Insights into planetary systems through JWST imaging of debris disks

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What is a debris disk?

Infrared emission of nearby main sequence stars above photosphere: e.g., Fomalhaut

Imaging shows emission from 130AU dust ring (Acke et al. 2012)
Debris disks are components of planetary systems

Planetesimal belts are analogous to the Kuiper belt and Asteroid belt.

Disk structure is indicative of the architecture of the planetary system.
Planets inevitably affect disk structure

**Planet:**
- $1M_{\text{jup}}$
- 5AU
- $e=0.1$
- $I=5^\circ$

**Disk:**
- 20-60AU

**Time:**
- 100Myr
- after formation

Matthews et al. PPVI
JWST contribution to debris disk science

(1) Scattered light coronagraphic imaging of structure in extrasolar Kuiper belts

(2) Mid-IR (coronagraphic) imaging of structure in extrasolar Kuiper belts and mid-planetary system planetesimal belts
(1) Scattered light coronagraphic imaging of structure in extrasolar Kuiper belts

HST images show detailed structure of Fomalhaut’s disk (Kalas et al. 2013): eccentricity, sharp inner edge, azimuthal gap

Also a planet (Fom-b) orbiting not along the inner edge, but on highly elliptical orbit
Debris disks are planet signposts, and provide constraints on planets

Debris disk coherence sets tight constraints on the Fom-b: either it’s very low mass, or was put on its belt-crossing orbit very recently (Beust et al. 2013)

Best explanation: ~M_{Neptune} and a cloud of irregular satellites around it (Kennedy & Wyatt 2011; Tamayo 2014)
NIRCAM imaging of disk structure

Will improve on what can currently be done from the ground and with HST

- Spiral in HD141569 (Clampin et al. 2003)
- Double ring in HD92945 (Golimowski et al. 2011)
- Brightness asymmetry in HD15115 (Rodigas et al. 2013)

- Deeper means fainter (less extreme, older) disks can be imaged
- Simultaneous imaging of planets interacting with disks
(2) Mid-IR imaging of structure in extrasolar Kuiper belts

Scattered light warp at 80AU in β Pic explained by a misaligned \(~9M_{\text{Jupiter}}\) planet at 8AU (Augereau et al. 2001; Lagrange et al. 2010)

Mid-IR (8-18\(\mu\)m) images show a clump at 52AU in the SW

But that clump is absent at 25\(\mu\)m
Multi-wavelength imaging is key to interpretation

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<th>Sub-mm continuum (planetesimals)</th>
<th>Mid-IR (small but bound dust)</th>
<th>Scattered light and short mid-IR (small unbound dust)</th>
<th>CO (short-lived gas)</th>
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<td><strong>Observed β Pic</strong></td>
<td>![Image](Dent et al. (subm))</td>
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<td><strong>Model (face-on)</strong></td>
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Clump (and different structure at different wavelengths) explained by a $> M_{\text{Neptune}}$ planet which migrated out to $\sim 60\text{AU}$ trapping planetesimals into its mean motion resonances (Wyatt 2006)
Ground-based mid-IR imaging is hard!

Most of the A star debris disks that can be resolved in the mid-IR from the ground have been imaged (Smith & Wyatt 2010)
Imaging with MIRI will be very productive

Almost all of the known debris disks around A stars will be imageable with MIRI (Smith & Wyatt 2010)
Mid-planetary system dust

Debris disk holes not always empty (Su et al. 2013); e.g., η Corvi (right) is a 1Gyr F star with 150AU Kuiper belt (Wyatt et al. 2005; Duchêne et al., in prep) and 1.5AU dust (Smith, Wyatt & Haniff 2009)

Origin of hot dust could be in mid-planetary system belts (like the asteroid belt), but could be cometary, and regardless is telling of planetary system

Dust at intermediate distances, if present, is most readily imaged at 10-25µm
Debris disks provide unique constraints on both the current architecture of extrasolar planetary systems and their formation and evolution.

JWST will:

- image extrasolar Kuiper belts and perturbing planets in scattered light
- image extrasolar Kuiper belts and mid-planetary system belts in mid-IR