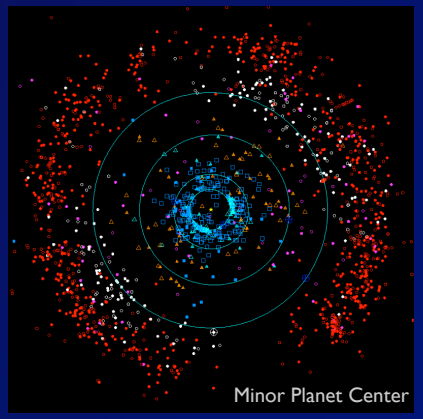
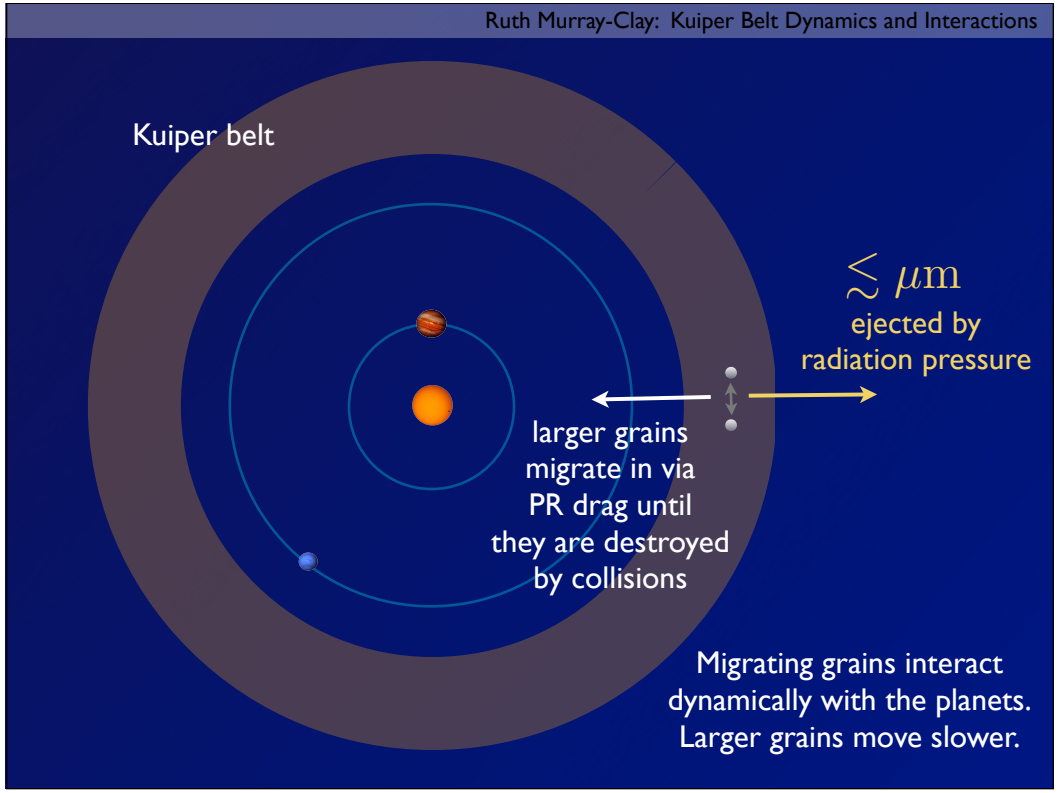
Kuiper Belt Dynamics and Interactions

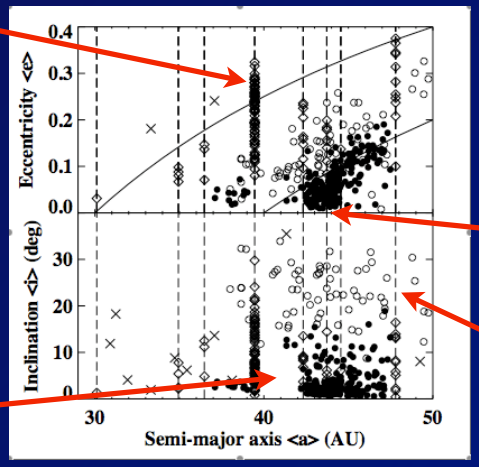


Ruth Murray-Clay
Harvard-Smithsonian Center for Astrophysics


Kuiper belt
$\lesssim \mu$m
ejected by
radiation pressure
larger grains
migrate in via
PR drag until
they are destroyed
by collisions
Migrating grains interact
dynamically with the planets.
Larger grains move slower.

Dynamical structure of the Kuiper belt

mean-motion resonances



low eccentricity, low inclination population

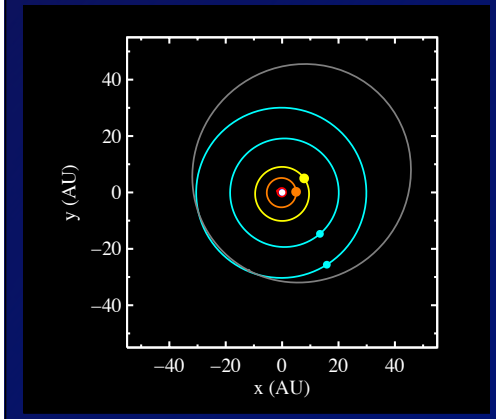
large inclinations

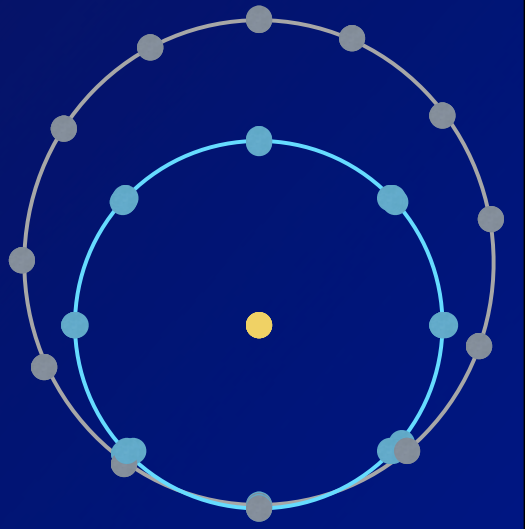
regions of instability

Deep Ecliptic Survey;
Chiang, Lithwick, Murray-Clay et al., PPV

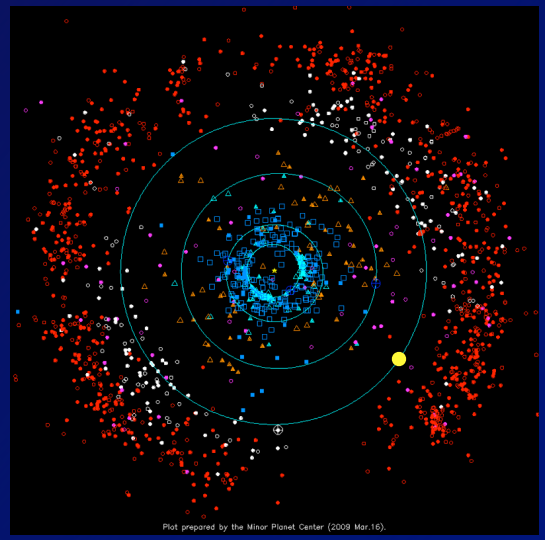
Mean-motion resonances provide stability

Pluto is protected from encounters with Neptune by the 3:2 mean-motion resonance





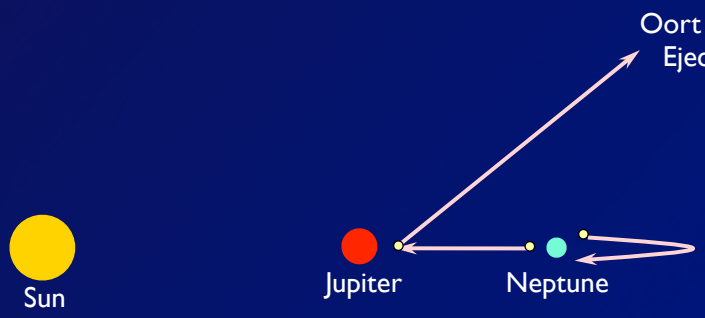
Observed resonant KBOs cross the orbit of Neptune but avoid its angular location



Minor Planet Center

Migration results from scattering planetesimals

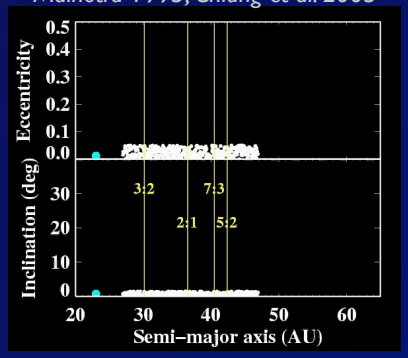
Fernandez and Ip 1984;
Malhotra 1993, 1995; Gomes et al. 2004

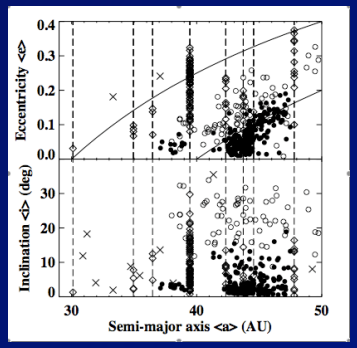


- back-reaction from each scattering kicks the planet a small amount
- global asymmetries in angular momentum transfer cause migration

Outward migration of Neptune can produce resonant capture

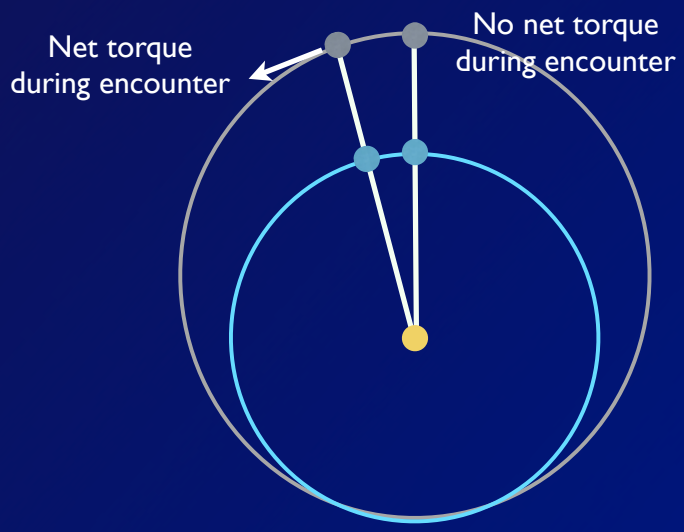
Malhotra 1995; Chiang et al. 2003



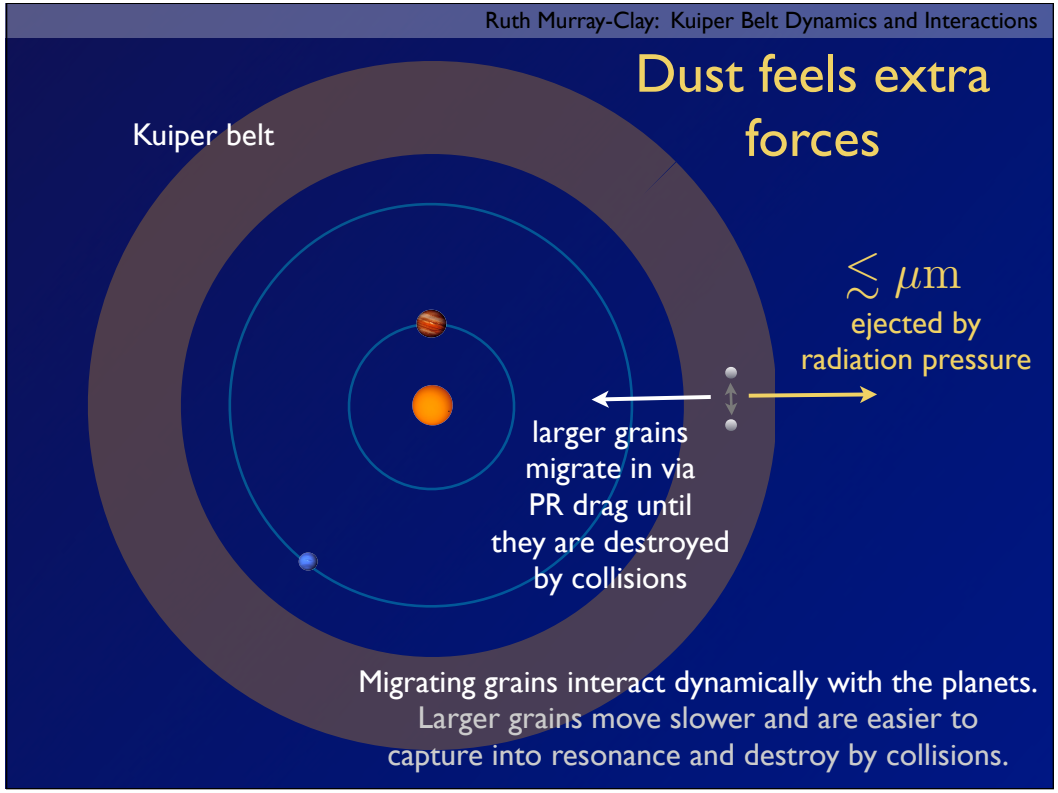


Deep Ecliptic Survey;
Chiang, Lithwick, Murray-Clay et al., PPV

Resonant Capture

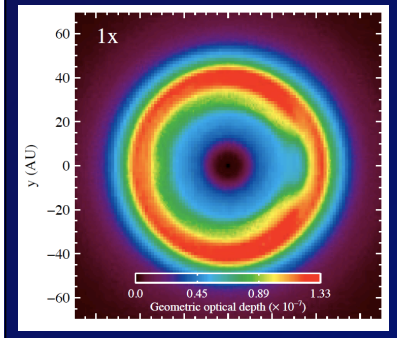


Eccentricity excitation:
perturbation pattern speed not equal to orbital speed

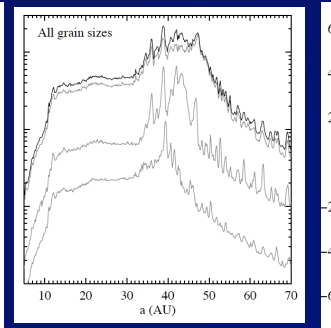

Dust feels extra forces
Kuiper belt
$\lesssim \mu$m
ejected by radiation pressure
larger grains migrate in via PR drag until they are destroyed by collisions
Migrating grains interact dynamically with the planets.
Larger grains move slower and are easier to capture into resonance and destroy by collisions.

Example outcome for the Kuiper belt

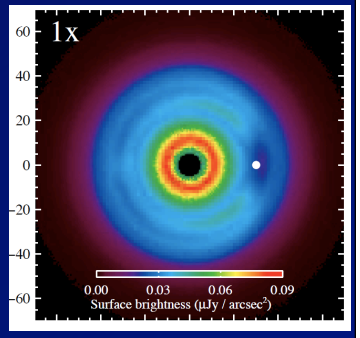
Kuchner & Stark, in prep.



azimuthal distribution of dust



radial distribution

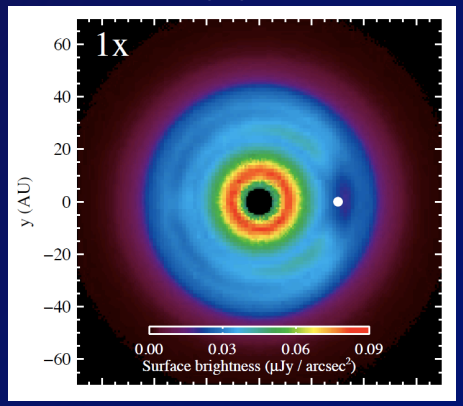


optical emission

What can we do with a view from 5 AU?

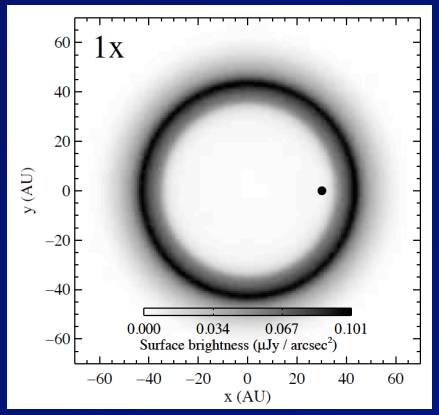
1) Test our basic theoretical understanding of dust dynamics in debris disks.

Kuchner & Stark, in prep.



optical

non-axisymmetric distribution

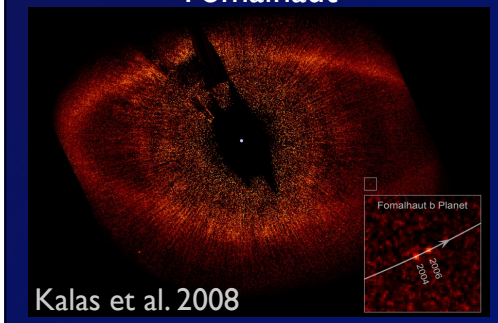


sub-mm

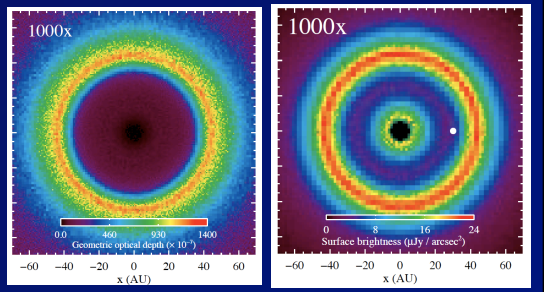
longer wavelengths trace source population

Understanding these properties is essential for probing extrasolar planets

Fomalhaut



debris disk interaction has been used to constrain the mass of a wide-separation planet



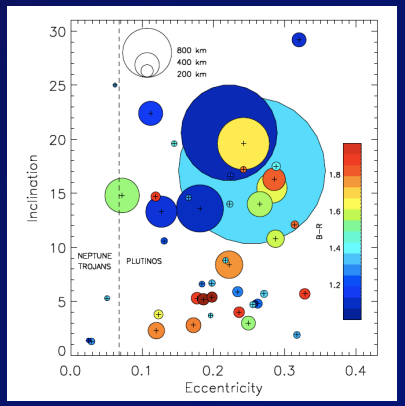
Kuchner & Stark, in prep.

In more massive disks, dust collides before it migrates in from the source population.

What can we do with a view from 5 AU?

2) Constrain theories of Kuiper belt formation by looking at variations in dust properties with inclination.

Low inclination Plutinos are distinct (as are low-inclination classicals)



Almeida et al. 2009

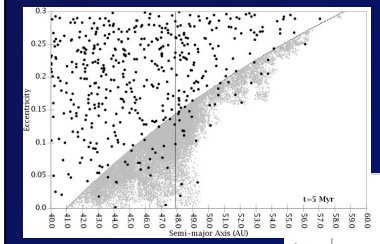
Resonant capture via migration does not change inclinations.

Eccentricities and inclinations in resonance are not correlated.

Resonant capture requires generating the two populations first.

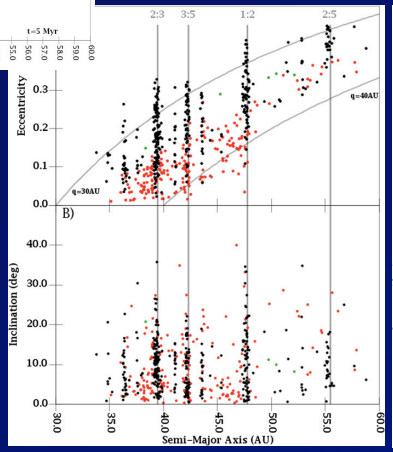
Test if color difference is from collision rate.

Nice model capture of resonant KBOs

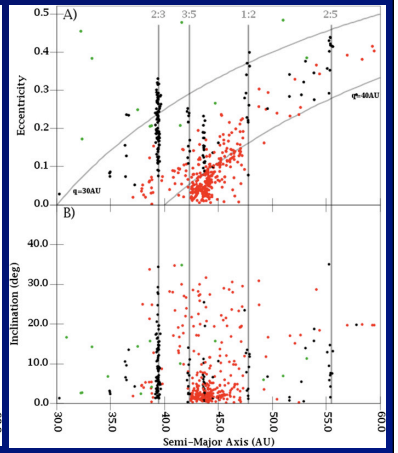


Population as Neptune's eccentricity is damped (plus a little migration).

Nice model



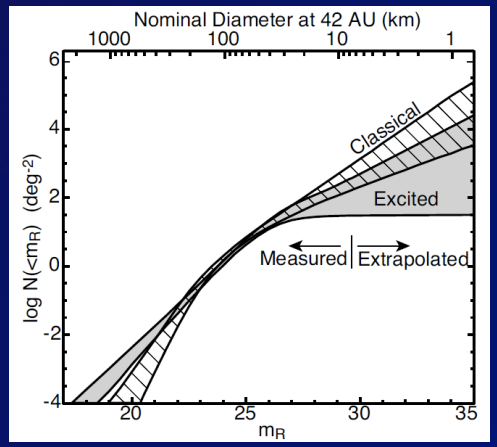
Observations



Levison et al. 2008

What can we do with a view from 5 AU?

3) Constrain how well we can use KBOs as collisionless test particles.



Bernstein et al. 2004

For example, a break in the size distribution due to present-day collisions could lead to different resonant populations of large and small bodies.

Kuiper belt dynamics and interactions: What can we do with a view from 5 AU?

- Measure the azimuthal distribution of dust to test our basic understanding of dust dynamics in debris disks.
- Look for differences in dust production rates and spectra with inclination distribution to test Kuiper belt formation scenarios.
- Constrain current collision rates and match to the size distribution and to dynamics of mid-sized bodies.