



Time – Resolving Sgr A* via the Time-Resolving Explorer (T-REX)

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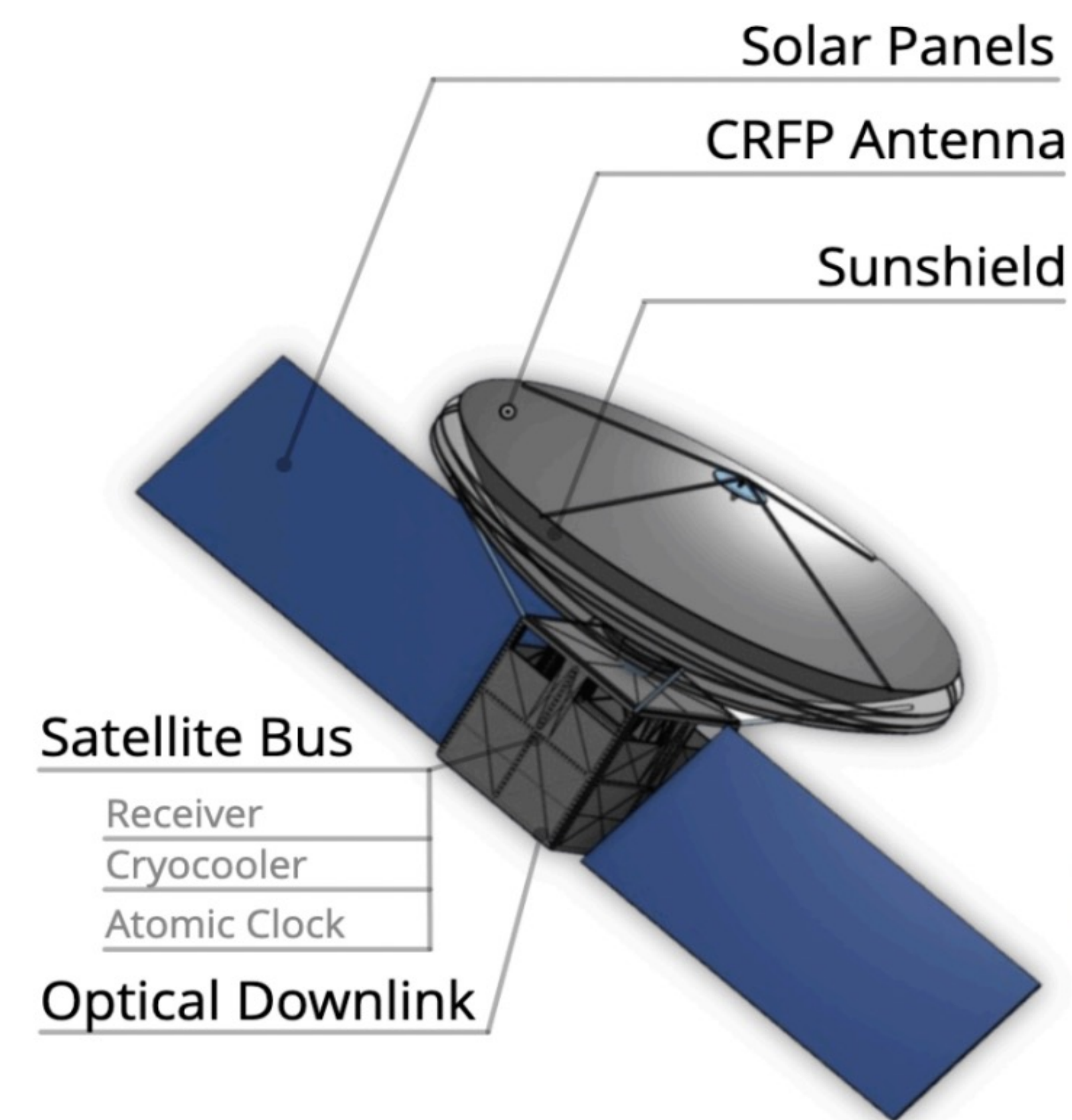
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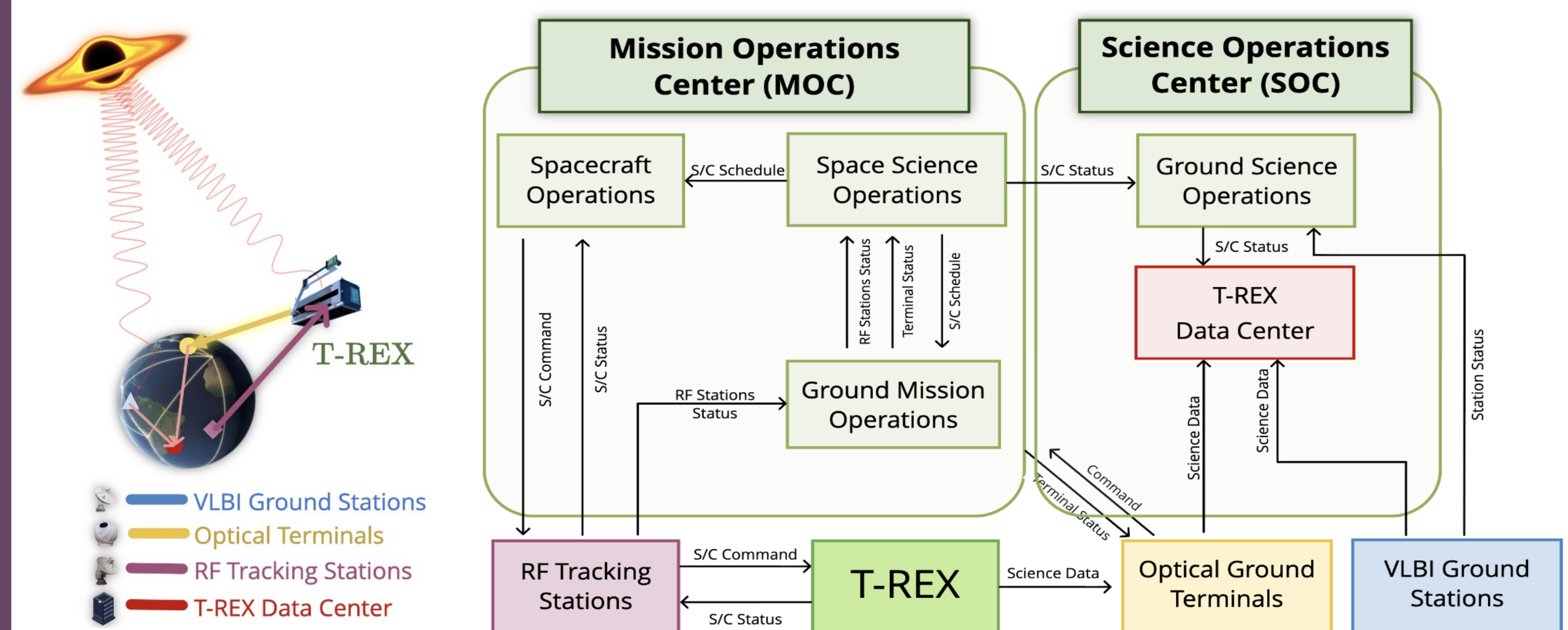
Abstract

The Time-Resolving Explorer (T-REX) is a proposed satellite mission which will capture the first video of a black hole. T-REX will achieve the finest temporal resolution in the history of astronomy, by leveraging a Low-Earth Orbit Very-Long-Baseline-Interferometry (VLBI) SmallSat platform. This will be enabled by laser downlink communications, ultra-stable oscillators and extensive ground-based supporting infrastructure. T-REX will constrain Sgr A*'s spin to $\leq 10\%$ ground truth by capturing time-resolved videos of Sgr A* at 86 GHz. T-REX will operate at $\lambda \sim 3.5\text{mm}$ with a $d \sim 2.5\text{m}$ antenna and a primary receiver temperature of $\sim 20\text{K}$. By virtue of its sub-ISCO 22 minute temporal resolution, T-REX will enable parameter estimation on transient astrophysical phenomena by capturing time-resolved videos of black hole accretion disks, quasi-periodic outbursts, relativistic jets from AGN, and tidal-disruption events.

Model



Mission



Primary Science Objectives

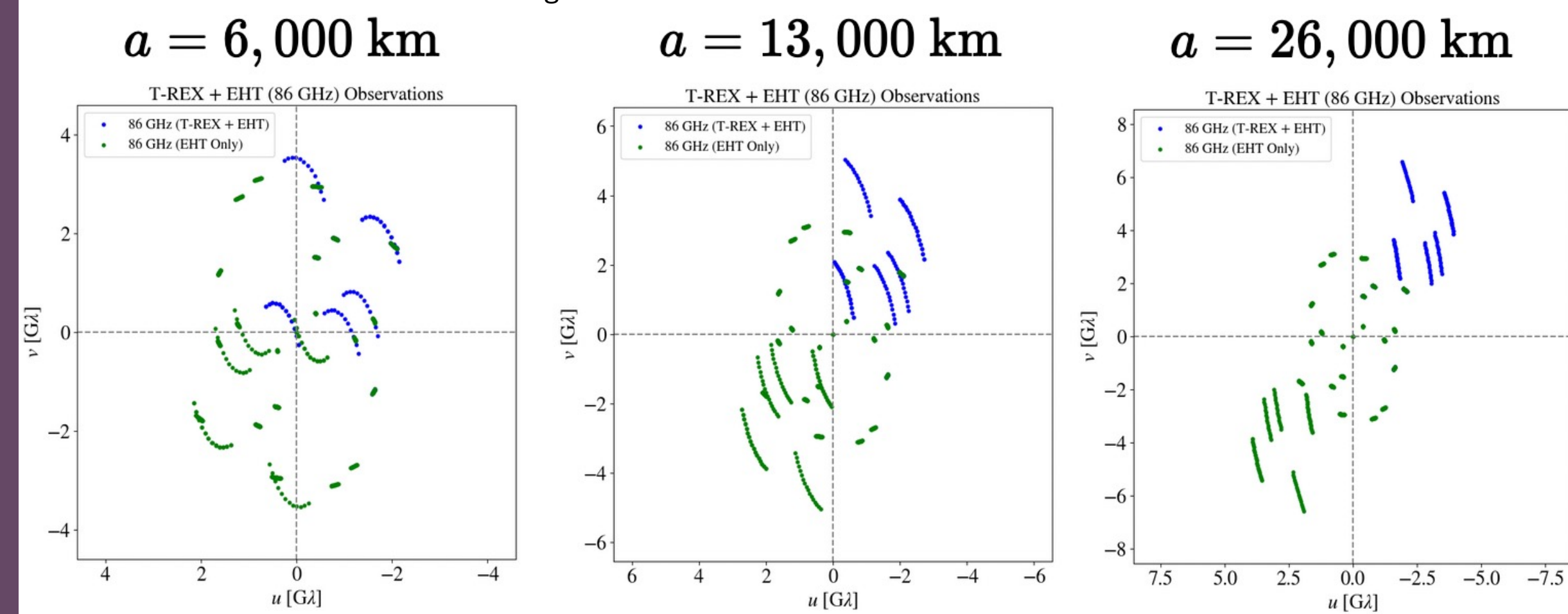
- 1) Capture Time-Resolved Videos of Sgr A* & M87.
- 2) Time-Resolving Binary Black Hole Systems.
- 3) Survey of Bright AGN at 86 GHz.

LEO Orbit & Time Resolution

Time-resolve Sgr A: $f_{\text{coverage}} > 50\%$ in $t < T_{\text{ISCO}} \sim 30\text{ min}$

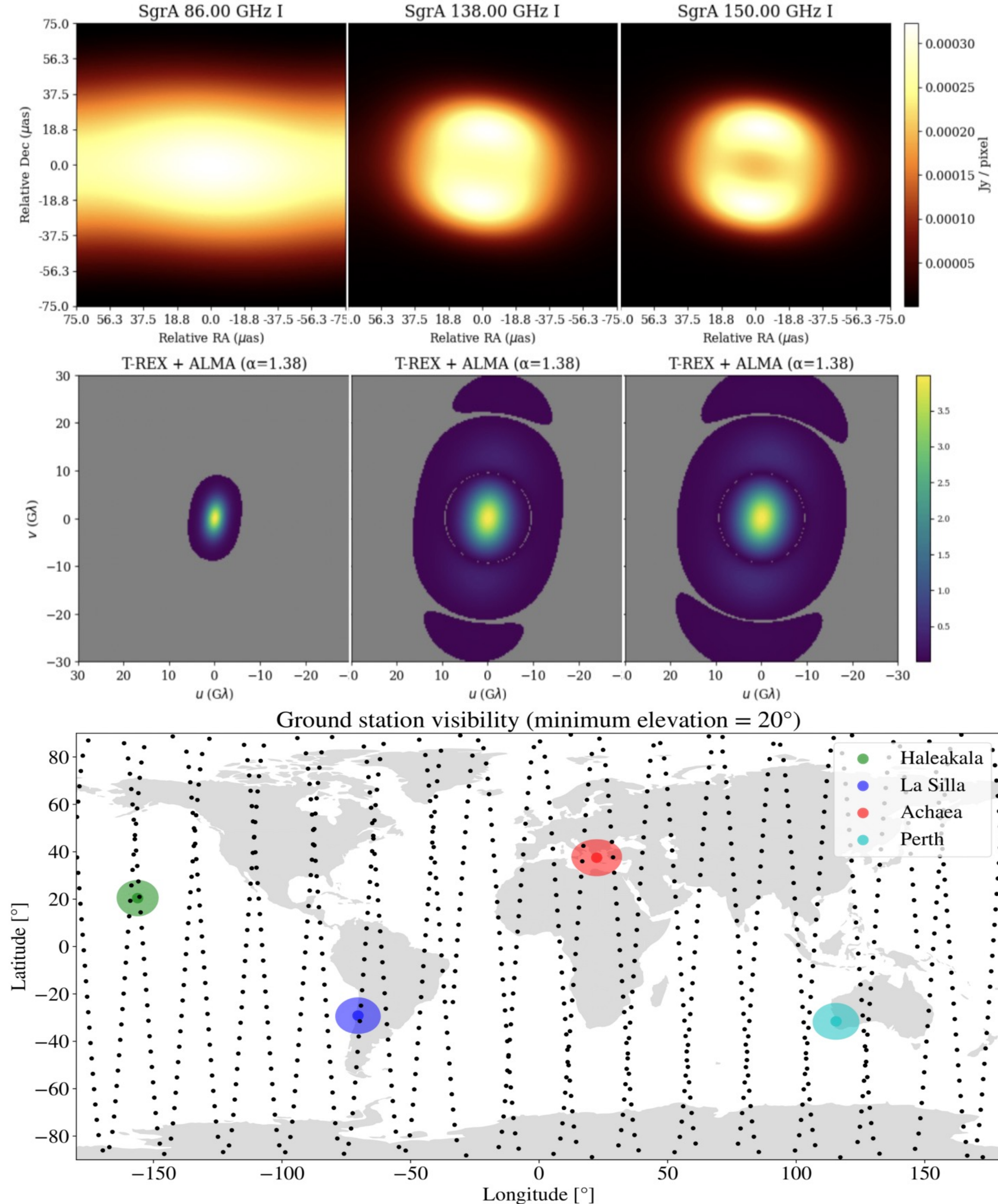
| Altitude | 6,000km (T-REX) | 13,000km | 26,000km |
|-----------------------|------------------|------------------|-----------------|
| t_{res} | 22.5 min | 60 min | 180 min |
| θ_{res} | 35 μs | 10 μs | 6 μs |

(Table 1) A trade-off between temporal resolution and angular resolution. T-REX maximizes temporal resolution to meet time-resolution constraints through a LEO orbit.



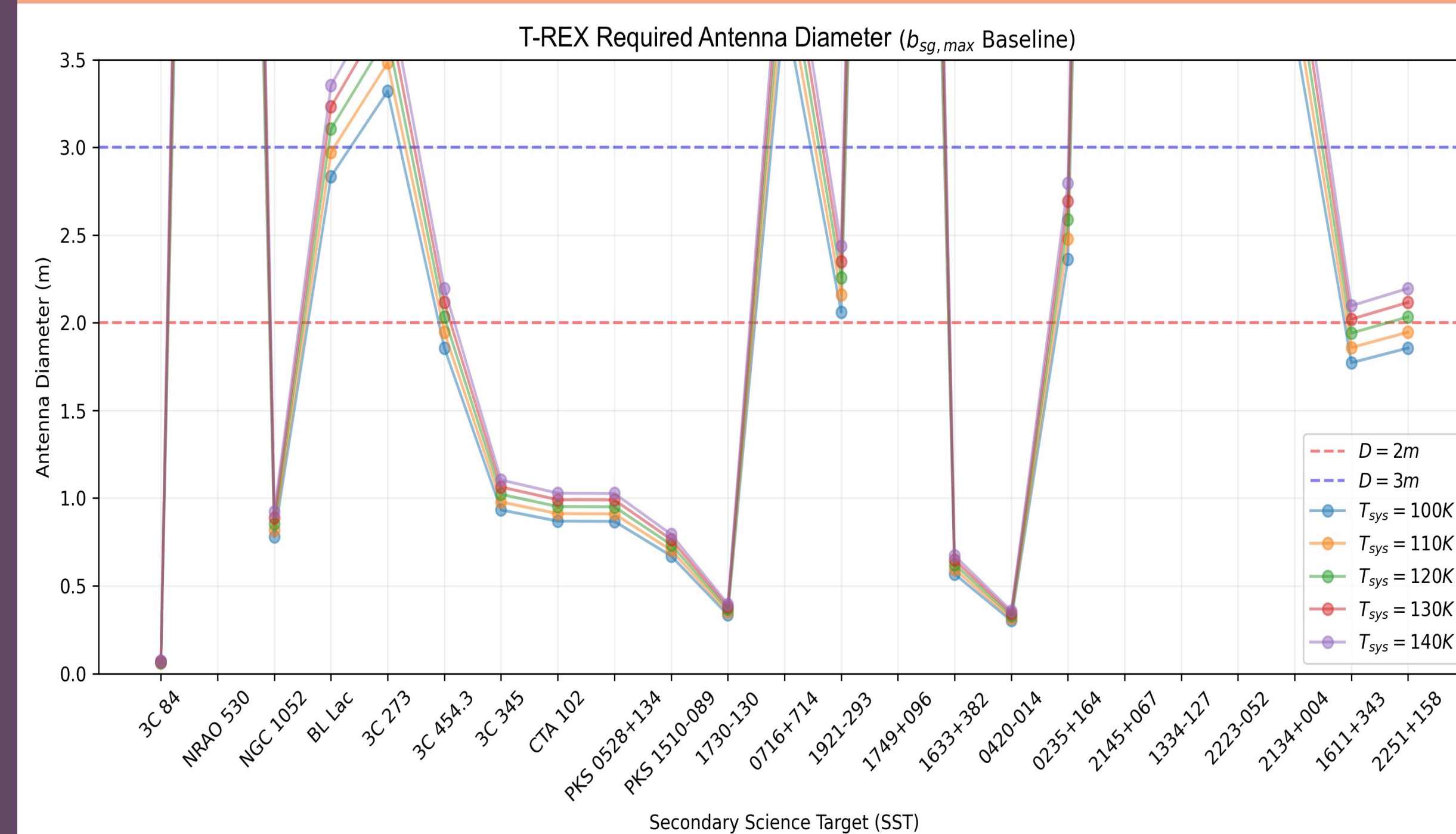
(Fig. 2) Sgr A*, 30 minute observations. Demonstrating the effect of different altitudes on (u,v) coverage.

Challenges: ISM Scattering & Downlink



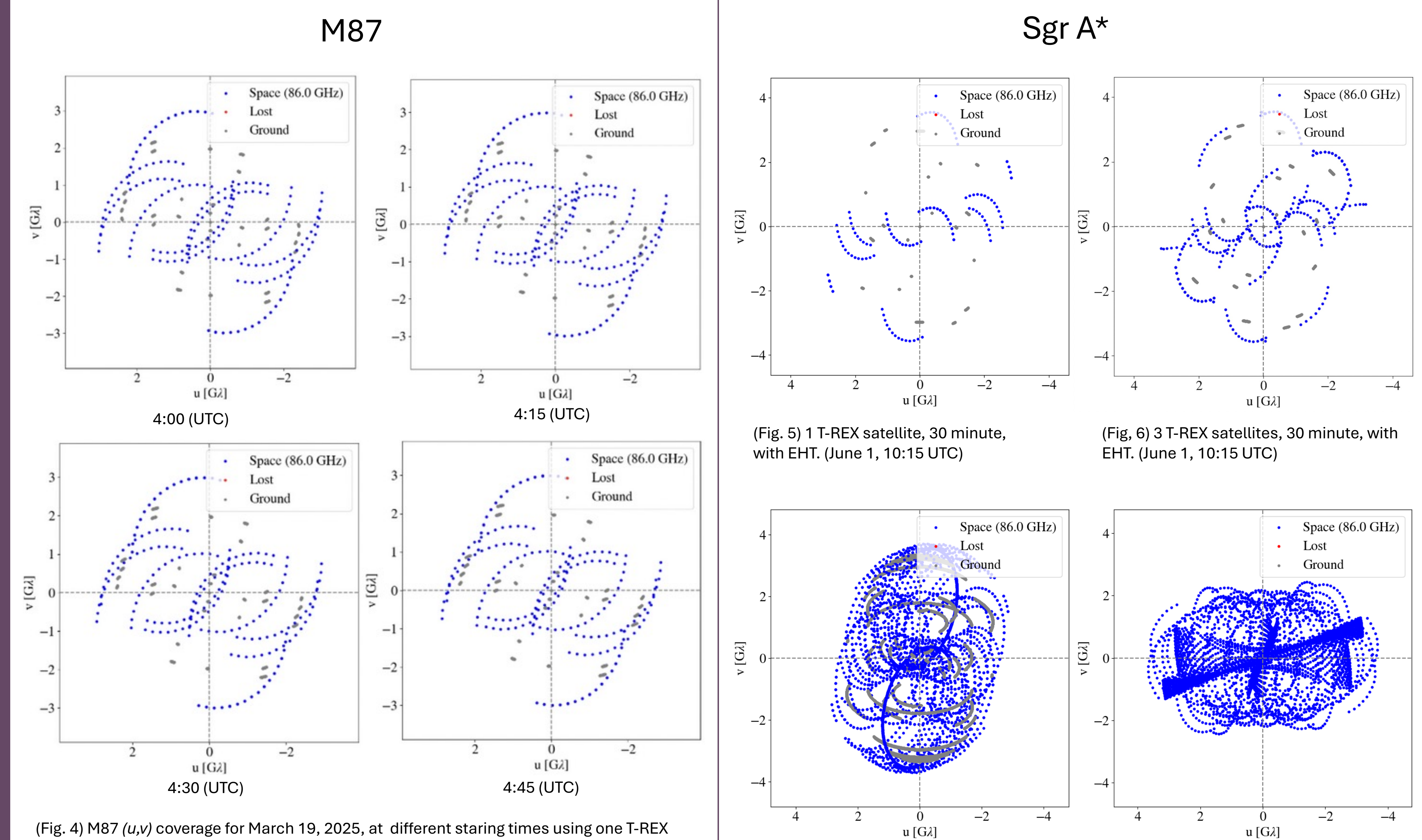
(Fig. 1) Top: ISM Scattering is a major problem for low-frequency observations of Sgr A. Mitigation techniques are being explored. Bottom: LEO offers limited downlinking coverage, requiring rapid downlinking speeds. The Terabyte Infrared Delivery system could resolve this, with speeds up to 100Gbps.

Antenna Design & Secondary Targets



(Fig. 3) T-REX antenna size (2.5m) is optimal for capturing most secondary science targets of interest (PSO2 & 3), while minimizing mission costs. Exact targets depend on cryocooler capabilities and final system temperature.

(u,v) Coverage Capabilities



(Fig. 4) M87 (u,v) coverage for March 19, 2025, at different staring times using one T-REX satellite co-observing with the EHT. 30 minute observation intervals. (u,v) coverage capabilities vary drastically with time of observation. Required coverage for time-resolution is achieved in under sub-ISCO time.

(Fig. 5) 1 T-REX satellite, 30 minute, with EHT. (June 1, 10:15 UTC)
(Fig. 6) 3 T-REX satellites, 30 minute, with EHT. (June 1, 10:15 UTC)
(Fig. 7) 1 T-REX satellite, 24 hour, with EHT. (June 1, 10:15 UTC)
(Fig. 8) 3 T-REX satellites, 24 hours, with ALMA. (June 1, 10:15 UTC)