

## CHAPTER 08: MOONS RINGS, AND PLUTO

## NOTES AND SKETCHES

**Current Moon Counts: These change!**

- ◆ Jupiter: 67
- ◆ Saturn: 62
- ◆ Uranus: 27
- ◆ Neptune: 13

**8.1: GALILEAN MOONS OF JUPITER****A Miniature Solar System**

- ◆ Larger solar system trends mirrored in Jupiter's system: Jupiter is the "sun," the Galilean satellites are "planets"
- ◆ Same pattern of decreasing density with distance
- ◆ Low eccentricity orbits, low inclination, rotation and revolution are prograde

**Io: The Most Active Moon**

- ◆ Iron core, rocky mantle
- ◆ Volcanoes!
- ◆ Very, very active: Frequent eruptions
- ◆ Eruptions are energetic: Largest volcano Loki emits more energy than all of Earth's volcanoes combined
- ◆ Weird, sort-of synchronous orbit: Not quite perfect, but tidal bulge always points toward Jupiter, creates tidal force which flexes interior to create volcanoes

**Europa: Liquid Water Locked in Ice**

- ◆ Smaller Fe core than Io, rocky mantle
- ◆ Very likely a thick layer of water bound by ice crust
- ◆ Surface features: No cratering, but "flows"
- ◆ Magnetic field! Implies that Jupiter's field acts on something (salt water is electrically conductive) below crust

**Ganymede and Callisto: Fraternal Twins****Ganymede**

- ◆ Similar layers as Europa: Fe core, rocky mantle, icy/slushy H<sub>2</sub>O covered by solid icy crust
- ◆ Larger than Mercury
- ◆ Craters and maria look similar to Earth's Moon
- ◆ Maria are ice, not rock
- ◆ Weak magnetic field: See Europa above

**Callisto**

- ◆ Does not appear to have differentiated layers
- ◆ Relatively homogeneous structure: Icy/rocky mixture
- ◆ Cratered surface: Rapid cooling preserves ripples (Valhalla)

**8.2: THE LARGE MOONS OF SATURN AND NEPTUNE****Titan: A Moon With An Atmosphere**

- ◆ Not quite as large or as massive as Ganymede, but almost twice the size of Earth's moon
- ◆ Exciting! We have actually landed there!
- ◆ Huygens hitched a lift on Cassini, parachuted down to Titan in Jan 05
- ◆ Geologic activity: Quakes and volcanoes
- ◆ Weather: Methane rain!
- ◆ Lakes: Too cold for liquid H<sub>2</sub>O, but lakes of liquid methane (CH<sub>4</sub>), ethane (C<sub>2</sub>H<sub>6</sub>), and propane (C<sub>3</sub>H<sub>8</sub>)

**Titan's Atmosphere**

- ◆ Thicker/more pressure than Earth, mostly nitrogen (98%) and methane
- ◆ 10x more gas than Earth's atmosphere. Seriously
- ◆ Complex chemical reactions occurring in atmosphere: hydrocarbon extravaganza (organic molecules detected)
- ◆ Small size = low gravity, but very cold (< 100K) means that molecules in atmosphere are moving very slowly (less than escape velocity)

## NOTES AND SKETCHES

**Triton: Captured From the Kuiper Belt?**

- ◆ High orbital inclination, retrograde direction suggest capture, not evolution
- ◆ Icy chunk with thin nitrogen atmosphere probably sourced from moon's interior
- ◆ Nitrogen geysers
- ◆ Doomed: Spiraling slowly towards Neptune

**8.3: THE MEDIUM-SIZED JOVIAN MOONS****Similar Properties**

- ◆ Saturn, Uranus, and Neptune all have similar medium sized moons
- ◆ 200–800 km diameter
- ◆ Rocky/icy composition (densities 1000–2000 kg/m<sup>3</sup>)
- ◆ Low eccentricity, tidally locked orbits

**Radiation Darkening**

- ◆ Uranian moons darker than Saturn's
- ◆ High-energy solar radiation breaks apart surface molecules
- ◆ This causes chemical reaction on surface (hydrocarbons again)
- ◆ No clue why this happens more at Uranus than Saturn

**Iapetus**

- ◆ Iapetus: Weird asymmetric coloration
- ◆ Light/bright icy hemisphere, darker cratered hemisphere
- ◆ Particles from Saturn's new ring? Radiation darkening?

**Mimas**

- ◆ Death star

**Enceladus**

- ◆ Very high albedo! Why so shiny?
- ◆ Water below surface: Geysers similar to Triton
- ◆ Icy ejecta gives Enceladus a coating of ice, also replenishes Saturn's E ring

**8.4: PLANETARY RINGS****Saturn's Spectacular Ring System**

- ◆ Rings not solid, made up of many, many chunks
- ◆ Low eccentricity orbits
- ◆ Mostly icy pieces, highly reflective (bright)
- ◆ Surprising amount of rocky bits (darker pieces you can't see until you get there)
- ◆ Cassini data shows thickness: Recent Saturn equinox: rings illuminated edge-on revealed thickness as much as 4 km in places

**The Newest Member of The Family**

- ◆ Starts 6 million km from planet, extends about 12 million km more
- ◆ Thickness is about 20 times diameter of Saturn
- ◆ Tilted about 27° from plane of main ring system (Saturn's equatorial plane)
- ◆ Huge volume, itty-bitty total mass: Not many particles, very far apart
- ◆ Moon Phoebe located in the center of ring
- ◆ Phoebe and ring particles orbit Saturn in retrograde direction

**The Roche Limit**

- ◆ What causes rings: Gravity (What, you were expecting some other answer?)
- ◆ Get too close to primary and tidal force is greater than internal gravitation force
- ◆ Object will be literally torn to pieces, and those pieces will form a ring
- ◆ Roche Limit: How close an object can get depends on what it orbits (2.4x planet radius for jovians)

## NOTES AND SKETCHES

**Fine Structure in Saturn's Rings**

- ◆ What causes fine structure: Gravity (You cannot possibly be surprised by this)
- ◆ Moonlets: Small by moon standards, but large by ring particle standards
- ◆ Moonlets can clear their orbits, create gaps between rings
- ◆ F ring: Shepherd moons push-pull on ring particle, create twisted/braided structure

**The Rings of Jupiter, Uranus, and Neptune**

- ◆ Yes, Jupiter has a ring. Not very impressive, but it has one.
- ◆ Uranus' rings tend to look like Saturn F: Narrow, dark, widely spaced, shepherd moons
- ◆ Neptune: Rings are dark, sparse, hard to see (shepherd satellites are probable)

**The Formation of Planetary Rings**

- ◆ Stuff gets caught, torn apart
- ◆ Eventually, rings dissipate as stuff slowly spirals into planet
- ◆ Look for Triton to create a spectacular ring system for Neptune...in about 100 million years

**8.5: BEYOND NEPTUNE****The Discovery of Pluto:****When Two (Or Three) Wrongs Make A Right**

- ◆ Orbital irregularities in Neptune: Gravity predicts how much mass/located where another planet would have to be
- ◆ Percival Lowell (Mars canal guy) made the prediction, assistant Clyde Tombaugh found the object in 1930
- ◆ Problem 1: Neptune does not really have irregular orbit—we measured the mass more accurately, and it's doing exactly what it should be doing (no need to invoke another planet's existence)
- ◆ Problem 2: Pluto found "only"  $6^\circ$  from predicted location—this is the astronomical equivalent of looking for a needle in a haystack, where you predicted the haystack would be here in Arkansas, but you found a needle in a haystack on the Moon. Sure, you found a needle, but no matter *what* you say, it was *not* the needle you were looking for
- ◆ Problem 3: Pluto is far too small to perturb the orbit of Neptune in any perceptible or measurable way

**The Pluto-Charon System**

- ◆ Pluto looks suspiciously like Triton (size, density, composition)
- ◆ Charon very large compared to Pluto: Co-planet
- ◆ Charon orbits in Pluto's equatorial plane (which is highly inclined with respect to ecliptic), circular, synchronous
- ◆ Two additional smaller moons (Nix, Hydra) confirmed by HST in 2006., one more (Kerberos) in 2011
- ◆ High eccentricity, high inclination, retrograde rotation: in-situ evolution unlikely, implies Kuiper Belt origin

**Plutoids and the Kuiper Belt**

- ◆ Over 1200 objects have been found in region at 40–50 AU
- ◆ KBO = Kuiper Belt Object
- ◆ No idea precisely how many KBOs are out there; gravity estimates  $\approx 100k$ , total mass still somewhat less than Earth
- ◆ Very small, very cold, very far = very hard to detect
- ◆ Dwarf planets: Includes largest KBOs, Pluto, even Ceres

**It's Not Like We've Never Done This Before**

- ◆ 25% of known KBOs exactly the same period as Pluto...coincidence? No, just gravity
- ◆ If Pluto was discovered today, it would automatically be grouped with the KBOs
- ◆ Back in the early 1800s, Vesta, Juno, Ceres, and Pallas (who??) were classified as planets
- ◆ When astronomers discovered that they were part of asteroid belt, they were *surprise!*—reclassified as asteroids