Vega: the star with comets?

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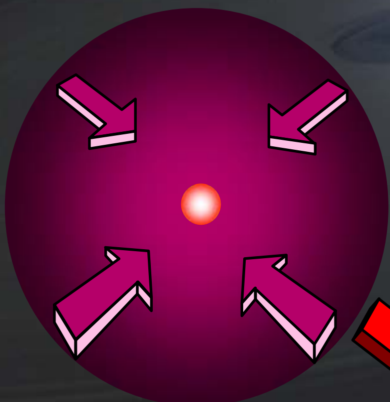
Stellar & planetary formation

Class 0. Cloud of gas and dust collapses



10,000 yr

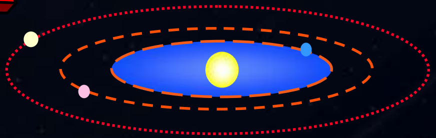
Class I. Optically thick accretion disk of gas and dust around new-born star

100,000 yr

Class II. Planets, comets and asteroids form. Gas is being blown.

1-10 Myr

Class III. MS star, planetary system



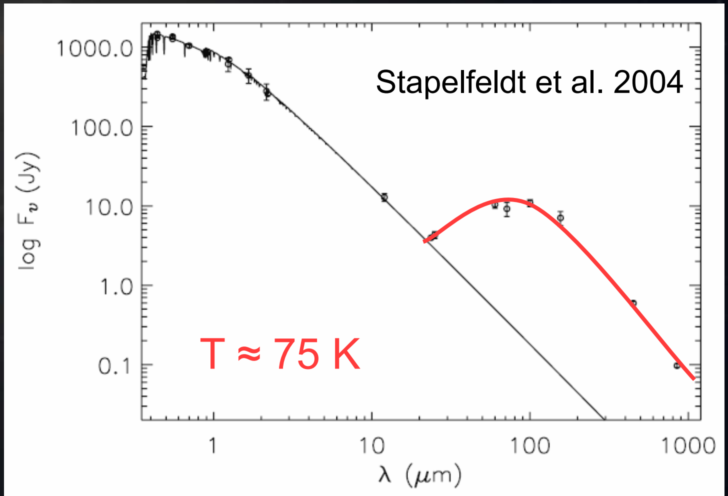
> 100 Myr

The solar zodiacal disk

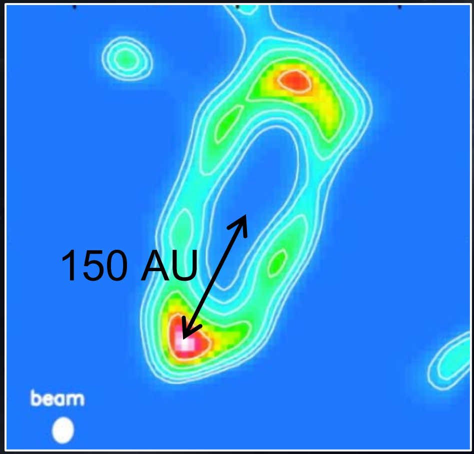
- Optically thin disk of second-generation silicate dust
  - Limited lifetime of a few Myr
  - Continuously replenished (comets, asteroids)
- Warm (~300 K) → luminous (~300 × Earth in mid-IR)
- Might be a severe limitation to Earth-like planet imaging

Are there exozodiacal disks?

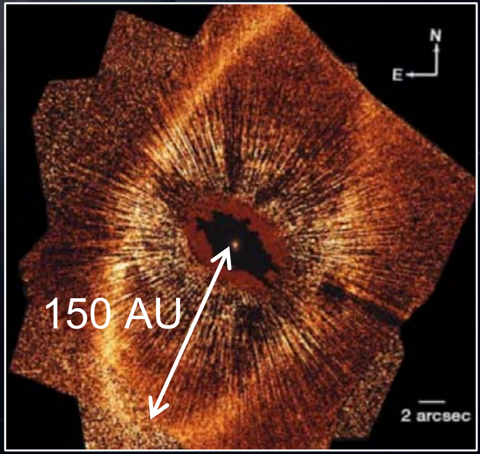
- Until now: only “debris disks”
  - Cold and distant (~100 AU)
  - Massive (~10^{-2} $M_{\oplus}$)
  - Similar to Kuiper belt
- Prototype debris disk stars:
  - Vega, β Pic, Fomalhaut, …
- Detected by
  - Far-IR excess flux
  - Sub-millimetre imaging
  - Visible imaging



Marsh et al. 2005 (350 μm)



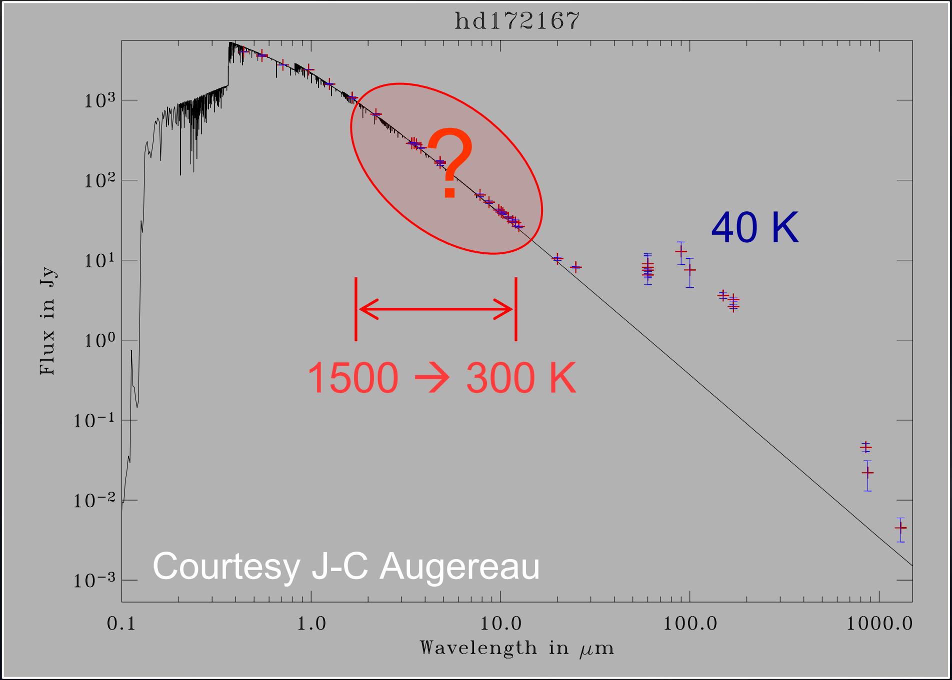
Kalas et al. 2005 (0.8 μm)

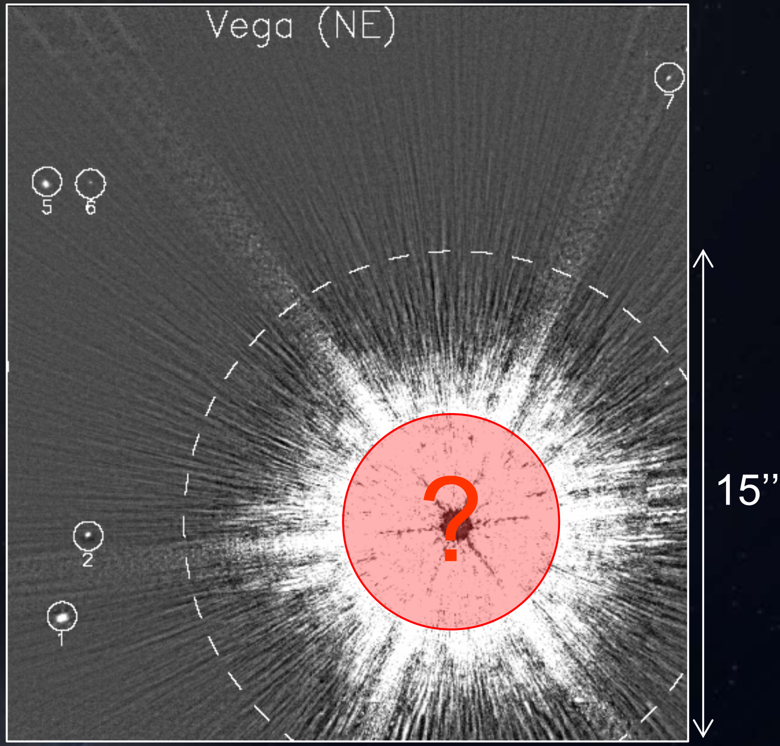


(150 AU ≈ 20’’ at 7.7 pc)

The elusiveness of warm dust

- Two major difficulties
  - High contrast (>1:100)
  - Small angular separation
    - Inner disk: a few 10 mas
    - Need IR interferometry



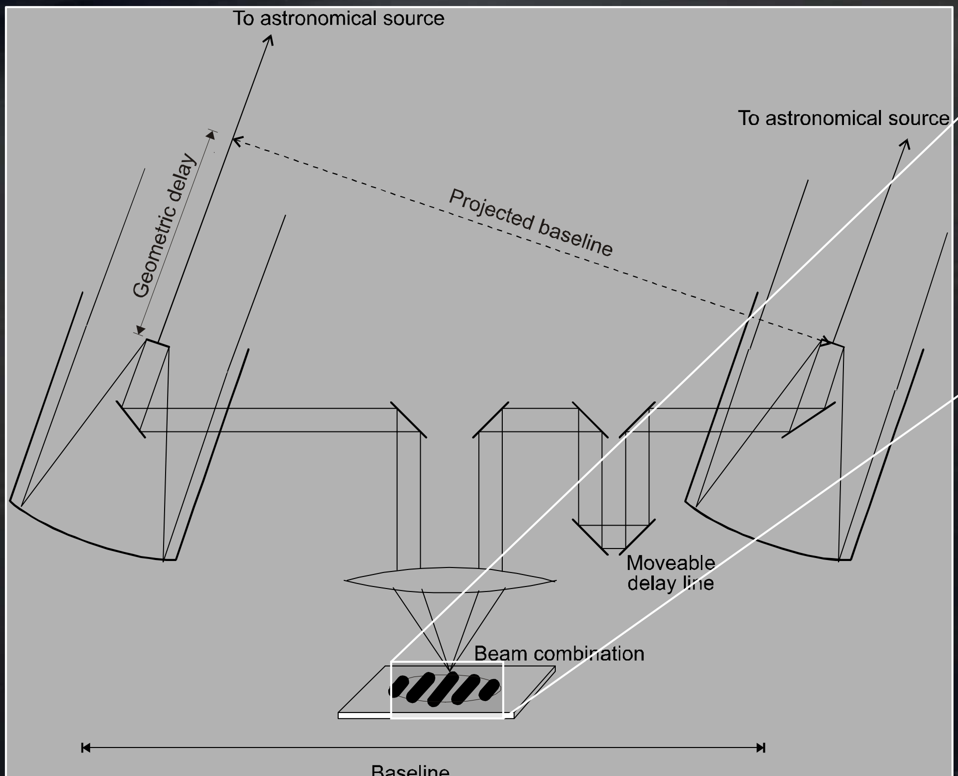


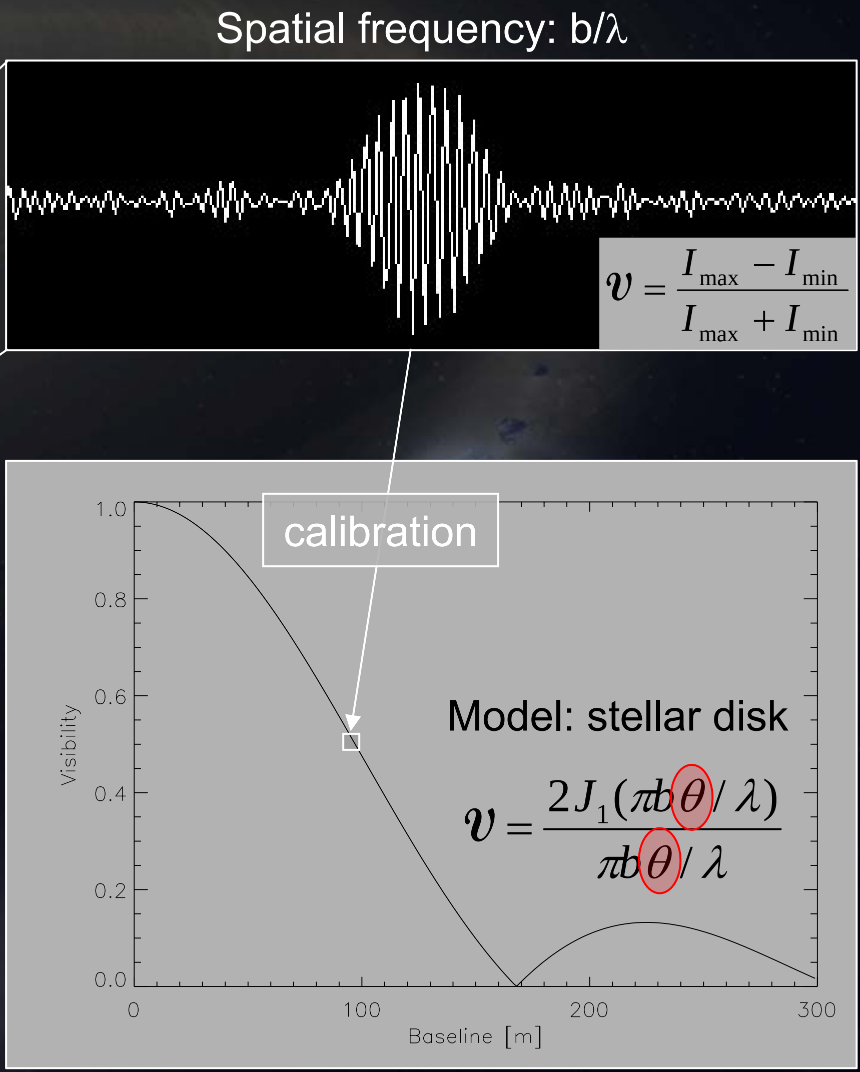
Macintosh et al. 2003 (Keck AO)

Our goals

- Astrophysical objectives
  - Are there significant amounts of warm dust in the inner disk of Vega-type stars?
  - Implications on the formation and evolution of planetary systems?
- Technical objective
  - Demonstrate high dynamic range capabilities of infrared interferometry

Stellar interferometry

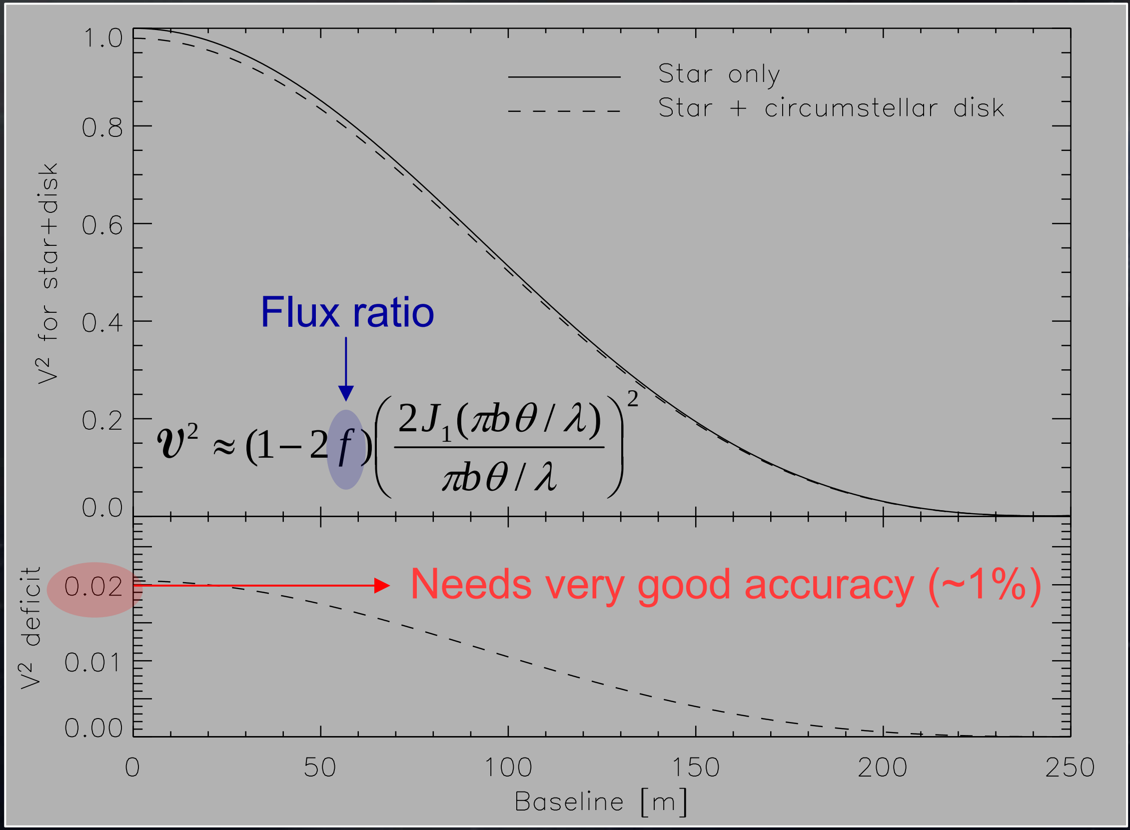




- van Cittert-Zernike theorem: each baseline gives one component of the Fourier transform of the source

Debris disks by interferometry

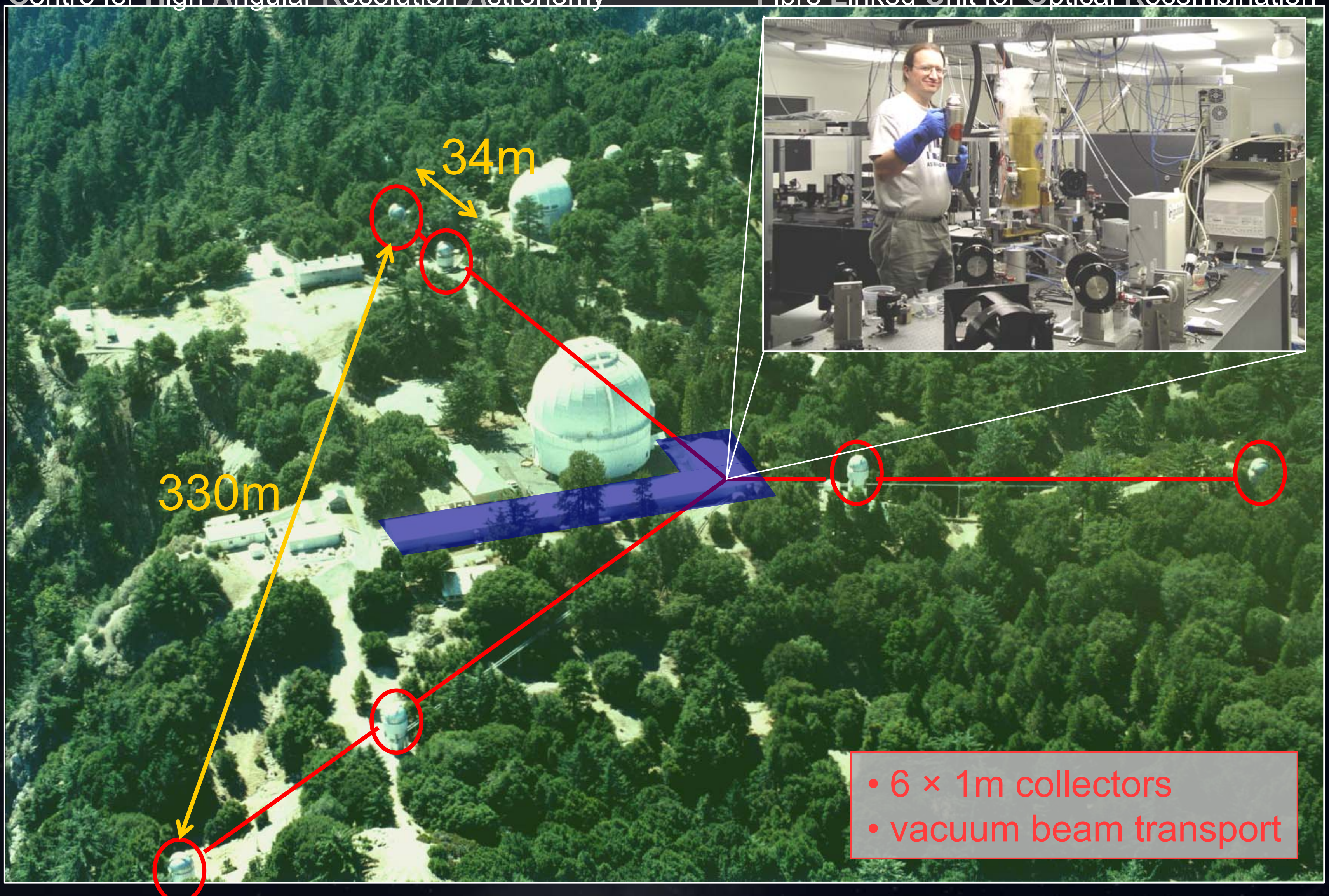
- Larger than angular resolution (λ/b) → contributes as an incoherent flux
- Induces a visibility deficit at all baselines
- Best detected at short baselines



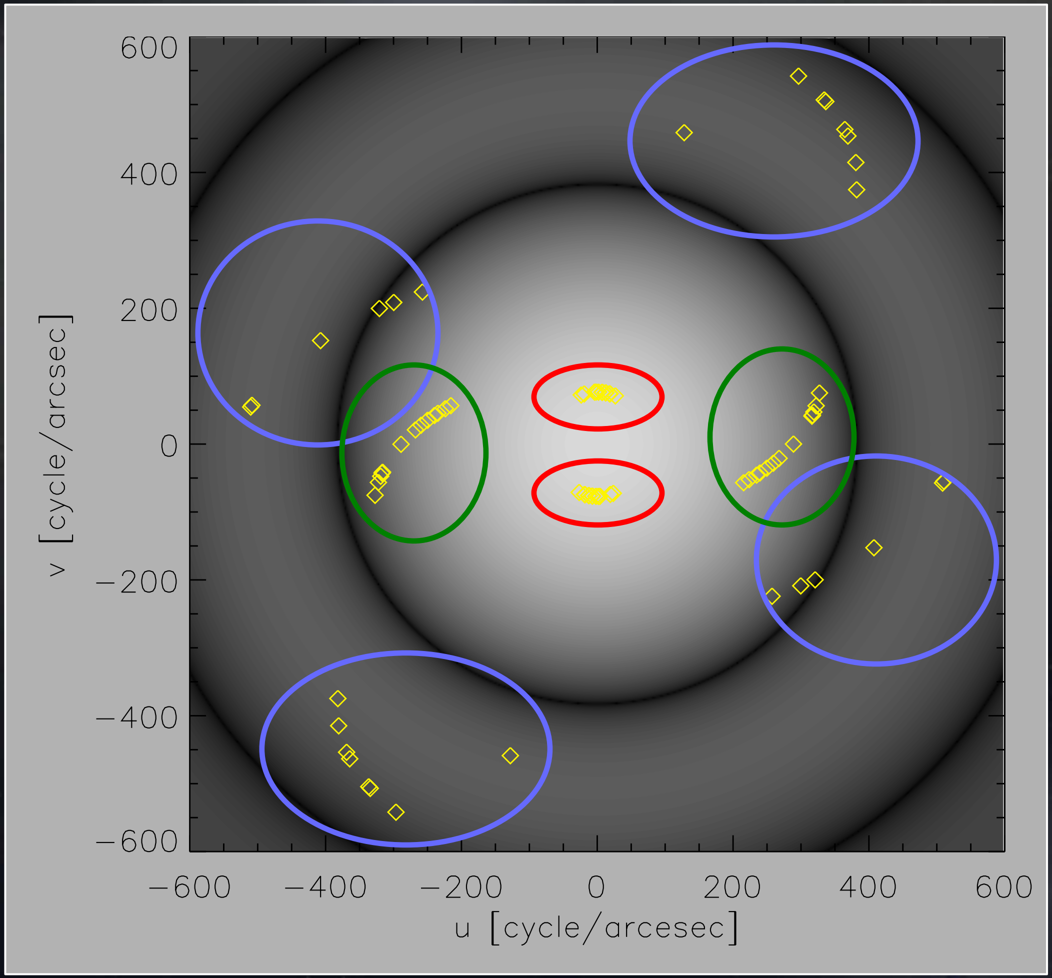
CHARA - FLUOR

Centre for High Angular Resolution Astronomy

Fibre Linked Unit for Optical Recombination

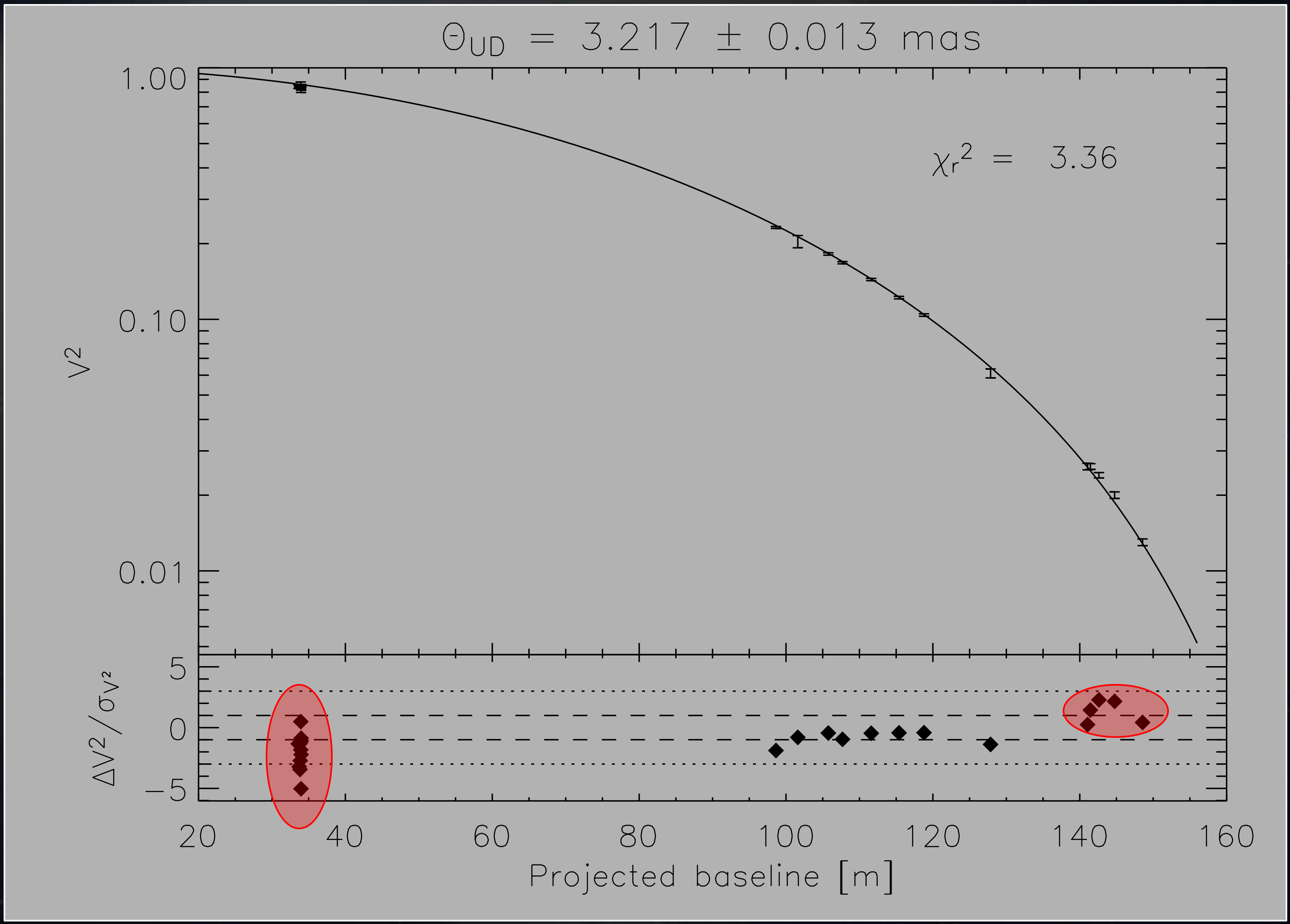


The Fourier Vega



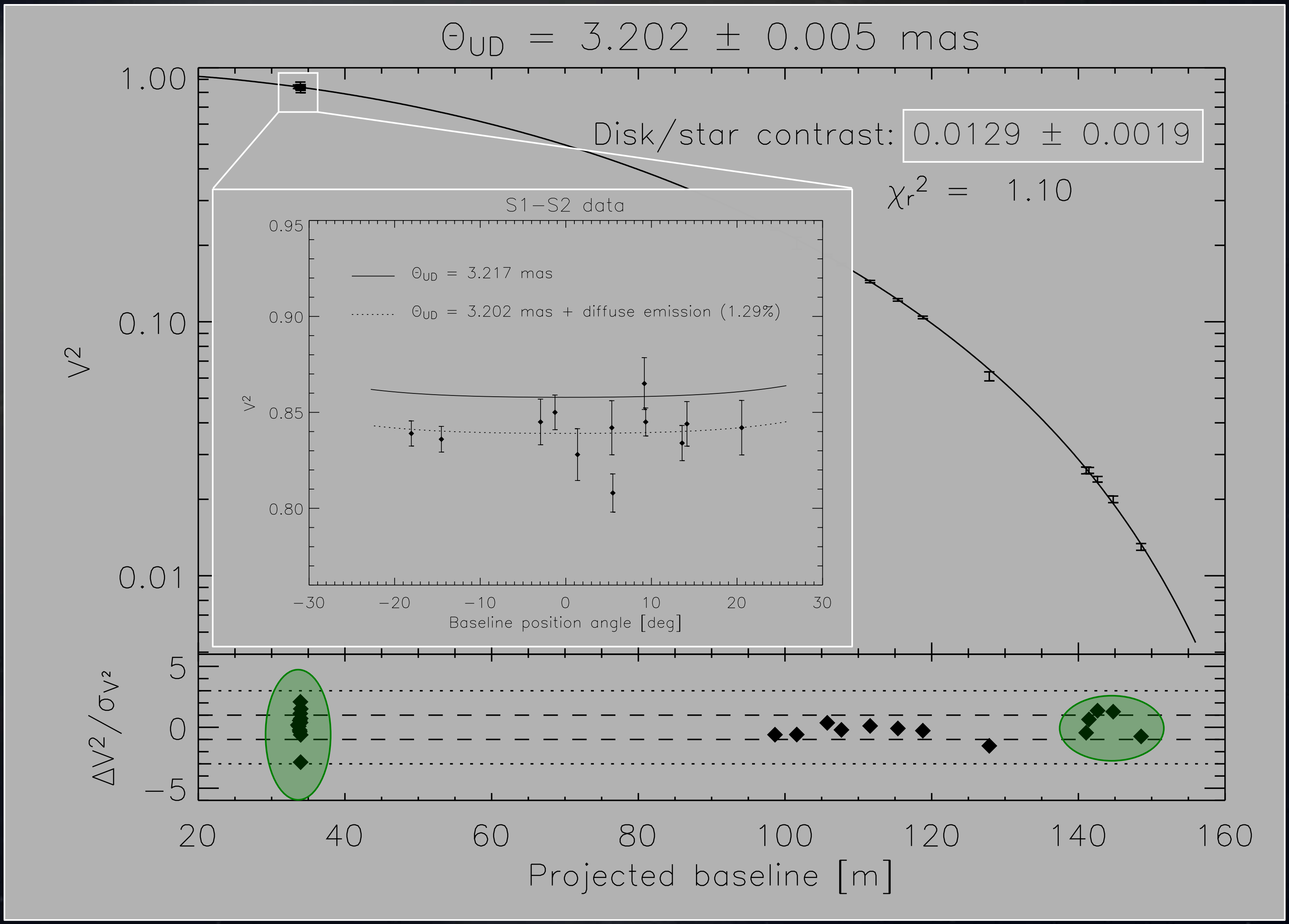
- Pole-on → no azimuthal dependence
- Stellar diameter (150 m)
- Limb darkening (280 m)
- Circumstellar dust (30 m)

Fitting a uniform stellar disk



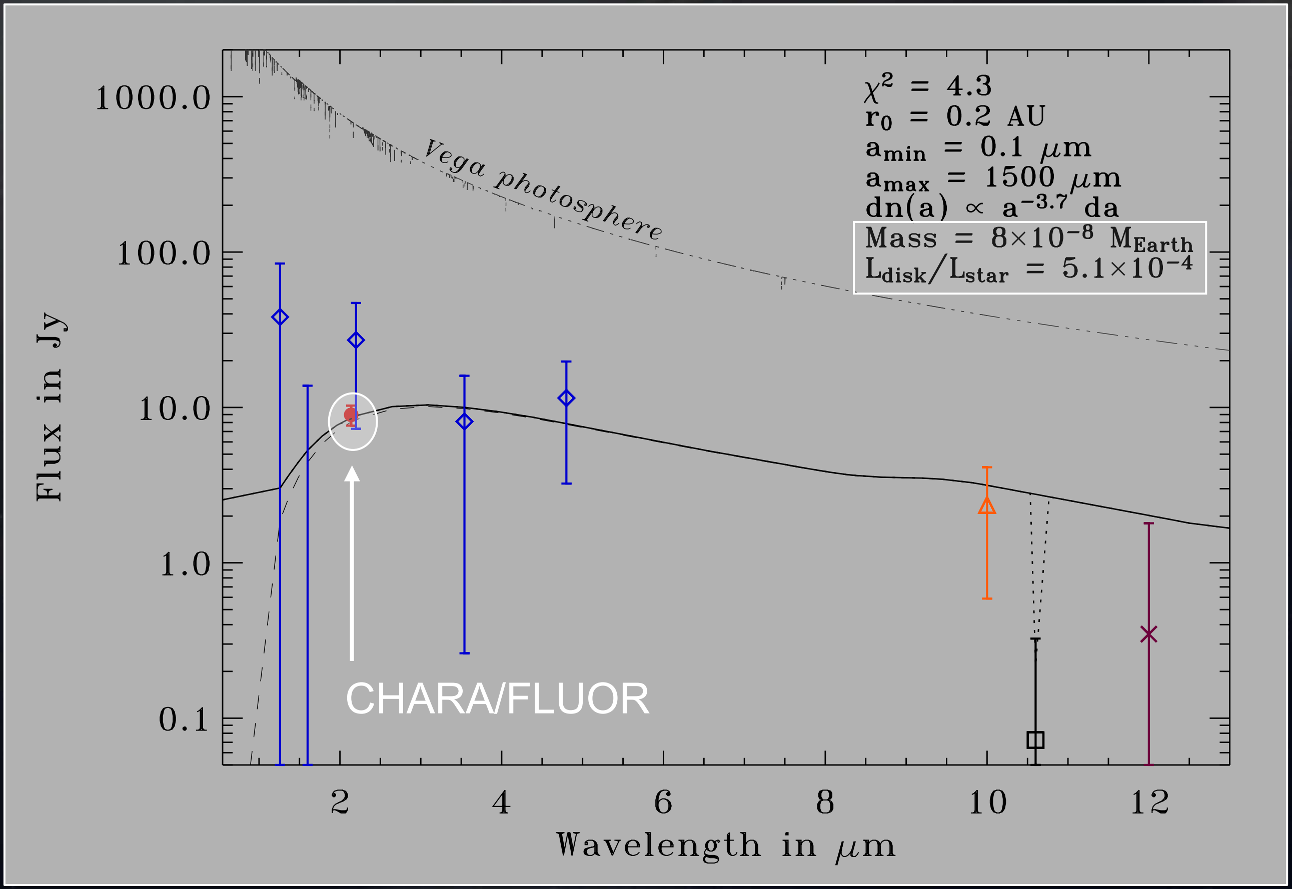
Fitting star + debris disk

Absil et al. 2006, A&A, in press



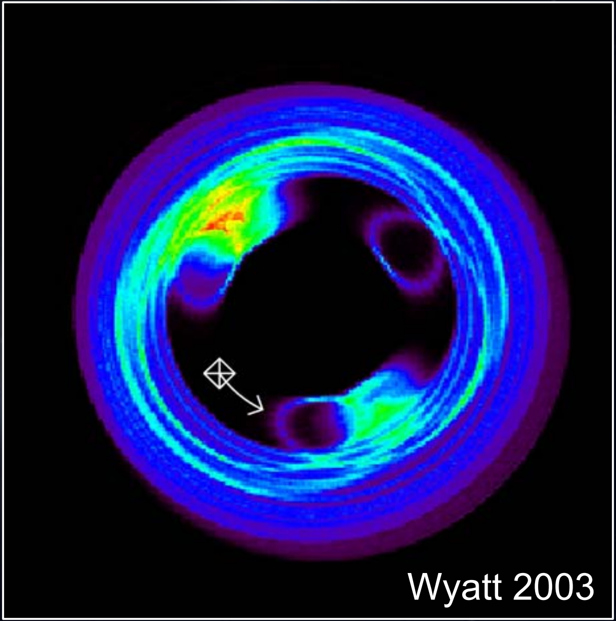
Nature of the dust grains

- Spectral Energy Distribution → physical properties
  - Small grains (mostly < 1 µm) at distances ~ 0.1 – 0.5 AU
  - Highly refractive grains (mostly carbons, up to 1700 K)

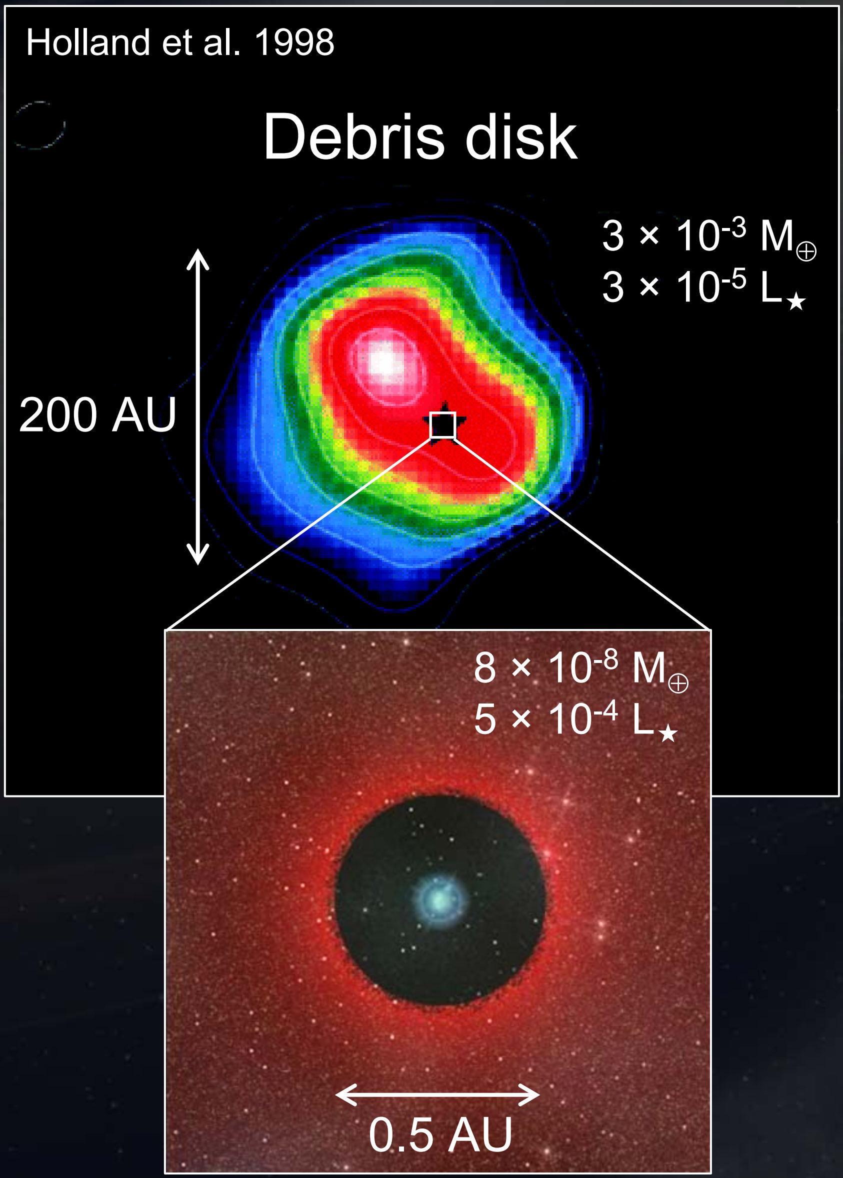


Origin of the dust

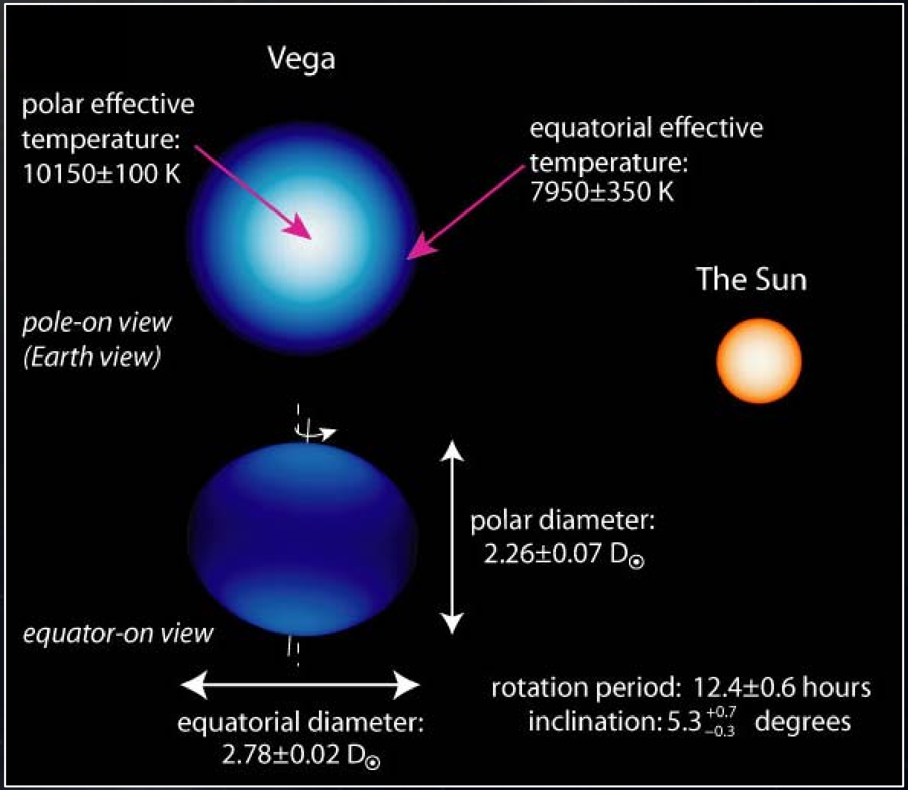
- Continuous replenishment
  - Radiation pressure → grains blown out in ~10 yr
  - High flux needed (~10^{-8} $M_\oplus$/yr)
- Cometary origin is favoured
  - Size and composition of the grains
- Late Heavy Bombardment scenario?
  - Age is compatible (~350 Myr)
  - Migrating Neptune suggested by Wyatt (2003)
  - About 10 Hale-Bopp per day!



Our new view of Vega



Photosphere



Aufdenberg et al, ApJ, in press

Summary and perspectives

- Investigated inner disk of Vega
  - Precise K-band flux ratio: 1.29 ± 0.19%
  - Properties and origin of dust grains
- Proven dynamic range capability
  - Contrast up to 1:100 demonstrated
- Perspectives
  - Survey the brightest Vega-type stars (K<5)
    - CHARA/FLUOR and VLTI/AMBER
  - Improve dynamical models