Community Access for Long Baseline Optical/Infrared Interferometry

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Long baseline optical/infrared interferometry (LBOI) provides a milliarcsecond view of the universe. The technique of LBOI is used to investigate a wide range of topics in stellar astrophysics involving high spatial resolution studies of stars and their circumstellar environments. Open access time to interferometers is moving LBOI into the mainstream of astronomical techniques. Continued support of open access time through NOAO into the next decade will expand the scientific productivity of U.S.-based interferometric arrays. This access will also help optimize the science return from large scale ground and space-based surveys by following up targets of interest discovered by these missions. Access to existing infrastructure will aid the development of technologies necessary for building the next generation of astronomical observatories that will push the limits on sensitivity and spatial resolution.

Science at Milliarcsecond Resolution – Resolving the size, shape, and surface features of nearby stars provides a detailed understanding of stellar structure and evolution that can be applied to our understanding of the global properties of distant populations. Over 700 refereed science publications based on results from LBOI have appeared over the last two decades. The main science topics include:

- Measuring radii and effective temperatures of stars across the H-R diagram.
- Investigating the impact of rotation on stellar structure (oblateness, gravity darkening).
- Imaging spots and convection patterns on the surfaces of stars.
- Characterizing the physical properties of exoplanet host stars and their planets.
- Calibrating and testing asteroseismic scaling relations for solar-type and giant stars.
- Measuring ages of young stars and open clusters based on stellar radii.
- Diameter variations in pulsating stars and the calibration of Cepheid distances.
- Studying disks, outflows, and processes of planet formation around young stars.
- Evolution of angular momentum and mass loss in massive stars.
- Dynamical masses and distances of close binary stars.
- Studying mass transfer and Roche lobe filling in interacting binaries.
- Resolving the angular expansion and development of asymmetries in nova explosions.
- Measuring the size of the central region in AGN cores.
- Investigating the galactic black hole Sgr A* accretion disk and the nuclear star cluster.
- Solar system asteroids (size and shape of single objects, binary orbits).

If an analogy is drawn to the post-WWII development of radio astronomy, LBOI is in a critical emergent phase wherein a variety of advances are likely to parallel the circumstances that led radio astronomy to become the indispensable tool that it is today. The parallels in development are highlighted in Figure 1, in which the publication histories from the two wavelength regimes are compared but shifted in time by 32 years. Aside from individual ramp-up profiles, the trends are remarkably similar.

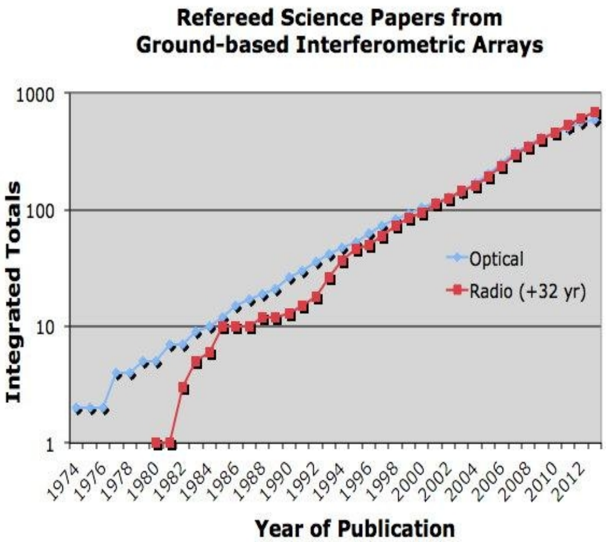

Figure 1: The running total of refereed science publications in optical and radio interferometry are compared. The radio data have been offset forward in time to account for the different effective starting dates.

Synergy with Ground and Spaced-Based Survey Missions – LBOI can optimize the science return from currently operating and planned survey missions.

- The GAIA mission will provide accurate parallaxes and distances for interferometric targets fainter than 6th magnitude in the visual; a special reduction mode could extend the bright limit down to 3rd magnitude. The GAIA parallaxes will allow direct estimates of stellar diameters.

- The Transiting Exoplanet Survey Satellite (TESS) will monitor over 200,000 stars in the solar neighborhood. The stars surveyed by TESS will be 30-100 times brighter than those observed by Kepler, providing significant overlap with targets resolvable through LBOI. The characterization of transiting planetary systems (planet radius, size of habitable zone) relies on measuring the stellar properties of the host star. Interferometric angular diameters combined with GAIA parallaxes and bolometric fluxes from spectral energy distributions will contribute precise stellar radii and effective temperatures. Moreover, these stellar properties can be used to calibrate and test asteroseismic scaling relations for stars with solar-like oscillations detected by TESS.

- Bright transient events discovered by sky surveys (e.g., the Zwicky Transient Facility) can be observed interferometrically to measure the spatial extent of the source. For instance, LBOI can resolve the angular expansion and development of asymmetries during the early stages of nova explosions. Another promising application would be to measure the image size and centroid displacement in gravitational microlensing events; this would break the degeneracy between the projected separation and mass ratio of a planet candidate relative to the host lens star.

Interferometry in a Global Context – The ESO VLTI opened in 2000 and is usually over-subscribed by a factor of three or more for competed, not guaranteed, time. The extent of European investment in LBOI is demonstrated by the recent upgrades of their instruments, for example GRAVITY, as well as the ESO funded annual summer schools on LBOI. We think the high demand for the VLTI is directly related to ESO's investment in making this time available to the community and promoting the LBOI technique.

CHARA has offered a guest observer program managed by NOAO since 2010 that now amounts to 50 nights per year through the support of the NSF/MSIP program. The NOAO calls for CHARA proposals in the 2017B and 2018A semesters were oversubscribed by a rate of ~ 2.1. As part of the MSIP program, CHARA has organized several community workshops at different locations throughout the U.S. with the goal of expanding the user base for stellar interferometry and encouraging new scientific investigations. We recommend that this program be expanded to include other facilities as they become available in order for the U.S. community to remain globally competitive. We also recommend organizing a coordinated summer school to provide tutorials and experience on reducing, calibrating, and analyzing LBOI data.

Roadmap for LBOI in the Future – The CHARA Array located on Mount Wilson, CA consists of six 1-m telescopes arranged in a Y configuration with baselines ranging from 34 to 331 m. The development and installation of adaptive optics (AO) on the telescopes is currently underway. This will provide a threefold increase in the amount of high quality observing time, along with an increase in sensitivity. Community access and a user-friendly data archive will continue to be strong components of the strategic plan at CHARA.

The Navy Precision Optical Interferometer (NPOI) in Flagstaff, AZ is currently upgrading from 12 cm siderostats to relocatable, AO-equipped 1 m telescopes, which will increase the light gathering power by 70x. Along with this upgrade, baselines up to 430 m and near-IR tracking will be implemented. With these upgrades, a CHARA-like program of community access will be proposed, allowing a diverse and robust set of science investigations to be carried out by the community at large.

The Magdalena Ridge Observatory Interferometer (MROI) is currently in final development stages. It will be a ten 1.4m telescope, scalable imaging array with baselines up to 347 m, providing 50-100x greater sensitivity compared with currently operating arrays. First light on the array will happen in 2018, with operational imaging beginning in the early 2020's.

We advocate open access to these state-of-the-art facilities administered through the NOAO, enabling a broad range of science investigations at milliarcsecond resolution for the U.S. astronomical community. The existing infrastructure can also be used as a testbed for developing the technologies necessary for building the next generation of ground-based interferometers, such as the Planet Formation Imager which seeks to image the formation of planets in circumstellar disks. This requires resources to keep these facilities operating in an efficient way and to upgrade instrumentation to maintain a competitive edge.

The NASA Astrophysics Roadmap over the next 30 years, "Enduring Quests, Daring Visions" reports that "All notional missions in the Visionary Era are Interferometers." This includes missions to spatially resolve habitable planets, study the earliest stages of star formation, and image the environment around black hole event horizons, the central regions of AGN, and other extreme astrophysical environments. The success of these future ventures requires an astronomical community with the technological skills to develop and build these missions and the scientific knowledge to exploit the observational power of these facilities. Community access to existing U.S.-based interferometers through NOAO coupled with coodinated summer schools would provide opportunities to build this workforce and also provide infrastructure for the development of technologies needed to support the next generation of interferometers.