Introductory Astronomy

Week 3: Solar System(s)

Clip 5: Beyond the Snow Line: Giants

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The Rich Life

- Beyond the snow line solids include water (5AU) and methane (30AU) so more prevalent
- Planetesimal and protoplanet formation much faster especially near snow line
- Jupiter grows fastest, reaching $10 - 15 M_{\oplus}$ with rocky core and watery mantle

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Giants

- Once core can bind gas (H_2,He) - grows rapidly until gas in orbit exhausted – 10My
- Core forms accretion disk as gas collapses: protostar at smaller scale – leftovers here are moons and rings
- Saturn farther out starts later, less gas

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More Giants?

- What about ice giants Uranus and Neptune?
- At present location would not grow in time
- Likely formed closer in and migrated out
- Later start – only $\sim M_{\oplus}$ of H_2

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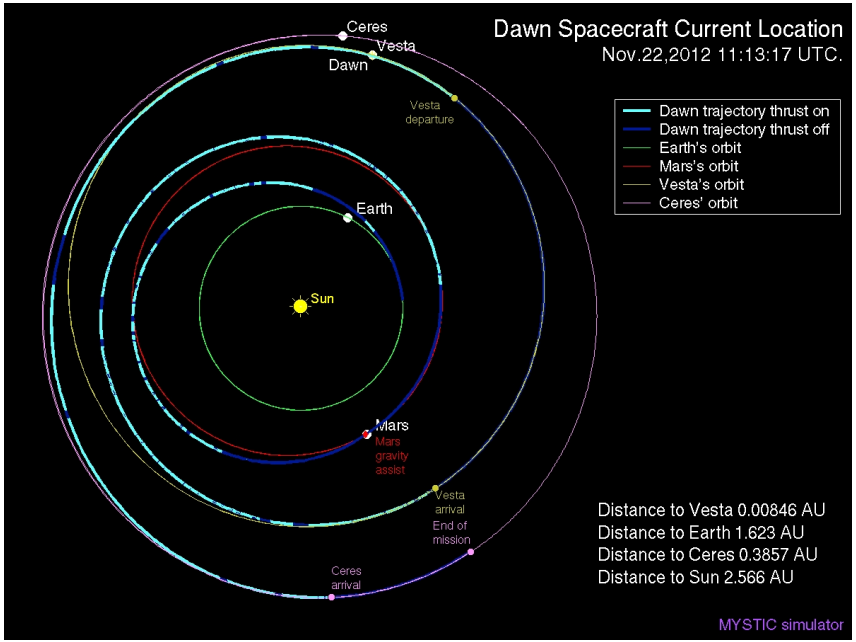
Changing Orbits?

- Newtonian two-body physics is freshman exercise
- Three-body problem unsolvable, chaotic
- Can think of lighter objects as perturbing orbits about most massive
- Near a planet a spacecraft or planetesimal goes into a hyperbolic scattering orbit
- After scattering off moving planet it goes into a new Solar orbit



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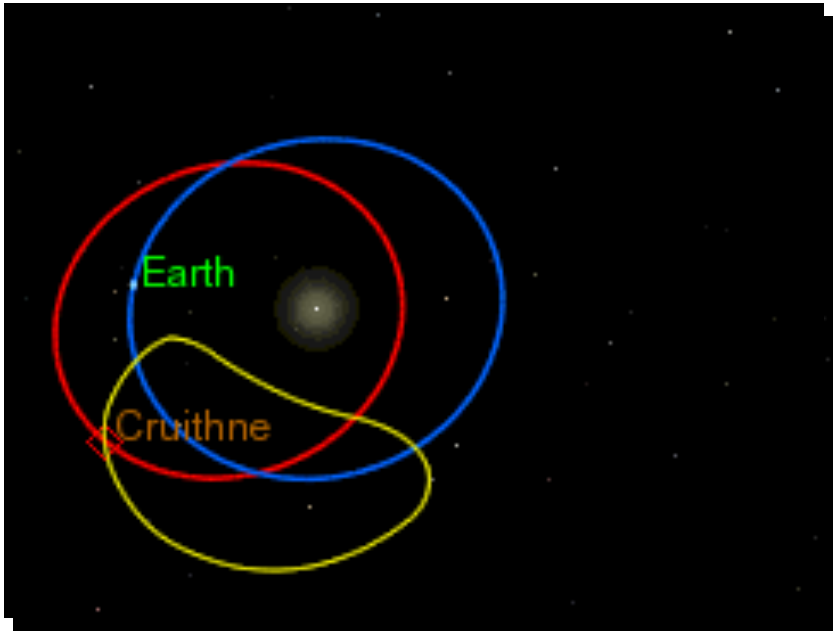
Orbital Resonance

- From a distance gravitational interaction perturbs orbit slightly
- If periods of Solar orbits of two objects are resonant perturbation is commensurate with orbit
- Successive perturbations add
- Can get (meta-)stable resonances
- More frequently resonance destabilizes orbit

Our Other Moon



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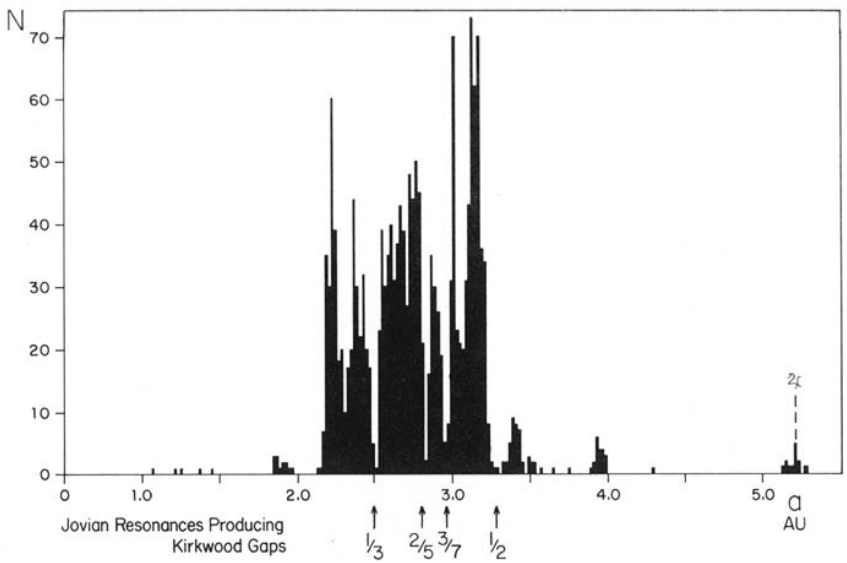
The Asteroid Belt

- 2-4AU out, planet formation disrupted by resonances with Jupiter (and Saturn)
- Orbits near resonance perturbed, creating more violent destructive collisions
- Some material ejected completely – resonant orbits unstable



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Moving Out – the Nice Model

- Four giants form 5.5-17AU from Sun exhausting disk
- Beyond this orbit, $35 M_{\oplus}$ of icy planetesimals to 35AU
- Collisions slow fragments, shift giants slowly out over a few My
- Motion brings Jupiter and Saturn into 2:1 resonance after 600My drawing both into eccentric orbits and destabilizing system
- The joint resonance further depletes asteroid belt

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More Niceness

- Saturn moves out, encountering Uranus and Neptune pushing them into eccentric orbits
- Here they encounter planetesimals destroying disk
- Some planetesimals scattered into higher orbits – Trans-Neptunian Objects
- Others slowed into inner Solar system creating heavy bombardment
- Remnants of disk create friction settling giants into current stable, nearly circular orbits

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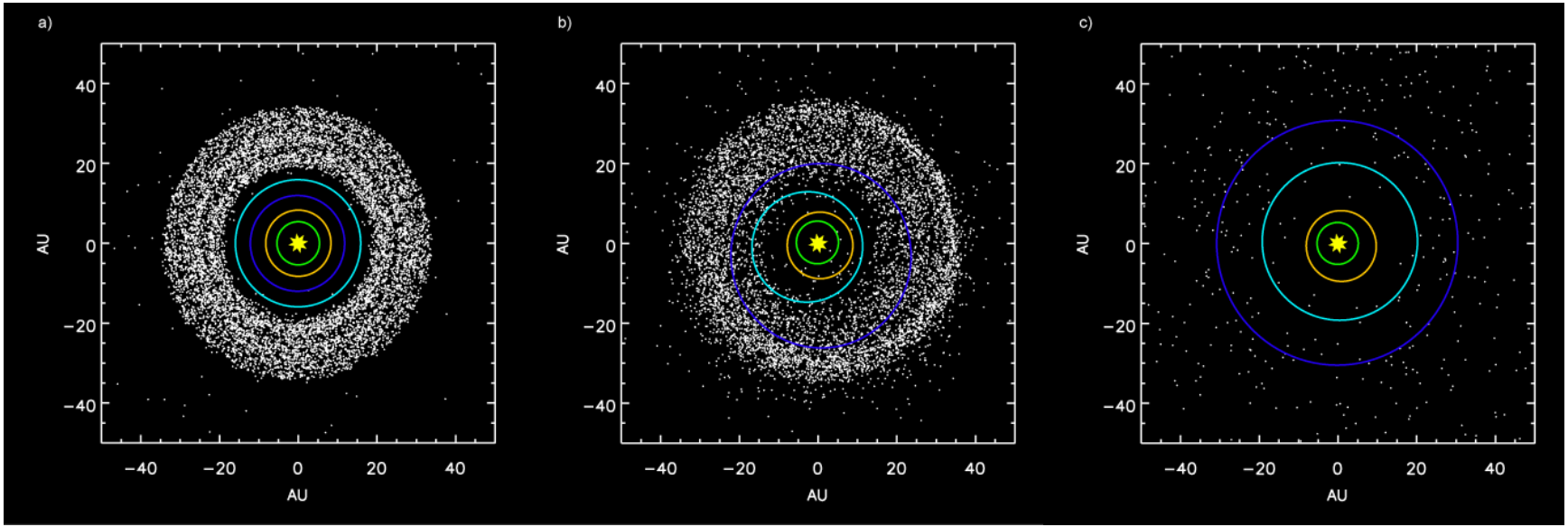
The Nice Model



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Questions

- Why are all planet orbits circular and in a plane? Why aren't comets'? ✔
- Why are planets and large Moons round? ✔
- Why aren't asteroids? ✔
- Why are inner planets small, rocky, dense while outer planets are large, fluid, light? ✔
- Why aren't asteroids a planet? ✔
- What is the story with Pluto?
- Why do some planets have magnetic fields and others not?
- What are rings? Why are Saturn's different?
- What made all the craters? Where did it go?
- Why do comets fall into inner Solar System? Why do asteroids fall into near-Earth orbits?
- If orbits can change – will planet orbits? Have they? ✔✗
- Where did it all come from? When? ✔

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Summary: Timeline

- 0: Supernova(e?) triggers collapse 4.56Bya
- 100Ky: Planetesimals
- 10My: Outer planets have formed
  Protoplanets in inner system
  T-tauri winds sweep away gas and dust
- 100My: Inner planets and Moon form
- 600My: Jupiter Saturn resonance. Outer planets migrate, asteroid belt depleted, heavy bombardment
- 700My: Current stable configuration. First life on Earth

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Credits

- Astronomy Animations: University of Nebraska-Lincoln Astronomy Education Group http://astro.unl.edu/
- Cruithne: Wikimedia Commons http://en.wikipedia.org/wiki/3753_Cruithne
- Dawn Trajectory: NASA/JPL http://dawn.jpl.nasa.gov/mission/live_shots.asp
- Kirkwood Gaps: NASA/JPL http://history.nasa.gov/SP-345/p56.htm
- Nice Model: Wikimedia Commons http://commons.wikimedia.org/wiki/File:Lhborbits.png

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