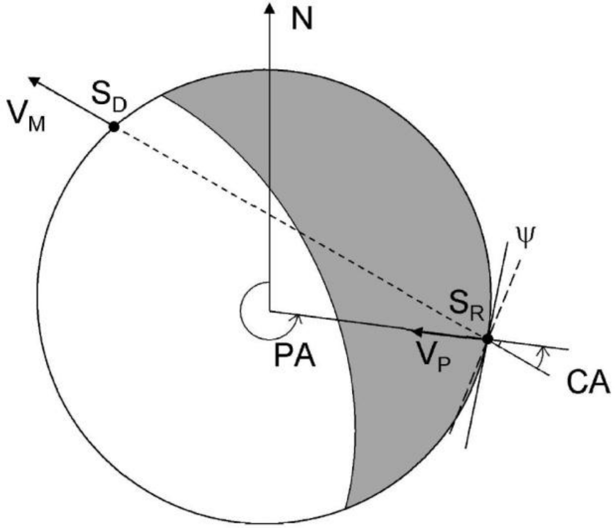


Investigating the geometry and physics of evolved giant stars

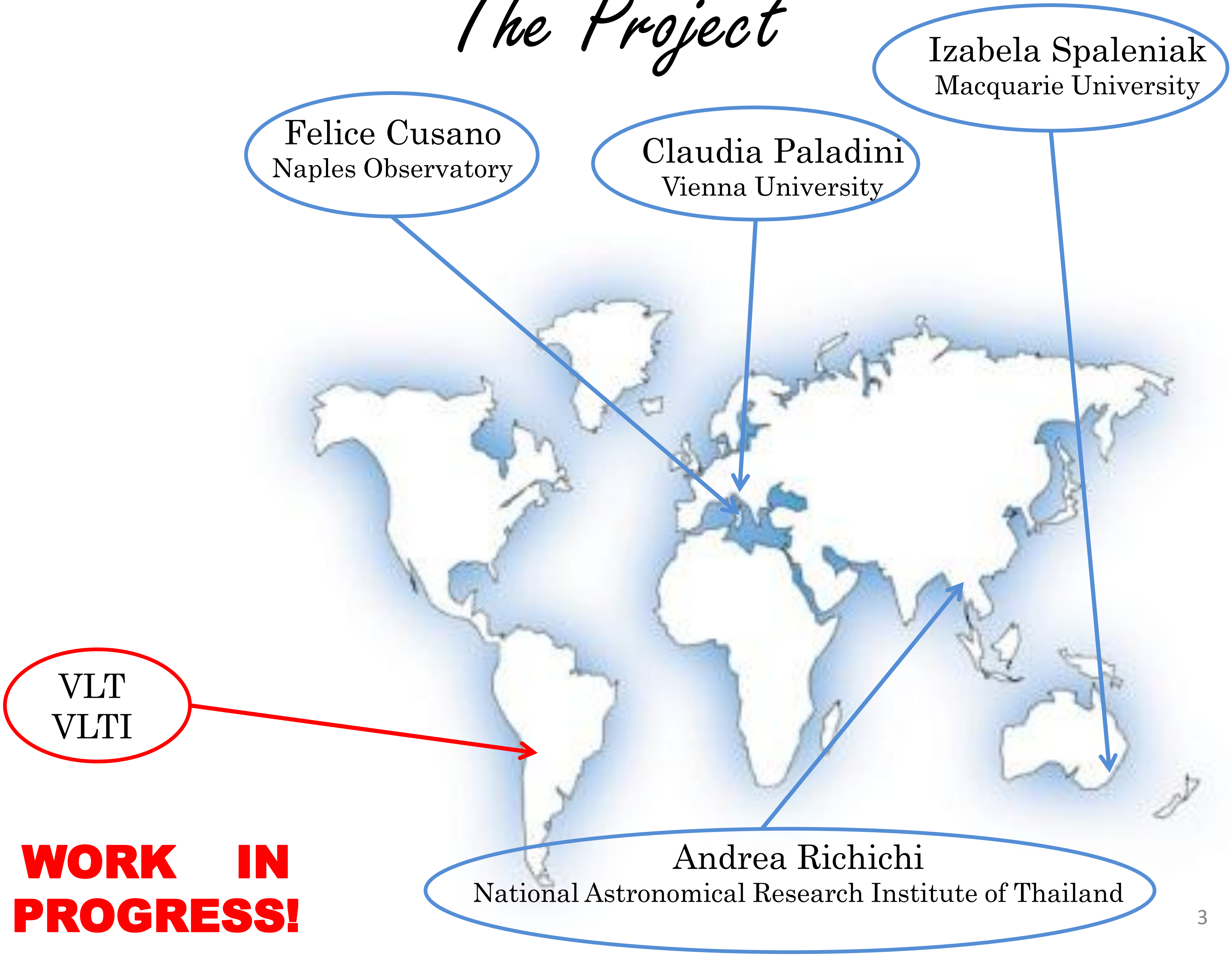
TX Psc and Other Beasts

Andrea Richichi
Ten years of VLTI, Garching, 25 October 2011

In Memory

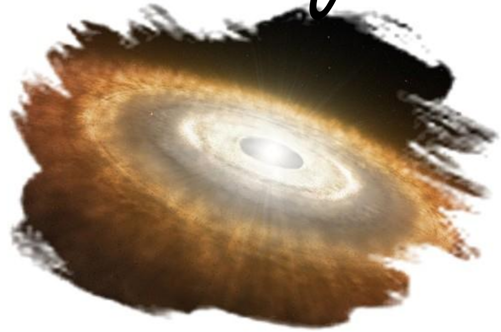
Alan Moorwood

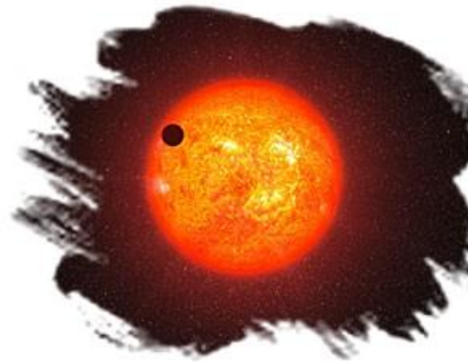
The Project

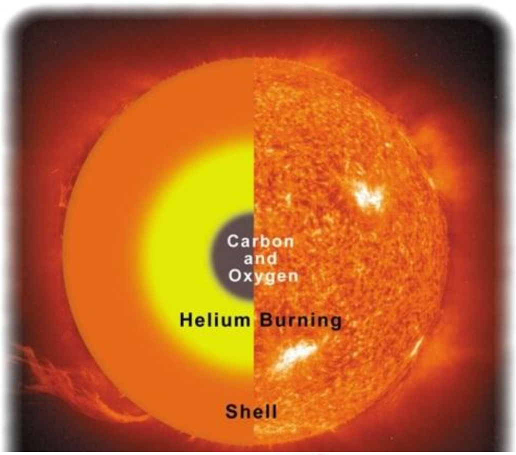


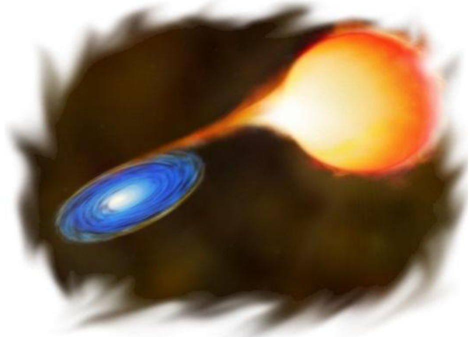
WORK IN PROGRESS!

Life and Death of a Sun-like Star









Biggest carbon footprint in the Galaxy!

Complications in Evolved Giants

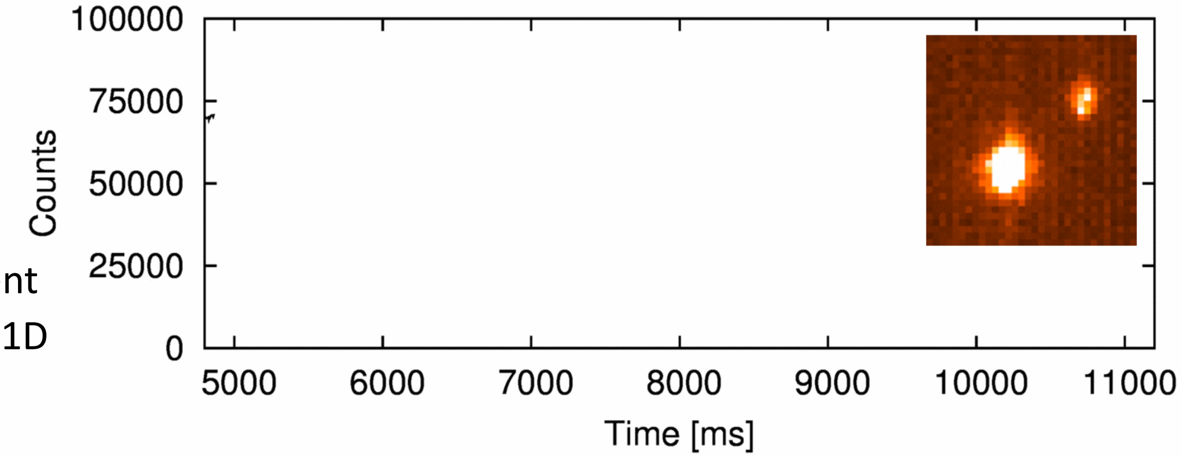
- **Marked variability (~1 y, irregular)**
- **non-BB SED (Extinction, τ in lines, IR excess)**
- **Circumstellar matter, limb-darkening**
- **Dust gradients, clumps, shells, sublimation**
- **Distances ~10^2 pc, ϕ < 10 mas**

- complex geometry, challenge to models
- near-IR range preferred
- Single telescope > 50 mas

Different Techniques for mas resolution

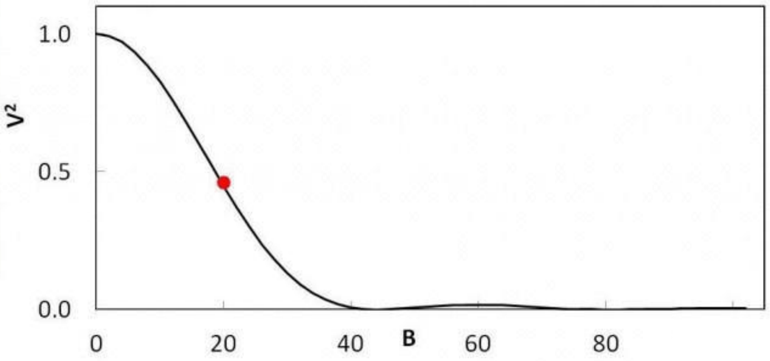
Lunar Occultations

Pros: easy, quick, economical, sensitive (K=12), model-independent
Cons: fixed-time, no/few repeats, 1D
Scope: discovery, one-shot



Interferometry

Pros: repeatability (2D, time)
Cons: complexity and timing, atmospheric conditions, data reduction, model-dependent, less sensitive
Scope: follow-up, details



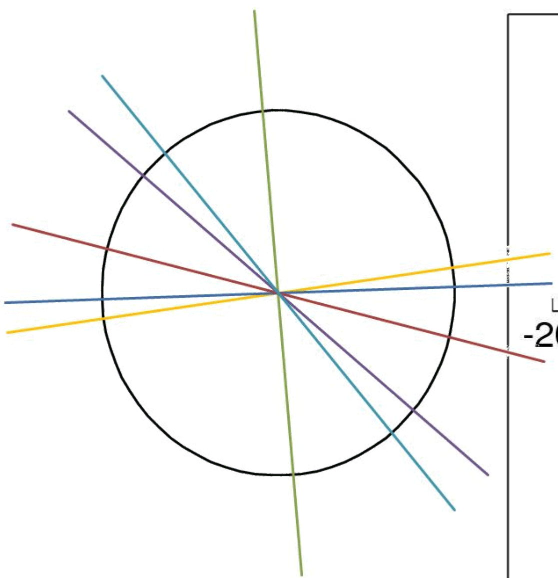
TX Psc

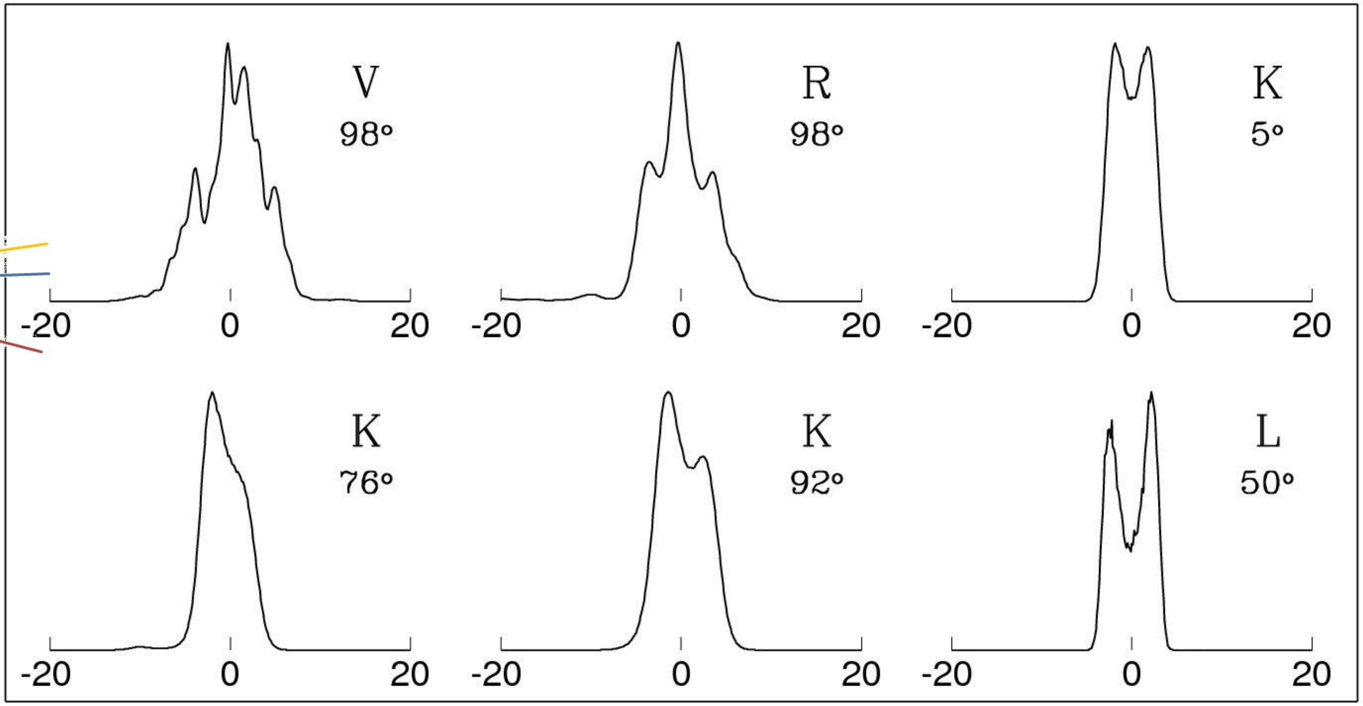
Spectra $C_{5,2}$-$C_{7,2}$ T_{eff} 2500-3800 K
Occultations, Interferometry, IND
Extensive modelling
ϕ 6.2-13.5 mas, M_{dot} 10^{-7}, shell $2.2R_*$

What is the meaning of "diameter"?

Observatory	UT Date	Filter Name	Observed Geometry CA	PA	″/s	ϕ_{UD} (mas)
Calern[a]	12-03-92	V	43°	98°	0.2590	9.5 ± 1.1
Calern[a]	12-03-92	R	43°	98°	0.2590	8.8 ± 0.7
Tirgo	12-03-92	K	35°	92°	0.2910	9.82 ± 0.10
Gurushikhar	27-01-93	K	24°	76°	0.2965	7.5 ± 0.5
WIRO	27-10-93	K	−56°	5°	0.2017	7.72 ± 0.06
Calar Alto	20-12-93	L	−14°	50°	0.3864	9.7 ± 0.2
Kavalur	13-02-94	K	−29°	40°	0.4126	8.6 ± 0.5

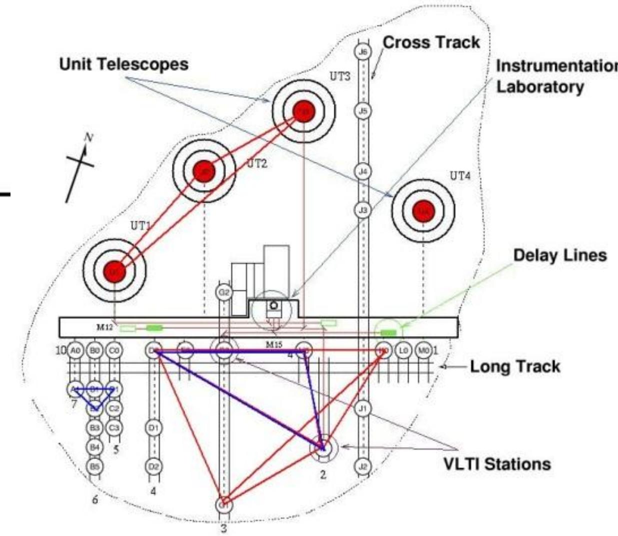
New occultation series starting in 2011

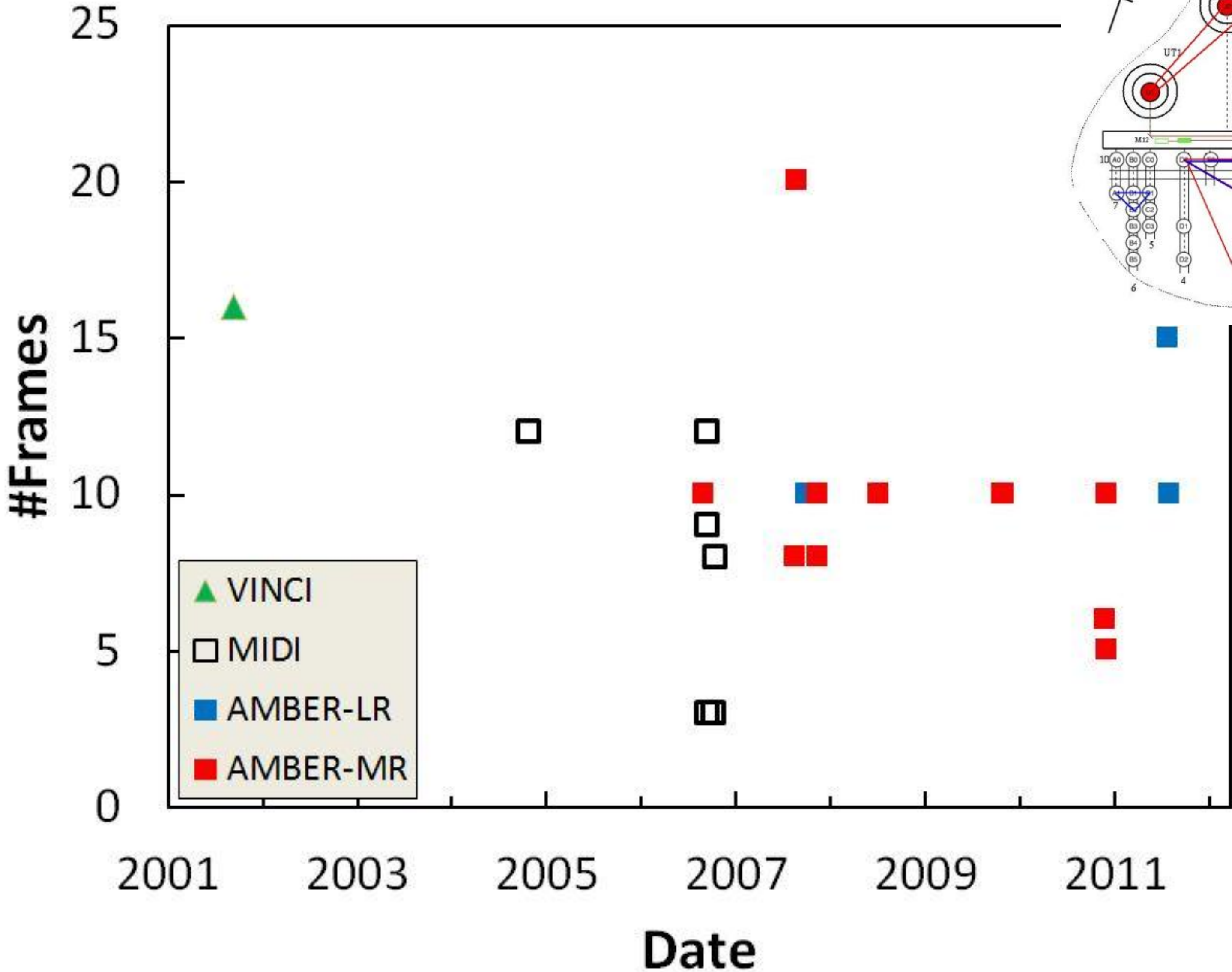




(Richichi et al 1995)

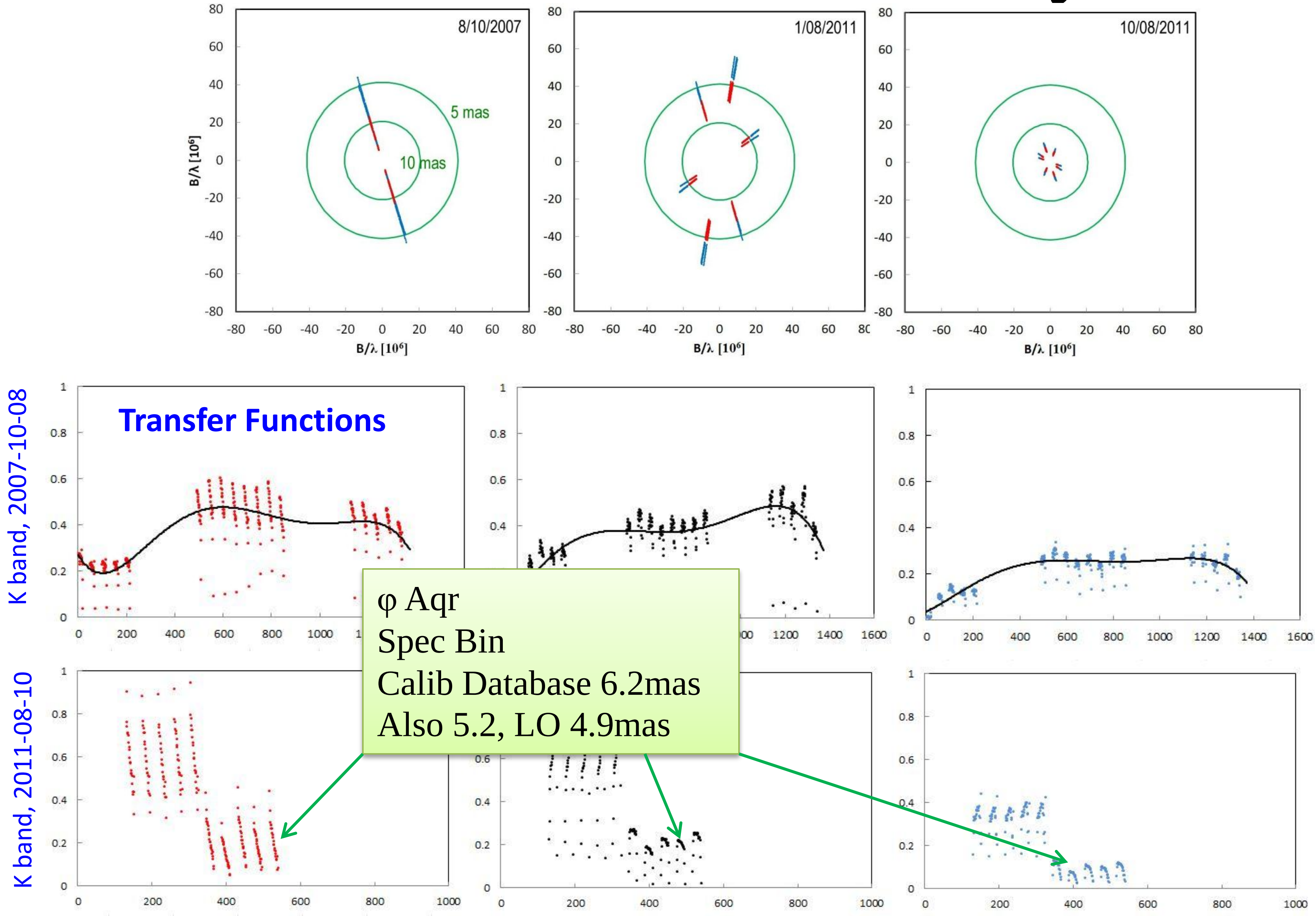
TX Psc @ VLTI





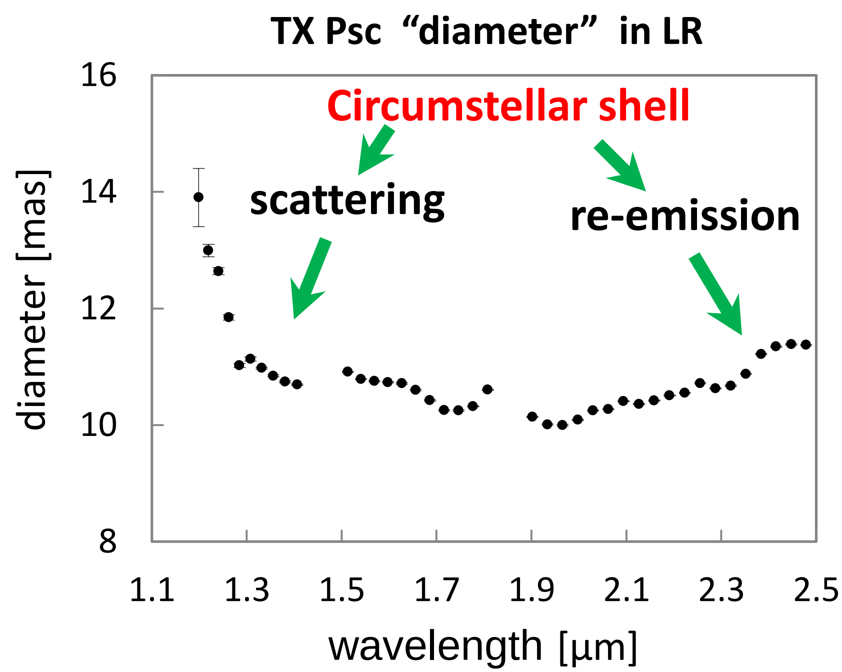
PI:Richichi et al
Verhoelst et al
Jorissen et al

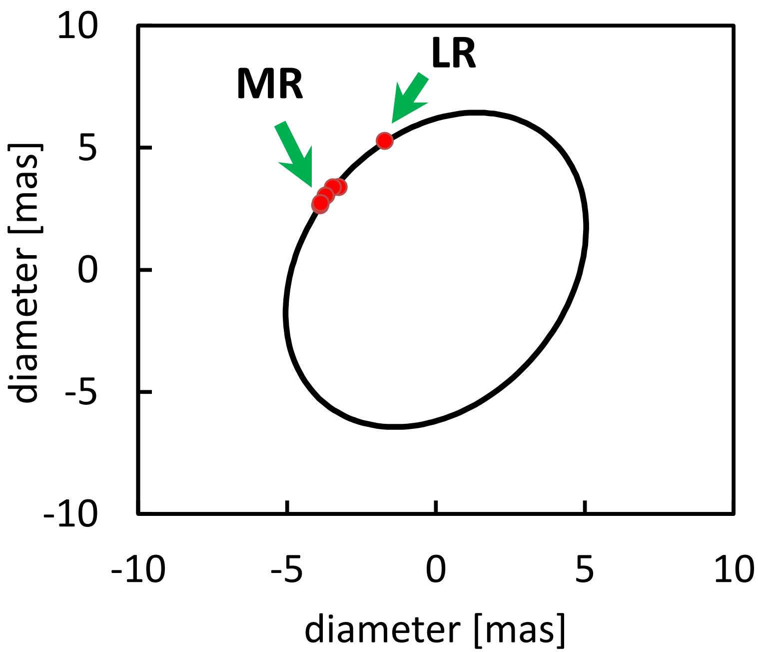
TX Psc @ VLTI: not so easy



TX Psc in 2007

- **Data from one night**
- **Simple UD approximation**
- **Evident diameter variation**

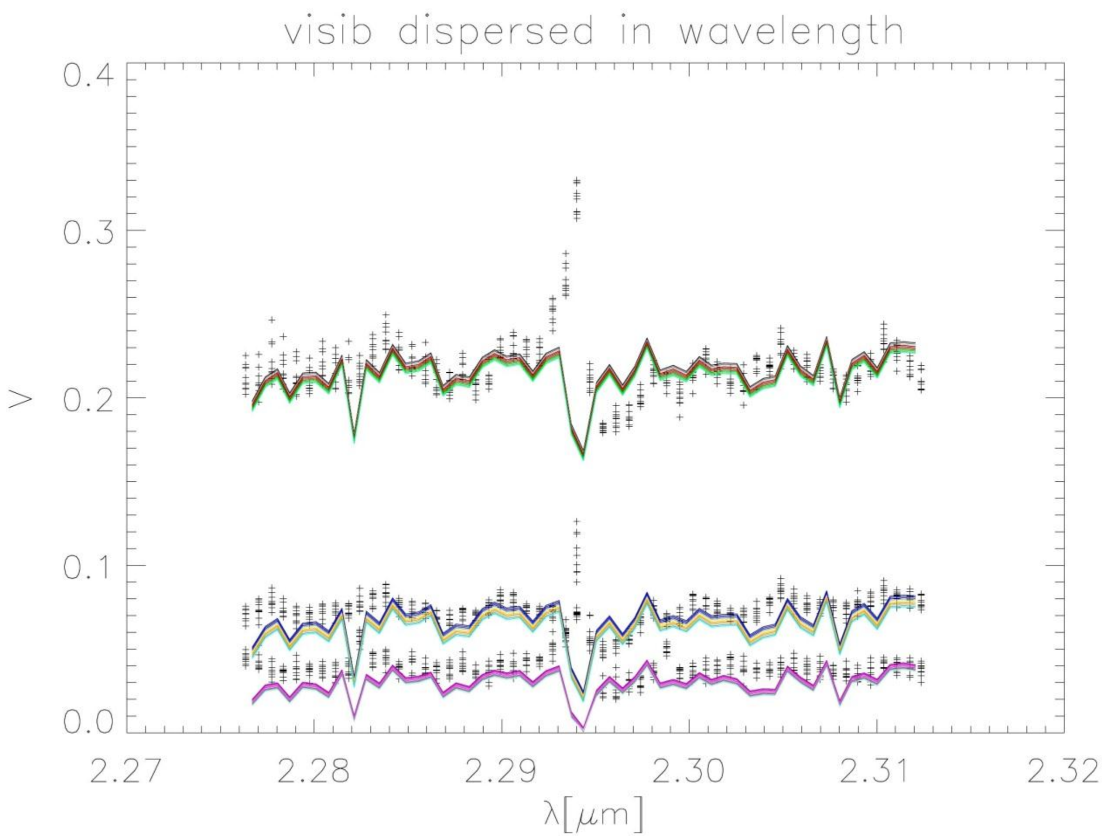




- **Data from Oct & Nov 2007 @2.3 µm**
- **Evidence of non-symmetry (simple "UD")**

Preliminary modelling, goals

In first approximation the observations will be compared with hydrostatic and dynamic model atmosphere (Aringer et al., 2009; Hoefner et al., 2003).
Stellar parameters (Teff, C/O, R and M) will be derived by combining AMBER data and ISO spectra. (Details on the method Paladini et al., 2011)



TX Psc spectrum vs. dynamic model atmosphere (Gautschy-Loidl et al., 2004)

$L = 5200\ L_{\odot}$
$T_{eff} = 3200$ K
C/O = 1.1
P = 295 d
R = 234 AU

Same model, compared to AMBER observables

Some other LO results

Over 800 occultations with ISAAC @ VLT, mostly in service mode as "filler", few visitor observations in crowded & extincted regions deep in the Galactic Bulge.
~80 new binaries (<0.1" sep) ~20 resolved diameters
Follow up with VLTI for some

17435399-2841285 SiO Maser 2.4 mas	*(Richichi et al 2008a)*
17453224-2833429 SiO Maser 2.9 mas	*(Richichi et al 2008a)*
17512677-2825371 OH Maser 13mas	*(Richichi et al 2008b)*
17540891-2820125 M8 5.3 mas	*(Richichi et al 2008b)*
17531817-2849492 CGCS3889 carbon star 5.8mas + shell	*(Richichi et al 2008b)*
17553507-2841150 carbon star, double, K=3.2->4.1	*(Richichi et al 2008b)*
17582187-2814522 PN ESO456-27 4.7 mas	*(Richichi et al 2008b)*
17184190-2716075 3.7mas, extended, J-K=4 no opt counterpart	*(Richichi et al 2010)*
18041209-2544257 4.3mas (3.9" pair, IR comp?), IRAS, Spitzer, Wise	*(Richichi et al 2011)*
18063774-2529277 10-20mas OH-IR, OH and SiO maser (K=9 decr 10.5)	*(Richichi et al 2011)*

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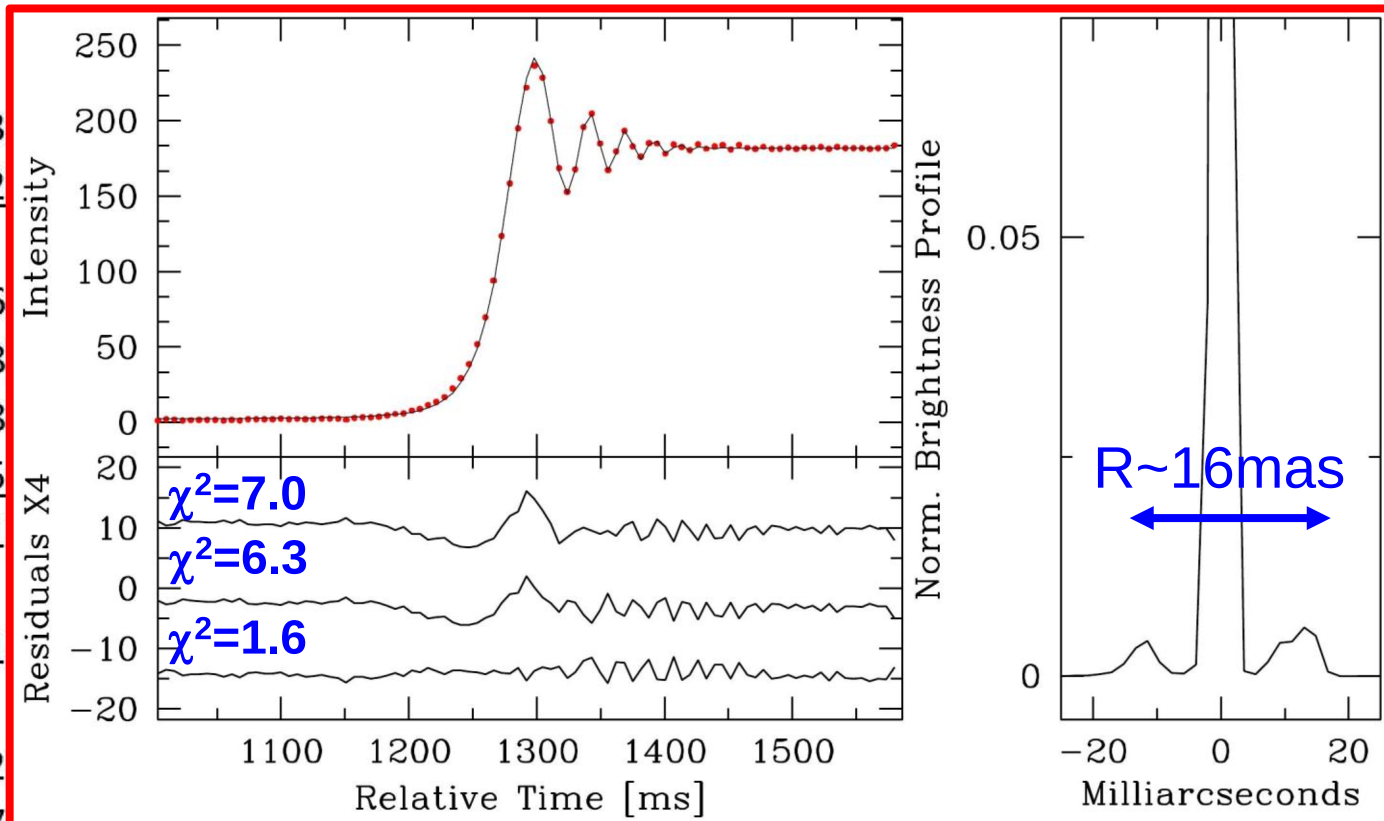
174353 … et al 2008a)
174532 … et al 2008a)
175126 … et al 2008b)
175408 … et al 2008b)
175318 … et al 2008b)
175535 … et al 2008b)
175821 … et al 2008b)
171841 … et al 2010)
180412 … et al 2011)
180637 … et al 2011)



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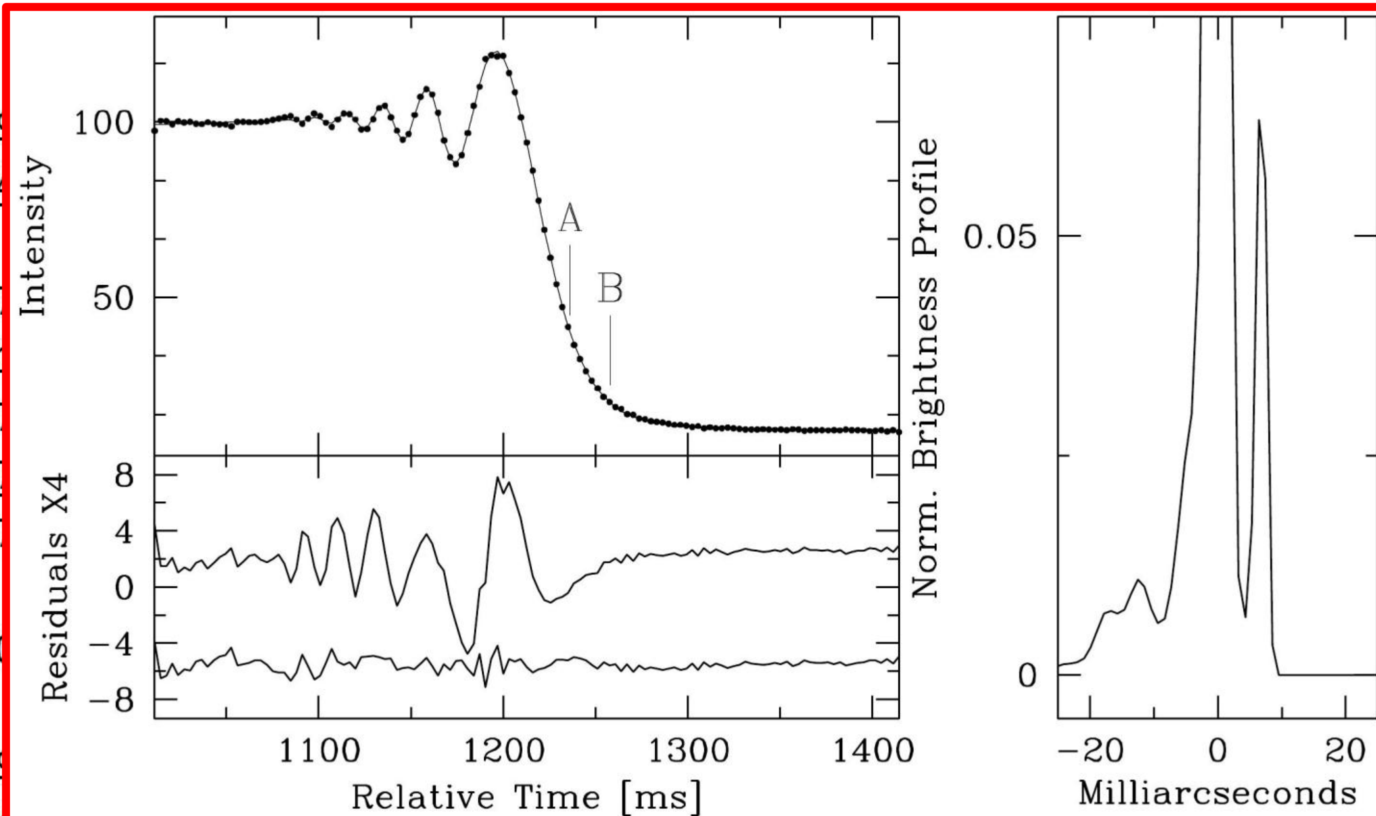

17435399 … al 2008a)

1745322 … al 2008a)

1751267 … al 2008b)

1754089 … al 2008b)

1753181 … al 2008b)

1755350 … al 2008b)

1758218 … al 2008b)

1718419 … al 2010)

1804120 … al 2011)

18063774 … al 2011)

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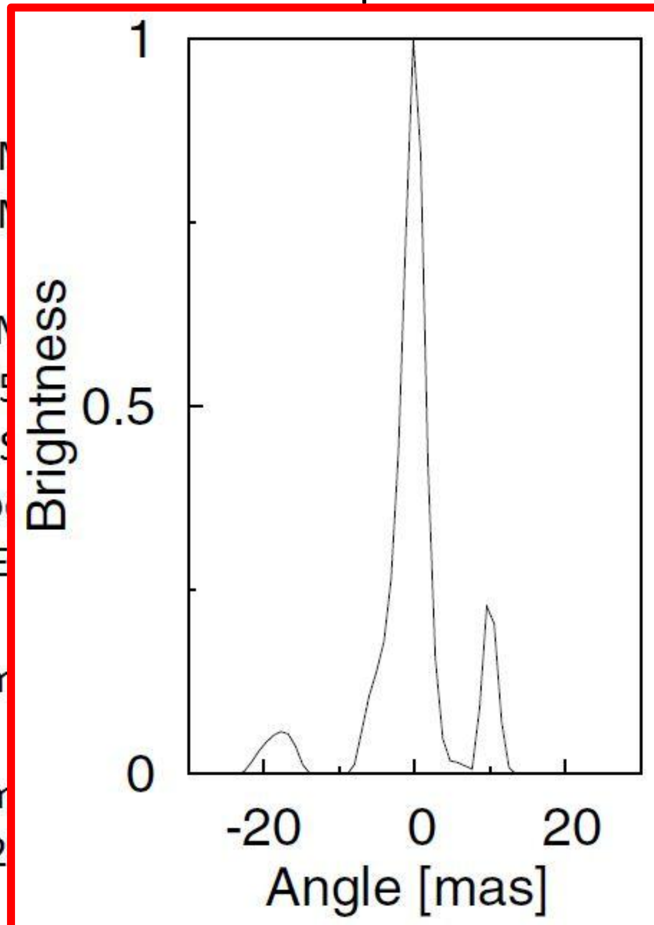

17435399-2841285 SiO M (Richichi et al 2008a)

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17582187-2814522 PN E (Richichi et al 2008b)

17184190-2716075 3.7m … part (Richichi et al 2010)

18041209-2544257 4.3m … er, Wise (Richichi et al 2011)

18063774-2529277 10-2 … 9 decr 10.5) (Richichi et al 2011)

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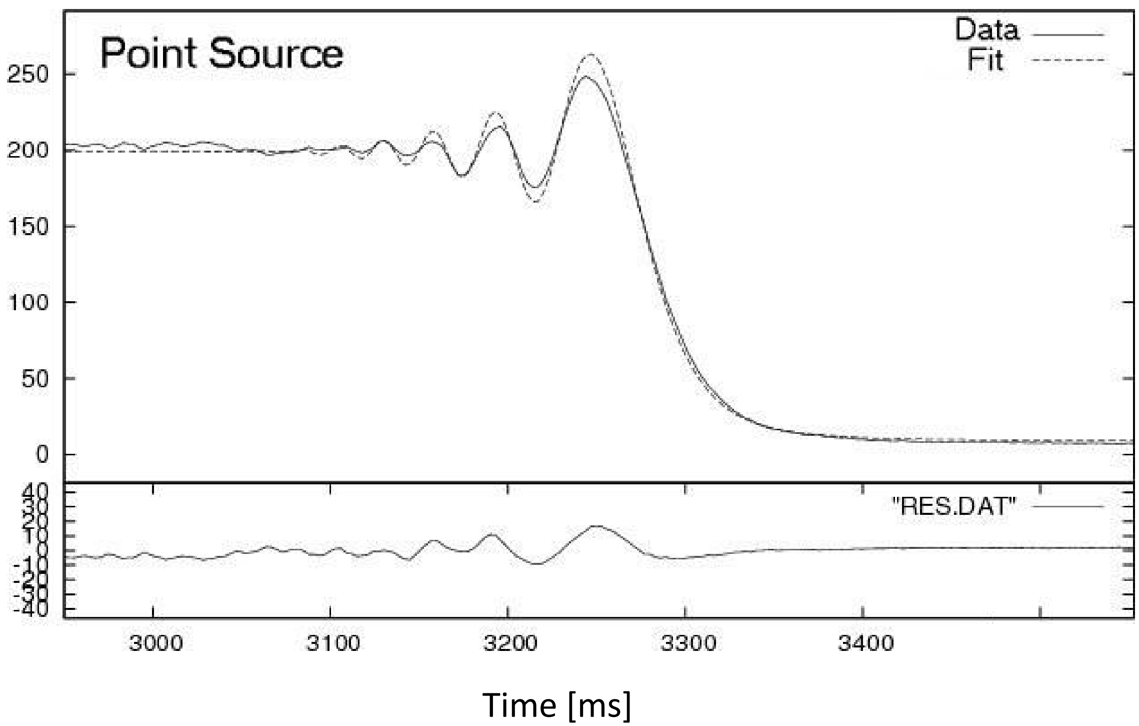
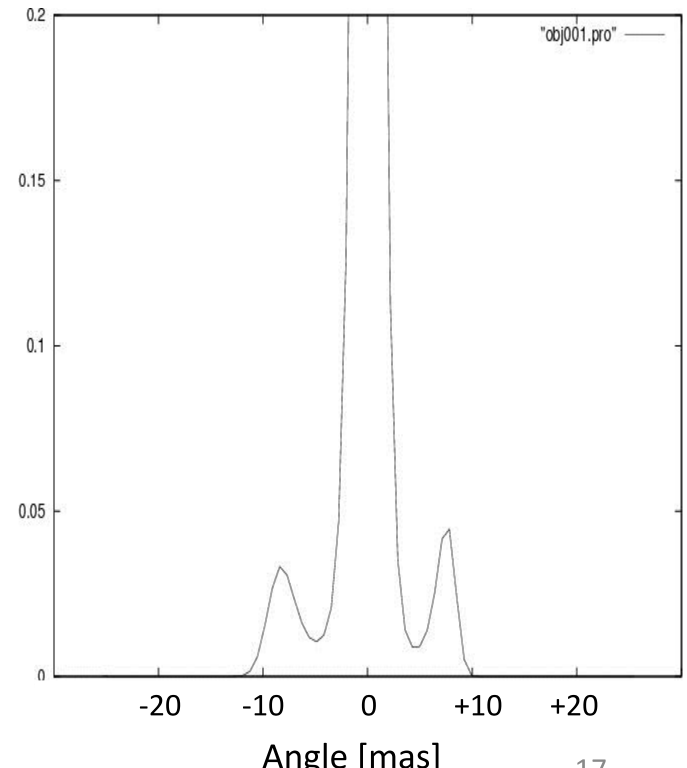
CGCS 3889 (occultation)

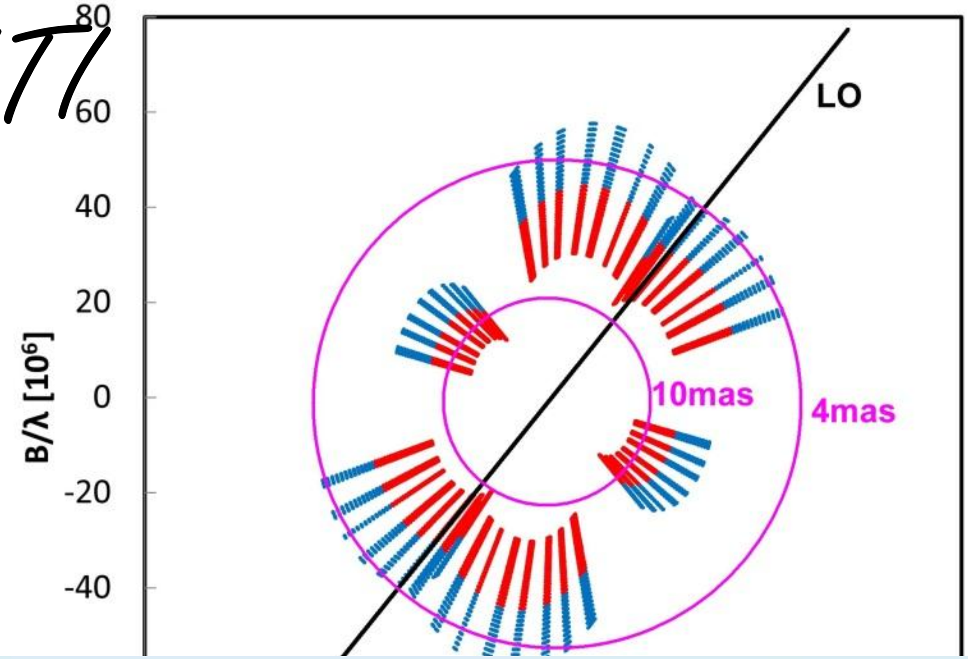
2MASS 17531817-2849492, K=4.3
CGCS 3889, V=11.6 mag
IRAS 17501-2849, 6 Jy @ 12 µm (N=1.8)
No distance estimates – probably few 100pc

5.8mas star + shell with 9.2% of K-band brightness
0.25" asymmetric profile, 2 maxima ±10 mas (2 R_*)



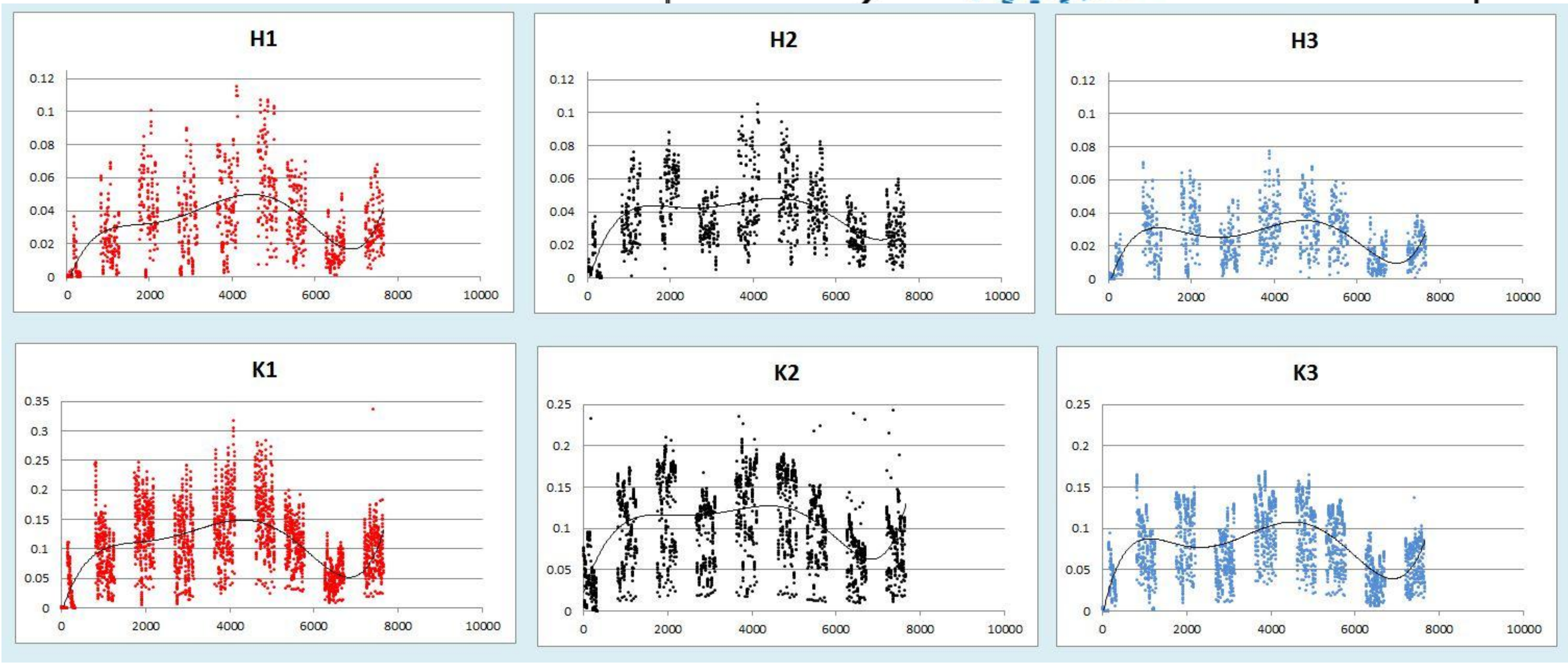


CGCS 3889 @ VLTI

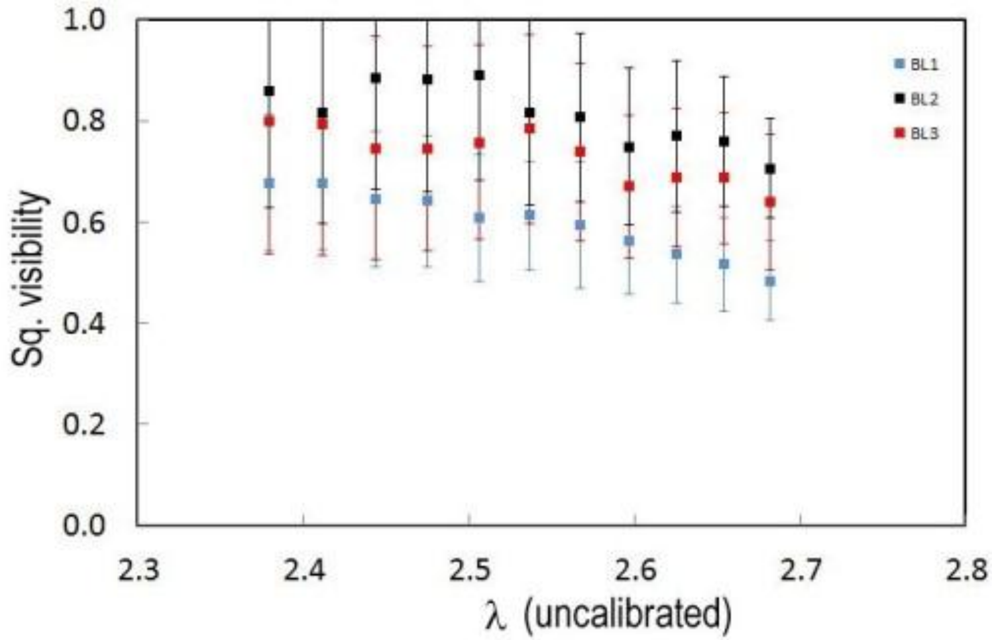


AMBER in LR
0.5n VM on June 30, 2011

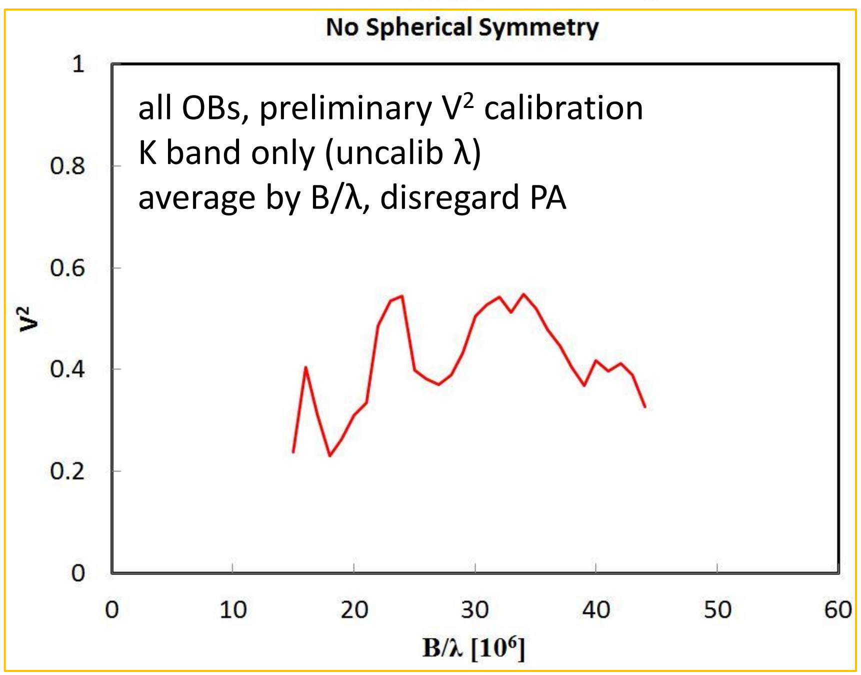
9 CALIB OBs, not all good.
Seeing 0.6-1.4
τ_0 1.6-3.2



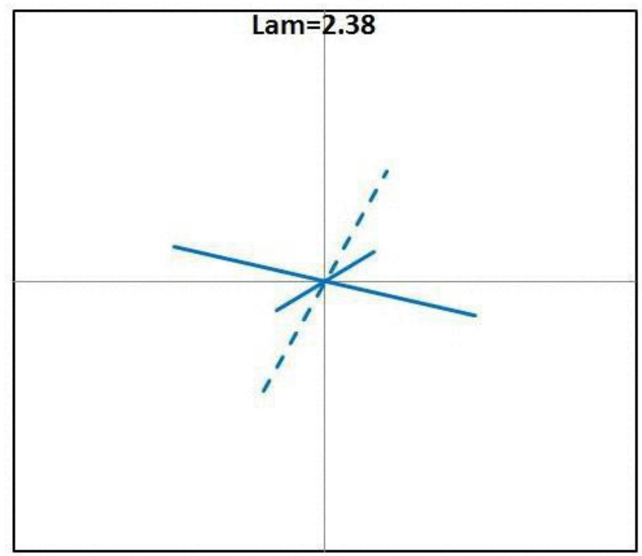
Initial results



<u>One OB (out of 8)</u>
K band, 3 wavelenghts
size increasing with lambda



5x5 mas – uncalib λ



Conclusions

Lunar occultations at a very large telescope provide a unique combination of high angular resolution and sensitivity to detect extended emission

Interferometry is essential for the necessary time and 2D coverage

The combination of these techniques is ideal in principle. In practice, numerous hurdles exist in data reduction and in obtaining the required monitoring. Calibration and accuracy are still a limiting factor.

So far two sources extensively observed at the VLTI. Data reduction in progress. Our goal is to derive model parameters (Teff, C/O, R, M) consistently with the geometrical asymmetries.