ASTR 220 Homework #2 Solutions
Spring 2005

1. The heavy bombardment was a period in the first 300 million years or so of the solar system's life when large, leftover planetesimals impacted all planets and moons in the solar system

   The bombarding objects were leftover debris, just like the asteroids and comets in the solar system today. Asteroids and comets are debris that did *not* hit the planets during the heavy bombardment.

2. This discovery would be surprising. According to the nebular theory of solar system formation, the temperature in the protoplanetary disk dictated which types of planets formed where. Close to the protosun, the temperature was hotter, so only metals and rocks could condense. Far from the Sun, it was cooler, so hydrogen compounds could also condense. In order to have jovian planets close to the "Sun", hydrogen compounds would have had to condense at higher temperatures than is possible.

3. This discovery would be surprising. According to the nebular theory of solar system formation, the planets got their orbital motions because of the rotation of the protoplanetary disk around the protosun. The disk was spinning in the same direction at all locations, so planets couldn't form and suddenly start orbiting in the other direction.

4. Suppose the solar nebula had cooled to 50 K before the solar wind blew it away. If that had happened, hydrogen compounds would have been able to condense in the inner solar system as well as the outer solar system. The terrestrial planets would have accreted the usual metals and rocks, as well as hydrogen compounds. Since hydrogen compounds were more abundant, they would have a higher proportion of hydrogen compounds than either rock or metal. They would be a lot larger and more massive than the terrestrial planets we know today.

5. This discovery would be surprising. The oldest meteorites we have discovered so far are about 4.55 billion yrs old. So were we just unlucky until the discovery of this meteorite that is 7.9 billion yrs old? Probably not. The oldest Moon rocks we have measured are about 4.4 billion yrs old. These rocks are from the Moon's highlands, which we believe are unchanged since the heavy bombardment. The nebular theory of solar system formation says that the heavy bombardment only lasted about 300 million yrs. What could the solar system have been doing for the rest of the time, from about 7.6 billion yrs ago until about 4.4 billion yrs ago? It's unlikely that we would never have found a rock that dated in between these.

6. This discovery would be surprising. The comet is orbiting in the inner solar system – the implication is that it never travels into the outer solar system. If the comet were always so close to the Sun, it would pretty rapidly sublimate away and essentially disappear. Plus, an object like that couldn't have formed so close to the Sun.

7. Craters on the Moon and on Earth were originally thought to be the tops of volcanoes. The circular shape is similar to the hole in the top of a volcano (sometimes also called a crater). Scientists also didn't believe enough impacts happened to cause all the craters on the Moon.

8. Why must a good scientific theory be able to be disproven? A theory is a guess about how something works, such as what caused a certain geologic feature to be created. If a theory has no chance of being proved wrong, it is untestable, so it isn't useful. We refine our theories by rigorous experimentation, so if experiments can provide no feedback, the theory can never be conclusive. One could claim any bizarre statement, and as long as it is outside of our ability to test, one could argue that it could be correct. But it's not a useful theory, because if we can't test it, we can not use it to further our knowledge of how nature works.

9. The two hypotheses are:
   (a) An object struck the Earth 65 million yrs ago.
   (b) The effects of the impact caused the mass extinction observed at the K-T boundary.

   The author separated these two hypotheses because it's possible to believe the first, but not the second. Also, proving that an object did strike the Earth 65 million years ago is possible, without proving the second hypothesis.

10. Here are the six predictions, and the scientific evidence relevant to each. (You didn't have to list the predictions.)
   (a) **Impact effects can be seen worldwide at the K-T boundary.** The iridium anomaly has in fact been found in over 100 sites around the world, including fresh and saltwater deposits.
   (b) **High iridium levels and shocked material should be rare in the rock surrounding the K-T boundary.** One one good sample exists that encompasses a wide range in geologic time around the K-T boundary (a core sample from the Pacific floor that dates from 35 - 65 million yrs ago), but on the K-T boundary region shows such features.
   (c) **High iridium levels should be associated with craters.** As of the writing of the book, two craters have been found with match up (in Australia and Scandinavia), but not finding much evidence does not mean much since erosion has likely weathered away most craters on Earth.
   (d) **There should be a thin, worldwide K-T boundary layer with high levels of iridium.** This is basically re-stating part of the first prediction, but the K-T boundary does seem to have a similar appearance almost everywhere that it is exposed.
   (e) **The K-T boundary should contain shocked, metamorphosed material characteristic of impacts.** Such findings were first introduced by Bruce Bohor at a site in Montana, then confirmed at K-T boundary sides all over the world. Shocked quartz and glassy spherules are quit common at the boundary.
   (f) **A big crater exactly 65 million years old must exist somewhere.** However, it is likely that if it is still identifiable after erosion, volcanism and tectonics have done their work, that it is under water and will be extremely difficult to detect. We will find out later in the book that the Chicxulub crater on the Yucatan peninsula is likely the crater created by the K-T impact.

   Which two predictions are the most well-met? The first prediction (and fourth, since it's so similar) and the fifth seem to be the best supported. The K-T boundary has been examined at many sites worldwide, and the impact effects have been seen at those sites.

   Which two predictions are the least well-met? The second prediction is not as well supported because of a limited number of sites where the prediction was examined. Trying to prove this prediction would be essentially searching for a lack of impact effects, which isn't something a lot of scientists want to do. The third prediction is also less-supported, since there aren't that many craters on Earth and not all have been studied yet for iridium abundances.