Optimast-SCI Technology: Precision In-Space Manufacturing for Structurally-Connected Interferometry

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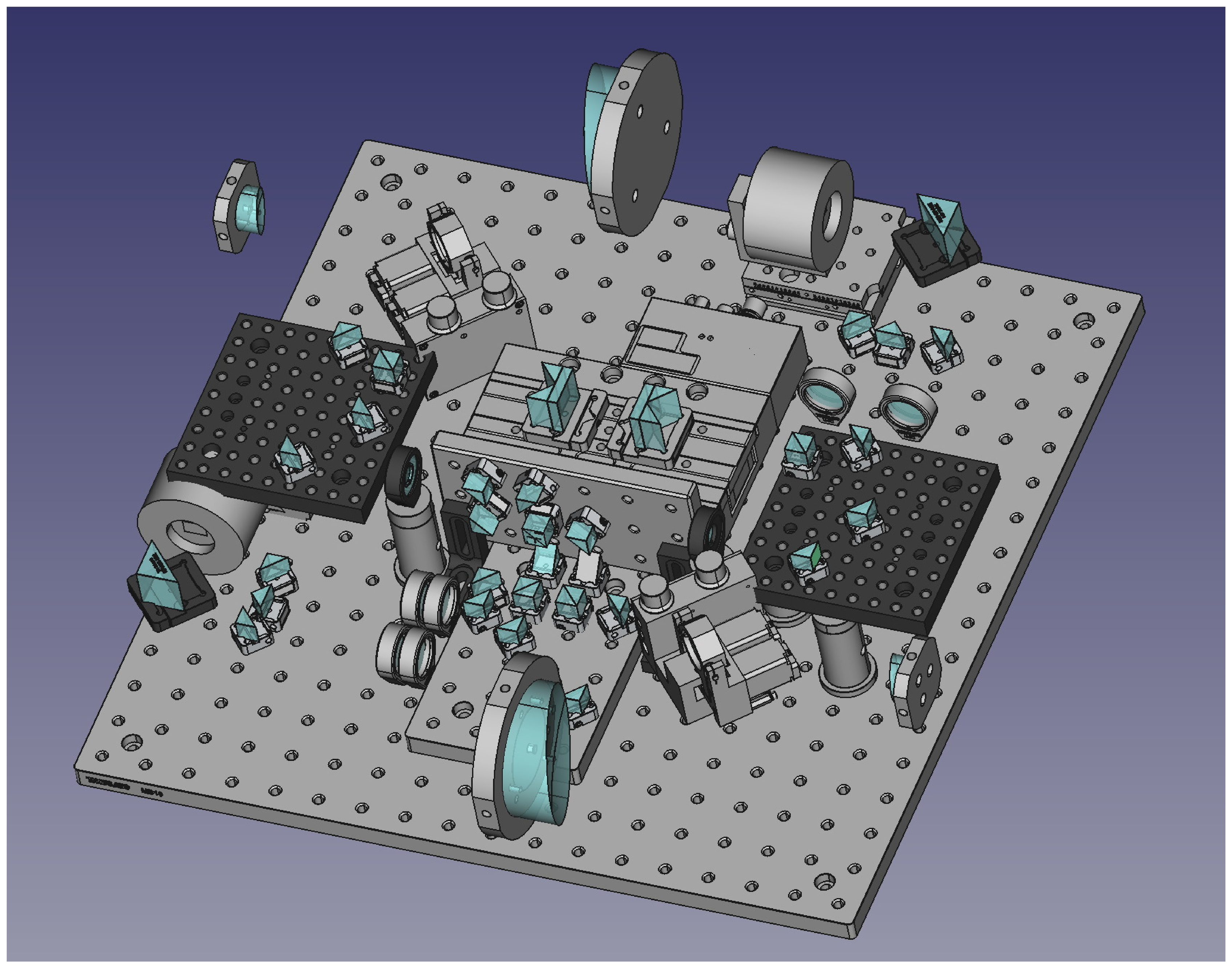


At the Heart of *Optimast-SCI*: A Simple Michelson Combiner

- Simple, pupil-plane combiner with ~0.1 micron tolerances (not nanometer or picometer)
- 75mm range delay line
- Static ABCD fringe tracking similar to PRIMA FSU (Sahlmann 2007)
- Modest spectral resolution (R~100)

***Optimast-SCI* is currently a NASA SBIR-funded Phase 2 study of a space-based optical interferometer enabled by in-space manufacturing**

SBIR Phase 2 Engineering demonstration units will be built this year for boom manufacturing, optics subsystems

Basic *Optimast-SCI* Parameters

Two-element interferometer
- 2 booms, 6-25m from 2 ESAMM units
  - Baselines selectable from 1 to 50m by running booms in & out
- Resolution: 2 to 6 ms (Rayleigh limit, better with superresolution modes)
- Spacecraft coherence time: 10sec (minimum)
- Sensitivity: $m_V \leq 12 - 16$
  - Out-performs all ground facilities by 2 – 6 magnitudes
- Two collecting apertures, each 2” – 6” (depending on mission)
- Bandpass: 0.4 – 1.0μm

Precision tracking of outboard mirrors
- Enables optical interferometry without massive structures

Orbit: non-LEO, nominally Earth-Sun L2
- Thermally quiet

Spacecraft
- Mass: 300-400 kg

Manufactured Booms versus Free-Fliers

Booms are superior to free fliers
- One spacecraft versus three
- No consumables for pointing
- Outboard units are significantly simpler than free-fliers
- Short booms: single structure from a mechanical perspective
- Long booms (>100m): akin to tethers; outboard unit control is 2 DOF, not 6 DOF (as for free-flier)
  - Long boom case could be treated as simplified free-flier demo
- Failure modes are more failsafe / recoverable

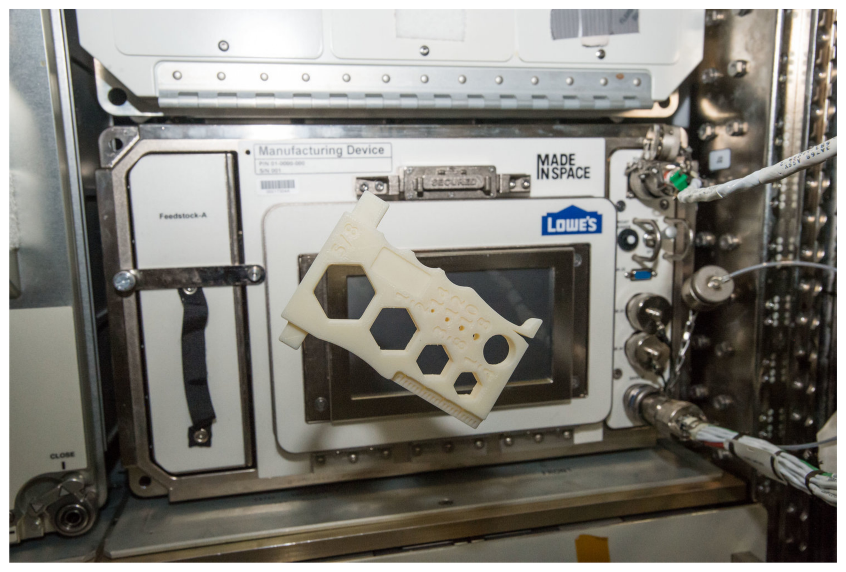
Why Additive Manufacturing in Space?

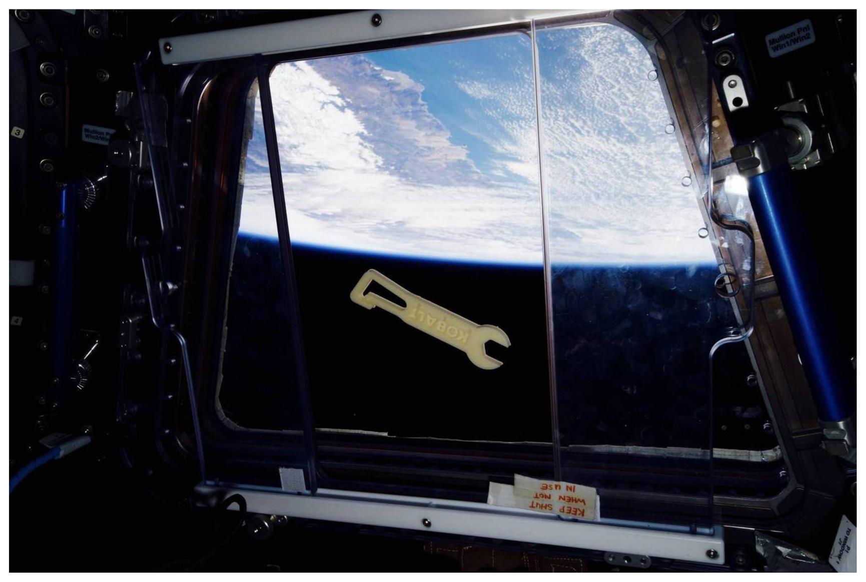
Weight savings
- Structures do not have to be hardened for launch

Volume savings
- Structures to not need to fit within launch shroud
- No complex ‘origami’ deployment mechanism

It is the logical progression of:
- *Delivery* of telescopes to space (HST)
- *Assembly* of telescopes in space (JWST)
- *Manufacturing* of telescopes in space

Allowing to achieve the:
- largest
- most sensitive
- highest resolution telescopes
- at the lowest cost





***Made In Space* Flight Units for Zero-G 3D Printing**

Flown Units aboard ISS

Technology Demonstrator 3D Printer (2014)
- Demonstrated fused deposition modeling process in a microgravity environment

Additive Manufacturing Facility (2016)
- Permanent commercial manufacturing facility
- Current materials: ABS, Green PE, PEI/PC

MIS Fiber Optics (2017)
- Successfully pulled ZBLAN in microgravity

MIS Braskem Recycler (2019)
- Reuse of 3D objects into feedstock

***Flight-Qualified*: ESAMM**
- Thermal-vac tested for flight: TRL 6
- Guinness World Record for longest single 3D printed piece: 37 meter boom (print terminated when shop space limit reached)

***Selected*: Archinaut One (2022)**
- $74M flight mission, printing solar array structures

Acknowledgements: This work has been supported by the NASA SBIR program, the Lowell Observatory, and Made In Space.

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Optimast-SCI Science: New Discovery Frontiers with Sensitive, Millarcsecond Resolution

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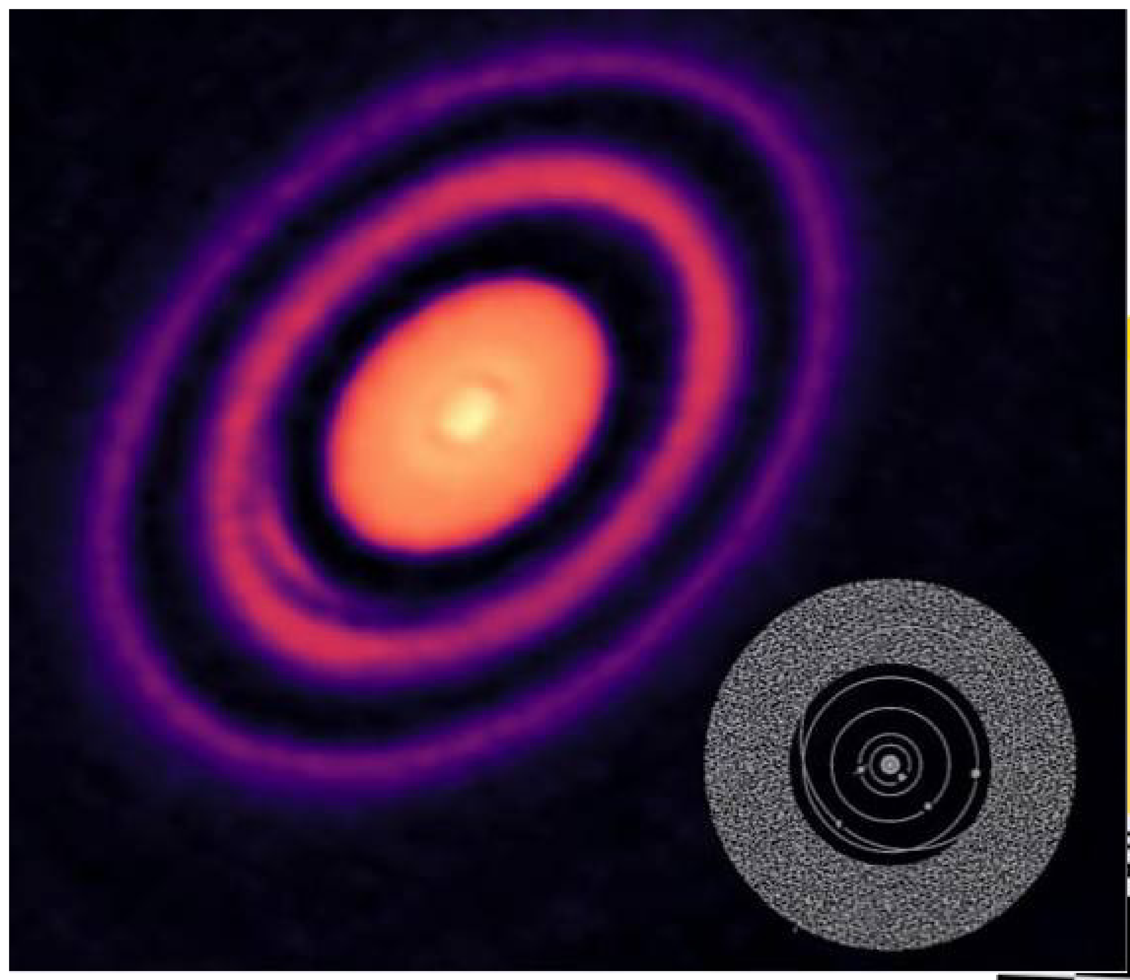
Optical interferometry from a space-based platform is freed from the limitations of the Earth's atmosphere.

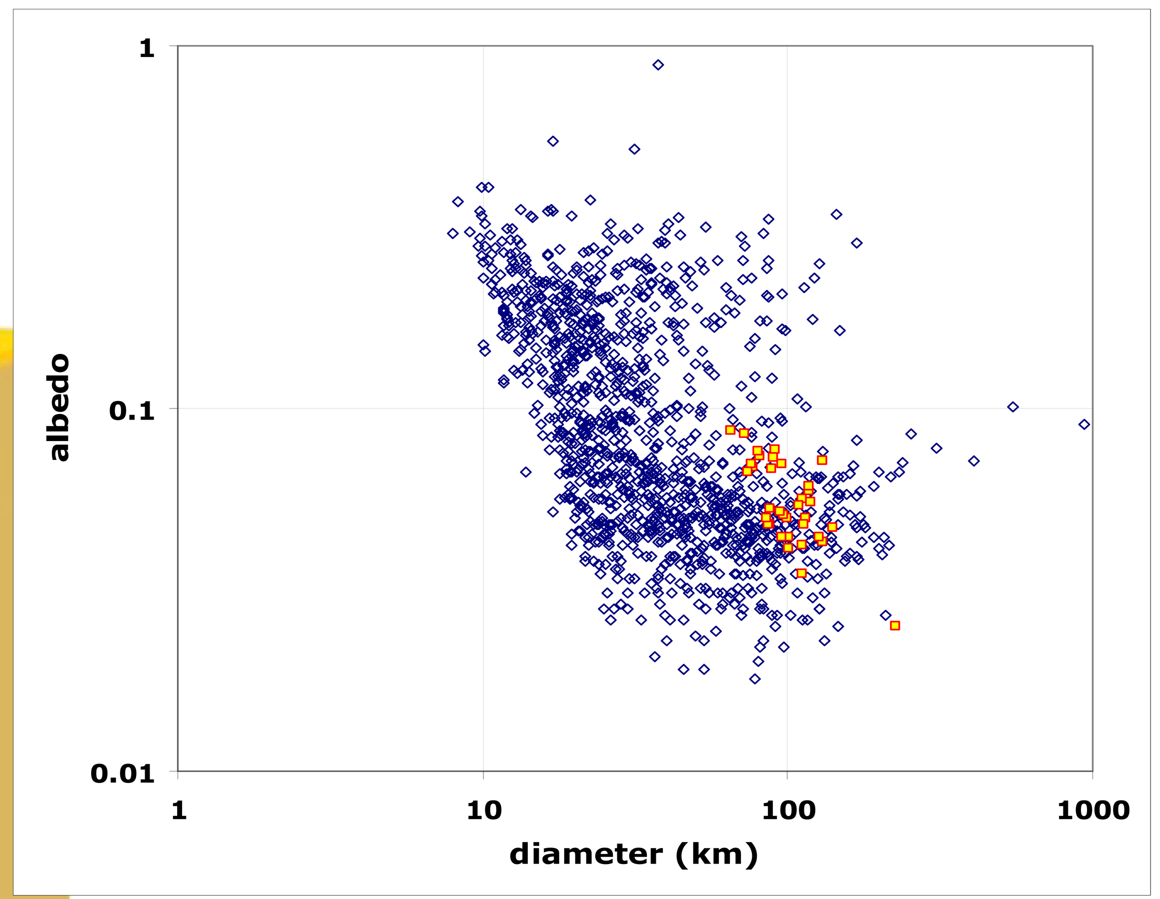
One fundamental benefit is **sensitivity**.

Gains of 100-1000× or more are possible, compared to ground-based optical interferometry.

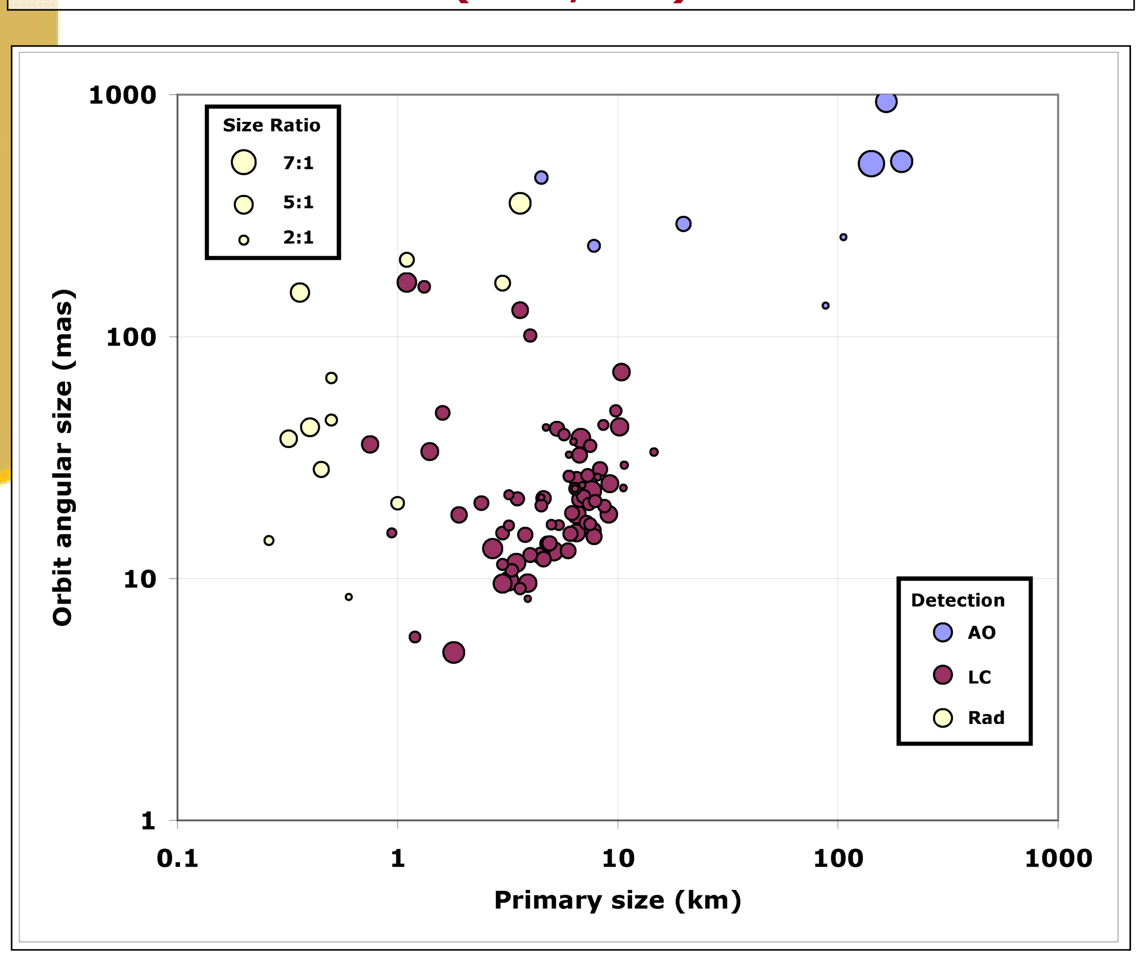


Imaging the Terrestrial Planet Forming Regions of Nearby YSOs

- ALMA observations are mapping out regions outside the water snow line; e.g. Isella+ 2018, HD163296 above, with 40mas resolution (inset on lower right is our own solar system)
- Optimast will have > 5× greater resolution
- Spanning 0.4-1.0μm, Optimast will image both scattered and thermal light



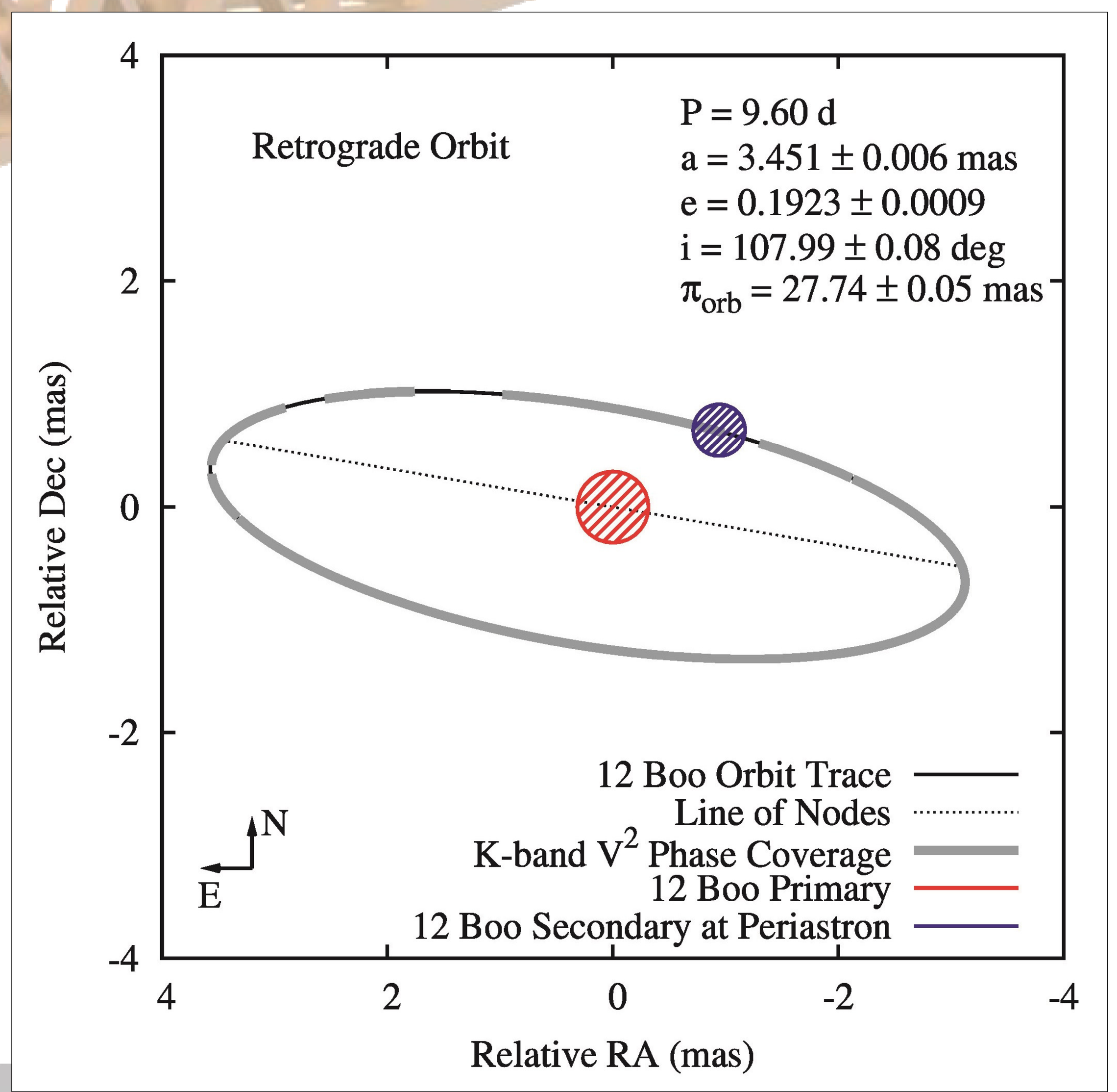
Single Object Targets Resolvable by Optimast (N>1,000)



Known Binary Targets for Orbit Mapping (N>100)

Fundamental Parameters of Low Mass Stellar Binaries

Follows ground-based work of bright stars.
•The orbit of 12 Boo (Boden et al. 2005) measured by the Palomar Testbed Interferometer, which determined component masses to 0.3%.
•Despite having a shorter base-line, with a shorter operational wavelength, Optimast will have similar angular resolution but for far fainter targets (e.g. low-mass stars).



Asteroid exploration: Flyby quality data without the flyby

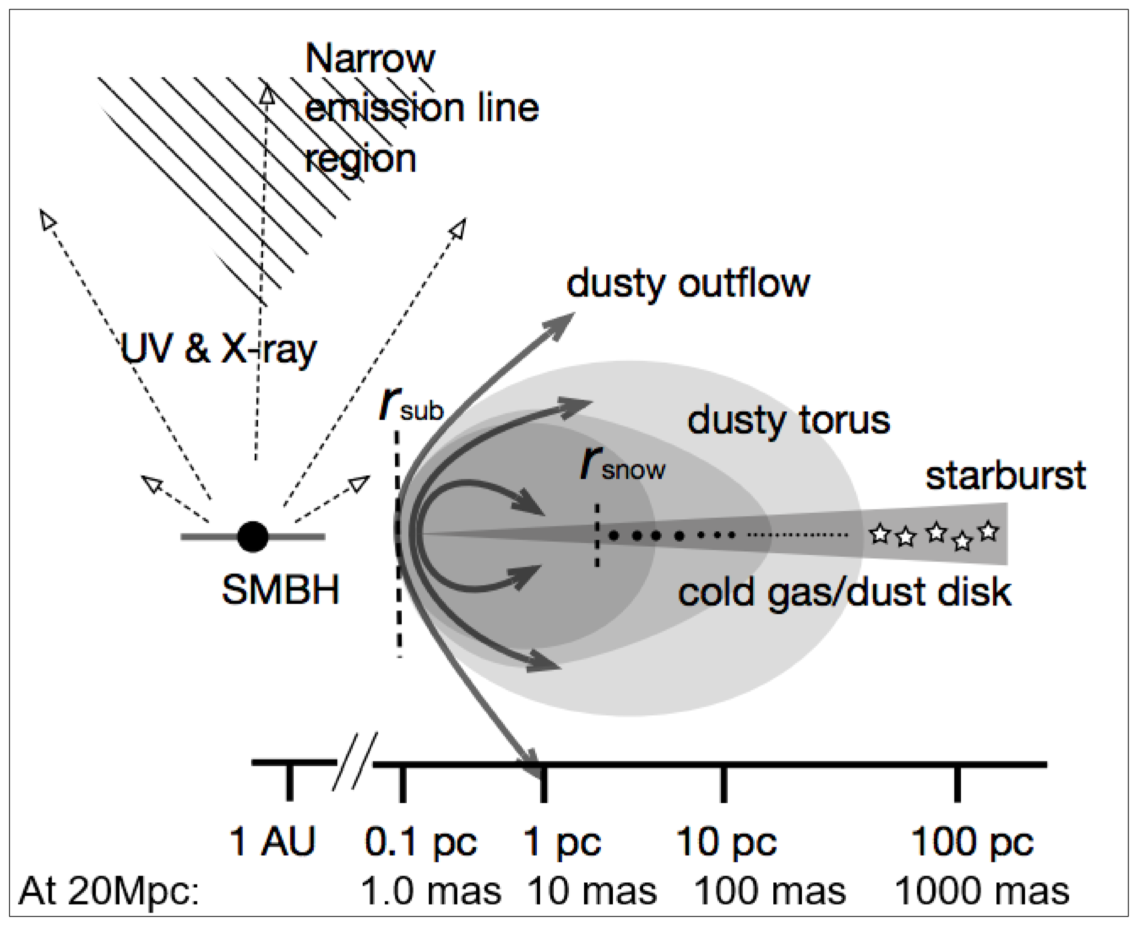
Extreme optical resolution (~2mas) from a two-element optical space interferometer:
- Shapes, sizes of ~10³ asteroids
- Orbit and mass determination for all known V<16 binaries
- Spatially resolved spectra-photometry in >10 wavelength bands
- Space-based operation enables **high sensitivity** for reflected light objects
- Application of ground-based interferometry techniques (well developed but limited to emitted light objects, i.e. stars)

Main Belt Asteroids
- Sizes, shapes for any object > 10km (H<12.3)
- Resolved surface mapping for > 30 km
- Rotation > 6 hours (<5° 'smear' in 300sec)
- Detection of binaries, Keplerian solutions for binary orbits
- Hundreds of possible targets

Near-Earth Asteroids
- Direct size determination for >10m objects (H<26)
- Mapping of binary orbits

Jupiter Trojans
- H<9.2 (~36 known targets)
- Orbits / shapes for targets, binary detection

Additional targets: gas giant moons, ice dwarfs



Probing the Inner Core Architecture of Active Galactic Nuclei

- At 20 Mpc, 1mas resolution probes the inner edge of the AGN disk
- The feedback process between the dusty wind and host galaxy
- What fraction of supermassive black holes are binary?

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