Characterization and origin of exo-zodi

Part I: The near-infrared (Must see: Part II by Grant Kennedy)

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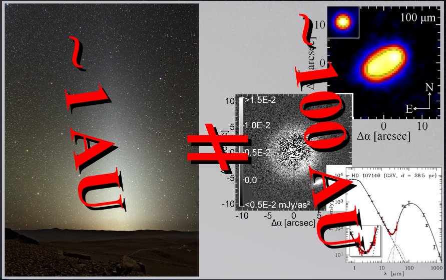
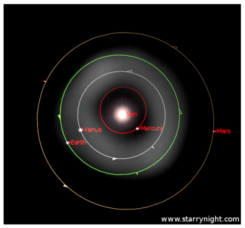
Exozodiacal dust

What is exozodiacal dust?

- Dust around main sequence stars, sublimation to few AU
- Analog to our zodiacal dust
- **NOT** a typical debris disk
  (But might be related, Bonsor et al. 2012a, b, 2013, 2014)

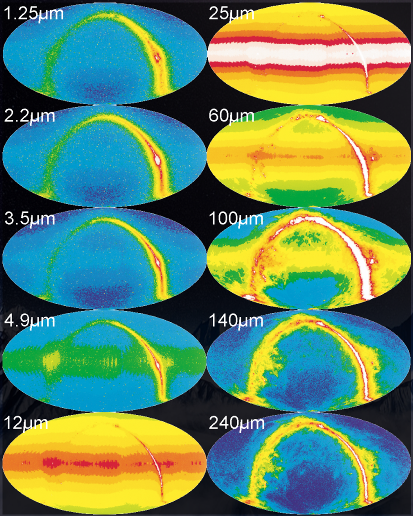


Why do we care?



- Dust in/near the habitable zone
- Implications for evolution & dynamics of inner planetary systems
- Impact on direct exo-Earth detection
  (Grant’s talk)

The Solar system zodiacal dust

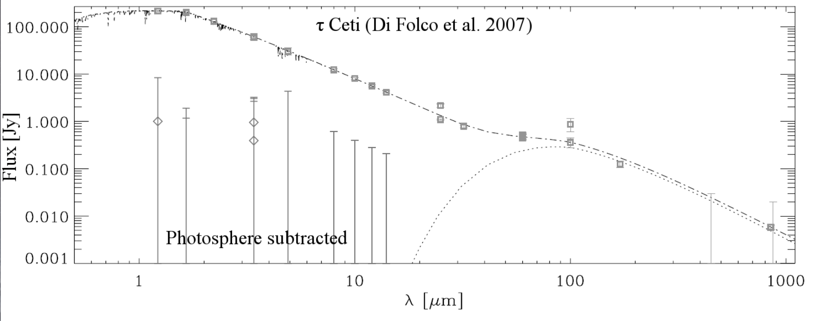


COBE/DIRBE (Kelsall et al. 1998)

- Dust inside a few AU
- Power law surface density ($\alpha \sim -0.5$)
  (Kelsall et al. 1998, Hahn et al. 2002)
- Continuous transition to F-corona at few $R_{\odot}$, T: few 100K to ~2000K
  (Kimura & Mann 1998, Hahn et al. 2002)
- Comet evaporation, asteroid collision, P-R drag
- Complex local structure (planetary interaction, local dust creation)

Exozodiacal dust

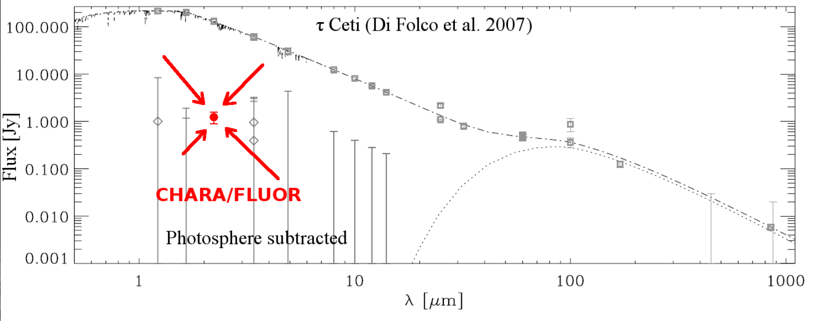
How to detect exozodiacal dust? (in the near-infrared)



- Our zodiacal dust is the most luminous component of our Solar System
- However, it would be too faint to be detected, e.g., by *Spitzer* (more than 100 times) or *WISE*

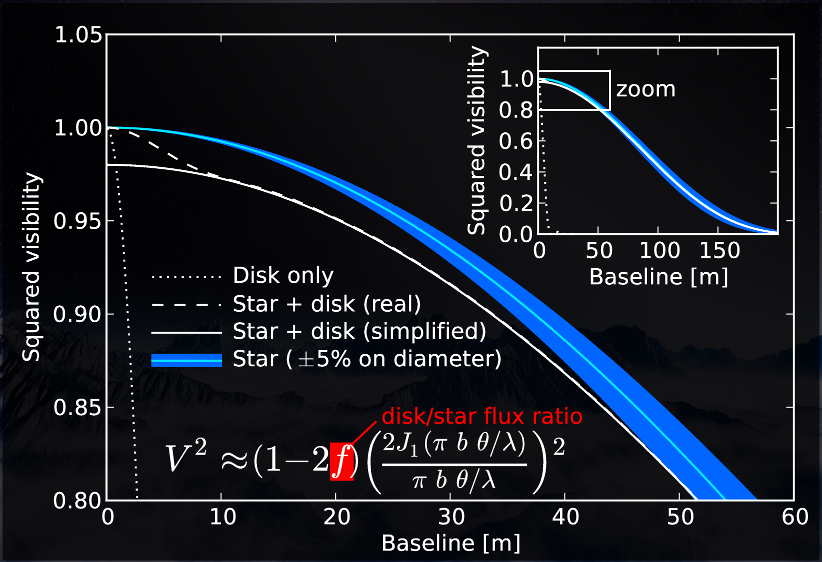
Exozodiacal dust

How to detect exozodiacal dust? (in the near-infrared)



- Emission alone would be detectable (10 mJy to 1 Jy), problem is photometric calibration or angular resolution
- Solution: infrared interferometry in order to disentangle stellar emission and dust emission

Detection strategy



$$V^2 \approx (1-2f)\left(\frac{2J_1(\pi\ b\ \theta/\lambda)}{\pi\ b\ \theta/\lambda}\right)^2$$

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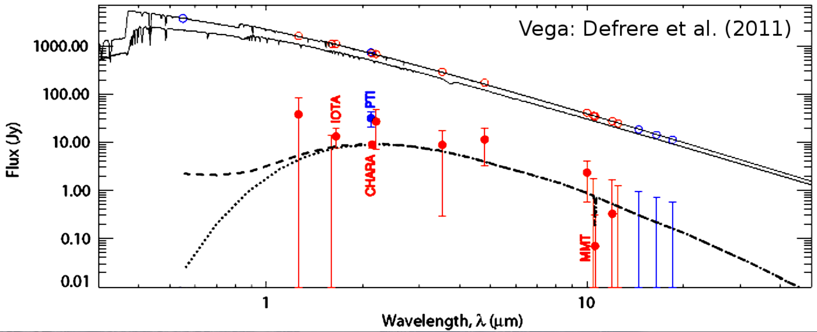
Exozodiacal dust

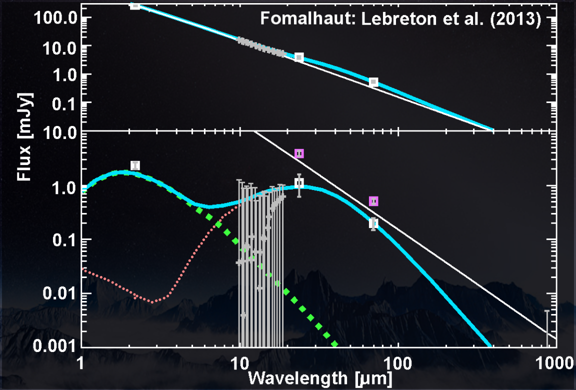
So, what do we learn from first detections?



- Very small grains (< blow-out size), hot, close to sublimation temperature/distance
- Dust mass $\sim 10^{-10}\,M_{earth}$, removal time scale ~ 1 year

Exozodiacal dust

So, what do we learn from first detections?



- Two belts to explain near-IR and mid-IR excess
- Outer belt can be in collisional equilibrium and replenish dust in inner belt

The EXOZODI *Survey(s)*

Several possible origins, but all have problems:

(Bonsor et al., 2012a, 2012b, 2013)

- Local collisions of large bodies
  - High amount vs. short lifetime of the dust

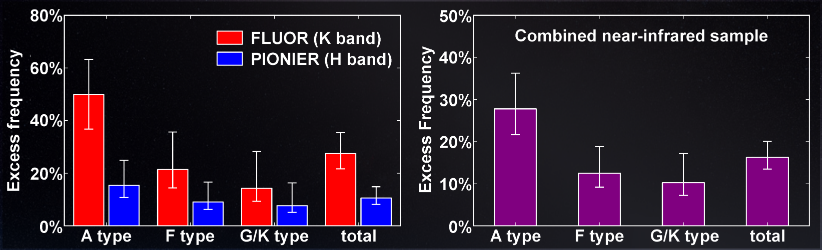
  ⇒ **Statistics** of frequency/dust mass vs. age
- Recent planetary collision
  - Low probability vs. high detection rate?

  ⇒ **Statistics** of frequency among stars in general
- Evaporation of comets
  - Large number of comets required (LHB?)

  ⇒ **Statistics**: exozodis and exo-Kuiper belts correlated?
- **Best shot so far:** Planetesimal driven planetary migration (Bonsor et al. 2014) and some dust trapping mechanism (Su et al. 2013, Lebreton et al. 2013)

The EXOZODI *Survey(s)*

Statistics based on ~130 stars observed:

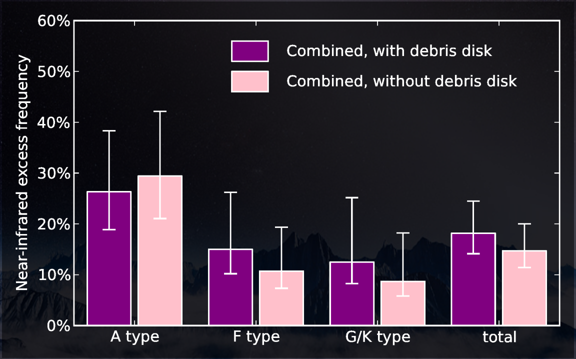


CHARA/FLUOR: Absil et al. 2013, VLTI/PIONIER: Ertel et al. 2014

- Detection rate with FLUOR (*K* band) by factor of ~2.5 higher than with PIONIER (*H* band)
- Correcting for this factor all statistics consistent between the two samples
- Detection rate decreasing with later spectral type
  ⇒ ***Like a normal debris disk?***

The EXOZODI *Survey(s)*

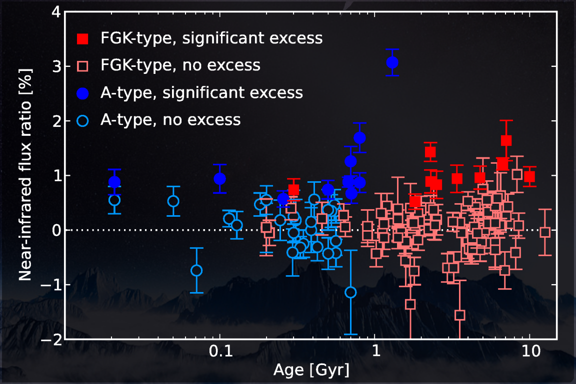
Statistics based on ~130 stars observed:



- No correlation with presence of cold dust
  ⇒ ***Not the same phenomenon!***

The EXOZODI *Survey(s)*

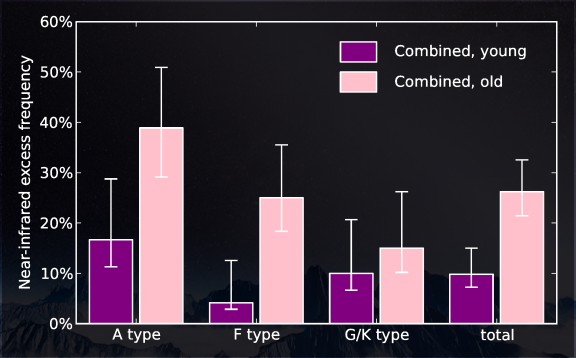
Statistics based on ~130 stars observed:



- No clear correlation with age
- If any, slight increase of excess with age?
  ⇒ ***No (simple) collisional equilibrium!***

The EXOZODI *Survey(s)*

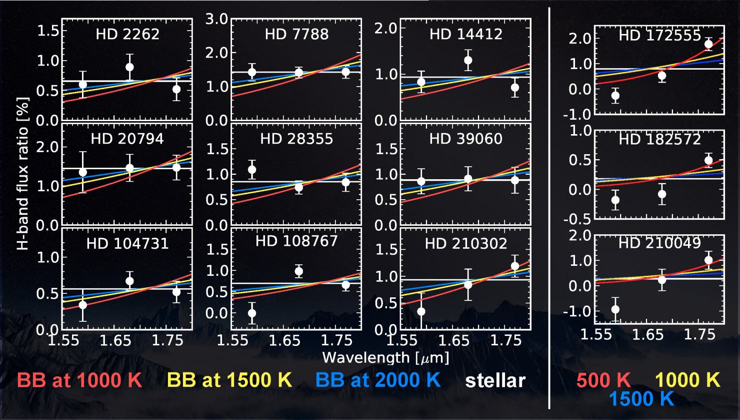
Statistics based on ~130 stars observed:



- Separate each spectral type bin in stars younger and ones older than median age in bin
- Tentative ***increase*** of detection rate with age
  ⇒ ***Some trapping mechanism?***

The EXOZODI *Survey(s)*

H band colors from PIONIER:

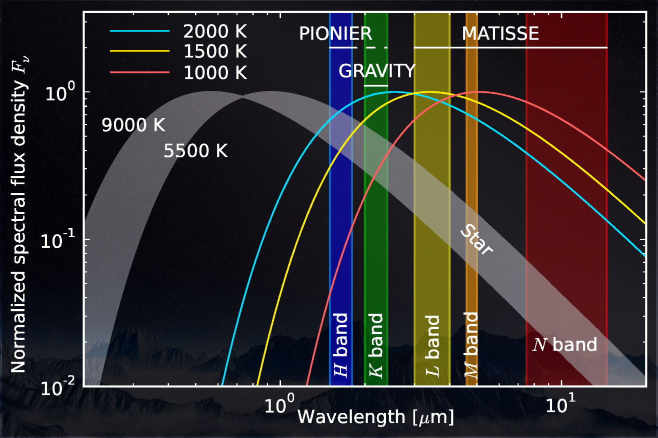


- Scattered light / extremely hot for some targets, others thermal emission – DIVERSITY
- *K* band vs. *H* band detection rate: Dust warm, *H* dominated by scattered light?

Conclusions from the EXOZODI project

- ~1/5 of all main sequence stars harbor near-IR bright exozodiacal dust
- Increase of detection rate from H ($\sim$11%) to K ($\sim$30%)
- If related to presence of outer debris disk very specific scenario required
- Very hard to explain, no clear, working scenario so far
- Potentially strong contribution of scattered light in near-IR

So far just *PIONIER*ing



- Full SEDs of all survey detections
- Connection between hot, habitable zone, and cold dust
- Long term variability surveys

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Thanks a lot!

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