Detection and characterisation of submm transient sources with a large single-dish telescope

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Abstract: The exploration of the time-variable astronomical sky at submm wavelengths is rapidly becoming more feasible with large sky surveys by Cosmic Microwave Background telescopes with tens of thousands of detectors. Observations with the Atacama Cosmology Telescope and South Pole Telescope have already detected some transients, and Simons Observatory and CCAT are expected to detect many more in the near future. Submm observations can provide valuable input into the evolution and origins of Gamma-Ray Bursts, Tidal Disruption Events, flaring stars, and many more types of objects. Follow-up observations to characterise these transients, and surveying to uncover fainter populations, will need high sensitivity and large fields of view at submm wavelengths, which could be provided by large single dish telescopes such as AtLAST. Should AtLAST be selected as ESO's next flagship project, it will be the first capable of discovering submm transients, providing a tremendous amount of synergy with the Cherenkov Telescope Array as well as telescopes like ALMA and the ELT that are capable of rapid follow-up and detailed characterization. Thermal emission from increasing numbers of low earth orbit satellites will present new challenges in the future - both for transient detection, and more widely with future high sensitivity observations through Earth's increasingly crowded orbital environments on the timescales being considered here.

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The Submm Transient Sky

The submillimetre transient sky is only beginning to be explored. Large CMB survey telescopes have recently demonstrated that repeated, wide-area observations can detect transient and highly variable sources, opening a new window on time-domain astronomy. Submillimetre observations probe dust emission, synchrotron radiation, and embedded environments that are often obscured at optical wavelengths, providing unique insight into gamma-ray bursts, tidal disruption events, stellar flares, active galactic nuclei, and other energetic phenomena.

Transients visible at submm wavelengths include:

- Flaring stars (duration typically <3 days)
- Protostars with variable accretion rates
- Gamma-ray bursts
- Supernovae
- Tidal disruption events (TDEs)
- Fast blue optical transients (FBOTs)
- … and asteroids and satellites

The submm transient sky has been observed with instruments like JCMT (Mairs et al. 2024), as well as Cosmic Microwave Background telescopes including the Atacama Cosmology Telescope (ACT; Hervías-Caimapo et al. 2024), and the South Pole Telescope (SPT; Guns et al. 2021). Simons Observatory (SO, Abitbol et al. 2025) is now entering regular observations and is expected to routinely detect transients, particularly with the 6m Large Aperture Telescope (LAT).

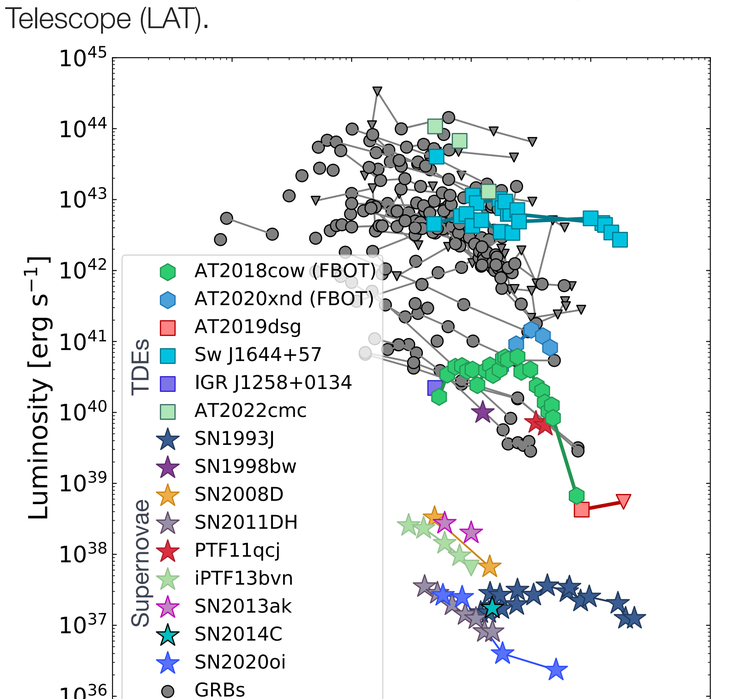

Fig. 1. Light curves of various extragalactic transients (SNe, GRBs, TDEs and FBOTs) at millimetre wavelengths, from Eftekhari et al. (2022)

AtLAST potential

AtLAST would provide the sensitivity and mapping speed needed to transform submillimetre transient astronomy. Alongside discovering new transient populations through dedicated monitoring surveys, it would deliver rapid, sensitive follow-up of alerts from facilities such as the Simons Observatory, CCAT, and multi-wavelength or multi-messenger observatories.

Simultaneous observations across multiple frequency bands would track the evolution of transient spectra and distinguish between emission mechanisms such as synchrotron, thermal dust, and free-free emission. Together, these capabilities would allow AtLAST to bridge the gap between wide-field survey telescopes and high-resolution interferometers, providing both discovery and detailed characterisation of transient sources.

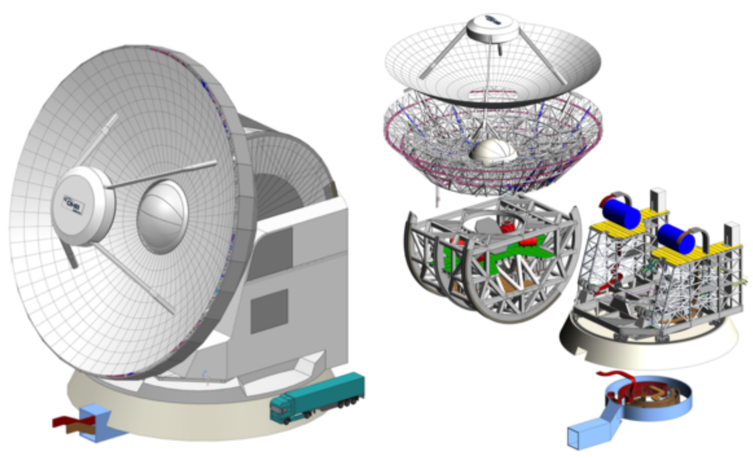

Fig. 2. Computer aided model of the AtLAST telescope. From Mroczkowski et al. (2025).

Technical requirements

Realising this science requires rapid response to external alerts, flexible scheduling, and repeated observations of large sky areas. Wide-field, multi-frequency instruments with stable, accurate photometric calibration are essential for detecting faint variability and measuring spectral evolution. Automated pipelines capable of real-time transient detection, difference imaging, and alert generation will enable AtLAST to identify new events efficiently and trigger timely follow-up, maximising its scientific return as a leading facility for submillimetre time-domain astronomy.

The ideal instrument for this work is a large (~50 m) single dish telescope that can simultaneously observe in the frequency range ~30–950 GHz with a large field of view and focal plane area, located at high altitude to minimise atmospheric noise - such as AtLAST.

Satellite constellations in the submm

Satellites reflect sunlight across the whole electromagnetic spectrum, including thermal radiation that can be seen in the infrared and submm. This can mimic astronomical transients, particularly when satellites move rapidly across the sky. The number of satellites has dramatically increased to over 15,000 and there are plans to launch perhaps millions more in the coming decades.

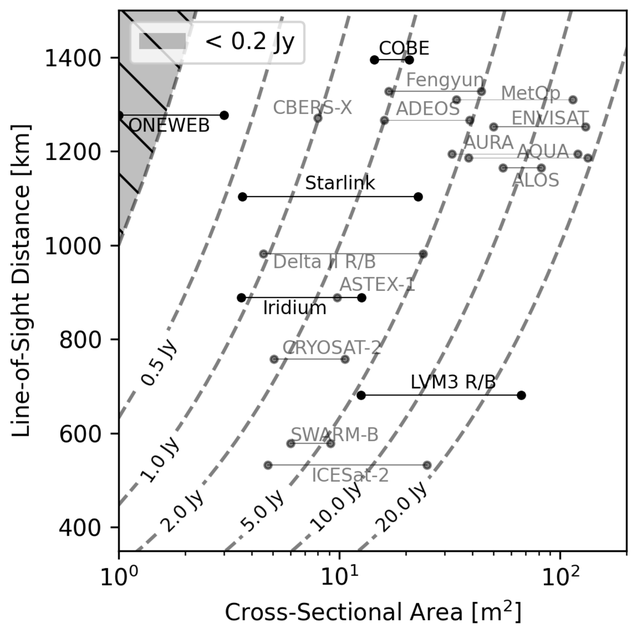

Fig. 3. Predicted thermal emission from satellites based on distance and apparent size. From Foster et al. (2025).

Observations with SPT (Foster et al. 2025) have shown that satellites are readily observable at Jansky brightness levels (similar levels to the brightest radio sources). Ongoing analysis of wide-field survey data from ACT (2007-2022) and the SO (ongoing) will be used to better understand the properties and prevalence of mm-bright satellites.

Satellites are already an important 'foreground' for transient submm observations, and their effects will increase significantly, particularly as low-Earth orbit satellites increase in both size and number. The International Astronomical Union's Centre for the Protection of the Dark & Quiet Sky (IAU CPS) is leading the effort to address the impact of satellite constellations on astronomy — please join at cps.iau.org !

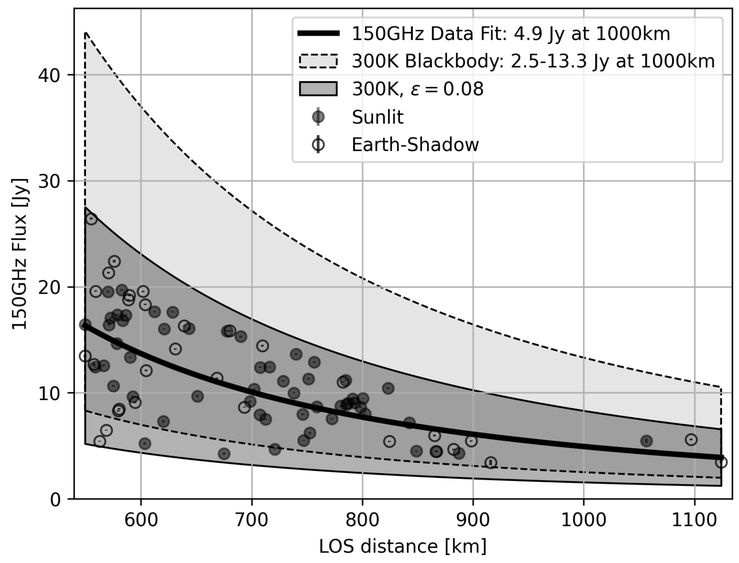

Fig. 4. South Pole Telescope observations of thermal emission from two LVM3 rocket upper stages. From Foster et al. (2025).

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