Science With The CHARA Array

Gail Schaefer

The CHARA Array of
Georgia State University

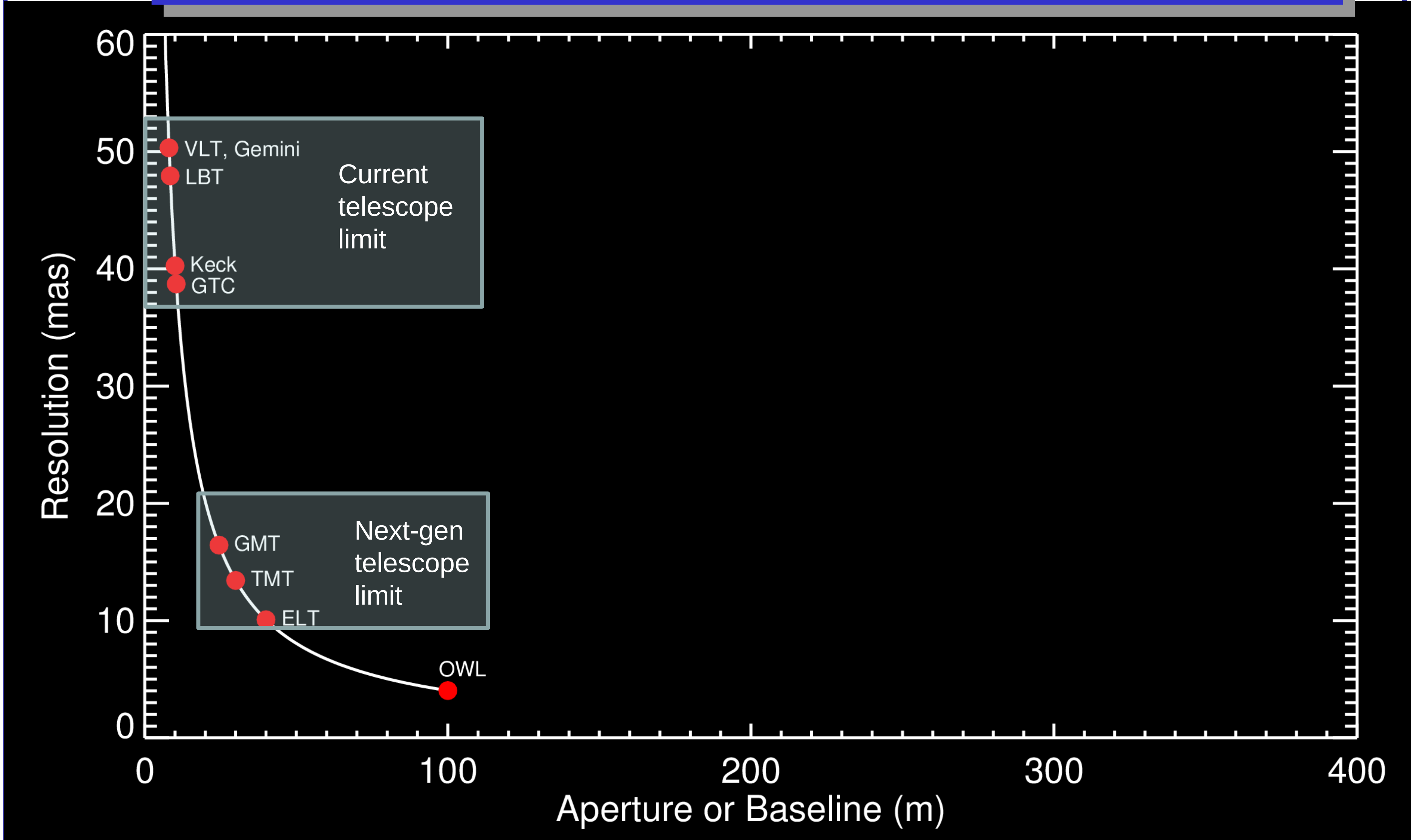
Mount Wilson, CA

CHARA Community Workshop

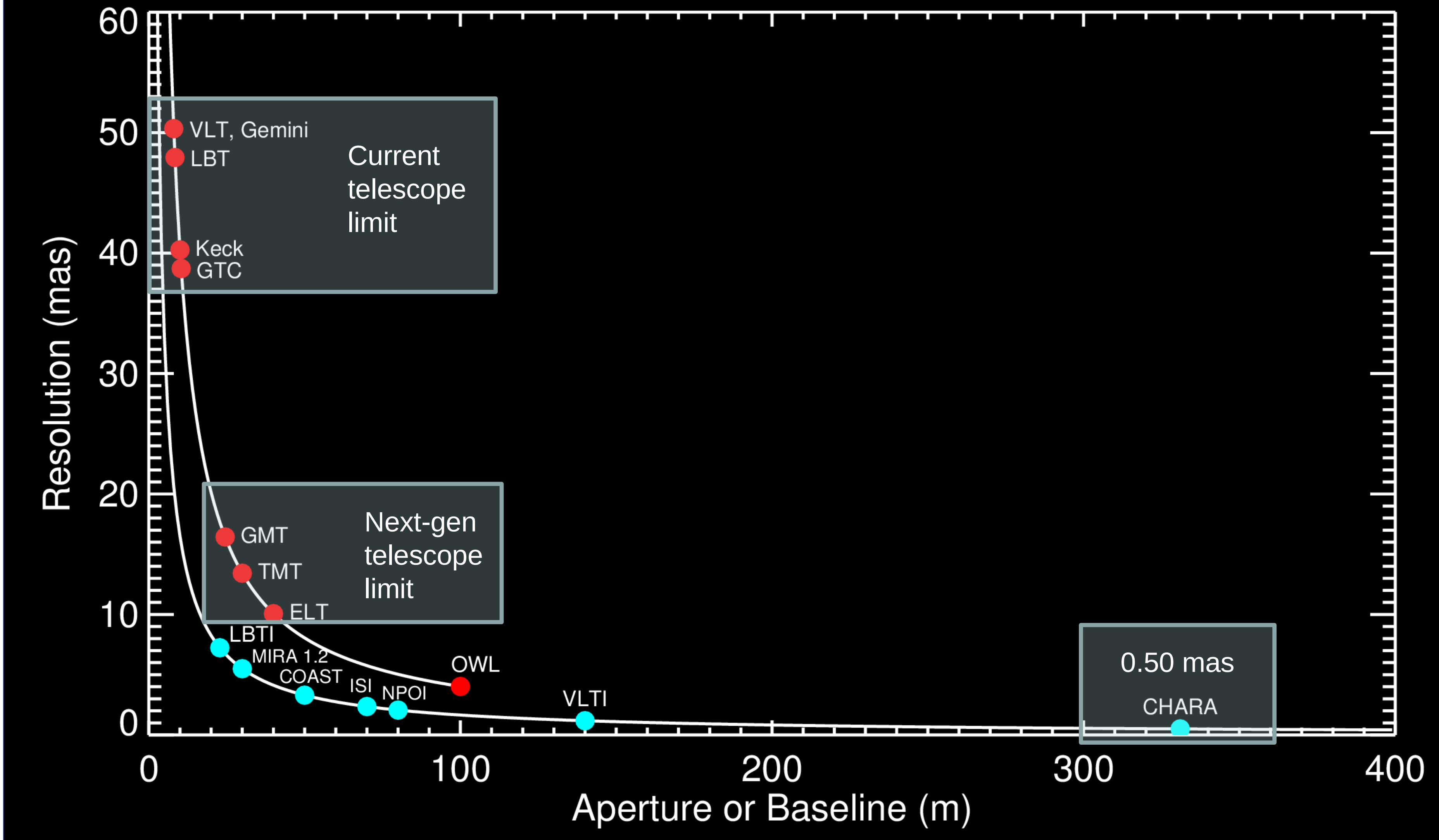
Schedule		
Stellar Astrophysics at High Angular Resolution	Gail Schaefer	30 minutes
Overview of the CHARA Array and Applying for Time	Douglas Gies	30 minutes
Discussion		

Thanks to the organizers of Cool Stars for hosting us!

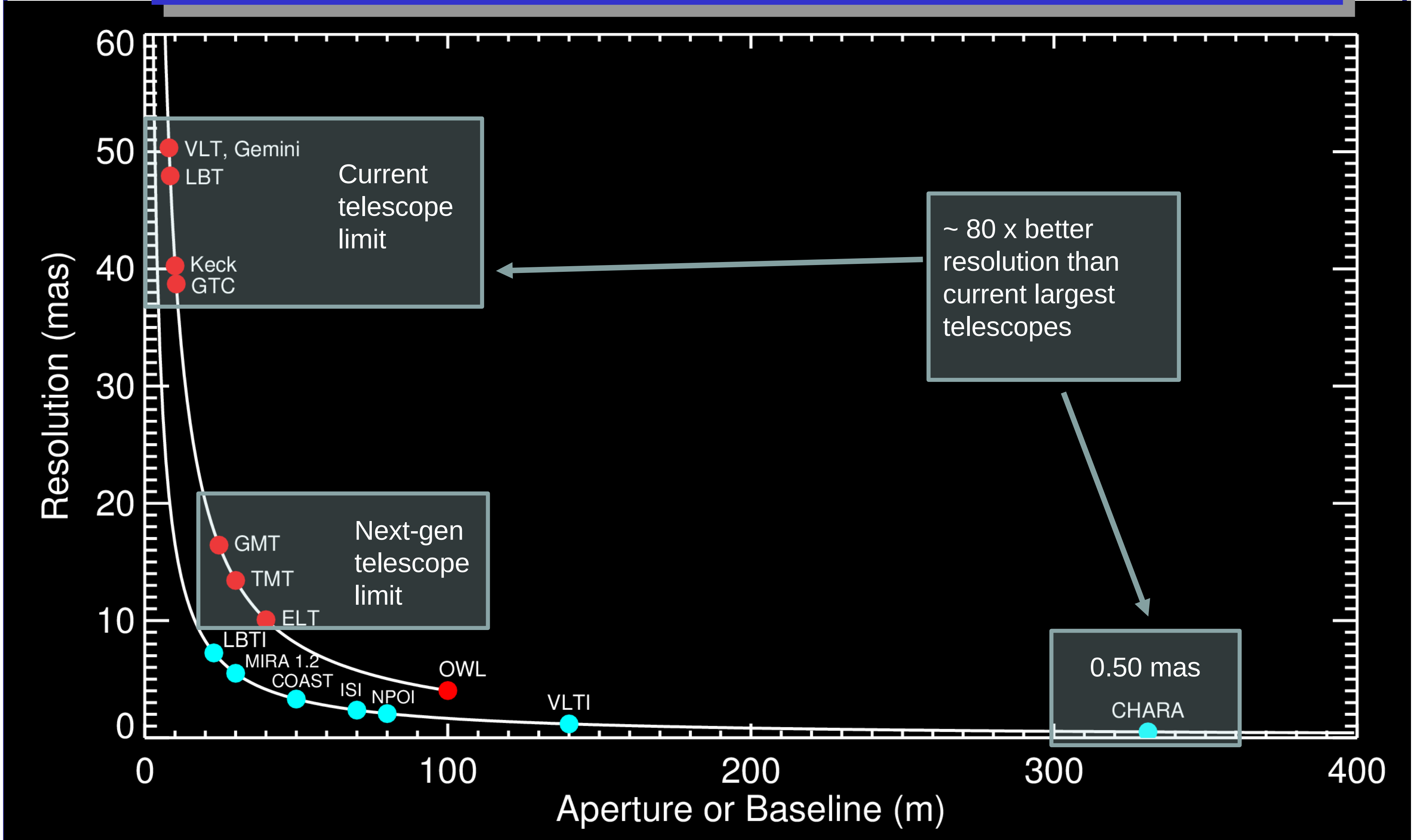
Angular Resolution
(Near IR)



Angular Resolution
(Near IR)



Angular Resolution
(Near IR)



Long Baseline Optical/Infrared Interferometers

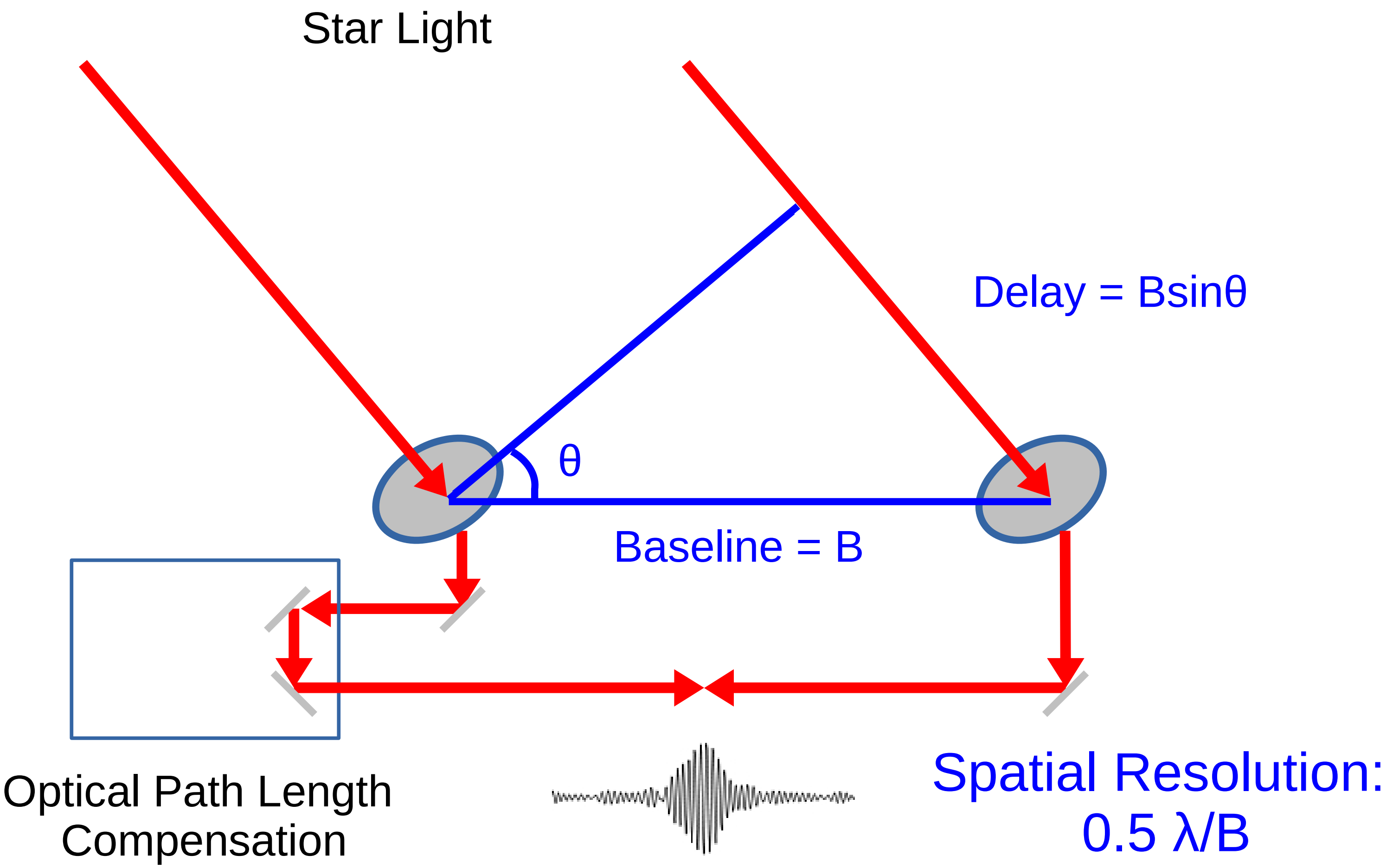

CHARA Array - Mount Wilson, CA


NPOI - Anderson Mesa, AZ


VLTI - Paranal, Chile

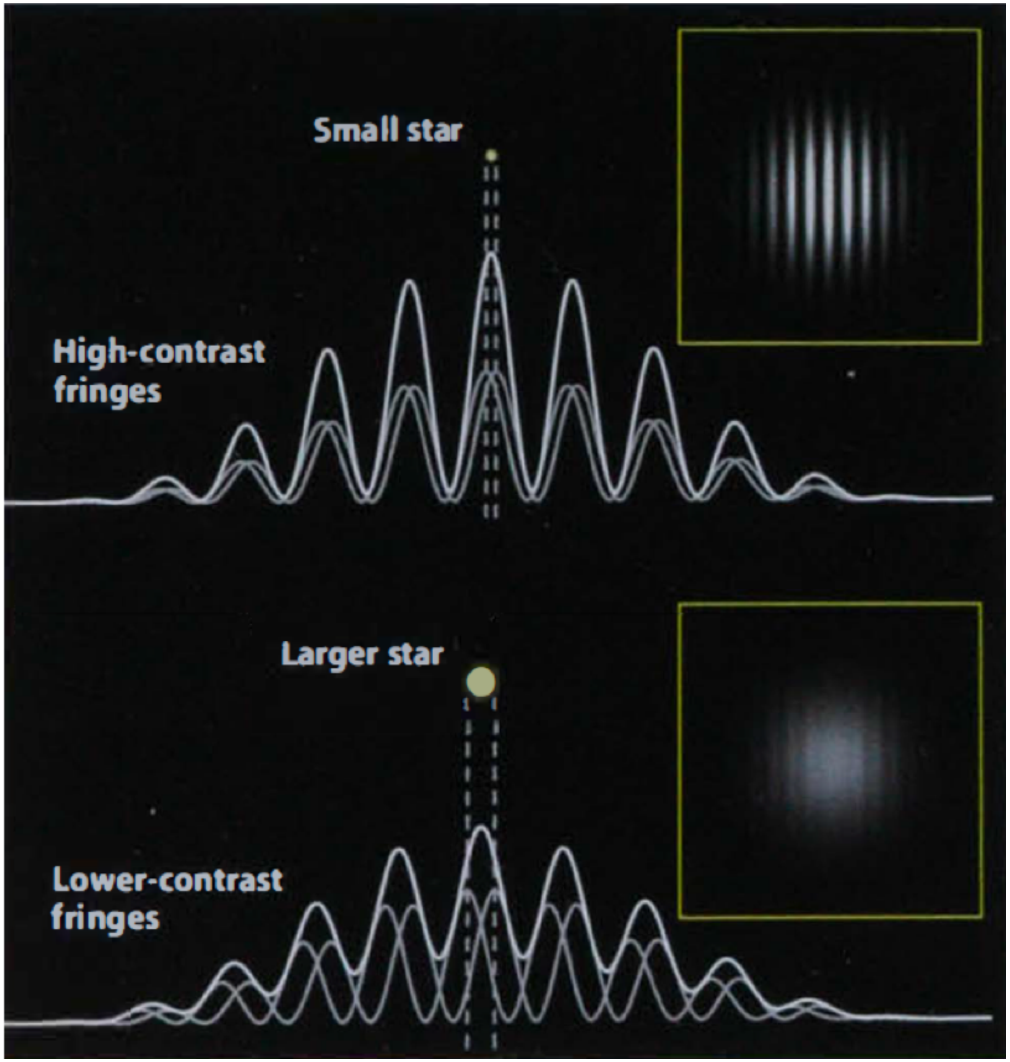

MROI - Magdalena Ridge, NM
(under construction)

Interferometer



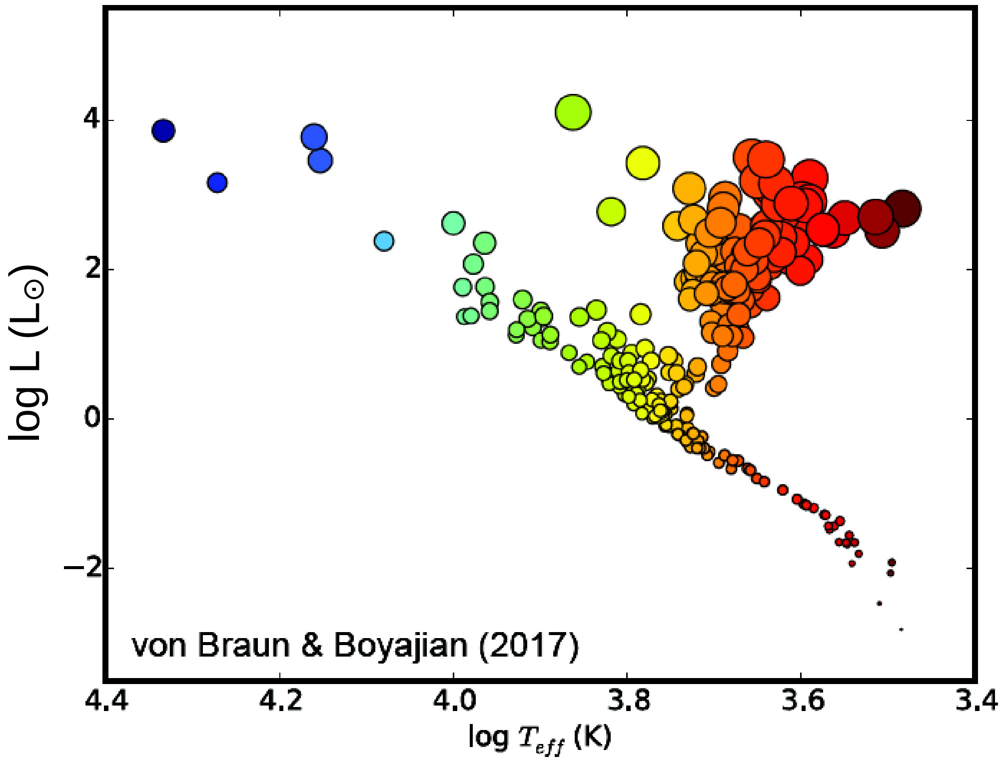
Resolution ~ 0.5 mas for 300 meter baseline in the H-band (1.6 μm)

Fringe Visibility:
Measures Size and Geometry of Source



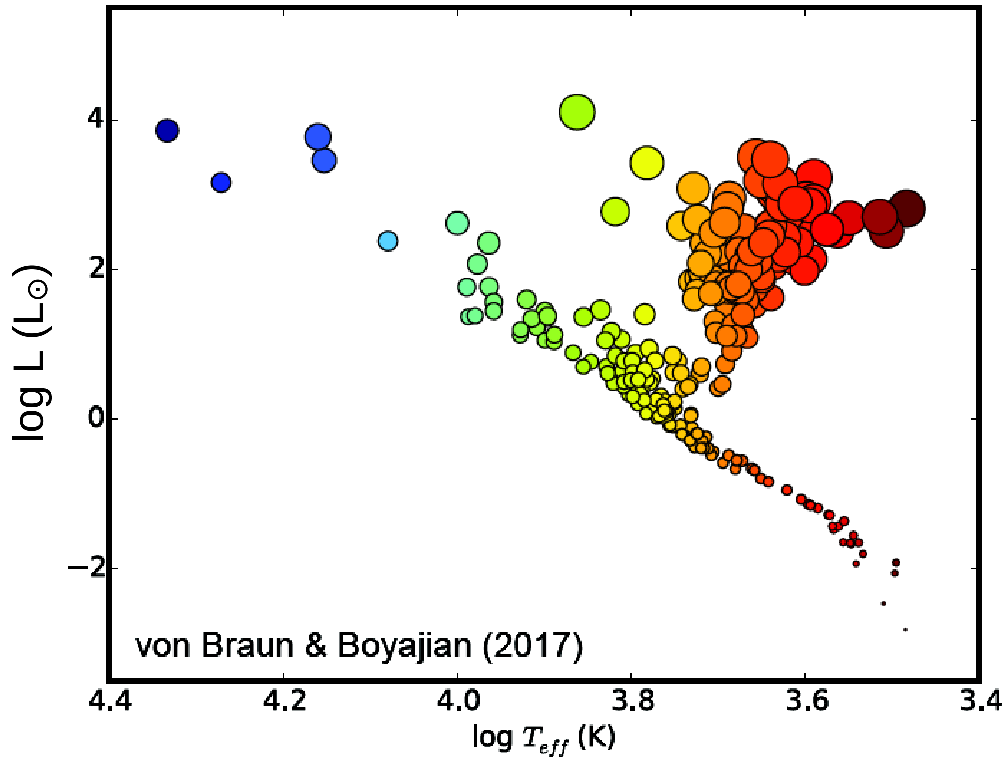
Lawson (2003)
Sky & Telescope

Stellar Diameters

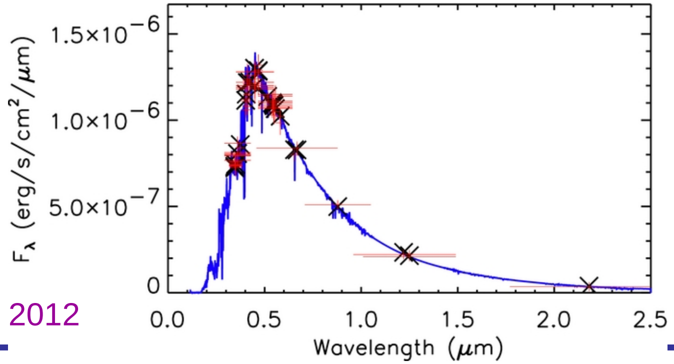


- Empirical HRD
- ~ 290 stars, σ_θ < 5%
- Angular diameter + parallax
  - Linear radius

Stellar Diameters

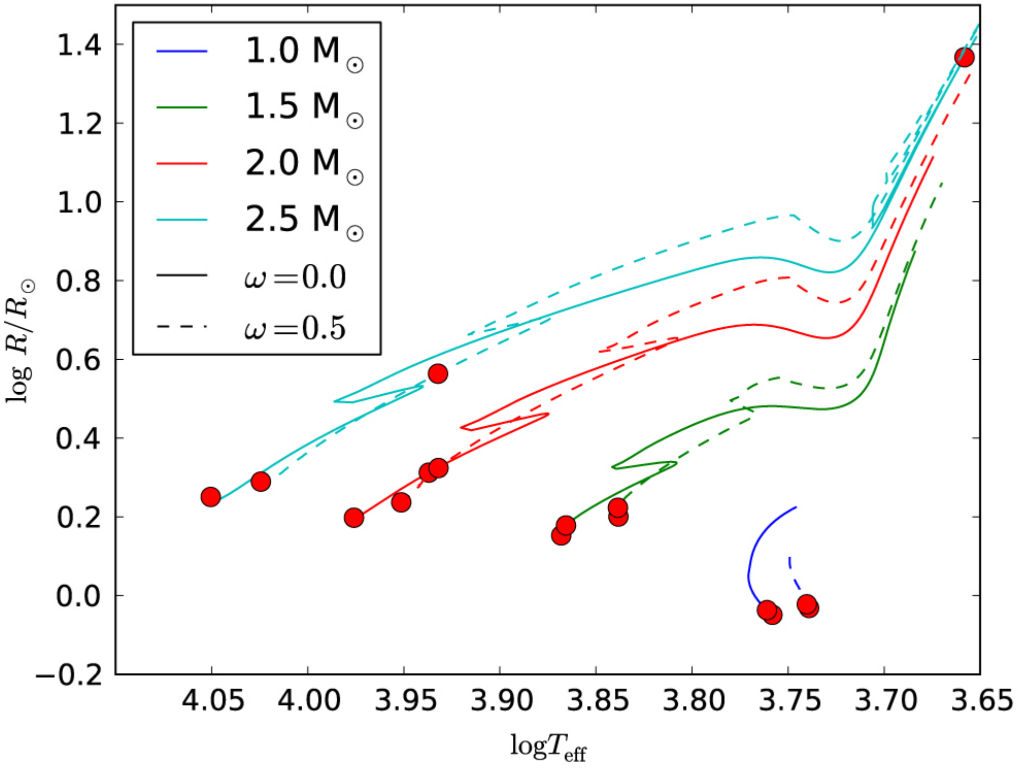


- Empirical HRD
- ~ 290 stars, σ_θ < 5%
- Angular diameter + parallax
  - Linear radius
- Effective Temperature
  - $F_{bol} = \frac{1}{4}\theta^2 \sigma T^4$



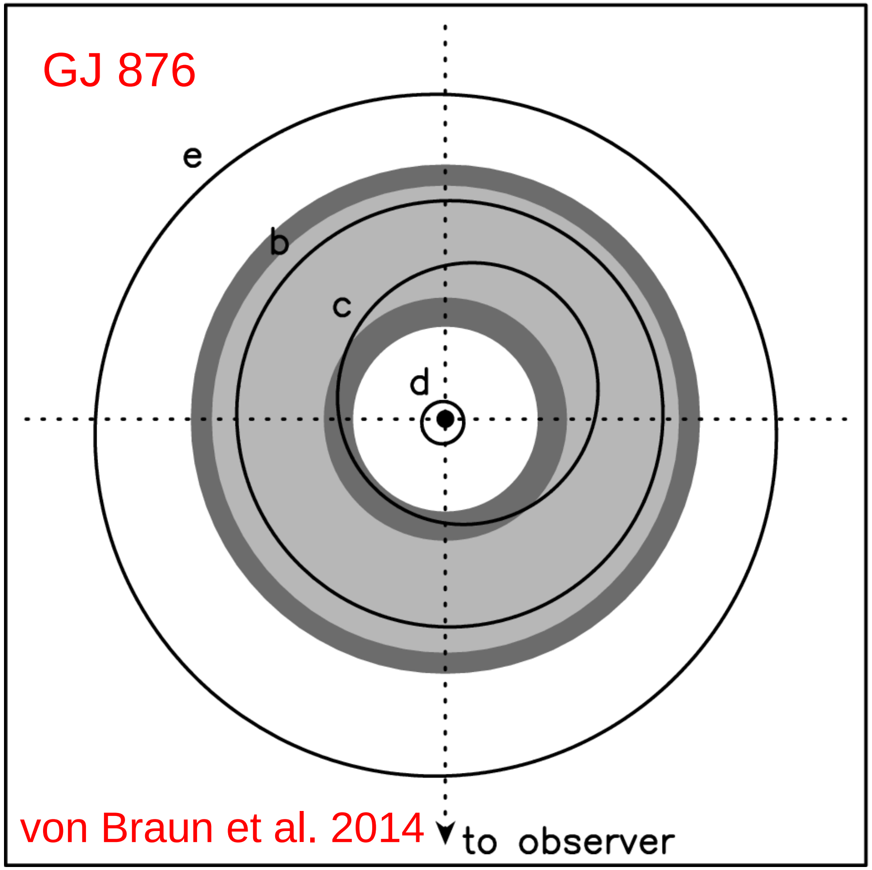
Boyajian et al. 2012

Stellar Ages



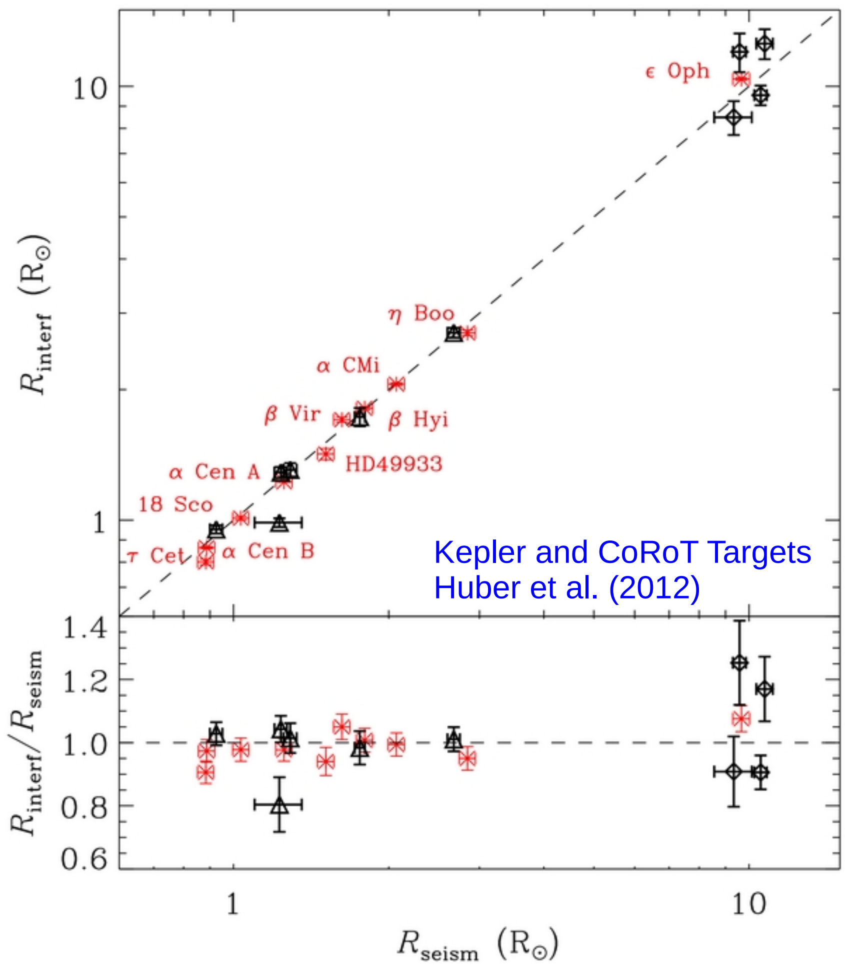
- Comparison of R, T_{eff}, L with evolutionary models
  - Masses and ages of stars
- Ages nearby moving groups
  - (Jones et al. 2015)
- Ages of exoplanet host stars
  - (Ligi et al. 2016)

Exoplanet Host Stars



- Age and mass of host star
- Size of habitable zones
  - L, Teff
- Physical parameters of planets
  - Radius of transiting planets

Asteroseismology



- Asteroseismology probes density and internal structure
- Test astroseismic scaling relations for main sequence and giant stars
  - Mass and Radius

Asteroseismology: Transiting Exoplanet Survey Satellite

- TESS Input Catalog
  - 596 million objects
  - 200,000 – 400,000 selected for high cadence
- Two-year mission
- Launched on April 18, 2018

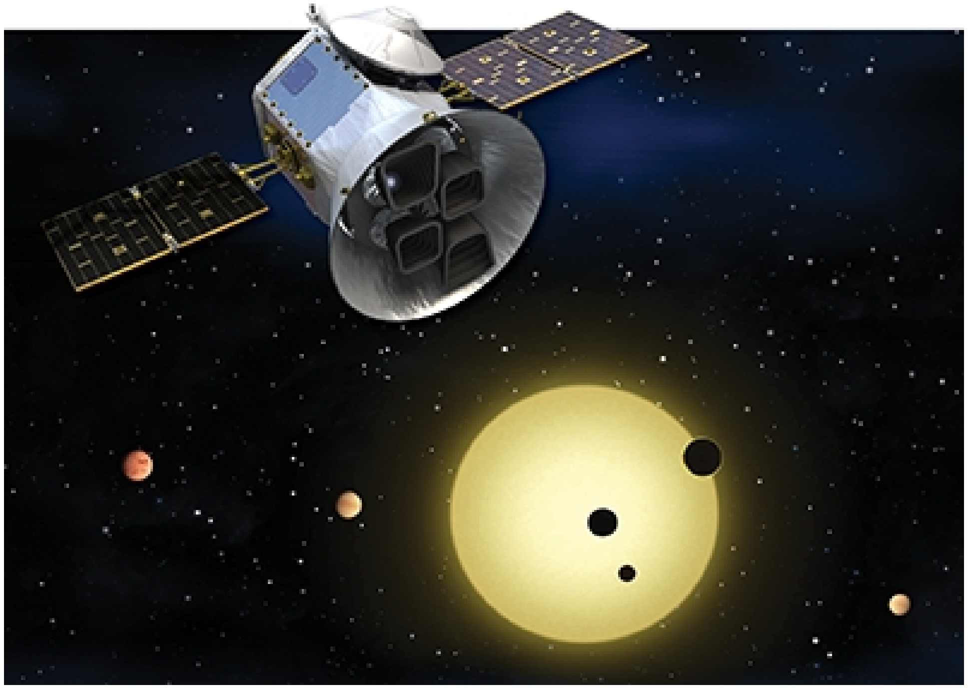
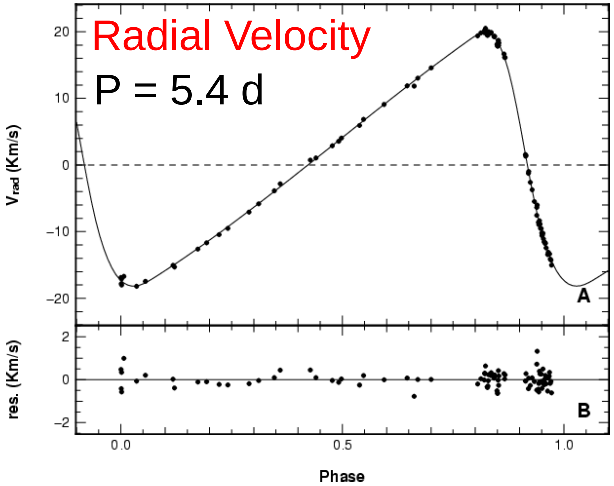
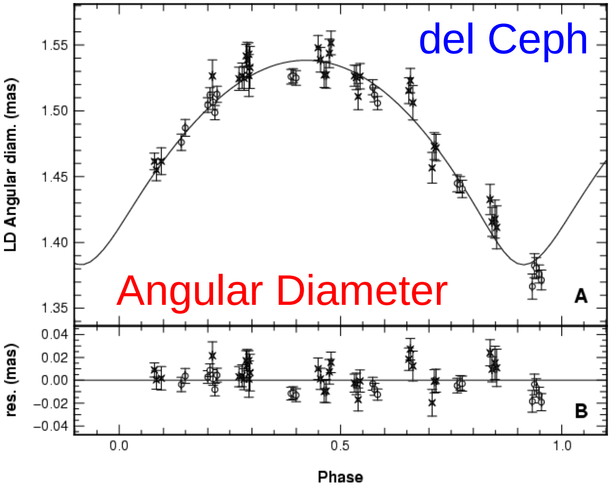


Image credit: NASA

- V < 7 mag
  - 4,864 stars resolvable (θ > 0.2 mas)
- V < 8 mag
  - 13,922 stars resolvable (θ > 0.2 mas)

Cepheids

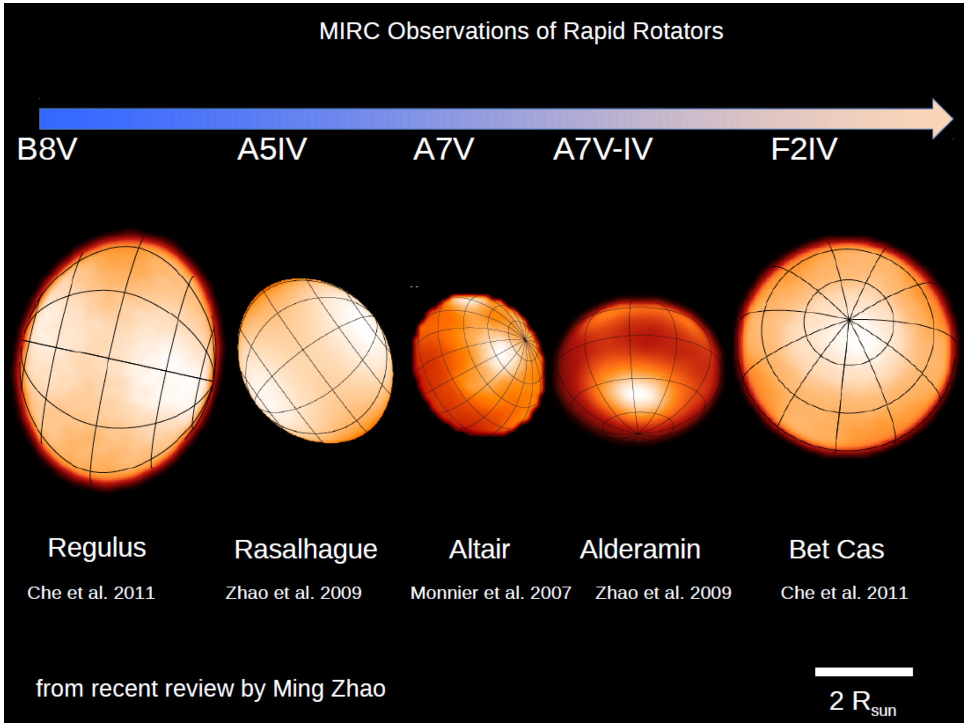




Merand et al 2005

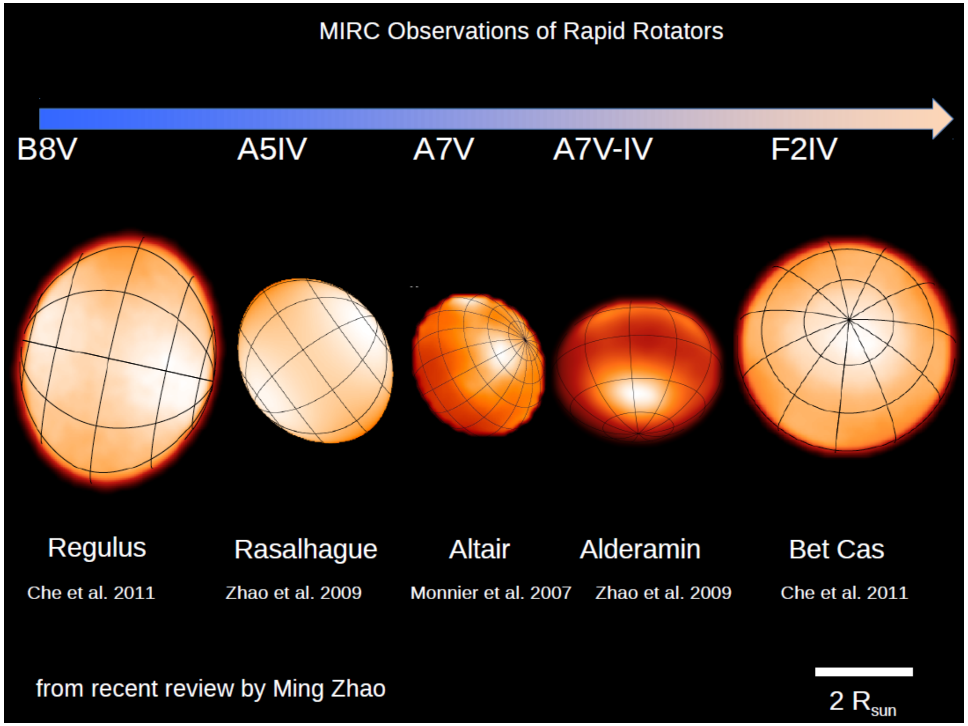
- Radial velocity and angular diameter variation over pulsational phase
- Calibration of Baade-Wesselink technique - pulsation parallaxes
- Simultaneously fit photometry, spectroscopy, interferometry (Merand et al. 2015)
  - Mitigate systematics in projection factor
  - 2% accuracy on radius and distance

Rapid Rotators

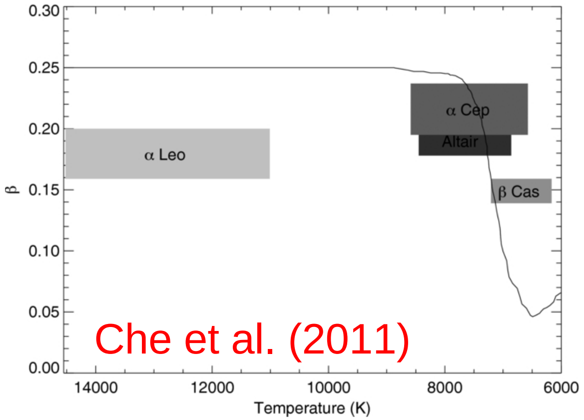


- Oblateness
- Gravity darkening
  - $T_{eff} \sim g^{\beta}$

Rapid Rotators

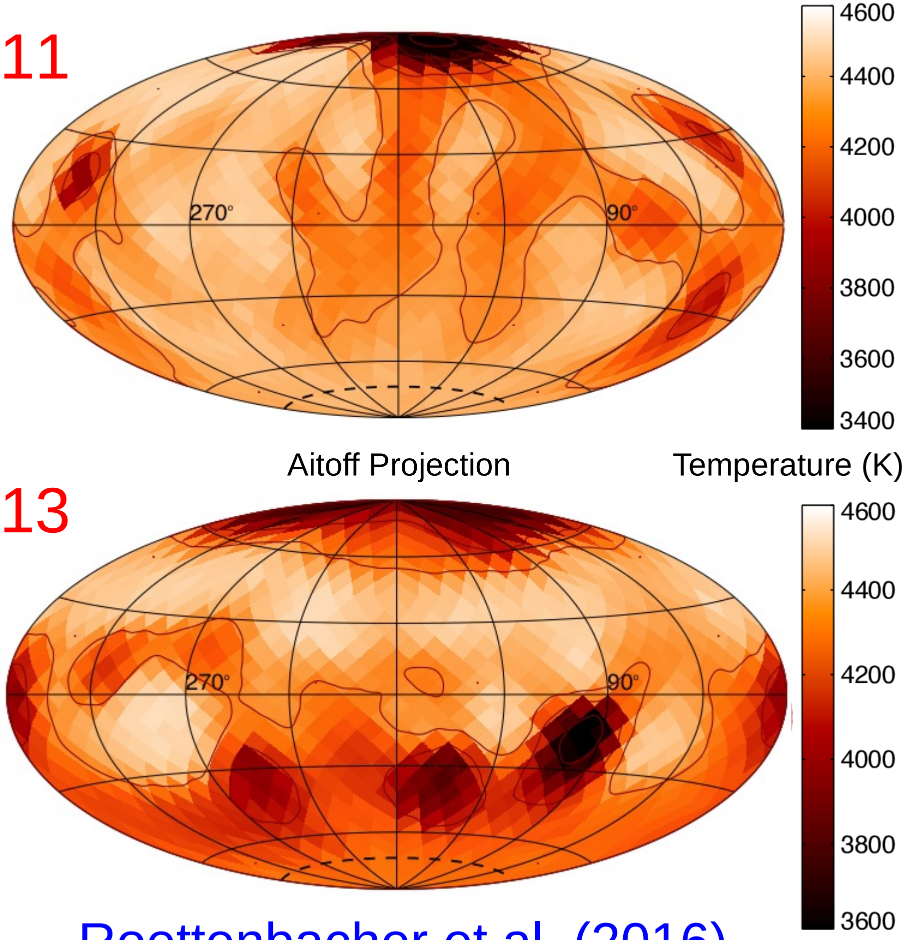


- Oblateness
- Gravity darkening
  - $T_{eff} \sim g^{\beta}$
  - von Zeipel model: $\beta = 0.25$
  - empirically derived $\beta = 0.19$



Spotted Stars

2011

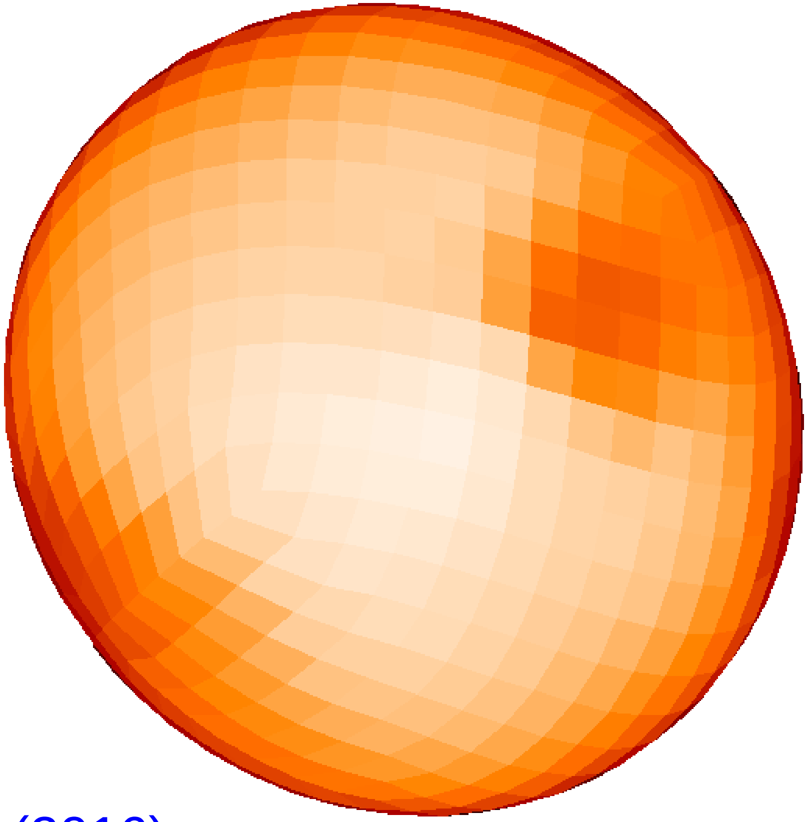


2013

- Magnetically active star zeta Andromedae
- Rotation Period: 18 days
- $\theta = 2.502 \pm 0.008$ mas
- Direct confirmation of persistent polar spot
- Transient lower latitude spots
- Can't be explained by solar dynamo

Roettenbacher et al. (2016)

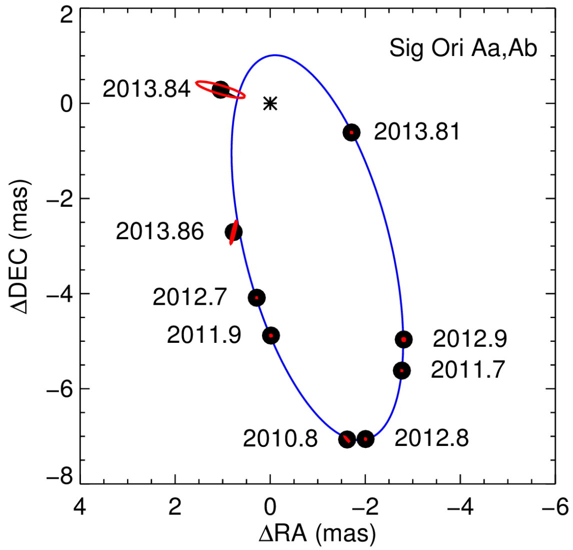
Spotted Stars



Roettenbacher et al. (2016)

Binary Stars

P = 143 d
a = 4.3 mas



Schaefer et al. (2016)

- Spatially resolved orbits of spectroscopic binaries
  - Masses and distances to 1-3% precision

Binary Stars

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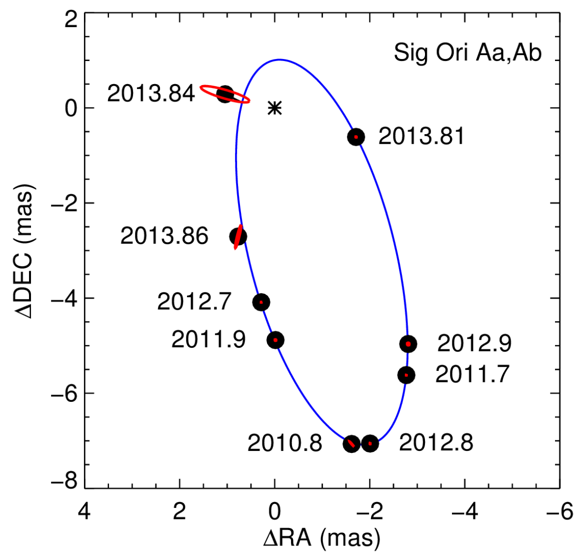


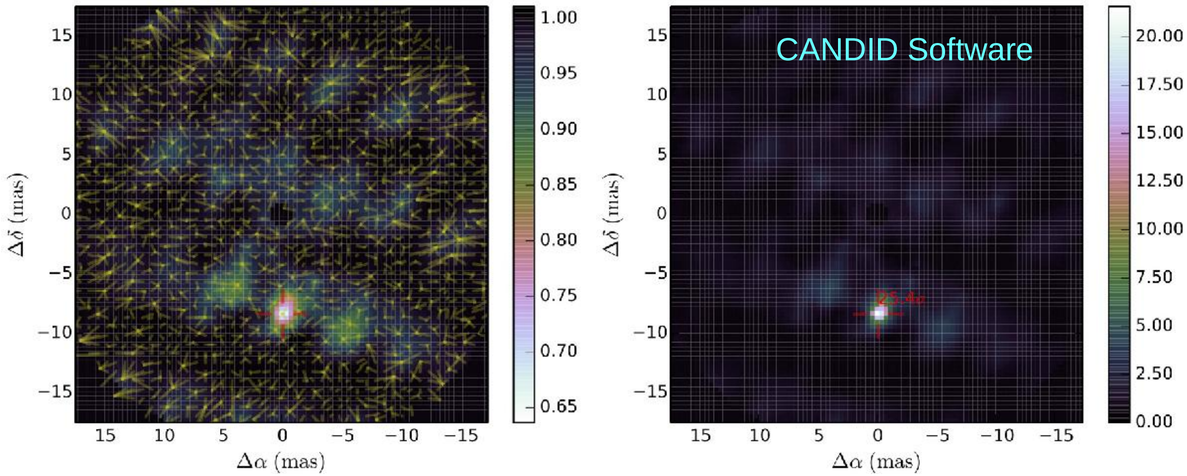
Schaefer et al. (2016)

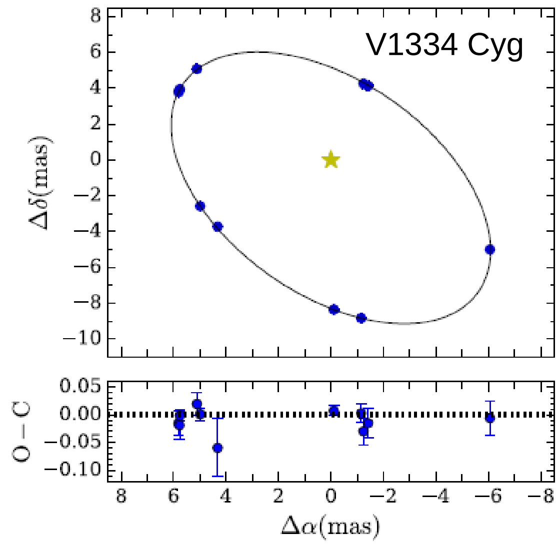
P = 13 d
a = 0.87 mas

Zhao et al. (2008)

- Spatially resolved orbits of spectroscopic binaries
  - Masses and distances to 1-3% precision
- Mass transfer – interacting systems
  - Mass donor is elongated - distortion due to Roche Lobe filling
  - Thick disk around mass gainer - elongated

High Contrast Binaries

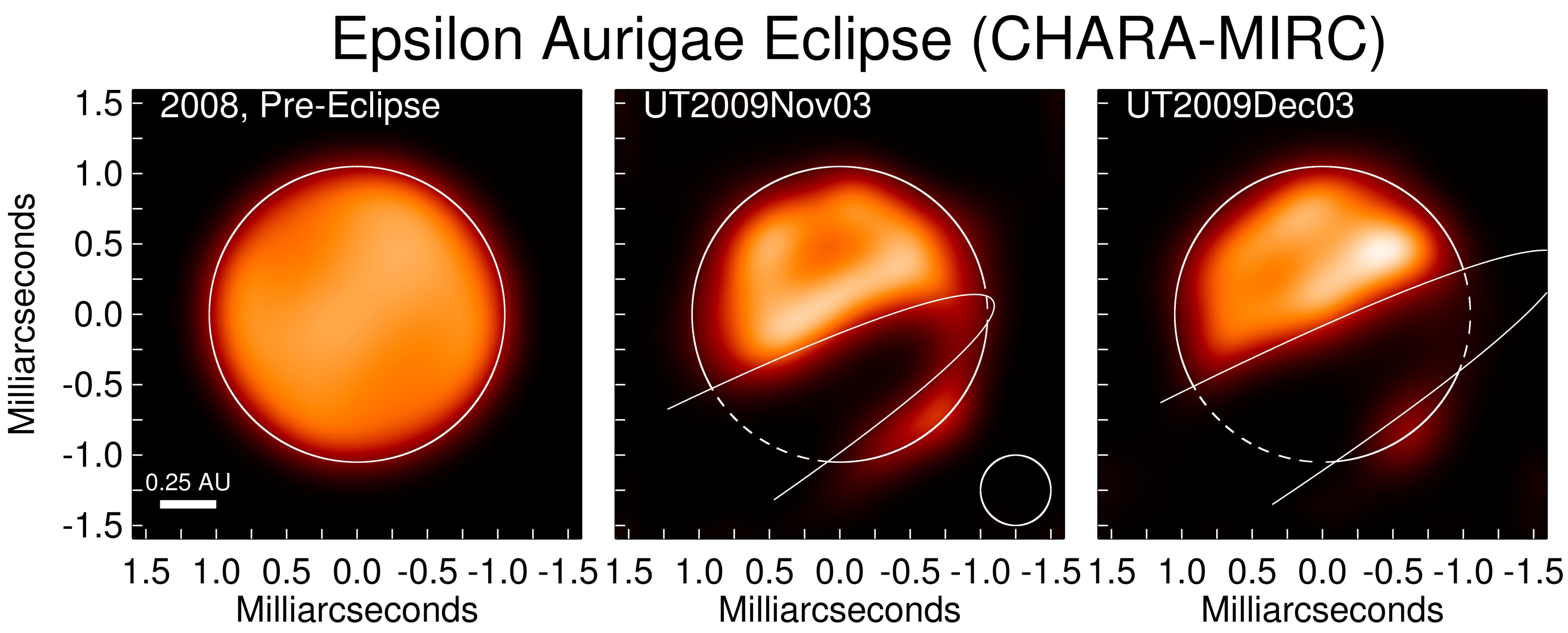




Gallenne et al. (2015, 2017)

- High contrast companions
  - Separations 0.5 - 50 mas
  - ΔH < 6 mag
  - Cepheids companions - Gallenne et al. 2013, 2015
  - RS CVn companions - Roettenbacher et al. 2015a, 2015b

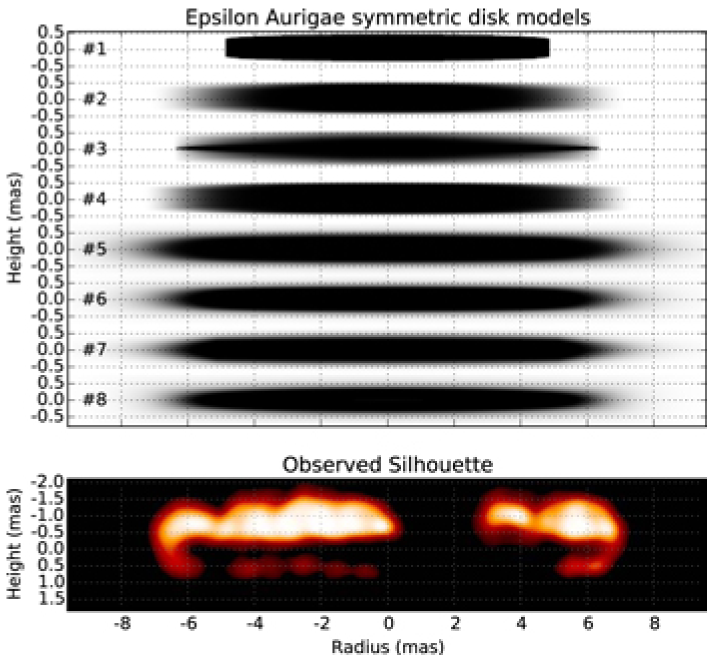
Transiting Disk: Epsilon Aurigae

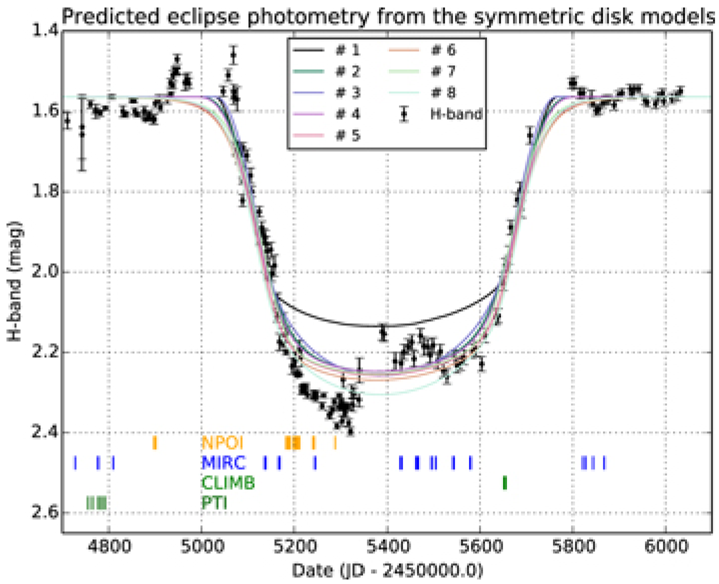


Limb-Darkened Disk:
θ_{LDD} = 2.22 ± 0.09 mas
μ_{LDD} = 0.50 ± 0.26

Kloppenborg et al. (2010)

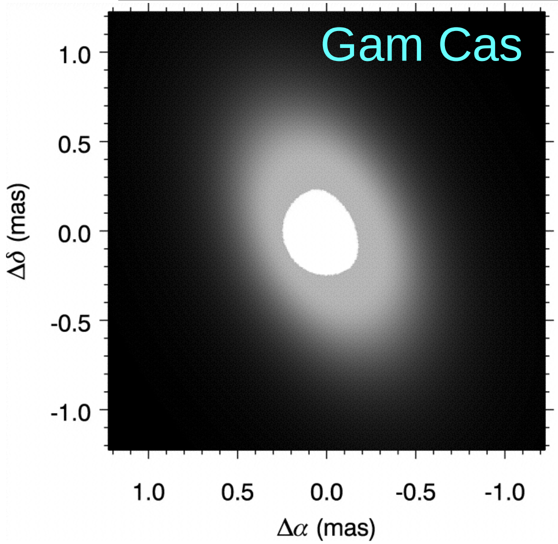
Transiting Disk: Epsilon Aurigae

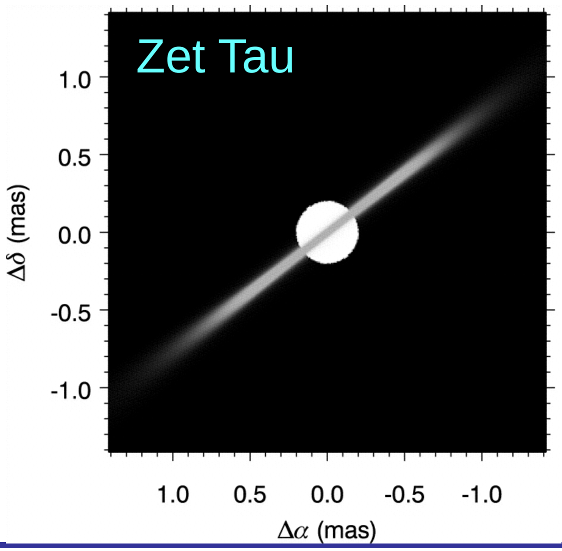




Kloppenborg et al. (2015)

Be Stars

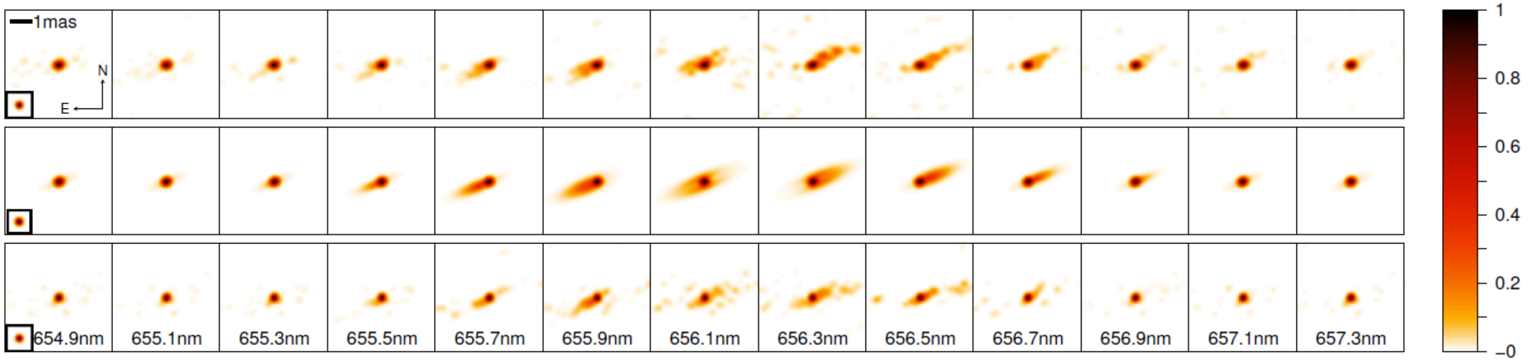


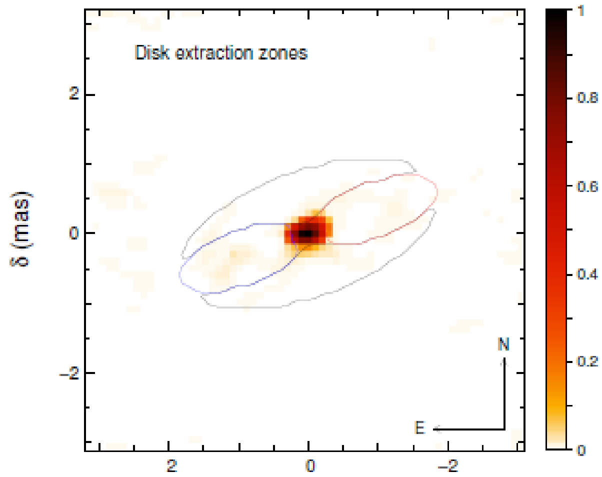


- Rapidly rotating B-type stars that eject gas into a circumstellar disk
- Geometry and physical structure of disks
- Kinematics
- Size vs. wavelength
- Investigate variability over time

Gies et al. (2007)

Kinematics of Be Star Disks

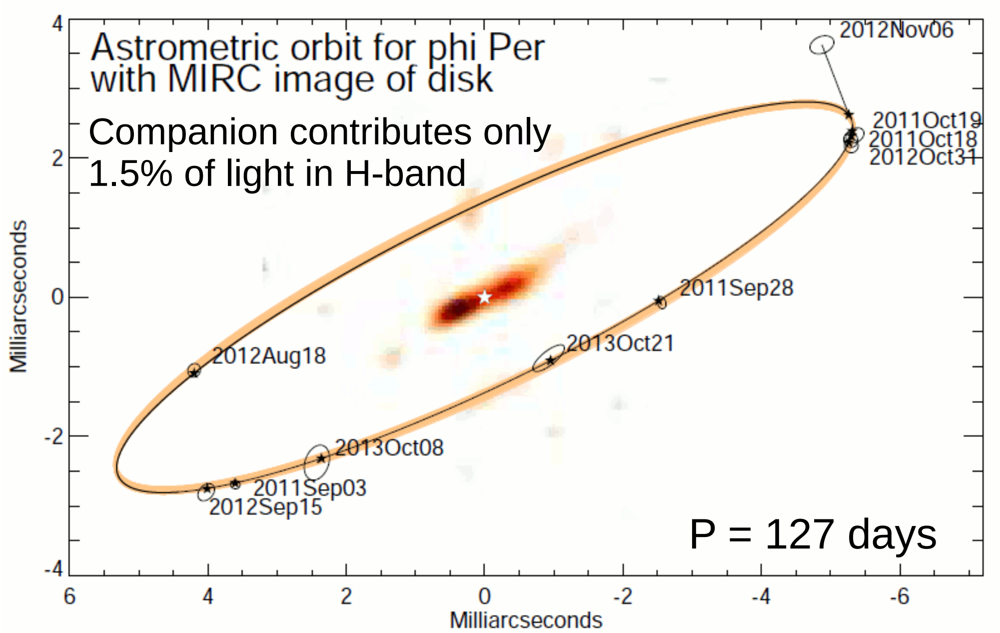




Mourard et al. 2015

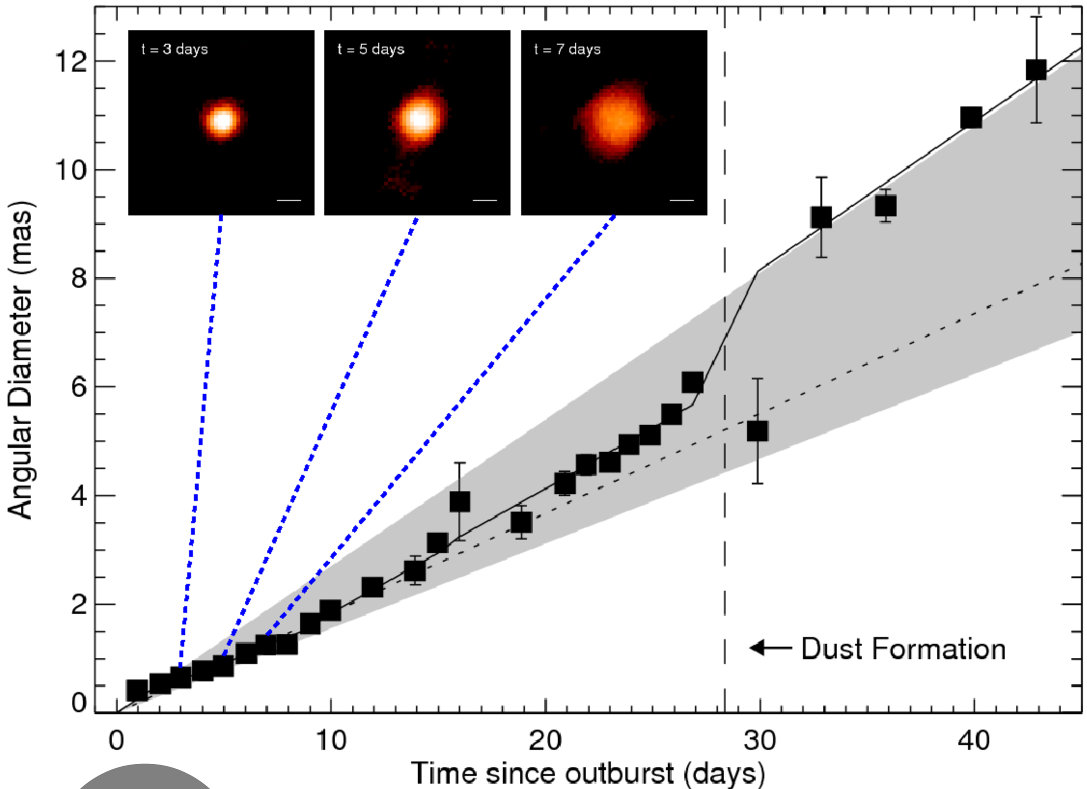
Binarity in Be Stars

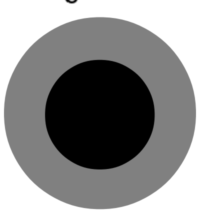
- Role of binarity in Be stars – past mass transfer events?
  - Spun up secondary orbiting stripped down remnant companion (neutron star, white dwarf, helium star)
  - High contrast at close separations



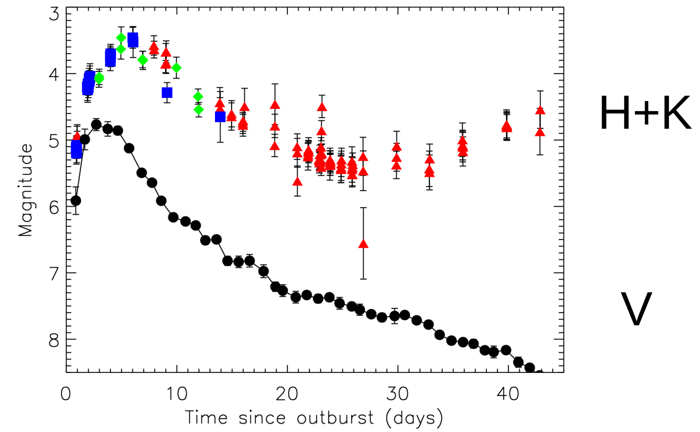
Mourard et al. (2015)

Nova Delphini 2013





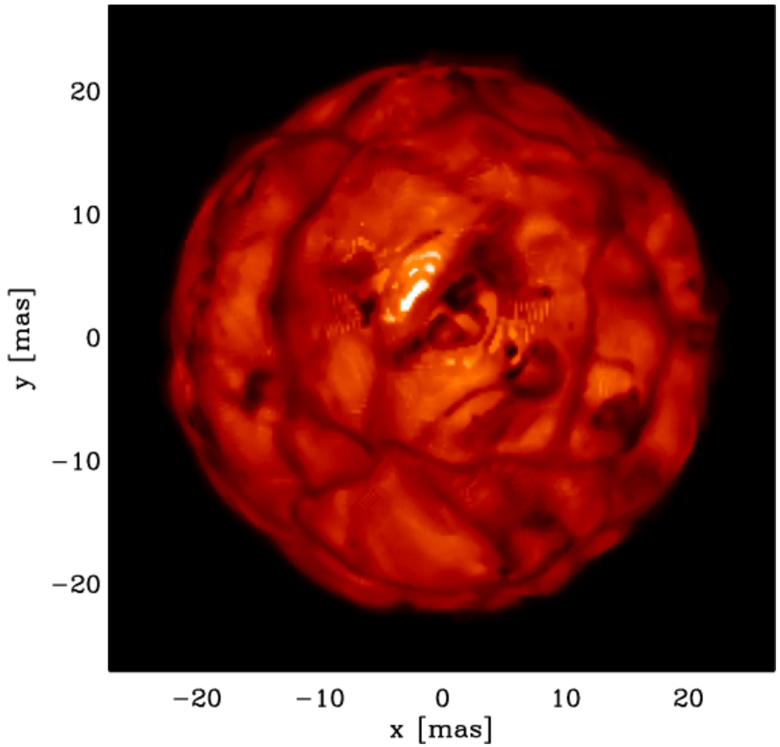
Schaefer et al. 2014



- Changes in apparent expansion – optically thick core surrounded by diffuse envelope that cools over time
- Geometric distance (4.5 kpc)
- Asymmetric shape detected as early as t = 2 days

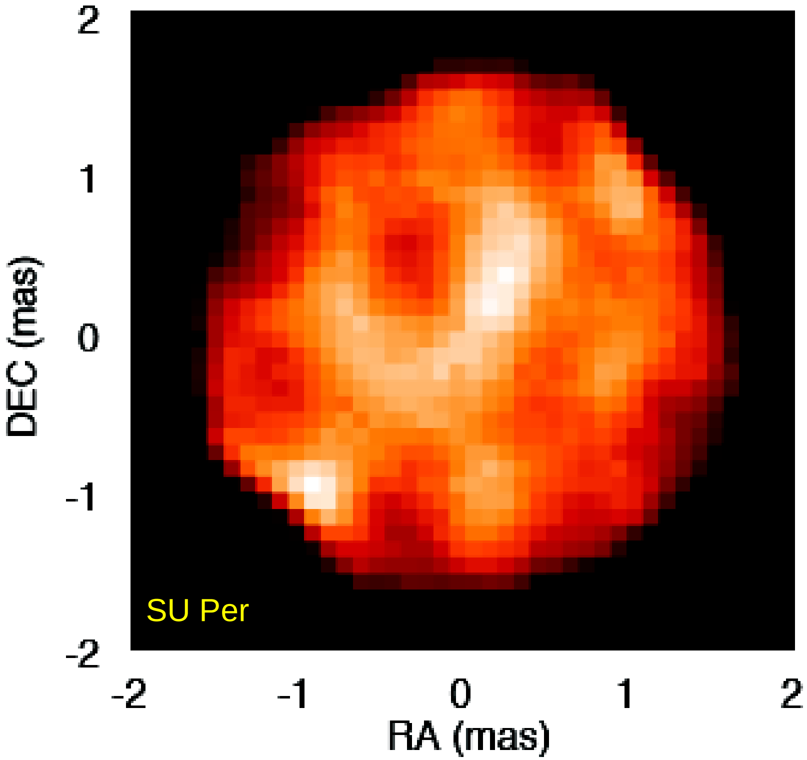
Stellar Convection

Model of Convection for Red Supergiant



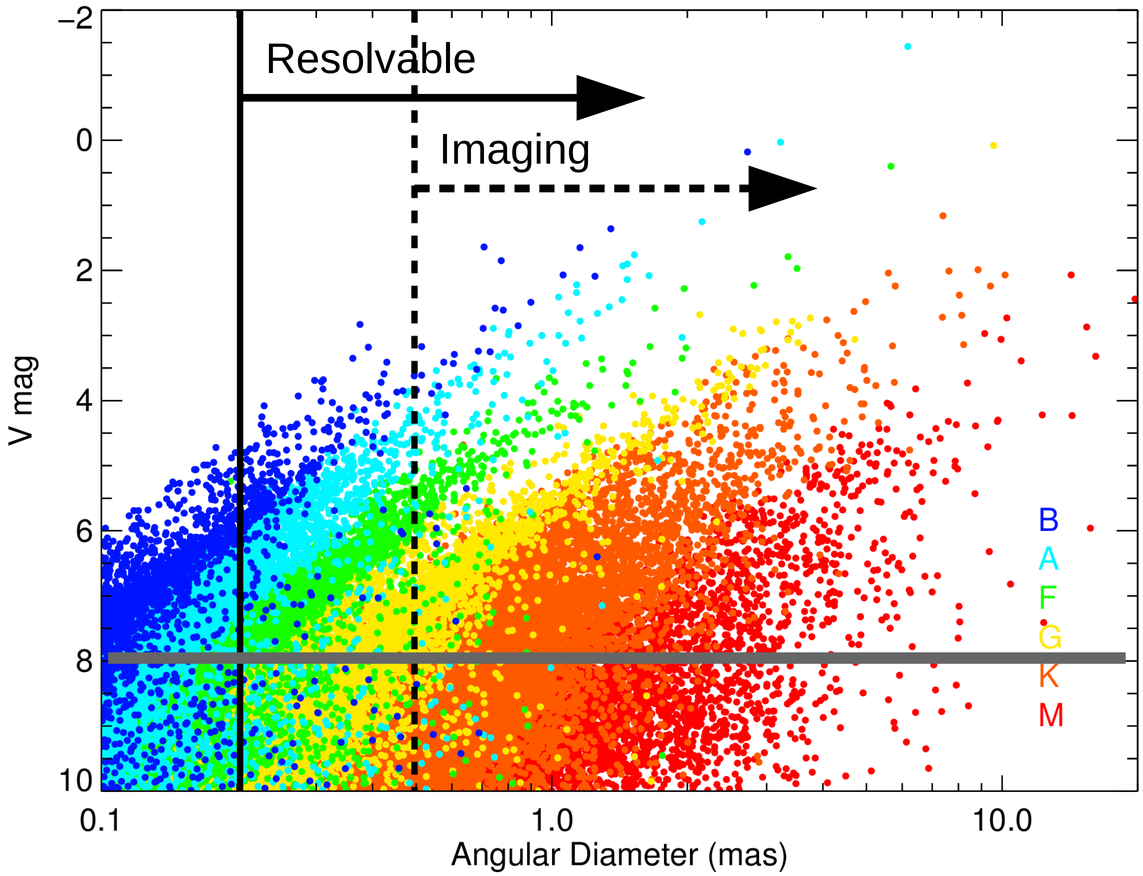
Chiavassa et al. (2010)

CHARA Image of SU Per



Norris et al. (in prep)

Looking Toward the Future...



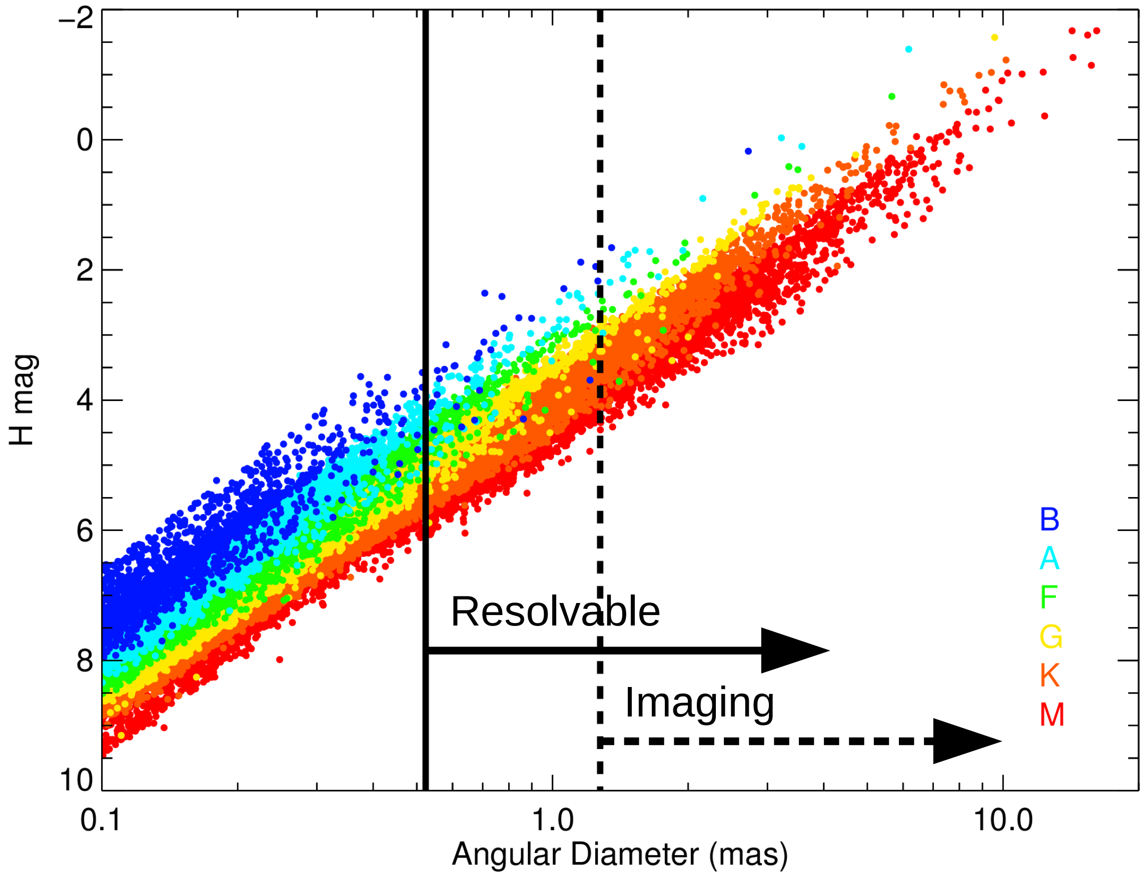
JMMC Stellar Diameter Catalog

DEC > -20°
V < 8 mag
θ > 0.2 mas

Nstar = 18,147

Imaging = 9,781

Looking Toward the Future...



JMMC Stellar Diameter Catalog

DEC > -20°
H < 8 mag
θ > 0.5 mas

Nstar = 19,116

Imaging = 3,558

Summary

- CHARA Array can resolve sizes of stars across the HR Diagram
- Improving our understanding of stellar structure and evolution
  - Stellar radius, effective temperature, dynamical masses
  - Limb darkening, gravity darkening
  - Rotation
  - Starspots
  - Mass loss
  - Convection
- Community access time
  - 50 nights available per year
  - NOAO proposals due in September and March