The Kuiper Belt

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Pluto: Head of the Plutino Family
(M. Buie)

Issues in Kuiper Belt science:

1. Resonance capture
2. Trojans
3. Dynamical heating
4. Edge
5. Colors and inclinations
6. Size distribution
7. Missing mass
The Kuiper Belt

Dr. Eugene Chiang, UC Berkeley (KITP Planet Formation Program 1/08/04)
Breakdown of all Resonant KBOs

Twotino (2:1) Snapshot

EC & Jordan 02
Faster Migration ($\tau \sim 10^6$ yr): Asymmetric Capture

Direct + Indirect Effects
Preference for $\phi > \pi$ set by outward migration

$\Delta \phi \equiv \frac{\tau_{\text{lib}}}{\tau_{\text{mig}}} \frac{\tau_{\text{lib}}}{\tau_{\text{orb}}}$

1. Asymmetric capture: Signature for migration

Murray-Clay & Chiang, in prep.
The Kuiper Belt

**First Discovered Neptunian Trojan**

2001 QR$_{322}$ (1:1)

(Chiang et al. 2003)

**Long-term stability**

⇒ Primordial resident

1 “Large” Neptune Trojan in 60°

⇒ ~20—60 Neptune Trojans vs. ~10 Jovian Trojans

“Large”: 130–230 km diameter

12%–4% visual albedo

“Move over Jupiter”
2. How do Trojans constrain host planet formation?

Fleming & Hamilton 2000; Marzari & Scholl 1998

Adiabatic invariant $D = \Delta \Phi_{110000} \frac{M_N^{1/4}}{a_N^{1/4}}$

Argues against violent orbital history for Neptune
Sweeping 5:2 resonance
Cold initial conditions: low capture efficiency

Sweeping 5:2 resonance
Hot initial conditions: high capture efficiency
3. How was the Belt pre-heated?

Problem: How to raise the perihelion after scattering

Other lines of evidence for pre-heating:

- 2002 CR105 (DES) min q = 42.0 AU “Extended scattered disk” (Gladman et al. 2002)
- Observed resonant inclinations too high (Brown 01)
4. Why is there an edge?

1. Present edge coincides with 2:1
   No coincidence (Levison & Morbidelli 03)

2. Primordial edge inside 2:1
   Radial drift of solids + critical metallicity
   threshold for planetesimal formation?
   (Youdin & Shu 02; Youdin & Chiang 03)
5. What does the Color-Inclination correlation for Non-Resonant KBOs mean? 

(4.1σ)

(Brown 01)
Bolstering the bi-modal inclination distribution

\[ C_J \approx \frac{1}{a} + 2 \sqrt{a (1 - e^2)} \cos \theta \]

\[ C_J < 3 \]

\[ C_J > 3 \]

(EG, unpublished)

6. Can one explain the size distribution?

\[ \frac{d \ln N}{d \ln R} = -4 \]

~250 km

(Bernstein et al. 04)
7. Where is the missing mass?

1. In the beginning, $\sim 10 \, M_\oplus$
   a. form Pluto
   b. form binaries (Goldreich, Lithwick, Sari 02)

2. In the end, $\sim 0.1 \, M_\oplus$

and can we get this dynamically rather than by counting objects?