**ASTR 621: Planetary Science**

1. Stevenson's 'laws' of origins studies
2. ISM properties
   (a) Important observations:
      i. Only molecules with a permanent dipole moment can be detected by their rotational emission lines, typically at mm and sub-mm wavelengths.
      ii. $H_2$, $C_2$ seen by their electronic absorption lines at optical wavelengths against bright background stars.
      iii. Cannot observe $CH_4$, $N_2$, $C_2H_2$ since no dipole
      iv. Earth's atmosphere prevents $H_2O$, $O_2$, $CO_2$
   (b) **ISM /= protosolar nebula!**
   (c) Magnetic field
   (d) Multiple star systems -8-
   (e) Angular momenta of stars -9-
   (f) Missing mass problem -9-
   (g) Young Stellar Objects (YSOs) -13- Best studied in the IR because they are surrounded by dust, the objects themselves are most luminous in the IR, and there is an increased contrast against the nebular background. T-Tauri stars -15-
      - UV excess
      - IR excess
      - High mass outflow

      T-Tauri stars:
      - Found in molecular clouds and OB associations.
      - $M \sim M_\odot$

   As a result, our information of what may be the dominant C, O, N molecules is indirect and incomplete.
3. Gravitational Collapse -18-
   (a) Jean's Criterion: Uniform, homogeneous gas at rest, infinite extent, assume adiabatic
      - $w^2 = c^2k^2 - 4\pi G\rho_o$; $w$ = frequency... the higher this is, the more stable the cloud is against collapse.
      - $n_{crit} = 10^6(T/20)^3(M_\odot/M)^2$ [cm$^{-3}$]
   (b) Comparison between observation and theory: Rotation and magnetic fields must preserve clouds since we see too many for the short timescales predicted by theory to be true.
   (c) Fragmentation

(d) Collapse modification

- $w^2 = c^2k^2 + 2(\omega k)^2/k^2 - 4\pi G\rho_o$
  $w^2$ is increased with a third term (always positive or zero) that accounts for rotation, which prevents collapse.

4. Dust in the Nebula -113-

5. Particle Motion in the nebula -124-

6. Processes that affect particle radial location in the nebula -129-

   (a) gas drag

   (b) radiation force

   (c) Poynting-Robertson Drag

   Yarkovsky effect: experienced by objects large enough to experience spatial variations in surface temperature
   $--> $ Spiraling radially outward!

7. The Hill radius
   Range of gravitational influence of planet orbiting a star.

8. Planetary Migration

   - Type I: linear, low-mass planets (¡ $M_{Saturn}$)
   - Type II: non-linear, gaps, larger masses

9. Comets