



BIOZONE

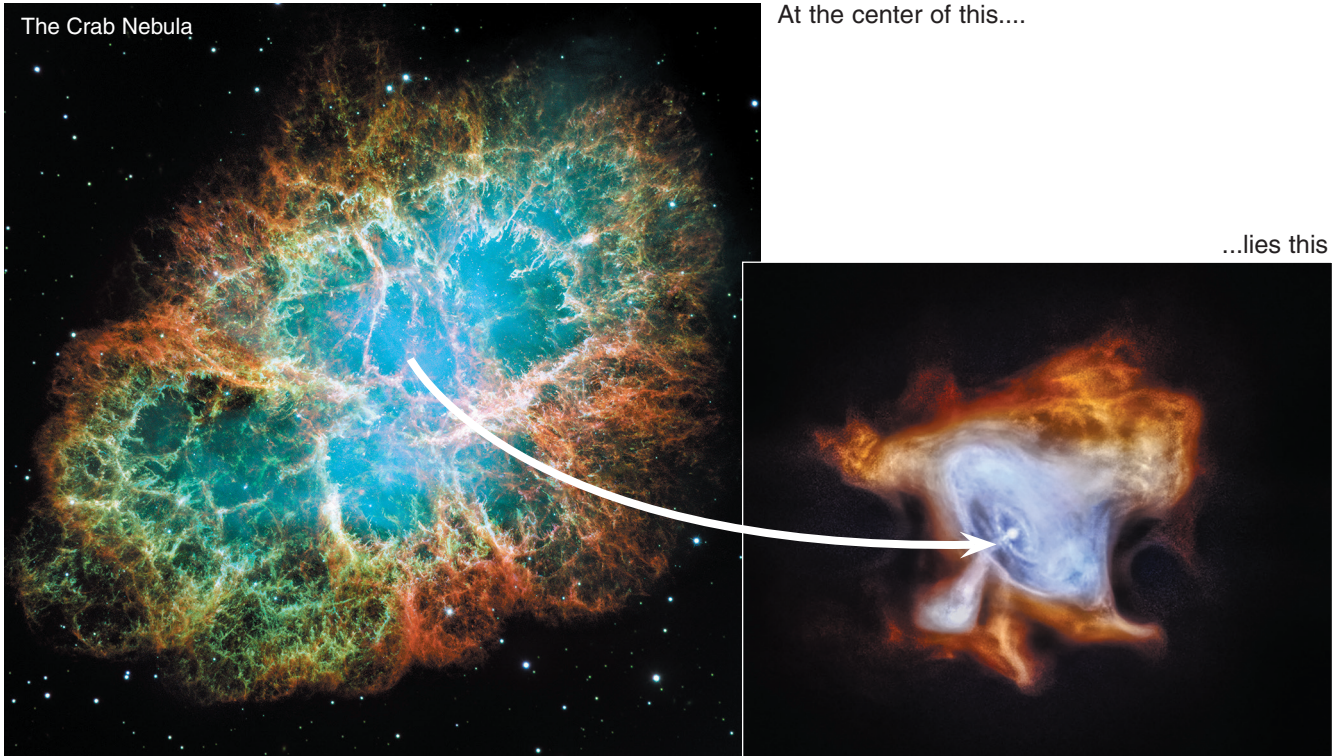
PHYSICS OF THE UNIVERSE

NGSS

INTEGRATING PHYSICS AND EARTH & SPACE SCIENCES

FREE SAMPLE
for classroom trial
This sample packet may be
photocopied and trialled
in the classroom.

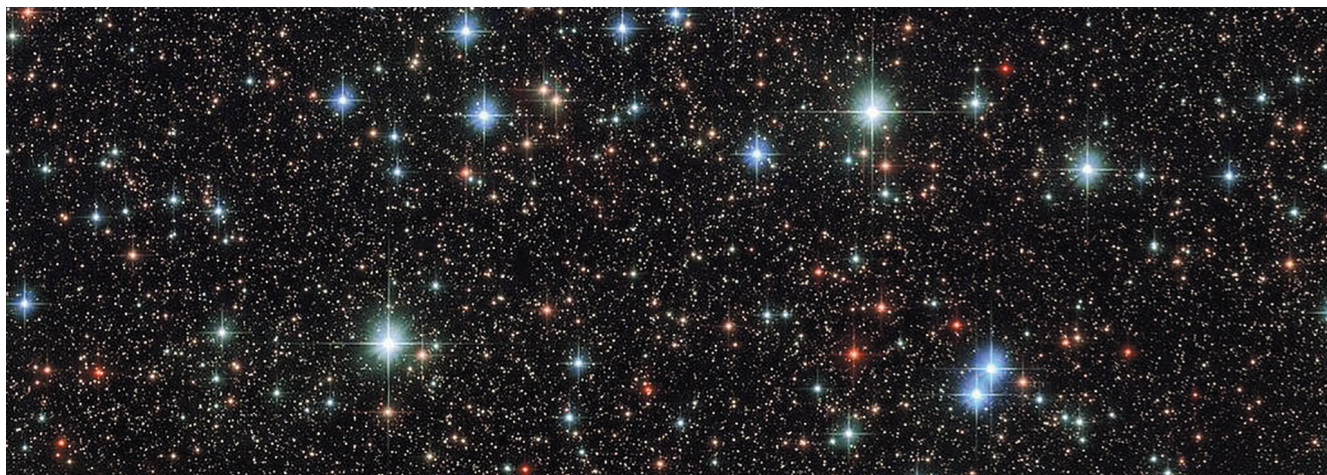
Anchoring phenomenon: The Crab Nebula contains more than can be seen with visible light



1. In 1054 Chinese astronomers observed a "guest star" in the sky. It remained visible for about two years. As a class, or in groups, discuss what might have caused this "guest star" to appear and produce the Crab Nebula as we see it today. Bullet your discussion points below:

2. The image on the right shows what is at the center of the Crab Nebula, but it can only be seen clearly when viewed in X-ray light. As a class, or in groups, discuss what you think the object at the center of the Crab Nebula is and what could have caused it. Why do you think it can only be seen clearly in X-ray light? Summarize your discussion points below:

[illegible]

ENGAGE: A colorful scene

The image above was taken by the Hubble Space Telescope in 2017. It is part of the constellation of Sagittarius (the Archer). The image shows stars of many different colors.

1. (a) When was the last time you went out at night and looked up at the stars (and spent time observing and thinking about their colors, positions, or distance)?

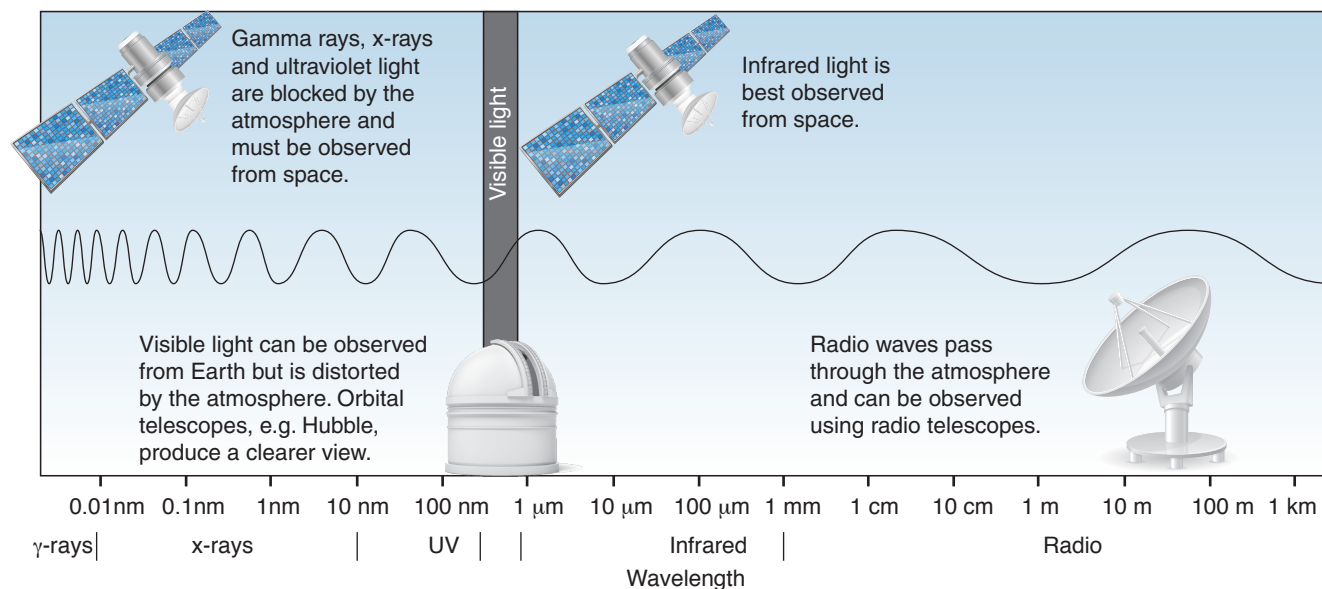
(b) Did you notice any differences in the stars you observed? What were they?

2. (a) What colors of stars can you see in the image?

(b) As a class discuss what the different colors may represent:

EXPLORE: Observing light from stars

The length of light waves range from nanometers to kilometers. Different wave types are affected in different ways by Earth's atmosphere. The range of frequencies of electromagnetic radiation and their respective wavelengths and photon energies is called the **electromagnetic spectrum** (below). To observe them all we need a range of equipment. In physics, electromagnetic radiation is often just called light, regardless of whether or not it is visible light.

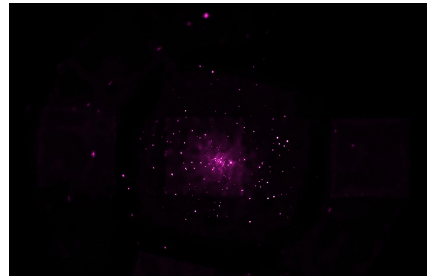




Optical telescopes allow us to see extremely faint objects in visible light. The image above shows the Andromeda Galaxy in visible light.



Infrared radiation passes through dust and gas particles allowing detection of otherwise hidden features. The image above shows the Andromeda Galaxy viewed with infrared light.



X-ray observation can help detect highly active but often invisible objects, e.g. black holes. The image above is the Andromeda Galaxy viewed in X-ray light.

All images NASA/JPL

3. Identify the observation methods for the following types of light waves:

(a) Visible light: _____

(b) Gamma rays and X-rays: _____

(c) Radio waves: _____

4. Why is observing objects in infrared a useful astronomy method? _____

5. Why do you think it is useful to observe a celestial object in more than one part of the electromagnetic spectrum? _____

EXPLORE: Magnitude and luminosity

- ▶ A star's apparent magnitude is how bright the star is to the naked eye. The scale is logarithmic: a magnitude 1 star is 2.5 times brighter than a magnitude 2 star. The absolute magnitude is the apparent magnitude of the star from a distance of 10 parsecs (32.6 light years). If the distance to the star is known, then the absolute magnitude can be calculated from apparent magnitude.
- ▶ Luminosity and absolute magnitude are related. The more luminous a star is, the smaller its absolute magnitude. In astronomy, luminosity is the total energy emitted over all wavelengths per unit of time (synonymous with watts (W)).
- ▶ The table below shows the apparent and absolute magnitudes, and the luminosity of several stars:

Star	Apparent magnitude	Absolute magnitude	Luminosity (Sun = 1)	Distance (light years)
Sun	-26.8	4.83	1	0
Aldebaran	0.75	-2.1	518	65
Betelgeuse	0.42	-2.9	150,000	640
Canis Majoris	7.9	-9.4	2.7 billion	3900
Vega	0.03	0.58	50	25

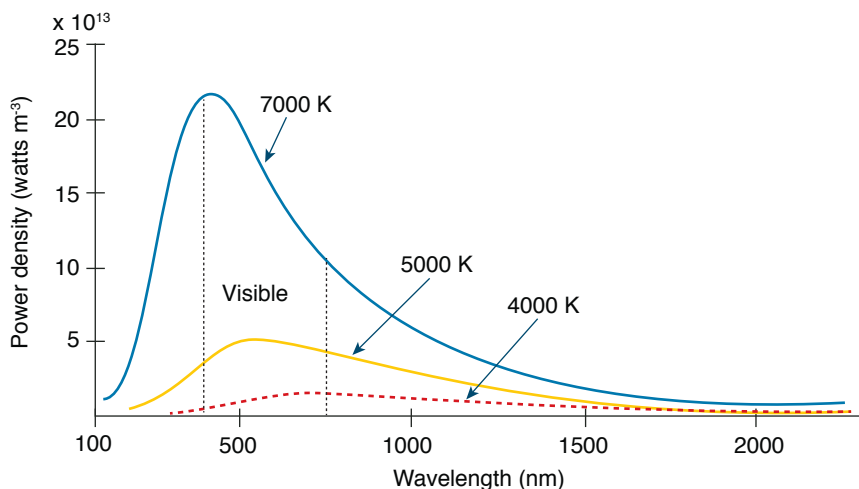
6. What is the apparent magnitude of the Sun? _____

7. The star Sirius has an apparent magnitude of -1.46 and an absolute magnitude of 1.4. What is meant by apparent magnitude and absolute magnitude?

EXPLORE: Star color and temperature

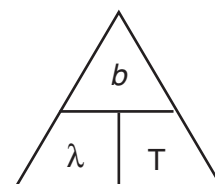
- ▶ Temperature can be inferred, in part, from color. For example a piece of iron heated in a hot flame will initially glow red, then orange-yellow as it gets hotter and finally may reach white hot.
- ▶ The temperature of stars can be determined from their color in a similar way (below). Remember short wavelengths produce blue colors, whereas long wavelengths produce redder colors.

Peak power at different wave lengths



By measuring the wavelength at a star's peak power density, the star's temperature can be determined using the Wien Displacement Law.

$$\text{Wavelength } \lambda_{\text{max}} (\text{m}) = \frac{b}{T}$$



Where b has a value of 2.898×10^{-3} and T is in degrees Kelvin (K)

8. The image on the right shows a sparkler as it is burning.

(a) Identify and label the three bright distinct colors that can be seen on the shaft of the burning sparkler:

(b) List the colors from hottest to coolest:

9. Returning to the image at the start of this activity, list the circled stars in order of their temperature from hottest to coldest:

10. (a) What color would a star emitting its peak energy at a wavelength of 300 nm appear?

(b) Why? _____



11. Use the Wien Displacement Law to determine the temperature of the following stars

Star	Wavelength (nm) at peak power density	Wavelength (m) at peak power density	Visible color	Temperature
Antares	934			
Vega	311			
Regulus	223			
OTS-44 brown dwarf	1260			
Sun	502			

EXPLORE: Patterns in the stars

12. The luminosity and temperature of stars can be plotted against each other. The data below is for a range of stars in the Milky Way galaxy. Plot the data in the tables on to the grid below. Note that the x axis is a logarithmic scale:

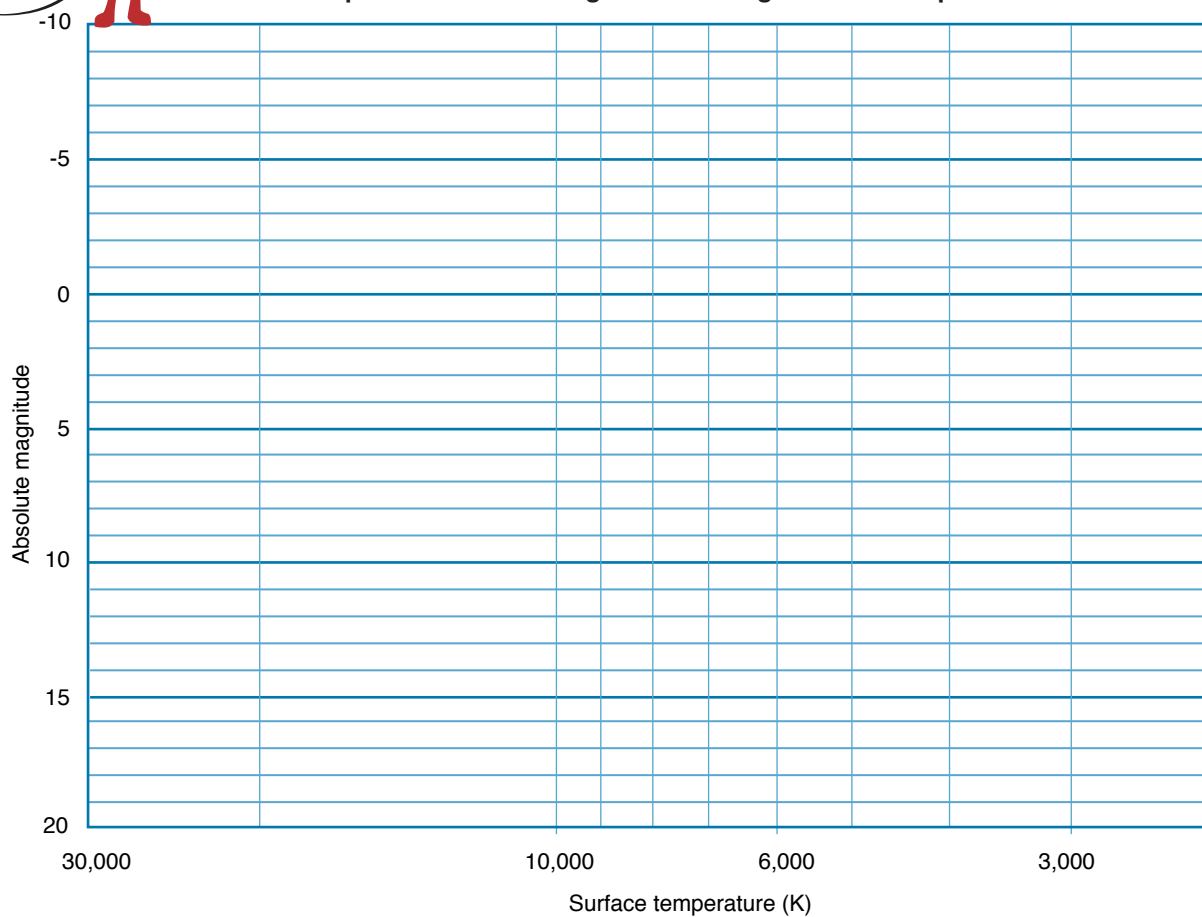
Star	Temperature (K)	Absolute magnitude
Sun	5840	4.8
61 Cygni	4130	7.6
Achernar	20,500	-2.4
Alpha Centauri	5840	4.5
Altair	8060	2.2
Arcturus	4590	-0.4
Barnard's Star	2800	13.2
Betelgeuse	3200	-5.7
Capella	5150	-0.6
Deneb	9340	-7.2

Star	Temperature (K)	Absolute magnitude
Epsilon Eridani	4590	6.1
Luyten 726-B	2670	16
Procyon A	6600	2.6
Procyon B	9700	13
Rigel	12,140	-7.2
Ross 128	2800	13.5
Alpha Crucis	28,000	-4.0
Sirius A	9620	1.4
Sirius B	14,800	11.2
Vega	9900	0.5

NEED HELP?
See Activity 76



Scatter plot of stars showing absolute magnitude vs temperature



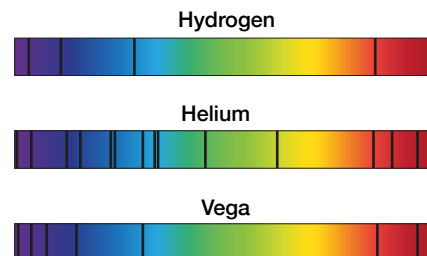
13. (a) Where are most of the stars found on the graph you have plotted? _____

(b) What do you notice about the outliers (data points well outside the main spread)? _____

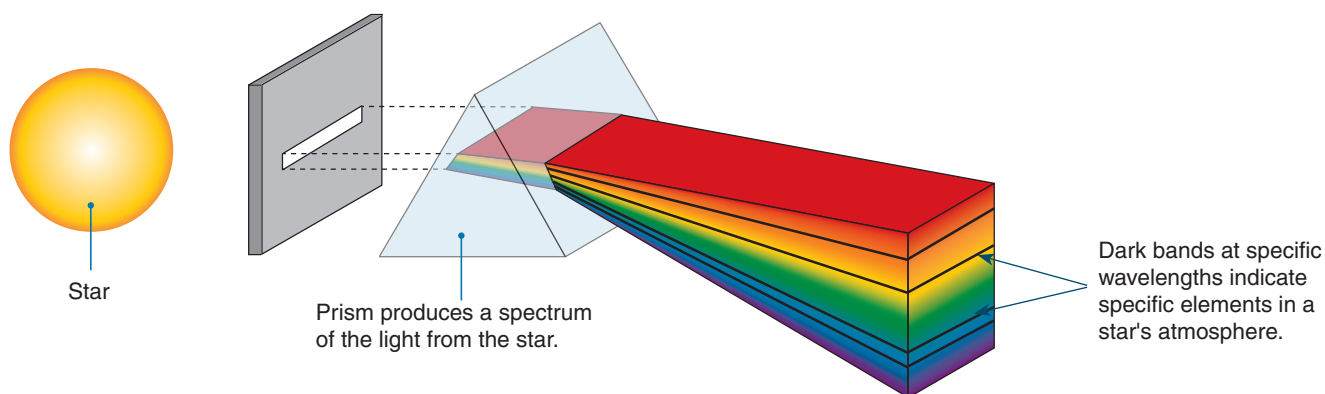
(c) Predict the color of Achernar: _____

EXPLAIN: How do we know what a star is made of?

- ▶ The composition of a star can be determined by its absorption spectrum.
- ▶ When white light from the interior of the star passes through its atmosphere, gaseous elements there absorb certain wavelengths, leaving dark bands in the electromagnetic spectrum that is finally emitted from the star. These dark lines can be compared to known element absorption lines.
- ▶ When reaching the Earth, the light can be passed through a prism to split it up into the spectrum of colors (ROYGBIV). Within this spectrum, black lines will indicate the "missing" wavelengths of light, i.e. those absorbed by elements in the star being observed.



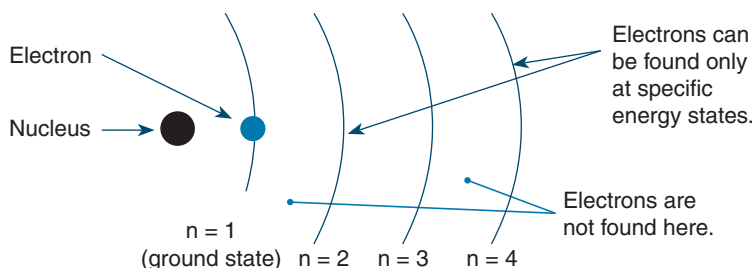
The absorption spectra of hydrogen and helium and the star Vega. Vega shows hydrogen absorption lines and weaker helium lines.



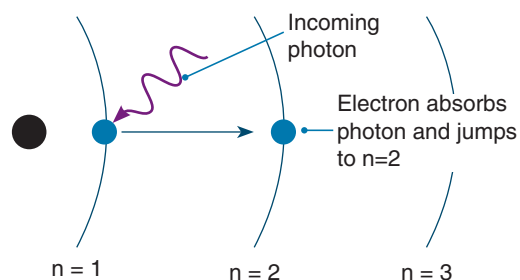
Absorption by atoms

The lines in a star's light spectrum are at specific wavelengths. These wavelengths correspond to the energy absorbed and re-emitted by electrons orbiting atoms in a star's atmosphere.

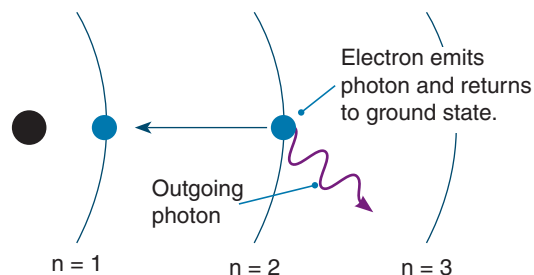
Every atom has shells or energy states around it where electrons can be found. These are given the notation n . $n = 1$ is the lowest energy state. Different elements have different numbers of electrons and this affects how photons of light interact with them, producing specific absorption spectra for each element (or ion).



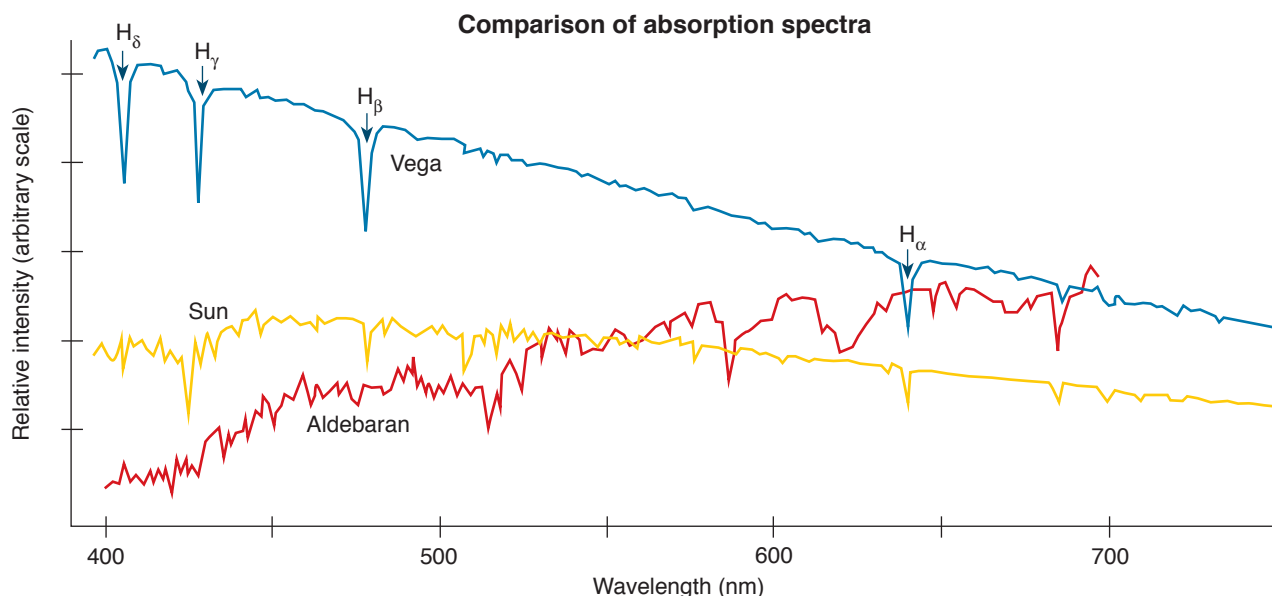
A hydrogen atom has one electron. Ordinarily it orbits the nucleus at an energy state of $n = 1$ (the ground state). If a photon of light with the right wavelength hits it, the electron will jump to the next level $n = 2$ (an excited state). The wavelength of the photon needed to do this is 121.4 nanometers. A photon with a wavelength of 103 nm will make the electron jump from $n = 1$ to $n = 3$.



As the electron returns to the ground state from $n = 2$, it emits a photon equal to what it absorbed (121.4 nm). The photon can be emitted in any direction and it is highly unlikely to be emitted in the same direction it was moving before being absorbed. For this reason we see a dark line in the light spectrum reaching us from the star as light from those wavelengths has been absorbed and emitted in a different direction to us.

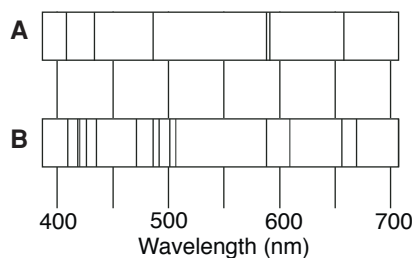
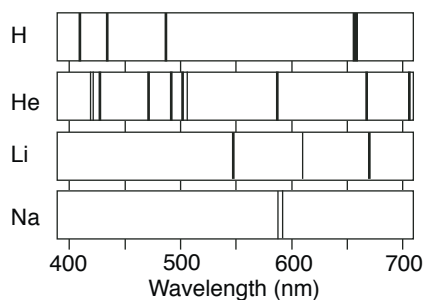


- ▶ The graph below shows the absorption curves for the star Vega, the Sun, and the star Aldebaran. Vega is a blue-white star with a surface temperature of about 9600 K, the Sun is a yellow star with a surface temperature of about 6000 K, and Aldebaran is an orange giant with a surface temperature of about 3900 K.
- ▶ The large dips indicated in the spectrum indicate hydrogen in the star's atmosphere, following the Balmer series of hydrogen lines (these are the hydrogen lines within the visible spectrum). The dip at 410 nm (H_δ) indicates an electron jumping from $n = 2$ to $n = 6$. Although the Sun also has large amounts of hydrogen, the dips are not as prominent. These differences are due to the stars being different in temperature and luminosity. Photons flowing from the Sun generally do not have enough energy to knock electrons in hydrogen up to higher energy states.



14. Explain briefly how the composition of a star can be determined: _____

15. The diagram below left shows the absorption spectra of four different elements. Use them to identify the elements present in the two hypothetical stars A and B, below right:



(a) A: _____

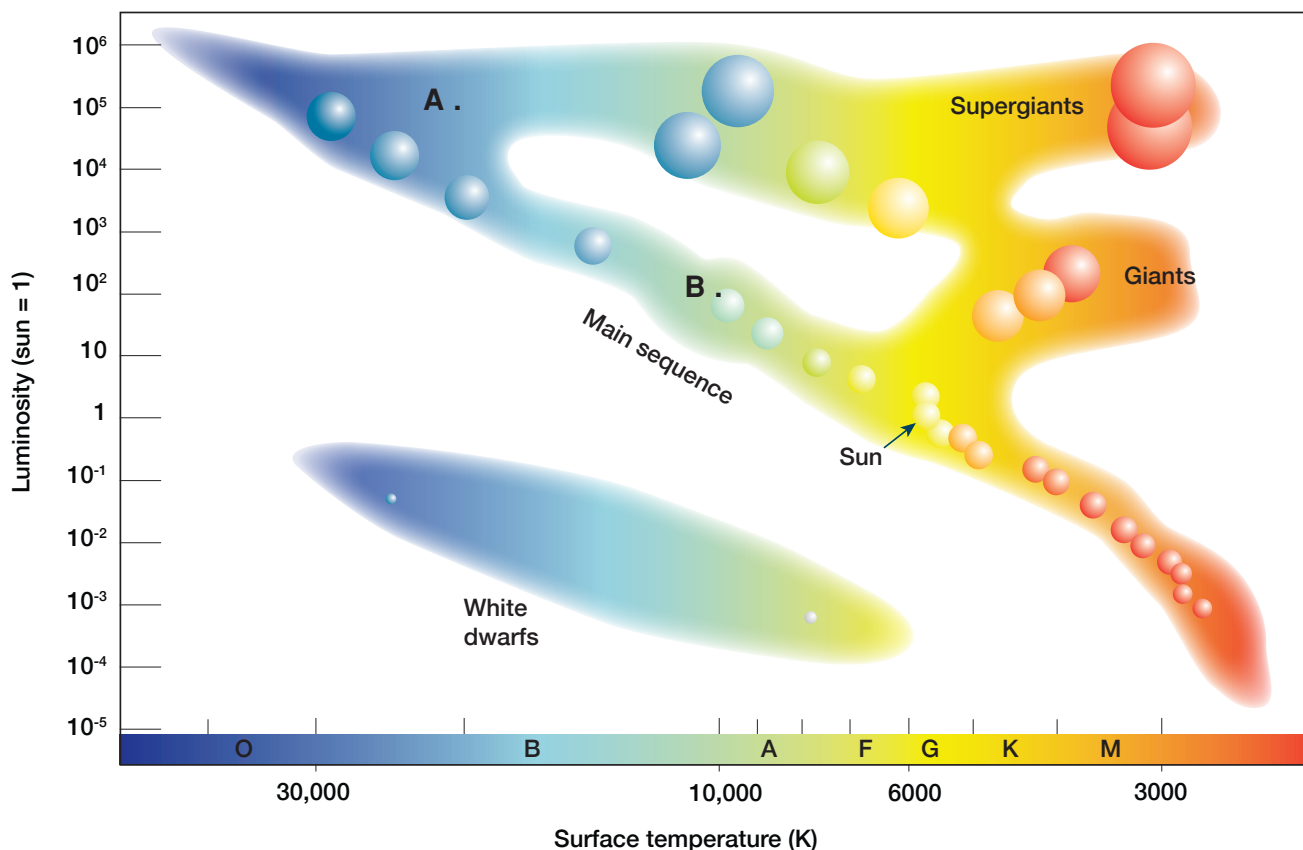
(b) B: _____

16. All stars are made up mostly of hydrogen and helium, with small amounts of heavier elements. Explain why the absorption spectra of very hot blue stars do not generally show hydrogen lines in the visible spectrum, whereas blue-white stars such as Vega show prominent hydrogen lines, and yellow stars like the Sun show only small hydrogen lines.

EXPLAIN: Patterns in the stars II

- Previously you made a scatter plot of the relationship between the absolute magnitude of stars and their temperature. The diagram below shows a complete diagram, called the Hertzsprung-Russell diagram.
- The position of a star on the graph tells us about that star's present stage in its life cycle. For most of their life, stars are found in the main sequence and are called main sequence stars. White dwarfs are found near the bottom left, while giant stars are found in the top right. As a star progresses through its life cycle, it will move off the main sequence. A star like the Sun will move to the upper right (red giants) before moving down to the lower left to become a white dwarf.

Hertzsprung-Russell diagram



17. Use the Hertzsprung-Russell diagram to determine the following:

- The surface temperature of the Sun: _____
- The temperature and luminosity of the star at the point labeled A: _____
- The temperature and luminosity of the star at the point labeled B: _____

18. Describe the position of the Sun on the diagram as it changes into a red giant and then to a white dwarf:

19. Why are most stars found in the main sequence part of the diagram? _____

20. Stars are classified based on their temperature and emission spectra as O, B, A, F, G, K, or M. Describe what you expect the hydrogen and helium emission spectra to look like for the following stars:

- An O class star: _____
- A F class star: _____



BIOZONE Corporation

18801 E. Mainstreet, Suite 240, Parker, CO, 80134-3445, UNITED STATES

PHONE 855-246-4555

FAX 855-935-3555

EMAIL sales@biozone.com

www.BIOZONE.com/us