Gemini Observations of Terrestrial Planet Formation

Dr. Carl Melis

NSF AAPF Fellow/UC San Diego CASS Postdoctoral Fellow

In collaboration with Ben Zuckerman, Inseok Song, Joseph Rhee, Michael Bessell, and Simon Murphy
Typical rocky planet experiences \(\sim 6\) giant impact events during formation (Stewart & Leinhardt 2012).

Hartmann & Davis (1975)
Signatures of Rocky Planet Formation

BD+20 307: one million times dustier than the Sun’s zodiacal cloud.

Slide 3 (of 20)
Gemini Confirmation and Characterization

- Mid-infrared imaging and spectroscopy.
Where did it go?

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Disk Parameters

Pre-2009 Epoch
• $T_{\text{dust}} \approx 450 \text{ K}; R_{\text{dust}} \approx 0.4 \text{ AU}$
• $L_{\text{IR}}/L_* \approx 11\%$
• $M_{\text{dust}} > 5 \times 10^{21} \text{ g}$

Post-2009 Epoch
• $T_{\text{dust}} \sim 200 \text{ K}; R_{\text{dust}} \sim 2 \text{ AU}$
• $L_{\text{IR}}/L_* \approx 0.1\%$
• $M_{\text{dust}} > 10^{21} \text{ g}$
• $L_{\text{IR}}/L_* < 0.05\%$ for any remaining 450 K dust.

⇒ Grains with radius up to $\sim 1\text{ mm}$ must be removed from 0.4 AU ($L_{\text{IR}}/L_* \propto a^{-1/2}$).
Is the disk hidden from view?

Lack of stellar dimming when disk flux is diminished.
Disk Removal I. Collisional Avalanche?

Artymowicz (1997), Grigorieva et al. (2007)

Runaway process within sufficiently dense disk systems.
Disk Removal II. Runaway Accretion?

Rafikov (2011)
Metzger et al. (2012)

Runaway process when gas is present.

Where did the gas come from?

Spectroscopy limits accretion rate to $< 10^{-10}\, M_\odot\, \text{yr}^{-1}$.
HD 131488 and HD 121191
HD 131488 Infrared Excess

![Spectral energy distribution](image)

**Fig. 2.** — Spectral energy distribution for HD 131488. The data points blueward of 1 μm
HD 121191 Infrared Excess

Fig. 5.— Spectral energy distribution for HD 121191. The brown curve is a stellar photosphere (7700K) and the dashed line represents the star + dust continuum (450K + 95K).
Dust Location

**HD 131488**

- $T_{\text{hot}} \approx 750 \text{ K}$
  - $\Rightarrow$ ~0.6 AU
- $T_{\text{cold}} \approx 100 \text{ K}$
  - $\Rightarrow$ ~35 AU

**HD 121191**

- $T_{\text{hot}} \approx 450 \text{ K}$
  - $\Rightarrow$ ~1.3 AU
- $T_{\text{cold}} \approx 95 \text{ K}$
  - $\Rightarrow$ ~28 AU

*Gemini Observatory/Lynette Cook*
The Epoch of Giant Impact Collisions

- IRAS/AKARI sensitivities of ~100 mJy can detect $\tau \sim 10^{-3}$ terrestrial planet zone debris disks for most nearby (d < 200 pc) stars.
### The Occurrence Rate of Terrestrial Planets

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<tr>
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<th>Solar-Mass</th>
<th>Intermediate-Mass</th>
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<tbody>
<tr>
<td><strong>Epoch of Terrestrial Dust Phenomenon</strong></td>
<td>30-100 Myr</td>
<td>10-20 Myr</td>
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<tr>
<td><strong>Rate of Terrestrial Dust Phenomenon</strong></td>
<td>1/300</td>
<td>1/200*</td>
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<td><strong>Lifetime of Phenomenon</strong></td>
<td>180,000 yr</td>
<td>70,000* yr</td>
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<td><strong>Lifetime of Largest Collisional Fragments</strong></td>
<td>~50,000 yr</td>
<td>~20,000 yr</td>
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<td><strong>Total Duration of Dusty Phase</strong></td>
<td>~150,000 yr</td>
<td>~60,000 yr</td>
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