
NPOI Update
14 March 2016
Gerard van Belle

The “Basics”

- NPOI = Navy Precision Optical Interferometer
    - (formerly Navy Prototype Optical Interferometer, Navy Optical Interferometer)
- Major funding by Oceanographer of the Navy and Office of Naval Research
- NPOI is collaboration b/w USNO, NRL & Lowell Observatory

- Lowell is science partner & contractor to USNO (infrastructure & ops)
- Several external collaborators, some with independent funding (NMT, TSU)

The NPOI Team

USNO:

Brian Luzum
Paul Shankland
Don Hutter
Jim Benson
Mike DiVittorio
Bob Zavala

NRL:

Richard Bevilacqua
Sergio Restaino
Tom Armstrong
Ellyn Baines
Jim Clark
Bob Hindsley
Henrique Schmitt

Lowell:

Jeff Hall
Gerard van Belle
Bill DeGroff
Victor Garcia
Jim Gorney
Teznie Pugh
Michael Sakosky
Jason Sanborn
Susan Strosahl
Steve Winchester
Stephen Zawicki

AZES:

Tim Buschmann
David Allen

ONR:

12 Navy Reservists

CMU:

Chris Tycner

TSU:

Matt Muterspaugh

NMT:

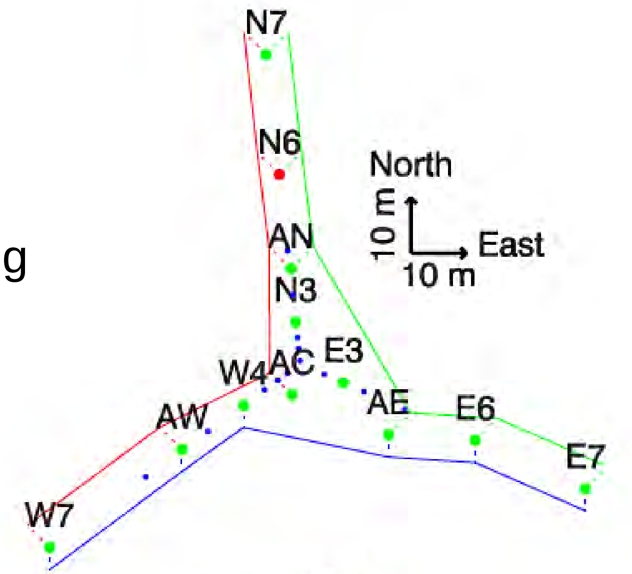
Anders Jorgensen

Imaging Array Expansion

Goals:

- Infrastructure @ 10 stations (8 complete, 2 partial)
  - Shelters & cabling for siderostat, acquisition & angle tracking
  - Enables 9 – 432 m baselines

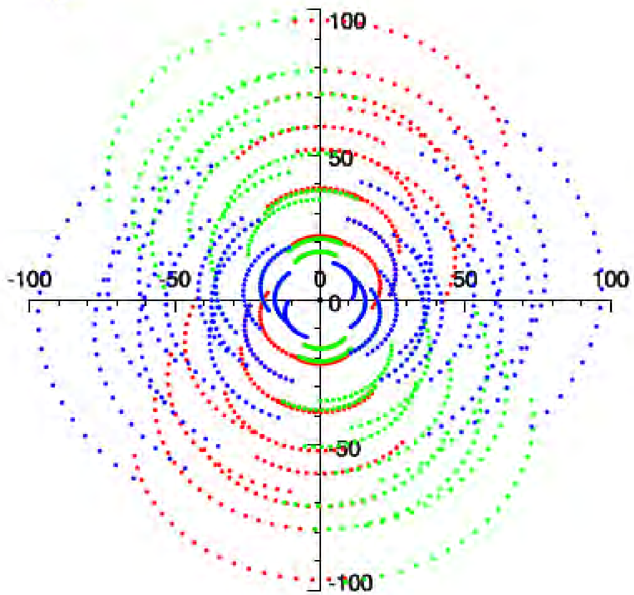
- 6 portable siderostats (functional, mostly)
  - In addition to 4 fixed astrometric stations



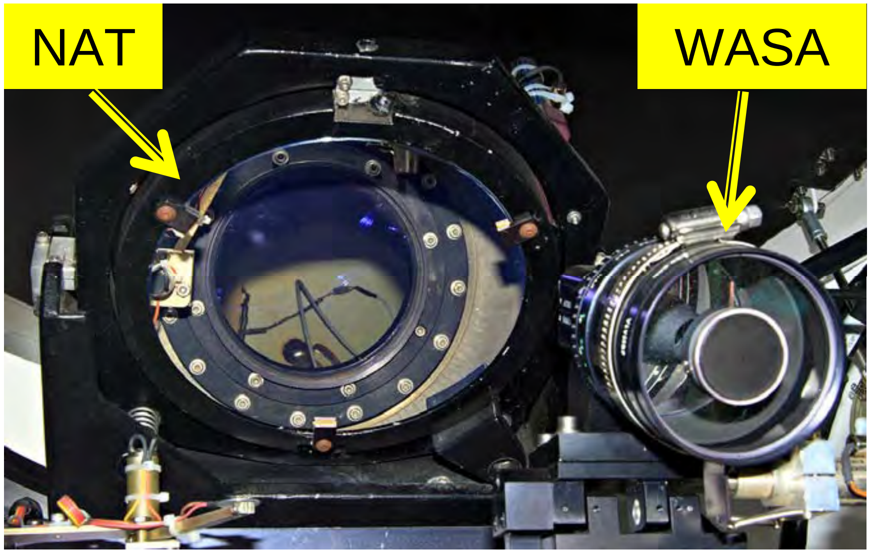
Enables:

- Geosatellite imaging techniques
  - Observe stars & satellites w/short, bootstrapped baselines

- High precision imaging
  - Observe O stars, solar analogs with baselines up to 432 m



“Imaging” Station

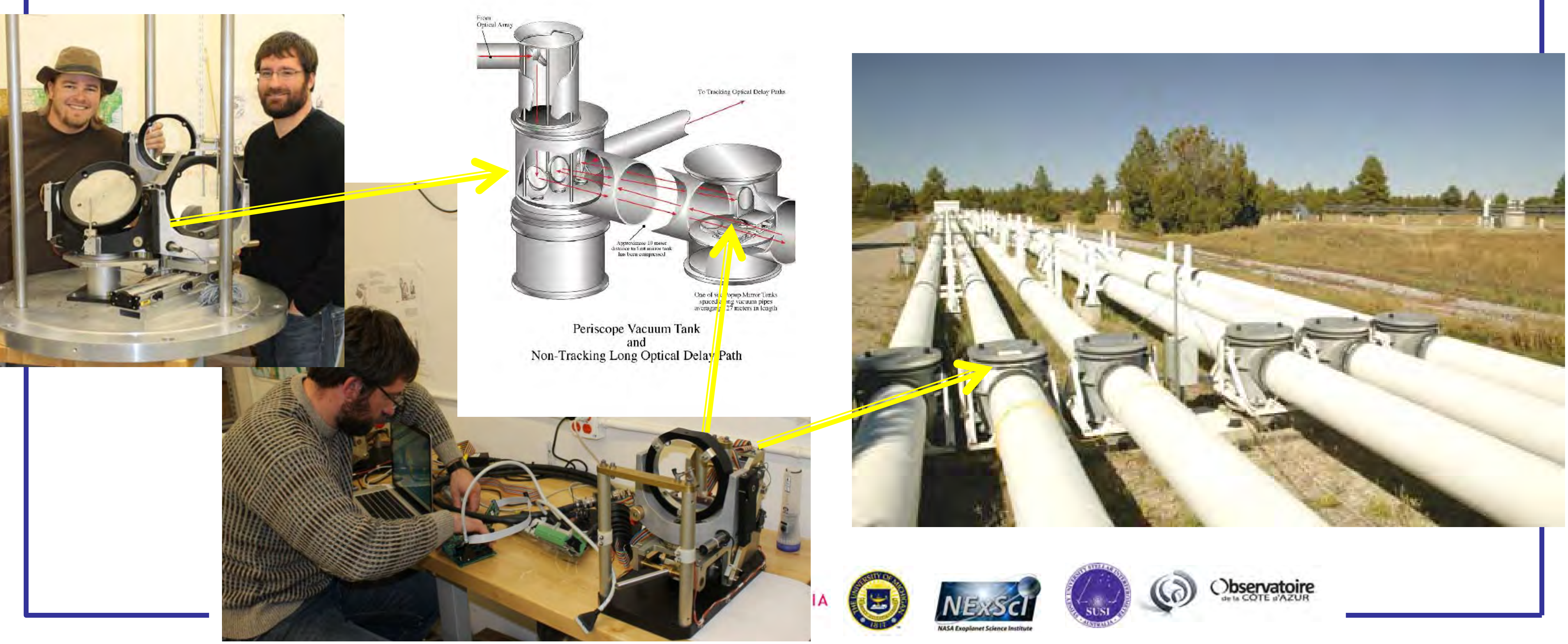


Siderostat

View down East Arm

Long Delay Lines (LDLs):

- Alignment of 72 “Popup” Mirrors in progress
- Integration to “Periscopes” to start this summer.



Beam Combiners

VISION:

- NSF funded (TSU)
- 6-beam, visible-light analog of MIRC
  - 16 Dec 2013: First bootstrapped fringe tracking (5 stations).
  - Currently fringe tracking to 4th magnitude
  - Instrument paper (Garcia+ 2016, PASP) in print, commissioning complete
  - “Big” stars, rotators, binary observations underway (multiple baselines, closure phase)

New Fringe Engine for NPOI “classic” beam combiner

- Hardware finished (AZES)
- Firmware & software (NMT), on-sky testing (Mar 2015, Sep 2015, Feb 2016) of baseline bootstrapping past 3rd zero

VISION Instrument Design

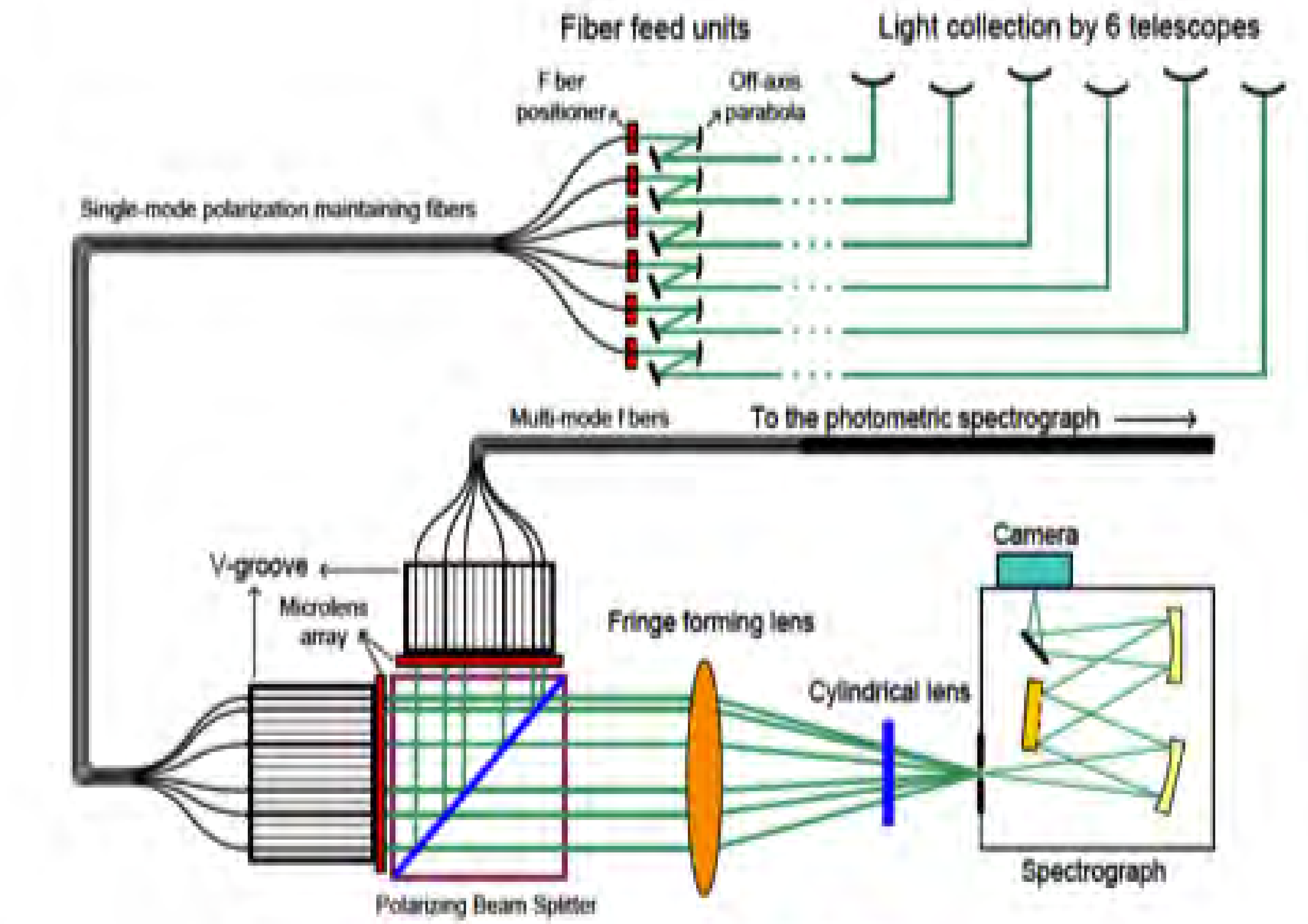
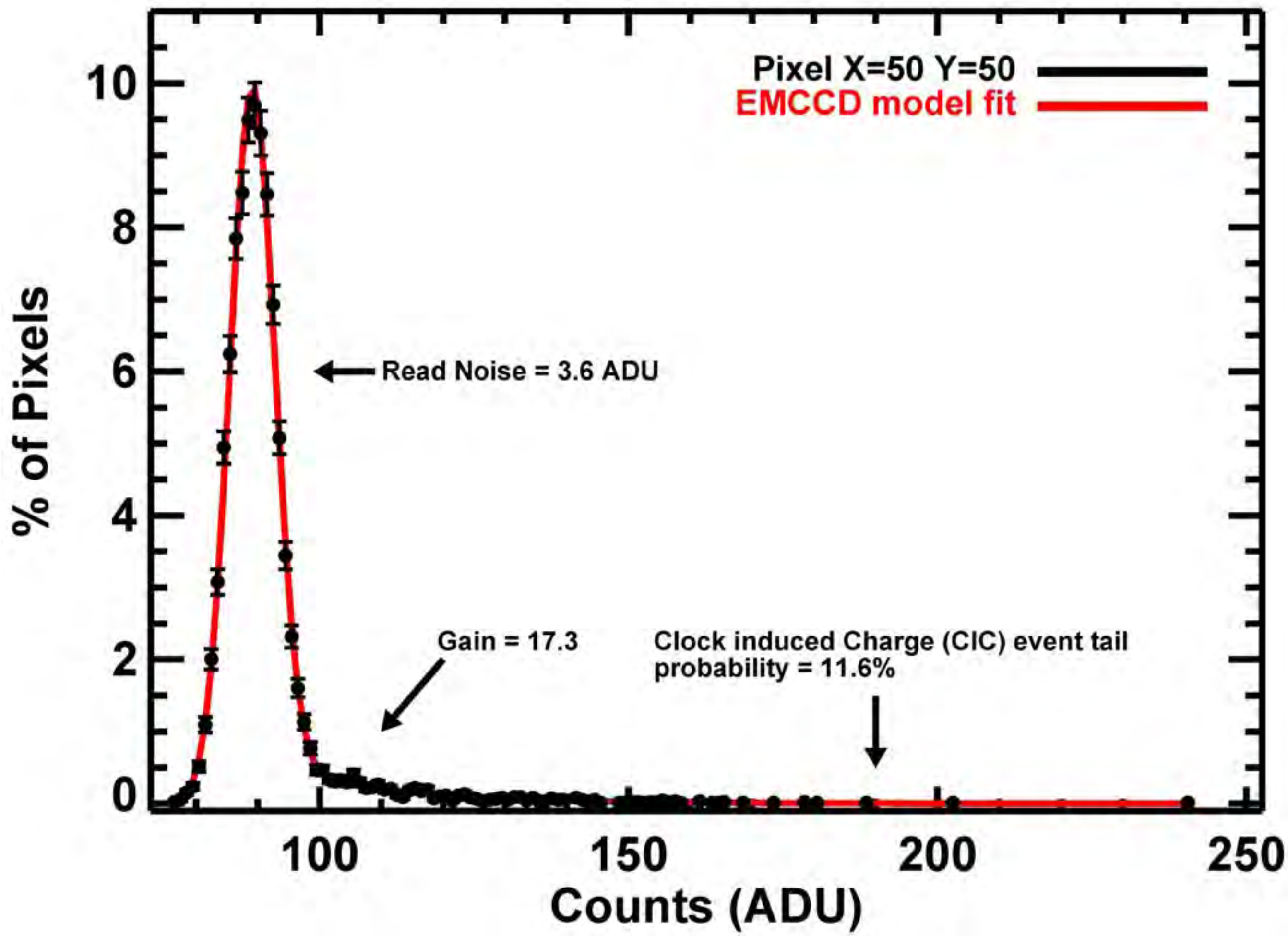


Figure 1. Schematic layout of VISION.

- 6-way simultaneous beam combiner
- Simple design: Fringes are made directly on a modern EMCCD
- Photometric channels on an EMCCD for calibration
- Fast fringe searching from an R=200 spectrograph
- Single-mode polarization maintaining fibers spatially filter light for increased visibility precision

VISION EMCCD Use

- Analysis of read noise, gain, and clock induced charge rate
- Implications for other use of EMCCDs
- CIC rate of VISION Andors: poor
  - Replacement cameras on order



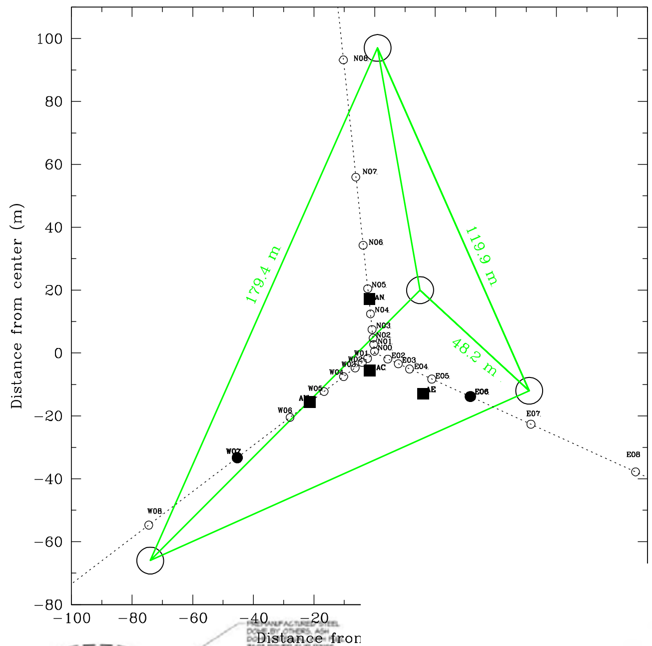
See detailed VISION talk on Wednesday

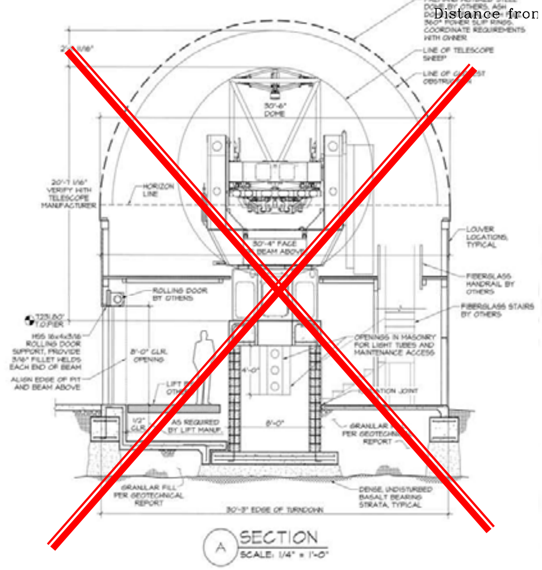
1.0m Telescopes

- **Goal:** large aperture array for visible/near-IR imaging

- **History:**
  - 2010: 4 × 1.8m telescopes from Keck gifted to USNO
  - 2015: 1.8m option declined by USNO

- **Currently:**
  - 2016: NRL & Lowell exploring sole-source contract for implementation of 3 × 1.0m telescopes, near-IR fringe tracking





UNAC Update (Jim Benson)

UNAC = "USNO – NPOI Astrometric Catalog"

- Goal: Catalog of ~ 1000 stars with positions accurate to < 16 mas (tied to ICRF).

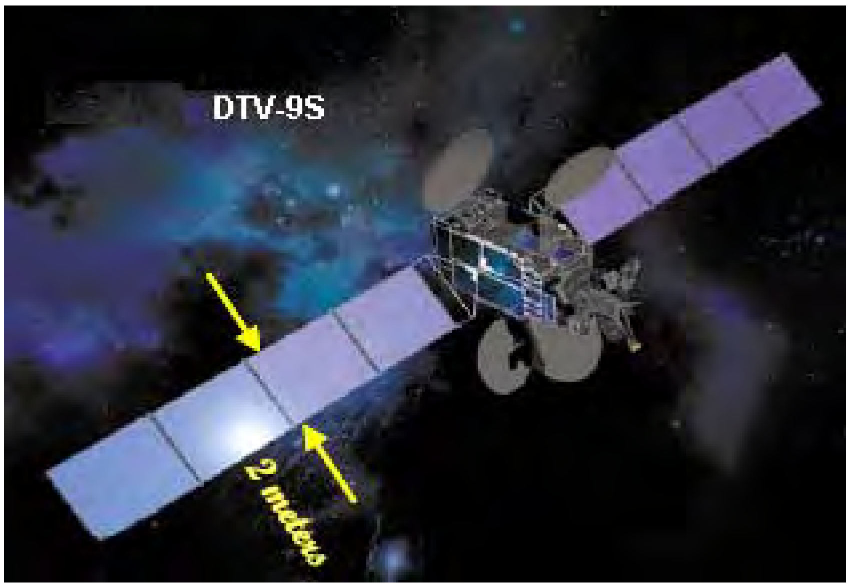
- 4 August 2014: internal USNO release of UNAC ver. 1.1
  - 59 stars (60 nights data)
  - $-11^\circ \leq \delta \leq +72^\circ$
  - Median position error ≈ 13 mas
  - Improved error distribution calc., only data from "locked" baselines, up to 5th-order thermal modeling

- From UNAC 1.1 to UNAC 1.2 ("publishable")
  - More QA work & tests of whether solid-earth tides are significant

GEOsat Imaging

- 2009: 1st Interferometric detection of GEOsat during "glint"

Hindsley et al. 2011, Applied Optics, 50, 2692



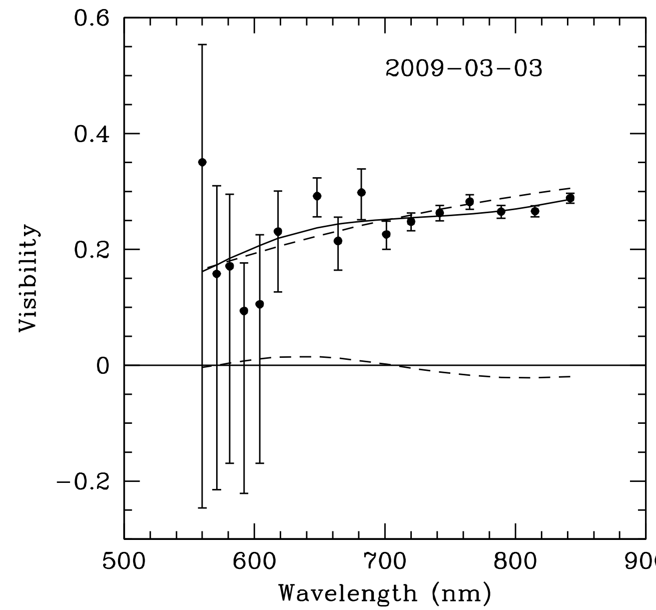


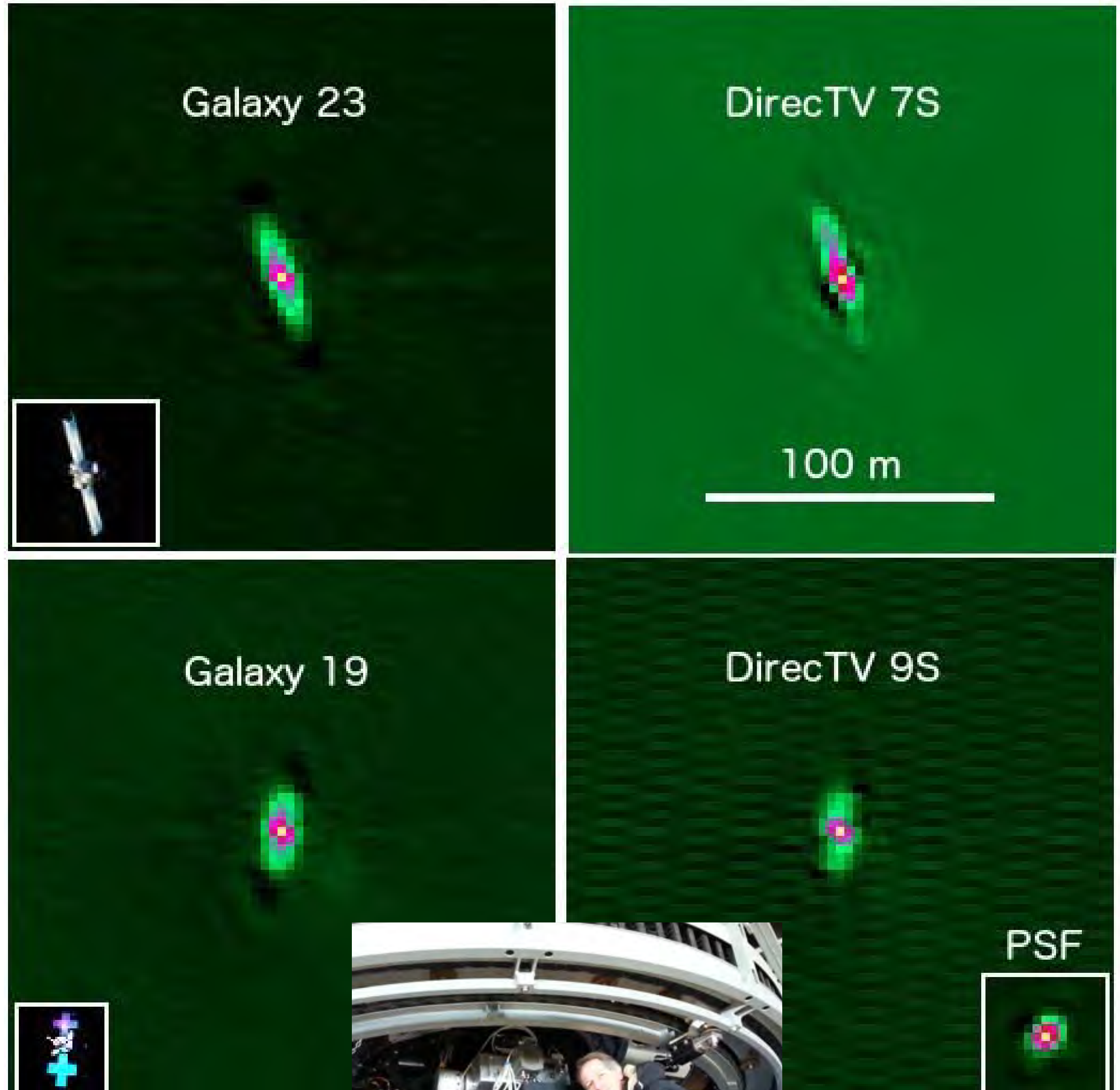
Fig. 5. Calibrated visibilities as a function of wavelength from 3 March 2009 data and from a two-component model fit to the data. The solid curve shows the flux-weighted sum of the two components from the first of the 3 March models shown in Table 1. This model consists of a smaller circular component of size 1.1 m (6.2 mas at geostationary distance) with 46% of the flux (upper dashed curve) and a larger component of 7 m (40 mas) with 54% of the flux (lower dashed curve). This larger, resolved component has a visibility amplitude of almost zero.

16

- Mar, Oct 2015: New multi-baseline observations

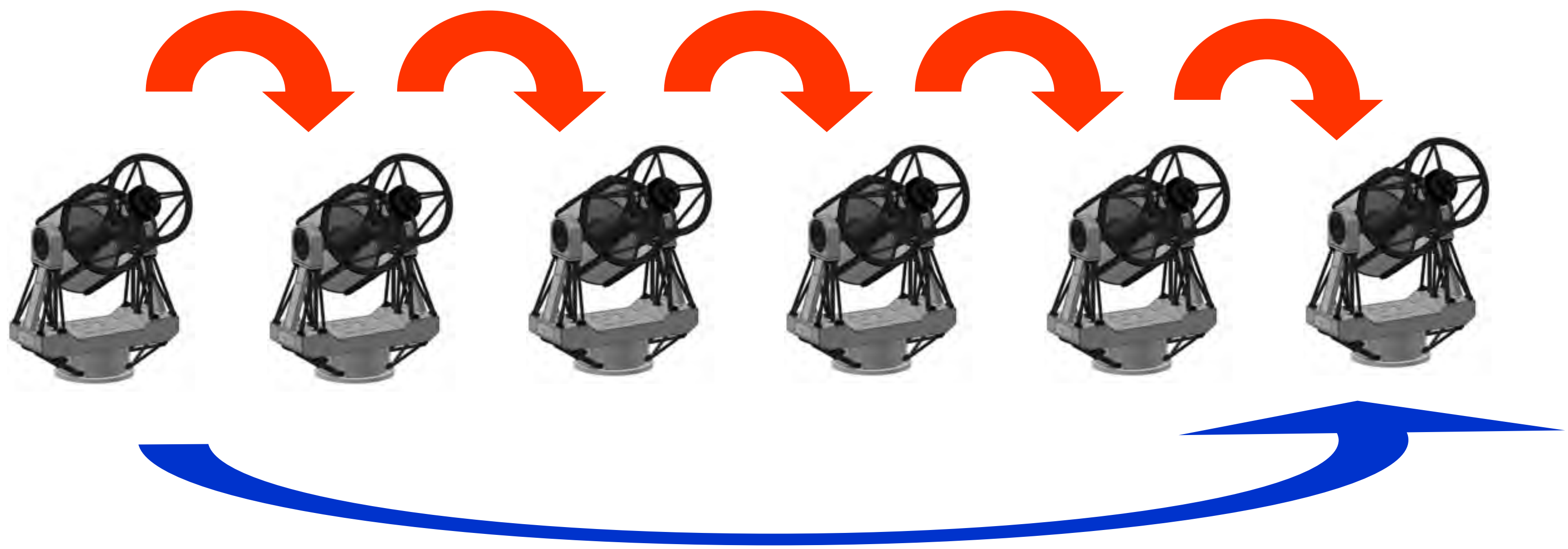
Speckle Imaging of Satellites

- Speckle imaging in visible with Lowell’s 4.3-m DCT
- Objects are ~50-100mas in size, V~12



Challenge: How to Collect Interesting Fringes?

- Solution: Wavelength-Baseline Bootstrapping
  - Track in the near-infrared with short baselines
  - Image in the visible with medium, long baselines
- *Also* takes advantage of the very red color of satellites



Binaries: 47 Oph

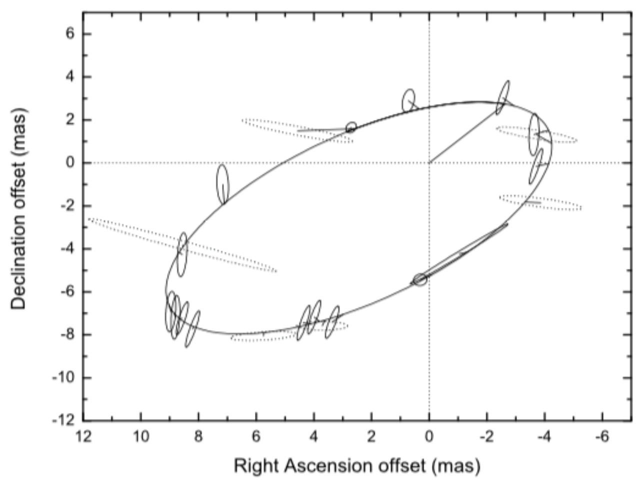


Fig. 1.— Apparent orbit and the interferometric data of 47 Oph. The ellipses indicate the astrometric uncertainty. The data with dot ellipses observed by the Mark III have already been published by Hummel (1997), and the data with solid ellipses are new data observed by the NPOI. The straight solid line indicates the periastron.

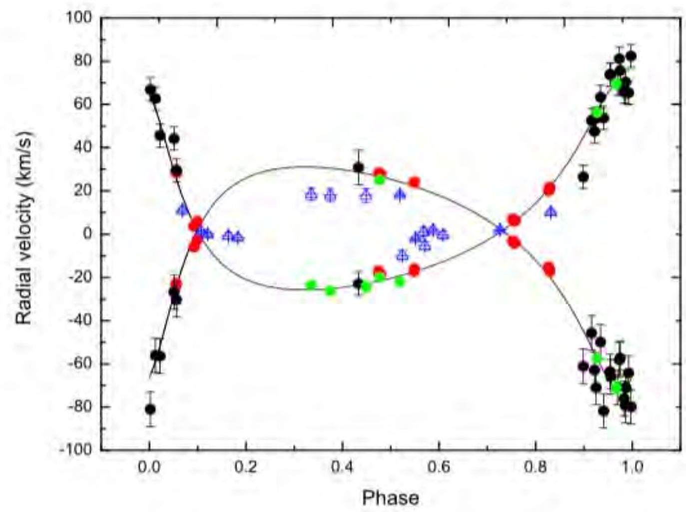
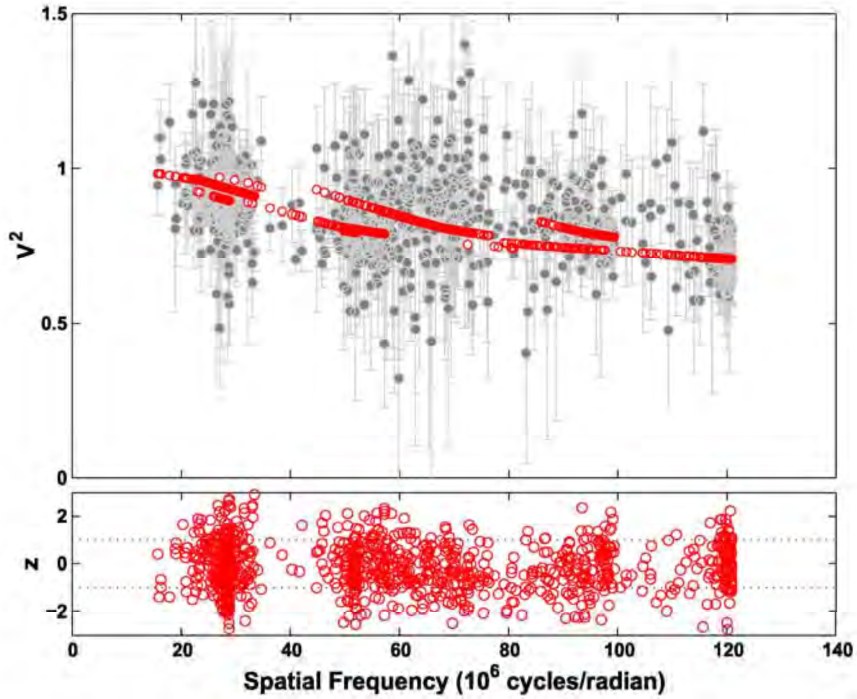


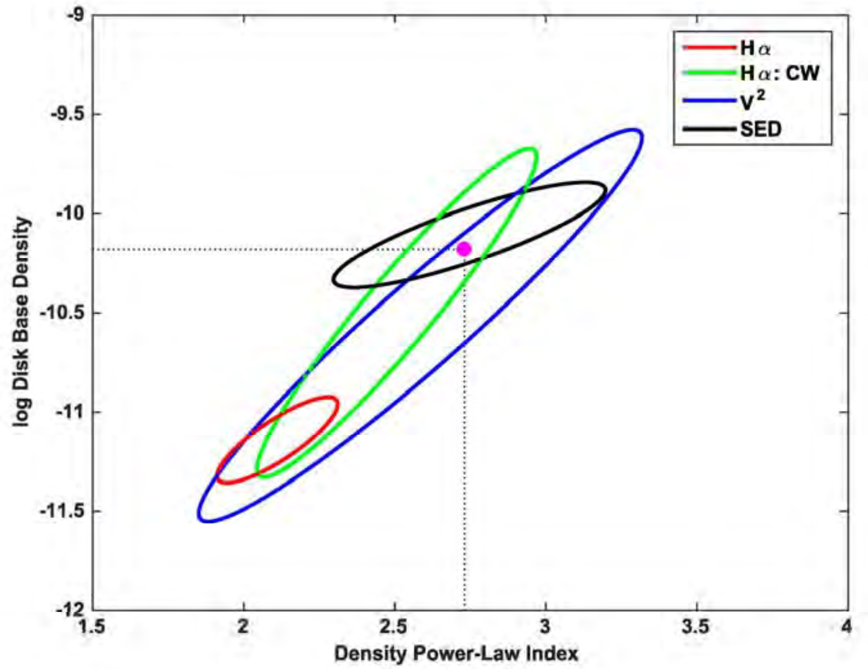
Fig. 2.— Radial velocity curve and the observed RV data. The black, green and red filled circles denote the RV data supplied by Parker (1915), Abt & Levy (1976) and measured by the present work, respectively. The blue triangles represent the RV data which were not used to fit the orbit.

- Wang, Hummel, Ren & Fu 2015, AJ, 149, 110

  - masses, orbital parallax, luminosities, radii & age derived

Circumstellar Disk of *o* Oph





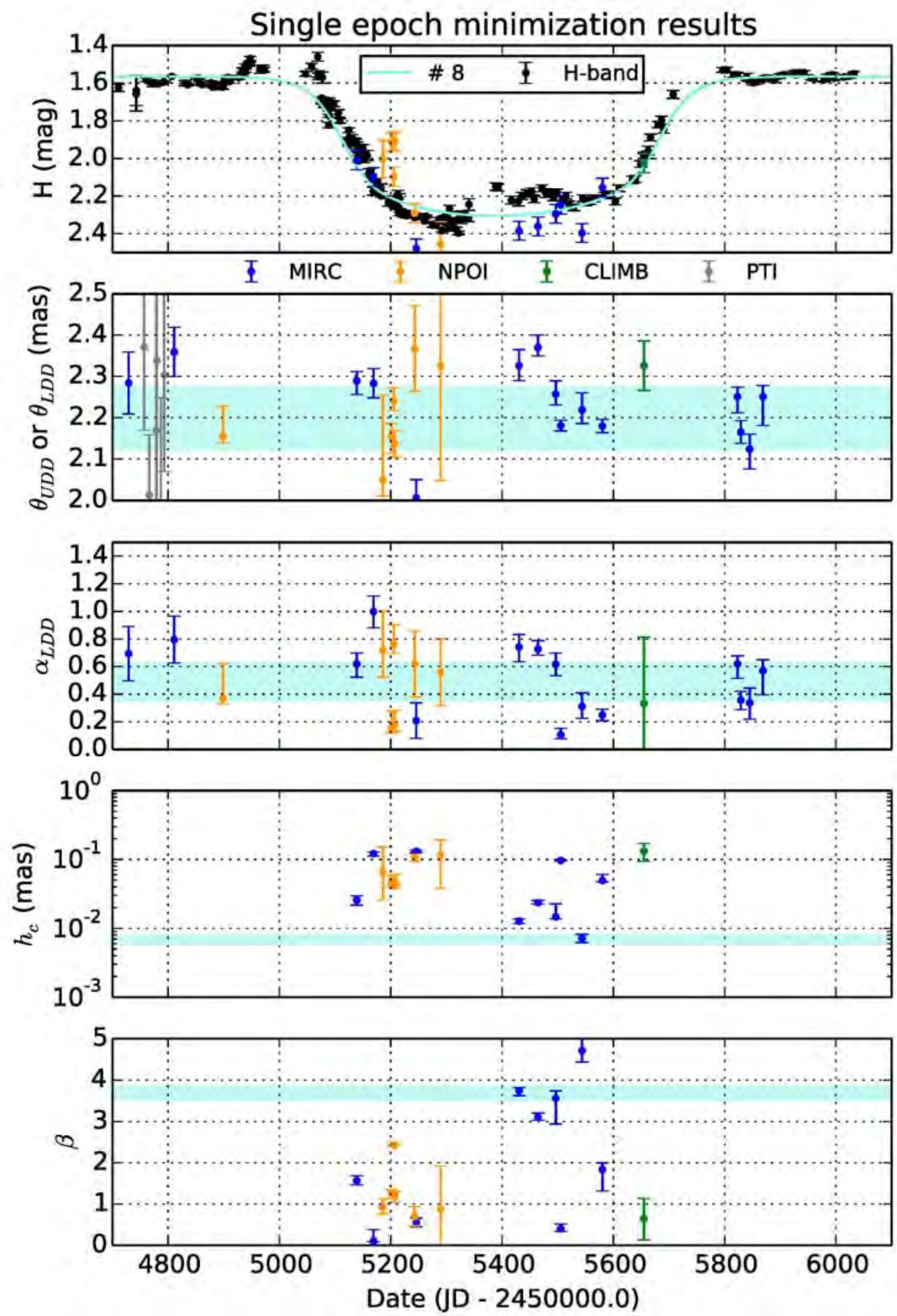
- Combined interferometry & spectroscopy
- Disk parameters of density, power-law index

Sigut+ 2015

The ε Aur Mega-Paper

- Combined forces of NPOI, PTI, and CHARA
- 106 nights of observing over 14 years [!]

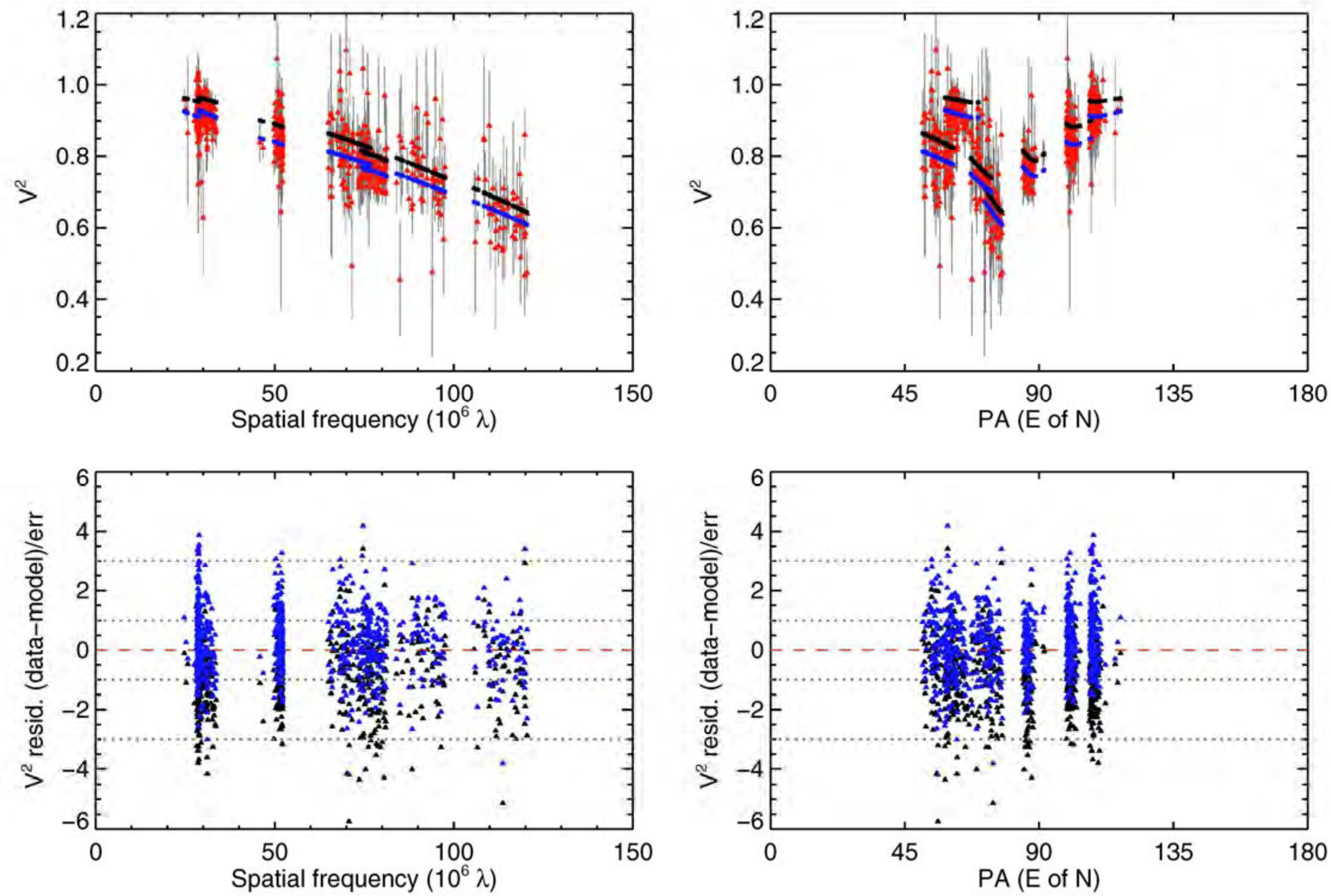
Kloppenborg+ 2015



Be star β CMi

- Testing of viscous decretion disk model
  - Conflict between flaring disk and shallower falloff models
- H α channel observations *(right)*
- [NB. Paper includes PRIMA data!]

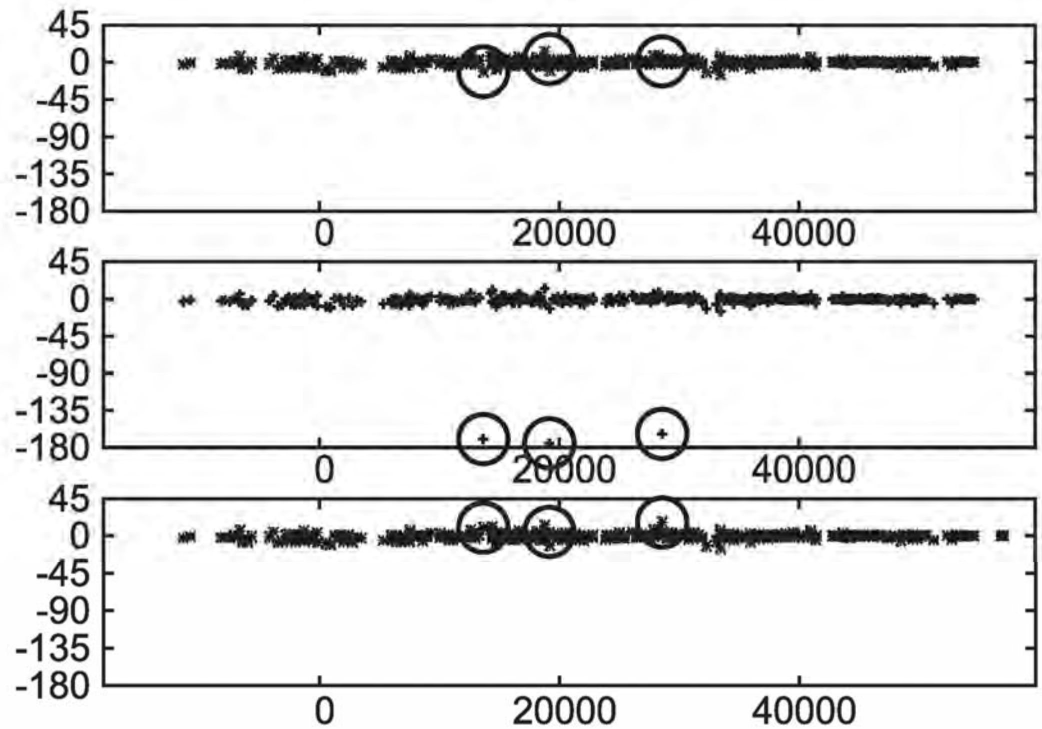
Klement+ 2015



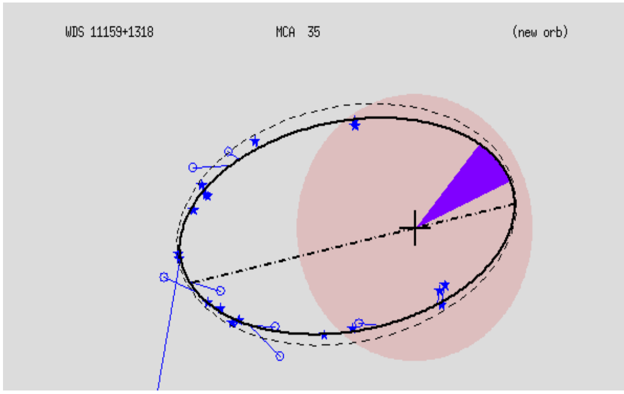
The Missed Eclipse of α Com

- Three bad measures led to bad predict on eclipse time
  - 2 months off
- Eclipse of 26 yr orbit missed by 7 days
- Caught retroactively with PTI-PHASES, CHARA, and NPOI measures

Muterspaugh+ 2015



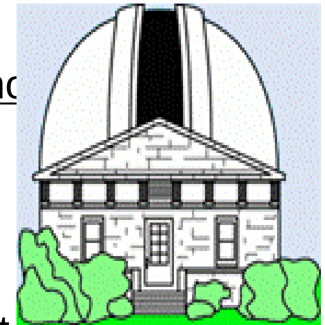
Updating Double Star Orbits with the NPOI



New Orbit (solid curve) vs. Old Orbit (dashed curve) for star **73 LEO** derived from newly collected data points (blue asterisks)

SEAP Student:
Jonathan Hurowitz
MIT, The Altamont School

Mentor:
Dr. Brian Mason
US Naval Observatory
Astrometry Department
brian.mason@usno.navy.mil



Project Objective:

• Reduce data taken by the Navy Precision Optical Interferometer (NPOI) in Flagstaff, AZ to update orbits of bright binary star systems with recent, highly accurate data.

Methods:

• Used OYSTER, a program written by former USNO employee Christian Hummel, that reduces NPOI data to find position angle and separation of binary star systems.

Results:

• Obtained 52 data points on five binary star systems: HR 233, τ PER, 36 TAU, 73 LEO, δ SGE, with an average of 5 measures per data point, accounting for over 100 nights of data dating back 6 years.

• Computed new orbital elements and errors for said systems.