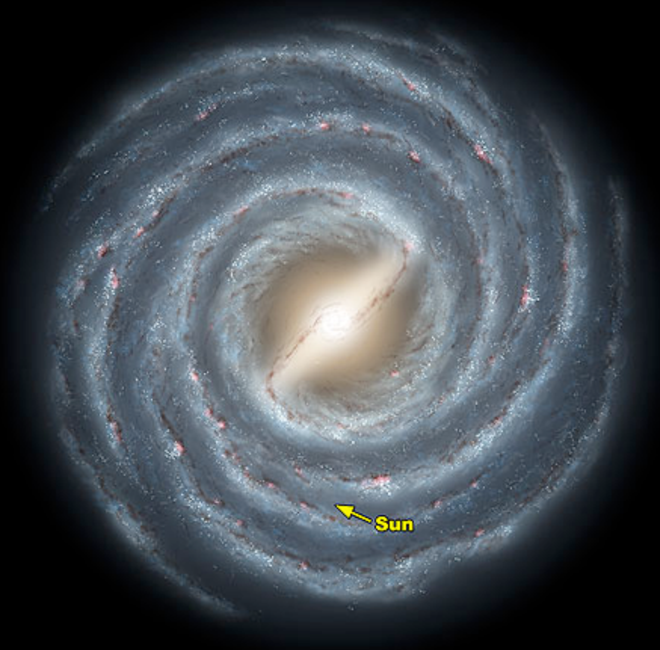
Stars and Planets



Dr. Mary Urquhart
University of Texas at Dallas
CAST 2007 Presentation

Activity 1:
Scale Model Solar System

Scale Factor of 1 to 10 billion

Based on Colorado Model Solar System, on the campus of University of Colorado at Boulder (which was also the inspiration for the scale model solar system on the National Mall in Washington D.C.

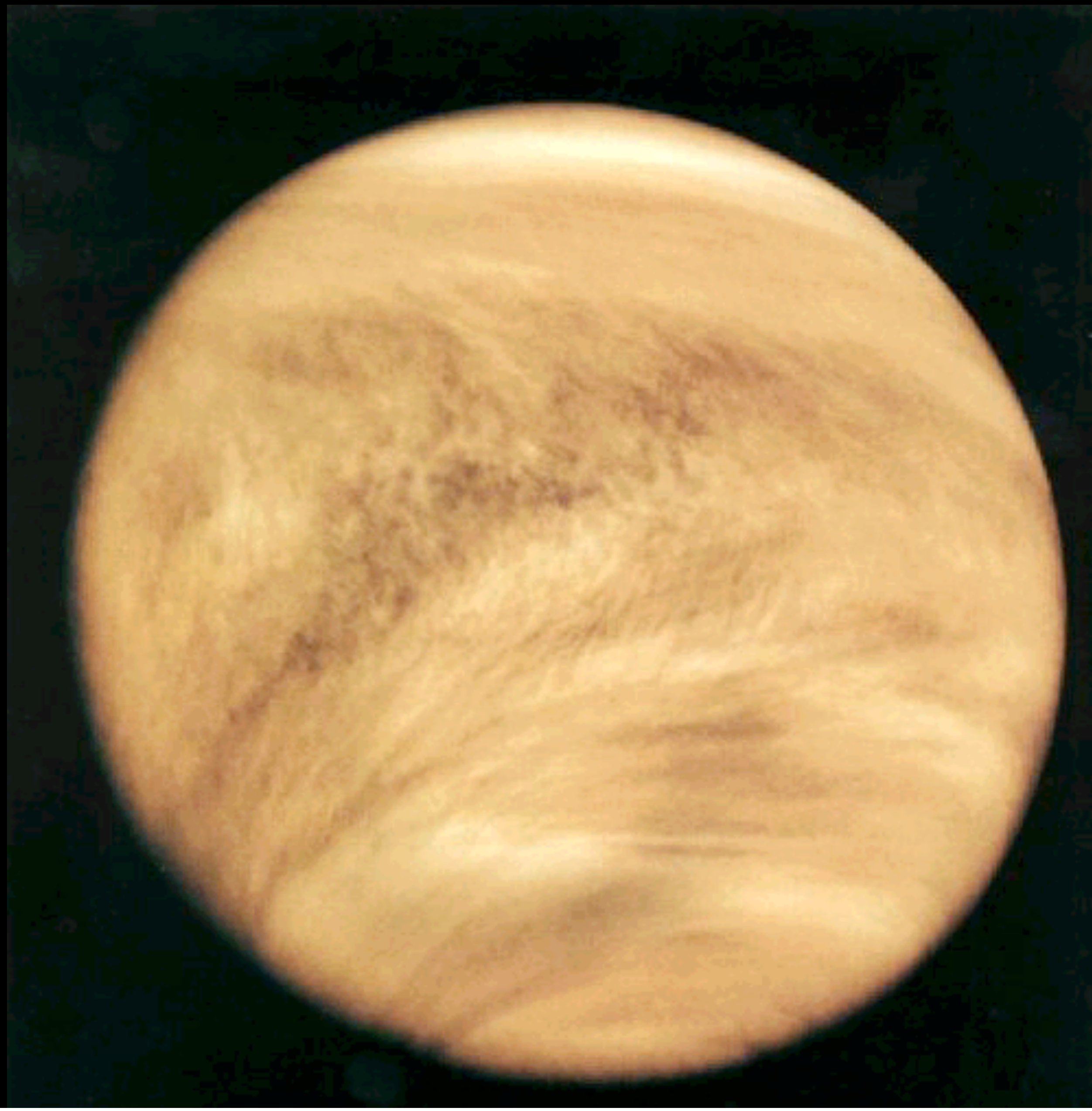
Key Concepts (Part 1)

- All planets are smaller than the Sun.
- The Earth is a very small planet.

Mercury

1

Venus



2

Earth

3

Mars

4

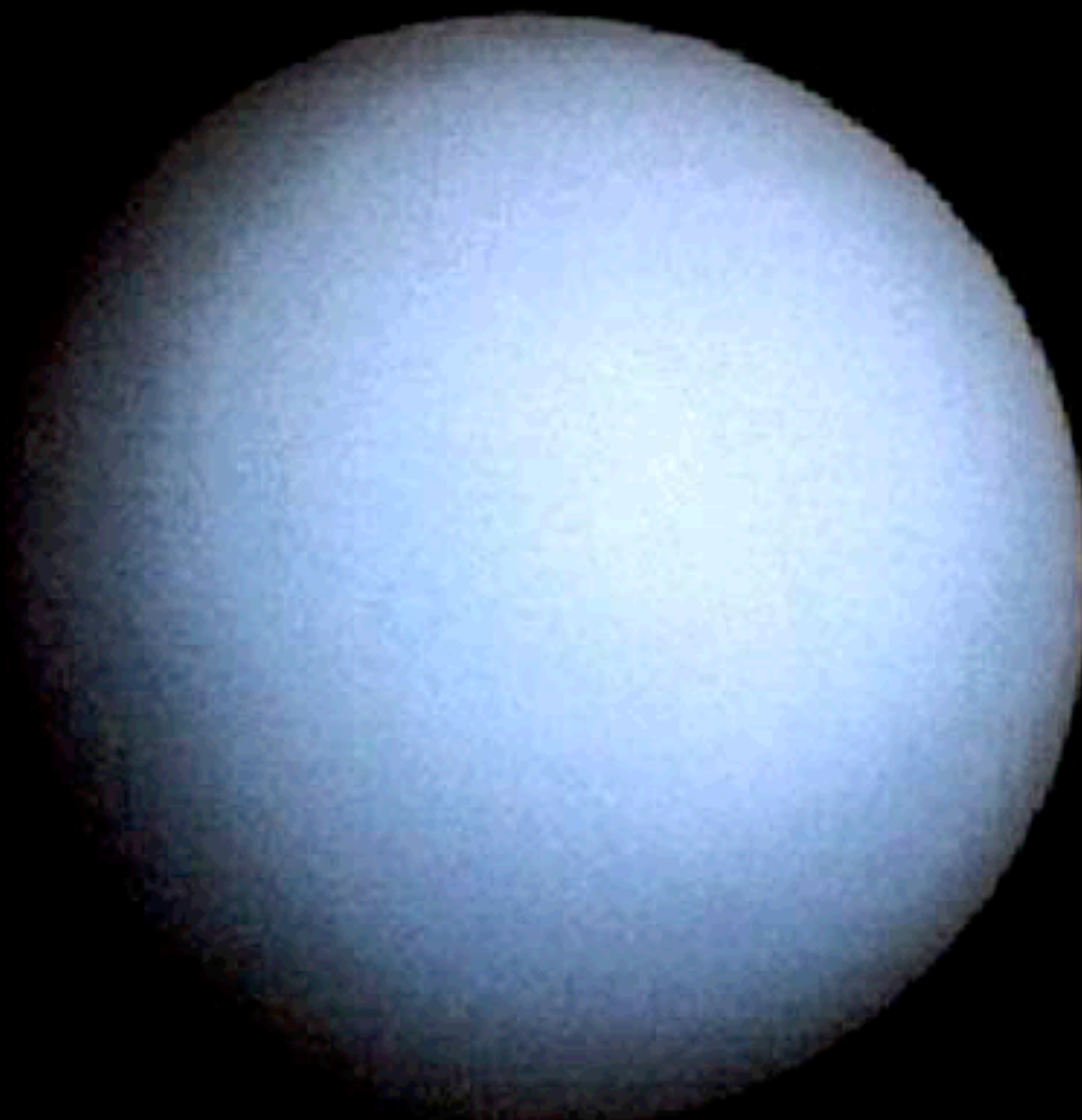
Jupiter

5

Saturn

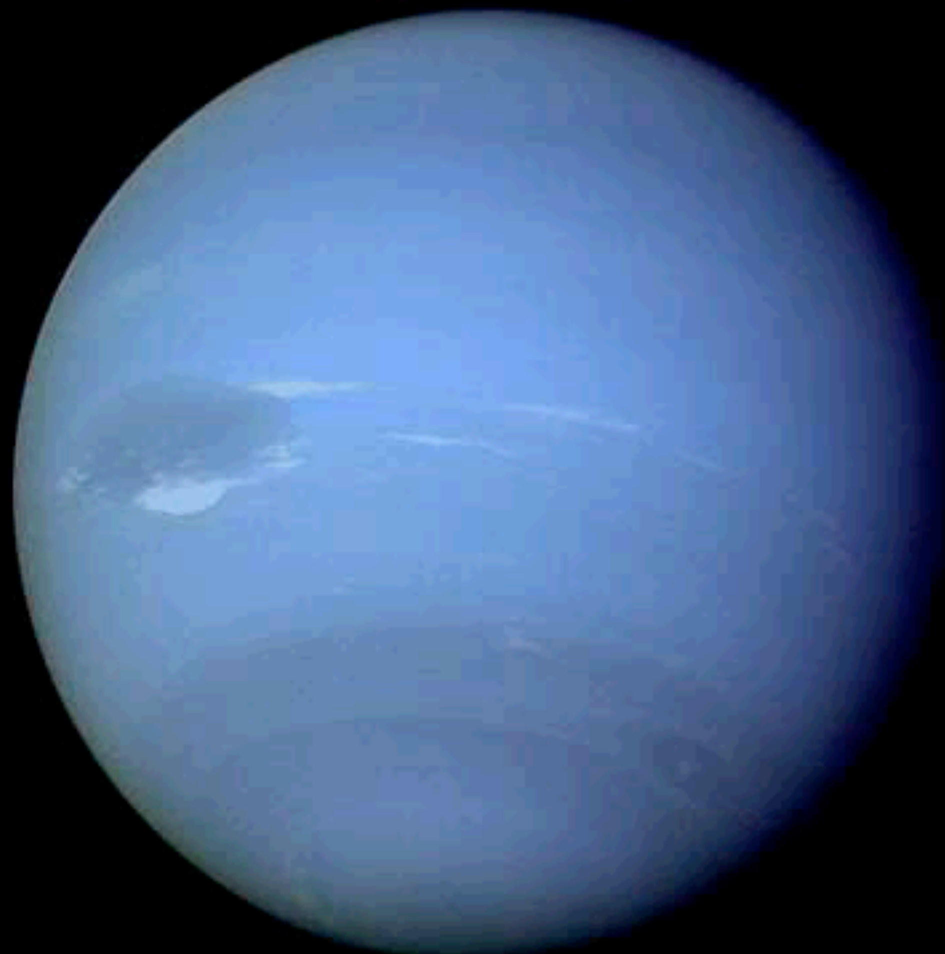
6

Uranus



7

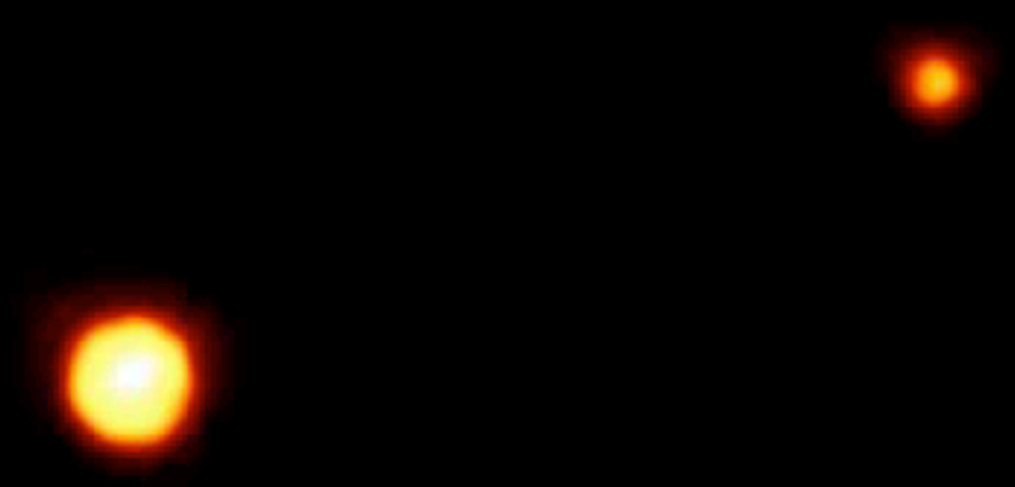
Neptune



8

Pluto?

(and its moon Charon)



9

The asteroid Ceres was once a planet, too. More on Pluto and the other dwarf planets for middle school presented on Friday (WS 2416) at 12:30 pm.

Key Concepts (Part 2)

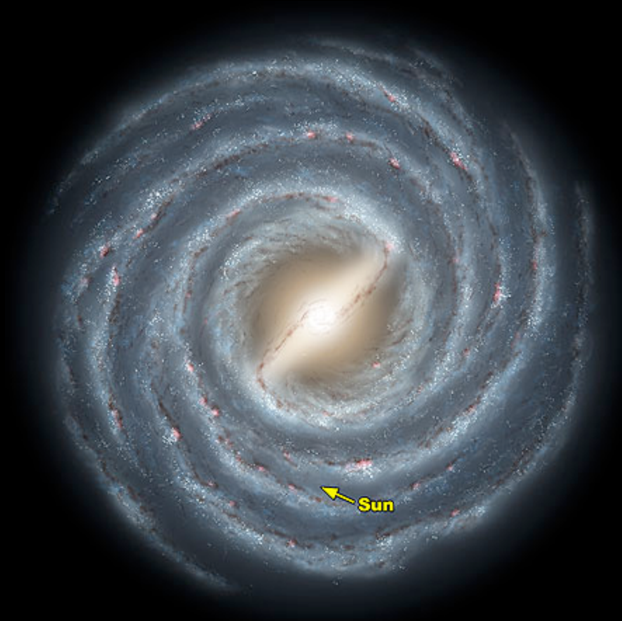
- The solar system is mainly empty space.
- The scale of the solar system is immense.
- The small inner planets (Mercury, Venus, Earth and Mars) are much closer to the Sun than the outer planets.

[redacted]

Lesson 2: Sizes of Stars

Uses same 1 to 10 billion scale factor as the Scale Model Solar System activity.

A Hundred (or Two) Billion Stars



Our Sun is but one star out of more than 200 billion stars in the Milky Way galaxy!

Aside: Why can't the galaxy used in the above image be a real picture of the Milky Way?

Spectral Classes of Stars

The spectral class of a star is dependent the temperature of the star's photosphere. There are seven major spectral classes:

O	30,000 - 60,000 K	Blue-white stars
B	10,000 - 30,000 K	Blue-white stars
A	7,500 - 10,000 K	White stars
F	6,000 - 7,500 K	Yellow-white
G	5,000 - 6,000 K	Yellow stars (like the Sun)
K	3,500 - 5,000K	Yellow-orange stars
M	< 3,500 K	Red stars

Newly adopted spectral classes of very low-mass stellar objects: L and T (these objects are considered by many to be brown dwarfs- true failed stars, and have too little mass for hydrogen fusion to begin, but do have the fusion of lithium and deuterium as a short-term energy source.

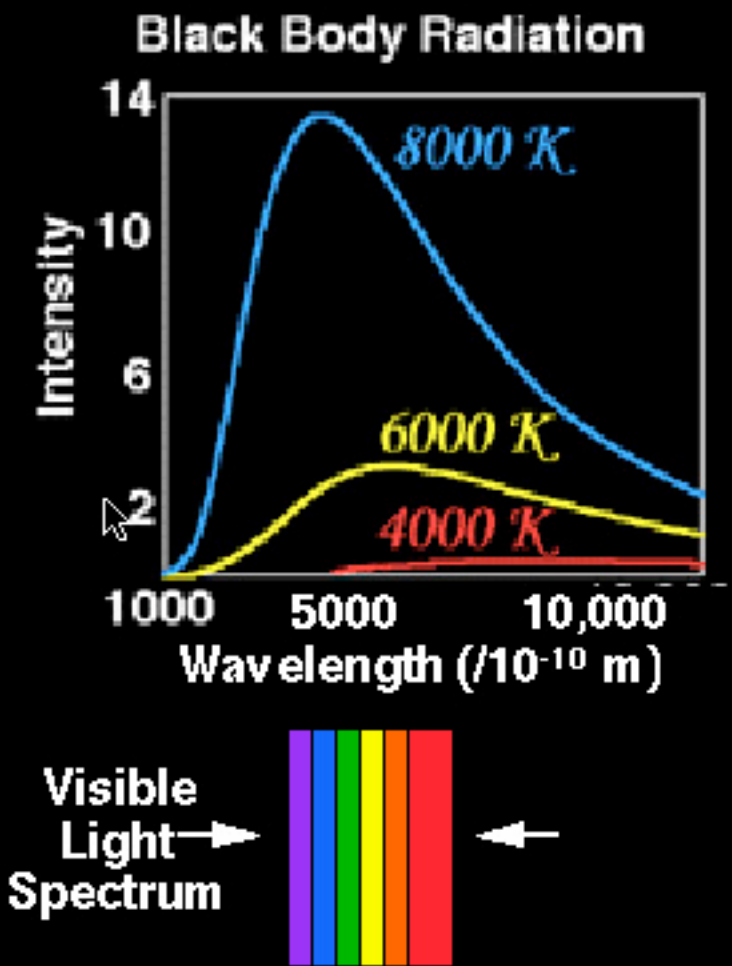
Remembering Classes

Traditional:
Oh **B**e **A** **F**ine **G**irl, **K**iss **M**e!

Or try:
Oh **B**e **A** **F**ine **G**uy, **K**iss **M**e!

A great activity for students of all ages is to have them create their own mnemonic phrases.

Black Body Radiation Temperature, and Color



Windows to the Universe has a classroom friendly explanation of black body radiation, temperature, and color.

Go to:

http://www.windows.ucar.edu/tour/link=/cool_stuff/tourstars_13.html

Image Source: http://www.windows.ucar.edu/tour/link=/cool_stuff/tourstars_13.html

[redacted]

Lesson 3: Distances of Stars

How Far Away are the Nearest Stars?

If we were to add the nearest star system, Alpha Centauri to our scale model solar system, how big a space would we need?

Would it be on campus?

Near campus?

Across town?

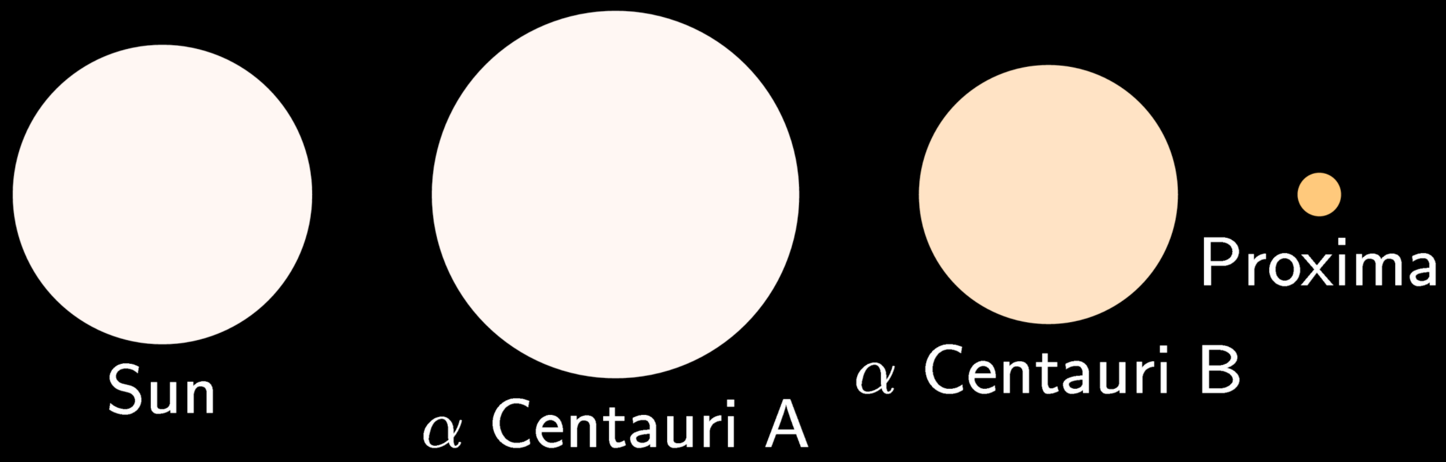
In another city?

On the other side of the US?

In another country?

Around the world?

Alpha Centauri System

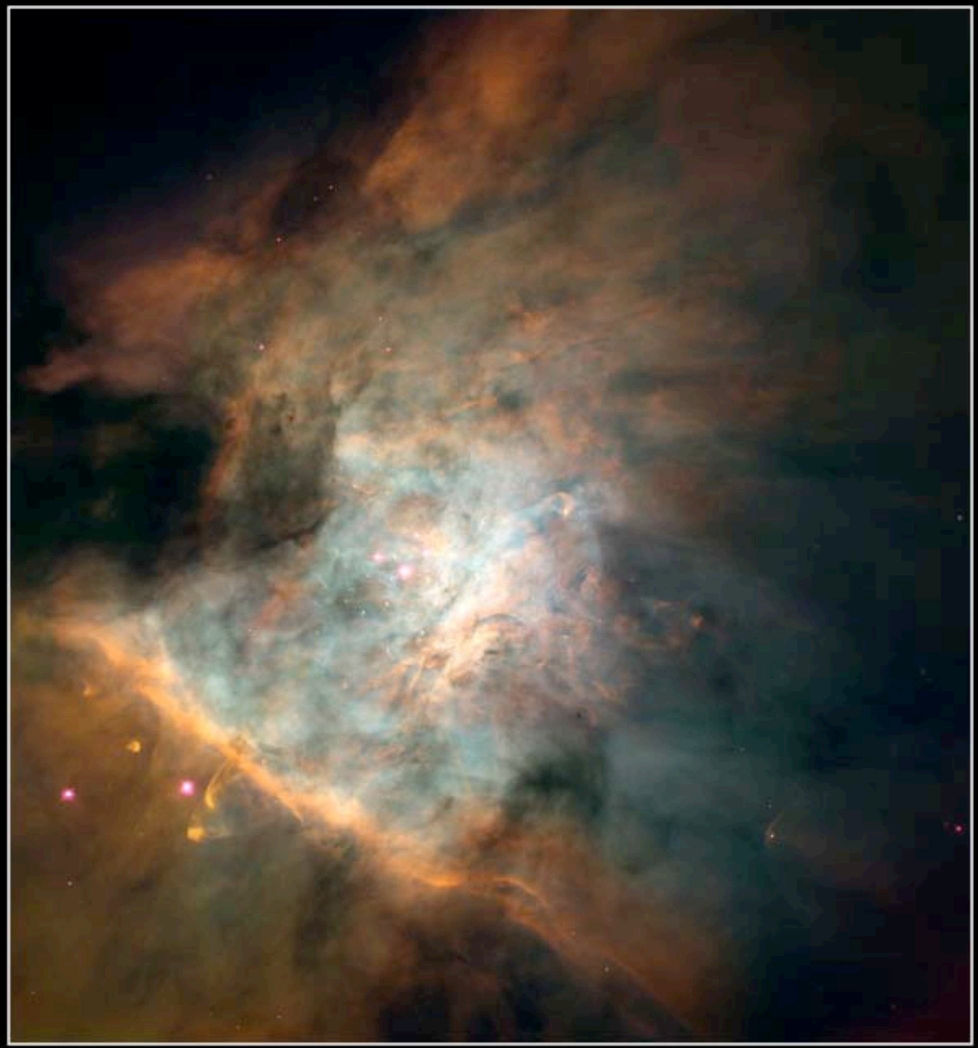


To scale for size, not distance.

[redacted]

Lesson 4: Star Birth

Orion Nebula: What do you see?

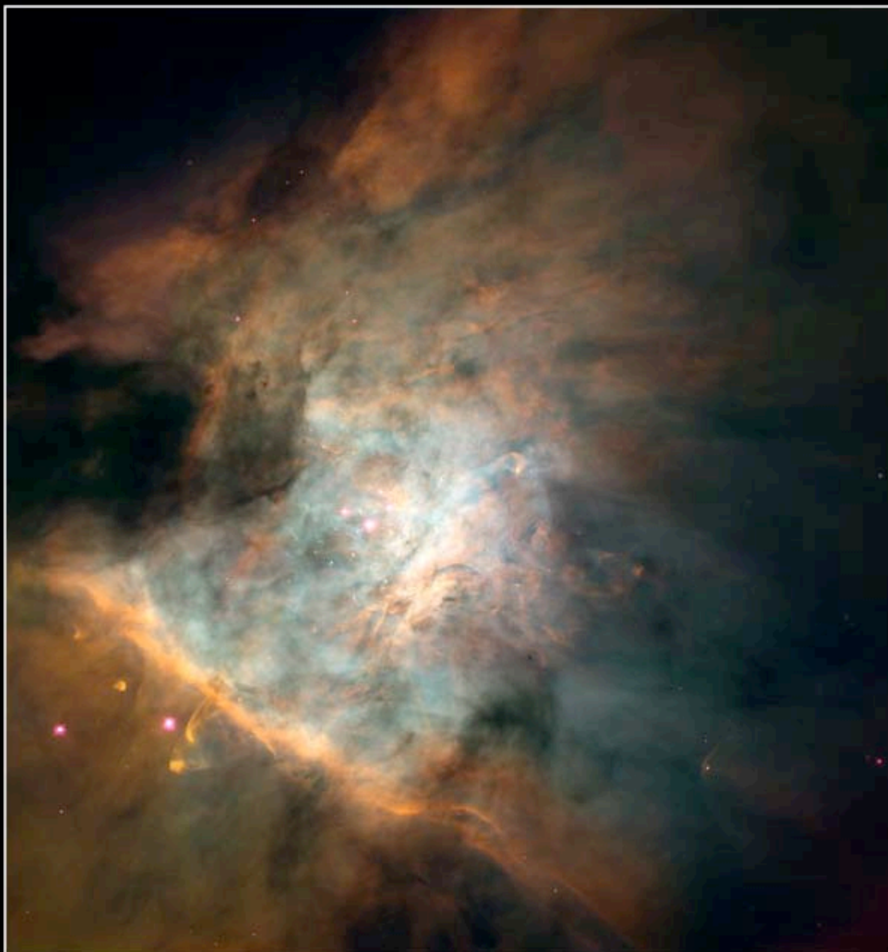


Orion Nebula Mosaic HST • WFPC2

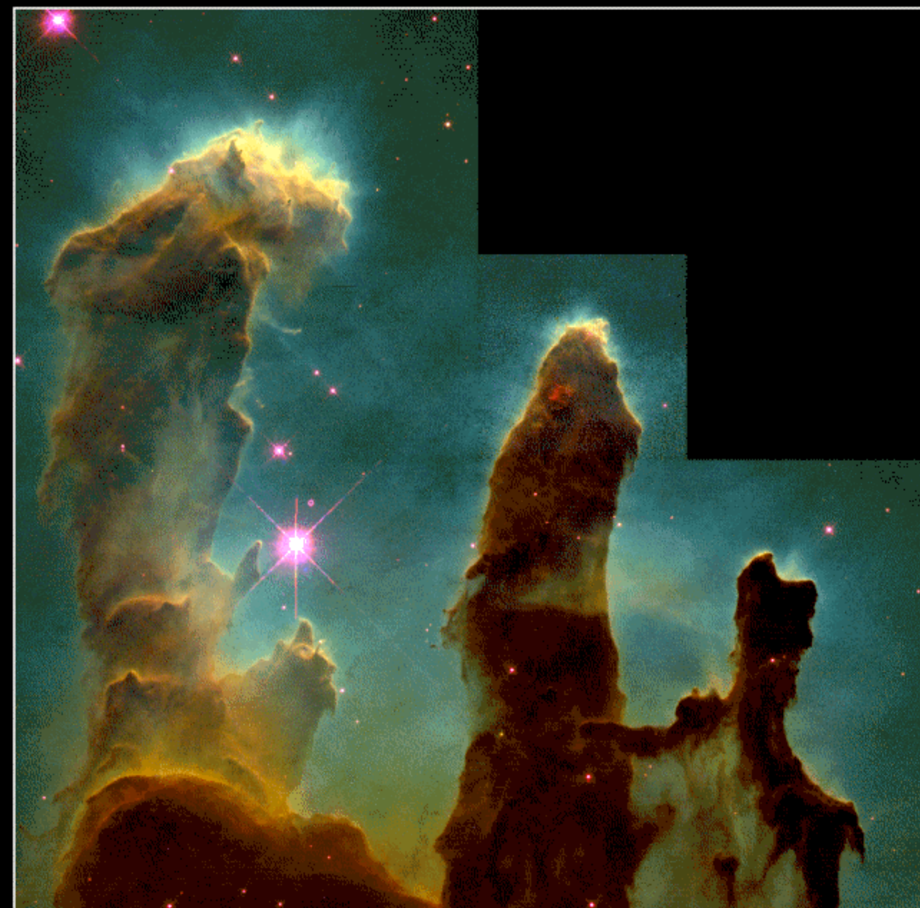
PRC95-45a • ST Scl OPO • November 20, 1995

C. R. O'Dell and S. K. Wong (Rice University), NASA

Emission Nebula are Stellar Nurseries



Orion Nebula Mosaic HST • WFPC2
PRC95-45a • ST ScI OPO • November 20, 1995
C. R. O'Dell and S. K. Wong (Rice University), NASA



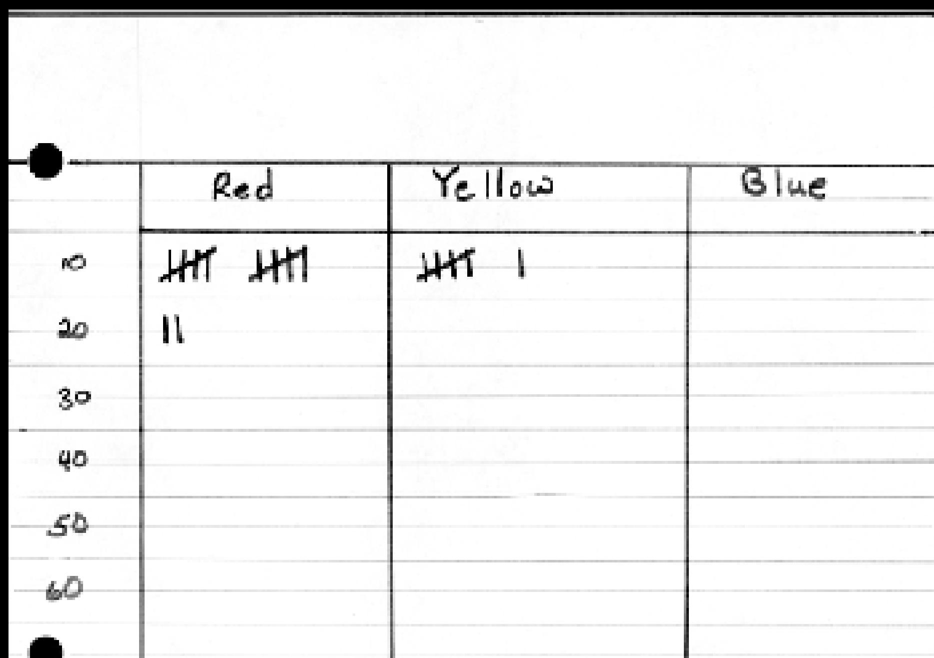
Gaseous Pillars • M16 HST • WFPC2
PRC95-44a • ST ScI OPO • November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

Eagle Nebula

Initial Mass Function

Not all stars are created equal!!

Activity:
Probability and Star Formation



	Red	Yellow	Blue
10	𝍸 𝍸	𝍸 |	
20	||		
30			
40			
50			
60			

Stellar Disks with Tails??

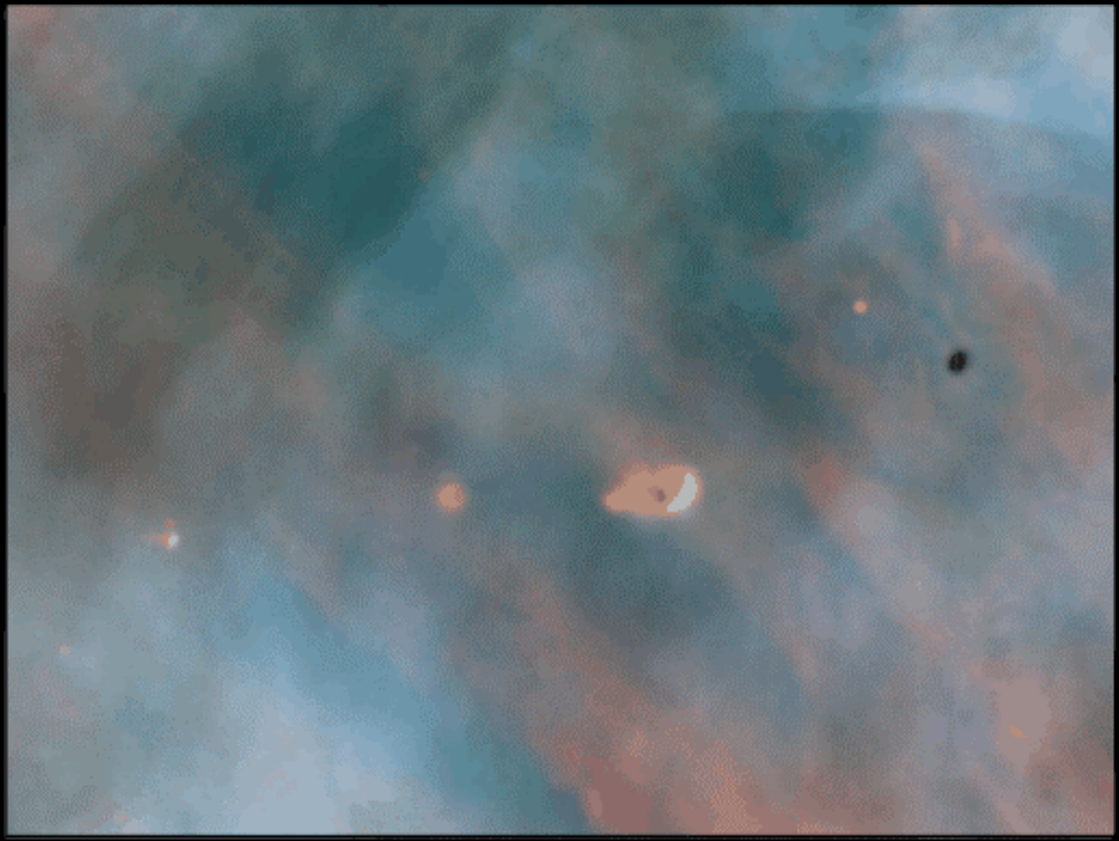
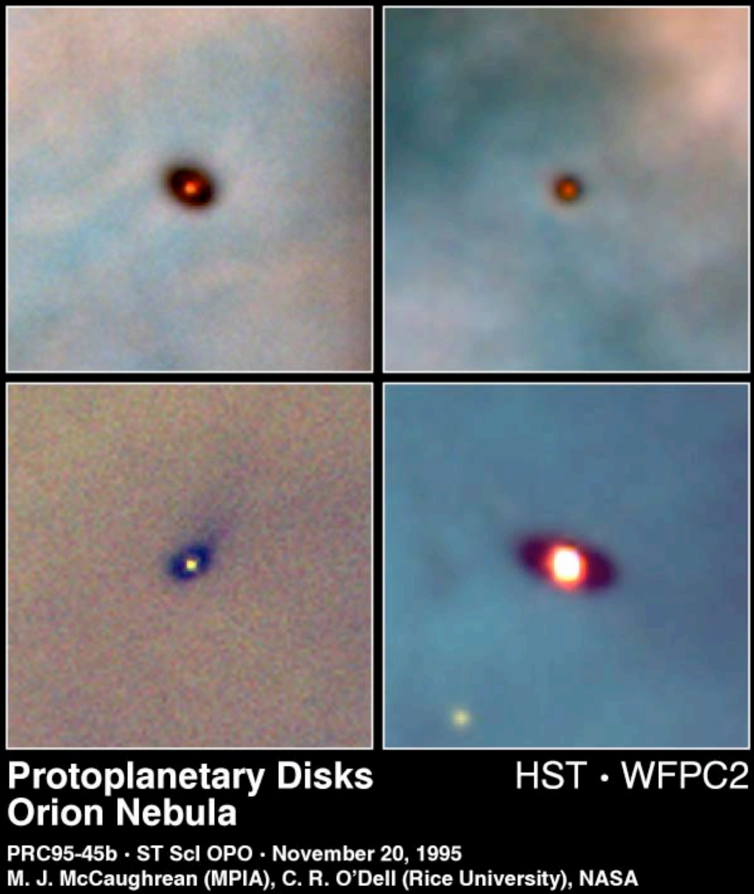


Image from: http://physics.hallym.ac.kr/education/stellar/hst/pubinfo/PR/94/24.html

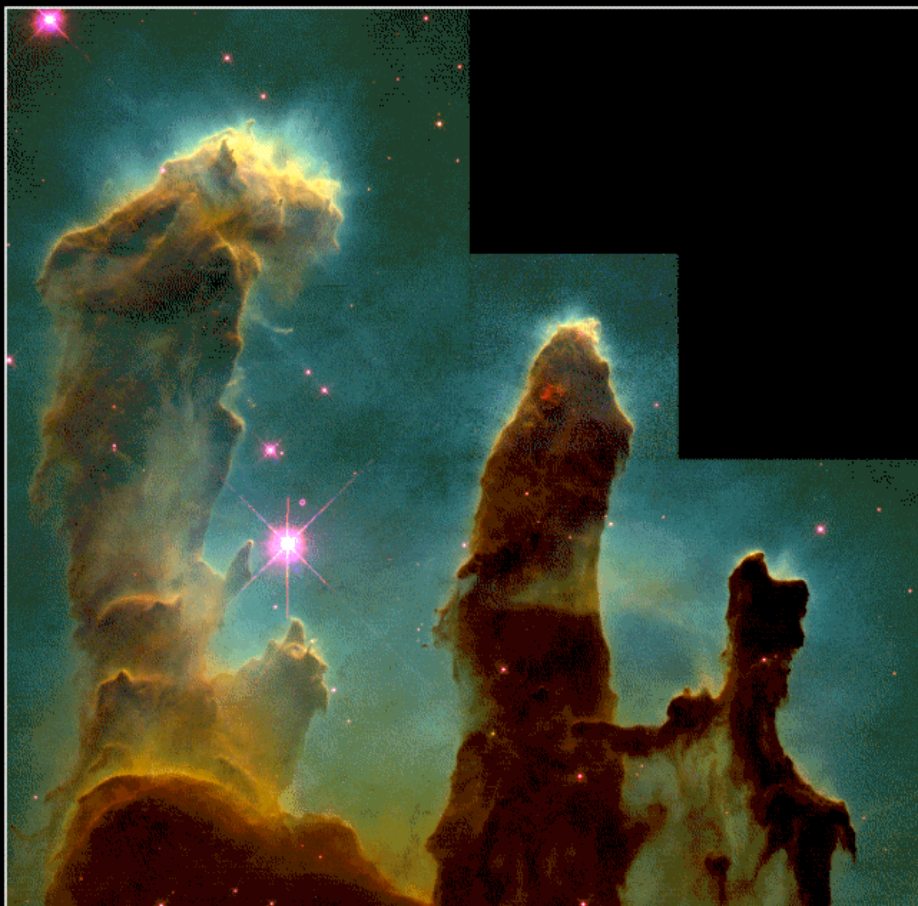
Many of the disks around young stars in the Orion nebula are being destroyed by the light and stellar winds of the hot O and B stars in their stellar nursery, giving the disks the appearance of tails pointing away from the cluster of massive stars.

Protoplanetary Disks in Orion



More information at: http://hubblesite.org/newscenter/archive/1995/45/image/b

Internet Explorations

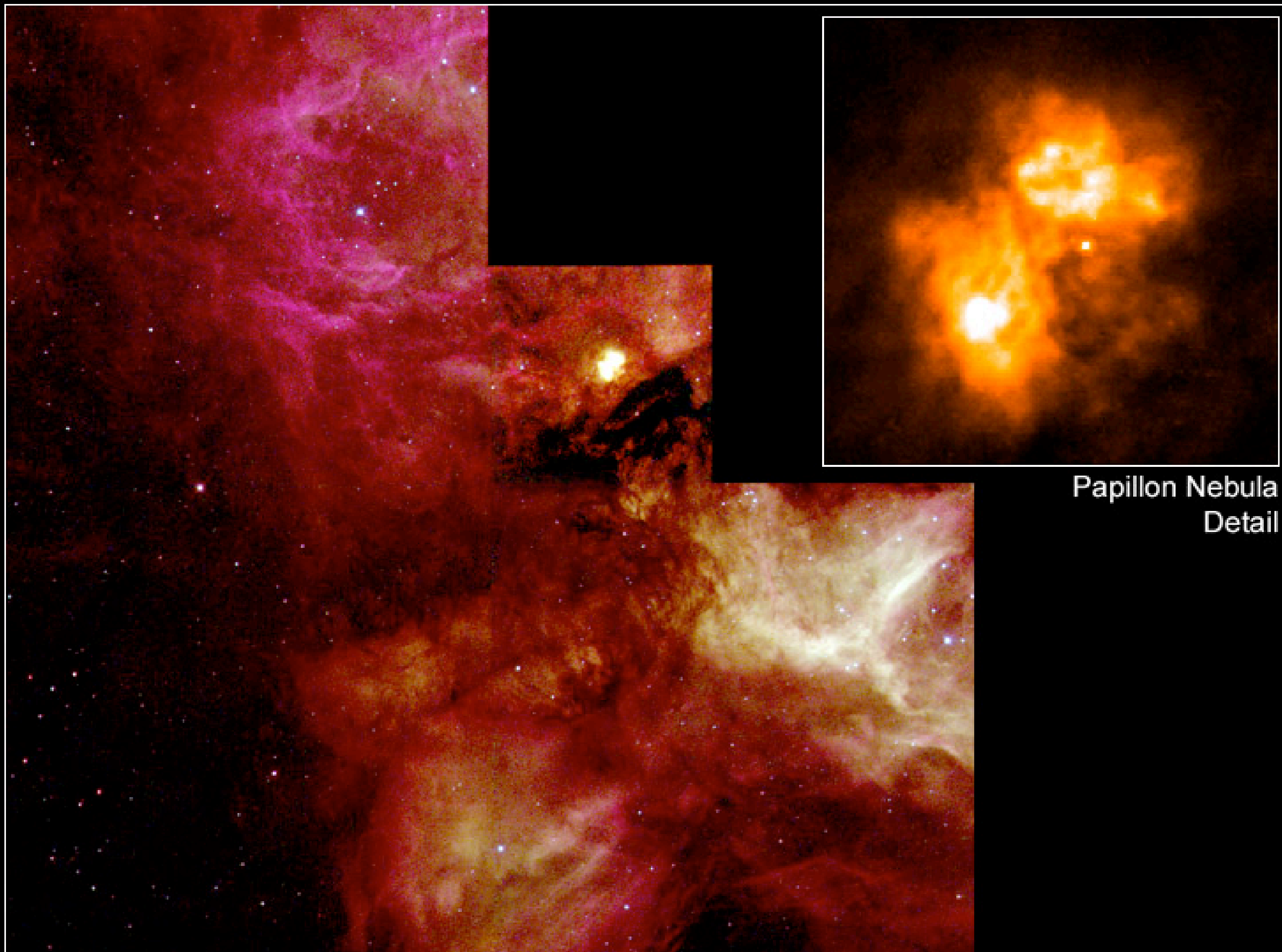


Gaseous Pillars · M16 HST · WFPC2

PRC95-44a · ST ScI OPO · November 2, 1995
J. Hester and P. Scowen (AZ State Univ.), NASA

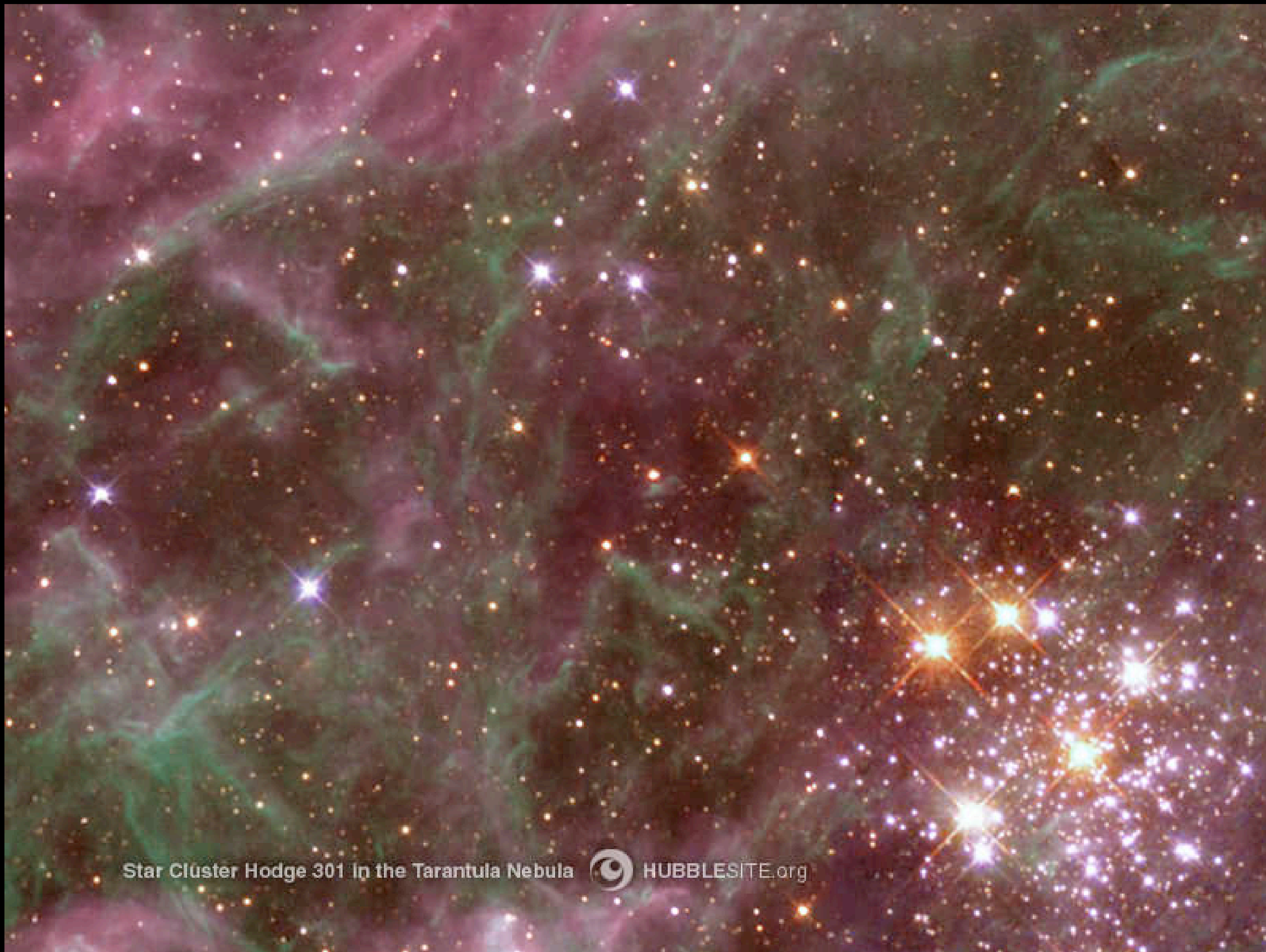
Trifid Nebula • M20 **HST** • WFPC2

NASA and J. Hester (Arizona State University) • STScI-PRC99-42



N159 in the Large Magellanic Cloud

PRC99-23 • STScI OPO • M. Heydari-Malayeri (Observatoire de Paris) and NASA


Star Cluster Hodge 301 in the Tarantula Nebula
HUBBLESITE.org

[redacted]

Lesson 5: Lifetimes of Stars

The Pleiades is a famous cluster of young stars visible in the constellation Taurus. When most of the gas and dust is gone from a stellar nursery, the young stars are in an open cluster. One day these star systems will drift apart. Image source: http://antwrp.gsfc.nasa.gov/apod/ap021201.html

In Lifetimes of Stars, students make a scale model of ***time***, rather than of size or distance.

Lifetimes of Stars

Our own star, the Sun, will "live" as a main sequence star for about 10 billion years. We are about halfway through its lifetime. However, because its brightness increases as it builds up helium in its core, the Earth will only be habitable for another couple billion years.

$$\text{Lifetime} = \frac{\text{fuel supply}}{\text{rate of consumption}} \propto \frac{M}{M^{3.5}} = \frac{1}{M^{2.5}}$$

To determine the lifetime of another star, take its mass, M, relative to the mass of the Sun, and use the equation above. Then you will have the lifetime of the star relative to our own Sun.

Comparing Stellar Lifetimes to the Geologic History of the Earth

Stars and Planets lesson 5: *Lifetimes of Stars*
Available at http://lyra.colorado.edu/mary/stars

How do the lifetimes of the different classes of main sequence stars compare with the history of our planet? Why are astronomers more interested in finding Earth-like planets around stars of particular classes? How long does it take before a planet would have “interesting” life, assuming the history of life on Earth is typical?

Star Birth and Death

The most massive stars die in dramatic explosions called supernova. These stars also spend the shortest time on the main sequence. This means that many massive stars die while still embedded in the same stellar nurseries in which they were born. Supernovae can also lead to more star formation!

Open Clusters

Image of the Pleiades: http://www.cv.nrao.edu/~pmurphy/images/astro/

Image from http://www.astropix.com/HTML/B_WINTER/M46.HTM

After several hundred million years, and perhaps several generations of high mass stars, the remaining gas and dust in a stellar nursery starts to dissipate, leaving an open cluster of young stars. These stars will eventually drift apart and become independent stars or star systems in the galaxy.

[redacted]

Lesson 6: Death of Stars

Crab Nebula, a supernova remnant *Image source:* http://antwrp.gsfc.nasa.gov/apod/ap991122.html

In this activity, we return back to scale modeling of size with the 1 to 10 billion scale factor to look at dying stars and stellar remnants

Stellar "Evolution"

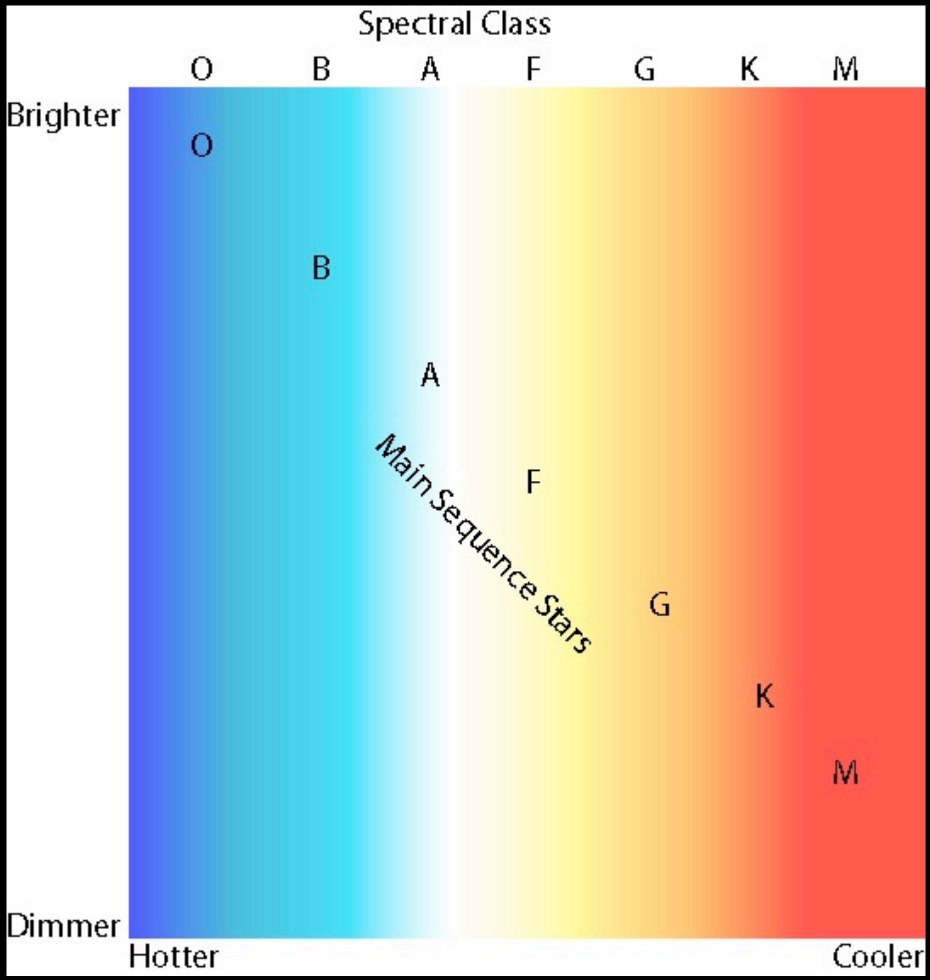
Stars, like people, change as they age. While on the main sequence, a star's color is directly related to its mass. Once a star runs out of hydrogen fuel in its core, however, everything changes! Stars will "evolve" off the main sequence with great changes in size, surface temperature, and luminosity. The final fate of an isolated star will be very dependent upon its initial mass.

At each stage of the life of a star, gravity plays a leading role.

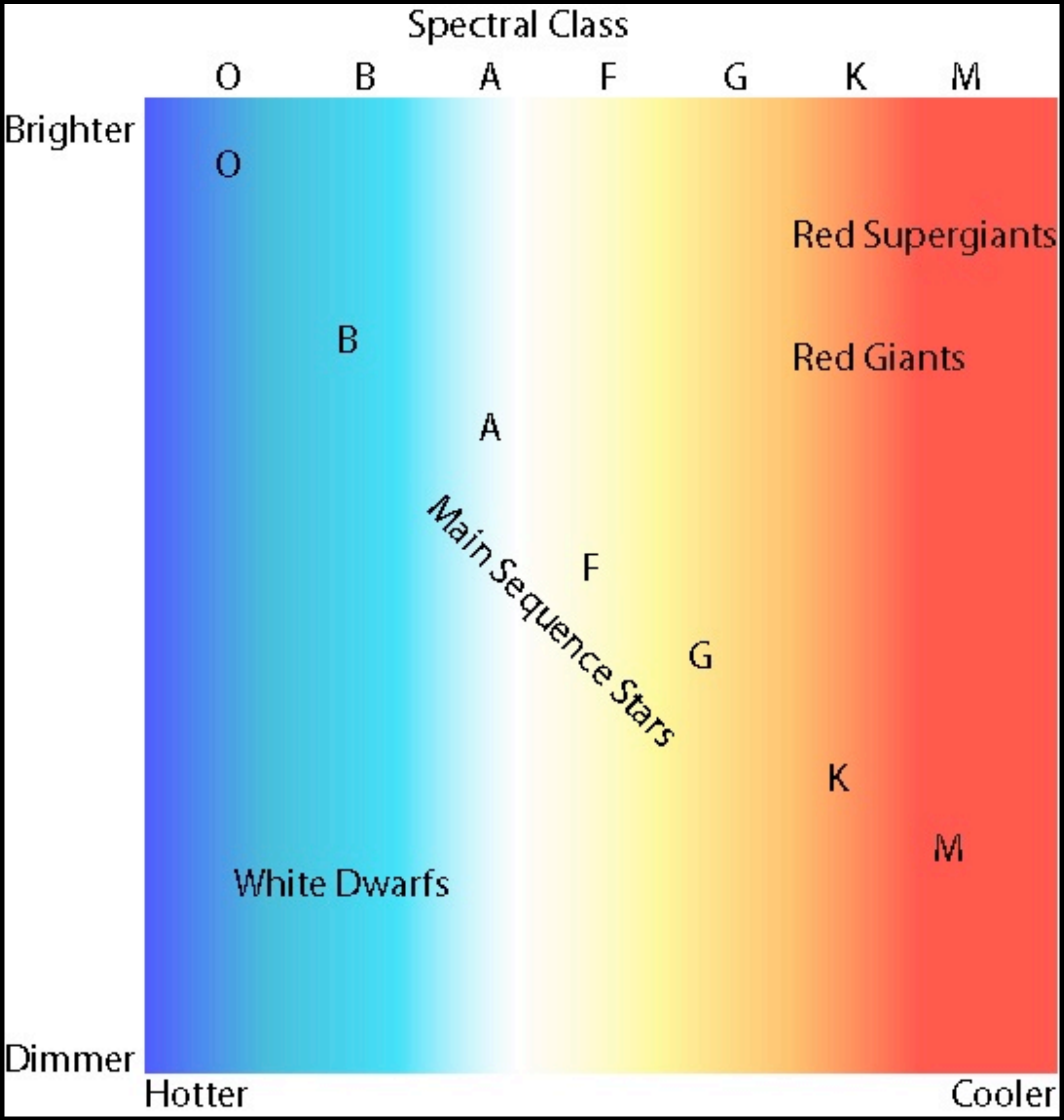
Class, Mass, and Luminosity

Once a star leaves the main sequence, its spectral class (dependent on surface temperature) has little to do with mass. Fortunately, evolved stars can easily be distinguished from main sequence stars by their luminosities (intrinsic brightness).

Hertzsprung-Russell Diagram



Leaving the Main Sequence



Online Lessons and Activities for HR Diagrams

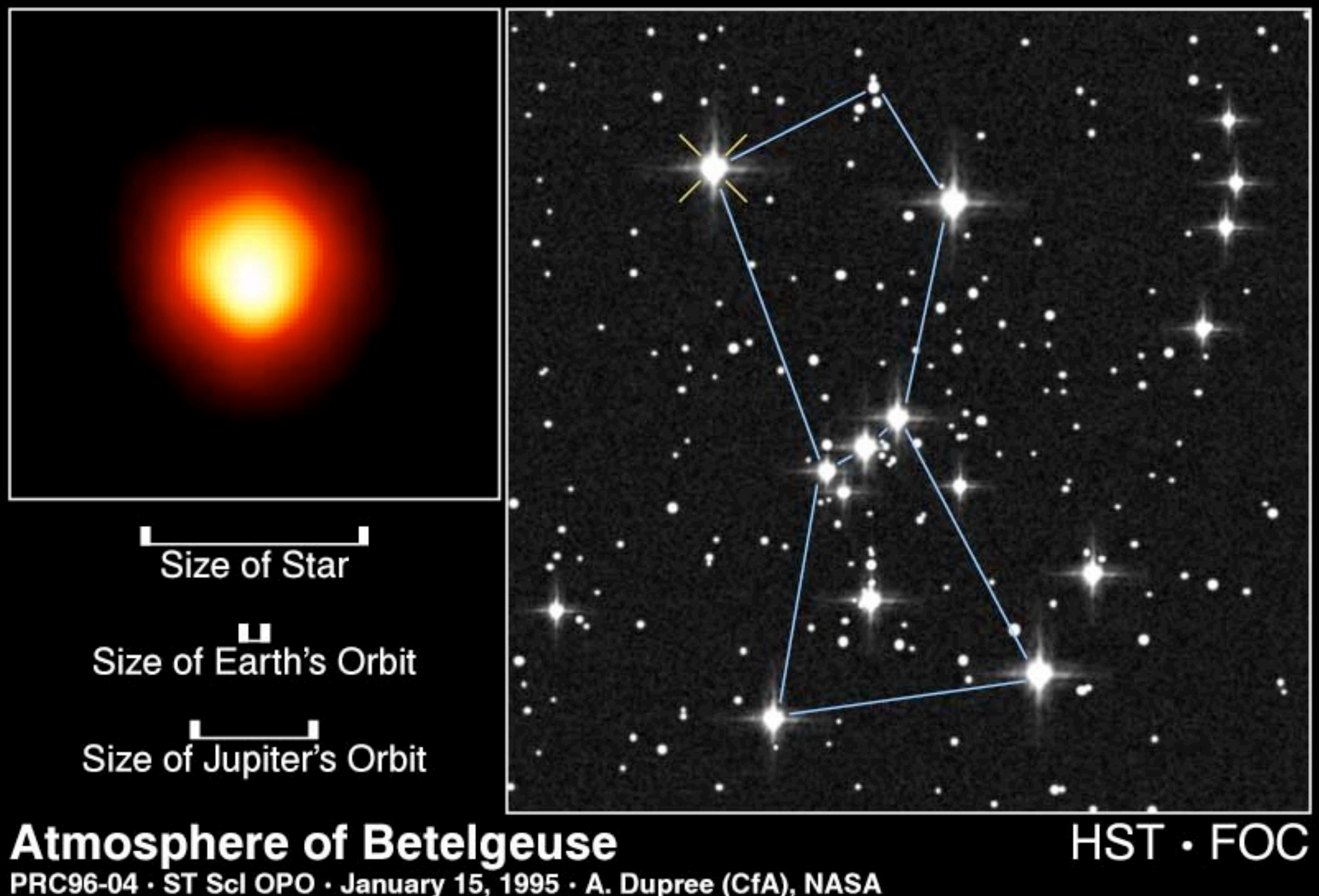
Try http://www.smv.org/jims/hr/hrEX.htm to construct your own H-R diagram. How did you do?

Then go to http://www.smv.org/jims/unit.htm to see the online lesson *How Hot is that Star?* From the beginning.

For an advanced high school interactive online lesson on HR diagrams, visit http://skyserver.sdss.org/dr1/en/proj/advanced/hr/. This is only one of many advanced and "beginner" lessons available from the Sloan Digital Sky Survey.

Jewels of the Night, is a High School lesson requiring access to a color printer. See http://www.noao.edu/education/jewels/home.html.

Red Giants and Supergiants



These stars generally produce more energy per unit time than they did when on the main sequence, resulting in a very bright, but cool, M class star.

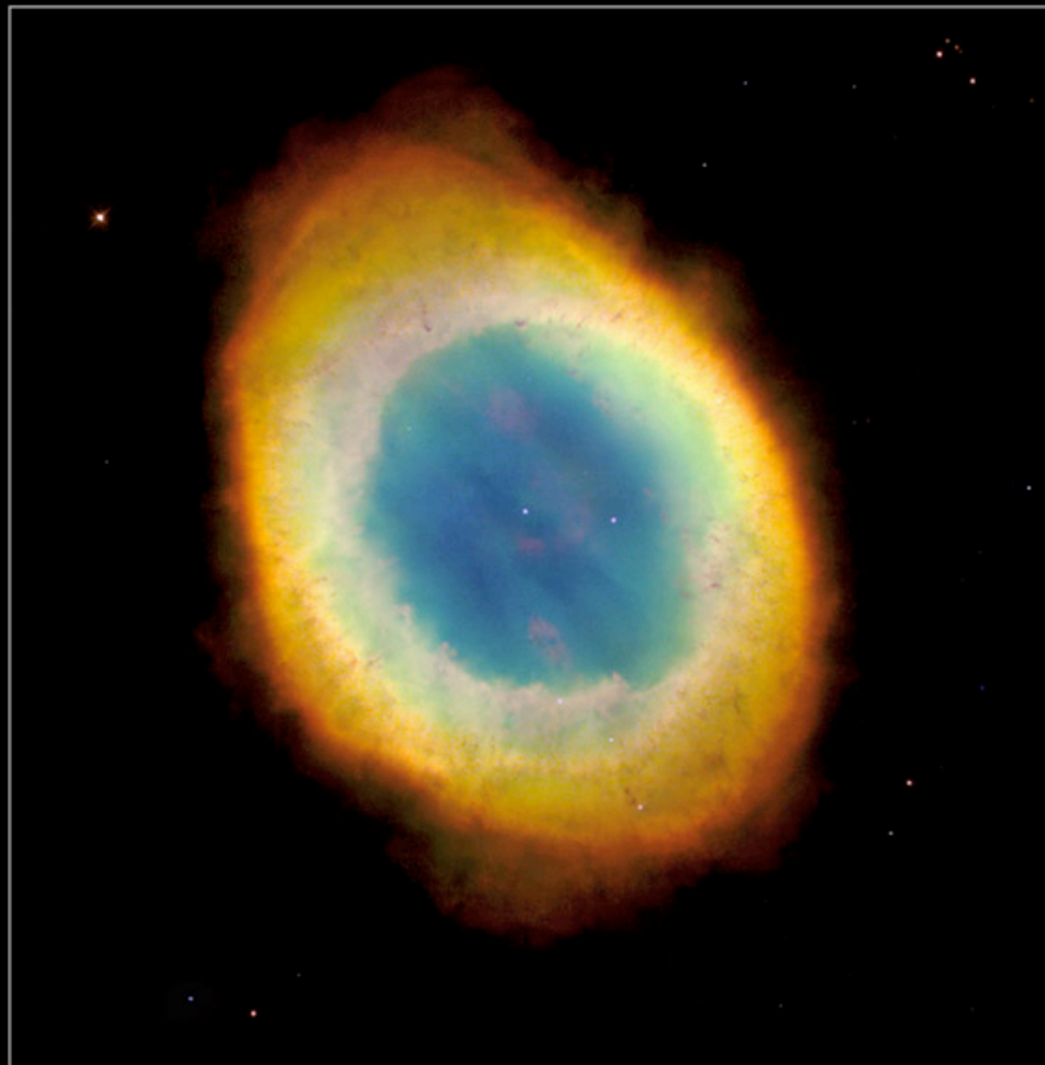
Scale Model Red Giants and Supergiants

Complete Table 1 in *Stars and Planets* lesson 5, *Death of Stars*

How do your scaled sizes for red giants and supergiants compare with the sizes of main sequence stars?

What does this tell you about the average density of giant stars?

Ring Nebula



PRC99-01 • Space Telescope Science Institute • Hubble Heritage Team (AURA/STScI/NASA)

NGC 2392 • "Eskimo" Nebula **HST** • WFPC2

NASA, A. Fruchter and the ERO Team (STScI) • STScI-PRC00-07

How Big is a White Dwarf?

Go to Table 2 in *Stars and Planets* lesson 5, *Death of Stars*

Compare the size of the white dwarf to the size and distances of planets in the solar system. Which object is closest to the size of a white dwarf?

What object could you use to represent a white dwarf?

Core of an Evolved Supergiant

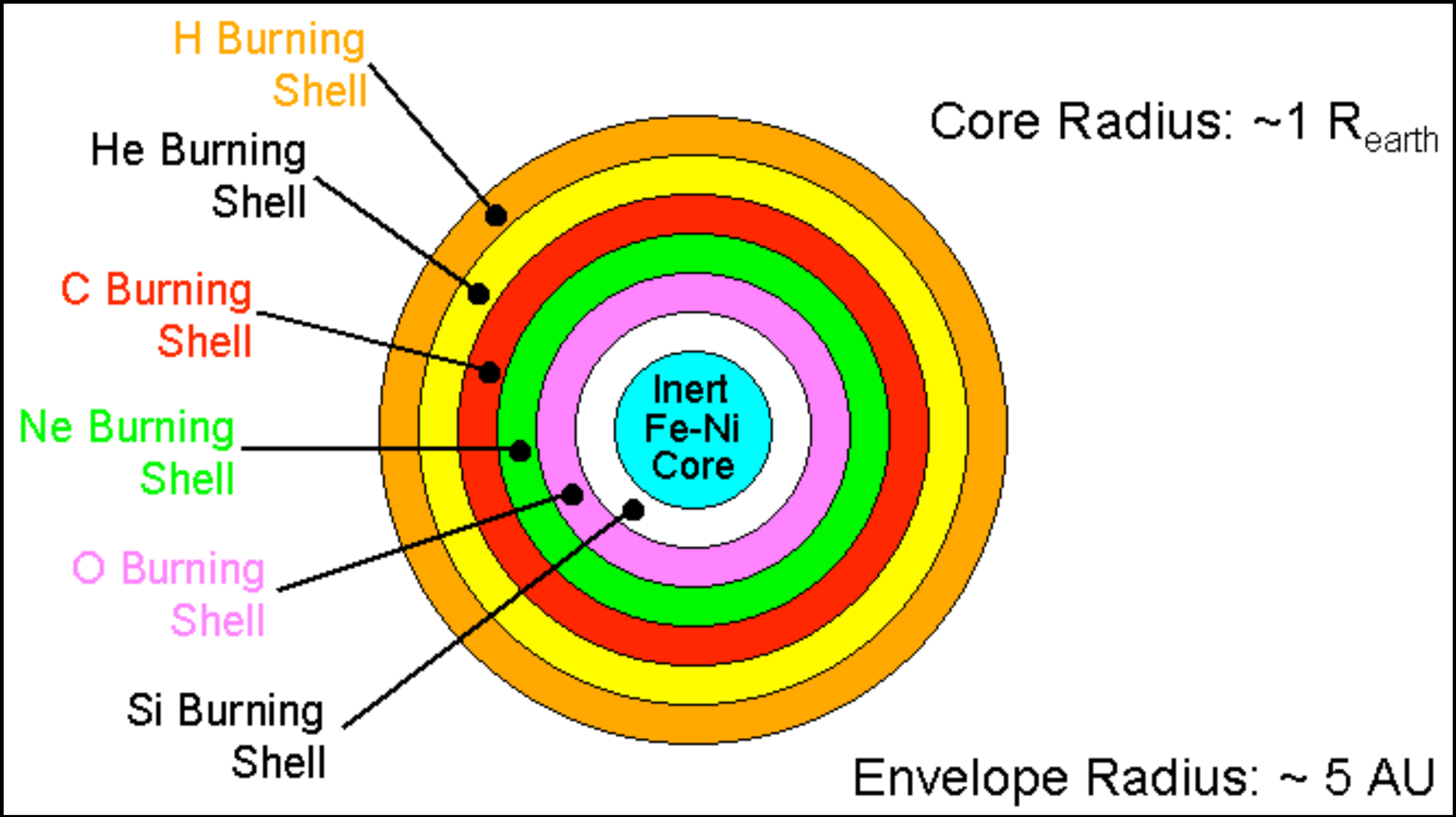


Image Source: http://www-astronomy.mps.ohio-state.edu/~pogge/Ast162/Unit2/himass.html

Si "burning" stage only lasts about 1 day!

More Illustrations and Information

http://chandra.harvard.edu/resources/illustrations/supernova.html

http://www.solstation.com/x-objects/crab-neb.htm

Result: Supernova!

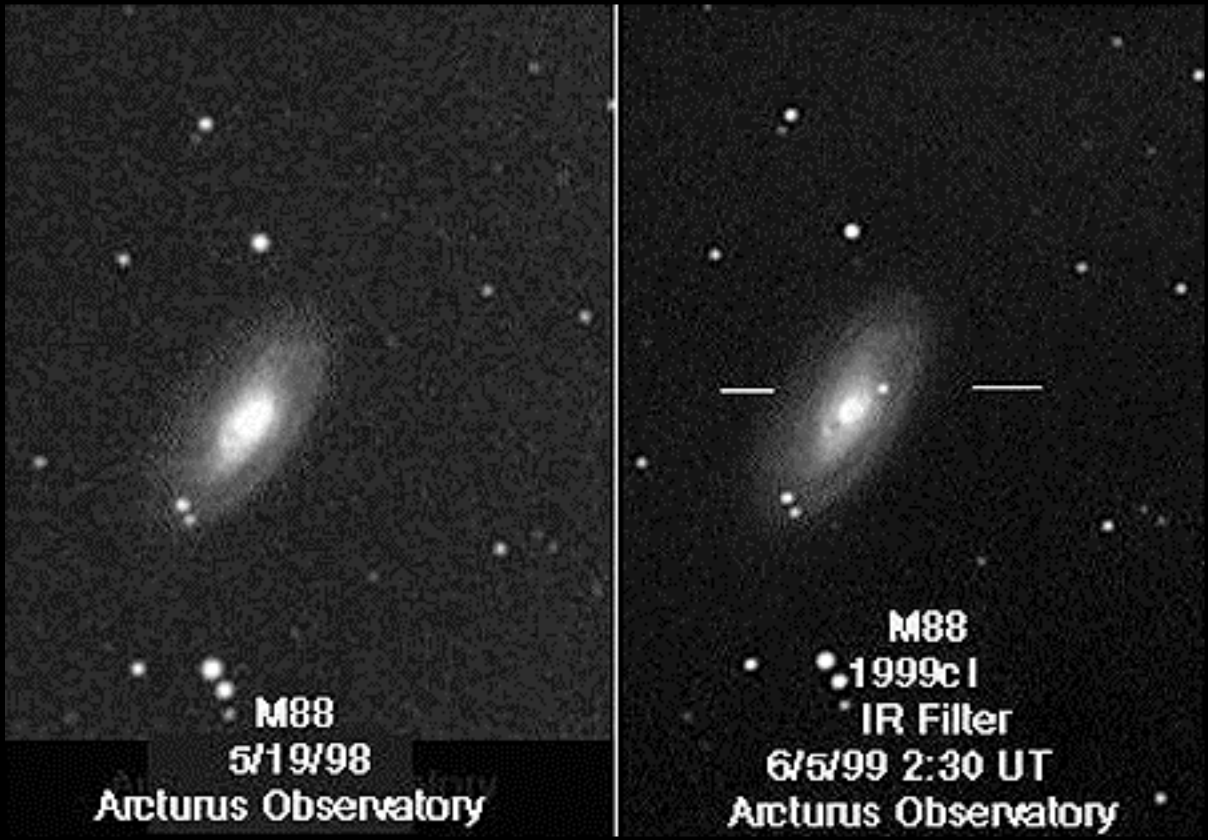


Image Source: http://rst.gsfc.nasa.gov/Sect20/A10.html

A supernova can be brighter than the light from an entire galaxy of more than 100 billion stars! Only rare, massive stars are massive enough to reach the iron limit and go supernova.

From Supernova to Neutron Star

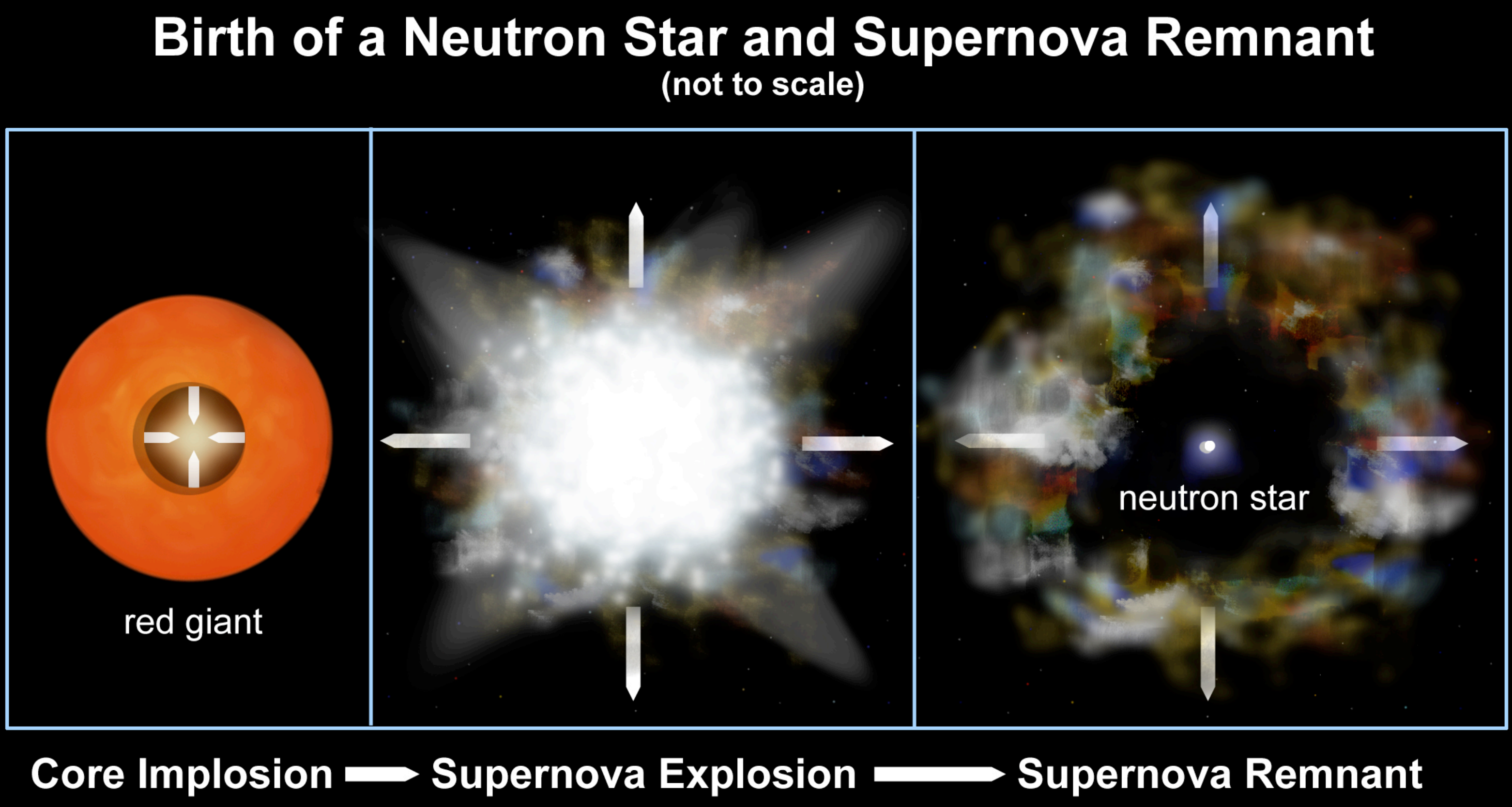


Illustration Credit: CXC/S (NASA), Lee, from http://chandra.harvard.edu/resources/illustrations/supernova.html

Crab Nebula

The result of a supernova recorded by Chinese astronomers in 1054.

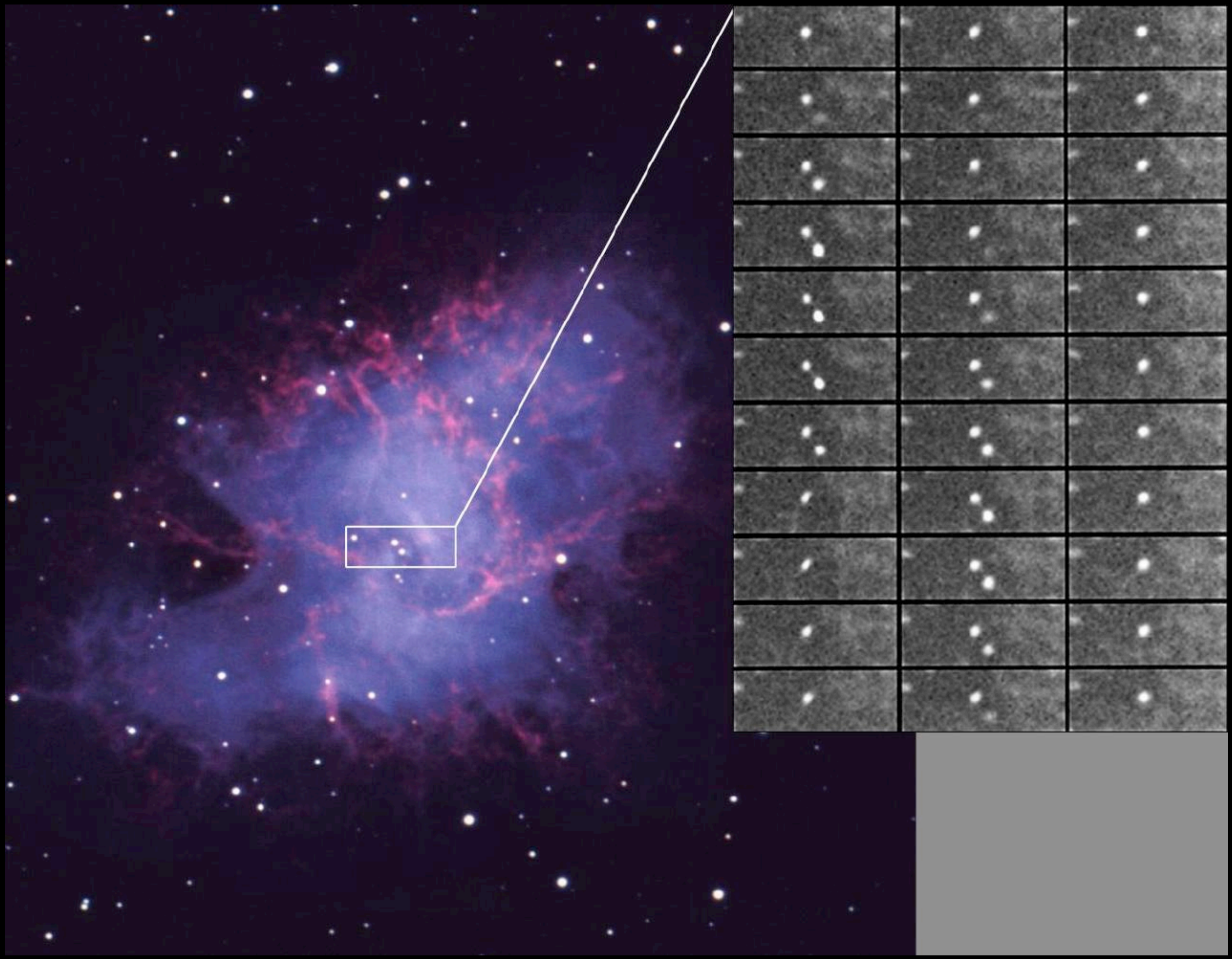


Image from http://www.noao.edu/image_gallery/html/im0565.html

What is left behind?

The core of the massive star continues to collapse. How much mass is left determines its final fate.

More Size Comparisons

Complete Table 2 in *Stars and Planets* lesson 5, *Death of Stars*

Why can't neutron stars and black holes be represented on a model with our 1 to 10 billion scale factor?

How would you help students understand the true size of a neutron star and the apparent size of a black hole?

Neutron Stars: So Dense, So Small!

Neutron stars are similar in size to cities, as shown by this illustration of a neutron star compared with Manhattan Island in N.Y.

Image Source: http://www.pas.rochester.edu/~afrank/A105/LectureXI/LectureXI.html

Density in the Extreme

Image Credit: Ann Feild (STScI)

Black holes contain less matter than the stars they were born from, and so have less gravity at a given distance. But, they are so small and dense, that other matter can come very close to their centers, and there the gravity is strong enough that even light can't escape.

Gravity in the Extreme: Black Holes

The gravitation pull of black holes is so great *only* because they are so unimaginably dense.

$\Rightarrow$ If the Earth became a black hole it would have a "diameter" of 0.01 m (1 cm).

At a given distance from the center of a black hole, its gravitational pull is no greater than any other object with the same mass.

Want to know what it is like to fall into a black hole? Check out http://casa.colorado.edu/~ajsh/schw.shtml.

[redacted]

Lesson 7: Planet Hunting

Part 1: Finding Planets

Part 2: New Discoveries

Finding Planets: Why Is It So Hard?

Finding Planets: Why Is It So Hard?

Problem 1: The sizes of planets and distances of stars.

“Trying to see the Earth from Alpha Centauri is like trying to see a candy sprinkle on a donut in New York when you are standing in San Francisco.” - from Planet Hunting

The discoveries of Uranus, Neptune, and the dwarf planets all required telescopes!

Finding Planets: Why Is It So Hard?

Problem 2: Stars are very bright and shine with their own light. Planets are very dim and shine by reflected light.

We can only see stars because of their brightness. All but two are no more than pinpoints of light in the sky, even with the best telescopes!

Pluto, as seen in a three minute exposure on a 24" telescope at Swathmore College in PA.

Image from http://www.science.widener.edu/~schultz/sproul10.html

Radial Velocity Measurement or Doppler Spectroscopy

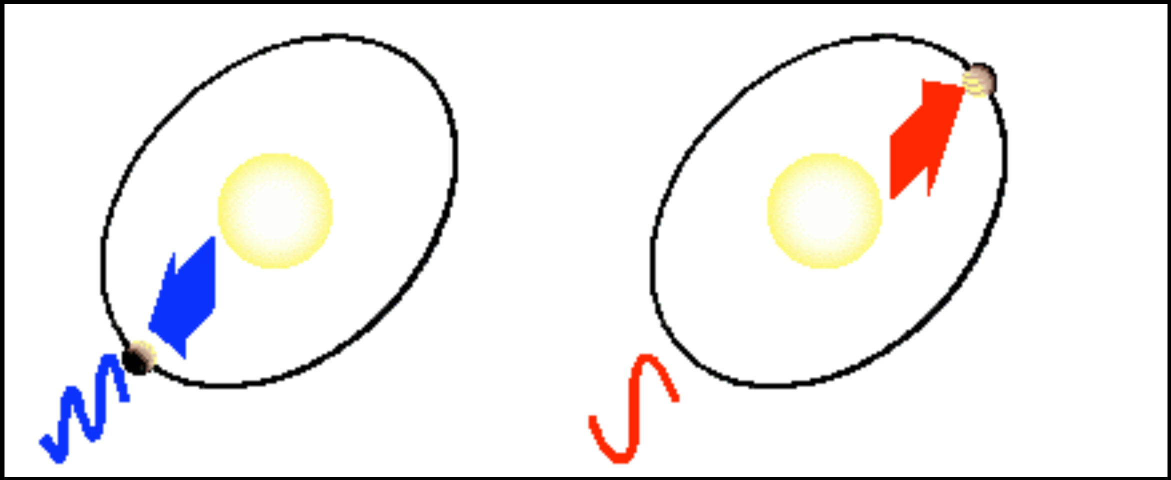


Image from http://www.hao.ucar.edu/public/research/stare/search.html

Any two objects in the Universe exert a gravitational pull on each other, including stars and planets. Astronomers can use a change in the frequency of light received from a star caused by the “wobble” of a star with a planet pulling on it to detect the planet. This works best for detecting massive planets close to their parent star.

Doppler Shift due to Stellar Wobble

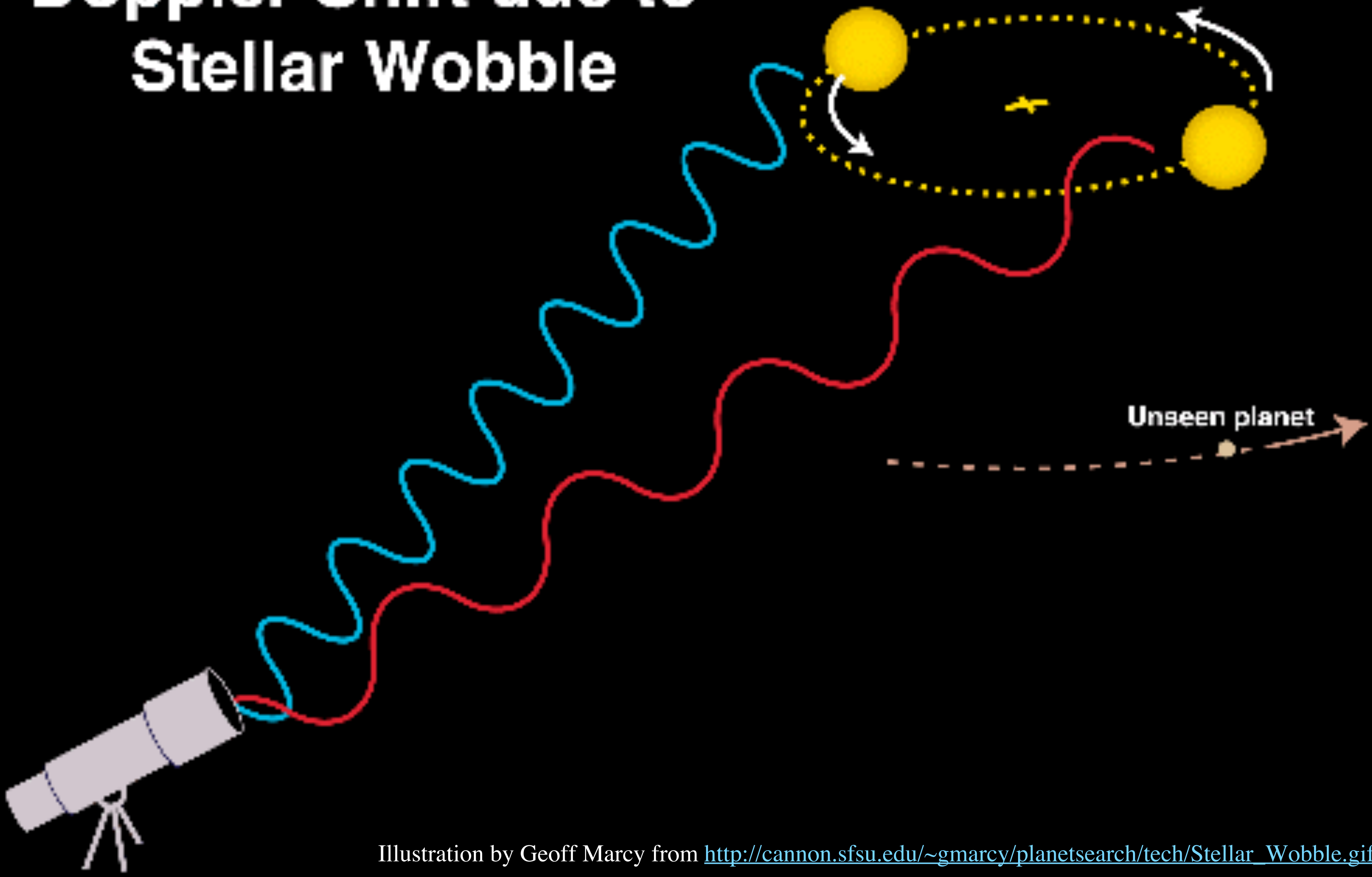


Illustration by Geoff Marcy from http://cannon.sfsu.edu/~gmarcy/planetsearch/tech/Stellar_Wobble.gif

Astrometry

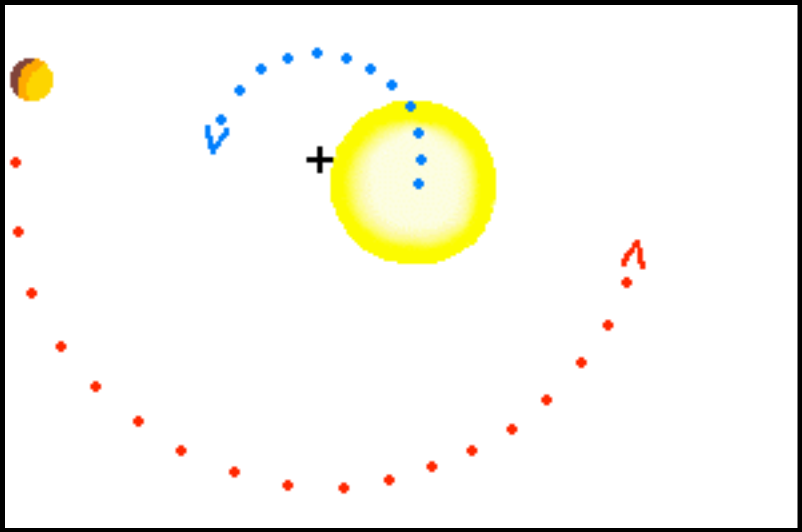
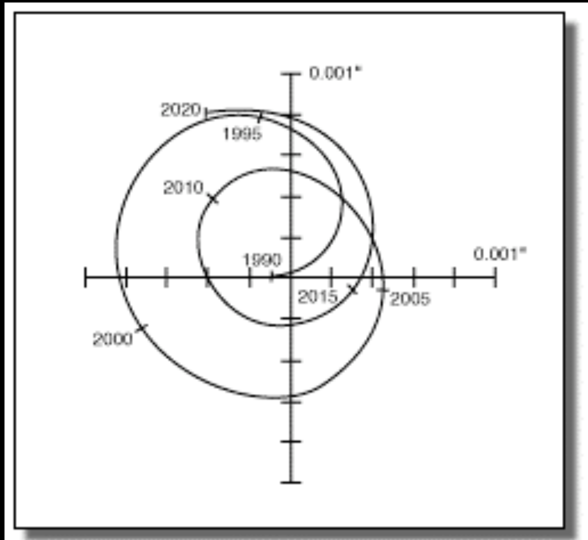


Image from http://www.hao.ucar.edu/public/research/stare/search.html

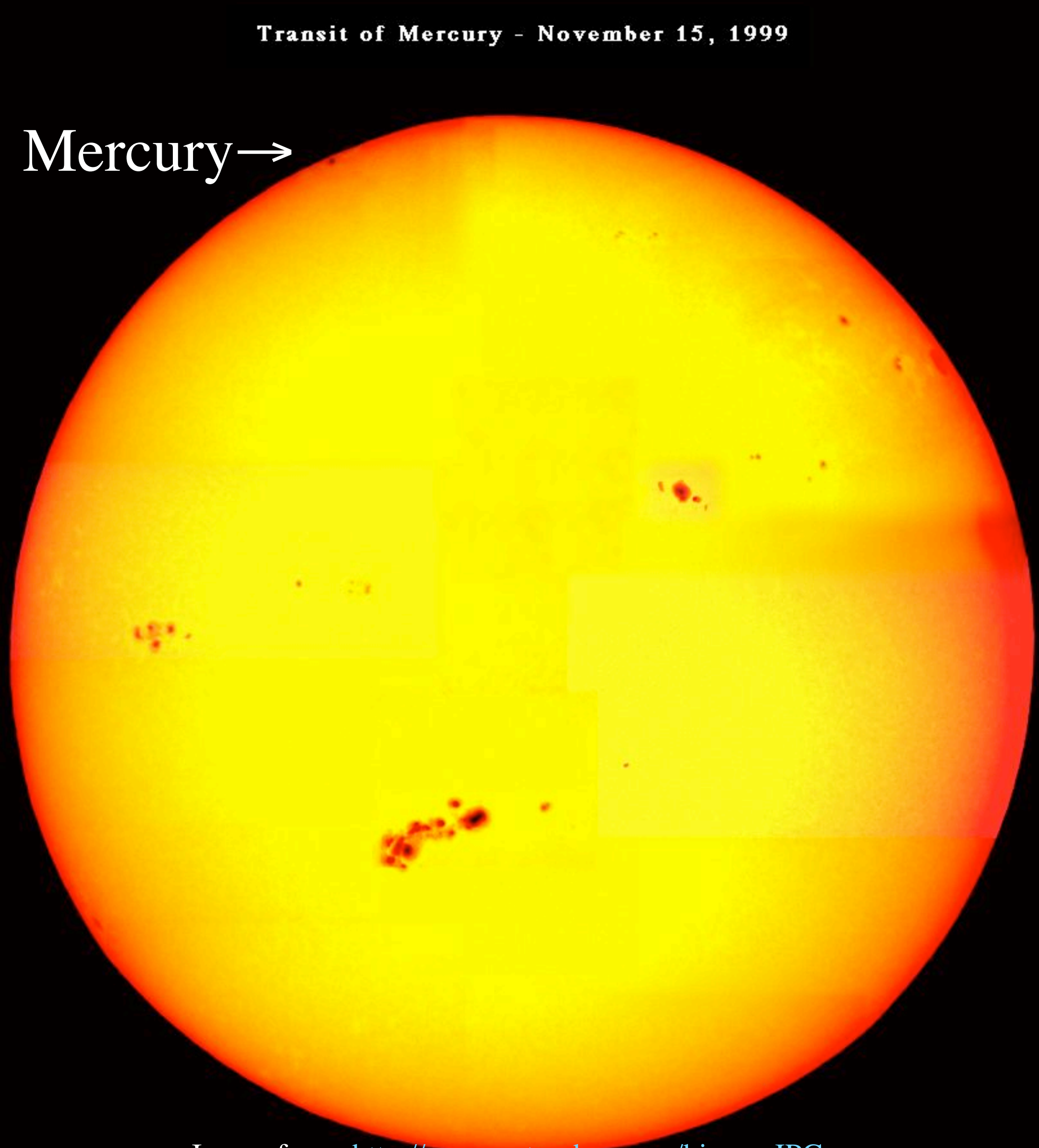


Astrometric displacement of the Sun due to Jupiter as seen from 10 parsecs.

http://sim.jpl.nasa.gov/science/images/my_wobble.gif

By measuring the position of a star with great precision, it is possible to directly detect the wobble of a star. This works best for detecting massive planets in tight orbits around stars in the solar neighborhood.

Transits and Photometry



A planet passing between us and its star will also decrease the amount of light we can see from the star…but not by much.

See more on the November 1999 transit of the planet Mercury at http://lyra.colorado.edu/public/pastperformances/mercury.html.

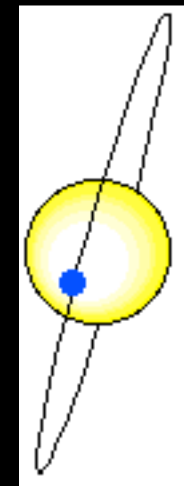
Image from: http://www.astrochem.org/bigsun.JPG

Scale Models of Planetary Systems

Using the same 1 to 10 billion scale factor we used for the Scale Model Solar System and our everyday objects to represent stars and planets, we can model the extrasolar planetary systems found around other stars.

An important point is that adding mass to a Jupiter-type planet does little to change its diameter. The planets simply become more dense with added mass until fusion beings.

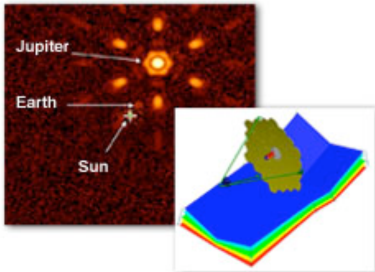
Kepler



Kepler is a NASA Discovery mission with the primary goal of finding Earth-like (terrestrial) planets around other stars. It is scheduled to launch in 2008 and will use the transit method from space.

Three transits of the same planet detected by Kepler will be treated as a confirmed detection. Kepler will be able to determine the orbital time of a detected planet, the size of the planet, and an estimate of its surface temperature.

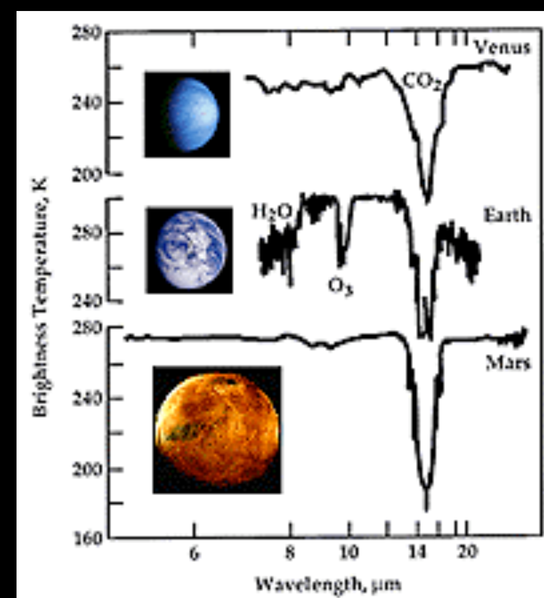
Learn more at http://www.kepler.arc.nasa.gov/



Terrestrial Planet Finder

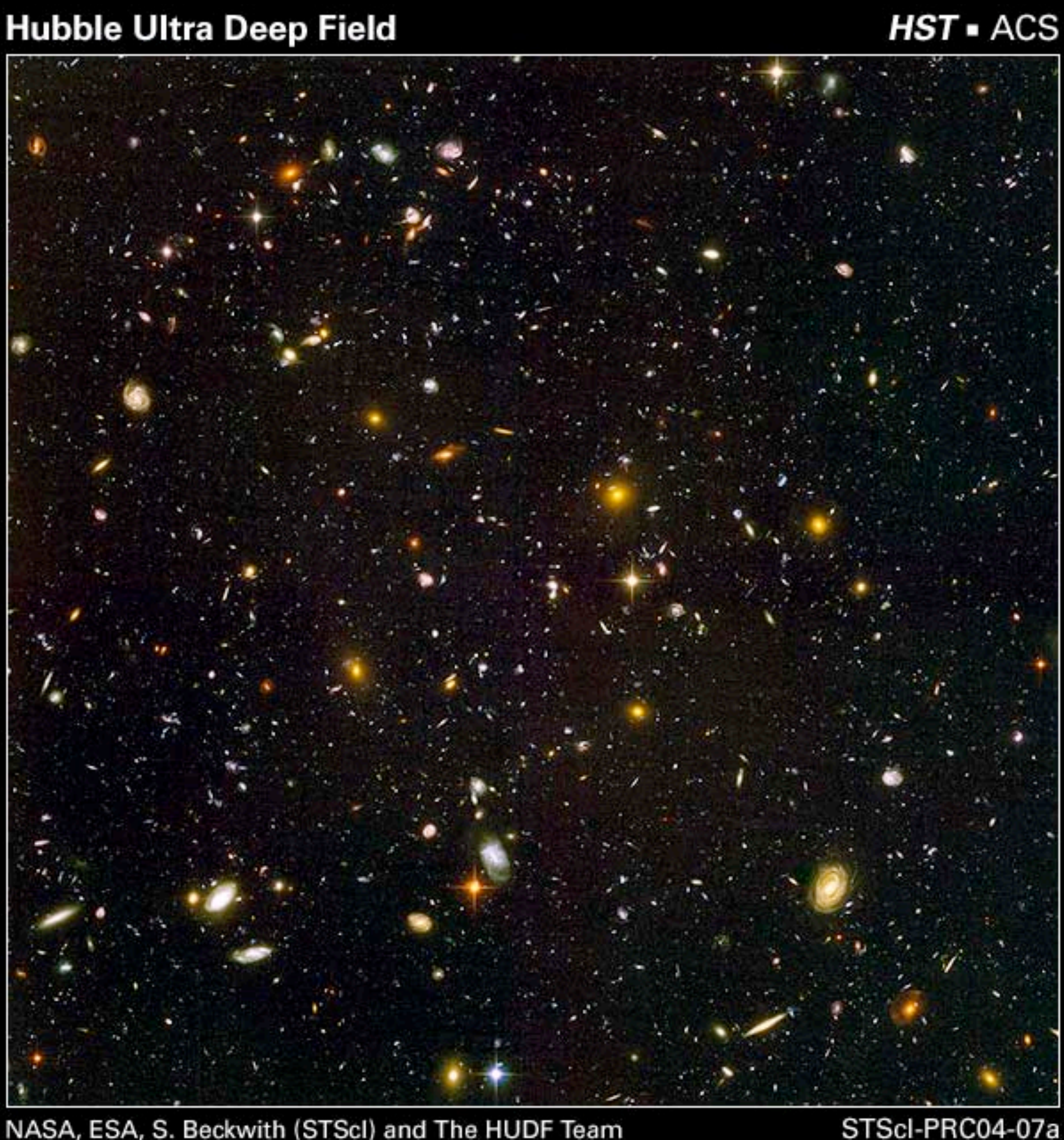
Terrestrial Planet Finder is a space-based mission, still under development at NASA, that has the goals of not only detecting Earth-like planets around other stars, but imaging those planets and returning spectra of their atmospheres to look for signatures of life.

Terrestrial Planet Finder will also be able to closely observe the planetary formation process in stellar nurseries, as well as targets of more general astrophysical interest.



Learn more at:
http://planetquest.jpl.nasa.gov/TPF/tpf_index.html

Lesson 8: Gaggle of Galaxies



How do sizes and distances of galaxies compare with stars?

What different types of galaxies can you see in Hubble Ultra Deep Field?

How would you classify the galaxies in this image?

Why are some galaxies red in the image, and how do they relate to the Big Bang?

The Milky Way - A Barred Spiral Galaxy

Image from
http://starchild.gsfc.nasa.gov/docs/StarChild/universe_level1/milky_way.html

The image on the left is an artist conception based on data from the Spitzer Space Telescope. The image on the left is really of our galaxy and was taken using infrared and microwave light. Because we are in the galactic disk, we see our own galaxy as a thin line that is thicker in the middle, where the central bulge is located.

The Milky Way on Edge

This image of the Milky Way, taken in Infrared by the *Two-Micron All Sky Survey* (http://www.ipac.caltech.edu/2mass/gallery/) shows the clouds of dust in the disk of the galaxy that obscure our view of many Milky Way stars. The disk of our galaxy is roughly 100,000 l.y. across, but has a maximum thickness of “only” a few 1,000 light years.

Andromeda and M33

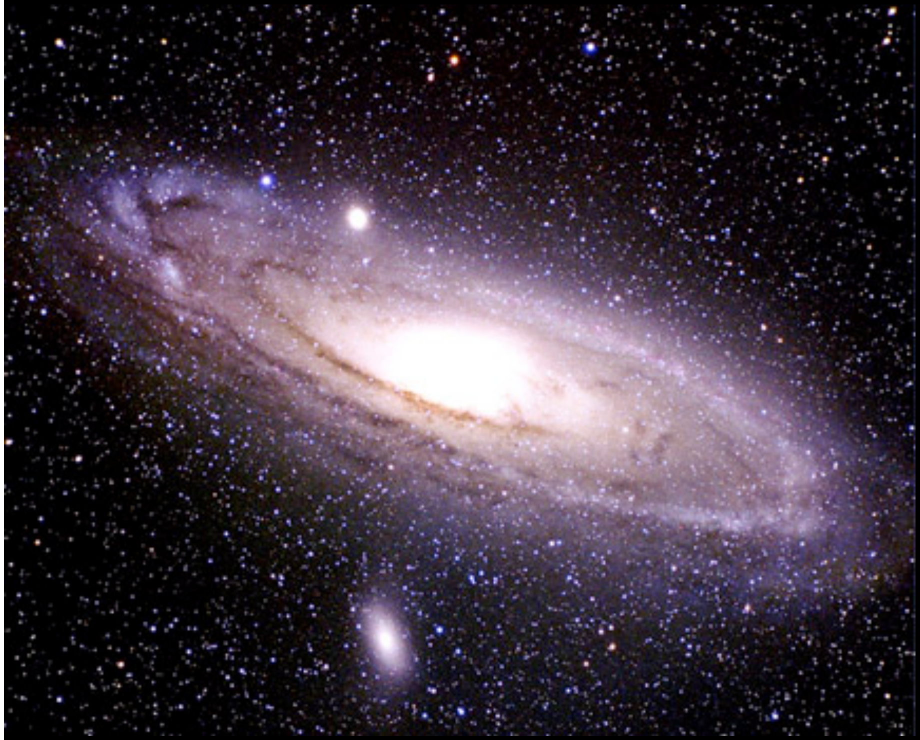


Image Source: http://www.astrophoto.com/M33.htm

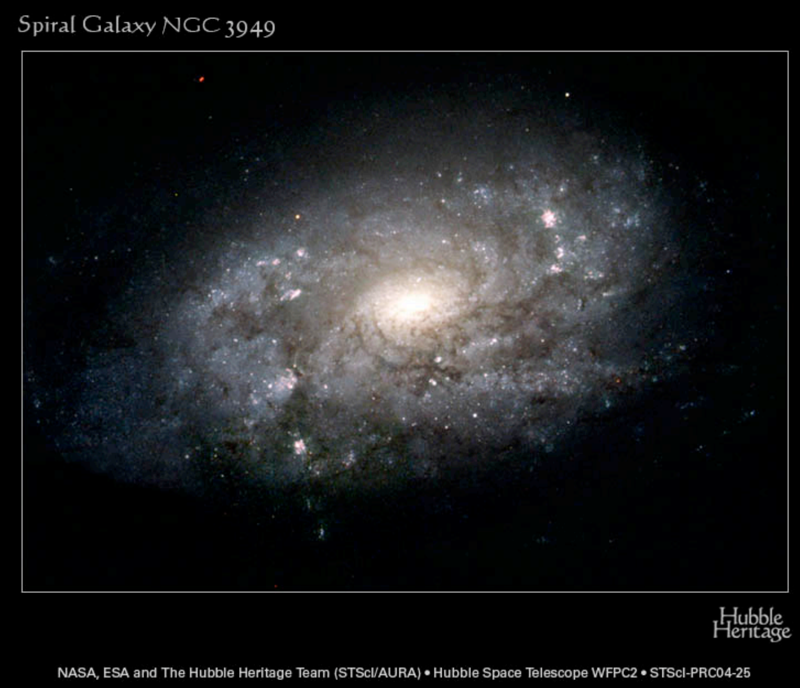
Image Source: http://isaac.exploratorium.edu/~pauld/activities/astronomy/cityuniversesizeillo.html

The largest visible galaxy in the local group (200,000 ly in diameter), Andromeda has the most stars of any local group galaxy, about 300 billion compared with our 200 billion stars. M33, by contrast is a small spiral galaxy with a mere 25 billion solar masses and a diameter of 50,000 ly. M 33 is also known as the “Triangulum Galaxy”.

A Gaggle of Galaxies

What types of galaxies can you see in this Hubble mosaic?

Major Types of Galaxies



http://www.seds.org/messier/m/m087.html

Most galaxies are spiral, elliptical (giant or dwarf), or irregular galaxies. At right is the Large Magellanic Cloud, an irregular galaxy orbiting the Milky Way.

http://www.seds.org/messier/xtra/ngc/lmc.html

Strange Galaxies

Sombrero Galaxy • M104

Hubble Heritage

NASA and The Hubble Heritage Team (AURA/STScI) • Hubble Space Telescope ACS • STScI-PRC03-28

Ring Galaxy AM 0644-741

Hubble Heritage

NASA, ESA, and The Hubble Heritage Team (STScI/AURA) • Hubble Space Telescope ACS • STScI-PRC04-15

Some galaxies are difficult to classify, like the Ring Galaxy, which is an odd spiral. The Sombrero Galaxy is a normal spiral, but looks odd in our side view. Some strange galaxies are the result of collisions with other galaxies. These collisions don't mean stars hit one another…they just get mixed up.

Galaxies NGC 2207 and IC 2163

Hubble Heritage

NASA and The Hubble Heritage Team (STScI) • Hubble Space Telescope WFPC2 • STScI-PRC99-41

Red Shift and an Expanding Universe

As the universe expands, light expands with it, increasing in wavelength.

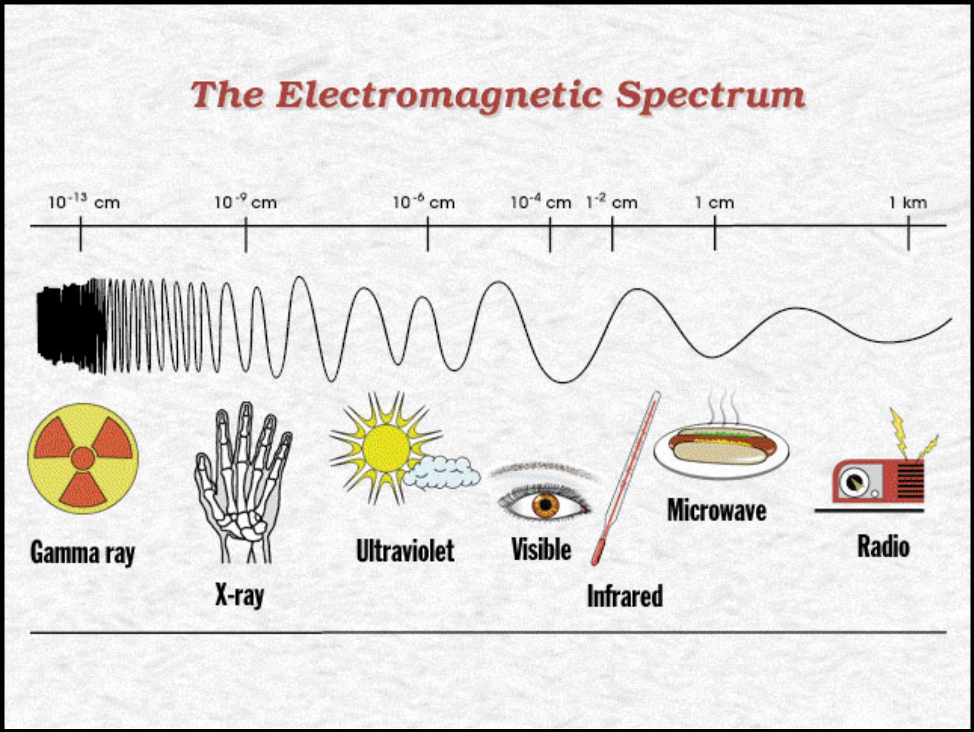


Image from: http://saturn.jpl.nasa.gov/mission/nav-uplink.cfm

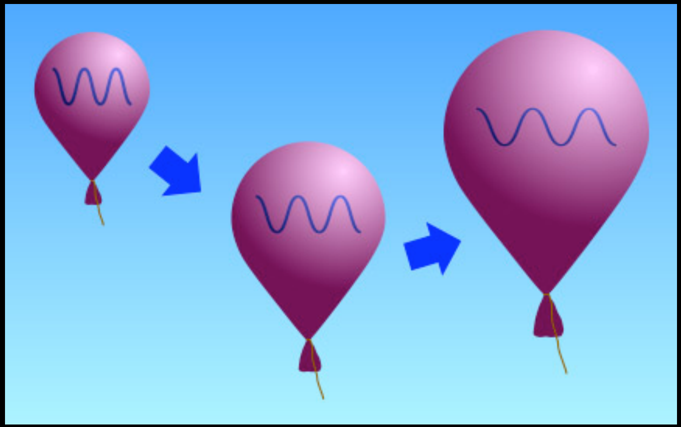


Image from
http://www.physics.hku.hk/~nature/CD/regular_e/lectures/chap19.html

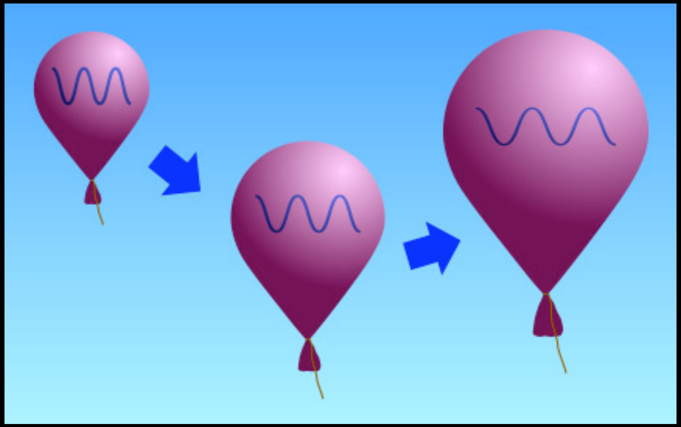
Red light is the longest wavelength of visible light, so this increase in wavelength is called redshift. The earliest visible light emitted in the Universe now is so large in wavelength that it is microwave radiation.

Hubble's Law (For the Teacher)

In the 1920's Edwin Hubble not only showed that many "nebula" were in fact other galaxies, but that galaxies appear to be speeding away from one another. The further away a galaxy was (measured with standard candles), the faster it seemed to move away from us!

velocity = H_o x distance, where H_o is a constant

A redshift can be described by the quantity *z*, where
$1 + z = \lambda_{observed}/\lambda_{rest}$



As light travels through space-time, it is expanded along with the rest of the universe, creating longer and longer wavelengths (redshift). The longer the amount of time the light has traveled through space, the greater the redshift.

Image from http://www.physics.hku.hk/~nature/CD/regular_e/lectures/chap19.html

Historical Views

In the second century A.D., the Greek astronomer and mathematician Ptolemy built a secular cosmology with the Earth at the center of the Universe. This cosmology of the nature of the Universe was adopted by the Catholic church.

Image From http://www-gap.dcs.stand.ac.uk/~history/Mathematicians/Ptolemy.html

Copernican Revolution: Led by Copernicus, Galileo, and Kepler, the Copernican Revolution gave science a Sun-centered view of the solar system, with the Sun as one of many stars in the Galaxy.

Einstein, like many astronomers of his day, initially believed that the Universe is static and has always been as it is today.

Expanding Universe

Objects in an expanding Universe don't just appear to speed away from one another…the distances between them are increasing, just like the distance between raisins increases in rising raisin bread!

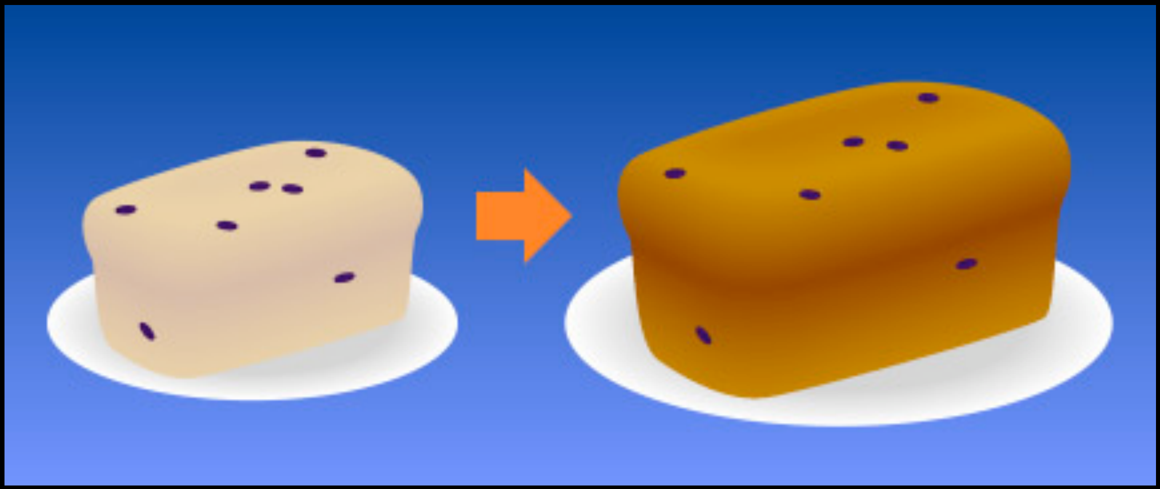


Image from http://www.physics.hku.hk/~nature/CD/regular_e/lectures/chap19.html

A raisin in the bread sees all other raisins move away from it. To the raisin, it looks like it is at the center of the expansion…but it really isn't. There is no measurable center of the Universe!

Not Everything Expands!

Objects bound together by fundamental forces…people, asteroids, planets, stars, galaxies, etc. *don't* expand with the Universe. These objects stay the same size. The distance between objects not bound to one another does increase with the expansion of the Universe.

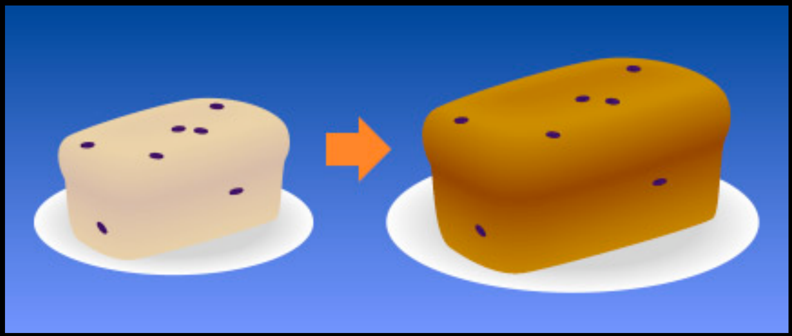


Image from http://www.physics.hku.hk/~nature/CD/regular_e/lectures/chap19.html

Think of glitter on the surface of an expanding balloon, or raisins in bread as galaxies. These objects stay the same size, even though when the balloon or bread expands.

Explore the Expanding Universe in the Classroom

The Universe activity from the *Sloan Digital Sky Survey*
http://skyserver.sdss.org/dr1/en/proj/basic/universe/default.asp

Middle School Student Friendly Center of the Universe Discussion from JPL
http://spaceplace.jpl.nasa.gov/phonedrmarc/jun2003.html

No Edge, No Center - Exploring the Shape of Our Universe is a high school activity with teacher guides from http://universe.sonoma.edu/activities/no_edges.html

A Ballooning Universe in **The Universe at Your Fingertips** (grades 8+) from Astronomical Society of the Pacific (http://www.astrosociety.org).

The Expanding Universe in *The Universe at Your Fingertips* (grades 8+)

Visualization of the Expansion of Space in **The Universe at Your Fingertips** (grades 8+)