Chapter 6: Measuring Variable Stars Visually

Summary

This chapter is an introduction to identifying and making magnitude estimates of variable stars in the classroom, using the slide and print sets which accompany this curriculum. The activities in this chapter prepare students to make successful observations of variable stars in the real sky, and to perform an accurate analysis of their data.

Terminology

accuracy	interpolation	photometry	significant digits
amplitude	Julian Day	precision	systematic error
comparison stars	light curve	random error	trend
extrapolation	percent error	range	

Common Misconceptions

1. *All error is caused by "human" error.*
2. *Data that do not "fit" the line are wrong.*
3. *The only information on a graph is the data plotted.*

SUGGESTIONS FOR THE POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 6.1: Interpolation

This is a simple but powerful activity if exploited to its full potential. The materials required are uncomplicated: a set of 10 cylinders of varying size, such as food and coffee cans, jars, tubes, and the like; and rulers, string, and graph paper. Provide some cylinders that are more difficult to measure due to their flexibility, such as paper towel tubes. This will add another dimension to the discussion of the results. Using the string to measure the circumference and then measuring the string with the ruler adds a further complication if students are not careful with their measurements. Each group of students needs to have the same set of cylinders and the same type of string in order to compare results.

Learning how to graph real data is a difficult activity for students who have never done so before: students think that their graphs should have the precision and exactness that occurs in the math classroom. Real information is frustrating—it often refuses to cooperate and line itself up properly. Learning how to interpret a trend, how to do the "best fit" curve, and what data are erroneous enough to leave out of the "best fit" is challenging. However, it is a vital and necessary skill for scientists to acquire, and worth the extra effort to learn.

Strongly emphasize to the students the importance of labeling the axes, making sure the proper units are attached, and determining an appropriate scale for the graph. The scale should allow the data points to cover the graph; the data should not be scrunched up in any one section of the graph, leaving large blank areas, or it will be harder to see the relationships. Also, data points should not fall directly on the axes. Students who have had some algebra can calculate the slope of the line, the specific relationship between the two variables being plotted. They are actually plotting C = d, which is a simple example of the straight line equation y = mx + b. Most students have difficulty recognizing this relationship outside of the mathematics classroom. The slope should be calculated from two values on the line which are *not* plotted values. Students should not get the mistaken impression that they can take two measurements for circumference and diameter and calculate the slope without doing any graphing. If one measurement is too imprecise, the results will be unreliable. A typical completed graph of this activity is included for your information (see opposite page).

NOTE: The students have been asked if they should remeasure or ignore what looks like a bad data set. Usually, in a situation where a measurement seems suspect, one will remeasure. This would be possible in any circumstance where the result is already known and students are determining their percent error—a measure of how precise their measurements were. In science, anomolous results are usually disregarded. After all, error cannot be eliminated. In variable star astronomy there is no way to remeasure, no way to go back in time to determine what was wrong. A magnitude estimation from an observer which radically differs from those of other observers made at the same time—after being checked for such problems as typographical errors—is flagged as being possibly erroneous. (See Poster Talk 13.2 for a discussion of the ways such errors are detected and corrected.) Although variable stars change in magnitude, every observer should see approximately the same magnitude at the same time for a star.

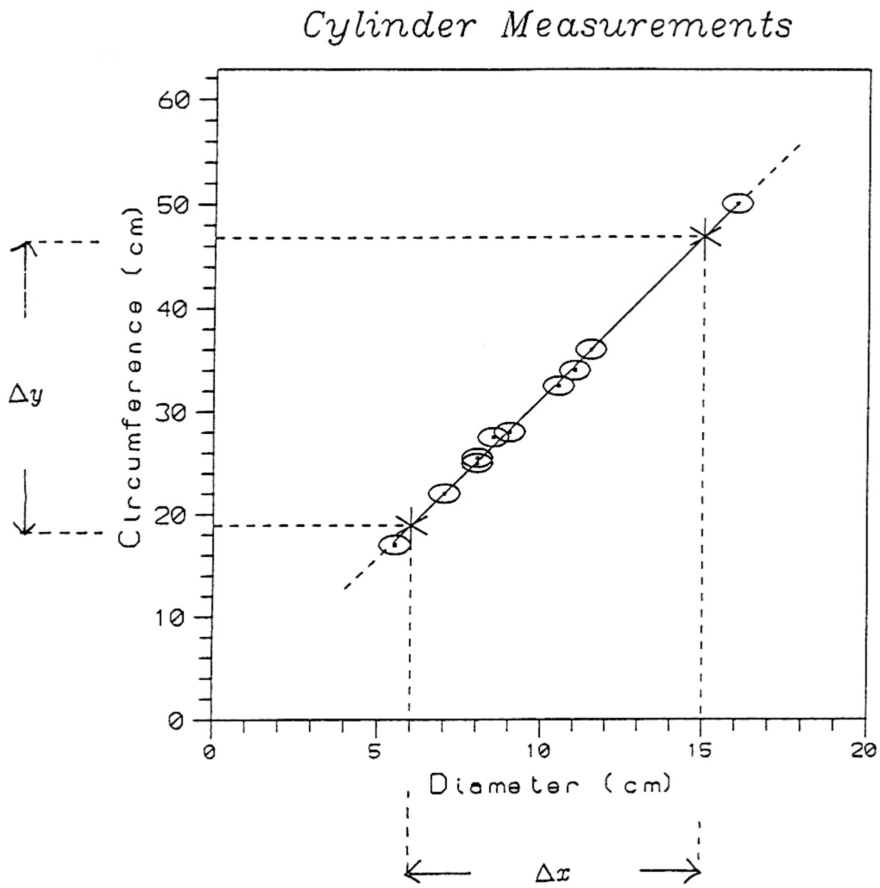
The following extensions are included in Investigation 6.3, although they could be addressed here as well, depending on the class.

Extensions

Calculating the percentage of error will tell the students how successfully they performed the measurements and determined the “best fit” curve (line). Having the students calculate the error for the entire classroom will give them solid proof that the more data points averaged, the smaller the percentage of error. The class average will be smaller than the individual averages. In variable star astronomy, the strength of the data depends upon the large number of observations. And of course, the purpose of this activity— interpolation—is important to both magnitude estimation and making best fit curves.

The students can also discuss random errors, and any systematic errors that might be inherent to this activity

Example of Completed Investigation 6.1 and Core Activity 6.3



$$C = \pi d$$

$$\pi = \frac{C}{d} = \frac{\Delta y}{\Delta x}$$

$$\Delta y = 46.8 - 18.9 = 27.9$$

$$\Delta x = 15 - 6 = 9$$

$$\text{estimated } \pi \approx \frac{27.9}{9} = 3.1$$

$$\text{true } \pi = 3.1416$$

$$\text{error } = \frac{3.1 - 3.1416}{3.1416} \times 100\% \approx -1\%$$

Core Activity 6.2: Estimating Magnitudes Using Interpolation

This is an extremely basic activity. Activity 6.4 is identical except that it uses real-sky images instead of paper charts. Depending on your class, you may use this as an activity or a demonstration to lead up to Activity 6.4, or leave it out altogether.

Core Activity 6.3: How Accurate Are Your Results?

Significant figures are not a favorite topic for students, but they are important in measuring. Students need to understand the difference between precision and accuracy, and at the least comprehend that when multiplying, dividing, adding, or subtracting numbers, the resulting answer is only as accurate as the least accurate measurement. The class should discuss here—whether for the first time or to reinforce a previous discussion—their results from the Investigation 6.1 graph; they should understand the difference between random and systematic error and recognize examples of each. The results should show that random errors will become insignificant when many data points are analyzed. Systematic errors are much more dangerous if they go undetected, as they will give inaccurate results.

Answers to Significant Digit Exercise

Exercise 5:

a) 3
b) 3
c) 2
d) 4
e) 4
f) 1
g) 6
h) 3
i) 5
j) 4

Exercise 6:

a) 72.6
b) 5.8
c) 181.9
d) 78.7 (=7.87 X 10^1)

Poster Page: The Dangers of Radiation

As an extension or alternative classroom project, you can involve students in an active discussion on the observation of artificial satellites. The material requirements are minimal, and there is much to discuss. There is a huge array of satellites—from HST and Mir to weather and other Earth-observing satellites, and they have a variety of orbits, from horizontal or inclined to geostationary and polar. Students can focus on a satellite they know, time its appearances, and then predict future sightings. It is not a simple task. A satellite's orbital plane does not remain fixed in space but rotates slowly about the Earth's axis due to gravitational perturbations. The direction of drift is to the west if the satellite is traveling eastward, at a rate of up to 8° per day, depending on the orbital inclination. The mass of the Earth controls the orbital period of a satellite. The Earth's gravity, gravitational perturbations, and the shape of the orbit all have an effect on the satellite's speed. Many physical laws are involved. There are several techniques for accurate visual observations of altitude, speed, rotation rate, and so on.

Core Activity 6.4: More Magnitude Estimations

Students will estimate magnitudes of the major star patterns for one or more constellations, given the brightest and dimmest stars for comparison. Practice with as many constellations as necessary for your class to become comfortable with their estimations. It will seem difficult at first, sometimes almost impossible; however, after a little practice it will become second nature. The magnitudes of all the bright stars within the constellations are listed in Core Activity 4.5: Constellation Plots.

Aur – 0.1 to 2.7
Cas – 2.2 to 3.4
Cep – 2.4 to 4.2
Cyg – 1.2 to 2.5
UMa – 1.8 to 3.3

HOA FUN

HOA Fun: You may elect to have your students use the HOA Fun software program included with this curriculum (see instructions in Appendix). It is designed as an introduction to observing variable stars over time and estimating their magnitudes. The program is not concerned with "accuracy"—there are no right or wrong answers. It is simply meant as a nonthreatening and entertaining look into the process of variable star astronomy.

Core Activity 6.5: Collecting Your Own Data

This activity involves estimating the magnitude of a single variable star, utilizing a paper starfield, as in Core Activity 6.2. For this activity, students are required to estimate the star's magnitude over time. The astronomical community uses the Julian Day (not to be confused with the Julian Calendar) as a unit of time. The students are given a brief description of what the Julian Day is and how it developed. An interesting discussion could be developed here about the topic of time. After all, what if suddenly eleven days were dropped from our calendar and the beginning of the year changed from January 1st to April 1st? What would be the consequences? Would landlords lose three-and-a-half months' rent? For almost 200 years Great Britain and America were out of sync with European calendar dates. Why did it last so long? Could that difference be maintained today? From sundials to atomic clocks, humanity has tried to simultaneously impose arbitrary timekeeping inventions on nature and use nature as clockwork. It has been an interesting and complicated business trying to keep time. You can get today's Julian Date (JD) from the JD calendar which comes with this curriculum.

Also included is Table 6.6, where the entire class can put their individual estimates together for group analysis. Assign each student an ID number using their initials, last name first (for example, Donna L. Young would become YDL). Have the students graph their data, either on the board or on a large piece of paper, or on an overhead transparency. Each student can use a different color and/or symbol to see how their estimates compare to their classmates. Have them draw in the "best fit" curve. Have the students keep their data sheets. The information in Table 6.6 will be used several times in Unit 5 for different types of data analysis.

Poster Page: Who Are the Amateur Astronomers?

HOA VIDEO

There are most probably amateur astronomers in your vicinity, or even amateur astronomy organizations. Amateur astronomers come from all occupations, and are enthusiastic about their hobby. You can learn more about them in the section of the HOA video entitled "Backyard Astronomy." Locate an amateur astronomer who would like to come visit your classroom and share their experiences with your students. They may even assist you in your variable star observations. They will know the best viewing places and times, and have an excellent knowledge of the night sky. If you are unable to find an amateur astronomer, contact AAVSO Headquarters, and they may be able to locate one for you. What famous people in history have also been amateur astronomers? Just what do amateur astronomers do? Are there other ways in which they make significant contributions to astronomy besides variable star observations?

Core Activity 6.6: Magnitude Estimation and Graphing with Slides (and/or Prints)

RESOURCE

If your students are going to observe the real sky, this activity will help to ensure their success. If you do not have access to a dark sky, or if it is not possible for your class to observe at night, this will be the culminating observational activity. The slide set included with this curriculum is a sequence taken of the variable star W Cyg, over a time frame of about 150 days. The slides show almost the full range in magnitude for this star. The slides and finder charts are used in tandem to locate W Cyg and its comparison stars. Also included is a series of prints identical to the Cygnus and W Cyg slide sets. The slides can seem confusing at first; however, with practice your students will rapidly become more proficient in making magnitude estimates. The prints can also be used alongside the slides and finder charts. Only one set is provided; additional sets can be purchased from the AAVSO, or the prints can be adequately reproduced with a good color copier.

You will need to practice and become adept at estimation with the slides yourself before your students engage in this activity. The most difficult aspect of using the slides is locating the variable star and its comparison stars. Take as much time as possible to practice this until you nearly have the stars' positions memorized. Three of the variable stars that are easiest to locate are W Cyg, chi Cyg, and R Aur. A slide of each of the HOA constellations is provided with the variable stars indicated.

It is also helpful to have students make their own transparency overlay for the prints, identifying W Cyg and the comparison stars, and labeling their magnitudes. Use a bright color, non-permanent pen or china marker (yellow or orange work well). Then the overlay can be moved from print to print as each successive slide is projected. NOTE: The star field will move around a little as you go from one print to another, as it is difficult for a photographer to set up in the exact same spot when photographing the sky several days apart. There are also other variable stars in Cygnus which you may want to use with the class for additional practice. They are indicated on the finder charts. A transparency master is included with the positions of variable star W Cyg and its comparison stars and their magnitudes. Chi Cyg is an excellent, and dramatic, example of a variable star. Its magnitude range is greater than that of W Cyg and is easy to estimate. It was not used as the prime variable star for this activity because it is a red star, which might make the activity more confusing for students (for most people, red objects in the night sky appear brighter than they really are).

W Cyg has a period of 131 days and a range in magnitude from 5.5 at maximum to 7.0 at minimum. The range that is covered with the series of slides is approximately the same range.

Chi Cyg has a period of 408 days and a range in magnitude from 4.3 at maximum to 14.1 at minimum. The range covered by the slides is approximately 5.6 to 10.4.

Transparency Master for Overlay of W Cyg Field Prints