Chapter 13
Measuring the properties of stars

What are the stages?

a: Low Mass Star
1. Nebula
2a. Main Sequence
3a. Red Giant
4a. Planetary Nebula
5a. White Dwarf
6a. Black Dwarf
5b. Neutron Star or Black Hole

b: High Mass Star
2b. Main Sequence
3b. Red Supergiant
4b. Supernova
Parallax measurements of the distances to the nearest stars use _____ as a baseline.
A. Earth's orbit
B. Earth's diameter
C. Earth-Moon distance
D. About the length of a football field
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A. Earth's orbit
B. Earth's diameter
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Star A and Star B have same temperatures, but Star A is more luminous than Star B. Based on this information, which of the following must be the case?

A. Star A is smaller than Star B.
B. Star A is larger than Star B.
C. Star A and Star B have same size.
D. Star A is more massive than Star B.
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A. Star A is smaller than Star B.
B. Star A is larger than Star B.
C. Star A and Star B have same size.
D. Star A is more massive than Star B.
Star A and Star B have the same size, but Star A is more luminous than Star B. Based on this information, which of the following must be the case?

A. Star A is cooler than Star B.
B. Star A is hotter than Star B.
C. Star A and Star B have same temperature.
D. Star A is more massive than Star B.
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A. Star A is cooler than Star B.
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Which of the following stars is reddish in color?
A. F6
B. A0
C. G5
D. B2
E. K9
Which of the following stars is reddish in color?

A. F6
B. A0
C. G5
D. B2
E. K9
In the above HR diagram sketch, which star is a white dwarf?

A. A  
B. B  
C. C  
D. D  
E. E
In the above HR diagram sketch, which star is a white dwarf?

A. A
B. B
C. C
D. D
E. E
80% of ________ type stars have orbiting companions.
A. O and B
B. A and F
C. F and G
D. K and M
80% of _________ type stars have orbiting companions.

A. O and B
B. A and F
C. F and G
D. K and M
The H-R diagram is a diagram plotting the stars according to their
A. Apparent brightness and temperature.
B. Spectral type and temperature.
C. Brightness and luminosity class.
D. Luminosity and temperature.
E. Mass and diameter.
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A. Apparent brightness and temperature.
B. Spectral type and temperature.
C. Brightness and luminosity class.
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Which of the following is a main sequence star hotter than the Sun? (Note: the Sun is a G2V star)

A. B2II  
B. G2II  
C. G2III  
D. G1V  
E. O2II
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A. B2II
B. G2II
C. G2III
D. G1V
E. O2II
Which of the following statements would explain the fact that larger molecules, such as amino acids, do not produce spectral lines in the OBAFGKM classification?
A. Larger molecules require higher temperatures to show absorption lines.
B. The spectra of hydrogen and helium are sufficient to classify stars.
C. The spectra of larger molecules are too complicated.
D. Larger molecules break apart at the high temperatures of stellar atmospheres.
E. All of the above.
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B. The spectra of hydrogen and helium are sufficient to classify stars.
C. The spectra of larger molecules are too complicated.
D. Larger molecules break apart at the high temperatures of stellar atmospheres.
E. All of the above.
The spectrum of a star shows the 656 nm absorption line shifted to 654 nm. Which of the following can we conclude about this star?

A. The star is approaching us with an approximate speed of 1,800 km/sec.
B. The star is receding with an approximate speed of 1,800 km/sec.
C. The star is approaching us with an approximate speed of 900 km/sec.
D. The star is receding with an approximate speed of 900 km/sec.
E. The star is spinning rapidly.
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D. The star is receding with an approximate speed of 900 km/sec.
E. The star is spinning rapidly.
What is the difference between spectroscopic and visual binaries?

A. Spectroscopic binaries have double spectral lines but do not move.

B. Visual binaries are pairs of stars in the same region in the sky but are not gravitationally interacting.

C. A visual binary does not show changes in the spectral lines.

D. In a visual binary we can see two distinct stars; in spectroscopic binaries, the images of the two stars cannot be resolved.
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The study of eclipsing binary stars is very important because it allows astronomers to determine
A. The distance between two stars.
B. The speed of stars from the Doppler shift of their spectral lines.
C. The diameters of stars.
D. The luminosity of each star.
E. The brightness of each star.
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B. The speed of stars from the Doppler shift of their spectral lines.
C. The diameters of stars.
D. The luminosity of each star.
E. The brightness of each star.
If a main sequence, giant, and a supergiant all have the same spectral class, what characteristic is known to make these stars different?

A. Luminosity.
B. Distance.
C. Surface temperature.
D. Color.
E. It shows that the more massive stars are cooler.
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B. Distance.
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D. Color.
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What can we conclude about a star because its luminosity varies in an irregular pattern?
A. The star is very young.
B. The star is very old.
C. The star is rotating.
D. A or B.
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A. The star is very young.
B. The star is very old.
C. The star is rotating.
D. A or B.
_____ can be used to measure the _____ of nearby stars.

A. Parallax measurements; radius
B. The method of standard candles; brightness
C. Interferometry; radius
Parallax measurements can be used to measure the radius of nearby stars.

A. Parallax measurements; radius
B. The method of standard candles; brightness
C. Interferometry; radius
If the distance between the Earth and a star is measured using parallax measurements, how far apart in time should the two measurements be made to make the parallax measurement as accurate as possible?

A. Instantaneously
B. A day
C. Six months
D. A year
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A. Instantaneously
B. A day
C. Six months
D. A year
The amount of energy emitted by a star each second is the _____ and is measured in _____.

A. Apparent brightness; degrees K
B. Temperature; degrees K
C. Apparent brightness; Watts
D. Luminosity; Watts
The amount of energy emitted by a star each second is the ____ and is measured in ____.
A. Apparent brightness; degrees K
B. Temperature; degrees K
C. Apparent brightness; Watts
D. Luminosity; Watts
The luminosity of a star is determined by the star's ___ and ____.
A. Brightness; temperature
B. Apparent brightness; surface temperature
C. Diameter; surface temperature
D. Distance; surface temperature
E. Diameter; distance
The luminosity of a star is determined by the star's ___ and ____.
A. Brightness; temperature
B. Apparent brightness; surface temperature
C. Diameter; surface temperature
D. Distance; surface temperature
E. Diameter; distance
A star of apparent magnitude ____ appears 2.51 times brighter than a star of apparent magnitude 4.

A. 1
B. 1.49
C. 3
D. 6.51
E. 10
A star of apparent magnitude ____ appears 2.51 times brighter than a star of apparent magnitude 4.

A. 1
B. 1.49
C. 3
D. 6.51
E. 10
The Balmer lines correspond to wavelengths in the ____ part of the spectrum of a ____ atom.
A. Ultraviolet; helium
B. Visible; hydrogen
C. Infrared; hydrogen
D. X-ray; helium
The Balmer lines correspond to wavelengths in the ____ part of the spectrum of a ____ atom.
A. Ultraviolet; helium
B. Visible; hydrogen
C. Infrared; hydrogen
D. X-ray; helium
An M type star 1000 times more luminous than the Sun will be located near the ___ part of the H-R diagram.
A. Top left
B. Top right
C. Center
D. Bottom right
E. Bottom left
An M type star 1000 times more luminous than the Sun will be located near the ___ part of the H-R diagram.

A. Top left
B. Top right
C. Center
D. Bottom right
E. Bottom left
Lines from molecules are strongest in ___ type stars.
A. A
B. F
C. M
D. K
E. O
Lines from molecules are strongest in ___ type stars.

A. A
B. F
C. M
D. K
E. O
Binary star systems are important because they allow astronomers to determine the mass and the _____ of the stars in the system.

A. Eclipsing; temperature
B. Spectroscopic; diameter
C. Spectroscopic; temperature
D. Eclipsing; diameter
E. Visual; temperature
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C. Spectroscopic; temperature
D. Eclipsing; diameter
E. Visual; temperature
A main sequence star has 3 times the mass of the Sun. Using _____ we find that the star is ____ times more luminous than the Sun.

A. The mass-luminosity relation; 9
B. The Stefan-Boltzmann law; 3
C. Wien's law; 3
D. The mass-luminosity relation; 3
E. The inverse-square law; 9
A main sequence star has 3 times the mass of the Sun. Using _____ we find that the star is ___ times more luminous than the Sun.

A. The mass-luminosity relation; 9
B. The Stefan-Boltzmann law; 3
C. Wien's law; 3
D. The mass-luminosity relation; 3
E. The inverse-square law; 9
If Star A is twice as far as Star B, and they are identical in all other ways, then the brightness of Star A would be

A. One-fourth the brightness of Star B.
B. One-half the brightness of Star B.
C. The same brightness as Star B.
D. Twice the brightness of Star B.
E. Four times the brightness of Star B.
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C. The same brightness as Star B.
D. Twice the brightness of Star B.
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How does Rigel, a bluish star, surface temperature compare to Betelgeuse, a reddish star.
A. Rigel's surface temperature is less than Betelgeuse's.
B. Rigel's surface temperature is greater than Betelgeuse's.
C. They have the same surface temperature because they are both members of the constellation Orion.
D. It is impossible to say without knowledge of the sizes of the stars.
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T or F

The hottest (O and B type) stars are usually binary stars, while the coolest (M type) stars are usually single stars.
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Wien's law implies that a blue star is cooler than a red star.
T or F

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The relative brightness of the stars as we see them in our sky is represented by their
A. Absolute magnitudes.
B. Apparent magnitude.
C. Surface temperature.
D. Luminosity.
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A. Absolute magnitudes.
B. Apparent magnitude.
C. Surface temperature.
D. Luminosity.
Luminosity (absolute brightness) of a star depends on its ___________.
A. Temperature
B. Radius
C. Distance from us
D. Both A and B
E. Both A and C
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A. Temperature
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D. Both A and B
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Which of the following stars has the hottest stellar surface temperature?

A. M6
B. A0
C. G5
D. B2
E. K9
Which of the following stars has the hottest stellar surface temperature?

A. M6
B. A0
C. G5
D. B2
E. K9
If it were possible to move a star closer to the Earth then its apparent magnitude number would ______ while its absolute magnitude number would _______.

A. Decrease; increase
B. Decrease; stay the same
C. Increase; decrease
D. Increase; stay the same
If it were possible to move a star closer to the Earth then its apparent magnitude number would ______ while its absolute magnitude number would _______.

A. Decrease; increase
B. Decrease; stay the same
C. Increase; decrease
D. Increase; stay the same
In which binary system can we observe both the stars separately and follow their orbits around each other?

A. Visual binary system.

B. Spectroscopic binary system.

C. Eclipsing binary system.
In which binary system can we observe both the stars separately and follow their orbits around each other?

A. Visual binary system.
B. Spectroscopic binary system.
C. Eclipsing binary system.
The star Aldebaran is a red giant, and is much more luminous than the Sun. What conclusions can be drawn from this fact?
A. Aldebaran is hotter and much more massive than the Sun.
B. Aldebaran is cooler than the Sun, but has larger diameter than the Sun.
C. In the HR diagram, Aldebaran is above and to the left of the Sun.
D. Aldebaran is a binary star.
E. None of the above.
The star Aldebaran is a red giant, and is much more luminous than the Sun. What conclusions can be drawn from this fact?

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B. Aldebaran is cooler than the Sun, but has larger diameter than the Sun.

C. In the HR diagram, Aldebaran is above and to the left of the Sun.

D. Aldebaran is a binary star.

E. None of the above.
The star Aldebaran is cooler and much more luminous than the Sun. Where do you expect to find Aldebaran in the H-R diagram?

A. Top left
B. Top right
C. Center
D. Bottom right
E. Bottom left
The star Aldebaran is cooler and much more luminous than the Sun. Where do you expect to find Aldebaran in the H-R diagram?

A. Top left

B. Top right

C. Center

D. Bottom right

E. Bottom left
How can we explain the fact that hydrogen Balmer lines are essentially absent in the hot O type and the cool M stars?
A. O type stars do not contain hydrogen.
B. In cool stars hydrogen combines to form large molecules.
C. In O stars hydrogen is ionized and in M stars the electrons of hydrogen are in level 1, not level 2.
D. All of the above.
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D. All of the above.
Binary star systems are very important because they allow
A. Measurement of star masses.
B. Measurement of the speed of stars.
C. More precise measurement of the distance of stars.
D. More precise measurement of the temperature of stars.
E. More precise measurement of the spectral type of stars.
Binary star systems are very important because they allow

A. Measurement of star masses.
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E. More precise measurement of the spectral type of stars.
Stars on the main sequence have different luminosities because
A. They have different chemical compositions.
B. They have different ages.
C. They are at different distances from the Sun.
D. They have different masses.
E. They have different apparent magnitudes.
Stars on the main sequence have different luminosities because

A. They have different chemical compositions.
B. They have different ages.
C. They are at different distances from the Sun.
D. They have different masses.
E. They have different apparent magnitudes.
Which of the following is not true for a pulsating star?

A. The surface temperature of a pulsating star changes periodically.
B. The outer layers of a pulsating star expand and contract periodically.
C. The luminosity changes periodically.
D. They are usually members of an eclipsing binary star system.
E. They show periodic shifts in their spectral lines.
Which of the following is not true for a pulsating star?

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D. They are usually members of an eclipsing binary star system.
E. They show periodic shifts in their spectral lines.
If a star has an apparent magnitude of 8 and an absolute magnitude of 6 it is
A. Much closer than 10 parsecs away.
B. Slightly closer than 10 parsecs away.
C. Exactly 10 parsecs away.
D. Slightly farther than 10 parsecs away.
E. Much farther than 10 parsecs away.
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E. Much farther than 10 parsecs away.
The parallax of a star is ____ usually measured in ____.
A. A distance; arcseconds
B. An angle; arcseconds
C. An angle; parsecs
D. A distance; AU's
The parallax of a star is ____ usually measured in ____.
A. A distance; arcseconds
B. An angle; arcseconds
C. An angle; parsecs
D. A distance; AUs
A light source at a distance of 1 meter that emits 50 Watts of visible radiation has the same ____ as a source emitting 200 Watts and is located ____.

A. Luminosity; 2 meters away
B. Luminosity; 4 meters away
C. Apparent brightness; 2 meters away
D. Apparent brightness; 4 meters away
A light source at a distance of 1 meter that emits 50 Watts of visible radiation has the same ____ as a source emitting 200 Watts and is located ____.

A. Luminosity; 2 meters away
B. Luminosity; 4 meters away
C. Apparent brightness; 2 meters away
D. Apparent brightness; 4 meters away
Star A star is located at the top left of the H-R diagram and has the same luminosity as Star B which is located at the top right of the H-R diagram. How must these stars differ?

A. Star A is hotter and bigger than Star B.
B. Star A is cooler and bigger than Star B.
C. Star A is hotter and smaller than Star B.
D. Star A is cooler and smaller than Star B.
Star A star is located at the top left of the H-R diagram and has the same luminosity as Star B which is located at the top right of the H-R diagram. How must these stars differ?
A. Star A is hotter and bigger than Star B.
B. Star A is cooler and bigger than Star B.
C. Star A is hotter and smaller than Star B.
D. Star A is cooler and smaller than Star B.
The hydrogen absorption lines are the strongest in ___ type stars.

A. A  
B. B  
C. O  
D. G
The hydrogen absorption lines are the strongest in ___ type stars.

A. A
B. B
C. O
D. G
White dwarfs have _____ spectral lines than red giants.

A. Narrower
B. Stronger
C. Weaker
D. Wider
White dwarfs have ____ spectral lines than red giants.
A. Narrower
B. Stronger
C. Weaker
D. Wider
If two stars are stacked vertically on an H-R diagram then they necessarily differ in their:

A. Distance.
B. Luminosity class.
C. Spectral class.
D. Temperature.
If two stars are stacked vertically on an H-R diagram then they necessarily differ in their
A. Distance.
B. Luminosity class.
C. Spectral class.
D. Temperature.
**Spectral Class G**
- Dark Blue
- 28,000 - 50,000 K
- Ionized Atoms, especially helium
- Example: Mintaka (O1-3III)

**Spectral Class B**
- Blue
- 10,000 - 28,000 K
- Neutral helium, some hydrogen
- Alpha Eridani A (B3V-IV)

**Spectral Class A**
- Light Blue
- 7,500 - 10,000 K
- Strong hydrogen, some ionized metals
- Sirius A (A0-1V)

**Spectral Class F**
- White
- 6,000 - 7,500 K
- Hydrogen and ionized metals, calcium and iron
- Procyon A (F5V-IV)

**Spectral Class G**
- Yellow
- 5,000 - 6,000 K
- Ionized calcium, both neutral and ionized metals
- Example: Sol (G2V)

**Spectral Class K**
- Orange
- 3,500 - 5,000 K
- Neutral Metals
- Alpha Centauri B (K0-3V)

**Spectral Class M**
- Red
- 2,500 - 3,500 K
- Ionized atoms, especially helium
- Wolf 359 (M5-8V)

**Non-Main Sequence Types**
- Class W: Wolf-Rayet Star
  - Up to 70,000 K
  - Carbon, nitrogen, or oxygen
  - Gamma Velorum A (WC)
- Class L: Dwarf Star
  - 1,300 - 2,000 K
  - Metal hydrides and alkali metals
  - VW Hyi
- Class T: Methane Dwarf
  - 700 - 1,000 K
  - Methane
  - Epsilon Indi Ba
- Class Y: Ammonia Dwarf
  - <700 K
  - Ammonia
  - Not yet observed
- Class C: Carbon
- Class S: Zirconium Oxide
- Classes MS and SC
- Class D: Dwarf
<table>
<thead>
<tr>
<th>Spectral Type</th>
<th>Color</th>
<th>Temperature (K)*</th>
<th>Spectral Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td><img src="image" alt="Blue Circle" /></td>
<td>28,000-50,000</td>
<td>Ionized helium, especially helium</td>
</tr>
<tr>
<td>B</td>
<td><img src="image" alt="Blue Circle" /></td>
<td>10,000-28,000</td>
<td>Helium, some hydrogen</td>
</tr>
<tr>
<td>A</td>
<td><img src="image" alt="White Circle" /></td>
<td>7,500-10,000</td>
<td>Strong hydrogen, some ionized metals**</td>
</tr>
<tr>
<td>F</td>
<td><img src="image" alt="Yellow Circle" /></td>
<td>6,000-7,500</td>
<td>Hydrogen and ionized metals such as calcium and iron</td>
</tr>
<tr>
<td>G</td>
<td><img src="image" alt="Yellow Circle" /></td>
<td>5,000-6,000</td>
<td>Both metals and ionized metals, especially ionized calcium</td>
</tr>
<tr>
<td>K</td>
<td><img src="image" alt="Orange Circle" /></td>
<td>3,500-5,000</td>
<td>Metals</td>
</tr>
<tr>
<td>M</td>
<td><img src="image" alt="Red Circle" /></td>
<td>2,500-3,500</td>
<td>Strong titanium oxide and some calcium</td>
</tr>
</tbody>
</table>

* To convert approximately to Fahrenheit, multiply by 9/5.
** Astronomers regard elements heavier than helium as metals.
# Spectral Class Characteristics

<table>
<thead>
<tr>
<th>Spectral Class</th>
<th>Intrinsic Color</th>
<th>Surface Temperature (K)</th>
<th>Prominent Absorption Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Blue</td>
<td>41,000</td>
<td>He⁺, O³⁺, N⁻⁻, Si⁺⁺⁺, He, H</td>
</tr>
<tr>
<td>B</td>
<td>Blue</td>
<td>31,000</td>
<td>He, H, O⁺, C⁺⁺, N⁺⁺, Si⁺⁺</td>
</tr>
<tr>
<td>A</td>
<td>Blue-white</td>
<td>9,600</td>
<td>H stronest, Ca⁺⁺, Mg⁺⁺, Fe⁺⁺</td>
</tr>
<tr>
<td>F</td>
<td>White</td>
<td>7,240</td>
<td>H weaker, Ca⁺, ionized metals</td>
</tr>
<tr>
<td>G</td>
<td>Yellow-white</td>
<td>5,920</td>
<td>H weaker, Ca⁺⁺⁺, ionized &amp; neutral metal</td>
</tr>
<tr>
<td>K</td>
<td>Orange</td>
<td>5,300</td>
<td>Ca⁺⁺⁺ stronest, neutral metals strong, H weaker</td>
</tr>
<tr>
<td>M</td>
<td>Red</td>
<td>3,850</td>
<td>Strong neutral atoms, TiO</td>
</tr>
</tbody>
</table>
## Spectral classification

<table>
<thead>
<tr>
<th>Type</th>
<th>Absorption lines</th>
<th>Temperature</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>(H I, He I,) He II, N III , O III, Si IV</td>
<td>&gt; 30000</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>H I, He I, O II, Si III</td>
<td>&gt; 10000</td>
<td>Orion's Belt</td>
</tr>
<tr>
<td>A</td>
<td>H I, Mg II, Si II, (Fe II, Ti II, Ca II)</td>
<td>&gt; 7000</td>
<td>Sirius</td>
</tr>
<tr>
<td>F</td>
<td>H I, Ca II, Fe I, Ti I, Fe II, Ti II</td>
<td>&gt; 6000</td>
<td>Procyon</td>
</tr>
<tr>
<td>G</td>
<td>(H I,) Ca II, Fe I, Ti I, etc., CH</td>
<td>&gt; 5300</td>
<td>Sun</td>
</tr>
<tr>
<td>K</td>
<td>Ca II, Ca I, etc., TiO</td>
<td>&gt; 4000</td>
<td>Arcturus</td>
</tr>
<tr>
<td>M</td>
<td>Ca I, TiO, etc.</td>
<td>&gt; 2000</td>
<td>Betelgeuse</td>
</tr>
</tbody>
</table>
Stars are divided into 7 spectral classes.

O, B, A, F, G, K, M

Hottest

Coolest
<table>
<thead>
<tr>
<th>Spectral Class</th>
<th>Color</th>
<th>Surface Temp. K</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Blue</td>
<td>50,000</td>
<td>Zeta Orionis</td>
</tr>
<tr>
<td>B</td>
<td>Blue</td>
<td>30,000</td>
<td>Rigel</td>
</tr>
<tr>
<td>A</td>
<td>Blue-White</td>
<td>10,000</td>
<td>Sirius</td>
</tr>
<tr>
<td>F</td>
<td>White</td>
<td>7,000</td>
<td>Procyon</td>
</tr>
<tr>
<td>G</td>
<td>Yellow-White</td>
<td>6,000</td>
<td>Sun</td>
</tr>
<tr>
<td>K</td>
<td>Orange</td>
<td>5,000</td>
<td>Arcturus</td>
</tr>
<tr>
<td>M</td>
<td>Red</td>
<td>3,000</td>
<td>Betelgeuse</td>
</tr>
<tr>
<td>Spectral Type</td>
<td>Example(s)</td>
<td>Temperature Range</td>
<td>Key Absorption Line Features</td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>O</td>
<td>Stars of Orion's Belt</td>
<td>&gt;30,000</td>
<td>Lines of ionized helium, weak hydrogen lines</td>
</tr>
<tr>
<td>B</td>
<td>Rigel</td>
<td>30,000 K–10,000 K</td>
<td>Lines of neutral helium, moderate hydrogen lines</td>
</tr>
<tr>
<td>A</td>
<td>Sirius</td>
<td>10,000 K–7,500 K</td>
<td>Very strong hydrogen lines</td>
</tr>
<tr>
<td>F</td>
<td>Polaris</td>
<td>7,500 K–6,000 K</td>
<td>Moderate hydrogen lines, moderate lines of ionized calcium</td>
</tr>
<tr>
<td>G</td>
<td>Sun, Alpha Centauri A</td>
<td>6,000 K–5,000 K</td>
<td>Weak hydrogen lines, strong lines of ionized calcium</td>
</tr>
<tr>
<td>K</td>
<td>Arcturus</td>
<td>5,000 K–3,500 K</td>
<td>Lines of neutral and singly ionized metals, some molecules</td>
</tr>
<tr>
<td>M</td>
<td>Betelgeuse, Proxima Centauri</td>
<td>&lt;3,500 K</td>
<td>Molecular lines strong</td>
</tr>
</tbody>
</table>

* All stars above 6,000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.
\[ b = \frac{L}{4\pi d^2} \]

\( \begin{align*}
\text{\(b\) = apparent brightness in W/m}^2
\text{\(L\) = Luminosity in W}
\text{\(d\) = distance in meters}
\end{align*} \)
The Hertzsprung-Russell Diagram

- Rigal
- Deneb
- Regulus
- Altair
- Sun
- Sirius B
- Procycon B
- Betelgeuse
- Aldebaran
- Alpha Centauri B

Brightness vs. Increasing Surface Temperature

Blue or Blue White, White, Yellow, Red-Orange, Red
\[ L = \sigma T^4 \times 4\pi R^2 \]

- **Luminosity**—total energy radiated per second by the star
- **Energy emitted** per second by 1 square meter
- **Number of square meters in surface area of the star**

The surface area of a sphere of radius \( R \) is \( 4\pi R^2 \)

1 square meter emits \( \sigma T^4 \) watts
Scale drawing of measured triangle

\[ d = b \tan A \]

Distance to be found

Baseline (known)

Scale: 1 cm = 1 meter
Life cycle of a Star

- Nebula
- Star
- Red Giant
- Red Dwarf
- White Dwarf
- Supernova
- Neutron Star
- Black Hole

Above (Fig. 2): Diagram of the Life cycle of a Star. Retrieved 25th May 2014, from; NASA, forwarded by; Observatory, N. S. (n.d.).
Life Cycle of a Small/Medium Star and a Massive Star

1. nebula

2. protostar

3. red giant or supergiant
   - if it is a small or medium star
   - if it is a massive star

4. white dwarf
   - or
   - supernova

5. black dwarf
   - or
   - black hole
   - or
   - neutron star
The Lifecycle of Stars

- Sun-Like Stars (up to 1.5 times the mass of the Sun)
- Red Giant
- Planetary Nebula
- White Dwarf
- Black Dwarf

Stellar Nursery

- Giant Stars (over 3 times the mass of the Sun)
- Red Supergiant
- Supernova
- Black Hole

- Huge Stars (from 1.5 to 3 times the mass of the Sun)
- Red Supergiant
- Supernova
- Neutron Star

Stars form in a nebula, from collapsing clouds of interstellar gas and dust.
The Lifecycle of a Star

Stellar Nebula

- Massive star
- Red Supergiant

Stable stage

Dying Star

- Red Giant
- Planetary Nebula

Supernova

- White Dwarf
- Neutron Star
- Black hole

- Black Dwarf
Luminosity $\rightarrow L = 4\pi r^2 \sigma T^4$

Radius $\rightarrow$

Temperature $\rightarrow$

area of the star

Stefan-Boltzmann constant
Binary Star Orbit

- Orbit of higher mass star
- Focal point
- Center of mass
- Radius vector
- Focal point
- Orbit of lower mass star
Star distances are measured in units of the distance from the Sun to the Earth, the Astronomical Unit. The nearer the star, the larger is the angle (called the parallax) between the January and the July observations.

Measurements can be made any time of the year, but are usually separated by six months.
b: baseline

d: distance to object

α: measured parallax angle

\[ d = \frac{(1/2 \ b)}{\tan(\alpha/2)} \]
\[ \theta = 31 \text{ arcminutes} \]

\[ 1^\circ = 60 \text{ arcminutes} \]

\[ 1 \text{ arcminute} = 60 \text{ arcseconds} \]
November 19, 2012
Pleiadian Alignment

Pleione
Atlante
Alcyone
Merope
Asterope
Taigete
Maia
Celeno
Elettra

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Distance and Parallax

Motion of a “nearby” star against a background of “fixed” stars

\[ 1 \text{ AU} = 1.496 \times 10^{11} \text{ m} \]

\[ \pi \equiv \text{“parallax angle”} \]

Parsec = “Distance \( d \) for \( \pi = 1 \) second of arc”

= 1 a.u. / \sin(1^\circ) = 3.086 \times 10^{16} \text{ m} = 3.26 \text{ light years}

Until recently, this had been measured for less than 10,000 stars!