# The CHARA Array Adaptive Optics Program

#### **Theo ten Brummelaar**

Associate Director Center for High Angular Resolution Astronomy Mount Wilson Observatory

CHARA

Georgia<u>State</u> University

**Georgia State University** 

# "Back in the day" (1991?)



# CHARA/GSU Participants & Funding

#### Principal Technical Staff:

Theo ten Brummelaar\* Harold McAlister Stephen Ridgway Gail Schaefer\* Laszlo Sturmann\* Judit Sturmann\* Nils Turner\*

#### Affiliated GSU Faculty: Douglas Gies

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 (~\$1.5 M yr<sup>-1</sup>): National Science Foundation Georgia State University College of Arts & Sciences Vice President for Research







NASA Exoplanet Science Institute

## The CHARA Collaboration







#### First science publication..... 5 years later!

### FIRST RESULTS FROM THE CHARA ARRAY. I. AN INTERFEROMETRIC AND SPECTROSCOPIC STUDY OF THE FAST ROTATOR $\alpha$ LEONIS (REGULUS)

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#### ABSTRACT

We report on K-band interferometric observations of the bright, rapidly rotating star Regulus (type B7 V) made with the CHARA Array on Mount Wilson, California. Through a combination of interferometric and spectroscopic measurements, we have determined for Regulus the equatorial and polar diameters and temperatures, the rotational velocity and period, the inclination and position angle of the spin axis, and the gravity darkening coefficient. These first results from the CHARA Array provide the first interferometric measurement of gravity darkening in a rapidly rotating star and represent the first detection of gravity darkening in a star that is not a member of an eclipsing binary system.

Subject headings: infrared: stars — stars: fundamental parameters — stars: individual ( $\alpha$  Leonis, Regulus) — stars: rotation — techniques: interferometric

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### Layout of the CHARA Array





CAD by Laszlo Sturmann

Rhoto by Steve Golden

## **Optics Laboratory**



## 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
- More to come... (MYSTIC, FRIEND....)





**ROCMI 2006** 







### 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,  $\sim$ 90% breakup)



**MIRC Observations of Rapid Rotators** 



**Regulus** Che et al. 2011

Zhao et al. 2009

Monnier et al. 2007 Zhao et al. 2009

Bet Cas Che et al. 2011

from recent review by Ming Zhao



from reconstructed image. The black circle on the left shows the aperture over the "quiet" photosphere. The "quiet" photosphere is defined as a part of the stellar surface devoid of flux gradients. The size of the aperture is identical to the minimum achievable angular resolution.

### βLyrae – First Imagery: 4-frame movie Zhao et al. <u>Science</u> 2007.

5 Jul 2007

#### 7 **Jul 200**7





Four images are consistent with model and show hints of mass exchange.

#### 9 Jul 2007



12 Jul 2007





Model of Linnell *et al.* 1988

## β Lyrae – The Movie



# Eps Aur – The Images Kloppenborg et al. Nature 2010.



# The expanding fireball of nova Delphini 2014 Schaefer et al Nature 2014



# **CHARA-AO** Program

- The CHARA Adaptive Optics Program is broken into 2 Phases.
- This is purely an artifact of funding realities.
- Phase I, which includes Wavefront Sensors for each telescope and non-common-path AO systems for the laboratory, was funded in 2010 and is now nearing completion.
- Phase II, which includes deformable mirrors for each telescope, should begin later this year.
- The program (as of two weeks ago) is fully funded.

# **CHARA-AO Program – Science Rational**



### **CHARA-AO Program – New Capabilities**



# **CHARA-AO Program – Science Rational**



# **CHARA-AO Program – Telescope WFS**





# **CHARA-AO Program – Telescope WFS**





## **CHARA-AO Program – Lab AO**



# **CHARA-AO Program – Software**

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## **CHARA-AO Program – Does it Work?**



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### **CHARA-AO Program – Does it Work?**





#### K Band Light (2.3μm)

Fiber Raster Scan using FLUOR. Fiber is single mode in K band. Left: AO Off. Right AO ON



V Light Beam Combiner FRIEND

Fibers are singlemode in visible band. Red: AO Off. Green: AO ON

### **CHARA-AO Program – Phase II**

- All results so far use Phase-I AO only.
- Just before this meeting we were told that Phase II, which will fund Deformable Mirrors for each telescope, will be supported by the NSF.
- These DMs must be large and will replace M4 in the current optical path.
- \$2.7M USD project.

### Algol the Movie: Baron et al 2011.

