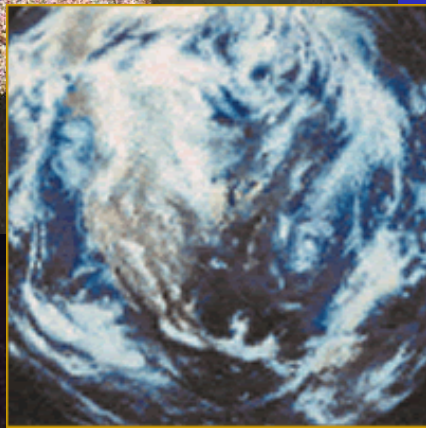
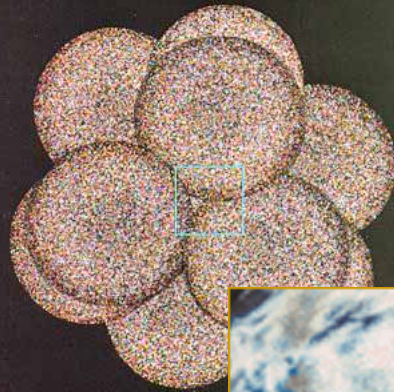


Order-of-Magnitude Problems in Planetary Science

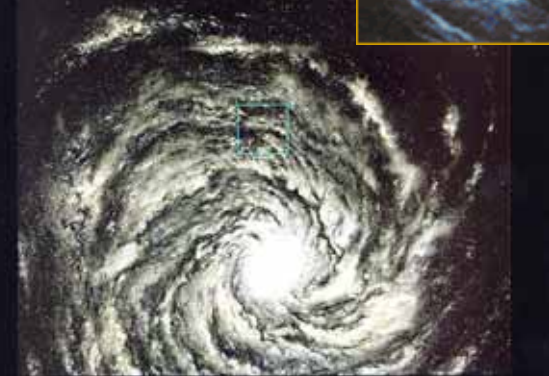
Kobe 2005
E. Chiang
UC Berkeley

- I. Planet Formation
- II. Planet-Disk Interaction
- III. Debris Disks
- IV. Mass Loss from Hot Jupiters



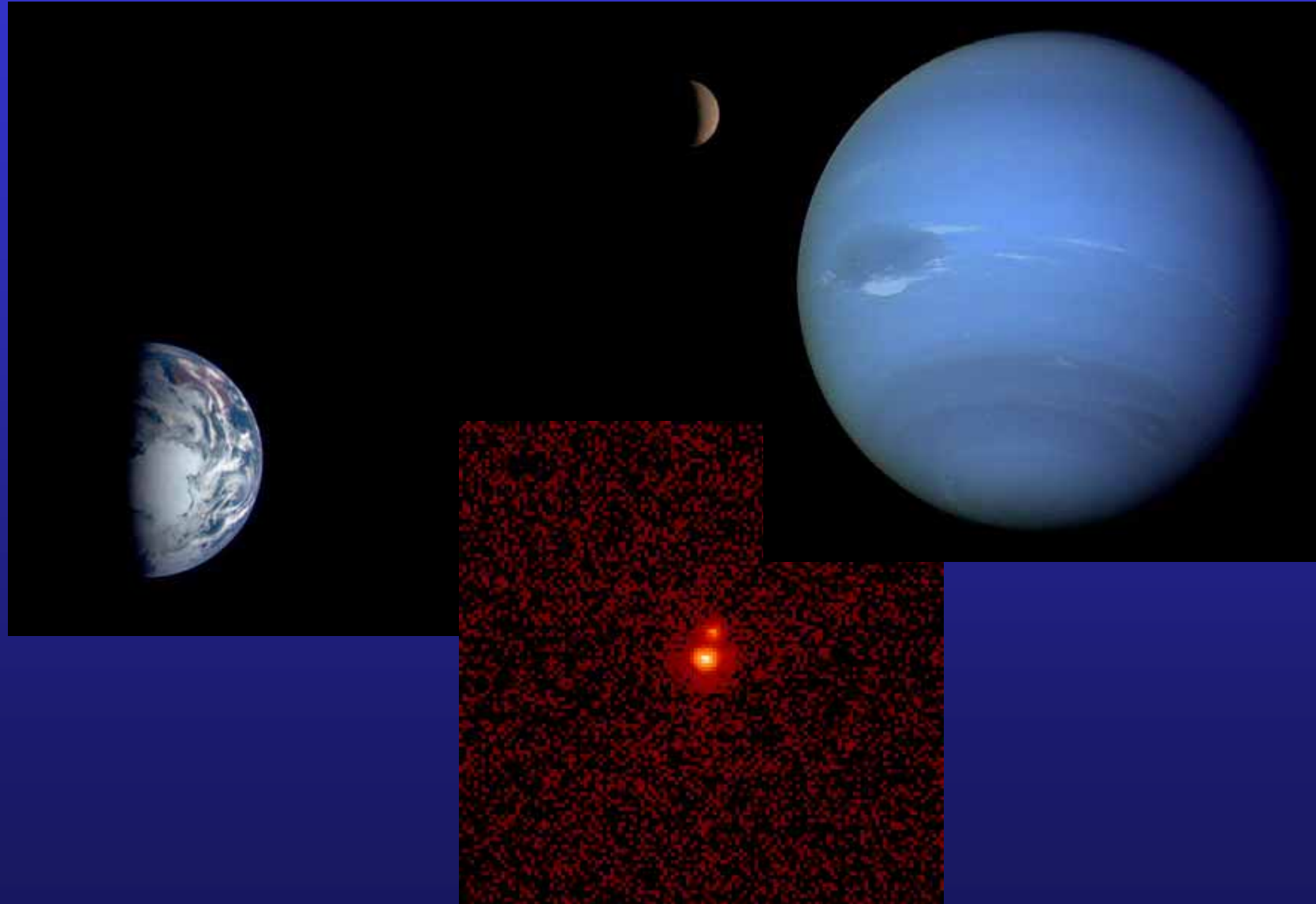
This is the scale of human compressibility, concentration, mass: A man is sitting on a warm October day. Around him are recreation and pleasure for mind and body. Between this image and the next frame inward, the size of the image would be once match the size of what it represents. "Of all things man is the smallest," wrote Protagoras the Sophist.

~100 thousand light-years

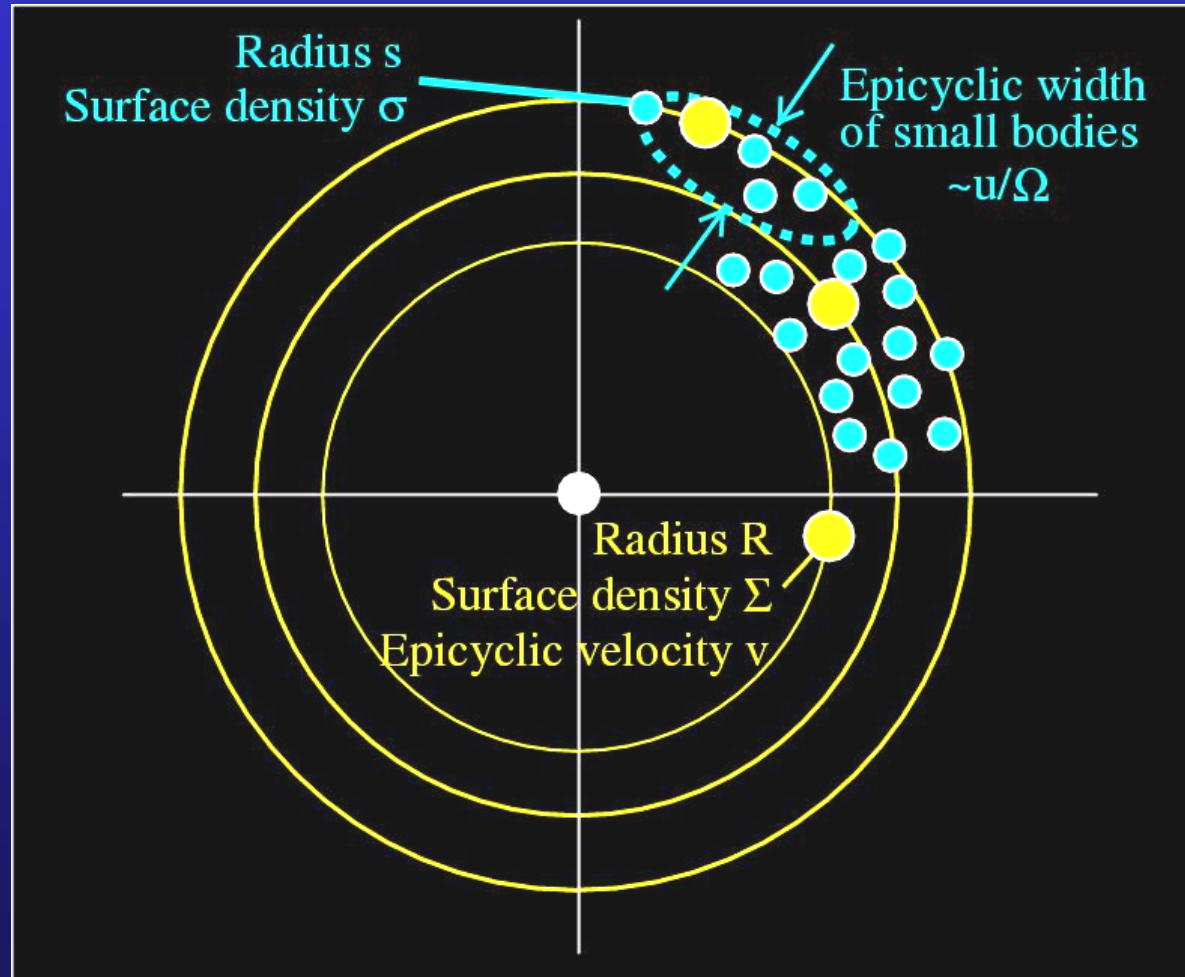


We look face-on directly at the Milky Way spiral. A hundred billion stars loosely bound by gravity encircle the central region, some passing close in, some in wide orbits. Our own sun swings with the one in dissipated passage clockwise about the distant galactic center, once every three hundred million years. External galaxies akin to our own are scattered throughout space as far as we can see. They too rotate slowly as they drift.

Solid body formation by coagulation

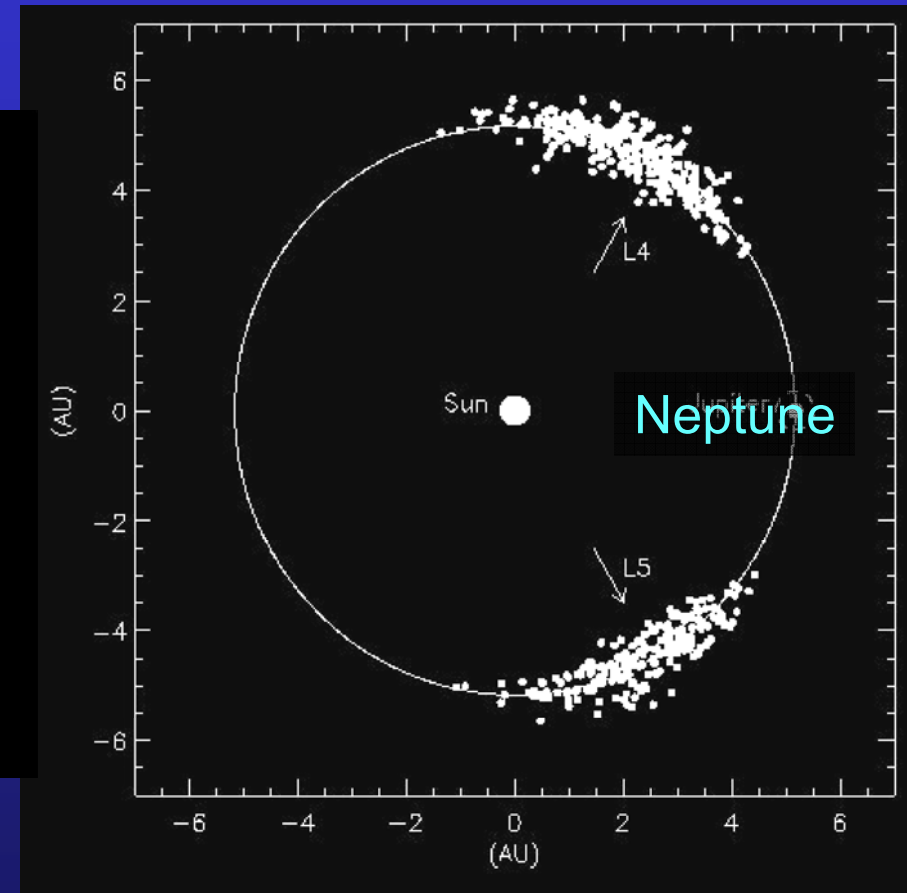
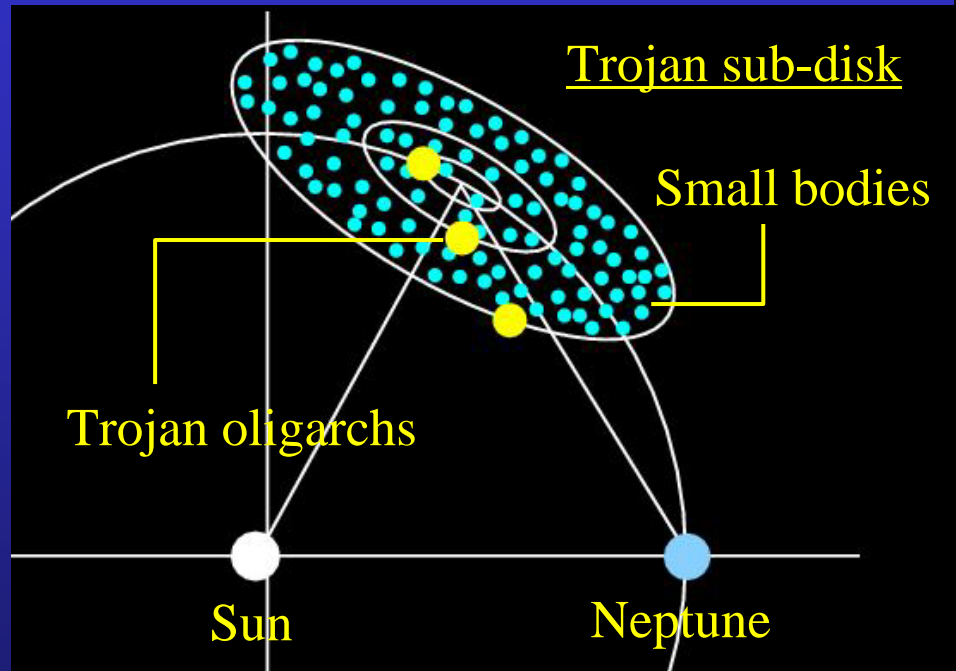


Dispersion-dominated Oligarchy



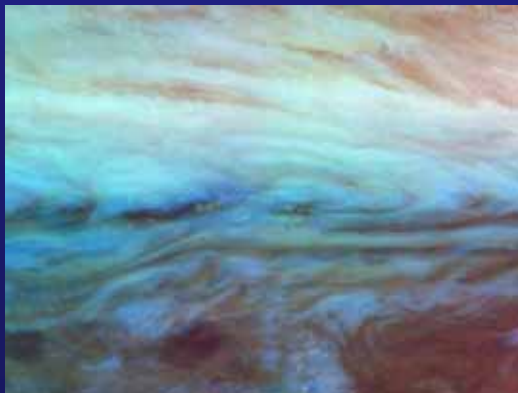
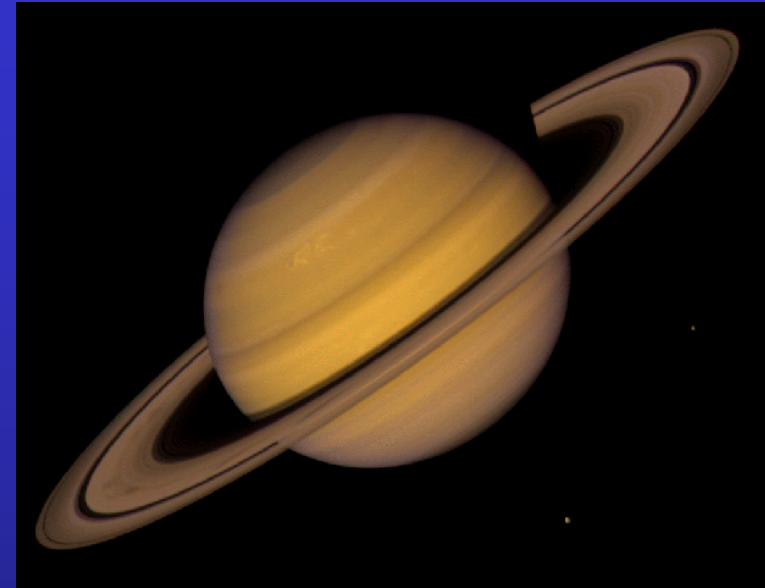
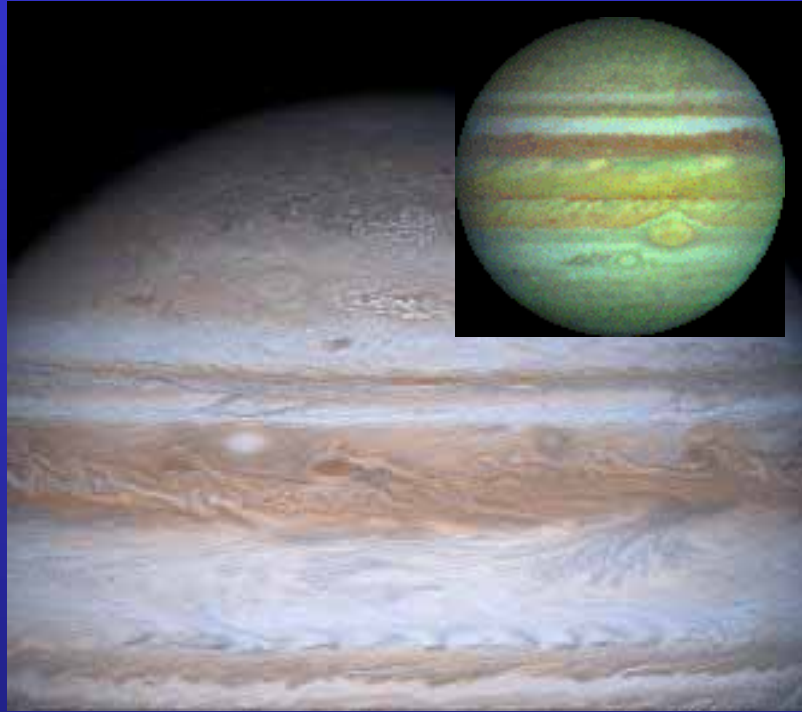
Neptune Trojans as Dispersion-Dominated Oligarchs

“Move over Jupiter”

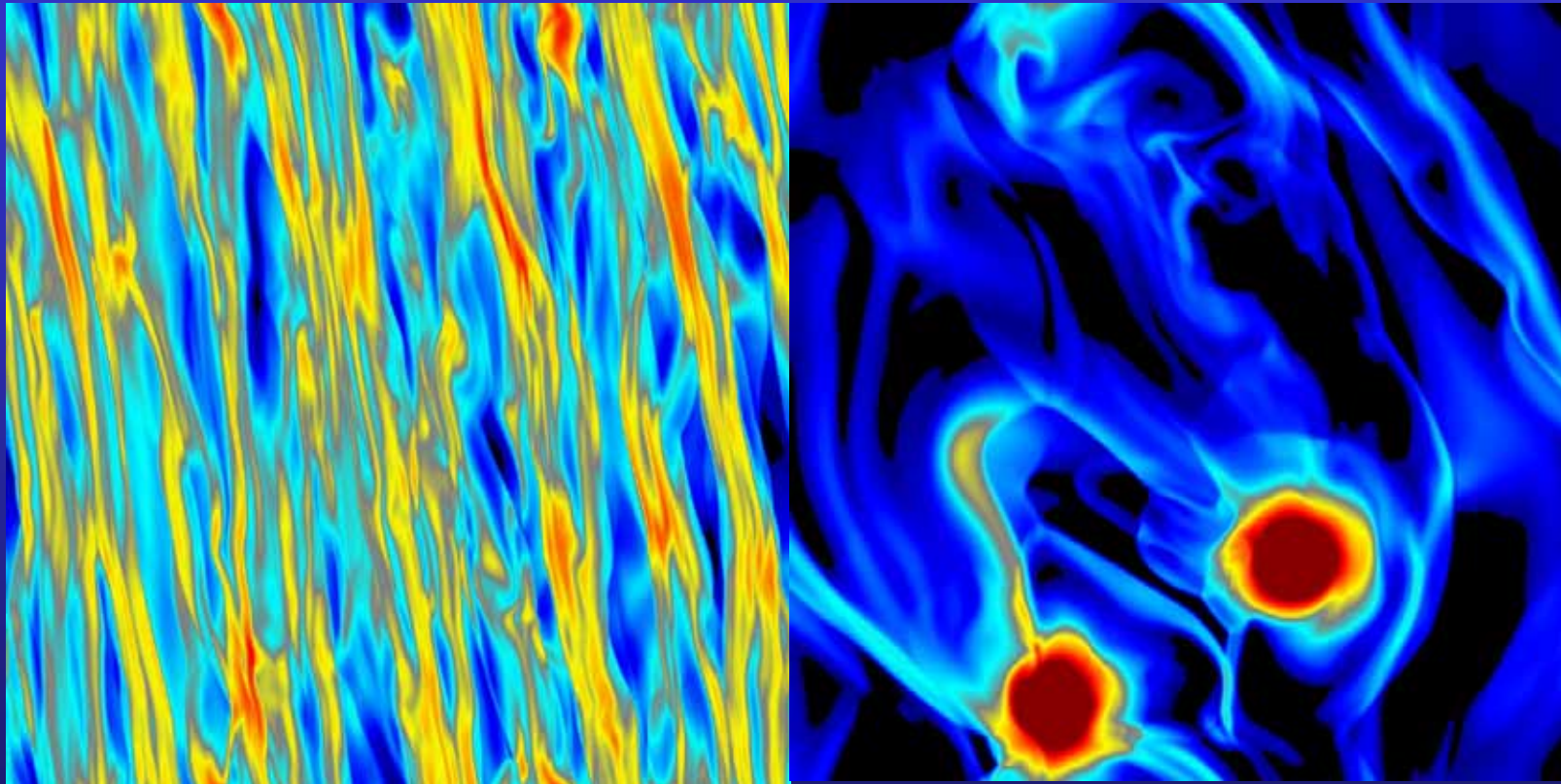


Chiang et al. 2003; Chiang & Lithwick 2005

Gaseous (Liquid) Planet Formation



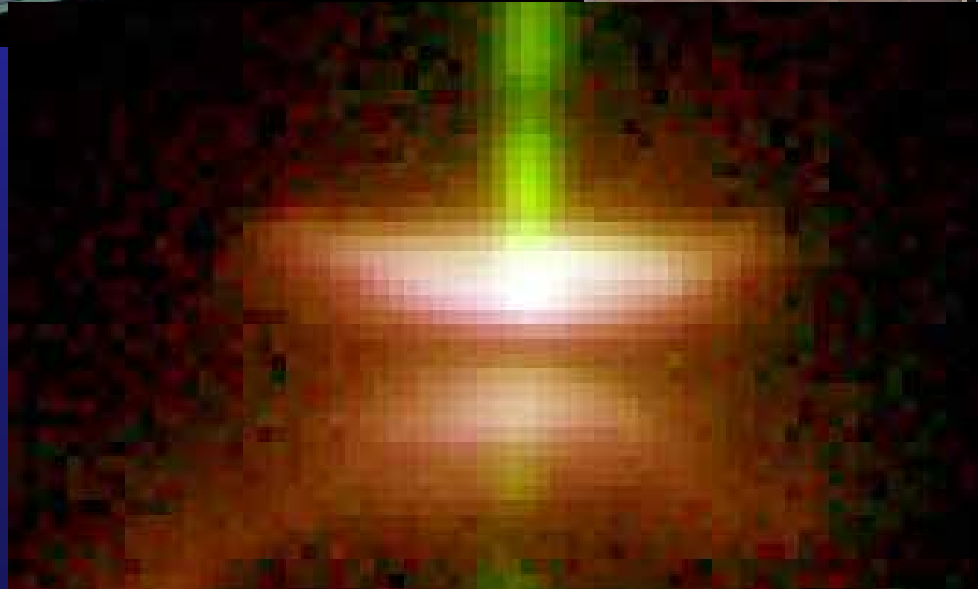
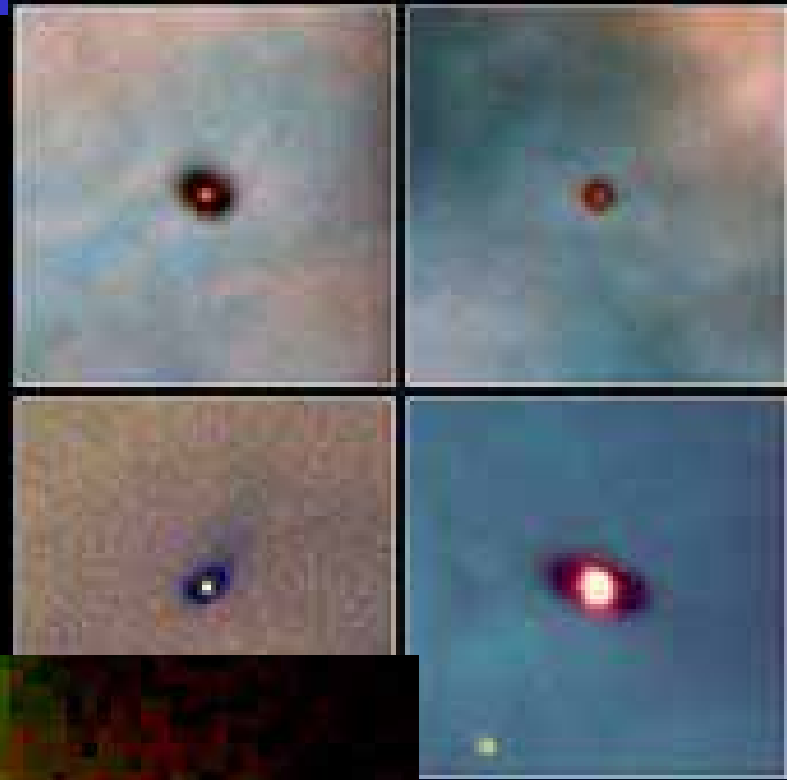
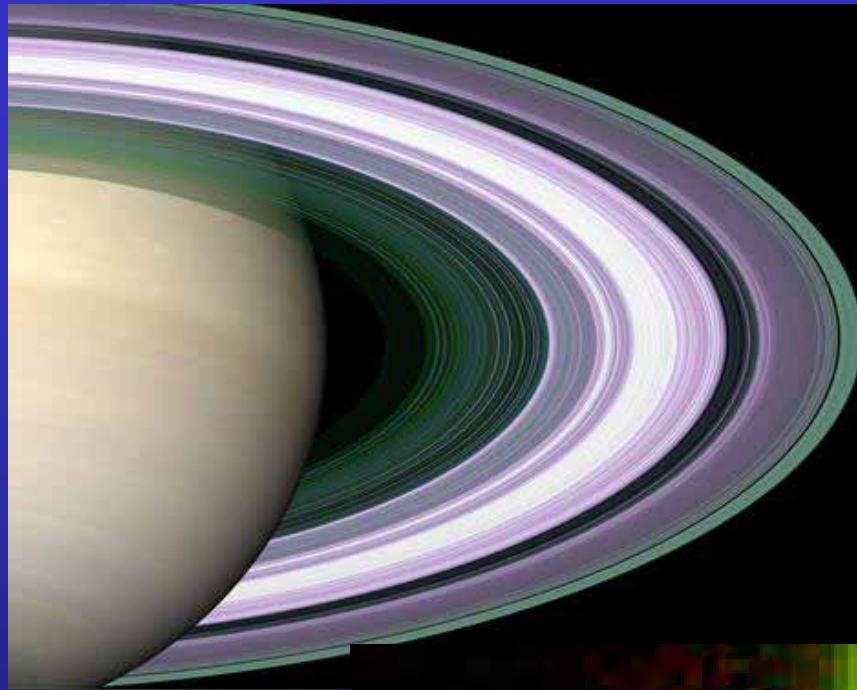
Cooling time vs. Collapse time



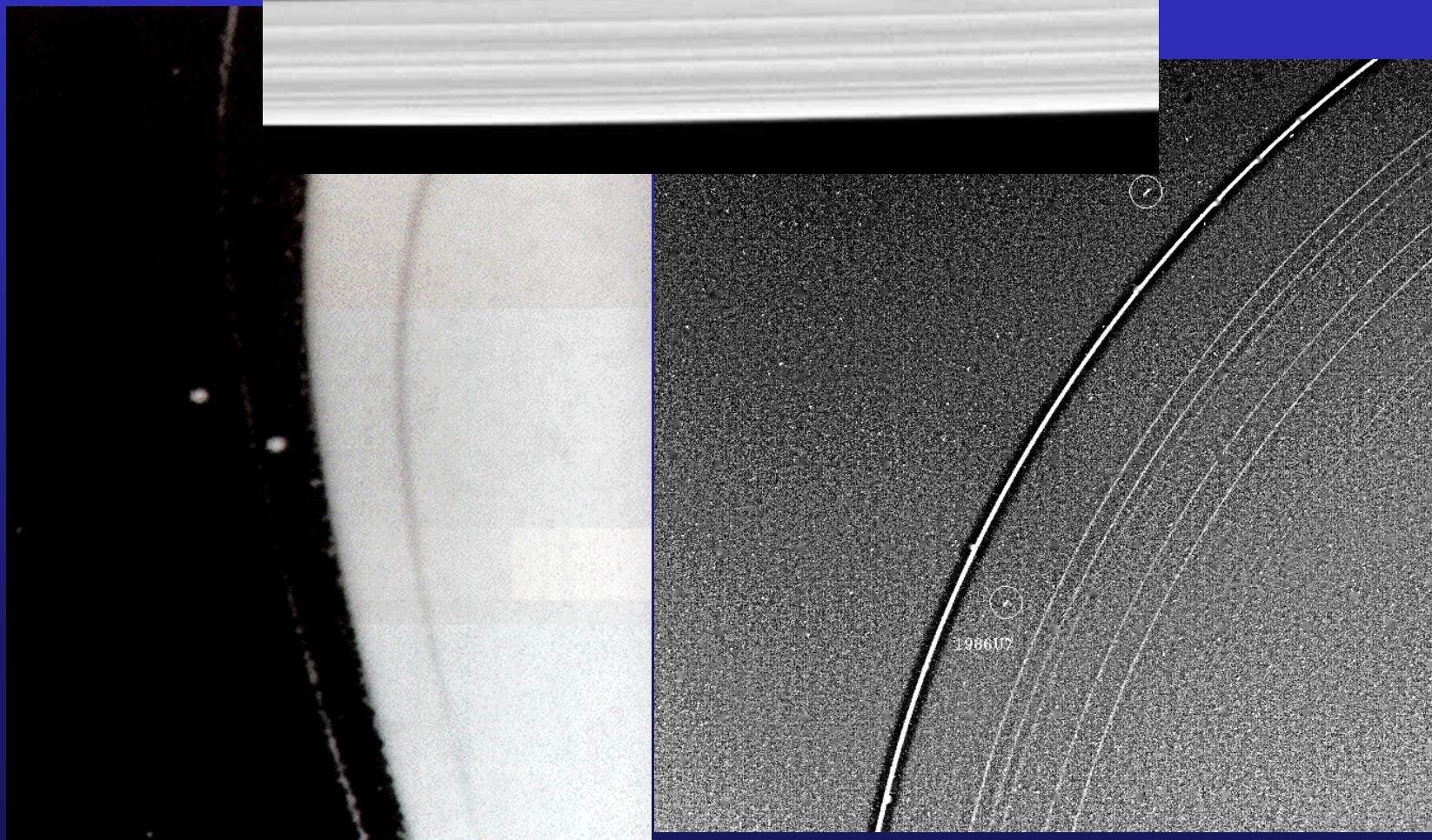
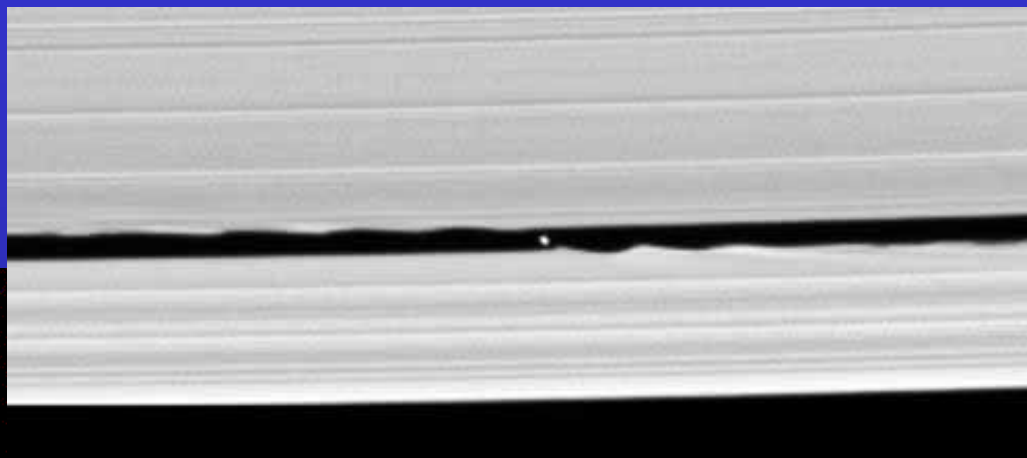
$$t_{\text{cool}} \sim 50/\Omega$$

$$t_{\text{cool}} \sim 2/\Omega$$

Viscous Disks

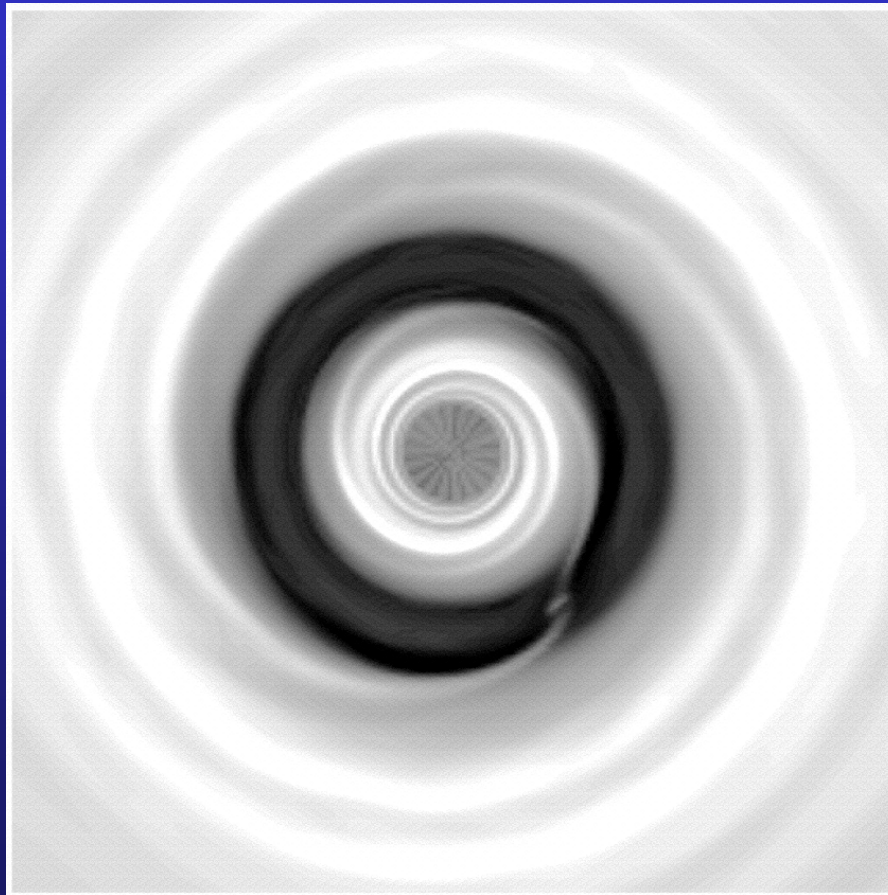


Gap Formation and Ring Confinement

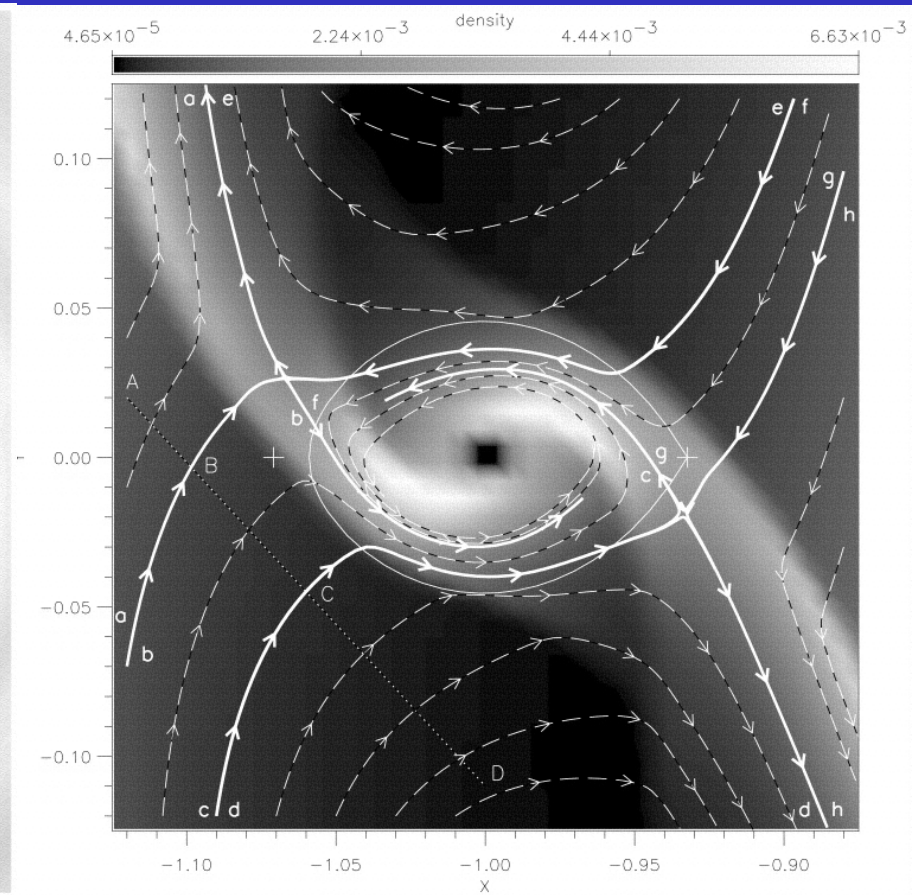


Unclean Gap Formation by Jovian Mass Planets

$$x \sim R_{\text{Hill}}$$

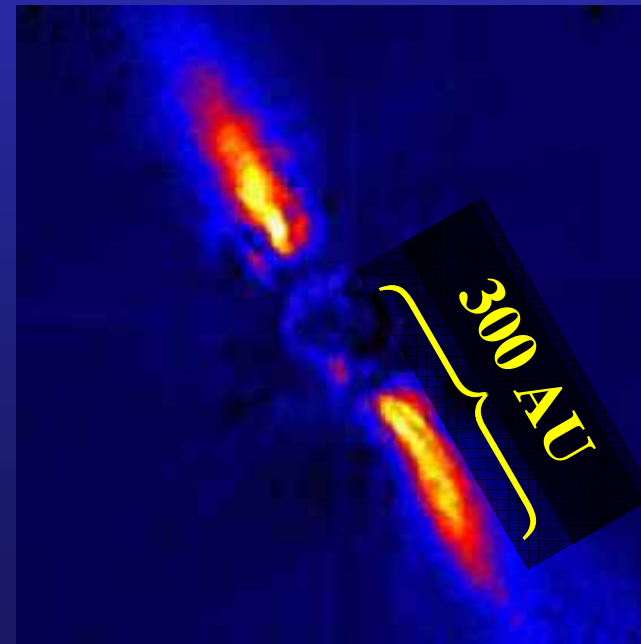
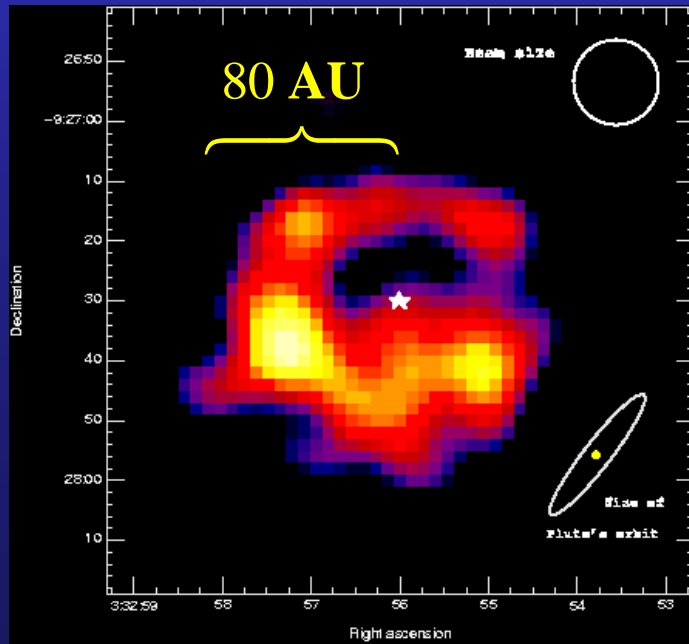
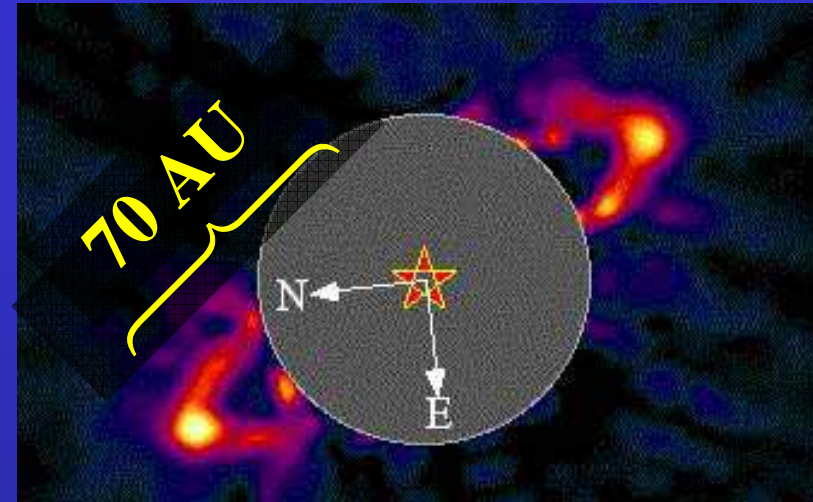


Bryden et al. 1999



Lubow et al. 1999

Debris Disks (Extrasolar Kuiper Belts)



Strength vs. size

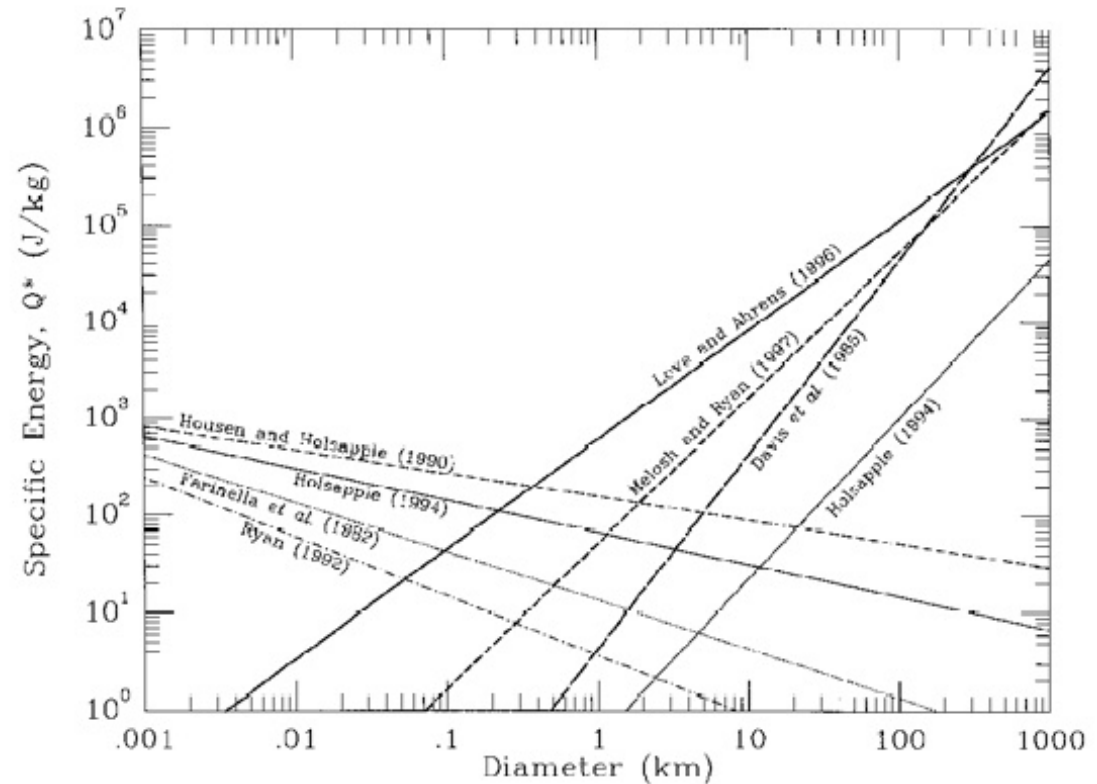
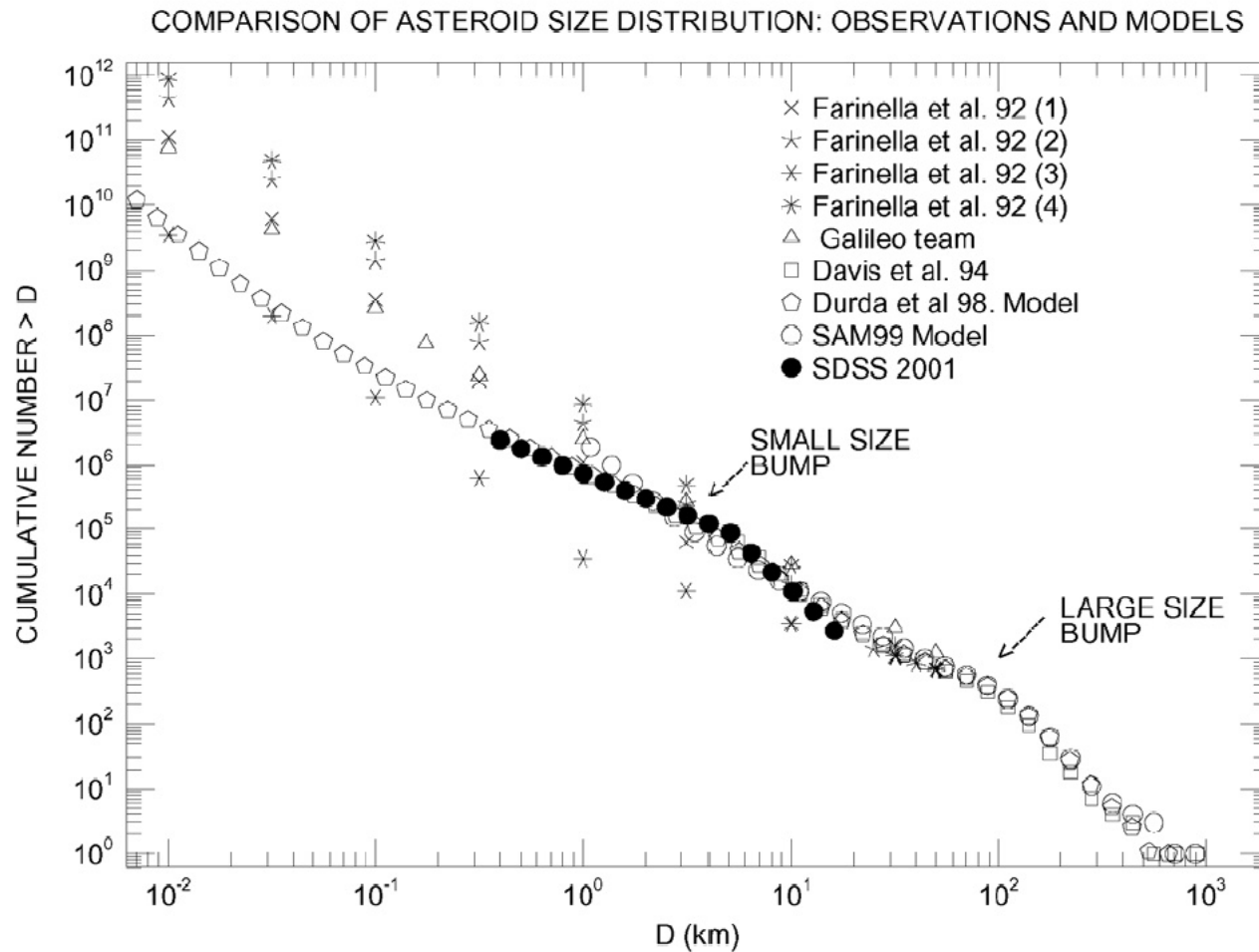


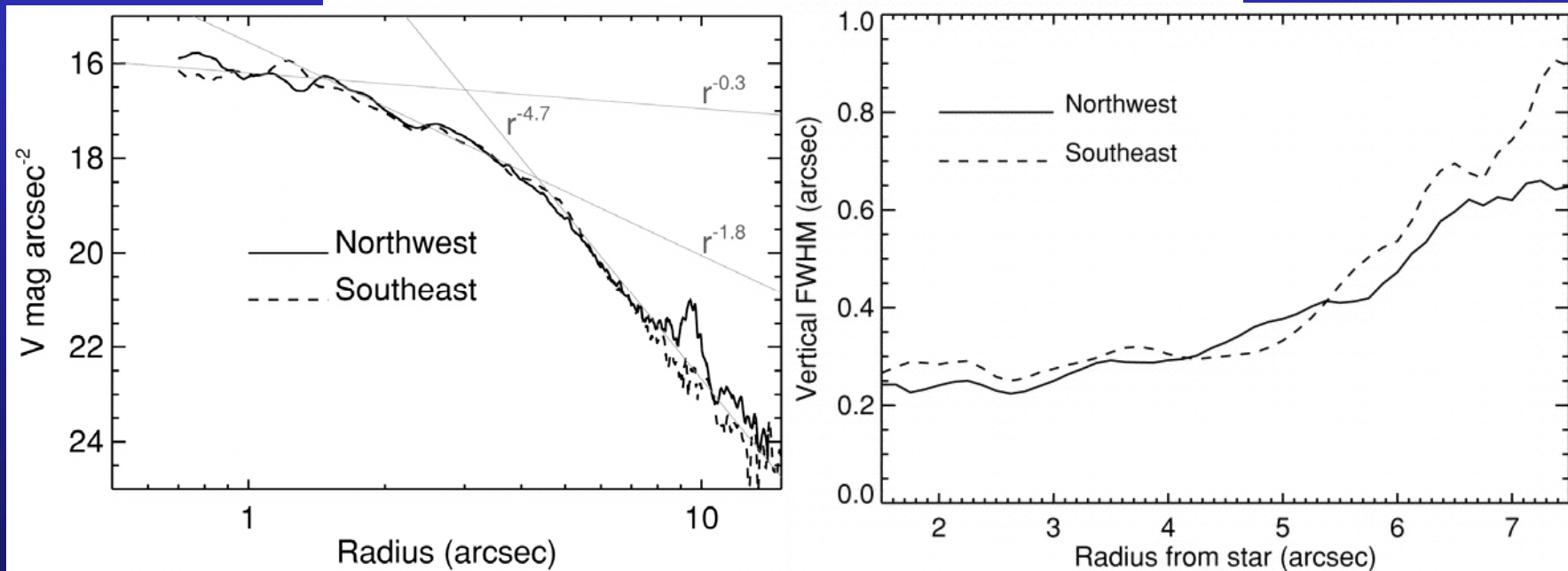
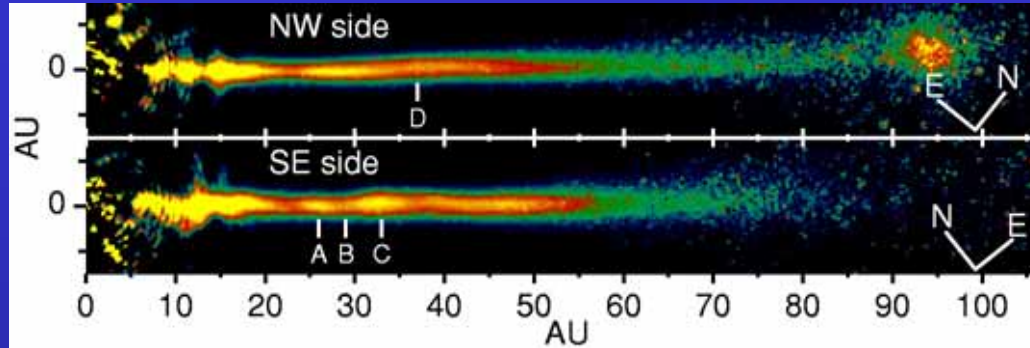
FIG. 1. Representative scaling laws in the strength- and gravity-scaling regimes. Critical specific energies in the strength-scaling regime are loosely constrained by laboratory impact experiments to values near 1500 J kg^{-1} (for solid, competent silicates) for target diameters of $\sim 8 \text{ cm}$. Strength-scaled specific energies decrease with target diameter as $D^{-0.24}$ (Housen and Holsapple 1990), $D^{-0.33}$ (Holsapple 1994), $D^{-0.5}$ (Farinella *et al.* 1982), or $D^{-0.61}$ (Ryan 1992). In the gravity-scaling regime the specific energy increases with increasing target size, scaling as $D^{1.13}$ (Love and Ahrens 1996), $D^{1.5}$ (Melosh and Ryan 1997), $D^{1.65}$ (Holsapple 1994), or $D^{2.0}$ (Davis *et al.* 1985; nominal parameters, including fragment dispersal).

Observed Main Belt Asteroid Size Distribution



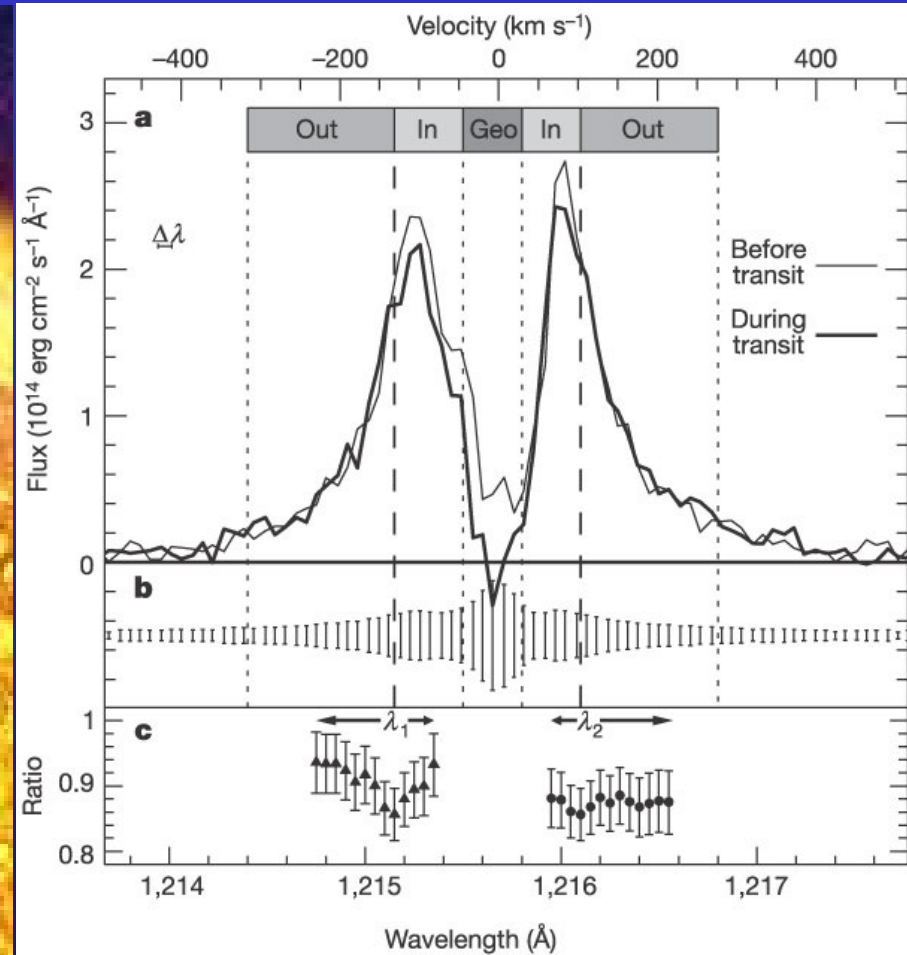
The asteroid size distribution (Davis 2002, in Asteroids III).

The Case of AU Microscopii



Krist et al. 2005

Photo-evaporating Hot Jupiters



Vidal-Madjar et al. 2003