ASTRO190 HOMEWORK #5, DUE March 4.

Please get help if you need it. My office hours are the hour after each lecture. Or arrange an appointment.

1. Dark Matter (2 pts). Briefly describe two methods that allow us to estimate its mass and its location in galaxies or clusters of galaxies.

2. Cosmic Geometry (2 pts). By the 1980s Sandage and his colleagues had extended observations of the Hubble Law to cosmic distances of five billion of light years. Their failure to find any trace of curvature in the Hubble Law showed that the cosmic mass density was at least a factor of ten short of closing space.

a. At about that time we found that the mass of dark matter was about five times greater than visible matter around galaxies and clusters of galaxies. How did this discovery affect our understanding of cosmic geometry?

b. By the year 2000 we learned that extremely luminous supernovae can be used as standard candles that extend our ability to measure distances and redshifts to distances of ten billion light years or more. How did this affect our understanding of cosmic geometry?

3. **Jerry Ostriker** (2 pts).

a. Ostriker (p. 166, 187-188) essentially invented DM just before it was discovered. He had argued that modern galaxies could not have formed unless dark matter was plentiful when the CMB was formed, and he asserted that the ratio of the mass of dark to luminous matter had to be close to present observational results. Why does dark matter play a vital role in galaxy formation?

b. Ostriker also argued on strictly theoretical grounds that the existence of galaxies requires that the results of Sandage and colleagues must be wrong. What was his argument?

4. Fine Tuning (4 pts). The Standard Big Bang Model must be delicately "fine tuned" like a superior musical instrument in order to successfully explain the properties of the present Universe. Ostriker & Mitton list three puzzles related to fine tuning, or "conundrums", called "The Horizon Problem", "The Flatness Problem", and the "The Exotic Particle Mystery" (pages 155-7).

a. Consider the first of these, the "Horizon Problem". What's the problem?

b. The Horizon Problem is resolved if the Universe suddenly "inflated" in size when it was extremely young. How does Inflation resolve the Horizon problem?

c. Consider the second of these, the "Flatness Problem". What's the problem?

d. Was this problem resolved prior to the discovery of dark energy? How?