Navy Optical Interferometer: Science Vision

8th Annual CHARA Science Meeting
29 Feb 2012
Atlanta, GA

Gerard van Belle
Lowell Observatory
Summary

- NOI will be the longest-baseline visible-light optical interferometer in the world
- NOI a partnership of Lowell, USNO, NRL
  - Lowell has a 15% guaranteed share
  - Cooperative development of NOI Science Vision
- Recently renamed from NPOI
  - Significance of dropping the ‘P’
NOI Parameters

- Current capabilities
- Funded upgrades
  - CPP, VISION
  - 12 months
- Possible further upgrades

<table>
<thead>
<tr>
<th>Item</th>
<th>Present</th>
<th>Upgrading</th>
<th>Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperture</td>
<td>12.5 cm</td>
<td>12.5 cm</td>
<td>1.8m</td>
</tr>
<tr>
<td># of Apertures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astrometry</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Imaging</td>
<td>2</td>
<td></td>
<td>Many</td>
</tr>
<tr>
<td>Baselines (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Astrometry</td>
<td>19-38</td>
<td>19-38</td>
<td>19-38</td>
</tr>
<tr>
<td>Imaging</td>
<td>2-79</td>
<td>2-437</td>
<td>2-437</td>
</tr>
<tr>
<td>Combination</td>
<td>2×3way</td>
<td>6-way</td>
<td>6-way</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>550-850nm</td>
<td>550-850nm</td>
<td>450-850nm JHKL Others?</td>
</tr>
</tbody>
</table>
Present Array Configuration
NOI Array Layout Evolution

- **Current**
  - 4 Astrometric stations
  - 2 Imaging stations
NOI Array Layout Evolution

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  - 4 Astrometric stations
  - 2 Imaging stations
- CPP Upgrade
  - Opens W10, E10, E7
NOI Array Layout Evolution

- **Current**
  - 4 Astrometric stations
  - 2 Imaging stations
- **CPP Upgrade**
  - Opens W10, E10, E7
- **Installation of 1.8m’s**
  - Maximum baseline: 180m
NOI Array Layout Evolution

- Current
  - 4 Astrometric stations
  - 2 Imaging stations
- CPP Upgrade
  - Opens W10, E10, E7
- Installation of 1.8m’s
  - Maximum baseline: 180m
- Comparison to CHARA
Current Science Endeavors

- ‘Mission-related’
  - USNO-NOI Astrometric Catalog (UNAC)
  - Imaging

- Binary Stars
  - Orbits

- Single Stars
  - Diameters, imaging
UNAC

- Goal ≤ 16 mas accuracy in both RA & Dec
- Institutional need
  - HIPPARCOS positions have degraded over time
- Looking at an early 2012 first release for ~115 stars
  - Forthcoming paper by Benson et al.
  - Significant further expansion in 2012
Binaries

- NOI particularly well-suited for binaries (or other order multiples)
- Orbital separations <1 to 750mas
- Orbital periods – well, how patient are you?

Binaries – Capabilities, Prospects

- In “imaging” mode, typically 200 multi-baseline scans/night (record 330)
- Binary detection possible in a little as 1-2 scans
- Only ~2 dozen multiple systems with optical orbits

Example: 15 Mon (V = 4.7; Δm = 1.6); image from one 32 second scan!
Stellar Surface Imaging

- ‘Nature-level’ examples from NOI on Altair, Vega
- Dozens more possible with the current facility
- Wealth of information on stellar structure due to von Zeipel effect
  - Rotation rate, inclination, temperature vs. latitude, energy transport

\[
\omega = 0.9
\]
Development of NOI

- Facility development
  - Additional instruments
  - Larger apertures
- Science users development
  - Increased facility utilization
- Overall facility **Science Vision** being established to guide the way
VISION Instrument

- Visible Imaging System for Interferometric Observations at NOI
- Full 6-way combination
- Spatial rather than temporal modulation
  - Avoids non-linearities
  - Full use of light
- CCD rather than APD sensing
  - No after-pulsing
- Photometric taps, spatial filtering
  - $V^2$ calibration $\sim 1\%$
- Simple, V-groove design
  - CP precision $< 1^\circ$
1.8m Telescopes

- Four 1.8-m telescopes originally to be added by NASA to Keck Observatory – now USNO property
- Adds capability to perform extreme-precision relative astrometry & wide-angle astrometry on fainter sources
- Sensitivity for high resolution and high dynamic range imaging
1.8m Telescopes

- Support for installation being sought from DoD
- USNO proceeding with site blueprint work at present
Direct Transit Observations

- NOI can observe exoplanet transits
- Planet’s shadow is ‘perfect’ star spot
- \( \lambda \)-specific observations \( \rightarrow \) atmospheric composition

\[
\begin{align*}
R_{\text{star}} &= 370 \, \mu\text{as} \\
R_{\text{planet}} &= 64 \, \mu\text{as} \\
b &= 120 \, \mu\text{as} \\
C_1 &= 181 \, \mu\text{as} \\
C_2 &= 95 \, \mu\text{as}
\end{align*}
\]

van Belle (2008)
Additional Instrumentation

- 1.4-m carbon fiber telescopes under development
- Instrument proposal possibilities
  - JHKL-band combiner
    - PMS disk imaging – young disks, transition disks
    - Debris disks / hot dust
    - PMS binaries
    - Asteroid sizes/shapes, binarity
  - High-precision closure phase combiner
    - Exoplanet imaging, transit event imaging
  - K-band FTK / V-band imaging
    - Low-mass stellar imaging/diameters
  - Others – high spectral resolution, etc.
Science Users Development

- Increased Lowell involvement
  - Use of 15% guaranteed time share
  - NOI is a marquee facility for which Lowell has privileged access

- Unique opportunity for Lowell Science Partners
  - Open access (eg. NOAO-CHARA) being considered but not currently available
  - However, LSP have NOI access via Lowell
DARPA Galileo BAA

- **Specifications**
  - Image objects geosync orbits
  - $m_v=11$
  - Notional ‘scene’ of 10m x 10m, 10cm resolution
  - Use of movable telescope(s), fibers is **required**
- **Broken up into 3 Tasks, 2 Phases**
  - Tasks: Telescope, Fiber backbone, System integration
  - Phase 1: SRR, Phase 2: PDR/CDR/prototype
- **Overall budget of $14M**
  - $500k per task in Phase 1, balance to Phase 2
- **Schedule:** 3mo for Phase 1, 18mo for Phase 2
Strawman Design

*Completely subject to revision due to better ideas, inconvenient truths, necessary descoping, other aspects of reality*

- 4 telescope demonstration
  - 3 × 1.8m fixed apertures
  - Movable 1.4m CFRP telescope
    - Position sensing using industry ‘Coordinates Measuring Machine’ (CMM) devices
  - Robo-AO Rayleigh LGS on each telescope
- Beam transport using single-mode polarization-maintaining photonic crystal fibers
  - ‘Magic’ fibers are ‘endlessly single mode’ from 400 to 2000+ nm
  - Pathlength monitoring using HeNe?
- Freespace delay using existing FDLs
  - Include fiber LDL?
- Back end
  - Pairwise K-band fringe tracking
    - Option: sub-e⁻ read noise SELEX / Teledyne eAPD detectors
  - RIJH-band imaging
Notional Architecture

- High-fidelity cartoon
- Red: TRL level
Notional Architecture (II)

- *All* components exist on some level
Proposal Development

- *System Integration* is the true challenge
  - And maybe schedule
  - Motivation for a 4-telescope demonstration
- Risk reduction part of our Phase 1?
  - Low TRL items: fiber transport, SELEX detector, CFRP telescope
- Design study trades
  - Wavelength spectrum allowances
  - Sensitivity budget
  - Still significant dispersion questions
- Multi-aperture system is the essential design goal *and* the essential need
- Proposal workshop at Lowell?
  - Attendance: ‘core’ partners, plus possible interested subcontractors
  - And, if awarded Phase 1 dollars, design workshop(s)?
Haben Sie Fragen?