

Study Questions for “Microcosm and Macrocosm” (Lectures Feb. 14 – Feb. 18)

- 1) List the four fundamental forces in order from strongest to weakest. (As I did in class, use the strengths of the forces between 2 almost touching protons as the basis for your comparison.) Describe at least two important roles each force plays in the evolution of the universe; include in your description a statement of whether the force is long range or short range.
- 2) What does it mean when we say that atoms are electrically neutral? Explain why neutral atoms that are relatively far apart (say 10 atomic diameters) have essentially no electromagnetic effect on each other, while nearby neutral atoms can have important electromagnetic effects. How do chemical forces fit into this picture?
- 3) Explain why “gravity is the only game in town” between the period of decoupling and when stars and galaxies form. What features of gravity allow it to be important when all three other fundamental forces are completely unimportant?
- 4) Compare the formation of a galaxy to the formation of the solar system. What plays the role of the sun in the case of a galaxy? What does the analogy to the twirling skater pulling in her arms tell us in each case?
- 5) What type of object is at the center of most (or all?) galaxies? Are the centers of galaxies dark (emitting no electromagnetic waves) or light? Why?
- 6) What is a quasar? Why are they only found in young galaxies? Why are all the quasars that have been found far away from the earth?
- 7) Why are “normal” galaxies “spiral shaped” rather than simply disk shaped, like a Frisbee? What are elliptical galaxies, and how are they formed?
- 8) What is the basic process that gives normal stars (like the sun) the energy to shine? (You don’t need to know the 3 individual reactions that make up this process; just tell what the “raw material” and the “product” are.) Where does the energy released come from? Why is the process slow? Why does the sun produce much less energy per kilogram than a human?
- 9) What is a “T-Tauri” event? When does it occur? Why is it much faster (much more “bomb-like”) than the standard process discussed in question #8?
- 10) Describe the interplay between the strong and the electromagnetic forces in the combining of two smaller nuclei to make a larger nucleus. (You might consider proton + deuterium makes ^3He as an example.) What is the Coulomb barrier? Why do processes that combine nuclei only occur after the core of a star has been greatly compressed? Why are such process called “*thermonuclear*” processes?
- 11) What happens to a star after it uses up all the raw material for the process discussed in question #8? Include in your discussion what happens in the core of the star as well as what happens to the outer layers.

- 12) Explain, using the idea of the Coulomb barrier, why “helium burning” requires a higher temperature than “hydrogen burning.” In stars that burn helium, what causes the higher core temperature in the first place?
- 13) Suppose the force of gravity were 1,000,000 times stronger than it is. Life as we know it would then have been unlikely to develop. Why? Repeat for a force of gravity 1,000,000 times weaker than it is. (By “life as we know it” I mean life on a planet circling a star, based on some complicated chemical reactions among atoms, and using for energy the electromagnetic radiation produced by the star. I don’t mean any more specific traits like “having arms and/or legs,” “using DNA,” or “based on cells.”) [Hint: consider whether stars could form in each case, and, if so, how long they would live. I did not discuss this question explicitly in class, so you will need to extrapolate from what I said to answer it. If you find it too hard --- which is quite possible, maybe even probable! --- just ask me about it after class or in office hours. You are of course also welcome to ask about any of the other study questions.]