ASTR 220 Homework #4 Solutions

1. *ECP: Ch. 9, Review Problems, #14.*

   This problem referred to Fig. 9.19. If we look at this figure, we can see that we would expect the following size objects to impact with the following approximate frequencies:

Impactor Size	Time Between Impacts
1 m	1 hr
10 m	1 month
100 m	100 yr
1 km	1 million yrs
10 km	100 million yrs
100 km	1 billion yrs

   How serious of a threat is there? The objects 100 m across and smaller would not threaten the existence of the human race. 100 m objects would create devastation similar to Tunguska: bad news for the people in the immediate vicinity, but not worldwide. So even though these objects hit the Earth more frequently, we don't have to worry about the world ending.

   Objects larger than 100 m across start to pose the threat of widespread devastation that could kill millions and possibly billions of people. Fortunately, these impacts happen very infrequently. This is a threat we need to prepare to defend ourselves against, but it's not likely to happen very soon.

2. *ECP: Ch. 9, Surprising Discoveries, #24.* You could look at this question two ways. You need to back up your view with a logical argument.

   As a surprising discovery: although there are a lot of near-Earth objects out there, so far none have had reliable predictions that they will hit the Earth. All impact predictions so far have been found to be near-misses once more observations have been taken.

   As a not-surprising discovery: there are a lot of near-Earth objects out there, so someday we're likely to find one that will hit the Earth. We can definitely make predictions of the positions of near-Earth objects out to 2064 or even farther.

3. *ECP: Ch. 6, Problems #29.*

   (a) Equal amounts of potassium-40 and argon-40. How old is the rock?

   From Fig. 6.28, we can look at the amounts of potassium-40 and argon-40. There is only one place on the graph where the amount of potassium-40 and argon-40 are the same. That's where the red potassium-40 line crosses the blue argon-40 line. At that point, only half of the potassium-40 remains and half has decayed into argon-40. From the x-axis of the graph, we can see this happens 1.25 billion years after the rock formed, so that must be the age of the rock.

   (b) Three times more argon-40 than potassium-40. How old is the rock?

   Again, on the graph, we can see where this must occur. When only 1/4 of the potassium-40 remains, 3/4 of it has decayed into argon-40. That means there is 3x more argon-40 than potassium-40. That happens after 2.5 billion years.

4. *NCC: The book states that about 70% of species became extinct as a result of the K-T impact. Approximately what percentage of individual organisms (both plant and animal) do you think died? Explain.*

This question does not have a definitive numerical answer, only estimates. You needed to give your estimate and back it up with a logical argument.

This idea is discussed at the beginning of Ch. 9. If 70% of species became extinct from the K-T impact, that means 30% survived. But how many individuals of each species must survive in order for the species to go on? If we're talking about animals, then we would guess that at least one male and female of the species must survive. If that happened, then well over 99% of individuals in a species could have been killed.

However, usually more than one couple is needed to make sure a species survives. There are a couple reasons for this: one of the pair could die from some accidental reason after the K-T impact. Secondly, if the genetic basis for an entire species is based on only two individuals, then later generations will have to in-breed to survive. In-breeding usually causes bad genes to occur more frequently in offspring, so that more defects and mutations lead to more deaths among offspring.

Consequently, probably more individuals than just one breeding pair were left from each species. But there may not have been many more. According to NCC, one scientist, David Carlisle, has estimated that more 99.99% of individuals in the surviving species were killed. The species then lived on by the remaining individuals breeding.

5. *NCC: In the book, ammonites, plants, forams, and dinosaurs are used as examples to test whether the K-T impact really was the cause of the mass extinction. One reason that these organisms were used as an example is because they have been well-studied by scientists. What's another reason why they are good examples to test the Alvarez Theory?*

   These four groups of organisms are also extremely diverse in how they lived. Ammonites and forams both lived in the oceans, but ammonites ate larger organisms like small fish while forams ate algae. Plants obviously depend on sunlight and are not predators; different types of plants were found all over the Earth. Finally, dinosaurs were animals with wide variety: some were predatory and some were herbivorous; some were large and some were small.

   Since these four groups of organisms are so diverse, any single event that could cause them all to become extinct must have been catastrophic and worldwide. That supports the Alvarez Theory.

6. *NCC: According to the book, there are only three good K-T boundary fossil sites in the entire world. How do you think this fact affects either confirming the predictions on pg. 175 or refuting the predictions? Explain.*

   In this answer, you should have presented a logical argument based on what you've read in the book.

   The predictions on pg. 175 are:

   (a) Prior to the K-T boundary, the dinosaurs were not already going extinct for some other reason. Their extinction was sudden and right at the boundary.

   (b) Dinosaur fossils are not found above the iridium horizon.

   These predictions are based on the two predictions made about the mass extinction at the K-T boundary.

   As we have talked about in class, dinosaur fossils are very rare. Only a small fraction of dinosaurs die under the right conditions to be fossilized. Since we only have three K-T boundary fossil sites in the world, that means we can only study a fraction of the small number of dinosaur fossils that may exist. The result is that the actual number of dinosaur fossils found just before the K-T boundary is very, very small.

This could affect confirming or refuting the predictions in several ways. First, the dinosaurs might appear to have gradually died out instead of going extinct suddenly. This is an application of the Signor-Lipps effect. The few fossils found may not mean that they were gradually dying out, but just that dinosaurs were not very numerous to begin with.

What if the three K-T boundary fossil sites were places that dinosaurs avoided for some reason? In that case, there would be extremely few dinosaur fossils before the K-T boundary, but it wouldn't mean that dinosaurs were already dying out.

These two ideas would strengthen the Alvarez Theory and the first prediction here: since we've found at least a few dinosaur fossils right before the K-T boundary, it's likely that there were far more dinosaurs actually living then. That means that dinosaurs weren't dying out prior to the K-T impact.

However, the few fossil sites could weaken the evidence for the second prediction. Based on three fossil sites, how can we say that there are absolutely no dinosaur fossils found above the K-T boundary? We haven't looked at the K-T boundary everywhere. It is true that we cannot examine the K-T boundary in every location in the world, but we should examine enough parts of the boundary to sufficiently rule out finding dinosaur fossils above the K-T boundary. Do you think three fossil sites is enough to do this?

7. *NCC: Explain what the "mean waiting time" is.*

   The mean waiting time is the average time between when events occur. For example, if the mean waiting time for an impact of a certain size is 100 million years, then, on average, they happen every 100 million years.

8. *NCC*

   (a) *Briefly describe the three theories behind the possibly 26 million yr periodicity of mass extinctions.*

   (b) *Which theory do you find the most believable? Explain.*

   The three theories are as follows:

   (a) **The Sun passing through the galactic disk.**. As the Sun orbits the center of the Milky Way, it bobs up and down slightly. During each bobbing motion, it passes through the disk of the galaxy. Most of the stars and gas in the galaxy are concentrated in the disk, so every time the Sun goes through the disk, it is closer to other stars. The increased gravitational force from the nearby stars may tug on Oort cloud comets and cause some to travel into the inner solar system.

   (b) **Sun's Hypothetical Companion Star Nemesis.** The Sun may have a small, faint companion star that orbits it, named Nemesis. When Nemesis is at the point in its orbit closest to the Sun, it passes through the Oort Cloud. Its gravitational force might send some comets into the inner solar system. Nemesis has not yet been found.

   (c) **Hypothetical Planet X.** A possible tenth planet may be orbiting the Sun beyond the orbit of Pluto. The precession of its orbit means that it would go through the Oort Cloud every 26 million years. Its gravitational force might disturb the comets there and send some into the inner solar system. Planet X has not been found. It would have to be about 4x the Earth's mass in order to have a gravitational force strong enough to cause the effects we see.

   Which theory is most believable? Most scientists today discount the Planet X theory. Now that we've discovered Kuiper Belt comets, it seems that any material leftover from the formation of the solar system beyond Neptune's orbit remained in relatively small chunks and didn't

accrete into a larger body. It's unlikely a planet 4x the mass of the Earth could accrete so far out, also, because the protoplanetary disk probably started to run out.

Both of the first two theories are being currently pursued. Astronomers are trying to more carefully determine the effects of the Sun passing through the plane of the galaxy. There are also astronomers searching for Nemesis.