

Chapter 11: Variable Stars, Light Curves, and Periodicity

Summary

The graph of the apparent brightness (magnitude) of a variable star versus time (Julian Day or JD) is called a light curve. It is the most important graph in variable star astronomy. This chapter is an introduction to the peculiarities of light curves, and how to plot and interpret them. The period of a variable star can be calculated from the light curve, by determining the times of maxima and minima.

Terminology

apsidal motion	Mira variables	RR Lyrae stars
barycenter	nebulosity	RV Tauri stars
cycle	novae	semiregular variables
dwarf novae	periastron	superhumps
envelope	perihelion	superoutburst
eruptive variables	period	supernovae
general relativity	Pogson's method of bisected chords	SU Ursae Majoris stars
light curves	precession of the perihelion	symbiotic stars
line of apsides	pulsating variables	T Tauri stars
maximum, maxima	R Coronae Borealis stars	U Geminorum Stars
minimum, minima	recurrent novae	variable stars

SUGGESTIONS FOR POSTER PAGES, INVESTIGATIONS, AND ACTIVITIES

Investigation 11.1: Recognizing Periodic Curves

The students are given several curves and given the task of identifying which ones are periodic. All the curves are actual curves from various types of variable stars. Some of the curves are obviously periodic, others are less obvious, and some do not have any obvious periodicity. At this point, it would be helpful to show the students the “Variable Stars” part of the HOA video, which explains the different types of variable stars and their natures. After students have chosen periodic curves and calculated their periods, they can use the summary of the different types of variable stars—included in both the Appendix and in the Chapter 11 introduction—to determine which types of variables are producing the different curves. Let them know that all of the light curves belong to

VSA VIDEO

different kinds of variable stars in the AAVSO International Database. While all variables vary in magnitude, not all variables are obviously periodic. You will note that (c) and (d) are the same types of variable, as are (e) and (f), etc., so that students can compare their light curves and easily see that even two of the same type of variable star can have very different light curves. Variables (a) and (b) have no obvious periodicity.

Note: Remember, you find the maximum and minimum magnitudes and period by looking at many cycles and taking the averages.

Answer Key (answers based on data shown in printed light curves on pages 192–194)

(a) R CrB

Maximum magnitude: 6.0

Minimum magnitude: 13.8

Period: No specific period

Type: R Coronae Borealis (RCB)

(f) Z UMa

Maximum magnitude: 6.8

Minimum magnitude: 8.7

Period: Star has more than one period

Type: Semiregular (SR)

(b) RS Oph

Maximum magnitude: 5.3

Minimum magnitude: 12.3

Period: No specific period

Type: Recurrent Nova (NR)

(g) Z Cam

Maximum magnitude: 10.5

Minimum magnitude: 13.2

Period: 22 days

Type: Z Camelopardalis (Z Cam)

(c) Chi Cyg

Maximum magnitude: 5.2

Minimum magnitude: 13.8

Period: 408 days

Type: Mira (M)

(h) SS Cyg

Maximum magnitude: 8.2

Minimum magnitude: 12.2

Period: 49.5 days

Type: U Geminorum (UG)

(d) S UMa

Maximum magnitude: 7.8

Minimum magnitude: 11.7

Period: 225.9 days

Type: Mira (M)

(i) CH Cyg

Maximum magnitude: 5.8

Minimum magnitude: 9.2

Period: Star has more than one period

Type: Z Andromedae (Z And)

(e) W Cyg

Maximum magnitude: 5.6

Minimum magnitude: 6.8

Period: Star has more than one period

Type: Semiregular (SR)

(j) X Cyg

Maximum magnitude: 6.0

Minimum magnitude: 7.0

Period: 16.4 days

Type: Cepheid (C)

Poster Page: Mapping the Universe (HIPPARCOS)

The history of astrometry is a good example of how technology drives knowledge. A lot of time and money are spent on mapping the positions of stars. It may not seem very important to students—after all, at this point all distances are almost incomprehensibly far away, so who cares if a star is 35 or 100 light-years away? Distance is one of the key factors in the equation called the distance modulus, discussed in Chapter 9. It is related to apparent and absolute magnitude. Absolute magnitude is related to the luminosity or power of a star. Knowing the luminosity gives us a lot of information about the evolutionary stage of a star, its physical characteristics, and its behavior. This knowledge has implications for the age of the universe and its ultimate fate, as well as for origins of life. Another generation of astrometric measuring satellites is already on the drawing board, even before the full implications of the HIPPARCOS data have been analyzed. The amazing fact is that we are able to map the universe from the Earth's own backyard.

Core Activity 11.2: Analyzing the Light Curve for Star X

The students will plot both their individual data sets (part A) and the class average data set (part B). They should see that the data are less scattered and the error is smaller for larger sets of data. Using the maxima and/or minima, they can calculate the period of Star X. Again, there is no exact or correct answer. The answer is what they get. They will also use the standard error of the average which they calculated and recorded in the previous chapter (Table 10.4, column [H]). The graph might get cluttered, since they will include the error bars and draw the envelope for both data sets. However, the best way to compare the error analysis of the two sets of data is to plot both of them on the same graph. Then the widths of the two envelopes are more apparent. You may elect to have one or both of the data sets transferred to transparencies to use as overlays on an overhead projector.

Core Activity 11.3: Analyzing the Light Curve for Delta Cephei

Hopefully there are some classroom data for observations of delta Cep. The students can then compare the analysis of their own observations with Star X. Even though the periods are different, they can compare the error bars and size of the envelope to get a feel for the precision of their observations and the accuracy of their results. Reinforce with your students that even though they are observing a variable star for which the period is known, the periods for new variables are not known, and variables often change their periods. Therefore it is essential to have results as accurate as possible because there is no “right” answer to compare the results with. Remind the students that if they want to compare their results (width of error bars and the envelope) from Star X with their results for delta Cep, they have to use the same size scale for the two graphs.

Core Activity 11.4: Pogson's Method of Bisected Chords

You may want to point out to your students that once again, averaging is taking place in this method of determining the maxima and minima points of a light curve. The entire curve involving maximum is taken into account, not just the high point in the curve. (The same is true for the minimum.) Therefore many observations and not just the two highest and lowest are being used for the analysis, giving more accuracy to the determination of the period.

Core Activity 11.5: VSTAR

Now that the students have a basic understanding of the statistical analyses involved with determining the periods of variable stars, they can use the VSTAR program. A VSTAR manual is included in the Appendix which will explain the program to the students. The first VSTAR activity is self-explanatory, and if the students have any questions, they can consult the VSTAR manual. **NOTE: If more than one student (or group of students) runs the program at the same time over a computer network, make sure each is running in a different subdirectory. If two groups run the program in the same subdirectory, they will overwrite each other's log files.**

VSTAR

Students can access the database for observational data and use the statistical package within the program to plot light curves, error bars, and envelopes. If they have delta Cep observational data, have them enter them into the program and determine the light curve, period, error bars, and envelope, and compare the results with their own calculations. They cannot add their observations to the database on this software package, but can enter their observations for analysis.

Poster Page: Radar Guns and Speeding Stars

Radar is an extremely useful tool to gather information, astronomical or otherwise. Exactly how does a radar gun work? How are winds measured on other planets using the Doppler effect? Students seldom understand how physical laws and principles impact their lives. When they do, they begin to understand that things that work seemingly like magic are only the application of very simple phenomena. Doppler is useful in many circumstances, and research into this area will probably turn up some surprises. When did Doppler discover this effect? How was it first used? How long did it take before it was employed by police to trap speeders? Do radar guns work from the front, the side, the back? Just how do radar detectors detect radar guns? Can both radar guns and radar detectors give inaccurate readings? There are other types of radar than Doppler radar. In meteorology and at airports, Doppler maps are used to determine wind speed and direction. Profiles from the ocean bottom are the result of the reflection of sound waves back from the ocean floor. With this type of radar, the difference in time is recorded. There is no change in frequency.