BIOZONE

PHYSICS OF THE UNIVERSE

NGSS

INTEGRATING PHYSICS AND EARTH & SPACE SCIENCES

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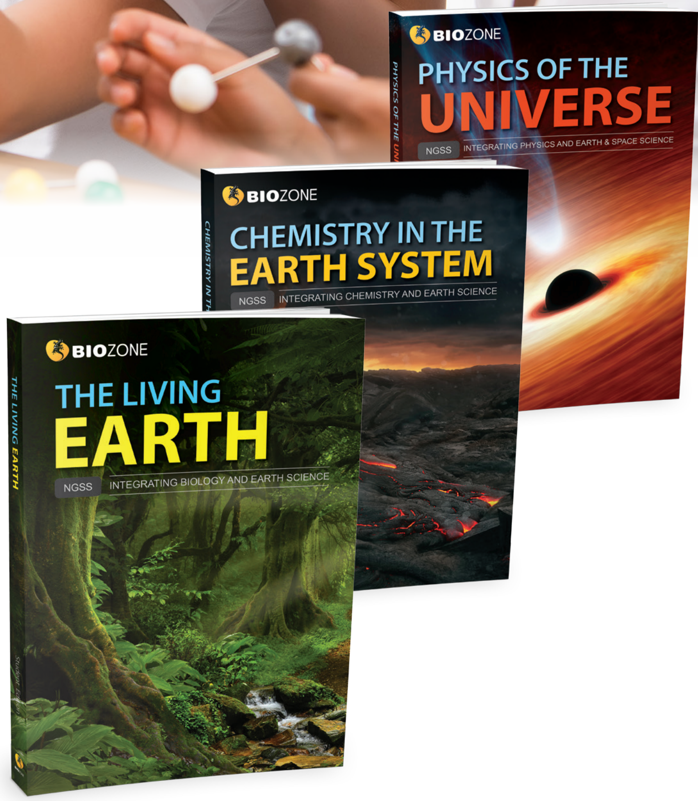
FOR CLASSROOM TRIAL



BIOZONE's new integrated titles for the **Next Generation Science Standards** for **California Public Schools (CA NGSS)** have been designed and written following the High School Three-Course Model.

Each of these phenomena-based titles integrates a three-dimensional approach to provide an engaging, relevant, and rigorous program of instruction.

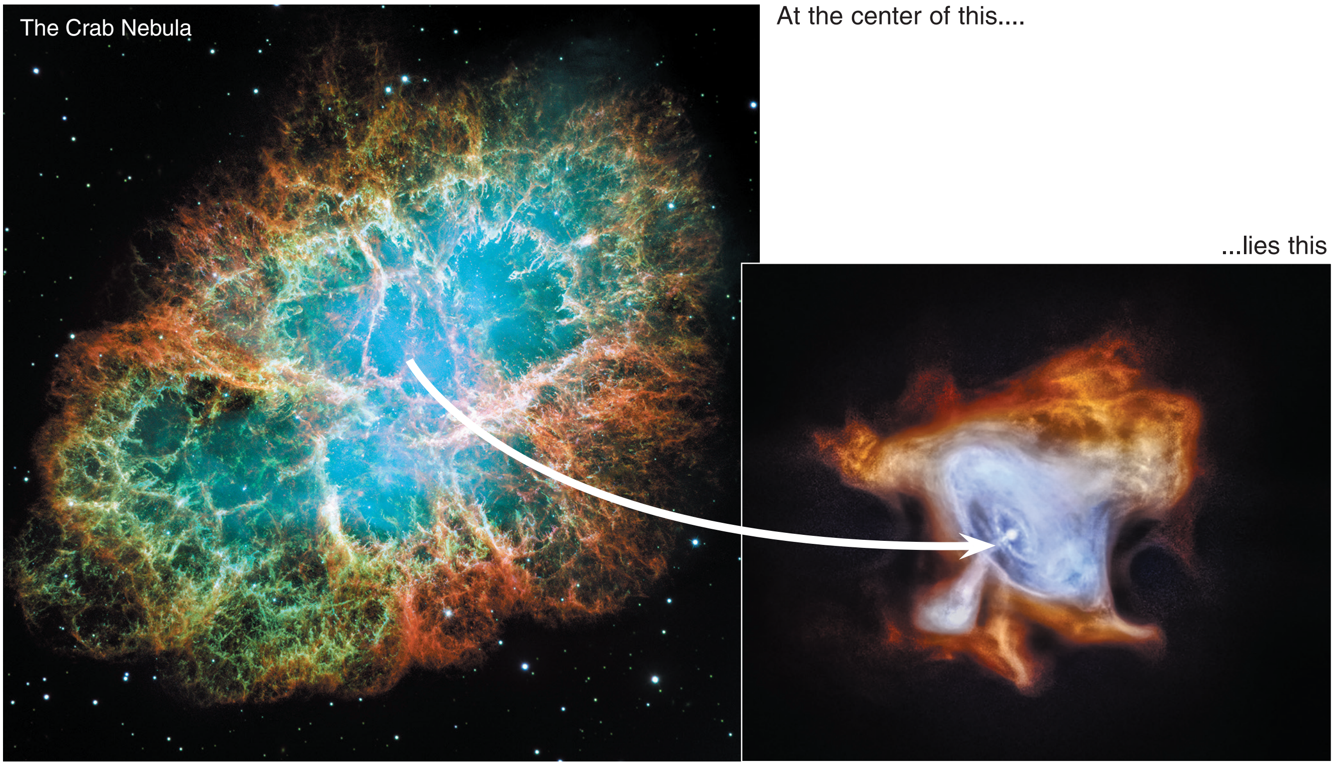
Departing from the more traditional approach of **BIOZONE's** Non-Integrated Series, the Integrated Series offers a learning experience anchored in student-relevant phenomena and problems.

FEATURES AND BENEFITS

- ✓ A **phenomena-based approach** employing the **5E instructional cycle**, aligning with how students learn science.
- ✓ Set **Instructional Segments** provide the book structure, enabling seamless navigation through the program.
- ✓ Full integration of the three dimensions of the **CA NGSS** enables students to deepen understanding of **Disciplinary Core Ideas** through their use of **Science and Engineering Practices** and application of **Crosscutting Concepts**.
- ✓ Activities provide multiple opportunities for students to use first-hand experience to explain phenomena and develop engineering solutions to solve relevant problems.
- ✓ Formative and summative assessments address all three dimensions.
- ✓ Proficiency in mathematics and computational thinking is strongly supported.
- ✓ The **California Environmental Principles and Concepts** are incorporated throughout.
- ✓ Understandings about the **Nature of Science** are supported through the **Science and Engineering Practices** and **Crosscutting Concepts**.
- ✓ Online learning supported through **BIOZONE's** resource hub, featuring videos, spreadsheet models, weblinks, and 3D models. Online courses also available through **BIOZONE Academy.**

IS6 Hidden in Plain Sight

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



The Crab Nebula was named by William Parsons in 1840 CE, but its origin was seen by Chinese astronomers in 1054 CE. The image above left is a mosaic created from images taken by the Hubble Space Telescope. The image above right was produced in 2014 by the Chandra X-ray observatory.

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:

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70 Star Light, Star Bright

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? ___

   ___

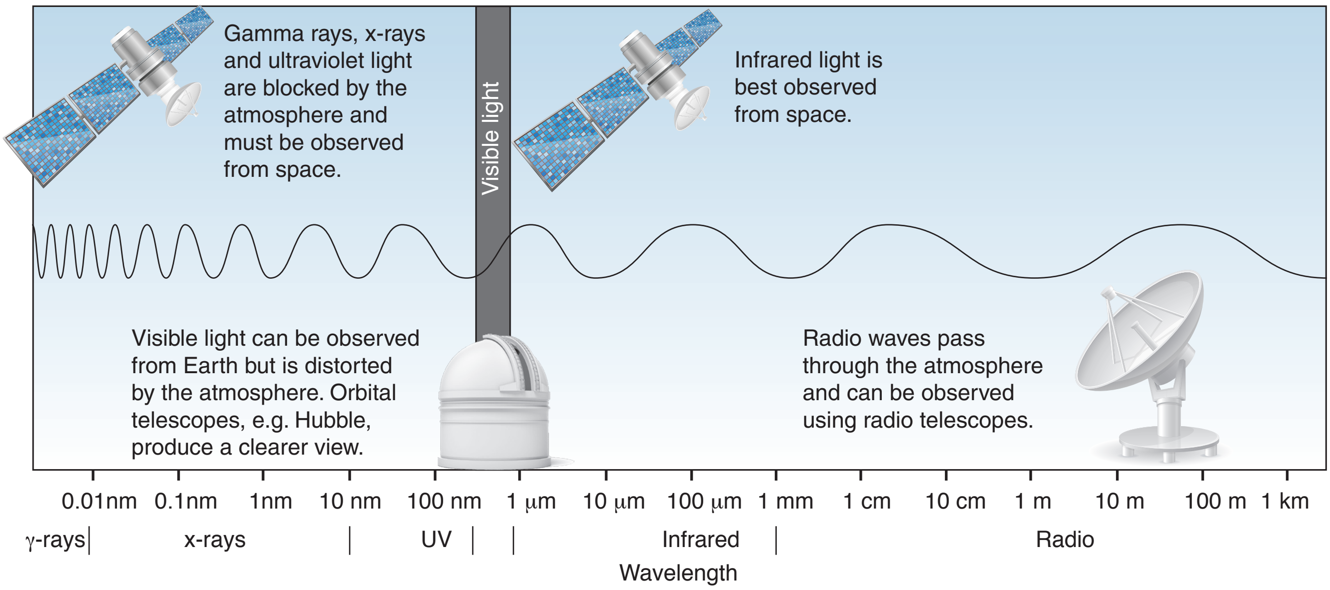
   (b) As a class discuss what the different colors may represent: ___

   ___

   ___

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.



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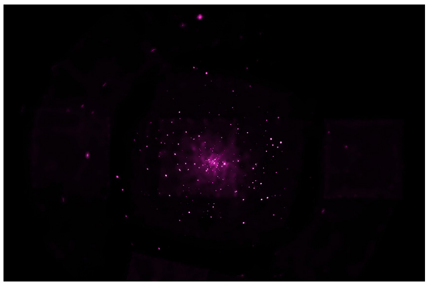
Optical telescopes allow us to see extremely faint objects in visible light. The image above shows the Andromeda Galaxy in visible light.

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.



All images NASA/JPL

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.

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 so 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?

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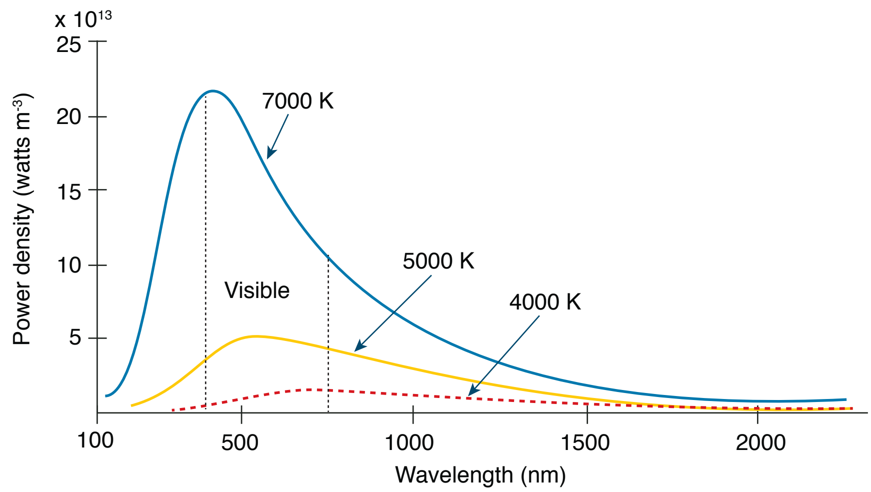
EXPLORE: Star color and temperature

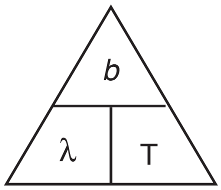
- Temperature can be inferred, in part, from color. For example a piece of iron heated in a hot flame will initially glow red, then orange-yellow as it gets hotter and finally may reach white hot.
- The temperature of stars can be determined from their color in a similar way (below). Remember short wavelengths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

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

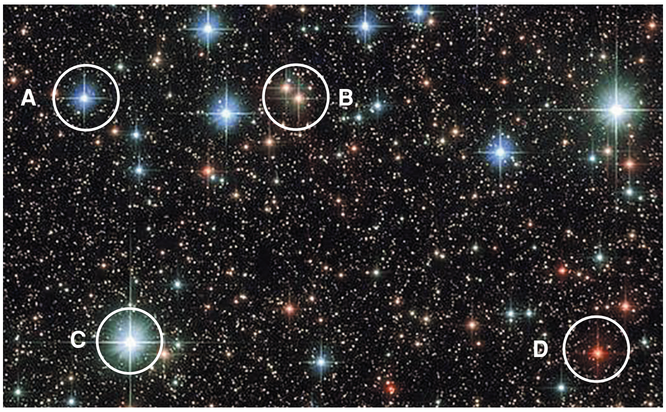


Where *b* has a value of 2.898 x 10^{-3} and T is in degrees Kelvin (K)

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			

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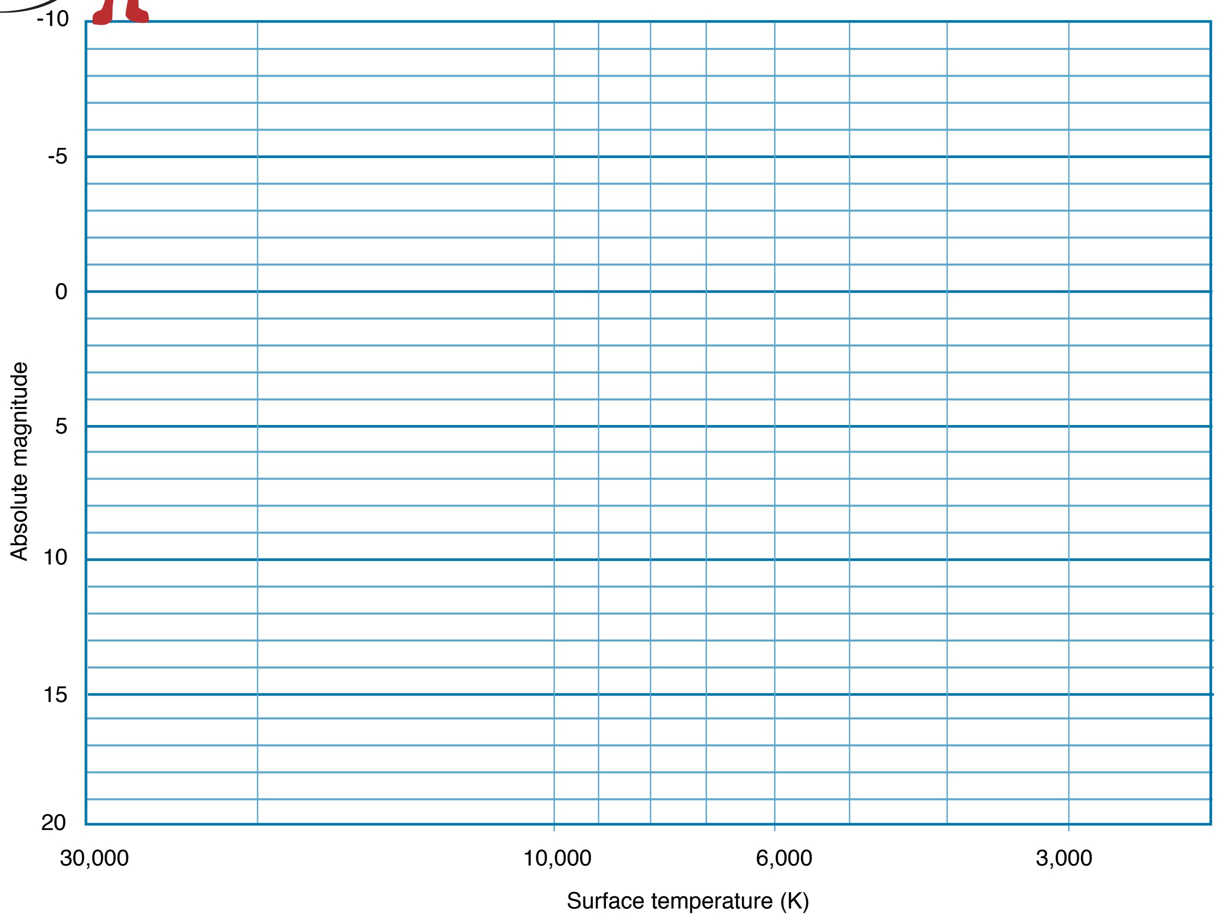
EXPLORE: Patterns in the stars

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

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: ______________________________

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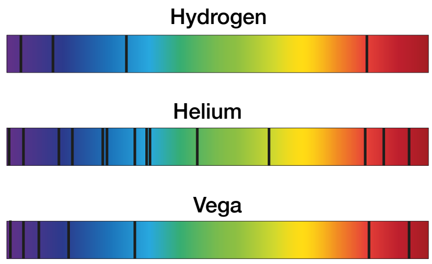
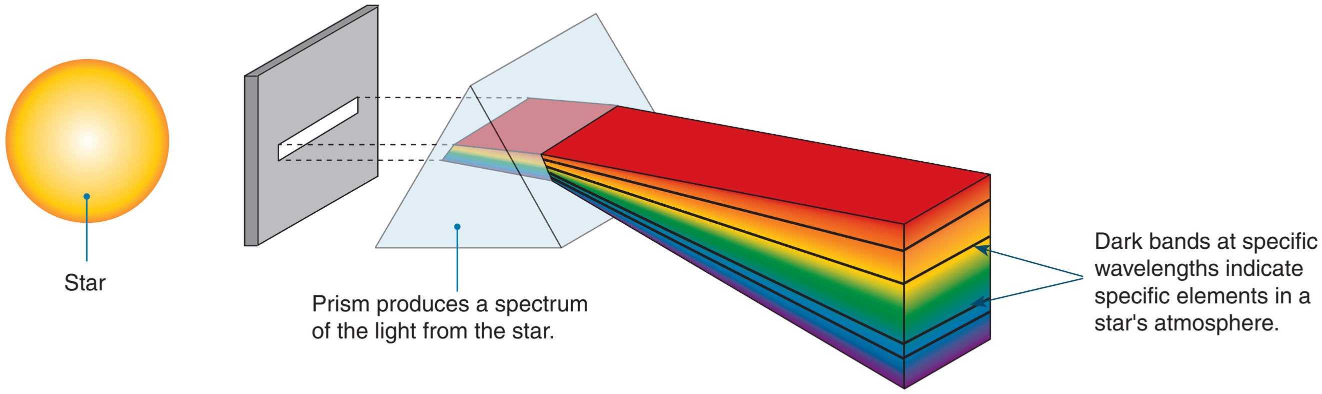
EXPLAIN: How do we know what a star is made of?

- 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.



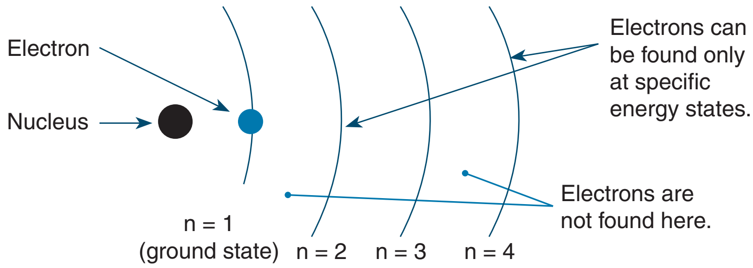
The absorption spectra of hydrogen and helium and the star Vega. Vega shows hydrogen absorption lines and weaker helium lines.



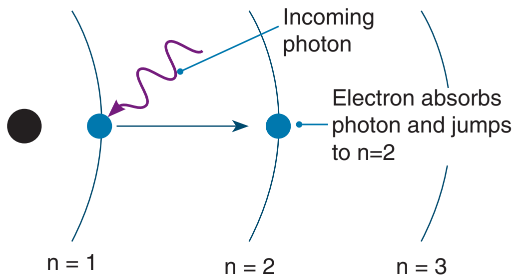
Absorption by atoms

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.

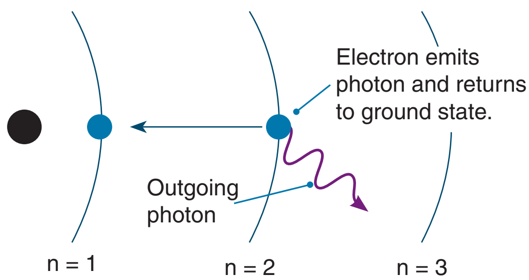
Every atom has shells or energy states around it where electrons can be found. These are given the notation **n**. n = 1 is the lowest energy state. Different elements have different numbers of electrons and this affects how photons of light interact with them, producing specific absorption spectra for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



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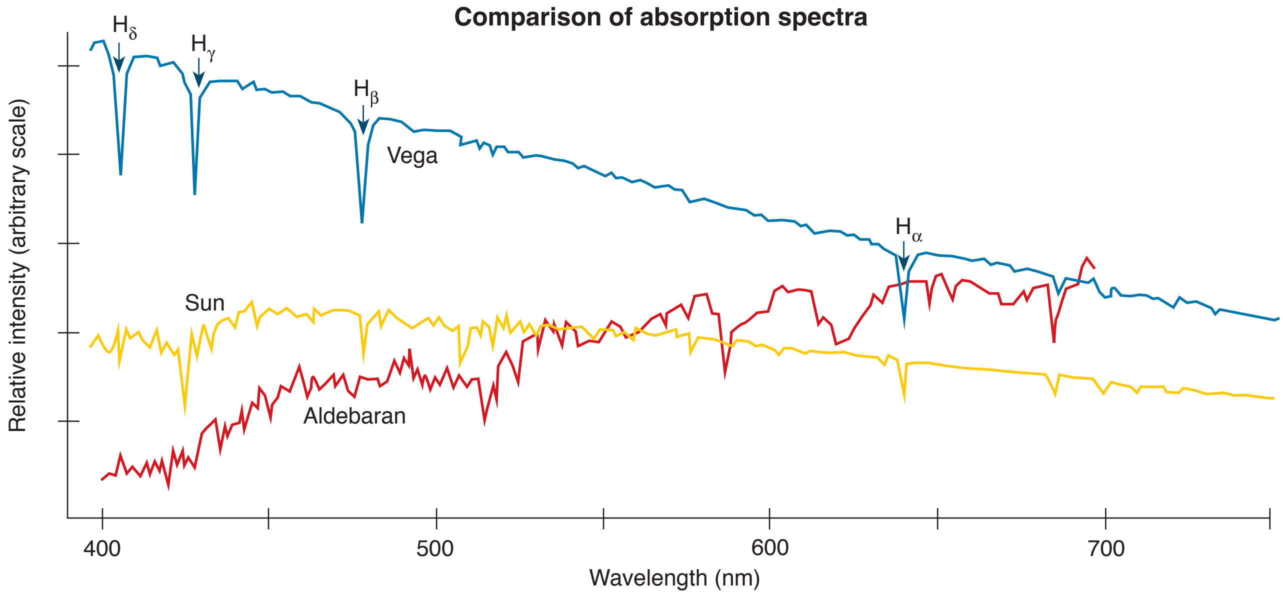
- The graph below shows the absorption curves for the star Vega, the Sun, and the star Aldebaran. Vega is a blue-white star with a surface temperature of about 9600 K, the Sun is a yellow star with a surface temperature of about 6000 K, and Aldebaran is a orange giant with a surface temperature of about 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.



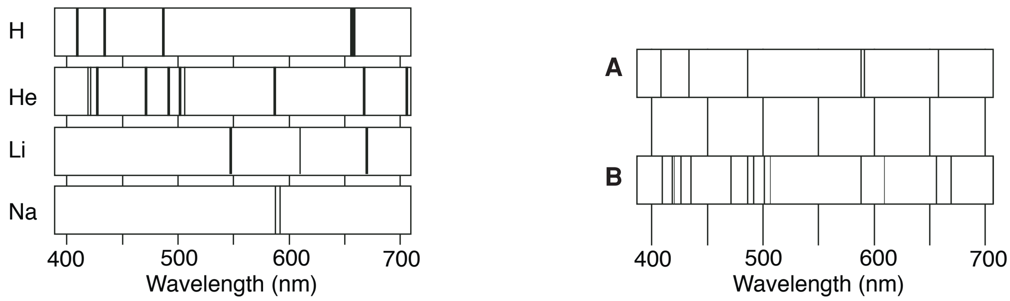
14. Explain briefly how the composition of a star can be determined: ______

______

______

______

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.

______

______

______

______

______

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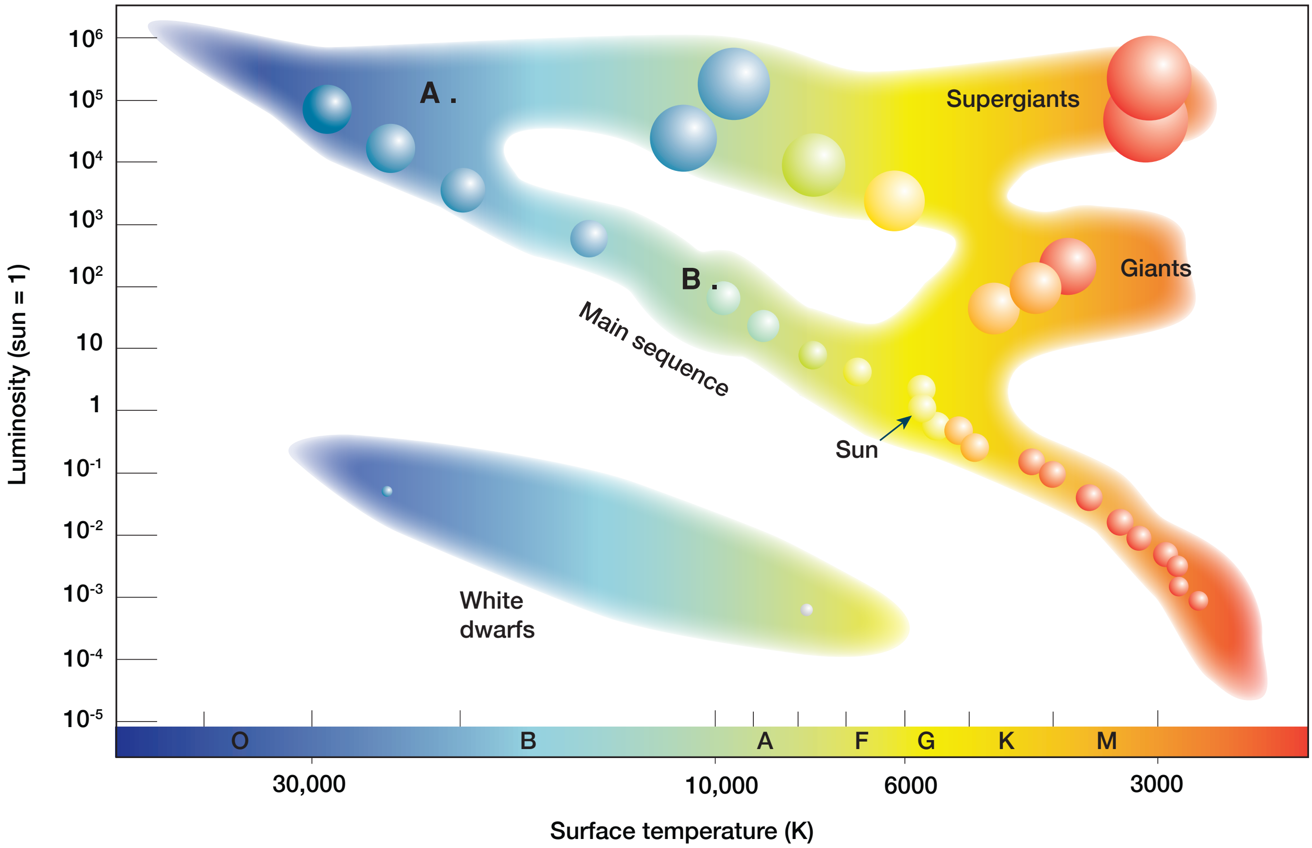
EXPLAIN: Patterns in the stars II

- 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:

(a) The surface temperature of the Sun: ____________________

(b) The temperature and luminosity of the star at the point labeled A: ____________________

(c) 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 would you expect the hydrogen and helium emission spectra to look like for the following stars:

(a) An O class star: ____________________

(b) A F class star: ____________________

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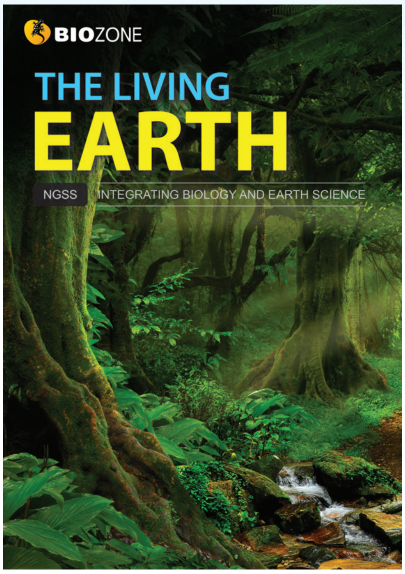

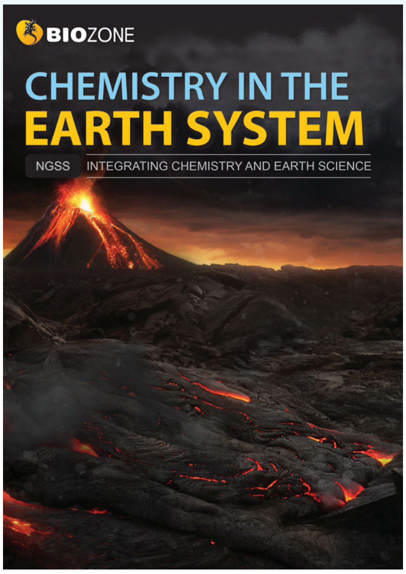

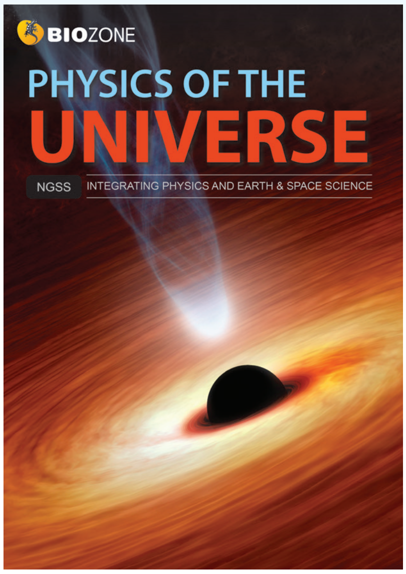

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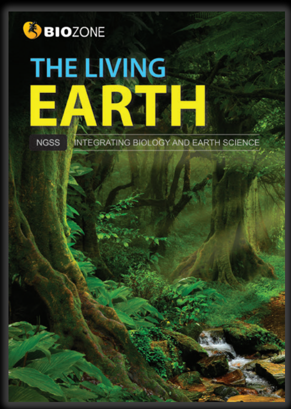

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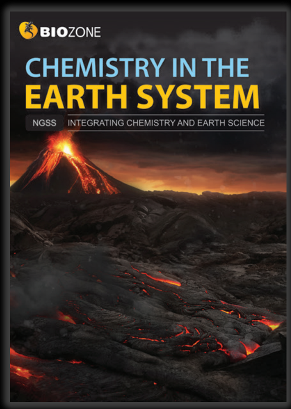

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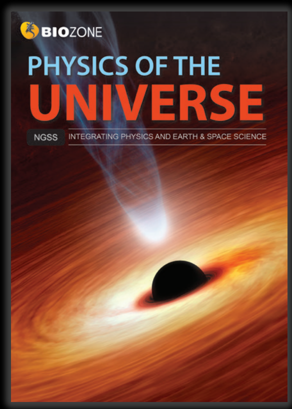

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