Chapter 9: The Life of a Star

Summary

Through spectroscopy, the analysis of starlight, we can determine the chemical composition and temperatures of stars and then classify them by spectral type. If the absolute magnitude is also known, stars can be plotted on a graph of spectral type versus absolute magnitude known as the Hertzsprung-Russell (H-R) diagram. The H-R diagram represents the evolutionary stages of stars, providing us with information on the current status of the thermonuclear fusion process in the stellar core.

Terminology

black body	electron degeneracy pressure	pulsars
black body radiation	H–R diagram	radiative zone
black holes	luminosity	red dwarf
brown dwarf	main sequence	singularity
convective zone	neutron degeneracy pressure	spectrophotometer
distance modulus	neutron star	spectroscopy
effective temperature	photosphere	Stefan-Boltzman's Law
	Planck's Law	Wien's Law

Common Misconceptions

1. *Each star's chemical composition varies greatly from that of other stars.*
2. *All stars eventually become black holes.*

SUGGESTIONS FOR THE POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 9.1: The Continuous Spectrum

For this activity you need to project a spectrum onto a piece of paper attached to a wall or board. Cut out a piece of sturdy cardboard the size of a 35mm slide that will fit into a slide projector. Cut a slit into the middle of the cardboard with a razor blade, approximately one inch long and 1/8th inch wide. Insert the cardboard into the slide projector so that the slit is vertically oriented. Tape a diffraction grating to the lens of the projector. The room has to be extremely dark. Turn the projector on and a continuous spectrum will appear on the paper or board.

Poster Page: "The Most Original Thinker of All..." (Antonia Maury)

There are many uses for spectral analysis besides determining the composition and temperature of stars. Students tend to think that something like spectroscopy is not really relevant to them because they are never introduced to these other uses.

Why did Hertzsprung publish his results in a popular photography magazine? Did he lack credibility in the professional scientific community because of his amateur status? Would he have known how to approach a more technical journal to publish his article? Would they have published the article of an amateur? History is full of examples of people whose work was unknown or unacknowledged for years. Sometimes others took credit for these people's work. Would this same problem exist today? Is it still possible for important results to go unrecognized? How would you go about communicating a new scientific relationship or development?

Core Activity 9.2: Plotting an H-R Diagram

If you are interested in having students study stellar spectra, you should consider the CLEA software. One CLEA program addresses stellar spectra. This astronomy software is free, and includes student manuals and activities. The original software is made for PCs; however, most programs are now available in Macintosh format. It can be downloaded from the internet or sent to you by mail. The address is included in the Resource List.

RESOURCE

A completed plot of this activity is included. Students should realize that neither plot will give an accurate picture of the average distribution of stellar types. However, the plot of both some of the brightest and some of the closest stars should have the same type of distribution that would be observed from any spot in the galaxy, since there is no preferred viewpoint. We would see approximately the same spectral types in the same amounts from any other planet within the disc of the galaxy. (See completed plot on opposite page.)

Before the students plot the variable stars in the next activity, have them discuss where they think these stars might be located on the H-R diagram.

Core Activity 9.3a and 9.3b: Variable Stars and the H-R Diagram

Variable stars are also on the H-R plot. The students should realize that they will have to plot two points for each star, one for maximum and one for minimum. Since these stars vary between these two points, a bar should connect the points. Variables are also classified according to spectral types, although the same star might range from one spectral class to another. Variable stars can occupy different places on the H-R diagram: some are main sequence stars, and others belong to the giant branch. A few range outside of a particular band. The students should label the variable star plot lines with the type of variable (see completed plot on following page).

We have included two different versions of this activity. In Core Activity 9. 3a, the absolute magnitudes and distances in parsecs have been calculated, so the students plot only the information. The second version, 9.3b, contains the parallax measurements, which have to be converted to parsecs by taking the reciprocal of the parallax. Also, the absolute magnitudes are not given, only the apparent magnitudes. The apparent magnitudes can be converted to absolute magnitudes by having the students use the distance modulus.

EXAMPLE. Use the distance modulus equation to calculate the absolute magnitude for delta Cep.

Since delta Cep is a variable star, the absolute magnitude at maximum will be brighter than the absolute magnitude at minimum. We will calculate both maximum and minimum values to find the range of absolute magnitude for delta Cep.

From Table 9.3b, for delta Cep, m = 3.5 – 4.4 and π = 0.00332"

Distance Modulus equation: $M = m - 5 \log_{10} (r/10)$

A. Calculate the absolute magnitude of delta Cep at maximum:
    1. Find r from the parallax: $r = 1/\pi = 1/0.00332 = 301.2048$
    2. $M = +3.5 - 5 \log_{10} (301.2048/10)$
    3. $M = +3.5 - 5 \log_{10} (30.1205)$
    4. $M = +3.5 - 5 (+1.4789)$
    5. $M = +3.5 - (+7.3945)$
    6. $M = +3.5 - 7.3945$
    7. $M = -3.89$
    8. M rounds off to –3.9 for delta Cep at maximum
B. Calculate the absolute magnitude of delta Cep at minimum:
    1. Find r from the parallax: $r = 1/\pi = 1/0.00332 = 301.2048$
    2. M = +4.4 – 5 log10 (301.2048/10)
    3. M = +4.4 – 5 log10 (30.1205)
    4. $M = +4.4 - 5 (+1.4789)$
    5. $M = +4.4 - (+7.3945)$
    6. $M = +4.4 - 7.3945$
    7. $M = -2.99$
    8. M rounds off to –3.0 for delta Cep at minimum

Thus, the absolute magnitude range for delta Cep = –3.9 to –3.0. (Remember, the larger the negative magnitude, the brighter is the star.)

Once the students have plotted the variable stars on the H-R diagram, have them look up the different types of variable stars in the VSTAR database and see what their light curves look like. They will see that different kinds of variable stars have particular patterns. Before they use VSTAR, have them discuss the behaviors of the variables and what differences the curves may have.

VSTAR

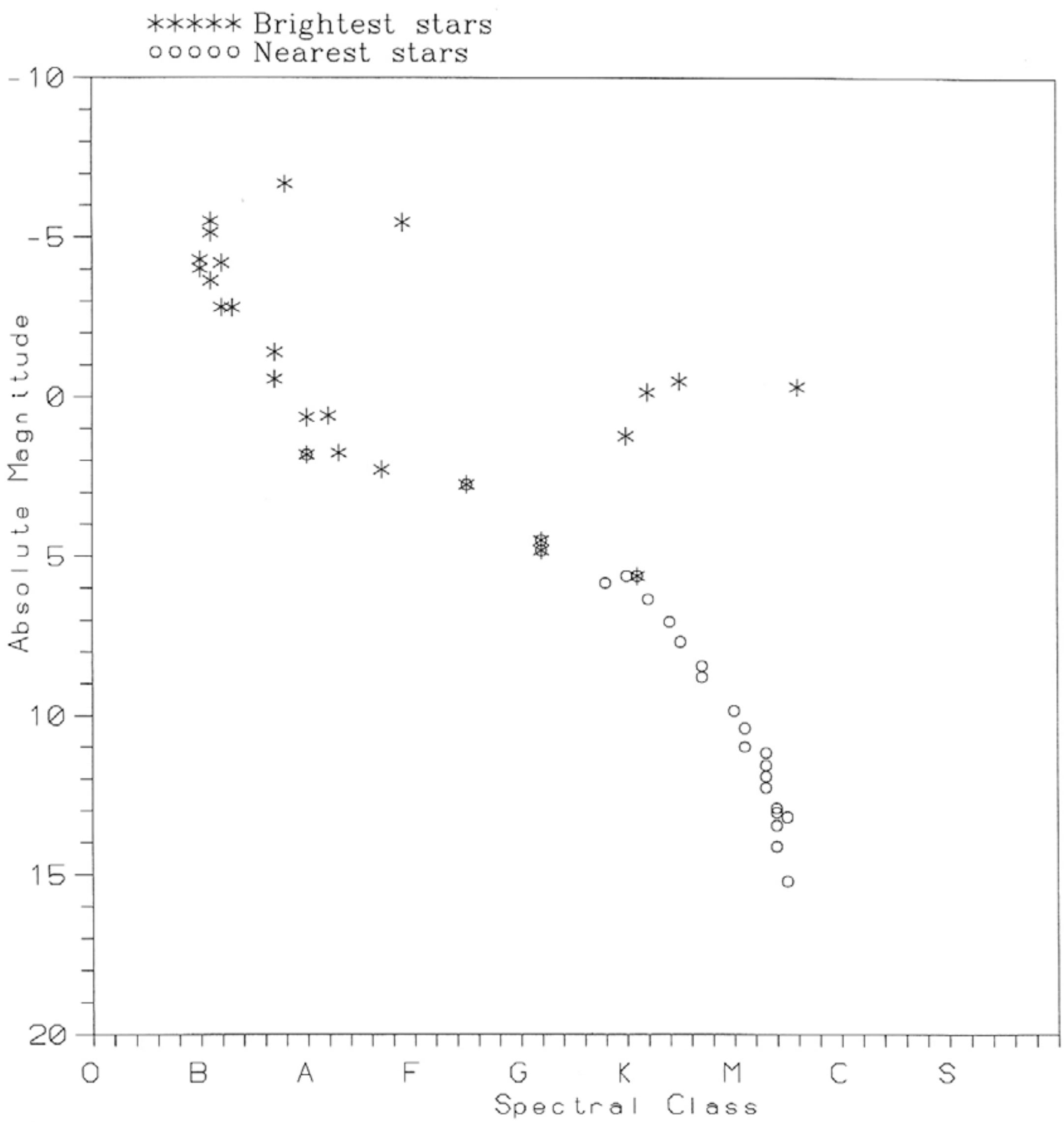
NOTE: There is a problem with the absolute magnitude values of the last two stars in Table 9.3a, RS Boo and VX Her. These two stars are not really as bright as they appear to be from the values given here; they are in fact always fainter than magnitude 0.0, with mean absolute magnitudes of +0.6 to +0.9. The falsely bright values which are given are derived from the HIPPARCOS measurements, and result from the fact that the accuracy of HIPPARCOS measurements is 0.001 arcsecond, and the parallaxes of some of the variables, including RS Boo and VX Her, are less than 0.001 arcsecond. The parallax measurements are therefore highly questionable, and at the limit of precise measurement an extremely small parallax measurement error will produce very large distance and absolute magnitude errors. The falsely bright absolute magnitude values are included in the table to keep the source of the absolute magnitude data consistent.

Poster Page: Planets or Stars?

The search for other planetary systems is similar to the search for other life-forms and for other planets which have the capability for the origin and evolution of life. Any search of this nature requires space travel either by astronauts or robots. It is a serious mission to research the possibilities of space stations, space ships, and the mining of planetary materials that would sustain further space travel. NASA has given it much consideration and conducted several feasibility studies on all aspects of extraterrestrial travel. The Biosphere outside Tucson, Arizona, is a privately-sponsored experiment in completely contained and self-reliant life. This type of living environment is necessary for the habitation of other planets. When considering the colonization of other planets, how does one take into account the gravity, radiation levels, varying types of atmospheres, and absence of necessary materials? Because of the unique aspects of each planet, different types of space colonies would be necessary for the Moon, Mars, Titan, and other yet-tobe discovered planets. In what ways would they be different? Why? This topic is potentially rich in interdisciplinary connections and research projects. NASA has a publication series entitled *Space Resources,* which describes the results of their studies on possible future projects involving non-terrestrial activities. (See Resource List for details.)

RESOURCE

Completed H–R Plot for Core Activity 9.2



Completed H–R Plot for Core Activities 9.2 and 9.3