AeSI

Artemis-enabled Stellar Imager: Imaging the Universe with sub-mas Resolution

Context/Background for AeSI

2005:
"Vision Mission" (VM) Concept for a free-flying, large baseline, UV/optical space interferometer called *Stellar Imager (SI)*

2024:
A new concept, derived from *SI* but intended for construction on the lunar surface and operated in conjunction with the human Artemis Program called *Artemis-enabled Stellar Imager* (AeSI)

What has changed in the last ~20 years? Why the lunar option now?

- The large "Vision Missions" (esp. interferometers) were mostly put on hold pending completion of JWST
- Per Pierre Bely et al. study[1], it was perceived that **unless there was a pre-existing infrastructure on the lunar surface,** it was easier and better to build a large space interferometer as a free-flyer. So the VM studies all considered free-flyers

[1] ("Kilometric baseline space interferometry," Proc. SPIE 2807, Space Telescopes and Instruments IV, (12 October 1996); doi: 10.1117/12.255123)

- Now the Artemis project plans to put humans and their infrastructure on the Moon within the next decade. **It is time to consider in detail the lunar option!**

A New Hope for Space Interferometry

- The environment is now changing with the Artemis Program and the aggressive push to establish a permanent human presence on the Moon, starting with a base near the lunar south pole, by 2026
- High interest in small science experiments that could take advantage of the infrastructure; the scale of those opportunities will grow
- We must begin concept development **now!**
- **Our NASA NIAC study will investigate the possibility of constructing a large-baseline, UV/optical interferometer near a human base to leverage off the Artemis infrastructure**

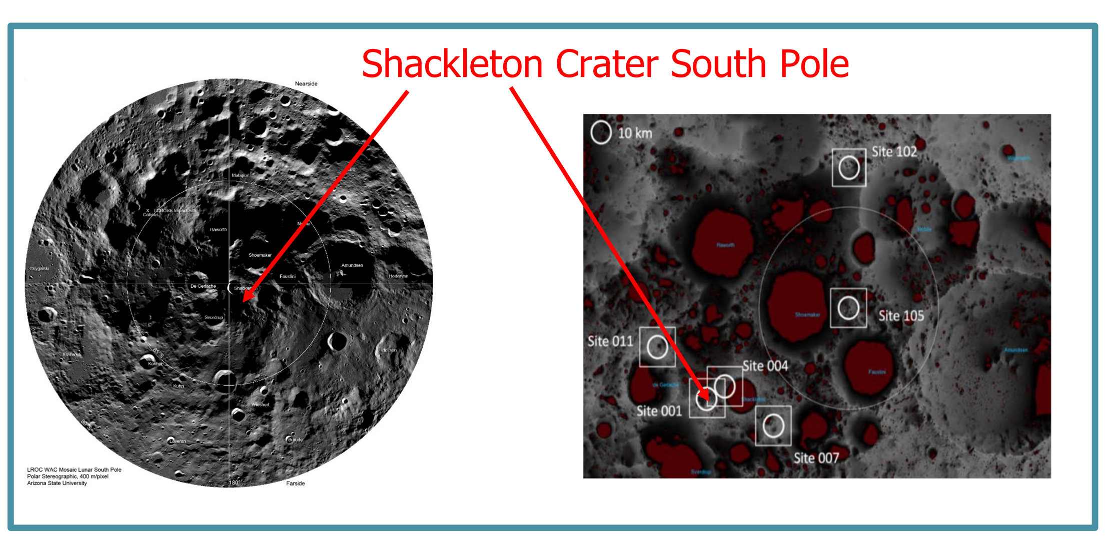


Fig. 1: One possible AeSI location, adjacent to an Artemis Station

Heritage for AeSI: Stellar Imager (SI)

- UV-Optical Interferometer to provide 0.1 mas spectral imaging of numerous astronomical phenomena, esp. magnetic field structures that govern: formation of stars & planetary systems, habitability of planets, space weather, transport processes on many scales in Universe
- A "Flagship" (Vision) mission in the NASA 2005 SSSC Roadmap and a candidate "Pathways to Life Observatory" in the NASA 2005 EUD Roadmap
- Mission Concept
  - 20-30 "mirrorsats" formation-flying w/ beam combining hub
  - Launch to Sun-earth L_2
  - Mission duration~10 yrs
  - baselines ~ 100-1000 m

SI Prime Science Goals

Image surface/sub-surface features of distant stars; measure their spatial/temporal variations to understand the underlying dynamo process(es)

Improve long-term forecasting of solar and stellar magnetic activity

Understand the impact of stellar magnetic activity on planetary climates and life

Understand transport processes controlled by magnetic fields throughout the Universe

Perform high angular resolution studies of Active Galactic Nuclei, Quasars, Supernovae, Interacting Binary Stars, Forming Stars/Disks

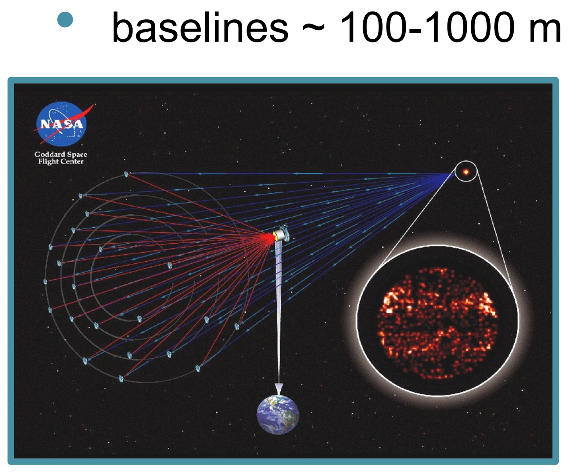


Fig. 2: http://hires.gsfc.nasa.gov/si/

Potential and Benefits

- **100x higher resolution than Hubble,** resolving stellar surfaces and inner regions of black hole environments
- **Perfect timing** to leverage planned Artemis human lunar infrastructure by late 2020's
- **Prospects superb:** ground-based optical interferometry works; forthcoming infrastructure makes a lunar surface architecture both practical and compelling
- **Boldly expands realm of the possible:** many studies of free-flying space interferometers exist, but only limited studies of lunar designs (far-side radio)
- **The capabilities of *AeSI* are truly game-changing** (Fig. 3) and include, e.g., the resolution of stellar surfaces and magnetic activity on nearby sun-like stars (~30 stars within 4 pc), convective cells on red supergiants out to 2 Kpc, planet-forming regions, the central regions of AGN, and much more!

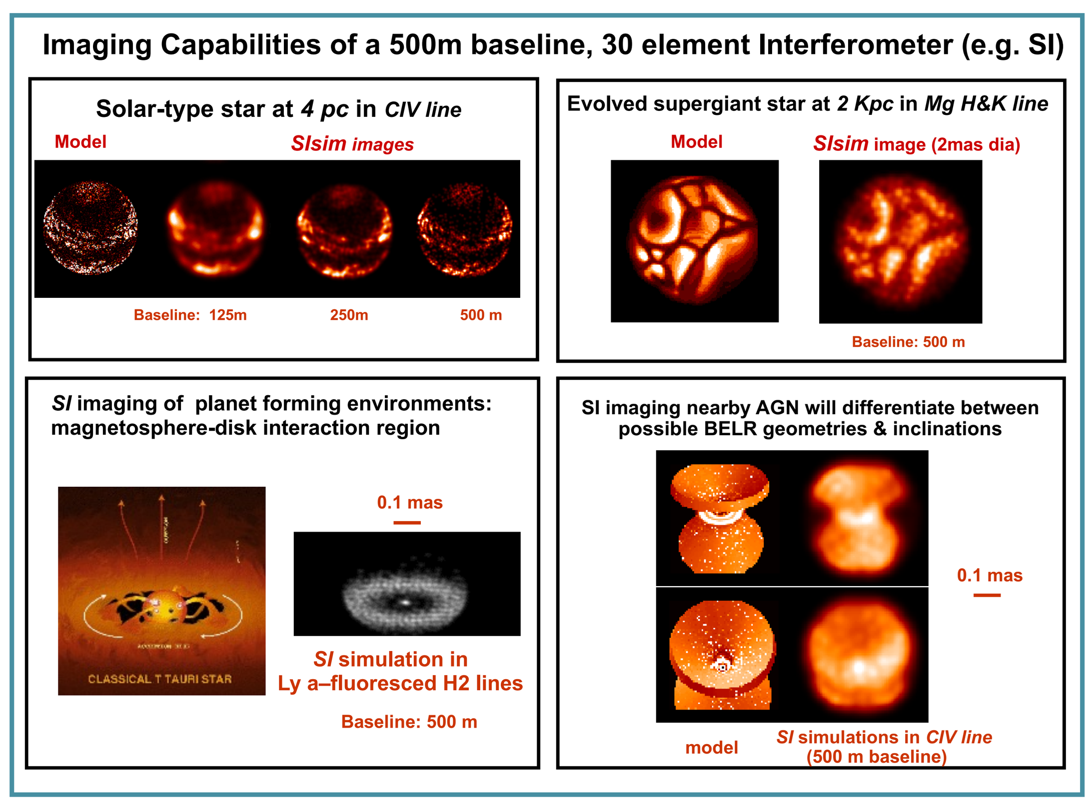


Fig. 3: Simulations of AeSI observations

Innovations

- **Build**: a 0.5 km baseline UV-Optical interferometer on the Moon
- **Novel technologies**: dust repellers, rovers to move delay-line optics and primary mirror stations on surface, hub to combine beams from stations in variable configurations, technologies needed for long-baseline interferometers in space
- **Eliminates** the need for precision formation flying
- **Science**: supports broad spectrum of science investigations
- **Timing**: can build as soon as infrastructure available on the Moon

Technical Approach

- **Major Tasks: Address problems specific to interferometers on the lunar surface**
  - Dust mitigation
  - How to accommodate delay lines without massive structures – consider rovers to move delay line mirrors
  - Determine support needed from human infrastructure
  - Develop plan for evolving facility over time
- **Goals: Determine**
  - Optimal array configurations
  - Beam combination techniques
  - Architecture

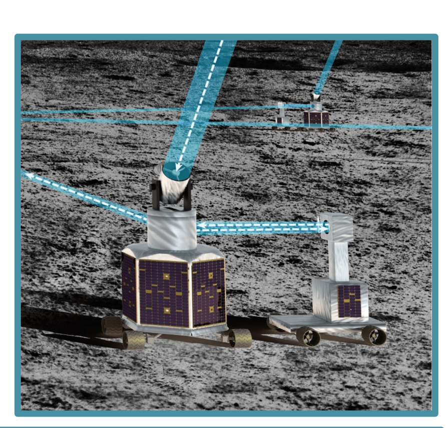
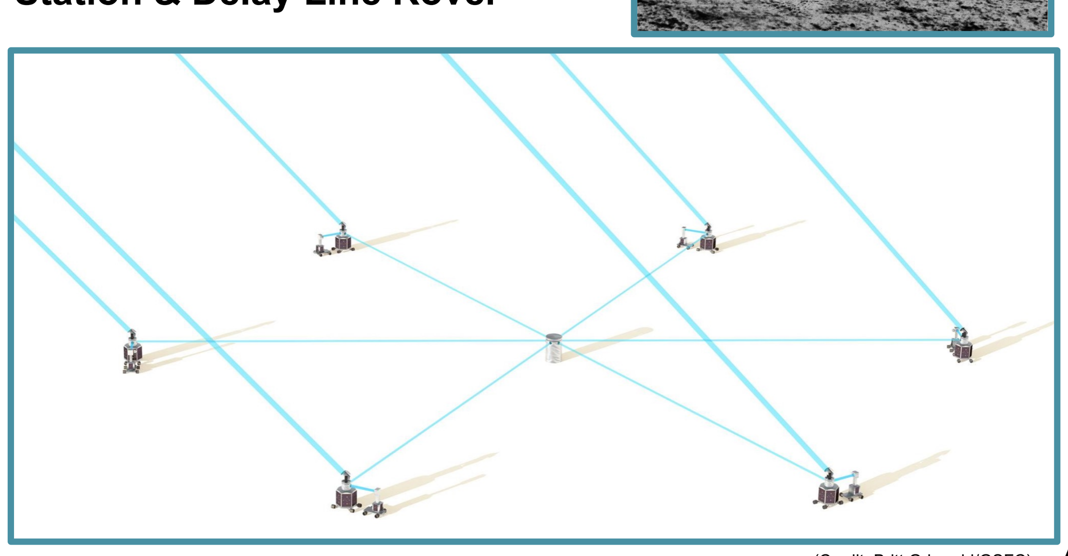


Fig. 4: Close-up of AeSI Primary Station & Delay Line Rover



(Credit: Britt Griswold/GSFC)

Fig. 5: Initial 6-element AeSI layout

AeSI Design Concept

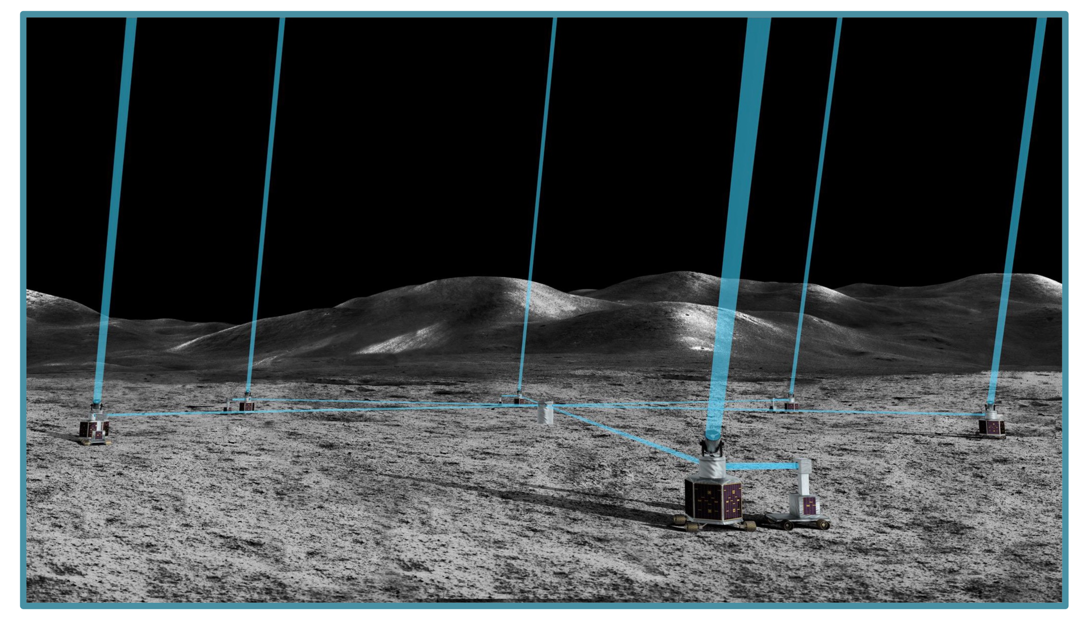


Fig. 6: Artist's Drawing of our AeSI concept - an initial six-element system that could be built as first step in a staged-development scenario.

Baseline Design:

- A 0.5 km diameter lunar-surface-based UV-optical Fizeau Interferometer, built and operated in conjunction with the human Artemis Program
- Start with ~6 primary, >0.2 meter mirror elements focusing on beam-combining hub, expand later to as many as 30 mirror elements in a staged deployment
- Size of primary mirrors can be increased in later Stages
- Uses rovers to provide path-length equalization
- Long-term, > 10-year mission to study stellar activity cycles:
  - individual telescopes/hub(s) can be refurbished or replaced by human or robotic servicing

Required Capabilities for UV/Optical Interferometer

- Wavelength coverage: 1200 – 5000 Å
- Access to UV emission lines from Ly-alpha 1216 Å to Mg II 2800 Å for stellar surface imaging
  - Important diagnostics of most abundant elements
  - much higher contrast between magnetic structures and background
  - smaller baselines (UV save 2-4x vs. optical, active regions 5x larger)
  - ~10-Å UV pass bands, e.g. C IV (100,000 K); Mg II h&k (10,000 K)
- Broadband, near-UV or optical (3,000-10,000 K) for high temporal resolution spatially-resolved asteroseismology to resolve internal structure
- Angular resolution of 50 micro-arcsec at 1200 Å (120 μas @2800 Å)
- ~1000 pixels of resolution over the surface of nearby dwarf stars
- Enable energy resolution/spectroscopy of detected structures
- A long-term (~ 10 year) mission to study stellar activity cycles:
  - individual telescopes/hubs can be refurbished or replaced

AeSI Team

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NASA Innovative Advanced Concepts