Chapter 12: Variable Stars and Phase Diagrams

Summary

Phase is the fractional part of a cycle of variation, and a graph of magnitude versus phase is called a phase diagram. A phase diagram shows the average behavior of a star during its cycle and helps to more accurately determine the measured period. This chapter presents both mathematical and computer statistical analysis techniques to determine periodicity.

Terminology

folded light curve	hydrostatic equilibrium	mometum
General Catalogue of Variable Stars	Mira	oscillator
helium flash	modular arithmetic	phase

SUGGESTIONS FOR THE POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 12.1: Periodic Cycles

The concept of phase is extremely important, and phase diagrams are powerful tools in deciphering variable star behaviors. Let the students explore this activity until they have an appreciation for the phenemonon of phase (i.e., that if all cycles are the same, it is not important which cycle is represented, only which part of the cycle). The students have a paper copy representing a portion of the light curve of V Cas. After the students have studied their paper model, make several overhead transparency copies for the class from the template following student page 208. Have them cut out the transparency models and lay them on top of each other. Students can then experiment with having a different starting point in the cycle. Have them try several ways of superimposing them, laying them end-to-end, and taping them together. Practicing with different beginnings to the cycle will help them appreciate what is meant by phase. No matter what they do, the results will always be the same—no matter when the first observation is taken in a star's cycle, no matter what point is chosen for the reference point on their phase diagram, the diagram will represent the behavior of the star. Even though there are minor differences, they can cut their model up into single cycles and lay them all on top of one another and see that one cycle is representative of all the behavior exhibited by the light curve of V Cas provided.

Core Activity 12.2: Folded Light Curve of the Variable Star SV Vul

This activity leads the students through the steps of constructing a folded light curve. Depending upon your group, this can be an independent classroom activity, or presented as a demonstration to the entire class. If necessary, review graphing techniques. The students are going to complete this same activity two more times. Each successive activity will involve a greater degree of complexity. With this first graph, the students will plot two cycles on top of each other, as in Figure 12.2. This will give them the basic idea of how a folded light curve is produced by plotting magnitude versus phase. A completed graph of this activity is provided on the opposite page.

Core Activity 12.3: Another Folded Light Curve of SV Vul

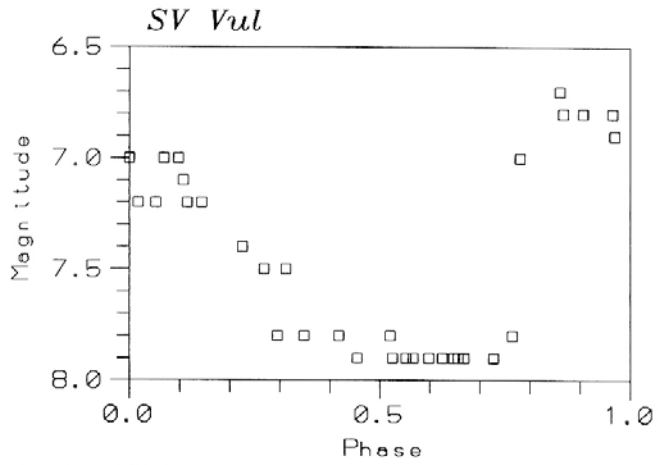
This time the students will plot each data point twice for two continuous phases so they have a graph of two complete cycles of behavior. This way neither the activity at maximum or minimum is cut off so the continuous cycle of activity can be easily seen. Since two consecutive cycles are represented, the 0 reference point is centered in the diagram and the phase runs from –1 to +1. A completed graph of this activity is provided on the opposite page.

Core Activity 12.4: Yet Another Folded Light Curve of SV Vul

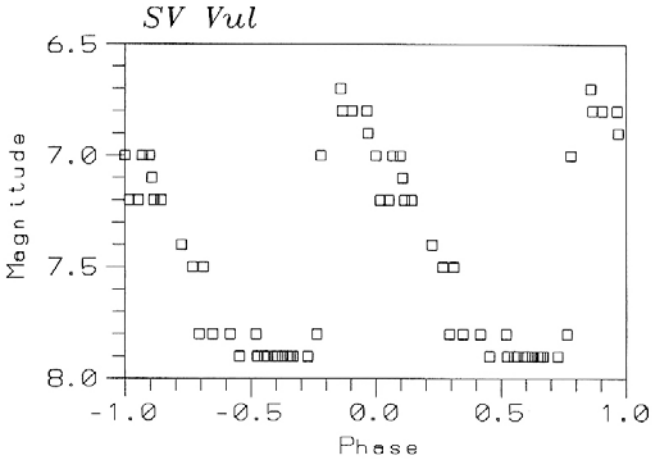
For the final graph, the students will plot the data the same way as in the previous graph with one important difference. Now instead of having the first JD as the reference point or 0 point, the more standardized method of using a JD when a variable star is at maximum is used. The phase still runs from -1 to +1; however, now the calculation of the JD from the JD at time of maximum is different, to take into account the negative numbers which will result. From now on, students should always calculate folded light curves using a time of maximum (except when analyzing eclipsing binaries, in which case a time of minimum is used) for the starting JD and plot two consecutive phases from –1to +1 on their graphs. A completed graph of this activity is provided on the next page.

Completed Folded Light Curves for:

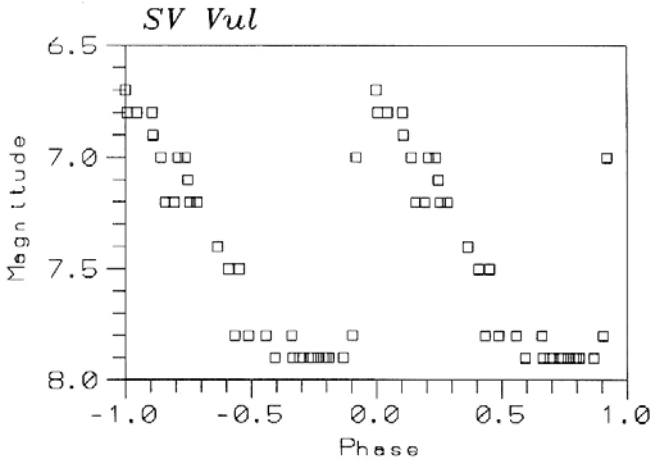
Core Activity 12.2



Core Activity 12.3



Core Activity 12.4



Poster Page: SS Cygni

Someone had to be the first person to recognize SS Cygni as a variable star. All variable stars, novae, supernovae, known comets, and asteroids were "discovered" by someone. The more recent ones are well documented; however, sometimes more ancient documents have gotten lost or misplaced over time. The history of the discoveries of some stars, such as: SS Cyg, Mira, and delta Cep, have been discussed within this manual. Have your students choose a star and try to find who first discovered its particular properties, or, in some cases, did not know that they had seen something new. Some astronomers just happened to be looking at the right part of the sky when something was about to happen, as with SN 1987A. Others looked at photographic plates for years before making a discovery, such as Clyde Tombaugh's discovery of Pluto.

Core Activity 12.5: Folded Light Curve of Star X and Delta Cep

You may have the students select what information to use for the phase diagram, or you could have different groups use different information in order to compare the results. They have their individual data, the classroom averages, and the results of Pogson's method of bisected chords, all of which probably gave a different period, so different groups can use the different periods in constructing the phase diagram. This would lead to additional classroom discussion about which results are more acceptable or reliable than others.

If the class has its own observational data, a folded light curve for delta Cep can now be constructed. Again, they can use their own measured period or the class average, or the results from Pogson's method. Perhaps they can compare results with other classrooms in other locations, or average all the data together to see the differences from or similarities to small data sets. If you have not yet given them the actual period of delta Cep, they can now ascertain on their own if their period determination was reasonable.

Core Activity 12.6: VSTAR

VSTAR

Now that students have gained an understanding of why plotting magnitude versus phase to get a folded light curve is a good method of presenting variable star data for further analysis, they are ready to let VSTAR do the work for them. This activity takes the students through the process of learning how the program determines the best period for a variable star.

Poster Talk: Theoretical Glue

This discussion incorporates many of the topics that have been introduced throughout this manual. It is an excellent example of how scientists rely on each other to construct knowledge. Scientists keep themselves current in research results within their fields of interest by accessing publications and technical journals. Any information they then use in their studies from other sources is listed when they in turn publish an article.

Models were discussed in the beginning chapters. A model of the surface of Earth, for example, is a simplistic model. We can easily understand the relationship of oceans, seas, and continents by looking at a globe. Models of stellar evolution are complex and dynamic. Scientists start with a simple model which poorly represents the actual star, and then build more and more complex models in an attempt to construct a model which is accurate enough to give further understanding of the processes involved