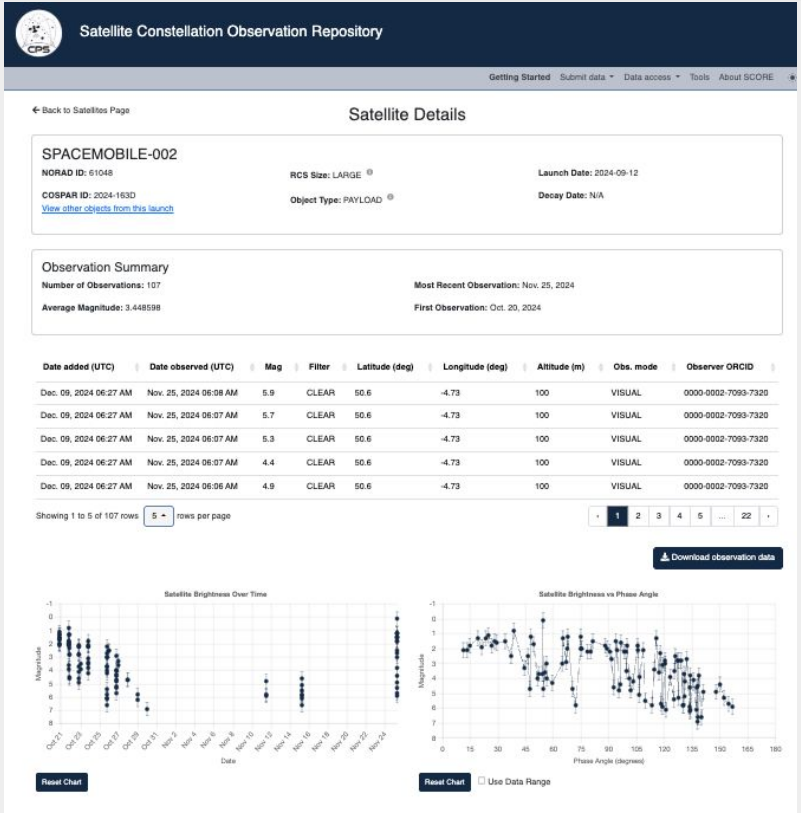
SatChecker Field of View service



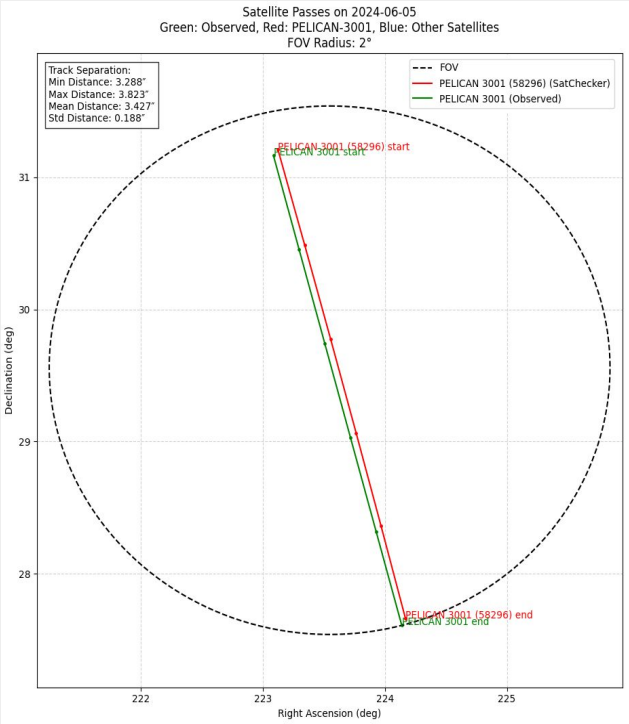


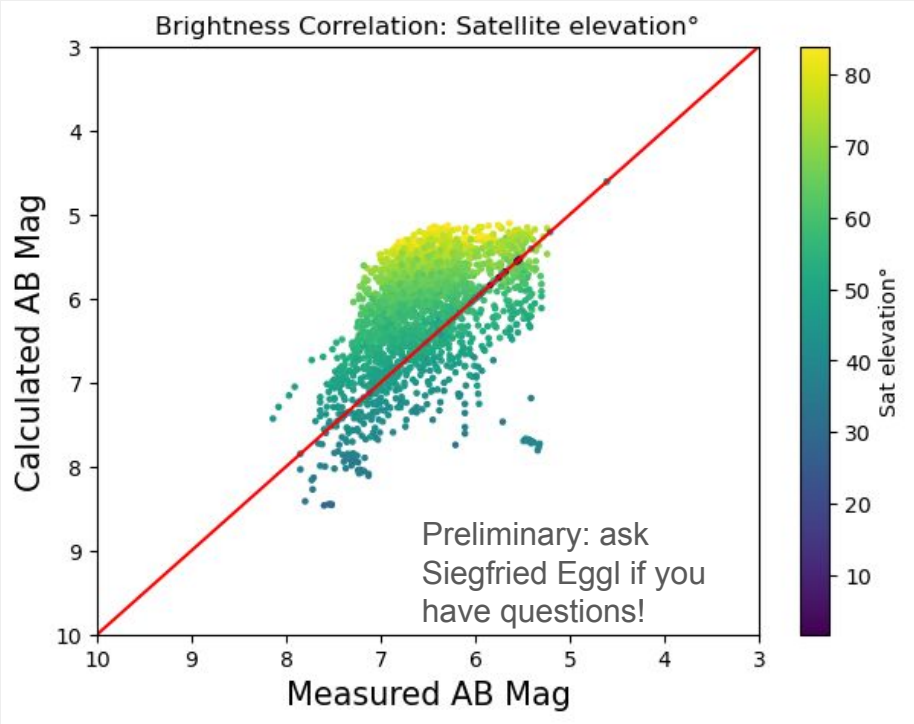
SCORE

- Satellite Constellation Observation Repository
- Brightness and position data repository
- Centralized place to store/link observation campaign data & other measurements of satellite brightnesses
- Provide data to operators and for simulations of satellite interference
- Collect observational data to support and improve satellite brightness models
- Observation format - CSV with specific headers
- Required: observation time (and uncertainty) observation location, apparent magnitude (and uncertainty), observing mode/filter/instrument
- Optional: RA/Dec position with uncertainties, range and range rate, comments
- Reference data from SatChecker added to each data point, including checking that the satellite was visible



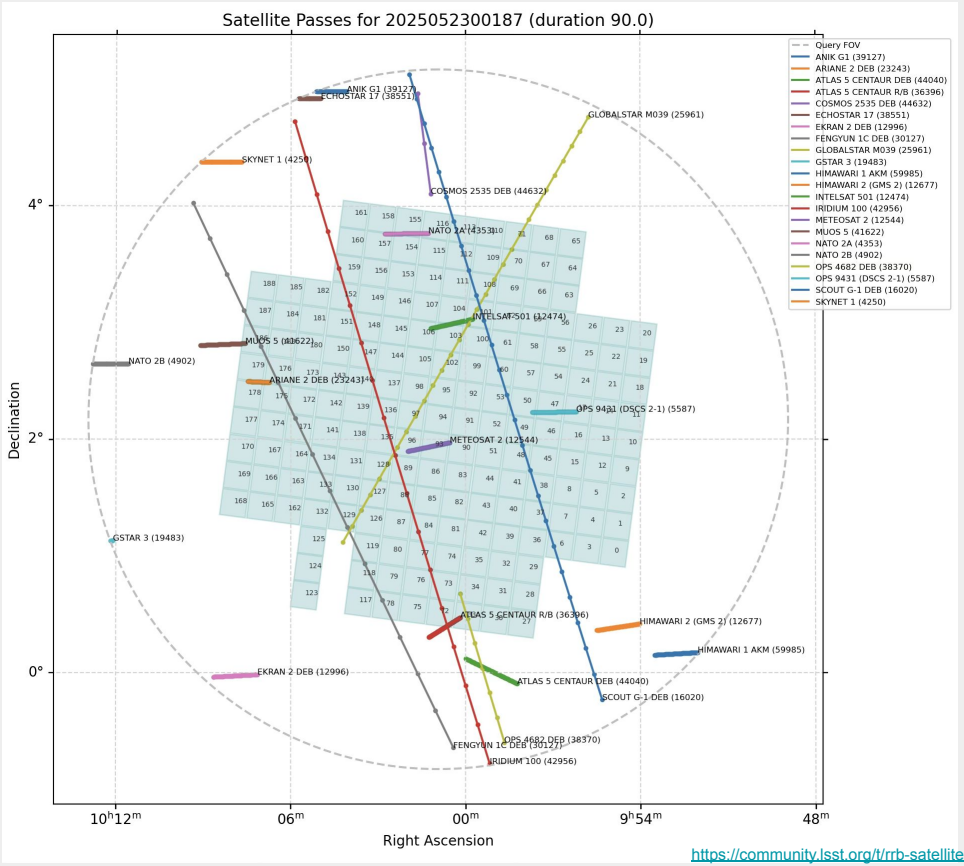
SatChecker + SCORE cross-validation

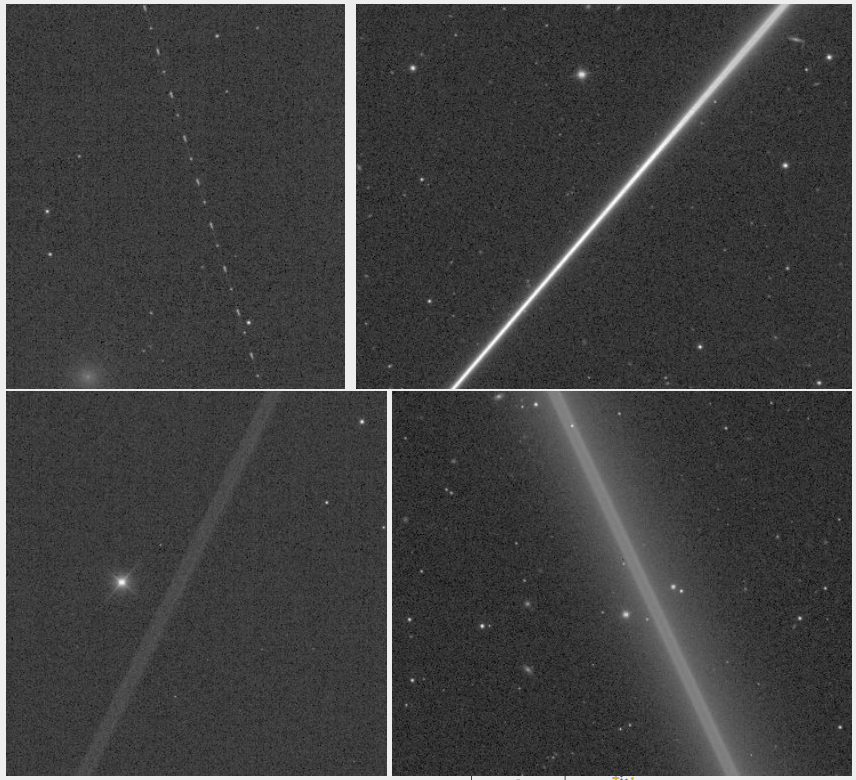




SatChecker + Rubin observations

From Jangid et al. poster at Rubin Community Forum

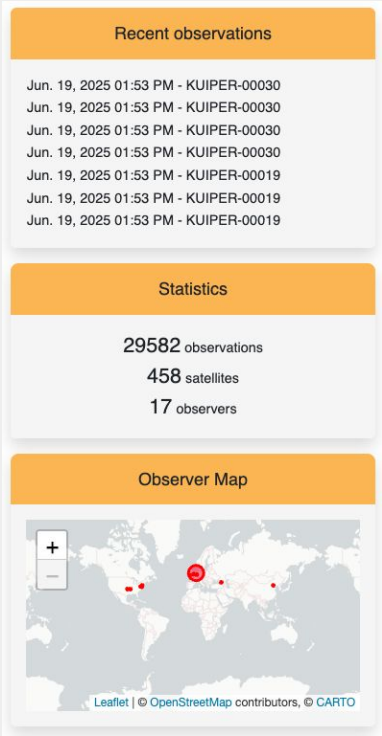




https://community.lsst.org/t/rrb-satellite-constellations-and-lsst-new-tools-and-impact-assessments/10729

Next steps

- TLEs have limited precision, no uncertainties, can miss maneuvers - more validation needed
- Need more observational data in SCORE!
  - Particularly Starlink (can then see if Starlink's supplementary TLEs are more accurate)
  - If you have observational data, please upload it!
- Interpolating ephemeris data (which has covariances) may be more accurate - starting with Starlink with this.
- Satellite brightness estimates
- FOV/observation interference alerts; Web UI for SatChecker; additional orbital data sources; asynchronous queries (long running ones)
- Data repository for radio observations of satellites
- Standardized data format for radio observation submissions
- API support for uploading observations
- Coordination on converting and uploading existing datasets
- With particular thanks to Michelle Dadighat for developing these tools!



Thanks for listening!

Questions?

Join CPS!

https://cps.iau.org