



## Variable Stars

Stars appear to shine with a constant light; however, thousands of stars vary in brightness. The brightness that a star appears to have (apparent magnitude) from our perspective here on Earth depends upon its distance from Earth and its actual intrinsic brightness (absolute magnitude.) The behavior of stars that vary in magnitude (brightness) - known as variable stars - can be studied by measuring their changes in brightness over time and plotting the changes on a graph called a light curve. Amateur astronomers around the world observe variable stars and assist professional astronomers by sending their data to variable star organizations, such as the American Association of Variable Star Observers (AAVSO) in Cambridge, Massachusetts. The behavior of some variable stars can be observed with the unaided eye or binoculars. Measuring and recording the changes in apparent magnitude and drawing the resulting light curves will allow you to begin to unravel the stories of the often turbulent and always exciting lives of variable stars. The collection and study of variable star data requires the ability to estimate the apparent magnitudes of stars. The two activities that follow will assist you in acquiring the skill of estimating the magnitudes of variable stars.

The two activities, Stellar Heartbeats and A Variable Star in Cygnus, have been adapted from the "Hands-On-Astrophysics, Variable Stars in Math, Science, and Computer Education" curriculum project developed and published by the American Association of Variable Star Observers (AAVSO.)

### Useful Resources:

- [Types of Variable Stars](http://www.aavso.org/vstar/types.stm) (at AAVSO)  
(<http://www.aavso.org/vstar/types.stm>)
- [Estimating Magnitudes Using Interpolation](http://hoa.aavso.org/estimating.html) (at AAVSO)  
(<http://hoa.aavso.org/estimating.html>)
- [Backyard Astronomers Trigger Multi-satellite Observing Campaign on SS Cygni](http://chandra.harvard.edu/chronicle/0101/aavso.html) (<http://chandra.harvard.edu/chronicle/0101/aavso.html>) and [Astronomers Team Up for Chandra Observations of SS Cygni](http://chandra.harvard.edu/chronicle/0300/aavso.html) (<http://chandra.harvard.edu/chronicle/0300/aavso.html>) (Chandra Chronicles Articles describing how the AAVSO amateur observers assisted the Chandra X-Ray Observatory)
- [Hands-On-Astrophysics](http://hoa.aavso.org) (<http://hoa.aavso.org>) Variable Stars in Math, Science, and Computer Education (at AAVSO)
- [HOAFUN](http://hoa.aavso.org/software.html) (at AAVSO - an interactive and easy-to-use tutorial for estimating the magnitudes of variable stars and understanding the light curves of different types of variable stars.)  
(<http://hoa.aavso.org/software.html>)

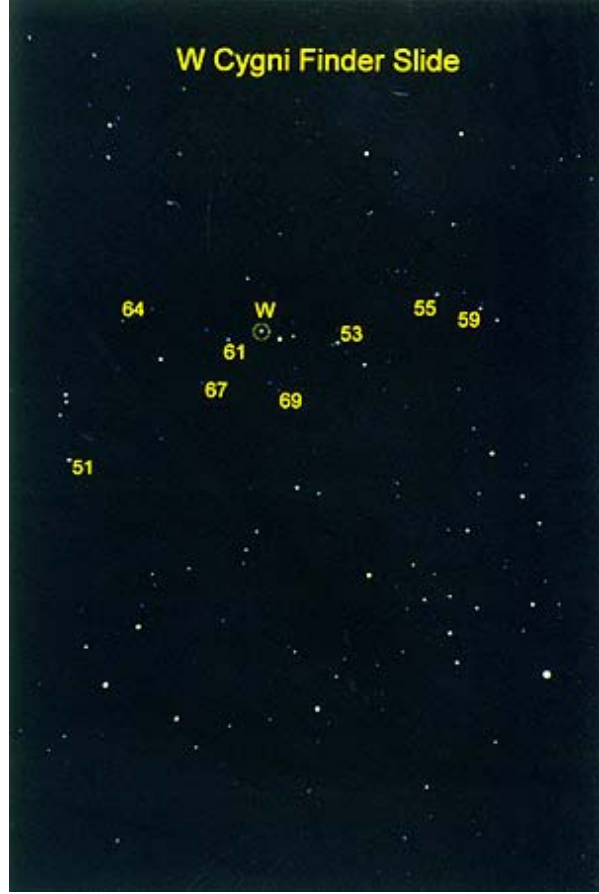


## Variable Stars in Cygnus

The constellation Cygnus was named by Erastheneas, a Greek who is famous for calculating the circumference of the Earth by measuring the length of a shadow cast by the Sun on a day when he knew its rays shone directly into the bottom of a well several kilometers away. Cygnus, represented as a flying swan, is also sometimes called the Northern Cross. The brightest apparent magnitude star in the constellation of Cygnus the swan is Deneb. Deneb is one of the three bright stars that make up the asterism of the summer triangle - a prominent feature of the summer and autumn night sky.

The area of the sky represented by the constellation Cygnus contains many variable stars. One of the variable stars in Cygnus is named W Cygni, or W Cyg.







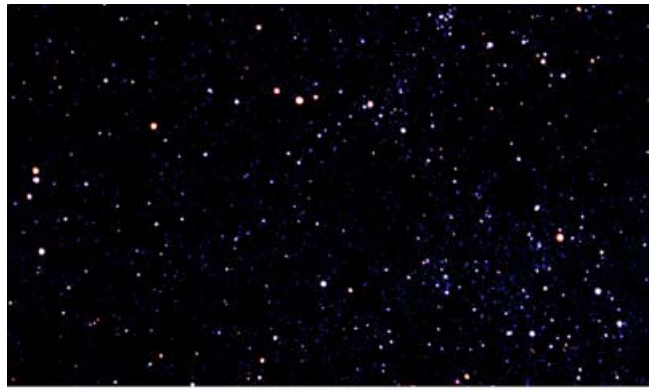
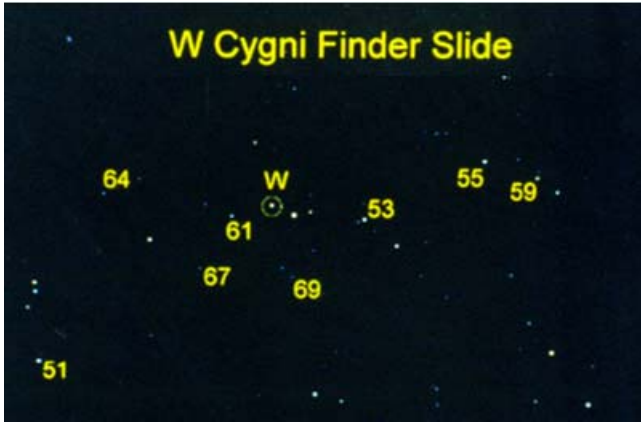
## Variable Stars in Cygnus

### Estimating Magnitudes

The W Cyg Field Slide #1 is the first of a series of 7 slides taken of the variable star over a period of approximately 150 days. The set covers nearly the entire range from maximum magnitude (brightest) to minimum magnitude (dimnest.) You will note as you move through the slides that W Cyg does not appear in exactly the same spot in each of the slides. This is because it is difficult for a photographer to set up in the exact same spot when photographing the sky several days apart. The slides also appear in different hues and sometimes with fewer stars in the field. This is the result of different atmospheric conditions on the dates that Cygnus and W Cyg were photographed.

A finder slide with W Cyg and the comparison stars circled has been provided on the next page. Use it to locate W Cyg and the magnitudes of the comparison stars in the sequence of images beneath it.

| Julian Day | Magnitude |  | Julian Day | Magnitude |
|------------|-----------|--|------------|-----------|
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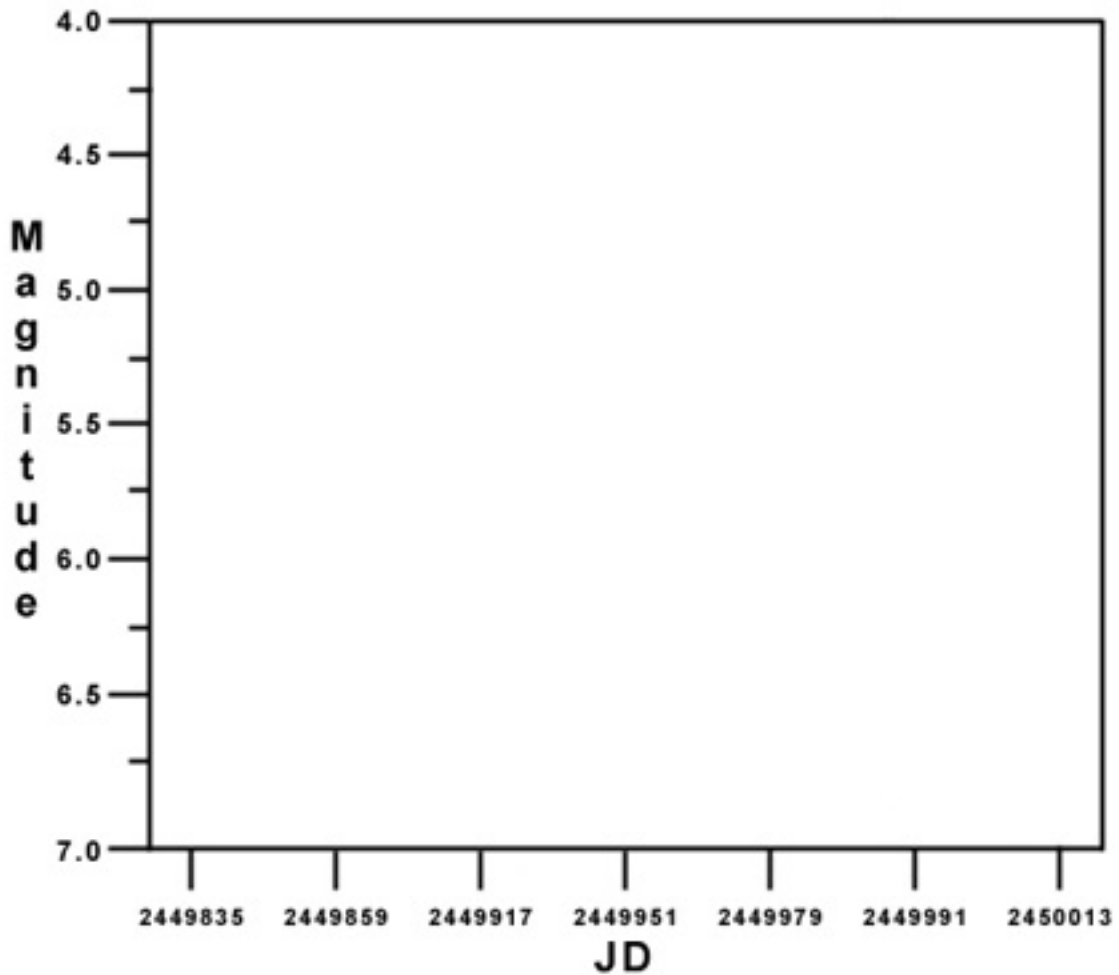




### Plotting Magnitudes

You are now ready to estimate the changing magnitude of an actual variable star. Print the page to plot your magnitude estimations on the graph provided. Place the transparency over each one of the seven Field Slides of W Cyg and record your estimated magnitudes directly onto the graph above the corresponding Julian Day (JD).

Study the resulting light curve. What are the maximum and minimum magnitudes for W Cyg? How many cycles are represented? Can you determine the period? Is this a Cepheid variable star?



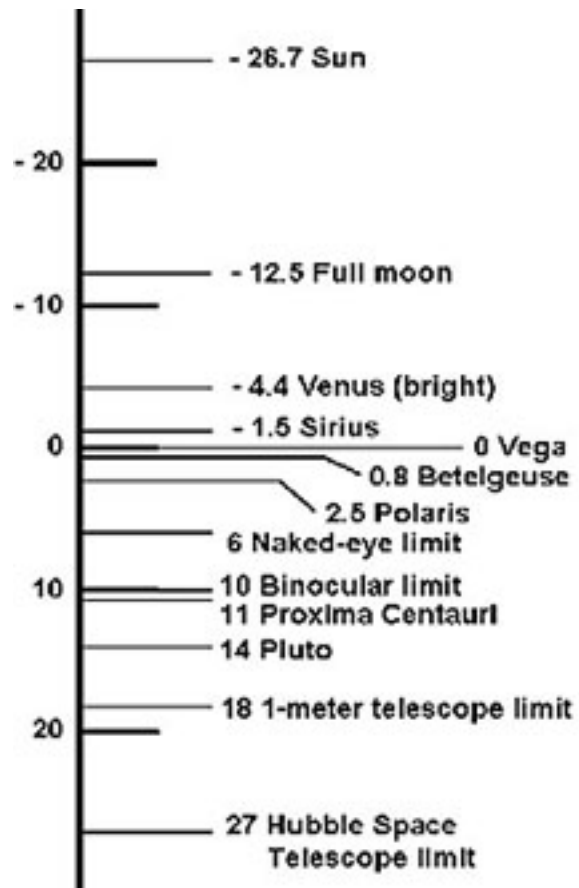


## Magnitudes

The method we use today to compare the apparent brightness (magnitude) of stars began with Hipparchus, a Greek astronomer who lived in the second century BC. Hipparchus called the brightest star in each constellation "first magnitude." Ptolemy, in 140 A.D., refined Hipparchus' system and used a 1 to 6 scale to compare star brightness, with 1 being the brightest and 6 the faintest. This is similar to the system used in ranking tennis players, etc. First rank is better than second, etc. Unfortunately, Ptolemy did not use the brightest star, Sirius, to set the scale, so it has a negative magnitude. (Imagine being ranked -1.5 in the tennis rankings!)

Astronomers in the mid-1800's quantified these numbers and modified the old Greek system. Measurements demonstrated that 1st magnitude stars were 100 times brighter than 6th magnitude stars. It has also been

calculated that the human eye perceives a one-magnitude change as being 2 and 1/2 times brighter, so a change in 5 magnitudes would seem to be 2.5 to the fifth power (or approximately 100) times brighter. Therefore a difference of 5 magnitudes has been defined as being equal to a factor of exactly 100 in apparent brightness.





## Julian Day System

Astronomers simplify their timekeeping by merely counting the days, and not months and years. Each date has a Julian Day number (JD), beginning at noon, which is the number of elapsed days since January 1st, 4713 B.C. For instance, January 1st, 1993, was JD 2448989; January 2nd, 1993, was JD 2448990; and January 1st, 2000, was JD 2451545. Why the year 4713 B.C.? The Julian Day system of numbering the days is a continuous count of days elapsed since the beginning of the Julian Period. This period was devised by Joseph Justus Scaliger, a French classical scholar in the 16th century. Scaliger calculated the Julian Period by multiplying three important chronological cycles: the 28-year solar cycle, the 19-year lunar cycle, and the 15-year cycle of tax assessment called the Roman Indiction. To establish a beginning point for his Julian Day system, Scaliger calculated the closest date before 1 B.C. which marked the first day for the beginning of all three cycles. This day is January 1, 4713 B.C., which is Julian Day number 1.