

OpenStax Astronomy, Ch.13: WS Solutions (Apr-2021)

Solutions

1. Why are asteroids and comets important to our understanding of solar system history?

Since comets and most asteroids are small, they have not undergone chemical differentiation as have large planet-sized bodies. As such, they retain the structure and composition they acquired upon formation. These objects provide evidence for the conditions that existed in the solar nebula and early solar system.

2. Describe the main differences between C-type and S-type asteroids.

S-types are stony or silicate-based bodies with few carbon compounds and are more reflective. The C-types are rich in carbon compounds and are less reflective. The C-types are considered primitive and are little changed since their formation.

3. Compare asteroids of the asteroid belt with Earth-approaching asteroids. What is the main difference between the two groups?

While compositionally similar, the asteroid belt objects have fairly stable orbits. Earth-approaching asteroids have rapidly changing orbits and could potentially collide with our planet. Such a collision could produce relatively minor to catastrophic damage.

4. Briefly describe NASA's Spaceguard Survey. How many objects have been found in this survey?

Begun in 1998, the Spaceguard Survey is designed to discover all near-Earth asteroids (NEAs) that are greater than 1 km in diameter. It is objects of this size that could cause globally significant damage, should one strike Earth. To date, close to 1000 objects of this size have been found.

5. Who first calculated the orbits of comets based on historical records dating back to antiquity?

Edmund Halley presented the calculations for 24 cometary orbits in 1705. One of these he predicted to return to the vicinity of Earth in 1758. That comet, which did indeed return as predicted, is now known as Halley's Comet.

6. Describe the nucleus of a typical comet and compare it with an asteroid of similar size.

Cometary nuclei are quite small, on the order of a few kilometers in diameter, and are composed of ices, volatile organic compounds, silicate grains, and dust. Asteroids of similar size are denser and contain more stony and/or metallic materials. Comets react strongly to solar heating, releasing gases and dust, sometimes forming long tails that point away from the Sun.

7. Describe the two types of comet tails and how each are formed.

Comets typically have both a dust tail and an ion tail. The dust tail is larger and brighter than the ion tail and is formed by the action of sunlight imparting energy to the dust particles and pushing them away gently from the nucleus. The ion tail is composed of charged particles and are pushed away by the streams of charged particles emanating from the Sun (the solar wind). The dust tail tends to curve as the particles go into orbit around the Sun, whereas the ion tail tends to be straighter as the charged particles are pushed in the direction that is away from the Sun.

8. What classification is given to objects such as Pluto and Eris, which are large enough to be round, and whose orbits lie beyond that of Neptune?



These objects are called dwarf planets, and given their location, are also called trans-Neptunian objects (TNOs).



9. Describe the origin and eventual fate of the comets we see from Earth.

Comets that “fall” into the inner solar system were once located either in the Oort cloud about 50,000 AU from the Sun or the Kuiper belt. The Oort cloud is far enough away that the gravitational influence of passing stars can perturb a comet’s orbit. Some perturbations can send a comet out into interstellar space never to return. But others can send the comet nucleus inward toward the Sun; it is these comets that occasionally dazzle us here on our planet. Kuiper belt chunks can be perturbed by interactions with Neptune. A comet headed toward the inner solar system could hit the Sun or impact a planet. Or it could be “caught” by an interaction with one of the giant planets to become a really short-period comet. A comet trapped in the inner solar system will have a lifespan of just a few thousand orbits before it collides with a planet or all the volatiles escape, making it a “dead” comet.

10. Give brief descriptions of both the Kuiper belt and the Oort cloud.

The Kuiper belt is a disk-shaped region of space beyond the orbit of Neptune that is dynamically stable. It is the source of short-period comets. The Oort cloud is much farther out than the Kuiper belt. It is a spherical region surrounding the Sun out to near 50,000 AU. This is the source of newly discovered long-period comets.

11. Give at least two reasons today’s astronomers are so interested in the discovery of additional Earth-approaching asteroids.

Earth-approaching asteroids are interesting for several reasons. Since they come close to Earth, they are relatively easy to study (by radar, for example); also, they may be the parent bodies of many meteorites, so that a better understanding of Earth-approaching asteroids will help us to understand the meteorites and the origin of the solar system. They could impact Earth, with catastrophic consequences, and we must know more about these objects and their orbits if we ever intend to try to defend ourselves against these impacts. They are the most easily accessible objects in the solar system to reach for space missions. They may one day be the target for human flights, and they could also supply critical resources to future space colonies.

12. Why is it hard to give exact diameters for even the larger objects in the Kuiper belt?

Since objects in the Kuiper belt are too far away to resolve their diameters directly, we estimate the diameter from the amount of reflected light. However, the amount of sunlight reflected depends not only the size of the reflector but also the albedo (what percent of the incident sunlight is reflected). Since we do not know what the surface of a given object out there is made of, we can only estimate the albedo, and thus, our estimates of size are only as good as the estimates of the albedo.

13. If the Oort cloud contains 10^{12} comets, and ten new comets are discovered coming close to the Sun each year, what percentage of the comets have been “used up” since the beginning of the solar system?

At a rate of 10 new comets per year, the total number in 4.5 billion years is 4.5×10^{10} comets. This amounts to about 4% of the total originally present, if there are 10^{12} comets in the Oort cloud today.