Characterizing Debris Dust and Gas in Exoplanetary Systems

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Exoplanetary Systems

- Exoplanet Observations
- Debris Disk Observations
Reconstructing the β Pictoris Planetary System

Extended disk of small grains up to ~1400 AU from the star (Golimowski et al. 2006)

~9 M\textsubscript{Jup} planet at 8-15 AU (Lagrange et al. 2010)
Reconstructing the β Pictoris Planetary System

Clump of comets at 50 - 60 AU (Dent et al. 2014)

Ring of large grains at 95 AU (Dent et al. 2014)
Science Goals

Outstanding Science Questions:
• What is the origin of gas in debris disks? Is it primarily produced in collisions?
• What is the composition of the gas and the underlying parent bodies?

Landscape:
• ALMA has spatially resolved ‘planetesimals birth rings’ and discovered CO toward more than a dozen young systems and C I toward a handful of systems
• SOFIA/HIRMES will enable searches for solid-state ice features and kinematic studies of the gas
## Infrared Spectral Features

<table>
<thead>
<tr>
<th>λ (µm)</th>
<th>Species</th>
<th>Diagnostic</th>
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<th>Species</th>
<th>Diagnostic</th>
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<tbody>
<tr>
<td>1-5</td>
<td>H$_2$O gas</td>
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<td>13.7</td>
<td>C$_2$H$_2$ gas</td>
<td>Organics</td>
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<td>3.8-4.2</td>
<td>SiO v=2-0</td>
<td>Giant Collision</td>
<td>14.0</td>
<td>HCN gas</td>
<td>Organics</td>
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<td>4.5-5.3</td>
<td>CO v=1-0</td>
<td>Mass and Temp</td>
<td>15-30</td>
<td>H$_2$O gas</td>
<td>Rotation water lines</td>
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<td>H$_2$O gas</td>
<td>Water bend</td>
<td>15.2</td>
<td>CO$_2$ ice</td>
<td>Thermal history</td>
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<td>6.2</td>
<td>PAH</td>
<td>Carbon-rich material</td>
<td>17.0</td>
<td>H$_2$ S(1)</td>
<td>Mass and Temp</td>
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<tr>
<td>7.7</td>
<td>CH$_4$ ice</td>
<td>Organics</td>
<td>18.5</td>
<td>(Mg,Fe)SiO$_3$</td>
<td>Crystalline pyroxene</td>
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<td>FeO</td>
<td>Oxides</td>
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<td>25.2</td>
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<td>H$_2^{18}$O gas</td>
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<td>Mg$_2$SiO$_4$</td>
<td>Crystalline silicates</td>
<td>27.5</td>
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<td>OH gas</td>
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<td>[Ne II]</td>
<td></td>
<td>28.2</td>
<td>H$_2$ S(0)</td>
<td>Mass and Temp</td>
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</table>
Observations

NIRSpec:
• Fixed Slit (S1600A) spectroscopy
• G140H/F100LP G235H/F170LP, G395/F290LP grism/filter combination (provide R~2700 spectroscopy at 0.977 – 4.123 μm)
• SUB1024A and SUB1024B subarrays (needed to avoid saturation)

MIRI:
• Medium Resolution Spectrograph
• Channels 1-4 observed simultaneously (provides R~3000 spectroscopy)
• Grating Settings A-Short, B-Medium, and C-Long are needed to cover the full wavelength range (4.88-28.34 μm)
NIRSpec Target: HD 32297

Spectral Type: A0V
Distance: 112 pc
$T_{\text{dust}}$: 190 K
$L_{\text{IR}}/L^*$: $2.7 \times 10^{-3}$
$M_{\text{dust}}$: $0.56 \pm 0.07 \, M_\oplus$
$R_{\text{dust}}$: $50 – 1680$ AU
Inclination: $90^\circ$ (edge-on)
Age: $\sim 10$ Myr

Redfield et al. (2007)

Schneider et al. (2014)
MIRI Target: η Tel

Spectral Type: A0V
Distance: 48 pc
$T_{\text{dust}}$: 140 K
$L_{\text{IR}}/L^*$: $2.4 \times 10^{-4}$
$M_{\text{dust}}$: 0.0.13 M$\oplus$
$R_{\text{dust}}$: 4 – 24 AU
Inclination: 90° (edge-on)
Age: ~20 Myr
Spectral Type: A0V
Distance: 48 pc
$T_{\text{dust}}$: 140 K
$L_{\text{IR}}/L_\star$: 2.4$x10^{-4}$
$M_{\text{dust}}$: 0.013 $M_\oplus$
$R_{\text{dust}}$: 4 – 24 AU
Inclination: 90° (edge-on)
Age: $\sim$20 Myr
MIRI Target: η Crv

Spectral Type: F2V
Distance: 18.3 pc
$T_{\text{dust}}$: 390 K (inner)
40 K (outer)
$M_{\text{dust}}$: 0.014$\pm$0.001 $M_\oplus$
$R_{\text{dust}}$: 2-4 (inner)
100-200 AU (outer)
Inclination: 35°
Age: 1.4 Gyr
Summary
12 hours total

Debris Gas:
1. Search for and characterize atomic and molecular gas emission to measure elemental abundances and gas excitation temperatures
2. Infer whether the gas is primordial or second-generation and constrain the production mechanism

Debris Dust:
1. For objects with silicate emission features, map change in grain properties as a function of stello-centric distance
2. Search for changes in the silicate emission features, indicative of on-going collisional activity