Task 2

Observing program and data analysis

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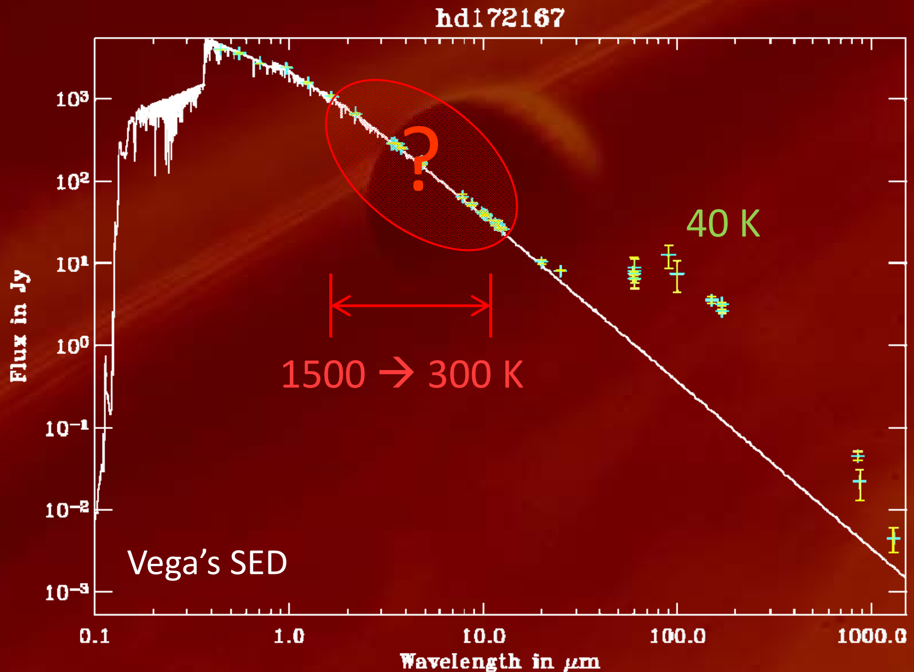
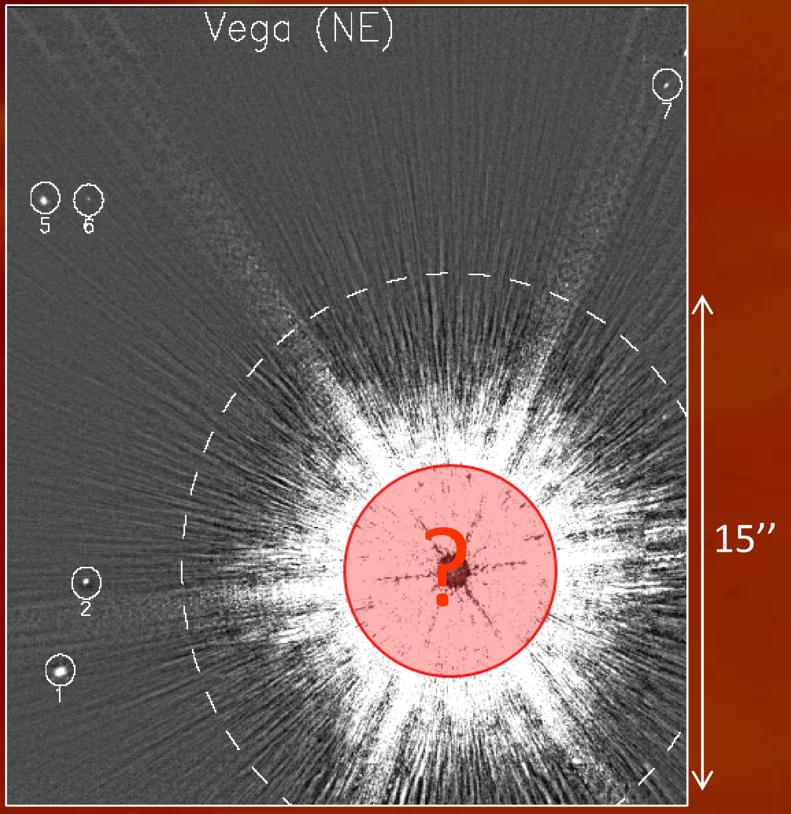
Why interferometry?

- High contrast (≥ 1:100)
- Small angular separation
  - Inner disc: a few 10 mas

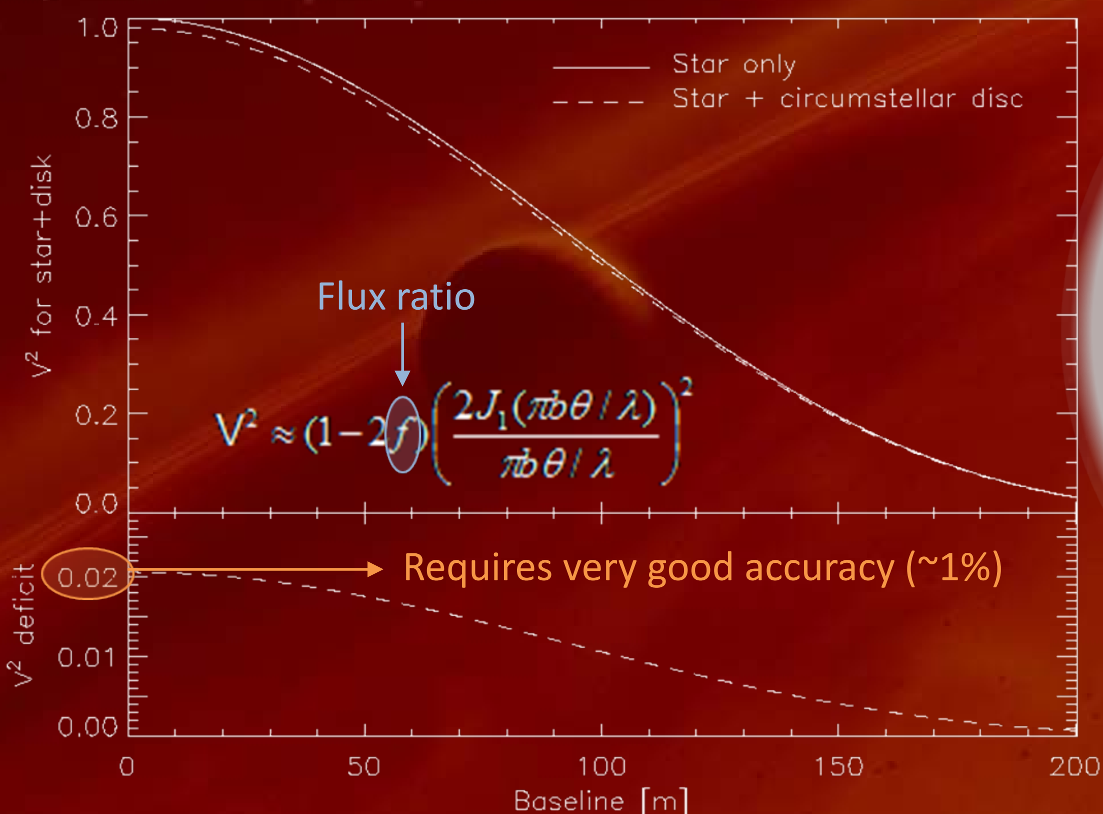


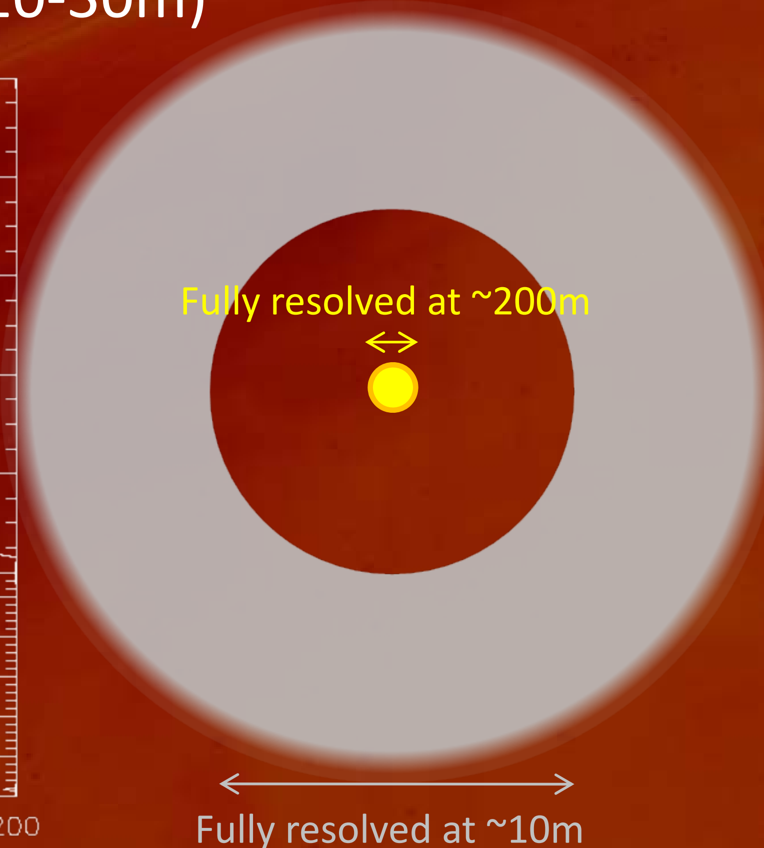


Macintosh et al. 2003 (Keck AO)

Principle of exozodi detection

- Disc larger than angular resolution (λ/B) → incoherent flux
- Induces a loss visibility at all baselines
- Best detected at short baselines (~10-30m)

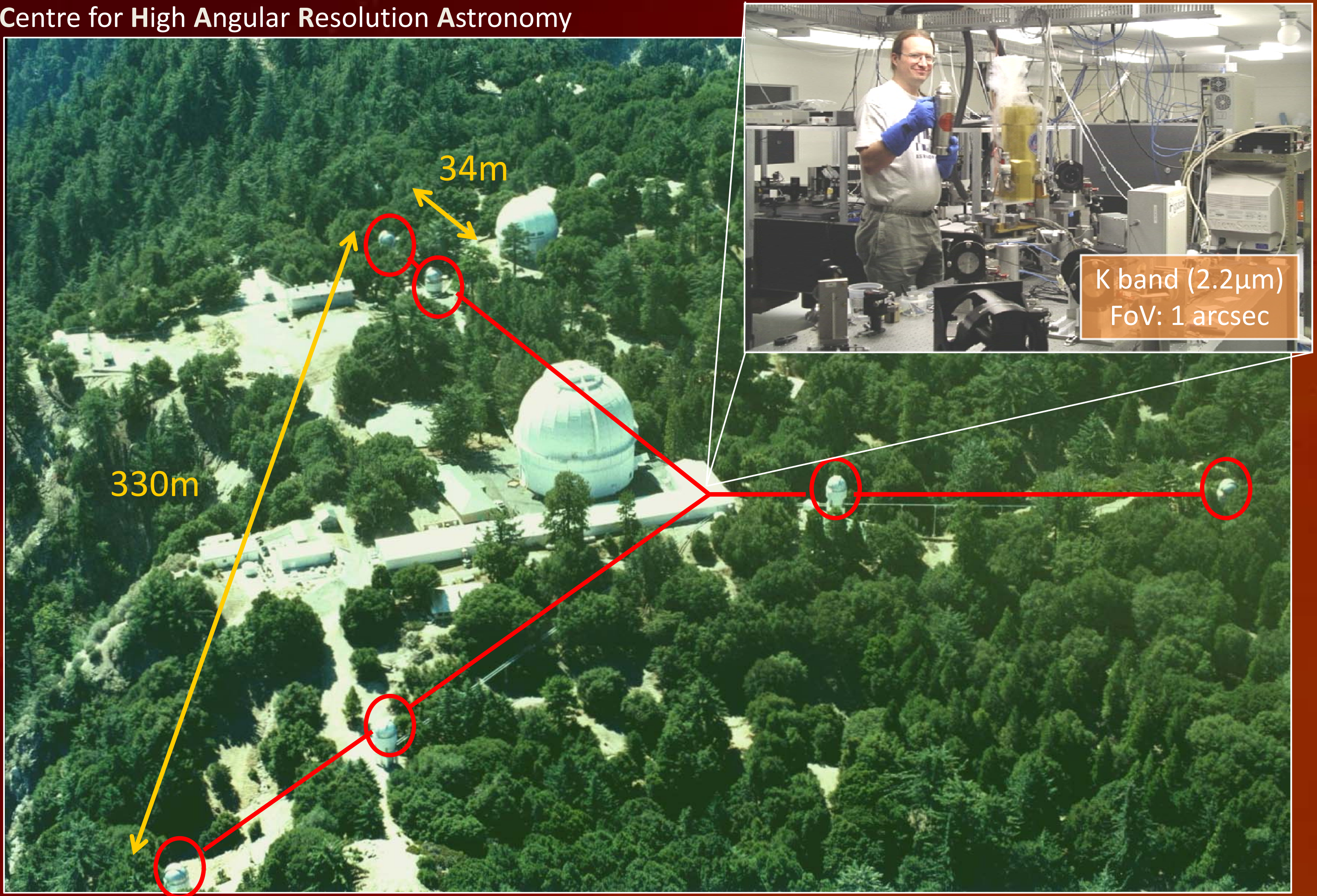




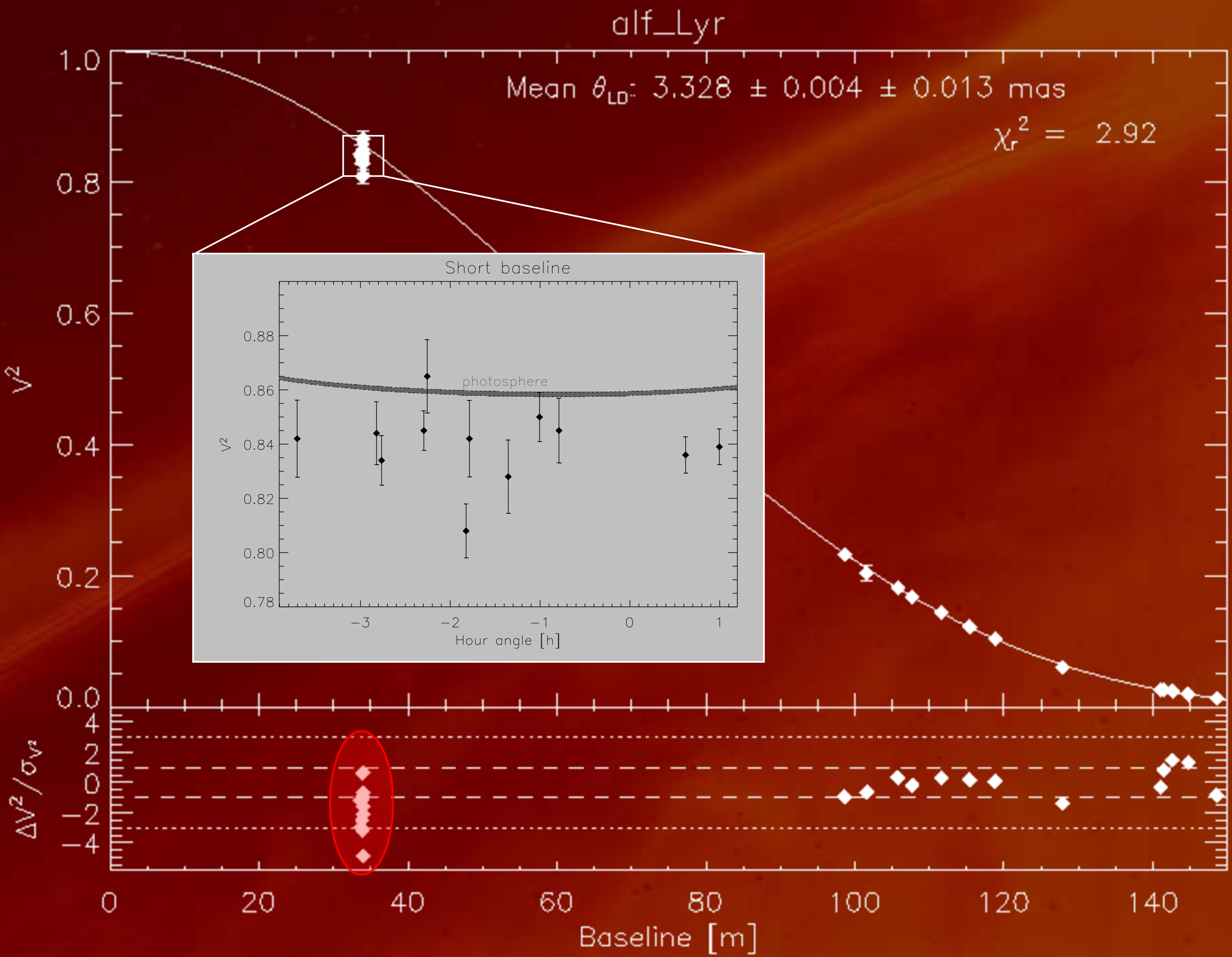
First test: Vega with CHARA/FLUOR

Centre for High Angular Resolution Astronomy

Fibre Linked Unit for Optical Recombination

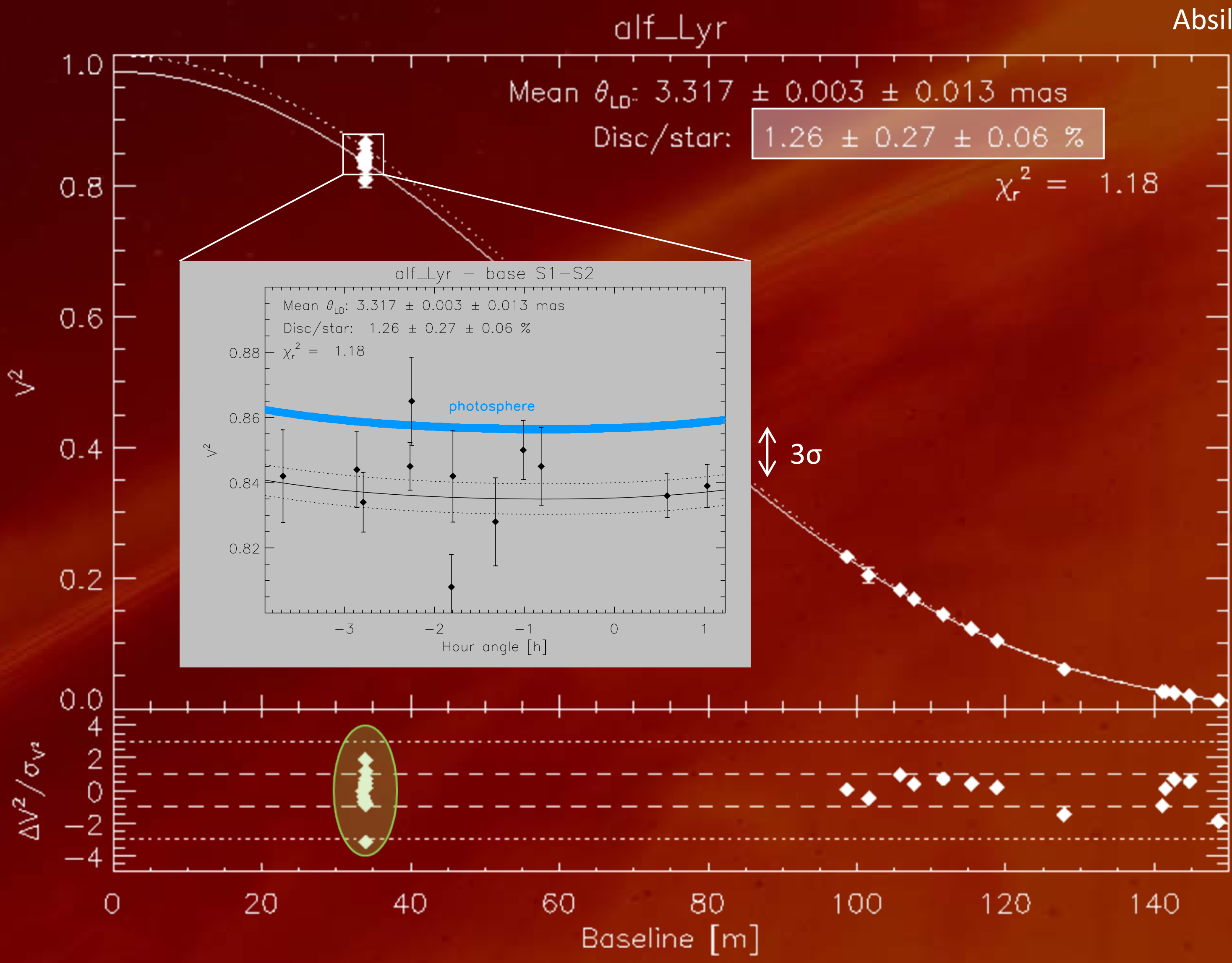


Vega: fitting photospheric model



Vega: fitting photosphere + disc

Absil *et al*. 2006

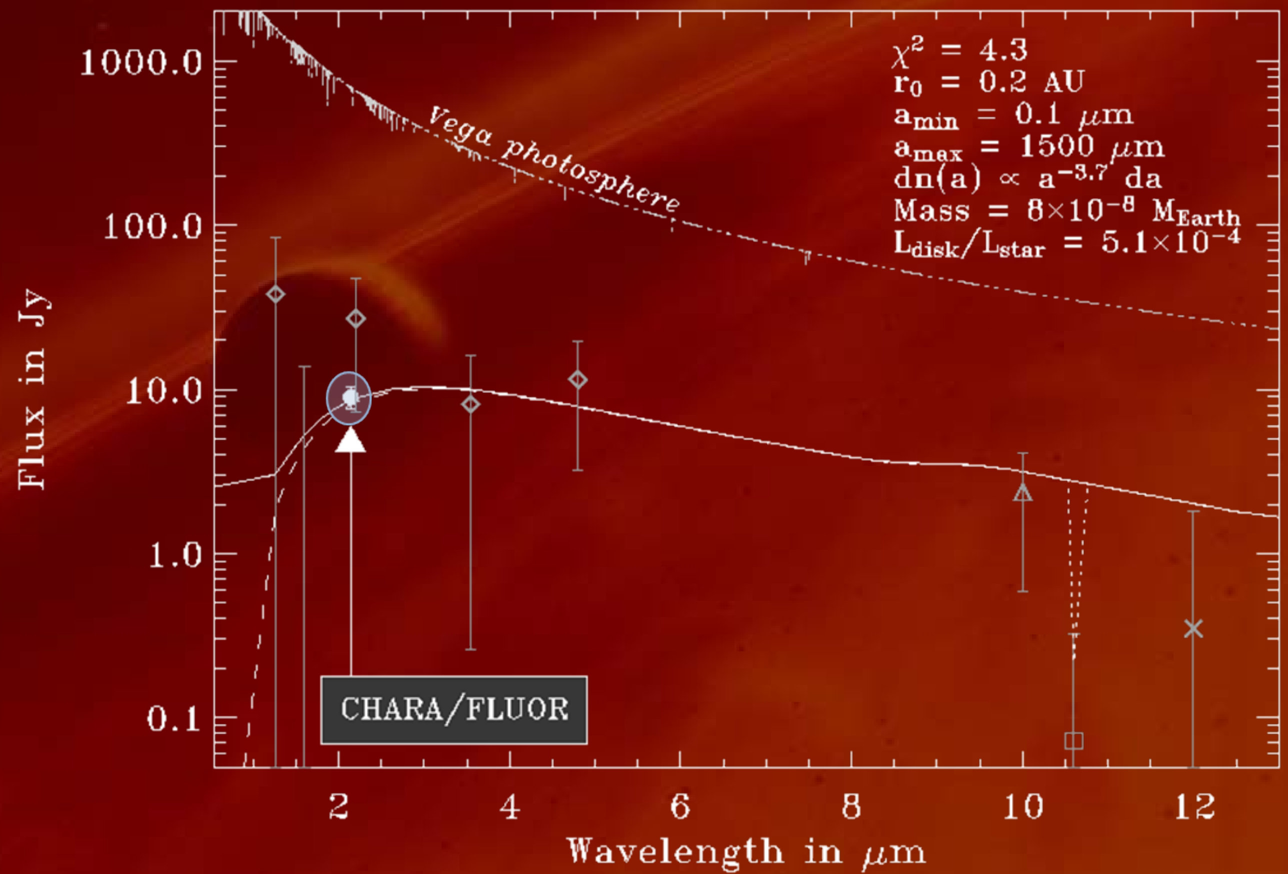


Possible sources of near-IR excess

- Point-like source?
  - RV and astrometry stable → no companion
  - Very low probability for background star
- Stellar wind / circumstellar gas?
  - A stars: very weak winds (~$10^{-12..14}$ $M_{\odot}$/yr)
  - Ae (Be) phenomenon: no evidence for Hα emission
- Circumstellar dust?
  - Thermal emission & reflected flux
- New, unknown phenomenon?
  - Cannot be ruled out (any idea?)

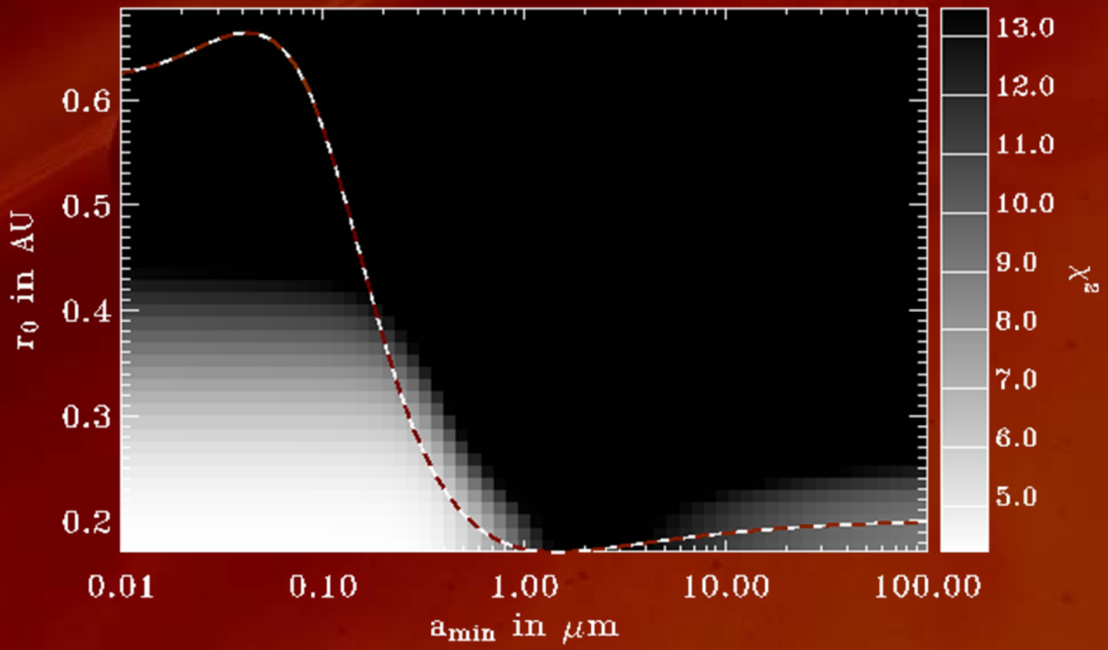
Reproducing the global SED

- Radiative transfer modelling of the inner debris disc
  - Compatible with spectro-photometric data



Best-fit disc properties

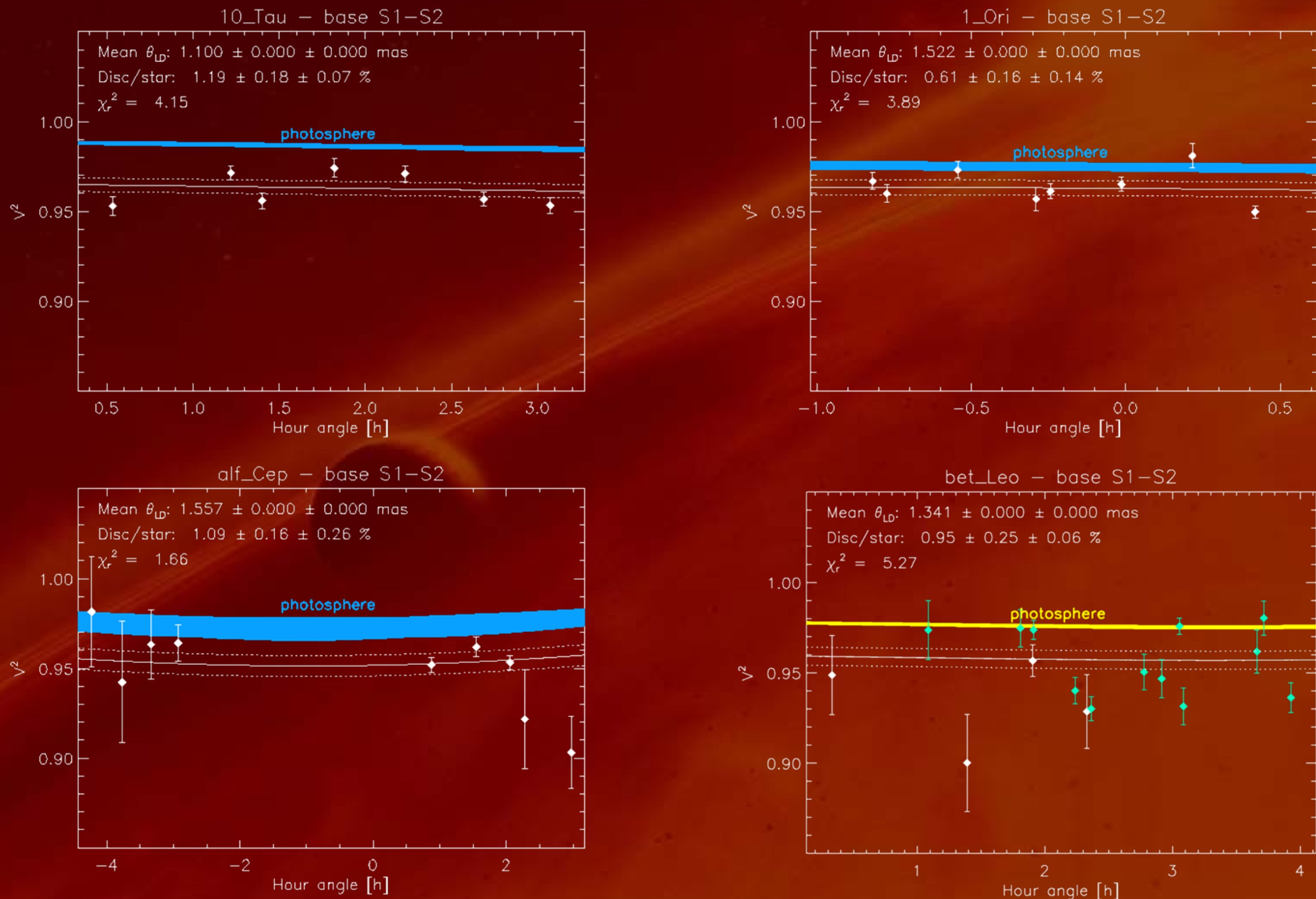
- χ^2 maps for various disc models
  - 2 parameters: mini grain size (a_{min}) and inner radius (r_0)
- Small grains (mostly < 1 µm) at distances ~ 0.1 – 0.5 AU
- Highly refractive grains, no silicate feature → carbons ≥ 50%
- Steep density power law: $\Sigma(r) \sim r^{-4}$ (Solar System: $r^{-0.3}$)



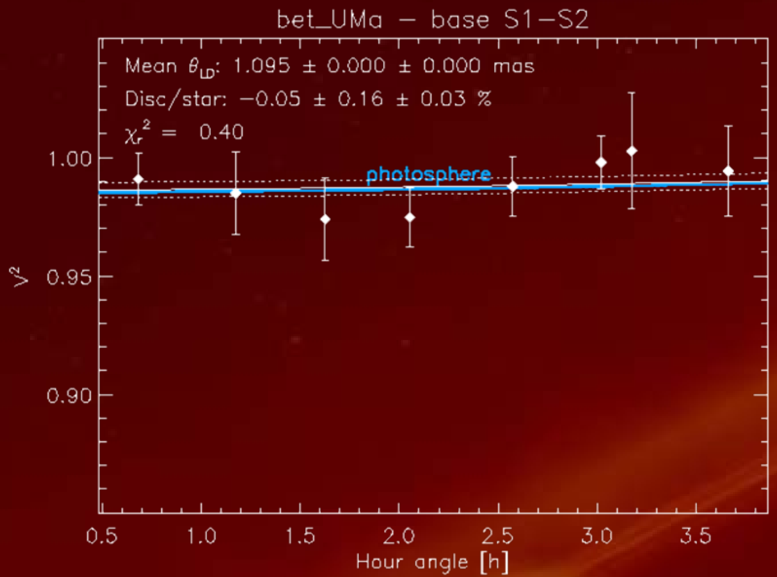
Survey @ CHARA/FLUOR

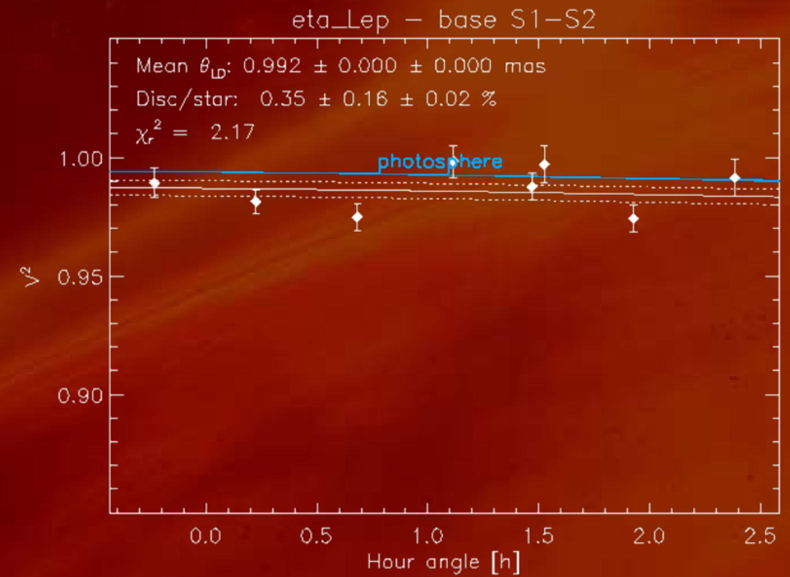
- Started in Fall 2006
- Targets
  - 25 debris disc stars with $K < 4$ and $dec > -15°$
  - Control sample (25 non-dusty main sequence)
- Observing pace
  - Good night → 16 calibrated data points
  - Need ~8 data points per star → 2 star/night
  - Per year: ~10 stars in 20 nights (efficiency: 1/4)
- Currently 40 stars observed (not all complete)

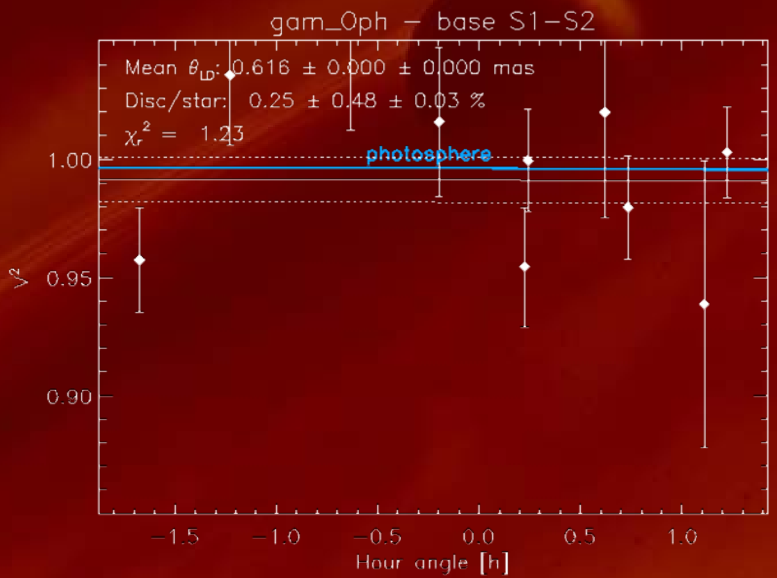
Examples of FLUOR detections

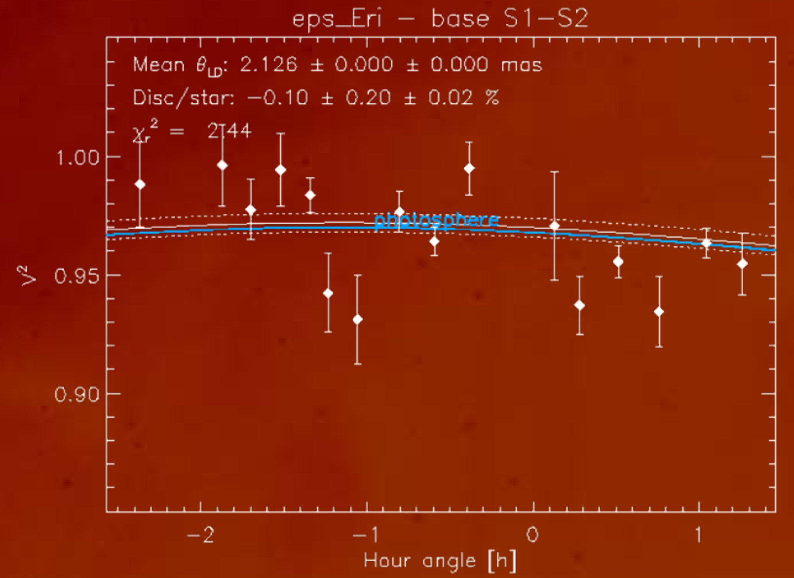


Examples of FLUOR non-detections

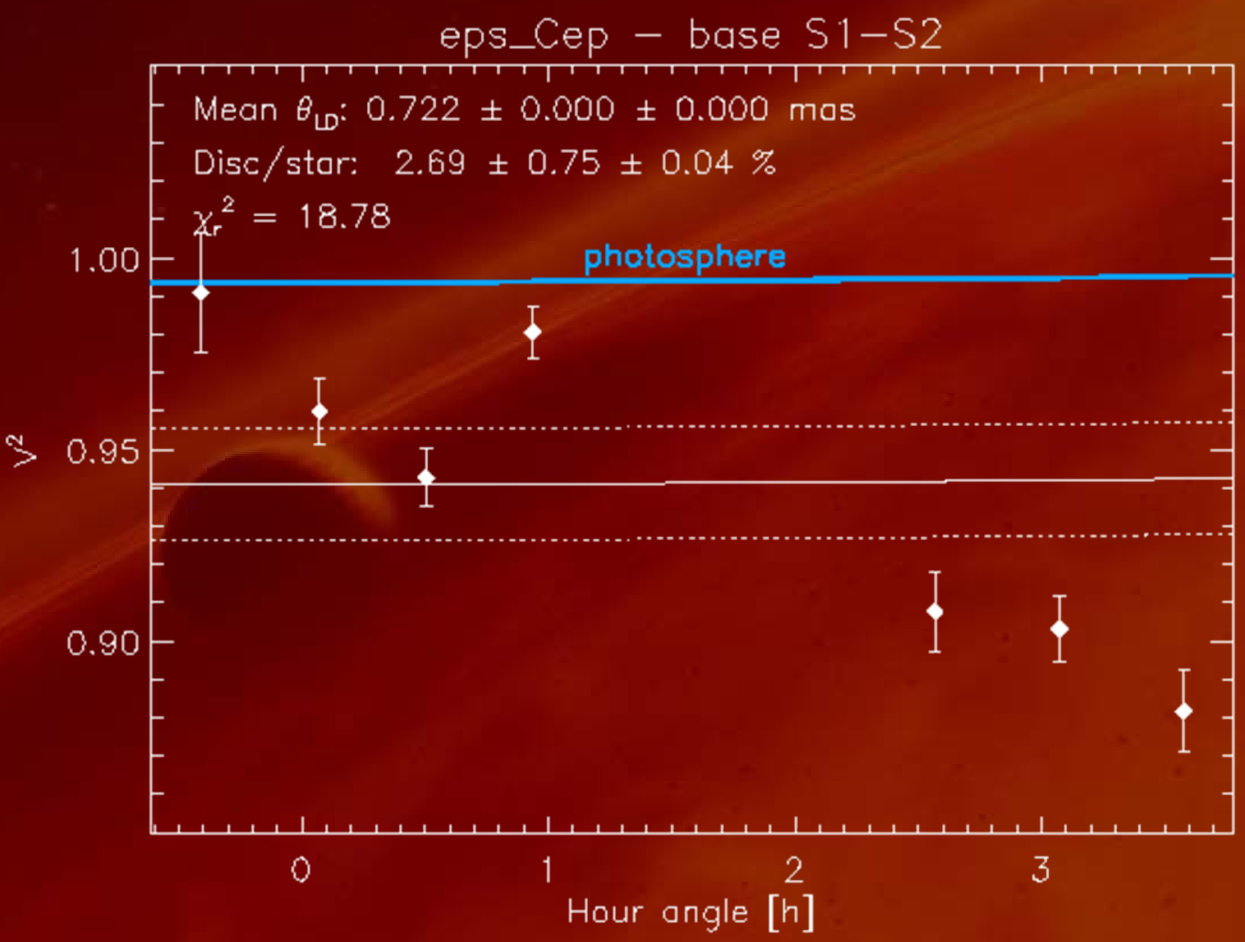






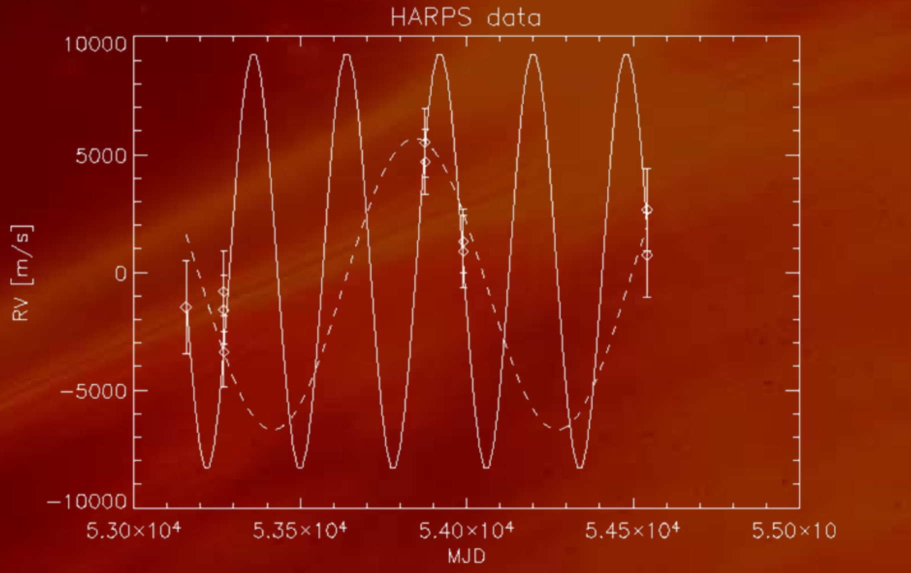


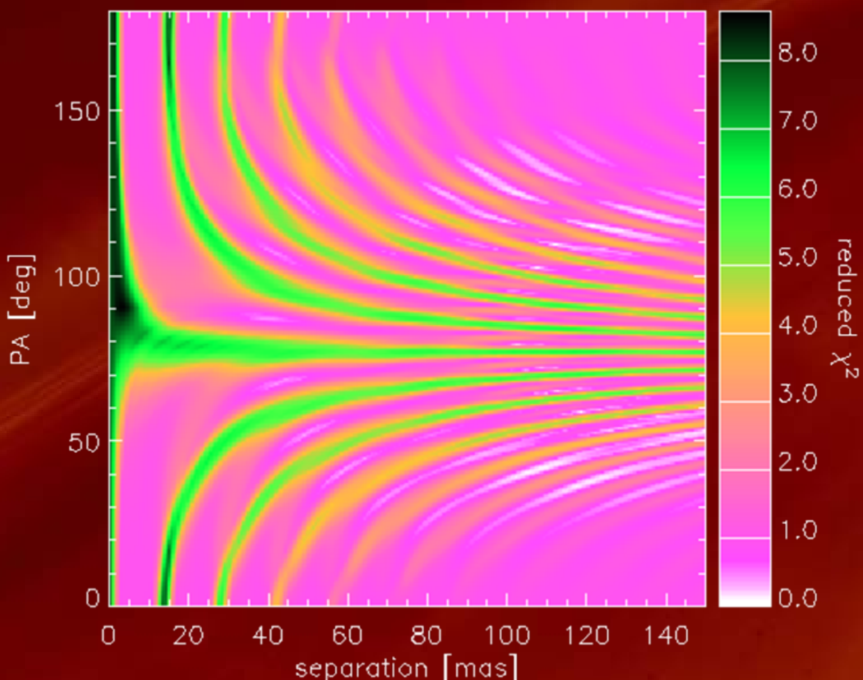
Eps Cep: an « obvious » binary

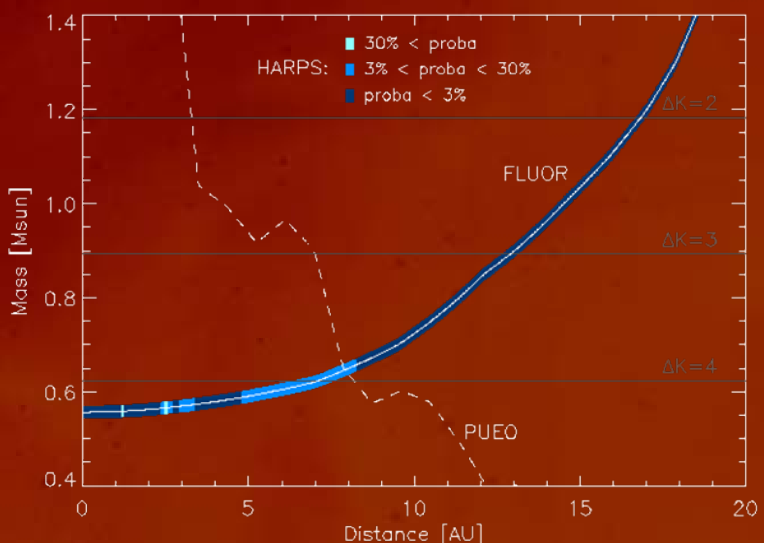


Zeta Aql: exozodi or companion?

- Possible presence of an M0V companion
- Maybe no cold dust?
  - Bad photospheric model



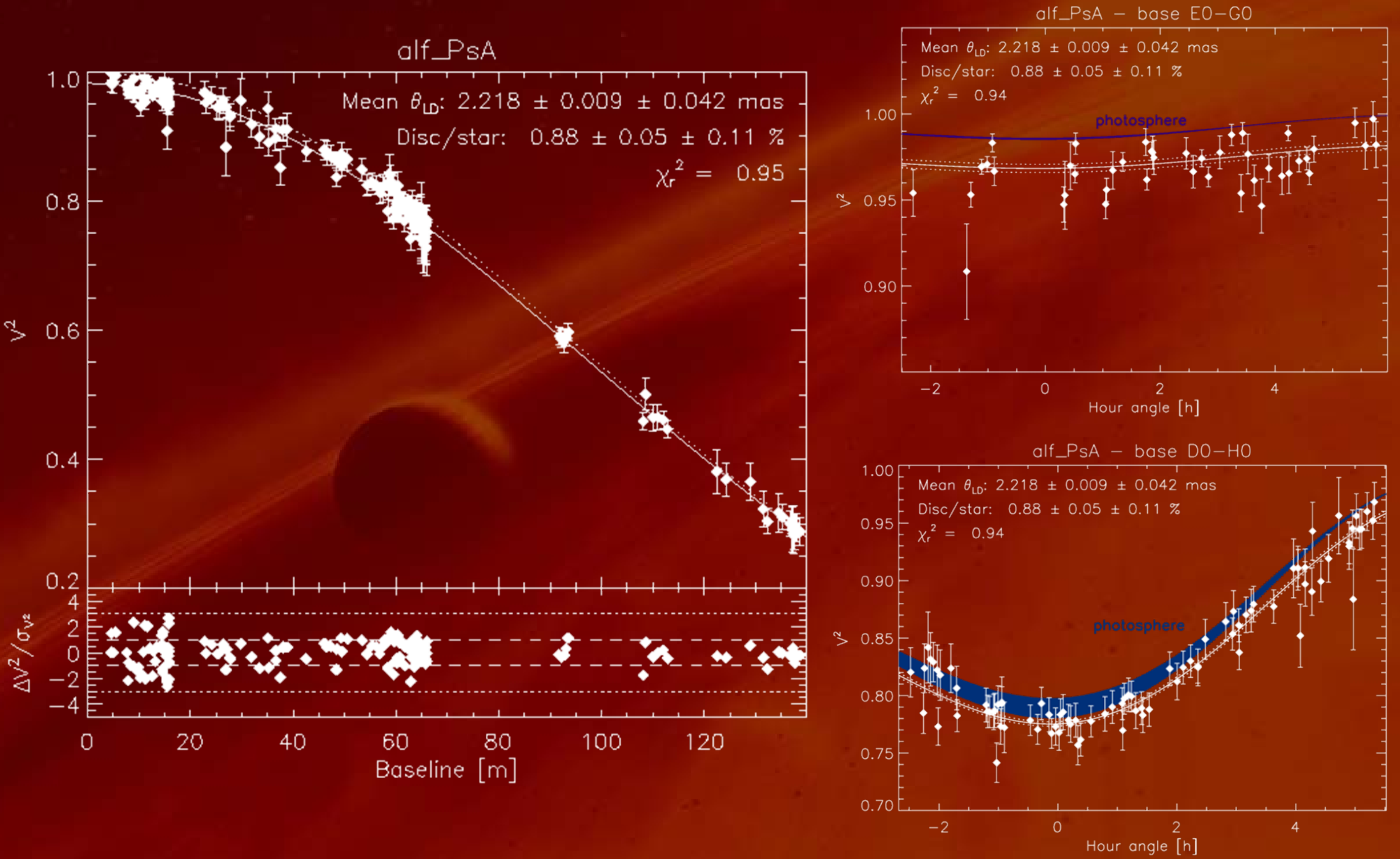




Survey @ VLTI/VINCI

- VINCI operated in 2002-2004
  - Conceptual copy of FLUOR
  - Mostly working on 40-cm siderostats for tests
- Archives searched for MS at short baselines
  - Observing strategy not always appropriate
  - 9 MS stars seem suitable (incl. Fomalhaut)
  - Data reduction mostly done
  - Calibration and data analysis to be finished
- Not included in upcoming statistics

VINCI result on Fomalhaut



Survey @ VLTI/PIONIER

- Exozodi survey initiated in P86 (11/2010)
- Started with commissionning only in P86
  - Pure stability tests in terms of V^2
  - Study of possible V^2 biases (magnitude / colour)
- %-level stability not yet reached
- No scientific result yet on exozodis
  - Real science starts in P87 (09/2011 run)

Survey status

- Out of 40 stars: 10 excesses ≥ 3σ → 25% ± 7%
- Excess per spectral type
  - 14 A stars: 6 excesses → 43% ± 13%
  - 12 F stars: 3 excesses → 25% ± 13%
  - 14 G/K stars: 1 excesses → 7% ± 7%
- Excess versus presence of cold dust
  - 24 debris disc stars: 6 excesses → 25% ± 9%
  - 16 non-debris stars: 4 excesses → 25% ± 11%
- Caveat: some unknown binaries may remain

Possible biases?

- Mean K-band magnitude vs spectral type
  - A → K = 2.4 (due to Vega and Fomalhaut)
  - F → K = 2.8
  - G/K → K = 2.8
- Sanity check on population at $< 3\sigma$
  - Mean excess: 0.03% ± 0.53%
  - Mean error on excess: 0.46%
  - Mean significance of excess: 0.22σ
  - Two stars with negative excess $\geq 3\sigma$ (poor quality)
- Very small bias toward positive excesses
  - No underlying population of small excesses???

Main goals of the ANR project

1. Increase the statistical sample
   – 100+ stars in each hemisphere
2. Investigate the age dependence
   – Mainly old MS stars up to now
3. Characterise the grain properties
   – Multi-colour information needed
4. Study exozodi morphology
   – Including possible binaries
5. Search for variability

1. Statistical sample

- Total of 103 known debris disc stars with K < 5 (w/o HSO)
- FLUOR
  - Increase sensitivity to K = 5 (new camera)
  - Double the current sample
  - Increase the observing efficiency → 2/3 years?
- PIONIER
  - Validate high precision in 2 < K < 5 regime
  - About 60 Southern targets + control sample
  - Expect 6 targets per night → 20 nights (partly Belgian GTO)

	# MS (K < 4)	# MS w. debris (K < 4)	# MS (K < 5)	# MS w. debris (K < 5)
All	303	45	1158	103
North	156	16	536	42
South	147	29	622	61
-10° < dec < +20°	73	8	256	21

2. Age dependence

- Young MS stars available at K < 6 limit (PIONIER)
  - Nearby (Southern) moving groups and associations
- Defined 3 age bins
  - Young: < 30 Myr
  - Intermediate: 30 – 200 Myr
  - Old: > 200 Myr
- Need to populate the first two bins
  - About 20 targets available per bin
- Share observing time with companion searches
  - Need ~7 nights for 40 targets (CNRS GTO + open time)

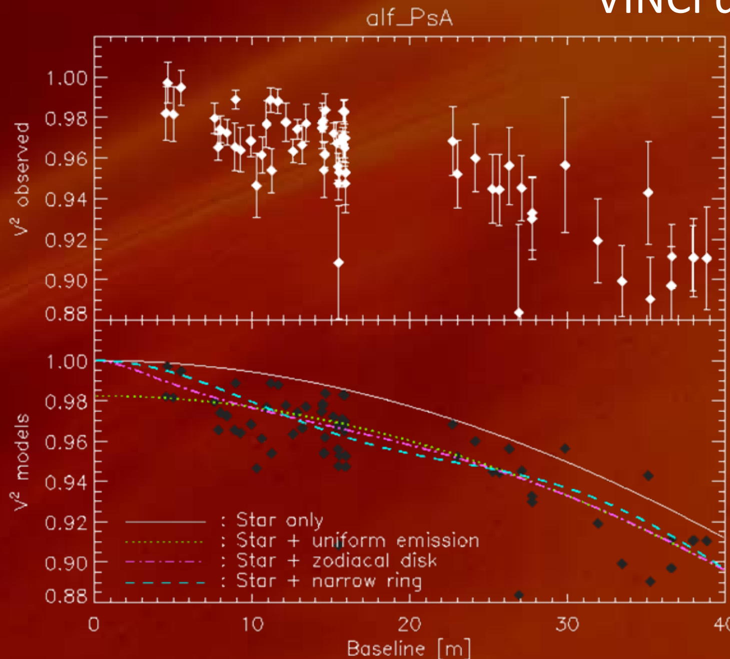
3. Grain properties

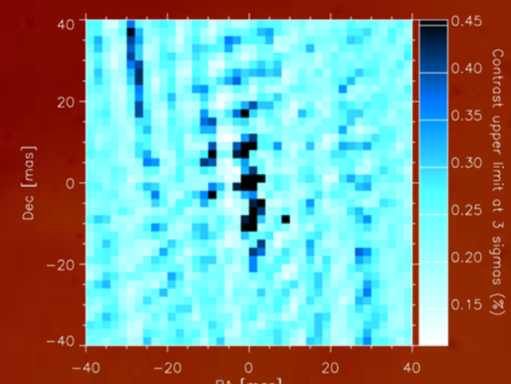
- Need multi-colour information
  - Does it need to be contemporaneous?
- Follow up FLUOR detections with PIONIER-H
  - 2n scheduled in P87 (Belgian GTO)
  - 5 targets with dec < +20°
  - Also 1n on Fomalhaut (see next slide)
- First two-colour modelling test on Vega
  - CHARA/FLUOR in K band in 2005
  - IOTA/IONIC in H band in 2006 (see Denis' talk)
- Other data (10μm): KIN, BLINC, MIDI?

4. Morphology

- Exozodi morphology affects short baselines
  - Need exquisite accuracy
  - P87: 1n on Fomalhaut (Belgian GTO)
- Discriminate binaries
  - PIONIER closure phases
  - Potentially CHARA/MIRC or CHARA/CLIMB for Northern targets?
  - 1:100 companions easy

VINCI data





PIONIER data

5. Variability

- Near-IR excess could vary on month- to year-timescale
  - Catastrophic event, comet evaporation, etc
  - Could be used to constrain dust origin
- First test on Vega at CHARA/FLUOR
  - First detection in 2005 (1.2% contrast)
  - Follow-up observations failed in 2010
  - New attempt in May 2011
- What next?
  - Follow-up all detections every ~3 years?
  - Need significant amount of extra time!

Task 2 summary

- Huge observing effort in next 2-3 years
  - ~80 nights in total on FLUOR + PIONIER
- Loads of data to reduce and analyse
  - Reduction pipelines mostly ready (see next talks)
  - IDL routines available for analysis
    - Exozodis with V^2, companions with CP
- A lot of human work besides observing
  - Finalise the target lists (check literature for all targets)
  - Photospheric models (based on ~~2MASS~~ photometry)
  - Run data reduction and analysis
  - Interpretation (models + statistics) and publication!