

# Orbiting Configurable Artificial Star (ORCAS) for Enhancing Ground-Based Adaptive Optics

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## ABSTRACT

Adaptive optics (AO) have greatly enhanced the capabilities of ground-based observatories in producing clear, high-resolution astronomical images of distant and faint targets. Calibration of these systems to measure and account for atmospheric interference is necessary to approach diffraction-limited imaging. Currently, AO imaging is restricted to near infrared wavelengths; expanding into the visible would enable new areas of science, targeting anything from high-redshift galaxies to planetary systems. **We propose a mission consisting of an orbiting laser guide star to calibrate these ground-based AO systems.** This mission can support observations for every science theme in the Astro2020 Decadal Survey, from galaxies to exoplanets. In order to maximize sky coverage, minimize maneuvering costs, and increase reaction times between targets, this mission includes four spacecraft with different paths across the sky. We calculate ideal laser aperture diameter, finding that diameters above  $\sim 7\text{cm}$  are acceptable for all considered altitudes, delivering more than minimum solar flux to the spacecraft and constraining laser spot size on the ground to under  $\sim 10\text{km}$ . This mission is projected to launch in 2025.

## MOTIVATION



Adaptive optics

No Adaptive optics

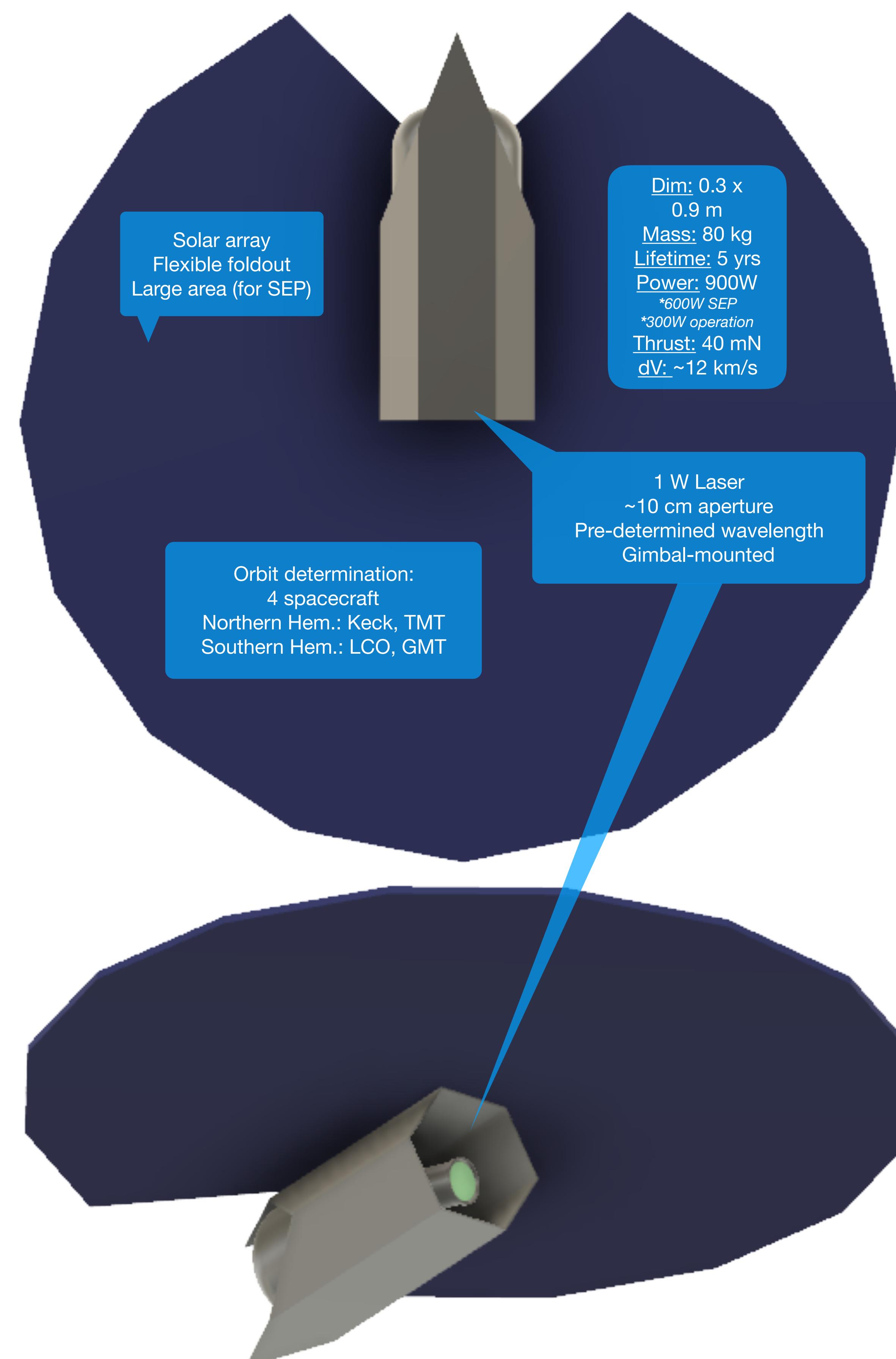
Image credit: VLT

### AO calibration:

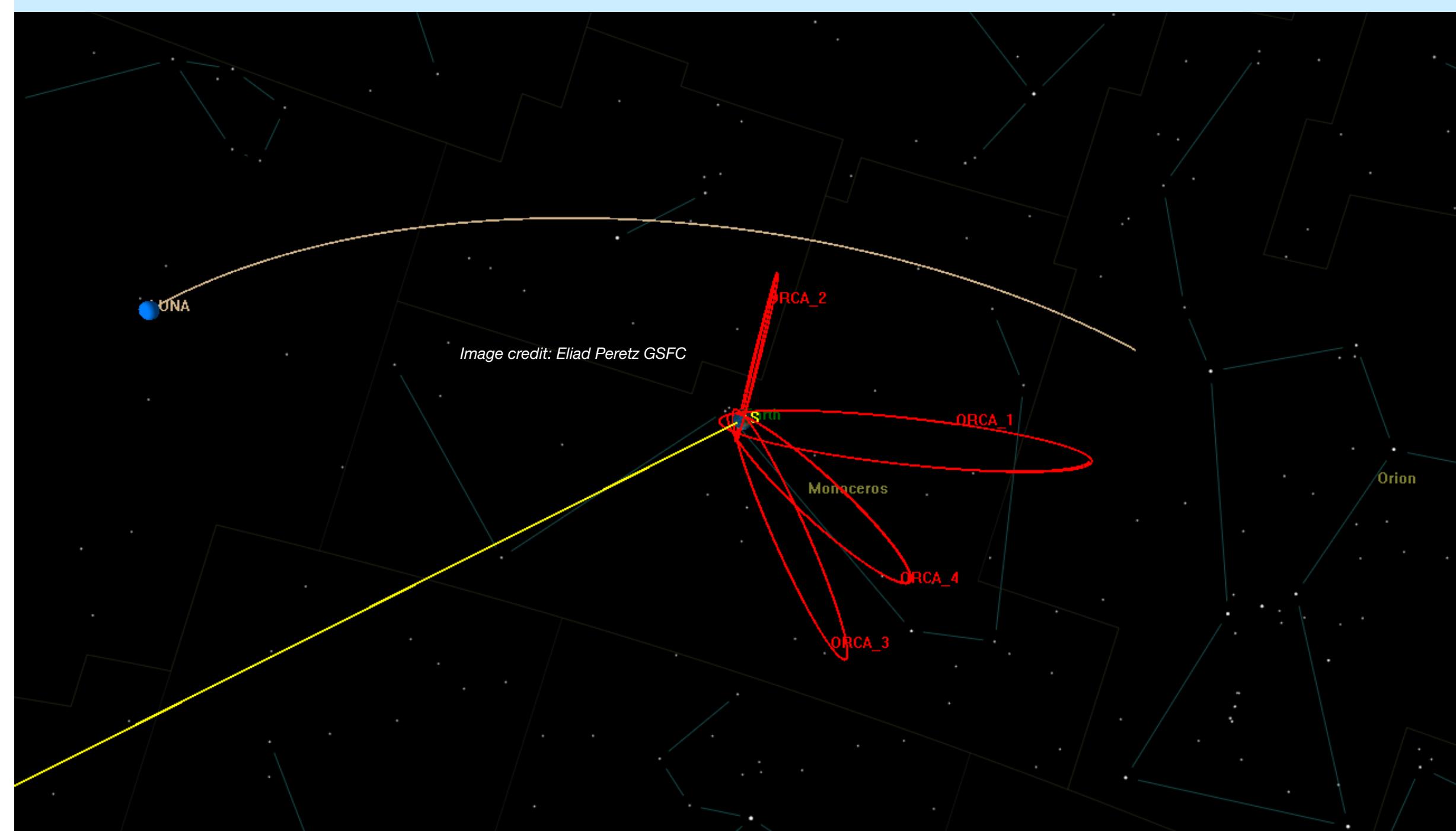
Natural Guide Star (NGS)

Ground-based laser guide star (gLGS)

Orbiting laser guide star (LGS)



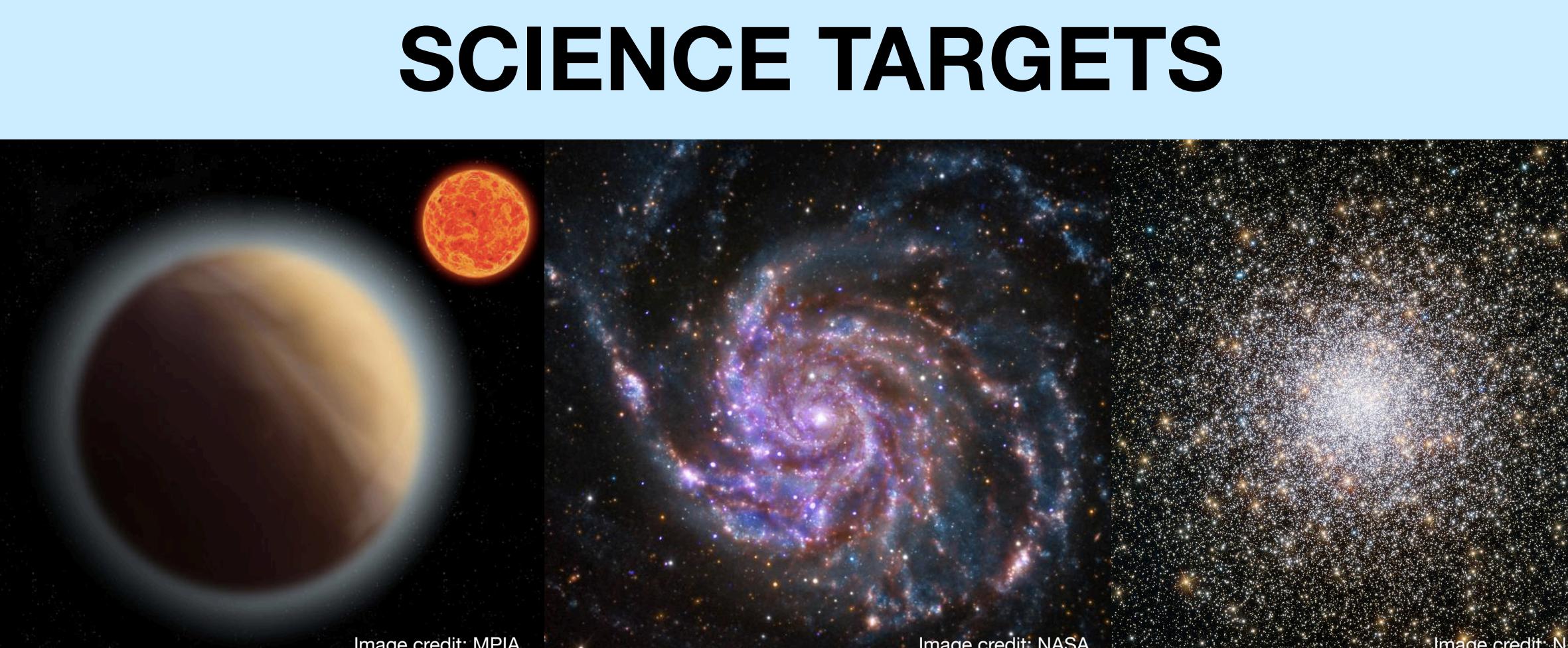
## ORBIT DETERMINATION



- Long elliptical orbit, beacon velocity (perpendicular to sightline) matches rotational velocity of observatory
- Must stay within isoplanatic patch ( $\sim 7 \text{ mas}$ ) during whole observation (30 mins-3 hours)
- Orbit precesses enough that active orbit management (using SEP) is required before observation.
- Altitude upper limit: laser spot size
- Altitude lower limit: minimum solar flux
- With 4 spacecraft and North-South coverage,  $>90\%$  of sky is observable throughout the year.

## ACKNOWLEDGEMENTS

We thank all those who contributed their time and expertise to the ORCAS project.



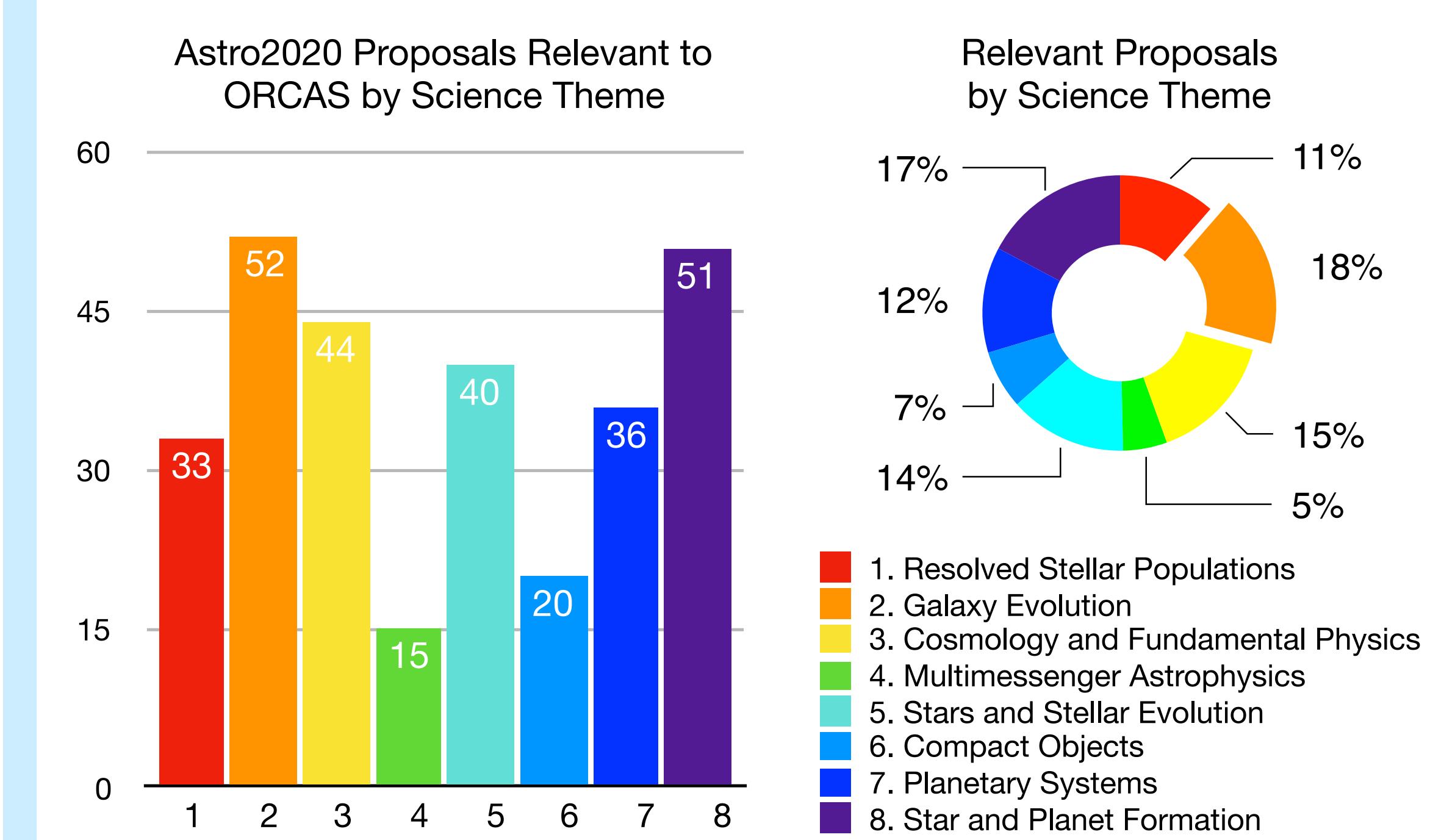
Resolve faint  $<30$  Mag objects

High ( $\sim \text{mas}$ ) angular resolution  
High number of targets

- Exoplanet atmospheres
- Star clusters
- High-redshift galaxies
- Protoplanetary disks
- Stellar atmospheres
- SNe Ia cosmology

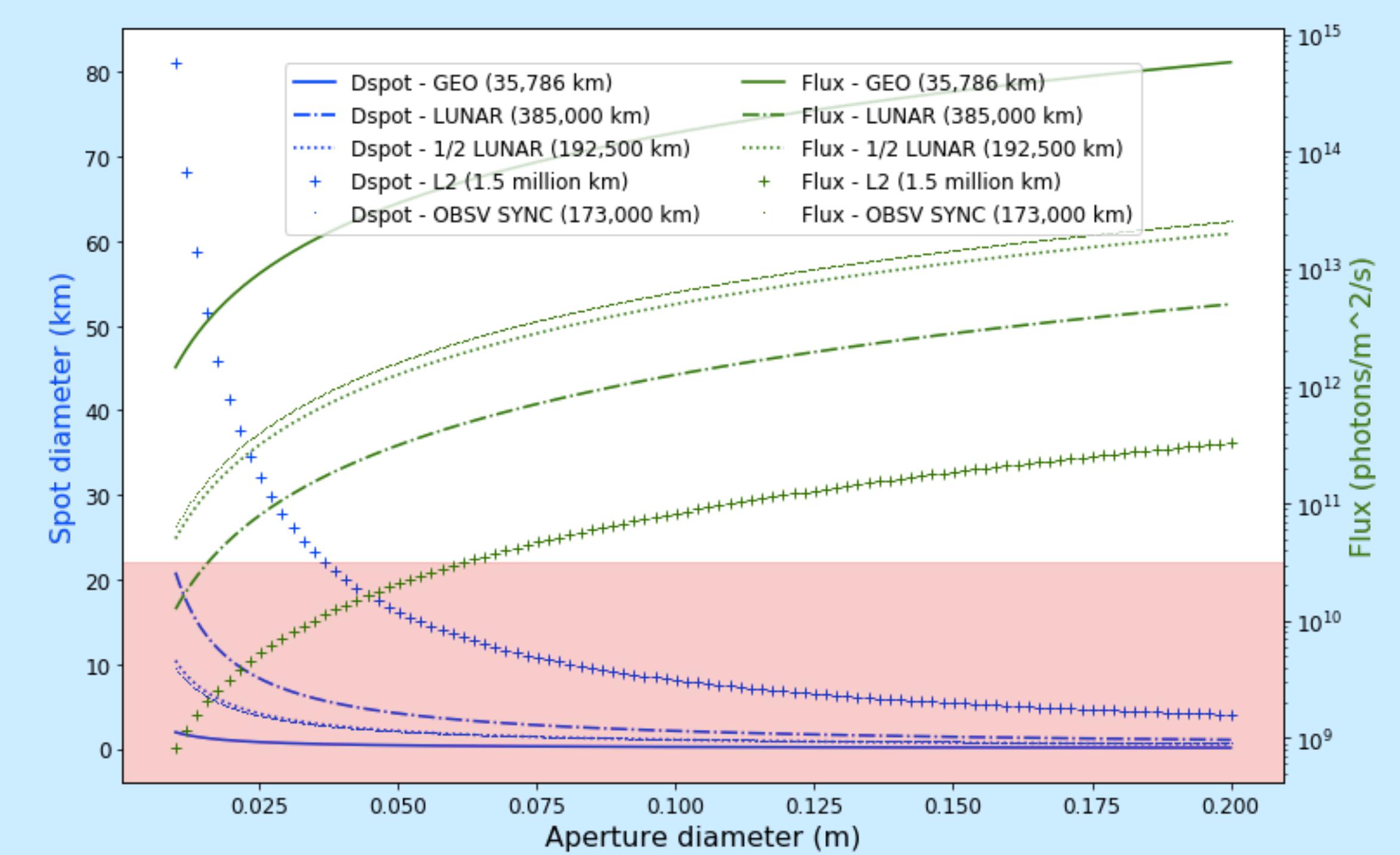
## RELEVANCE

Survey of Astro2020 proposals indicated ORCAS mission would serve needs of 26% of community interests.



## LASER BEAM DIVERGENCE

Effects of beam divergence on spot size and incident flux



- Laser spot size must be large enough to easily point at collector, small enough to deliver sufficient flux.
- Red area is region of insufficient flux (plotted in green). Flux constraint is not prohibitive.
- Spot size acceptable for apertures  $\geq 3 \text{ cm}$ , flux acceptable for apertures  $\geq 7 \text{ cm}$ .

## FUTURE WORK

- Quantify necessary steps to integrate with ground-based facilities (optimal laser wavelength, calibration distance, hardware compatibility).
- Determine orbit maneuvers necessary post-launch, navigating between targets.
- Establish fuel usage and requirements