Grain Orbits in the Pluto-Charon System: Modeling Non-Gravitational Forces

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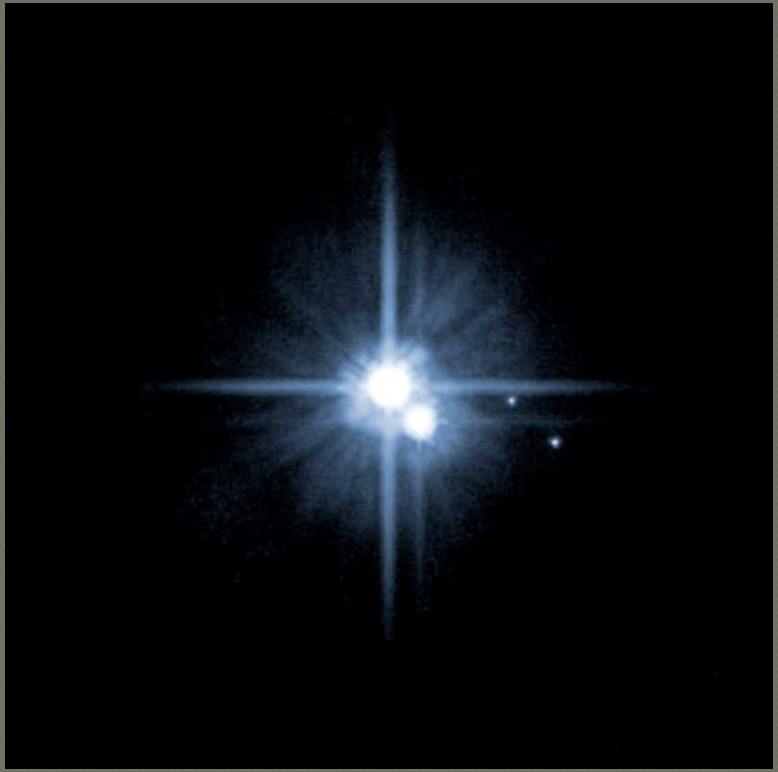
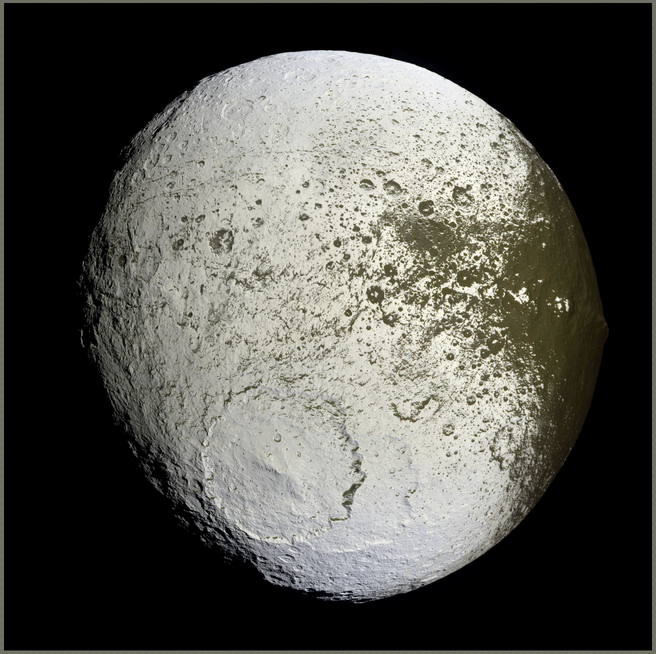
Pluto – A Complex Dynamical System For Dust Particles

- Gravitation
  - 1 major moon, 4 smaller
  - Mass Ratios (~1:8 for Charon & Pluto)
- Ejection From Impacts
  - Low escape velocities
  - Transfer of material
- Radiation Pressure
  - Solar radiation ~ solar gravity
- Atmospheric Drag
  - Maybe time variant



The Paper – Porter & Grundy 2014



Iapetus (Saturn) Sweeps Up Material From Phoebe Ring

- Simulate material transfer between bodies (D ~ 1-1000 μ m)
- Impact ejecta swept up by Pluto and Charon
  - Change albedo of surface
  - Observed by New Horizons
- Forces incorporated:
  - Solar radiation pressure
  - Gravity
  - Atmospheric drag
  - Other forces ignored

But Did They Do It Right?

Checking Their Equations: Rad Pressure

Radiation Pressure

$$ma = \frac{Q_{pr} F_{\odot} A}{c}, \quad m = \frac{4}{3}\pi R^3 \rho, \quad \& \quad A = \pi R^2$$

MATH

$$\ddot{r} = \frac{3}{8\pi} \frac{L_{\odot} Q_{pr}}{c\rho} \frac{\vec{r}}{r^3 D}$$

$$\ddot{r} = -\frac{3}{4} \frac{\rho_{atm}}{\rho_{dust}} \frac{C_D}{D} v^2 \left(\frac{\vec{v}}{v} \right)$$

MATH

Atmospheric Drag

$$ma = \frac{1}{2} \rho_{atm} v^2 C_D A, \quad m = \frac{4}{3}\pi R^3 \rho_{dust}, \quad \& \quad A = \pi R^2$$

Negligible?: Poynting-Robertson Drag

Time scale of Poynting-Robertson Drag:

$$t_{PR} \approx 530 \frac{a^2_{Planet(AU)}}{\beta} yr$$

For 1 micron diameter particle, ~ 10^5yrs

The approximate effect for planet-centered orbits:

$$a = a_0 e^{-t/t_{PR}}$$

Would take 2.7 Myr to decay a dust particle from Nix to Pluto

Maximum Integration Time: 10^6 days!

Negligible?: Reflected & Re-Emitted Light

Another source of radiation pressure! After a lot of algebra…

$$\frac{F_i}{F_{g,P}} = \frac{3}{64\pi}\frac{L_\odot}{c r_p^2}\frac{R_p^2}{GM_p}\frac{Q_{pr}}{\rho_d R_d} Z_i$$

$$Z_i = \begin{cases} 1 - A_{Bond,P} & for\ \ re-emission \\ A_{Bond,P} & for\ \ reflection \end{cases}$$

Or in a more digestible form:

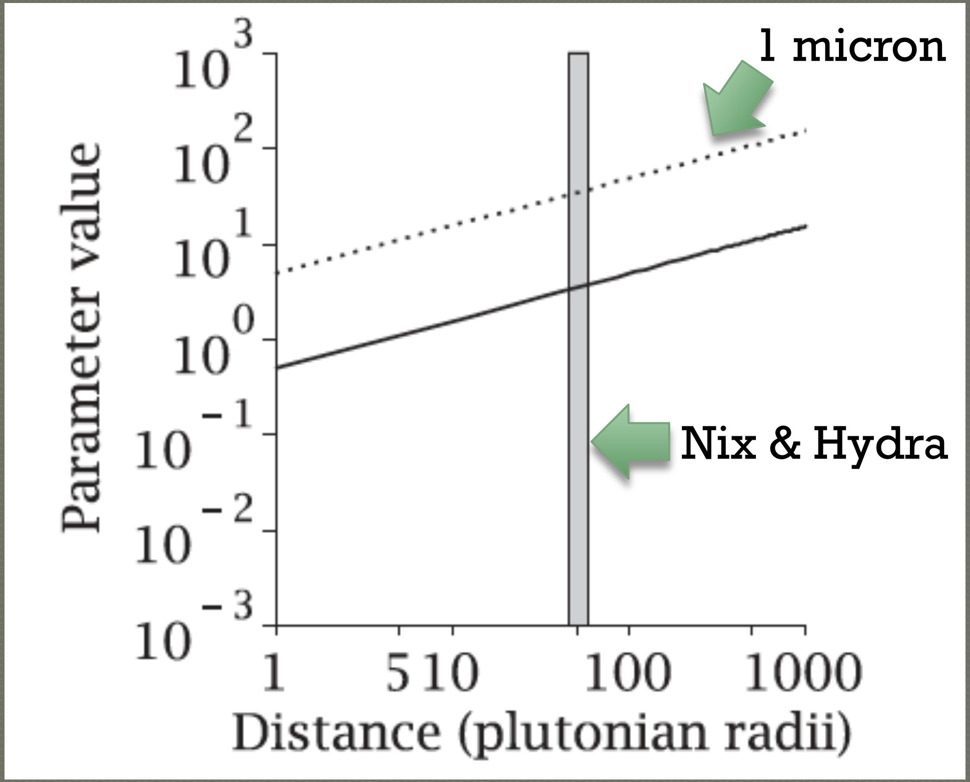
$$\frac{F_{refl}}{F_{g,P}} = 8.3 \cdot 10^{-13} m \left(\frac{A_{Bond,P}}{R_d}\right)\left(\frac{1 + e \cdot \cos f}{1 - e^2}\right)^2$$

$$\frac{F_{re\text{-}emit}}{F_{g,P}} = 8.3 \cdot 10^{-13} m \left(\frac{1 - A_{Bond,P}}{R_d}\right)\left(\frac{1 + e \cdot \cos f}{1 - e^2}\right)^2$$

So, even with the smallest grain size, the upper limits are $\sim 10^{-6}$

Some Potential Issues

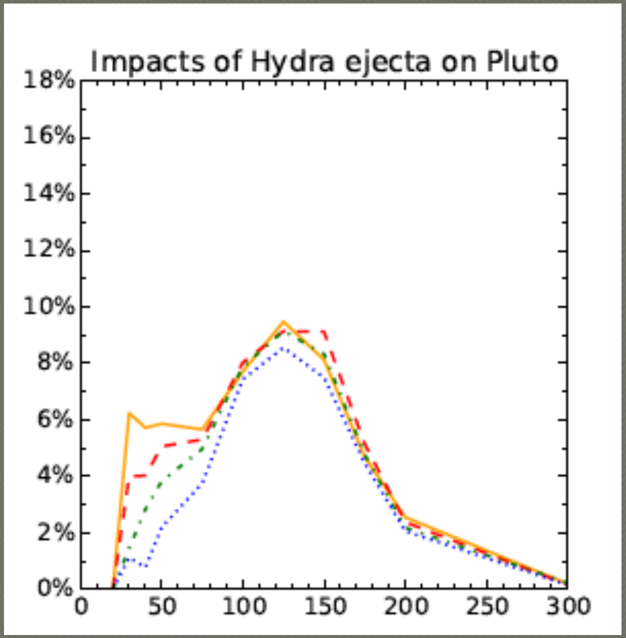
- Radiation Pressure Seems Too Small
  - Porter & Grundy 2014 claim it has a weak effect for most orbits
  - Seems to contradict the literature

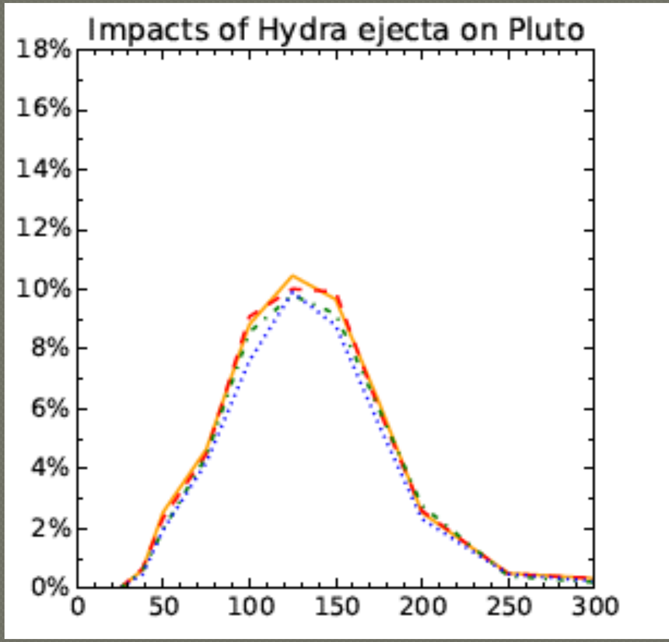


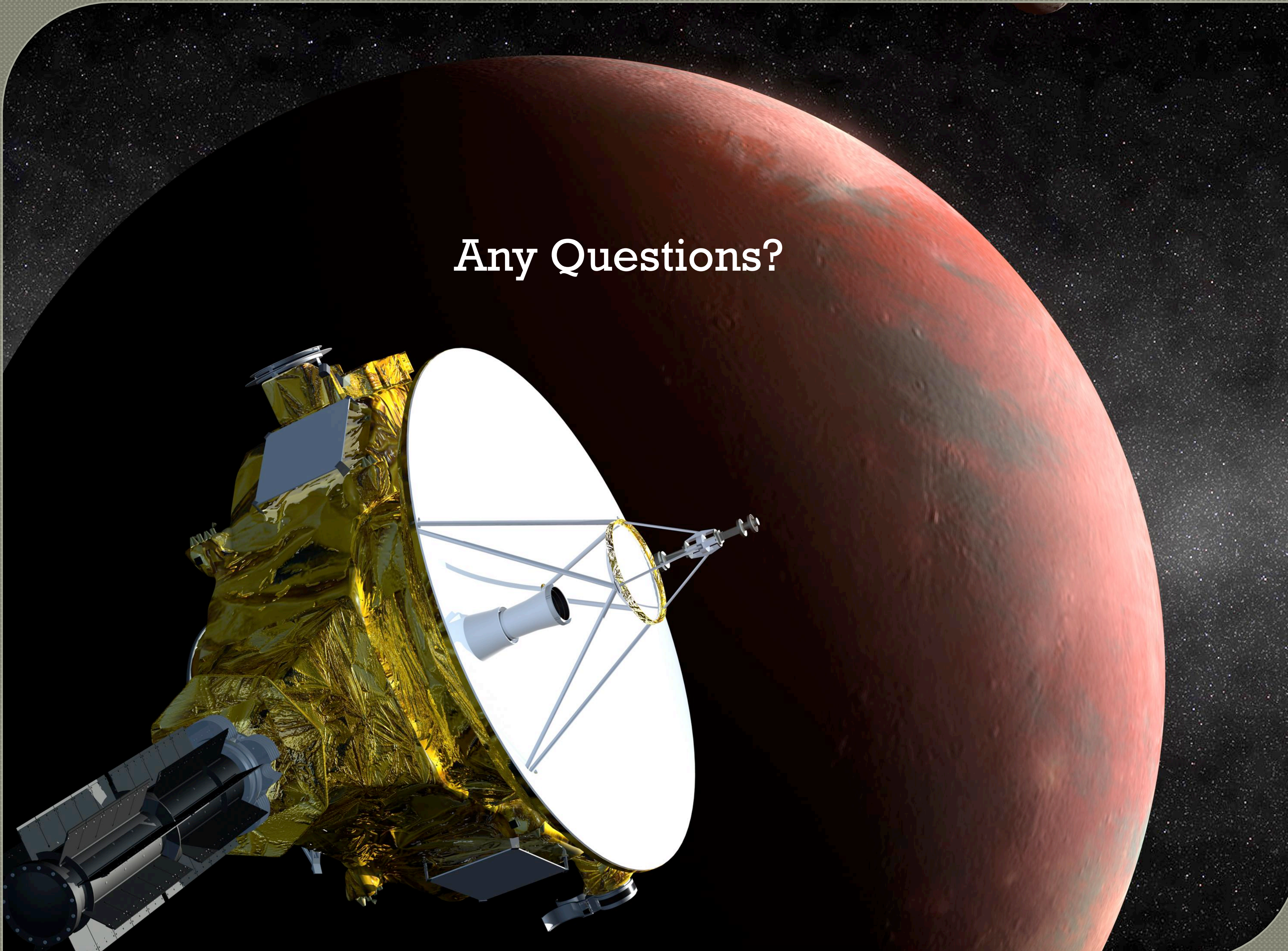
Peres dos Santos et al. 2013

Some Potential Issues

- Surprising drag results
  - Atmospheric drag seems to cause low-velocity ejecta to be less likely to impact Pluto or Charon






Any Questions?

Sources

- Porter & Grundy 2014, arXiv: 1403.4873v1
- Hamilton 1993, Icarus 101, 244
- Pires dos Santos et al. 2013, MNRAS 430, 2761