LightBeam: Milliarcsecond Imaging in the NUV and Visible

Leveraging Optical Interferometry and In-Space Robotic Manufacturing and Assembly

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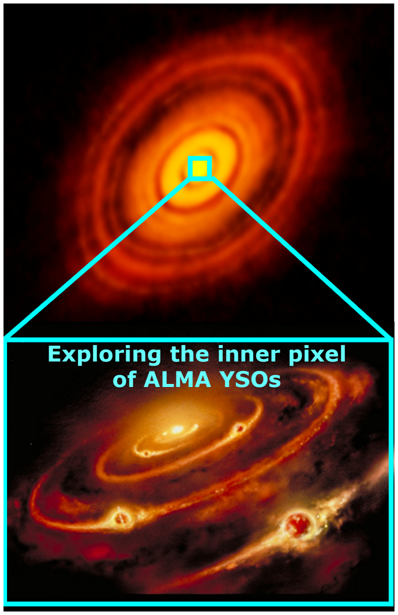


A Unique Observatory

Extreme optical resolution (~3mas) from a two-element optical space interferometer:
- Space-based operation enables **high sensitivity** for faint objects: Space-based operations overcomes Earth's atmosphere limits on interferometry
- Operations down **to 2500A** enabled by in-space operations
- Spatially resolved spectra-photometry in >10-100 wavelength bands across the visible
- Application of **well-demonstrated** interferometry techniques

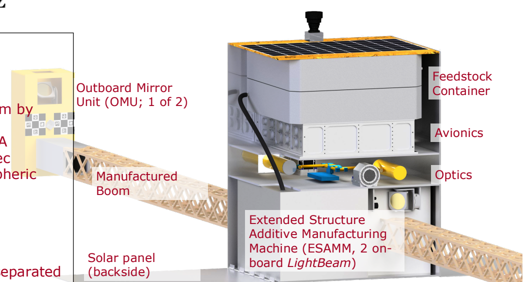
Interested? The *LightBeam* Science Team needs you - contact us today!

Basic *LightBeam* Parameters

Two-element interferometer
- 2x10m booms from 2 ESAMM units
  - Baselines selectable from 1 to 20m by running booms in & out
- **Resolution limit: 3.1 mas** @ 2500A
- Spacecraft coherence time: >1000sec
  - NB. Typical ground-based atmospheric coherence time: 1-10ms
- **Sensitivity: $m \leq 17$ in 1000sec**
  - Out-performs all ground-based interferometers
  - Two 2" collecting apertures
- **Visible bandpass: 0.25 – 1.1μm** separated into 10-100 wavelength bands

SmallSat Spacecraft
- ESPA-class for volume & mass (~125kg)
- Under development for a 2021 MIDEx MO Small Complete Mission proposal submission

Orbit: non-LEO, nominally Earth-Sun L1
- Thermally quiet, with Earth look-back for NEOs



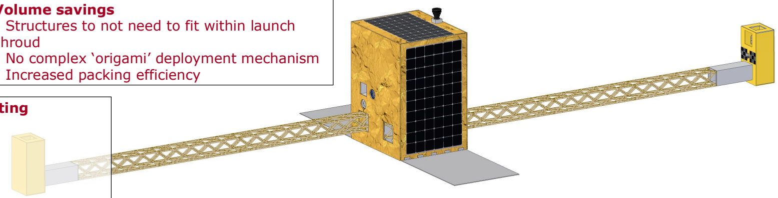
Cutaway view of the *LightBeam* design (above). Two outboard mirrors feed light to a beam combiner aboard the central spacecraft, synthesizing a large (20m), sparse aperture telescope. The bottom level is the additive manufacturing ESAMM units. The lower middle level is the optics bay; the upper middle top level is the avionics bay, under the feedstock container on top.

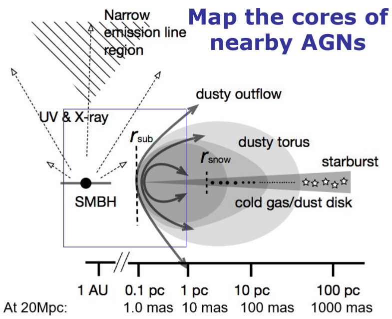
Below, a view of *LightBeam* with partially deployed optics booms.

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
- Increased packing efficiency





Redwire / 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

Fiber Optics (2017)
- Successfully pulled ZBLAN in microgravity

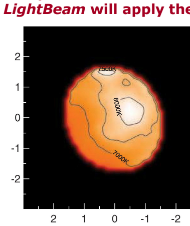
Recycler (2019)
- Demonstrated reuse of 3D printed materials

Ceramic Manufacturing Module (2020)
- Demonstration of 3D printing of bladed disks ('blisks')

***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)

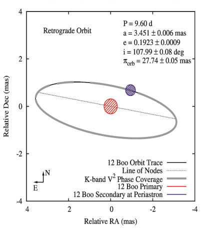
***Selected*: Archinaut One (2022)**
- $74M standalone flight mission, printing solar array structures

Examples Results of Size/Shape, and a Binary Orbit from Stellar Astronomy: *LightBeam* will apply these demonstrated techniques to far fainter targets



Size, Shape of Altair from Monnier et al. 2007.
Using the CHARA Array, Monnier et al. were able image the surface of Altair, illustrating (a) its 1.835±0.007 mas equatorial radius, (b) its 24.2±0.9% shape oblateness (due to rapid rotation), and (c) its pole-to-equator intensity profile (due to gravity darkening).

***LightBeam* will use these techniques to map disk structures across the universe.**



Orbit of 12 Boo from Boden et al. 2005.
Using the Palomar Testbed Interferometer, Boden et al. were able to map the orbit of 12 Boo and fit a Keplerian orbit, resulting in ~0.33% mass determinations.

***LightBeam* will have the sensitivity, resolution and contrast to map the orbits of low-mass stars.**

Core Science Program

Young Stellar Objects
- *LightBeam* will be able to explore the inner pixel of ALMA targets
- Morphology of disk structures in the terrestrial planet forming region will complement ice giant maps

Active Galactic Nuclei
- *LightBeam* can probe the inner 0.1-1.0 parcsec of AGN out to 20 Mpc
- Unique mapping of the inner edge of the dusty torus, exploring core binarity

Low-Mass Binaries
- Direct orbit determinations for the lowest mass stars will provide mass measures

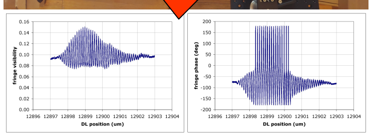
Main Belt Asteroids & Jupiter Trojans
- Sizes, shapes for any main belt object > 10km (H<12.3)
- Resolved surface mapping for > 30 km
- ~36 known Jupiter Trojans
- Detection of binaries, Keplerian solutions for binary orbits
- Additional targets: gas giant moons, ice dwarfs

This work is currently a NASA SBIR-funded Phase 2 study of a space-based optical interferometer enabled by in-space manufacturing.

Beam Combiner Demo
- Built at home during COVID
- Demo'd beam combination, tracking

Manufacturing Units
- Advanced designs for OI mission undergoing lab tests

Integrated testing
- Beam combiner and printed booms being tested together with target tracking tests



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