Observed & Predicted Debris Disks Structures Beyond the Reach of Kepler

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Outline

- Radial structure
- Azimuthal structure
- Resonant structure
- Massive Collisions
What Happens to a Dust Grain After It’s Produced?

Radiation pressure size-sorts grains.

Krivov (2010)
Grains collide & fragment (?), happens once every ~100 orbits in observed debris disks
Radiation pressure size-sorts grains.

Krivov (2010)
Radial Structure: Size Sorting

Radiation pressure, drag, & collisions combine to size-sort grains radially: Dohnanyi in the “birth ring,” non-Dohnanyi in the “halo” (see Strubbe & Chiang 2006)
Radial Structure: Size Sorting

Planets can significantly alter the expected size distribution.

Thebault (2013)

Exterior to every planet, there exists a semi-major axis interior to which resonances overlap & orbits are unstable.
Azimuthal Structure: Pericenter Glow

Grains at pericenter are closer to star, thus hotter and brighter.

Wyatt et al. (1999)

Acke et al. (2012)
Resonant Structure (via Drag Effects)

Poynting-Robertson & stellar wind drag slowly reduces $a$ and $e$, causing dust to spiral inward on $\sim$Myr timescales.

Wyatt & Whipple (1950)

$a =$ semi-major axis
$q =$ periastron distance

$a_L$, $q_L$, $a_S$, $q_S$, $q_G$
Resonant Structure: Mean Motion Resonances

Grains can become trapped in mean motion resonances with planets, or ejected

Kuchner & Holman (2002)
Resonant Structure in the Solar System’s Debris Disk

Earth creates an observable resonant structure.

Reach et al. 1995
Resonant Structure in the Solar System’s Debris Disk

Earth’s resonant structure is likely “clumpy.”
Neptune likely creates a resonant structure in the Kuiper Belt dust cloud observable from afar.
Resonant Structures in Debris Disks: Dust Grains

Dust not readily trapped into resonances in the outer regions of observable debris disks

Kuchner & Stark (2010)
Resonant Structures in Debris Disks: Parent Bodies

Parent bodies could already be in resonance, creating observable asymmetries in sub-mm.
Resonant Structures in Debris Disks: Resolved Images
Resonant Structures in Debris Disks: Inner Disks

Planets more massive than Neptune could create resonant structure detectable with Kepler.

Stark et al. (2011)
No resonant structures associated with hot Jupiters have been found thus far.
Massive Collisions

Kral et al. (2013)

Kral: moving spiral of unbound grains (~<kyrs), then uniform disk

Kral et al. (2013)
Massive Collisions

Parent bodies

Unbound grains

Bound grains

Jackson et al. (2014)

Jackson: after moving spiral, a pinch-point asymmetry lasts ~Myrs producing stationary large grain asymmetry & jet of unbound grains
Evidence for Massive Collisions

Stark et al. (2014)
From GO 12228 Program (G. Schneider, PI)

New multi-roll HST STIS image of HD 181327 reveals asymmetries that cannot be explained by geometric, scattering, or projection effects.
Evidence for Massive Collisions

Residual HD 181327 asymmetries consistent with collisional ejecta or ISM warping.
β Pic: CO Asymmetry

Dent et al. (2014)
Source of $\beta$ Pic Asymmetry

Resonance, Recent Collision, or Pinch Point?

Rotates Rotates Stationary

Figure from Wyatt (2006)

Kral et al. (2013)

Jackson et al. (2014)