The Solar System

It had taken millions of years for the first stars to go supernova, but in the aftermath, the universe had already changed. Instead of cloudy nebulas of light gases like hydrogen and helium, nebulas now contained heavier elements: iron, and nickel, and carbon, and oxygen. Instead of nebulae collapsing to form stars, now they were forming less massive but more interesting structures: solar systems among them. Our own system is an interestingly complicated structure. It has a star at its center, but it is surrounded by planets that are all orbiting in a common disc, and an asteroid belt (in that same disc,) as well as various comets and other miscellaneous astral bodies. The main question is, why? Why is most of our system found in a flat disc? Why is there a star at the center? Why do all the planets and asteroids rotate in the same direction?

The vast majority of systems that contain anything more than gases and stars evolved later in the life of our universe, and they contain the heavy elements necessary to build interesting structures like comets and asteroids, and planets and moons, and plants and animals. But all such systems began as a cloud of matter that was drawn together by the shared force of gravity. Almost always, these clouds were rotating, and like an ice-skater pulling in their arms, as gravity pulled the clouds together into denser clumps, they began to rotate faster. As the condensing cloud collapsed and spun faster, they began to flatten out into a spinning disc. This echoes the basic structure of our solar system, with all the planets and asteroids found in the narrow disc circling the sun. This is sometimes known as the ecliptic plane.

Another peculiar feature of a spinning disc nebula is that more massive objects and materials tend to move towards the outer edge of the disc. In the case of our solar system, this meant that the lightest elements like hydrogen remained at the center, while heavier elements like iron, nickel, oxygen and carbon were found further from the center. Eventually, enough of this hydrogen had gathered at the center of the system that its shared gravity was enough to start hydrogen fusion. Our star was born.

In the meantime, clumps of matter were gathering together as they collided, in some cases sticking into larger lumps. If they remained small and rocky and irregular, these objects (which could still be miles across) are now known as asteroids if large, or meteoroids if small. As these continued to collide and accumulate into larger groups, they began to have enough gravity that the force was enough to pull all parts of the clump towards the center equally, forming rough spheres. As they continued to grow, their gravity grew stronger, and they began to clear out a path as they orbited the sun as nearby matter was drawn in to join the growing mass. These were first planets. (Planetoids and/or dwarf planets are merely large objects that orbit the sun, but that don’t have enough gravity to totally clear out the path of their orbit.) Occasionally a smaller mass would get captured by a planet (or planetoid,) but be moving with enough velocity that it could avoid falling into the planet itself. These objects would continue to fall around their planet, now as a moon or satellite. (In general, larger objects are considered moons.)

As the large planets accumulated matter, they began to take on a predictable structure: the denser and heavier elements and compounds would sink towards the middle of the planet, while the lightest and least dense would float to the surface. In general, this results in a planet with a denser and sometimes rocky core on its interior, with some sort of atmospheric envelope. In all likelihood, all the planets in our solar system began this way, as growing accumulations of dense matter surrounded by a fragile shell of light gases.

A major thing to consider is the existence of the star at the center of this system: as it fuses the hydrogen it is made of, energy is released. This energy leaves the sun as electromagnetic radiation, which radiates throughout the solar system. How did this affect the planets? Well, the general answer is, the closer a planet is to the sun, the hotter it gets. This can have a few interesting effects. First, closer planets are far less likely to have a dense atmosphere, thick with gases. Why? Because the heat from the sun has literally boiled the atmosphere off into space, forcing out of the inner Solar System. This is why the inner planets of Mercury, Mars, Venus and Earth all have relatively thin atmospheres: the sun heated them so much that the gases began moving fast enough to escape the gravity of their planets. This gas could cool as it moved away from the center of the system, condensing and gathering together where it could once again be attracted by the shared gravity of planets, but far enough from the sun that the atmosphere could become stable. This is why the outer planets (Saturn, Jupiter, Neptune and Uranus) are gas giants, made mostly of gases that were driven out of the inner system by the sun’s heat. It is also why they are so very cold compared to the inner planets.

There are some features of the various planets that can explain their current characteristics, which include their temperature, characteristics of the atmosphere, weather, climate and seasons. One of the first is whether a planet has active volcanic activity. Some of the planets that formed along with the rest of the Solar System 4.5 BYA contained large amounts of radioactive material. These radioactive elements were relatively dense and heavy, so they sank to the center of the planet, where they slowly break apart, and release heat energy. This keeps the interior of the planet hot enough that rock remains liquid, and this liquid rock can escape to the surface as volcanoes. When this happens, gases trapped in the liquid rock can escape into the atmosphere. This appears to be the case for Venus and Earth, which both have active volcanoes releasing gas into the atmosphere. In the case of Mars, it seems this was once true, but the interior of Mars ultimately cooled off enough that it solidified, and the atmosphere has been growing thinner ever since, as the sun blows what remains off into space.

Another reason the planets nearby the sun can maintain an atmosphere is if they have a solid metallic core. In the case of Earth, the center of our planet is almost certainly a giant spinning sphere of solid iron and nickel. Why is this important? Because as it spins, it creates a magnetic field around Earth’s atmosphere. This field acts like a shield, redirecting dangerous radiation from the sun around our planet. This prevents Earth’s atmosphere from getting blown off into space as much of Mars’ has. Venus lacks this protective shield, but its volcanoes are so active that the atmosphere it loses is more than replaced. This is why Venus has an atmosphere that is 90 times thicker than our own. An advantage of having an atmosphere at least as thick as Earth’s is that it acts like an insulating blanket, trapping heat and raising the surface temperature. Of course, on Venus this is an example of too much of a good thing: the atmosphere is too thick, and has too much of the gas called Carbon Dioxide. The result is that Venus absorbs much of the solar radiation that it encounters, trapping it as heat. The surface temperature there is high enough to melt soft metals, and is far too hot for life as we know it.

In general, then, the planets of our solar system follow a general rule. Closer to the sun means more heat and resultantly less atmosphere, as on Mercury, which has virtually no atmosphere to think of and blazingly hot temperatures on the side facing the sun. Mars is larger and cooler, but has lost most of its atmosphere. As we move away from the sun, temperatures drop and atmospheres thicken, especially for unusual planets like Venus, with its highly active volcanoes, and Earth, with its magnetic field.

We then reach the asteroid belt, a collection of asteroids of varying sizes that never managed to collect into a planet because they were constantly being tugged at by other objects nearby, such as the first of the Gas Giants: Jupiter. These are the outer planets, and they are so far from the sun that they absorb very little heat from its radiation. In general, they are very cool at their surface, despite their thick atmospheres. In fact, they are mostly atmosphere, growing denser as we move towards their core. By the time we reach the outermost planets, they are so cold that most of the gases they are made of actually were now liquids and solids.

Still, these general rules for planet behavior don’t explain everything. To understand why our planet has climate and seasons, we will need to investigate further.

Use the CARs format to respond to the following prompts:

1. Explain why the solar system is a flat disc.
2. Explain what types of objects are found in a solar system, and how they can be told apart.
3. Explain what factors affect the temperature and atmosphere of planets.