The connection between inner and outer debris disks probed by infrared interferometry

Olivier Absil
University of Liège

From Atoms to Pebbles – Herschel’s view of Star and Planet Formation
Grenoble, 22 March 2012
**Inner vs. Outer Debris Disk**

- **T ~ 40 K**
  - Small near/mid-IR excess
  - Difficult to resolve (< 0.1")

- **T > 300 K**
  - Prominent far-IR excess
  - Easy to resolve (>1")

Lisse et al. 2012

![Graph showing flux vs. wavelength for inner and outer disk regions.](image)
INFRARED INTERFEROMETRY MAY HELP

- Disk larger than angular resolution ($\lambda/B$) $\rightarrow$ incoherent flux
  - Induces a visibility drop at all baselines
- Best detected at short baselines ($\sim$10-30m)

\[ v^2 \approx (1 - 20 \left( \frac{2J_1(\pi b\theta/\lambda)}{\pi b\theta/\lambda} \right)^2 \]

requires very good accuracy ($<$1%)

Flux ratio

Resolved at 200m

$\sim$2 mas

$\sim$ 40 mas $\rightarrow$ resolved at 10m
HIGH PRECISION INTERFEROMETERS

FLUOR at CHARA

IONIC at IOTA

(VINCI) PIONIER at VLTI
Vega viewed by CHARA/FLUOR

Absil et al. 2006

Mean \( \theta \) : 3.328 \( \pm 0.003 \pm 0.013 \) mas

Disc/stor: 1.26 \( \pm 0.27 + \frac{GM}{r^2} \) \( 0.92 \)

\( \chi^2 = 1.18 \)
Radiative transfer modeling

- H- and K-band interferometry (CHARA/FLUOR, IOTA/IONIC)
- N-band nulling interferometry (MMT/BLINC)
- Archival near- to mid-IR spectro-photometry

Defrère et al. 2011
Most probable dust properties

- Bayesian $\chi^2$ analysis of large parameter space
  - Grains < blowout size
  - Hot grains (> 1000 K)
  - Presence of carbons ≥ 10%
  - Distance: ~ 0.1 – 0.5 AU
  - Steep density power law: $\alpha < -3 \rightarrow$ ring?

- Mass: ~$2 \times 10^{-9} \ M_{\text{Earth}}$
- Luminosity: ~$5 \times 10^{-4} \ L_{\text{star}}$

(same approach as in Lebreton et al. 44)
Next step: low-resolution spectra

- Dispersed fringes with PIONIER (soon FLUOR)
  - Flux ratio measurements across H and/or K band
  - Direct constraint on dust temperature

Defrère et al. (in prep)
Origin of hot dust: steady state?

- Local production?
- Connection to outer disk?
  - Poynting-Robertson drag?
  - Multiple scattering of comets?
Steady state multiple scattering

- Requires 3+ planets and $10^3 M_E$ in cold reservoir

Bonsor et al. 50
ORIGIN OF HOT DUST: TRANSIENT?

- Isolated event?
  - Large collision (e.g. Earth-Moon)
  - Break-up of giant comet

- Dynamical perturbations?
  - Falling Evaporating Bodies
    - Asteroid belt disturbed by MMR with massive planet
  - Late Heavy Bombardment
    - Global rearrangement

- Statistical study may help
Debris disk survey at CHARA/FLUOR

- Magnitude-limited sample ($K < 4$)
  - 25 cold disk host stars ($\text{dec} > -15^\circ$)
  - “Unbiased” control sample: 25 stars w/o cold dust

- Observed most stars, ~42 of sufficient quality

- One surprise: companion to epsilon Cephei

Mawet et al. 2011

330 mas separation, 2% flux ratio
**PRELIMINARY STATISTICS VS. SPECTRAL TYPE**

- Many more K-band excesses than anticipated!
  - Still need confirmation that this is (only) dust
- A-type stars more prone to hot dust
  - Same trend as in cold disks, frequency compatible
  - Suggests that they could be related (scattering?)

| Spectral Type | Hot Dust (Absil et al., in prep) | Cold Dust (Herschel/PACS)
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<tr>
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<tbody>
<tr>
<td>A</td>
<td>38%</td>
<td>DEBRIS 30%</td>
</tr>
<tr>
<td>F</td>
<td>21%</td>
<td>DUNES 25%</td>
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<tr>
<td>GK</td>
<td>27%</td>
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<table>
<thead>
<tr>
<th>Spectral Type</th>
<th>Exozod detection frequency</th>
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<tbody>
<tr>
<td>A</td>
<td>37%</td>
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<tr>
<td>A</td>
<td>20%</td>
</tr>
<tr>
<td>F</td>
<td>25%</td>
</tr>
<tr>
<td>G</td>
<td>33%</td>
</tr>
<tr>
<td>FG</td>
<td>16%</td>
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<tr>
<td>K</td>
<td>19%</td>
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Preliminary statistics vs. cold dust

- No correlation with cold dust reservoirs
  - Suggests transient event rather than steady state

![Bar chart showing exozodi detection frequency for cold dust and no cold dust. The chart indicates 32% for cold dust and 25% for no cold dust.](chart.png)
**PERSPECTIVES**

- **EXOZODI project** (French ANR, 2011-2015)
- Extend survey to confirm statistics (goal: 200 stars)
  - North: refurbished FLUOR at CHARA
  - South: PIONIER at VLTI (Le Bouquin et al.)
- Investigate age dependence
- Follow up detections
  - Discriminate with potential binaries
  - Multi-color information for SED modeling
- Search for variability
- Improve models (RT, dynamics, collisions)

**EXOZODI team**
- Augereau (PI)
- Thébault (Co-PI)
- Absil
- Beust
- Bonsor
- Coudé du Foresto
- Defrère
- Ertel
- Kral
- Lebreton
- Le Bouquin
- Marbeuf
- ...

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