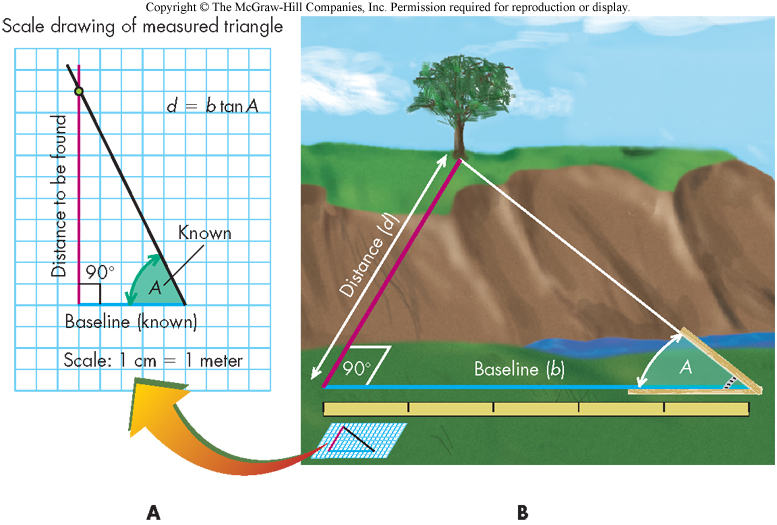
###### **Chapter 13 – Properties of Stars** Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**The Family of Stars**

* Those tiny glints of light in the night sky are in reality huge, dazzling \_\_\_\_\_ **\_\_\_\_\_\_\_,** many of which are **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** than the Sun
* They look dim because of their **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
* Astronomers cannot probe stars directly, and consequently must devise **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** to ascertain their intrinsic properties
* **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** to stars and galaxies **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
* Distance is very important for determining the **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** of astronomical objects

**Triangulation**

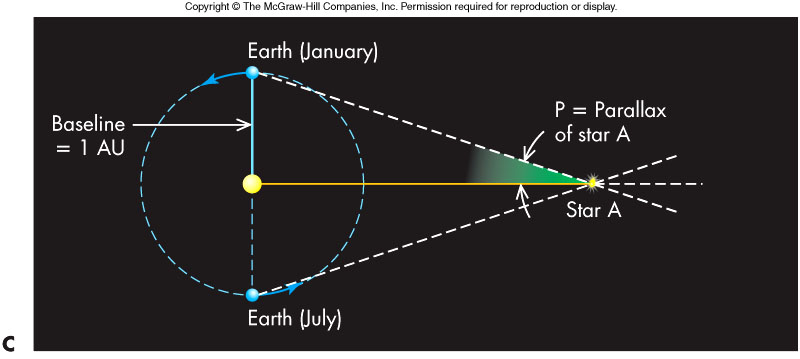


* Fundamental method for measuring distances to nearby stars is \_\_\_\_\_\_\_\_\_\_\_\_\_
* Measure length of a triangle’s “\_\_\_\_\_\_\_\_\_\_\_\_\_\_” and the angles from the ends of this baseline to a distant object
* Use trigonometry or a scaled drawing to determine distance to object



**Trigonometric Parallax**

**Calculating Distance Using Parallax**

****

* A method of triangulation used by astronomers is called *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
  + Baseline is the Earth’s orbit radius \_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_ measured with respect to very distant stars
* The shift of nearby stars is small, so angles are measured in \_\_\_\_\_\_\_\_\_\_\_\_\_
* The parallax angle, *\_\_*, is half the angular shift of the nearby star, and its distance in parsecs is given by:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* A *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.*
* Useful only to distances of about 250 parsecs



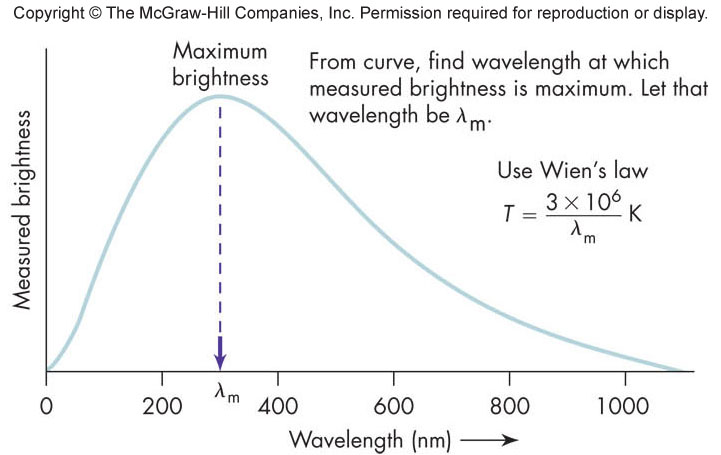
**Example: Distance to Sirius**

* Measured parallax angle for Sirius is 0.377 arc second
* From the formula,

Light, the Astronomer’s Tool

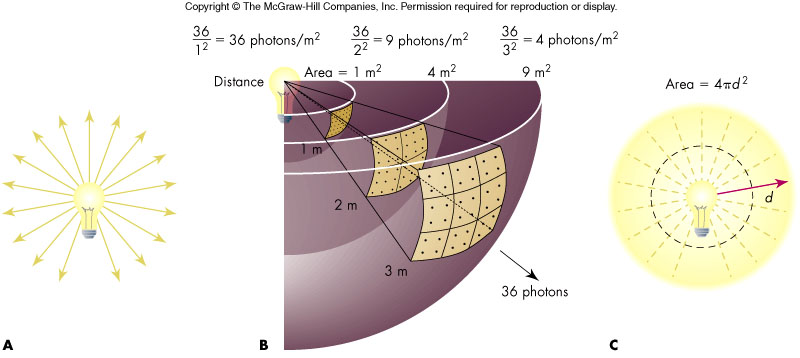
* Astronomers want to know the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of stars
* This information helps to understand the nature of stars as well as their \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The light from stars received at Earth is all that is available for this analysis

Temperature

* The \_\_\_\_\_\_\_\_\_\_\_\_\_\_ indicates its \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ – blue stars are hotter than red stars
* More precisely, a star’s surface temperature (in Kelvin) is given by the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (nm) at which the star radiates most strongly

**Luminosity**

* The amount of energy a star emits each second is its *\_\_\_\_\_\_\_\_\_\_\_\_\_* (usually abbreviated as *L*)
* A typical unit of measurement for luminosity is the \_\_\_\_\_\_\_\_\_\_\_\_\_\_.
* Compare a 100-watt bulb to the Sun’s luminosity, 4 × 1026 watts
* Luminosity is a measure of a star’s \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (or \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Knowing a star’s luminosity will allow a determination of a star’s \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



**The Inverse-Square Law**

* The *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* relates an object’s luminosity to its \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (how bright it appears to us)
* This law can be thought of as the result of a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, spreading out evenly in all directions as they leave the source
* The photons have to cross \_\_\_\_\_\_\_\_\_\_\_\_\_\_ concentric spherical shells.
* For a given shell, the number of photons crossing \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* The inverse-square law (IS) is:
* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* at a distance *d* from a source of luminosity *L*
* This relationship is called the inverse-square law because the distance appears in the denominator as a square
* The inverse-square law is one of the most important mathematical tools available to astronomers:
* Given \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, a star’s *L* can be found (A star’s *B* can easily be measured by an electronic device, called a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, connected to a telescope.)
* Or if *L* is known in advance, a star’s distance can be found

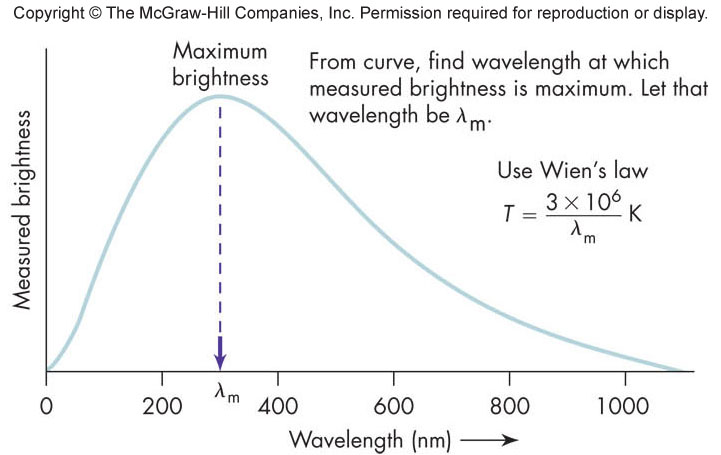
**The “Standard Candle” Method**

* If an object’s \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_brightness is known, its distance can be determined from its \_\_\_\_\_\_\_\_\_\_\_brightness
* Astronomers call this method of distance determination the \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* This method is the principle manner in which astronomers determine distances in the universe

**Radius**

* Common sense: Two objects of the same temperature but different sizes, the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ than the smaller one
* In stellar terms: a star of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ than a smaller star at the same temperature

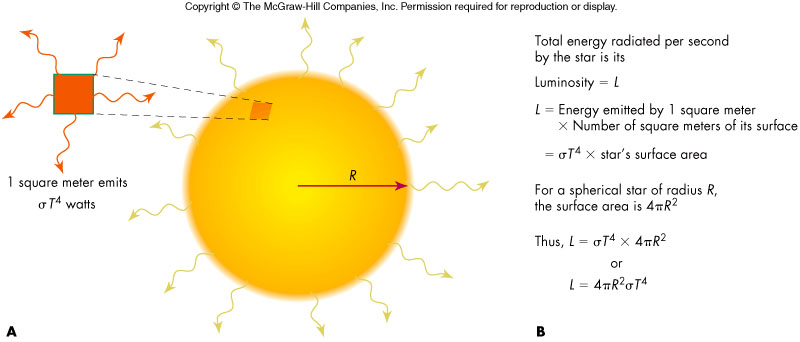
**Knowing L “In Advance”**



* We first need to know how much energy is emitted per unit area of a surface held at a certain temperature
* The Stefan-Boltzmann (SB) Law gives this:
* Here s is the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Tying It All Together**

* The Stefan-Boltzmann law **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** but not hot, low-density gases
* We can combine SB and IS to get:

*R* is the radius of the star

* Given *L* and *T*, we can then find a star’s radius!
* The methods using the Stefan-Boltzmann law and \_\_\_\_\_\_\_\_\_\_\_\_\_\_observations show that stars differ enormously in radius
  + Some stars are hundreds of times larger than the Sun and are referred to as *\_\_\_\_\_\_\_\_\_\_\_\_*
  + Stars smaller than the giants are called *\_\_\_\_\_\_\_\_\_\_\_\_\_*

**Example: Measuring the Radius of Sirius**

* Solving for a star’s radius can be simplified if we apply *L* = 4p*R*2s*T*4 to both the star and the Sun, divide the two equations, and solve for radius:
* Where s refers to the star and ¤ refers to the Sun

Given for Sirius *Ls* = 25*L*¤, *Ts* = 10,000 K, and for the Sun *T*¤= 6000 K, one finds *Rs* = 1.8*R*¤

**The Magnitude Scale**

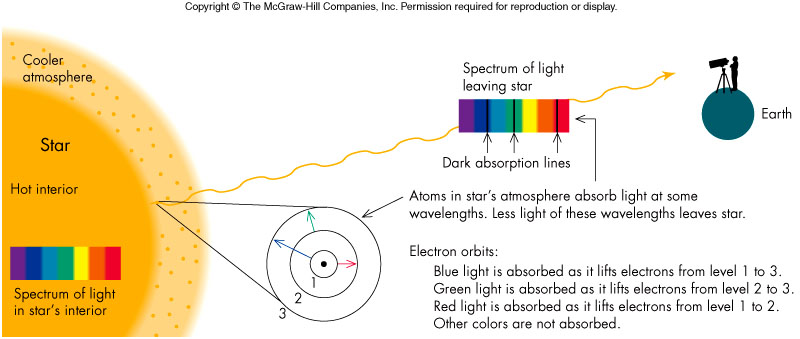
* About 150 B.C., the Greek astronomer Hipparchus measured apparent brightness of stars using units called *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
  + Brightest stars had \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + The system is still used today and units of measurement are called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to emphasize how bright a star looks to an observer
* A star’s apparent magnitude depends on the star’s luminosity and distance – a star may appear dim because it is very far away or it does not emit much energy
* The apparent magnitude can be confusing
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Modern calibrations of the scale create negative magnitudes
  + Magnitude differences equate to brightness ratios:
    - A difference of 5 magnitudes = a brightness ratio of 100
    - 1 magnitude difference = brightness ratio of 1001/5=2.512
* Astronomers use *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* to measure a star’s luminosity
  + The absolute magnitude of a star is the apparent magnitude that same star would have at 10 parsecs
  + A comparison of absolute magnitudes is now a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + An absolute magnitude of 0 approximately equates to a luminosity of 100*L*¤

**The Spectra of Stars**

* A star’s spectrum typically depicts \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* A spectrum also can reveal a star’s \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* On certain occasions, it may reveal \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Measuring a Star’s Composition**

* As light moves through the gas of a star’s surface layers, atoms absorb radiation at some wavelengths, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ lines in the star’s spectrum
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Determining a star’s surface composition is then a matter of \_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ lines to those known for atoms



* To find the \_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_ in the star, we use the \_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* This technique of determining composition and abundance can be tricky!
* Possible overlap of absorption lines from several varieties of atoms being present
* \_\_\_\_\_\_\_\_\_\_\_\_\_ can also \_\_\_\_\_\_\_\_ how \_\_\_\_\_\_\_\_\_\_\_\_an absorption line is

Temperature’s Effect on Spectra

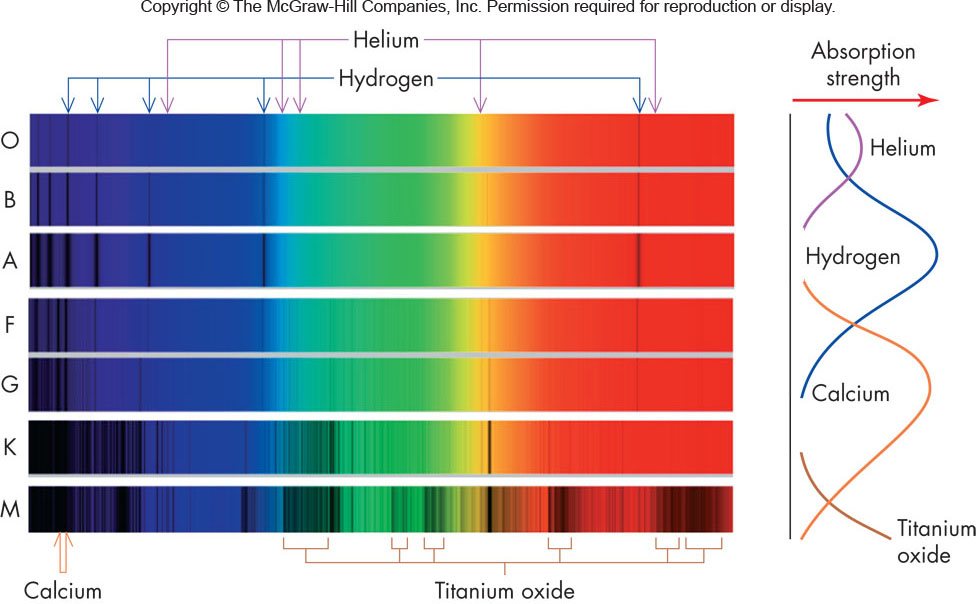
* A \_\_\_\_\_\_\_\_ is \_\_\_\_\_\_\_\_when its energy matches the difference between two electron energy levels and an electron occupies the \_\_\_\_\_\_\_\_\_\_\_\_\_
* Higher temperatures\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, on average, to \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ – lower temperatures, lower electron levels
* Consequently, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_on the presence or absence of an electron at the right energy level and this is very much \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Adjusting for temperature, a star’s composition can be found – interestingly, virtually all stars have compositions very similar to the Sun’s: \_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_, and a 2% mix of the remaining elements

**Early Classification of Stars**

* Historically, stars were first classified into four groups according to their color (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_), which were subsequently subdivided into classes using the letters \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Modern Classification of Stars**

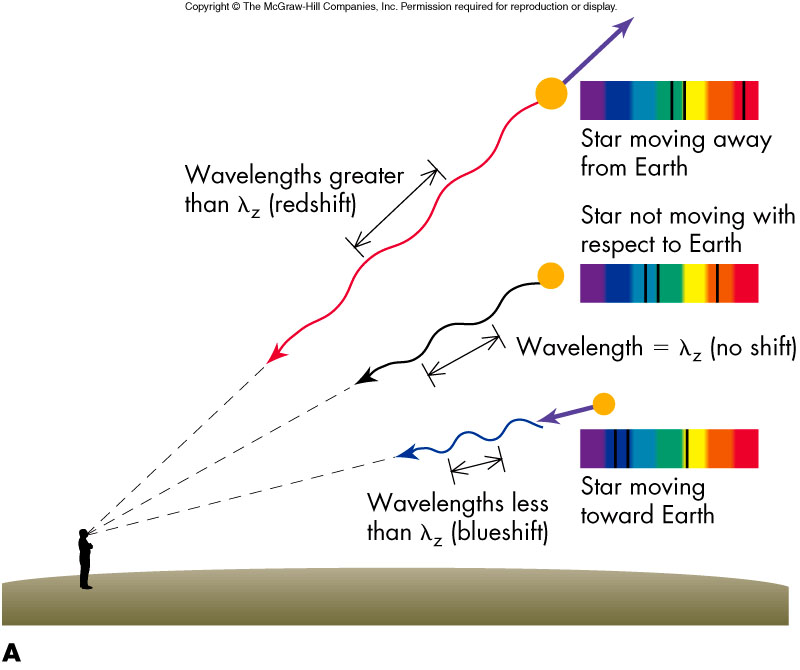
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ discovered the classes were more orderly in appearance if rearranged by temperature – Her reordered sequence became \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_) and are today known as *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_then demonstrated the physical connection between temperature and the resulting absorption lines



**Spectral Classification**

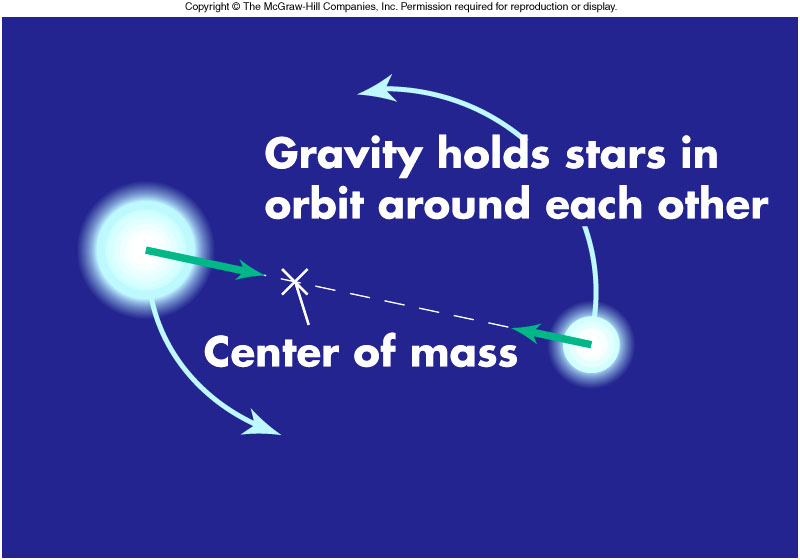
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ absorption lines indicate that hydrogen is in a highly \_\_\_\_\_\_\_\_\_\_\_\_
* \_\_\_\_\_\_\_\_\_\_ have just the right temperature to put \_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, which results in strong absorption lines in the visible
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are of a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ to show absorption lines of metals such as calcium and iron, elements that are typically ionized in hotter stars
* **\_\_\_\_\_\_\_\_\_\_\_\_** stars are cool enough to form molecules and their absorption “bands” become evident.
* Temperature range: more than \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and less than \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ stars
* Spectral classes subdivided with numbers - the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

**Measuring a Star’s Motion**

* A star’s motion is determined from the Doppler shift of its spectral lines
  + The amount of shift depends on the star’s \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ which is the star’s speed along the line of sight
  + Given that we measure \_\_\_\_\_\_ the shift in wavelength of an absorption line of wavelength *\_\_\_\_\_*, the radial speed *v* is given by:
  + c is the speed of light
* Note that *\_\_\_\_*is the wavelength of the absorption line for an object at rest and its value is determined from laboratory measurements on nonmoving sources
* An \_\_\_\_\_\_\_\_\_\_\_\_\_\_ means the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ a decrease means it is approaching – speed across the line on site cannot be determined from \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Doppler measurements and related analysis show:
  + \_\_\_\_\_\_\_\_\_\_\_\_ and that those near the Sun share approximately the same direction and speed of revolution (\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_) around the center of our galaxy
  + Superimposed on this orbital motion are small random motions of about 20 km/sec
  + In addition to their motion through space, stars spin on their axes and this spin can be measured using the Doppler shift technique – \_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Binary Stars**

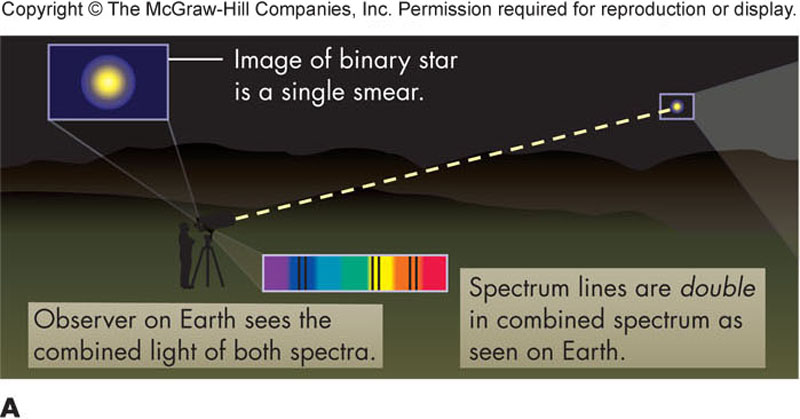
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ that revolve around each other as a result of their mutual gravitational attraction are called *\_\_\_\_\_\_\_\_\_\_\_\_\_*
* Binary star systems offer one of the few ways to measure \_\_\_\_\_\_\_\_\_\_\_\_\_ – and stellar mass plays the leading role in a star’s evolution
* At least 40% of all stars known have orbiting companions (some more than one)
* Most binary stars are only a few AU apart – a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



Visual Binary Stars

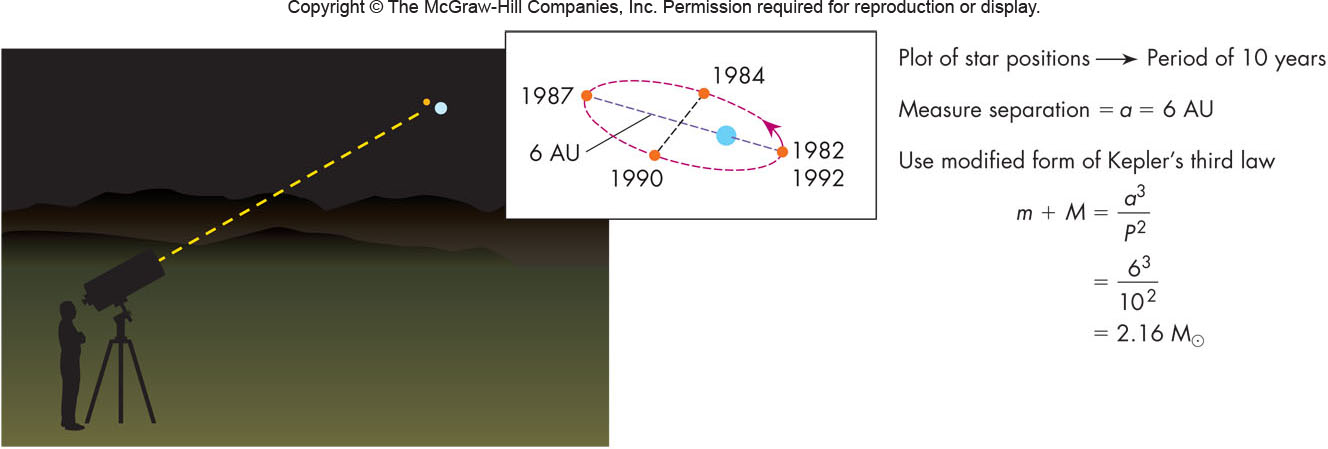
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_are binary systems where we can directly see the orbital motion of the stars about each other by \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Spectroscopic Binaries



* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are systems that are inferred to be binary by a comparison of the system’s spectra over time.
* Doppler analysis of the spectra can give a \_\_\_\_\_\_\_\_\_\_\_\_\_ and by observing a full cycle of the motion the \_\_\_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_can be determined

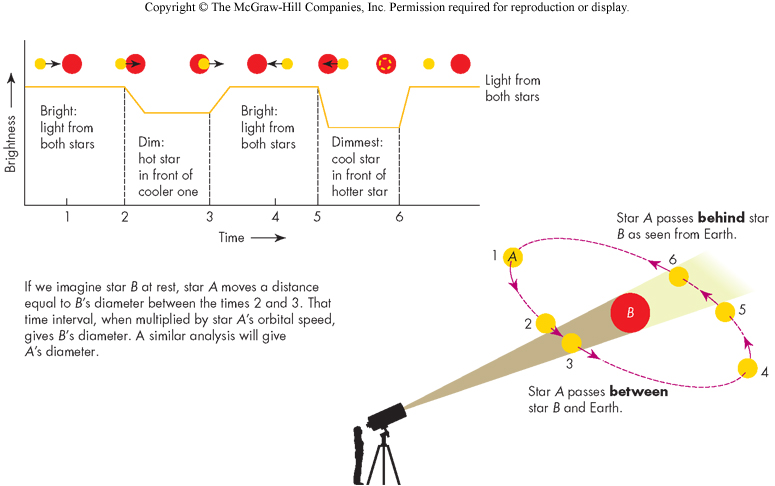
Stellar Masses



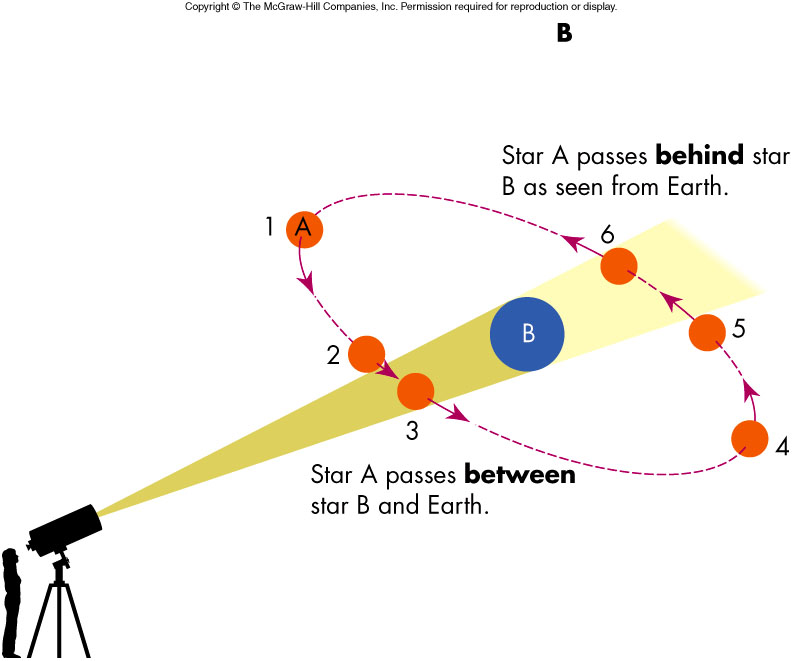
* Kepler’s third law as modified by Newton is

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are the binary star masses (in solar masses), *P* is their period of revolution (in years), and *a* is the semimajor axis of one star’s orbit about the other (in AU)

* *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*are determined from observations (may take a few years) and the above equation gives the combined mass (*m* + *M*)
* Further observations of the stars’ orbit will allow the determination of each star’s individual mass
* Most stars have masses that fall in the narrow range\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



Eclipsing Binaries

* A binary star system in which one star can eclipse the other star is called an \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_
* Watching such a system over time will reveal a combined light output that will periodically dim
* The duration and manner in which the combined light curve changes together with the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_allows astronomers to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_of the two eclipsing stars

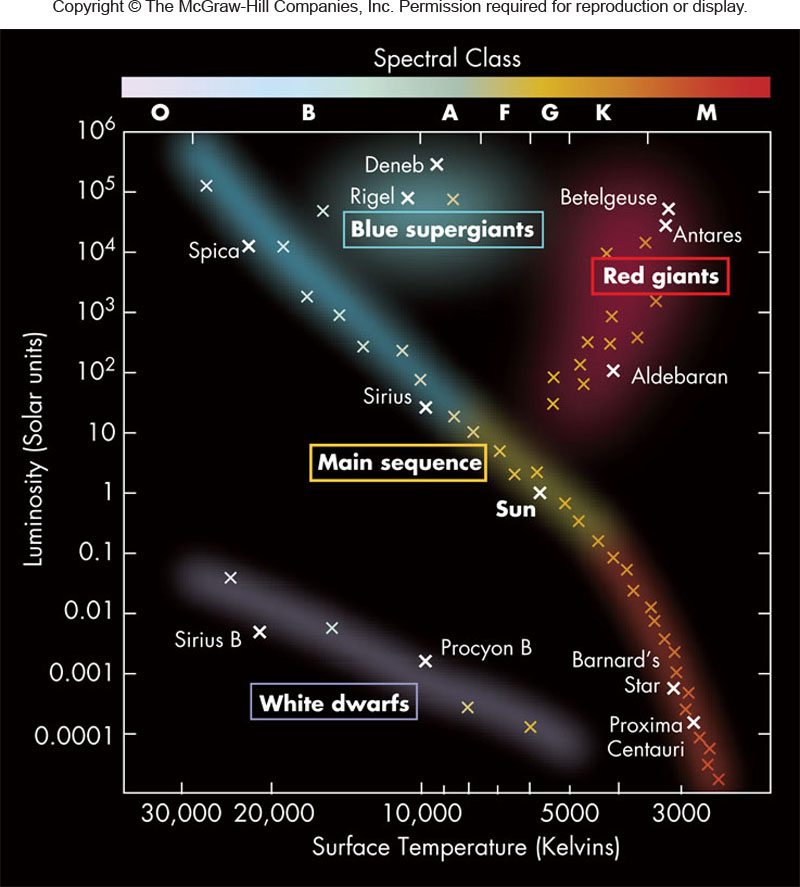
Summary of Stellar Properties

* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Parallax (triangulation) for nearby stars (distances less than 250 pc)
  + Standard-candle method for more distant stars
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Wien’s law (color-temperature relation)
  + Spectral class (O hot; M cool)
* [\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_](http://www.teachastronomy.com/videos/Stars/Stellar-Luminosity)
  + Measure star’s apparent brightness and distance and then calculate with inverse square law
  + Luminosity class of spectrum (to be discussed)
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Spectral lines observed in a star
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Stefan-Boltzmann law (measure *L* and *T*, solve for *R*)
  + Interferometer (gives angular size of star; from distance and angular size, calculate radius)
  + Eclipsing binary light curve (duration of eclipse phases)
* \_\_\_\_\_\_\_\_\_\_\_\_\_
  + Modified form of Kepler’s third law applied to binary stars
* \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Doppler shift of spectrum lines

Putting it all together –\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

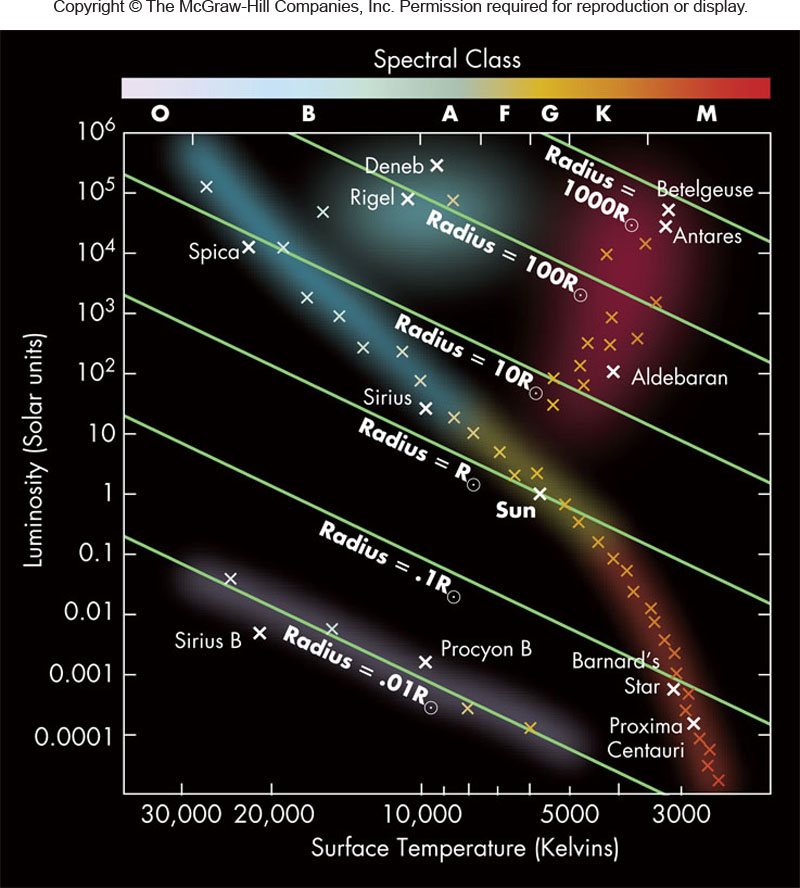
* So far, only properties of stars have been discussed – this follows the historical development of studying stars
* The next step is to understand why stars have these properties in the combinations observed
* This step in our understanding comes from the H-R diagram, developed independently by Ejnar Hertzsprung and Henry Norris Russell in 1912

The HR Diagram



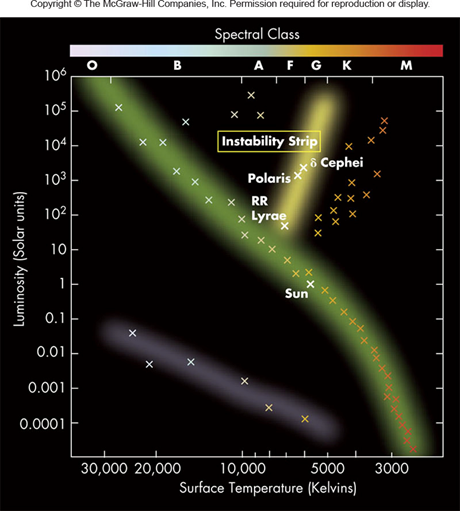
* The *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_* is a plot of stellar \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Interestingly, most of the stars on the H-R diagram lie along a smooth diagonal running from hot, luminous stars (upper left part of diagram) to cool, dim ones (lower right part of diagram)
* By tradition, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_of the H-R diagram and \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ are on the left with \_\_\_\_\_\_\_\_\_\_\_\_ stars on the right (Note: temperature does not run in a traditional direction)
* The diagonally running group of stars on the H-R diagram is referred to as the *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
* Generally, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_be on the main sequence; however, a few stars will be cool but very luminous (upper right part of H-R diagram), while others will be hot and dim (lower left part of H-R diagram)

Analyzing the HR Diagram



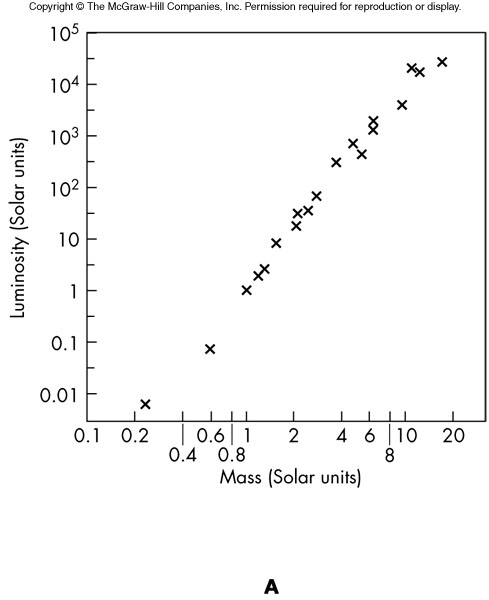
* The Stefan-Boltzmann law is a key to understanding the H-R diagram
  + For stars of a given temperature, **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
  + Therefore, as one moves up the H-R diagram, a star’s radius must become bigger
  + On the other hand, for a given luminosity, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Therefore, as one moves right on the H-R diagram, a star’s radius must increase
  + The net effect of this is that the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_of the diagram and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Giants and Dwarfs

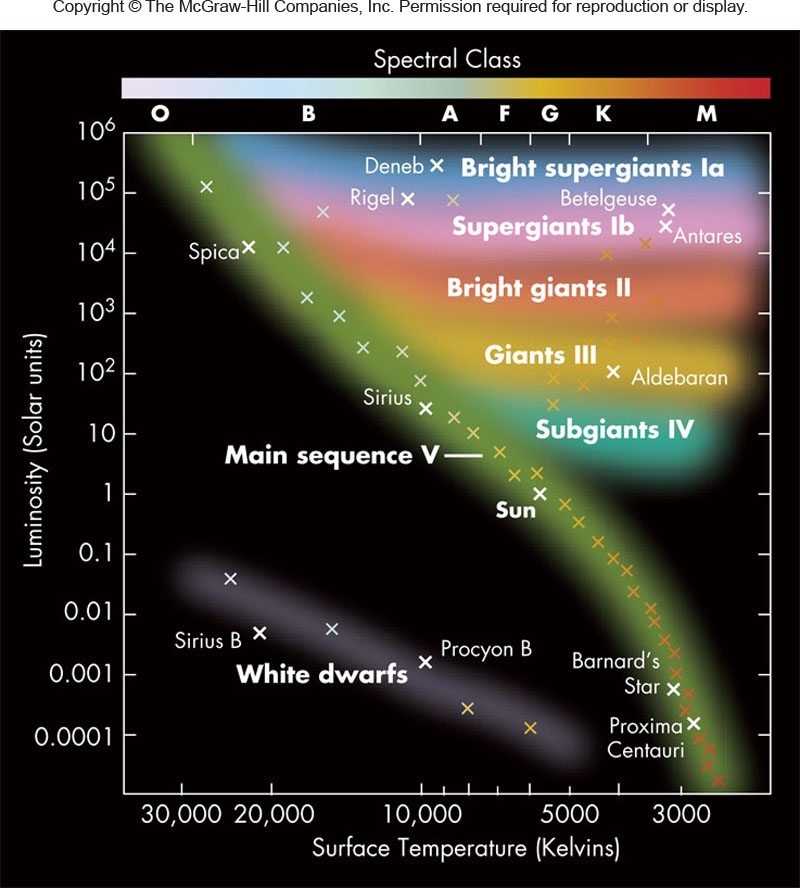


* Stars in the upper left are called *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*(red because of the low temperatures there)
* Stars in the lower right are *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
* Three stellar types: main sequence, red giants, and white dwarfs

The Mass-Luminosity Relation



* Main-sequence stars obey a *\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_,* approximately given by:
* *L* and *M* are measured in solar units
* Consequence: Stars at top of main-sequence are more massive than stars lower down



Luminosity Classes

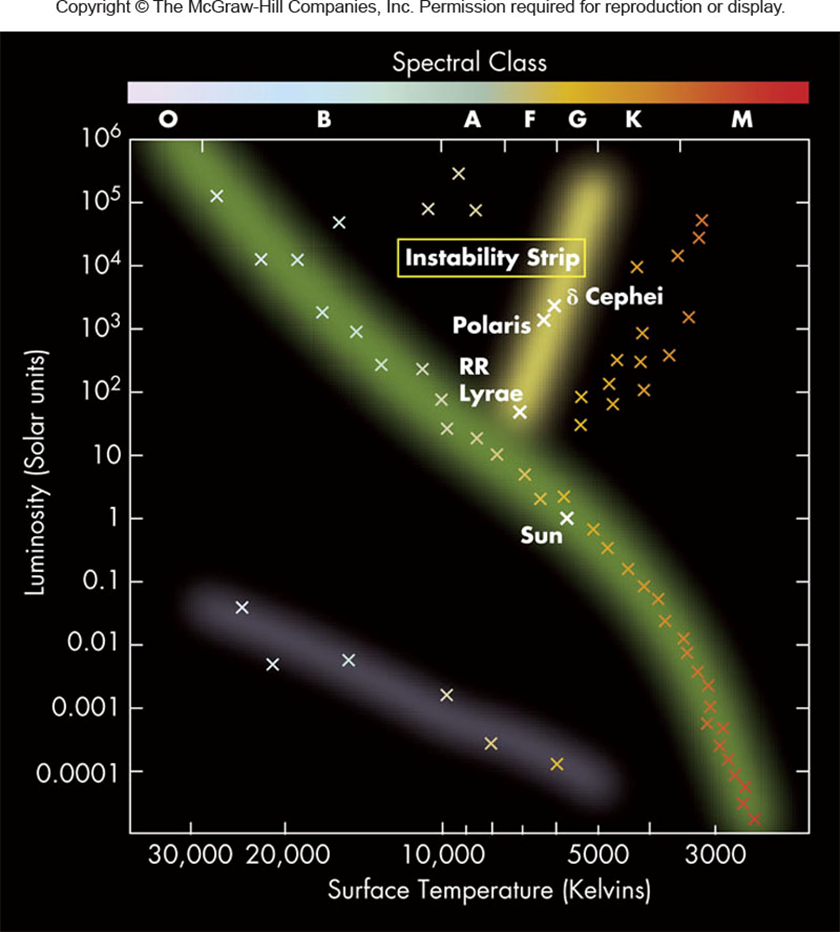
* Luminous stars (in upper right of H-R diagram) tend to be less dense, hence narrow absorption lines
* H-R diagram broken into luminosity classes: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + Star classification example: The Sun is G2V

Summary of the HR Diagram

* Most stars lie on the main sequence
  + Of these, the hottest stars are blue and more luminous, while the coolest stars are red and dim
  + Star’s position on sequence determines its mass, being more near the top of the sequence
* Three classes of stars:
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
  + \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

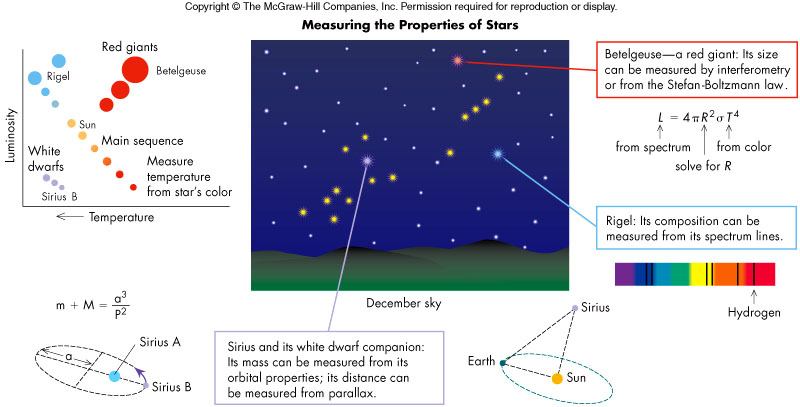
Variable Stars

* Not all stars have a constant luminosity – some change brightness: *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*
* There are several varieties of stars that vary and are important distance indicators
* Especially important are the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ stars with rhythmically \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
* Most variable stars plotted on H-R diagram lie in the narrow “\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_”



The Instability Strip

* Most variable stars plotted on H-R diagram lie in the narrow \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_



Summary