Long-baseline interferometry study of the symbiotic star CH Cyg

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Ettore Pedretti
Scottish Universities Physics Alliance
School of Physics and Astronomy
University of St Andrews

Collaborators

J. D. Monnier, University of Michigan

N. D. Thureau, University of St Andrews

Ming Zhao, Jet Propulsion Laboratory

R. Millan-Gabet, NASA Exoplanet Science Institute

W. A. Traub , Jet Propulsion Laboratory

S. Ragland , Keck Observatory

J-P. Berger, Observatoire de Grenoble

F. P. Schloerb, University of Massachusetts

N. P. Carleton, Center for Astrophysics

M. G. Lacasse, Center for Astrophysics

Symbiotic stars

- Mass transfer binaries, mass-losing M giant or Mira, accreting companion (usually a white dwarf).
- Multiple outbursts, bipolar radio jets, x-ray jets.
- D=dusty-type, S=stellar-type from infrared spectrum (Webster & Allen, 1975).
- D-type longer period than S-type.

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SYMBIOTIC STARS: CONTINUALLY EMBARRASSING BINARIES

J. Mikołajewska

N. Copernicus Astronomical Center, Bartycka 18, 00-716 Warsaw, Poland

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Abstract. This paper aims at presenting the state-of-the-art in understanding of symbiotic binaries. In particular, we discuss their basic parameters, the mechanisms of mass loss and accretion and the role of these processes in the observed activity of symbiotic systems.

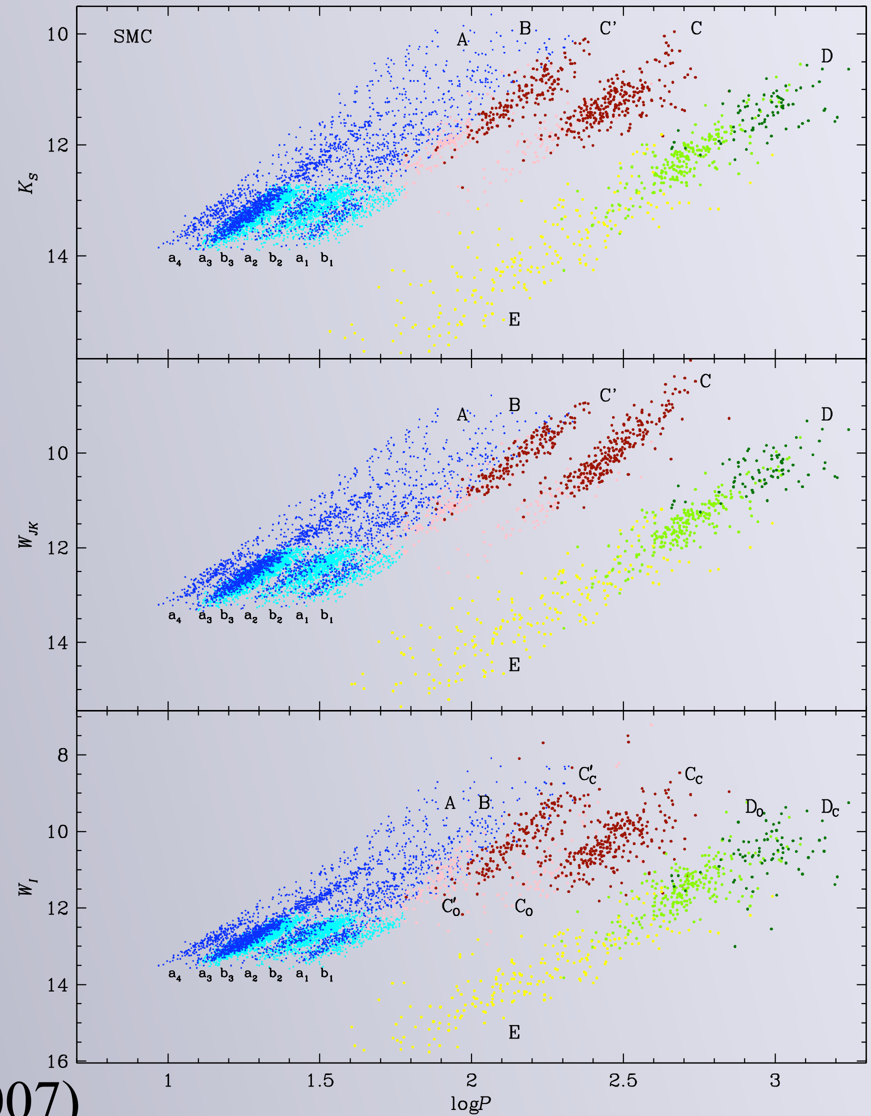
Key words: stars: binaries: symbiotic – stars: fundamental parameters – stars: mass loss

1. INTRODUCTION

Long Secondary Period (LSP)

- The only type of stellar variability currently not understood.
- 25-30% red giant stars show LSP, but modulation depends on luminosity of star. Maybe as high as 50%.
- LSP follow PL relation, Wood sequence D (Wood et al., 1999).

P-L diagrams of variable red giants in the SMC



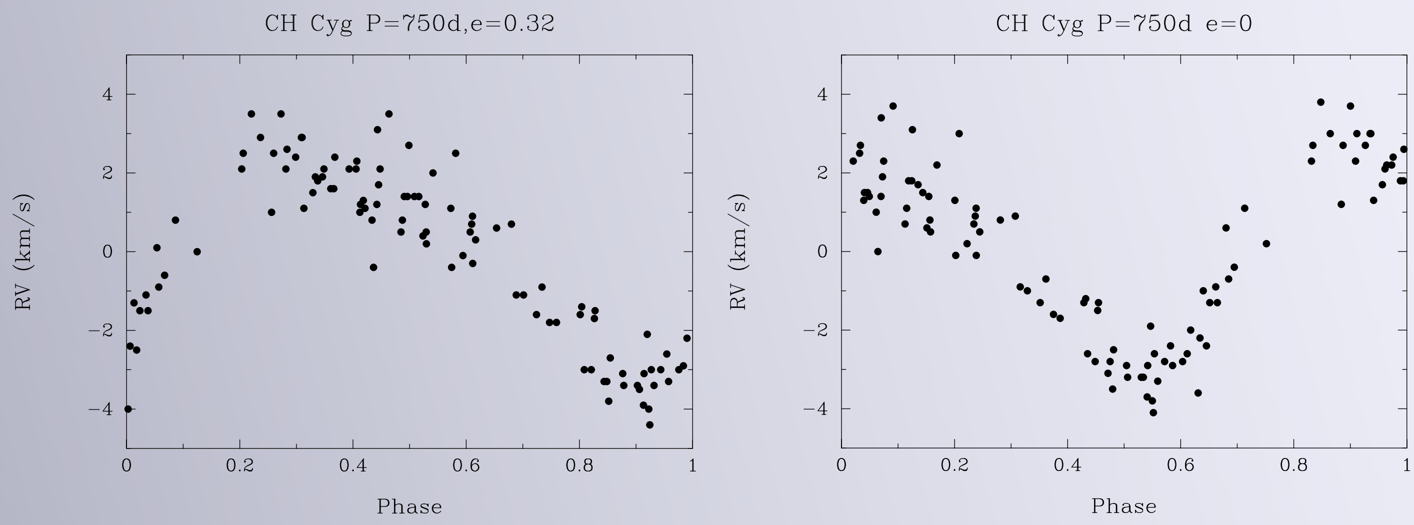
Soszynski et al. (2007)

[redacted]

CH Cyg

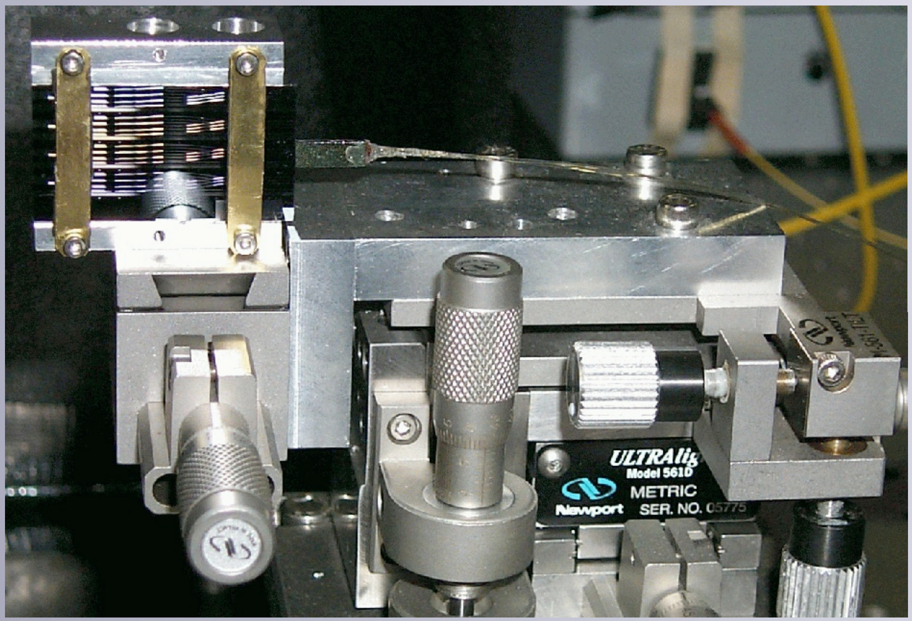
- CH Cyg composite spectra M star and hot component.
- Two periods found in RV measurements: 1.5 yr. and 14.5 yr.
- Two periods found in photometry: 100 day (M giant oscillation) and 770 days.
- M giant/white dwarf pair (1.5 yr orbit) with a G star companion ?(Hinkle et al, 1993).
- M giant/white dwarf pair (14.5 yr) and non-radial oscillation or low-mass companion (Hinkle et al 2008).

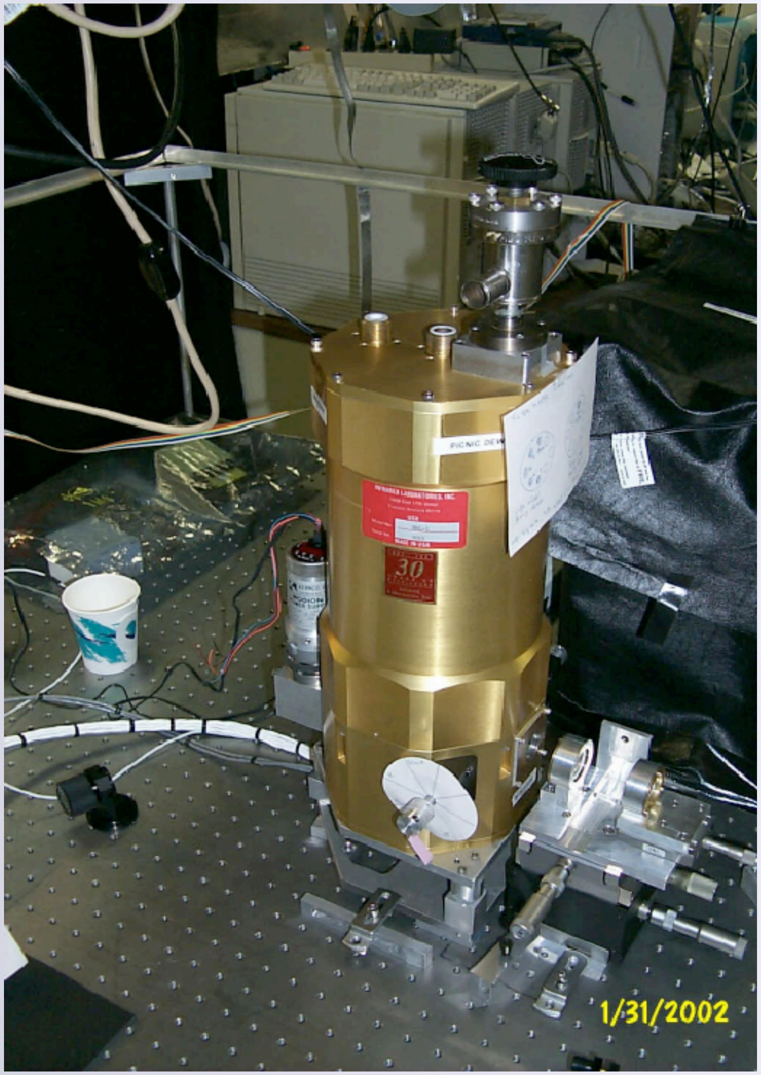
RV measurements for CH Cyg



Credits: Frank Fekel.

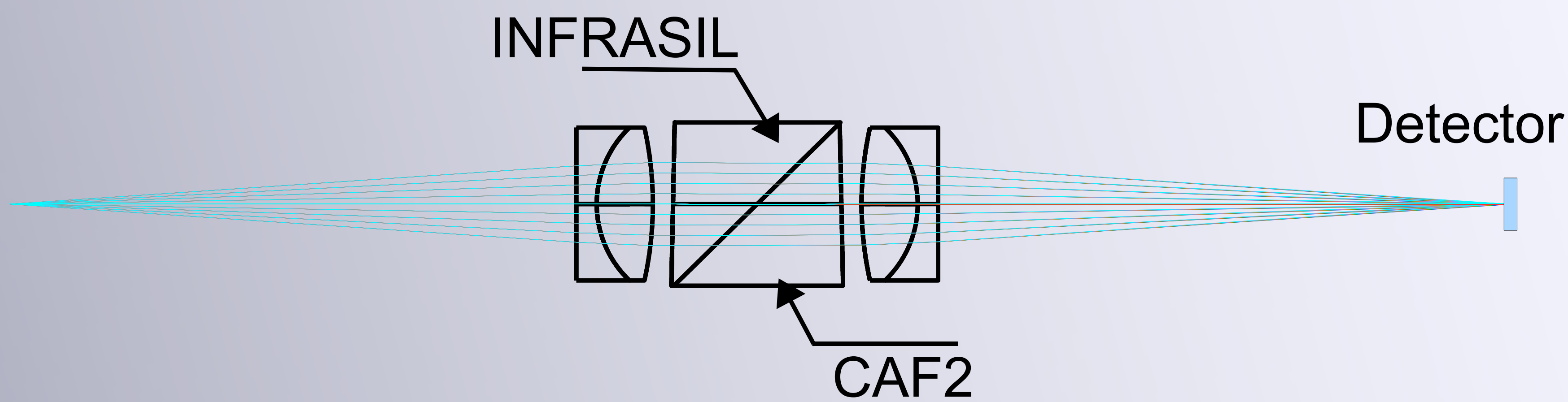
The IOTA combiner



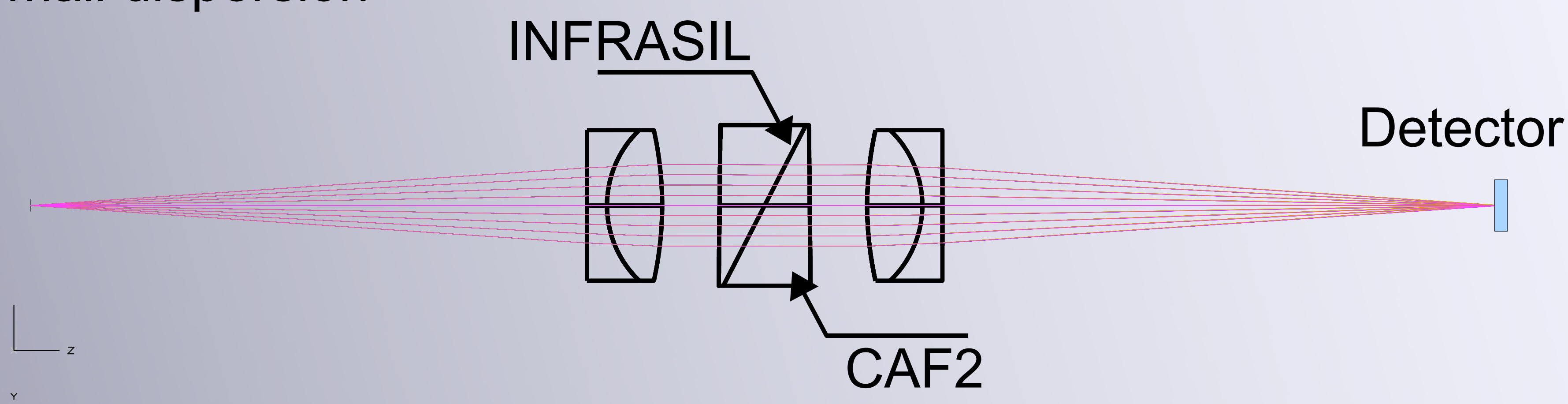


Infrasil CaF2 prisms

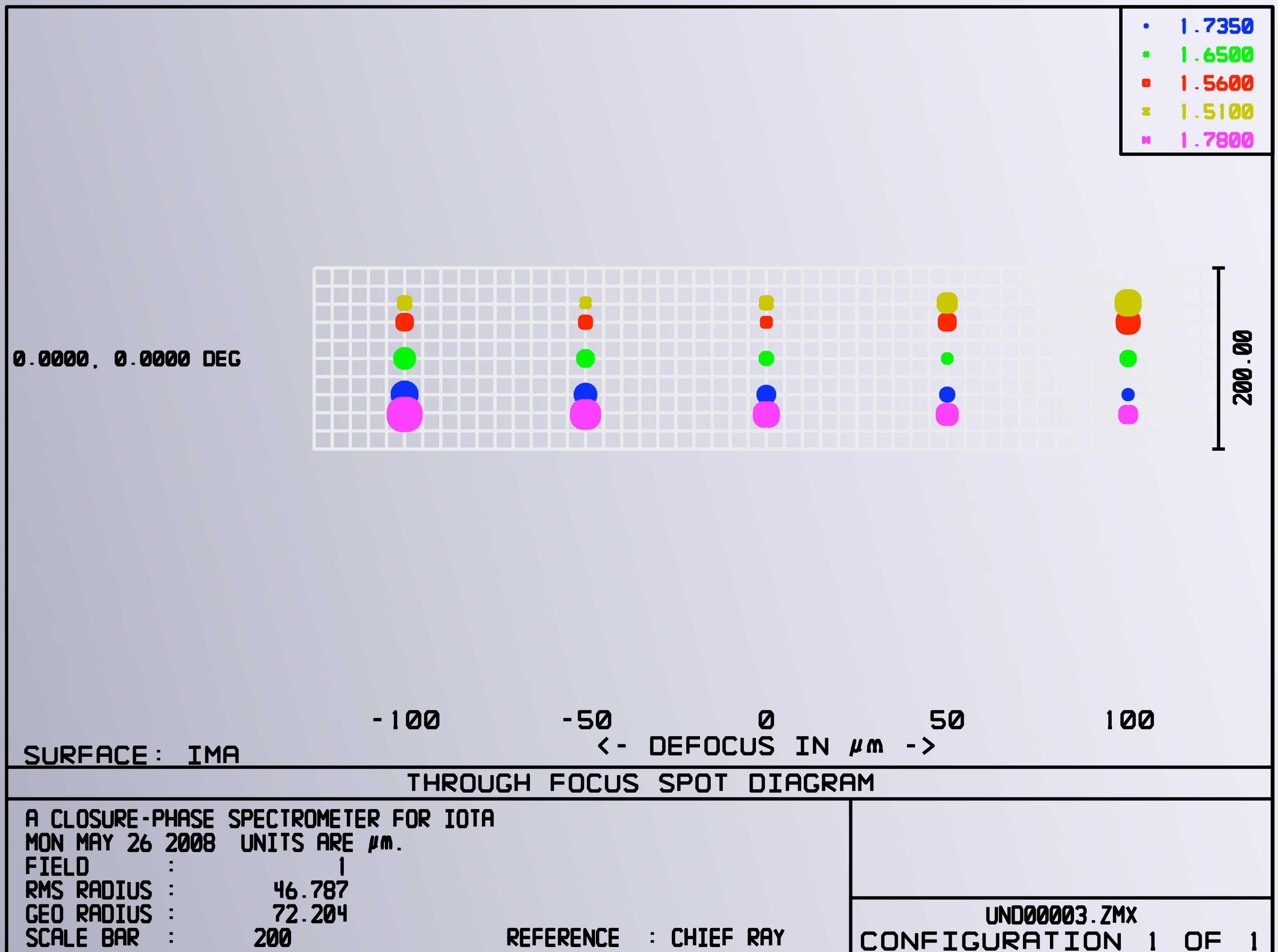
Large dispersion



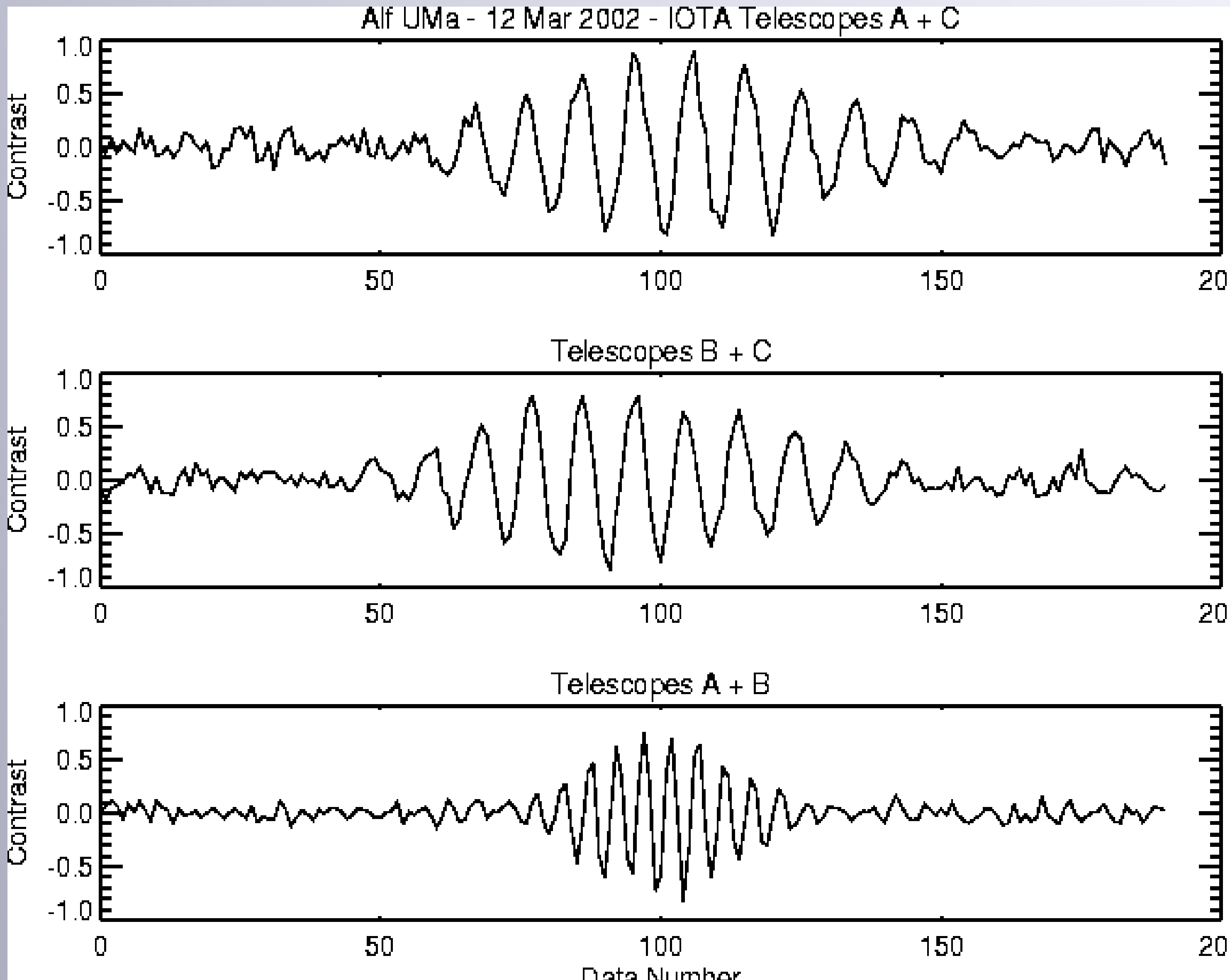
Small dispersion



Spot diagram from Zemax



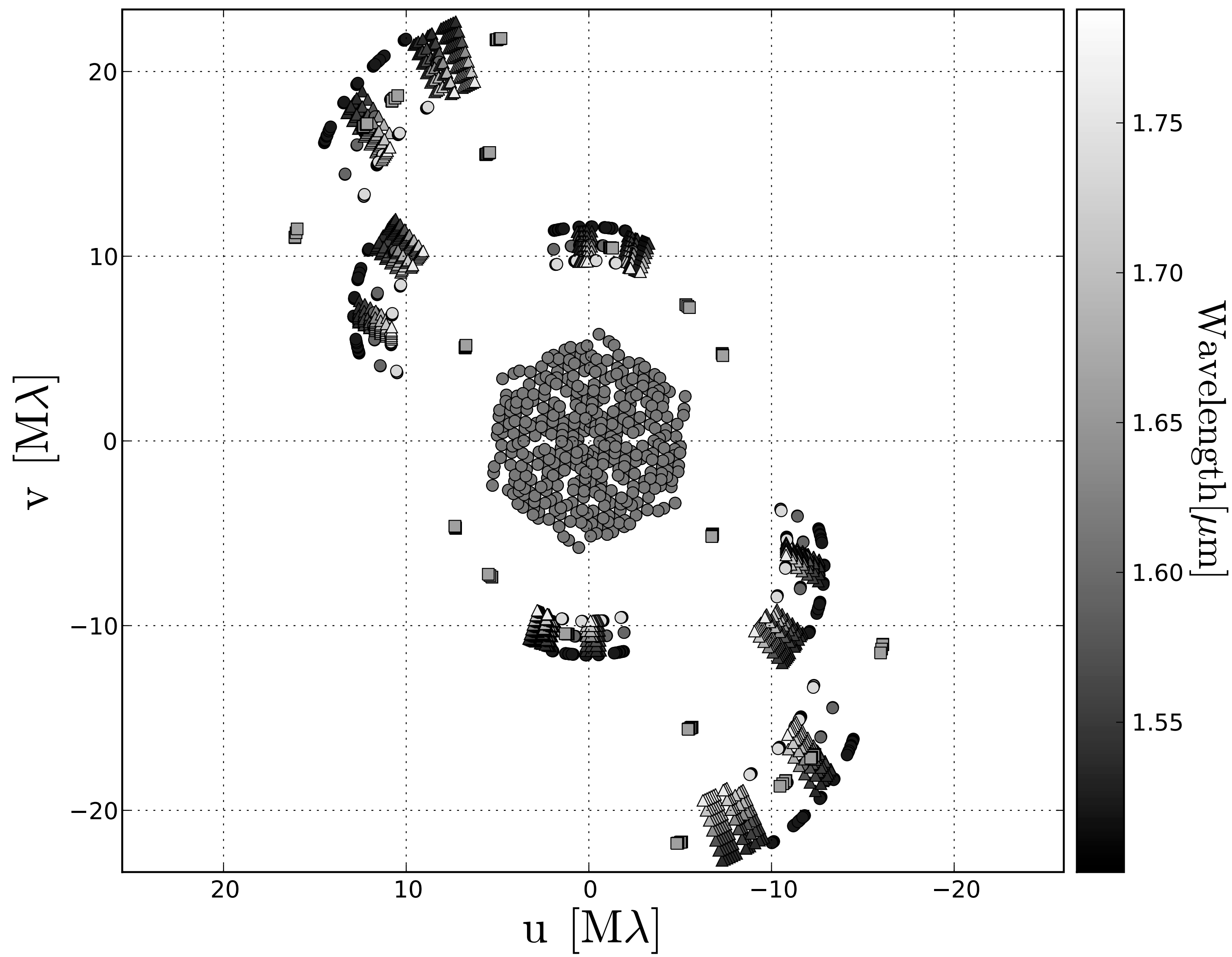
IOTA 3-Telescope Fringes



Log of observations

Date (UT)	Mean JD	Phase	Telescope	λ (μm)	$\Delta\lambda$ (μm)	Calibrator names
2004Apr23	2453119	0.40	IOTA , A35–B15–C10	1.51	0.090	α Lyr, α Aql
2004Apr24	2453120	0.40	IOTA , A35–B15–C10	1.64	0.100	α Lyr, α Aql
2004Apr25	2453121	0.40	IOTA , A35–B15–C10	1.64	0.100	α Lyr, α Aql
2004Apr26	2453122	0.40	IOTA , A35–B15–C10	1.78	0.090	α Lyr, α Aql
2004Apr29	2453125	0.41	IOTA , A35–B15–C10	1.78	0.090	α Lyr, ρ Ser
2004Apr30	2453126	0.41	IOTA , A35–B15–C10	1.78	0.090	α Lyr, ν Hya
2004May01	2453127	0.41	IOTA , A35–B15–C10	1.78	0.090	α Lyr, α Aql
2004Apr09	2453105	0.38	Keck A, Golay mask	1.64	0.025	α Lyr
2005Jun06	2453528	0.94	IOTA , A35–B15–C10	1.66	0.300	α Lyr
2005Jun08	2453530	0.95	IOTA , A25–B15–C10	1.66	0.300	α Lyr
2006Apr24	2453850	0.37	IOTA , A35–B15–C10	1.66	0.043×7^1	α Lyr, βHer
2006Apr30	2453856	0.38	IOTA , A35–B15–C10	1.66	0.043×7^a	α Lyr, βHer
2006May01	2453857	0.38	IOTA , A35–B15–C10	1.66	0.043×7^a	α Lyr, βHer
2006May02	2453858	0.38	IOTA , A35–B15–C10	1.66	0.043×7^a	α Lyr, βHer

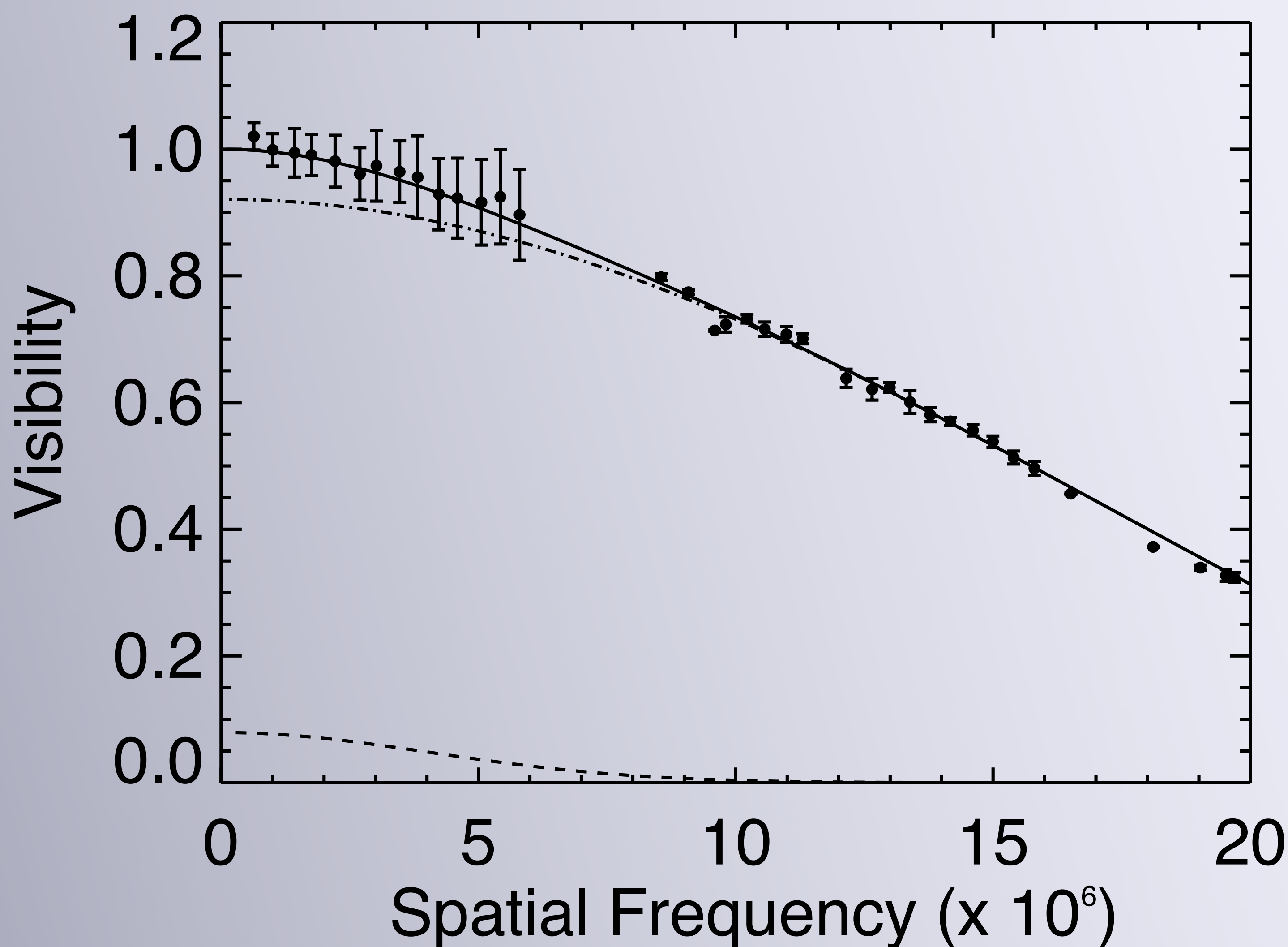
uv coverage for CH Cyg from 2004 to 2006



Calibrator information

Calibrator name	Spectral type	Adopted UD (mas)	Reference(s)
α Lyr	A0V	3.22±0.01	Absil et al (2006)
βHer	G7IIIa	3.40±0.03	This work
ρ Ser	K5III	3.28±0.04	Borde et al (2002)
α Aql	A7V	3.46±0.04	Van Belle et al (2001)

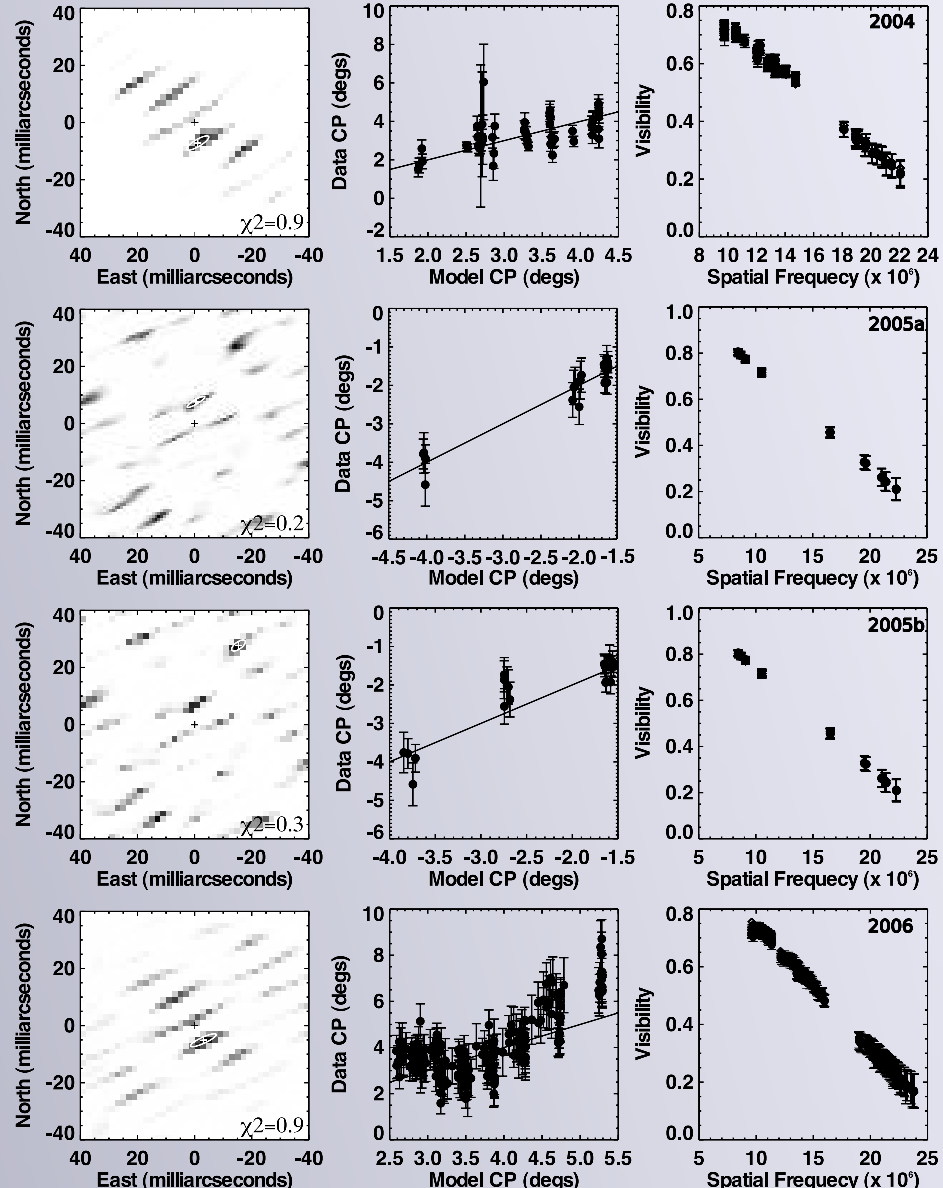
Uniform disk + Gaussian disk model



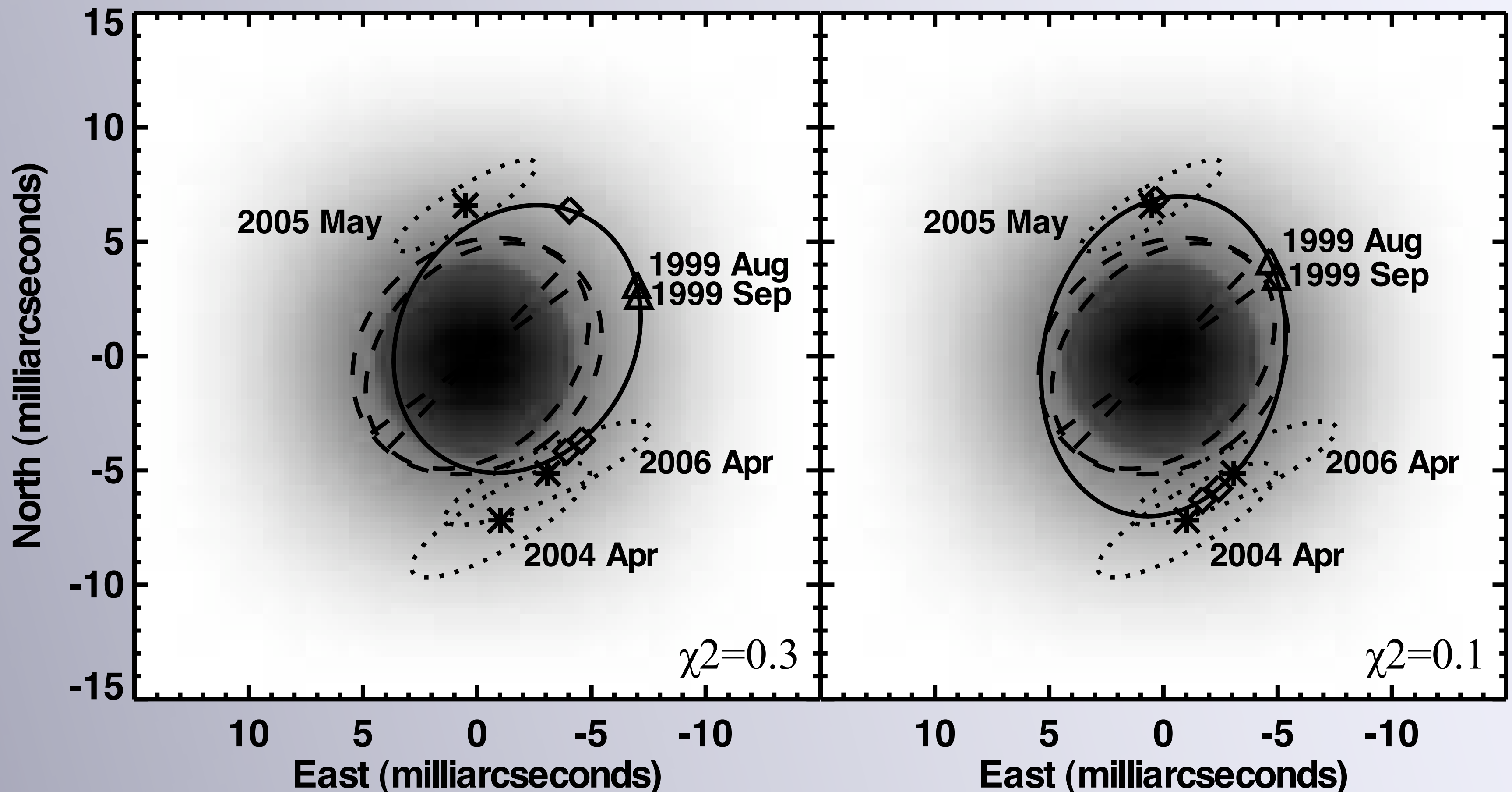
Uniform disk + Gaussian disk model

Size M–giant (mas)	FWHM dust[1] (mas)	Flux ratio (M giant /dust)	P.A. (°)	Axis ratio dust (M/m)	χ^2
8.74±0.02	19.1±1.0	11.6±0.3	0.0	1.0	1.3
8.74±0.02	19.2±0.9	11.6±0.1	103±5	1.28±0.01	1.2

Binary search around CH Cyg



Two solutions: elliptical and circular orbits



Pedretti et al, 2009 MNRAS

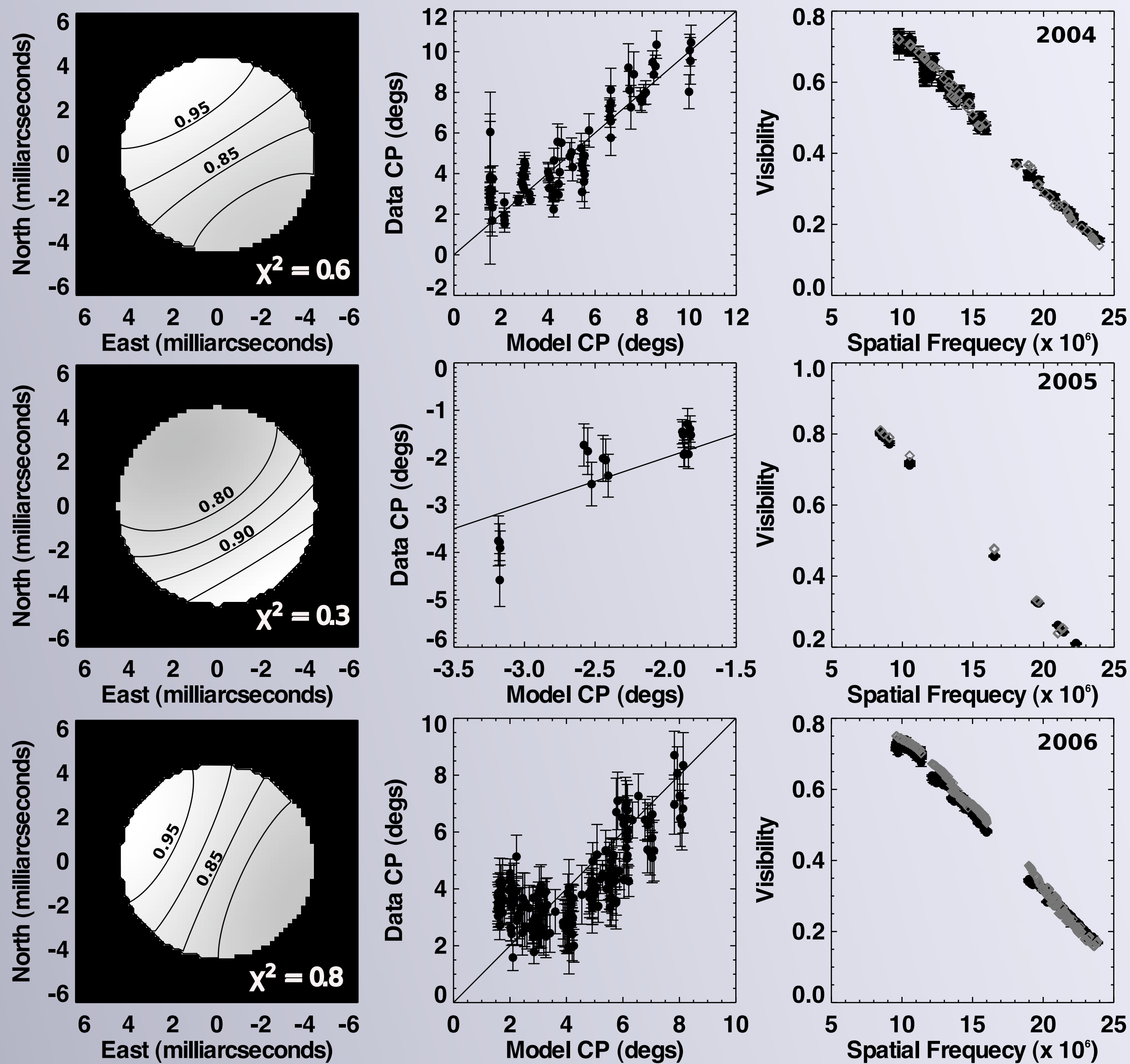
Binary parameters

Parameters	Circular solution	Elliptical solution
Radial velocity		
P (days)	749.8±2.3	750.1±1.3
$T0$ (HJD)	2446823.2±7.7	2447293.5±12.9
ω (°)	0.0	229.5±7.7
e	0.0	0.330±0.041
K (Km s^{-1})	2.87±0.13	2.87±0.13
γ (Km s^{-1})	-59.93±0.10	-59.91±0.09
$a \sin i$ (Km)	2.96x10^7±0.29x10^7	2.79x10^7±1.23x10^7
$f(m)$ ($M_\odot$)	0.00018±0.0002	0.00015±0.0002
Interferometry		
i (°)	138±10	146±6
Ω (°)	347±7	337±8
a (mas)	7.1±0.3	6.3±0.3

Derived parameters

M_2 ($M_\odot$)	0.1	0.2	0.3	0.4	0.5	0.6
Circular orbit						
M_1 ($M_\odot$)	0.3	0.9	1.8	2.8	3.9	5.2
R_1 ($R_\odot$)	156	221	270	312	349	382
L_1 ($L_\odot$)	2037	4073	6110	8146	10183	12219
a (AU)	1.2	1.7	2.0	2.3	2.6	2.9
D (pc)	166	235	288	332	371	407
Elliptical orbit						
M_1 ($M_\odot$)	0.2	0.7	1.4	2.2	3.2	4.2
R_1 ($R_\odot$)	165	233	285	330	369	404
L_1 ($L_\odot$)	2267	4534	6801	9068	11335	13601
a (AU)	1.5	1.6	1.9	2.2	2.5	2.7
D (pc)	143	248	304	351	392	430

Non radial-oscillations

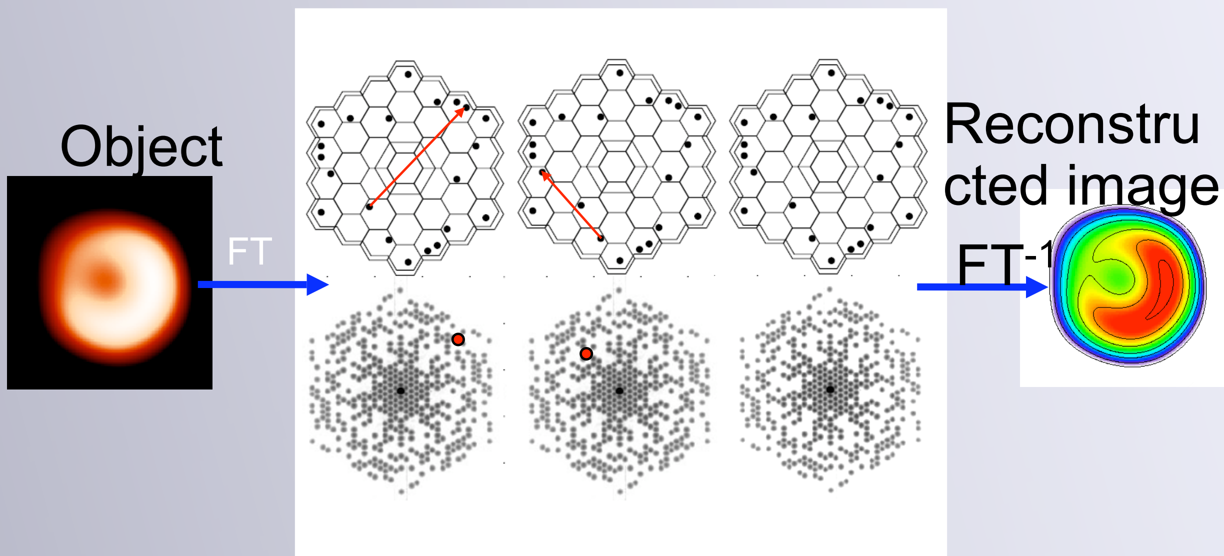


Conclusions

- Simple models explain the asymmetries detected through infrared interferometry in the S-type symbiotic star CH Cyg.
- We do not detect significant change of angular size rendering radial pulsation a less likely explanation for the 2.1-yr variability.
- We detect a large change in brightness across the M~giant and/or a low mass companion in close orbit around the star.
- Combined effect of pulsation and low-mass companion could explain the behaviour of the radial-velocity curves and the asymmetries detected in closure-phase data?

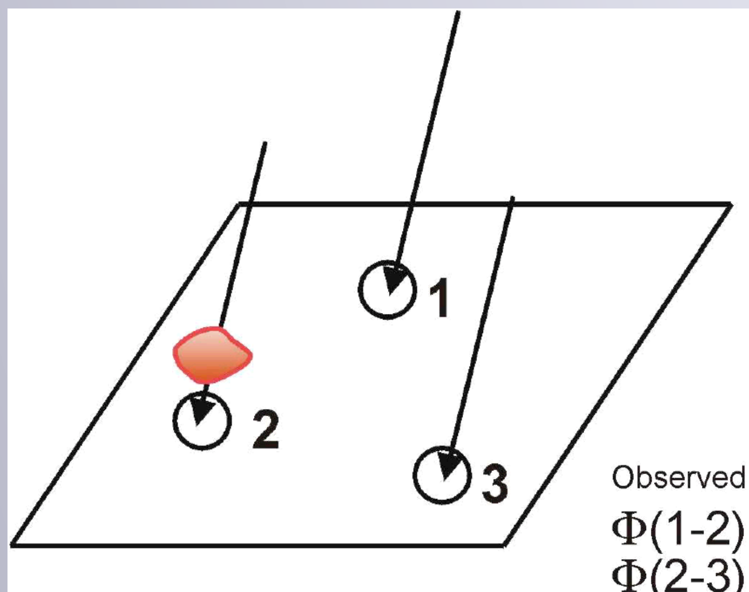
Research impact on society and knowledge transfer

Interferometry Primer: The uv Plane



- "A dusty torus around the luminous young star LkHa 101" by Peter Tuthill, John Monnier, and William Danchi Volume 409, February 22, 2001
- Michelson Interferometry with the Keck I Telescope : Tuthill, P. G.; Monnier, J. D.; Danchi, W. C.; Wishnow, E. H.; Haniff, C. A. 2000, Publications of the Astronomical Society of the Pacific, 112, 555-565

Interferometry Primer: Closure Phase



The "Closure Phase" Is Not Corrupted by Atmosphere

Observed		Intrinsic		Atmosphere

$$\Phi(1\text{-}2) = \Phi_o(1\text{-}2) + [\phi(2)-\phi(1)]$$
$$\Phi(2\text{-}3) = \Phi_o(2\text{-}3) + [\phi(3)-\phi(2)]$$
$$\Phi(3\text{-}1) = \Phi_o(3\text{-}1) + [\phi(1)-\phi(3)]$$

Closure Phase (1-2-3) $= \Phi_o(1\text{-}2)+\Phi_o(2\text{-}3)+\Phi_o(3\text{-}1)$

Credit: John Monnier, Michelson Summer School, 1999