

Binary Stars and the CHARA Array Mount Wilson Observatory



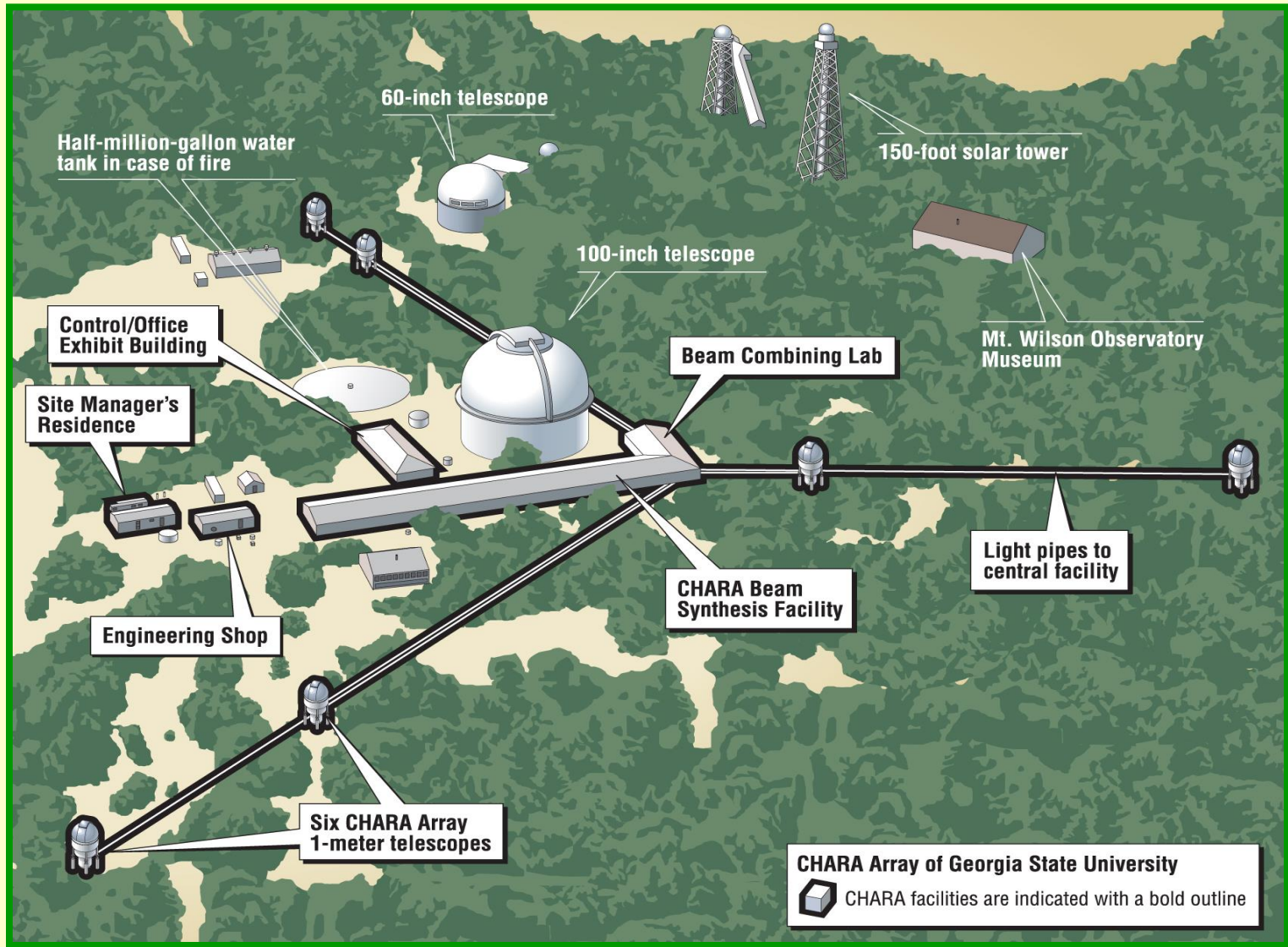
Theo ten Brummelaar

**Associate Director
Center for High Angular Resolution Astronomy
Mount Wilson Observatory**

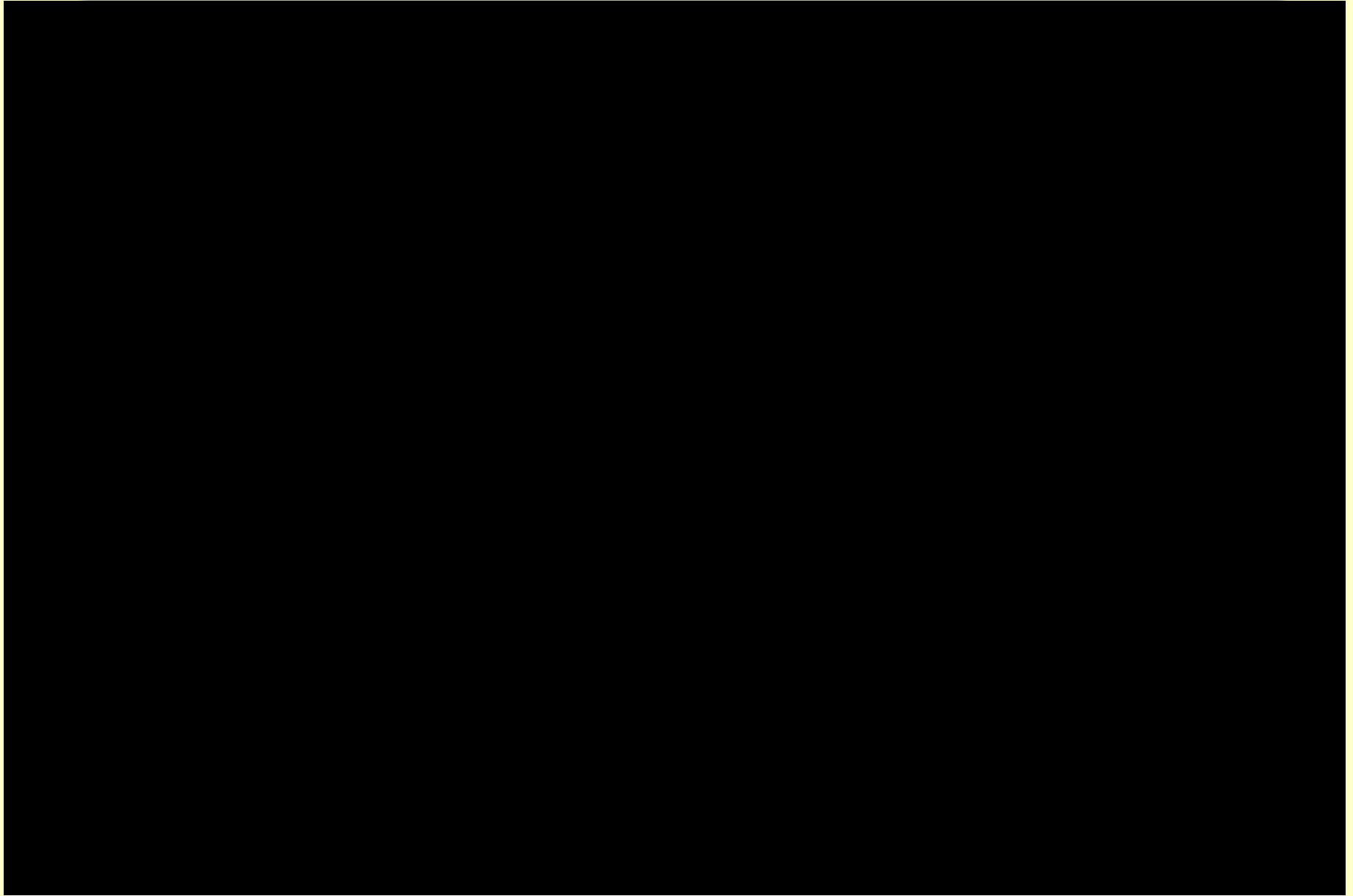
Georgia State University



Layout of the CHARA Array

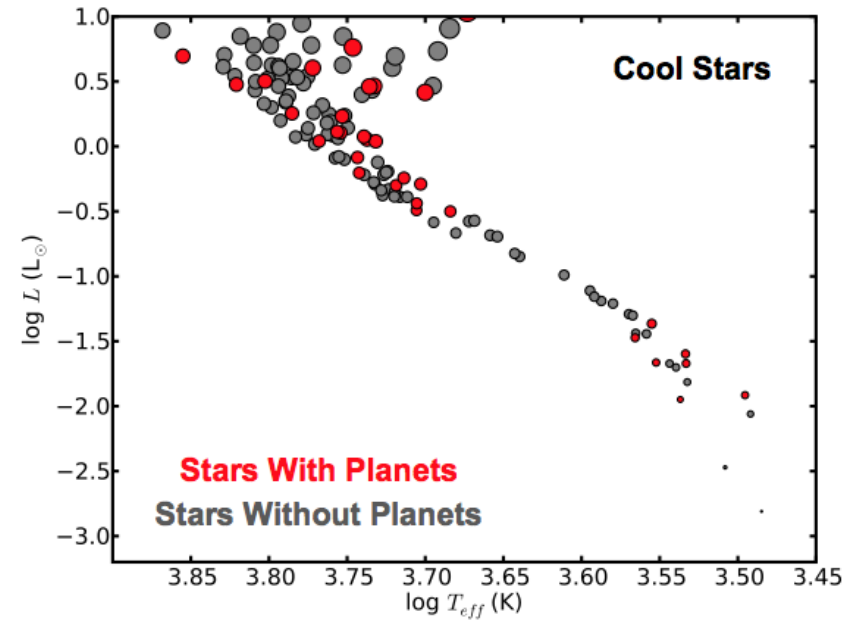
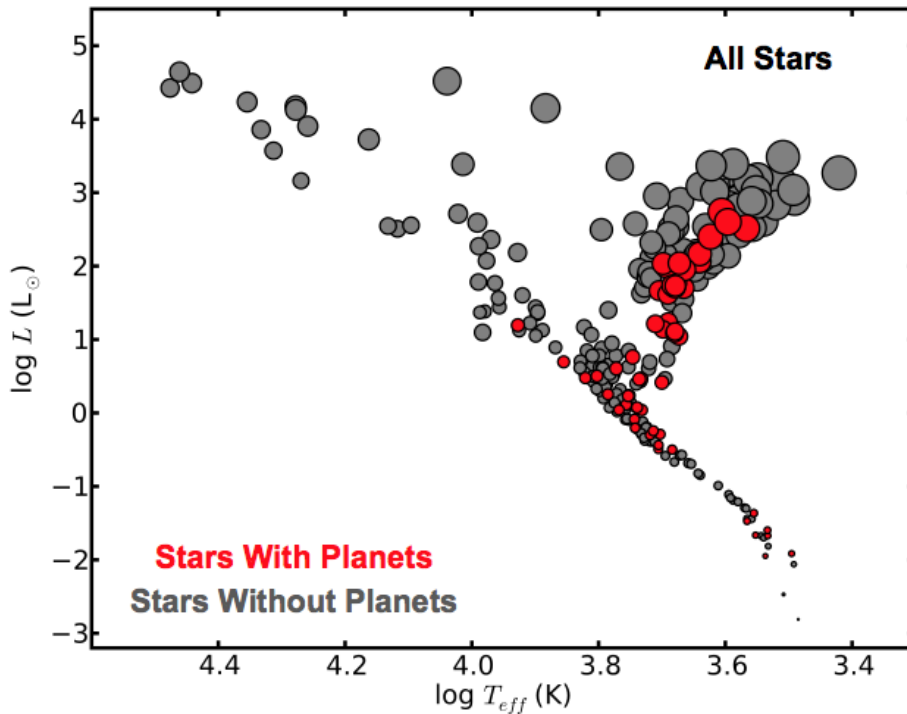


The 30 second CHARA tour.



An Interferometric HR Diagram

Compliments of Tabetha Boyajian and Kaspar von Braun



$\log T_{eff} (K)$

Measurements as shown in grid boxes from **CHARA** arrays.
These data from **2009**

β Lyrae – First Imagery: 4-frame movie

Zhao et al. Science 2007.

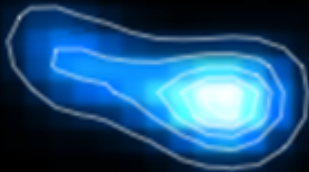
5 Jul 2007



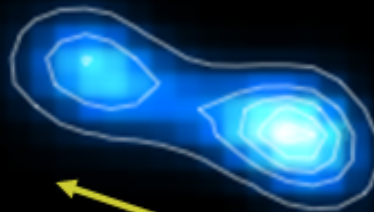
7 Jul 2007



9 Jul 2007



12 Jul 2007



1 mas \sim 0.3 AU

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



Model of
Linnell et al.
1988

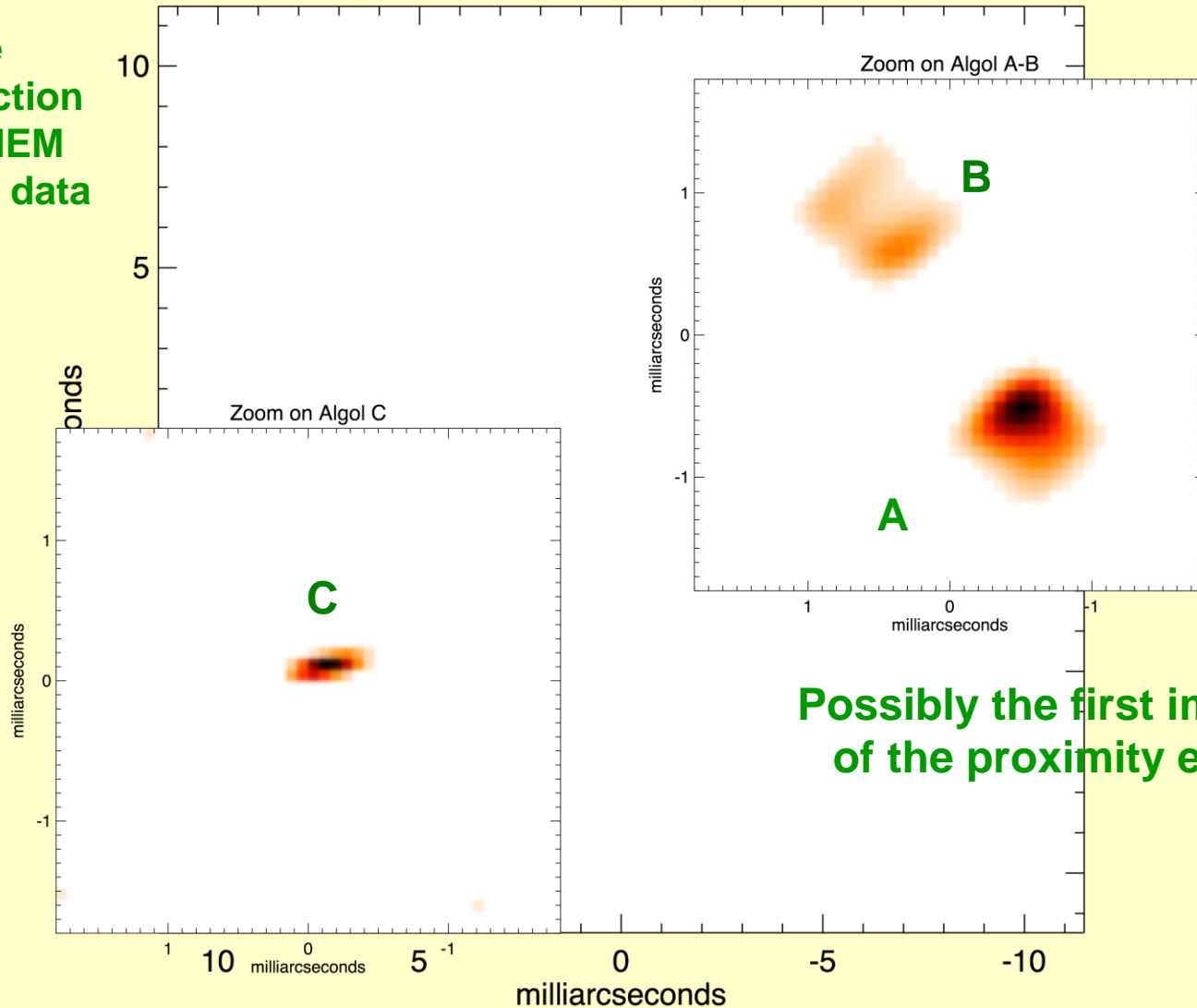
β Lyrae – The Movie



First resolved images of the Algol system

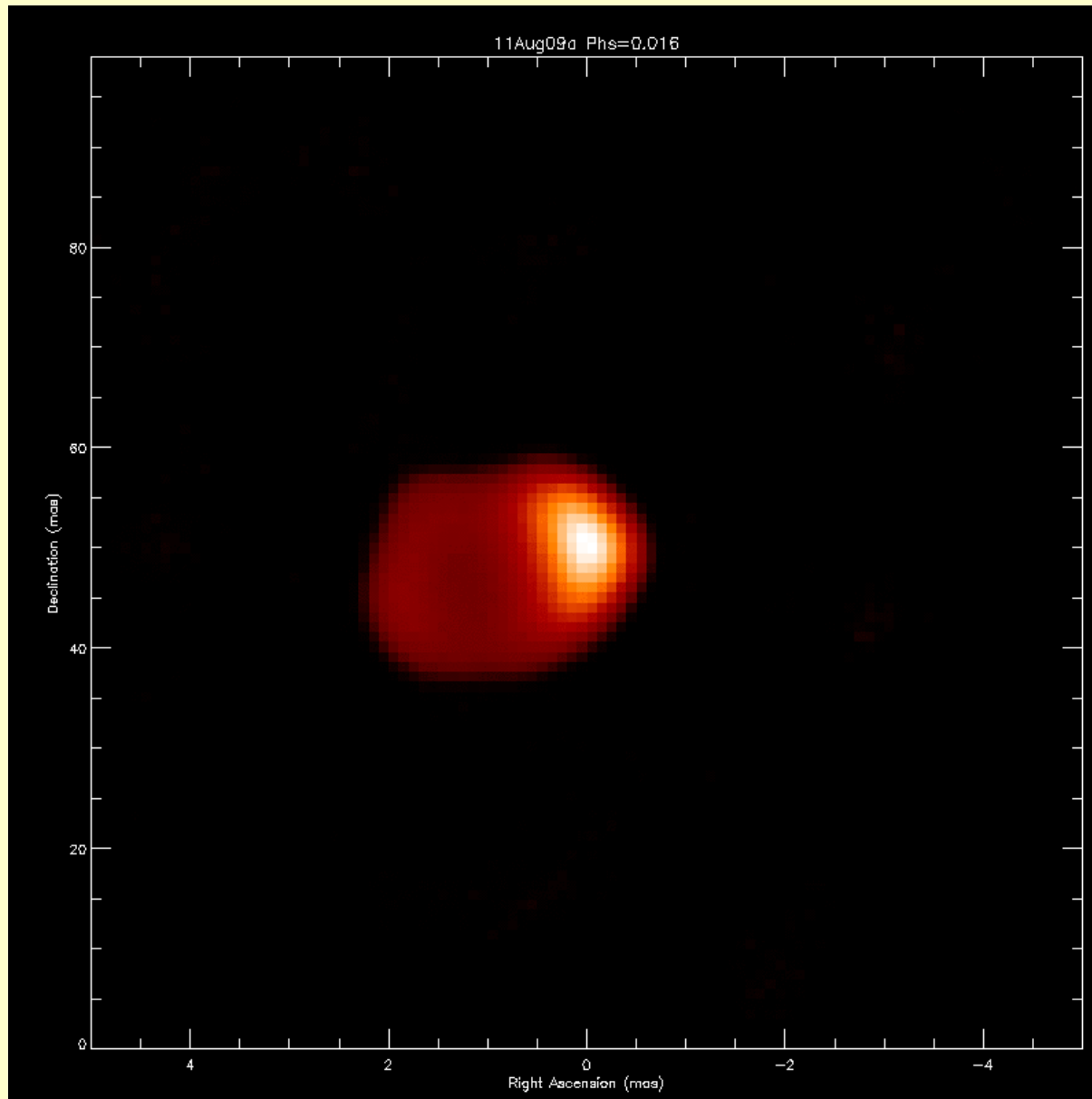
Algol Reconstruction - 12 Aug 2009

Image reconstruction with BS MEM from MIRC data



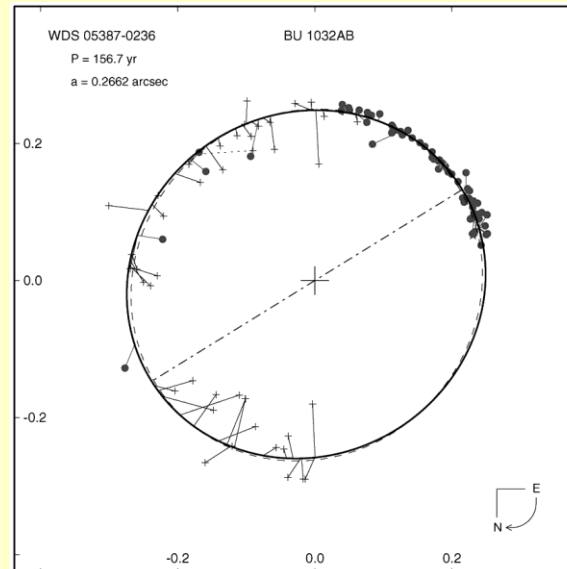
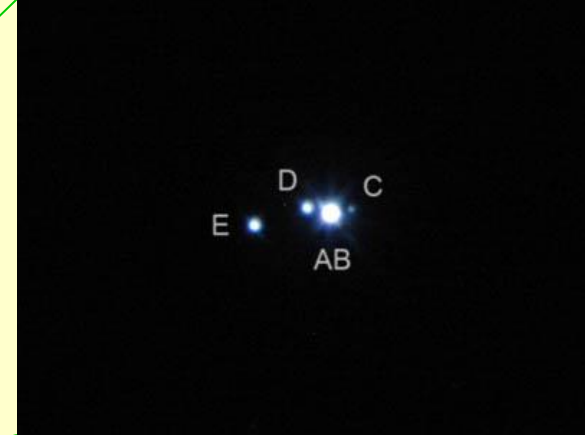
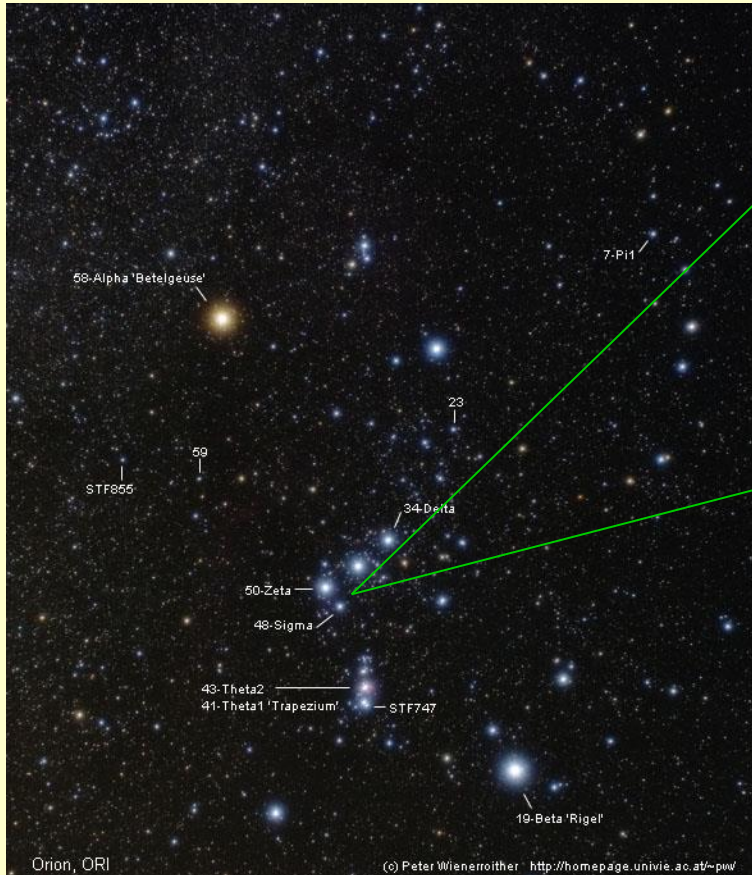
Possibly the first images of the proximity effect

Algol the Movie: Baron et al 2011.



Sigma Orionis: O-Star Triple (Aa,Ab, B)

Image credit: <http://astronomy.kez.nu>



**Visual Orbit
Sigma Ori A-B**

Turner et al. 2008

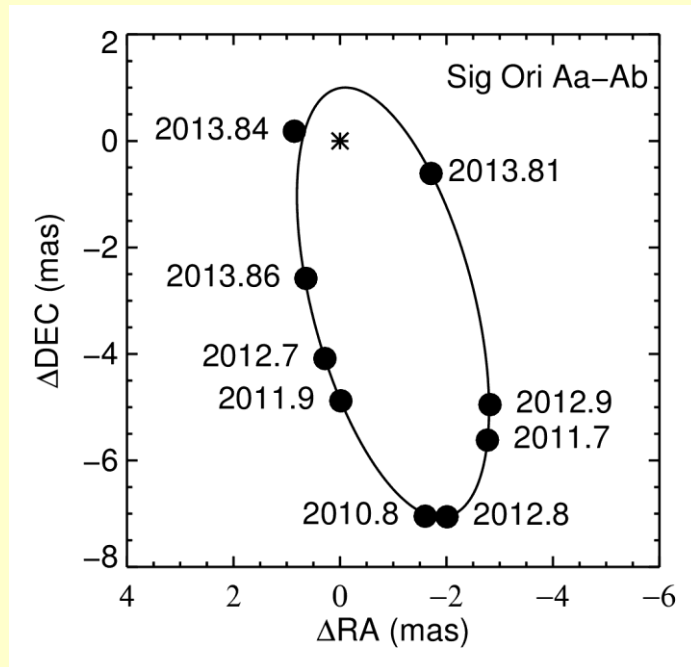
**Speckle, AO,
visual data**

**P = 156.7 yr
a = 266.2 mas**

Image credit: Peter Wienerroither

Orbit of Sigma Ori Aa,Ab

Visual Orbit – CHARA/MIRC



Masses and distance:

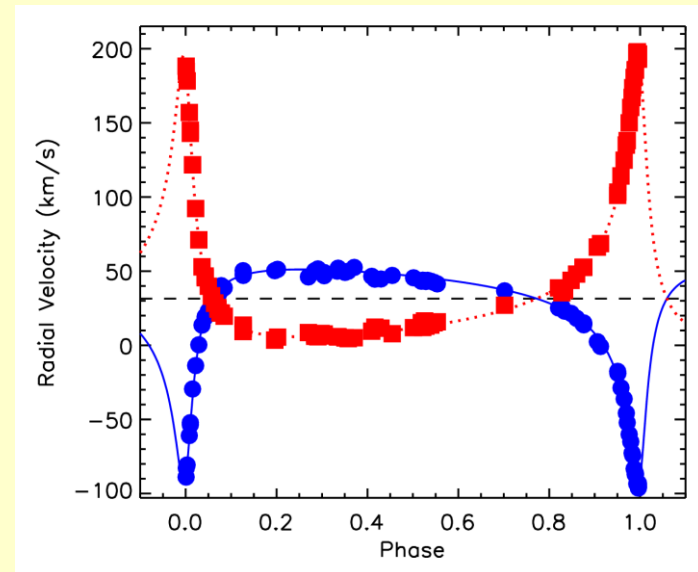
$$M_{Aa} = 16.9 \pm 0.2 M_{\odot}$$

$$M_{Ab} = 12.9 \pm 0.2 M_{\odot}$$

$$d = 388.9 \pm 0.8 \text{ pc}$$

Schaefer et al. (in prep)

Radial Velocities from Simon-Diaz et al. 2014



Orbital Parameters:

$$P = 143.20 \pm 0.003 \text{ days}$$

$$e = 0.7792 \pm 0.0003$$

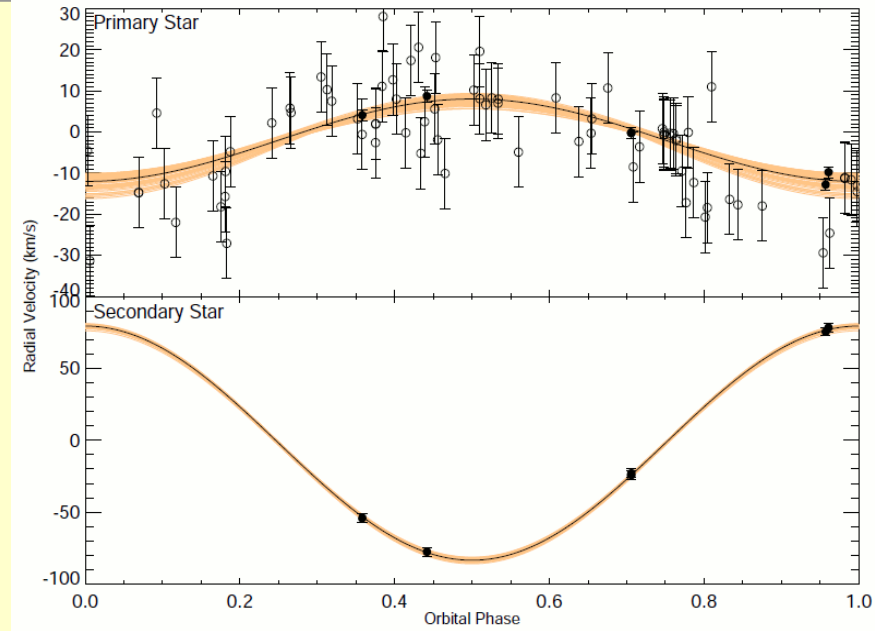
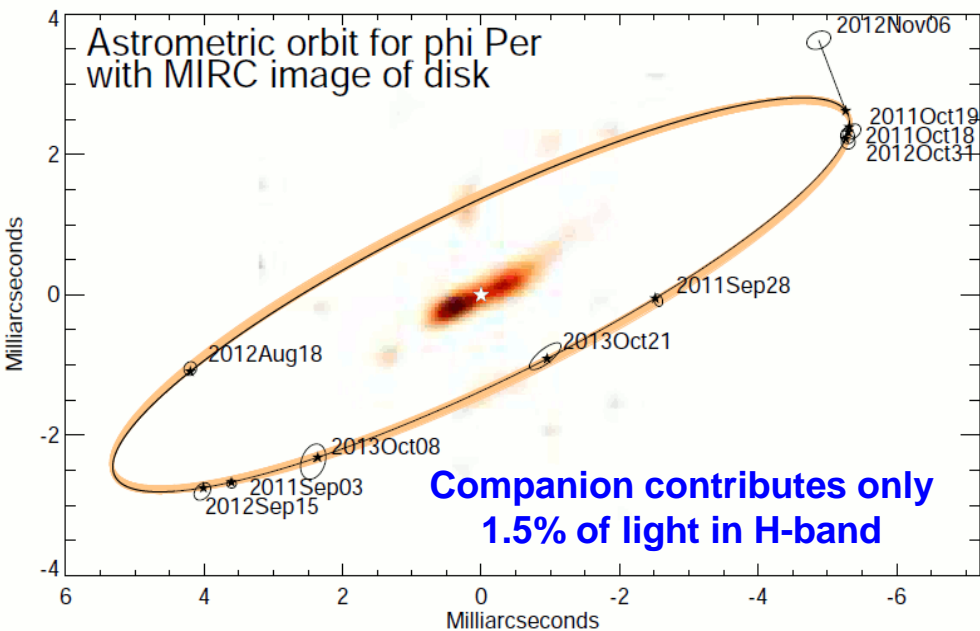
$$a = 4.268 \pm 0.002 \text{ mas}$$

$$i = 56.40^{\circ} \pm 0.06^{\circ}$$

$$K_{Aa} = 72.4 \pm 0.3 \text{ km/s}$$

$$K_{Ab} = 95.2 \pm 0.2 \text{ km/s}$$

Imaging a Be Star disk and the orbit its faint companion



Disk Properties:

$f_{\text{star}} = 70\% \pm 6\%$

$f_{\text{disk}} = 29\% \pm 6\%$

$f_{\text{comp}} = 1.5\% \pm 0.3\%$

major = 1.44 ± 0.41 mas

minor = 0.22 ± 0.12 mas

PA = $-64^\circ \pm 3^\circ$

$i = 82^\circ \pm 4^\circ$

Orbital Parameters:

$P = 126.7$ days

$e = 0$

$a = 5.89 \pm 0.02$ mas

$i = 77.6^\circ \pm 0.3^\circ$

Masses and distance:

$M_a = 9.6 \pm 0.3 M_\odot$

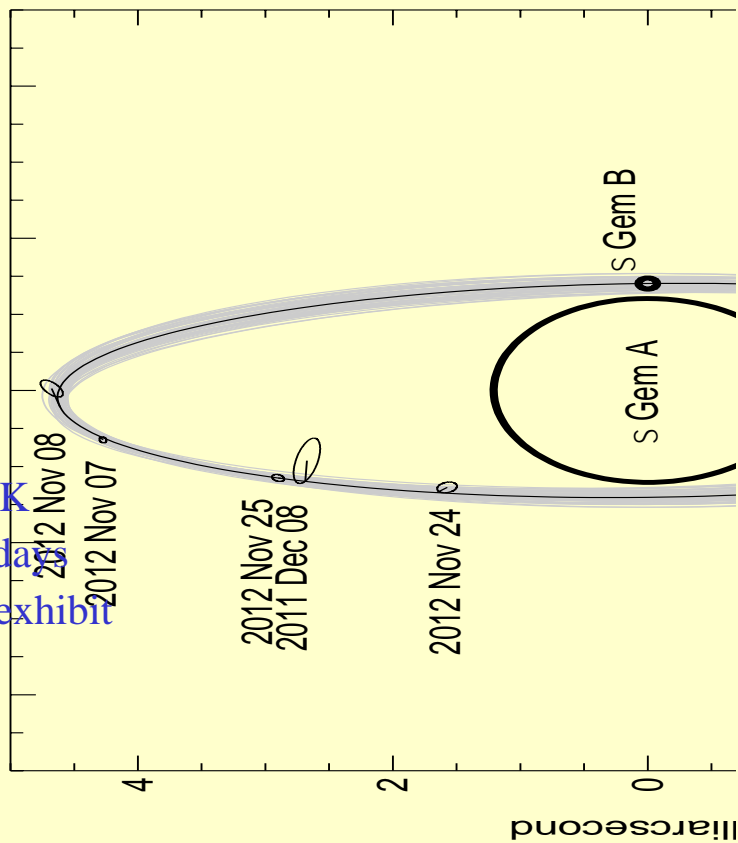
$M_b = 1.2 \pm 0.2 M_\odot$

$d = 186 \pm 3$ pc

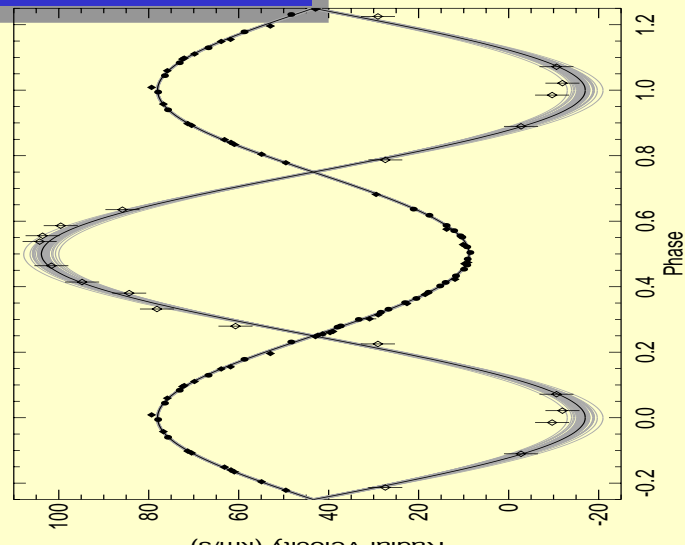
Mourard et al. 2015

σ Gem – Orbit

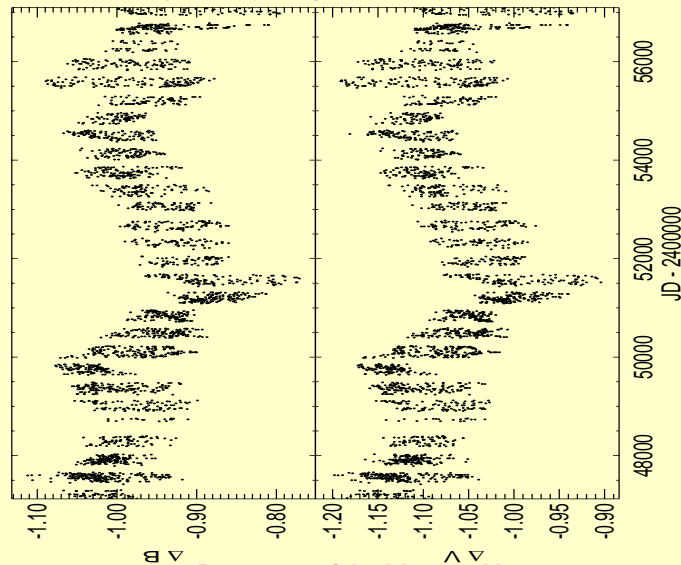
- $T_{\text{eff}} \sim 4530$ K
- $P_{\text{rot}} \sim 19.6$ days
- Known to exhibit starspots
- $\beta = 270:1$



Roettenbacher et al. 2015a



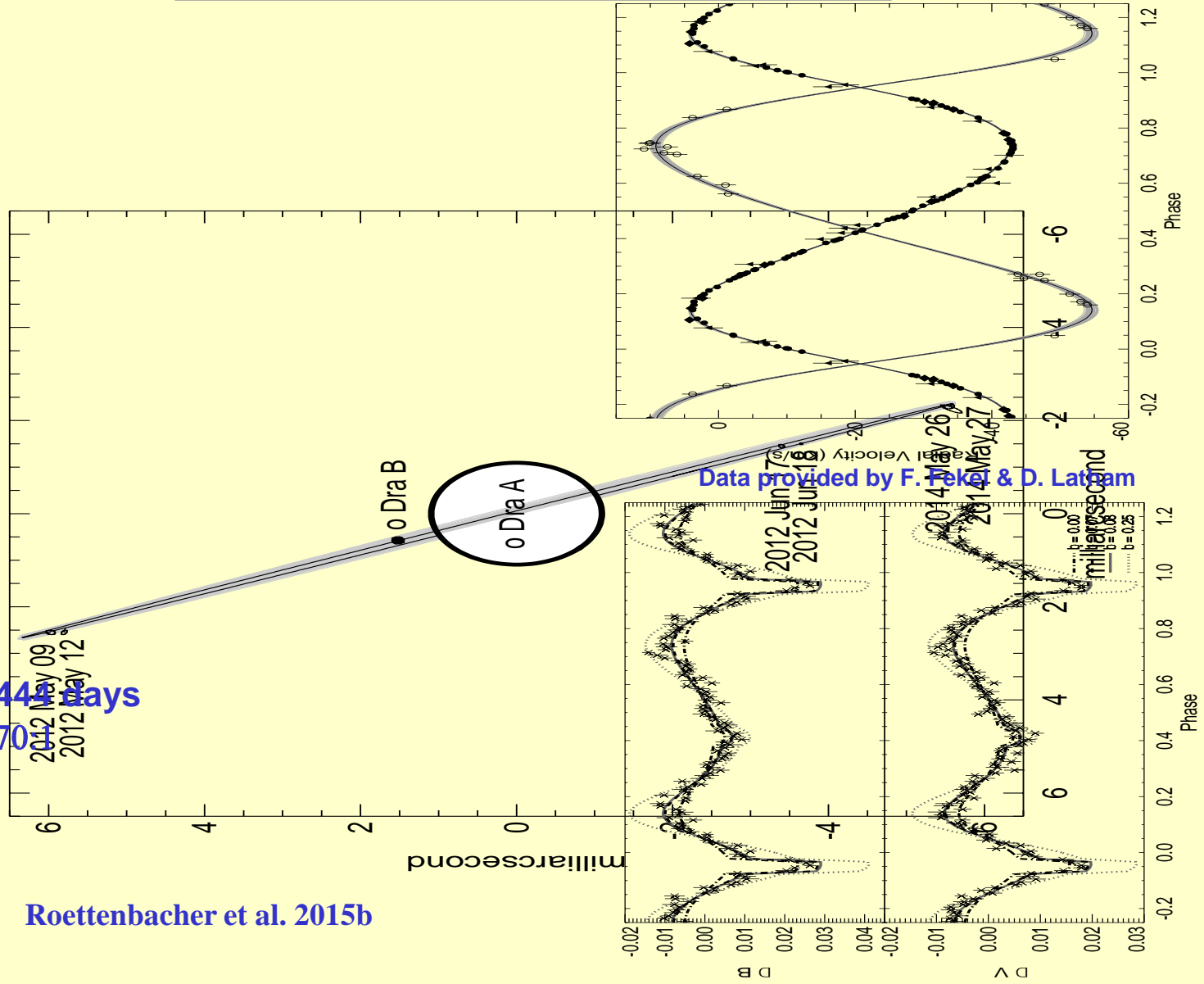
Data provided by F. Fekel & D. Latham



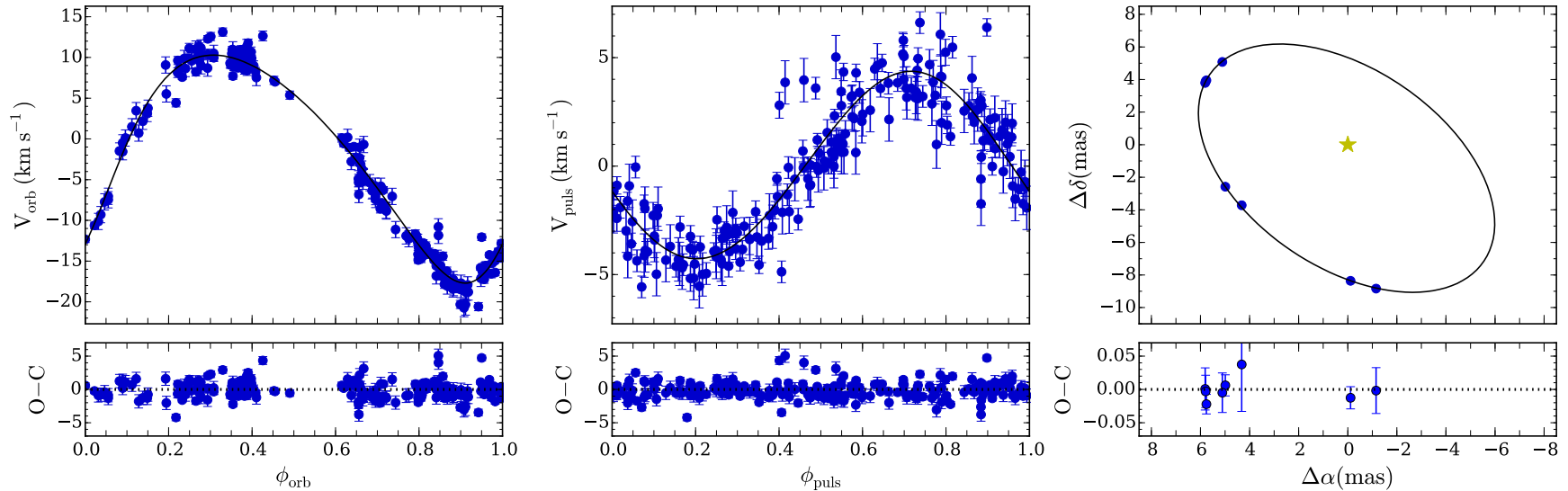
Data provided by G. Henry

o Dra – Orbit

$P_{\text{orb}} = 138.44$ days
 $\beta = 370$



Binary Cepheid Program – Masses and Distances



Cepheid V1334 Cyg (Gallenne et al. 2013)

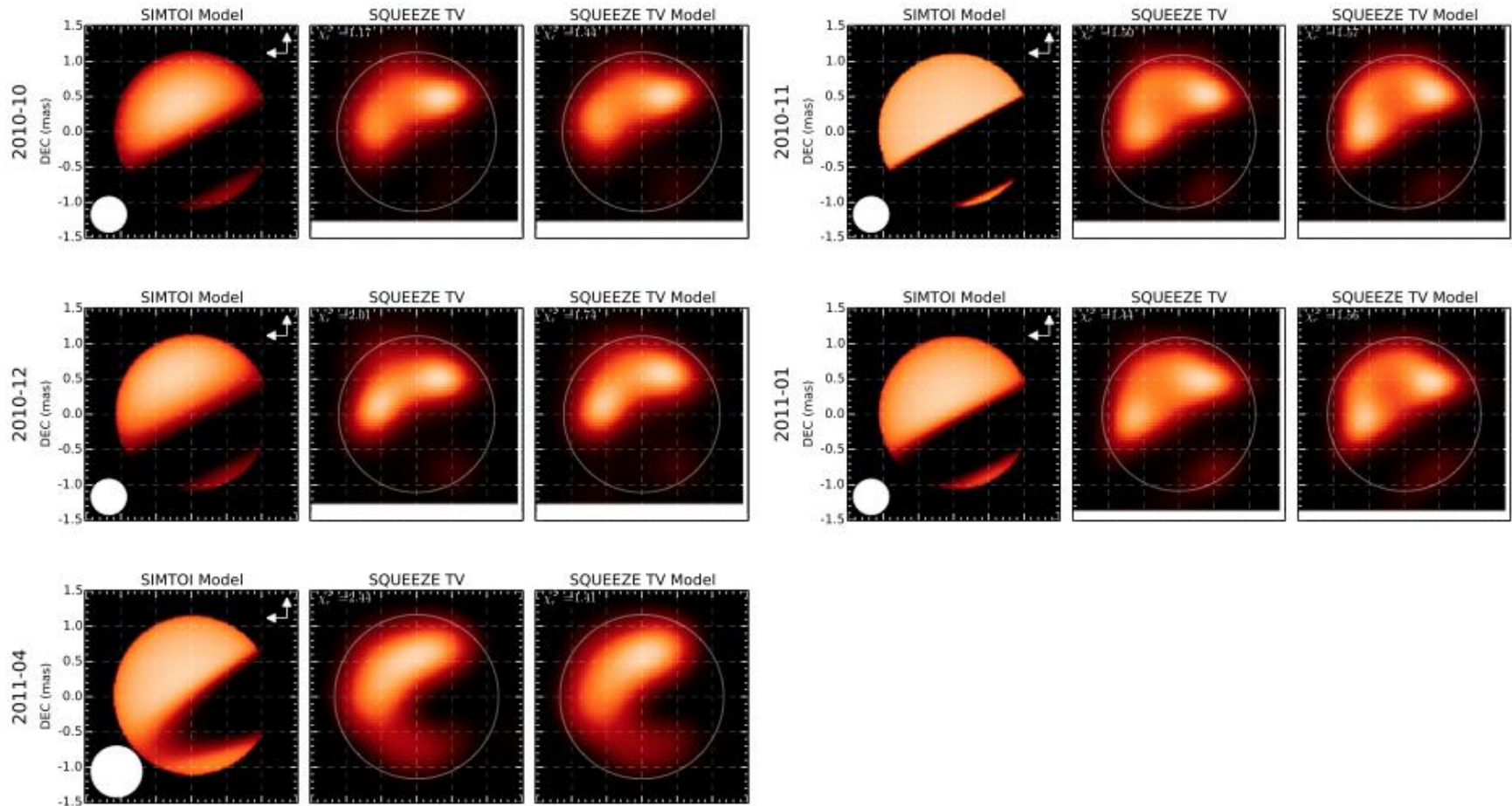
- Flux Ratio 3%
- Companion detected by MIRC
- Single lined spectroscopic binary, waiting for HST/STIS for second line.

Cepheid RT Aur (Gallenne et al. 2015)

- Record for Interferometry – Flux Ratio of 455:1

	Spectroscopy only (Evans 2000)	This work
Orbit		
P_{orb} (days)	1937.5 ± 2.1	1938.6 ± 1.2
T_p (HJD)	$2\,443\,607 \pm 14$	$2\,443\,616.1 \pm 7.3$
e	0.197 ± 0.009	0.190 ± 0.013
K_1 (km s ⁻¹)	14.1 ± 0.1	13.86 ± 0.17
v_γ (km s ⁻¹)	-1.8 ± 0.1	-1.9 ± 0.1
ω (°)	226.3 ± 2.9	228.7 ± 1.6
Ω (°)	–	206.3 ± 9.4
a (mas)	–	8.54 ± 0.51
i (°)	–	124.7 ± 1.8
m_{H}	–	8.47 ± 0.15
Pulsation		
P_{puls} (days)	3.33251 ± 0.00001	3.33250 ± 0.00002
T_0^{p} (HJD)	2 440 124.5330	2 440 124.5330
A_1	–	4.35 ± 0.15
A_2	–	1.81 ± 0.11
B_1	–	0.08 ± 0.06
B_2	–	2.72 ± 1.30

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



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www.mtwilson.edu

