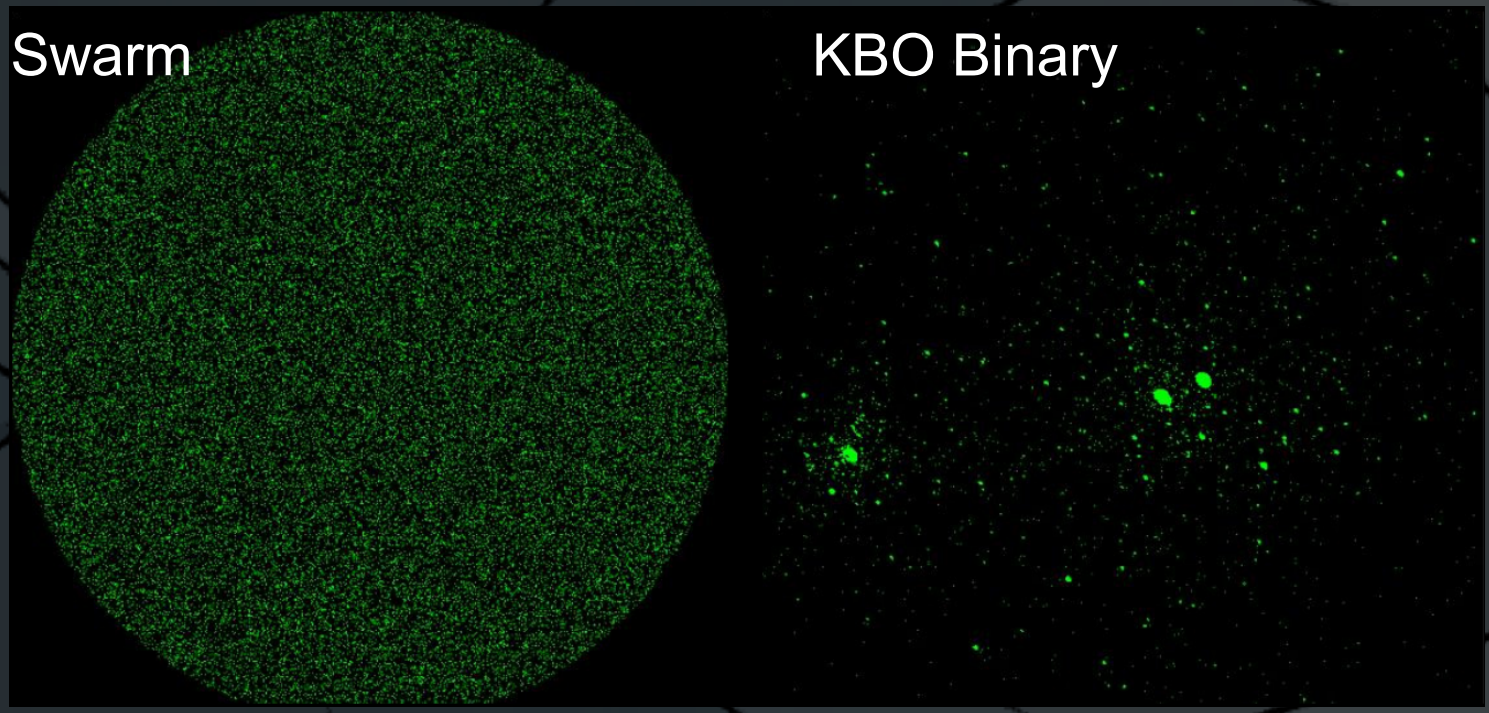
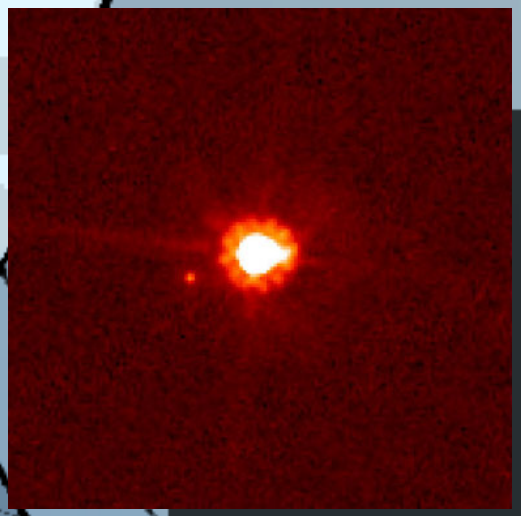
Binary KBO Formation Through Gravitational Instability:

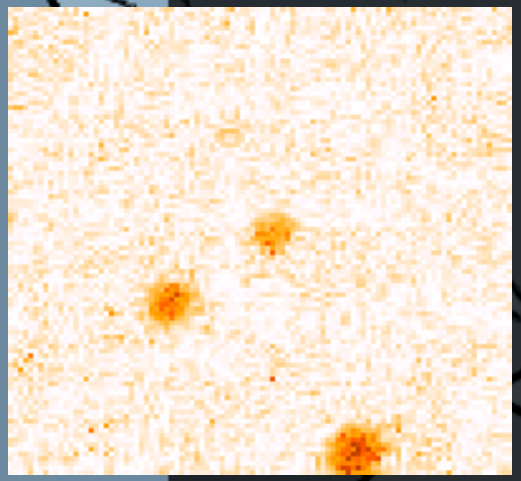
Presented by Jonathan Fraine

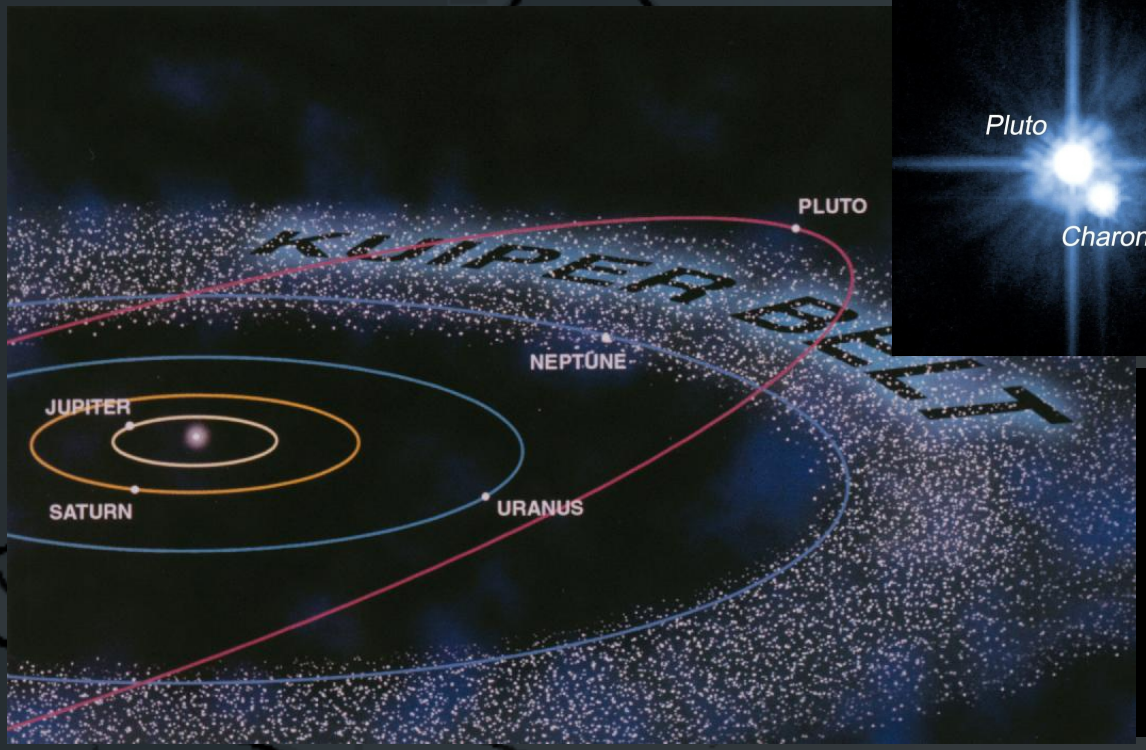


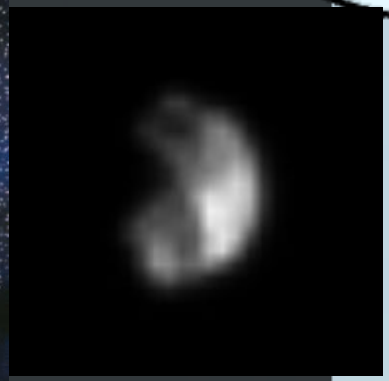
Background Research:
"Formation of Kuiper Belt Binaries by Gravitational Collapse"
by D. Nesvorny, A. Youdin and D. Richardson.

Kuiper Belt Objects (KBOs)



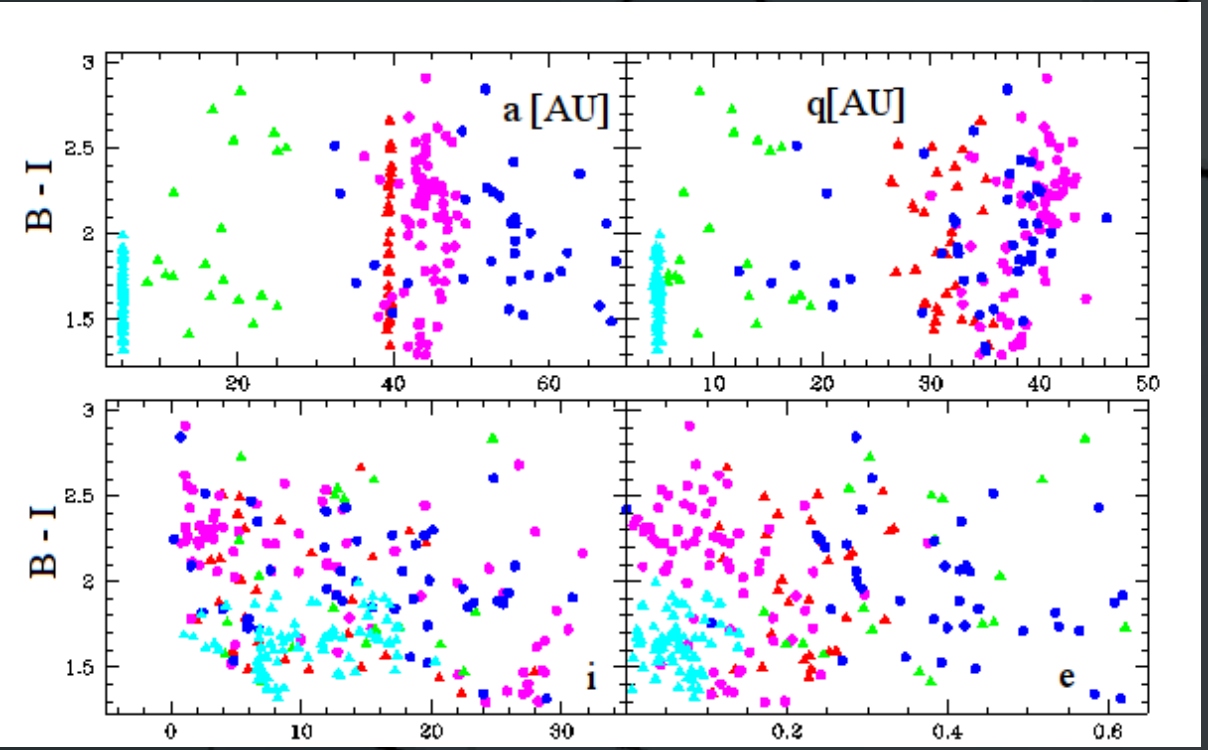






- Asteroids or comet with a = 30 – 50+ AU
- Likely primitive debris from early planet formation
- Primarilly comprised of methane, ammonia, water ice

KBO Dynamics vs Color



Pink = KBO

Blue = SDO

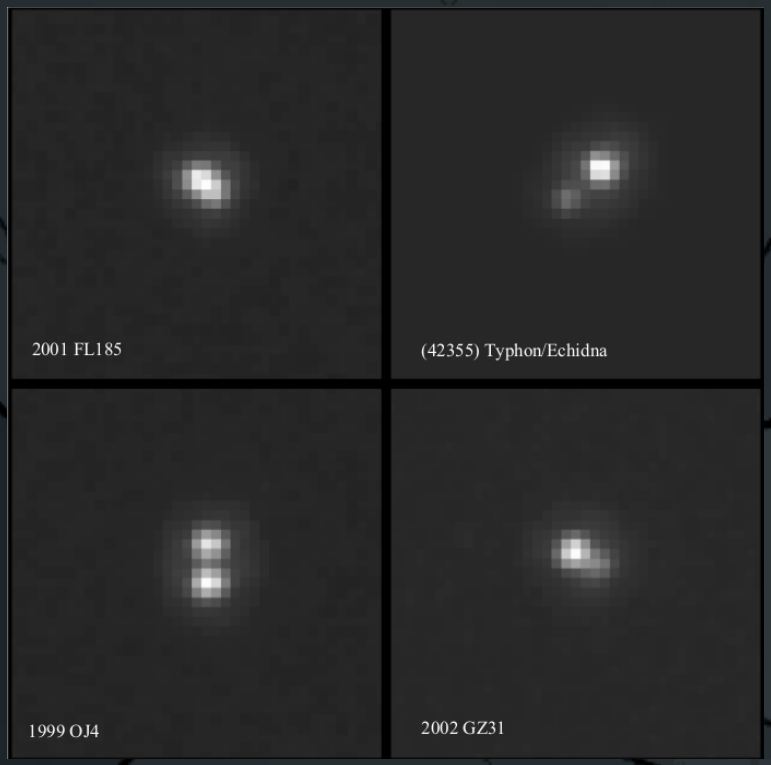
Green = Centaurs

Cyan = Trojan

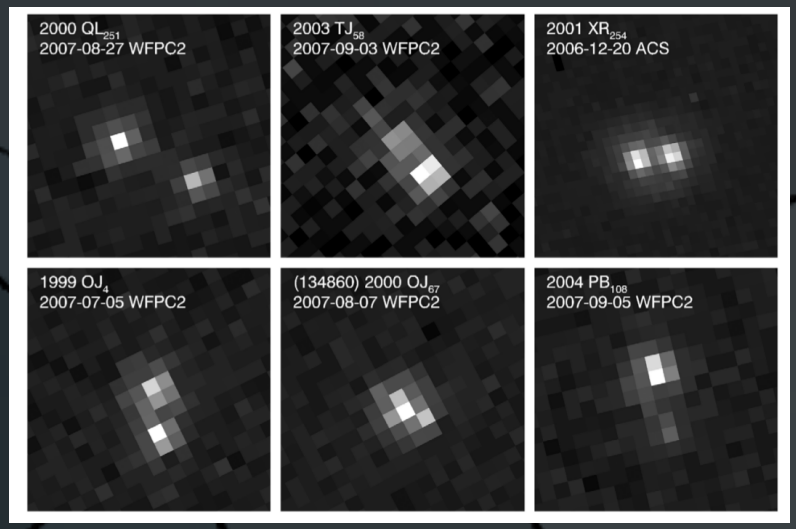
Red = Plutino (2:3)

Black = Comets

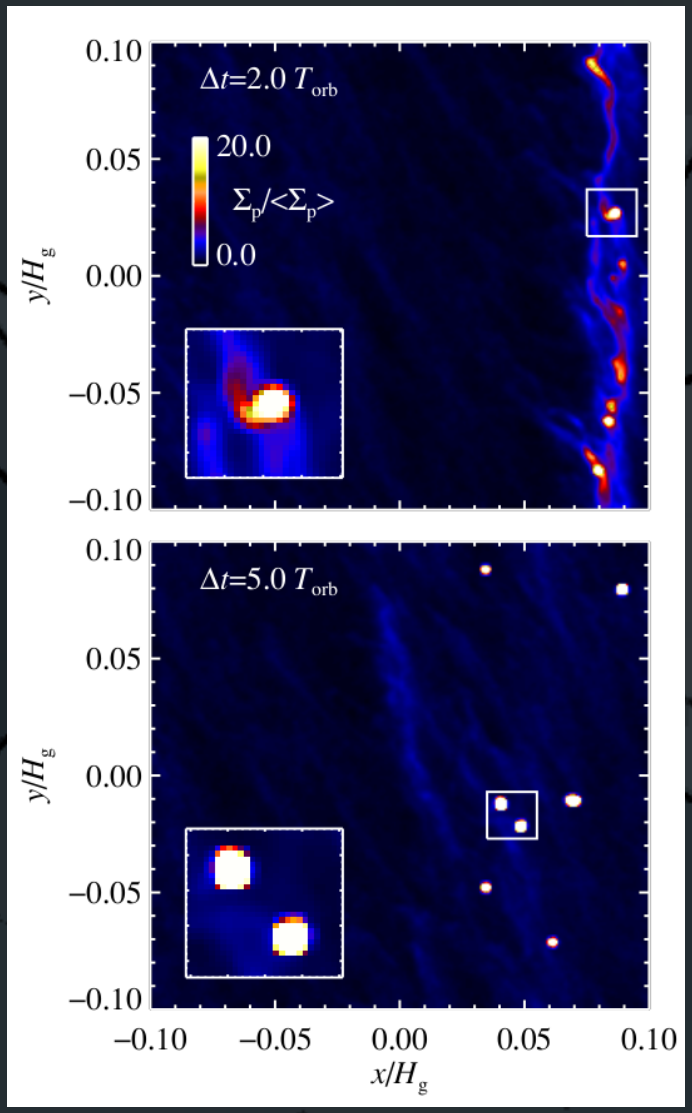
Binary Kuiper Belt Objects (KBOs)



- 48 Resolved KBO Binaries
- Expected KB binary fraction: 17-32%
- Useful:
  - Masses and densities
  - Compare colors (23)
  - Probe formation models

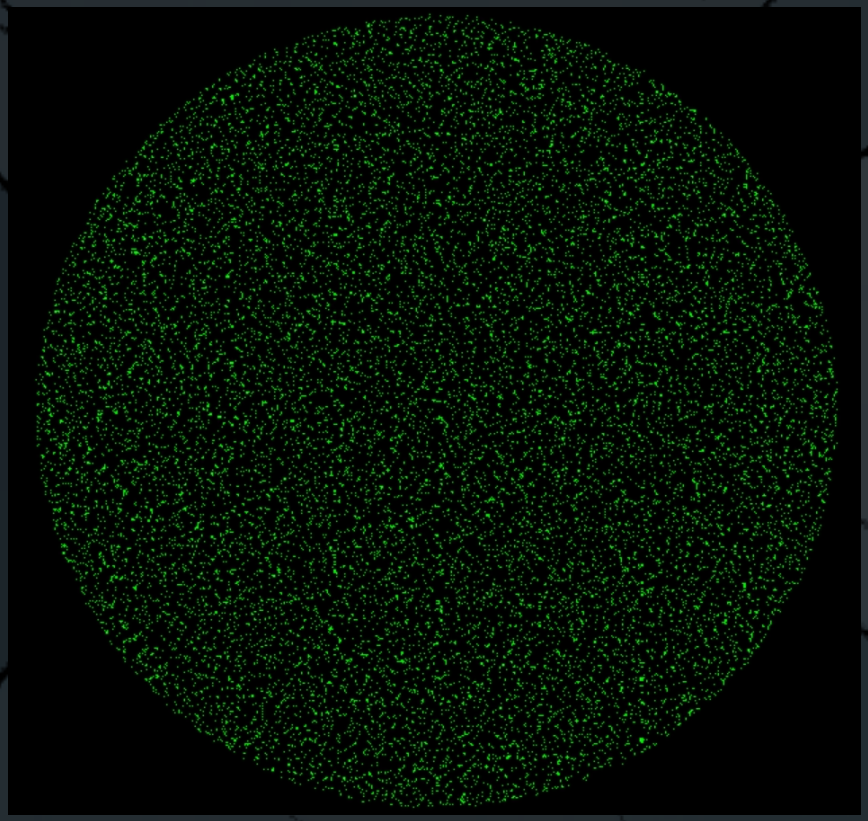


Gas Dynamics in Protoplanetary Disk



- Gas & Dust undergo instabilities through dynamical turbulence
- Streaming instabilities result from fluids of different velocities flowing past one another
- Clumps (overdensities) form in in the midplane (Johanson 2007)
- These turbulent eddies collapse into planetesimals (Nesvorny 2010)

Gravitational Collapse of Swarm



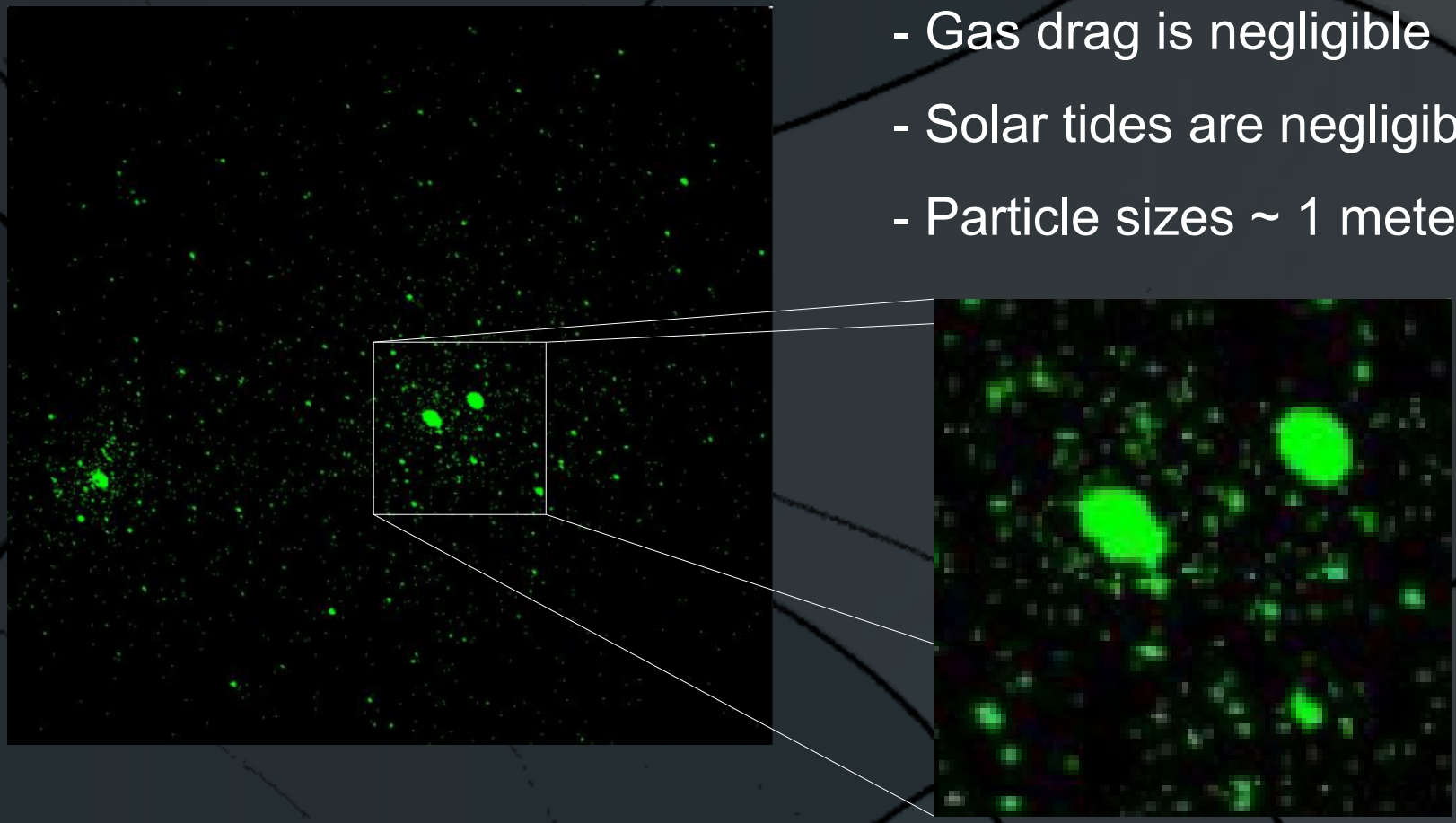
- These turbulent eddies collapse into planetesimals (Nesvorny 2010)
- Studyin the collapse itself can determine the likelihood of binary formation and thus binary fraction
- Principle model parameters:

  R_{tot} = radius of a KBO that constains all of the mass with a density of 1.0 g/cm^3

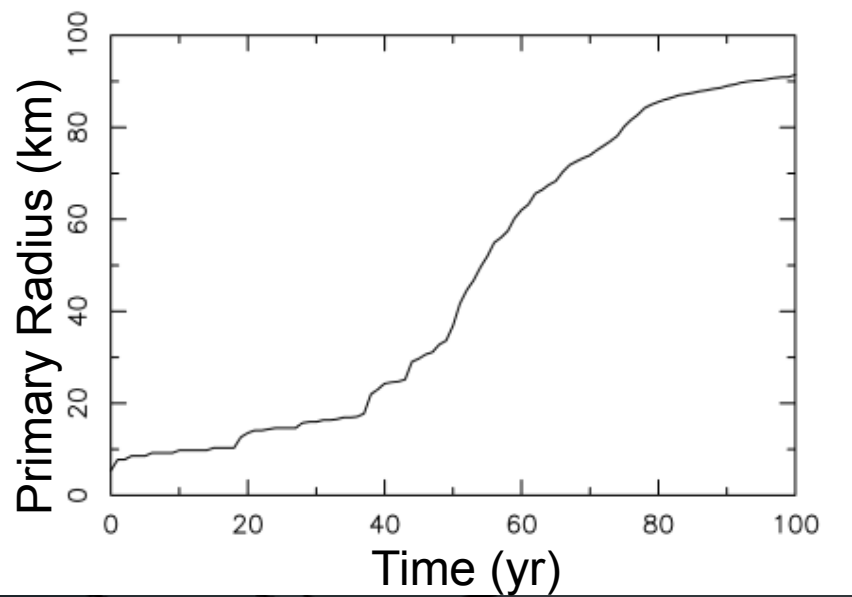
  Ω = orbital frequency of swarm around its own center of mass

Gravitational Collapse of Swarm

- Assumption:
  - Gas drag is negligible
  - Solar tides are negligible
  - Particle sizes ~ 1 meter



Gravitational Collapse Results



Growth rate of radius varies with time

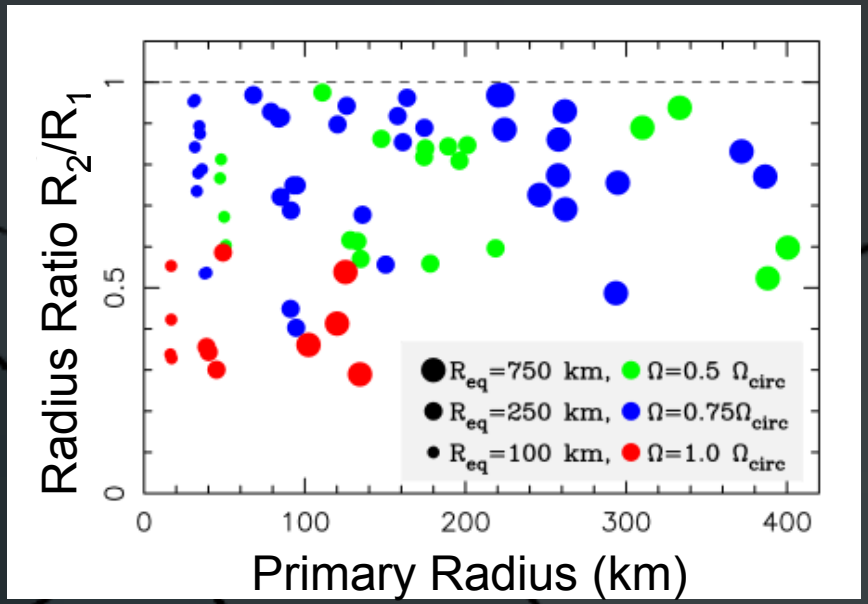
Variation is similar to 'runaway' growth found in terrestial formation through core accretion

The radius ratio R_2/R_1 is dependent on:

Primary radius (x-axis)

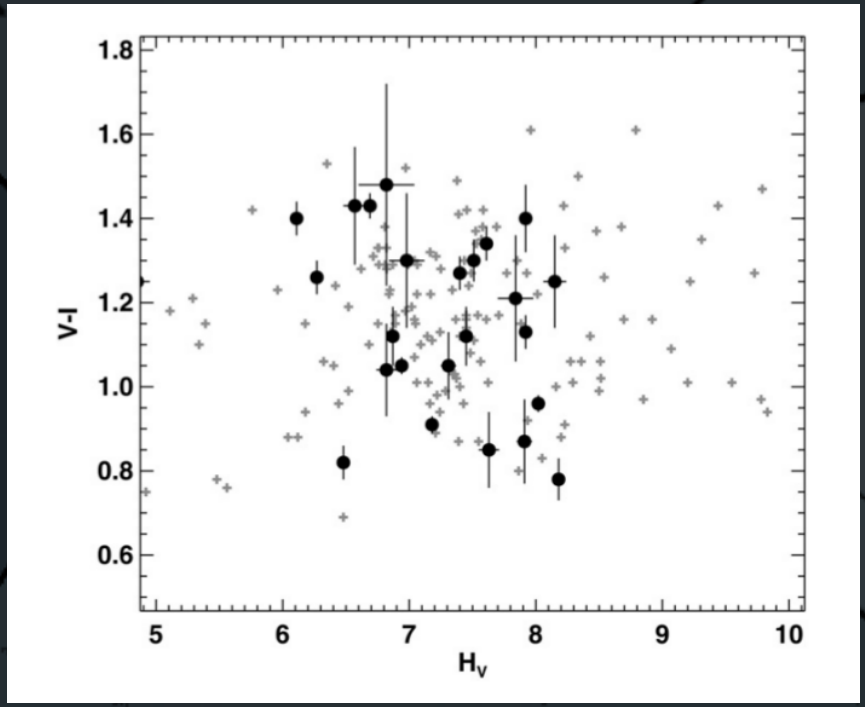
Initial rotational frequency of swarm

green = 0.50 Ω_{circ}
blue = 0.75 Ω_{circ}
red = 1.00 Ω_{circ}

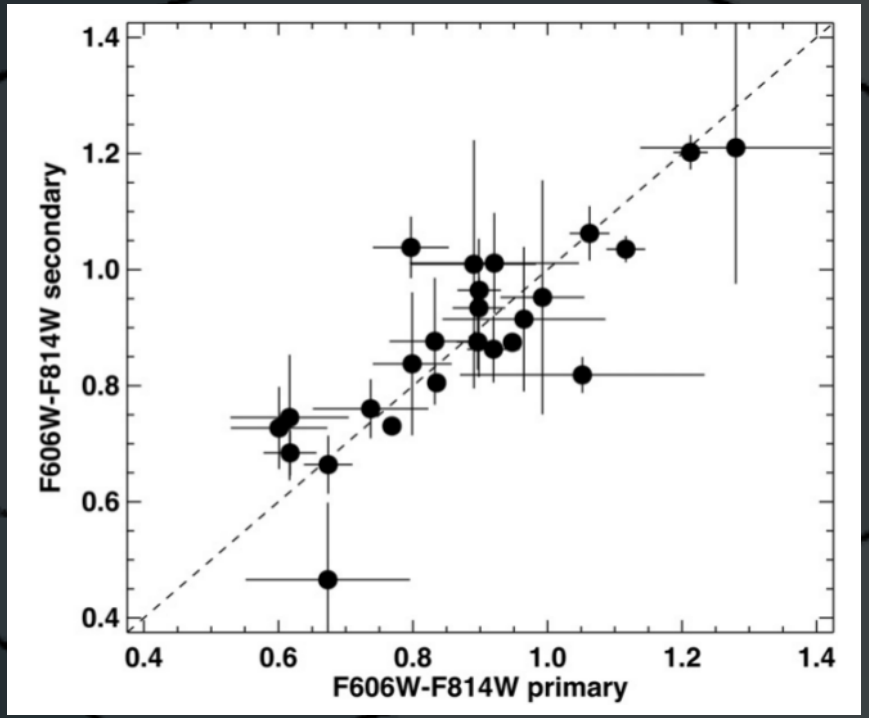


KBO Colors

Color Distribution of KBOs



Color Ratio of KBO Binaries



Conclusions

- Graviational collapse is a viable process for binary KBO formation with tunable (0 – 100%) binary fraction
- It allows for 1- 100 km size planetesimals in binary orbits of ~10,000 km separation
- It predicts that primary and secondary components must have identical colors.
- Long term tidal disruption could would limit more than excite the binary fraction

Fun Fact: KBOs are sometimes referred to as “cubewanos”

Can you guess why?