The CHARA Array
Mount Wilson Observatory

Theo ten Brummelaar

Associate Director
Center for High Angular Resolution Astronomy
Mount Wilson Observatory

Georgia State University

CHARA/GSU Participants & Funding

Principal Technical Staff:
Theo ten Brummelaar*
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Todd Henry
Russel White

**Mt. Wilson-based*

Support Staff:
Larry Webster, Site Manager*
Chris Farrington, Operator*
Steve Golden, Asst. Site Manager*
Norm Vargas, Operator*
Nic Scott, Operator/Grad-Student*
Brenda Stith, Business Manager
Dwayne Torres, Machinist

Construction Funding (~$20 M):
National Science Foundation
Georgia State University
W. M. Keck Foundation
David & Lucile Packard Foundation

Current Science Funding (~$1.0 M yr^{-1}):
National Science Foundation
Georgia State University
College of Arts & Sciences
Vice President for Research

Mount Wilson Observatory

View from the mountain – September 2009

The CHARA Consortium

Georgia State University

NSF

NOAO

THE UNIVERSITY OF MICHIGAN
ARTES · SCIENTIA · VERITAS
1817

SUSI
SYDNEY UNIVERSITY STELLAR INTERFEROMETER
AUSTRALIA

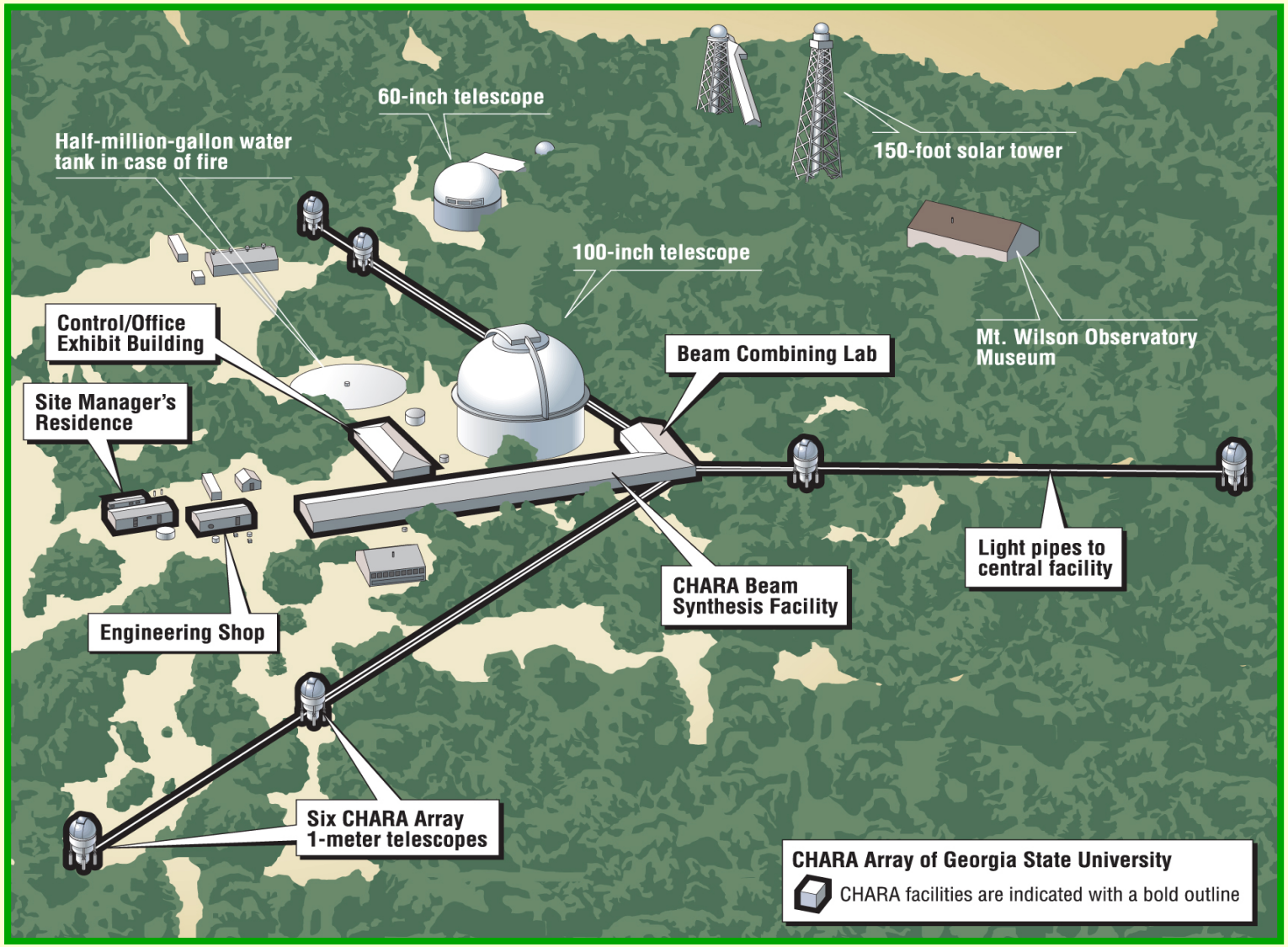
l'Observatoire de Paris | LESIA

Observatoire de la CÔTE d'AZUR

Max-Planck-Institut für Radioastronomie

NExScI
NASA Exoplanet Science Institute

Layout of the CHARA Array



Telescopes

CAD by Laszlo Sturmann

Photo by Steve Golden

Vacuum Light Tubes I

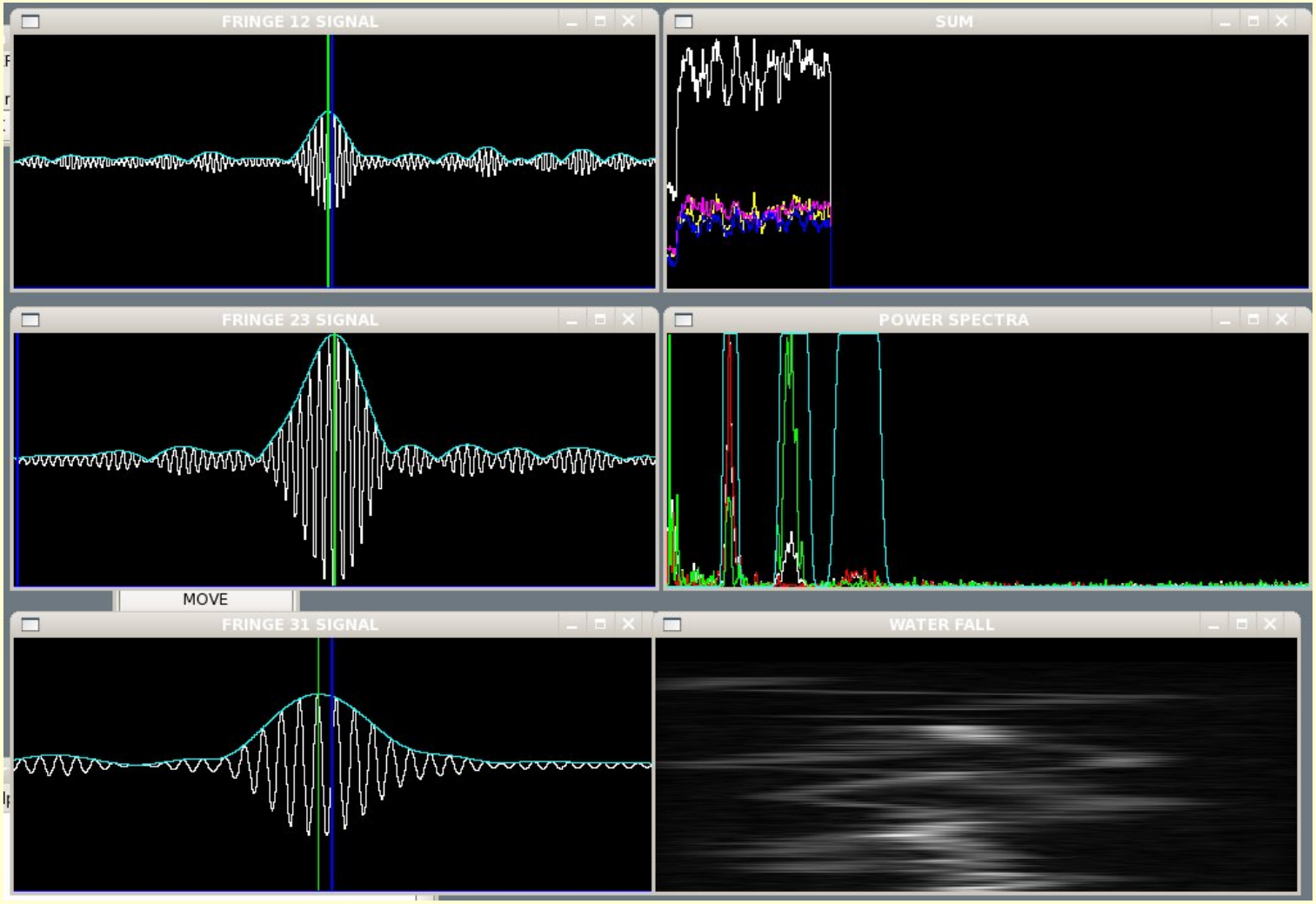
Feed Light from Each Telescope to the Central Lab

The 30 second CHARA tour

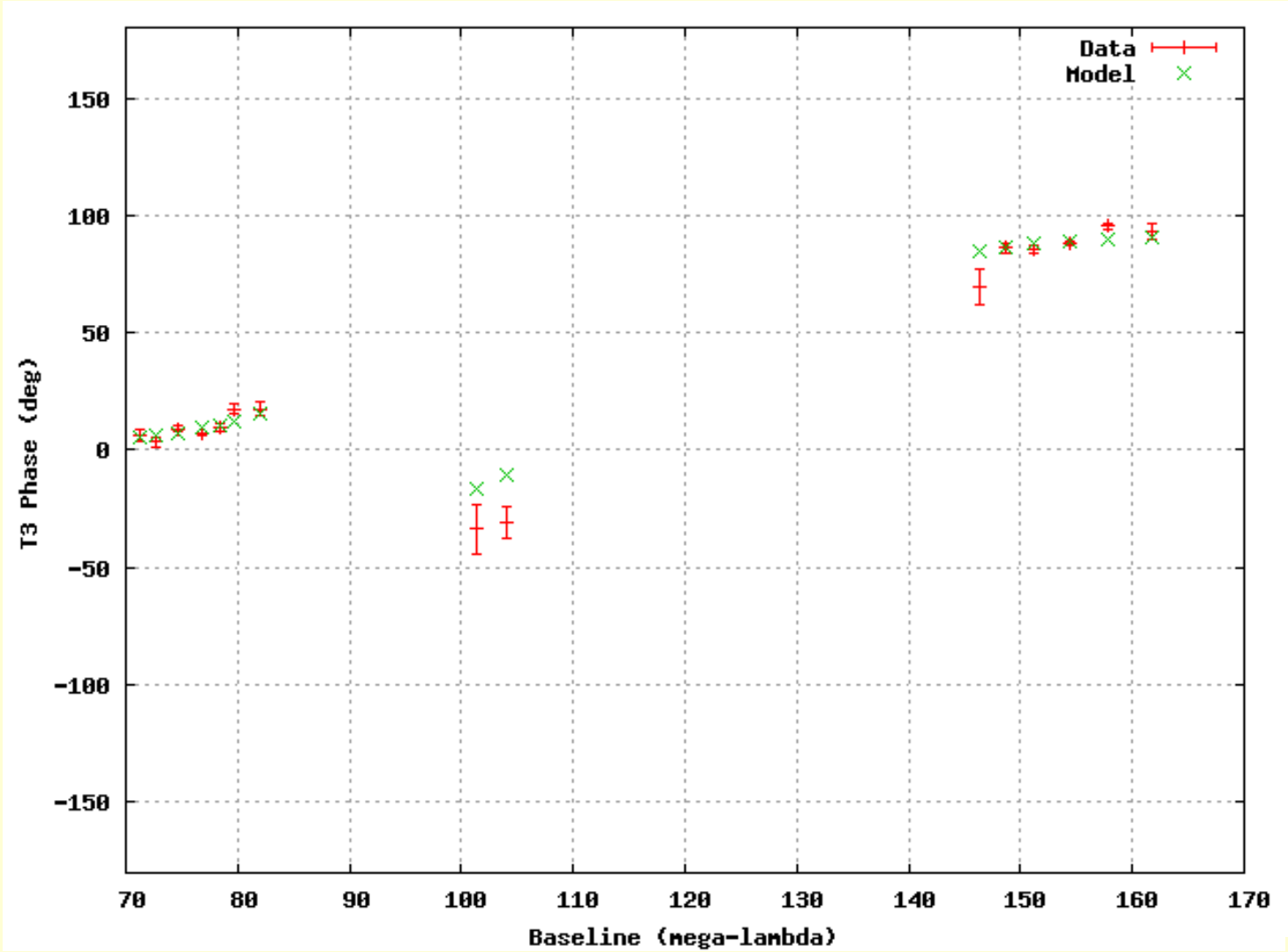
"Beam Combiners are us"

- CHARA CLASSIC – 2 way open air J, H & K
- CHARA CLIMB – 2x3 way open air J, H & K
- FLUOR – 2 way fiber based K band
- MIRC – 6 way fiber based imager J, H & K
- VEGA – 4 way open air V,R,I R=30000
- PAVO – 3 way aperture plane V,R,I
- CHAMP – 6 beam fringe tracker J, H & K

CLIMB: CLassic Interferometry on Multiple Baselines

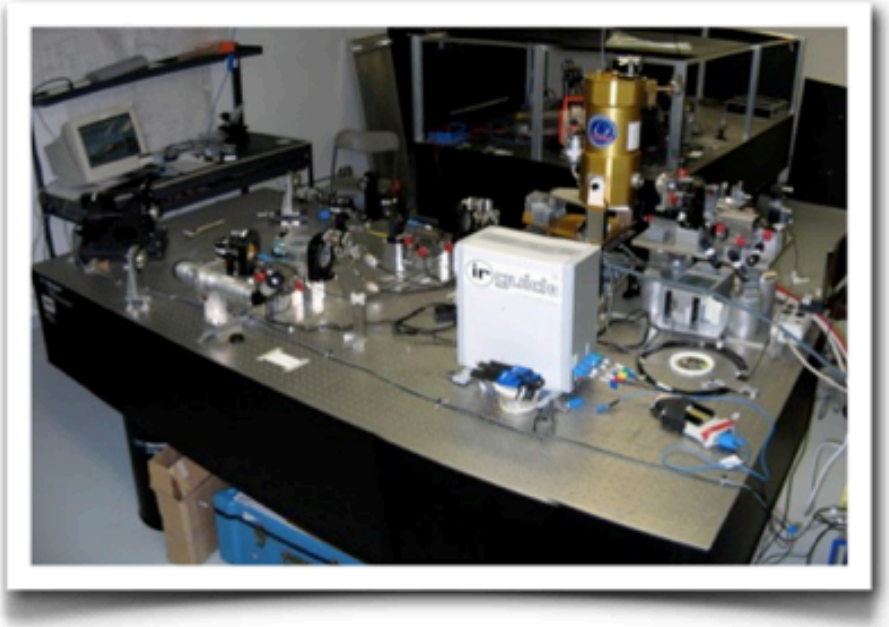


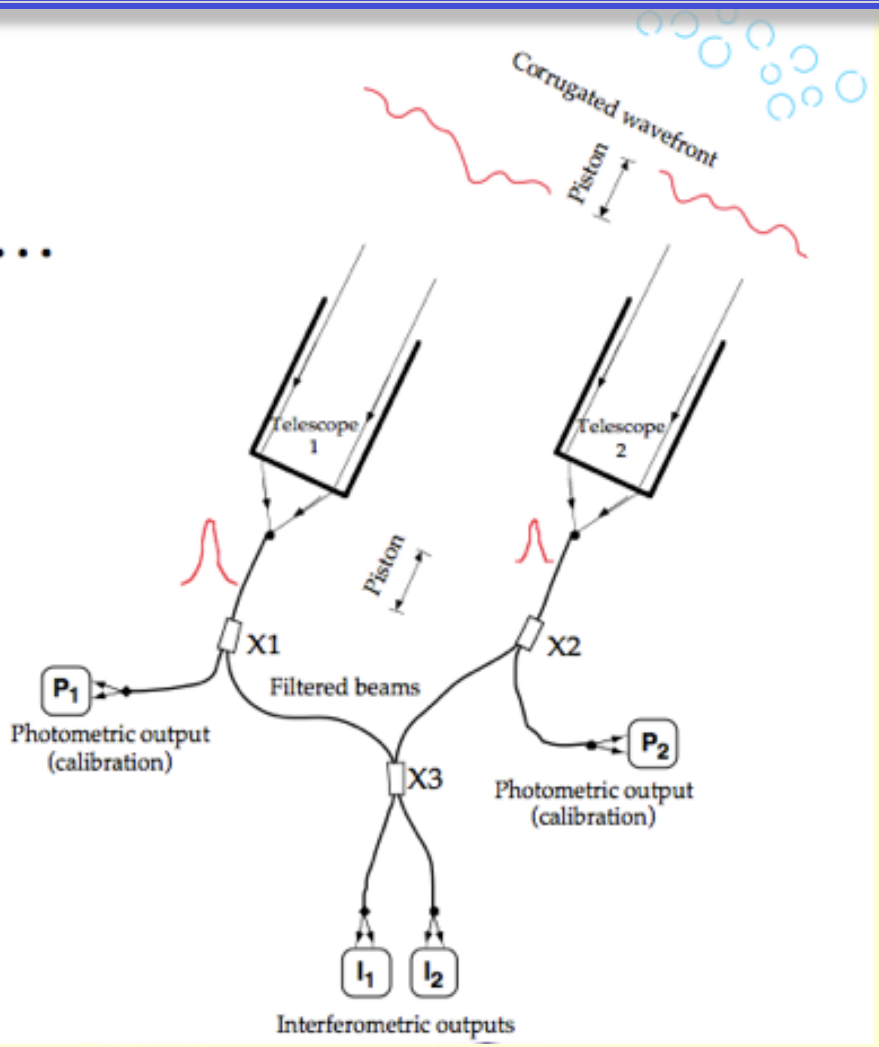
CLIMB: Example data Eps Aur 2011



FLUOR: Fiber Linked Unit for Optical Recombination

- High accuracy V^2 science
  - Two telescopes so no phase…
  - Broad K band (so far)

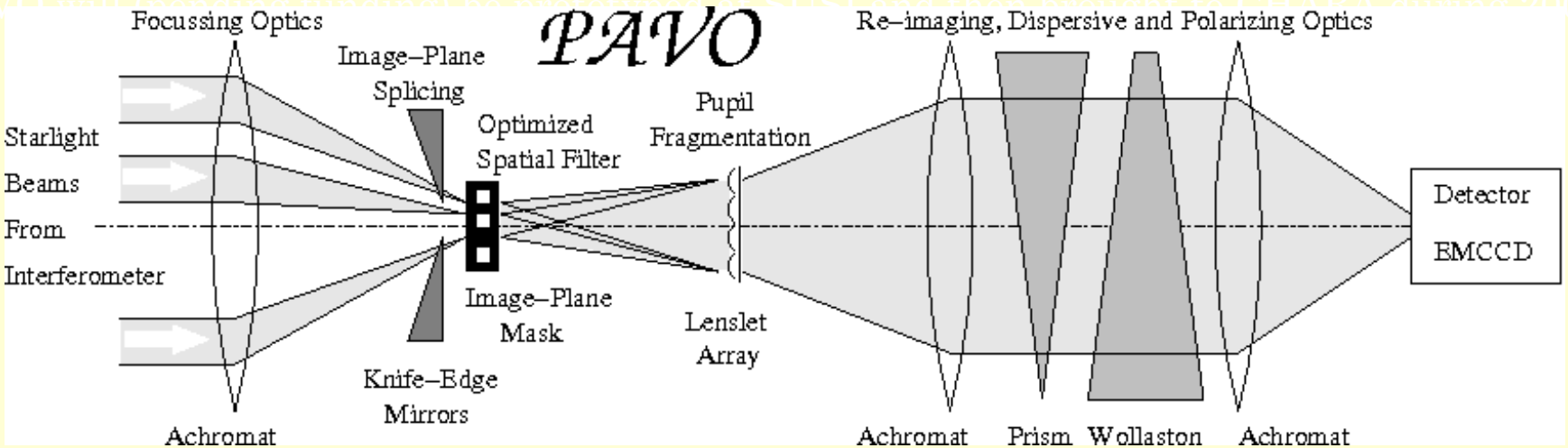




What is PAVO (A Spanish turkey) ?

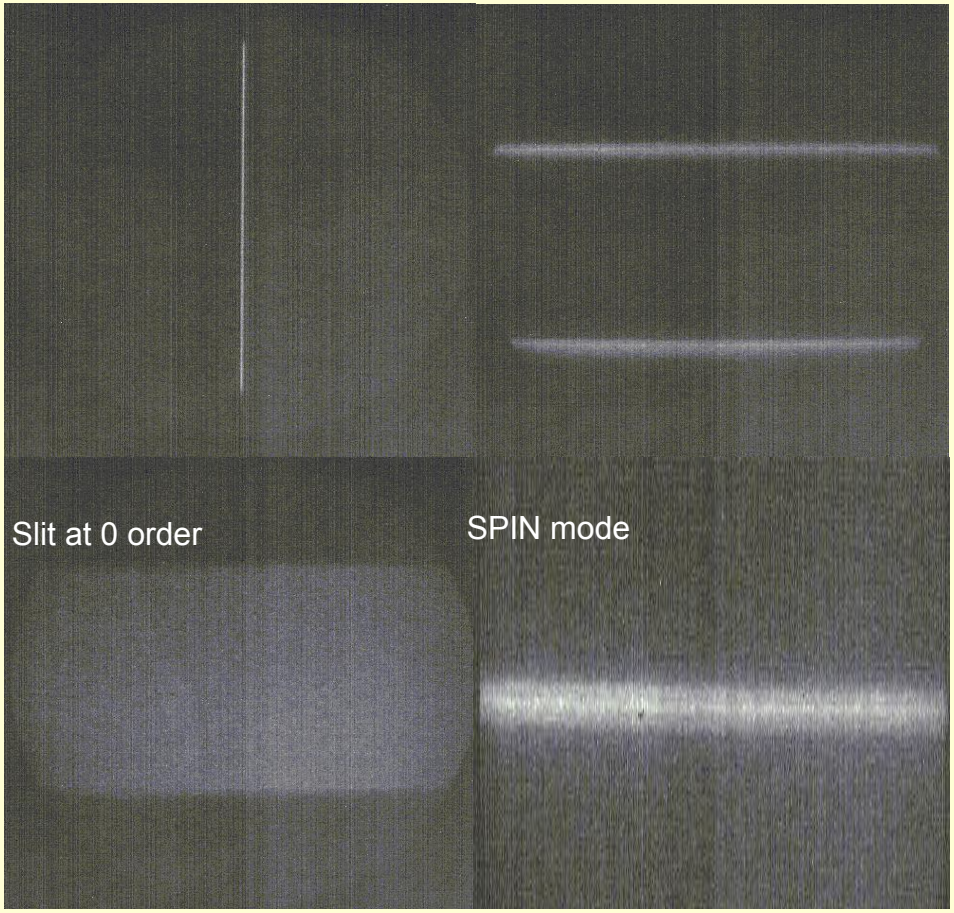
- PAVO is an integral-field-unit for measuring spatially-modulated pupil-plane fringes.
- PAVO combines three beams for closure phase and has the highest sensitivity of all instruments in the visible wavebands.
- PAVO has been completed at CHARA and, weather pending, will be comissioned at SUSI next week.

PAVO is an integral-field-unit for measuring spatially-modulated pupil-plane fringes.
PAVO will (pending funding) be prototyped on SUSI and then brought to CHARA during 2009



VEGA: Visible spEctroGraph and polArimeter

- Highest spectral resolution in the visible (R=30000).
- Combines up to four beams
- Uses a combination of Single Slit Spectroscopy, Speckle Interferometry and "Real" Interferometry.

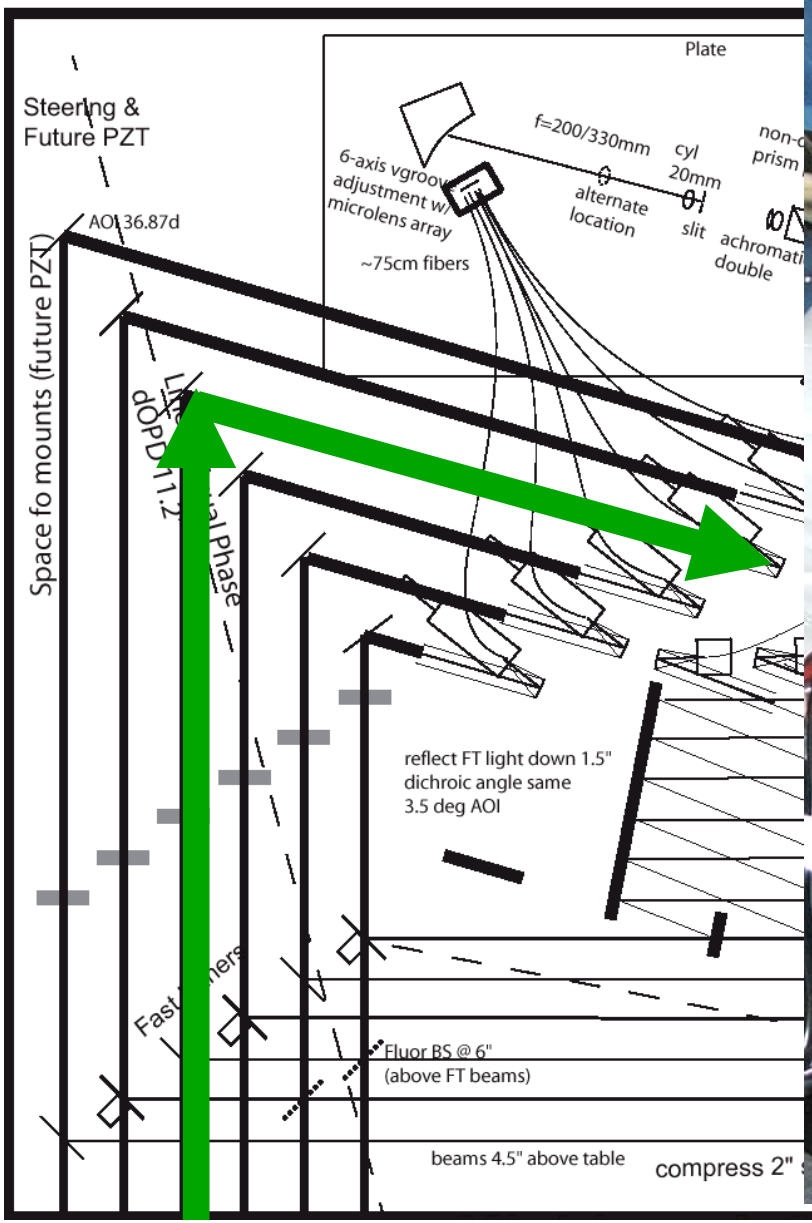


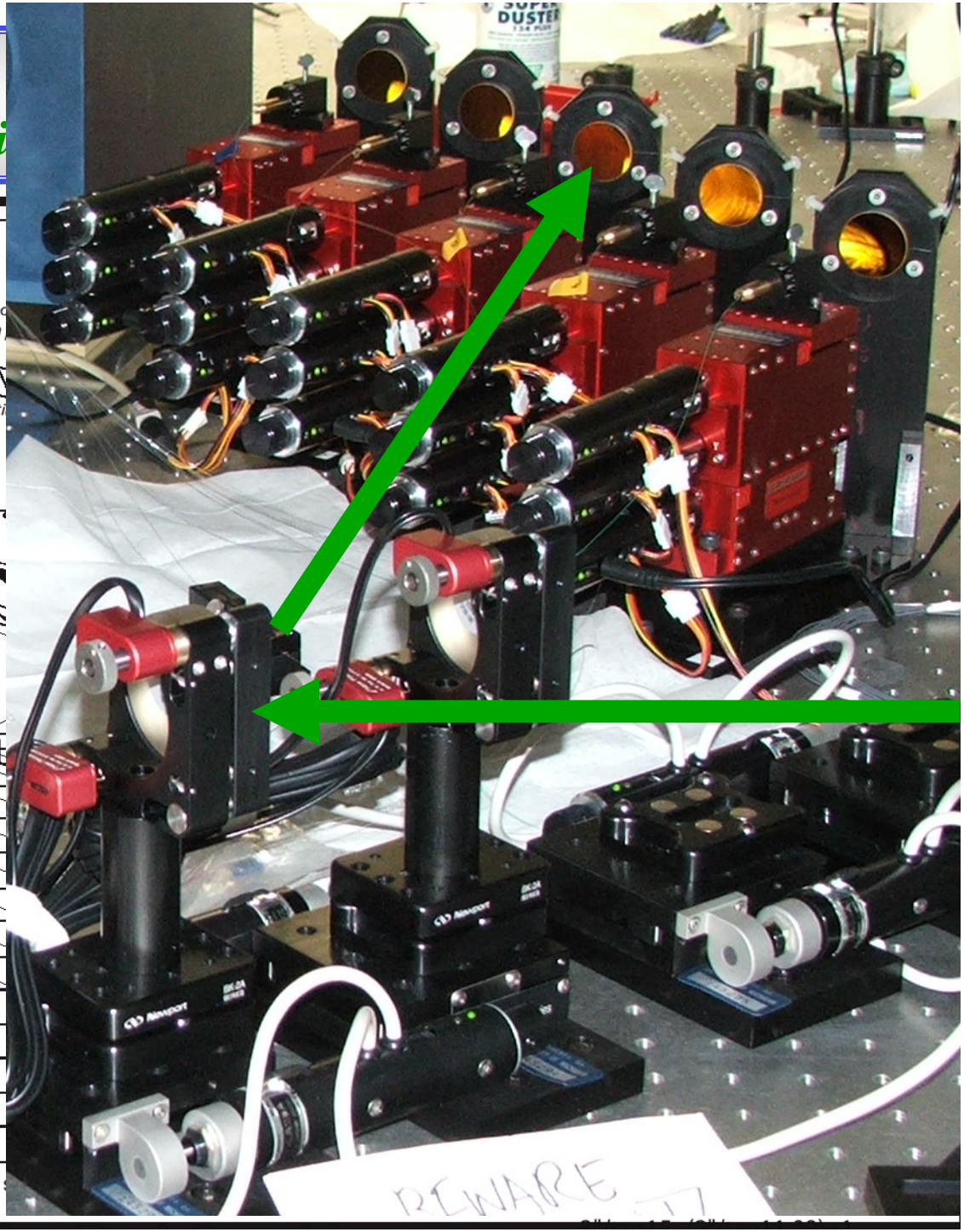
Dispersed flat field

Dispersed fringes

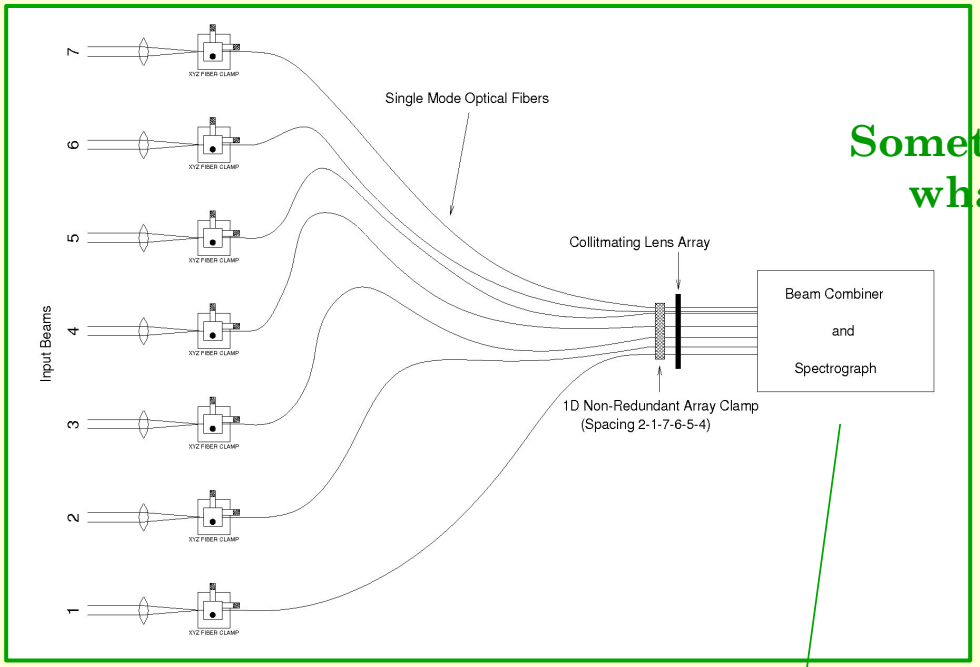
MIRC: Michigan

Maki

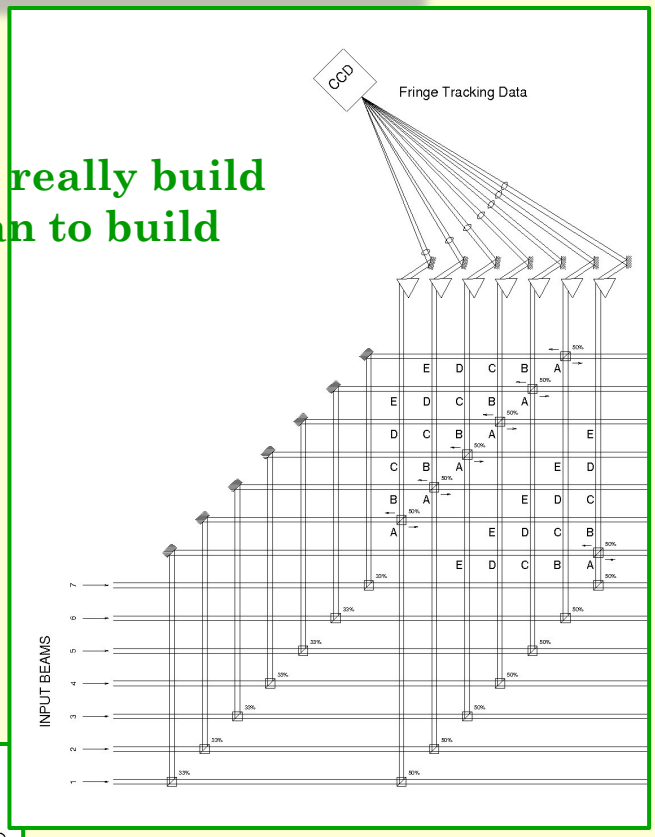


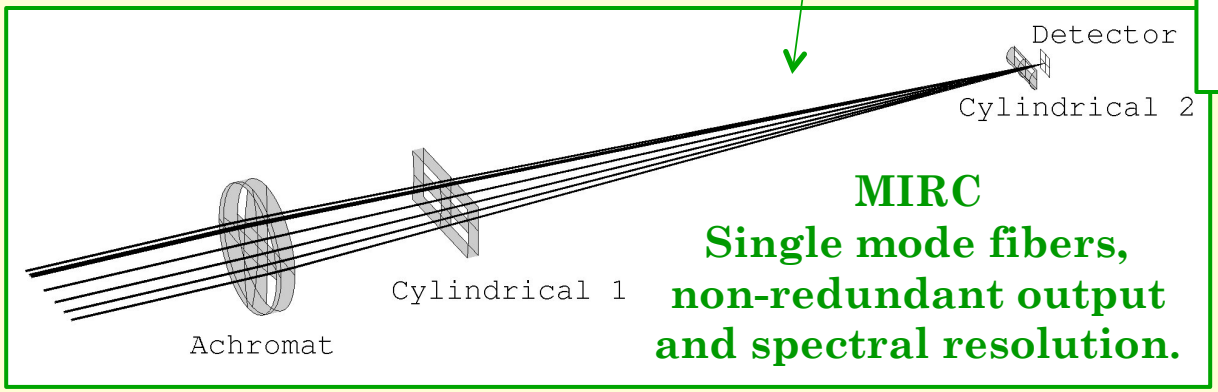


Diagrams from SPIE 1994



Sometimes you really build what you plan to build





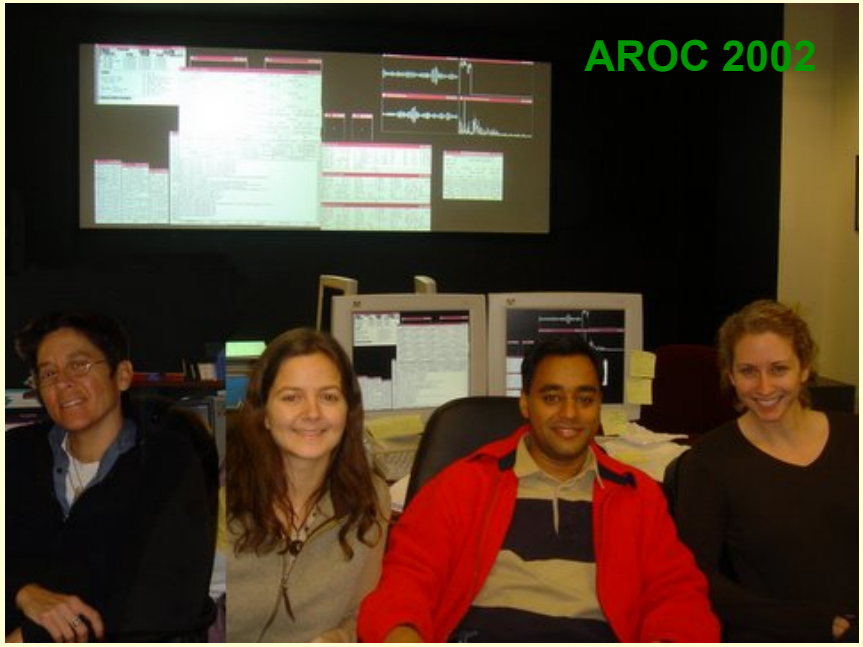
MIRC
Single mode fibers, non-redundant output and spectral resolution.

CHAMP
Separation of science beam combiner from fringe tracker.

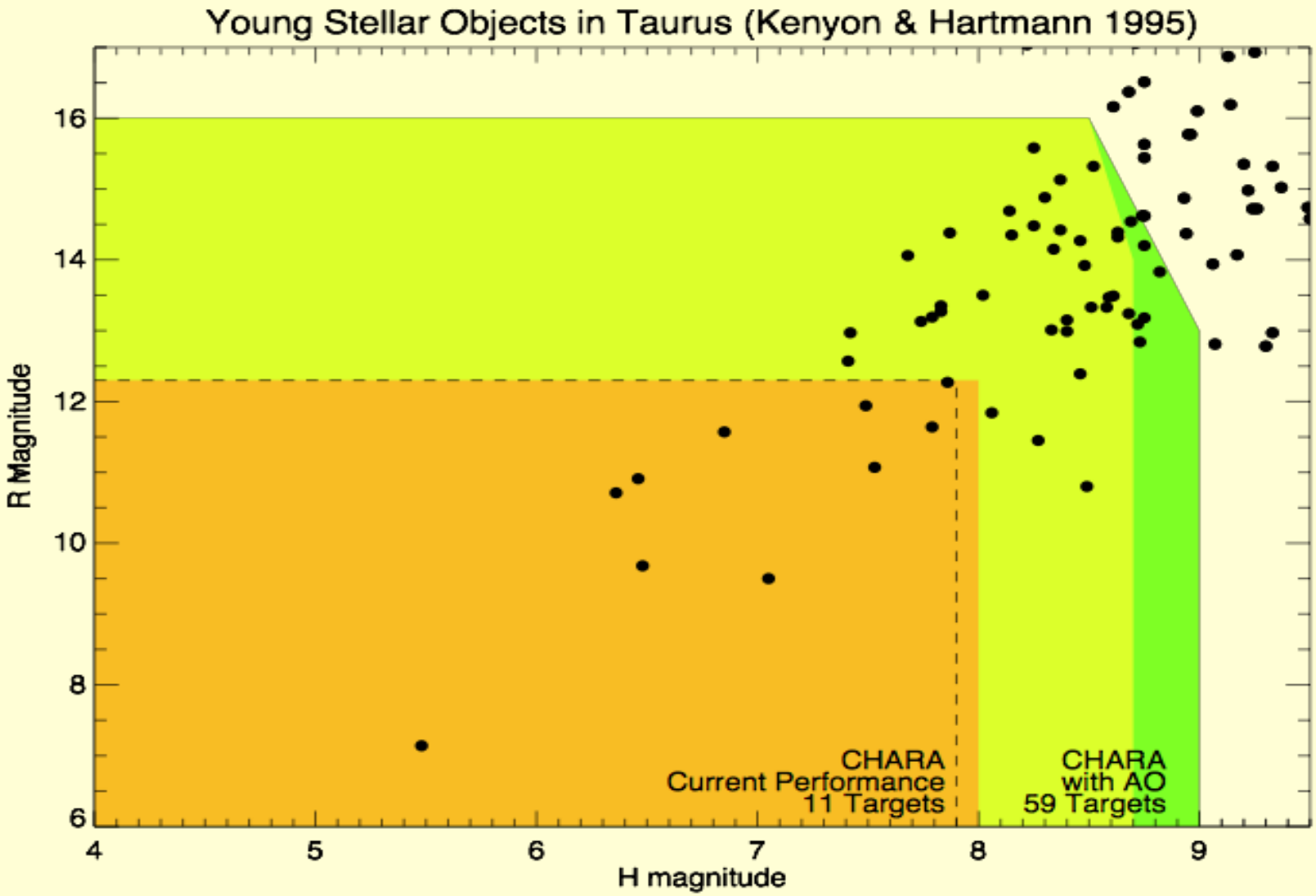
NOAO open time since 2010

- Prompted in part by USCI activity and an expressed interest from NOAO/ReStar.
- 50-100 Hours of CHARA time allocated per year.
- Time awarded by an independent NOAO TAC.
- Over subscribed by 3.7 in 2010, 4.9 in 2011, and 2.5 in 2012.
- Many proposals came from people already interested in interferometry, less so now.
- Many proposals originated in Europe.

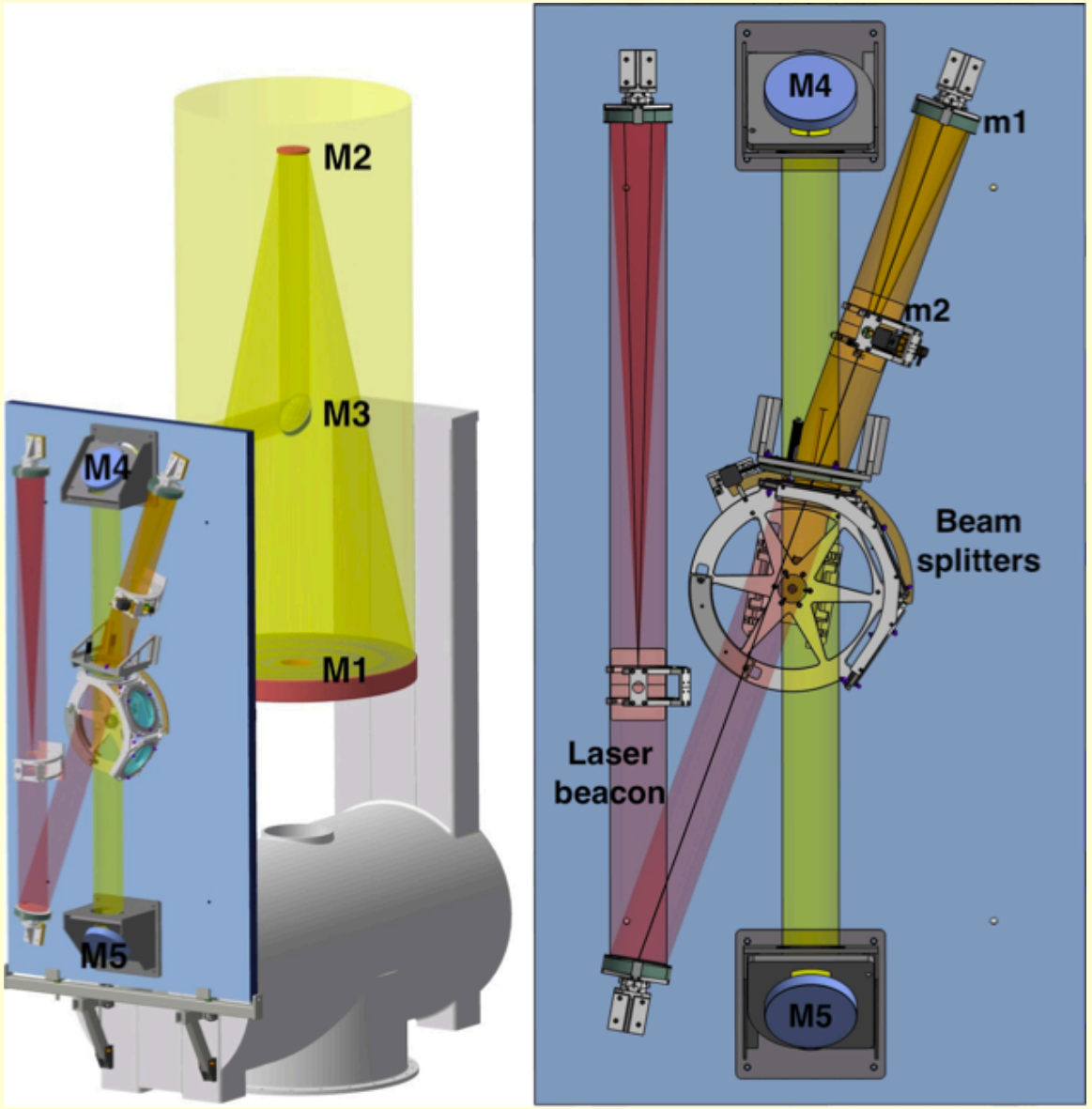
ROCMI 2006



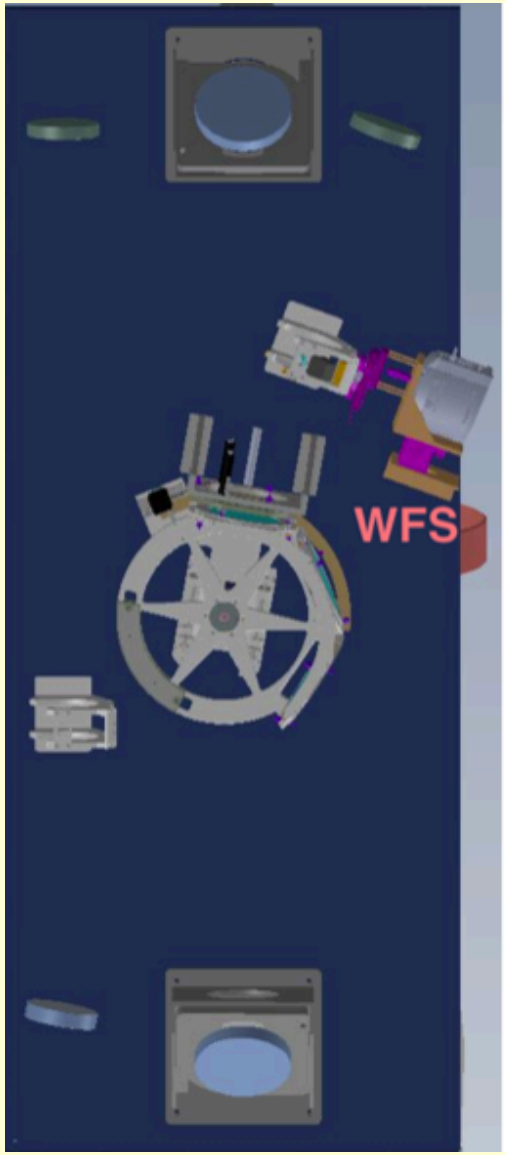
CHARA-AO Program

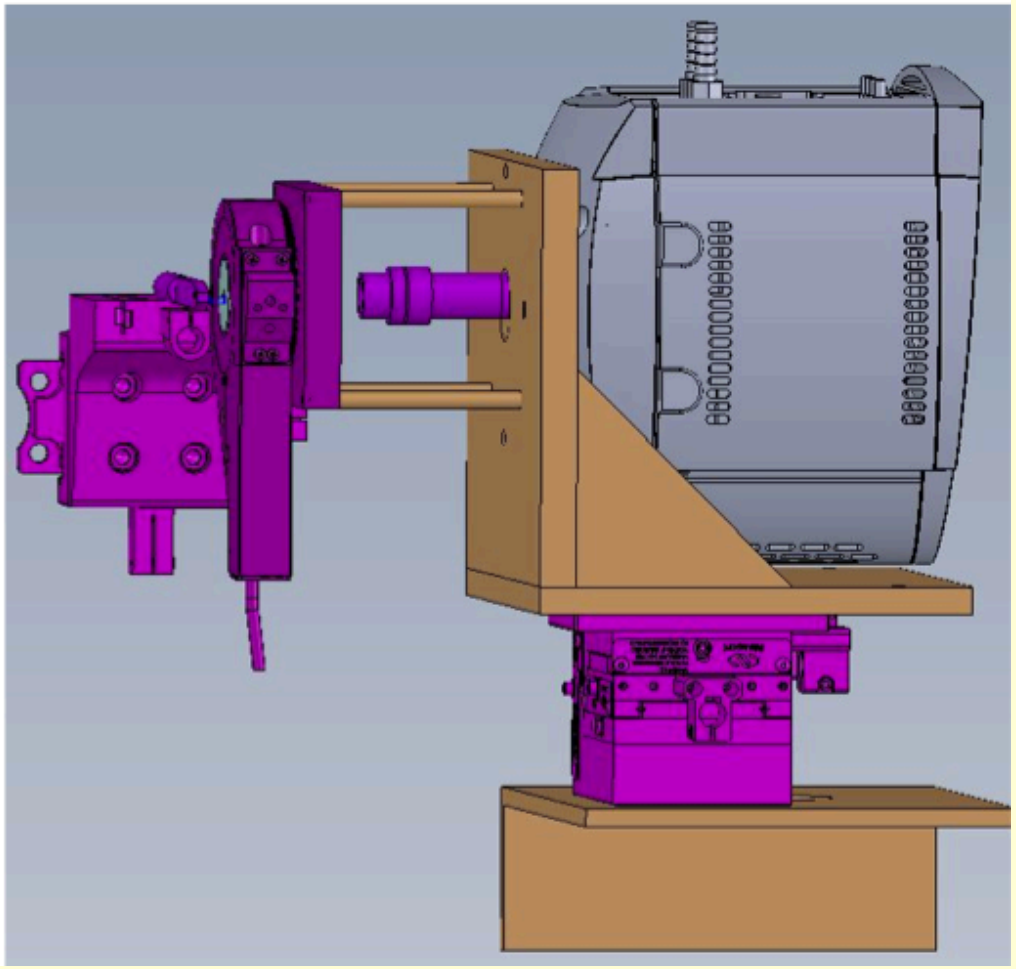


CHARA-AO Program

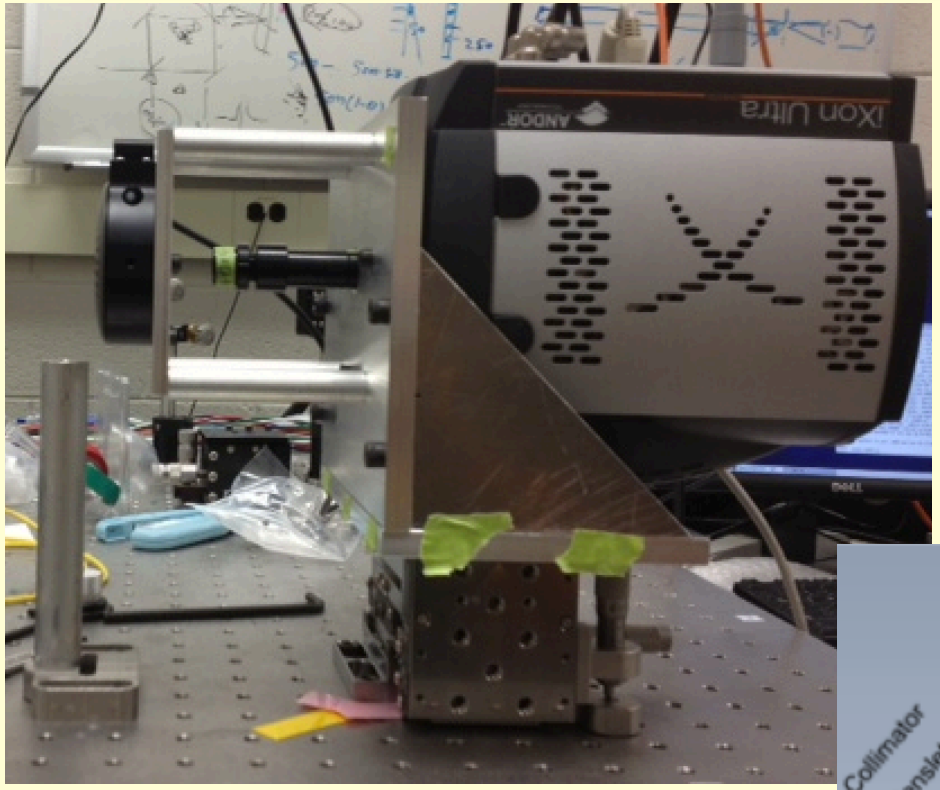


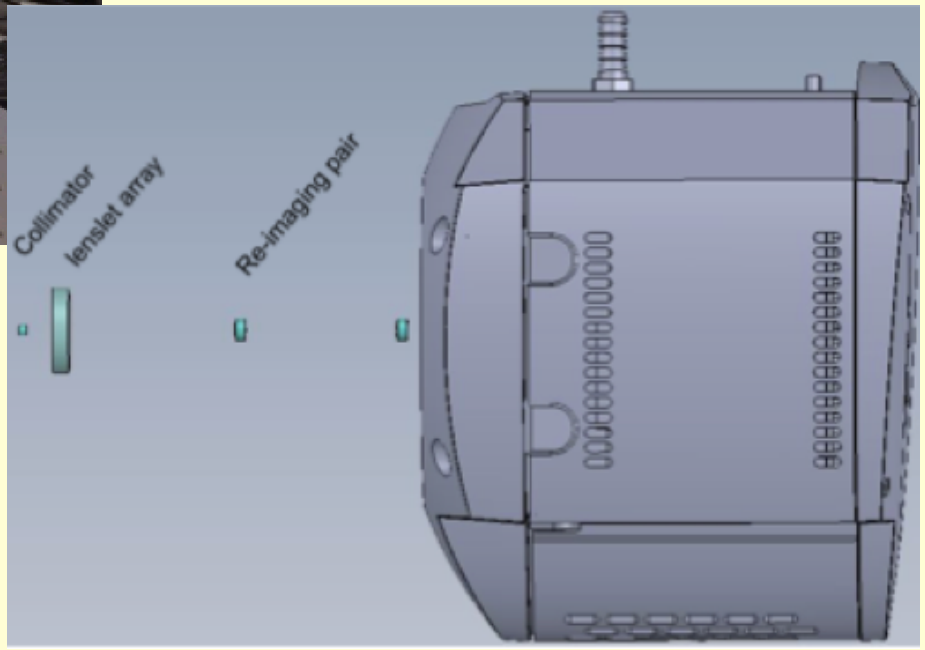
CHARA-AO Program





CHARA-AO Program



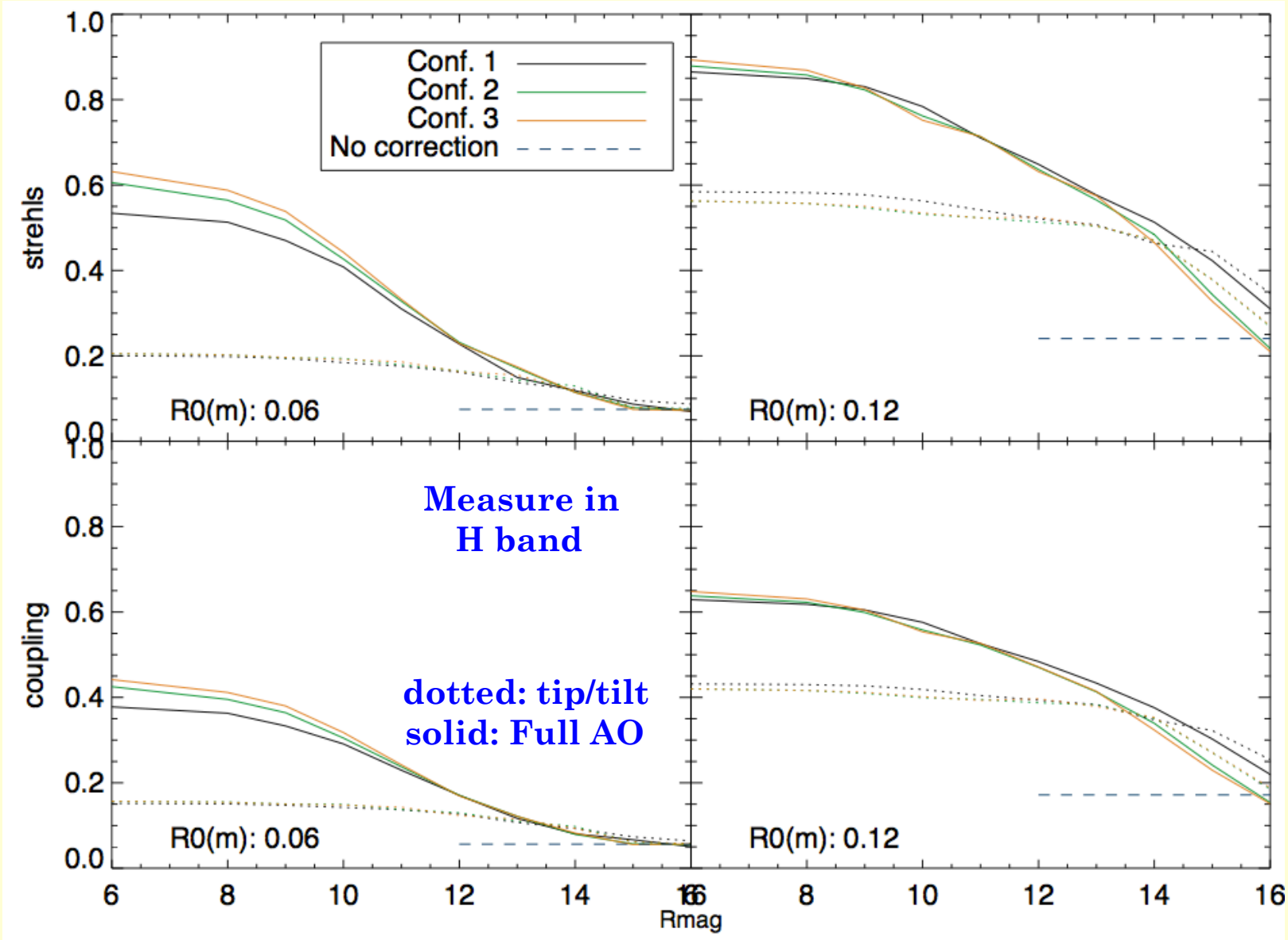


Configurations to be tested

	Pro	Con
More lenslet	Better sampling	Worse SNR
More actuator	Better performance	More expensive

	lenslet configuration	DM configuration
Configuration 1	18-lenslet	31-actuator
Configuration 2	36-lenslet	31-actuator
Configuration 3	36-lenslet	61-actuator

Simulation Results



Status of the AO Program

- Phase I fully funded by NSF ($1.2M)

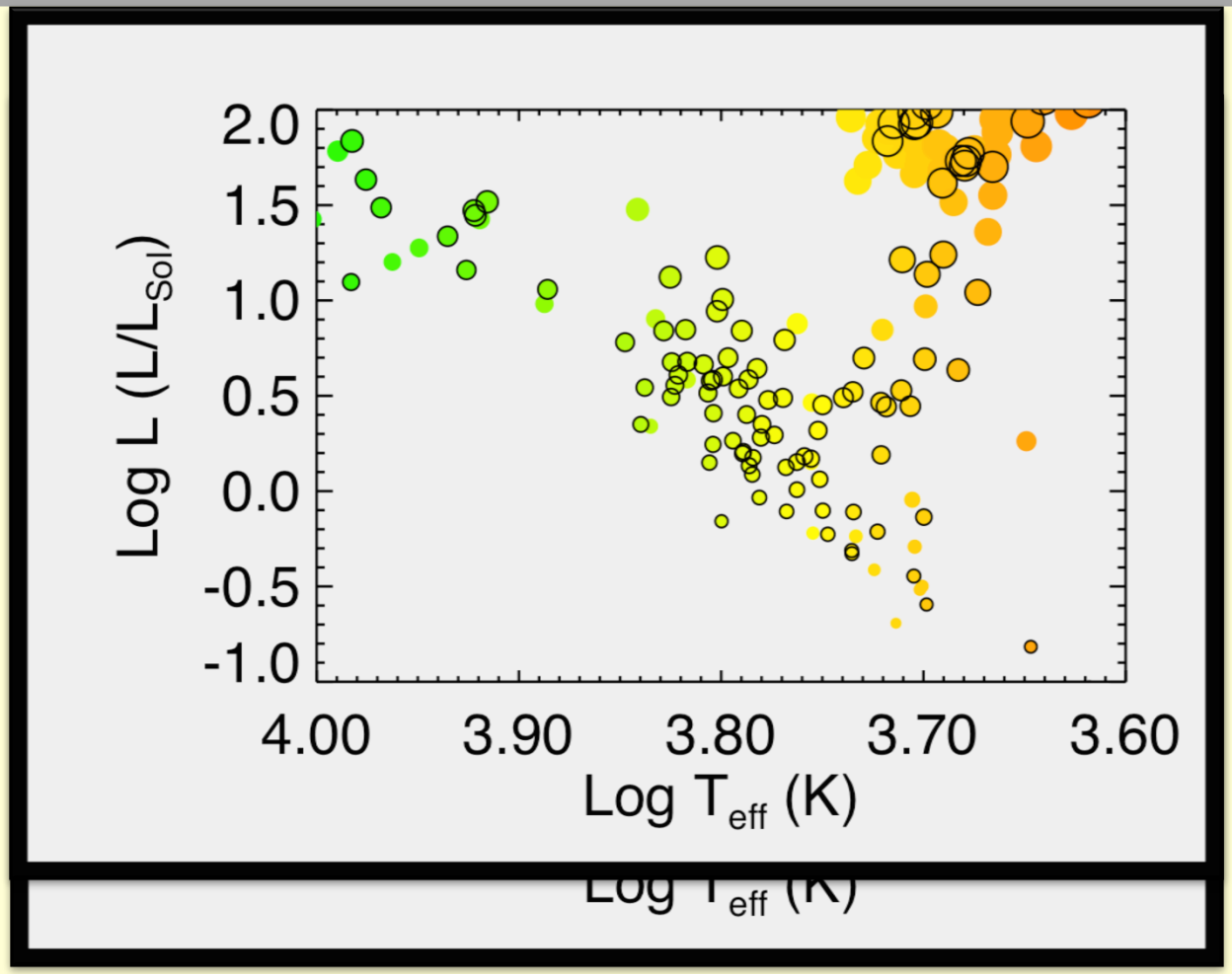
- Phase I includes Wave Front Sensors on all telescopes, 'Slow' WFS in lab, and small Deformable Mirrors in the Lab for static corrections.

- Phase II ($1.1M) will consist of adding large DMs at the telescopes and closing the loop.

- We will seek Phase II funding once we have had the first science results from Phase I.

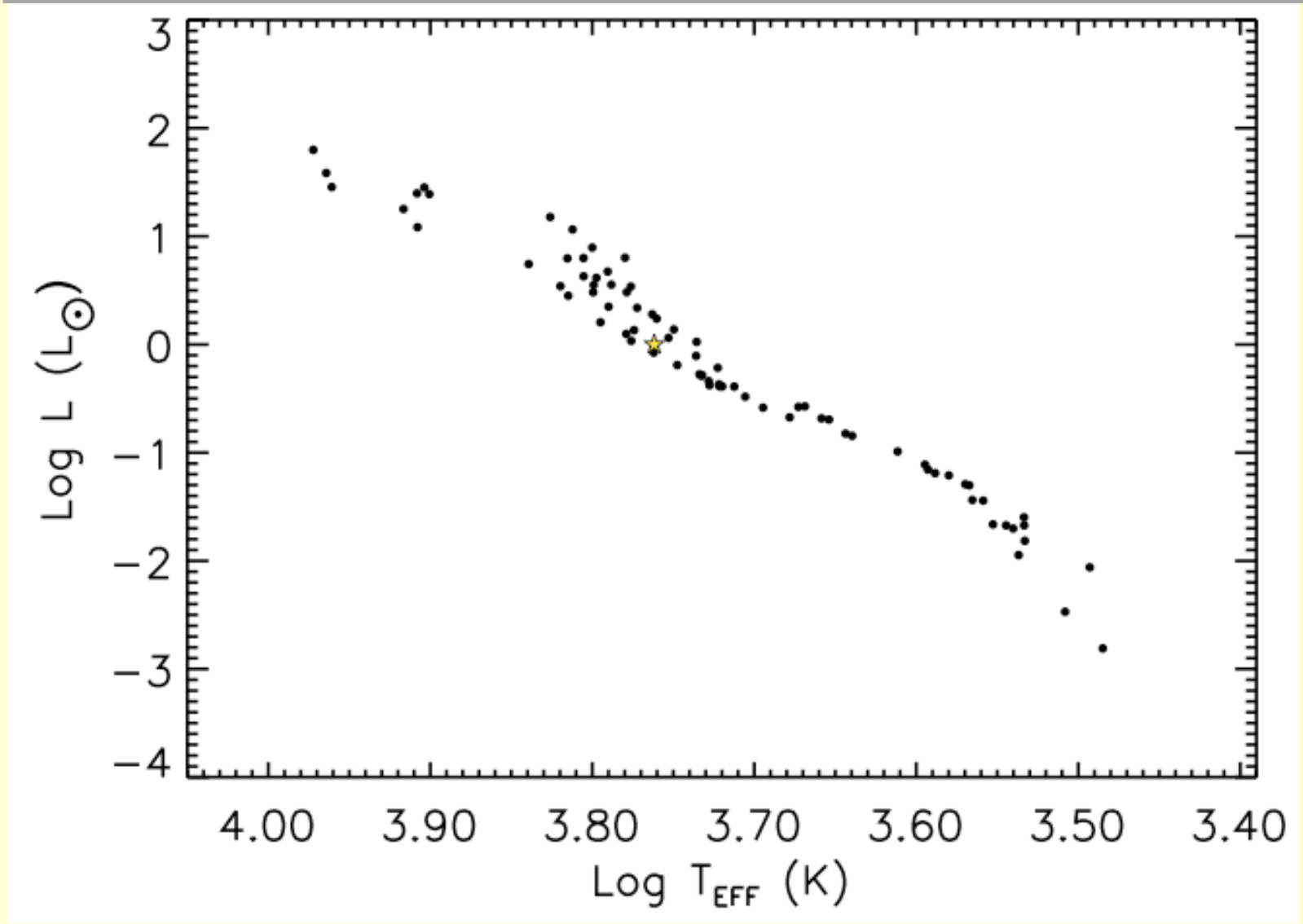
An Interferometric HR Diagram: 2009

Compliments of Tabetha Boyajian



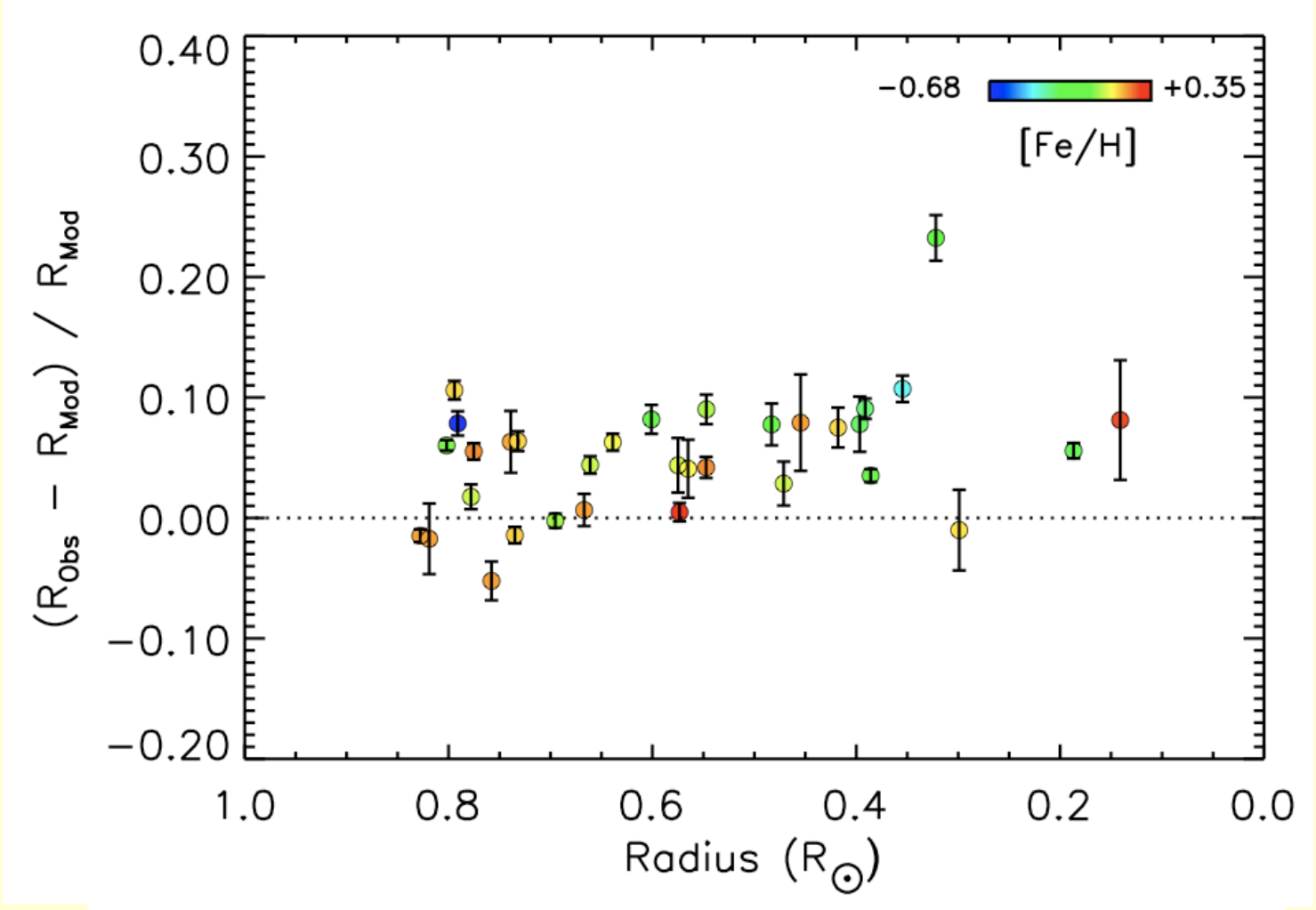
***Measurements outlined in black are from the CHARA Array. Does not include new results presented next on K-M dwarfs.**

Low Mass Stars in Particular are a Focus of Recent Work (Boyajian 2012 in press)



How do direct measurements compare to semi-empirical values?

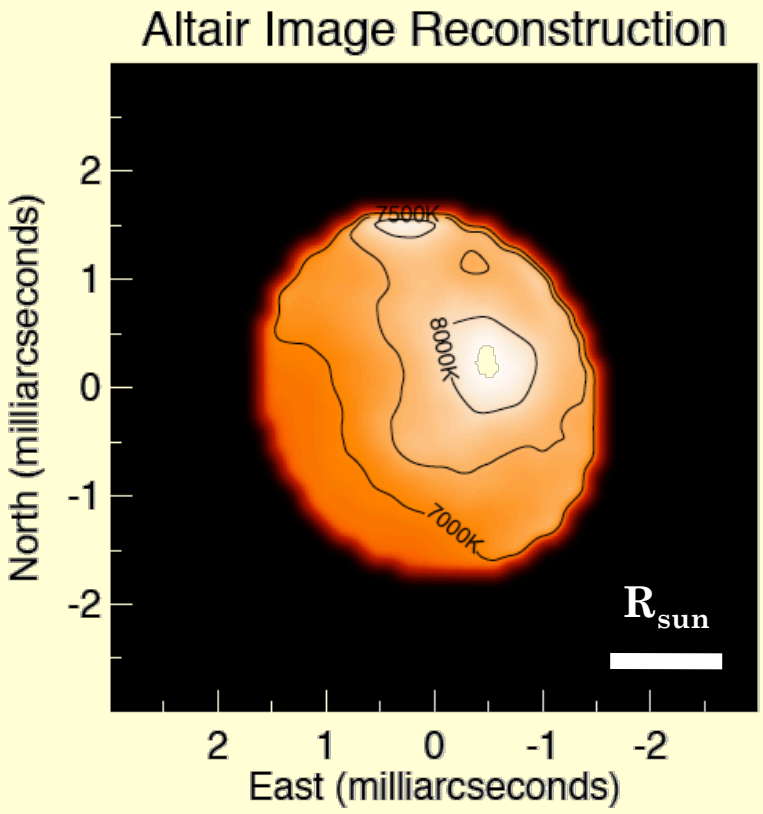
Solid: Empirical Fit. Dash/Dot: Dartmouth 5 Gyr isochrones [Fe/H] = 0. Dotted: [Fe/H] = -0.5

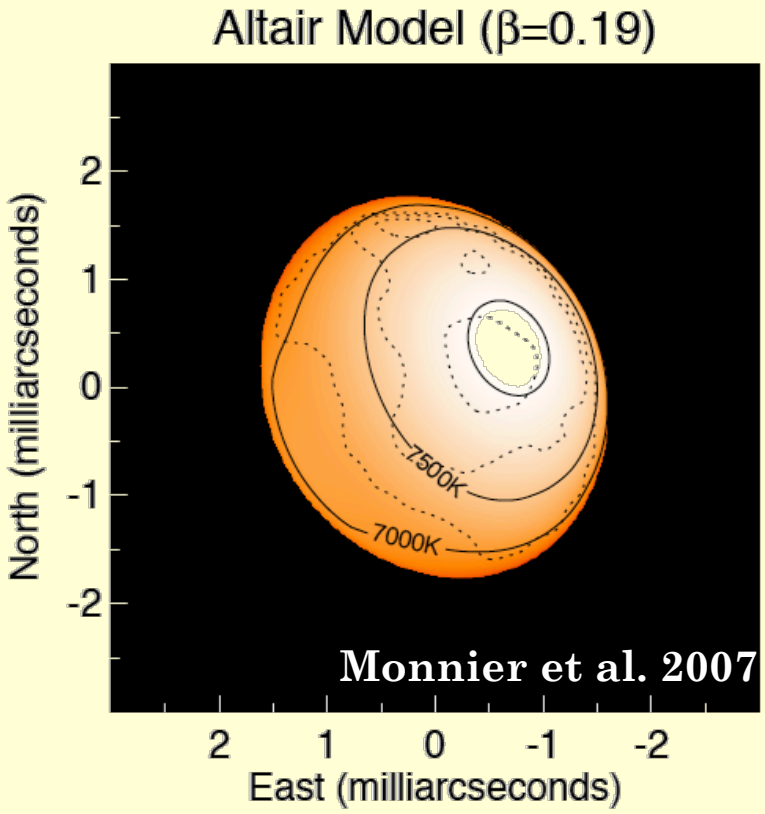


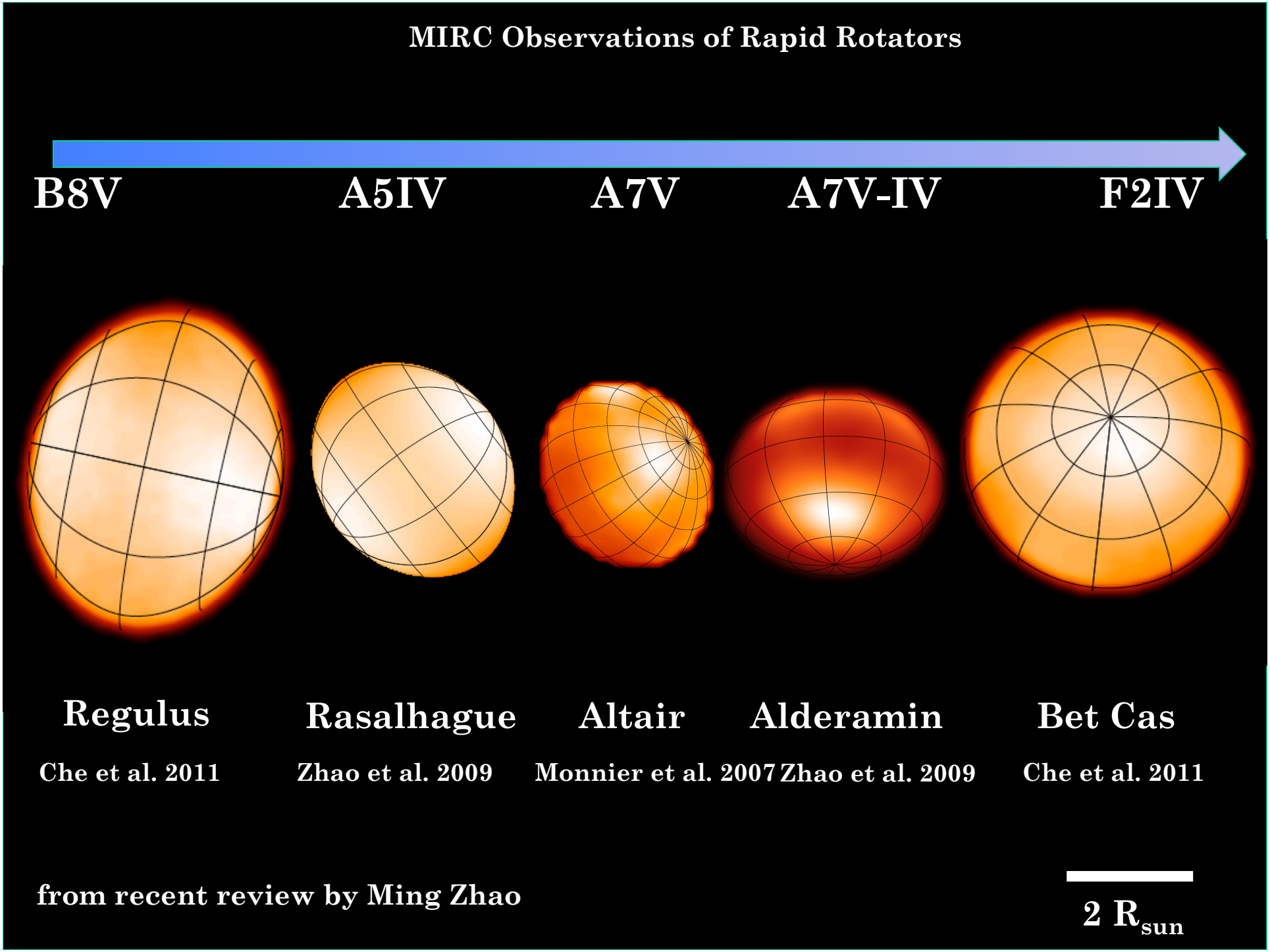
Boyajian et al. 2012, in press

First image of a main-sequence star
(besides the Sun…)

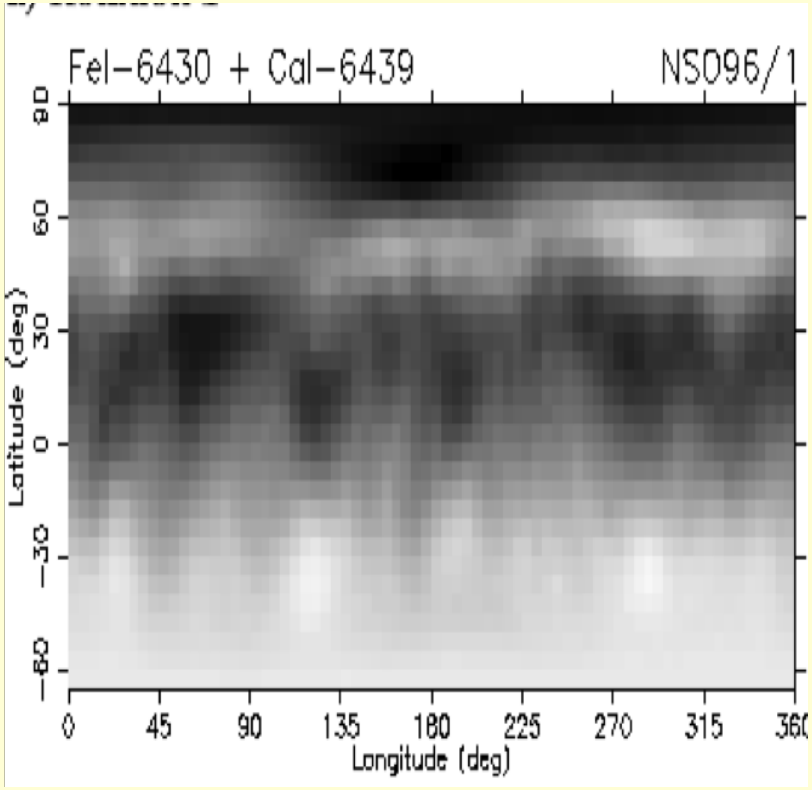
- Altair (a Aql, V=0.7)
  - Nearby hot star (d=5.1pc, SType A7V, T=7850 K)
  - Rapidly rotating (v sin i = 240 km/s, ~90% breakup)

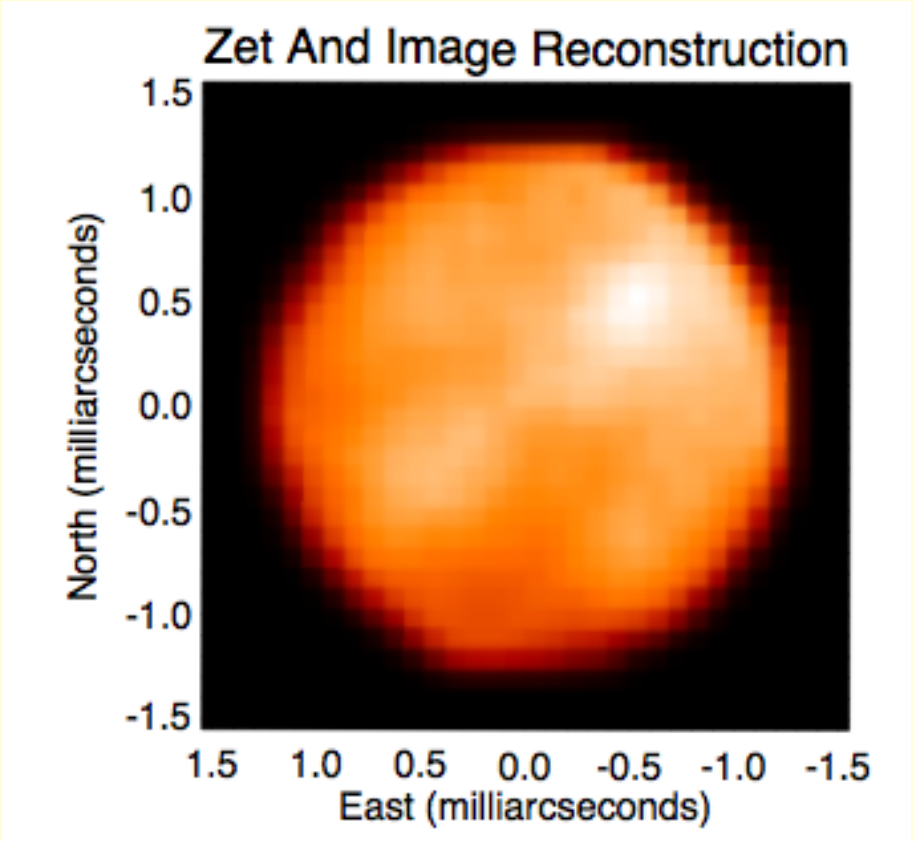





MIRC Observations of Rapid Rotators
B8V
A5IV
A7V
A7V-IV
F2IV
Regulus
Che et al. 2011
Rasalhague
Zhao et al. 2009
Altair
Monnier et al. 2007
Alderamin
Zhao et al. 2009
Bet Cas
Che et al. 2011
from recent review by Ming Zhao
2 R$_{sun}$

Spotted K giant ζ Andromeda

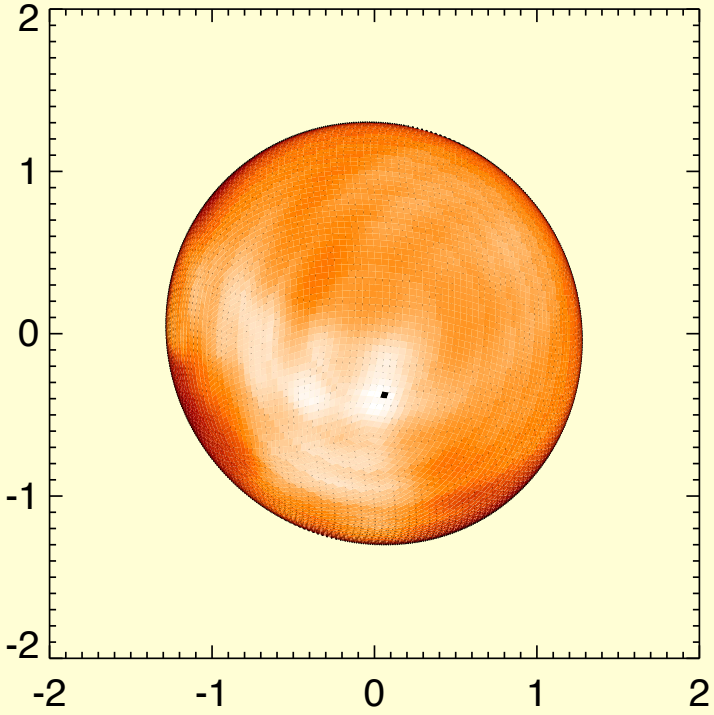


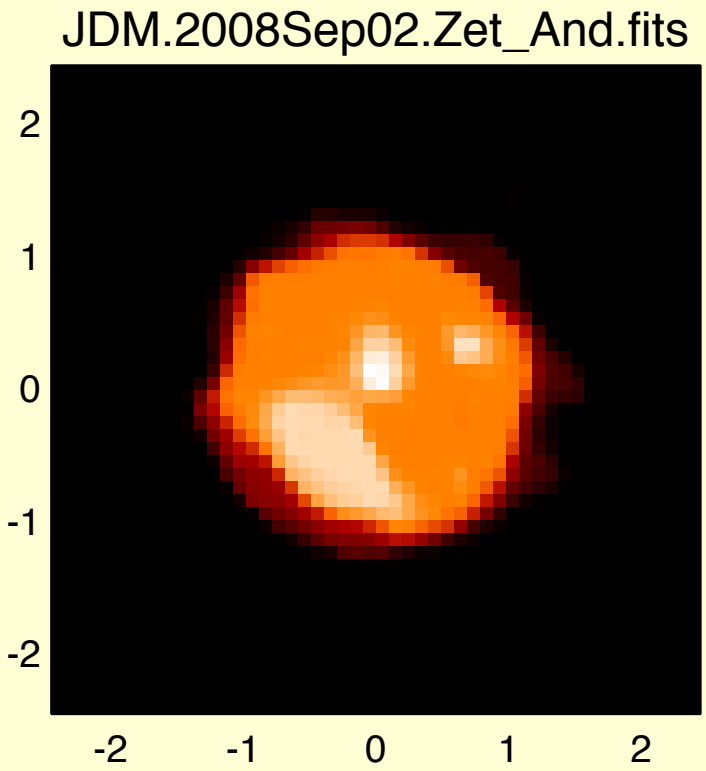


Doppler Imaging (Kovari et al. 2007)

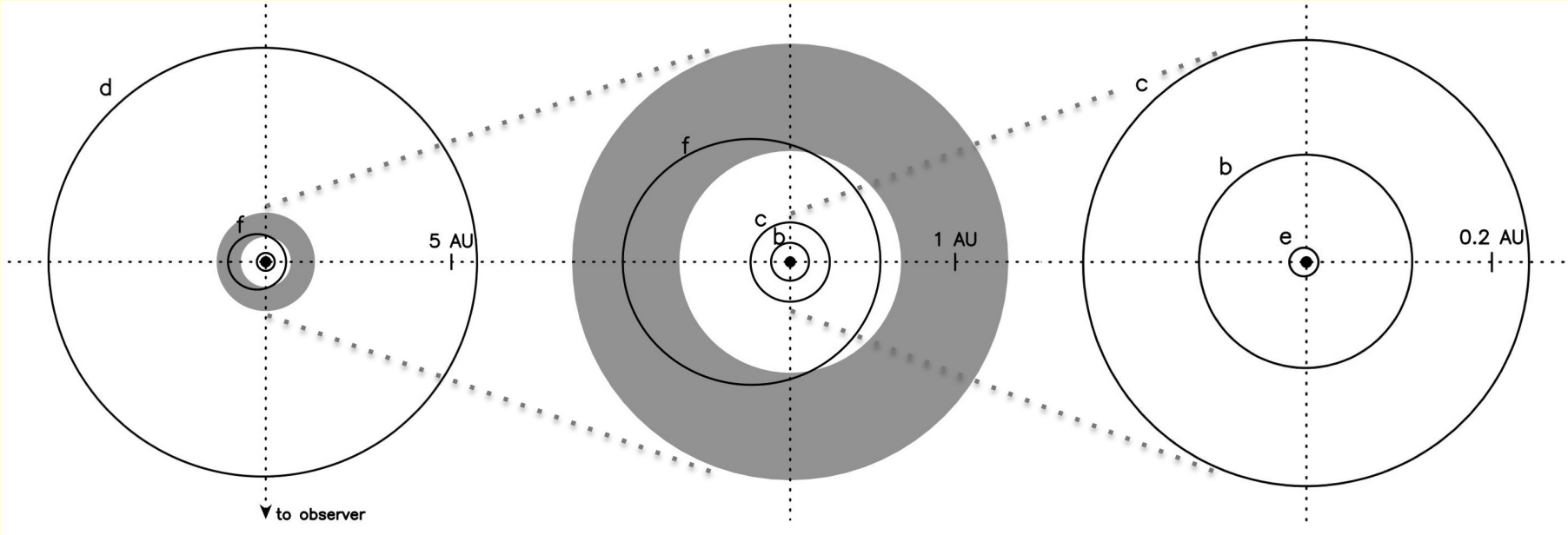
CHARA-MIRC image (Pedretti et al. 2010)

First Baby Step: Finding the Orientation





Stellar Diameters lead to Habital Zones : 55 Cancri A



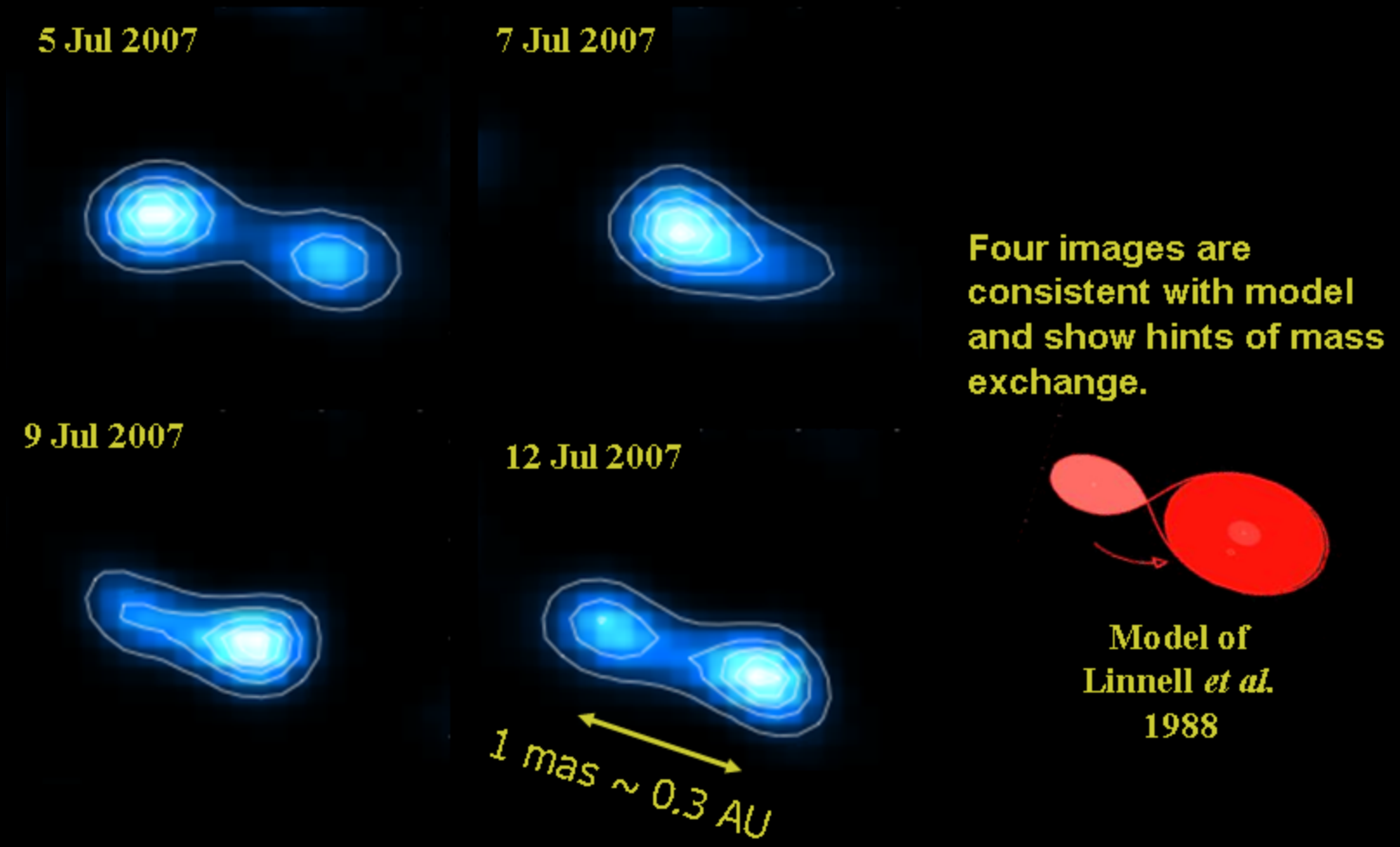
Planet	K (ms^{-1})	$M \sin i$ (M_{Jup})	P (days)	a (AU)	e	ω (deg)
e	6.2(2)	0.0260(10)	0.736537(13)	0.01560(11)	0.17(4)	181(2)
b	71.4(3)	0.825(3)	14.6507(4)	0.1148(8)	0.010(3)	139(17)
c	10.2(2)	0.171(4)	44.364(7)	0.2403(17)	0.005(3)	252.(41)
f	5.4(3)	0.155(8)	259.8(5)	0.781(6)	0.30(5)	180.(10))
d	46.8(6)	3.82(4)	5169.(53)	5.74(4)	0.014(9)	186(8)

von Braun et al. (2011c)

Orbital parameters Dawson & Fabrycky (2010)

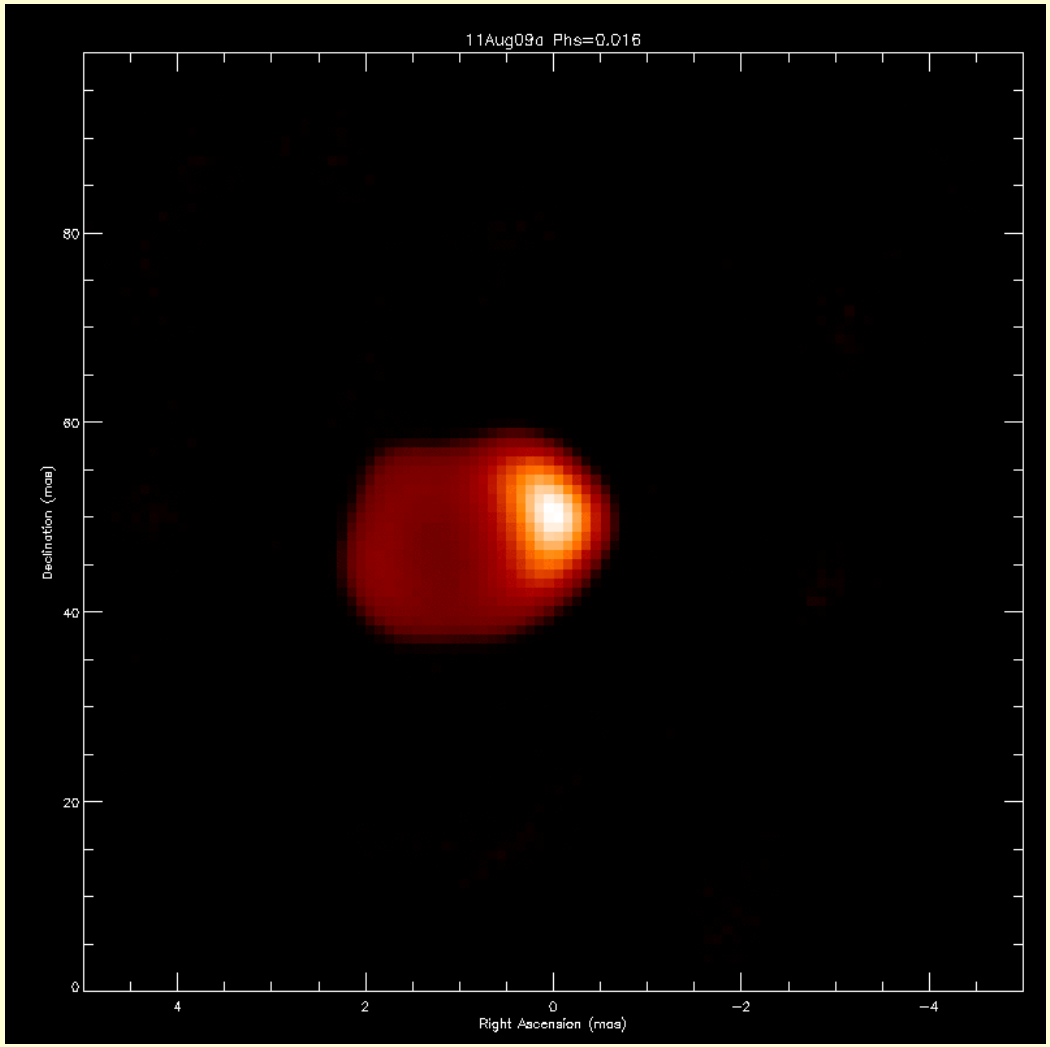
βLyrae – First Imagery: 4-frame movie

Zhao et al. Science 2007.

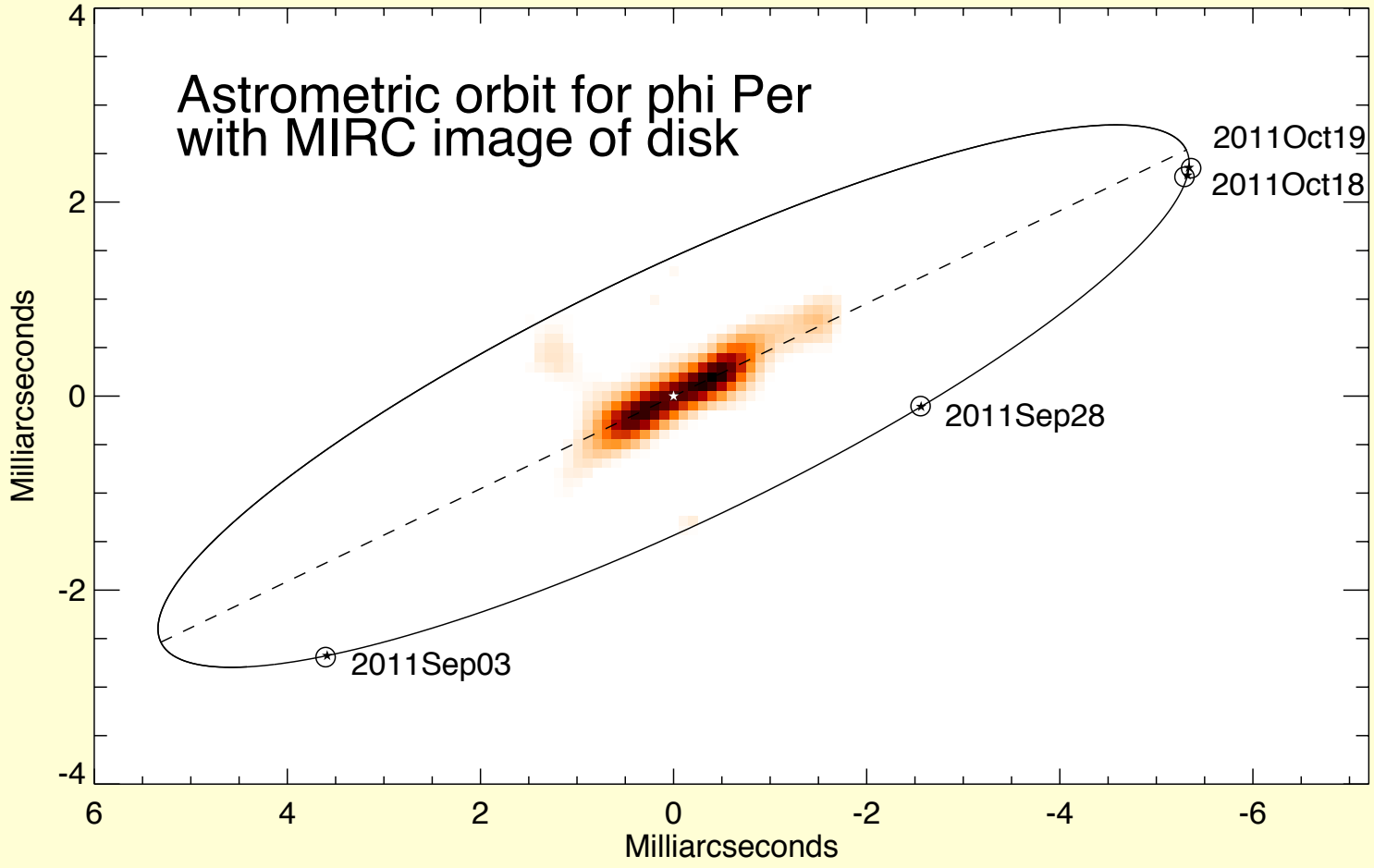


β Lyrae – The Movie

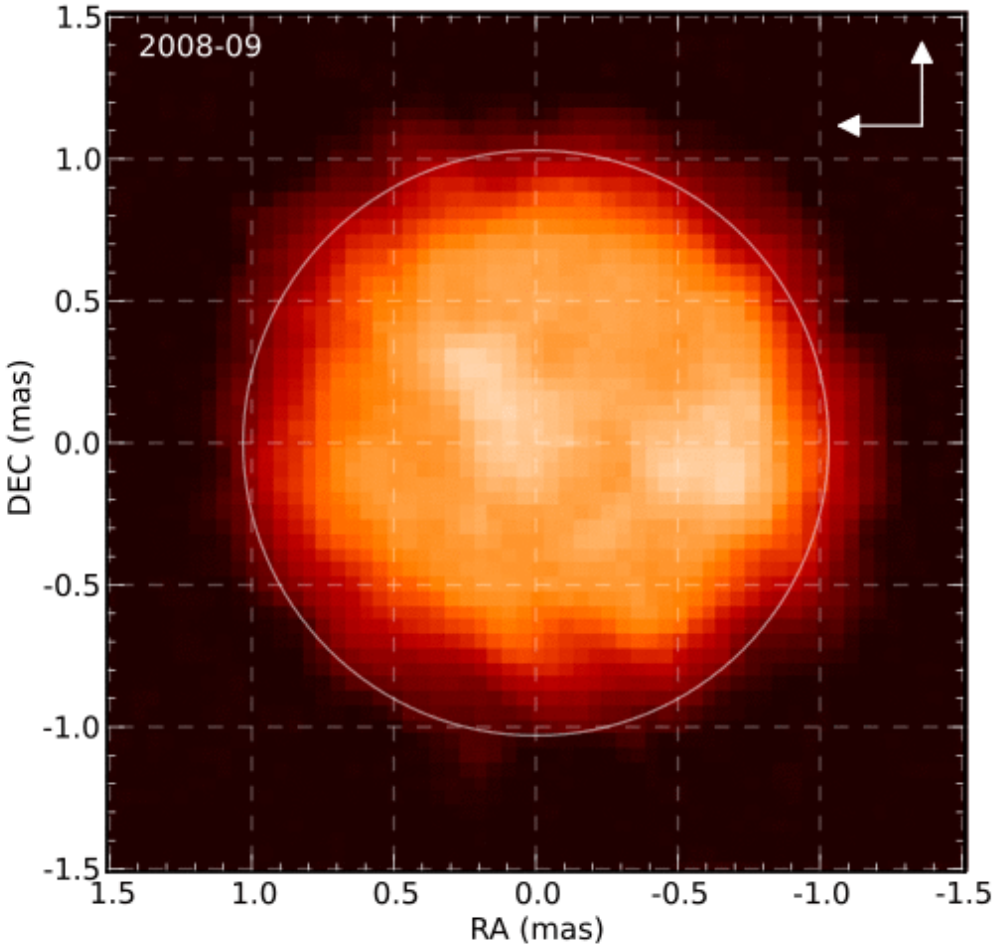
Algol the Movie: Baron et al 2011.



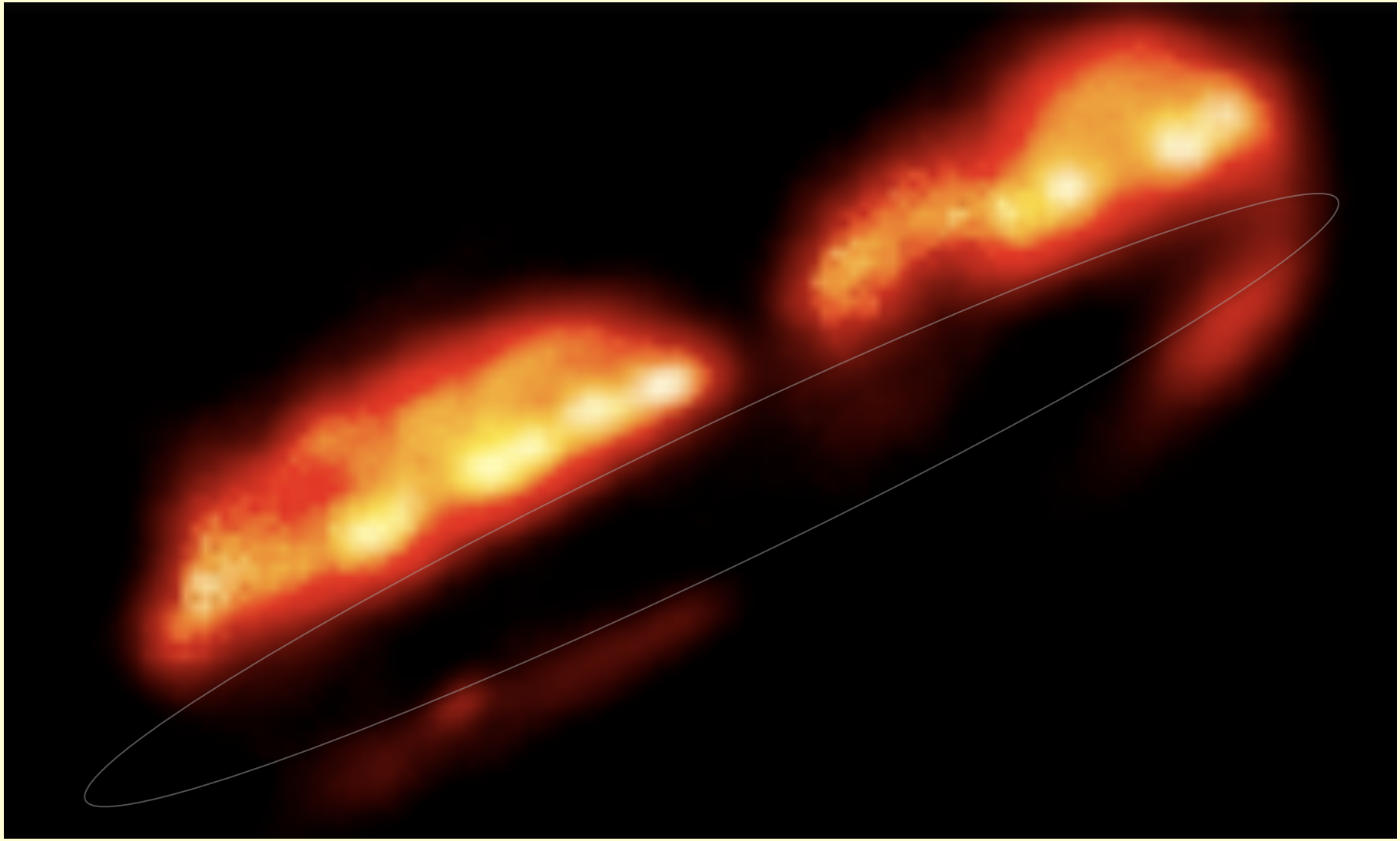
Imaging a Be Star disk and the orbit of its faint companion



Eps Aur – Thrice in a lifetime? (Kloppenborg et. al. 2013 in press)



Eps Aur: The shape of the Disk.



Klonnenborg et al. 2011

How do I get Observing time at CHARA?

- **NOAO Open Observing time for 2014 is OPEN RIGHT NOW**

The proposal deadline is Sept 26.

http://ast.noao.edu/sites/default/files/cfp2014a_0.pdf

http://www.noao.edu/gateway/chara/

- **Through direct collaborations with one of us or one of our member groups.**

- **Have a good idea? Come and talk to us.**

- **We plan to open up more time at CHARA through the new NSF/MSIP program. A large number of NOAO proposals will help.**

CHARA Research Sponsored by

National Science Foundation
W. M. Keck Foundation
GSU College of Arts & Sciences
State of Georgia
NASA Exoplanet Science Inst.
David & Lucile Packard Foundation

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