Navy Optical Interferometer: Science Vision

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

Gerard van Belle
Lowell Observatory

Summary

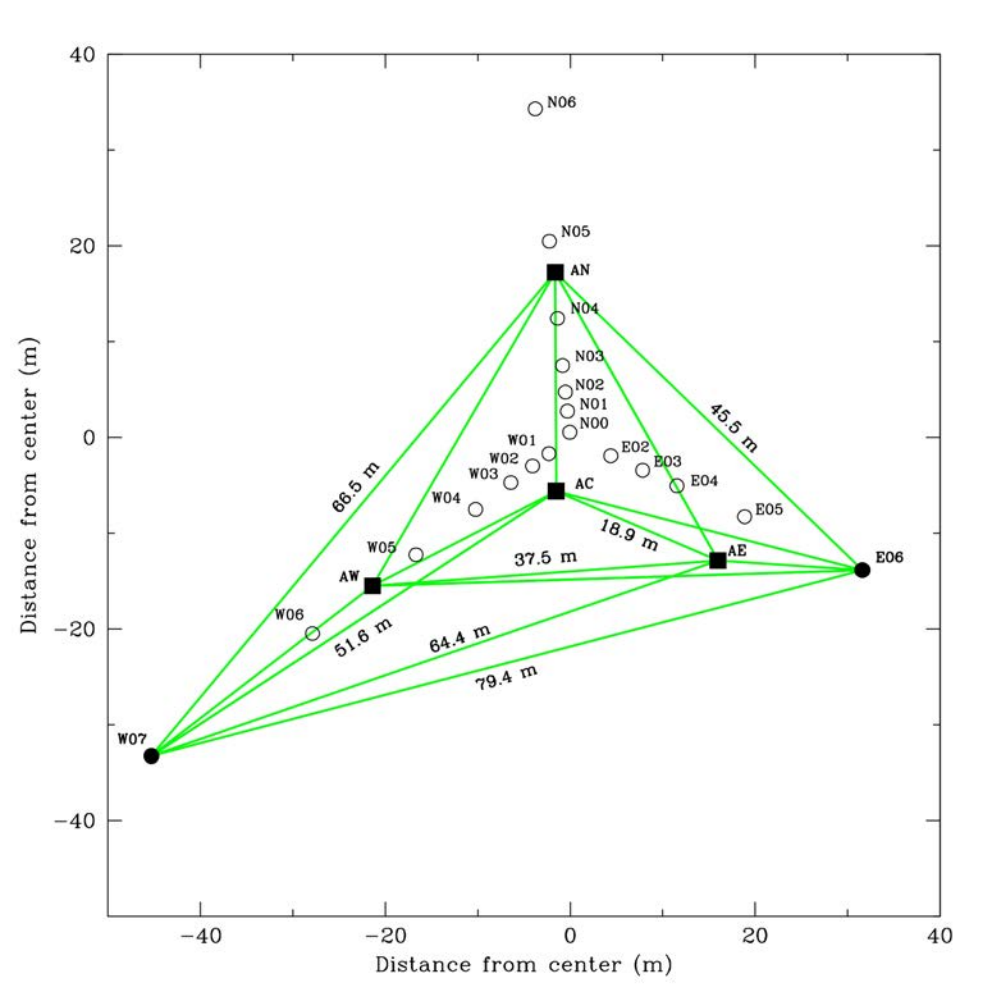
- NOI will be the longest-baseline visible-light optical interferometer in the world
- NOI a partnership of Lowell, USNO, NRL
  - Lowell has a 15% guaranteed share
  - Cooperative development of **NOI Science Vision**
- Recently renamed from NPOI
  - Significance of dropping the ‘P’

NOI Parameters

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

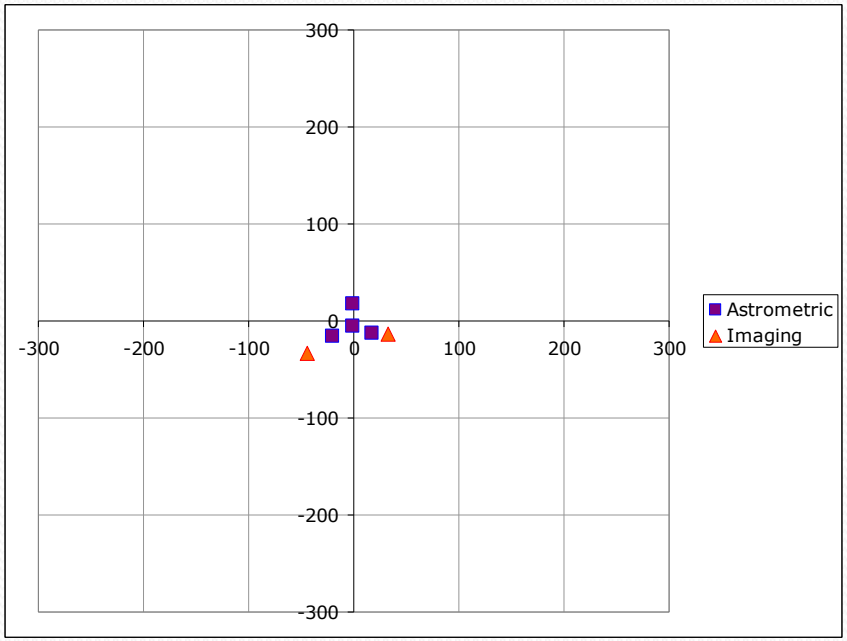
Item		Present	Upgrading	Possible
Aperture		12.5 cm	12.5 cm	1.8m
# of Apertures	Astrometry	4	4	4
	Imaging	2	4	Many
Baselines (m)	Astrometry	19-38	19-38	19-38
	Imaging	2-79	2-437	2-437
Combination		2×3way	6-way	6-way
Bandwidth		550-850nm	550-850nm	450-850nm
				JHKL
				Others?

Present Array Configuration



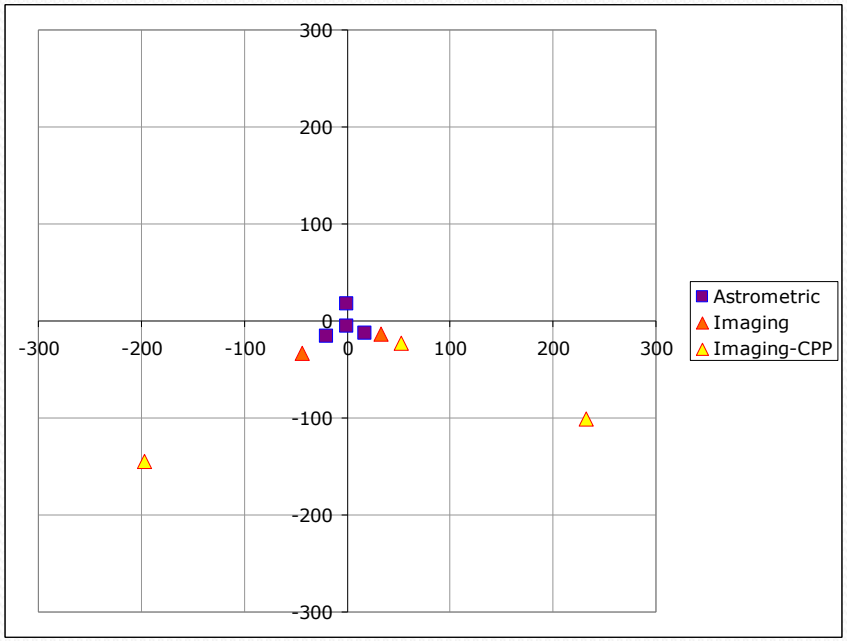
NOI Array Layout Evolution

- Current
  - 4 Astrometric stations
  - 2 Imaging stations



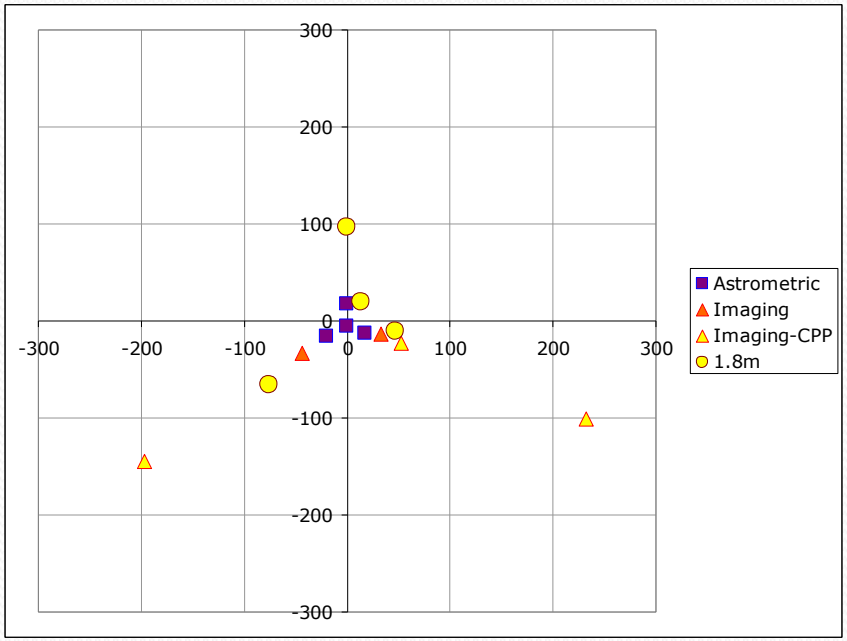
NOI Array Layout Evolution

- Current
  - 4 Astrometric stations
  - 2 Imaging stations
- CPP Upgrade
  - Opens W10, E10, E7



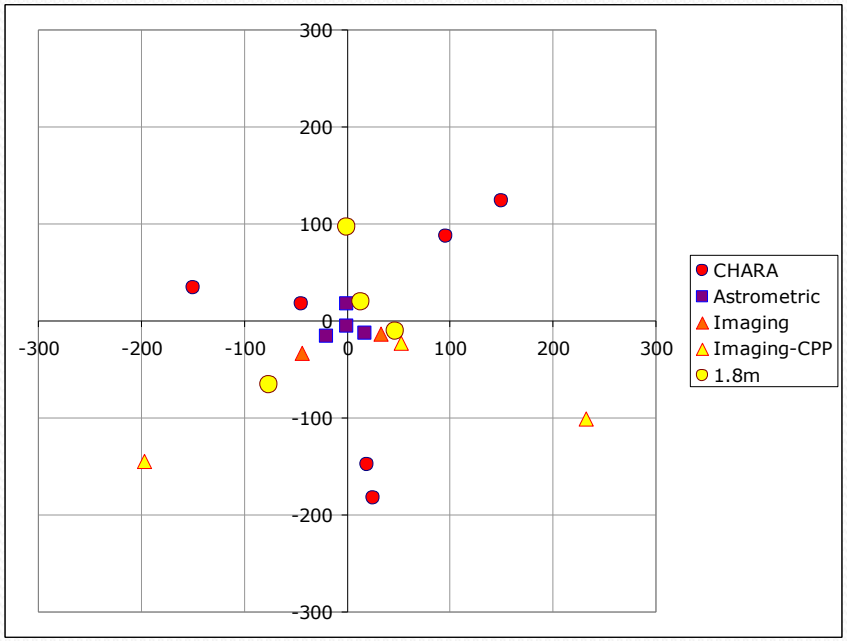
NOI Array Layout Evolution

- 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

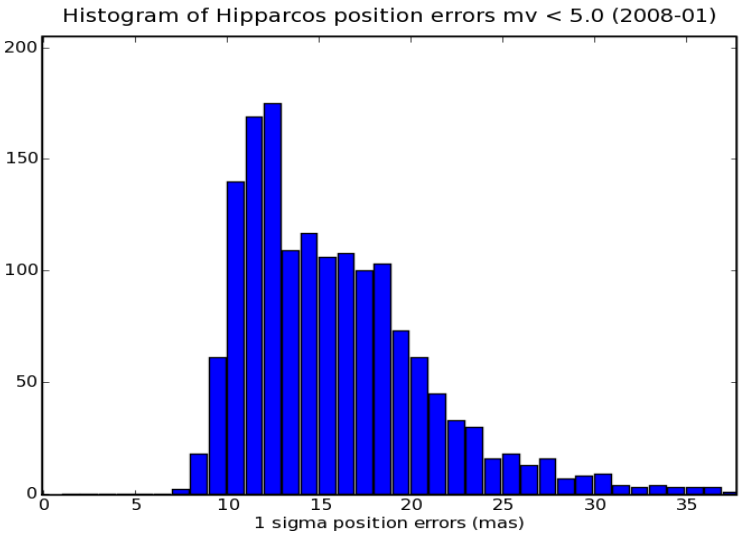


Current Science Endeavors

- ‘Mission-related’
  - USNO-NOI Astrometric Catalog (UNAC)
  - Imaging
- Binary Stars
  - Orbits
- Single Stars
  - Diameters, imaging

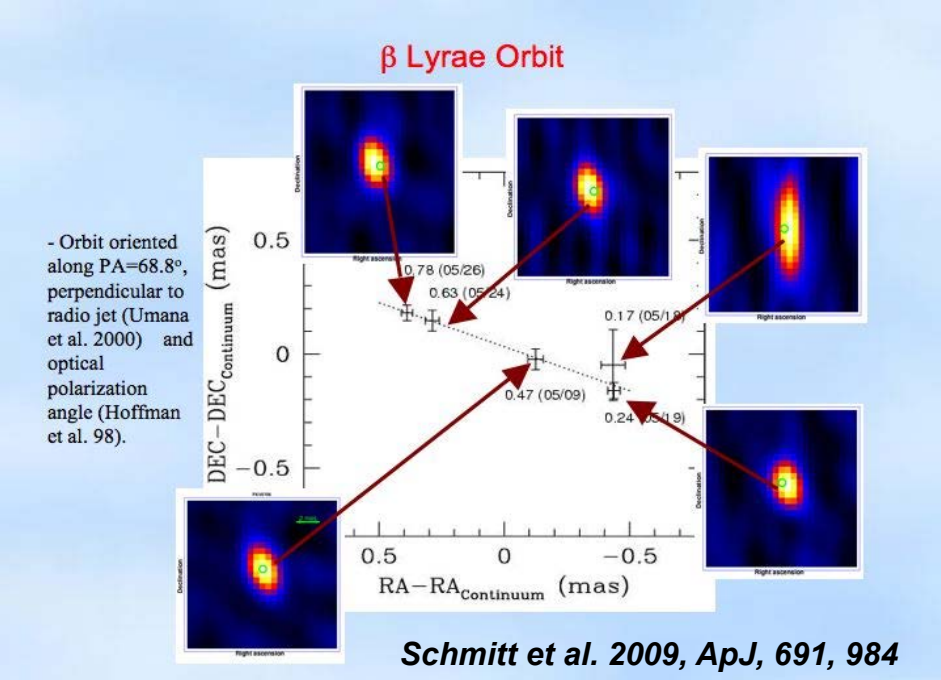
UNAC

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

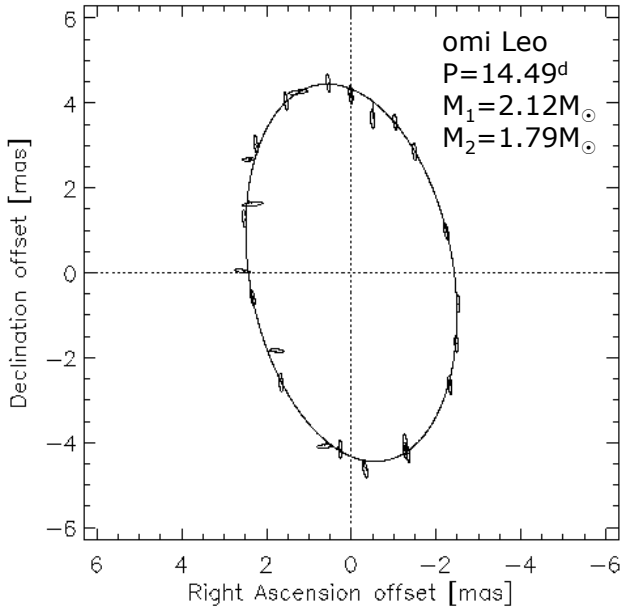


Binaries

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



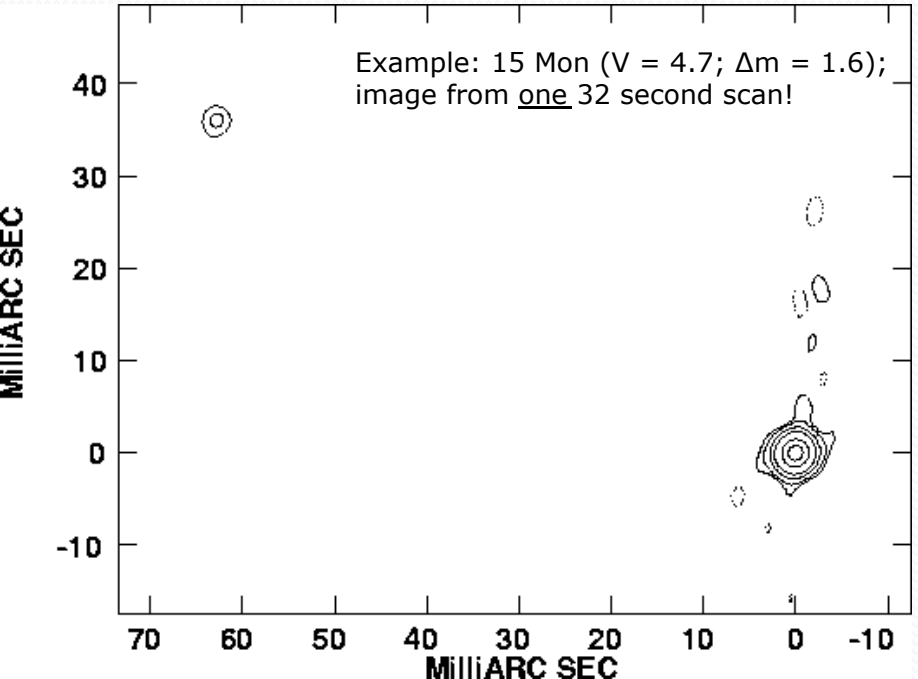
Schmitt et al. 2009, ApJ, 691, 984

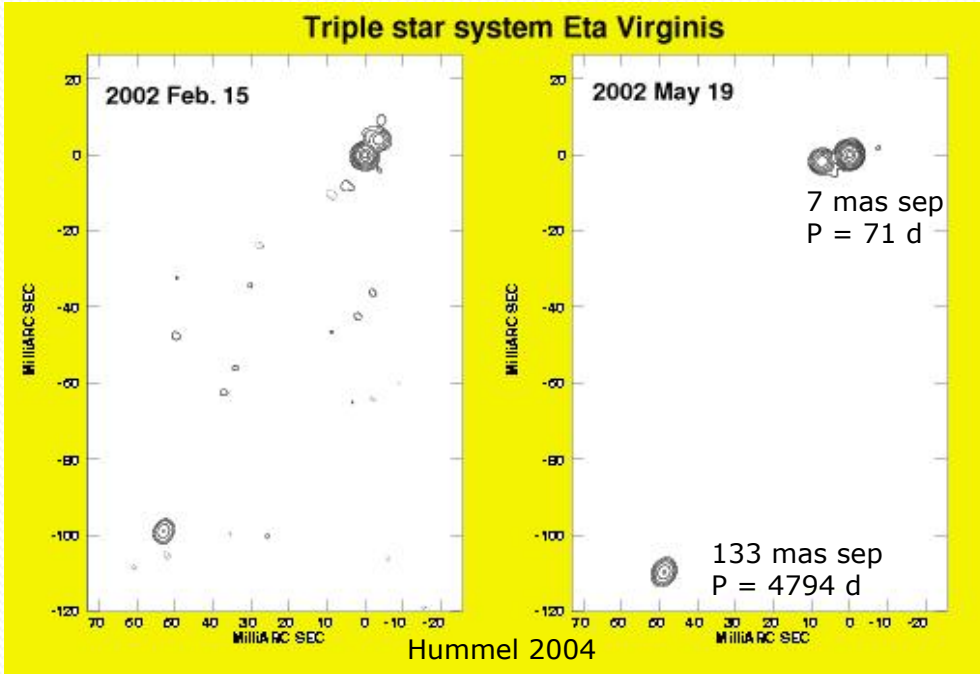


Hummel et al. 2001, AJ, 121, 1623

Binaries – Capabilities, Prospects

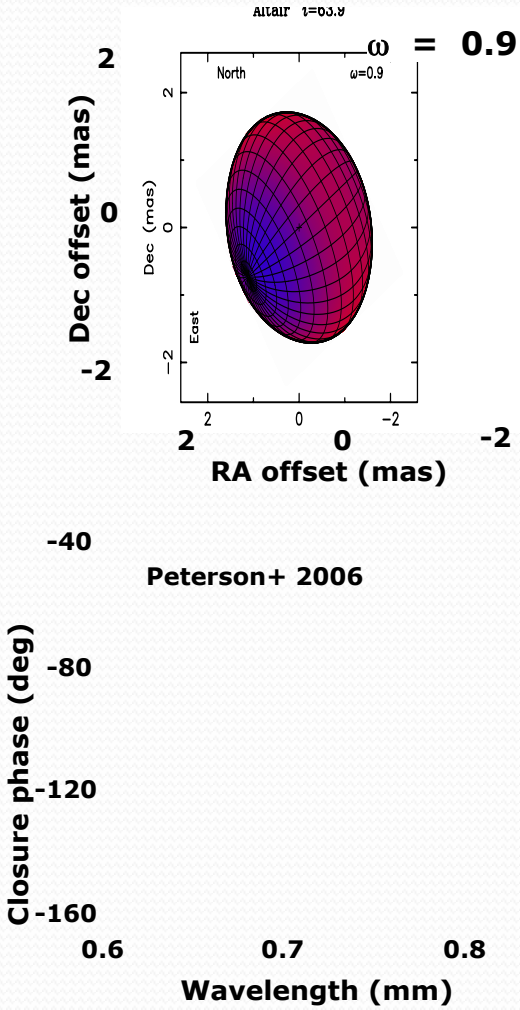
- In "imaging" mode, typically 200 multi-baseline scans/night (record 330)
- Binary detection possible in a little as 1-2 scans
- Only ~2 dozen multiple systems with optical orbits





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



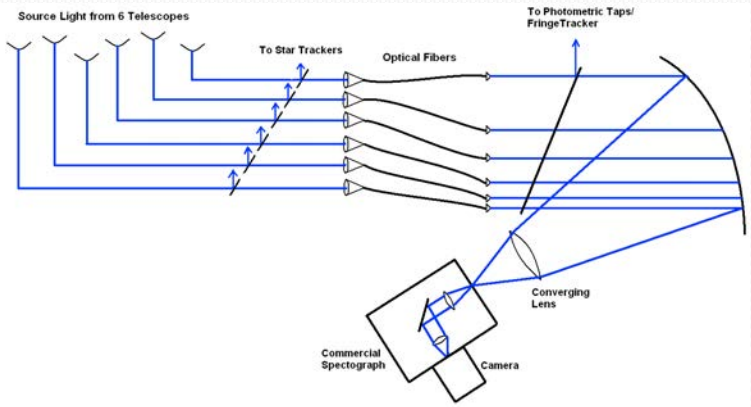
Development of NOI

- Facility development
  - Additional instruments
  - Larger apertures
- Science users development
  - Increased facility utilization

- Overall facility **Science Vision** being established to guide the way

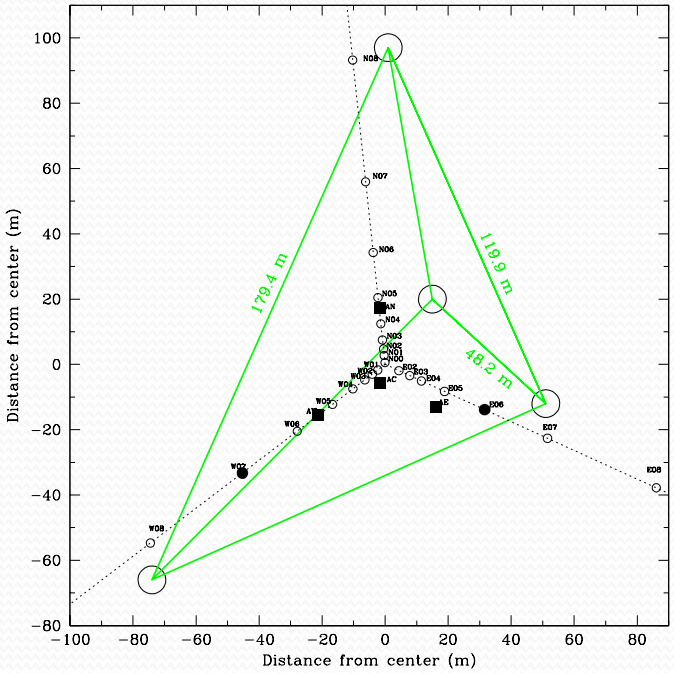
VISION Instrument

- 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 ~1%
- Simple, V-groove design
  - CP precision <1°?



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



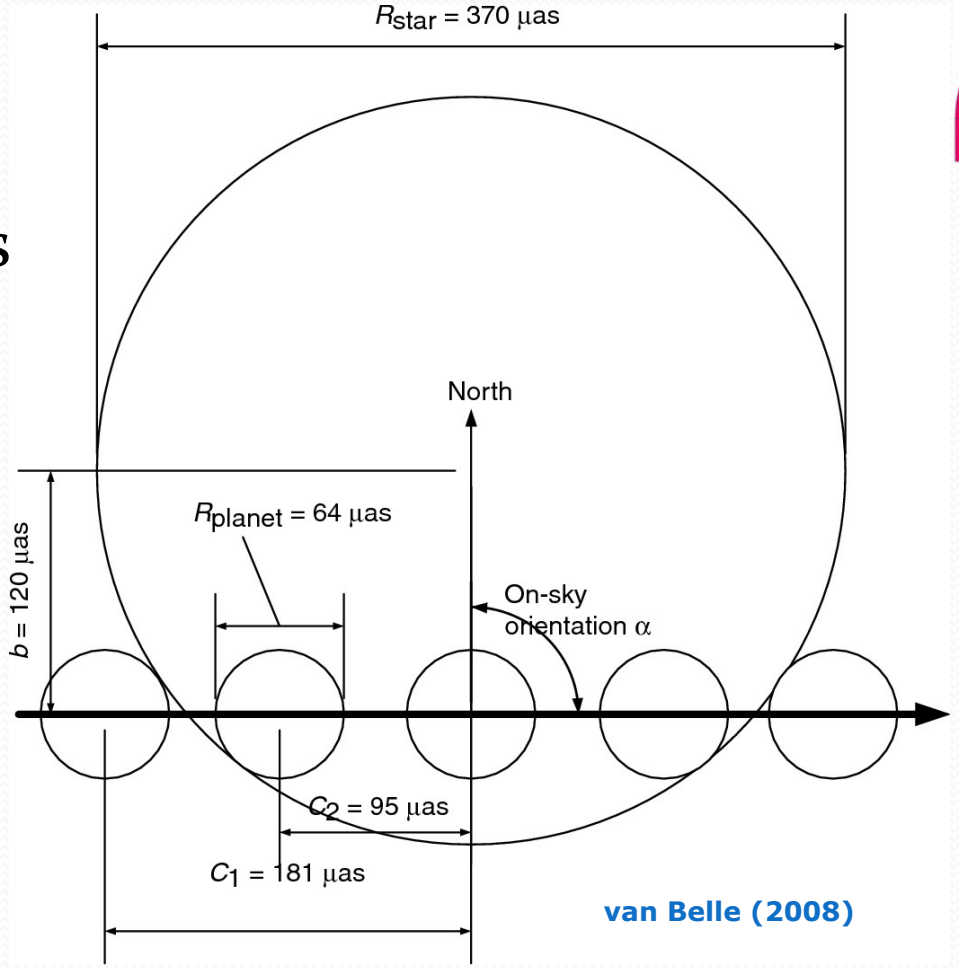
1.8m Telescopes

Conceptual View of NOI 1.8m Domes from Prime Lake

- 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
- λ-specific observations → atmospheric composition



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 in to 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: 3^{mo} for Phase 1, 18^{mo} for Phase 2

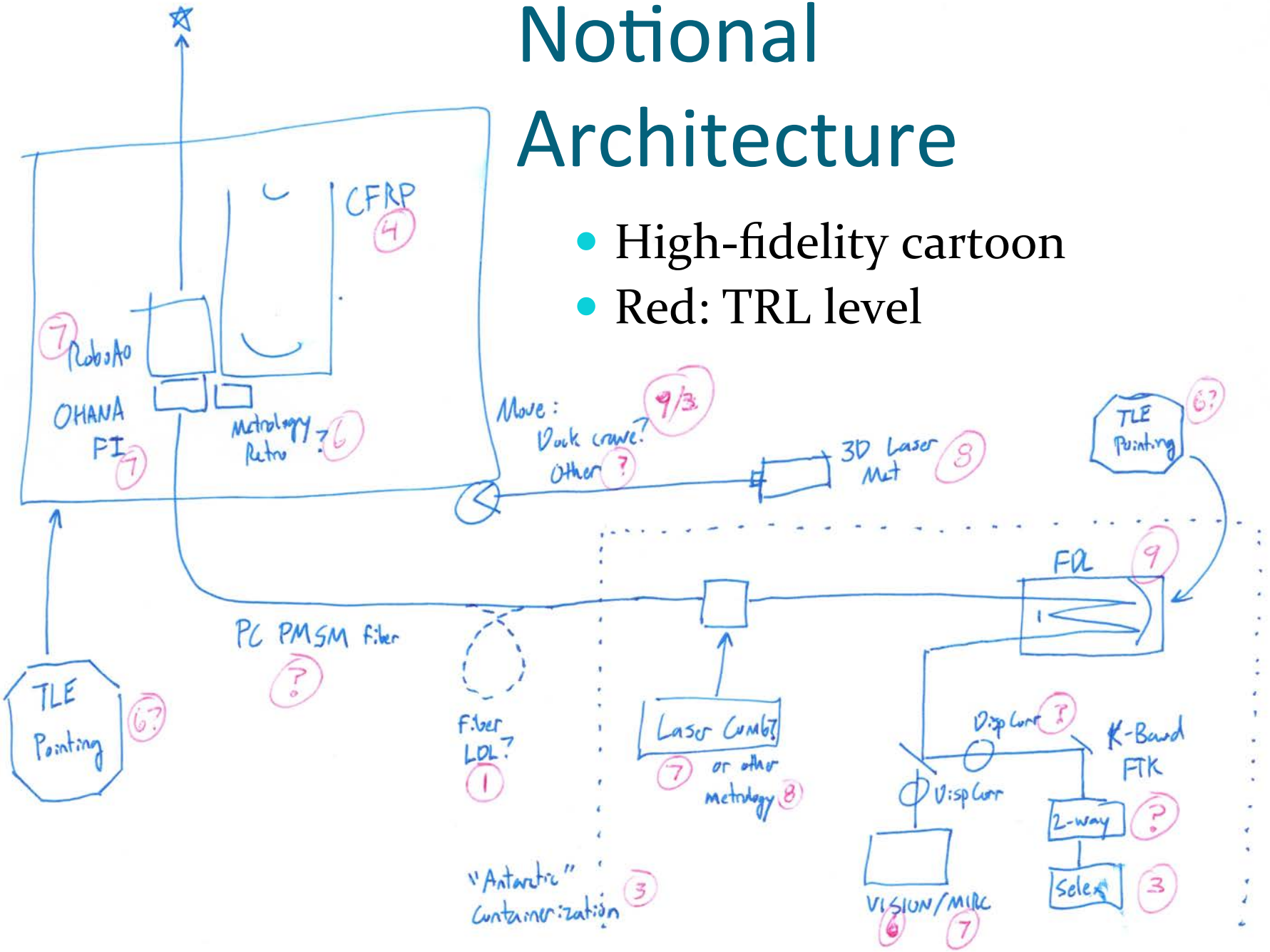
Strawman Design

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

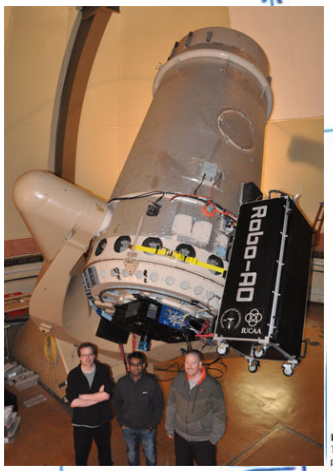
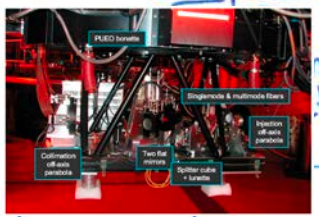
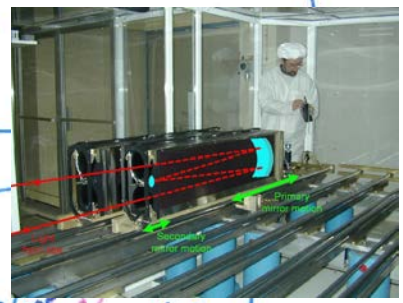
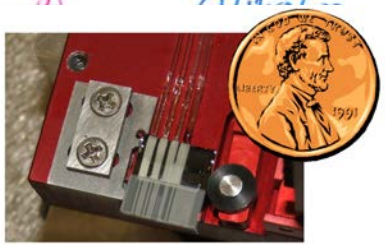
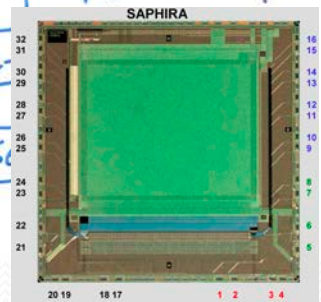


Figure 12 (Left) 3-D design of the NPOI 1.4m Cassegrain telescope (Right) Assembled NPOI Telescope shown in assembly structure at CMA. Complete OTA weight is 115 kg. The telescope is being painted and optics will be completed the end of 2007.









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?