The CHARA/FLUOR survey of debris disk stars: results and statistics

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Zodiacal dust in the Solar system

- Within ~1 AU, the **inner solar system is filled with dust** near the ecliptic plane
- Origin:
  - **Comets (90%, Nesvorny et al. 2010)**
  - **Asteroid collisions**
- It's **not a smooth cloud**:
  - Dust bands: asteroids families?
  - Resonant ring caused by the Earth

Why we care about exozodiacal dust?

Exozodiacal dust = dust clouds in and around the habitable zone of stars

1. Understand exoplanetary systems
   - Planetary system formation and evolution theories
   - Dust-planet interaction
2. Prepare future exo-Earth imaging missions
   - Solar zodiacal cloud ~300 times brighter than Earth (IR and Visible)
   - Asymmetric features can mimic the planetary signal

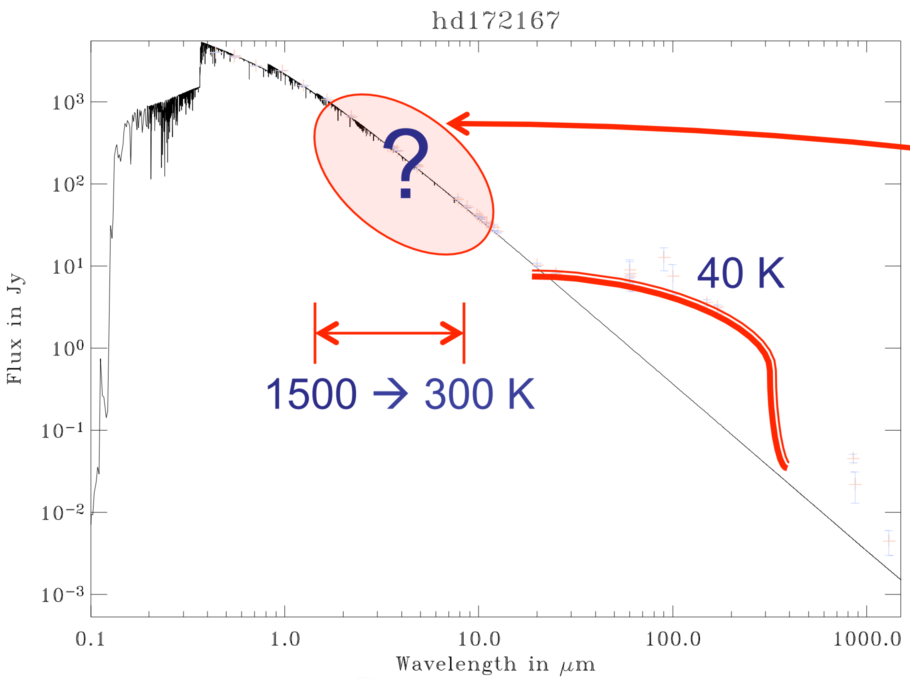
What do we know?
…not much

- Single-dish photometry
  - ✓ Spitzer: ~1% of 152 main-sequence stars (Lawler et al., 2009)
  - ✓ WISE: ~1% of 350 main-sequence stars (Morales et al. 2012)
  - ✓ Sensitivity threshold ~1000 zodis

- Infrared interferometry
  - ✓ KIN : ~10 detections out of 41 main-sequence stars (Millan-Gabet et al., 2011, Mennesson et al. in prep).
  - ✓ VLTI/MIDI: HD 69830 and η Crv (Smith et al., 2009), HD 113766 and HD 172555 (Smith et al. 2012), β Pic (di Folco et al., in prep).

The observing challenge

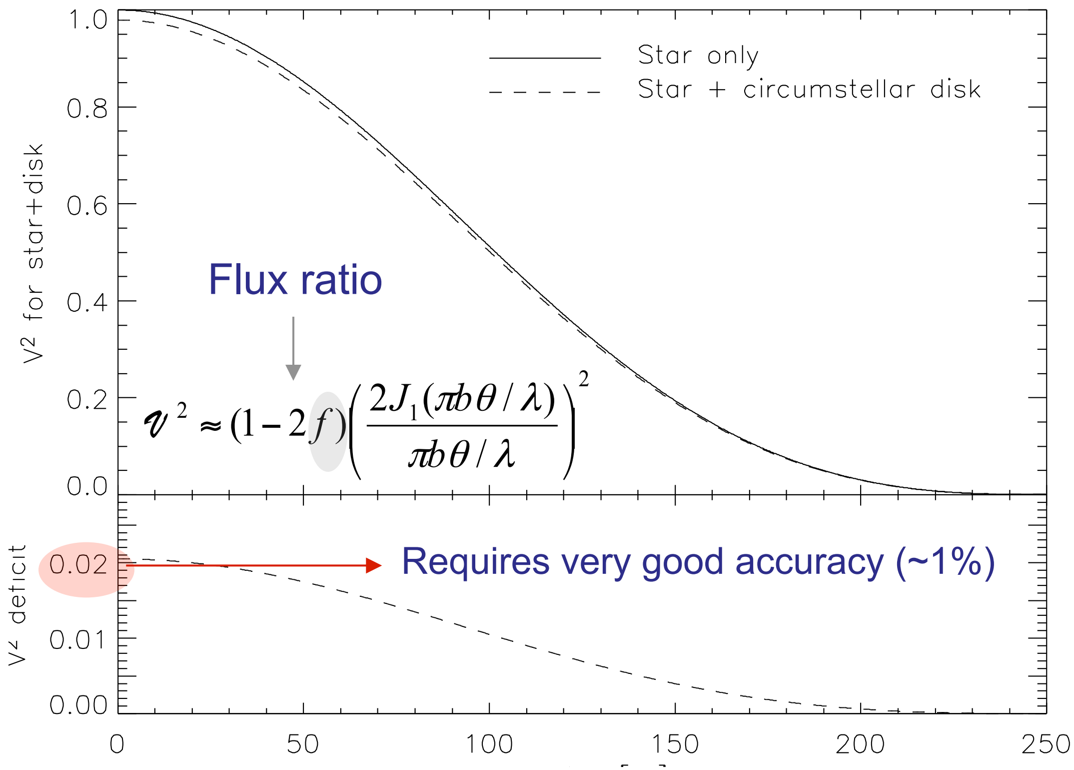
- High contrast (≥ 1:100)
- Small angular separation
  - ✓ Inner disc: a few 10 mas
  - ✓ Requires IR interferometry

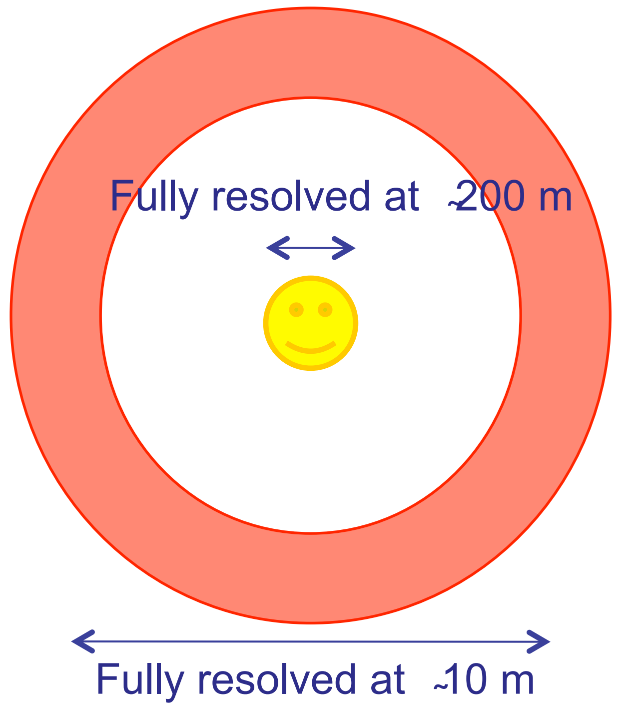


Georgia State University

Detection strategy

- Disc larger than angular resolution (λ/b) → incoherent flux
- Induces a visibility deficit at all baselines
- Best detected at short baselines





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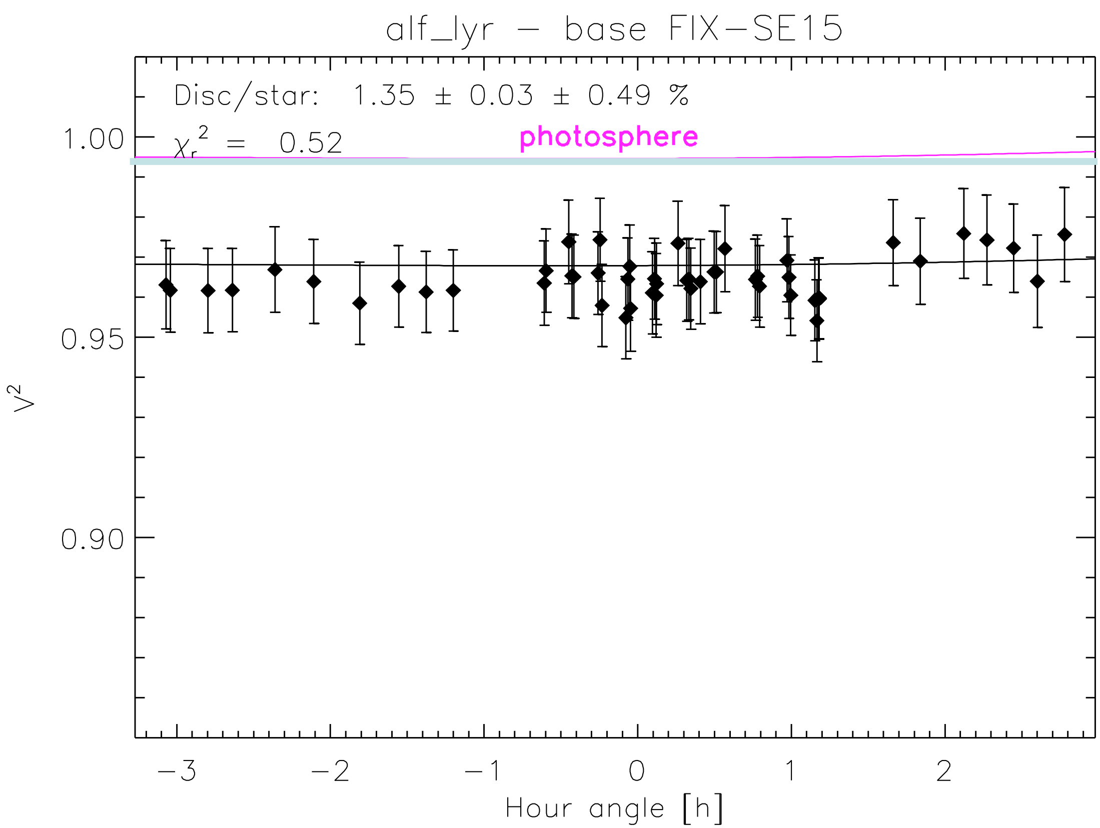
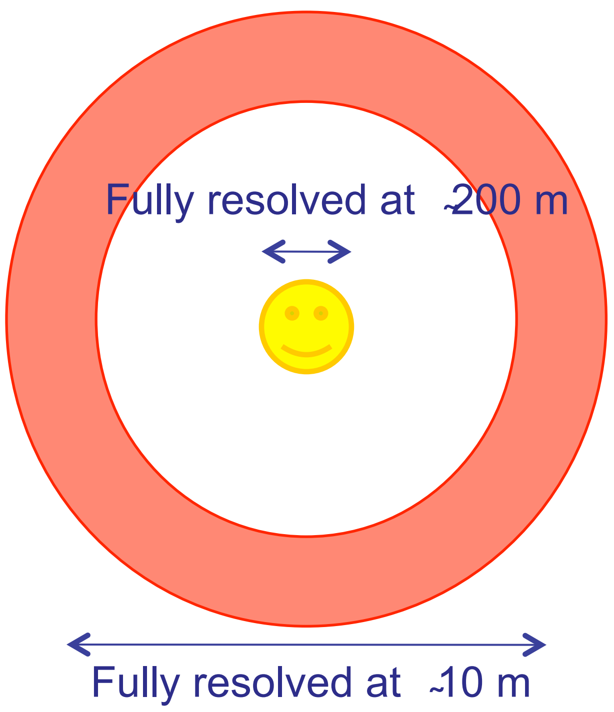
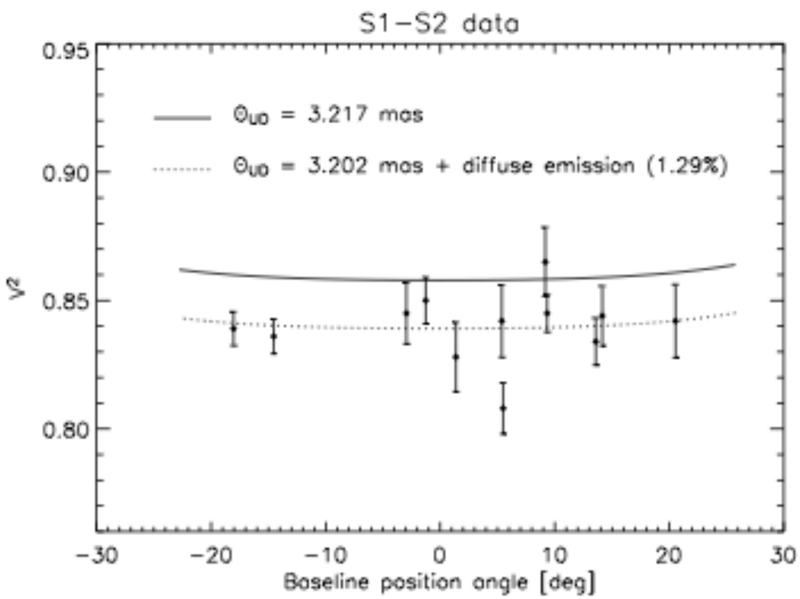
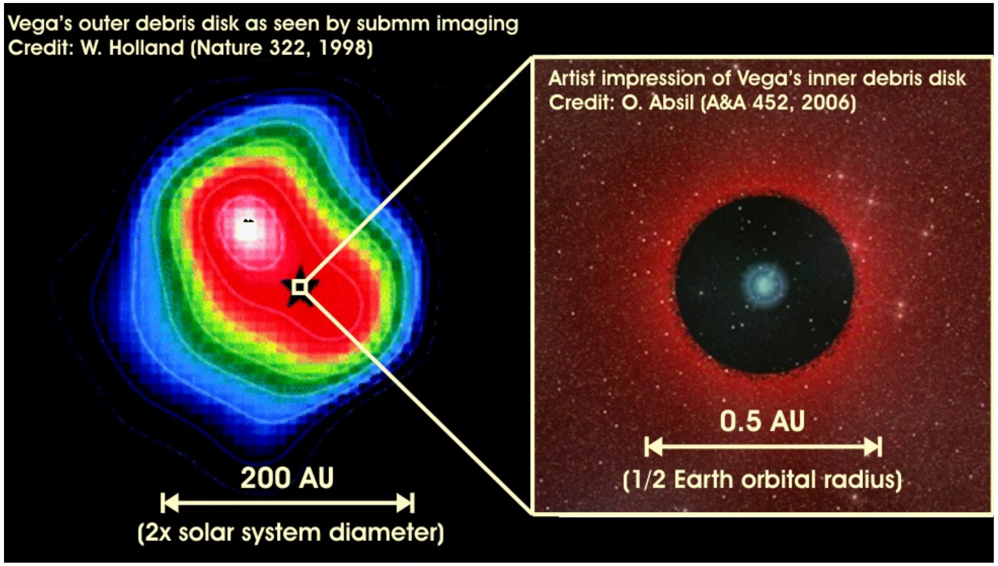




Origin of the survey

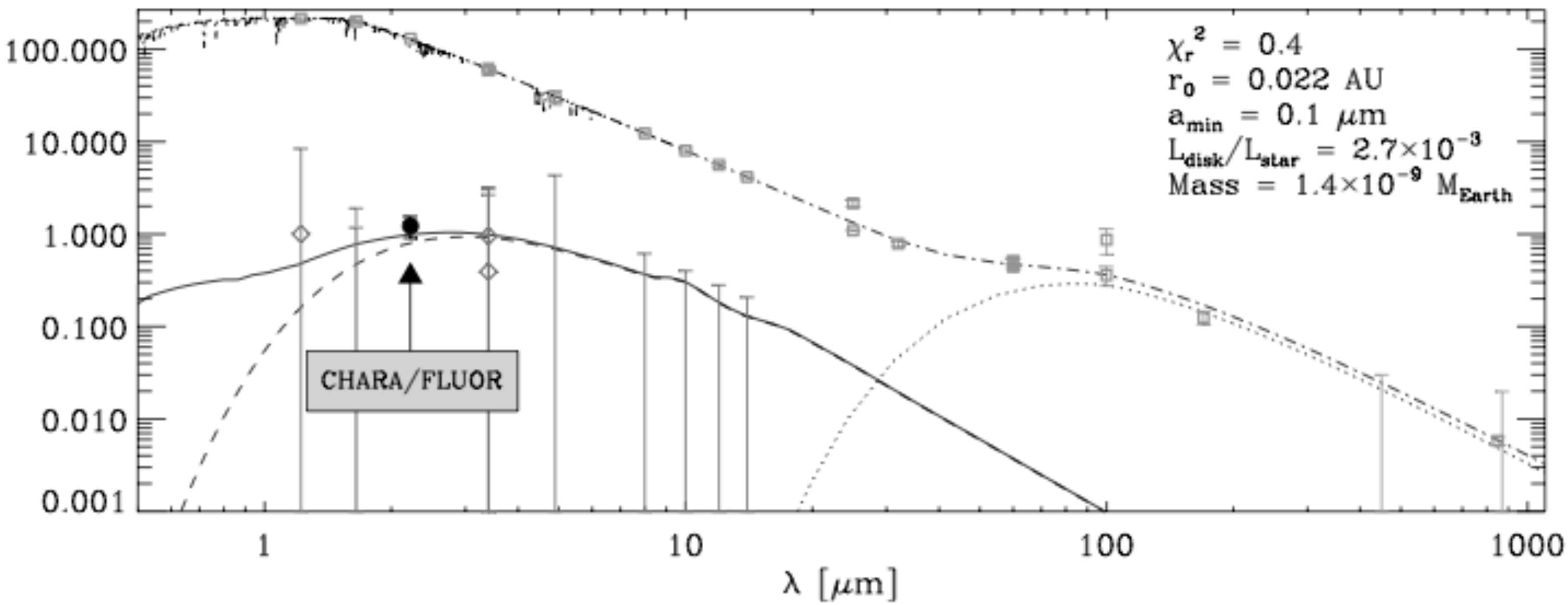
- First detection in 2005 around Vega (Absil et al. 2006):
  - Initial excess detection of 1.29% +/- 0.19% in the K-band
  - Confirmed 1-year later by IOTA/IONIC in the H-band (Defrère et al. 2011)





First results of the survey

- Survey initiated in Fall 2006:
  - ✓ Paper 2 (di Folco et al. 2007): two stars – one detection (τ Ceti , G8V, ~10Gyr,).
  - ✓ Paper 3 (Absil et al. 2008): 7 additional stars -- one detection (ζ Aql, companion thought to be a possibility at that time)



Survey overview

1. The target sample

- Selection criteria:
  - ✓ Well sampled across spectral types;
  - ✓ Similar quantity of stars with and without outer dust disks;
  - ✓ No binary (<5”).
- The final sample:

	A	F	G-K	Total
Outer reservoir	7	7	5	19
No outer reservoir	5	8	10	23
Total	12	15	15	42

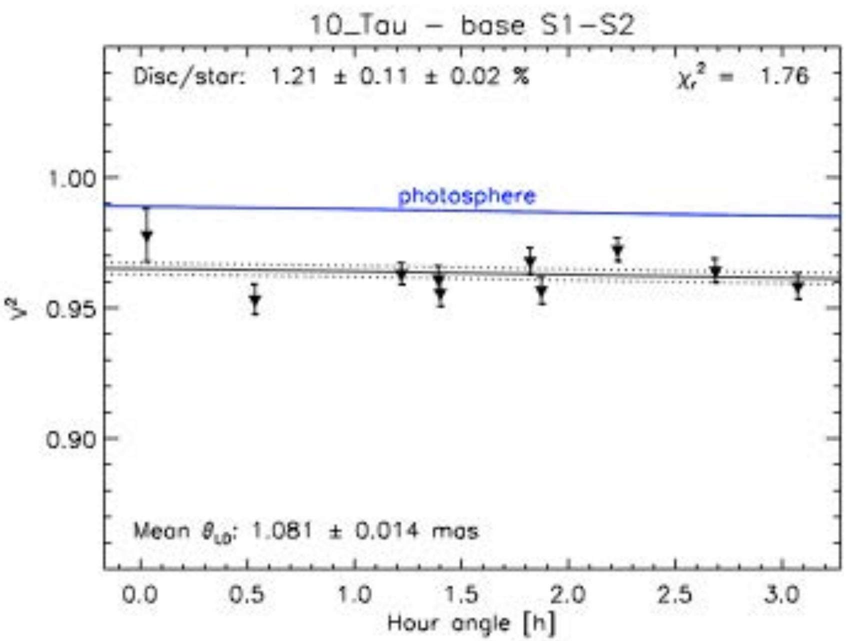
Survey overview

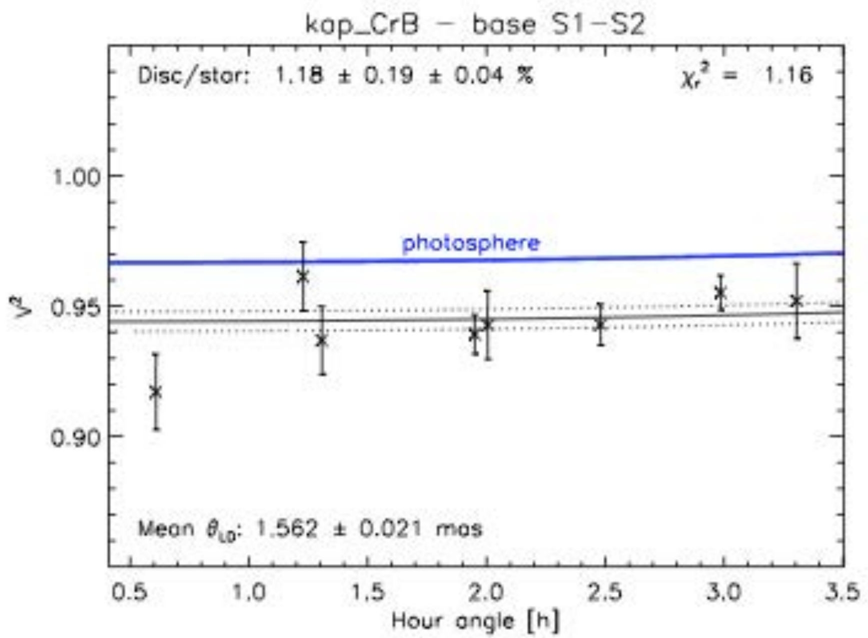
2. Observing schedule

2006	2007	2008
91 OBs on 14 stars	2007A: fire shutdown 2007B: 8 OBs on 14 stars	85 OBs on 17 stars

2009	2010	2011
108 OBs on 20 stars	76 OBs on 12 stars	2011A: 127 OBs on 14 stars

Examples of new detections





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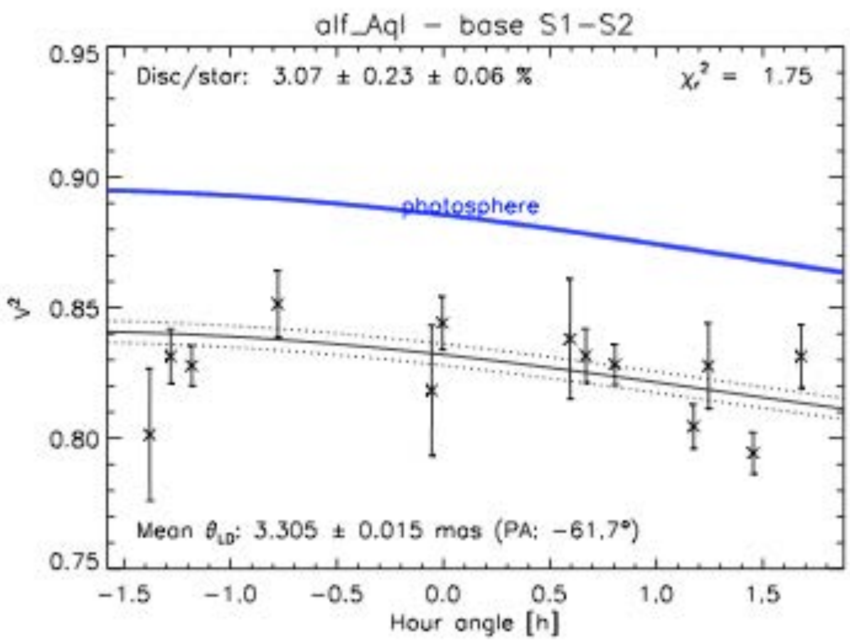
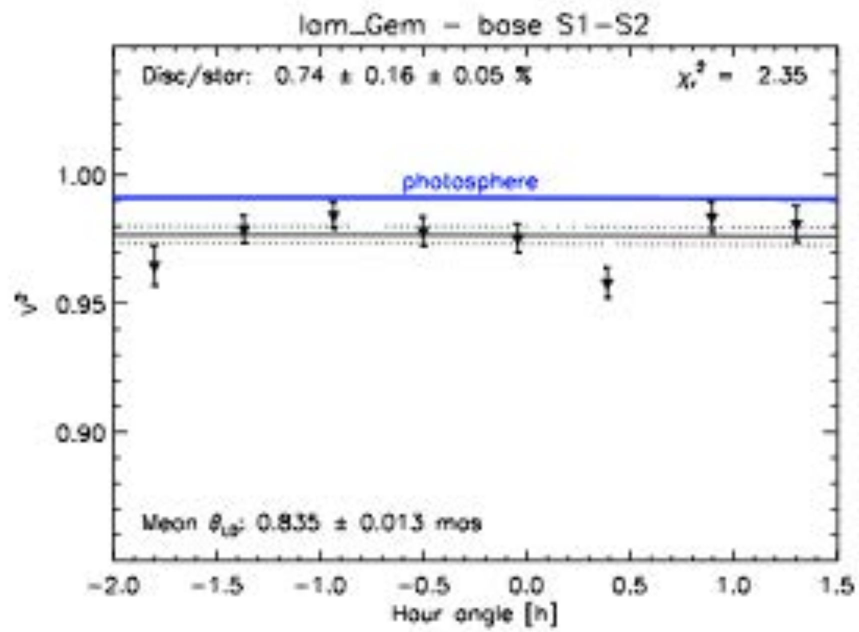
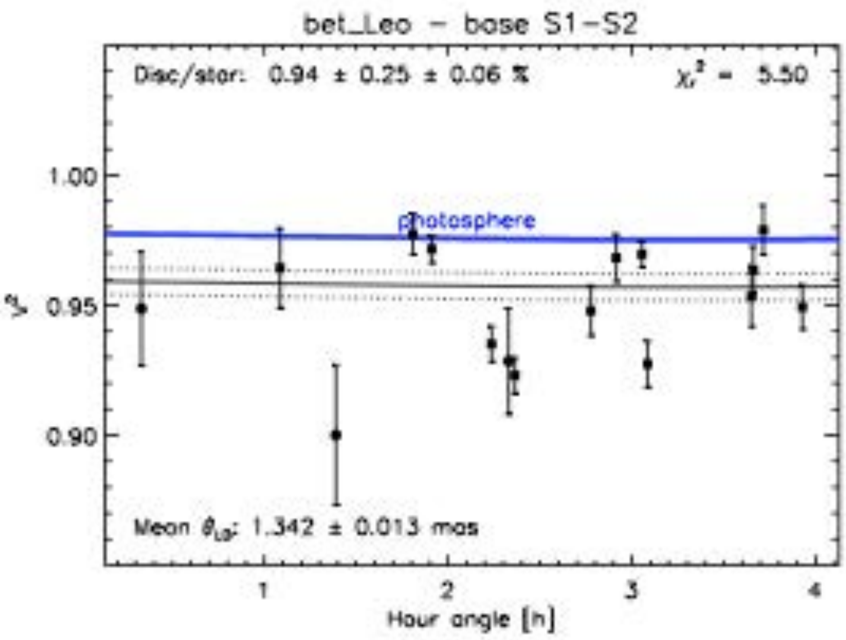
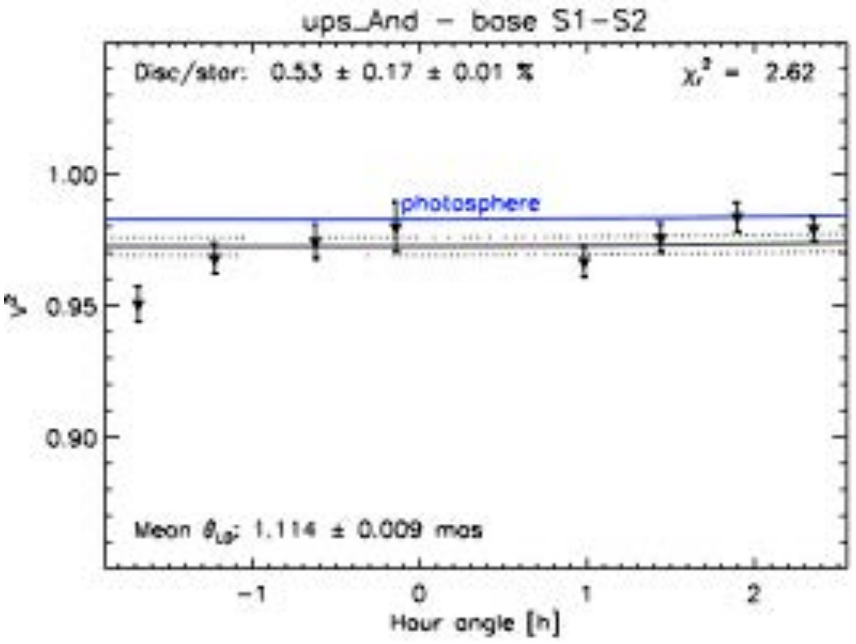


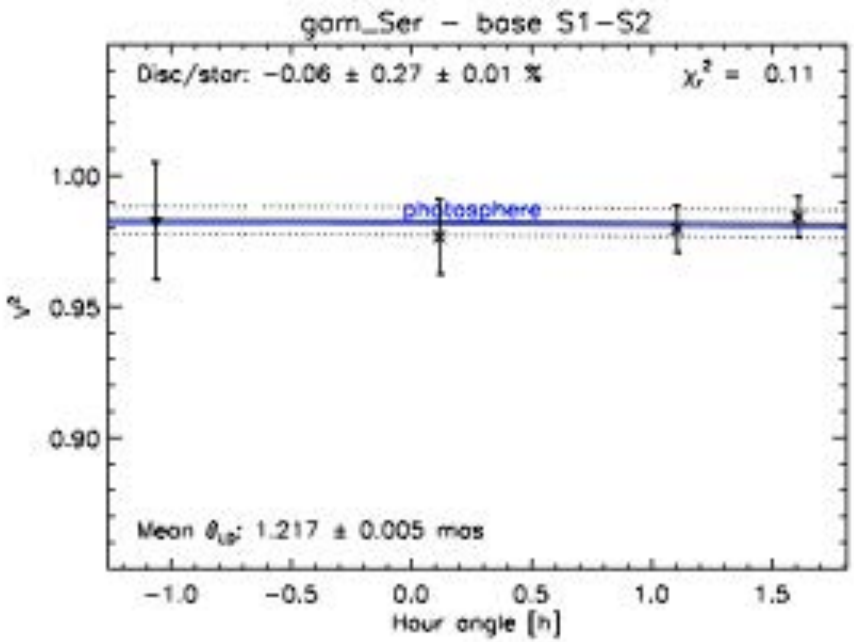


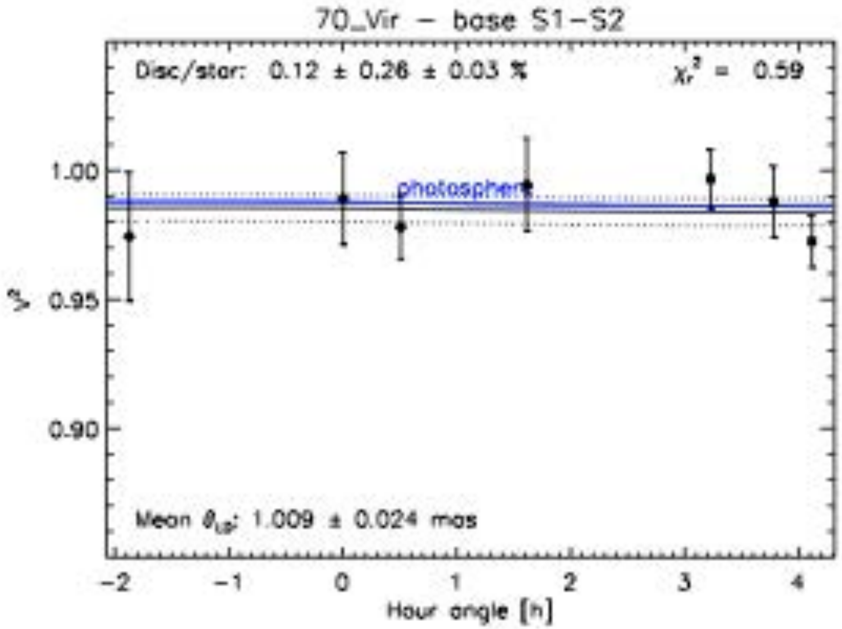
Examples of marginal detections





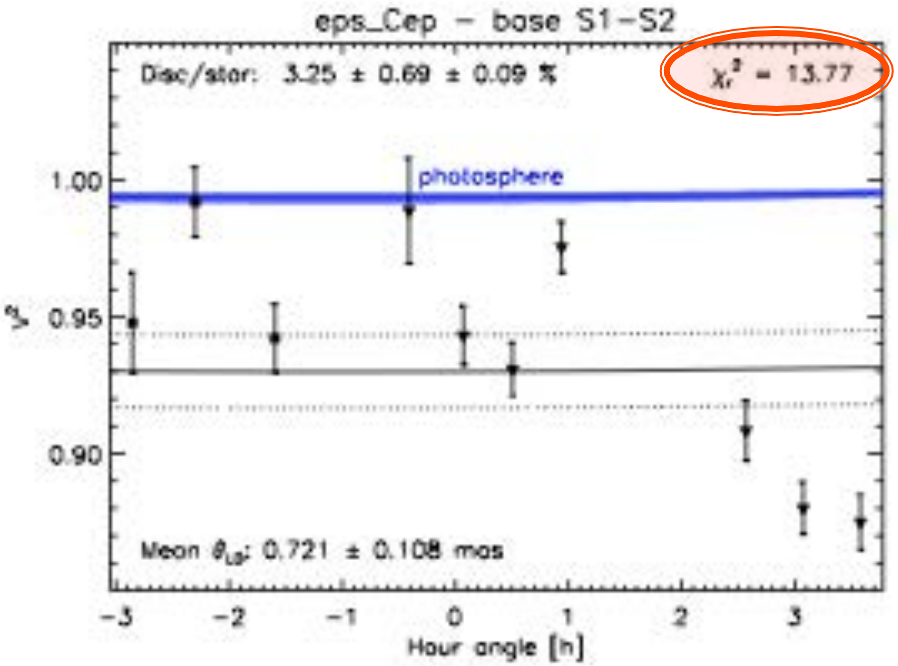
Examples of non-detections





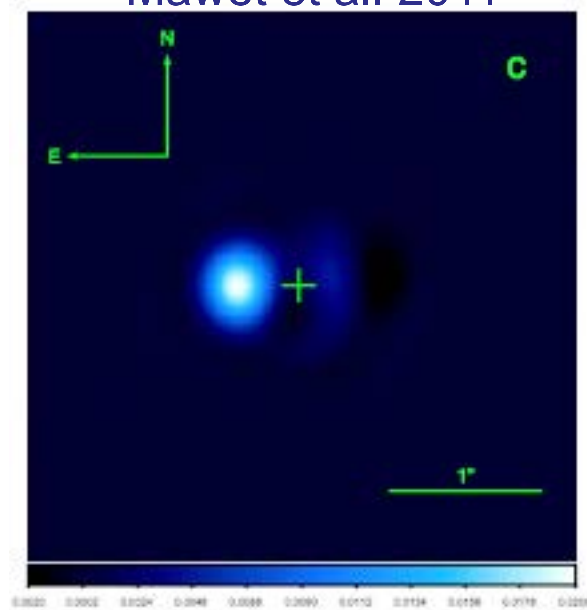
ε Cep: a clear binary

2008-2009 FLUOR data



2010 coronagraphic image (Palomar)

Mawet et al. 2011

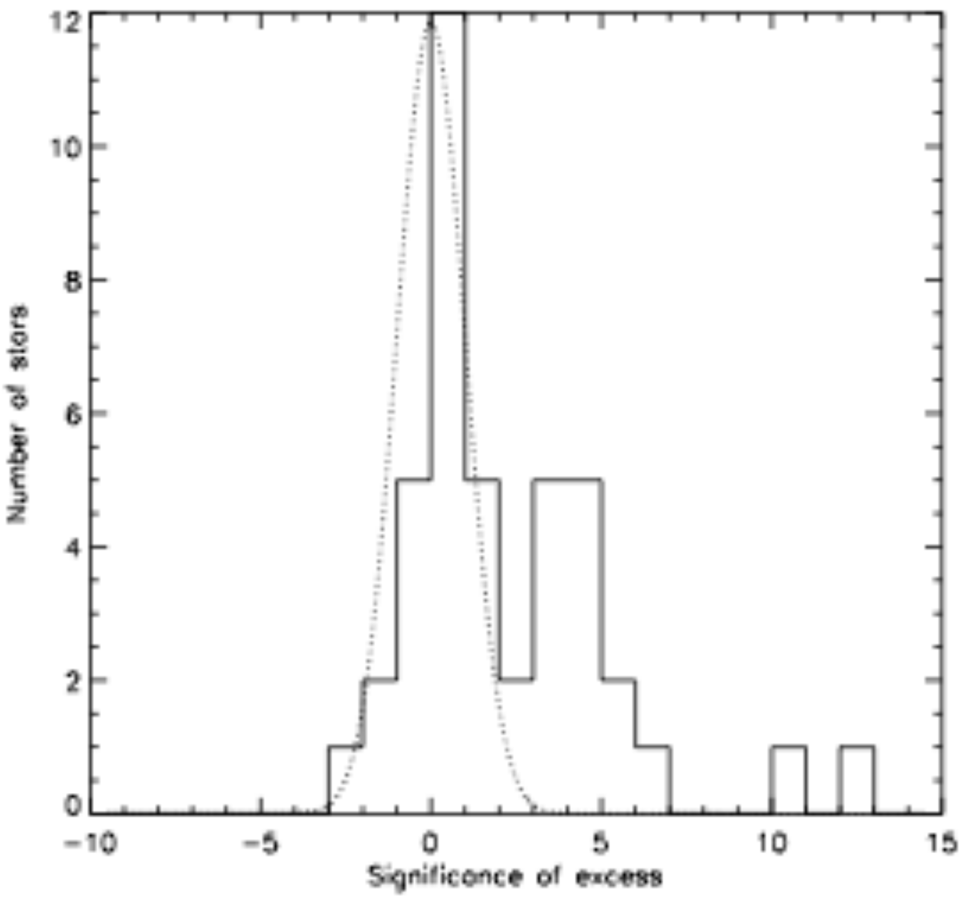


K8-M2 companion

K=7.8

>8.6 AU (>320 mas)

Statistical analysis

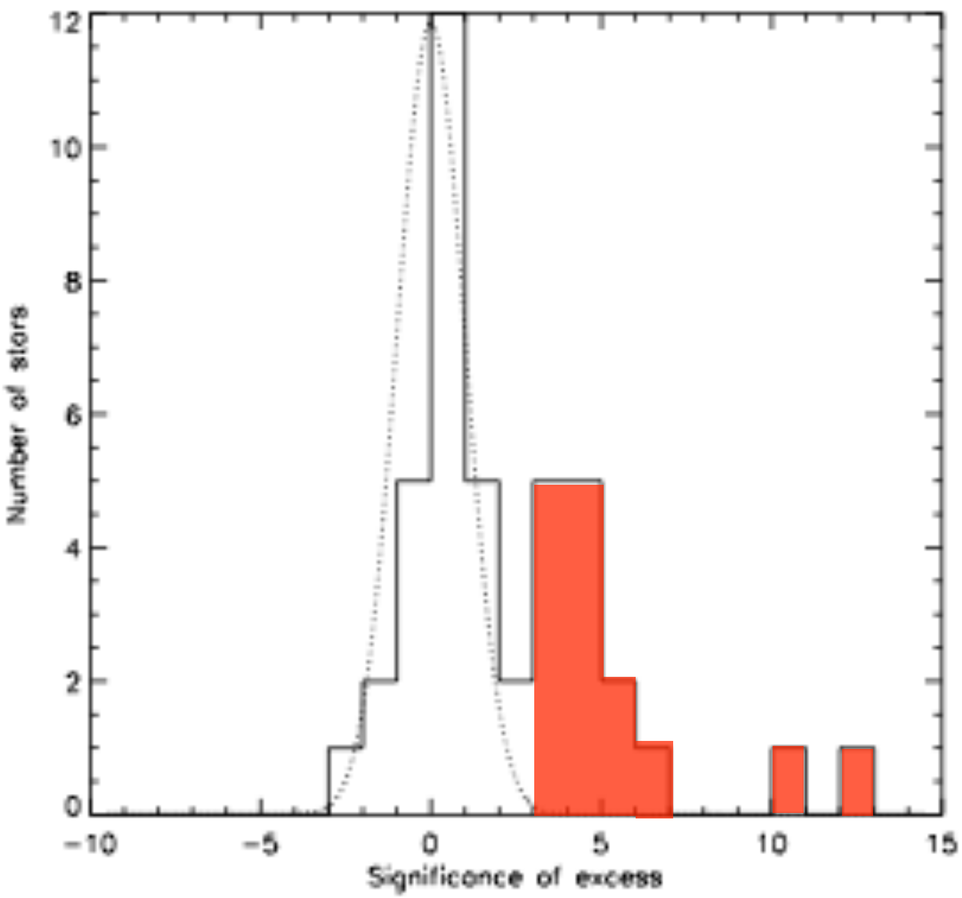


Bimodal distribution:

- Gaussian non-detection
- Group of detection peaked at 4-σ

No negative detection below 3-σ

Statistical analysis



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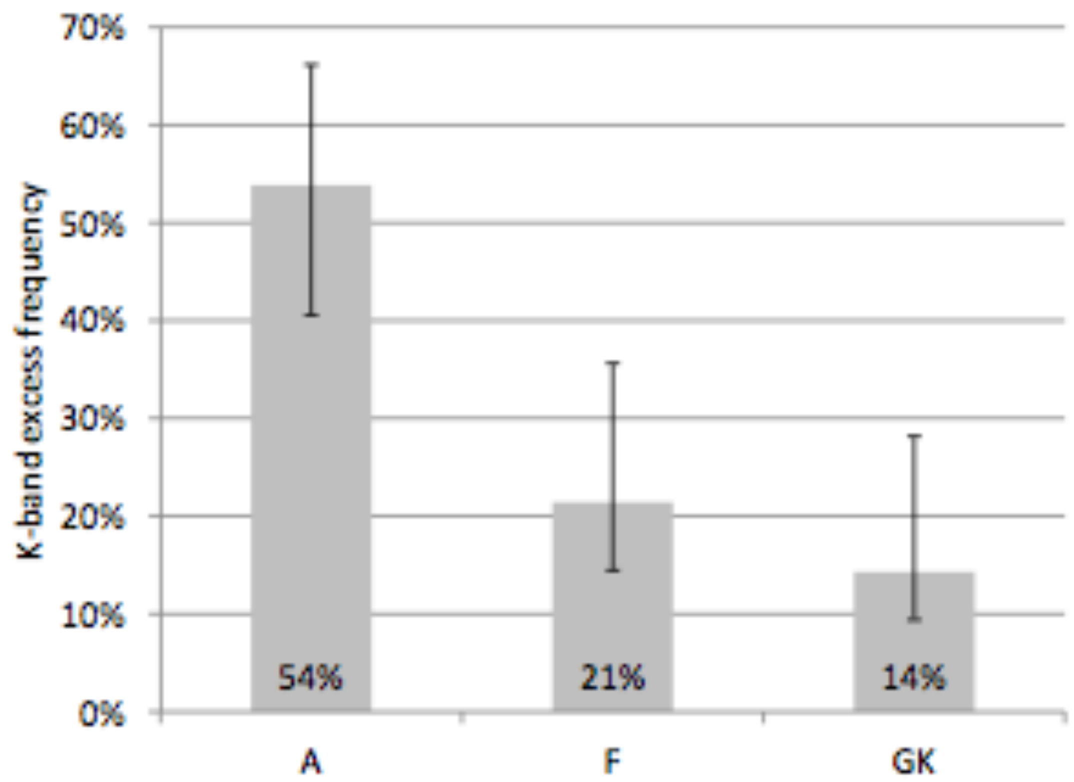
Statistical analysis

1. Excess frequency vs spectral type



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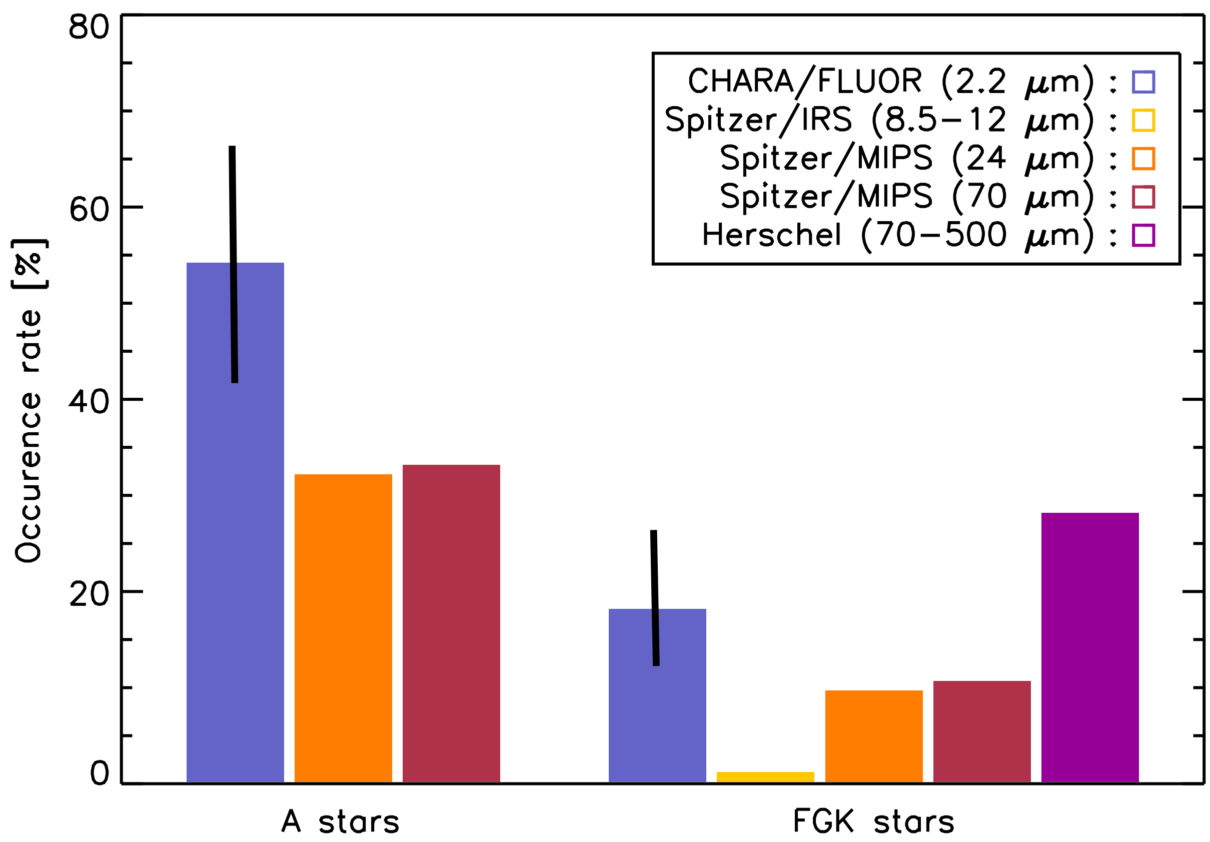
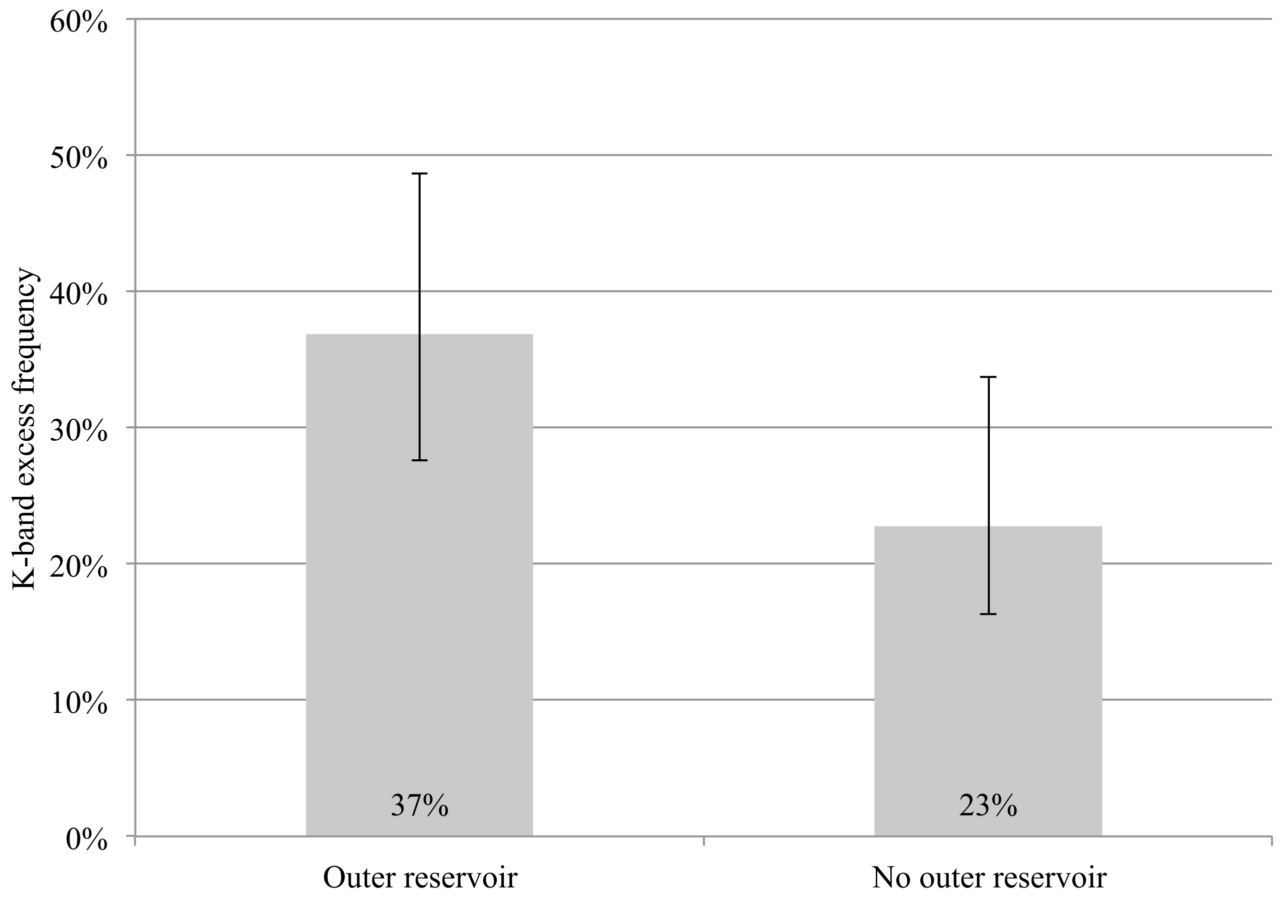


Statistical analysis

2. Excess frequency vs cold dust presence



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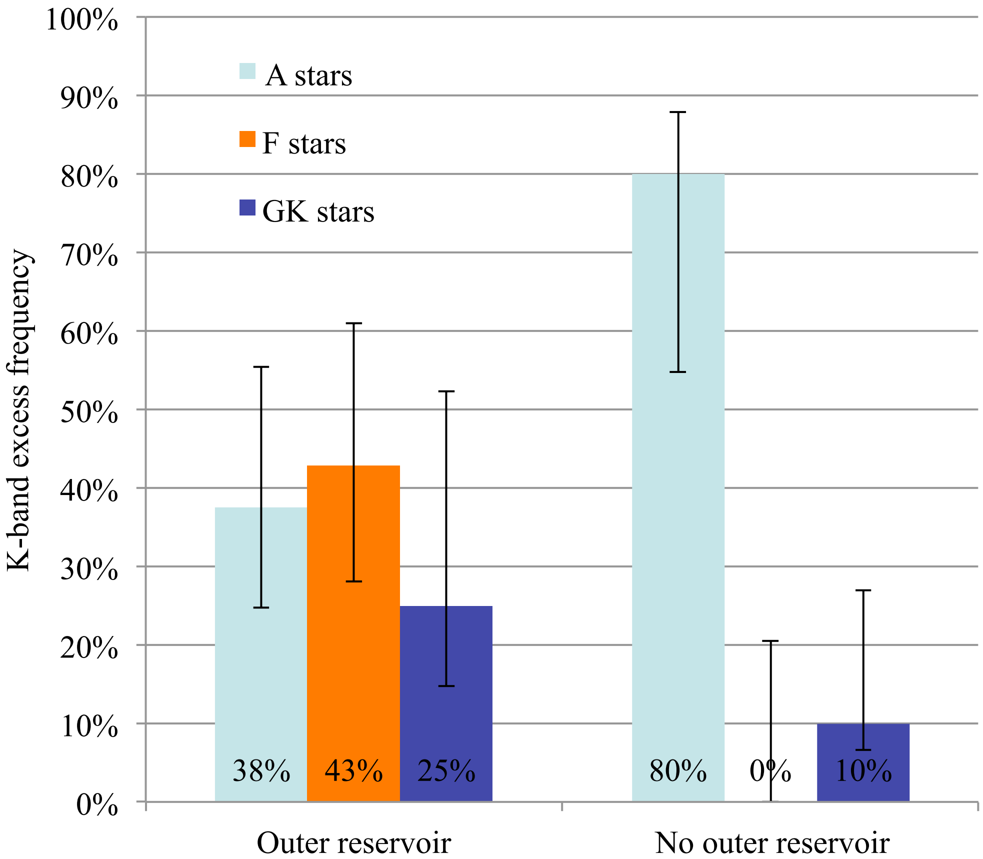
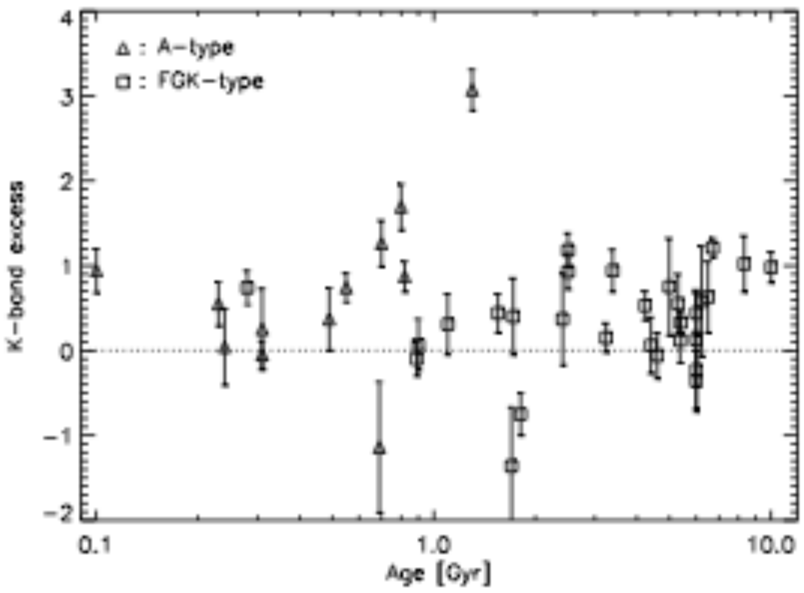
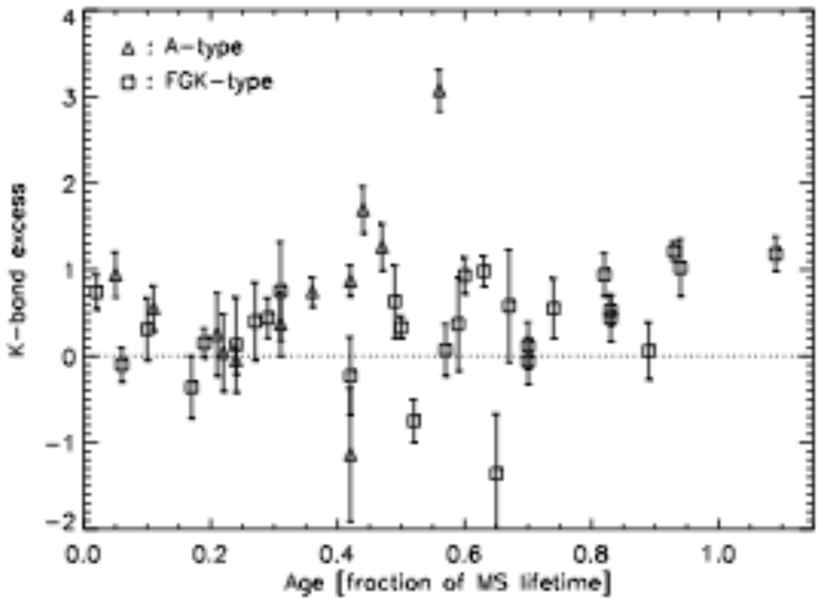


- Spectral type matters for stars with no outer reservoir
- Different mechanism?
- Only 5 A stars without outer reservoir

Statistical analysis

3. Excess frequency vs age and fractional age

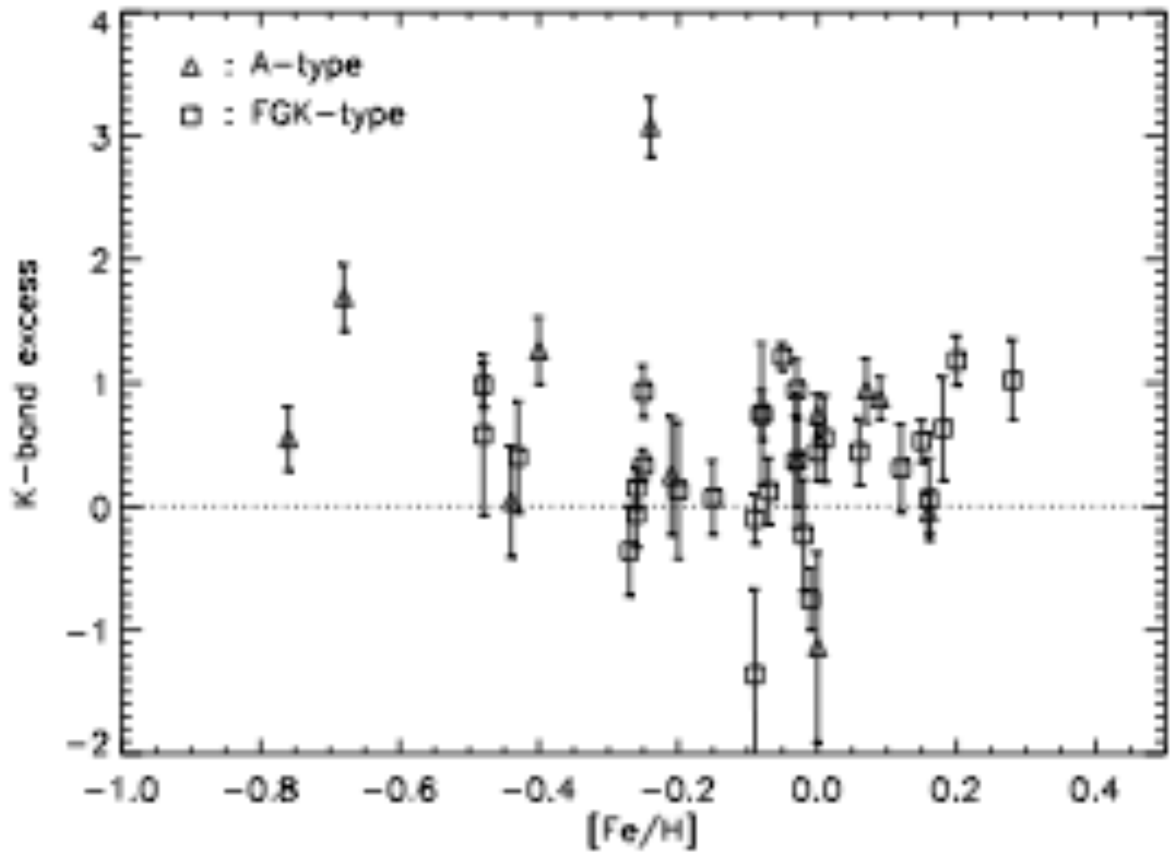




- No significant trend

Statistical analysis

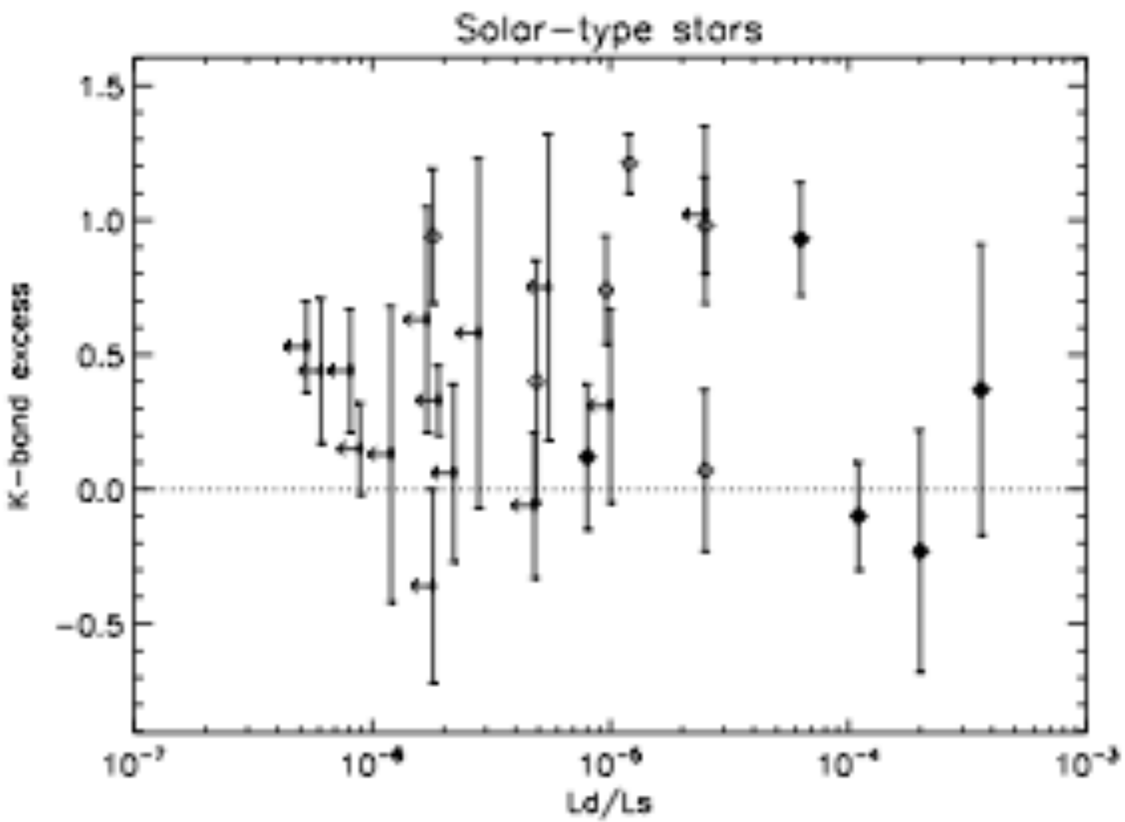
3. Excess frequency vs stellar metallicity



- No significant trend

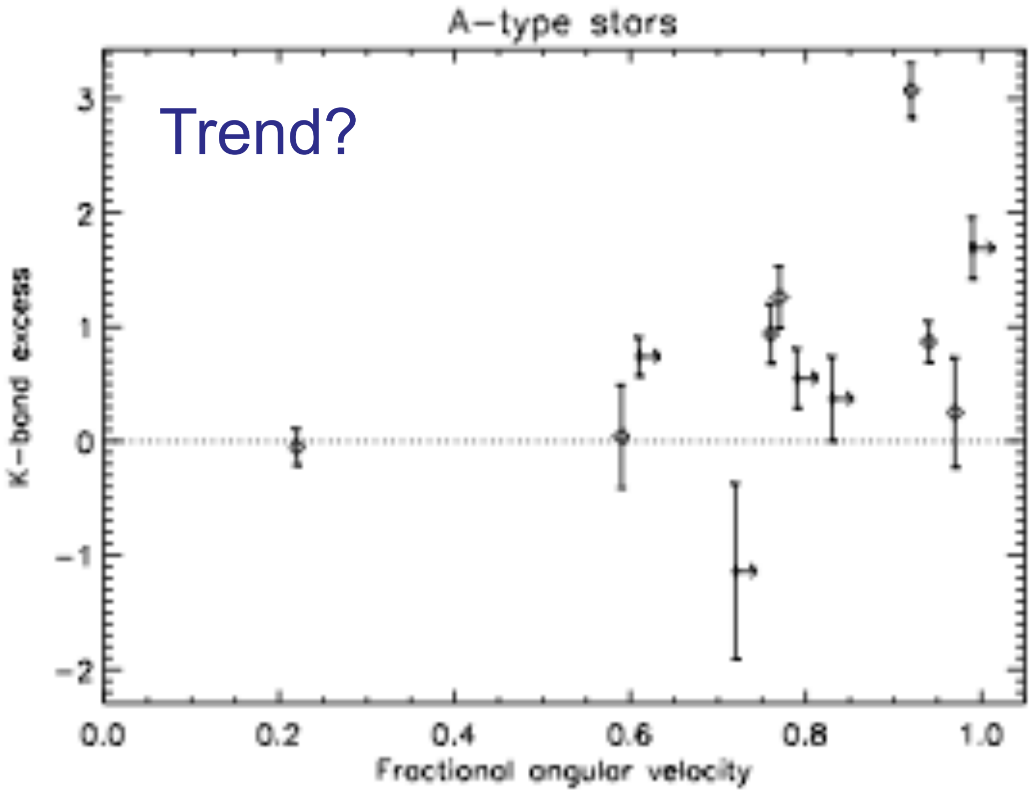
Statistical analysis

4. Excess frequency vs fractional luminosity



Statistical analysis

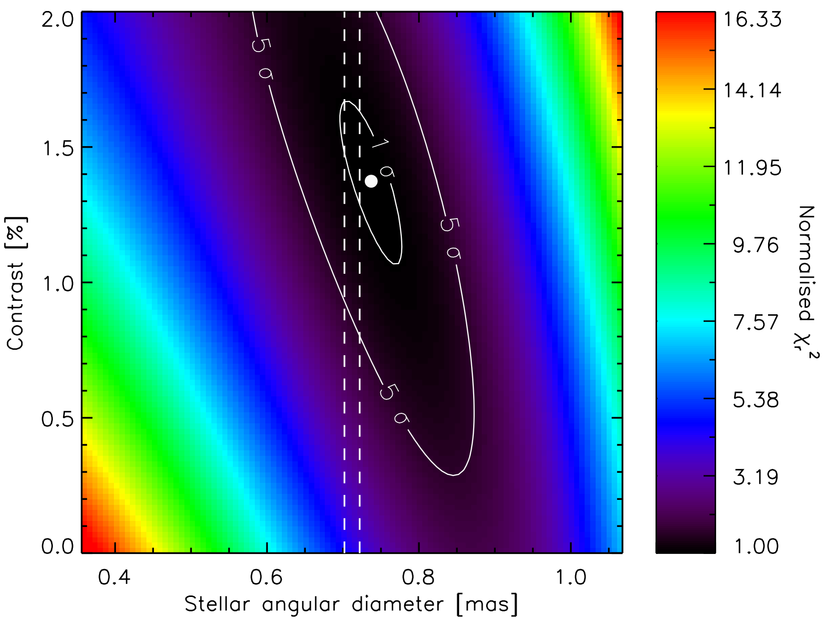
4. Excess frequency vs fractional angular velocity

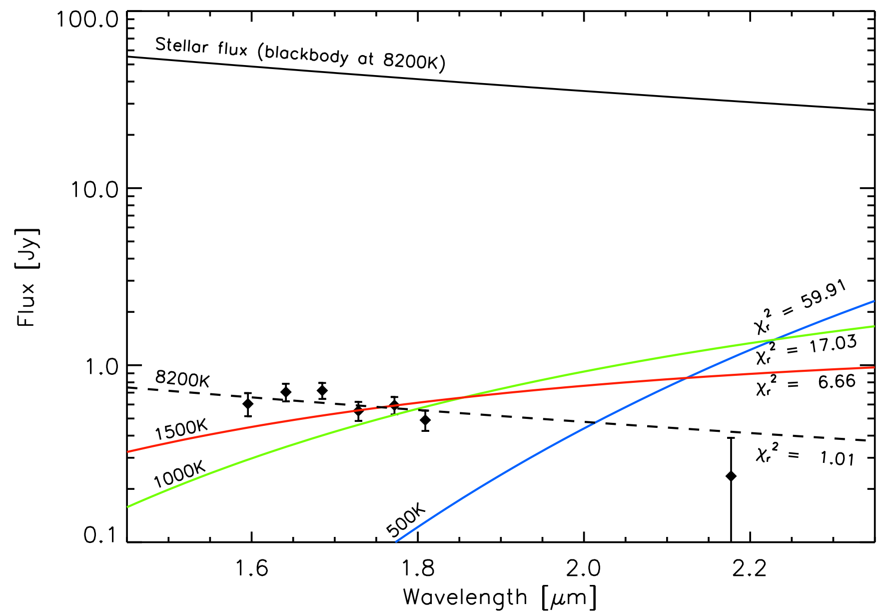


- Near-IR emission of winds from <1.5 R* (would not be resolved)
- Mass-loss of A stars expected to be very low.

The quest for hot dust continues

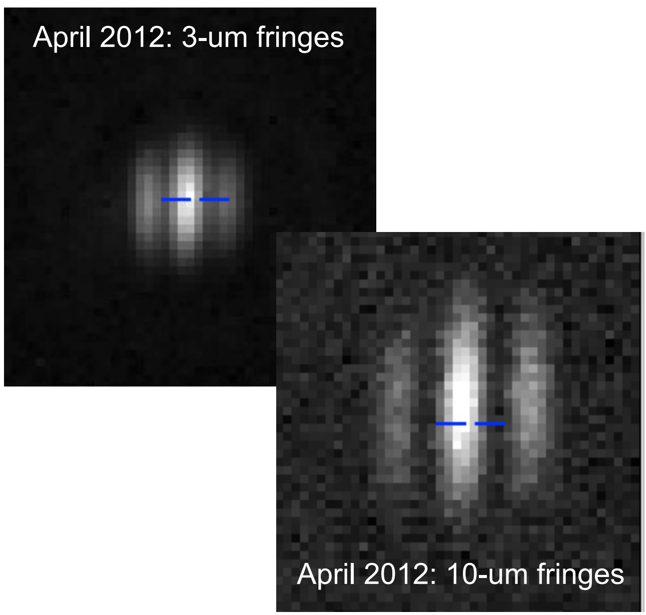
- FLUOR is now JOUFLU (see Scott's and Mennesson's talks)
- Ongoing survey in the Southern hemisphere with VLTI/PIONIER
  - Spectral information (H and K bands)
  - ~100 stars observed (Ertel et al., in prep)
  - First detection: β Pic (Defrère et al. 2012):

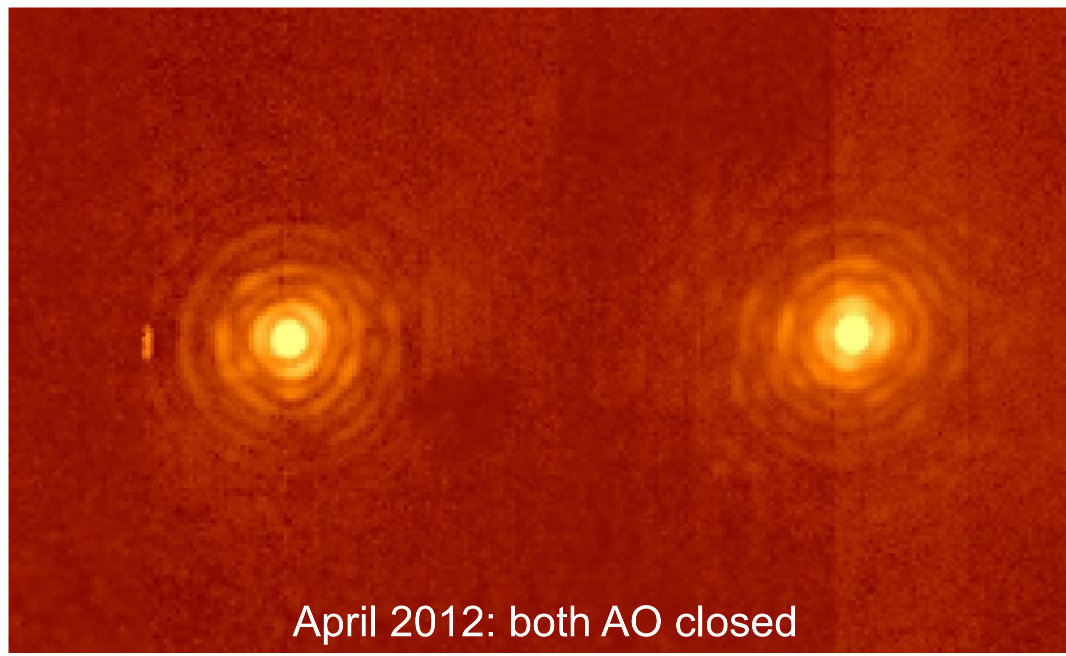




The quest for warm dust too

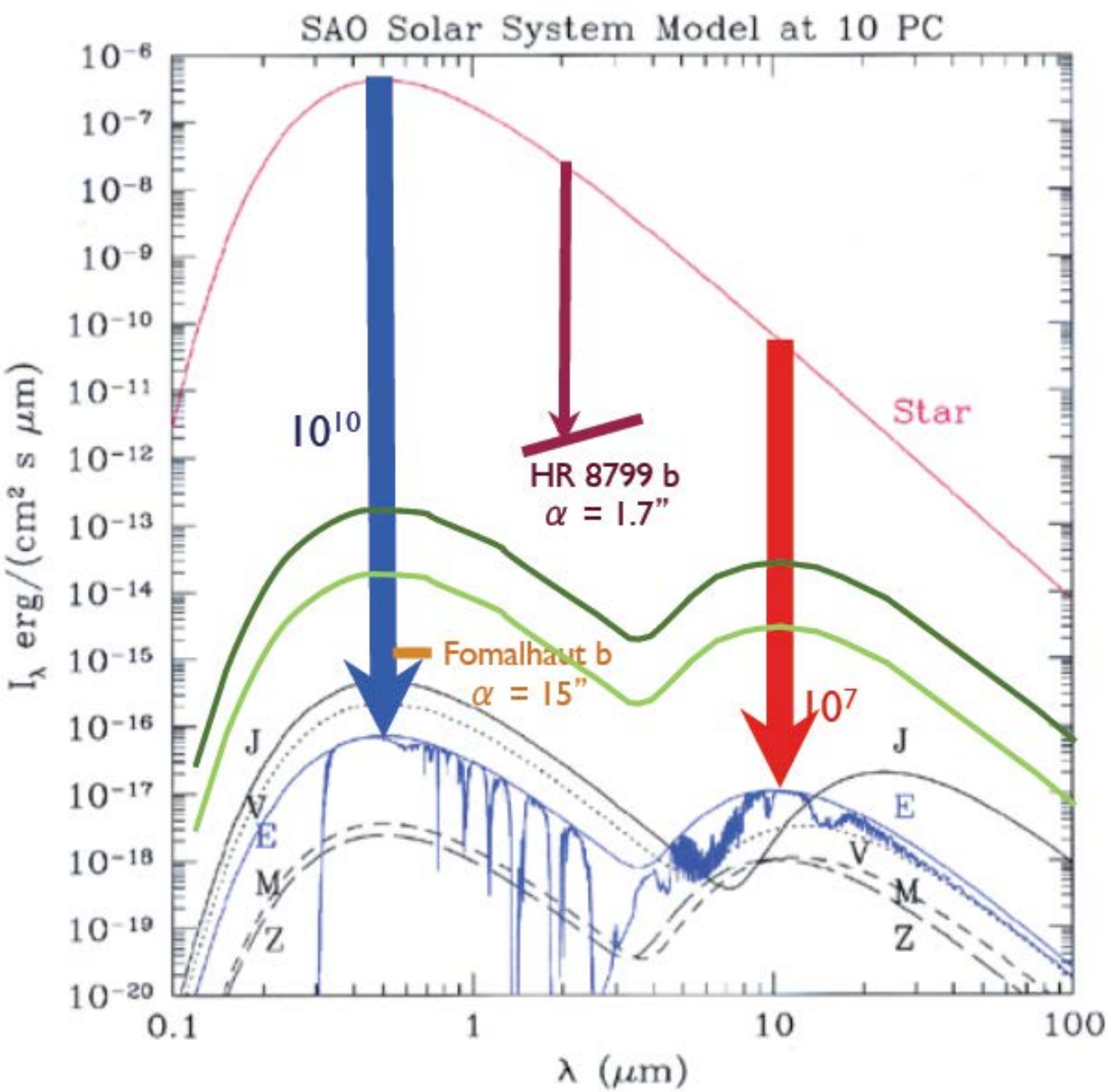
- LBTI is underway:
  - ✓ Will reach the level required to prepare future exoEarth imaging instruments (10 zodis at 10 microns)
  - ✓ First null data obtained in September 2012 (in open-loop)
  - ✓ See next talk!





THANK YOU

The problem for direct imaging



- Visible: 10^{-10} fainter
- IR: 10^{-7} fainter

Current state of the art

- Fomalhaut b: 10^{-9}, but 150x separation
- HR 8799b: 10^{-4} but 17x sep.

Our Zodiacal dust cloud:

- 1 zodi = ~300x Earth at 550 nm and 10 μm.