Unit 5: ANALYSIS OF VARIABLE STARS

Variable star data have many advantages for teaching science and math skills. You will be using real data, most of them useful for astronomical research. They contain real errors, which must be understood and measured before the results can be interpreted. The next five chapters deal with the mathematical analysis techniques which must be applied to the variable star observational data. Chapter 10, "Statistical Concepts," introduces the concepts of scatter, range, average deviation, and standard deviation. Chapter 11, "Variable Stars, Light Curves, and Periodicity," discusses the different types of variable stars and the characteristics of their light curves, which are plots of magnitude versus time, and the most important graphs in variable star astronomy. Chapter 12, "Variable Stars and Phase Diagrams," introduces phase diagrams and utilizes the VSTAR software program for more in-depth analysis of period determination. Chapter 13, "Variable Stars and O–C Diagrams," is an introduction to prediction and O–C diagrams, a more advanced method of analyzing periods and the differences between observation and prediction.

CONTENTS FOR UNIT 5

Poster Page: Radar Guns and Speeding Stars
Space Talk on DI Her–A Puzzling Binary System

CHAPTER 12: VARIABLE STARS AND PHASE DIAGRAMS

This chapter introduces phase diagrams, which show the average behavior of a star during its cycle and determine the accuracy of the measured period. Mathematical and computer techniques for determining periodicity are also presented utilizing the VSTAR software program.

Investigation 12.1: Periodic Cycles
Core Activity 12.2: Folded Light Curve of the Variable Star SV Vul
Core Activity 12.3: Another Folded Light Curve of SV Vul
Core Activity 12.4: Yet Another Folded Light Curve of SV Vul
Poster Page: SS Cygni
Activity 12.5: Folded Light Curve of Star X and Delta Cep
Core Activity 12.6: VSTAR
Space Talk on Mira Stars
Poster Talk: "Theoretical Glue"

CHAPTER 13: VARIABLE STARS AND O–C DIAGRAMS

This chapter introduces the concept that processes that are periodic are predictable. For periodic variable stars, astronomers can use prediction to plan their observation of the stars, and also to look for deviations from periodicity. This chapter introduces the O–C diagram, which can determine deviations from predicted values.

Investigation 13.1: Constructing an O–C Diagram
Core Activity 13.2: Understanding O–C with Miras
Core Activity 13.3: Prediction of SS Cyg
Activity 13.4: Prediction and Observation of Delta Cep
Poster Page: Universal Models
Core Activity 13.5: Prediction and Analysis of the Period of R Cyg
Activity 13.6: O–C for Eclipsing Binary Stars
Space Talk on The Eclipsing Binary
Poster Page: The Birch Street Irregulars

Relationship to National Science Standards and Benchmarks

Benchmarks discusses *The Nature of Mathematics* and the fact that students need to perceive mathematics as part of the scientific endeavor, and must comprehend the nature of mathematical thinking. This unit focuses on two of the sections involving *The Nature of Mathematics: Patterns and Relationships* and *Mathematical Inquiry.* The students will develop mathematical models to represent variations in stellar behavior and to predict future behaviors. Mathematical analyses will show how well further observations match the expected behaviors. From these analyses, it is possible then to develop further mathematical manipulations to study the differences between the observed and calculated variations.

In the *National Science Standards* content standards dealing with *Evidence, Models, and Explanation* and *Constancy, Change, and Measurement,* mathematical models represented by equations, graphical models of several types, and computer models and analyses are supported as necessary for scientific inquiry.

In the *Science as Inquiry* content standard, the national standards promote the use of computers for collecting, analyzing, and presenting models of events. It states that students need to be able to access, gather, store, retrieve, and organize data using appropriate software. Students will need to formulate and revise explanations for stellar behaviors when the predictions from their investigations do not match further observations. Alternative models and explanations will need to be developed. In this unit, students will produce graphical and computer models which behave in the same way as the objects under investigation. They will make predictions which then can be verified by further observations, and analyze the differences between prediction and observation to develop alternative models and explanations. Students will see that mathematics, especially statistical analysis, is an integral part of the development of scientific knowledge and understanding.

Chapter 10: Statistical Concepts

Summary

This chapter is an introduction to the statistical techniques important in the study of variable stars. The following concepts are presented: range, relative frequency, histogram, average deviation, standard deviation, normal distribution, the normal curve, and error bars. The students will use the data for Star X from Core Activity 6.5 to learn how to apply these concepts to the analysis of stars that vary in magnitude.

Terminology

average deviation	histogram	sensitive
bin/bin value	normal curve	standard deviation
double blind	normal distribution	standard error of the average
error bar	range	statistics
false-alarm probability	relative frequency	variance

NOTE: If you have high school or college students with good mathematical knowledge and abilities, a more technical version of "Statistical Concepts" is available. This alternate version of Chapter 10 can be found on the HOA web page, or you can order a hard copy from the AAVSO.

SUGGESTIONS FOR POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 10.1: Finding the Average

You may want to do only either height or arm length, depending on your class. They will be using only one data set to construct a histogram at the end of Core Activity 10.2. There are several variations to this activity if they need more practice. Is foot length related to height? To arm length? Will the students decide to remove their shoes? If not, the different heights of their shoes will affect the measurements. Where on the arm will they start the measurement? Will they all decide on the same spot? Will everybody be able to use *exactly* that same spot? Students may try to control some of these variables. Whether or not they can, there will be a range of different results. Students should see that there is less scatter when the measurements for the entire class are averaged together. Have students discuss the different random and systematic errors that are involved with their measurements.

Core Activity 10.2: Constructing a Histogram

Histograms are used extensively. They are bar graphs that show the relative frequency with which numbers or events occur. Show your students that histograms are a popular tool for visualizing mathematical results.The newspaper *USA Today* usually has several examples each day, related to such topics as manufacturing, politics, consumer goods, and sales. Use every opportunity to show students that a technique which appears in a science class or textbook has applications in the outside world.

Core Activity 10.3: Finding the Average Deviation

Students will now start using the information from Table 6.6 with the class estimates for Star X. The answers they calculate will depend upon the data in Table 6.6. If your students do not have the ability to handle the equation for average deviation, then they can simply use the written summary within the activity. Students who feel uncomfortable with math will be surprised to find that the words they have been using to perform a math function actually has a formula which would once have intimidated them.

Poster Page: Hands-On Universe

The Hands-On Universe (HOU) program provides comprehensive curriculum activities that integrate many of the topics and skills outlined in the national goals for science and math education with open-ended astronomical investigations. HOU is currently developing activities and tools for middle school students and informal education centers, as well as implementing HOU in regional high school networks around the world. Curriculum developers at TERC (Technical Education Research Center) have created a set of seven curriculum units and teacher notes for high school classes. These have been piloted and field-tested in several schools, and other activities and units are currently under development. In addition to the curriculum units, HOU professional development workshops are available. To see what is available, access the HOU website. Their address is http://www.handsonuniverse.org.

Core Activity 10.4: Variance and the Standard Deviation

Once again, the equation does not need to be used in this activity unless your students have the ability to handle it. The analysis of standard deviation (SD) differs from average deviation only by squaring the values instead of taking the absolute value. The students should recognize that the SD gives a larger deviation from the mean than the average deviation and therefore is more "sensitive"—or, rather, gives a more accurate deviation.
The answers to the exercises are not given, as they depend upon the magnitude estimates for Star X. Remember, in this curriculum the answers are not right or wrong. We are concerned only with the process. Whatever the students get for answers *are* the answers. This is real science. We are looking for the answers because we do not know what they

are, so the results have no "wrongness" or "rightness" to them. This is true of all the observable variable star data gathered. What you see is what you get. The analysis of the data will either reveal any poor measurements or blend them into the averaging techniques. What is important is that students discuss among themselves and with you what the results mean so that they can acquire an understanding of the process.

Core Activity 10.5: The Standard Error of the Average—The Error Bar

The students will be using the error bar analysis data in Chapter 11 when they actually graph the light curve for Star X.

Poster Page: Variable Star Mythology

Many variable stars are observable with the unaided eye and have quite possibly played a role in developing mythologies. This poster page is an interesting research-based editorial concerning the story of Perseus, Cassiopeia, Andromeda, Cepheus, and Pegasus. An excellent movie about these constellations is *Clash of the Titans*. (See Resource List for details). NOTE: If you have younger students you may want to erase one brief scene of Perseus' mother walking nude along a beach. Otherwise, it is a family film with no obscenities, nudity, or excessive violence. It is long, however—nearly 2½ hours. There are other unaided-eye variables that may have contributed to mythology, and it is a rich topic for research.

RESOURCE

Activity 10.6: Statistical Analysis of Delta Cephei

If your class (or any student) has been observing delta Cep, they can now repeat the steps they followed for Star X to produce the same analysis for delta Cep. Or you may elect to access the VSTAR database and select a series of observations for delta Cep or some other variable star. Different groups of students could be assigned different variables, and then compare their results.

VSTAR