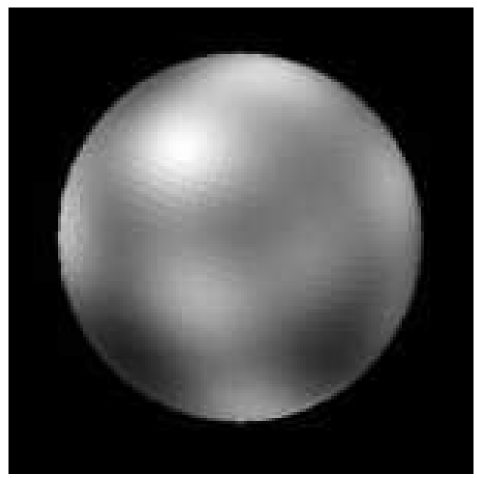
Textbook Reading

Lesson 2: Astronomy

The solar system is the place that is affected by the gravity our sun. Our solar system includes rocky terrestrial planets (Mercury, Venus, Earth, and Mars), gas giants (Jupiter and Saturn), ice giants (Uranus and Neptune), and assorted chunks of ice and dust that make up various comets and asteroids. The eight planets follow a near-circular orbit around the sun, and many have moons. We'll be going into detail about these objects during our hour-long teleclass, so we won't be spending time on it here. However, we will cover the huge number of comets, asteroids, and other objects follow their own path around the sun, many of which have yet to be discovered.

What Happened to Pluto?

Pluto was once considered one of the planets, but in recent years was demoted to 'dwarf planet' status. (This photo, by the way, is the ONLY picture we currently have of Pluto.) Many people figured it got whacked out of existence; while others thought we had discovered a larger planet X in its place. It turns out that neither are true. But before I talk about Pluto, let's go back in time to the discovery of another planet in our solar system, Ceres.



In 1801, Giuseppe Piazzi was looking in the asteroid belt region between Mars and Jupiter and was startled to find a large object there. He named it Ceres, and over the next several years, ten more 'planets' were discovered… then twenty, then fifty… and then a new definition of planet was defined, which moved all of these new 'planets' into the asteroid belt.

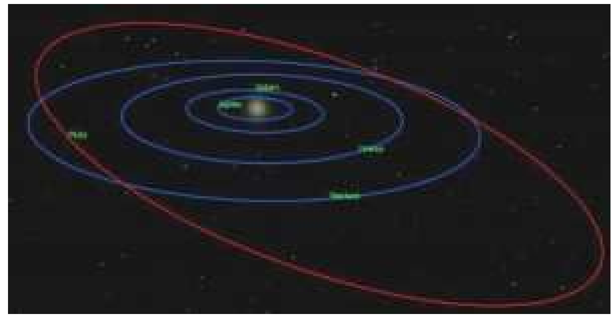
Back then, their observational equipment only allowed them to see large objects, and Ceres is the largest asteroid in the belt, so they naturally thought it was by itself and supposed it to be a planet, not a large rock amidst smaller ones.

Today, the same thing is happening with Pluto. Pluto is very small and far away, and it's hard to see things that far and that small. But we keep trying, anyway!

Basically, astronomers found Pluto and named it a planet… then they found Charon, which is roughly half the size of Pluto, so we called it a moon. But then we discovered that Charon orbits a point that is between the Charon and Pluto, owing to the fact that Charon and Pluto are near the same size.

For comparison, the moon is 1/4 Earth's diameter, 1/50 Earth's volume, and 1/80 Earth's mass. Then we found two smaller objects (Hydra and Nix) that also orbit around the pair… making it four objects instead of the original one! But it gets worse, because then we found more objects beyond Pluto that were bigger… hundreds more!

So at the end of it, scientists had to redefine what it means to be a planet, and Pluto didn't make the cut. But neither did the 700 other objects that we had in our line-up.

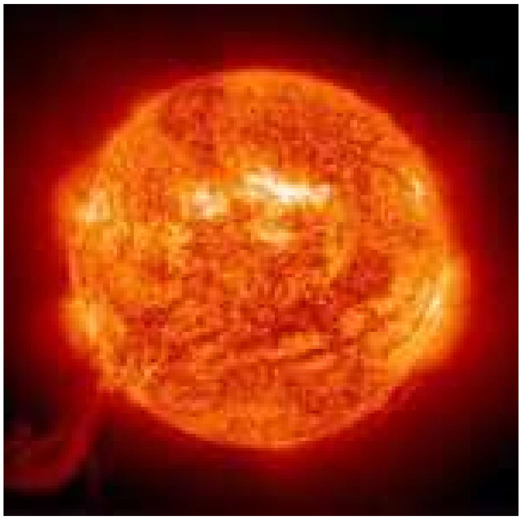


If you take a look at all the objects and ask yourself "Which one doesn't belong?", you'd find yourself looking hard at Pluto. It's the only one on a seriously inclined orbit (shown in red), the only one with an elliptical orbit that crosses another planet's orbit (Neptune's), and is extremely small compared to its neighbors. This is exactly what astronomers figured.

So Pluto was reclassified and the whole kit and caboodle was chunked as Kuiper Belt Objects (KBOs). This is the sort of thing that happens when you're working in a new field, trying to make sense and define things as you go. Every so often, you learn new things and need to go back and readjust assumptions made in the past.

Our Sun

The sun holds 99% of the mass of our solar system. The sun's equator takes about 25 days to rotate around once, but the poles take 34 days. You may have heard that the sun is a huge ball of burning gas. But the sun is not on fire, like a candle. You can't blow it out or reignite it. So, where does the energy come from?



The nuclear reactions deep in the core transforms 600 million tons per second of hydrogen into helium using a chemical processes called the proton-proton chain.

This gives off huge amounts of energy which gradually works its way from the 15 million-degree Celsius temperature core to the 15,000 degree Celsius surface. Once at the surface, it takes light only 8 minutes to travel the 93 million miles to reach earth. (So if the sun suddenly blinked out, we wouldn't know it for 8 minutes.)

The corona is hundreds of times hotter than the photosphere and extends for millions of miles outward. The only time you can see the corona is during an eclipse because the main part of the sun is so bright.

The visible surface of the sun is called the photosphere, and is made mostly of plasma (remember the grape experiment?) that bubbles up hot and cold regions of gas. When an area cools down, it becomes darker (called sunspots). Solar flares (massive explosions on the surface), sunspots, and loops are all related the sun's magnetic field. While scientists are still trying to figure this stuff out, here's the latest of what they do know...

The sun is a large ball of really hot gas - which means there are lots of naked charged particles zipping around. And the sun also rotates, but the poles and the equator move and different speeds (don't forget – it's not a solid ball but more like a cloud of gas).

When charged particles move, they make magnetic fields (that's one of the basic laws of physics). And the different rotation rates allow the magnetic fields to 'wind up' and cause massive magnetic loops to eject from the surface, growing stronger and stronger until they wind up flipping the north and south poles of the sun (called 'solar maximum'). The poles flip every eleven years.

There have been several satellites specially created to observe the sun, including Ulysses (launched 1990, studied solar wind and magnetic fields at the poles), Yohkoh (1991-2001, studied x-rays and gamma radiation from solar flares), SOHO (launched 1995, studies interior and surface), and TRACE (launched 1998, studies the corona and magnetic field).

Kuiper Belt and Beyond

The Kuiper Belt is an icy region that extends from just beyond Neptune (from 3.7 billion miles to 7.4 billion miles from the sun). Most objects in this region take hundreds of years t orbit the sun from this distance. This is where most comets and asteroids from our solar system hang out. The largest object out there is Eris, but we're still finding new ones all the time.

Eris is the largest known dwarf planet (the other dwarfs are Ceres and Pluto), orbiting 10 billion miles away from the sun. It takes Eris 560 years to complete one trip around the sun. Sedna is the coldest object we've found in our solar system. It's a tiny rock (930 miles across) about 8.4 billion miles away from the sun, discovered in 2003. It would be like trying to spot a single grain of sand in California from the Moon.

Gerard Kuiper (1905-1973) is known as the father of planetary science for his discoveries of moons in the solar system as well as detecting atmospheres on Titan and Mars.

The Oort cloud lies just beyond the Kuiper belt, housing an estimated 1 trillion comets. The Oort cloud is so large that it occasionally gets stirred up by nearby stars (like Alpha-Centauri, our nearest neighbor). When this happens, the gravitational effect can either bump the comet's orbit toward our sun, or sling it forever out of our system toward other stars. Jan Oort (1900-1992) was one of the world's top astronomers who first figured out that our solar system was surrounded by a cloud of comets. He also figured out the where the center of our galaxy is (in Sagittarius).

Galaxies

Stars like to live together in families. Galaxies are stars that are pulled and held together by gravity. Some galaxies are sparse while others are packed so dense you can't see through them. Galaxies also like to hang out with other galaxies (called galaxy clusters), but not all galaxies belong to clusters, and not all stars belong to a galaxy.

Active galaxies have very unusual behavior. Most galaxies have super-massive black holes in the center, many of which lie dormant. Scientists think active galaxies are the ones where the black hole is actively feeding on in-falling material. What scientists can detect are huge bursts of energy in the form of x-ray and gamma rays spewing up and out of the plane of the galaxy - a sure sign of a voracious black hole. There are several different types of active galaxies, including radio galaxies (edge-on view of galaxies emitting jets), quasars (3/4 view of the galaxy emitting jets), blazars (aligned so we're looking straight down into the black hole jet), and others. Our own galaxy, the Milky Way, has a super-massive black hole at its center, which is currently quiet and dormant.

Globular and Open Clusters

When you look up at the night sky, it seems like the pinpoints of light are each isolated from each other. When viewed through a telescope, however, single stars can actually transform into tens of millions of stars. Globular clusters are massive groups of stars held together by gravity, using housing between tens of thousands to millions of stars (think New York City). Open clusters are made up of stars that all have the same chemical composition, but don't usually stay together for long.

Planetary Nebulae

Dying stars blow off shells of heated gas that glow in beautiful patterns. William Hershel (1795) coined the term 'planetary nebula' because the ones he looked at through 18th century telescopes looked like planets. They actually have nothing to do with planets – they are shells of dust feathering away.

Neutron Stars and Pulsars

When a star uses up its fuel, the way it dies depends on how massive it was to begin with. Smaller stars simply fizzle out into white dwarfs, while larger stars can go supernova. A recent supernova explosion was SN 1987. The light from Supernova 1987A reached the Earth on February 23, 1987 and was close enough to see with a naked eye from the Southern Hemisphere.

Neutron stars are formed from stars that go supernova, but aren't big and fat enough to turn into a black hole. When a star this size explodes, it blows off its outer layers of gases and the inner core collapses down and crushes the atoms together so much that protons and electrons fuse into neutrons. The neutrons are so densely packed together that the space between them is basically gone. Pick up a strand of your hair right now – feel how heavy it is? If this was made of neutron material, it would weigh the same as the empire state building.

As the neutron star forms, it starts to rotate and form huge magnetic fields. We already know that when you have magnetic fields, electrical fields are not far behind. Neutron stars can wind up spinning very fast, spewing jets of high-energy x-ray particles out the poles. When our telescopes detect the x-rays from a neutron star, we call it a pulsar.

Neutron stars with HUGE magnetic fields are known as magnetars, but because they were first modeled in 1992, not a lot is known about them. We currently know about only a handful of these, and thankfully none are near the Earth. To get a better sense of these things, compare the magnetic fields: the Earth registers at 1 gauss, Jupiter is 1,000 gauss, solar flares are 1,000 gauss, and a magnetars has magnetic fields that register 1,000,000,000,000,000 gauss.

Black Holes

Black holes are the leftovers of a BIG supernova. When a star explodes, it collapses down into a white dwarf or a neutron star. However, if the star is large enough, there is nothing to keep it from collapsing, so it continues to collapse forever. It becomes so small and dense that the gravitational pull is so great that light itself can't escape.

What would it be like to fall into a black hole? Well, there are two different perspectives. Imagine your friend Alice parked her spaceship a safe distance away, just outside the event horizon. She's not in any danger of being pulled in – she just wants to watch you go in.

As you float toward to black hole, she sees you drift toward it, picking up speed as you get closer. She sees you going faster and faster, speeding up so that you're going near break-neck speed, and then you get close to the event horizon (the 'point of no return' – think about being in a boat going over Niagara Falls – there's a point that you can't escape going over no matter how hard you paddle). She sees you slow down as you approach the event horizon, turn redder and redder, and slowly fade away. She never actually sees you go in.

From your point of view, however, things went a little differently. First, you headed toward the black hole feet-first, and initially went slowly. As you got closer, your speed picked up faster and faster until the gravitational pull at your feet was different from the pull at your heat, at which time you became 'spaghettified' (no kidding – that is the real astronomical term for this effect) where you were pulled into a super-thin, super-long string and finally shredded on the subatomic level.

So, how do you avoid such a fate? The only way you can detect a black hole is to look at what happening around it. If a star seems to be yanked about, but there's nothing there to do the gravitational pulling, you can bet it's a black hole. Stuff doesn't just fall straight into a black hole, either. When matter approaches the black hole, it stars to swirl around an accretion disk, which heats up the particles in the disk and lights up the disk so it's visible in the x-ray part of the spectrum (even though the black hole itself is not). You can also detect black holes by the way light is bent when passing by.

Gravity Bending Light

Gravitational lensing is one way we can "see" a black hole. When light leaves a star, it continues in a straight line until yanked on by the gravity of a massive object (like a galaxy or black hole). The gravity will bend the light and change its course, which can show up as streaks or multiple, distorted images on your film where they should be pinpoints of light (see the streaks in the photo?).