



# The Navy Precision Optical Interferometer

## *Current Status, Future Upgrades*

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September 24<sup>th</sup>, 2013



# The NPOI Team

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## ■ USNO

- Paul Shankland
- **Don Hutter**
- Jim Benson
- Mike DiVittorio
- Bob Zavala

## ■ AZ Embedded Systems

- Tim Buschmann
- David Allen

## ■ Lowell Observatory

- Jeff Hall
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- Ron Winner

## ■ NRL

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- Ellyn Baines
- Jim Clark
- Henrique Schmitt
- Chris Wilcox

## ■ TSU

- Matt Muterspaugh
- Mike Williamson

## ■ Vanderbilt

- Victor Garcia

## ■ NMT

- Anders Jorgensen





# Tour: Navy Precision Optical Interferometer

Flagstaff, AZ (~7,200' / 2,200 m)  
79-m baseline  
Six 12-cm apertures

[432-m baseline]  
[Four 1.8-m apertures]

Anderson  
Mesa



# Basics



- **NPOI = Navy Precision Optical Interferometer**
  - Major funding by Oceanographer of the Navy and Office of Naval Research
  - Additional instrument funding from National Science Foundation
- NPOI is collaboration b/w USNO, NRL & Lowell Observatory
- Lowell is both a science partner, and a contractor to USNO (infrastructure & ops) & NRL (site projects)



# NPOI Current Capabilities

- Simultaneous, group-delay fringe tracking on multiple baselines (6 stations)
- Bandpass 550-850nm in 16 channels ( $R \sim 30-50$ )
- Single-baseline fringe tracking to  $m_V = 6.7$
- Multi-baseline fringe tracking w/closure phase to  $m_V \sim 6.0$
- Wide-angle astrometry with 5-10mas accuracy on bright stars
- Operated by one observer, scheduled  $\sim 355$  nights/year

*NPOI Imaging Siderostat*



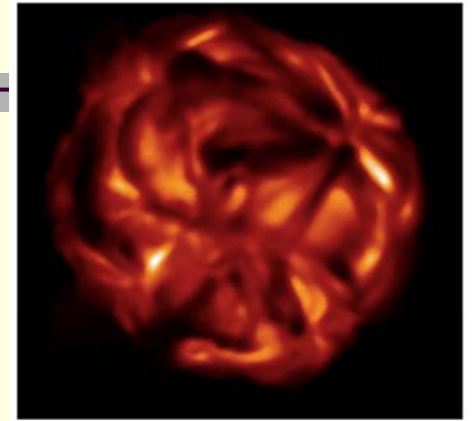
# Facility Upgrades in Progress

- Completion of 6-station “imaging” (portable) siderostat array:
  - New enclosures for star acquisition & tip-tilt optics installed for 5 of 6 stations
  - New domes installed for 5 of 6 imaging siderostats
  - 2 more imaging stations to be commissioned in 2013
  - Long baselines to 432 m & ‘compact’ configurations
  - To complete: integration of Long Delay Lines
- Control systems upgrades:
  - PC-based siderostat controllers for astrometric & imaging stations (4 installed; 5 more this year)
  - PC-based Fast Delay Line (FDL) control system:
    - Delivered to site & tested with 2 FDLs thus far
    - Significant performance improvement

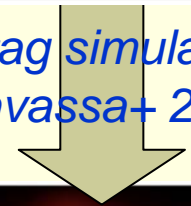


# ‘Classic’ Instrument Upgrade in Progress

- New Fringe Engine read-out electronics
  - FPGA hardware finished; firmware & software under development
  - 32 → 96 channels, 30<sup>sec</sup> → unlimited integration time
  - Flexible FTK algorithms
- Baseline bootstrapping, coherent integration
- Recently approved as a 3-year NSF-funded upgrade program



*Freytag simulation  
(Chiavassa+ 2010)*



*6x6 pixel imaging  
(NPOI 2014?)*



# VISION Instrument Commissioning in Progress

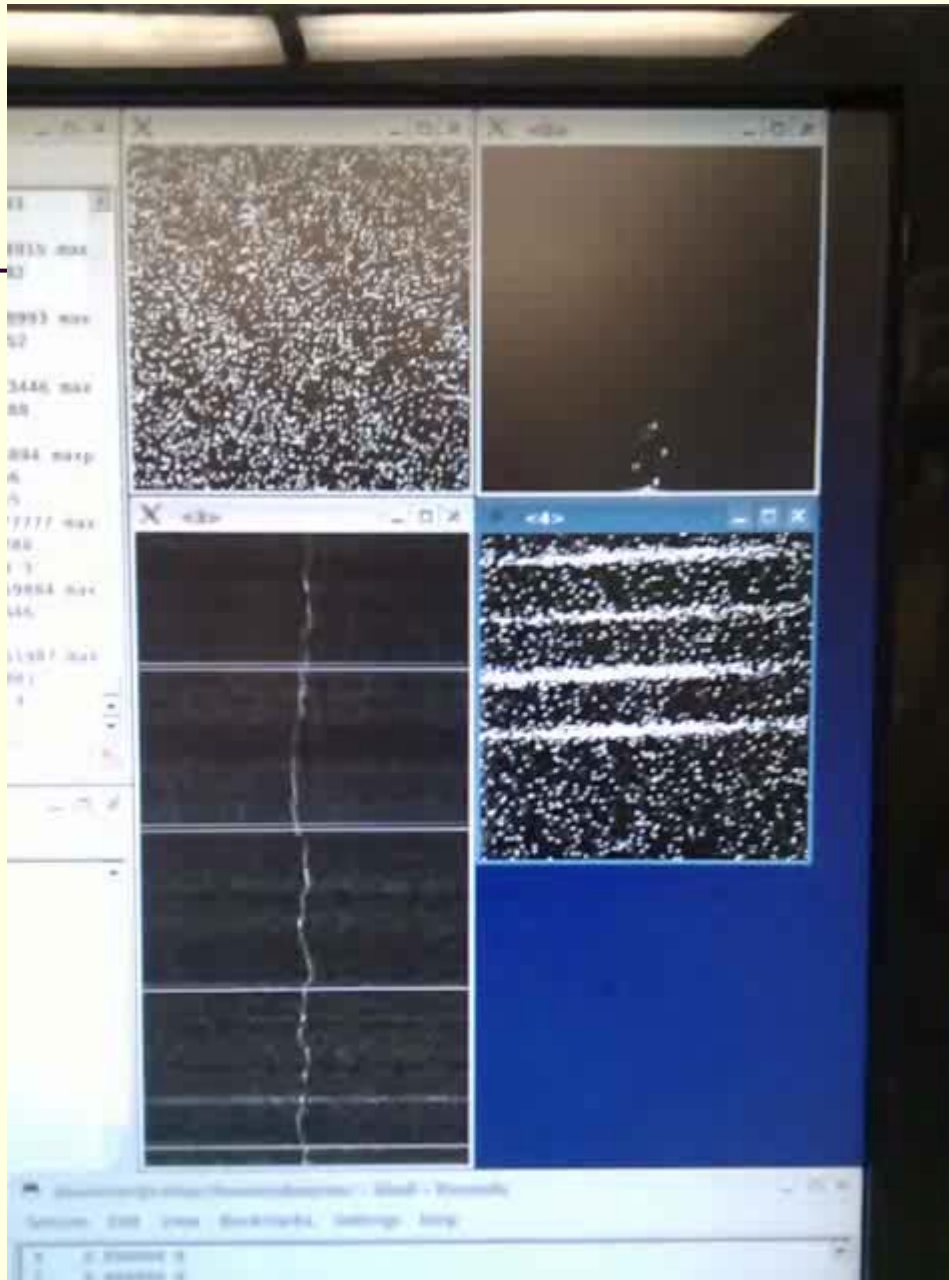
- VISION NSF project: PI Matthew Muterspaugh (TSU)
  - Visible “MIRC++” combiner for NPOI
- Improvement
  - Visibility precision  $\sim 10\times$
  - No delay nonlinearities, APD afterpulsing
  - Full 6-way combination, flexible spectral resolution ( $R \sim 50, 2000$ )
  - Modern equipment, CCD
- Commissioning ongoing
  - First fringes: Oct 2012
  - Four-way combination: Jan 2013
  - Grad student (V. Garcia) now on-site for full-time commissioning work





**Fringes in  
Image Plane**  
(barely seen  
above the noise)

**'Waterfall'  
plot for  
single  
tracking  
baseline**  
(left-right motion  
due to residual  
atmospheric  
piston)



## FFT of Fringes

### Spatial Frequency versus Delay

- Each 'Hot Pixel' row is one baseline of six
- Bottom pixel is DC term
- Some baselines very hard to see because fringe contrast is low (for long baselines)
- Left-right motion due to atmospheric piston
- Pixels should line up in a single vertical line but don't due to uncorrected static piston offsets

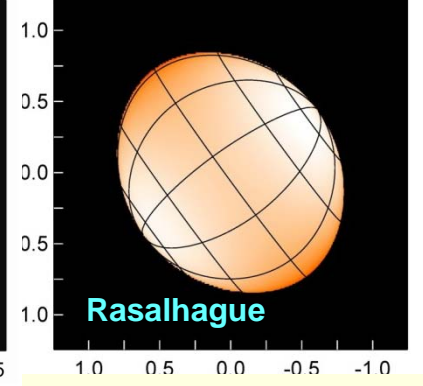
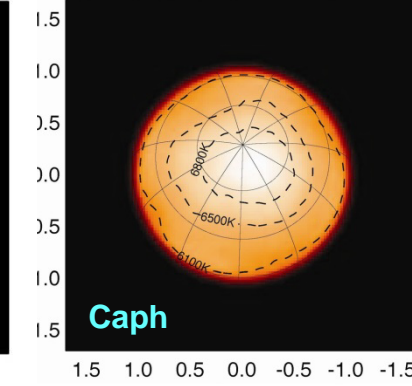
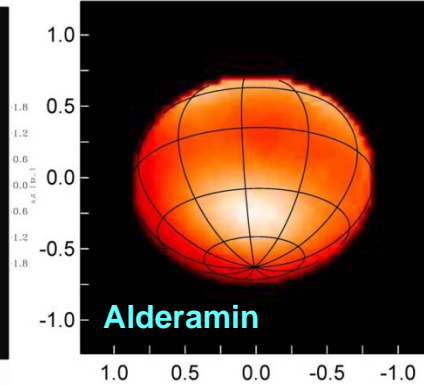
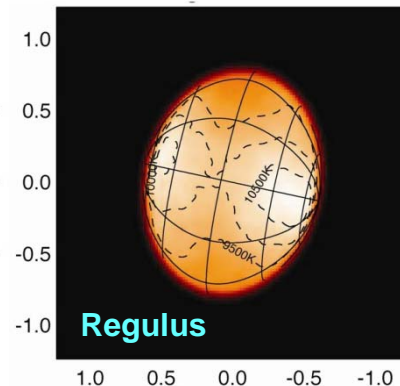
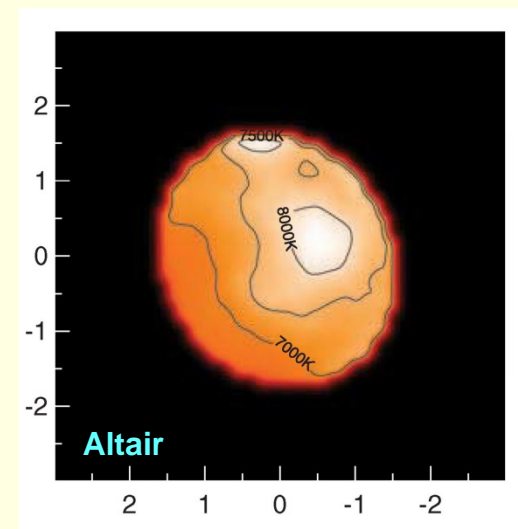
**Photometry  
for each of 4  
telescopes**

**Four simultaneous  
telescopes  
=  
Six baselines  
(and 3 independent  
closure phases)**



# Stars are Photogenic

- Progression over the past 10 years
  1. Simple modeling (PTI)
  2. Detection of surface features (NPOI)
  3. Direct imaging (CHARA, shown)
- Already starting to see some surprises
  - Stellar structure not as expected from simple models
- Next step: time-series images → movies

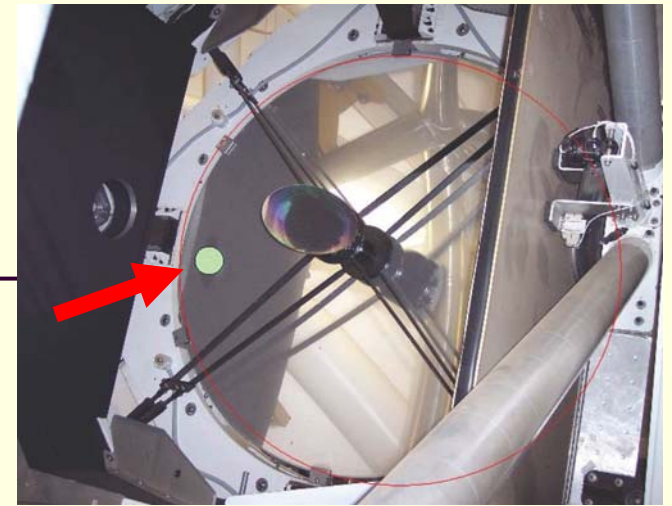


**Monnier+ 2007, Zhao+ 2009, Che+ 2011: 4-way CHARA-MIRC Images**



# 1.8-m Upgrade

- Four 1.8-m telescope were built by NASA for the Keck Interferometer
  - Not installed for non-technical reasons
  - 'Over-engineered' for narrow-angle astrometry
  - Good for NPOI wide-angle astrometry mission
  - [One on loan to Mt. Stromlo]
- 'Gifted' to USNO from CARA in 2010
- Final engineering plan in 2011
- USFS site permit in 2012



***Relative size of current 5" siderostats and 1.8-m telescope***







Ready to be  
done with the  
VLTI school?

## TODAY'S LESSON :

1. Ongoing upgrades
  1. VISION
  2. Classic
  3. Additional stations
  4. Long baselines
2. 1.8-m apertures are coming!

Any questions?

