# Simulation of an Eclipse of WZ Sge

Introduction:

When you observe a star through a telescope and take a picture of it, the CCD camera attached to the telescope can collect light from the star and tell how bright it is. The brighter the star is, the greater the number recorded by the camera.

In the case of almost all stars, you cannot see the stars as anything other than a single point. The light from the stars is combined into a grand total reported by the camera.

In this simulation, we are going to see why an eclipsing binary changes its apparent brightness through simulating the amount of light emitted by it. We will use WZ Sge as our specific example, simulating the system with a paper and pencil model of the inter-acting binary.

In the WZ Sge system, a low-mass brown dwarf orbits a white dwarf surrounded by an accretion disk. The modeling activity explains the structure of the system.

This activity will help you interpret the real measurements of the system made by the Spitzer Space telescope, which is the next ac-tivity.
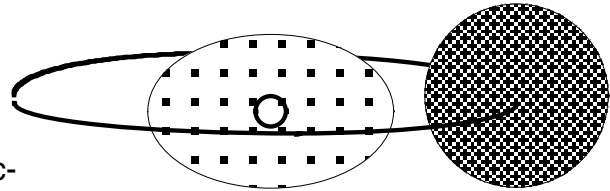
Preparing the model

1. Cut out the two figures on the last page. The squares represent surface area that we can see.

2. In the oval shaped figure, representing a white dwarf and its accretion disk, write a '5' in each box. In the center of this figure, enter a '30' in the small circle.

3. In the circular shaped figure, which represents the brown dwarf, write a '1' in each box.

4. The squares represent the readings a CCD camera might capture if the object were close enough for us to resolve as larger than a point. Adding all the numbers to-gether represents the brightness of the system as observed with a telescope and camera.

5. If the system eclipses, one of the objects passes in front of the other and blocks the light from it. This reduces the total brightness of the system.

6. Begin by placing the two objects side by side, with the brown dwarf (circle) on the left. Add up all the numbers on both objects and write down the total in the first line of the data table.

Simulating the orbit
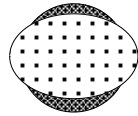
Using Figure 1 as a guide, slide the figures around to simulate the motion of the brown dwarf as it orbits the white dwarf and its accretion disk. The system is seen edge on, so sometimes the brown dwarf is in front of the white dwarf, and sometimes the white dwarf is in front of the brown dwarf. Sometimes one or the other is only partially obscured.
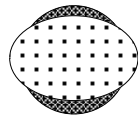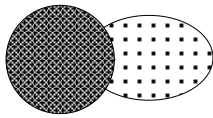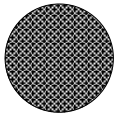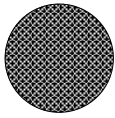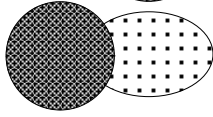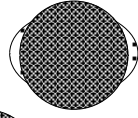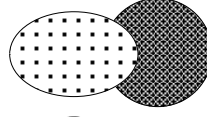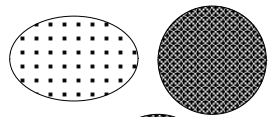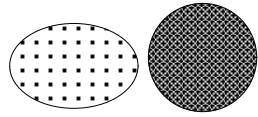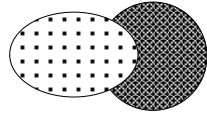
Taking simulated measurements

For each of the 11 positions shown in the diagram at left, count all the boxes you can see and multiply by the number inside the box. If you saw 100 boxes with a 1, you would count the total brightness for that portion as 100. If you see 30 boxes with a 5, you would count the total brightness for that portion as 150. Add the total brightness seen for each shape together. If some boxes are partially covered, do not count them.

Take a simulated measurement for each of the positions shown in the figure. Record your measurements in the data table.

Prepare a light curve

When you are finished, plot the points on the light curve grid provided. Next, label the graph with the following positions:
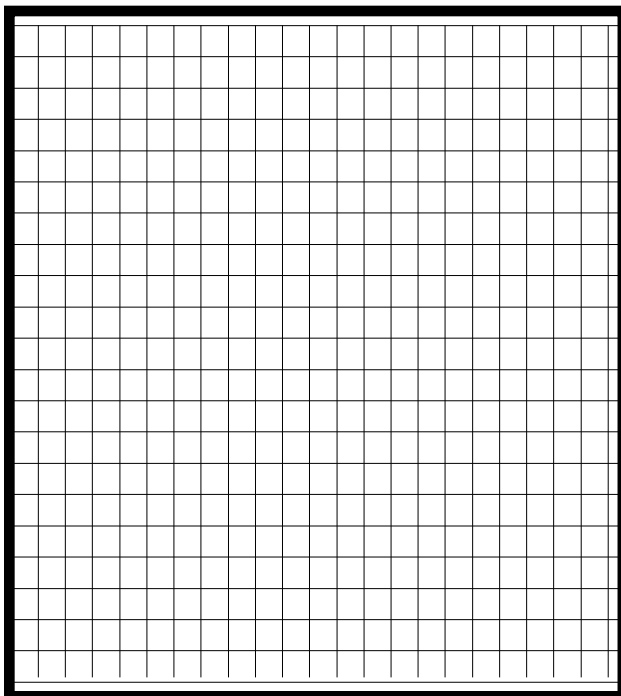
A) The location where the white dwarf is directly in front of the brown dwarf

B) The location where the brown dwarf is directly in front of the white dwarf

C) The location(s) where neither object obscures the other object

Figure 1.

D) The period of time representing one complete orbit of the system. (Use an arrow indicating where the period starts to where it ends.)

Name_____ Date _____ Period_____

Data Table

Position number	Total brightness of brown dwarf	Total brightness of white dwarf & accretion disk	Total brightness of system
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10			
11.			

Graphing

Use total brightness on the 'y'axis, and position number (representing 'time') on the x axis.

You will need to pick a scale that makes the graph as large as possible on the grid.

Make sure you label the axes with "total brightness" and "time".

It is generally not necessary to connect the dots in experiments using real data. However, in this simulated experiment, it may help you see the trends better if you do connect the dots.

Name_____ Date _____ Period_____

What if Questions

1. What if the brown dwarf were much smaller than the white dwarf and its accretion disk? How would the graph change?

2. What would the graph look like if the system were face on (seen from above)?

3. What if the white dwarf and accretion disk were very small compared to the brown dwarf? How would the graph look then?

4. What would the graph look like if the two objects were nearly the same overall brightness?

5. If the accretion disk had a bright, hot spot (say, one box with a 12 in it) how would the graph change?

6. The white dwarf is simulated by a small, bright spot at the center of the accretion disk. The disk itself is, overall, brighter than the white dwarf within it. How can this be if the white dwarf is represented by the largest number in the diagram?

7. Describe some of the problems with this paper model in terms of how it does and does not represent the actual cataclysmic binary system Wz Sge.
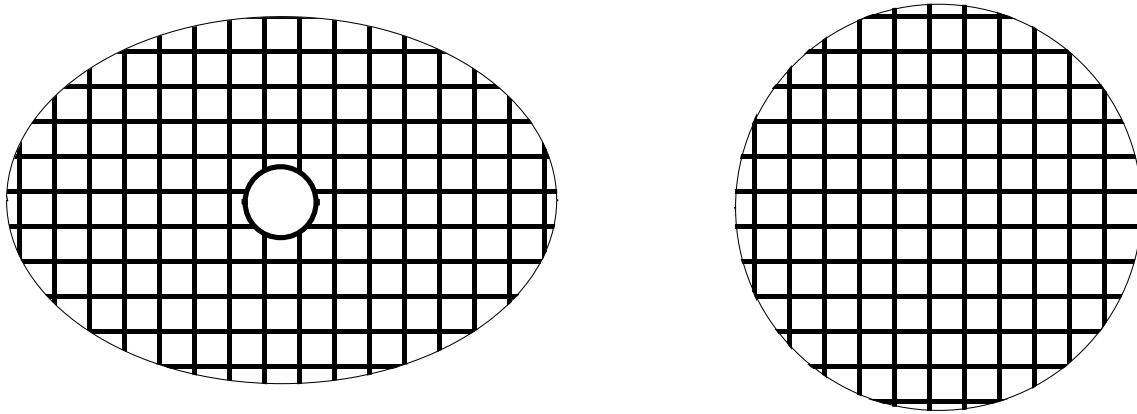
Cut Out Page

Figure 2. Cut out these shapes. The circle is the brown dwarf and the oval is the accretion disk and white dwarf.

Do not enter values in fractional squares.

For the brown dwarf, enter a '1' in every whole square.

For the accretion disk, enter a '5' in every whole square.

For the white dwarf (the small circle in the center of the oval) enter '30'.

Key to Questions

1. What if the brown dwarf were much smaller than the white dwarf and its accretion disk? How would the graph change?

If the brown dwarf were smaller the dip in the graph that occurs when the brown dwarf is in front would not be as deep, and there would be a period of time when it stays at a reduced brightness ...the dip of the graph would be flat on the bottom instead of a point.

2. What would the graph look like if the system were face on (seen from above)?

No eclipse would occur and the graph would be flat, always the same brightness as long as the system is stable and not erupting.

3. What if the white dwarf and accretion disk were very small compared to the brown dwarf? How would the graph look then?

The graph would drop much more when the white dwarf and its accretion disk are obscured. The graph would drop less when the white dwarf is in front of the brown dwarf.

4. What would the graph look like if the two objects were nearly the same overall brightness?

The two dips in the graph would be approximately the same depth.

5. If the accretion disk had a bright, hot spot (say, one box with a 12 in it) how would the graph change?

There would be a small, but detectable drop in overall brightness suddenly when the hot spot is covered. The reverse would happen when it is uncovered. In a three dimensional system sometimes the hot spot would be on the other side of the system and it may or may not be visible then.

6. The white dwarf is simulated by a small, bright spot at the center of the accretion disk. The disk itself is, overall, brighter than the white dwarf within it. How can this be if the white dwarf is represented by the largest number in the diagram?

Even though the white dwarf has the brightest individual number on the simulation, the disk emits more light overall because it has a greater surface area.

7. Describe some of the problems with this paper model in terms of how it does and does not represent the actual cataclysmic binary system Wz Sge.

There are many compromises made in the simulation. First the surface brightness of the objects is not uniform. The simulation does not account for the inclination of the system, the presence of a hot spot, or the fact that the brown dwarf is not symmetrical.