CATACLYSMIC VARIABLES PRELAB

1. What makes CV's special?
2. What kind of information can you derive from CV light curves?
3. If you see such a system and it has an almost constant light output between flares, how are you viewing it?
4. How bright of an outburst can you observe in CV's, in magnitudes?

CATACLYSMIC VARIABLES

What will you learn in this Lab?

This lab will introduce you to another type of variable stars – Cataclysmic Variables. These are stars that undergo changes in their apparent and intrinsic brightness due to massive explosions or mass transfer events on their surfaces. This is a relatively poorly understood field in astronomy, so a major component of research in this area involves getting as much new data on this type of star as possible. You will use some real light curves acquired at ASU's Braeside Observatory to investigate them further.

What do I need to bring to the Class with me to do this Lab?

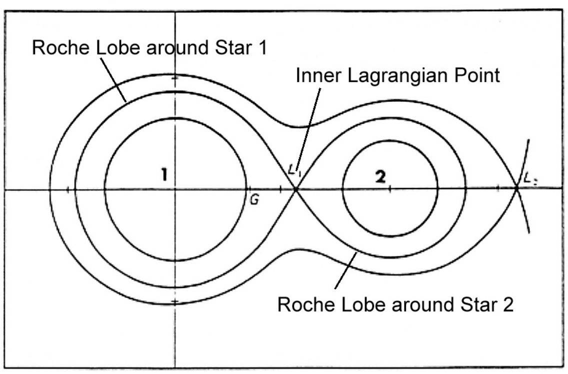
For this lab you will need:

- A copy of this lab script
- A pencil
- A scientific calculator

Introduction:

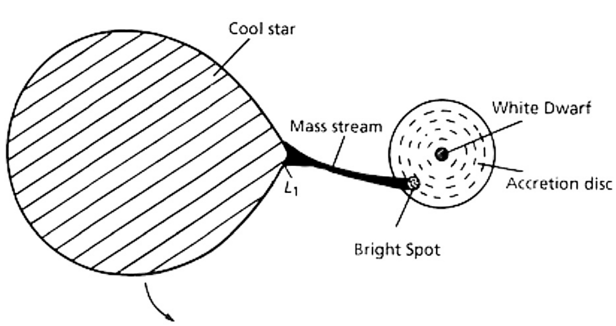
When initially exposed to the field of Cataclysmic Variables (CV's), it is easy to become quite overwhelmed. There are as many different categories of CV's as there are distinct explosive types, usually named after the first or brightest example discovered, eg. SU UMa stars. It is not far wrong to describe this field as more of an exercise in zoology than anything else at this time. Astronomers are employing every opportunity to observe, and continue to observe, as many of these stars as possible to gain more clues about their complex and violent nature.

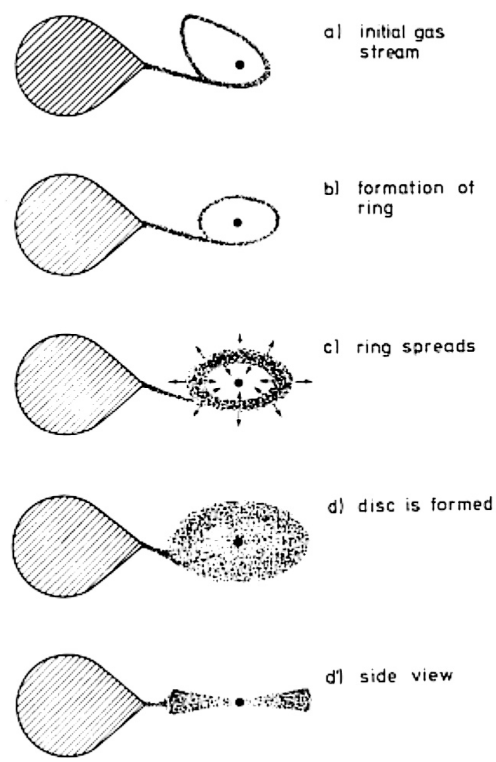
The Nature of the Beast



CV's are almost all binary star systems – two stars orbiting each other at varying distances, but close enough to affect each other physically. In most cases they are comprised of a small bright star married with a large cooler star. The small star is the more massive of the two (quite counterintuitively) and is in the process of stripping material away from the larger star through their mutual Lagrangian point that joins their Roche lobes. [*Review*: the Roche lobe marks the boundary to the zone within which that star controls any material through its gravity. Outside that boundary material is free to be attracted by either star].

As the smaller star attracts more material, its Roche lobe increases in size (because its mass, and therefore gravitational field, increase), perpetuating the process. As the material tries to fall onto the smaller star its spirals into an





accretion disk around the star. This disk becomes heated by both the viscous action of the gas in the disk and the heating from the star itself. Ultimately the disk glows quite intensely, contributing directly to the brightness of the system. The material that falls onto the disk in a well-defined location called the *hot spot*. This spot is usually very bright and can be distinctly seen in light curves when it is eclipsed or rotates out of our field of view.

Quiescent States

Most CV's spend their time in what's called a *Quiescent State*, not doing too much of anything. In this state there is little if any mass transfer going on, and what there is contributes little additional energy to the accretion disk. This state is usually marked observationally by a simple, regular oscillation in apparent brightness if the system is seen "edge-on" as the system rotates and alternately eclipses each component. Such light curves allow us to make estimates of the brightness of each component separately.

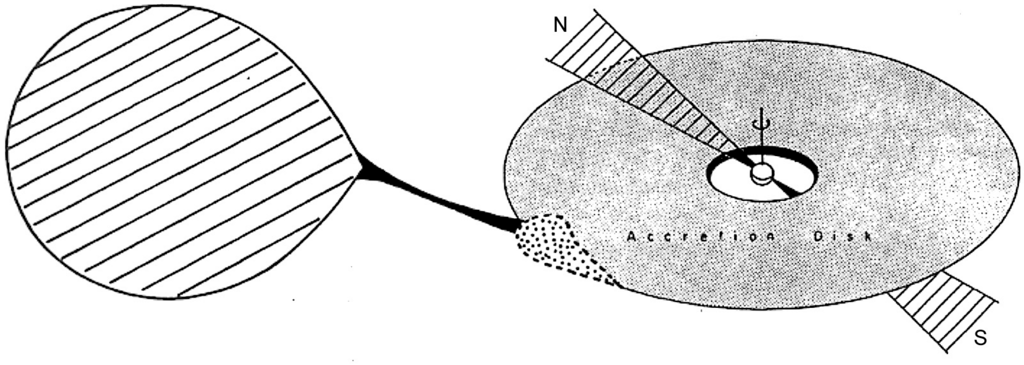
Similarly, star systems that are much further apart will look this way because they are never close enough to engage in mass transfer and therefore affect the systems brightness.

Systems that have an almost constant brightness output are generally being viewed from above or below the orbital plane and therefore no eclipsing occurs along our line of sight (see figure above).

Properties that can be derived for this class of star include the orbital period for eclipsing systems, the relative brightness of the two stars (how much brighter one star is than the other), and whether the variations in brightness are symmetric or lop-sided. This will tell astronomers if the stars are affecting each other at all (warping each other with gravity) or whether they're simply orbiting each other well outside of each other's sphere of influence.

DQ Her Stars

These stars are characterized by a relatively short period of several hours in their light curves, interspersed by a very bright peak in brightness about 2-3 magnitudes in height. This peak in brightness corresponds to the *hot spot* coming into view as the system rotates. These systems are generally seen as eclipsers or close to it.

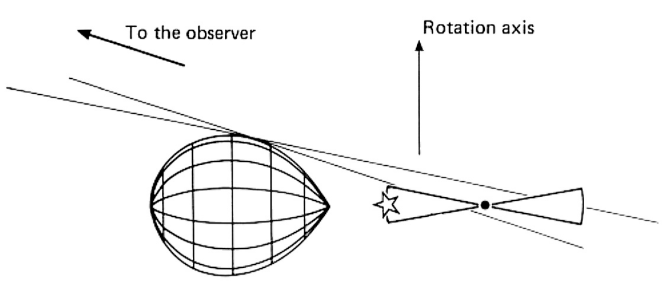


This is the common view of DQ Her stars – a magnetized, fast rotating neutron star surrounded by the accretion disk with a powerful hot spot on the outer edge of the disk. This hot spot is only seen at certain very discrete times in the orbital sequence when the emission peaks. Also superimposed upon the light curve is a high frequency component that corresponds to the fast rotation rate of the central bright star as it illuminates the disk with a *searchlight* beam of emission along its magnetic polar axis (see diagram).

Properties that can be measured with this type of star are the orbital period of the two stars, the surge in brightness of the hot spot, and the degree to which the background brightness (of the disk) is changing with time. In some cases you can resolve the flickering in the disk emission, which gives you the rotation period of the neutron star directly. All these properties affect models of the system and tell us information about the physics of the system.

U Gem Stars

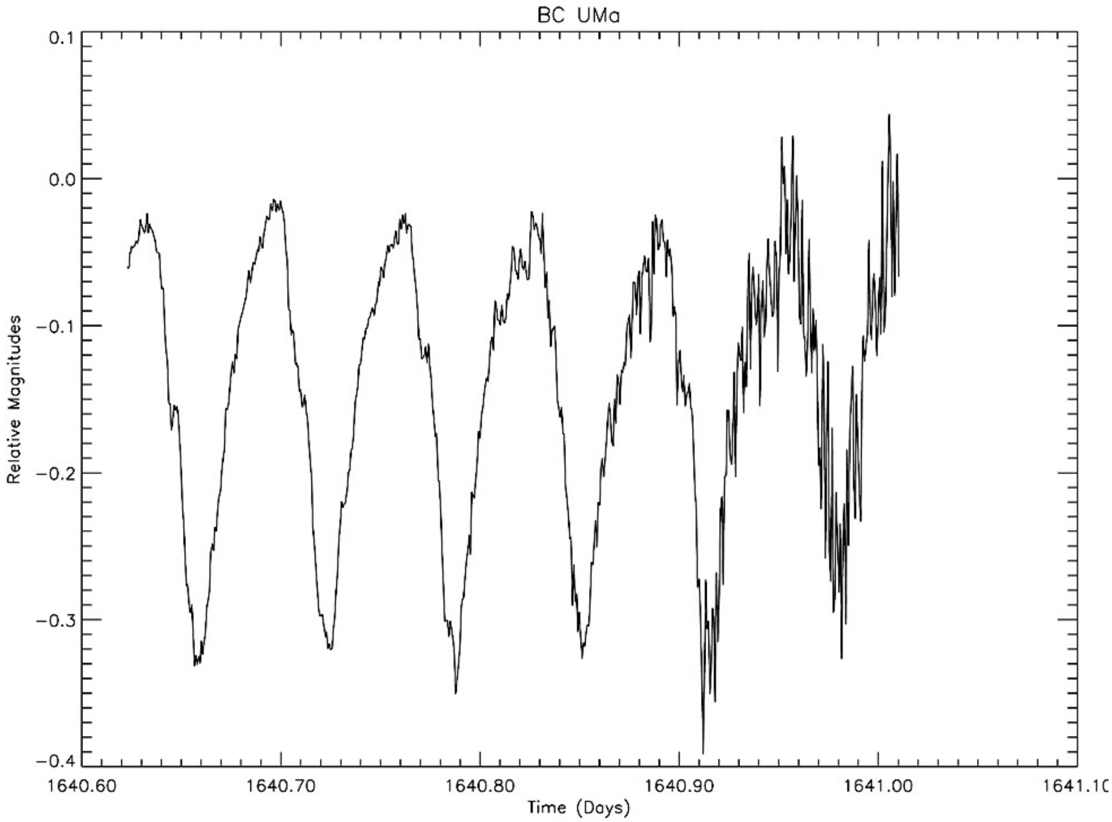
These are binary systems that do not eclipse as dramatically as DQ Her stars, but have a very distended and teardrop shaped secondary star that partially obscures and exposes the bright accretion disk as the system rotates. Again there is a surge in brightness as the hot spot comes into view, but there is also a *hump* in the light curve at a lower level that reflects the alternate obscuration and exposure of bright parts of the disk by the intervening outer layers of the secondary star, see below.

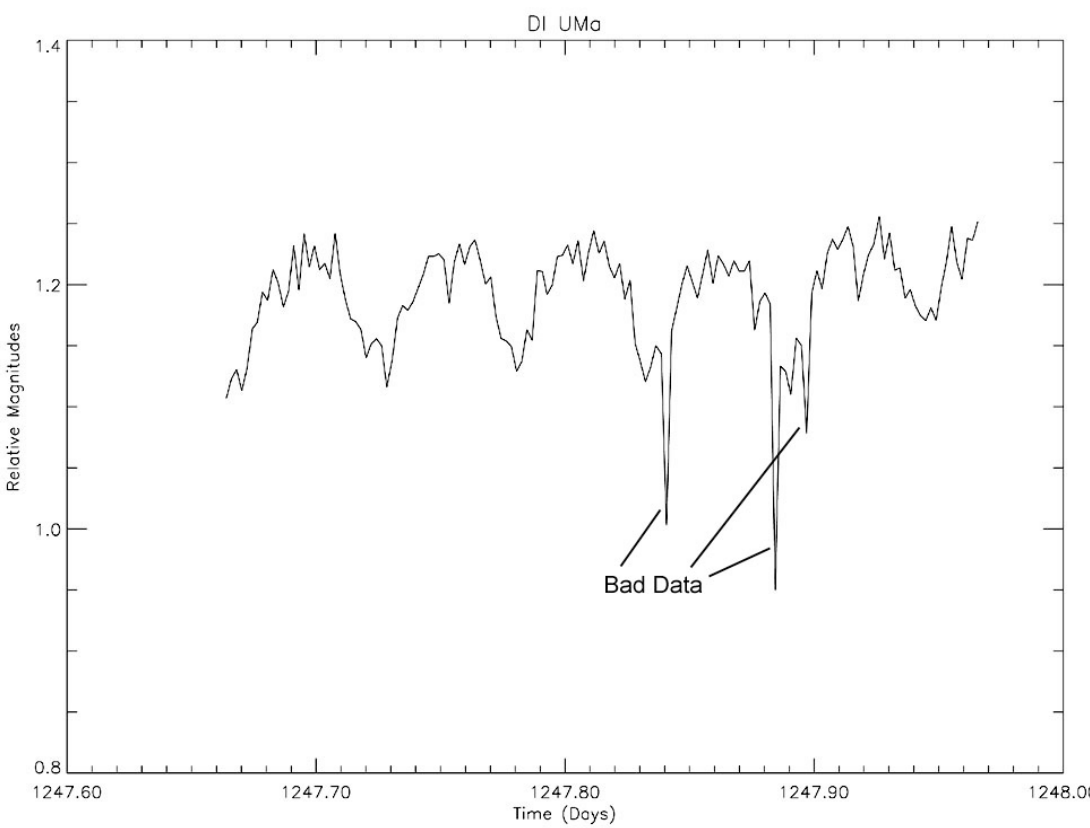


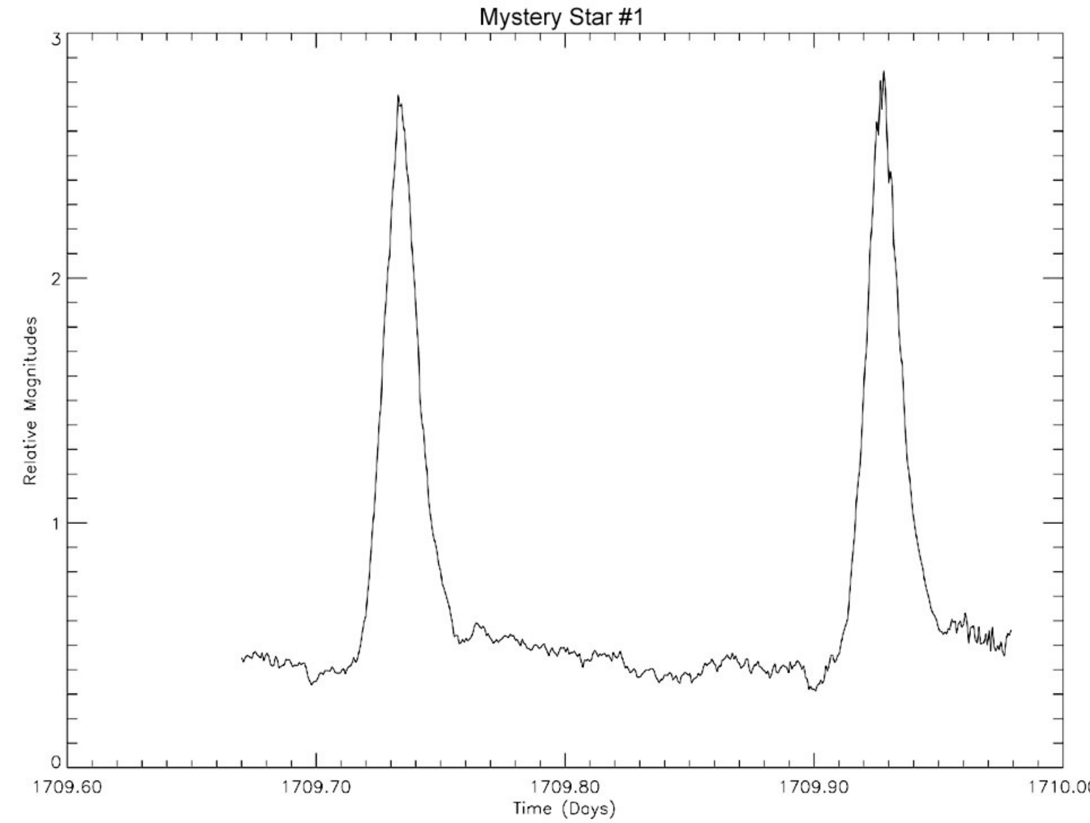
Properties of these stars that can be derived are: orbital period, the magnitude of the *hump* variation as a percentage of the total light, the size of the hot spot peak, and how long (as a fraction of the total orbital period) that the eclipse of the disk lasts as it passes out of view behind the larger star. The length of time the hot spot is seen is also a constraint on models of such systems since it gives us a feel for how flared the outer edge of the accretion disk is.

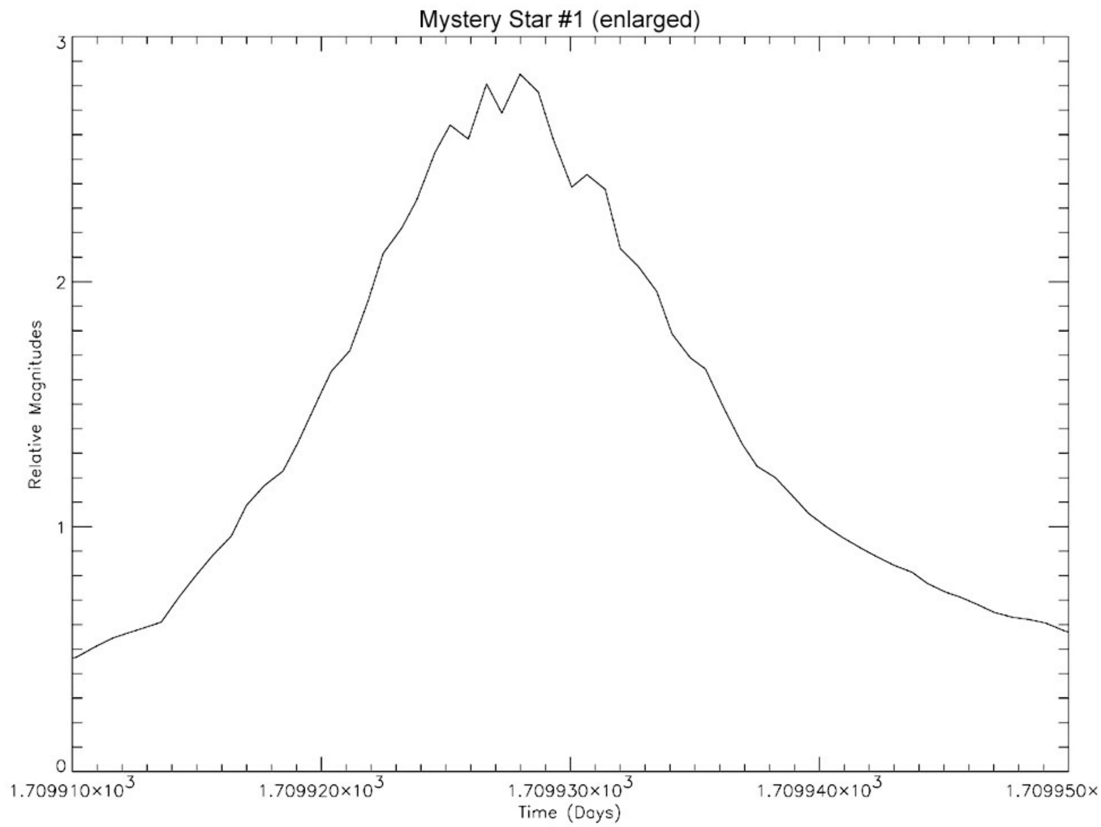
Procedure

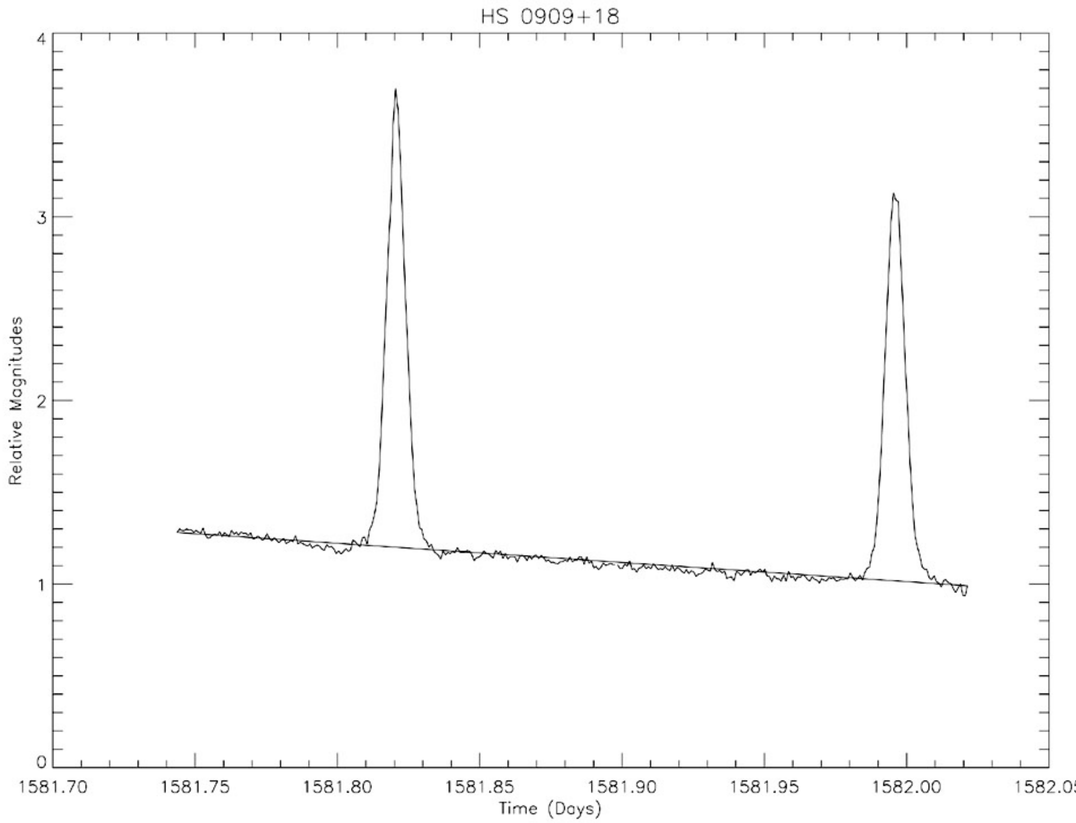
We're going to give you some real light curves obtained from ASU's Braeside Observatory in Flagstaff, Arizona. Pay attention to the legends on each axis, and study the characteristics of the light curves when compared to the discussions above. See if you can figure out what types of CV's you're looking at, and once you've made your decision, try and figure out what other properties you can derive.

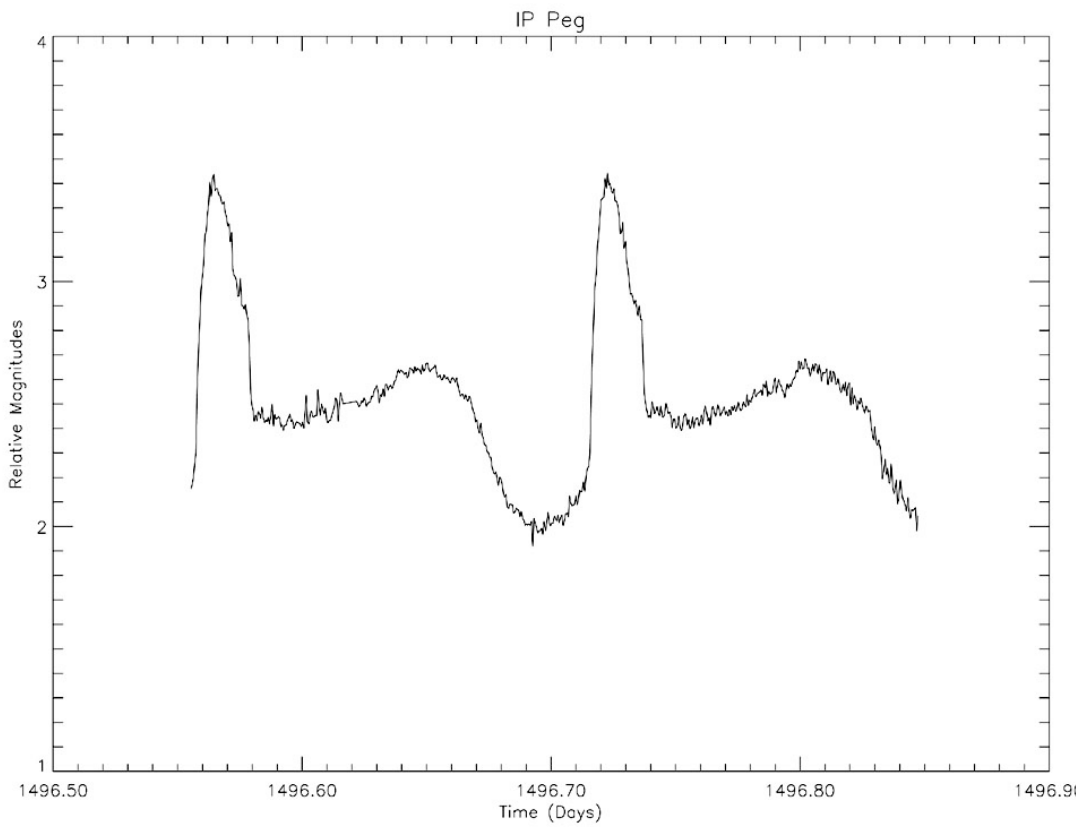

BC UMa
Relative Magnitudes
Time (Days)
0.1
0.0
−0.1
−0.2
−0.3
−0.4
1640.60
1640.70
1640.80
1640.90
1641.00
1641.10

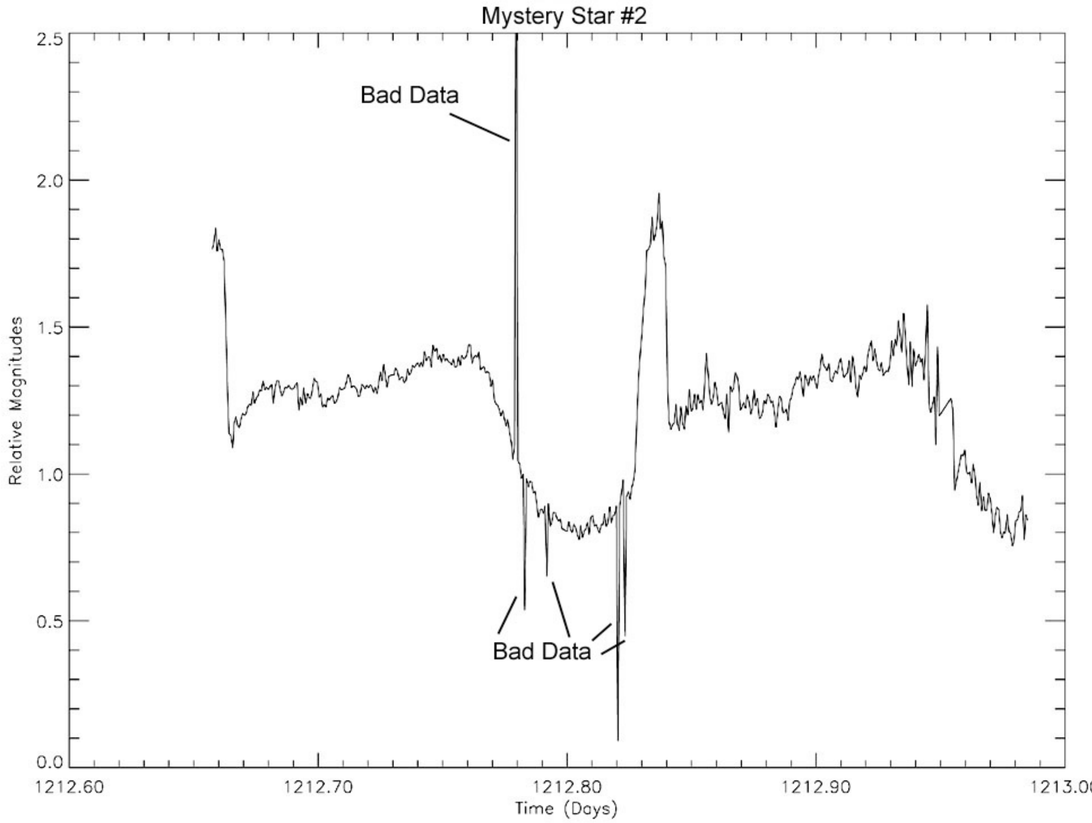

DI UMa
Relative Magnitudes
Time (Days)
Bad Data
1.4
1.2
1.0
0.8
1247.60
1247.70
1247.80
1247.90
1248.00


Mystery Star #1
Relative Magnitudes
Time (Days)
0
1
2
3
1709.60
1709.70
1709.80
1709.90
1710.0C


Mystery Star #1 (enlarged)
Relative Magnitudes
Time (Days)
0
1
2
3
1.709910×10³
1.709920×10³
1.709930×10³
1.709940×10³
1.709950×


HS 0909+18
Relative Magnitudes
0
1
2
3
4
1581.70
1581.75
1581.80
1581.85
1581.90
1581.95
1582.00
Time (Days)


IP Peg
Relative Magnitudes
1
2
3
4
1496.50
1496.60
1496.70
1496.80
Time (Days)



For each star state your case plainly, and rationalize how you came to your decisions in light of the properties of each system.

Discuss the limitations of this approach and how confident you feel in your allocations. What aspects are you confident in, and what aspects are you not?

Questions

Your lab report should include answers to the following questions:

1. Given what you've been told about CV's, what are the primary defining points about these objects that make them so interesting?
2. Did you find examples of the (limited) set of CV's presented here? Be aware that there are as many as a dozen individual classifications of CV's. Why do you suppose there are so many distinct types given that most, if not all, are explainable by an accreting binary model?
3. Did you find any evidence of *flicker* due to the fast rotation of a neutron star? If so, given that these objects are only about 100 km in diameter, what is the equatorial rotation speed of these objects? [Compare this to the equatorial rotation speed of about 1600 km/hr for Earth]
4. Look at the time scales on the graphs. About how often do you need to take a brightness measurement to be able to track the evolution/rotation of such objects?

