Imperial College London

SIMONS OBSERVATORY UNITED KINGDOM

Detecting millimetre transients (and avoiding satellites) with the Large Aperture Telescope of Simons Observatory

Mike Peel

3 June 2024

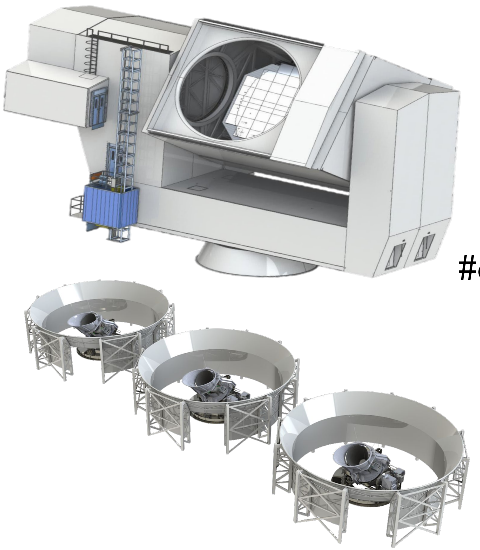
UK Transients 2024

This work is presented on behalf of the Simons Observatory collaboration. Simons Observatory is supported by the Simons Foundation, the Heising-Simons Foundation, and other research institutions within the collaboration.

The Simons Observatory

Located at 5200 meters in Northern Chile

+3 SATs with UK and Japan funds



#optics tube
7/13

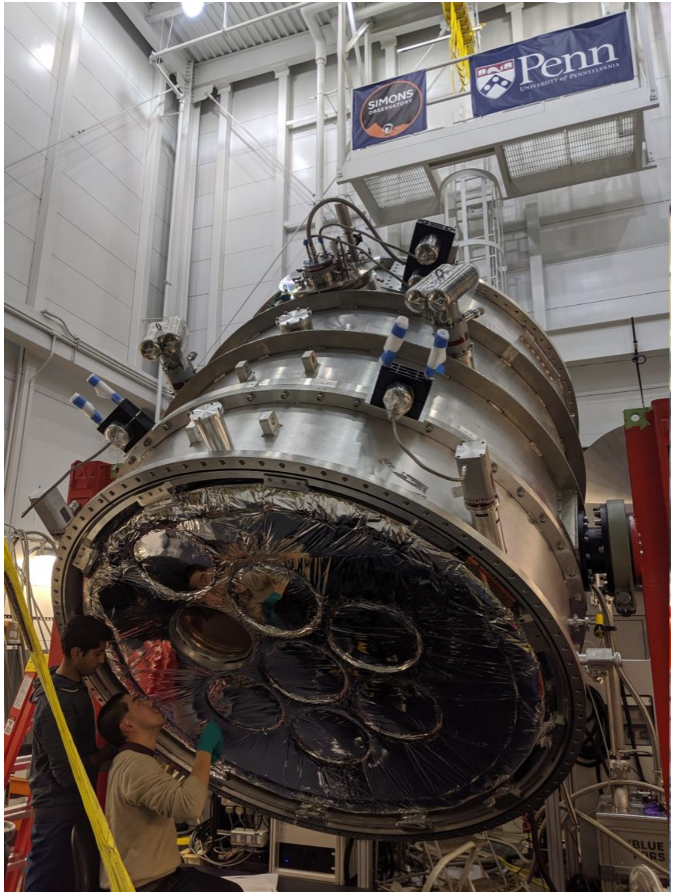
#optics tube
(7+1)/13

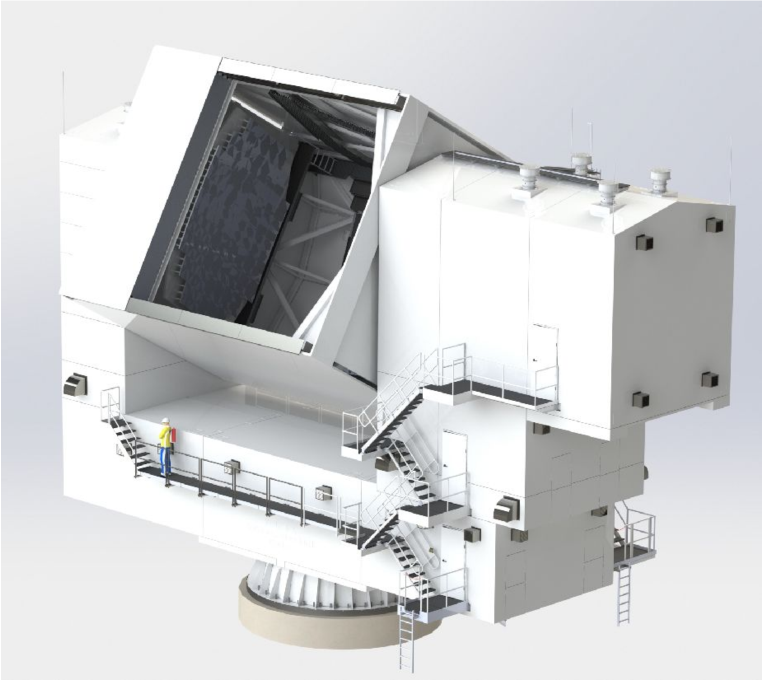
Twice better sensitivity to primordial gravitational waves

2023～

2026～

SO Construction is Underway





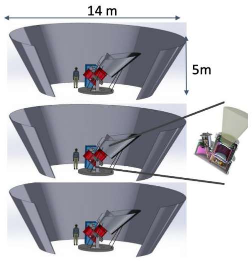
New 6-meter-primary telescope

Detectors measure 6 wavelength bands:

1-10 mm (30-280 GHz)

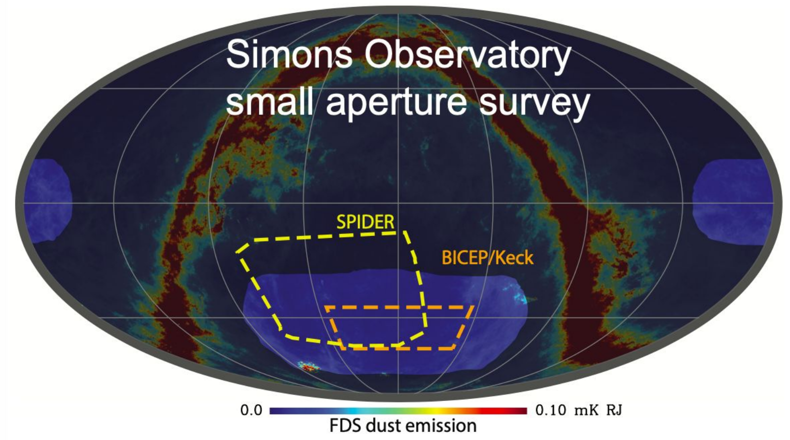
>30,000 Transition Edge Sensor detectors

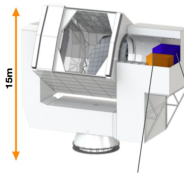
SO Surveys



	SATs ($f_{sky} = 0.1$)		
Freq. [GHz]	FWHM ($'$)	Noise (baseline) [μK-arcmin]	Noise (goal) [μK-arcmin]
27	91	35	25
39	63	21	17
93	30	2.6	1.9
145	17	3.3	2.1
225	11	6.3	4.2
280	9	16	10

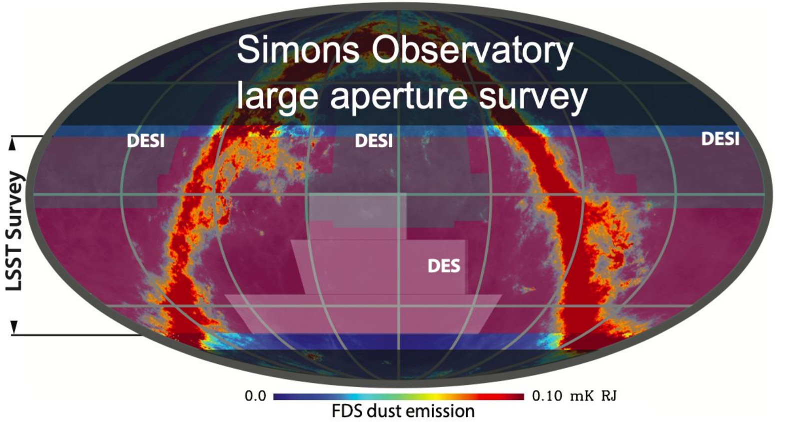
2 μk-arcmin





	LAT ($f_{sky} = 0.4$)		
Freq. [GHz]	FWHM ($'$)	Noise (baseline) [μK-arcmin]	Noise (goal) [μK-arcmin]
27	7.4	71	52
39	5.1	36	27
93	2.2	8.0	5.8
145	1.4	10	6.3
225	1.0	22	15
280	0.9	54	37

6 μk-arcmin



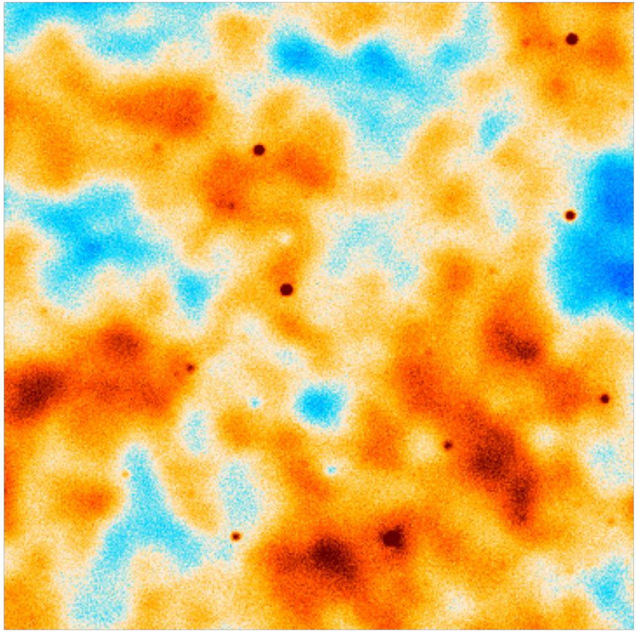
From June, 2020 SO+LSS Zoomference

SO: New Opportunities in mm-Transient Science

Variable Active Galactic Nuclei:
track thousands daily/weekly/monthly at 1-10 mm.

Potential of mm transients:
e.g. orphan afterglows of Gamma Ray Bursts

Potential follow-up of Rubin Observatory optical transients



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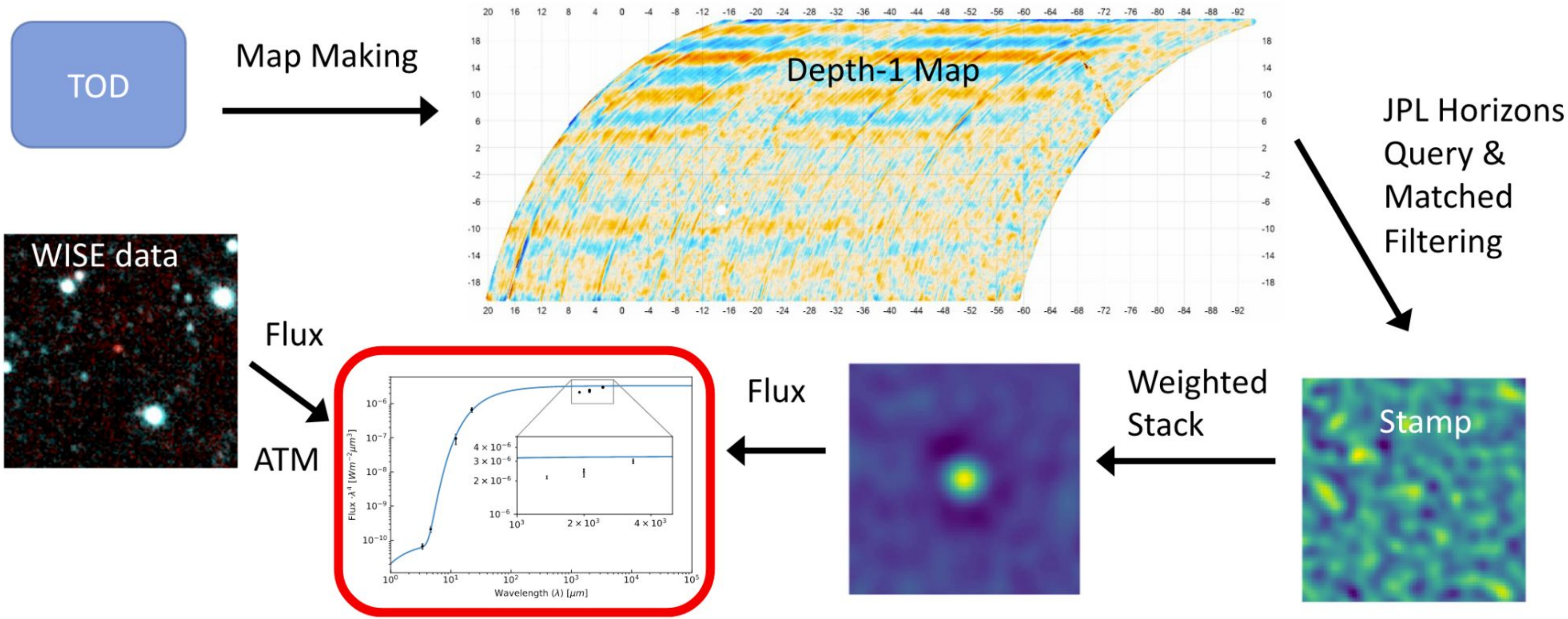
ACT-T J061647-402140: a Strongly Variable, Flaring Source at 90, 150 and 220 GHz Positionally Coincident with the Transient Gamma-Ray Blazar, Fermi 0617-4026

ATel #12738; *Sigurd Naess (Center for Computational Astrophysics, Flatiron Institute) on behalf of the ACT Collaboration*
on 8 May 2019; 23:32 UT
Credential Certification: John P. Hughes (jph@physics.rutgers.edu)

Subjects: Millimeter, Gamma Ray, AGN, Blazar, Transient, Variables

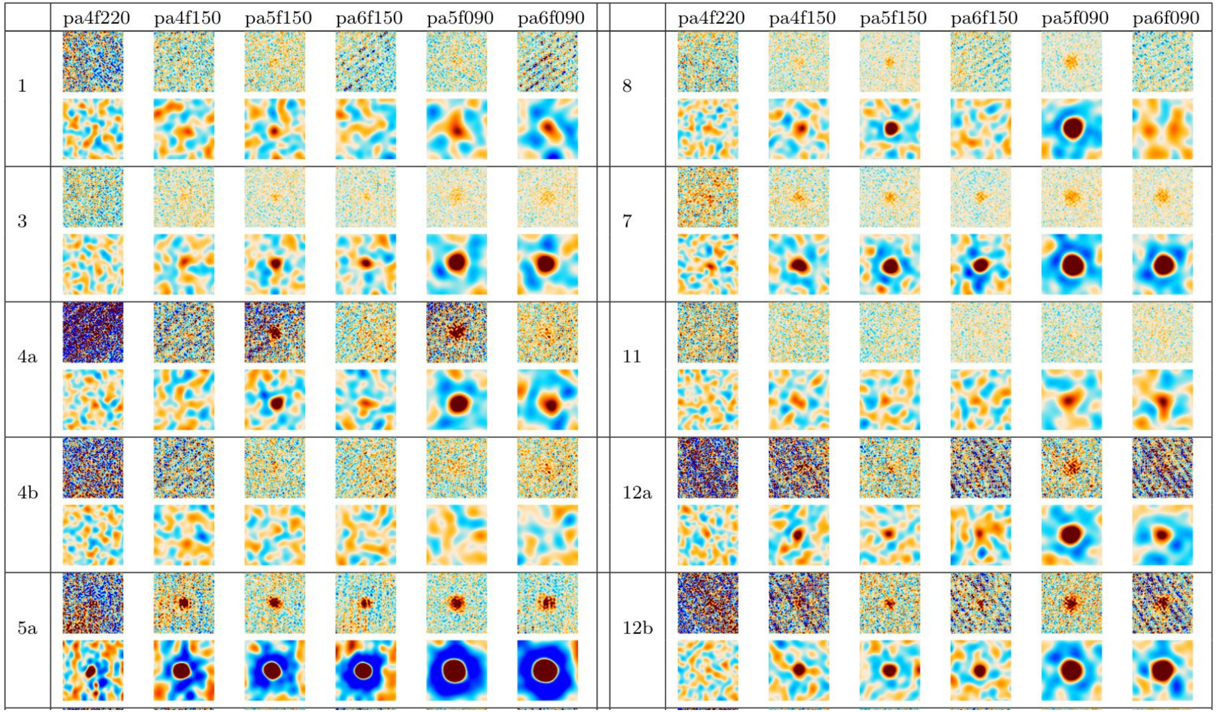
In addition to wealth of CMB science (early and late-time signals), 30k high-z dusty galaxies, 20k clusters and Galactic science

Depth-1 maps: example from Atacama Cosmology Telescope



Orlowski-Scherer et al. (2023), The Atacama Cosmology Telescope: Millimeter Observations of a Population of Asteroids or: ACTeroids, arXiv:2306.05468

3 day maps: example from Atacama Cosmology Telescope



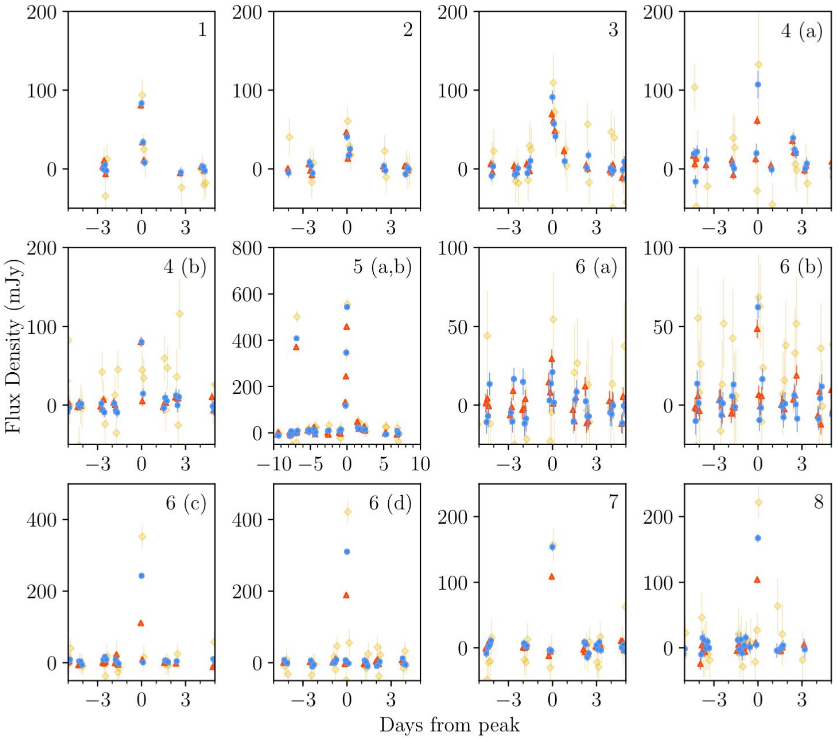
Other approaches under discussion, but could also do:

- Looking for variable sources directly in the time-ordered data
- Stacking on moving sources where positions are well known
- Follow-up of optical/radio transients identified with other surveys

Li et al. (2023), The Atacama Cosmology Telescope: Systematic Transient Search of 3-Day Maps, arXiv:2303.04767

Stellar flares

- Example from South Pole Telescope: Guns et al. (2021), Detection of Galactic and Extragalactic Millimeter-Wavelength Transient Sources with SPT-3G, arXiv:2103.06166
- From variable stars, mostly known X-ray transmitters, but mix of types:
  - M dwarfs
  - RS CVn
  - BY Dra variable
  - Rotational variable
- SO will see many of these, at fainter flux density levels, and across more of the sky



Asteroids - examples from South Pole Telescope

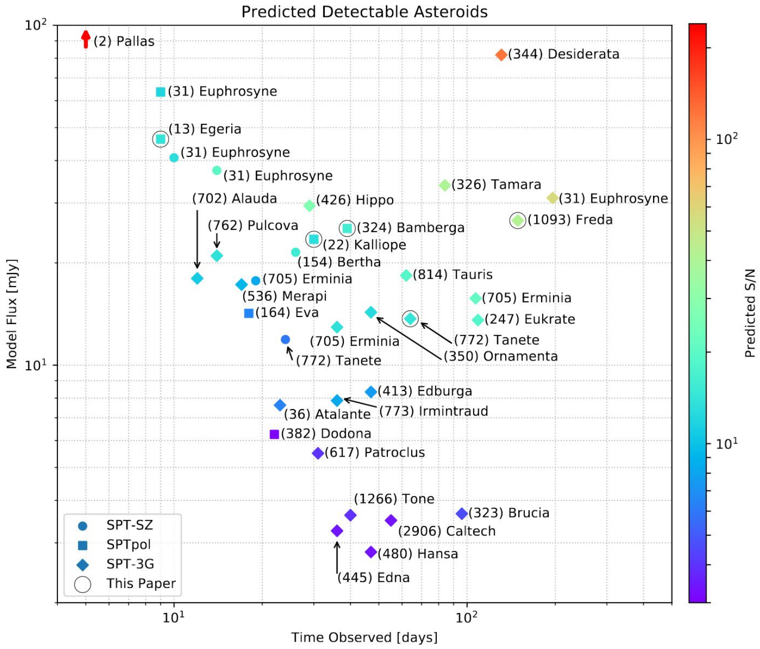


Figure 7. Objects with predicted S/N > 3 at 2.0 mm in all historic and planned future SPT data. We expect to observe (2) Pallas, plotted off scale, with a mean flux density near 725 mJy.

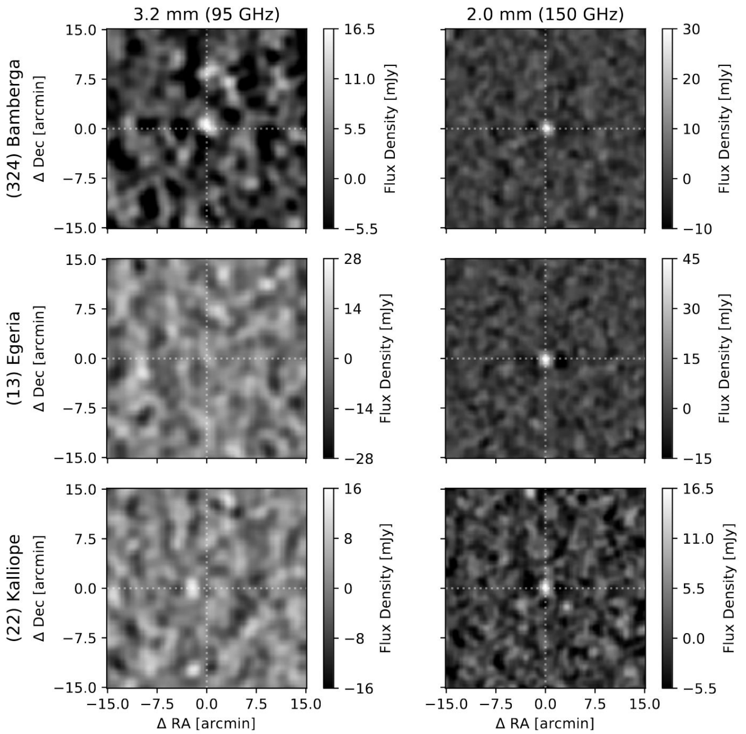
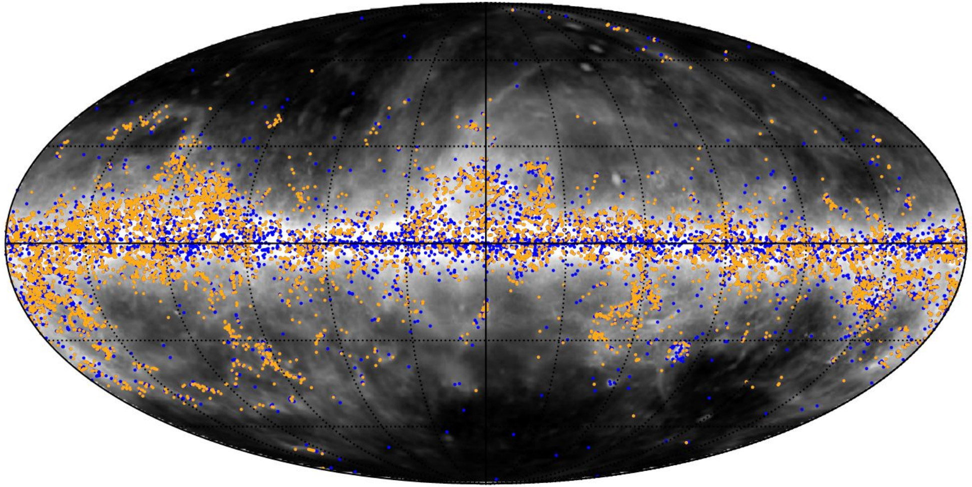


Figure 4. Mean flux measurements of (324) Bamberga (top horizontal panels), (13) Egeria (middle horizontal panels), and (22) Kalliope (bottom horizontal panels) at 3.2 mm (left vertical panels) and 2.0 mm (right vertical panels). Color scales for (13) Egeria and (22) Kalliope at 3.2 mm are set at 4-sigma levels; the rest peak near the mean flux values detected for each asteroid.

Chichura et al. (2022), "Asteroid Measurements at Millimeter Wavelengths with the South Pole Telescope", arXiv:2202.01406
Also see Orlowski-Scherer et al. (2024), "The Atacama Cosmology Telescope: Millimeter Observations of a Population of Asteroids or: ACTeroids", arXiv:2306.05468

Also lots of Galactic & extragalactic sources to analyse

- E.g., Clancy et al. (2023), "Polarization fraction of Planck Galactic cold clumps and forecasts for the Simons Observatory", MNRAS (accepted), arXiv:2303.02788
- Based on Planck data, stacking analysis shows ~2% polarisation on average
- Expect to see ~12,000 cold clumps in intensity + ~430 in polarisation in SO
- Also many extragalactic sources (radio sources like quasars, thermal sources like nearby galaxies, etc.)
- (some varying, others not, but all interesting, e.g., spectral energy distributions/component separation/etc.)



Cold cores in Planck data: blue, complete set, orange, high S/N & well-separated subset used in Clancy et al. (2023)

Satellite constellations

Satellites have always been an issue for astronomy.

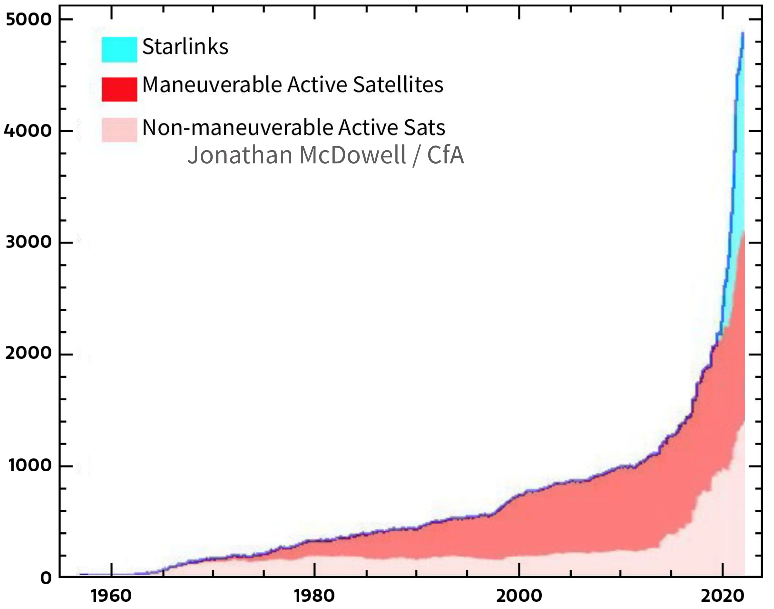
Starlink started launches in 2019. **Doubled the number of satellites in the last 5 years,** in Low Earth Orbit (LEO)

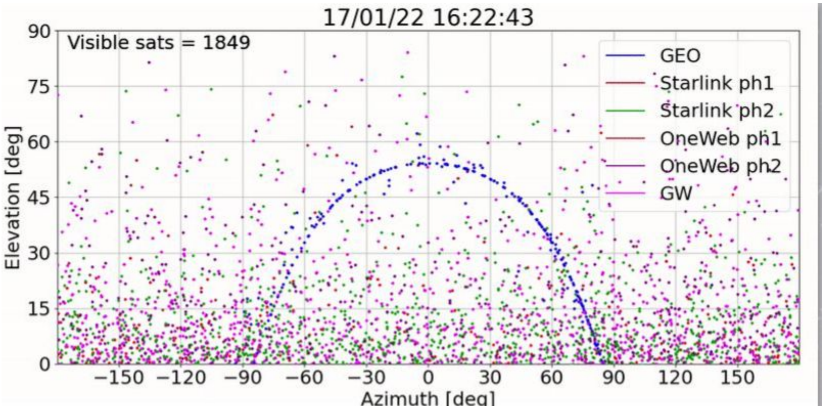
O**ver 1,000,000 new satellites proposed in the next decade**, via Starlink/OneWeb/Kuiper/many other companies.

Can (and already have!) mimic astronomical transients (GN-z11-flash was a rocket body...)

Join us at SatHub to collect and analyze satellite observations, and build software tools.
Part of the IAU Centre for the Protection of the Dark and Quiet Sky from Satellite Constellation Interference.

Apply here: https://cps.iau.org/



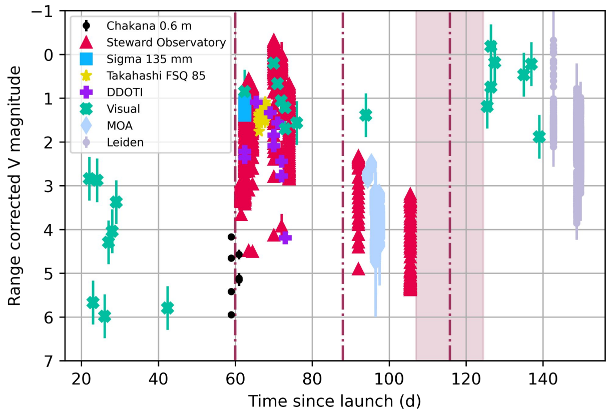


Bright across the EM spectrum

Reflections from the sun in late evenings / early mornings in optical/nir.
Large direct-to-cell satellites can be the brightest objects in the sky, e.g., BlueWalker3 (negative mag!).
Will affect surveys like LSST with Vera C. Rubin Observatory, amongst others. Not even Hubble escapes due to LEO (but JWST in L2 is fine).

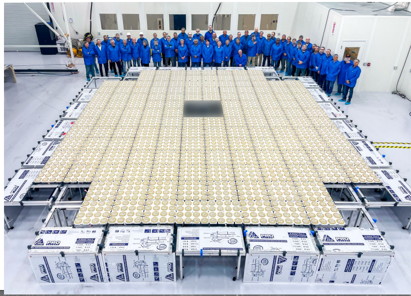
Active and highly variable transmissions at radio frequencies.
QUIJOTE observing at 10-20GHz used to just see geostationary satellites, now Starlink is everywhere.
Even seen with LOFAR/SKA-low at ~100MHz through unintended emission (digital hardware etc. also transmits at clock freqs!)

Likely bright in submm/mm through thermal emission.

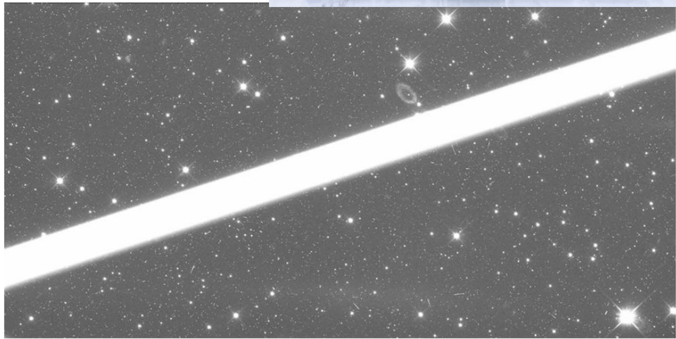


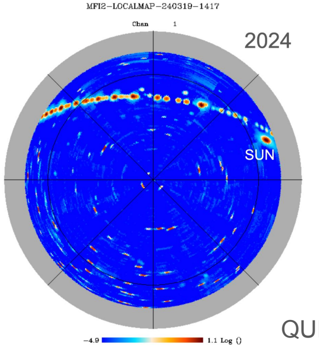
https://www.nature.com/articles/s41586-023-06672-7

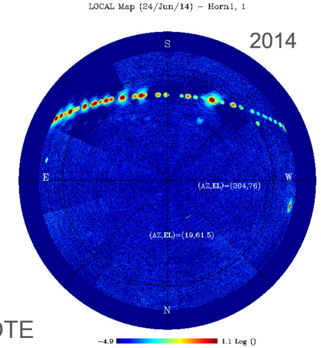
BlueWalker3



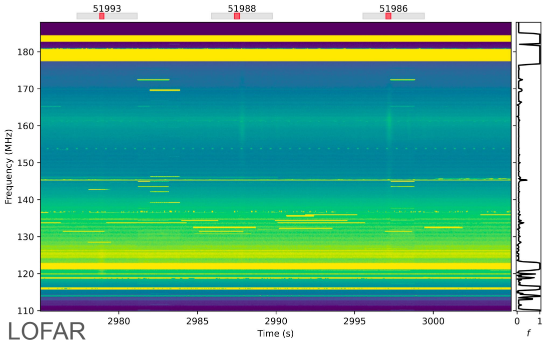
Hubble







QUIJOTE

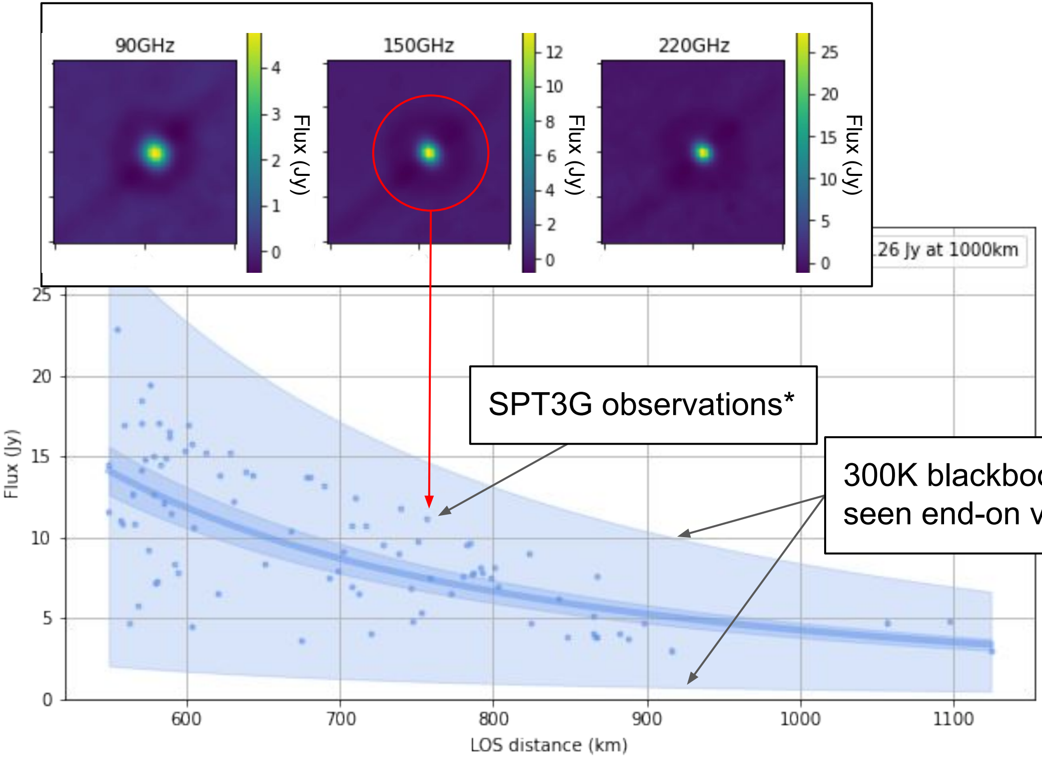


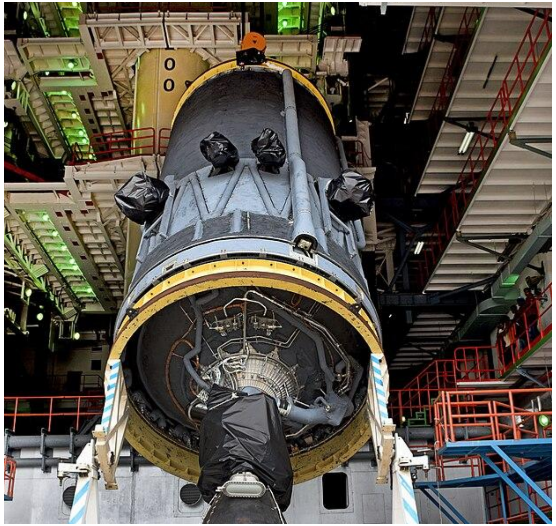
LOFAR

(with thanks to Allen Foster, who has a paper in progress on this!)

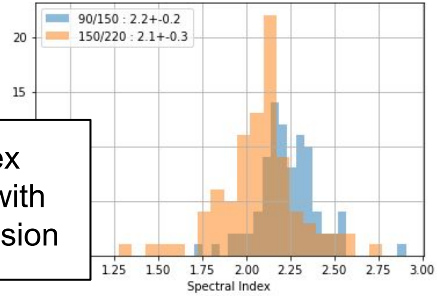
Example from SPT3G - Thermal Emission

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





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



Spectral index ~consistent with thermal emission

* observed both in direct sunlight and in Earth's shadow. Very high S/N.

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Conclusions

- Simons Observatory is under construction, will start observations soon
- SATs will give powerful constraints for B-modes on large angular scales
- LAT will give high resolution science, including transients
- Expect to see transients from a variety of different sources (stars, AGN, other Galactic and solar system objects) - planning to share alerts publicly.
- May also see satellites through their thermal emission (and/or octaves of active transmissions)
- Lots to learn in the years to come!
- For more on satellites, come to our RAS NAM session this year!
- Questions?