

# Study Guide

## Beginning Astronomy

Cooler gas between the observer and a source of continuous radiation gives what kind of spectrum?

- a. continuous
- b. emission
- c. absorption

I came to class today because:

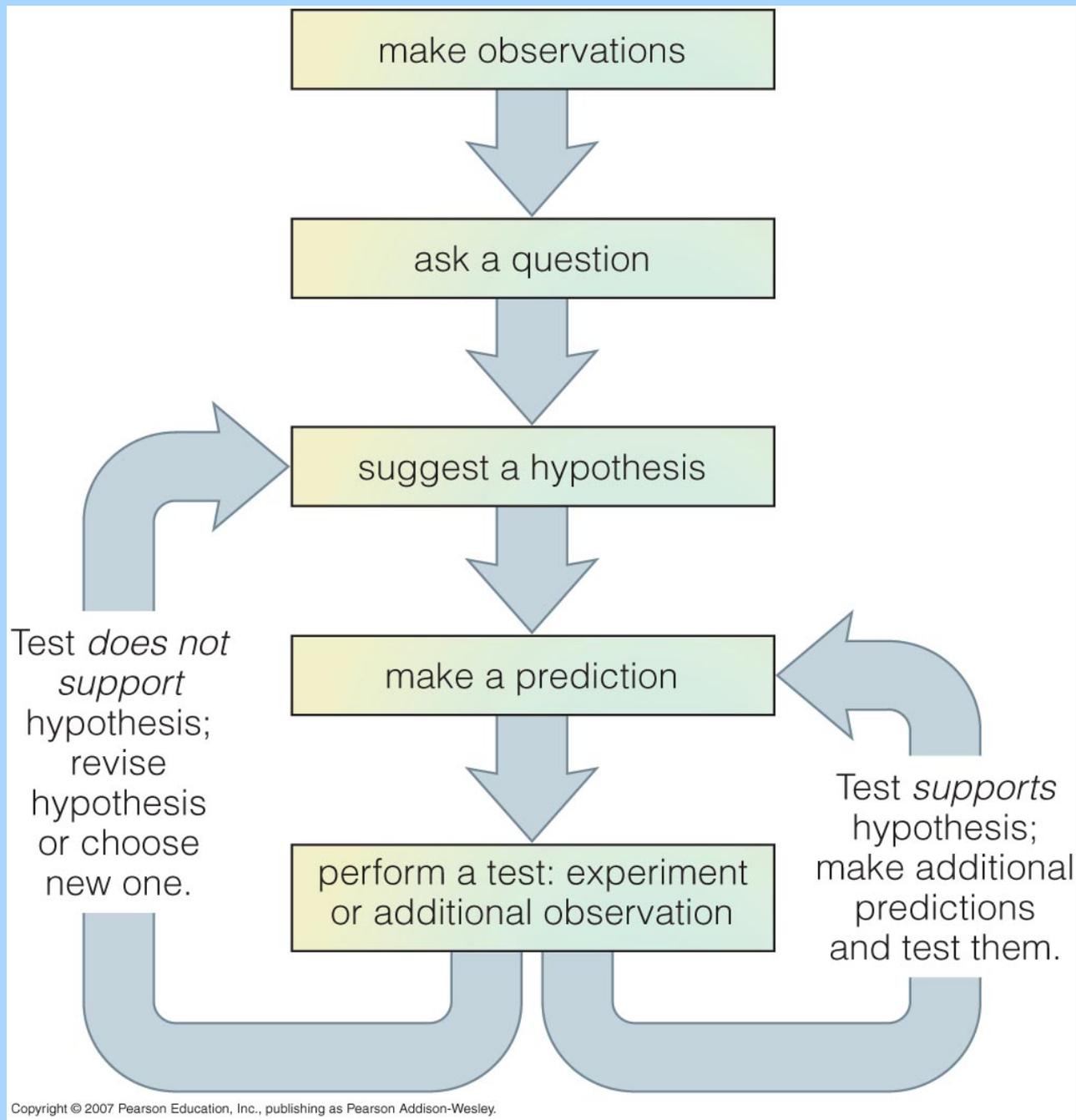
- a. It's the right thing to do.
- b. 2 or 3 clicker points will make or break my grade.
- c. I'm hiding from the police and I need an alibi.
- d. I can't decide so I'll answer D.
- e. Or maybe E.

As you travel southward from Canada to the United States, the Pole Star (Polaris)

- a. gets lower in the sky
- b. gets higher in the sky
- c. keeps the same elevation angle above the horizon

Say it is 10 AM in College Station, Texas. What time is it in New York?

- a. 10 AM
- b. 11 AM
- c. 9 AM
- d. 8 AM



You must know these things:

Earth's diameter is about 8000 miles

Moon's distance is about 60 Earth radii (240,000 miles)

Average distance of Earth to Sun is about 93 million miles (150 million km)

One light-year is how far light travels in a vacuum in a year, about 6 trillion miles.

“Parsec” is short for “parallax of a second of arc”  
1 pc  $\sim$  3.26 light-years. Distance in pc is the reciprocal of the parallax in arcsec ( $d = 1/p$ ).

The Milky Way galaxy is about 75,000 light-years in diameter. The solar system orbits the Galactic center at 220 km/sec on a nearly circular orbit. We are about 8000 pc (25,000 light-years) from the center of the Galaxy.

Nearby galaxies have distances measured in millions of light-years.

The most distant galaxies we can possibly detect are at distances of about 13 billion light-years. When observing them we are looking 13 billion years into the past.

# Phases of the Moon



It takes the Moon ~29.5 days to go through its cycles of phases. It just keeps orbiting the Earth, month after month after month. So if you know when full moon or new moon occurs, you can figure out approximately when the last quarter moon occurred, the next quarter moon will occur, or any other phase for that matter.

If you can draw a picture of the Moon going around the Earth, with the Sun off to one side, you can understand the phases. You don't really need to memorize what follows on the next few slides!

The Moon goes through phases because it is basically spherical and the angle between the Earth, Moon, and Sun changes day to day.

When the Moon is new, it is in the same direction as the Sun, so it rises when the Sun rises and sets when the Sun sets.

When the Moon is 50 percent illuminated and at first quarter phase, it is one week (roughly) after new Moon. The first quarter Moon is high in the south at sunset. The first quarter Moon will set at roughly midnight.

The full Moon is full because it is on the opposite part of the sky from the Sun. The full Moon rises at sunset. The full Moon will set approximately at sunrise.

A total lunar eclipse can only happen at full Moon. A total lunar eclipse occurs when the Moon passes into the Earth's shadow.

A third quarter Moon occurs a week after full Moon. The third quarter Moon rises roughly at midnight. The third quarter Moon is high in the south at sunrise.

A young crescent Moon occurs between new Moon and first quarter. The young crescent Moon will be visible in the west or SW after sunset. It will set before midnight.

The gibbous Moon between first quarter and full Moon is visible in the east (maybe SE) after sunset and will be visible most of the night.

The old gibbous Moon occurs between the time of full Moon and third quarter. The old gibbous Moon will rise in mid-evening and will be visible all night.

The old crescent Moon rises long after midnight. It can be seen in the east or southeast before sunrise.

*Gibbous* comes from the Latin word for humpbacked.

The first quarter moon is one week through its 4-week cycle.

The first two weeks of the cycle of the moon is shown below by its position at sunset on 14 successive evenings. As the moon grows fatter from new to full, it is said to wax.

The full moon is two weeks through its 4-week cycle.

*Waxing gibbous*

*Waxing crescent*

THE SKY AT SUNSET

Full moon rises at sunset

New moon is invisible near the sun

East

South

West

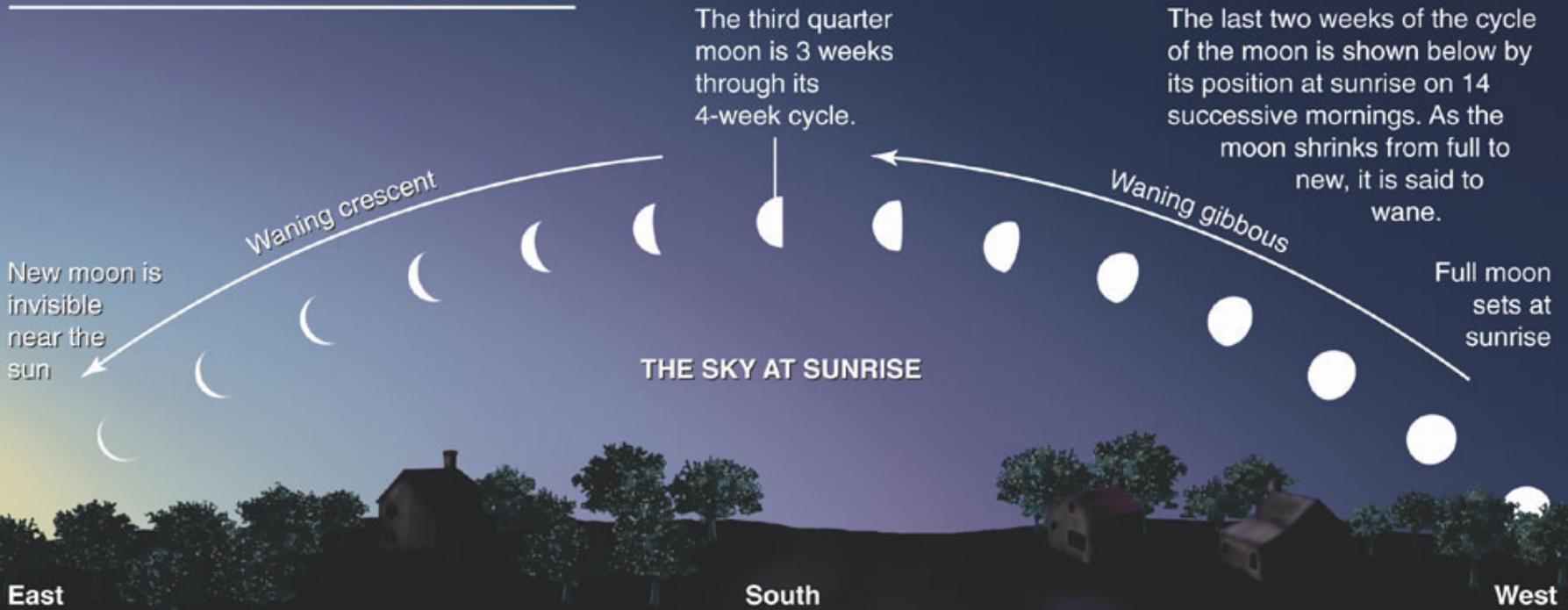
You can use the diagram on the opposite page to determine when the moon rises and sets at different phases.

### TIMES OF MOONRISE AND MOONSET

Phase	Moonrise	Moonset
New	Dawn	Sunset
First quarter	Noon	Midnight
Full	Sunset	Dawn
Third quarter	Midnight	Noon



▲ This diagram is to scale. The moon's orbit is about 30 Earth diameters in radius. Because the orbit is slightly elliptical, the moon's angular diameter in the sky can vary by plus or minus 6 percent. Because the orbit is tipped a bit over 5 degrees, the moon does not follow the ecliptic exactly.



## Telescopes

Probably the most important thing about a telescope is the quality of the optics. Obviously, if the primary light gathering element is poorly made, or the secondary, or the eyepieces, you won't be able to do much useful observing. Also, if your observing site has air pollution, light pollution, or bad seeing, that will seriously hamper your endeavors.

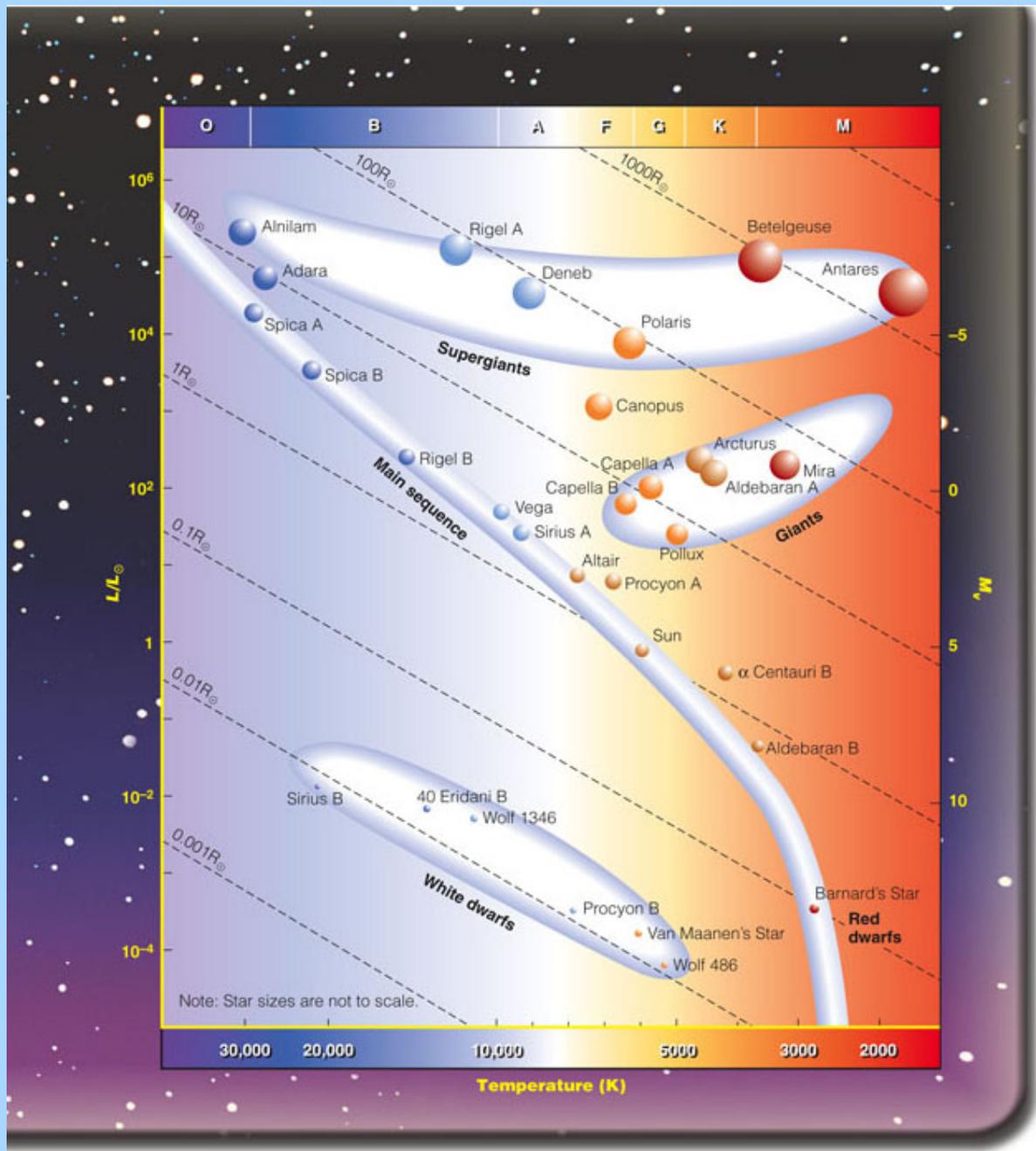
But let us assume that you do have a well made telescope at a dark site with lots of clear, steady nights. What then is important?

The most important parameter for a telescope is the *light gathering power*, which is proportional to the area of the main objective. Since it is possible to make a mirror much larger than a lens for the same amount of money, you can get a more powerful telescope for your budget by investing in a *reflector*, as opposed to a refractor. Also, since the refraction of light is a function of wavelength, it is not possible to make a refractor totally free of *chromatic aberration*.

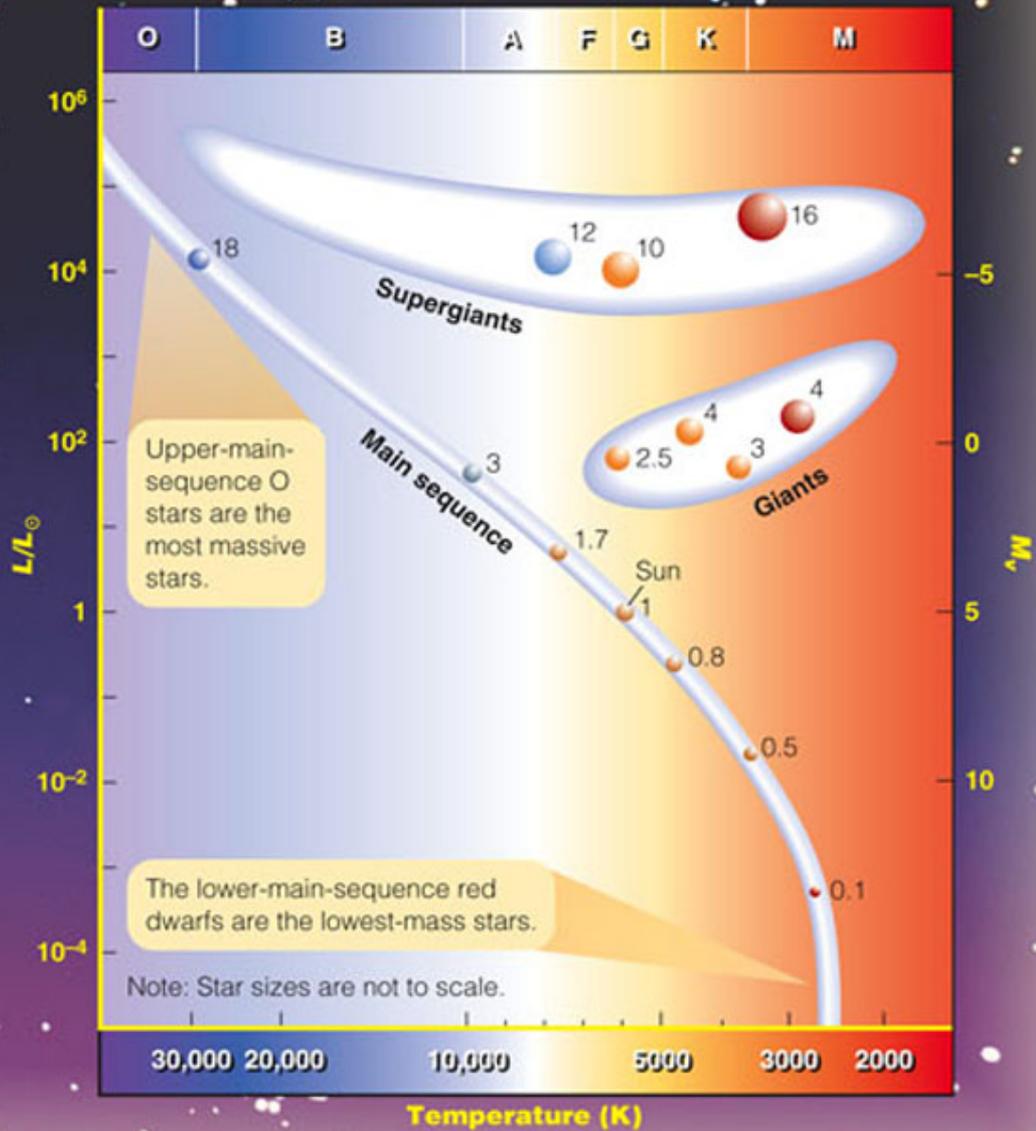
For optical viewing any telescope can get any magnification whatsoever, since the magnification is simply the focal length of the primary divided by the focal length of the eyepiece. For practical reasons, it is rare to be able to use more than 200X on a 6-inch to 10-inch telescope (like most commercial telescopes).

Stars and stellar evolution

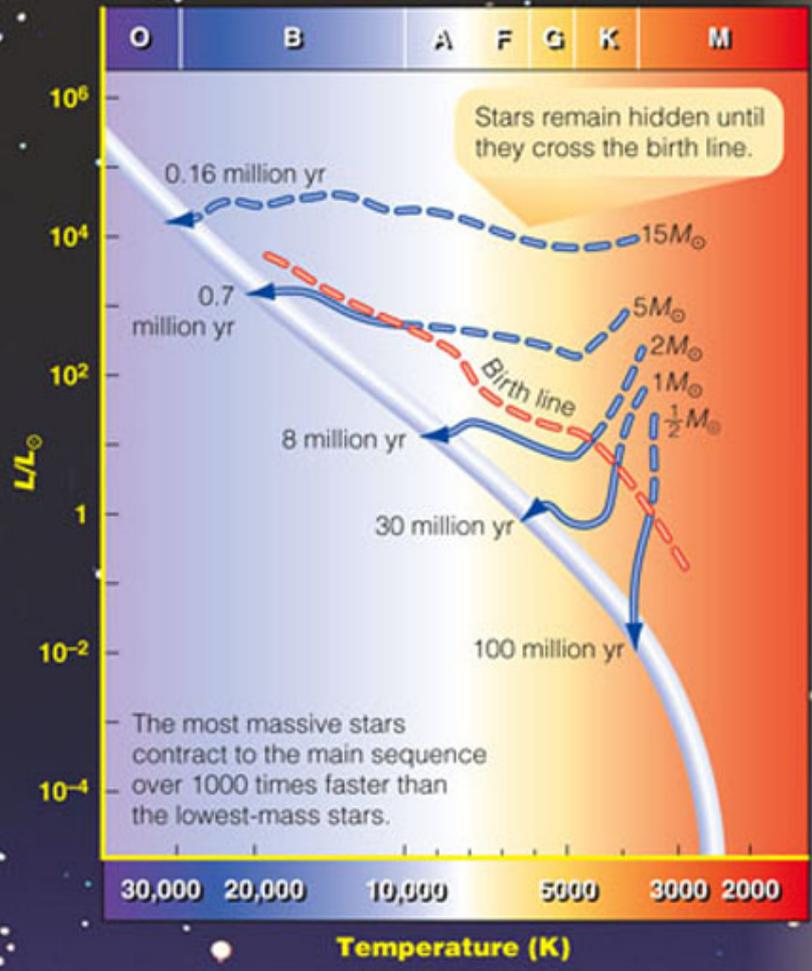
The Hertzsprung-Russell Diagram



This is the Hertzsprung-Russell diagram, a plot of the luminosities of stars vs. a measure of their temperatures. Stars at the top of the diagram are more luminous and larger than the Sun. Those at the bottom are smaller and less luminous.

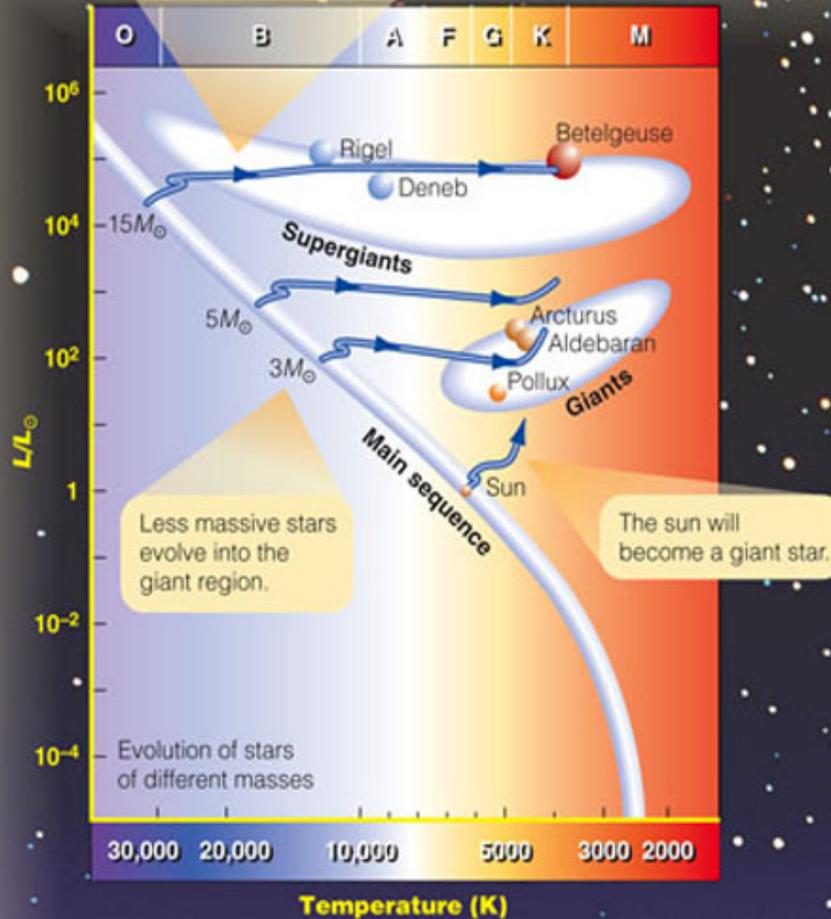


The main sequence is also a mass sequence.



More massive stars contract faster to the main sequence in the process of formation.

Massive stars evolve from the main sequence into the supergiant region.



Once stars have used up their core hydrogen they evolve to become giants or supergiants.

(Well, red dwarfs with less than 0.4 solar masses do something else.)

Main sequence lifetime scales with mass as follows:

$$T_* / T_{\text{Sun}} = (M_* / M_{\text{sun}})^{-2.5}$$

The main sequence lifetime of the Sun is 10 billion years. A star with mass of 10 solar masses will use up its core hydrogen in 30 million years.

## Stars

mass = 0.4 solar masses (red dwarfs), or less

nuclear energy generated mainly by: proton-proton cycle

fully convective – means that they eventually convert *all* of their hydrogen into helium

main sequence lifetime > 200 billion years

will *not* become a giant

could become a helium white dwarf

## Stars

mass = 1.0 solar masses (like the Sun)

nuclear energy primarily generated by: proton-proton cycle

structure: radiative core, convective envelope

main sequence lifetime = 10 billion years

becomes a red giant, then.....

end state = carbon-oxygen white dwarf star

## Stars

mass = 2.0 solar masses (like Sirius)

nuclear energy principally generated by: CNO cycle

structure: convective core, radiative envelope

main sequence lifetime = 1.8 billion years

becomes a red giant, produces a planetary nebulae

end state = carbon-oxygen white dwarf star

# Stars

mass = 8.0 solar masses or more (like Betelgeuse)

nuclear energy principally generated by: CNO cycle,  
then in shells, then eventually they get iron cores

structure: convective core, radiative envelope

main sequence lifetime < 55 million years

become supergiants

end state = Type II supernova --> neutron star, pulsar,  
or black hole

## Stellar temperatures and colors

Spectral type	Photospheric temperature (degrees K)	color
O9	34,000	blue
A0	10,000	white
G2	6,000	yellow
K2	4,830	orange
M5	3,170	red

Harvard spectral classification scheme – the spectral types from hot to cool are OBAFGKM

Spectral type	spectral characteristics
O	helium lines, weak H lines
B	weaker He line, stronger H lines
A	strongest H lines
F	weaker H lines, some metallic lines
G	weaker still H lines, strong lines of calcium, iron, sodium
K	even stronger lines of Ca, Na
M	molecular bands such as TiO, VO

Stars are fueled by nuclear *fusion* in their cores. Most stars spend 90 percent of their lives as main sequence stars, converting H into He.

Nuclear *fission*, on the other hand, is the breaking apart of heavy nuclei such as uranium.

You can remember the word **fusion** because you know that to fuse two objects means to stick them together.

In their cores massive stars will successively produce helium, carbon, oxygen, neon, sodium, magnesium, oxygen, silicon, sulfur, phosphorus, nickel, up to iron.

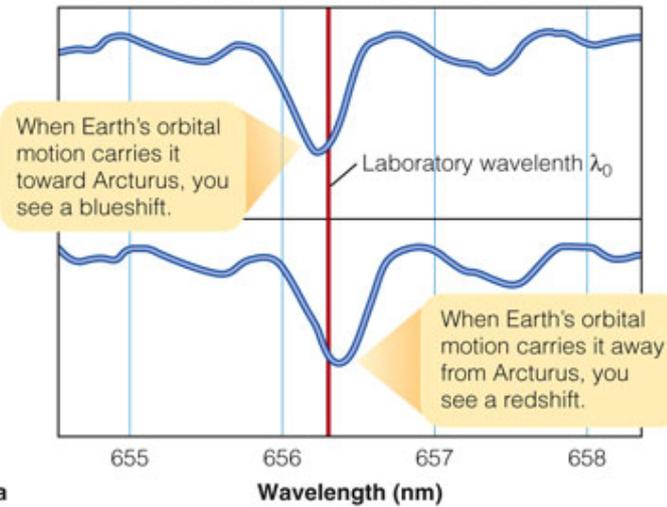
## Doppler shifts, blue shifts, red shifts

The Doppler shift is the fractional change of the wavelengths of a source of light (or sound) compared to the speed of the waves. For a light source with relative velocity  $v$  along the line of sight

$$z = v/c = \Delta\lambda / \lambda$$

If the source's waves are shifted to shorter wavelengths, the distance between the observer and the source is decreasing. These are blue shifts. If the distance is increasing, the observed wavelengths are greater than the laboratory values. These are red shifts.

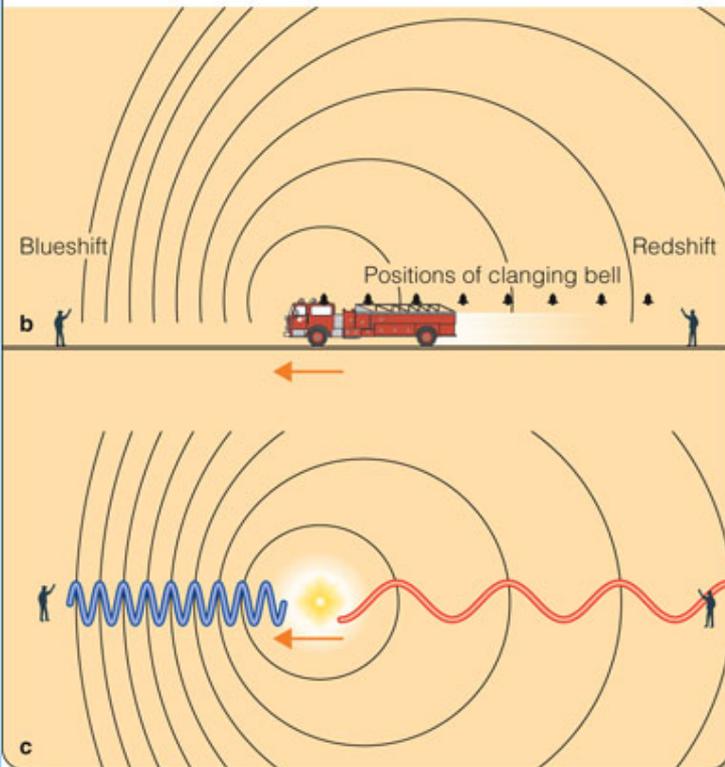
Balmer Alpha line in the spectrum of Arcturus

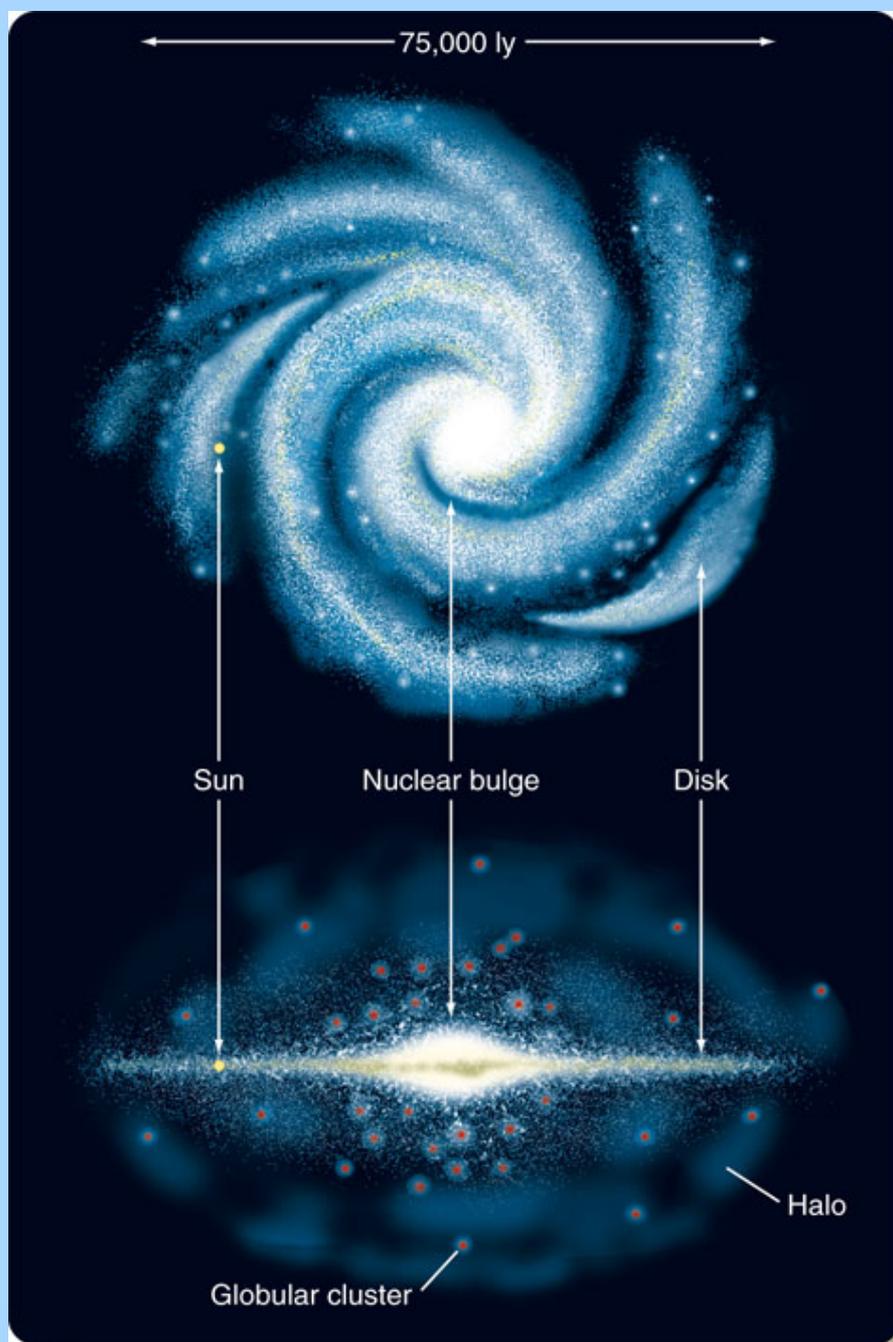


Spectral lines of stars in our galaxy are shifted only a little bit because the velocities are small compared to the speed of light.

The velocity of a speeding ambulance can be much larger percentage of the speed of sound.

Distant galaxies can have very large redshifts.





The Milky Way is a large spiral galaxy. The Sun is located about  $\frac{2}{3}$  of the way from the center to the edge of the visible disk. The Sun is located in the plane of the Galaxy. The center of the Galaxy is about 8000 parsecs away, in the constellation Sagittarius. The diameter of the Galaxy is about 25,000 parsecs, or about 75,000 light-years. The center of the globular cluster system is also the center of the Galaxy.

Where did various kinds of atoms come from?

During the first 5 minutes after the Big Bang protons, helium nuclei, a teeny bit of deuterium and lithium, plus lots of electrons were created. 400,000 years later the universe was cool enough for the electrons to combine with those protons to make neutral hydrogen atoms, and other electrons combined with the helium nuclei to make neutral helium. Roughly 75% of the universe (by mass) was hydrogen and roughly 25% was helium.

Once gas clouds collapsed into stars, nuclear fusion in the cores of stars created more helium, plus other atoms, all the way to iron (in stars 8 solar masses or more).

Single, massive stars that blew up as Type II supernovae created 50% of the natural elements heavier than iron. So most of the silver and gold in your fillings or in your jewelry was created in some supernova explosion before the Sun formed.

But all the protons in the universe were created during the first second after the Big Bang. In fact, the temperature was just right to make protons and anti-protons a few microseconds after the Big Bang.

There is a very slight excess of matter over anti-matter, which is why there are stars and planets today.

For summary of cosmology, refer to the full  
Powerpoint lecture devoted to quasars, gravitational  
lenses, and cosmology.