the Stars

I. Position and Motion
Parallax, Proper Motion, Redshift

II. Size
Dwarfs, Giants, Stefan-Boltzman

III. Brightness
Magnitude, flux, distance

IV. Color & Temperature
B-*V* index, Spectral Type

V. H-R diagrams
Luminosity Classes

The Size of the Stars

How do we know?

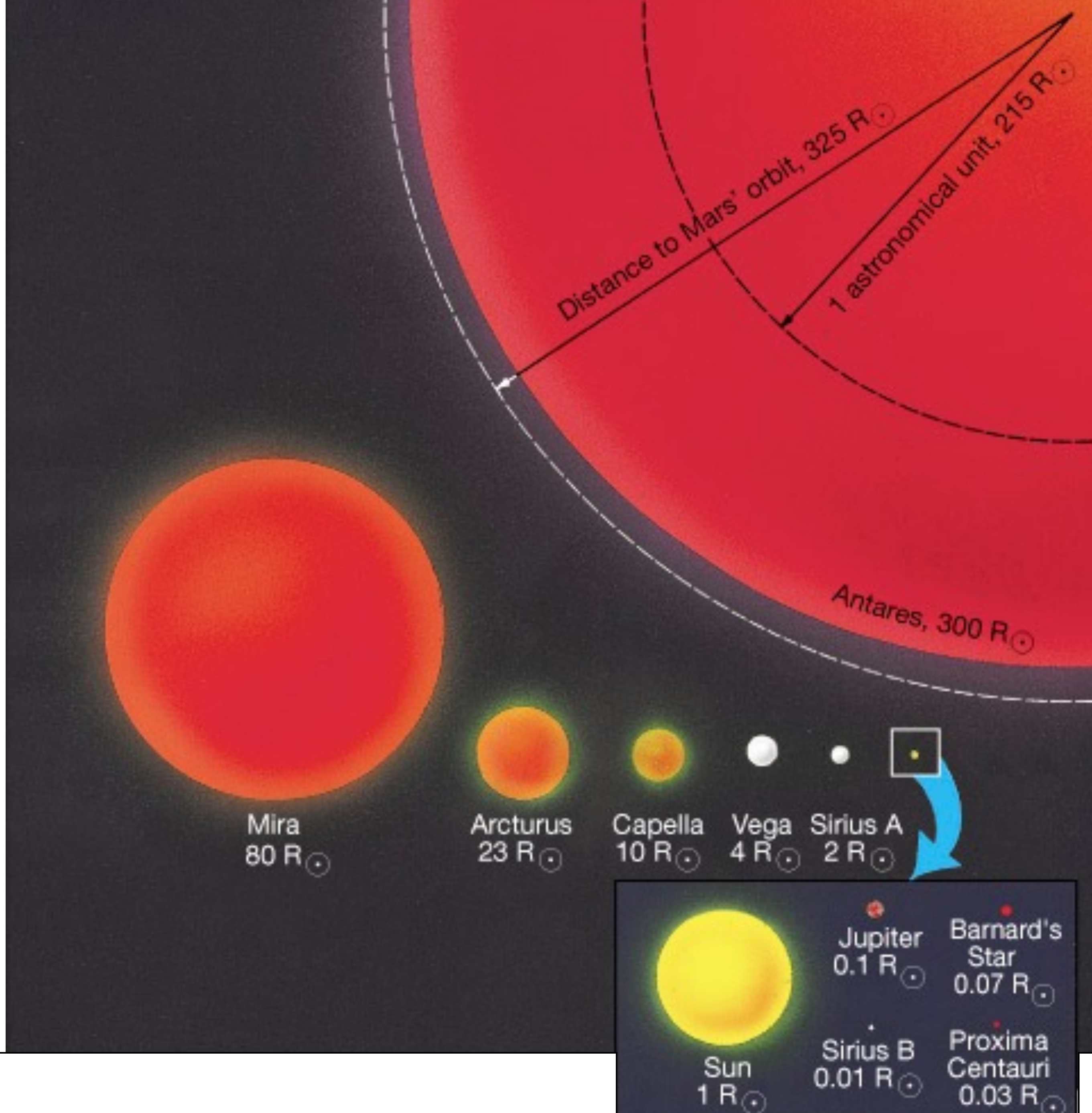
	The student will be able to:	HW:
1	Define and apply stellar parallax and the unit of the parsec. ✓	1 – 3
2	Relate parallax and the parsec to skinny triangles and other units such as meters and light years. ✓	
3	Define and describe proper motion. ✓	4 – 6
4	Describe and apply methods by which the velocity of a star through space may be determined by including both radial and transverse velocity. ✓	
5	Describe direct and indirect methods used to determine the size of a star and classify stars as giants, supergiants, or dwarfs.	7 – 8
6	State and apply the relation between luminosity, radius, and temperature.	
7	State and apply the relation between luminosity, distance, and energy flux.	9 – 16
8	Define and contrast the concepts: absolute magnitude, intrinsic brightness, luminosity, and apparent magnitude, apparent brightness, energy flux.	
9	Explain and apply the magnitude scale of brightness.	
10	Describe and apply the relation between a stars color and its temperature.	17
11	Define, describe, and apply color index and explain its application in photometry and its relationship to blackbody radiation and Wein's Law.	
12	State in order of temperature the stellar spectral classes and list characteristics and examples of each.	18
13	Describe and define the Hertzsprung-Russell diagram in terms of each axis.	19 – 23
14	Plot a star's coordinates on the H-R diagram.	
15	Explain and illustrate how the H-R diagram is used to help classify and understand different types of stars such as main sequence stars, red giants, blue giants, supergiants, red dwarfs, and white dwarfs.	
16	Define, describe, and give examples of the stellar luminosity classes.	24 – 25
17	Describe and apply the method of spectroscopic parallax and explain the importance of luminosity class to this method.	
18	Describe and explain methods for determining a star's mass and relate to the different types of binary-star systems: visual binary, spectroscopic binary, and eclipsing binary.	26
19	Describe and explain the significance of a star's mass in determining its location on the H-R diagram and in determining the lifetime of the star.	27
20	Describe properties and significance of open clusters and globular clusters.	

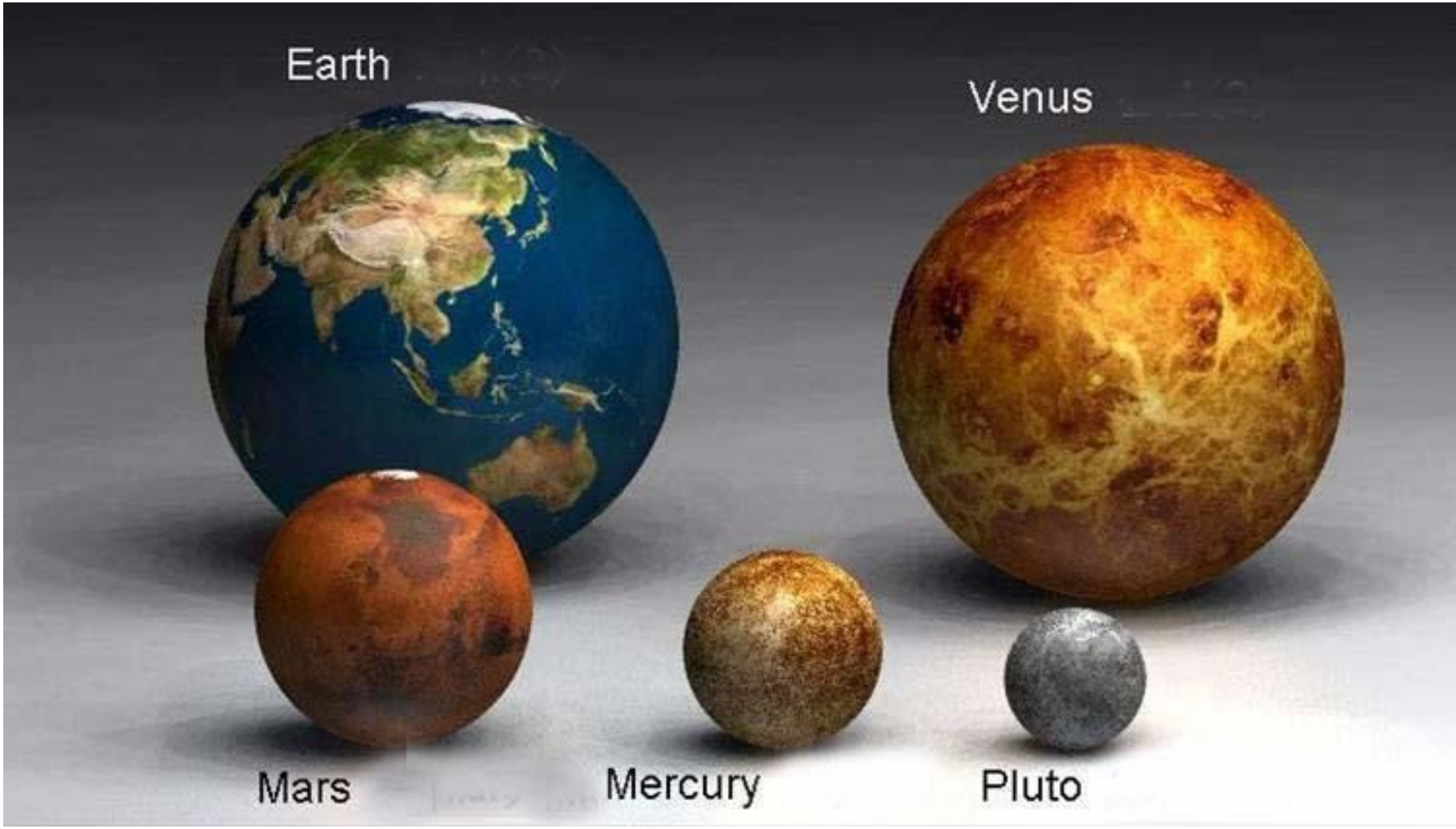
Range of Sizes

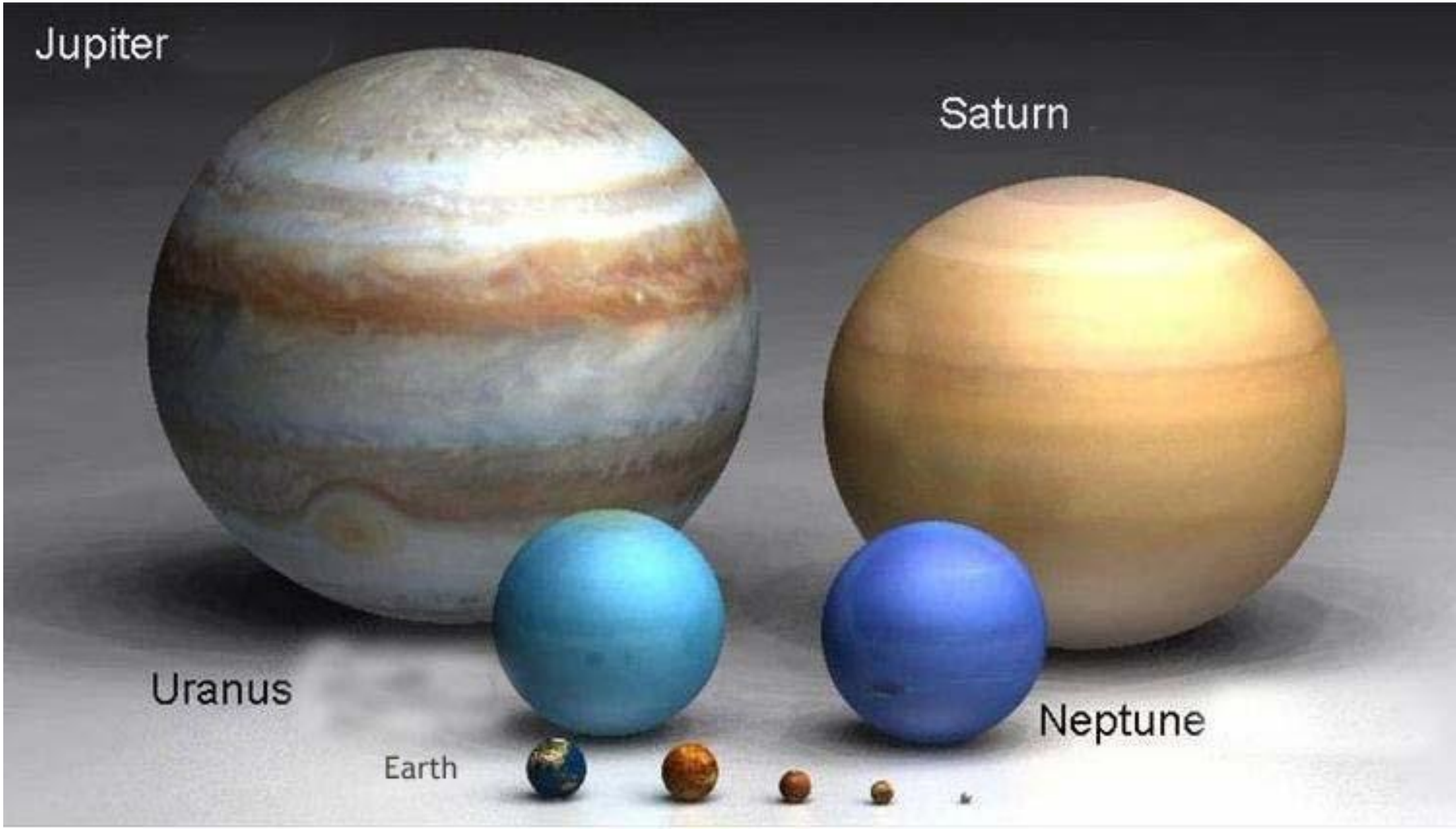
- The diameters of the stars vary greatly.
- Stars can be hundreds of times greater or smaller in diameter than the Sun.
- The radius or diameter of the Sun is used as a sort of “unit” for measuring other stars.
- The symbol for the radius of the Sun: $R_{\odot}$

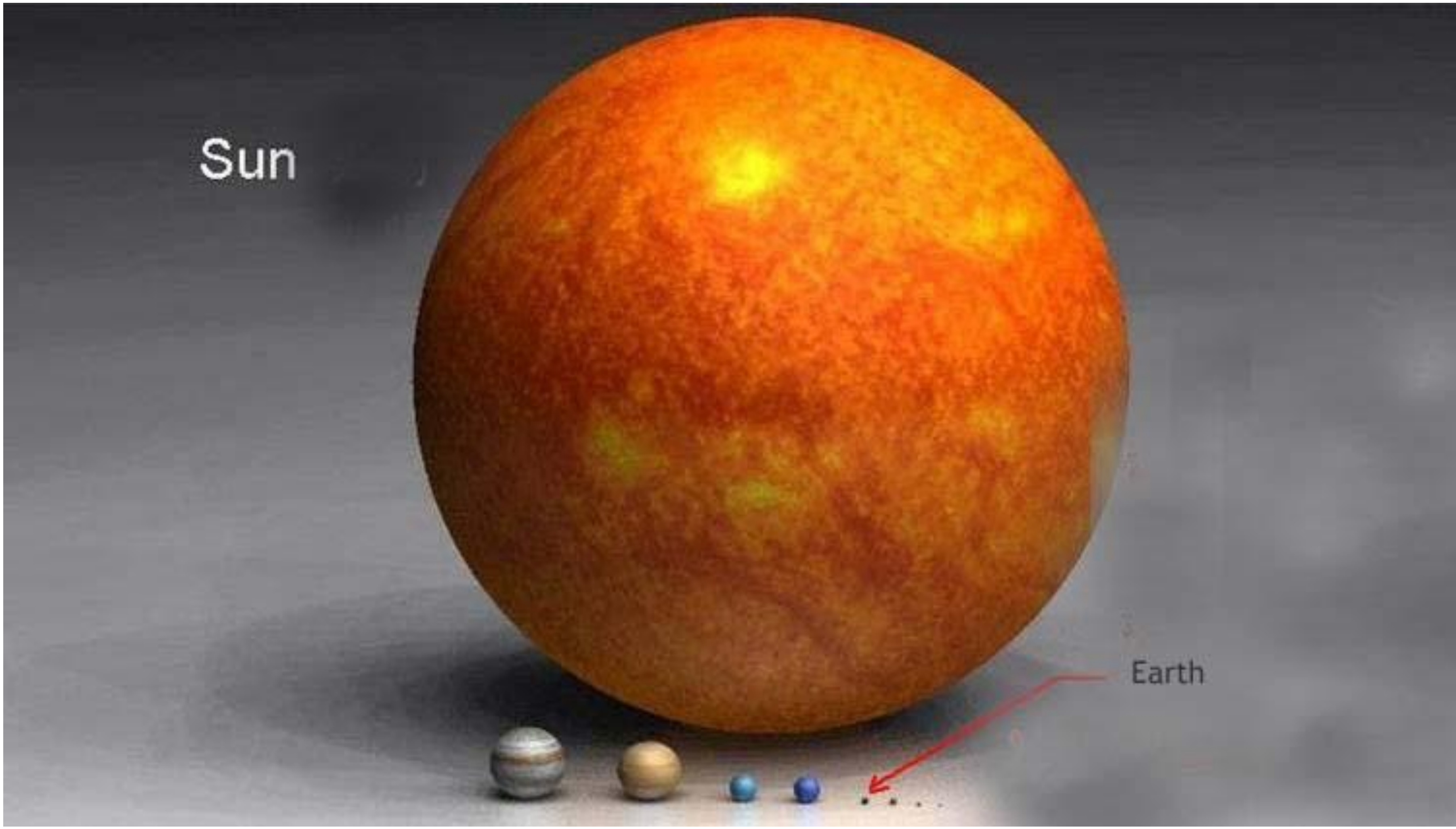
Classifications

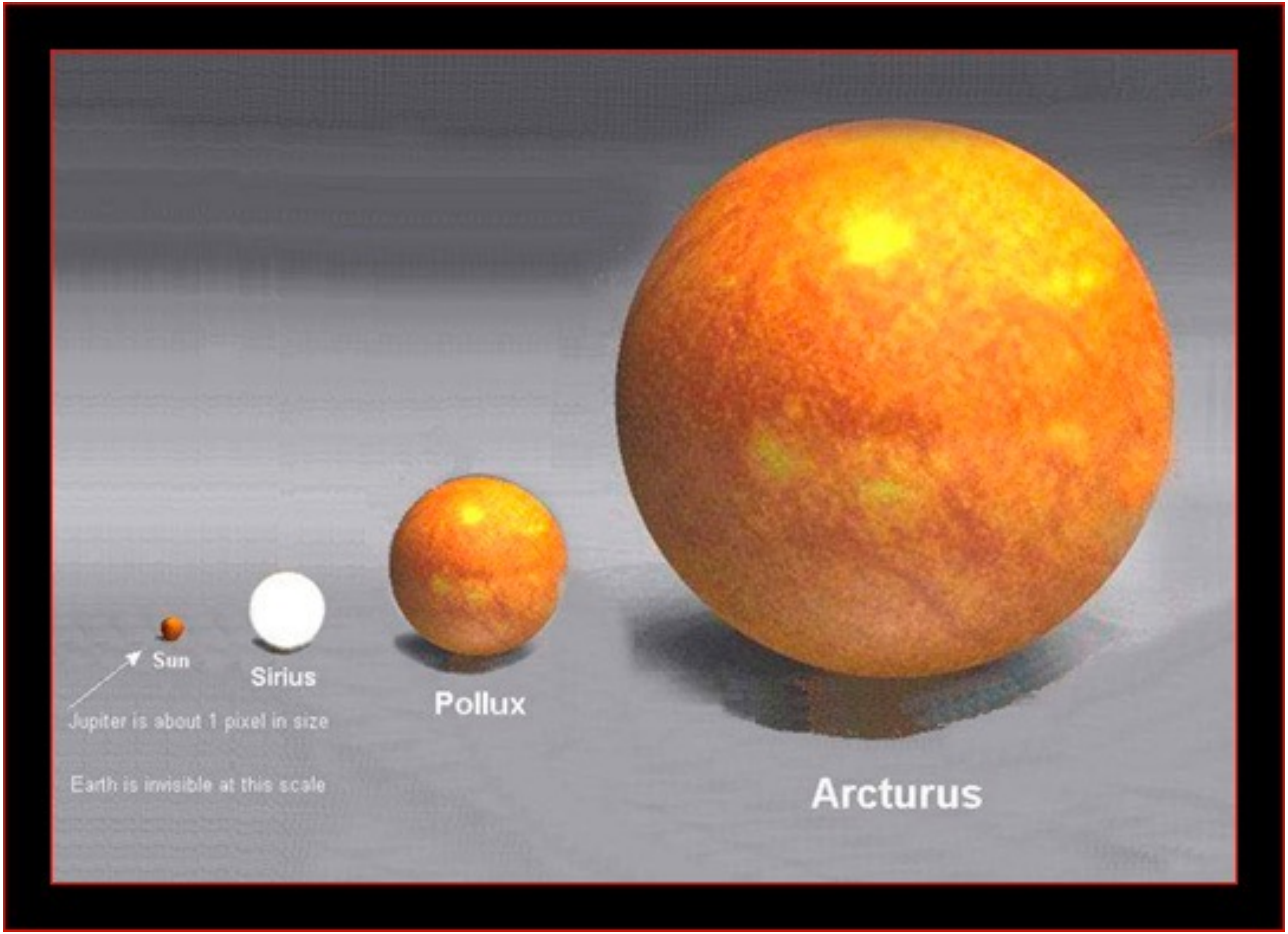
- Dwarf Star = any star of diameter comparable to the Sun or smaller.
  $R \leq 10\ R_{\odot}$
- Giant Star = a star between 10 and 100 times greater in diameter than the Sun.
  $10\ R_{\odot} \leq R \leq 100\ R_{\odot}$
- Supergiant Star = a star greater than 100 solar diameters (and into the thousands)
  $R \geq 100\ R_{\odot}$

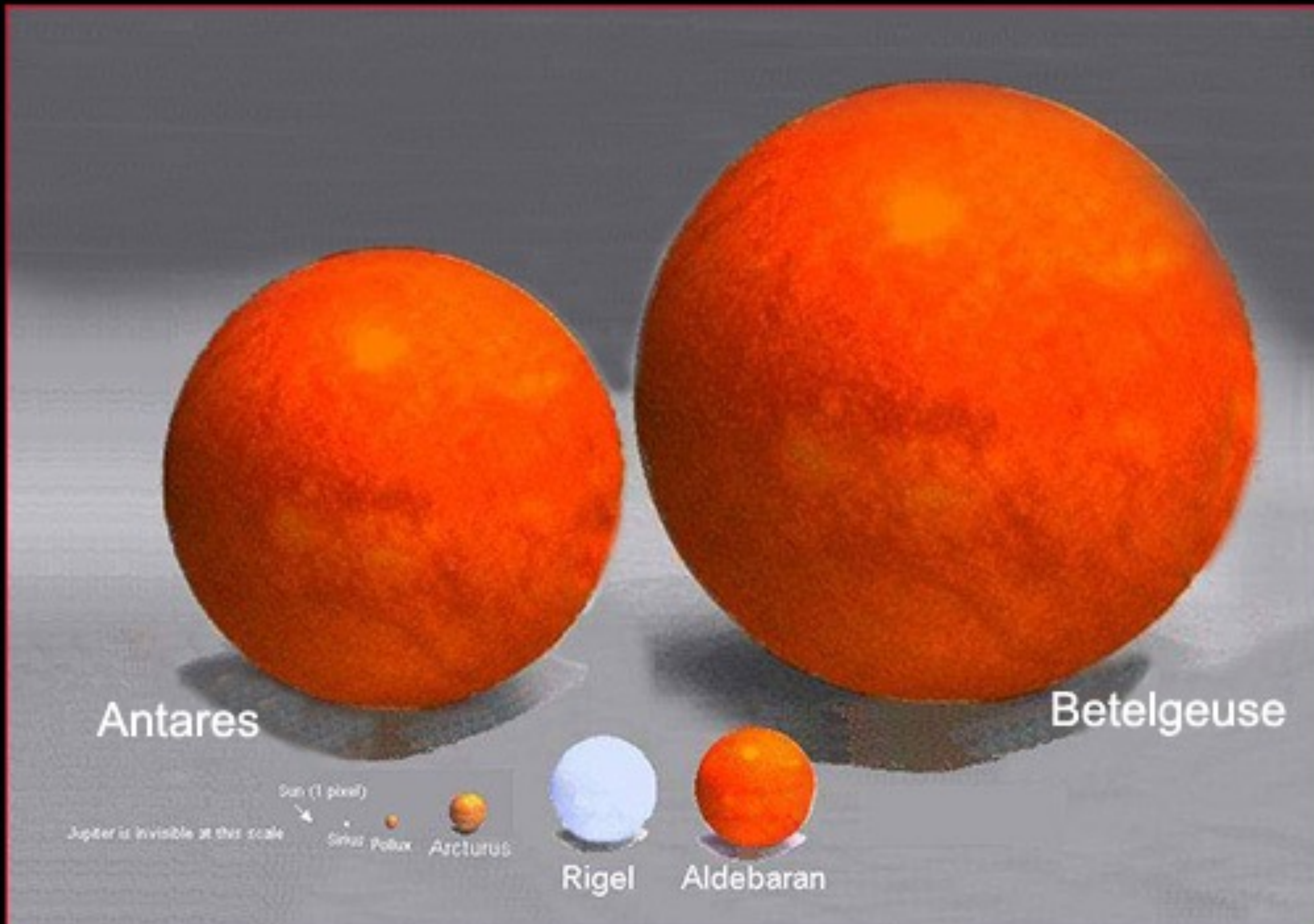

Distance to Mars' orbit, 325 R⊙
1 astronomical unit, 215 R⊙
Antares, 300 R⊙
Mira
80 R⊙
Arcturus
23 R⊙
Capella
10 R⊙
Vega
4 R⊙
Sirius A
2 R⊙
Sun
1 R⊙
Jupiter
0.1 R⊙
Barnard's Star
0.07 R⊙
Sirius B
0.01 R⊙
Proxima Centauri
0.03 R⊙


Earth
Venus
Mars
Mercury
Pluto


Jupiter
Saturn
Uranus
Neptune
Earth


Sun
Earth

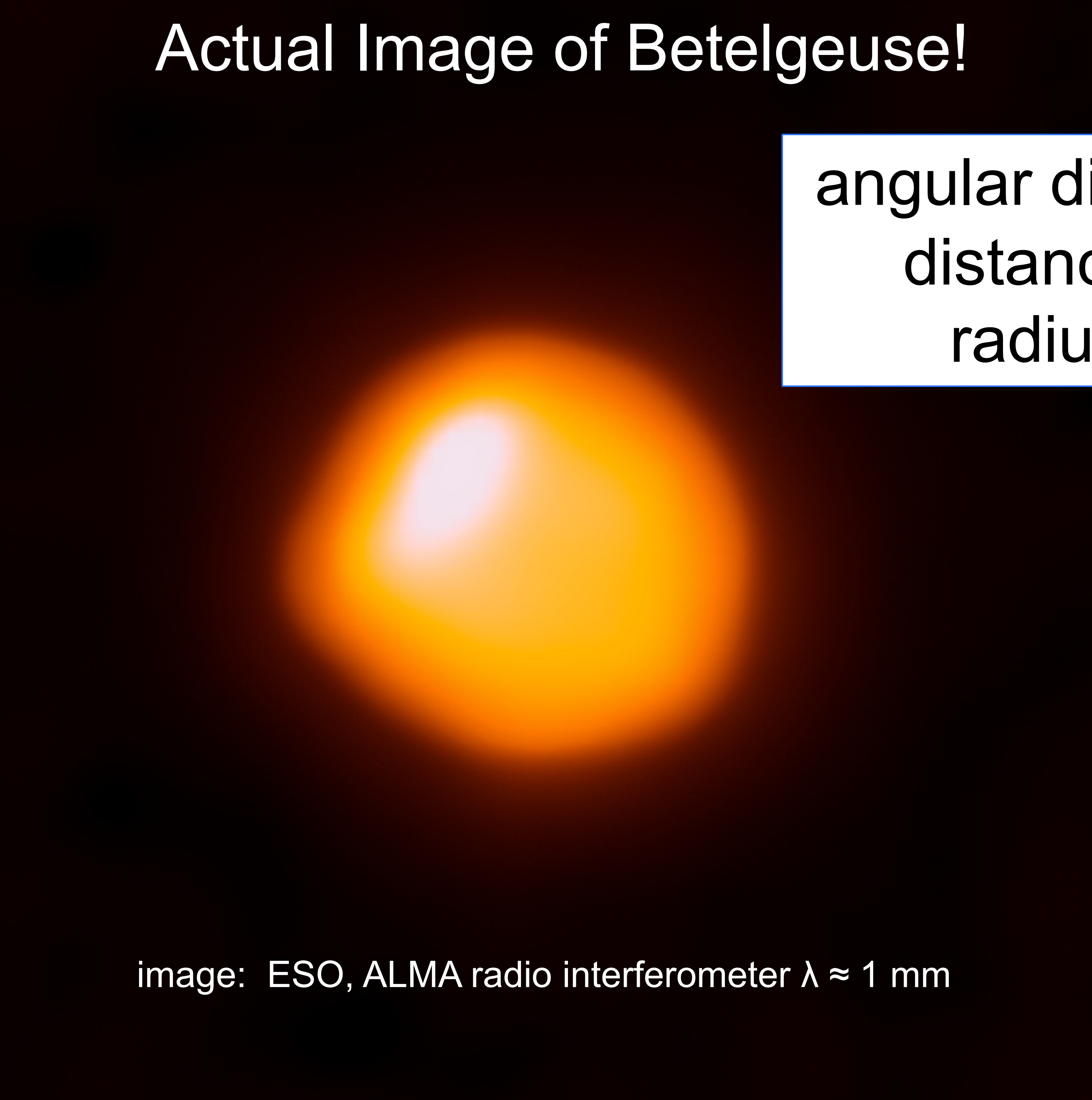

Sun
Sirius
Pollux
Jupiter is about 1 pixel in size
Earth is invisible at this scale
Arcturus


Antares
Betelgeuse
Sun (1 pixel)
Jupiter is invisible at this scale
Sirius
Pollux
Arcturus
Rigel
Aldebaran

3 Methods for Finding Size

- The very largest of stars can be imaged with high magnification. The apparent angular diameter and distance yields the true diameter. (skinny triangle!)
- Some star's diameters may be determined due to eclipsing binaries.
- Most often the known luminosity and temperature of a star are used to infer the diameter.

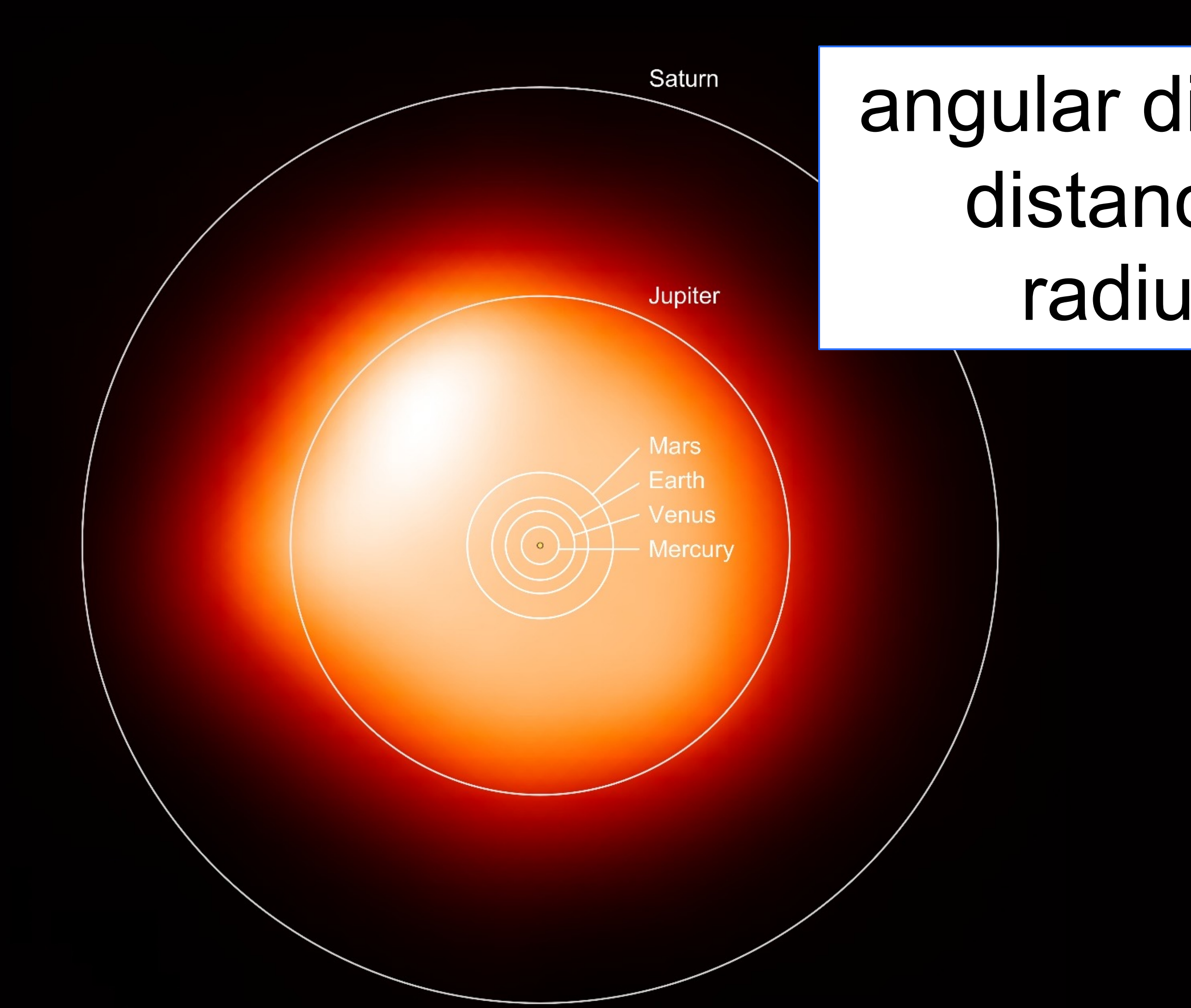
Actual Image of Betelgeuse!



angular dia. = 0.045″
distance = 130 pc
radius = 630 $R_\odot$

image: ESO, ALMA radio interferometer $\lambda \approx 1$ mm

Actual Image of Betelgeuse!

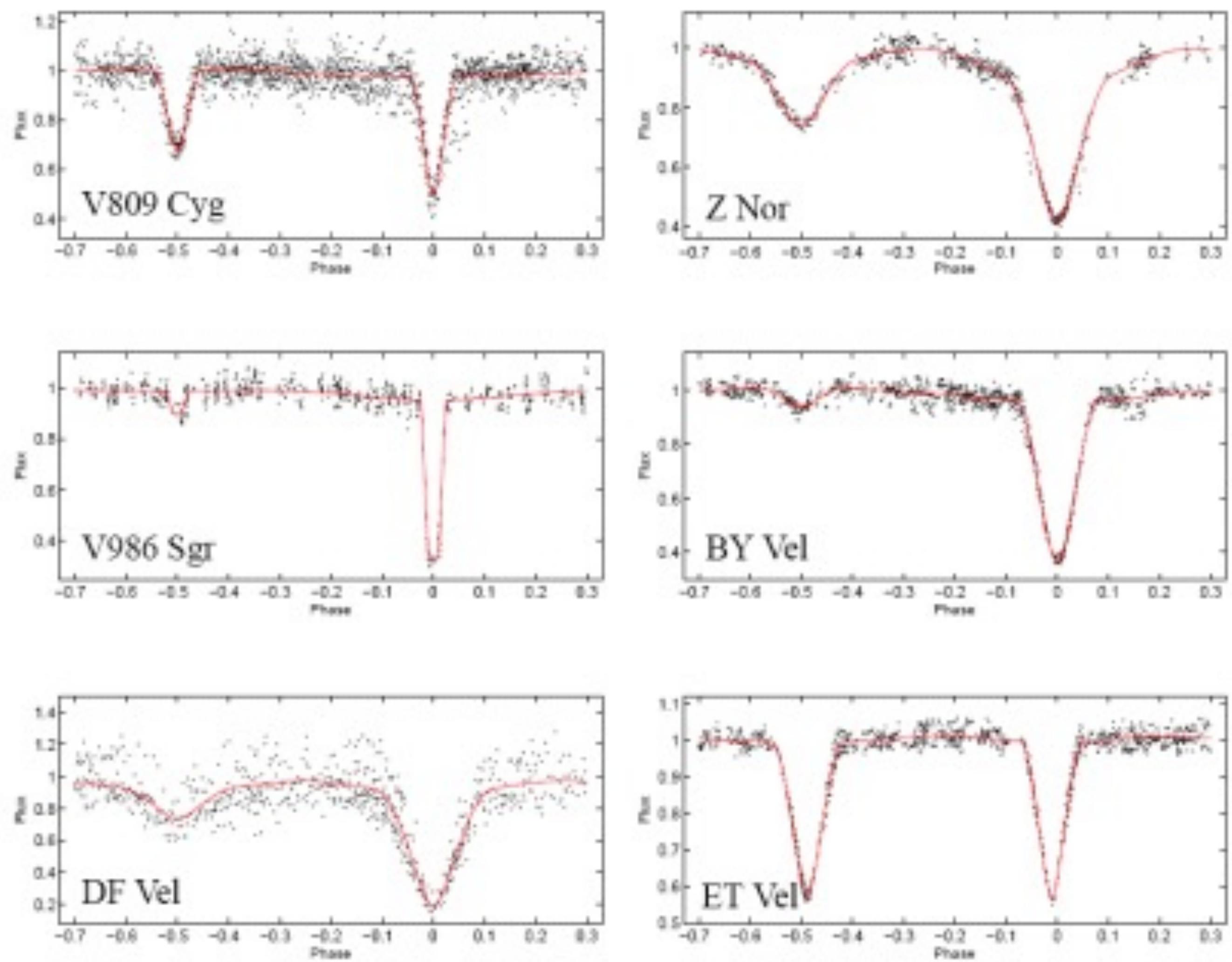


angular dia. = 0.045″
distance = 130 pc
radius = 630 $R_\odot$

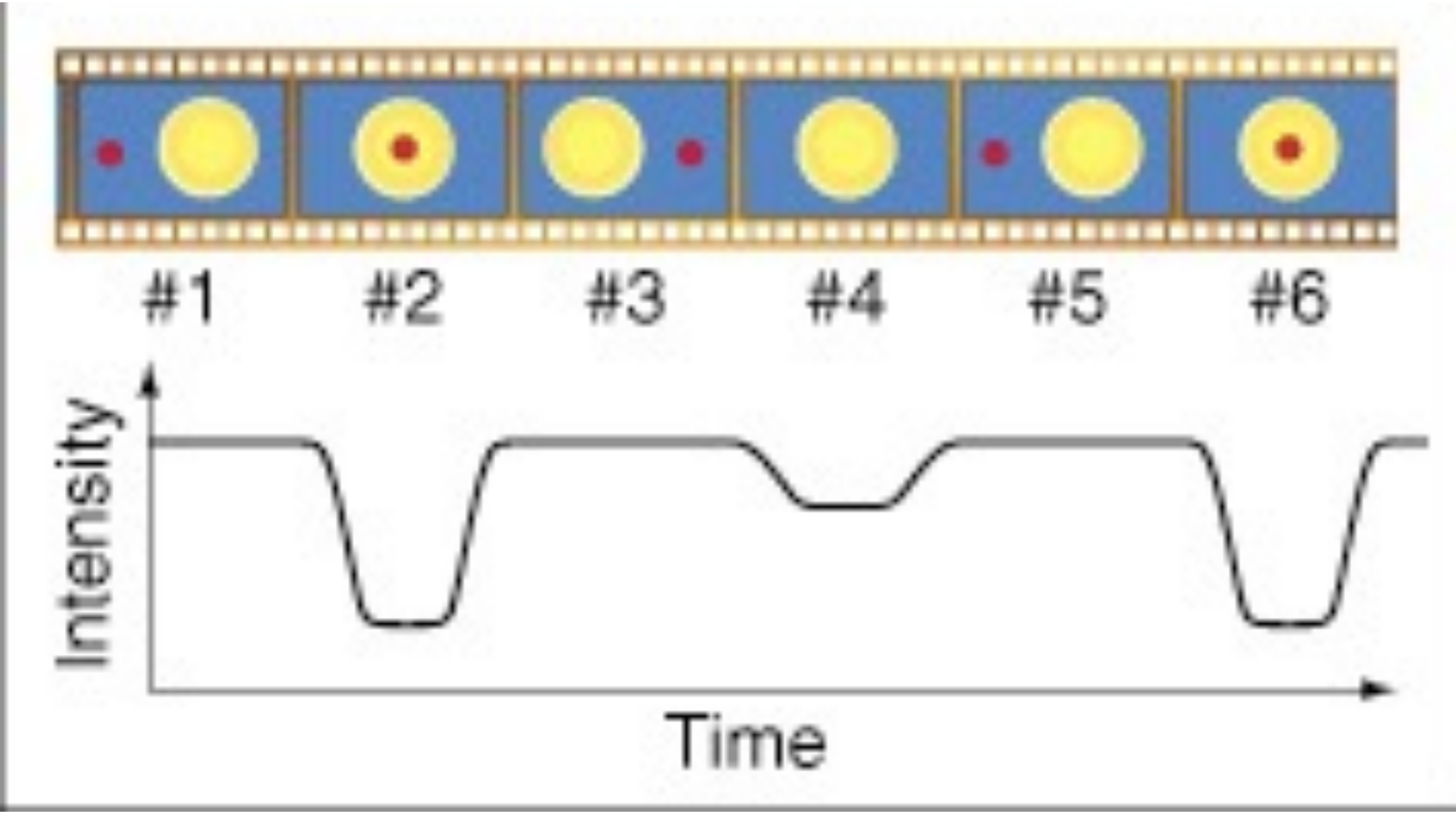
image: ESO, ALMA radio interferometer $\lambda \approx 1$ mm

0.015"

These are example “light curves” – a commonly used astronomical graph. It shows the relative brightness of a star versus time or phase. The black dots are actual measurements made with a photometer. The dips in brightness shown on these graphs are typical patterns for eclipsing binary star systems.



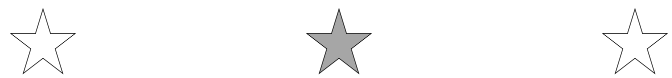
Eclipsing Binary Star System:



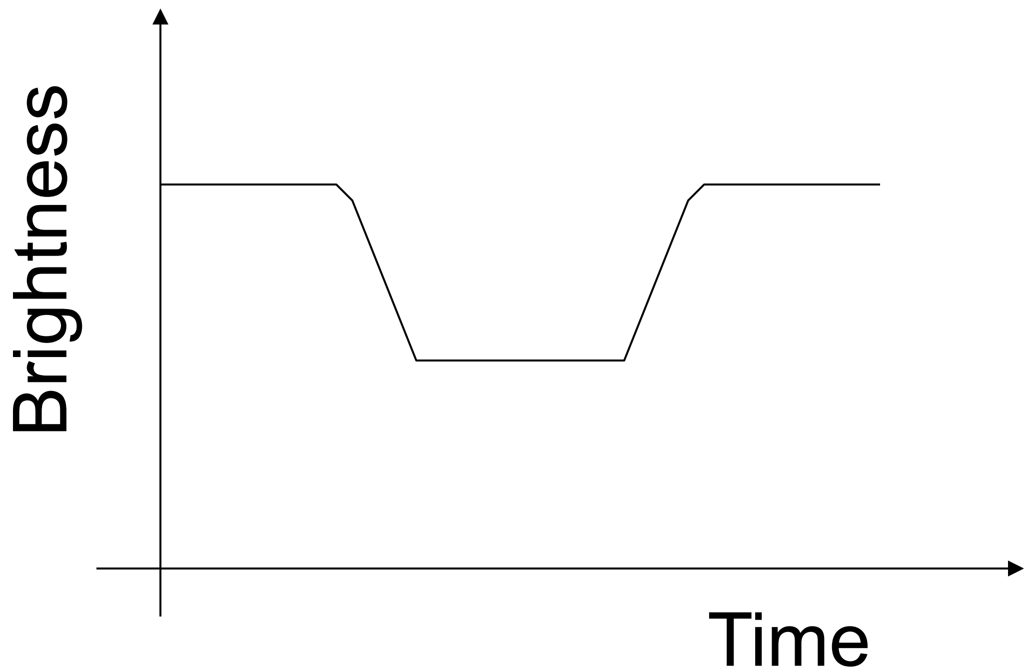
Notes on Multiple Star Systems

- More than half of the largest and brightest stars are found in multiple star systems – the most common type is binary (2 stars).
- Smaller, dimmer stars tend to be single lone stars.
- A binary is an *eclipsing* binary only if the plane of the orbits is oriented toward Earth.
- Observable binaries yield important data for determining stellar properties such as diameter and mass.

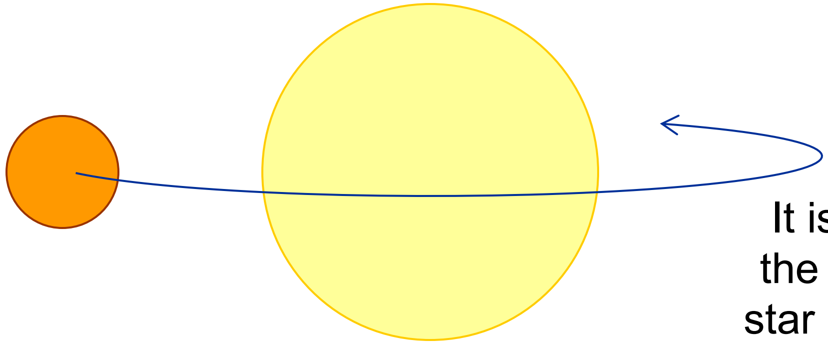
What we see or measure with photometer:



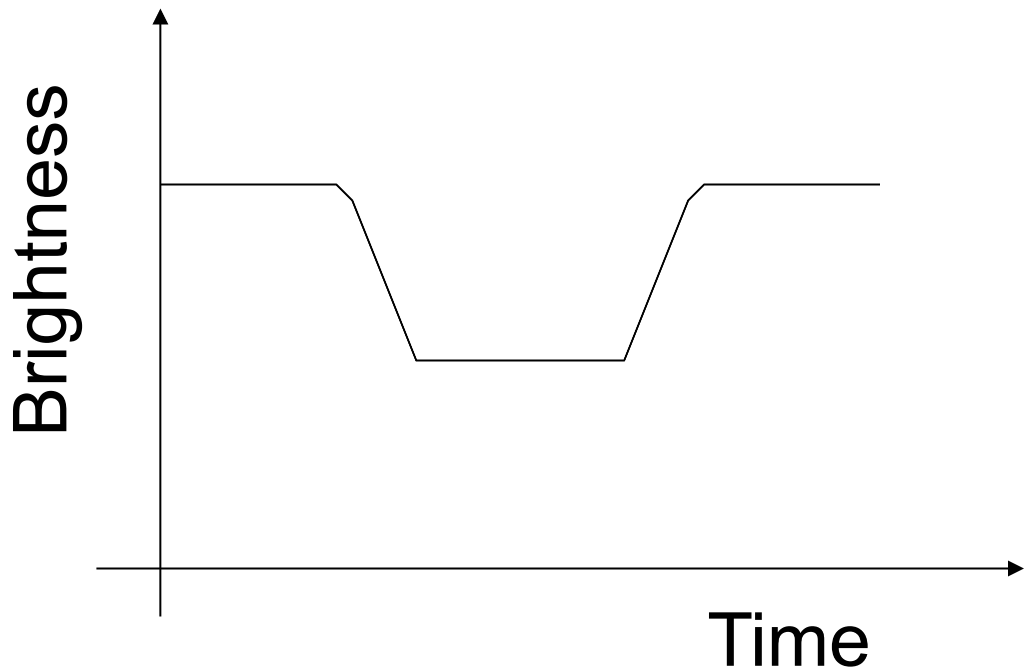
Star periodically
dims a little bit



What we can’t see, but conclude is happening:



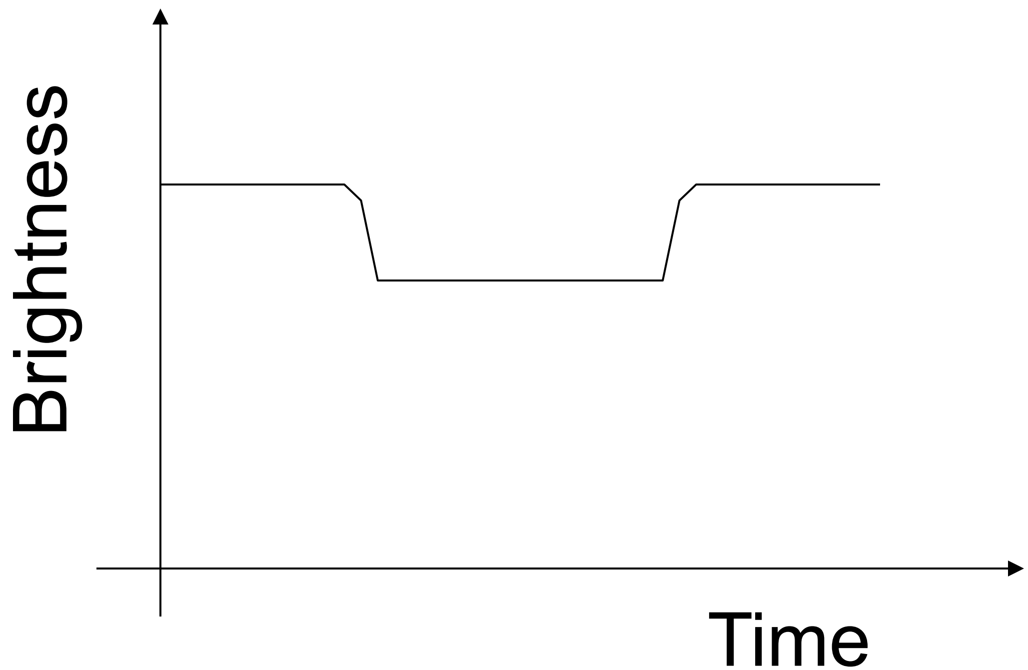
It is a binary star system and the dimming occurs when one star passes in front of the other.

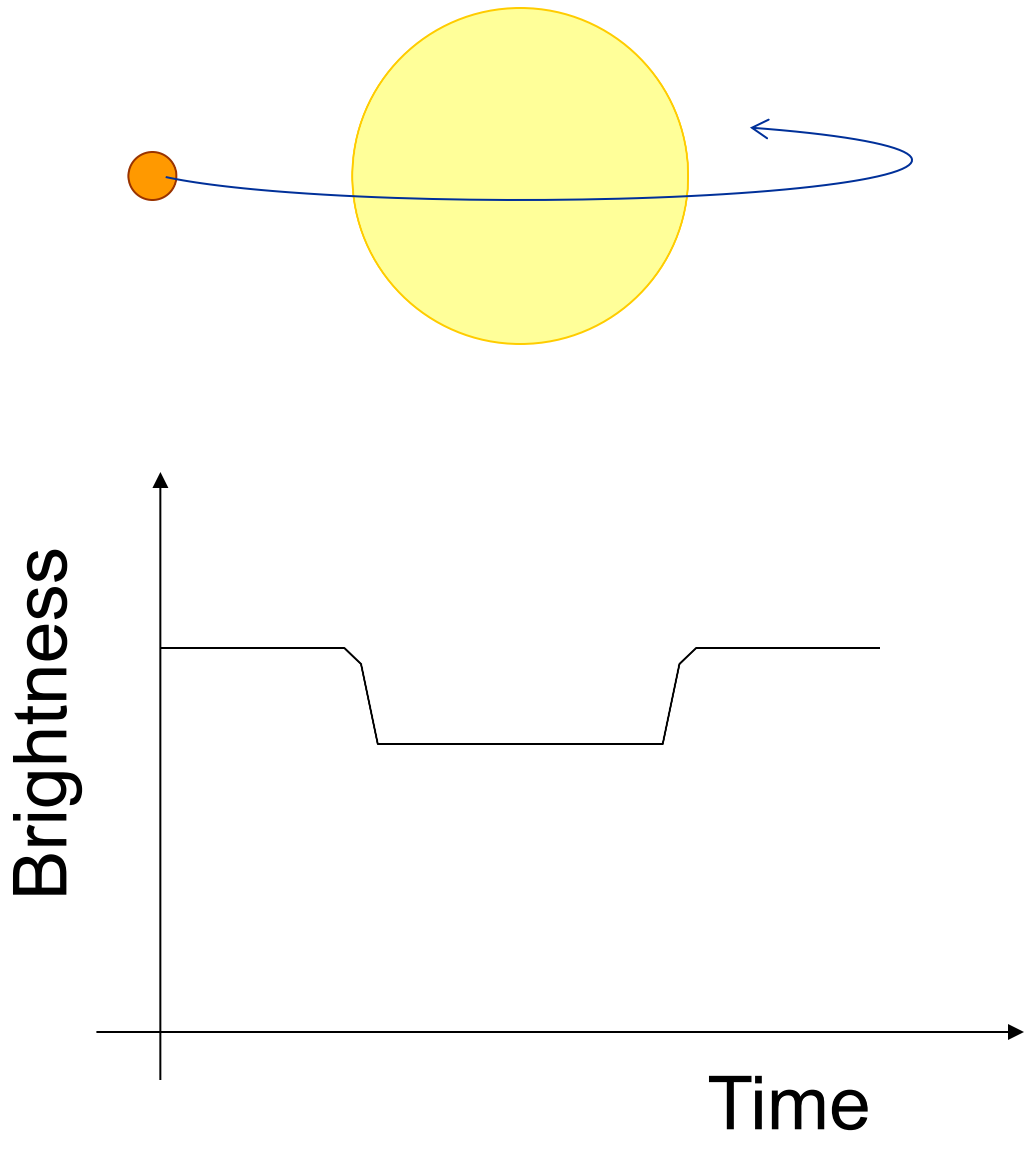


What could account for the differences in this graph versus the previous?

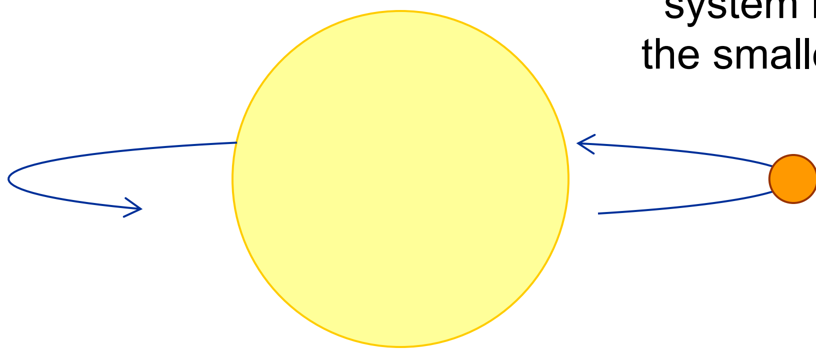
☆ ★ ☆

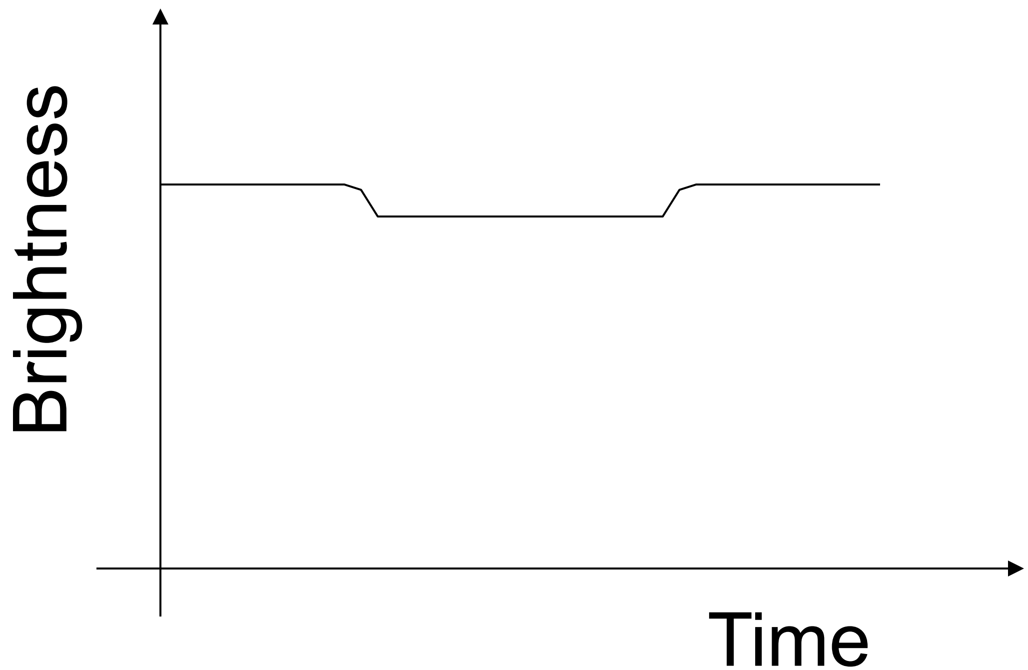
Discuss with classmate(s).




Brightness
Time

The total light of the binary system is also dimmed when the smaller star passes behind.





Indirect Method to Find Size

- For a given temperature, the larger a star, the more luminous it is.
- For a given diameter, the hotter a star, the more luminous it is.
- By finding luminosity and temperature astronomers can calculate the size of a star.

Web Links Astronomy

Home | AP Physics 1 | AP Physics 2 | AP Physics C | Astronomy

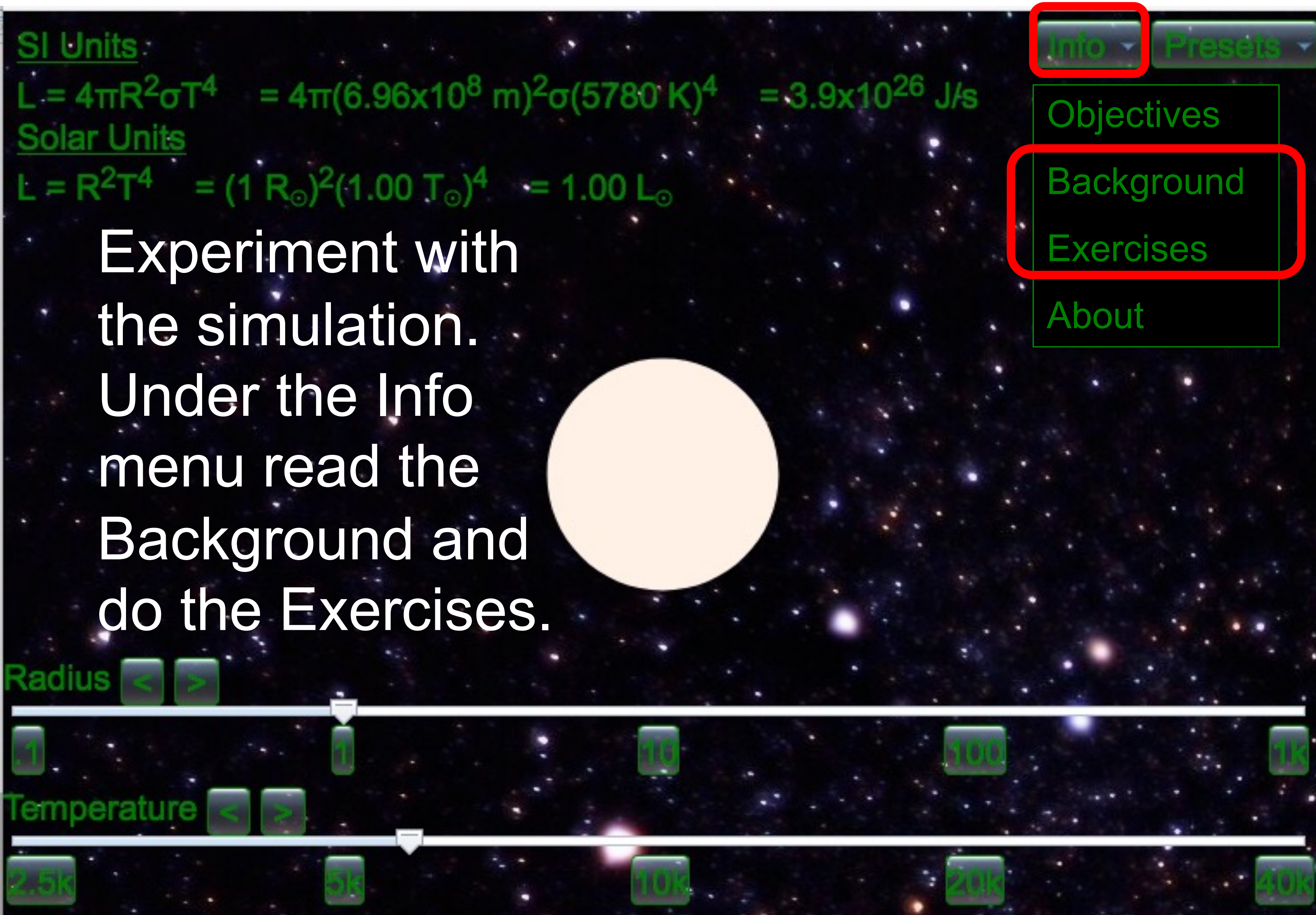
Various Animations - Fusion, Blackbody Radiation

The Stars

- 88 IAU Constellations - convenient Wikipedia index with hyperlinks
- Lists of Stars - hyperlinks to various Wikipedia pages - nearest, brightest, most luminous, etc.
- In-The-Sky Star Data - Information, charts, etc. organized by constellation
- The Internet Stellar Database - Collection of dat
- 100,000 Stars - Interactive 3D view of Sun's cos
- Various Animations - Parallax, Proper Motion, H-R Diagram, Eclipsing Binaries
- Eclipsing Binary Simulator - Interactive applet from University of Nebraska
- AAVSO - Variable Stars Data, Info, etc.
- Luminosity Simulation - Explore Luminosity vs Temperature vs Diameter from University of Nebraska
- Spectral Types - Java applet illustrating connection with temperature
- Spectroscopic Binaries - Animations showning shifts in spectra
- Interactive HR Diagram - HTML5 simulation: relations of temperature, color, radius, luminosity, etc.
- Pulsar Signals - Audio clips of radio "sounds" from Jodrell Bank
- Pulsar Signals - Audio clips of radio "sounds" from Cornell

Luminosity Simulation

Experiment with the simulation. Under the Info menu read the Background and do the Exercises.



Stefan-Boltzman Law

$$L = r^2 T^4$$

Where: L = luminosity
r = radius (or diameter)
T = surface temperature
Note: all values in solar units

Practice With $L = r^2T^4$

1. Suppose star A is twice the diameter of the Sun but has the same temperature. What is its luminosity?
2. Suppose star B is twice the temperature of the Sun but has the same radius. What is its luminosity?
3. Find Altair in the table – calculate its luminosity using its radius and temperature. Compare to the published value.
4. Pick another star from the table and calculate L using r and T. Does it work?

This can be solved for radius or diameter. All results and values are multiples of the Sun's properties.

$$r = \sqrt{\frac{L}{T^4}} = \frac{\sqrt{L}}{T^2}$$

Practice Finding Size

4. Suppose star D is four times the luminosity of the Sun but has the same temperature. What is its radius?
5. Suppose star E twice the temperature of the Sun but has the same luminosity. What is its radius?
6. Suppose star F has temperature 7000 K and luminosity 1000 times that of the Sun. Find its diameter.
7. Find the radii of Acrux A and B and fill in the table. Are these dwarfs? giants? supergiants?