Honors Seminar 259 — cheat sheet for 9/29/2008 — Andrew Baker

Stevenson (2001)

You should read the whole article. Key questions:

1. What are the two lines of evidence the author presents to argue that the solar system and the Jovian satellites did *not* form in the same way? In what respect is the formation of the Earth-Moon system again different?

2. Are the Jovian satellites that we see now likely to have been the only ones ever formed?

Key terms:

- **accretion** = process by which a large mass builds up through the slow addition of smaller particles or masses
- **accumulation time** = length of time it takes for a solid body to build up to a given mass from a gas structure (e.g., a disk)
- **angular momentum** = roughly speaking, the product of the mass, distance, and velocity of one object orbiting another (or of an object spinning about its own axis); this is a quantity that is *conserved* (i.e., remains constant) unless one applies a *torque* to the system
- **collapse time** = length of time it takes for a gas cloud to collapse into a condensed structure (e.g., a disk)
- **differentiation** = the extent to which the various consitutents of a mixture (e.g., the rock and ice constituting a planetary satellite) have separated from each other
- **heat of vaporization** = energy per unit mass required to convert a substance into a vapor
- **migration** = process by which one body revolving around another moves to a different orbital radius due to gravitational interactions with other orbiting material
- **orbital time** = length of time it takes for one body to revolve around another
- **prograde** = adjective describing orbital motion that is in a "right hand" sense (as described by the direction your right hand's fingers curl when your right hand's thumb is pointing up)

Canup & Ward (2002)

For this paper, you can read only the abstract, §1 (skipping the details of the equations in §1.4), and §4 (skipping the appendix), which comes to about seven pages total. Key questions:

1. What is the difference between the protoplanetary disk and a circumplanetary disk?

2. How are mineral deposits on the inside of a pipe similar (in the authors' view) to the Jovian satellites?

3. Qualitatively, what are the differences between the "spin-out disk", "accretion disk", "impact-generated disk" and "co-accretion" models for the formation of the Jovian satellites?

4. What is the "incomplete differentiation" of Callisto, and what does it tell us about the timescale on which it formed?

5. Why might the authors favor the "least restrictive" model for the formation of the Jovian satellites?

6. What are the problems with the "minimum mass subnebula disk" model, and how does the "gas-starved disk" model solve them?

Key terms:

- **accretion radius** = radius from which an object in formation pulls in gas
- **density wave** = a progapating disturbance of higher density in a gas disk (as in the case of surface waves on a body of water, the material itself does not move at the same velocity that the wave does)
- **eccentricity** = degree to which an orbit is not circular
- **envelope** = outer layers of a collapsing gas cloud (as distinct from the central *core*)
- **Galilean satellites** = Io, Europa, Ganymede, and Callisto (the four largest satellites of Jupiter that were discovered by Galileo)
- **gravitational binding energy** = the potential energy that becomes available when a particle moves closer to the body to which it is gravitationally attracted
- **gravitational focusing factor** = factor by which gravity makes it more likely that two objects passing near each other will actually collide
- **Hill radius** = the radius within which one body (say, Jupiter) is grvitationally dominant over the larger body (say, the Sun) about which it revolves
- **hydrocode** = hydrodynamic code, for a particular type of computational modelling
- **hydrostatic equilibrium** = the condition in which pressure and gravity forces precisely balance
- **inviscid** = not viscous
- **Kelvin-Helmholtz cooling** = process by which outer layers of a star, planet, or gas structure cool and shrink (thereby heating the inner layers back up again, at least for a while)

- **L1 and L2 points** = two of five "Lagrange" points at which the combined gravitational attraction of a larger and a smaller body (e.g., the Sun and Jupiter) could allow a third body to orbit the latter in an apparently "stationary" position
- **Laplace resonance** = regular relationship between the orbits of Io, Europa, and Ganymede
- **Lindblad resonance** = a particular location within a rotating disk defined by its dynamical properties
- $M_\oplus$ = mass of the Earth ($\approx 6 \times 10^{27}$ g)
- $M_\odot$ = mass of the Sun ($\approx 2 \times 10^{33}$ g)
- **minimum mass nebula** = in models for the formation of the solar system, a cloud of gas that would have the same composition as the Sun and exactly as much mass of "heavy" elements to build the planets as they are observed today (i.e., *more* mass overall than the sum of the masses of the current planets)
- **moment of intertia** = a single number that depends on how the mass within a body is distributed; given two objects with identical masses, the object with higher moment of intertia (e.g., a hoop) will be tougher to get spinning than the object with lower moment of inertia (e.g., a disk)
- N**-body simulation** = numerical simulation involving a large number (N) of particles
- $O(10^2)$ = of "order" 100 (i.e., a few hundreds)
- **obliquity** = tilt of an astronomical body's spin axis with respect to its axis of revolution
- **optically thin** = capable of being penetrated by radiation
- **orbital decay** = tendency of an orbiting body to lose angular momentum and slip inward to a smaller radius
- **photospheric** = adjective describing the surface of a star or gas structure
- **Roche lobe** = volume of space within the Hill radius (in this context)
- **scale height** = typically, half the thickness of a disk measured in cross-section
- **sound speed** = rate at which "news" of a disturbance can be propagated in a given medium (sound in air is one example, but not the only one)
- **specific angular momentum** = angular momentum per unit mass
- **sublimation** = process in which a solid is converted directly to gas phase
- **surface density** = mass per unit area (calculated as though you are looking at a disk from above)

- **tidal interactions** = phenomena that result from the fact that a large body pulls on the near and far sides of a small body with different gravitational forces
- **torque** = force applied at a particular radius, which can lead to the gain or loss of amgular momentum
- **type I migration** = orbital decay experienced by a relatively small body that does not open up a gap in a disk, and that loses angular momentum to the disk
- **type II migration** = orbital decay experienced by a relatively large body that does open up a gap in a disk, and that loses angular momentum slowly as the disk gas inside the gap tries to spread outward
- **viscosity** = roughly speaking, the resistance and stickiness of a fluid (e.g., motor oil is much more viscous than water)

Canup & Ward (2006)

For this paper, you should read only the first page and the last paragraph ("General implications"); you may also find Figures 2, 3, and 4 interesting. Key questions:

1. What is the relationship between this paper and Canup & Ward (2002)?
2. What are the differences between the "regular" and "irregular" satellites of the outer planets?
3. Why do the authors claim that they can characterize the amount of gas in a circumplanetary disk as a "quasi-steady state"?
4. If we detect an extrasolar planet of a given mass, what can we conclude about the mass(es) of any satellite(s) in orbit about it, according to the authors of this paper?

Key terms:

- **aerodynamically bound** = tied together via frictional forces
- **aerodynamic drag** = a generalization of air resistance to the friction exerted by any fluid
- **analytical** = in this context, describes a pencil-and-paper calcluation rather than a simulation done with a computer
- **order of magnitude** = factor of ten