Astronomy — PS 7 — Solar System Properties

April 27, 2021

In Chapters 6 and 7, which we had to cover hastily, we met the four small rocky planets and the four gas giants. Problem Set 6 was designed to see what the rocky planets have in common and what the gas giants have in common. The densities of the rocky planets were all in the range 4-6 kg/liter. The four gas giants were in the range 0.7-1.6 kg/liter. If you wanted to be very rough, you'd say the rocky planets were about 5 kg/liter and the gas giants were about 1 kg/liter.

This problem set is designed to help you make some sense of the other categories of objects in the Solar System which Pasachoff and Filippenko covered in Chapter 8 and Section 9.1.

Planets vs. Dwarf Planets

Pluto was our first example of a dwarf planet. It was demoted from being the 9th planet by the IAU because it has not cleared its orbit. In particular, it crosses Neptune's orbit, and since Neptune's mass is almost 8,000 times that of Pluto's, whenever they get close enough to clear each other, it is Pluto that will be flung out of orbit, not Neptune. In addition, Pluto's orbit overlaps with many other Kuiper-Belt Objects, and it hasn't cleared them.

Pluto actually consists of two objects, Pluto and Charon

1. What are the diameters of Pluto and Charon as quoted by Pasachoff and Filippenko, in Section 8.1?

Kuiper Belt Objects

Neptune's semi-major axis is about 30 AU. The Kuiper Belt Objects (KBOs) are mostly beyond Neptune according to the plots at the top of p. 233, and they go out to about 50AU. Many 10s of thousands of KBOs larger than 100km are thought to exist.

Among the larger KBOs so far discovered, are Varuna and Quaoar. These are about 1300km in diameter making them larger than Charon.

2. Would it be fair to say — based on size and distance — that Pluto and Charon are just especially large KBOs?

An object larger than Pluto that is currently 97AU from the Sun was first sighted in 2003 and confirmed in 2005. On p. 232, Pasachoff and Filippenko discuss its discovery.

3. Why is this object, now called Eris, thought to be in such a highly tilted orbit relative to the ecliptic?

Comets and the Oort Cloud

Comets are distinguished from other solar system objects insofar as they sometimes have long tails of gas and dust.

The comet's tails emanate from its nucleus which appear to be dark rock surrounding ices of various kinds. The nucleus of Halley's Comet was photographed up close by the Giotto spacecraft during its most recent approach in 1986. It is about 30km across.

Since we have defined a comet as an object having a tail, perhaps it is an oxymoron to talk of tailless comets. However, the comets we see are thought to be part of the Oort cloud, which extends to 50,000AU. Occasionally one of these objects gets flung towards the Sun and when it does, it heats up enough to begin ejecting gas and dust and form a tail.

On p. 236, Pasachoff and Filippenko discuss two categories of comets, one of which is "nearly isotropic" meaning that they are not concentrated along the plane of the ecliptic.

4. What is the other major category of comets?

Meteoroids

Meteoroids are small chunks from the size of a grain of sand to a boulder (about 1m). Anything larger than that is usually called an asteroid.

5. What is the distinction between a meteoroid and a meteorite according to Pasachoff and Filippenko?

Asteroids

In addition to the KBOs, the Oort cloud, and the meteoroids, there is a large number of objects in the orbit between Mars (at 1.5AU) and Jupiter (at 5.2AU). Hundreds are over 100km across and six are over 300km across. Most are less than 10km, and ones less than 1m are usually called meteoroids. The meteoroids that come to Earth may often be the result of collisions between asteroids. Over 600,000 asteroids have so far been found. The two largest asteroids are Vesta and Ceres. Ceres is almost 1000km in diameter. Vesta is 530km in diameter and is not quite spherical, so maybe it doesn't quite count as a dwarf planet.

Due to the large number of asteroids, with vast numbers still being found, Pasachoff and Filippenko quote a roughly 1% chance each century (or once in 10,000 years) that an asteroid greater than 200m will collide with Earth. Objects 50-60m across are expected to arrive about once every 1,000 years.

6. How often are objects in the 20m size range expected to arrive?

The Formation of the Solar System

Although there are a large variety of objects in the solar system, a systematic understanding of how they assembled has emerged, and Pasachoff and Filippenko discuss it in Section 9.1. They discuss the conservation of angular momentum, wherein the early solar system cannot shed its spin, and indeed, as it contracts, it spins faster, just as ice skaters spin faster when they draw their arms in. The solar system started with a random amount of spin, and since it cannot shed it, it retains it today. The spinning material formed into a large spinning disk. It is highly worth studying the story described in Figure 9-5 to know the best story

7. As the gas and dust started sticking together, the first thing it formed were _____ and this category is objects that are about _____ in diameter.

8. What is the frost line (referred to in Section 9.1b and on p. 218, and what is distinctive about objects that form inside the frost line vs. outside it?

9. How did the gas giants get so ridiculously large?

10. The asteroids in the asteroid belt today have only _____ per cent of the mass that was initially at their location. Why did no planet form where the asteroid belt is now?