Friday, Oct. 31

Syllabus, class notes, and homeworks are at:
www.as.utexas.edu → courses → AST 301, Lacy

Reading for this week: chapter 11

The Wednesday help session is in GRG 424 at 5:00 (for the entire semester).

Our Schedule

Aug 27:	Ch 1+App A	The Scale of the Cosmos
Sep 3:	Ch 2+3	The Sky, Cycles in the Sky
Sep 8:	Ch 4	The Origin of Modern Astronomy
Sep 15:	Ch 5	Telescopes
		Sep 19: Exam #1, Ch 1-5
Sep 22:	Ch 6	Starlight and Atoms
Sep 29:	Ch 7	The Sun
Oct 6:	Ch 8	The Family of Stars
Oct 13:	Ch 9	The Formation and Structure of Stars
Oct 20:	Ch 10	The Lives and Deaths of Stars
		Oct 24: Exam #2, Ch 6-10
Oct 27:	Ch 11	Neutron Stars and Black Holes
Nov 3:	Ch 12	The Milky Way Galaxy
Nov 10:	Ch 15	Cosmology
Nov 17:	Ch 16	The Origin of the Solar System
Nov 24:	Ch 17	The Terrestrial Planets
Dec 1:	Ch 18	The Outer Solar System
		Dec 5: Exam #3, Ch 10-12,15-19

1. Describe (preferably with a sketch) what astronomers mean by the word parallax. Explain (perhaps with your sketch) why parallax depends on distance in the way it does. (See the sketch on the board.) Astronomical parallax is the change in the direction to a star due to the change in the position of the observer as the Earth orbits around the Sun. From the sketch you can see that a more distant star has a smaller parallax angle than a nearer one has.

2. a) Make a sketch of a hydrogen atom, labeling its parts.
(See the sketch.) For ordinary hydrogen, there is one proton in the nucleus and one electron orbiting around it. Deuterium (heavy hydrogen) also has one neutron in its nucleus.
b) How would a hydrogen ion differ from a hydrogen atom?
The electron would be missing, or it would have an extra electron.
c) Describe a change that might occur to your hydrogen atom if it absorbed a photon. (Assume it is still a hydrogen atom, not an ion, after absorbing the photon.)
The electron could jump up to a bigger orbit.

1. a) If I wanted to measure the mass of a star, what measurements would I have to make? (Telling me to measure the luminosity and read the mass off of the mass-luminosity diagram is not a good answer. That's a way to calculate the mass, but I don't consider it to be a measurement of the mass.)
Measure the period and size of the orbit of two stars orbiting around each other.
b) How would the star whose mass I want to measure have to be special? Can all stars' masses be measured by the method you gave?
It must be in a binary. (Unless we can find a planet orbiting around another star.)

2. a) Make a sketch of a helium atom, labeling its parts, including the particles inside of the nucleus.
(See the sketch.) It has two protons and two neutrons in its nucleus and two electrons orbiting around the nucleus.
b) How would a helium ion differ from a helium atom?
It would be missing an electron or it might have one extra electron.
c) Describe a change that might occur to your helium atom if it absorbed a photon. (Assume it is still a helium atom, not an ion, after absorbing the photon.)
One of its electrons might have jumped up to a bigger orbit.

3. In class we ran electricity through a glass tube containing hydrogen gas.
a) Describe the spectrum we saw when we looked at the tube through our plastic diffraction gratings. (You should know what the spectrum of hot hydrogen gas looks like, at least qualitatively, even if you missed class that day.)
We saw an emission line spectrum. There was light only at a few wavelengths, not a continuous spectrum.
b) What situation (which we couldn't set up in class) would be required for hydrogen gas to show an absorption line spectrum?
If hydrogen gas was in front of or surrounded a light bulb it could absorb the wavelengths that hot hydrogen emits. It must be cooler than the light bulb to be seen in absorption. (Actually, to see the visible absorption lines of hydrogen it can't be too cool since the electron would have to be in the second orbit to absorb a visible wavelength photon.)

4. Polaris is directly above the Sun on an H-R diagram.
a) What does this tell you about how these star differ and how they are similar?
Polaris has the same surface temperature as the Sun but it is more luminous.
b) Polaris's luminosity is about 10,000 times that of the Sun.
How can this be? What must be different about Polaris to make its luminosity 10,000 times that of the Sun? Be quantitative (there should be a number in your answer), and remember that Polaris is directly above the Sun on an H-R diagram.
It must have 10,000 times the surface area of the Sun. This means it must have 100 times the radius or diameter of the Sun.
c) The Sun's flux is much greater than Polaris's flux. How can this be when Polaris has a much greater luminosity?
The Sun is much closer to us than Polaris is.

5. a) How do we know that nuclear fusion is occurring inside of the Sun? (I want to know what measurements have been made that demonstrate that the Sun is generating energy by nuclear fusion rather than by contraction or by chemical reactions.)
We observe the neutrinos that are made in the nuclear reactions.
b) How can we determine how much energy is being generated in the Sun?
We can measure the luminosity of the Sun, knowing that the Sun radiates the same amount of energy from its surface as it generates.

6. a) The Sun is in hydrostatic equilibrium. What does this mean? What is the definition of hydrostatic equilibrium as we apply it to the Sun?
Pressure of the gas inside the Sun, pushing out, balances the Sun's gravity, pulling in.
b) Give an example of an equilibrium (not necessarily an astronomical example) different from hydrostatic and thermal equilibrium.
The force of the floor pushing up on my feet balances the force of gravity pulling me down.
A balance between supply and demand sets prices. If supply exceeds demand, the suppliers will lower prices to try to sell more. This will encourage more people to buy their product until the demand matches the supply.

Topics for this week

Compare the two types of supernova: how do they differ in the cause of the explosion and in what is left behind?

Describe neutron stars.

Describe pulsars.

Why do neutron stars rotate so quickly?

Why couldn’t white dwarfs or other stars rotate as quickly?

Define ‘escape speed’.

Describe black holes.

What evidence do we have that there is a very massive black hole at the center of the Milky Way?

Relativity

Einstein showed that Newton's laws aren't valid when objects move at speeds near the speed of light.

When an object moving at nearly the speed of light is given energy it doesn't go much faster. Instead it gets more massive.

He also showed that it is better to look at gravity not as a force, but as a distortion of space around massive objects, making objects that come near massive objects follow curved paths.

That is his explanation for the fact that Galileo's two balls fell together. They were both following the natural path through curved space.

Black Holes

If massive objects follow apparently curved paths through space because space-time is curved by gravity, light must also be affected by gravity.

In fact, if an object is dense enough that escape speed from its surface is greater than the speed of light, light will not be able to escape from the object.

This is a black hole.

The theory of General Relativity says that if a mass M is

inside of a radius R with $$\frac{2GM}{R} = c^2$$

the mass will all fall to the center, and not even light will ever get out.

It’s not so bad

Although you need to use General Relativity to calculate the paths of objects near a black hole, farther away you can still use Newton’s laws.

If the Sun collapsed into a radius of 3 km it would be a black hole.

But the Earth would still orbit it just like it does now.

General Relativity give the same predictions as Newton’s laws is long as you are far enough from an object that the orbital speed is much less than the speed of light.

Gas orbiting around the center of the Milky Way

When I was a graduate student, I observed ionized gas near the center of the Milky Way.

From the Doppler shift, I could measure the speed of the motion of the gas.

The gas closer to the center was moving faster.

Gas at about 1.7 pc (5 ly) from the center moves at about 100 km/s.

Gas at about 1/6 pc (0.5 ly) moves at about 300 km/s.

Gas orbits around massive objects according to Kepler's laws just like solid objects do.

Gas orbiting around the center of the Milky Way

We used an infrared emission line of ionized neon to observe the ionized gas near the center of the Milky Way and measure its Doppler shift.

Gas at about 1.7 pc (5 ly) from the center moves at about 100 km/s.

Gas at about 1/6 pc (0.5 ly) moves at about 300 km/s.

We can use these numbers with Kepler's 3rd law to calculate the mass that the gas is orbiting around.

$M = a^3 / P^2$ and $P = (2\pi a) / v$

so $M = v^2 a / (2\pi)^2$ (if you use the right units for v and a)

Mass in the Center of the Milky Way

distance	speed	period	mass
1.7 pc	100 km/s	110,000 yr	$4 \times 10^6\ M_{sun}$
1.0 pc	125 km/s	50,000 yr	$3.5 \times 10^6\ M_{sun}$
0.5 pc	170 km/s	18,000 yr	$3 \times 10^6\ M_{sun}$
0.2 pc	270 km/s	5,000 yr	$3 \times 10^6\ M_{sun}$

There are lots of stars near there (that's why the mass inside of 1.7 pc from the center is greater than the mass inside of 0.2 pc) but there can't be 3×10^6 stars inside of 0.2 pc.

We argued that there is a $3 \times 10^6\ M_{sun}$ black hole there.

But astronomers weren't convinced that gravity was the only force causing the gas to orbit.

Stars orbiting around the black hole

Recently astronomers have observed stars orbiting around the center, and they think that only gravity could make them orbit.

They come to the same conclusion we did.

See http://www.mpe.mpg.de/ir/GC/