Astronomy 5 Lecture Notes

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Professor Michael Rich has office hours at 1pm on Wednesday. Denyz Melchor has office hours 12pm on Mondays at Knudsen 3145P. Her email is `denyzamelchor@g.ucla.edu`

Lost of the simplest organisms on Earth live near deep sea vents, including "smokers", which have never been found anywhere except around those vents. One of the most common organisms on Earth is cyanobacteria, which are responsible for putting diatomic oxygen gas in our atmosphere.

If life is found on other planets, we hypothesize that they are single-celled, like bacteria. Looking for extremophiles on Earth helps us understand which extreme environments on other planets could support life.

There is no research to actually look for extraterrestrial life, but there is research on exoplanets. Unfortunately, exoplanets are very hard to observe. The main way to observe them is using the "transit method", which means seeing how much a star appears to dim periodically due to a planet orbiting it.

There are roughly 100 billion stars in our galaxy, and about the same number of "terrestrial planets" (although most terrestrial planets can't support life).

In a span of only 50 years, we have sent spacecrafts to every planet in the solar system. We have also visited major moons and other bodies, the farthest of which is the Kuiper Belt object Arrakoth, 45 AU away. We have photographed volcanos on Jupiter's moon Io, as well as plumes of salt water from Saturn's moon Enceladus. Here's a picture of a volcano on Io:

A star is a huge ball of mostly hydrogen plasma which generates heat and light by nuclear fusion. Our star, the sun, has about 333000 times as much mass as the Earth. Larger stars have shorter lifespans. The sun is about halfway through its 10 million year lifespan.

A planet is a moderately large object which orbits a star, and shines mainly by reflecting light. Most planets are classified as either "rocky", "icy", or "gaseous". Pluto and other objects farther from the sun than Neptune are now called "dwarf planets".

A satellite is an object which orbits a much more massive object. A natural satellite which orbits a planet is called a moon.

An asteroid is a relatively small and rocky object which orbits a star. Since asteroids are small, they are typically not spherical. A comet is a relatively small and icy object which orbits a star.

A nebula is a huge interstellar cloud of gas/plasma and dust (mainly hydrogen).

A galaxy is a cluster of stars held together by gravity, all orbiting a common center. We don't understand galaxies very well – the outer parts seem to orbit the center much faster than we'd expect based on the amount of mass we observe closer to the center of the galaxy, which has led us to look for "dark matter" which interacts with ordinary matter mostly via gravity.

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To pass this class, you need to attempt every homwork (if there is homework), go to the midterm and the final, and have at least 60% attendance.

Most of the exam content is based on lectures. There will be practice exams.

Fun fact: professor Rich was a PhD advisor to Neil Tyson.

Saturn's moon Enceladus has plumes of salt water, and under the surface, it contains phosphorus, which is essential to life.

A planet is defined as a moderately large object which orbits a star and shine only by relfecting light from that star. A moon is any object which orbits a planet.

An astronomical unit is the average distance from Earth to the sun, but was redefined in 2012 to be 1.5×10^{11} m, or roughly 93 million miles. A light-year is 63000 astronomical units. A parsec (which is a portmanteau of "parallax" and "arccsecond") is 206000 AU, or 3.26 light-years.

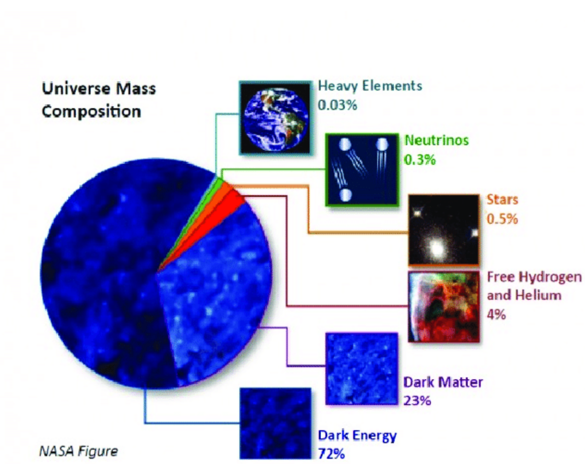
Our galaxy is disk-shaped, roughly a thousand light-years thick and 100 thousand light years in diameter. We are 28 thousand light years from the center, and take about 230 million years to make a full orbit. Our solar system orbits the galaxy at a speed of around 540,000 mph.

The Earth has mass $5.97 \times 10^{24} kg$ and radius 4000 miles (6400 kilometers). The equator rotates at a speed of 2π(4000 miles)/(1 day) = 1000 mph = 1650 km/h.

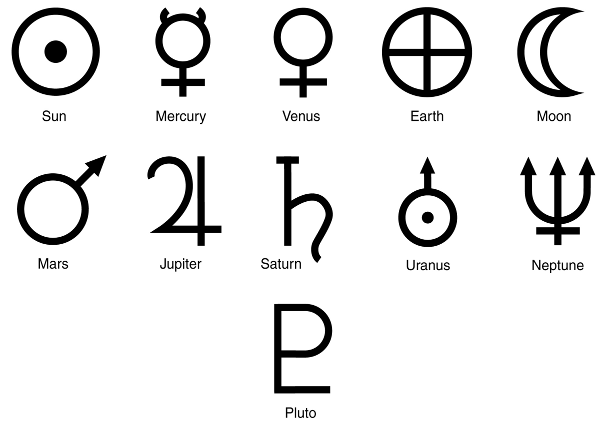
The distance from the Earth to the sun is 147.1 million km at the closest point (perihelion) and 152.1 million km at the farthest point (aphelion). The average distance is called an astronomical unit, or AU (1 AU is about 150 million km). The eccentricity of the Earth's orbit is 0.017, which is negligible, and the typical speed of the Earth around the sun is 2π(150 million km)/(1 year) = 108000 km/h.

The cosmic calendar is a tool for undertanding the timeline of our universe. If that timeline were scaled down from 13.8 billion years to a single year, such that the big bang was January first. In this calendar, the MIlky Way forms in March, the Sun and planets form in August, the oldest know life appears in Spetember, and the first Multicellular life arises in November. Dinosaurs aren't wiped out until December 29th, and written language is invented 15 seconds before midnight.

The current mass composition of the universe is predicted to be as follows:



In astrophysics, we often use the following symbols as subsripts – for example, $R_\oplus$ is the radius of the Earth.



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The nearest star, Alpha Centaurus, is about 4.25 light-years away.

All planets orbit the sun in the same plane as the Earth. The Earth's axis of rotation is 23.5 degrees from being perpendicular to that plane. From the north's spring equinox (March 20) to the north's fall equinox (September 22), the southern hemisphere receives more radiation than the northern hemisphere, and the opposite is true for the other half of the year. The winter solstice, which marks the beginning of winter, is December 21 in the north and June 21 in the south. The summer solstice, which marks the beginning of summer, is June 21 in the north and December 21 in the south. The farther you are from the equator (the higher the absolute value of your latitude), the more dramatic your seasons are. In the arctic circle (¿67 degrees north) and the antarctic circle (¿67 degrees south), there is one day a year where the sun stays at the horizon.

An apparent path of the Sun through the sky on one day is called an ecliptic. The group of constellations which lie along the ecliptic is called the zodiac.

One reason people refused to believe the heliocentric model was because they could not observe parallax until the 1860s. In 1543, Copernicus used a heliocentric model to predict the distance of each planet to the sun, although he assumed all orbits are perfect circles. Tycho Brahe (1546-1601) compiled observation of planetary orbits accurate to about 1 arcminute, which motivated the invention of the telescope, helping to start the scientific revolution. Johannes Kepler (1571-1630) noticed tiny discrepancies in Brahe's observations which made Kepler suggest that orbits are elliptical.

Kepler's 1st law: The orbit of each planet around the sun is an ellipse, with the Sun at one focus.

Kepler's 2nd law: The rate at which the line segment from a planet to the sun sweeps out area is constant. In layman's terms, this means a planet's speed is inversely proportional to its distance from the sun.

Kepler's 3rd law: If p is the orbital period of a planet (in years), and a is the maximum distance to the sun (in AU), also called the semi-major axis of the ellipse, then $p^2 = a^3$.

Galileo Galilei (1564-1642) argued against the Aristotlean view of the heavens by (1) proving a moving Earth would not experience "wind" or cause us to feel noticeable force, (2) showing the heavens aren't perfect, because we can observe sunspots, and (3) claiming stars are way too far for us to observe any parallax. Newton's first law, which came later, also contradicted Aristotle's claim that moving objects will slow down without an external force.

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