JOUVENCE OF FLUOR (JOUFLU) AND EXOZODI DEBRIS DISKS

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Thanks to

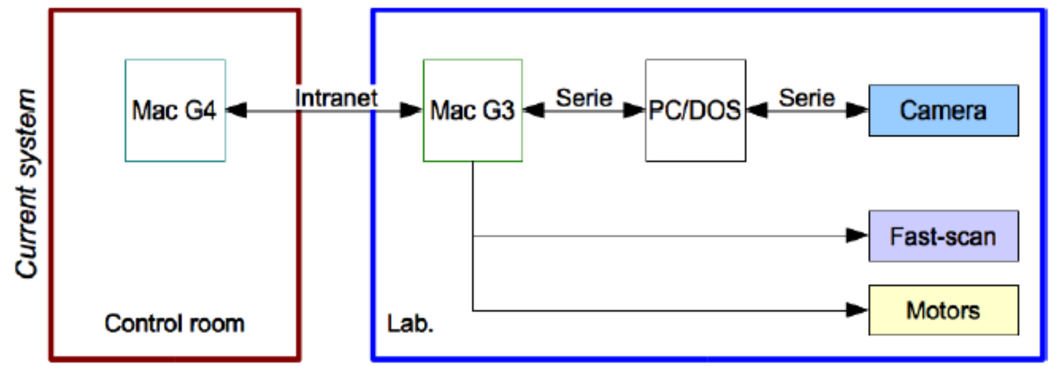
- Hal McAlister
- Vincent Coudé du Foresto
- Theo ten Brummelaar
- Stephen Ridgway
- Olivier Absil
- Emilie LHOME
- Benjamin Mollier

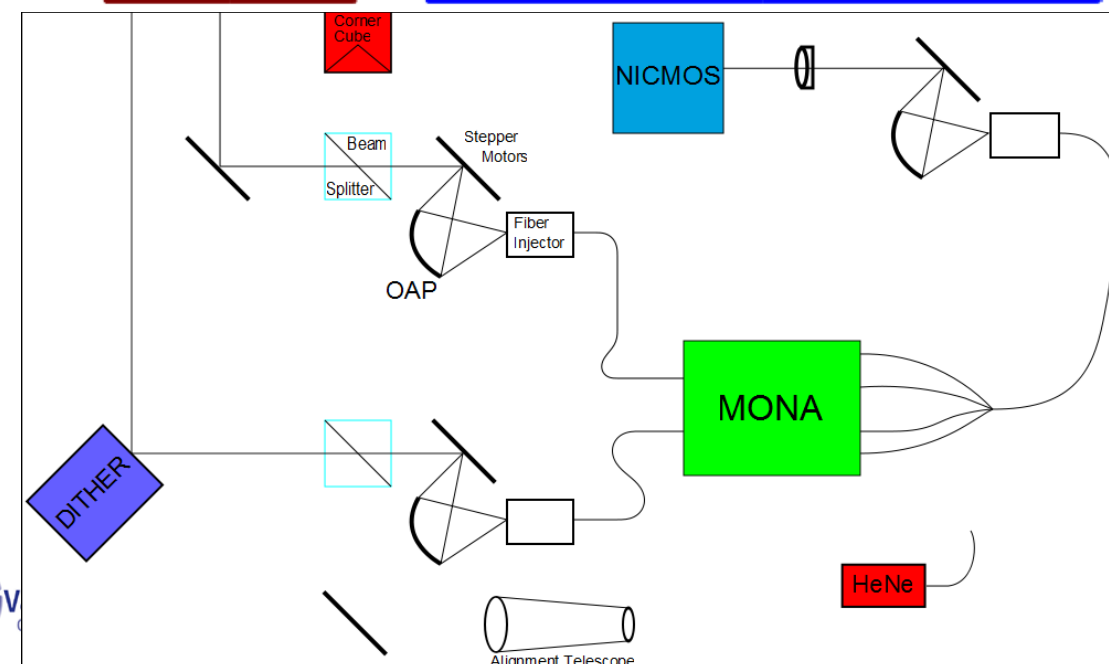
What's new

- FLUOR software upgrades – Summer 2011
- Remote ops setup – Fall 2011
- Remote ops observing run – Oct 2011
- FLUOR hardware upgrades – Feb 2012
  - JouFLU
- Software preparations – Feb 2012
- JouFLU install – Feb 2012
- Component qualification testing – Mar 2012

What ~~is~~ was FLUOR?

- Fiber Linked Unit for Optical Recombination
- Very Brief history of FLUOR
  - 1992 IOTA (5 to 30m baseline)
  - 2002 moved to CHARA
- 2-way beam fiber combiner
- K band, $\lambda = 2.0 - 2.4\ \mu m$
- High precision visibilities
- K mag limit ~ 5
- Dynamic range ~ 300
- Limited by
  - Piston
  - chromatic bias
  - Number of scans





Spatial filtering with fibers

- Single mode fiber
- X coupler, 2 Y couplers
- 125 μm square fiber bundle
- 2 photometric outputs
- 2 interferometric outputs
- Interferometric efficiency (fringe contrast) stable to < 1%
- Visibility precision ~ 0.3%
- Limited by Piston

Uses

- Debris disks and exozodiacal dust around stars
- Young star circumstellar environment, disks
- Cepheid variables, Baade-Wesselink Method
- Mira variables
- Faint companion binaries
- High precision measurement of extended sources
- High dynamic range sources (contrast ratios of 10^2 to 10^6)

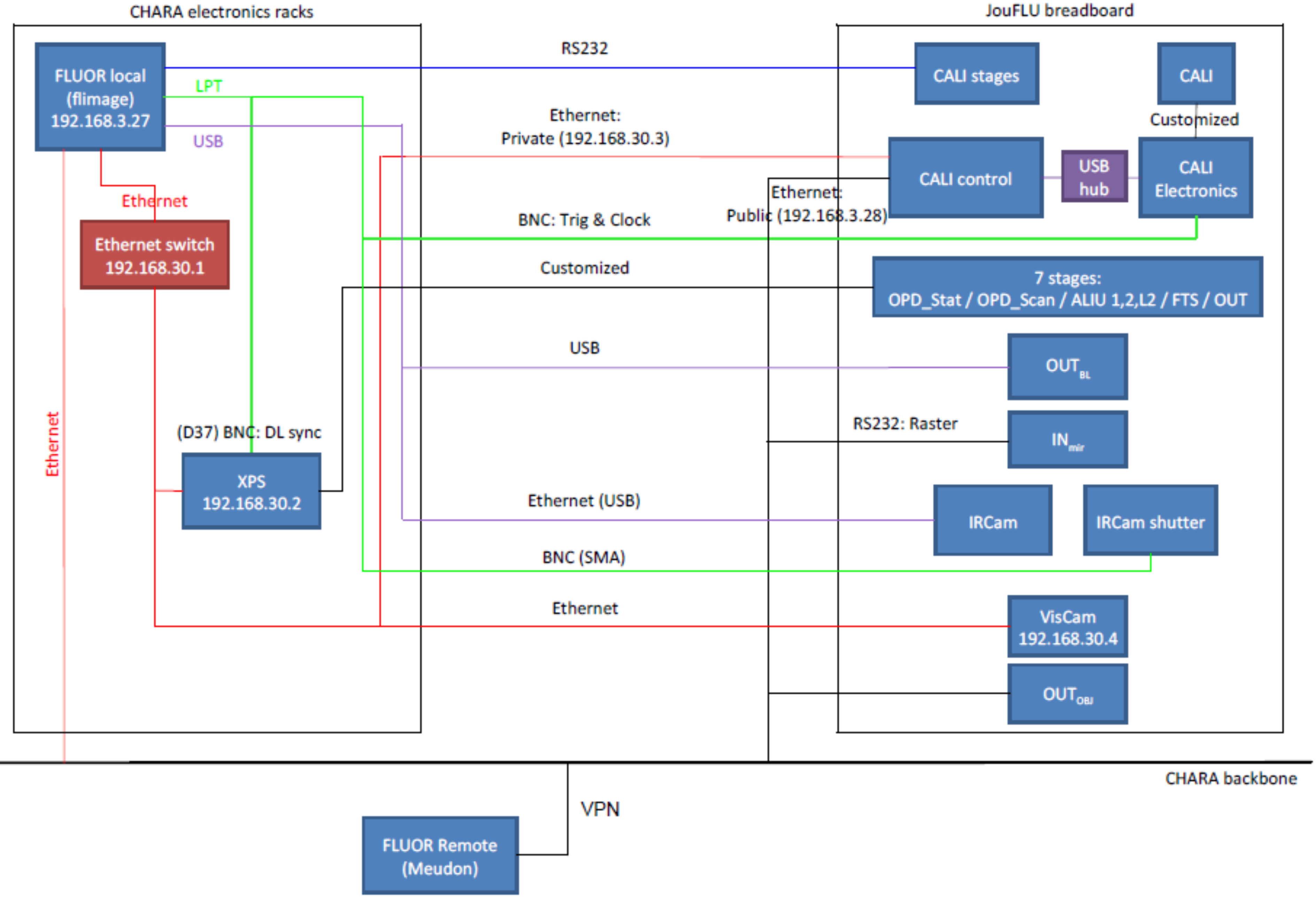
JouFLU

- High speed, high sensitivity camera (CALI)
- Remote operations
- Spectral dispersion mode
- Pupil imaging
- Improved fiber injection
- Improved alignment procedure

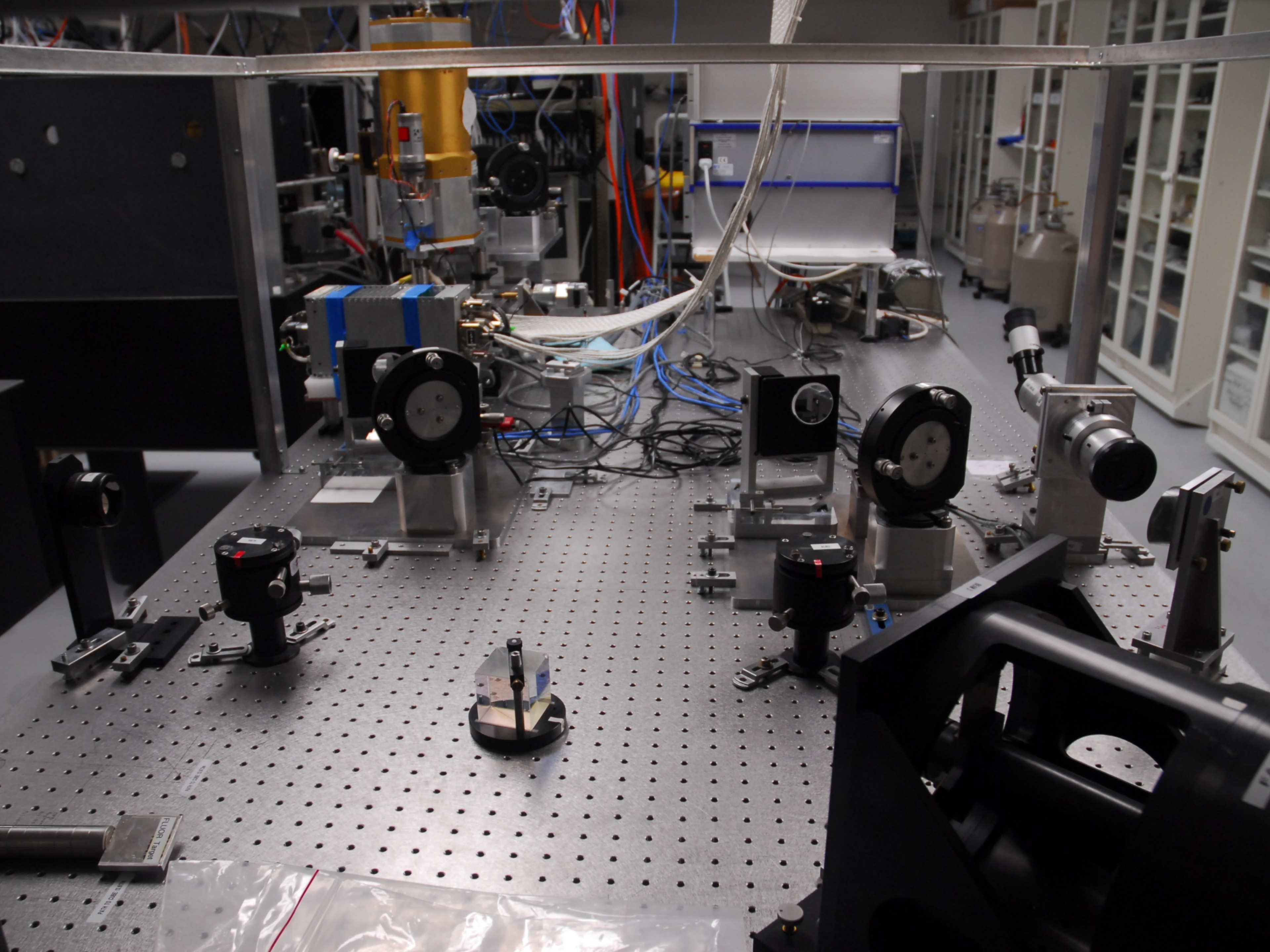
Change to C

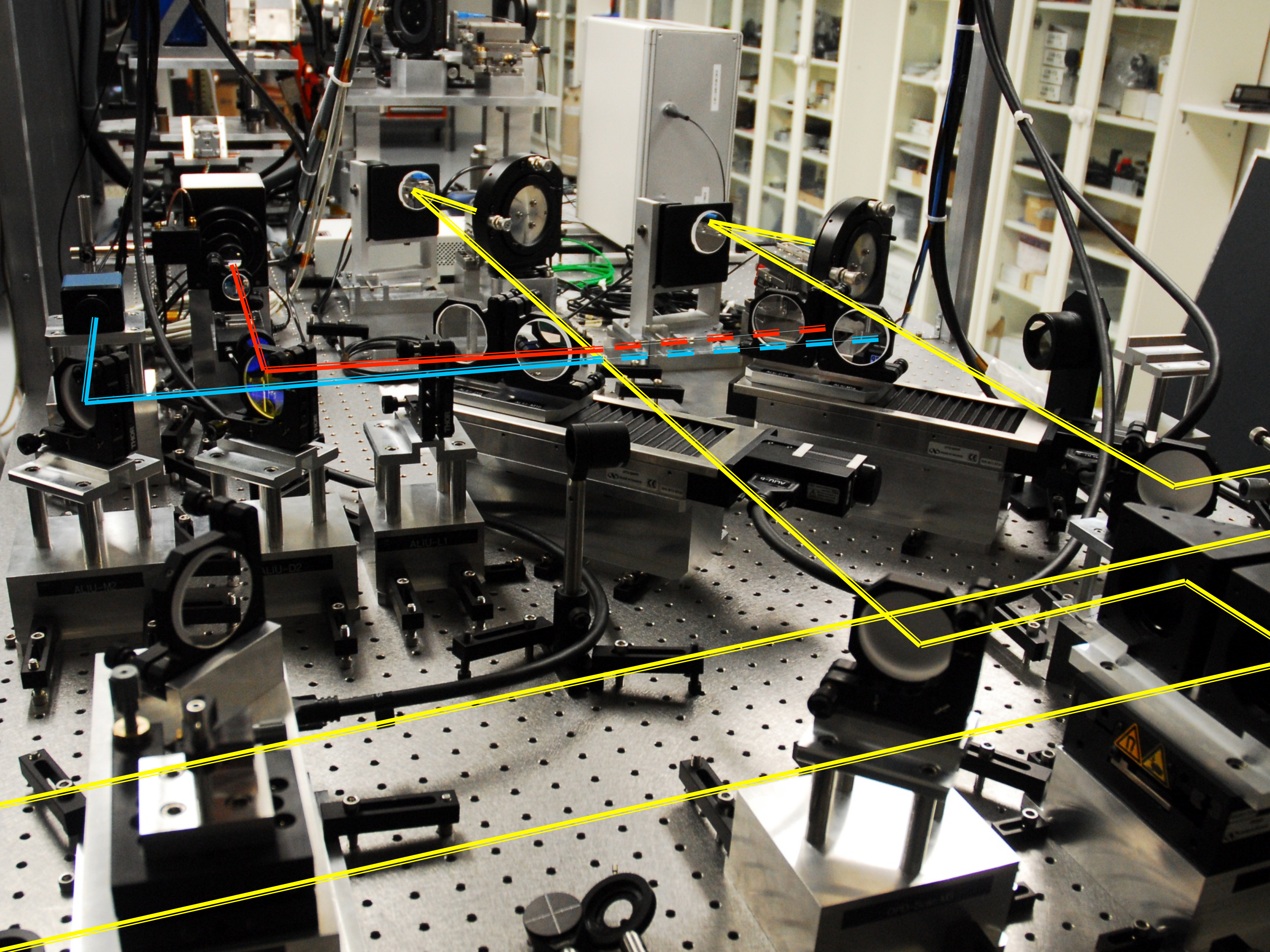
- Compatibility
- Maintenance
- Long term support
- Many layers of automation added for the user (stage selection & fiber alignment)

- Repurpose macs



CHARA electronics racks
JouFLU breadboard
RS232
FLUOR local
(flimage)
192.168.3.27
LPT
USB
CALI stages
CALI
Customized
Ethernet:
Private (192.168.30.3)
CALI control
USB
hub
CALI
Electronics
Ethernet
Ethernet:
Public (192.168.3.28)
BNC: Trig & Clock
Ethernet switch
192.168.30.1
Customized
7 stages:
OPD_Stat / OPD_Scan / ALIU 1,2,L2 / FTS / OUT
USB
OUT_BL
RS232: Raster
IN_mir
Ethernet
(D37) BNC: DL sync
XPS
192.168.30.2
Ethernet (USB)
IRCam
IRCam shutter
BNC (SMA)
Ethernet
VisCam
192.168.30.4
OUT_OBJ
CHARA backbone
VPN
FLUOR Remote
(Meudon)


FLUOR Target


ALIU-M2
ALIU-D2
ALIU-L1


MIRC

Current status report

- Remote ops tested and working
- All optical-mechanical components installed
- Rough alignment completed
  - Higher precision to be completed in March
- CALI data retrieved through CHARA
- IRcam tested and working with white light
- Most software functionality complete
- Expect first fringes in March

Remote operations

VPN
Meudon (PROC?)
Atlanta (AROC)
Sydney (ROCS)
Michigan (ROCMi)
Nice (GROC)

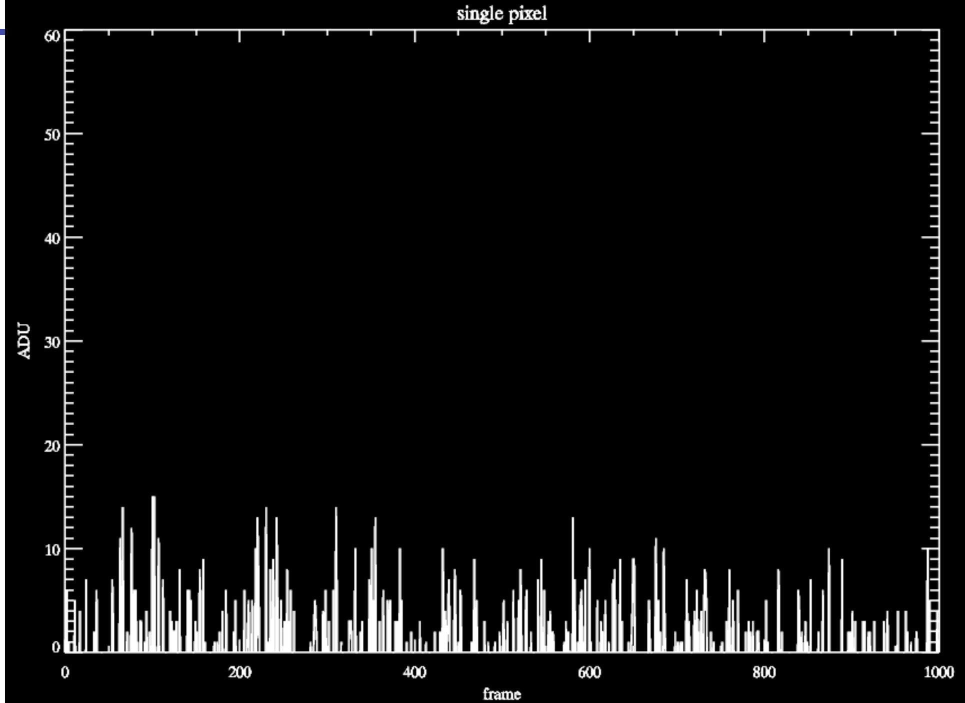
CALI

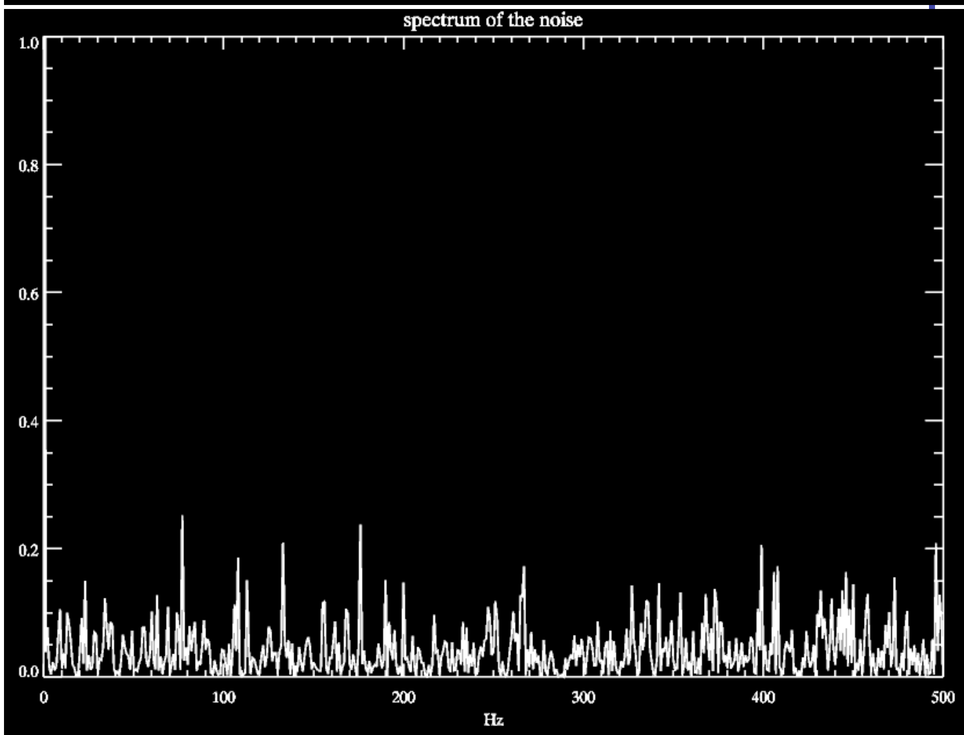
- PICNIC camera
- Mean rms @ 500Hz

  6.5 ADU

  Stand Dev ~16 e^-

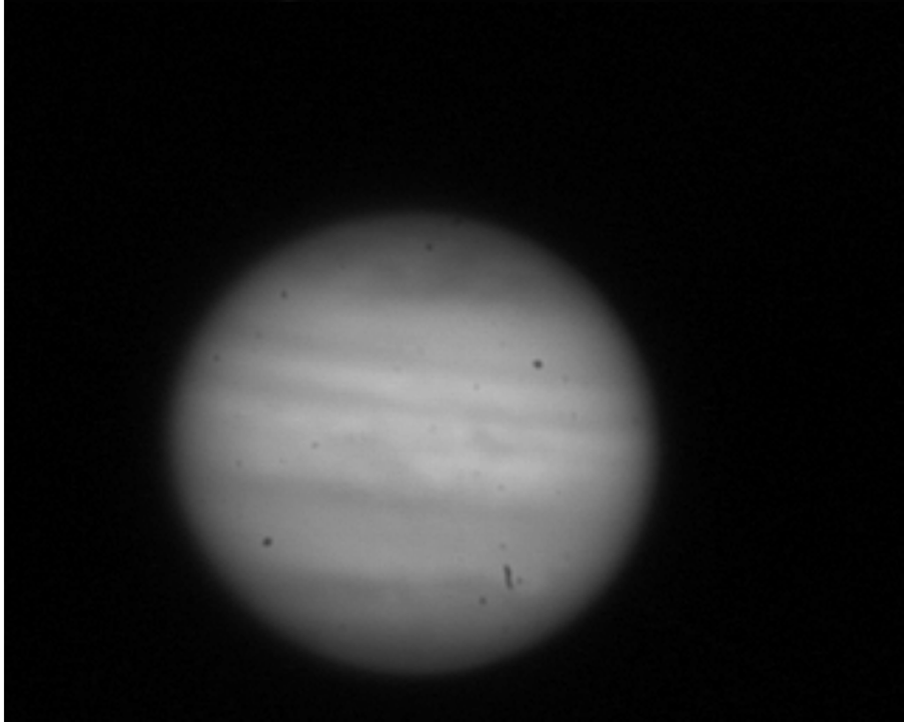
  non-destructive, inc nloops best
- Sensitivity gain of ~1 - 2 magnitude
- Twofold gain of statistical precision
  - Increase data throughput
  - Serial → ethernet
  - 150 interferograms → 600





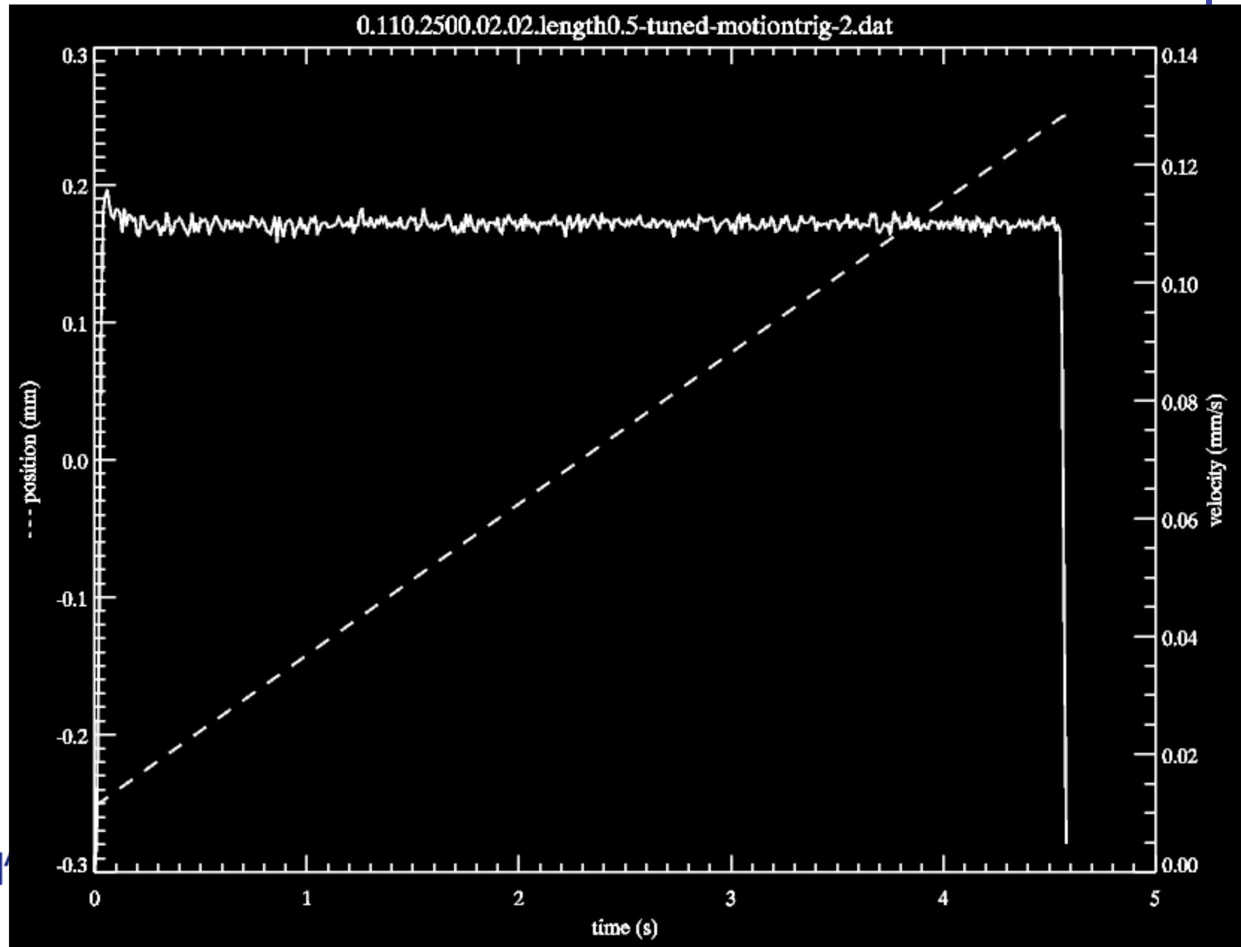
Alignment imaging

- Viscam –image plane
- Ircam –pupil plane
  - 320 by 256 InGaAs
  - H Mag limit = 10 (in tests)
  - H Mag limit = 5 (expected at CHARA)



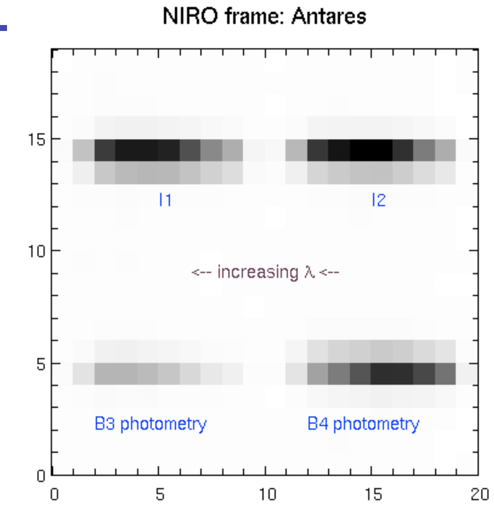
OPD Scan

- Fringe scanning
- Velocity rms ~ 1% over full range
- XMS50
- 110 μm s^{-1} velocity
- 100 Hz fringe scan
- 50 mm travel range
- Replaces piezo stack
- Linear DC motor

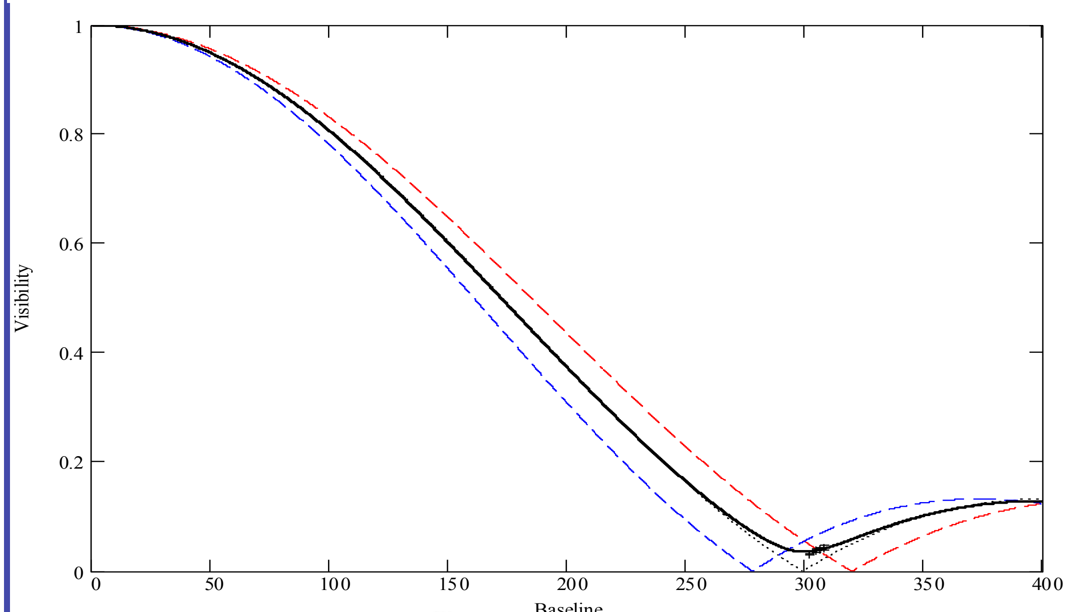


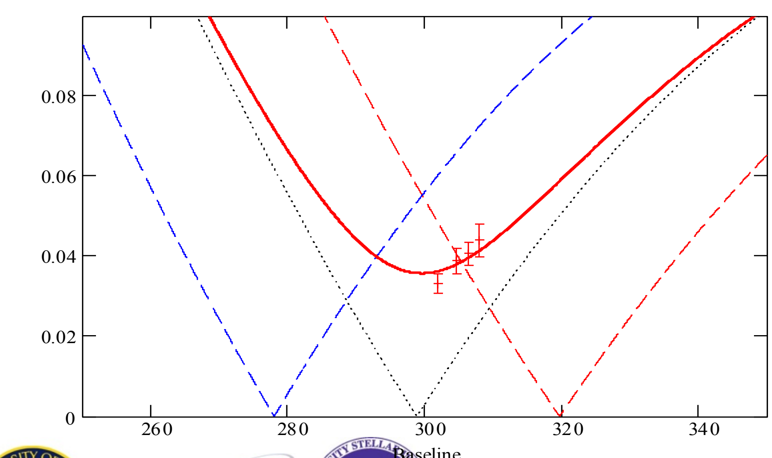
Georgia State University NSF NOAO

Spectral dispersion

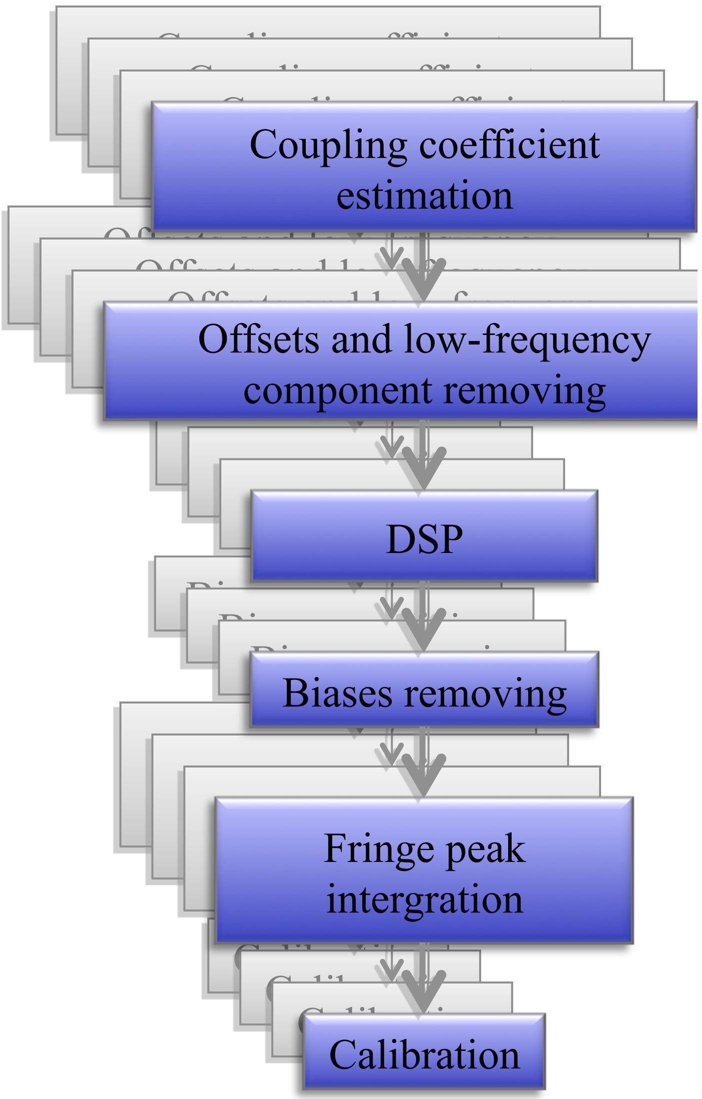


- K band, R=50, 10 spectral channels, ZnSe prism
- Remove chromatic biases / bandwidth smearing

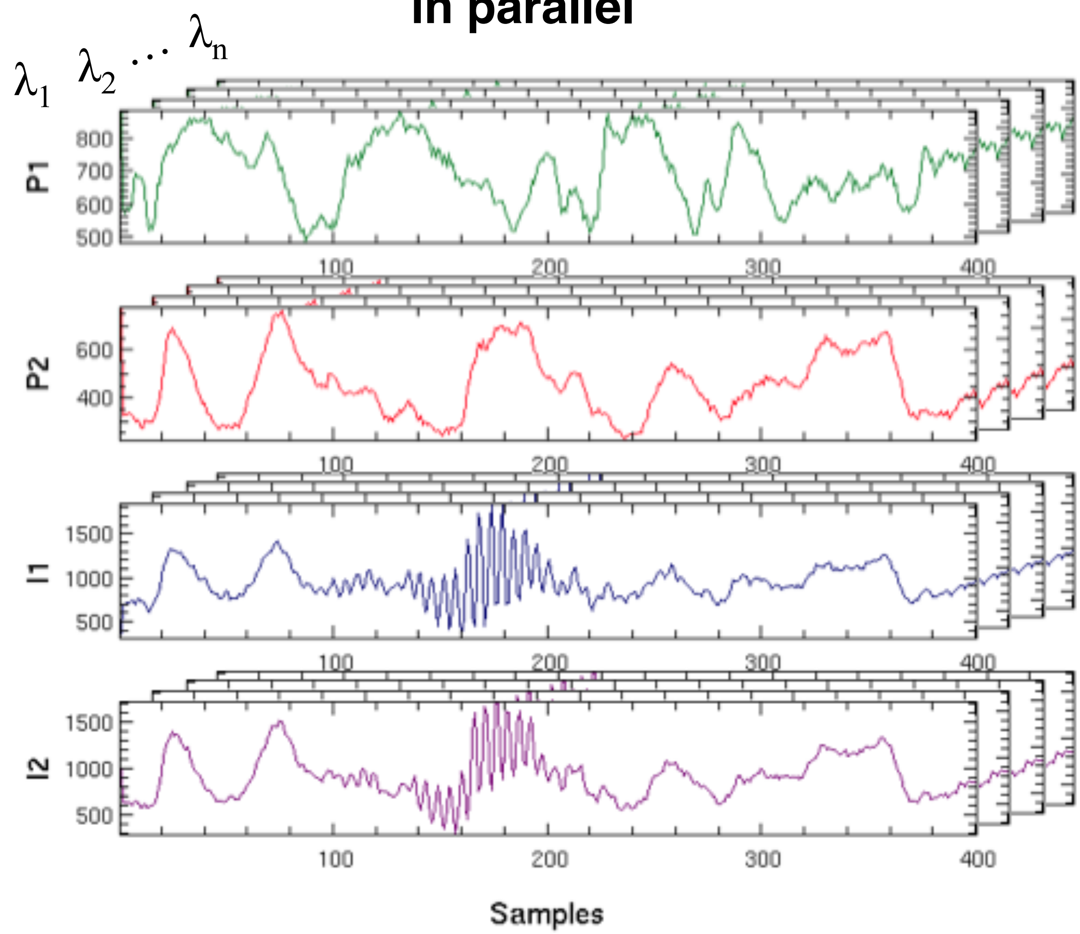




Basic reduction in dispersive mode



First idea: Reduce each channel in parallel



Problem : if pixels are not correctly aligned

- [private use glyph]$_i$ are not the same on I1 and I2.
- We cannot calculate I2 – I1…

  … and eliminated correlated noise.
- But, we have 2 times more spectral channels !

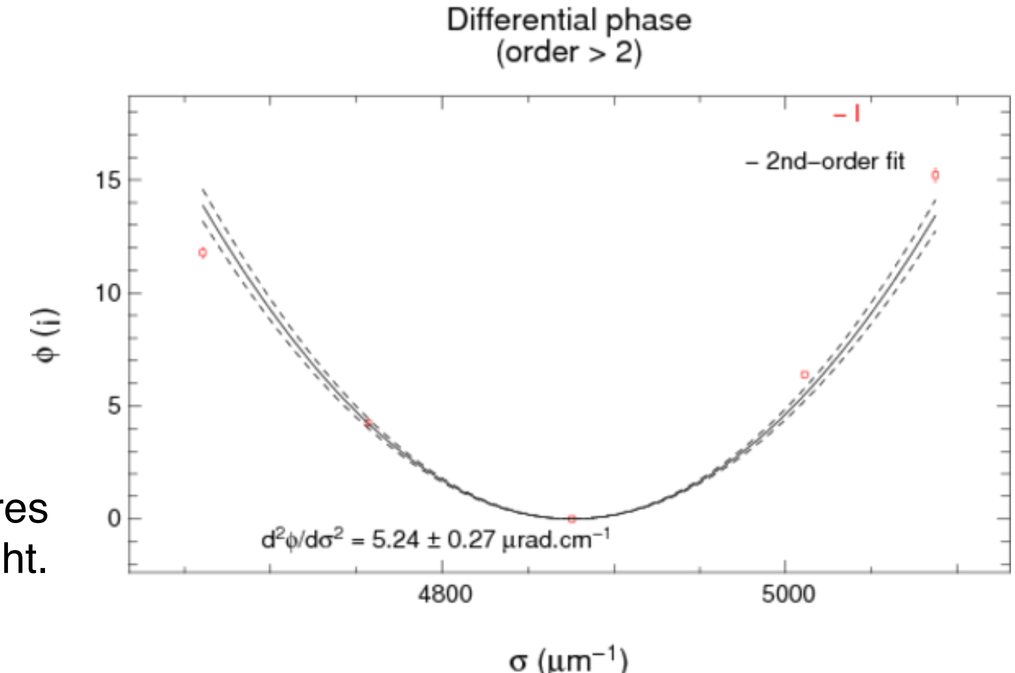
- Idea : Can we use spectral resolution to estimate piston?

  … and obtain information on differential phase.

New : Differential phase

- 2-telescopes interferometry does not allow to measure information about phase of visibility.
- But if we have several spectral channel, we can estimate differential phase between 2 channels

$$\Delta\phi = \phi(\sigma) - \phi(\sigma_0)$$



Phase curvature of FLUOR. Measures obtained in May 2004 with white light.

DEBRIS DISKS

~100 AU

– left over from planetary formation, late heavy bombardment period?

20% of systems are thought to harbor DD

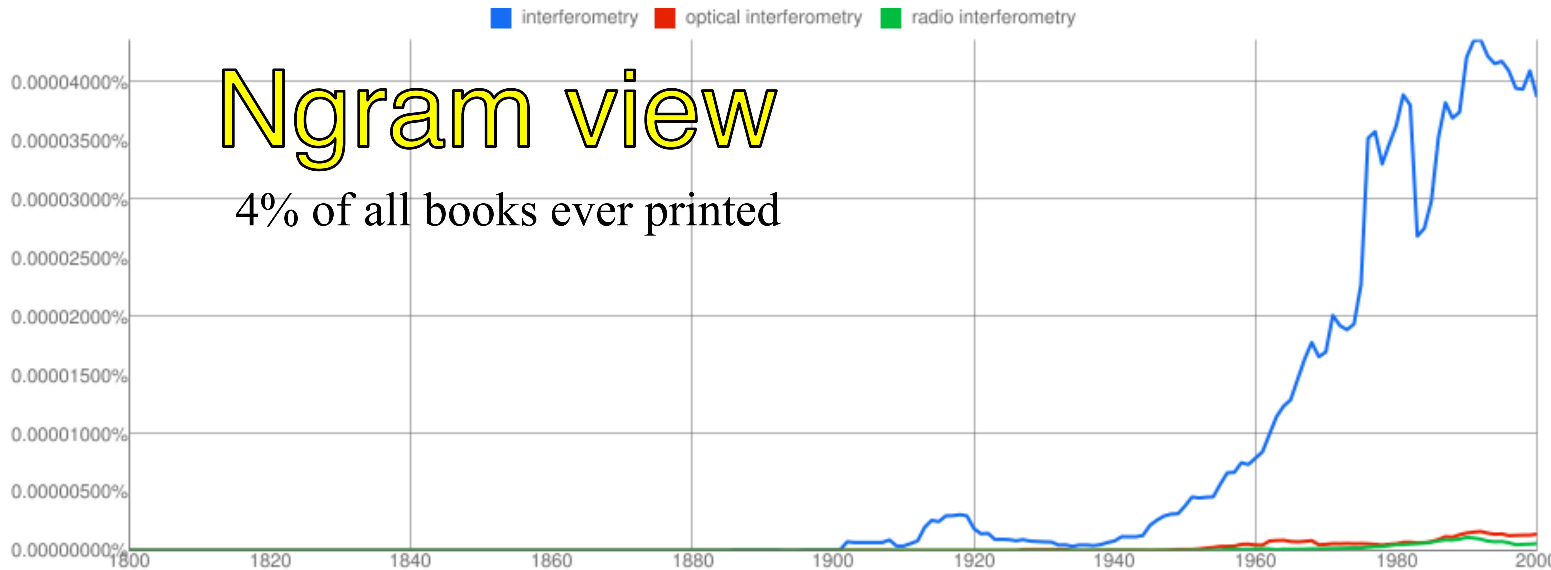
Space missions: IRAS, HST, ISO, Spitzer, Herschel

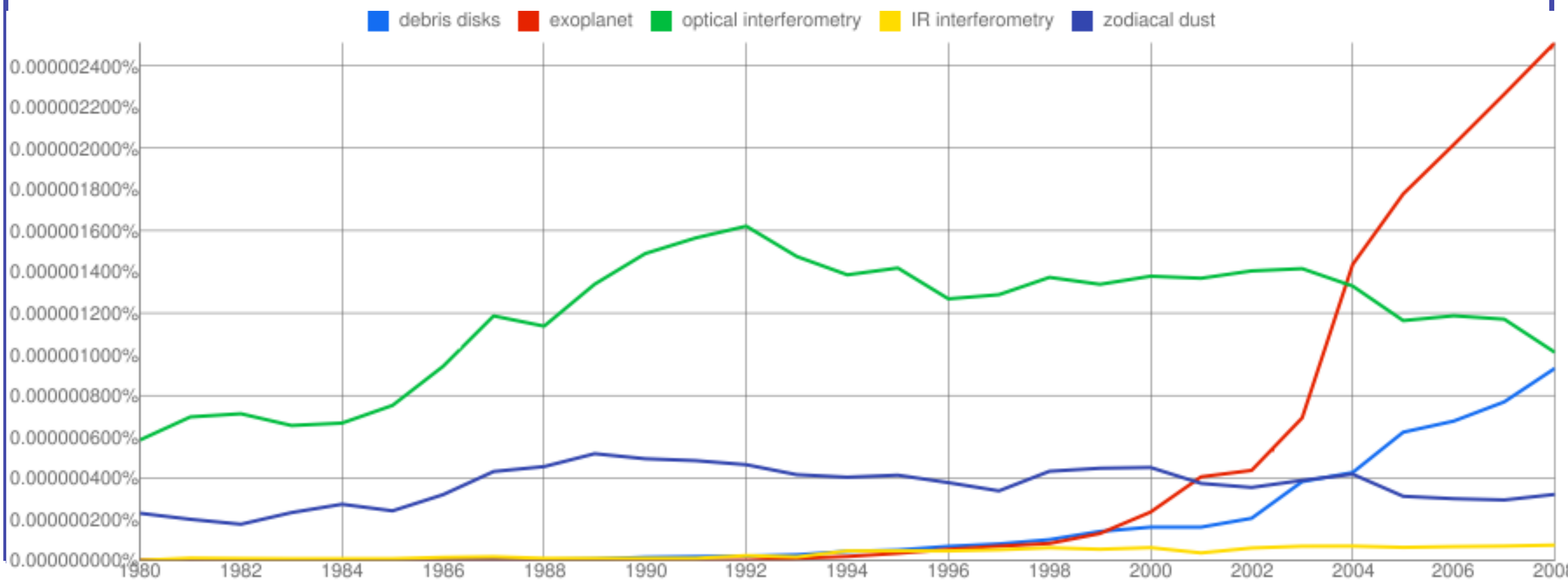
- Far-IR excess
- Sub-mm imaging
- Visible imaging

Structure & asymmetry exoplanets?

Ngram view

4% of all books ever printed





ZODIACAL LIGHT

Exozodiacal analogs

Circumstellar dust

< 1 AU

Warm (300K)

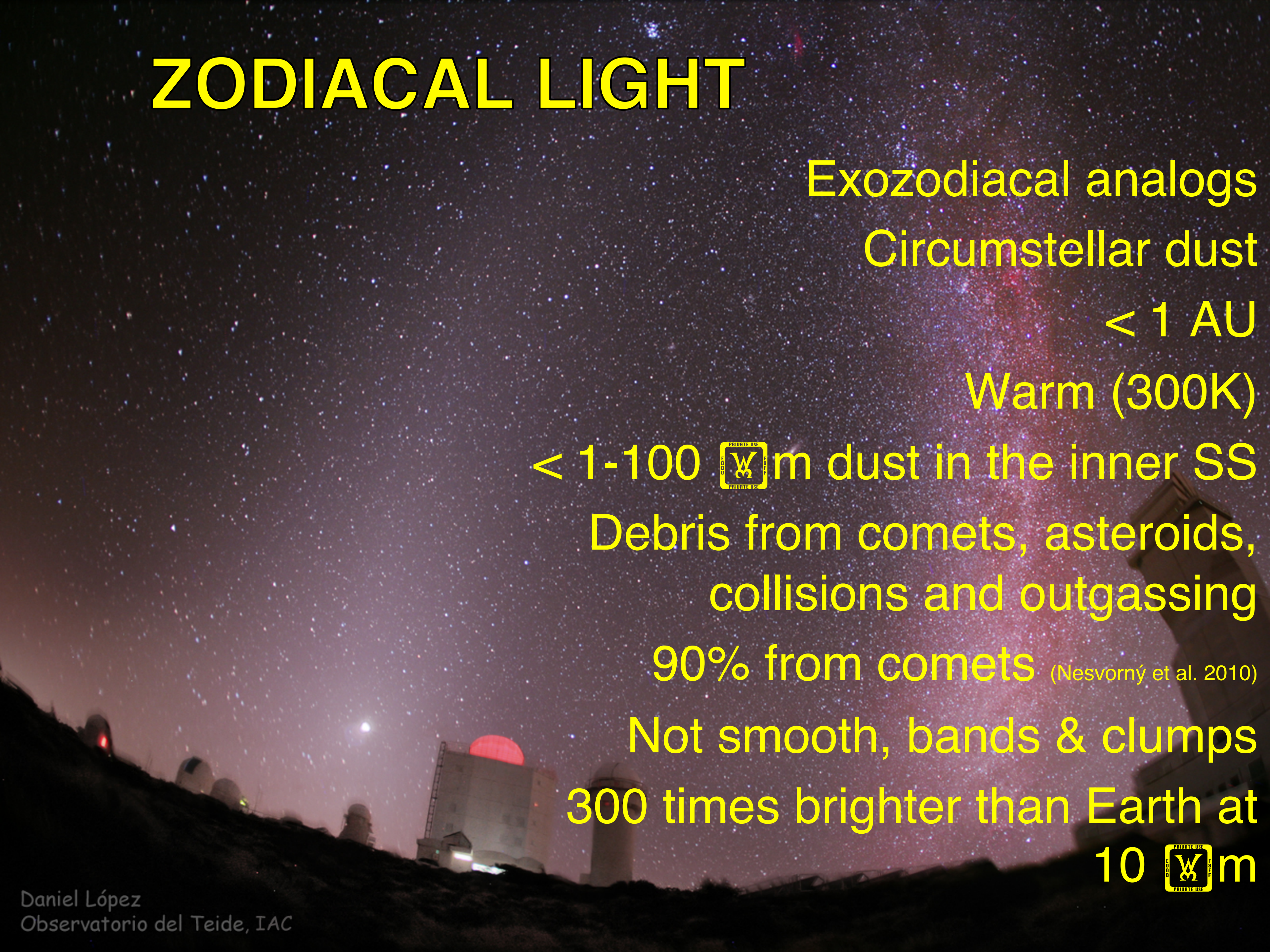
< 1-100 μm dust in the inner SS

Debris from comets, asteroids, collisions and outgassing

90% from comets (Nesvorný et al. 2010)

Not smooth, bands & clumps

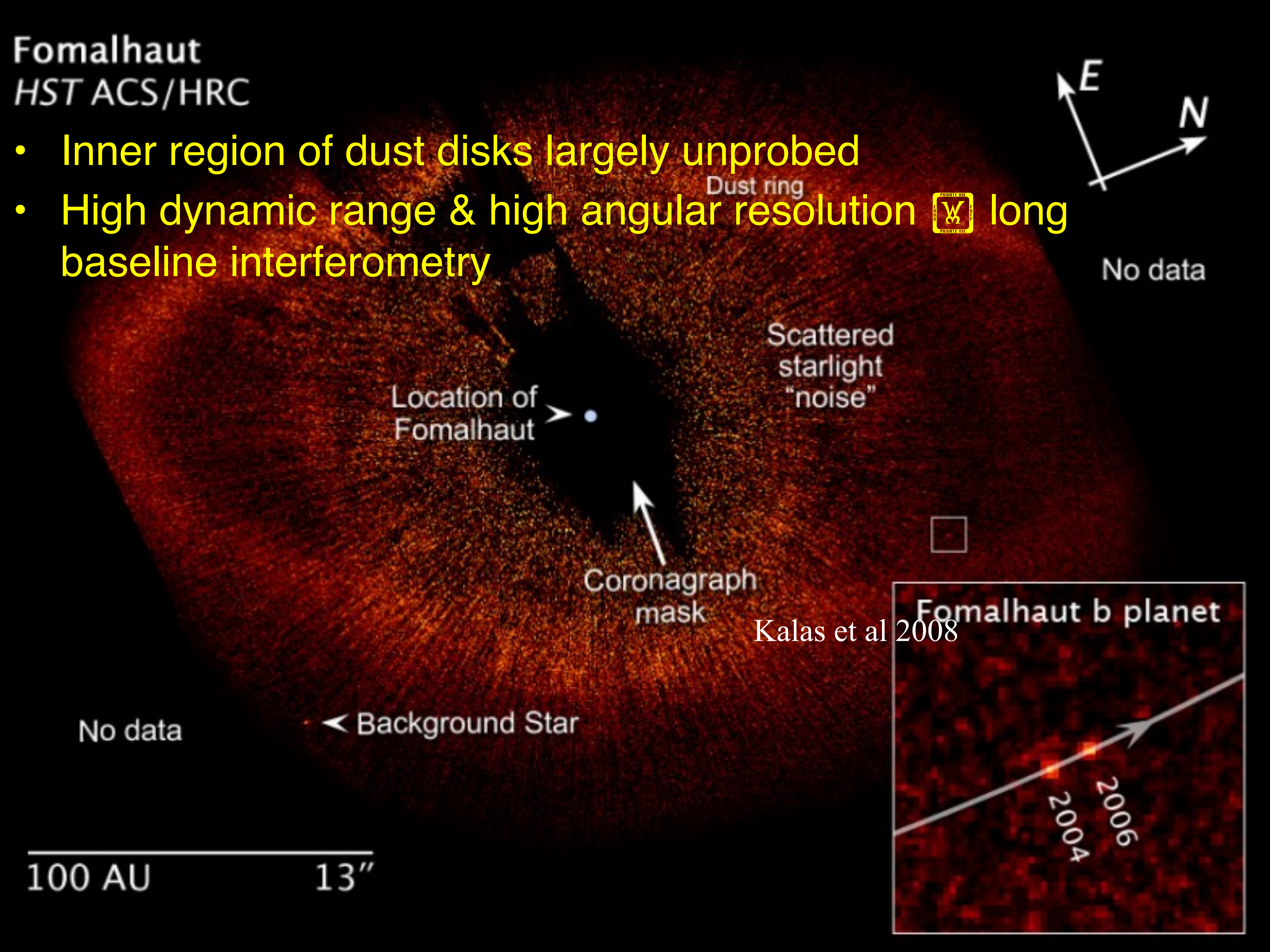
300 times brighter than Earth at 10 μm



Zodiacal light

- Zodi & debris disks are tenuous but huge in surface area
- Exozodi dust emission w/i PSF of 4m telescope at i=60 is 2 magnitudes brighter than Earth at 10pc (Exoplanets, Sara Seager, 2011)
- Current detection limit is ~1000 zodis, want down to 100 or 10s

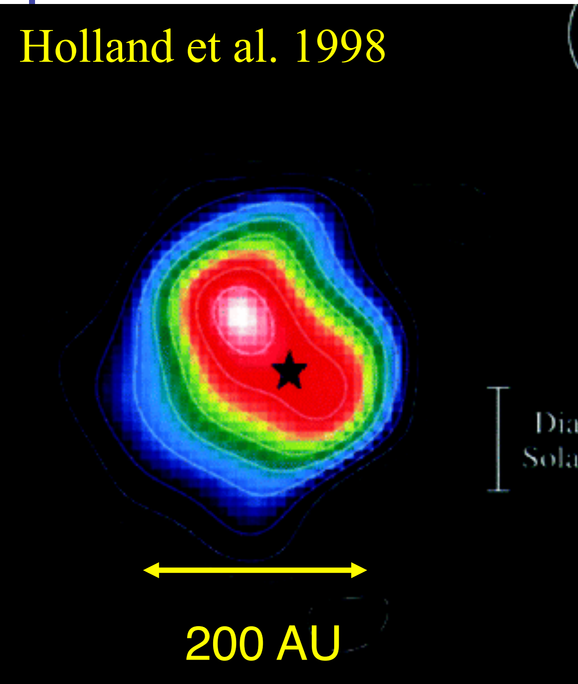
- Inner region of dust disks largely unprobed
- High dynamic range & high angular resolution → long baseline interferometry

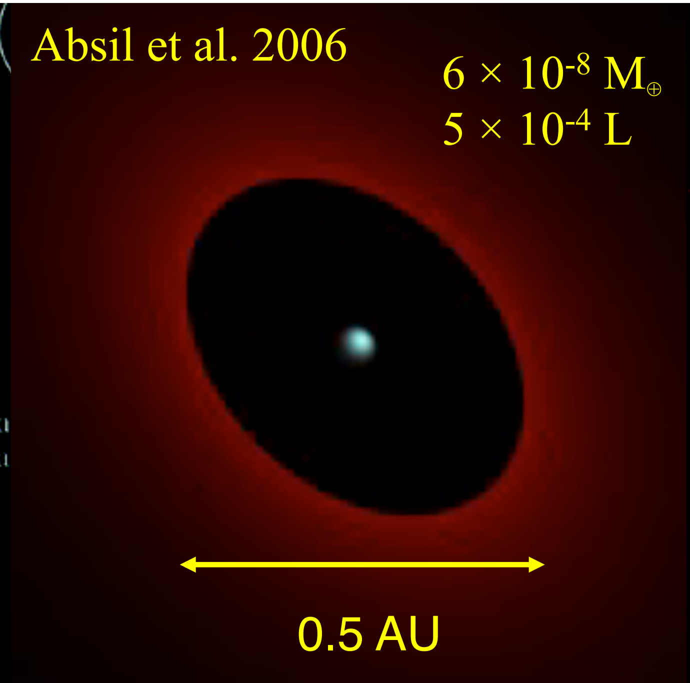


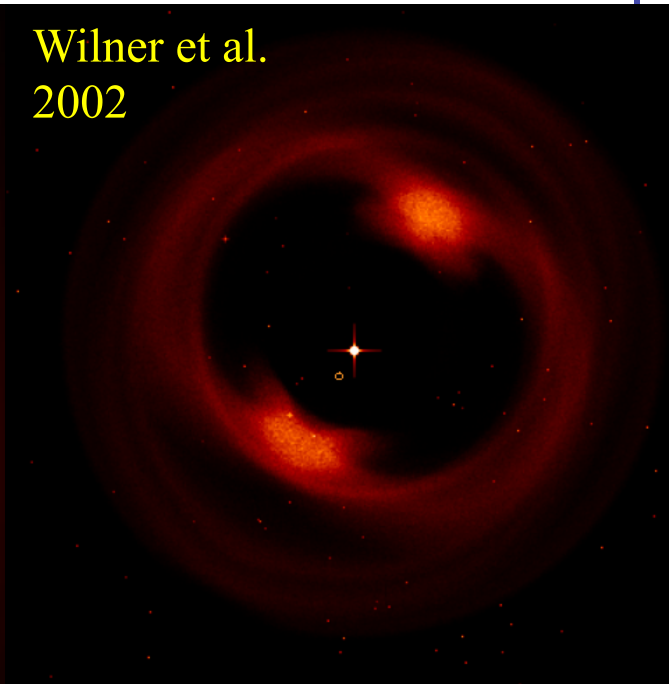
Kalas et al 2008

Vega inner disk

- First detected with NIR interferometry in 2006 (Absil et al.)
- LHB ~350 Myr age
- Sublimation radius ~ 0.1 AU
- Small grains <1 μm 0.1 to 0.5 AU

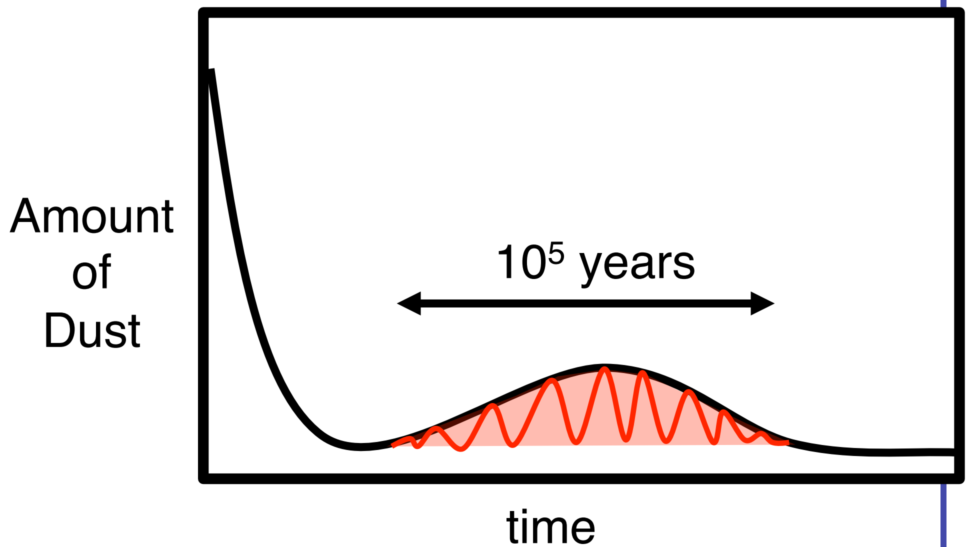






Evolution / dynamics

- Dust production mechanism poorly understood
- Close-in dust extremely short lived
  ~ 10 yr
  ~ 10^{-8} $M_{\oplus}$/yr to replenish
  (10 Hale-Bopp's per day)
- Destruction factors:
  – Sublimation
  – Radiation Pressure
  – Poynting-Robertson (P-R) drag



Revisit Vega and others

• Vega	A0V 450 Myr	7.7 pc
• Eta Corvi	F2V 1.5 Gyr	18.2 pc
• Beta Leo	A3V 100 - 380 Myr	11.1 pc
• Altair	A7V < 1 Gyr	5.1 pc
• 70 Vir	G5V 8.2 Gyr	18.0 pc
• 61 Cygni A – No clear excess observed	K5V 4 Gyr	3.5 pc
• ksi Boo – No clear excess observed	G8V 200 Myr	6.7 pc
• Iot Vir – No clear excess observed	F7IV 4.5 Gyr	22.2 pc
• Lambda Serp – Existing data poor quality	G0V 3.8 - 6.7 Gyr	11.8 pc

JouFLU observations

- Proposal submitted for 2012 Summer Season
  - Will combine with existing debris disk data

Fringe locking/statistical distribution reductions

- SPIE with Charles Hanot
  - "self-calibrating", uses statistical distributions of intensities to determine visibility , assumes no temporal correlation b/t beam intensities and Gaussian errors
  - Order of magnitude improvement over existing methods
  - Requires high number of fast scans

JouFLU & CHAMP

- Gives phase stability
- Reduce piston error
- Longer duration scans
- Improve statistics

Stabilizes OPD
Increased integration time
Increased sensitivity

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