SCEPTER

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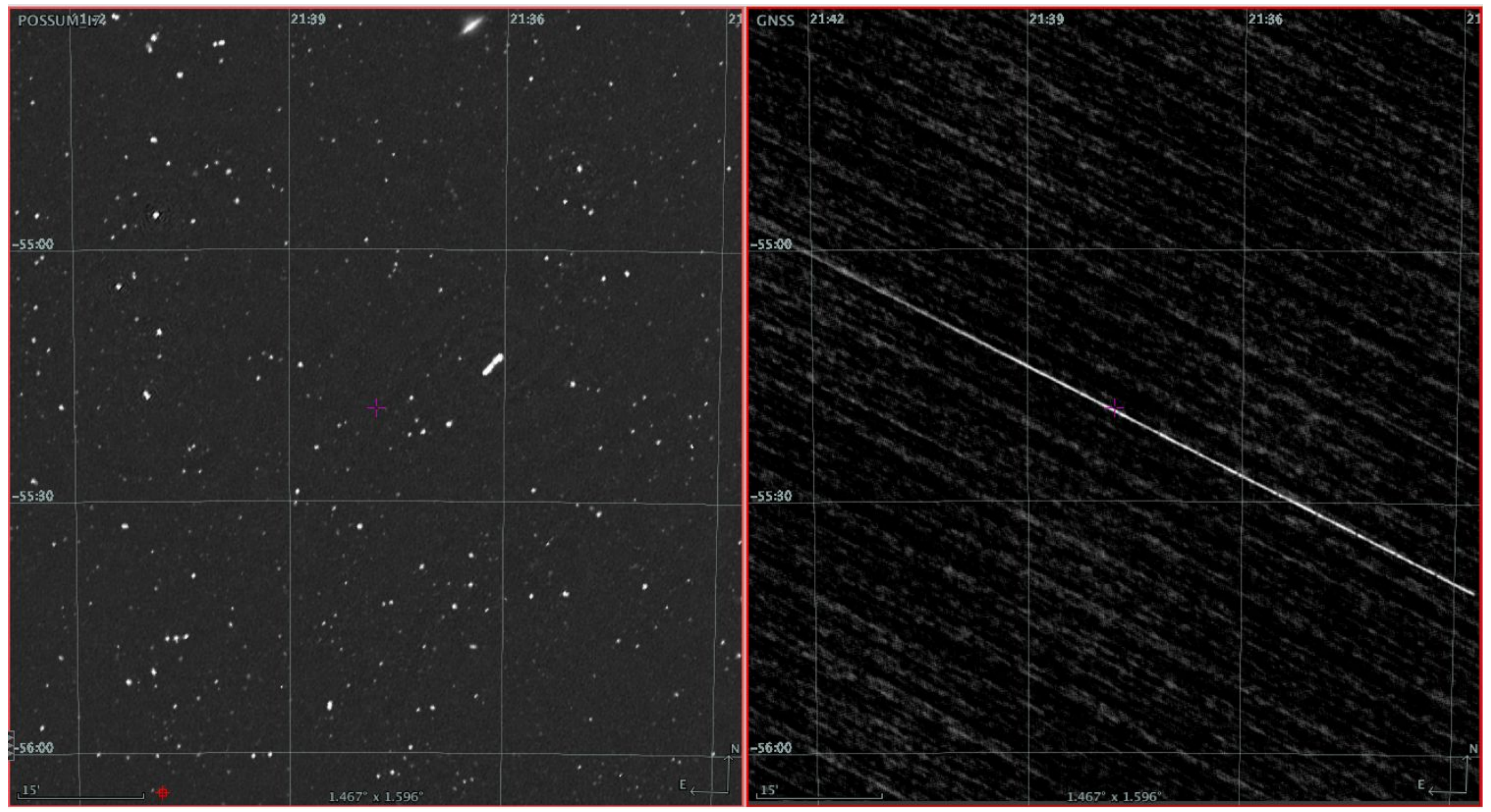
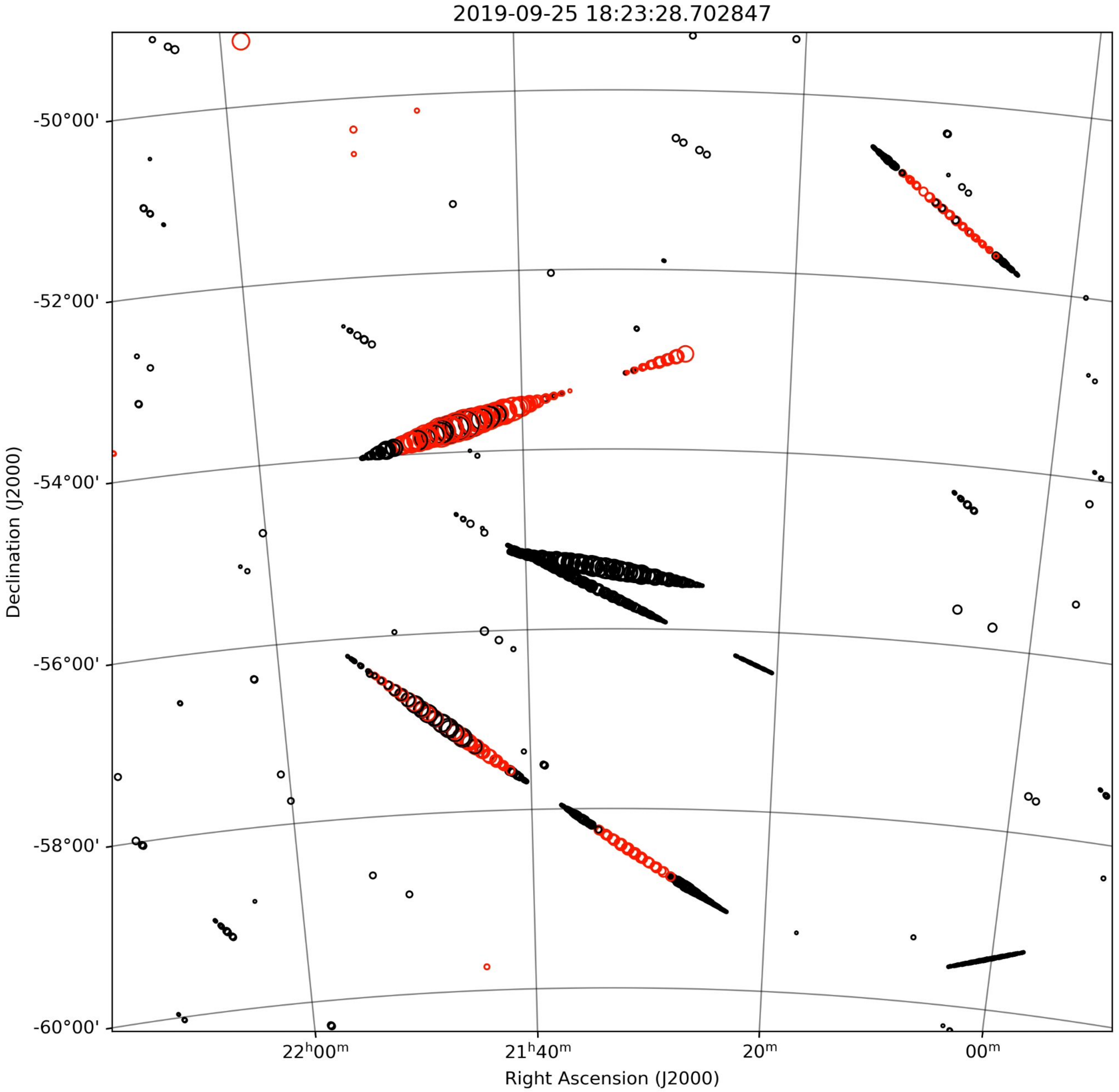
Satellite emission

Transient-like appearance, but orders of magnitude higher in power



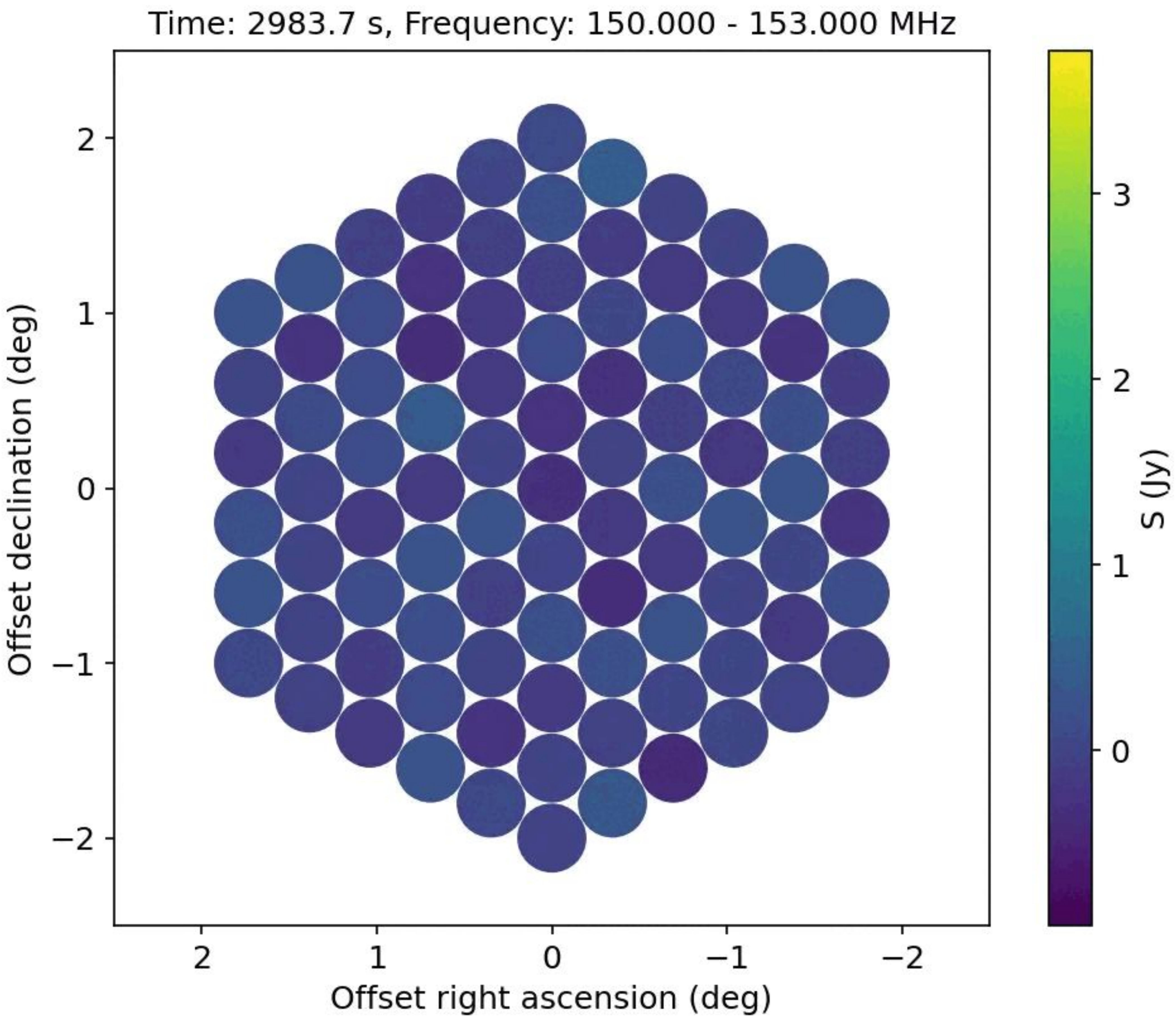
Not only just within field of view emission, but strong RFI signals through the side lobe



Example image of satellites transiting through the field of view of the Australian SKA Pathfinder telescope (ASKAP), the circles indicate the signal to noise of the satellite source and colors indicate a positive (black) or negative (red) flux value. Credit: Emil Lenc

Unintended Emissions (UEMR)

Starlink passing through the field of view of the LOFAR radio telescope



Credit: Di Vruno et al. 2023

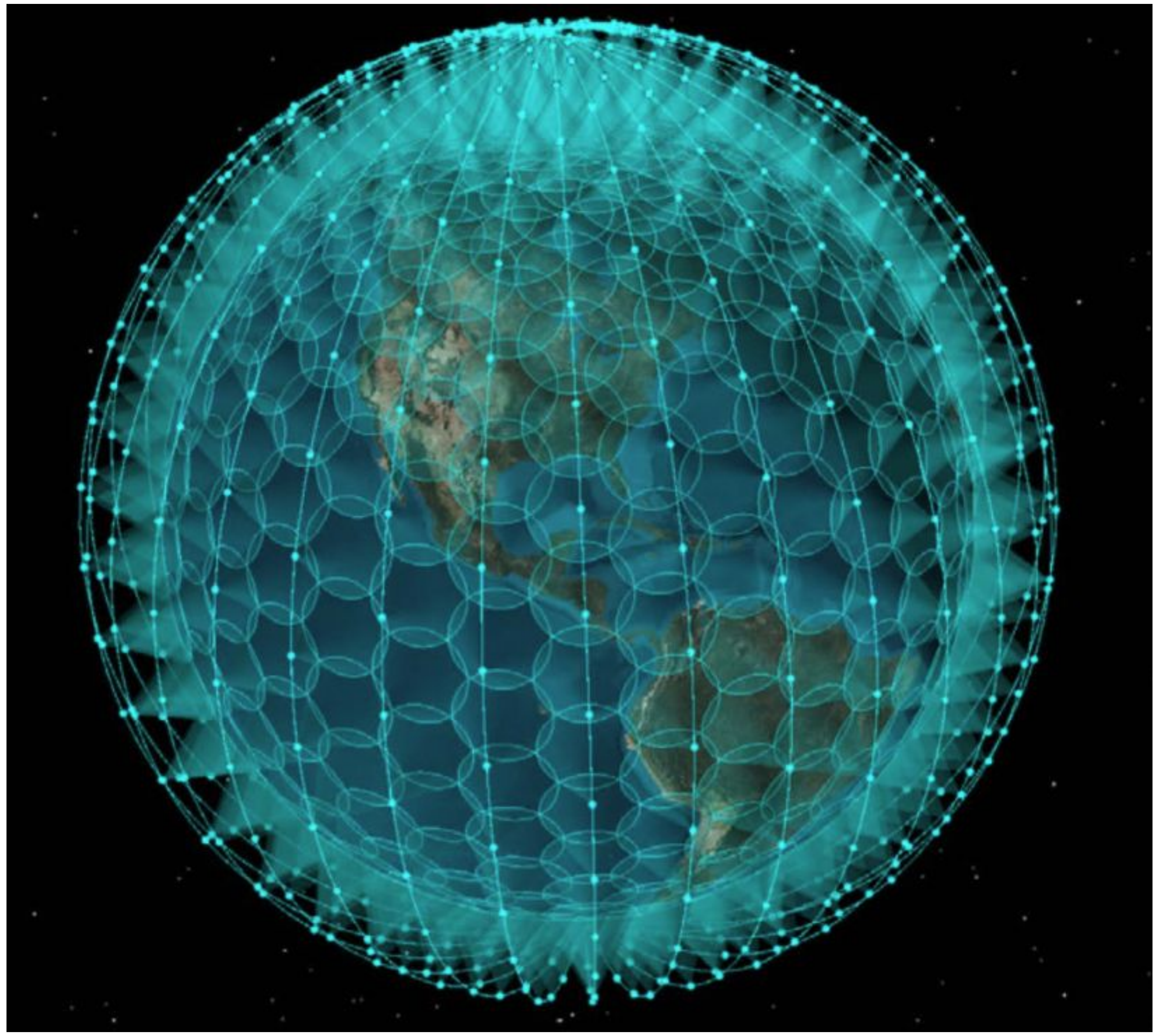
Credit:Danielle Futselaar

Oneweb Constellation

ITU allocated Ku-Band downlink transmission for satellite constellations such as Oneweb, Starlink

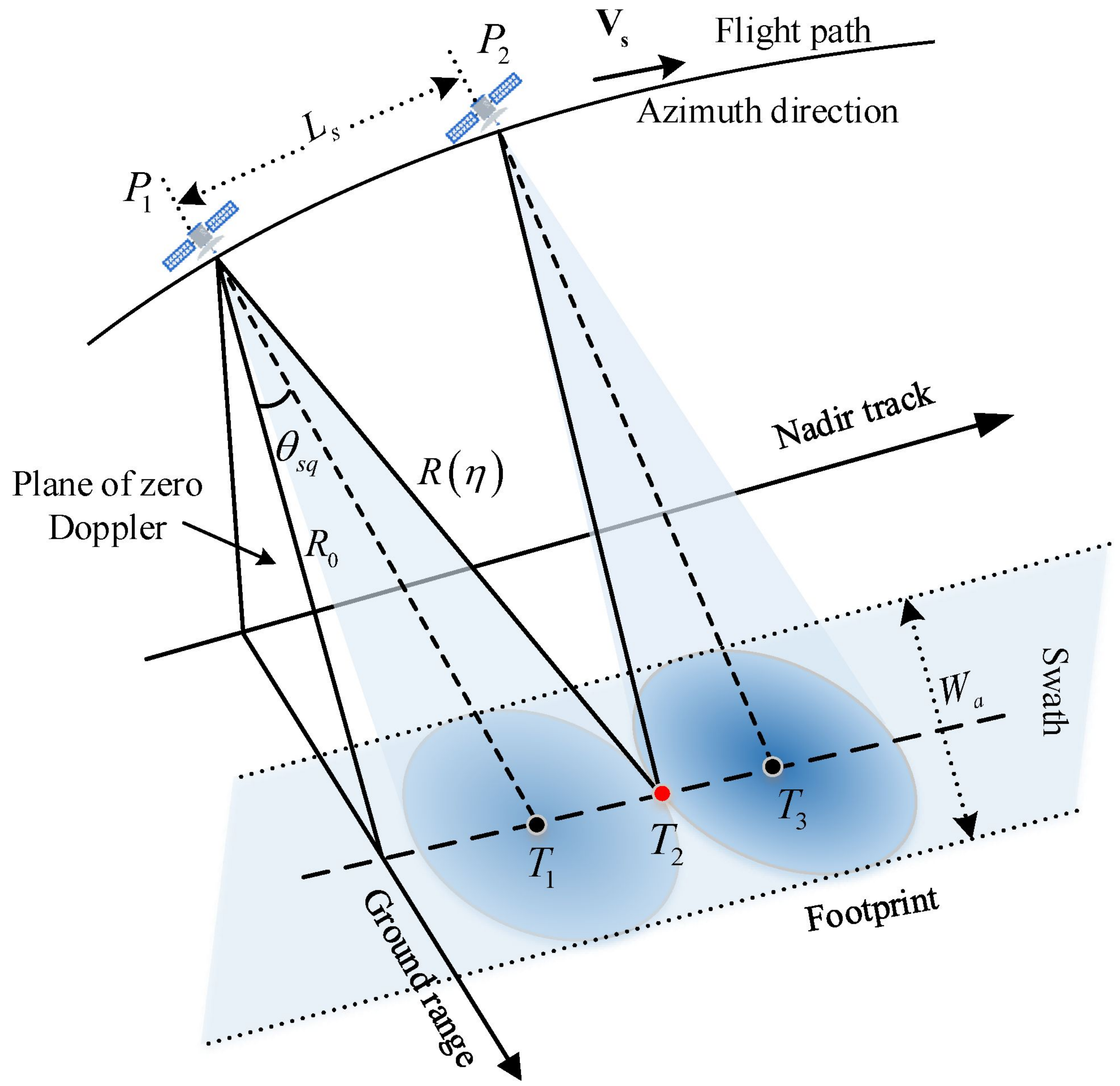
250 MHz channels, between 10.7-12.7 GHz

Number of Satellites	720
Orbits	Polar Orbits
Number of Planes	18
Satellites per Plane	40
Altitude	1200
Inclination to motion vector	87.9

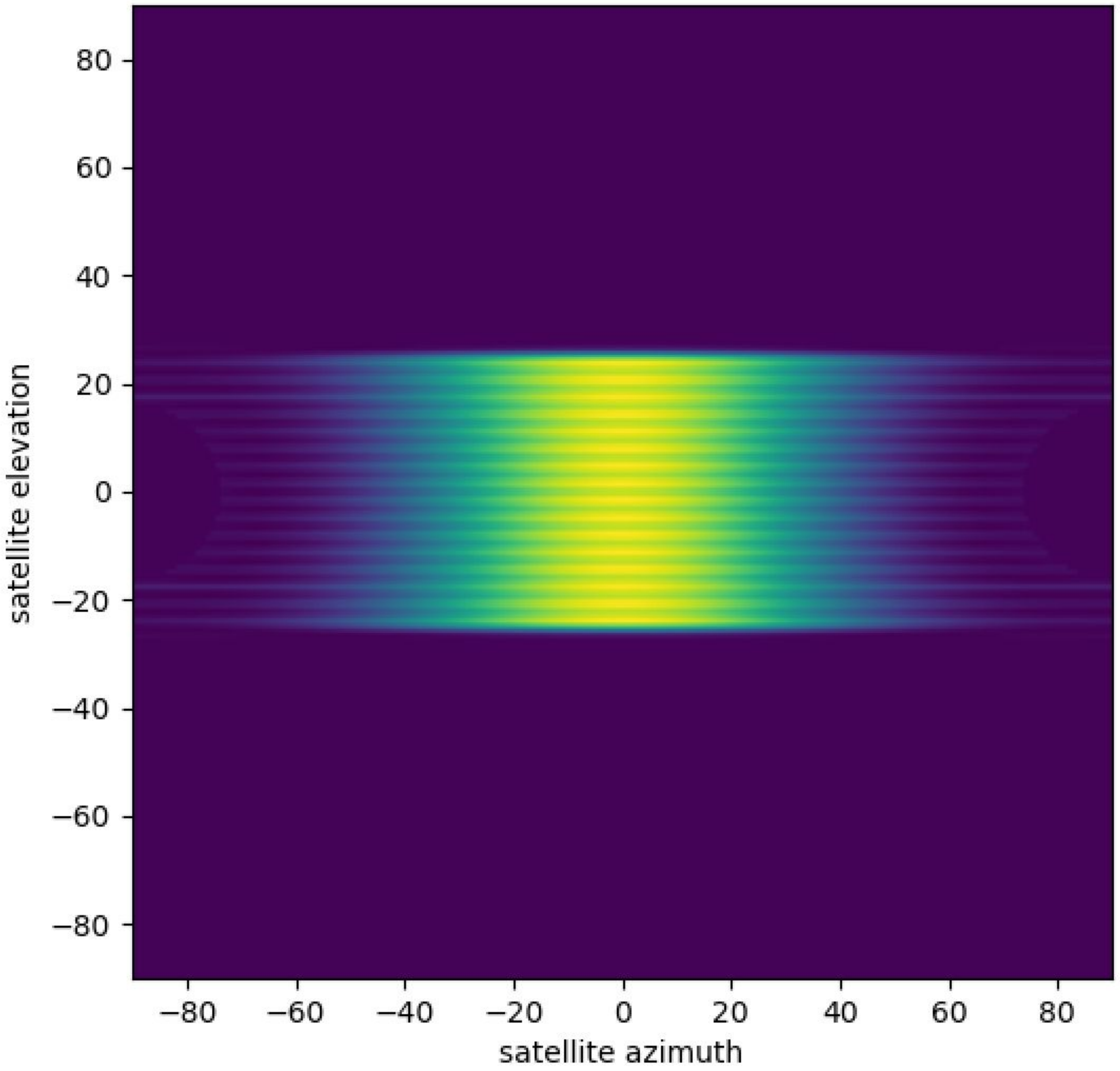


Oneweb Satellite and Transmitter

- Elevation relative to Nadir
- 16 beams ±27 degrees along track with >20 deg azimuth width



Example of Nadir pointing by RS satellites (Li et al. 2023 Remote Sensing)

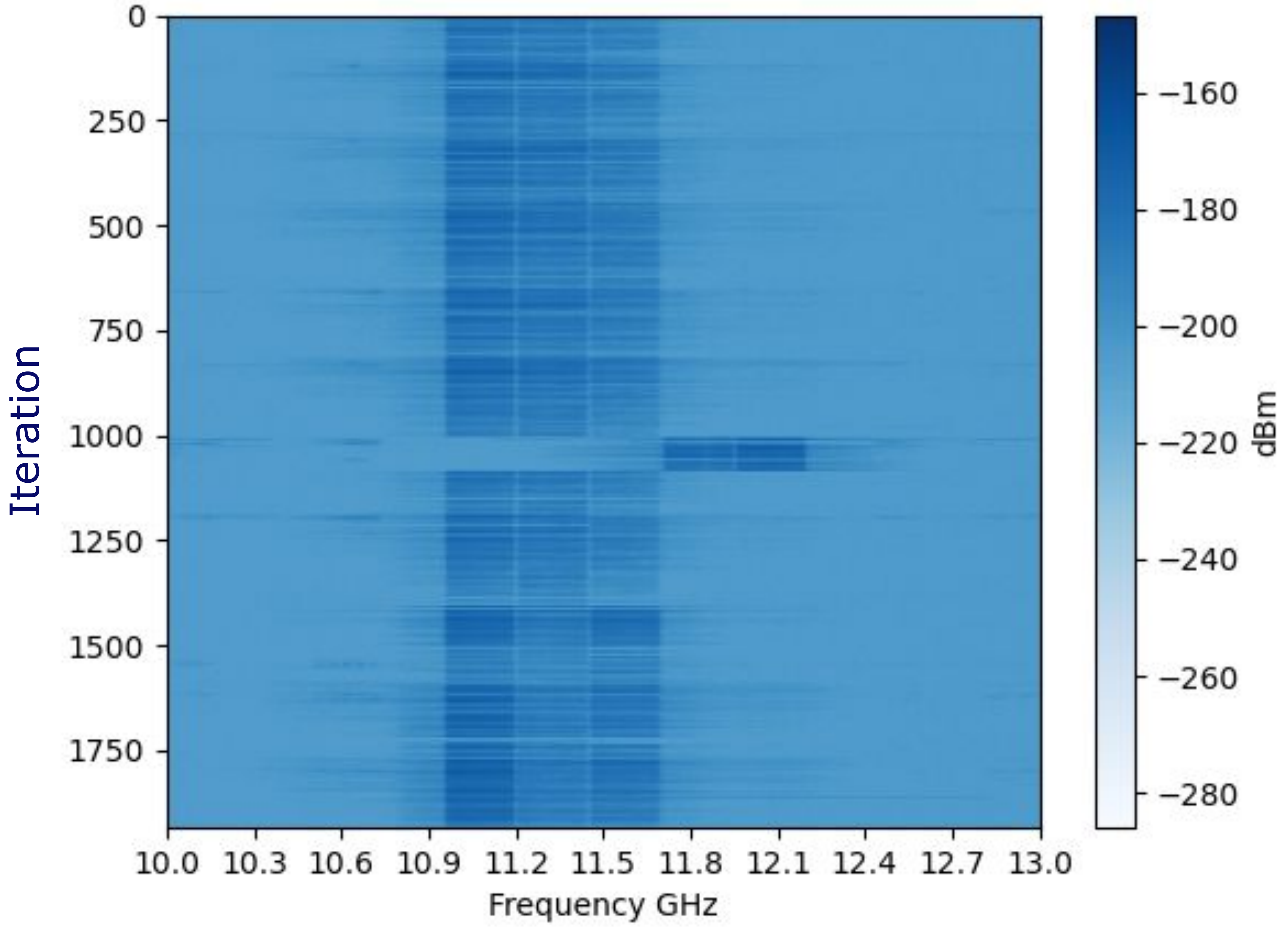


Theoretical beam pattern of a satellite transmitter with 16 elliptical beams along the satellite elevation track

Active Downlink Transmissions

8x250 MHz channels across Ku Band at 10.7 GHz

Adjacent to 10.6-10.7 RAS band



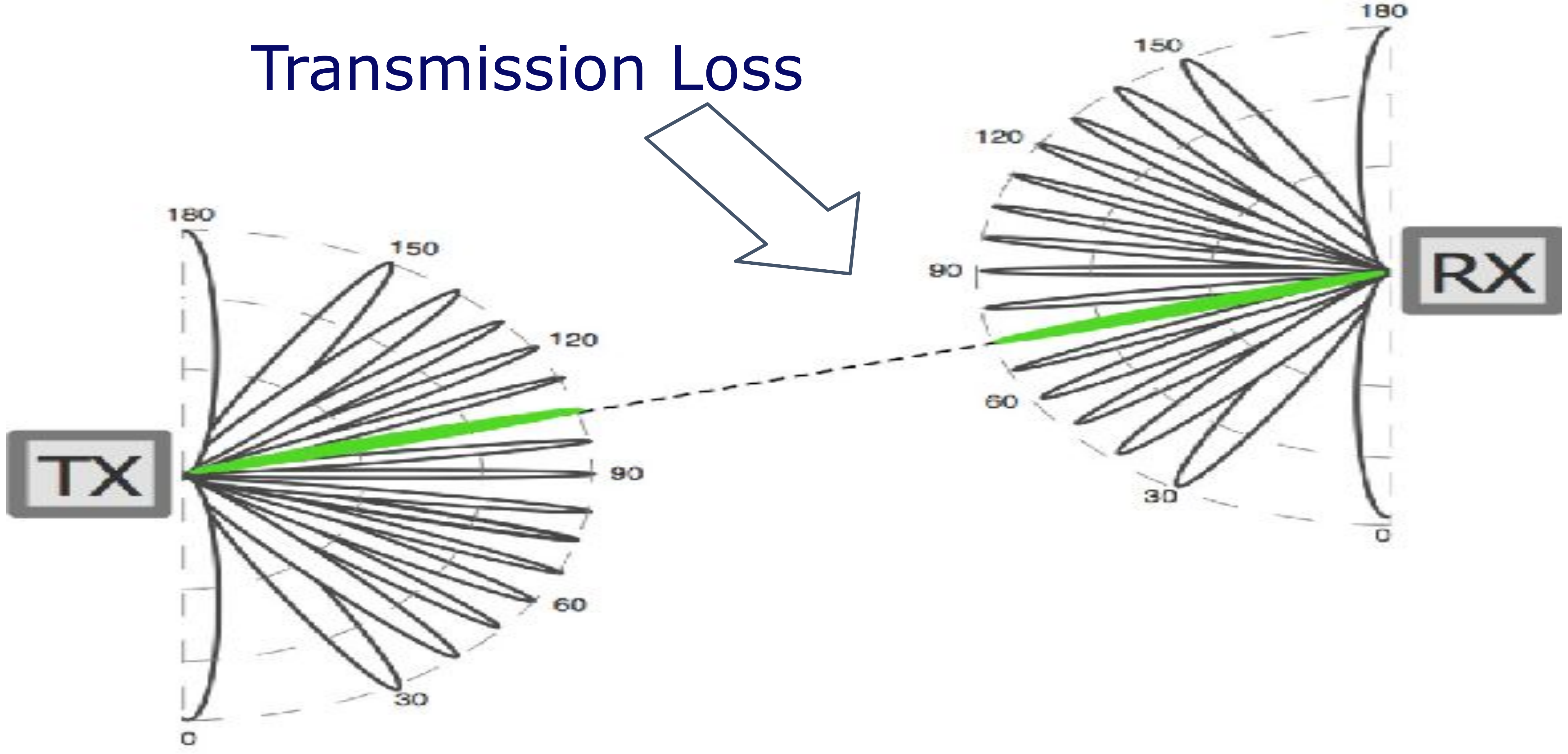
SKA Band 5b

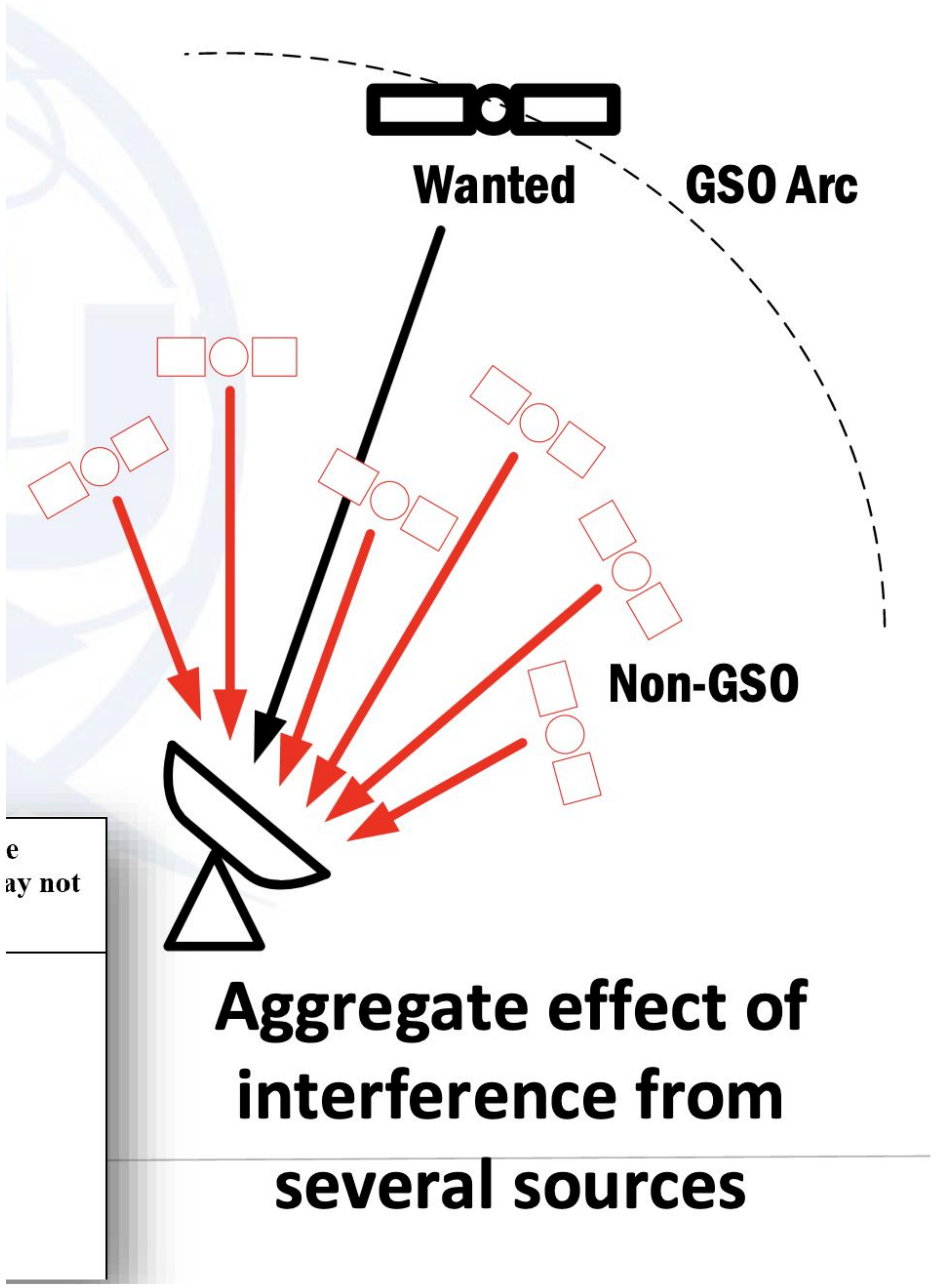
RAS protection band 10.68–10.7 GHz

Telescope	Band	Frequency Range (MHz)	Available Bandwidth (MHz)	Notes (MHz)
SKA1-Low	N/A	50 - 350	300	(1)
SKA1-Mid	1	350 - 1050	700	(1)
	2	950 - 1760	810	(1)
	3	1650 - 3050	1400	(2)
	4	2800 - 5180	2380	(2)
	5a	4600 - 8500	3900	(1)
	5b	8300 - 15400	2 x 2500	(1)

EPFD regulations

- Equivalent power flux density
- Needed for ITU regulations to quantify amount of contamination.
- Aggregate Sidelobes may be more significant





Example of EPFD calculations for satellite communications

Scepter

Simulation **C**onstellation **E**mission **P**atterns in **Te**lescopes (**R**adio)

Developed by Harry Qiu, Boris Sorokin and Federico Di Vruno (SKAO Spectrum Management Team)

Estimation on science impact from satellites for Astronomy(Harry) and ITU-R (Sorokin) purposes.

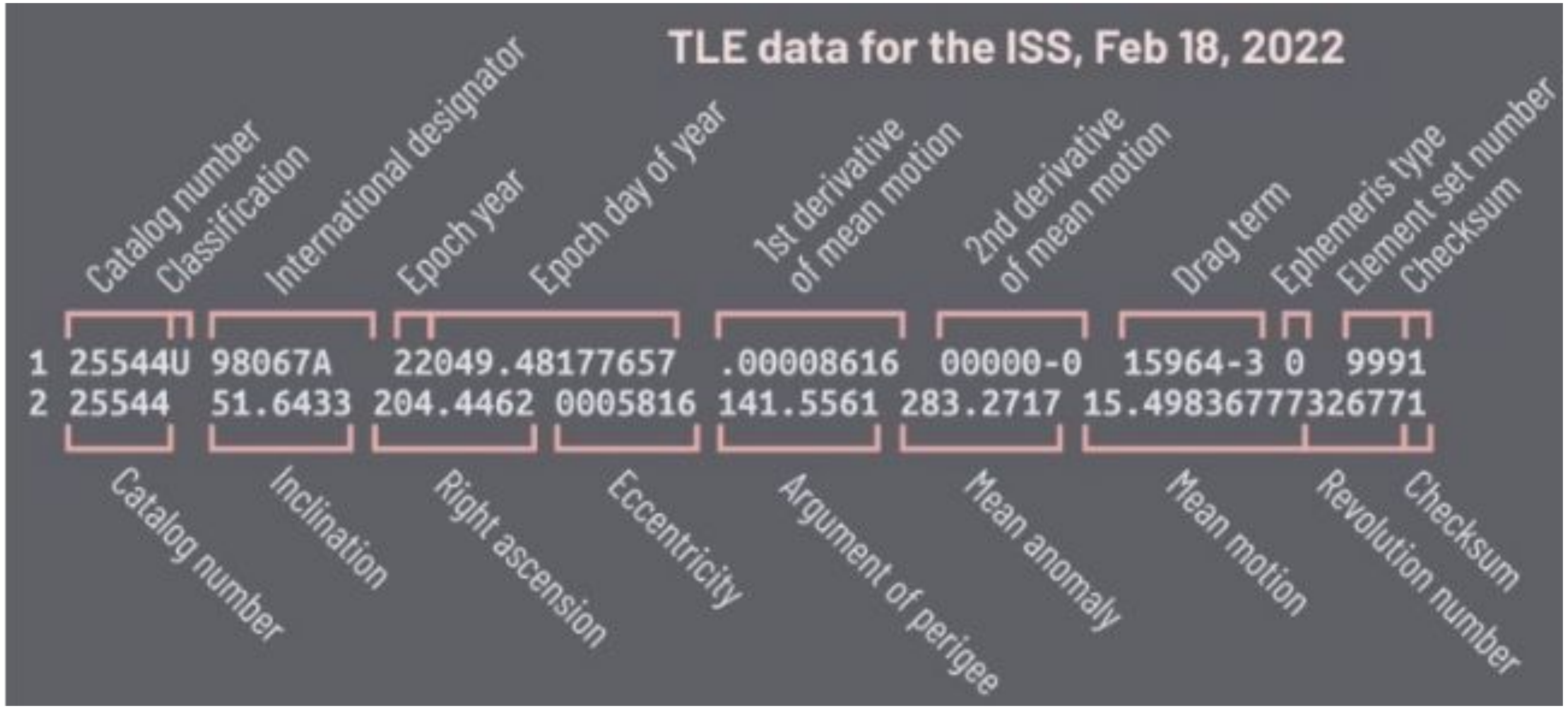
github.com/hqiu-nju/scepter

How are we tracking our satellites

- Much of the current information available on satellites and debris is transferred in the form of “Two-line element sets”.

- These arese are an “averaged” representation of a satellite’s orbit over the course of one revolution, rather than an instantaneous measurement of position and velocity.

- Alternatives exist, e.g ephemeris models, but data size is much larger



Credit: flatearth.ws/tle

Propagating TLEs

SGP4 (Simplified General Perturbations 4)

Various python wrappers

Provides coordinates in GCI frame etc —> convert

Where are satellites in each station/antenna frame?

Where is the telescope in each satellite frame?

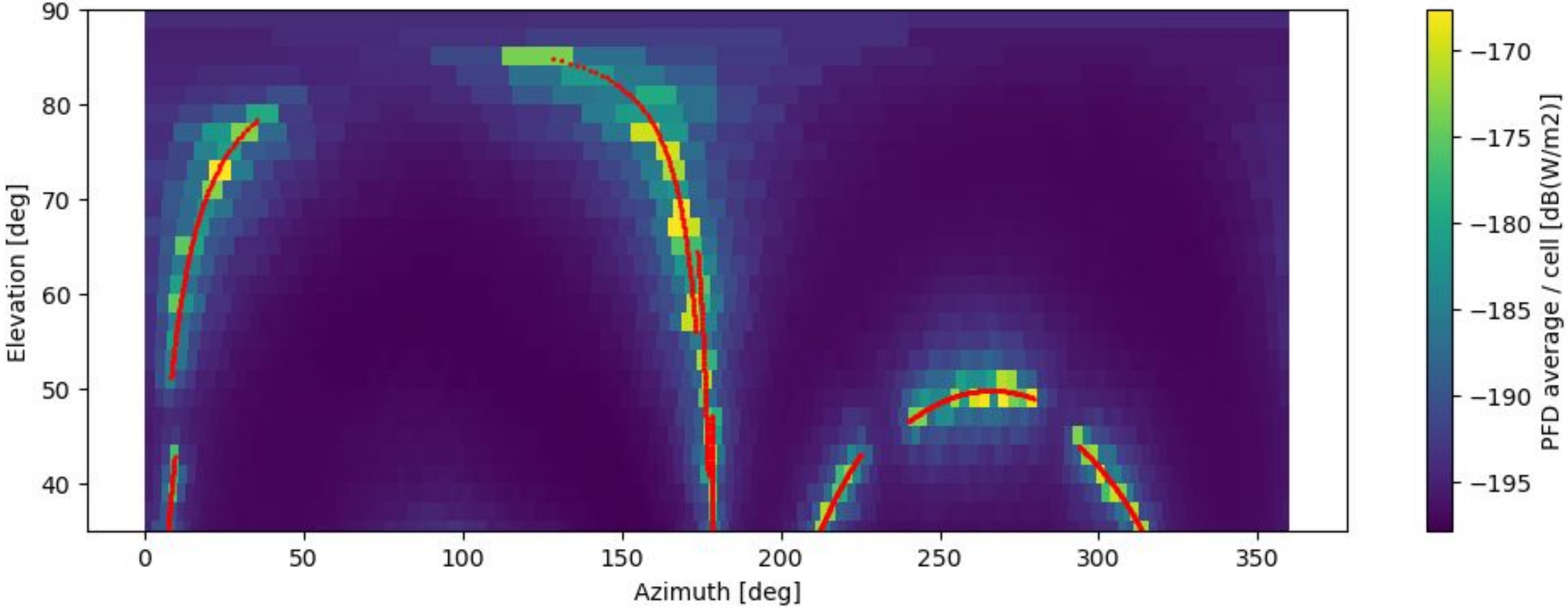
Workflow


Telescope Locations
Satellite TLEs
Observation Time Stamp and Pointing
Transmitter and Gain Model
SGP4 Propagation
Satellite Distance
Satellite Coordinates at Observatory Location
Telescope Coordinates in Sat Ref Frame
Telescope and Satellite Pointing Offset
FSPL Correction
Power Flux Density

Example Scenarios

simulating 631 satellites, 100x 1s iterations

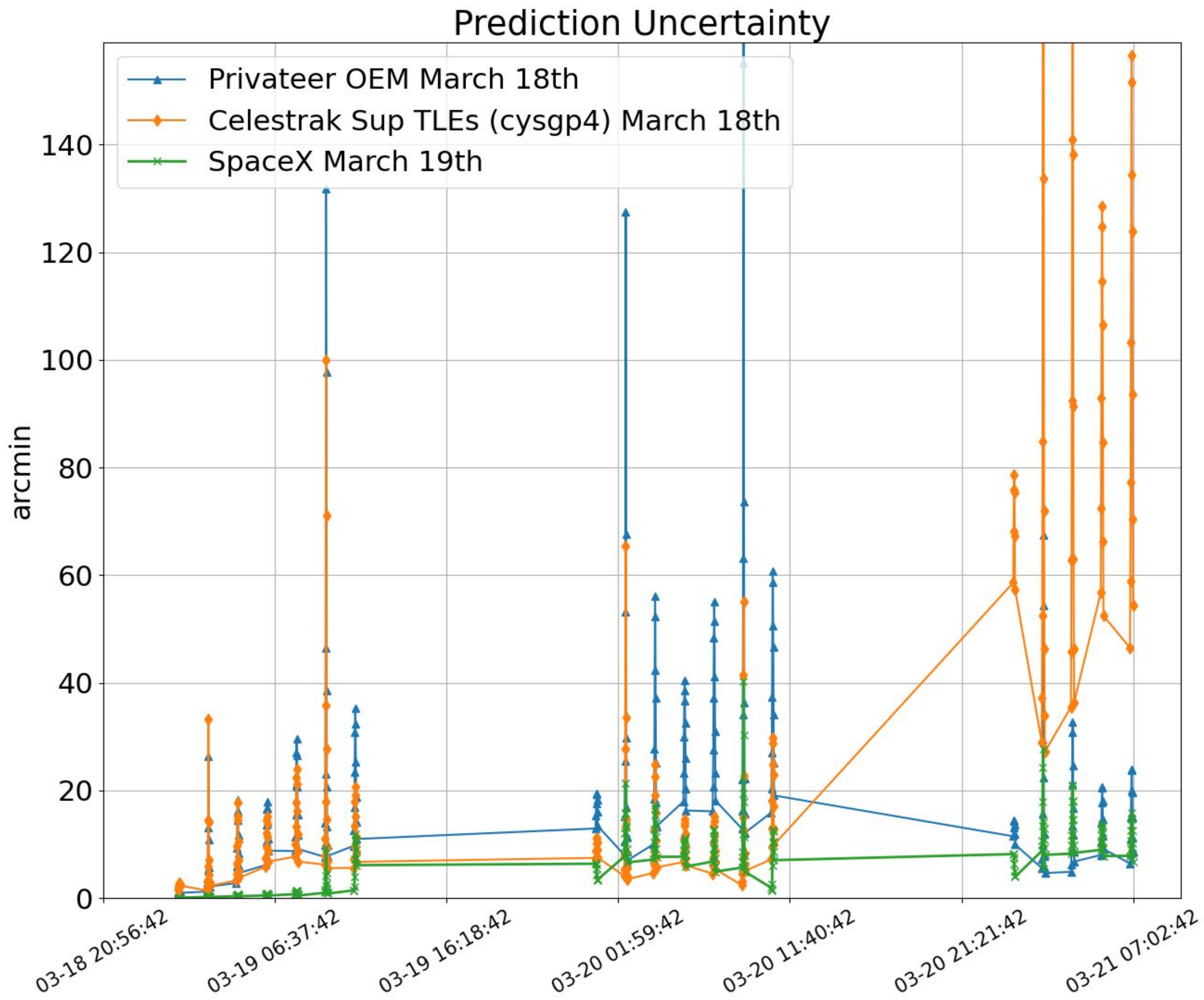
At Parkes, 100 seconds, assuming active beams pointing at 20 degrees elevation in satellite frame



Current Issues

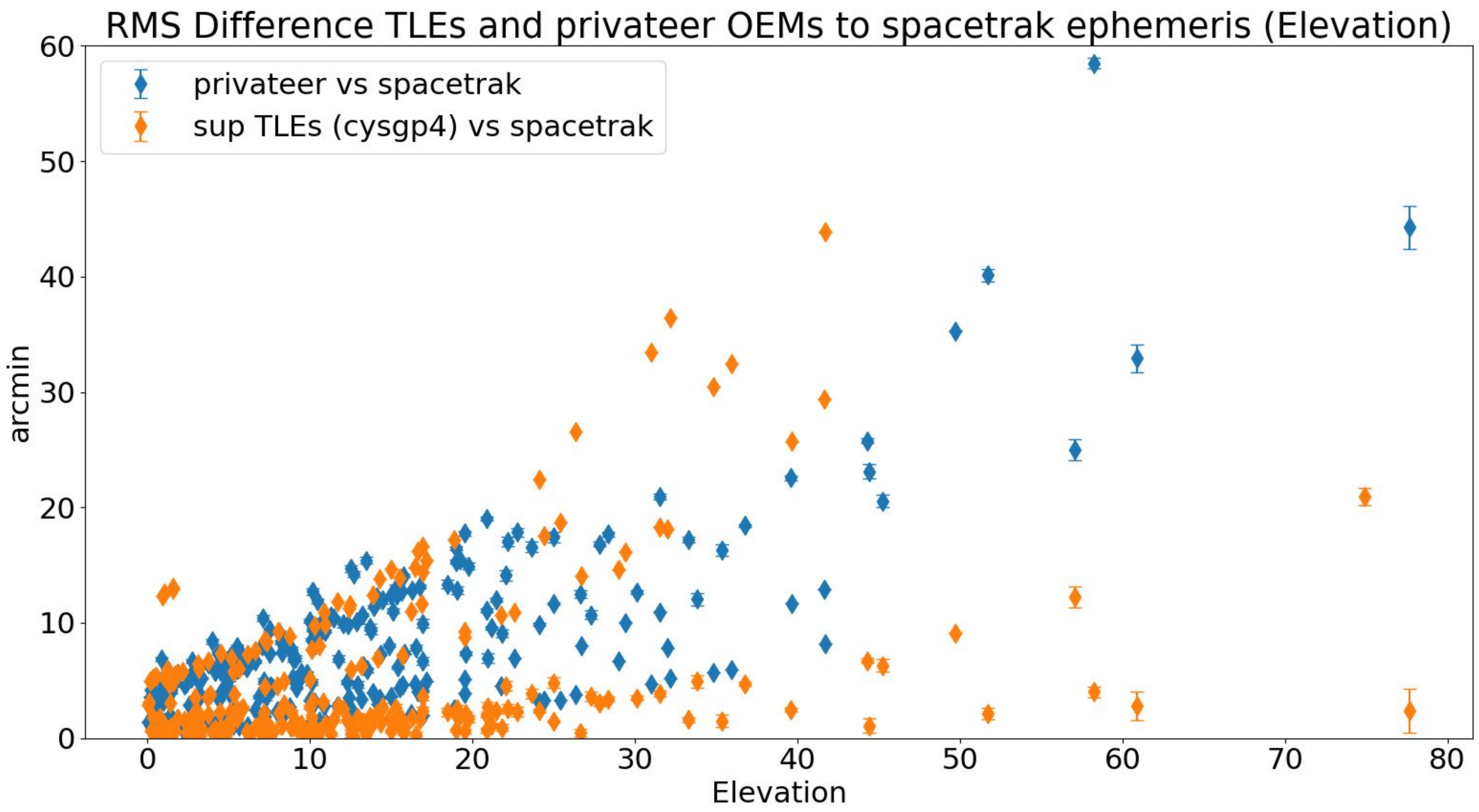
- Propagation speed could be faster
- TLEs are not accurate enough, also some LEO constellations shift orbit frequently
- Fringe between stations can be estimated but real data simulation is tricky. Current idea is applying a reverse near field geometry delay correction to a measurement set with a satellite 'sky model'

TLEs…. They start drifting off!



UKSA study PS24309, supported by IAU CPS Sathub, May 2025

OEMs are better, but they’re huge



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