Center for Backyard Astrophysics-Arkansas

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Astrophysics Anyone?

Are you bored of the beaten Messier path and trying to attain pretty pictures of faint fuzzy things? Let the stars get into your eyes!

Get INVOLVED in astronomical research. Apply your knowledge and skills.

Amateur-Professional Research Collaborations

Observations of Variable Stars

- Supernovae patrol
- Nova discovery
- Binary stars
- Pulsating stars

Minor Planet Searches

- Comet Discovery and Orbit Determination
- Asteroid Detection and Orbit Determination
- Asteroid Rotation Curves

Inspirational and Serendipitous Imagery

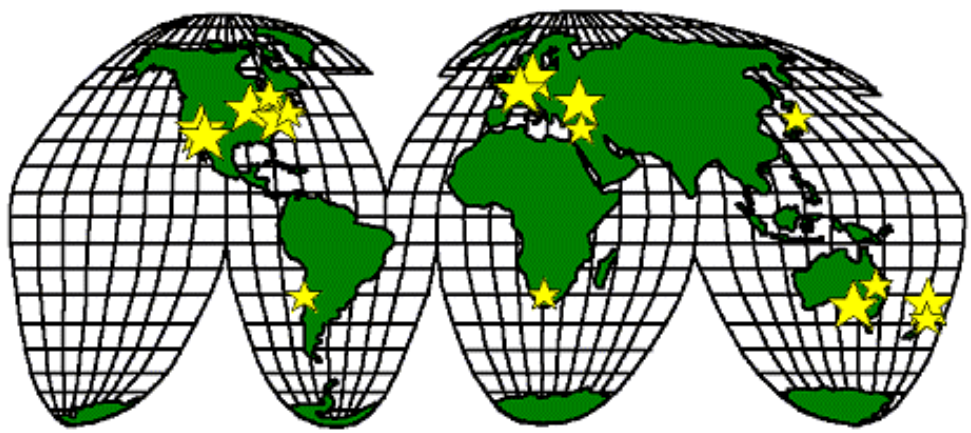
- Nebulosities, Space Shuttle, Aurora

Arkansas

Center for Backyard Astrophysics

(CBA)

A global network of small telescopes dedicated to photometry of cataclysmic variables.

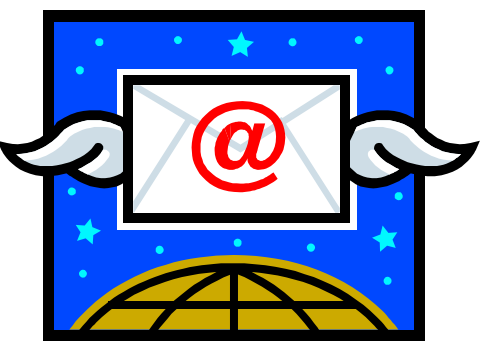


CBA Essentials "The Toys"

A TELESCOPE: Most members telescopes are in the range 8"-24" but we'll trade aperture for drive quality any day. A good drive and even a 6" can do great work on brighter variables.

A DETECTOR: A CCD camera is definitely a must. Sometimes we supplement with photometric and spectroscopic observations at professional observatories. The SBIG STx cameras are popular for a variety of reasons, including low cost.

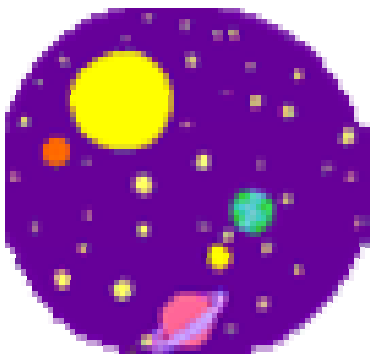
A COMPUTER: Surprisingly, an old 486 is as "advanced" as you need for doing this kind of work. A Pentium, lots of RAM and high CPU speeds are of course exceedingly helpful.



E-MAIL: Rapid communication is essential, corresponding with people around the world. The universe is a VERY active place.

Other Equipment

Software: Astronomical imaging comes in two flavors, acquisition (easy) and analysis (hard). CCDs always come with commercial software solutions to acquire data. Dealing with that data is another story. We typically collect hundreds of images in sequence for time series and there is still not an easy, fast, portable solution for obtaining the final desired product, differential magnitude versus julian day. We do have suggestions, some may be good for you.



Charts and Atlases: We've got 'em, and we share 'em. We can't have anyone lost out there in the universe.

THE MOST IMPORTANT FACTOR OF ALL; LOVE: Not a tool , but a mere necessity, ***an enduring love of stargazing and the desire to couple that with astronomical research.*** This is a demanding activity that will test both.

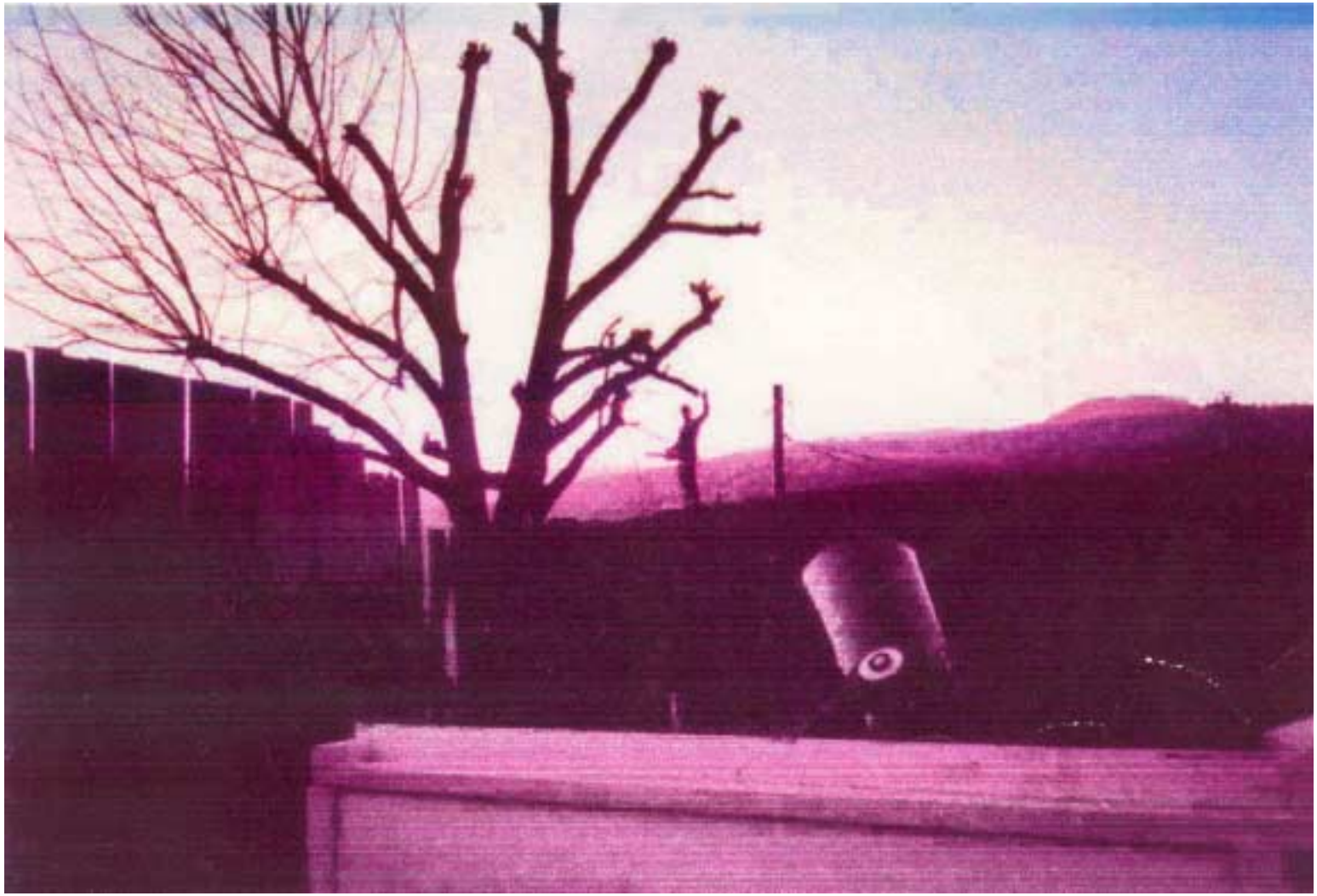
We Want You

"My biggest fear is that people won't observe because they can't…
-get the right comparison star on the chip
-don't have the right filter or right equipment
-can't perfect their flat fielding, etc.

The CBA is sort of like an infantry charge up a well-defended hill. Grab SOMETHING that looks like a weapon, tone up that ol' blood-curdling scream, and join the charge. Don't wait for the supply sergeant to issue better weapons. Sling lead into the enemy ranks and keep the pressure up. At the very least, maybe you'll take a bullet which would have otherwise wiped out some really fancy telescope."

--- Joe Patterson (de facto CBA director)

Passion, Dedication or Maniacal?

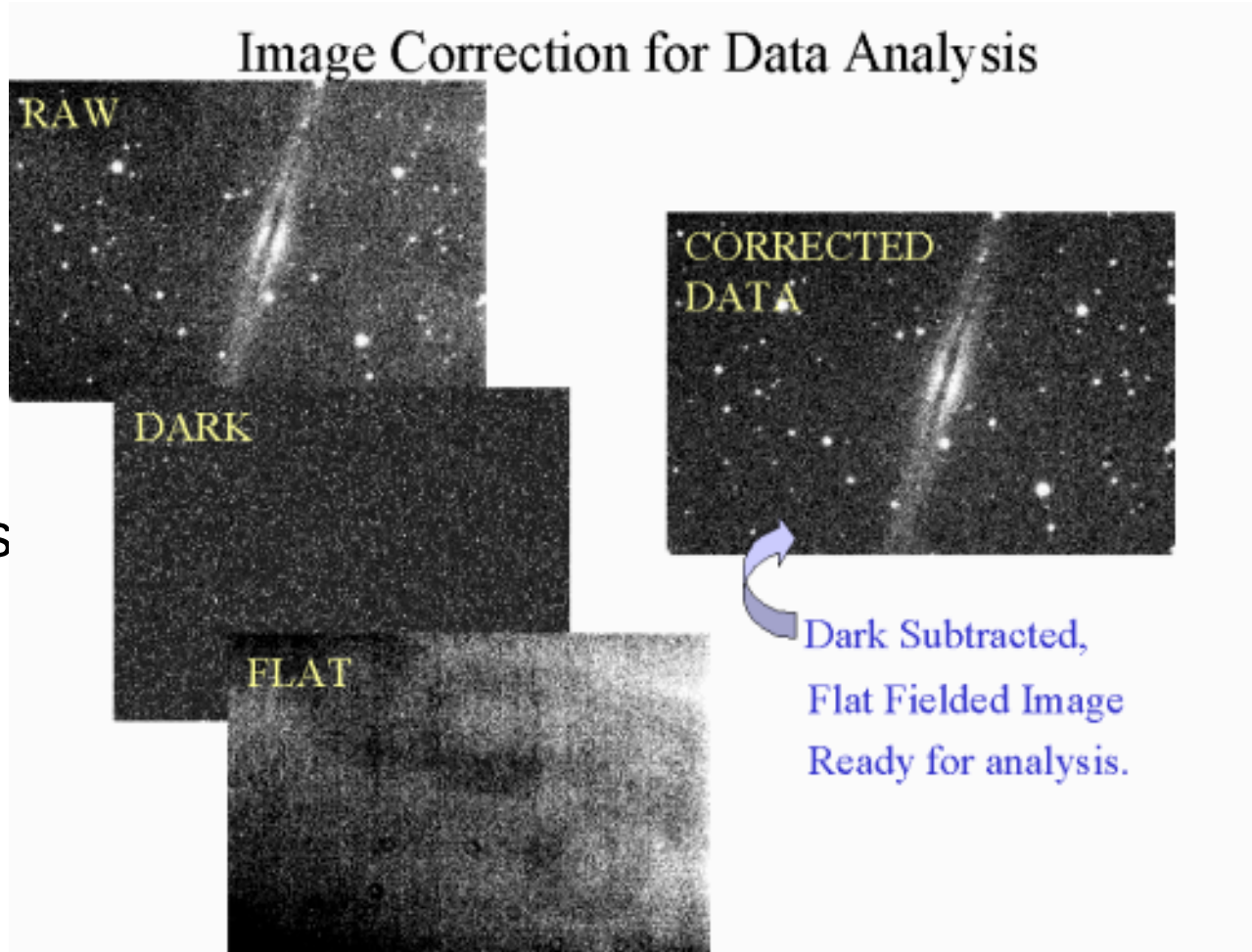


Amateur astronomer Tut Campbell's Whispering Pines Observatory (Harrison Arkansas), shortly after learning that the star we desired to study was coming up rather early in the evening in an inconvenient location along the horizon.

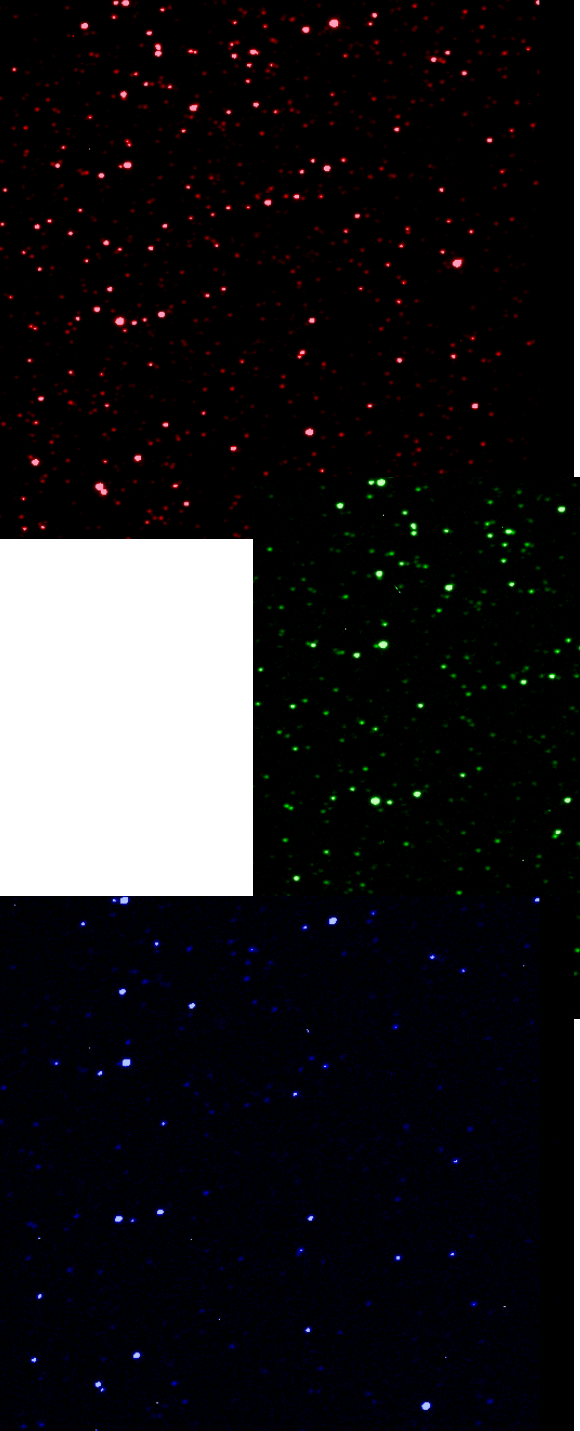
Photometry

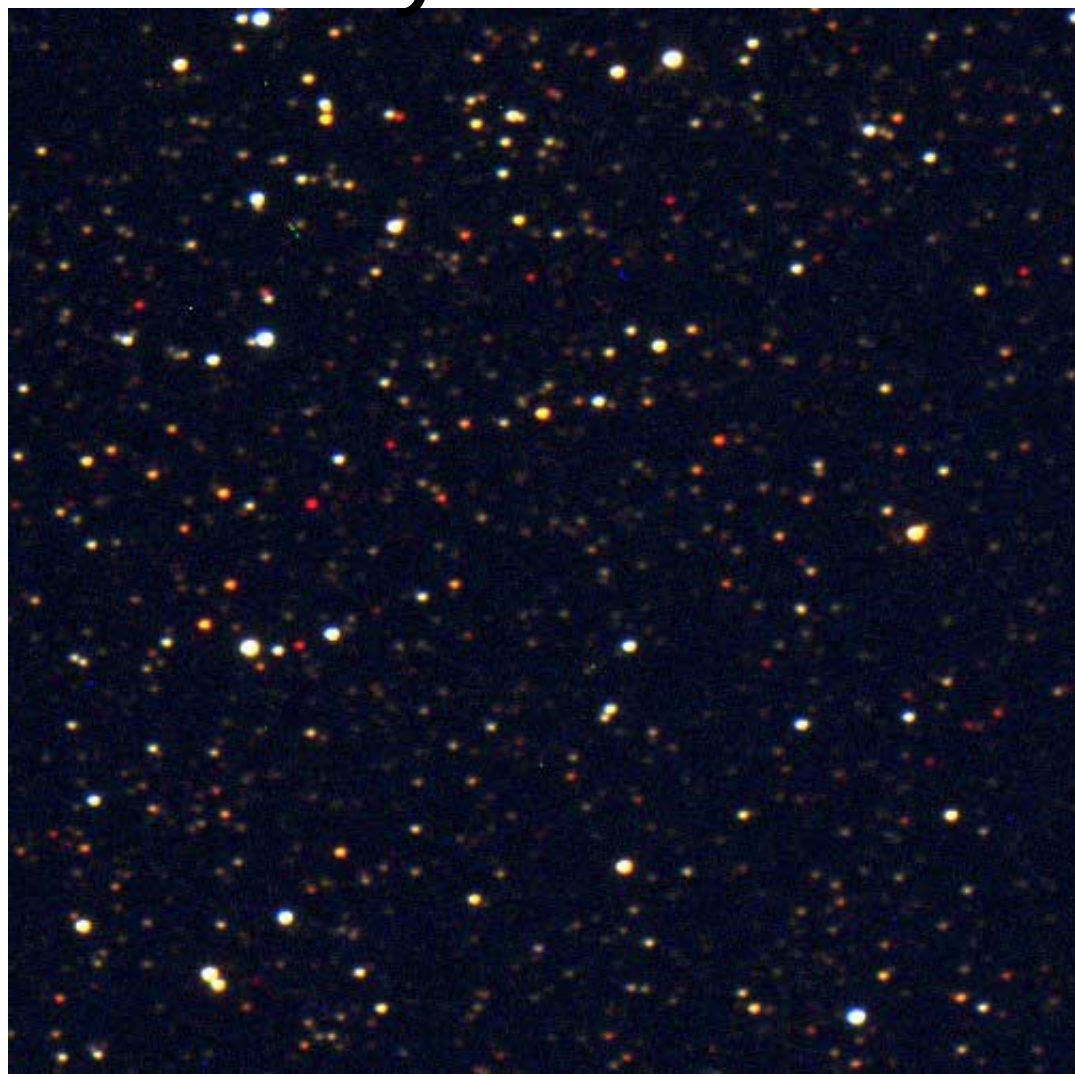
Photometric CCD imaging is used to create light curves which are then analyzed to determine the characteristics of interacting binary systems.

- Orbital parameters
  - Orbital periods
  - Eclipse geometries
  - Inclinations
- Physical parameters
  - Temperatures
  - Sizes
  - Masses



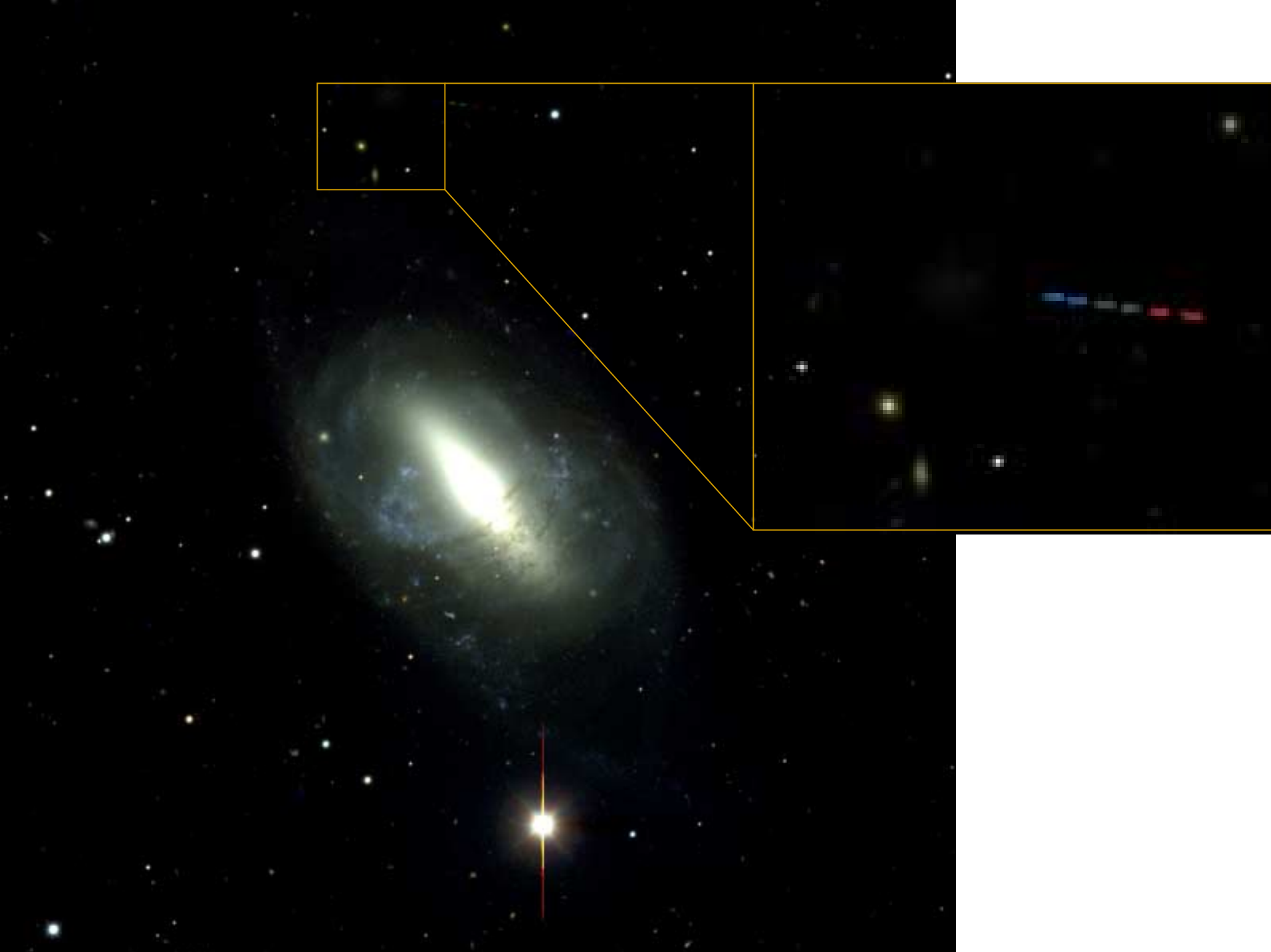
Photometry



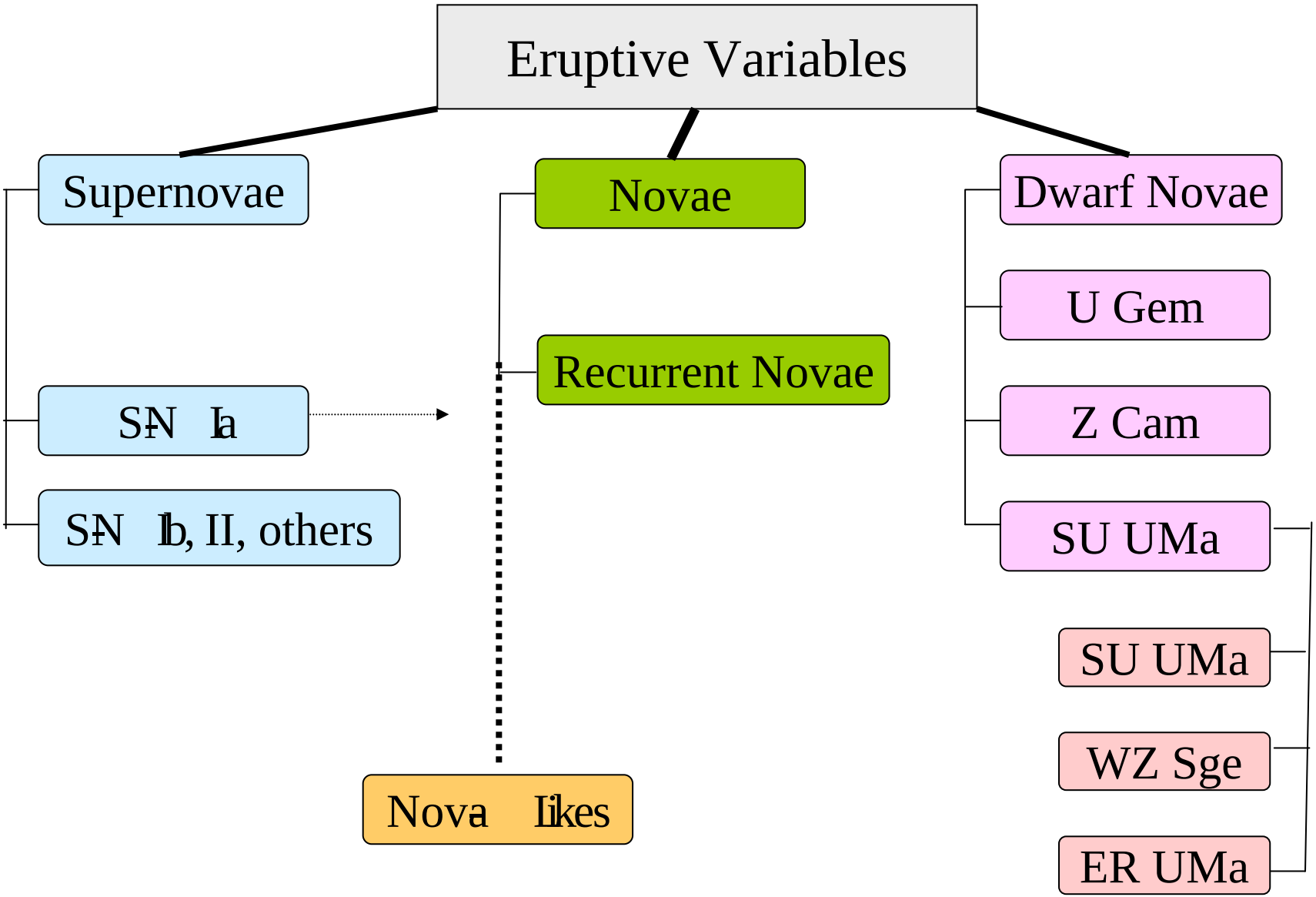


Of course you can also make pretty pictures!

But the manipulation is not always good for science

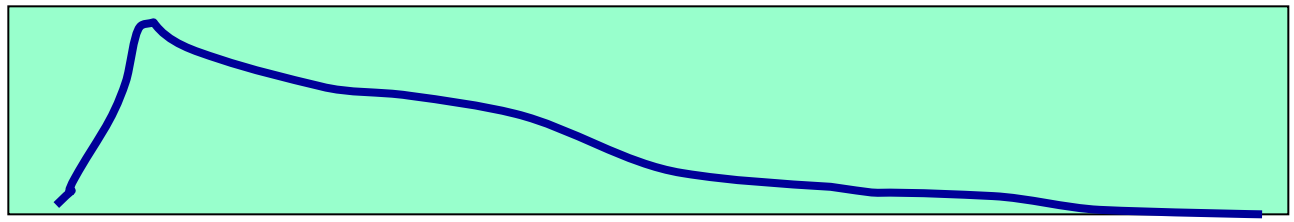


Cataclysmic Variable Taxonomy



Cataclysmic Variable Outburst Behaviors

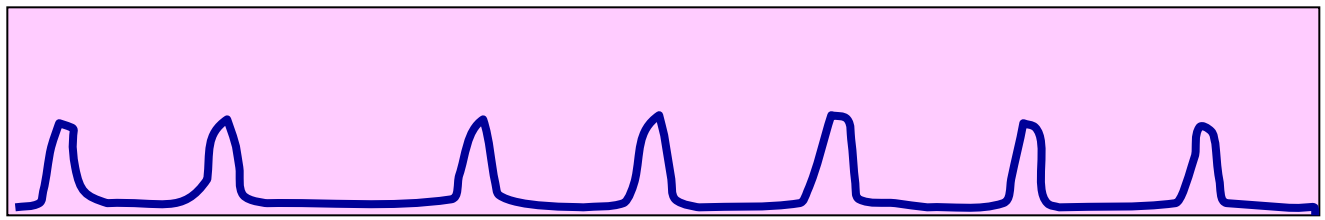
Novae



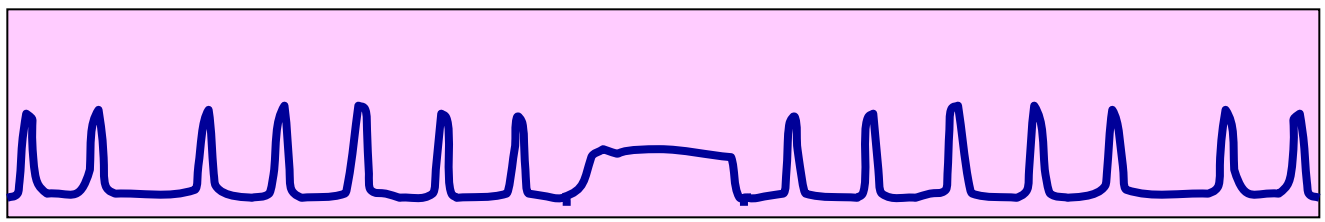
Weeks to months

Dwarf Novae

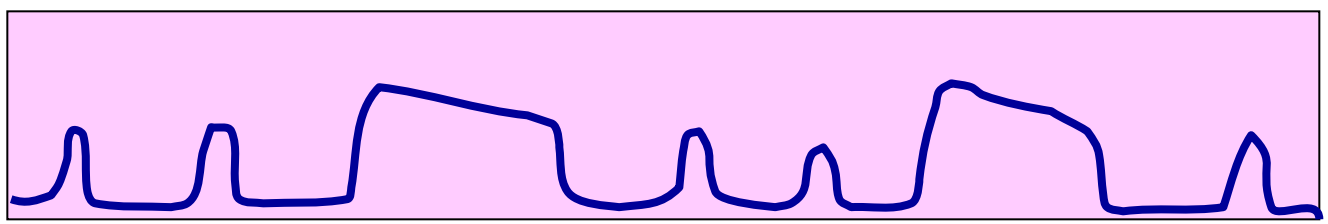
U Gem



Z Cam

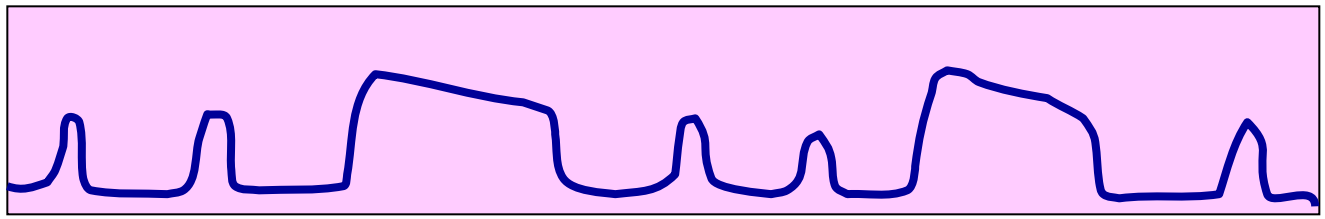


SU UMa



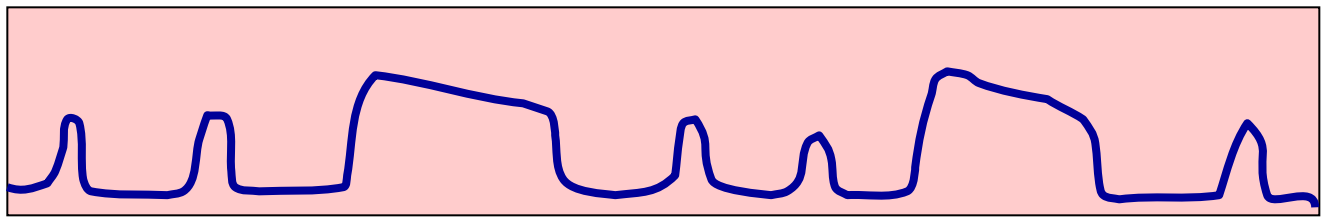
SU UMa-type Dwarf Novae Outbursts

SU UMa

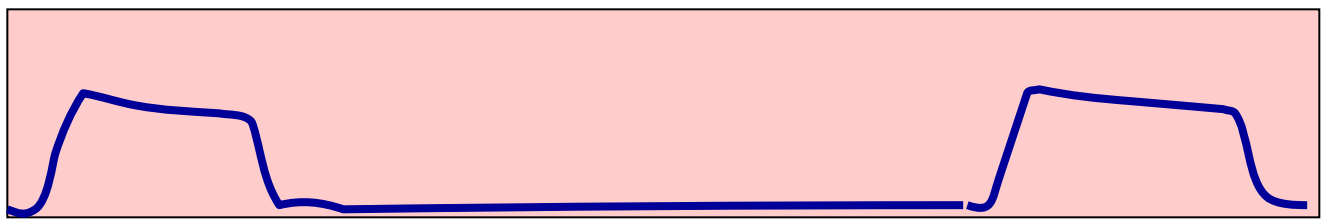


Weeks to months

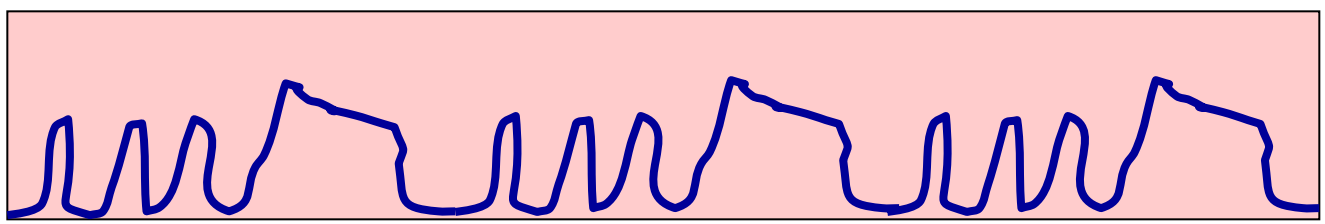
SU UMa



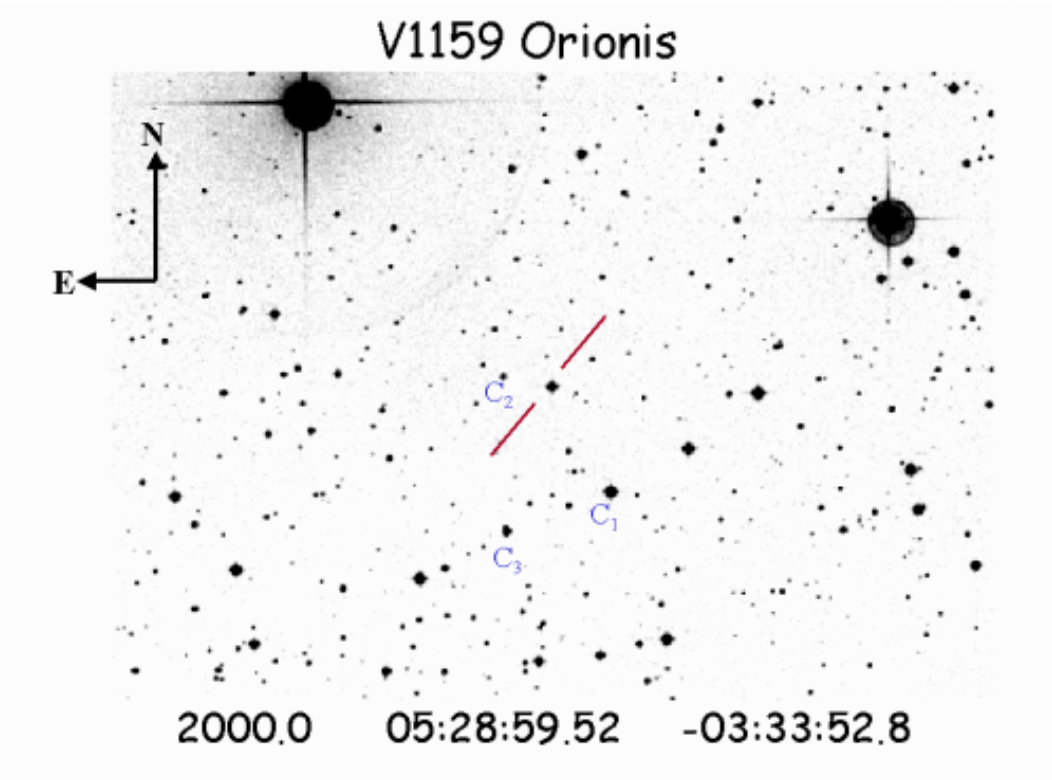
WZ Sge

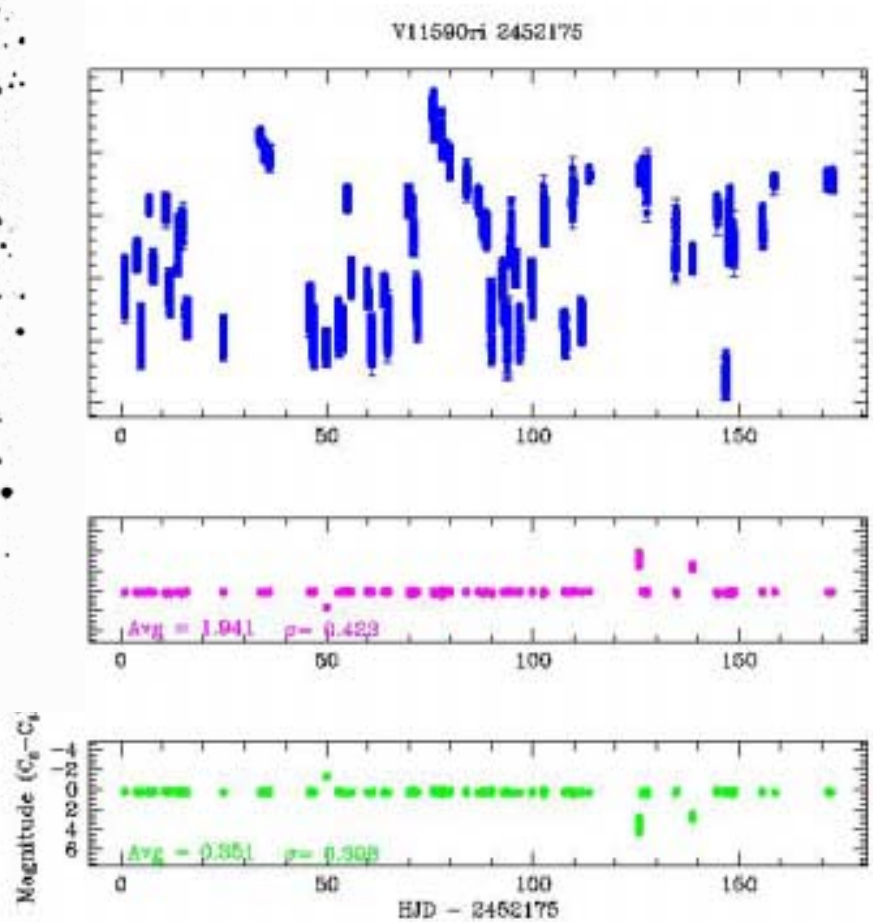


ER UMa



An SU UMa System



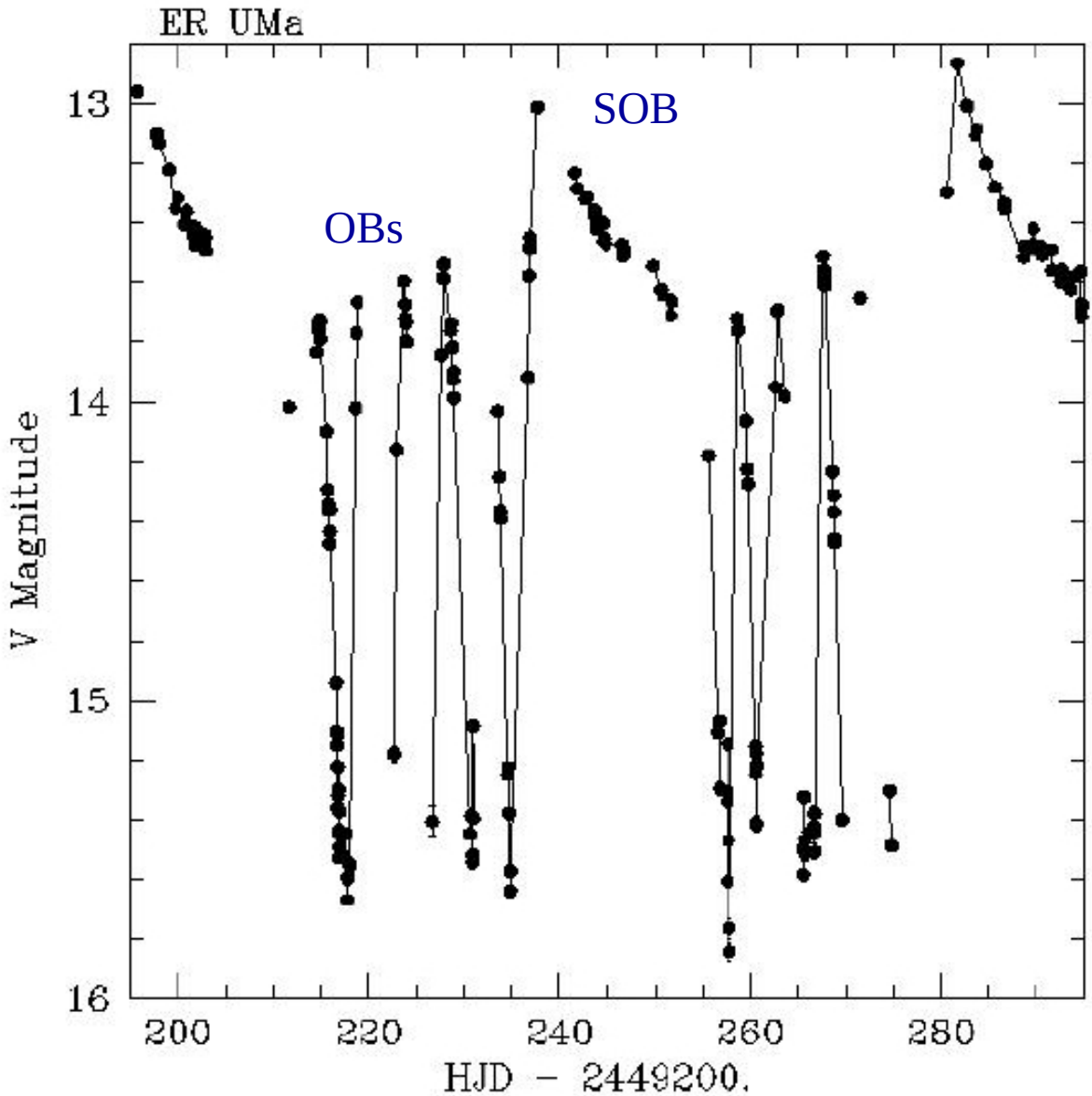


A differential light curve is generated by comparing the brightness of the target variable to an assumed constant non-variable star, whose consistency is checked against the brightness of another assumed non-variable star.

SU UMa-type Light Curve

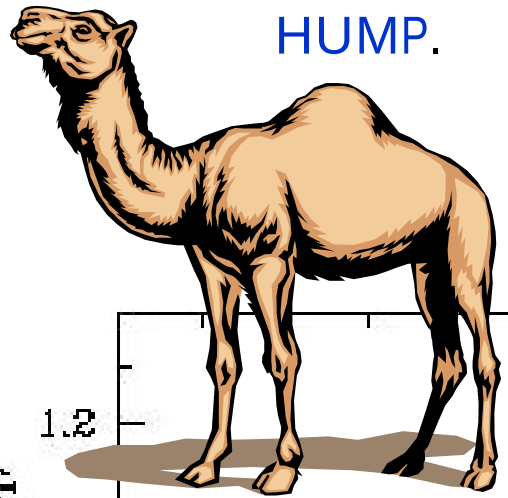
SU UMa-type dwarf novae exhibit normal outbursts, interspersed between superoutbursts (SOBs) which last a little longer, and are a little brighter than normal outbursts (OBs).

ALL these systems exhibit *superhumps* during superoutbursts.



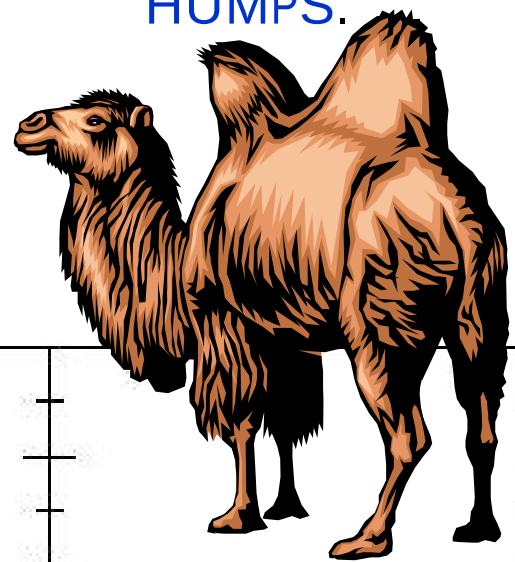
Superhumping Astrophysics

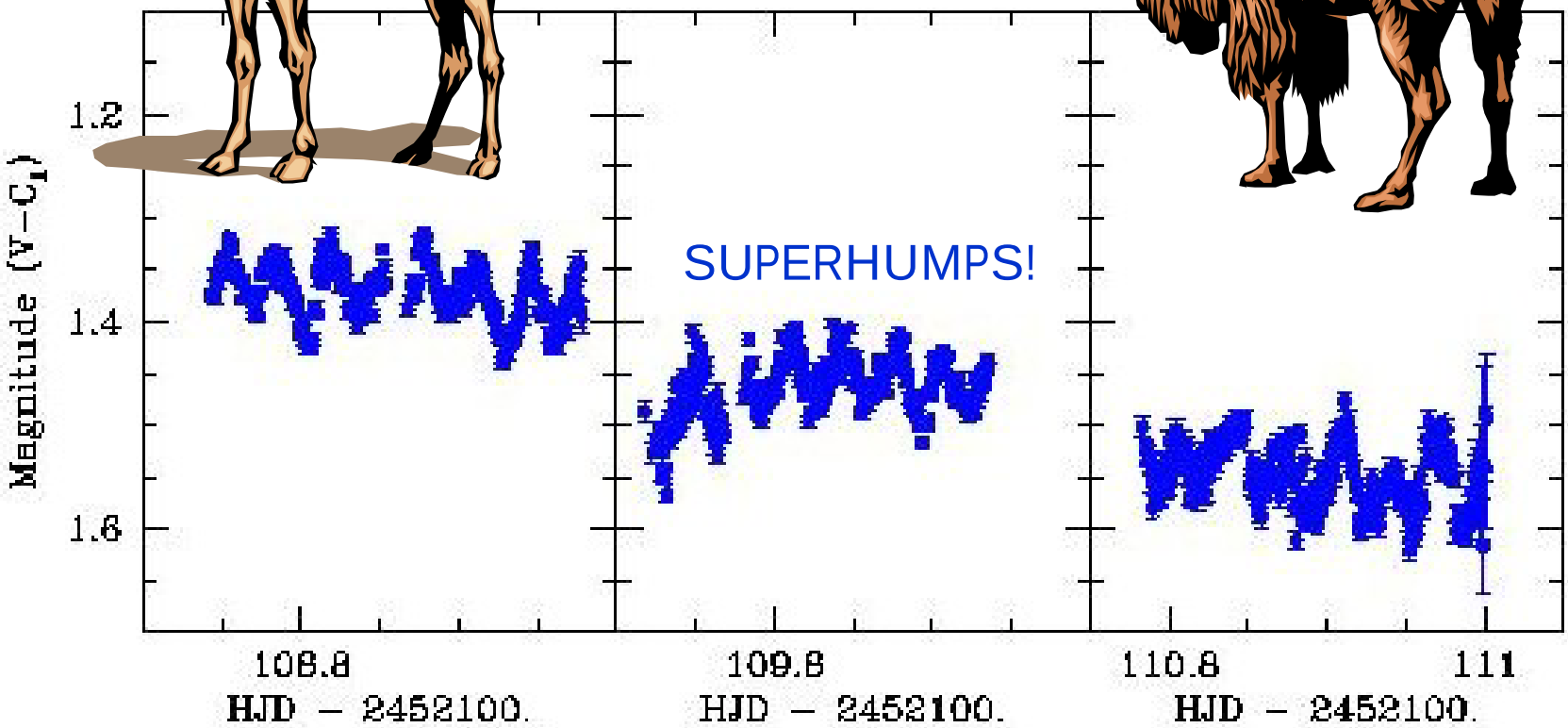
"We're not talking student dorms on weekends, this is out of this world!"



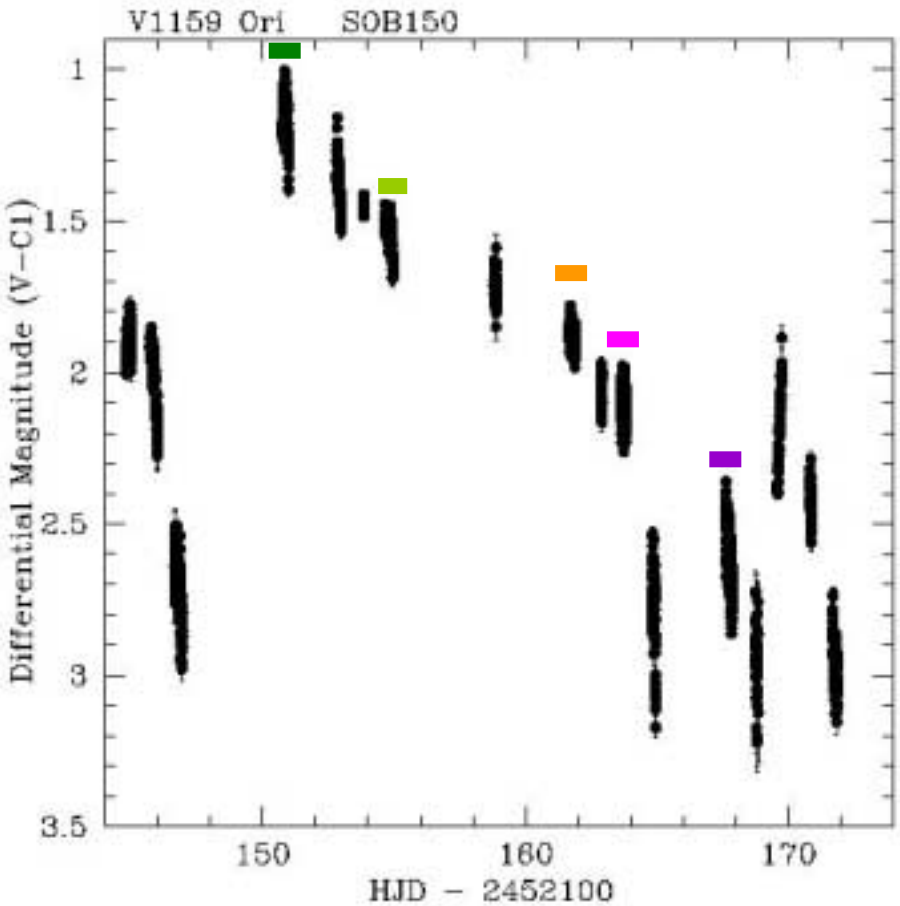
HUMP.

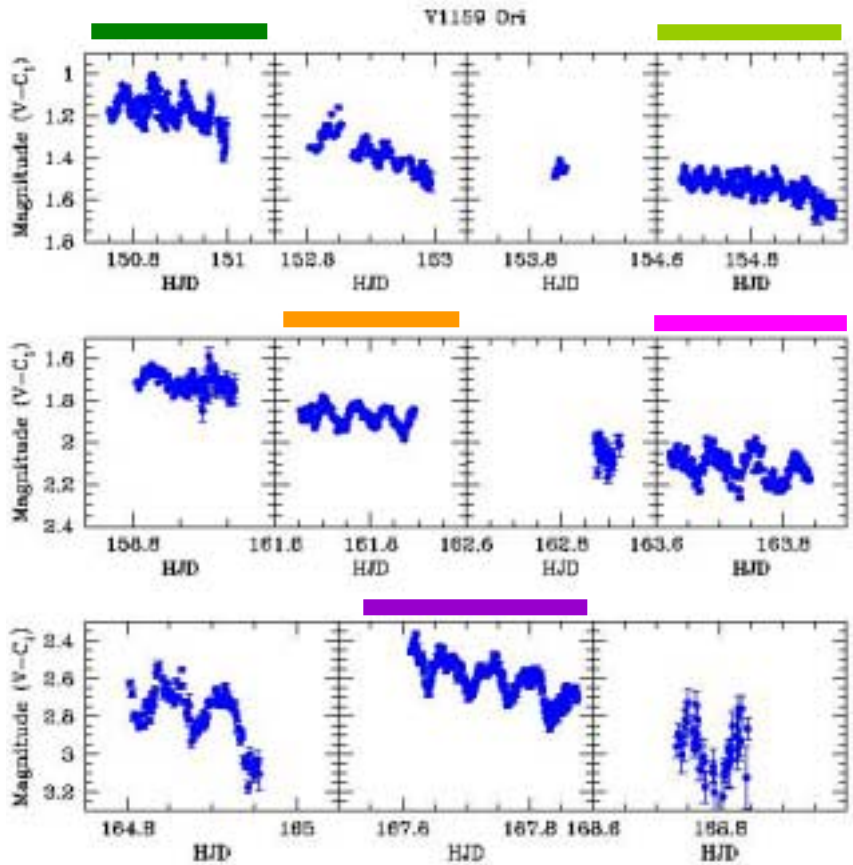
HUMPS.





SOB with Superhumps

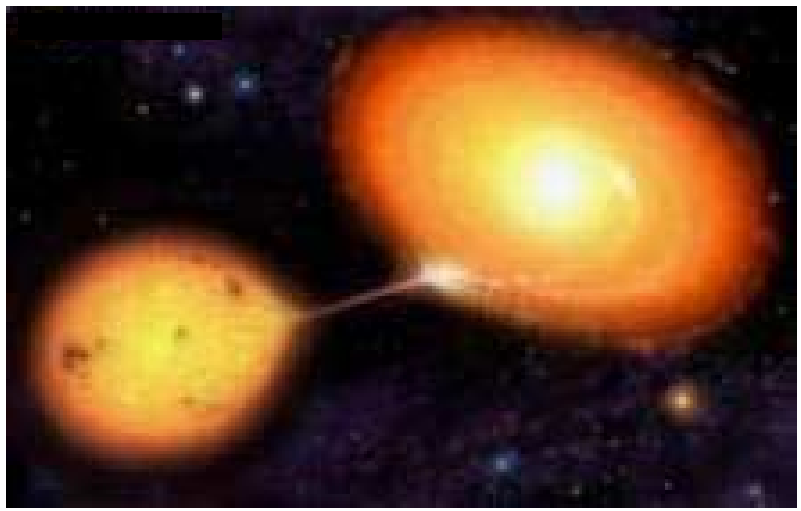


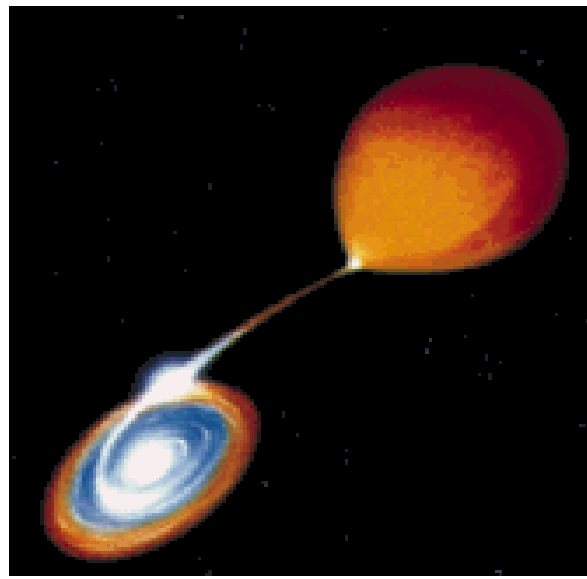


Gross Cataclysmic Variable Anatomy

Binary Stellar Systems:

80 minutes < $P_{orbital}$ < 15 hours

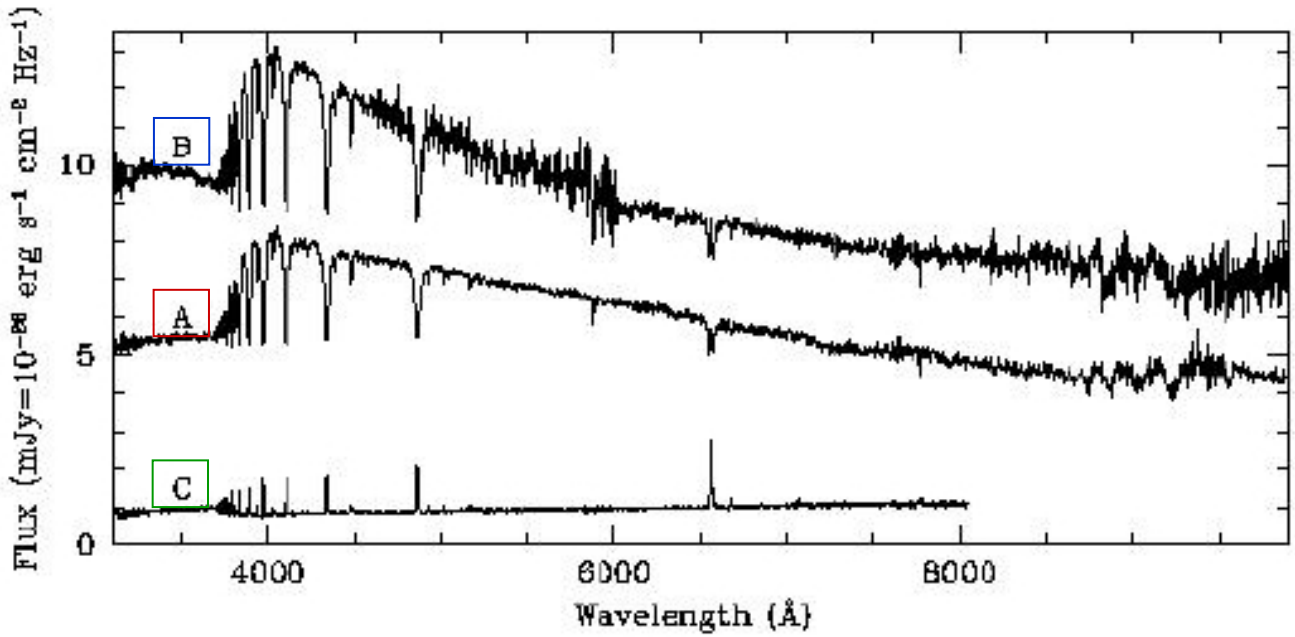




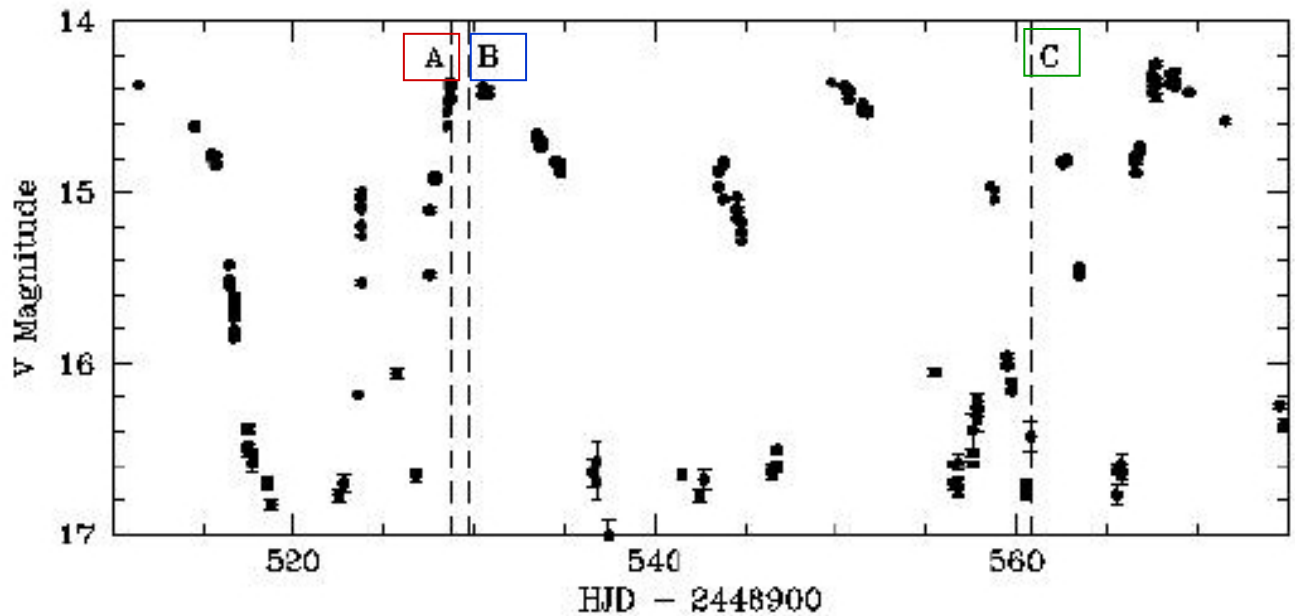
1. Primary: Degenerate White Dwarf, accreting hydrogen rich material via disk
2. Secondary: Low-mass, Main Sequence, Roche Lobe Filling Star
3. Accretion Stream, Hot Spot, Accretion Disk
   (Accretion Driven via Angular Momentum Losses, P_{orb} Shrinks Over Time)

Spectroscopy

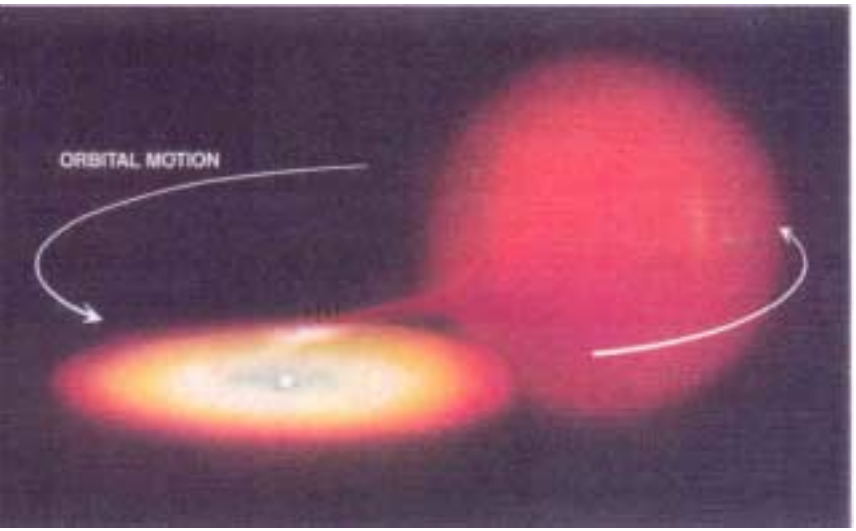
The accretion disk dominates light levels at ALL wavelengths in CVs.



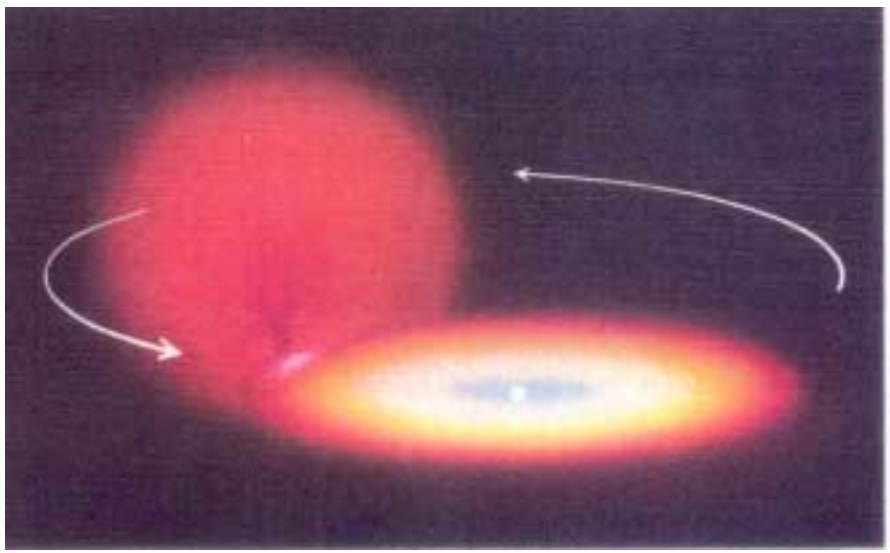
The white dwarf and secondary stars are rarely seen over the accretion disk.

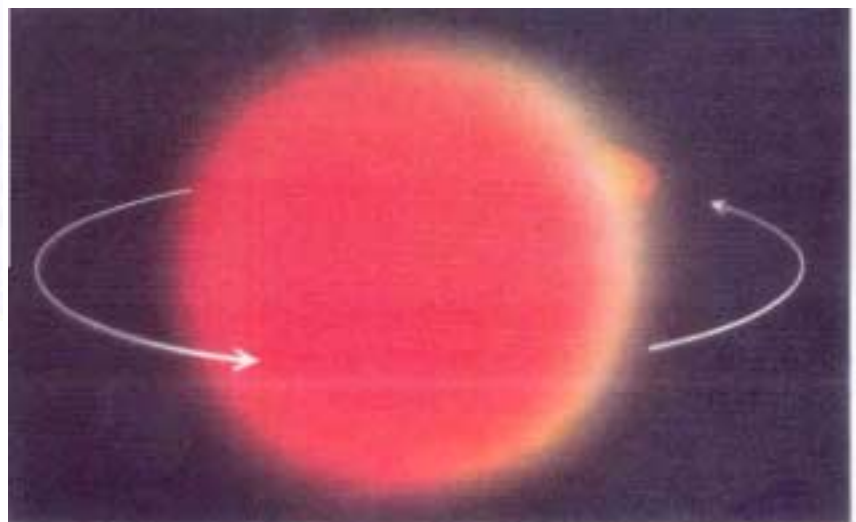


Accretion Disk Eclipses

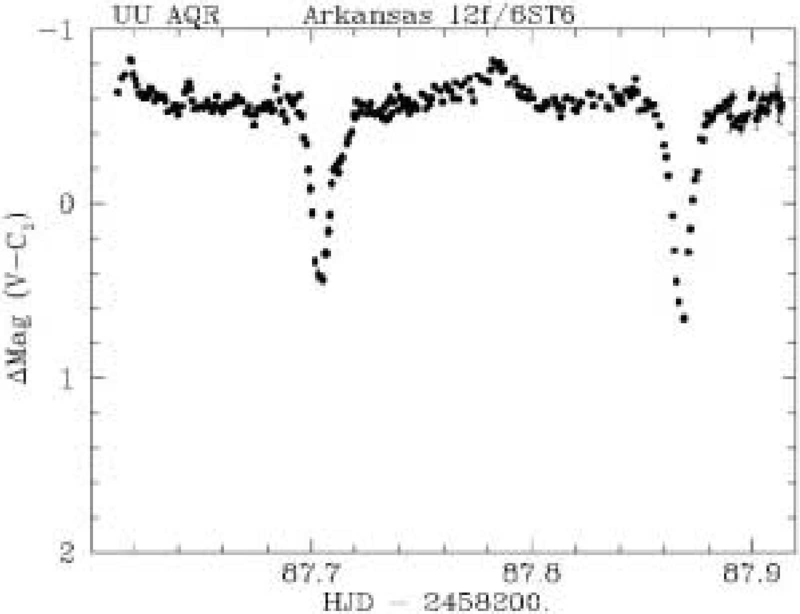


The geometry of the binary yields spatial information for an accretion disk during its orbit if we are lucky enough to witness eclipses from our location.

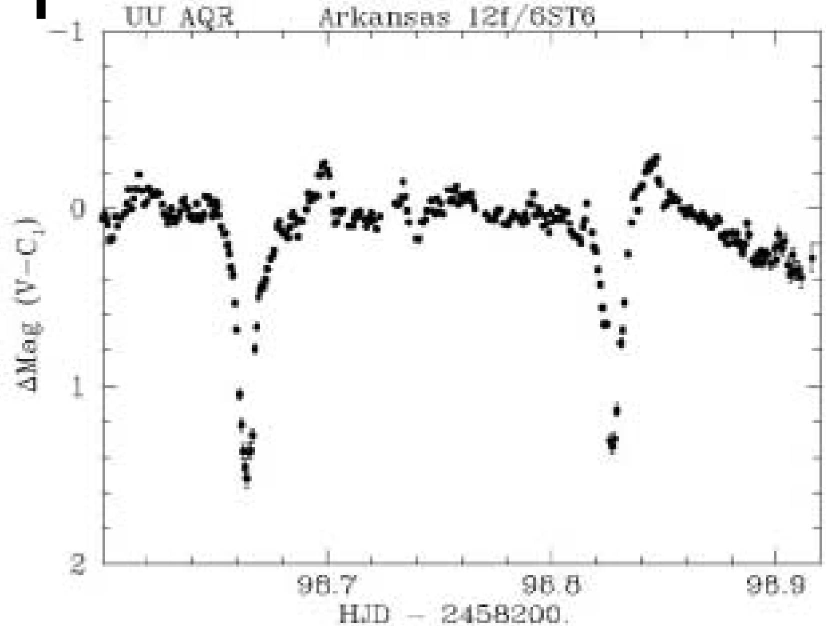




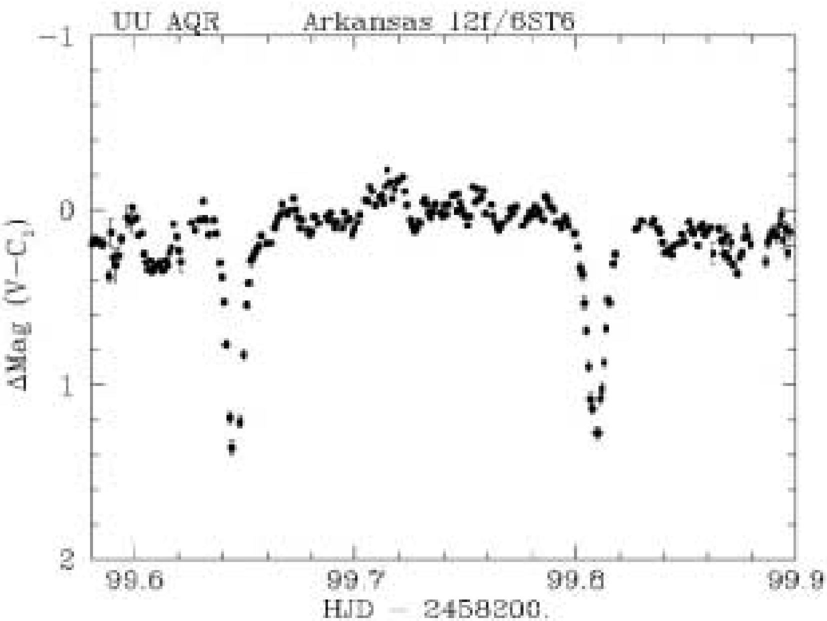
CV Eclipses



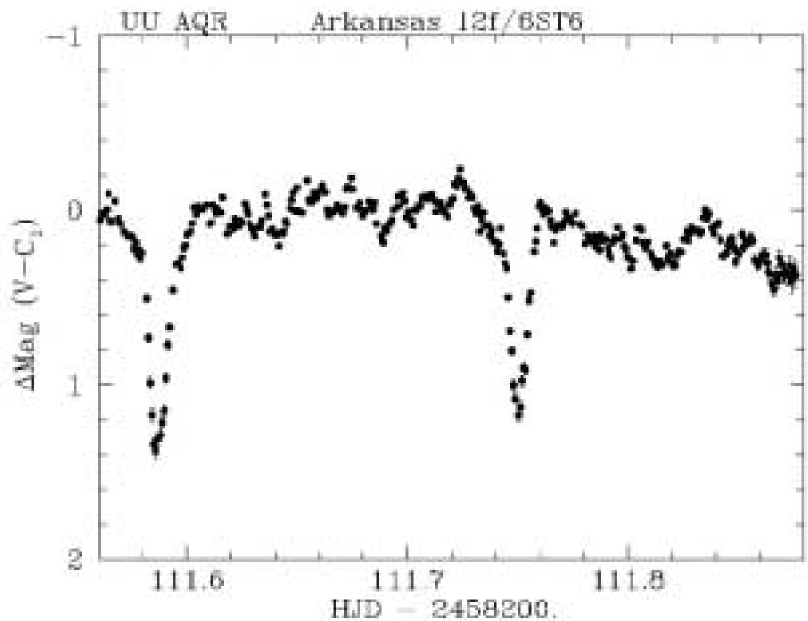
UU AQR Arkansas 12f/6ST6
ΔMag (V−C1)
HJD − 2458200.
87.7
87.8
87.9



UU AQR Arkansas 12f/6ST6
ΔMag (V−C1)
HJD − 2458200.
98.7
98.8
98.9

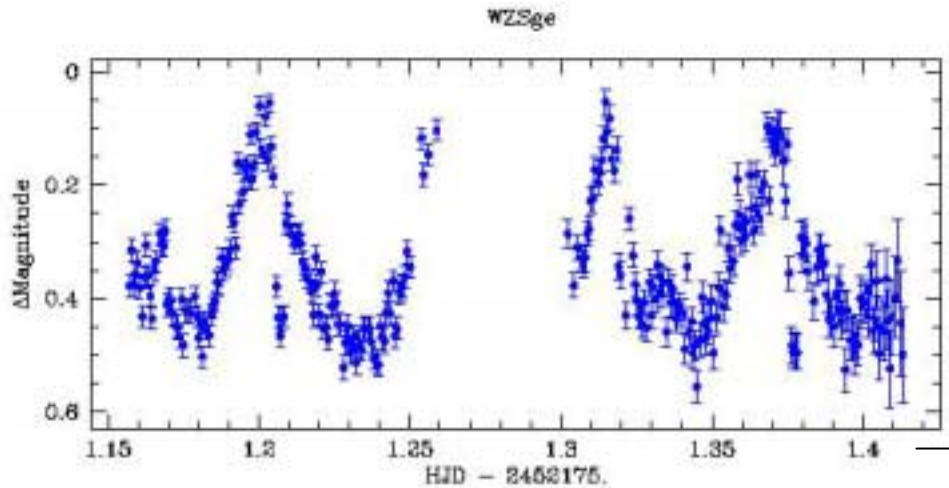


UU AQR Arkansas 12f/6ST6
ΔMag (V−C1)
HJD − 2458200.
99.6
99.7
99.8
99.9

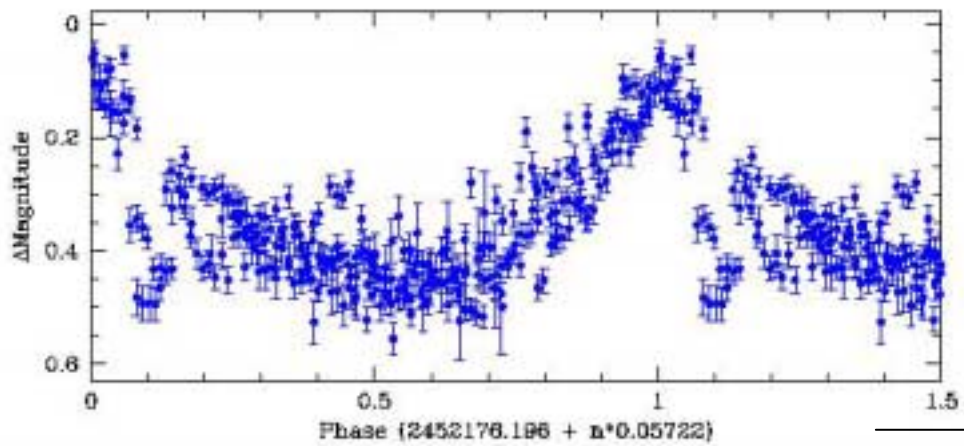


UU AQR Arkansas 12f/6ST6
ΔMag (V−C1)
HJD − 2458200.
111.6
111.7
111.8

Superhumps Convolved With Eclipses



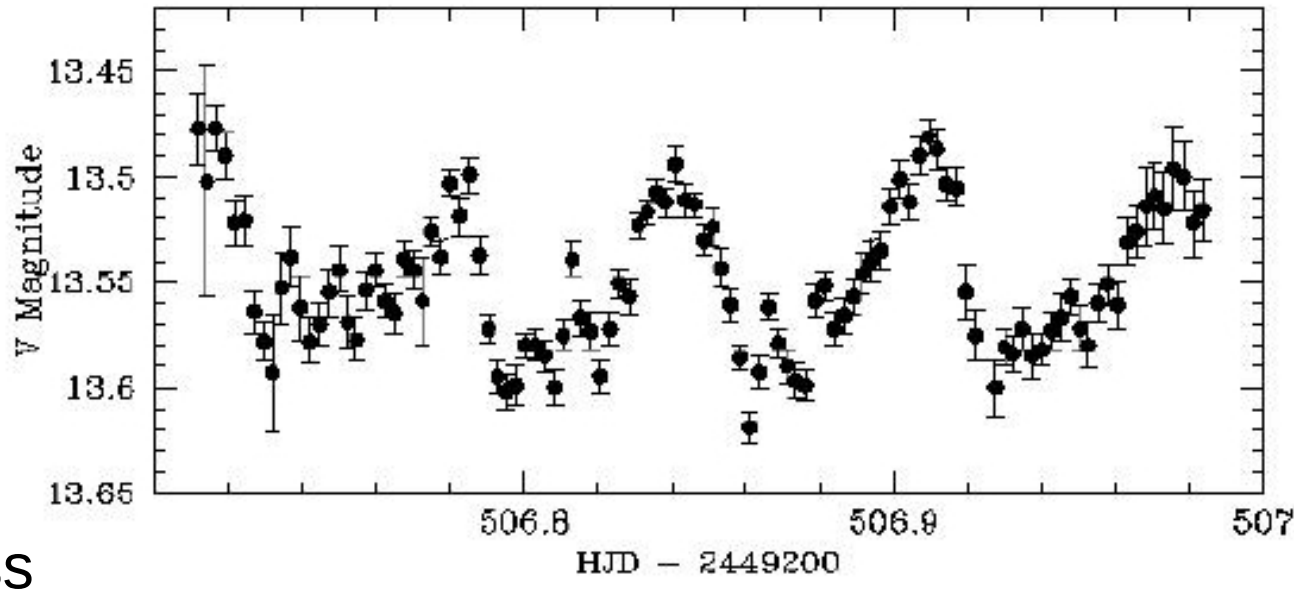
Hours

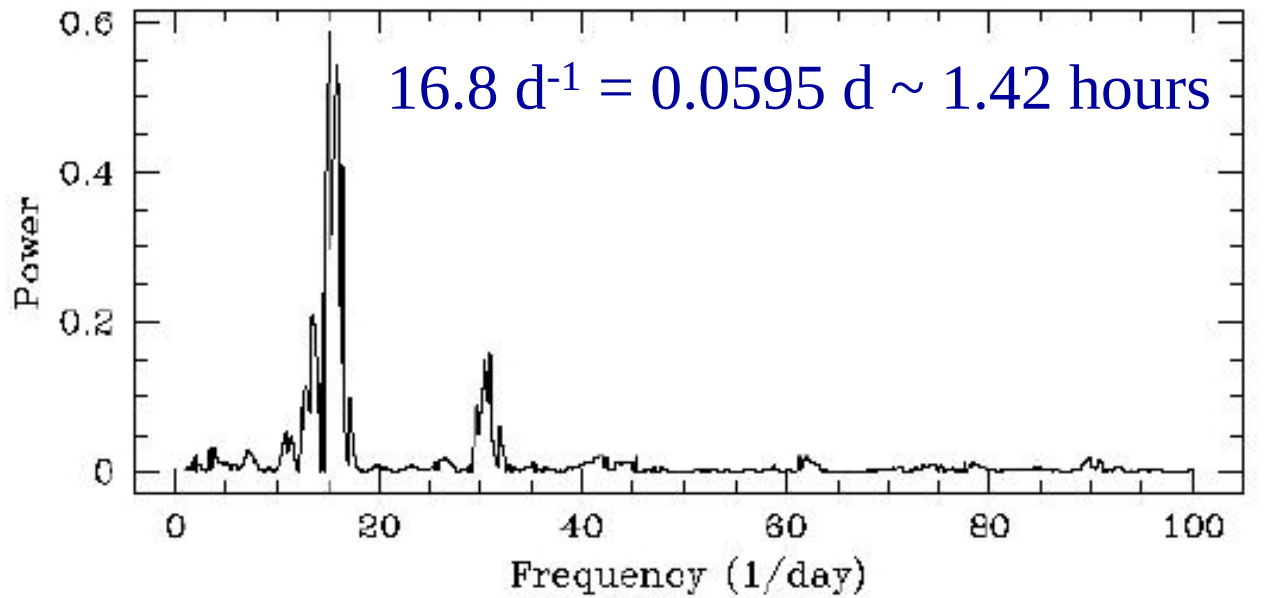


Orbital
Phase “Folded”

Superhump Period Correlates Well With…

- Orbital Period
- Mass Ratio
- System Brightness
  - distance



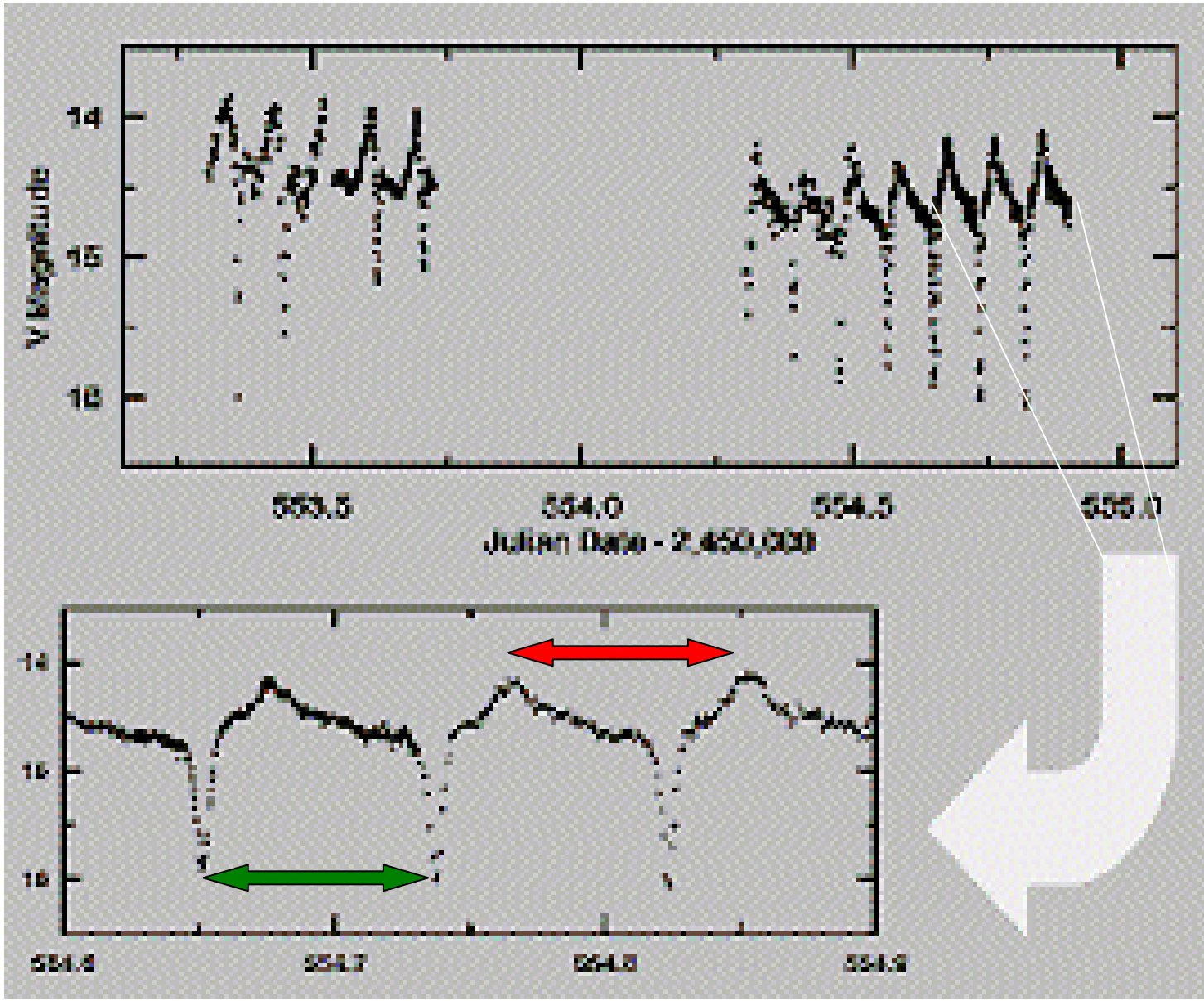


Superhumps During a Superoutburst

Superhumps* are light variations with a period a few % larger than the orbital period.

P_{orb} = eclipses

$P_{sh} > P_{orb}$



If you can't get P_{orb}, P_{sh} will do, If you don't have P_{sh} then God Bless You

- Obtaining P_{orb} requires:
  - Eclipses (Rarity)
  - Radial Velocities (Spectra = Big Telescope = Lots of Time)
    - Very problematic

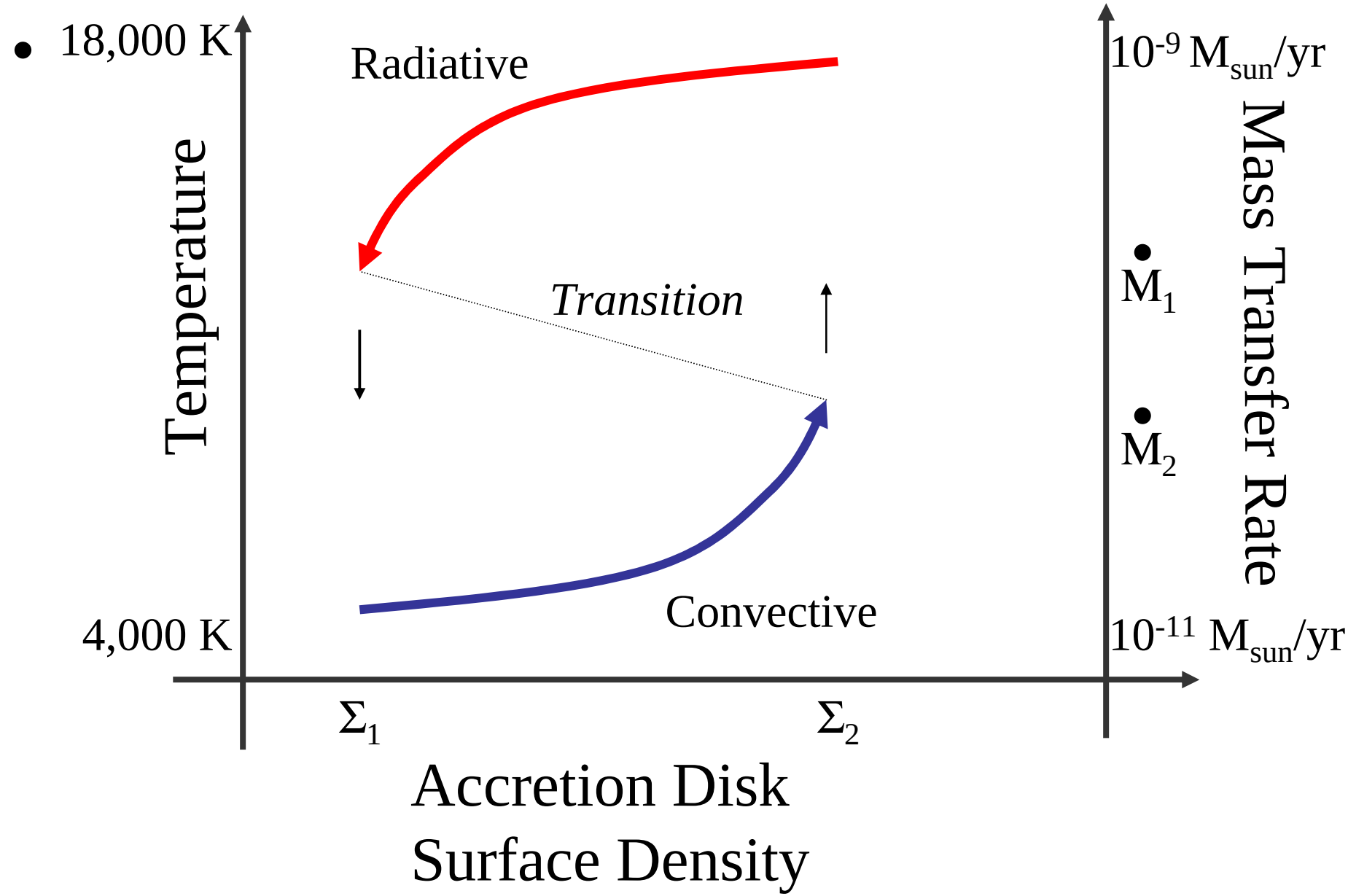
- Obtaining P_{sh} requires:
  - Photometry of superhumps during bright superoutbursts
  - Small Telescope (a few hours, 1 night)

- P_{SH} correlates well with P_{orb}
  - orbital period
  - mass ratio
  - absolute magnitude (distance)

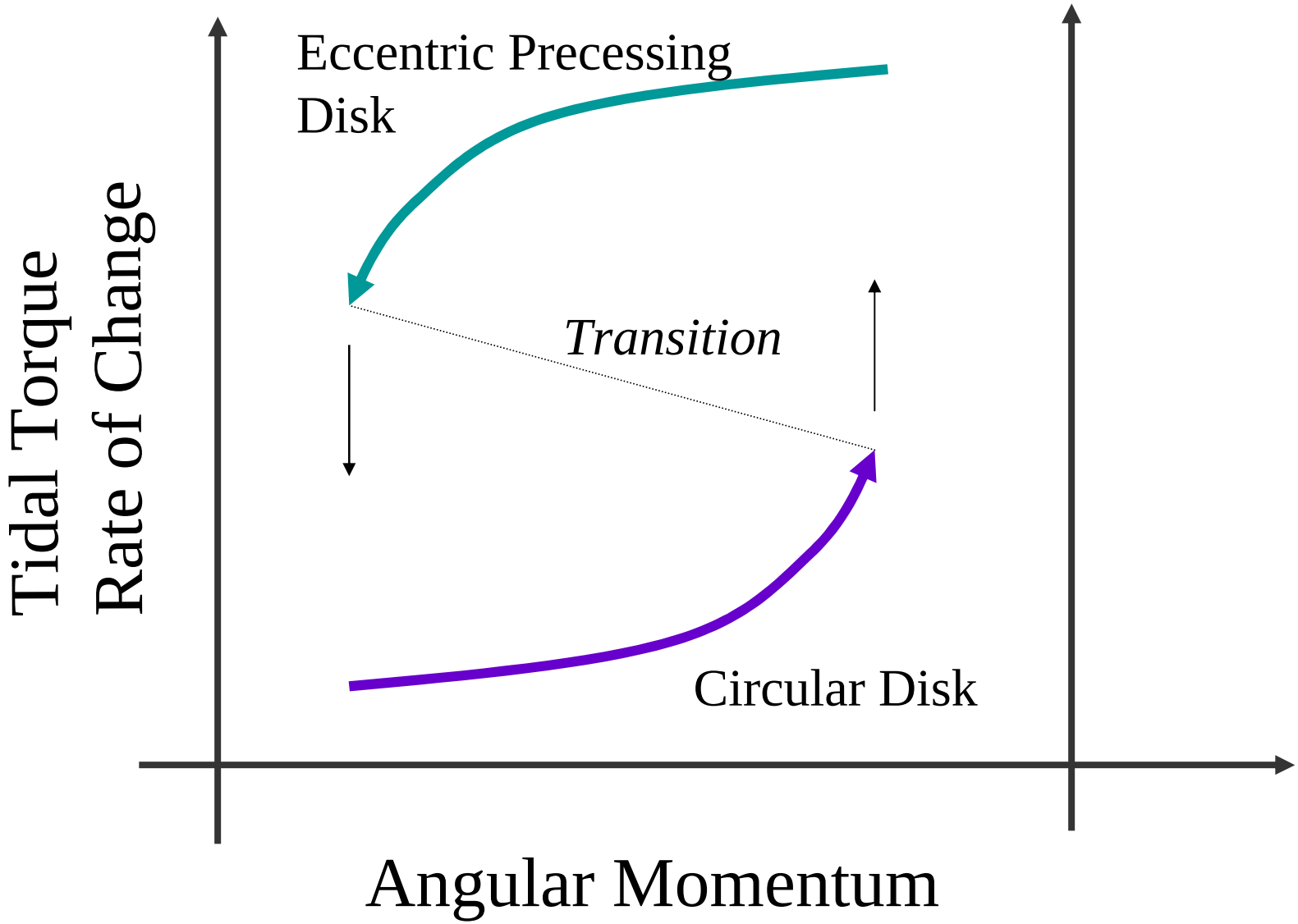
Investigations

- What superhump changes occur during a superoutburst?
  - Period changes in P_{sh} as correlated during a single superoutburst event
- What are the Supercycle-to-Supercycle variations?
  - Period changes in P_{sh} as correlated from one SOB to the next SOB
- When do superhumps start? Why?
- When do superhumps stop? Why?
- What are the Star-to-Star variations?
  - How do these correlate with P_{orb} and mass ratio and other parameters
  - Cataclysmic Variable evolution

Accretion Disk Limit Cycle



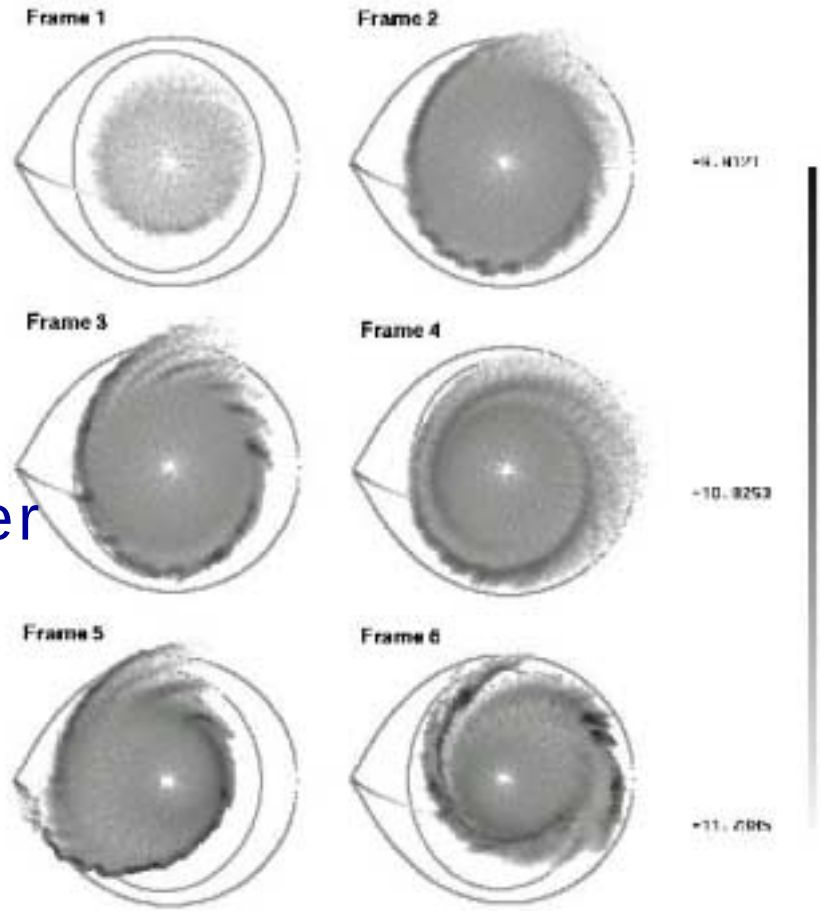
Accretion Disk Tidal Instability



Eccentric Precessing Accretion Disk (A.K.A. Superhump Mechanism)

Normal outbursts are unable to deplete the disk entirely. As the accretion disk grows, it reaches a radius for which tidal instability sets in, causing it to become eccentric, precess, enhancing mass transfer and emptying the disk.

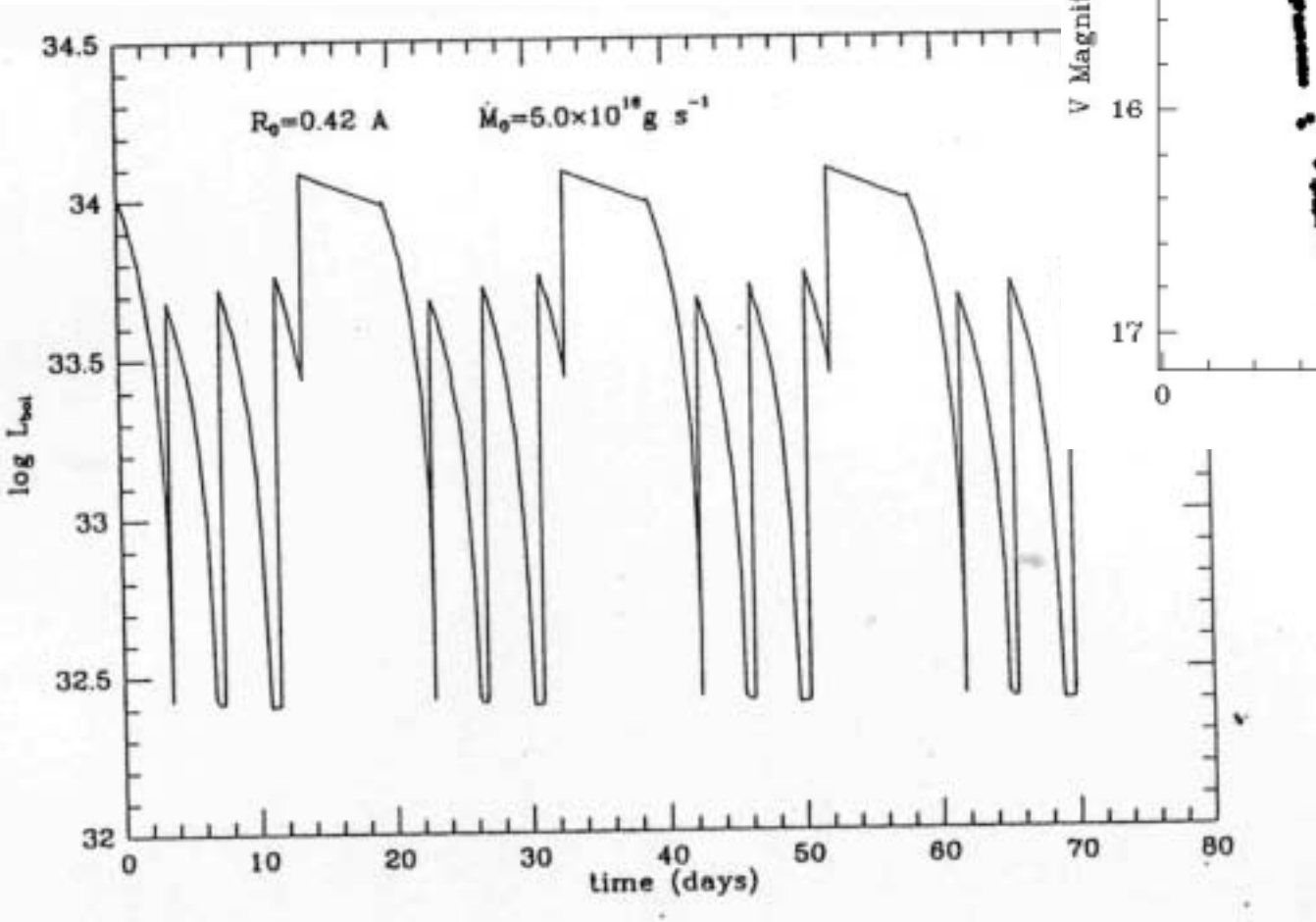
ALL dwarf nova below the CV period gap show superhumps during superoutbursts.

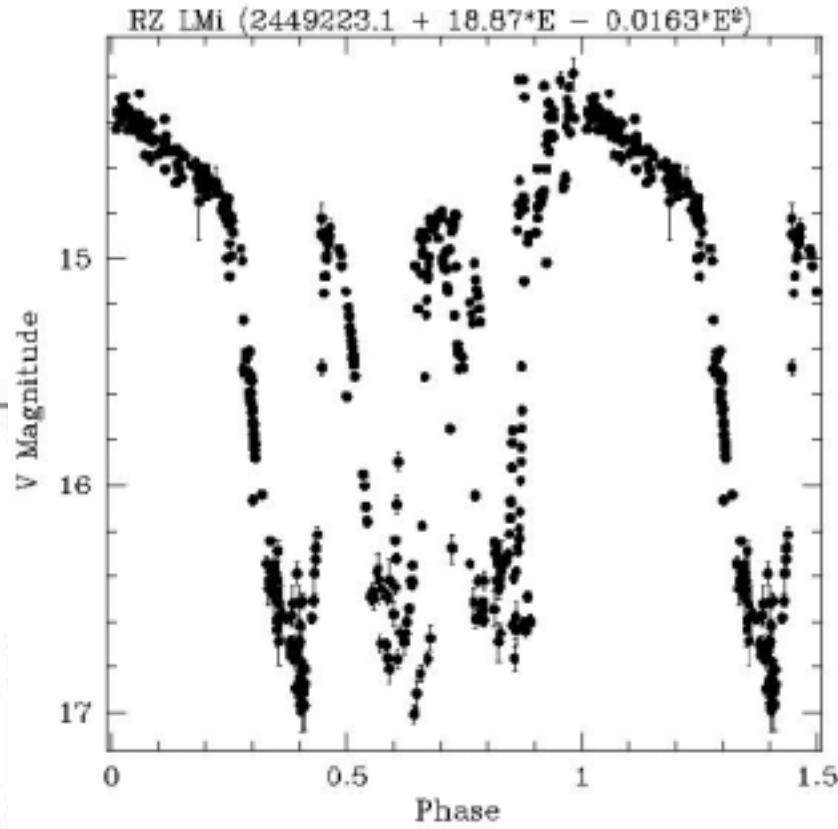


Light Curve Simulation

Osaki

Thermal-Tidal Instability

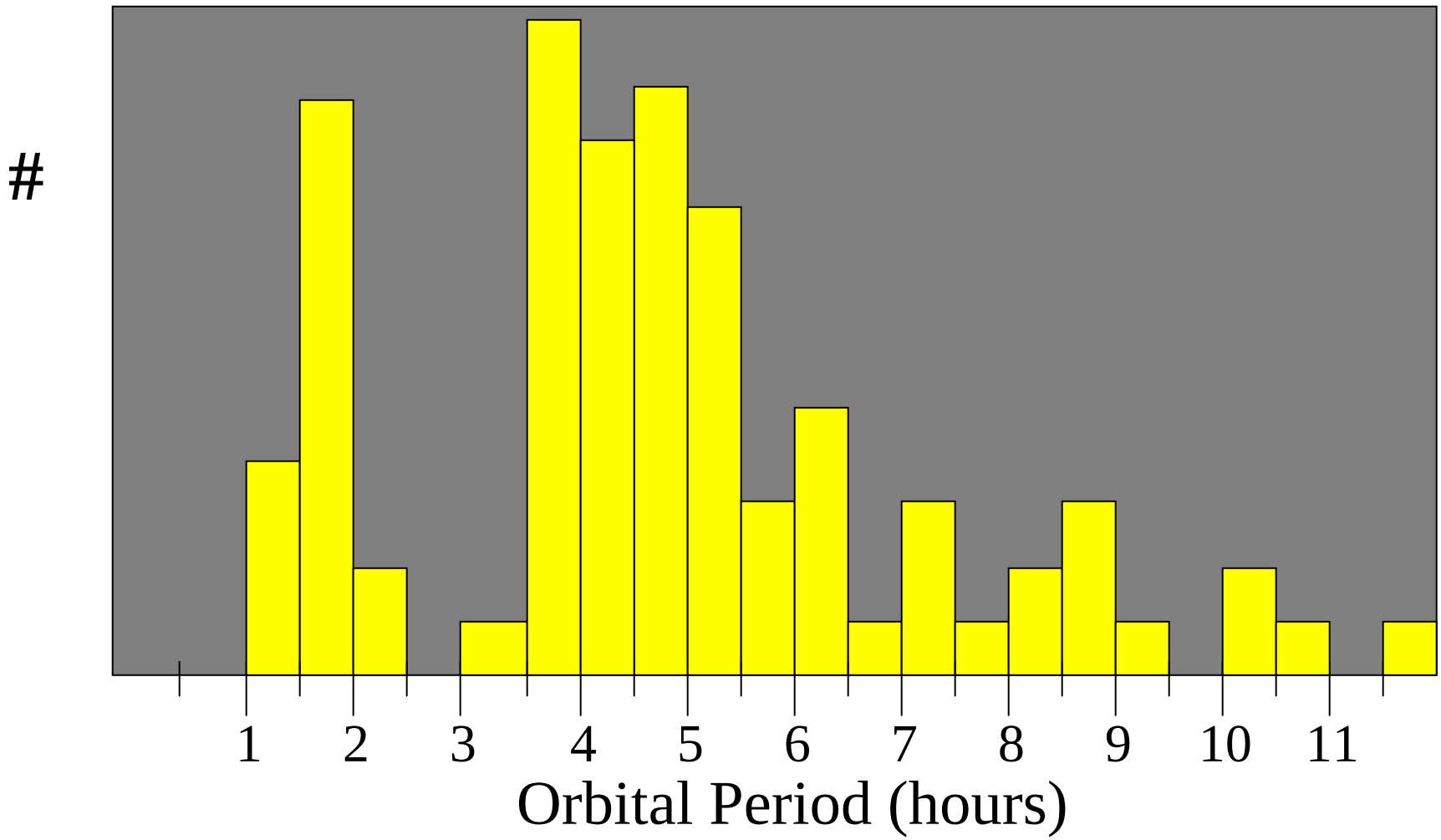




CV Orbital Period Distribution Histogram

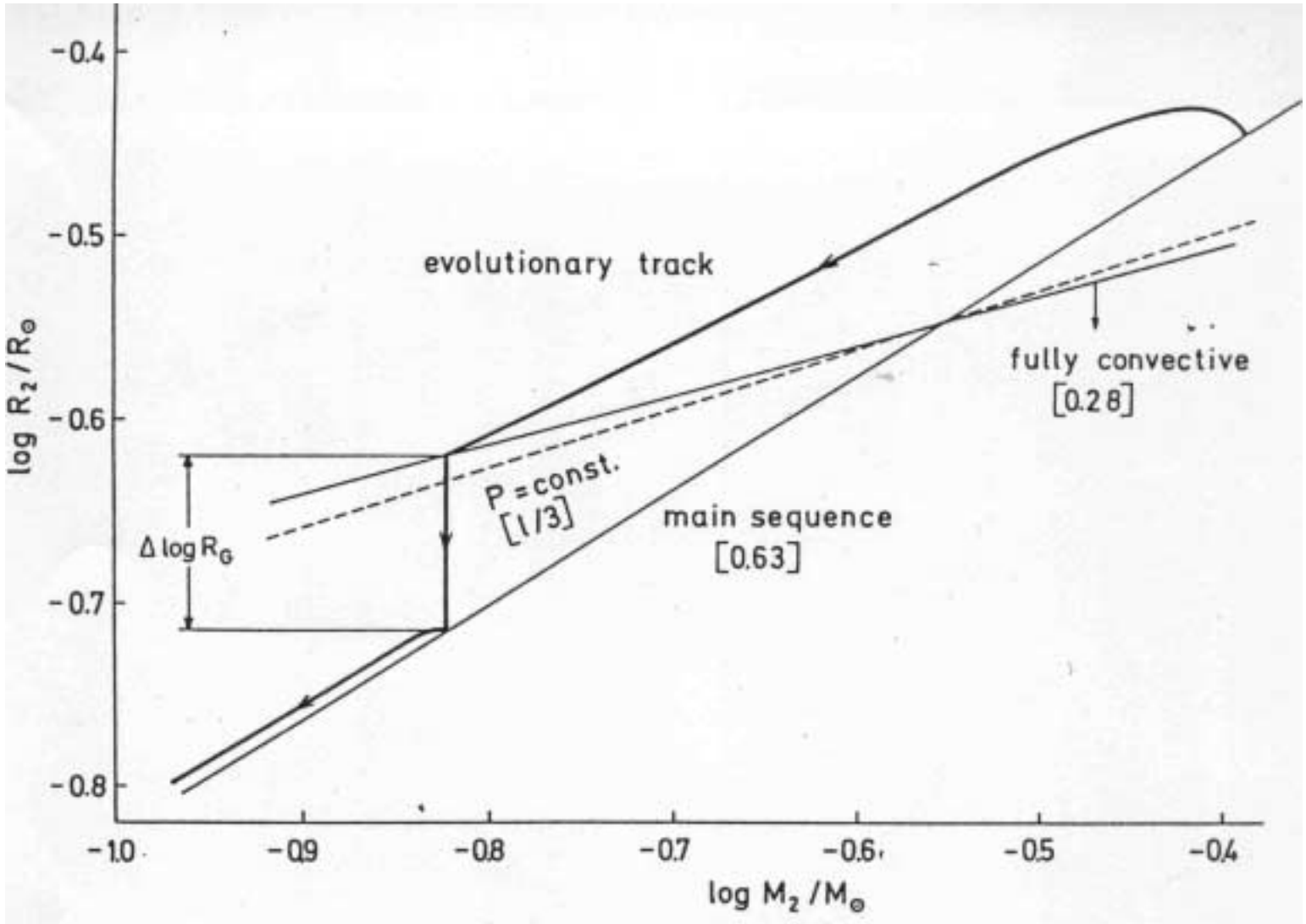
Sharp Cut-off Below 80 Minutes!

Dearth of Systems in the range ~ 2-3 hours?



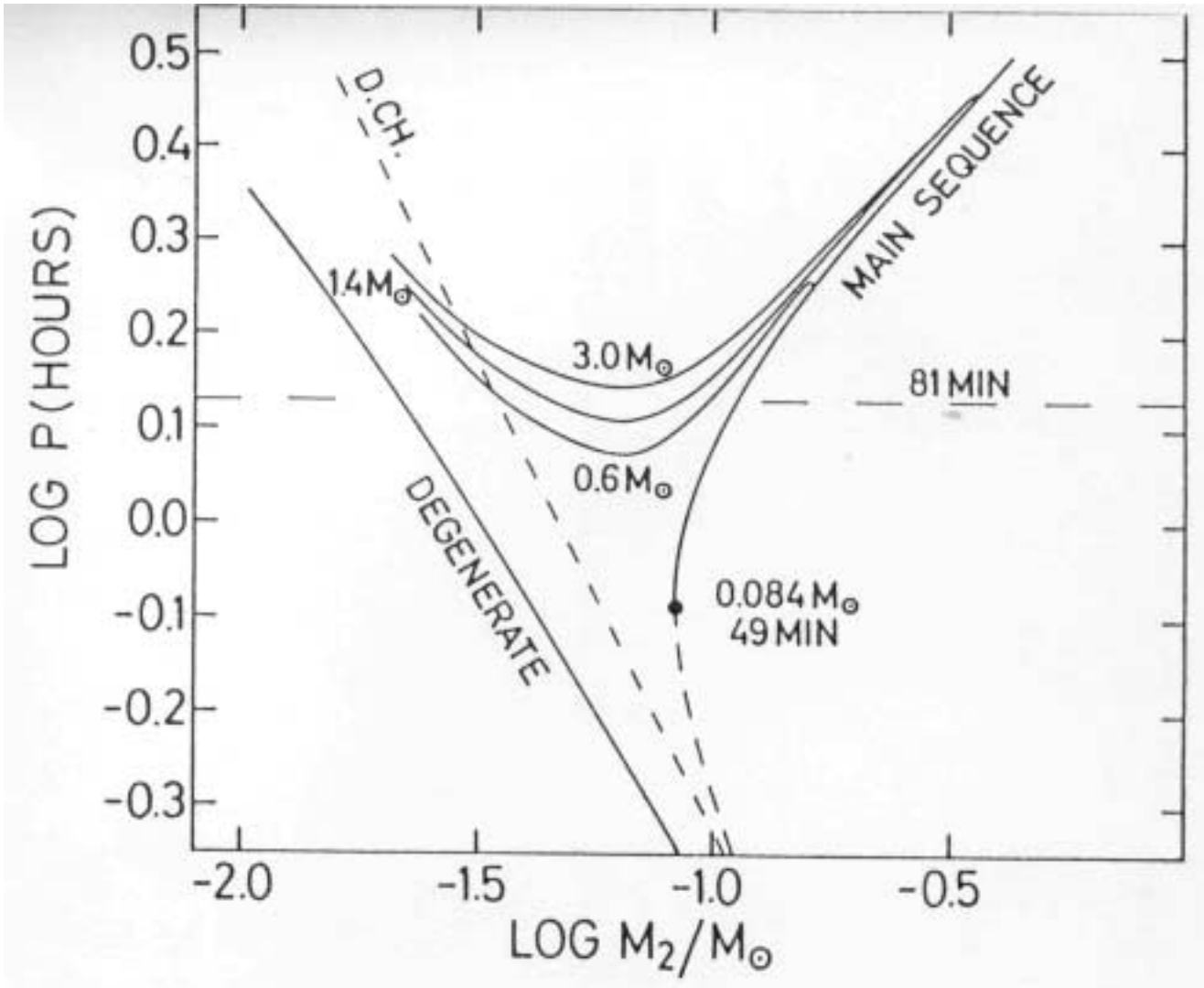
CV Binary Evolutionary Track

At low-mass, transition from a radiative-convective to a fully convective star, there is a change in secondary structure.

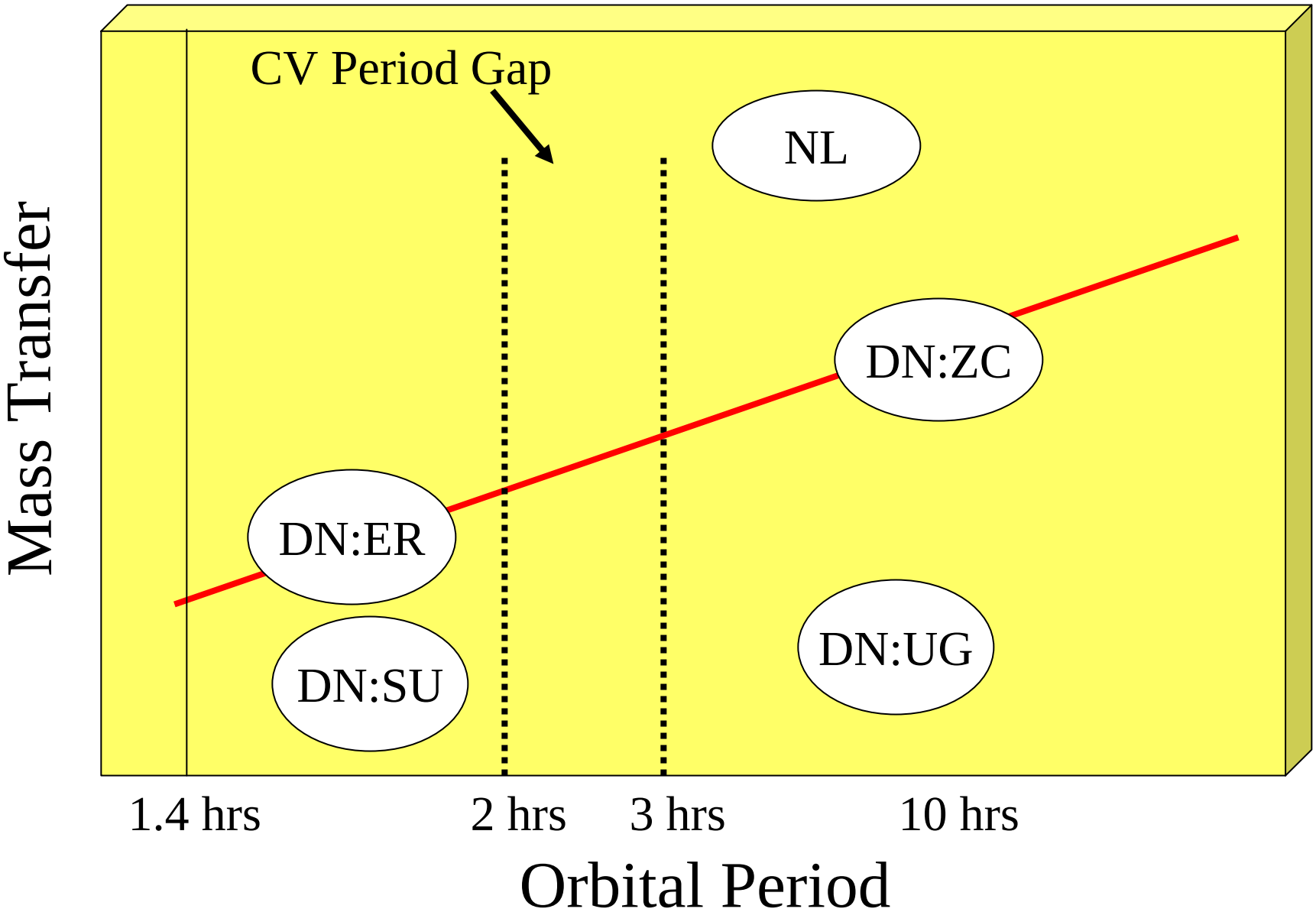


Onset of Degeneracy

Transition of secondary from extreme low-mass main sequence star to a white dwarf.

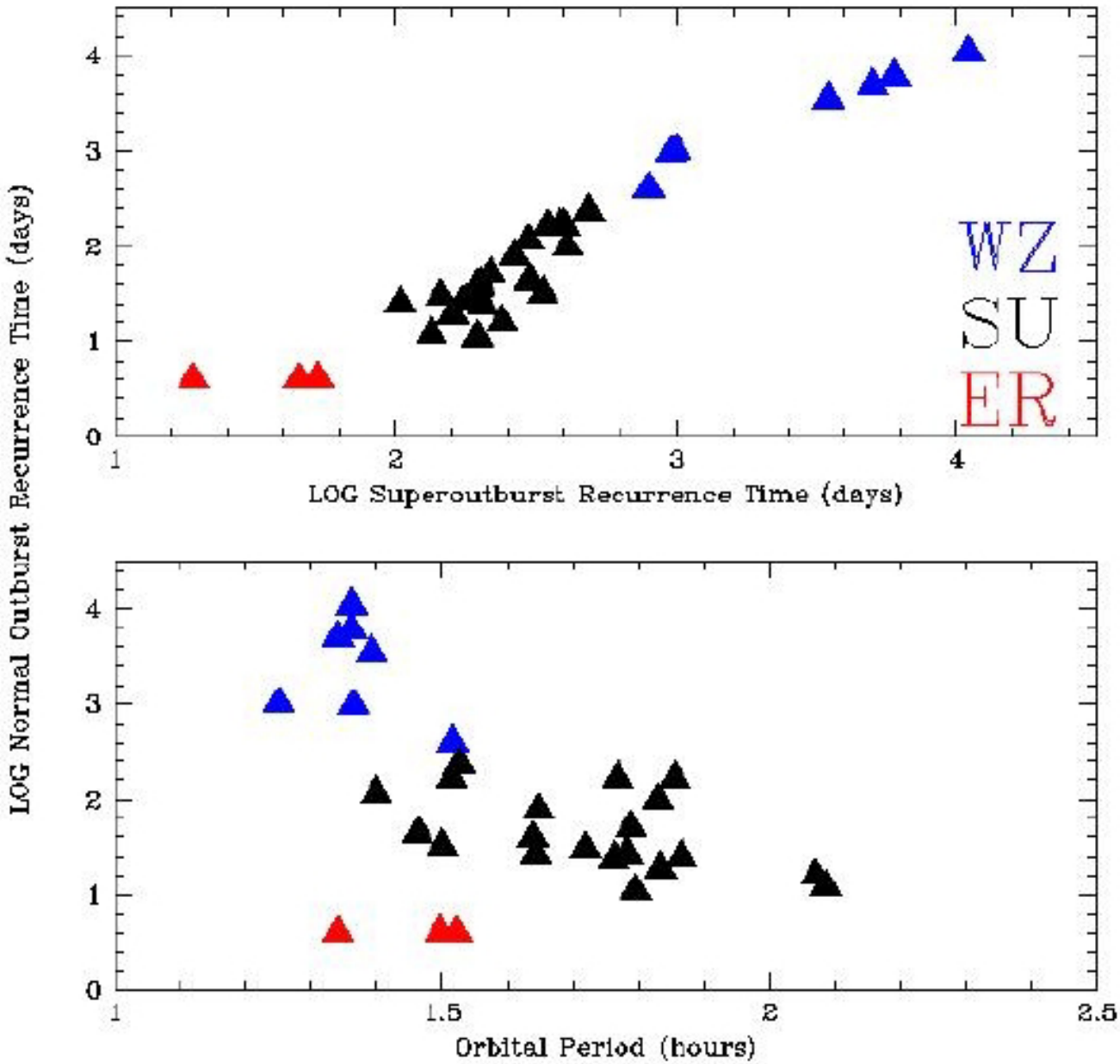


Mass Transfer Rates and CV Orbital Periods



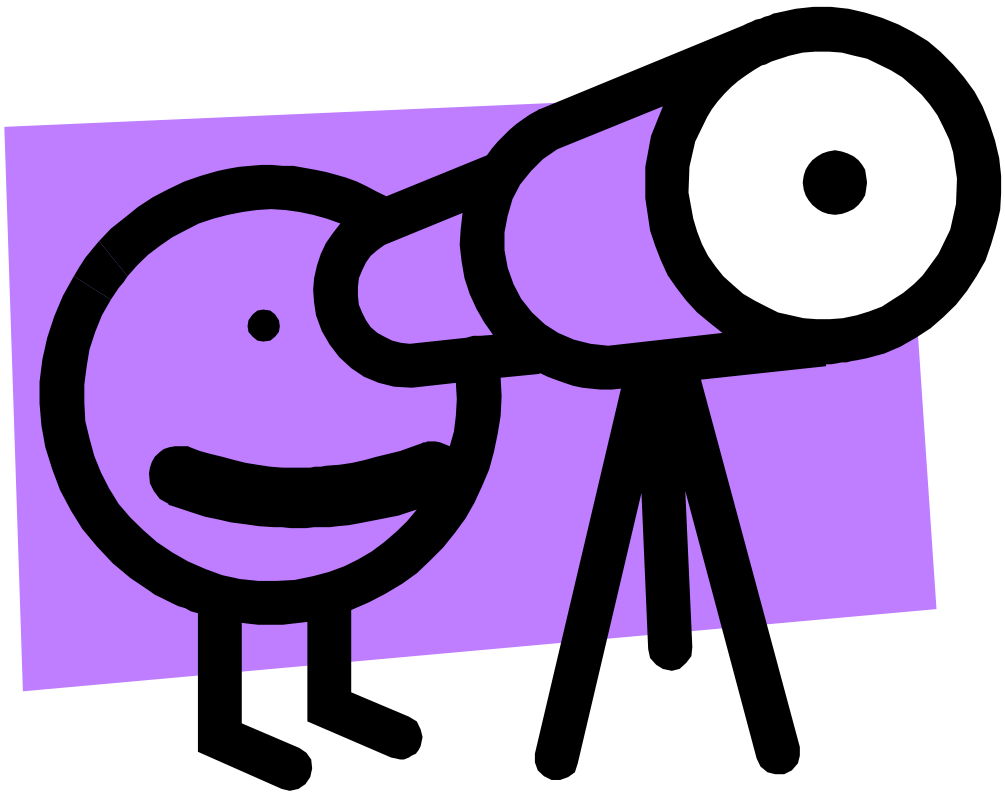
SU UMa-class Dwarf Nova Outburst Characteristics

The shortest orbital period systems exhibit the most widely discrepant deviations from the canonical SU UMa outburst behavior?!

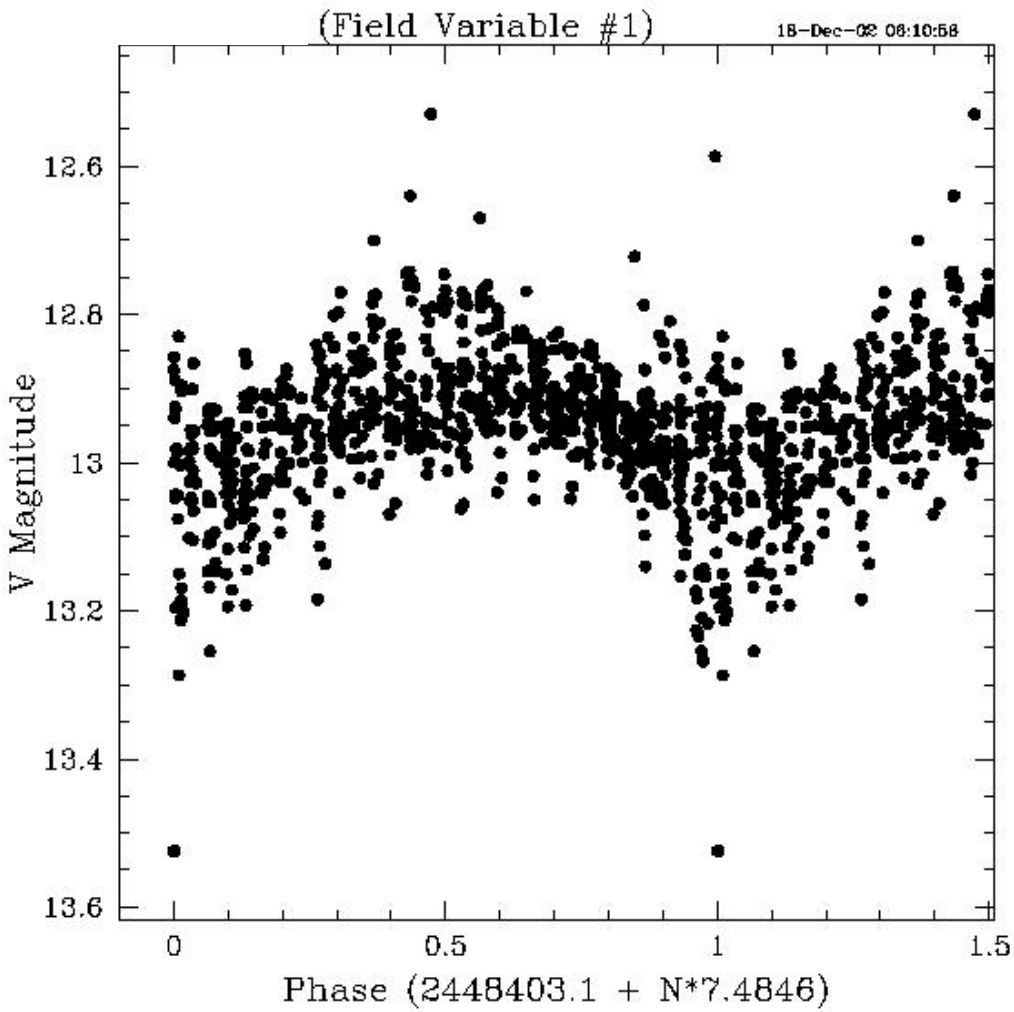


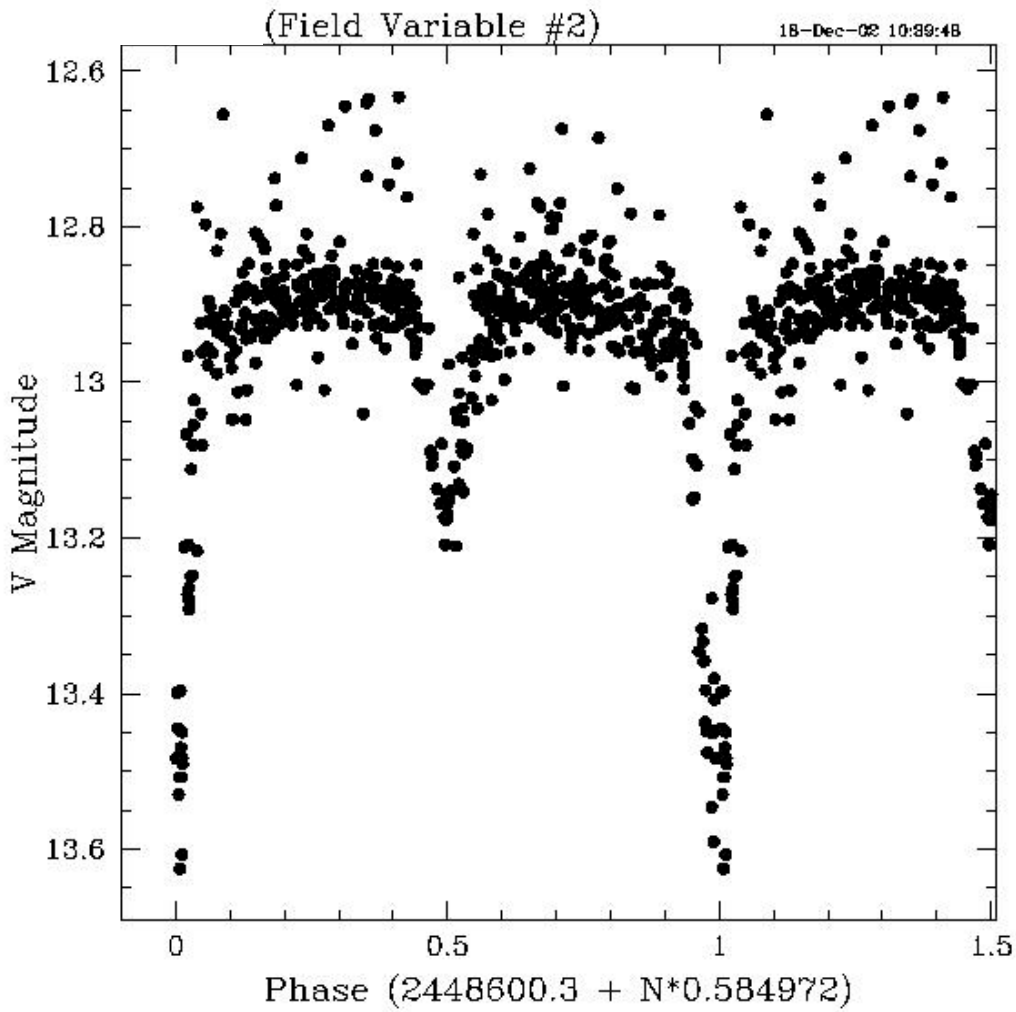
Serendipitous Discoveries

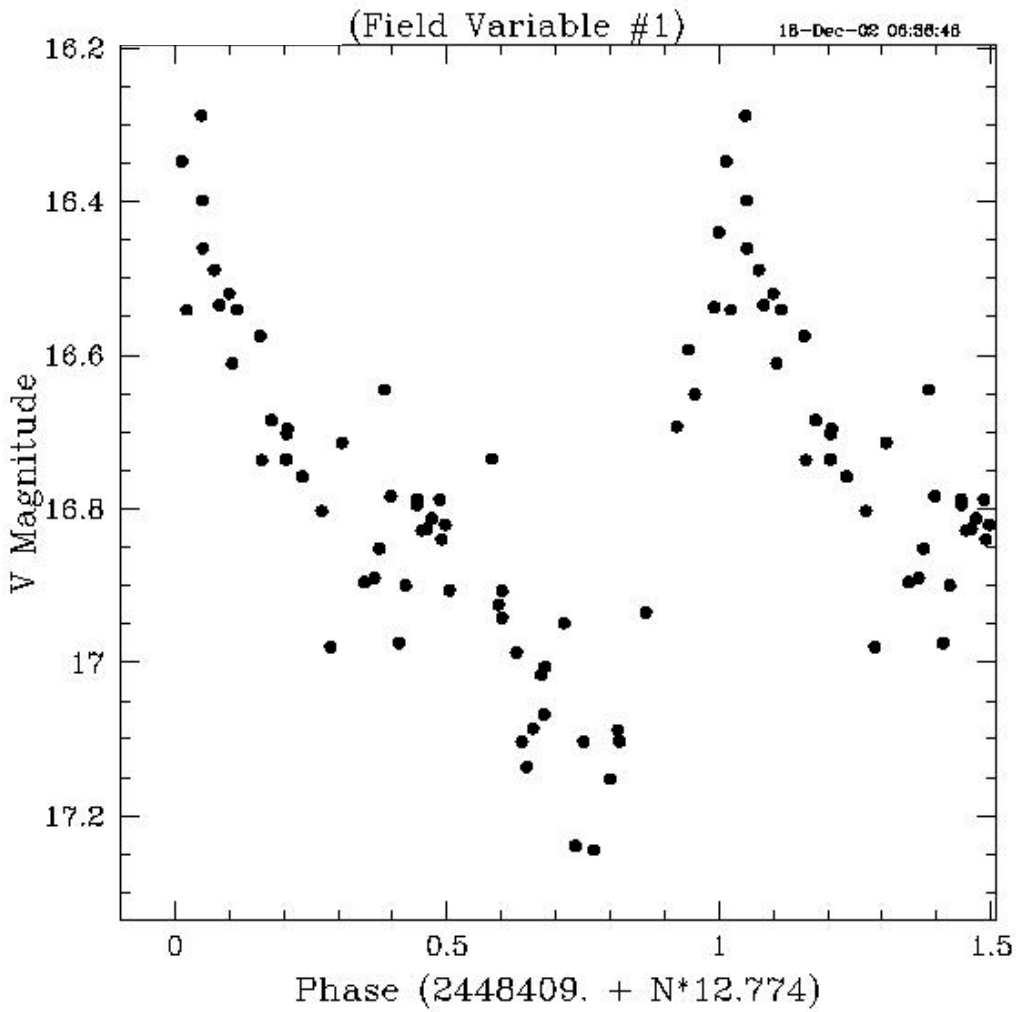
- CCD Images capture many, many stars in one frame
  - The light curve of any star in the field can be acquired and analyzed.
  - Many variable stars await discovery, identification and study.

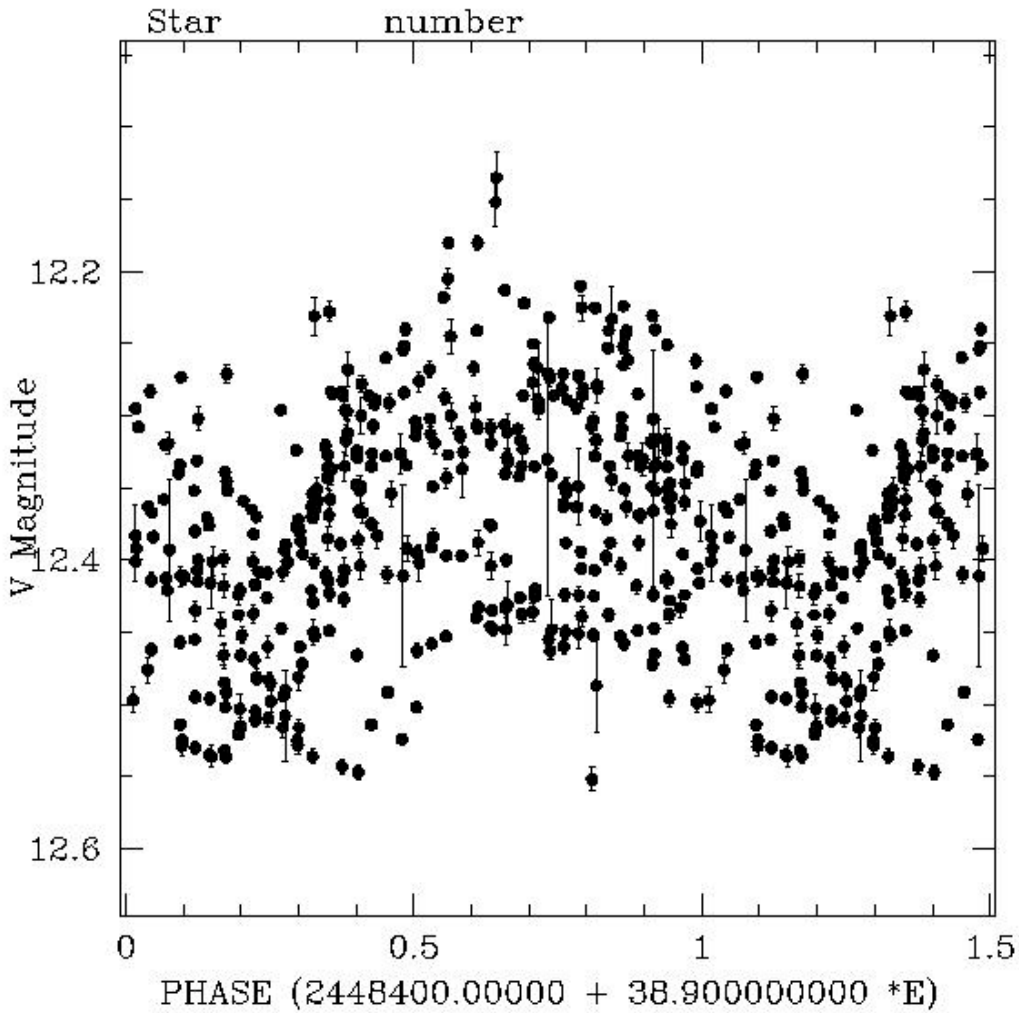


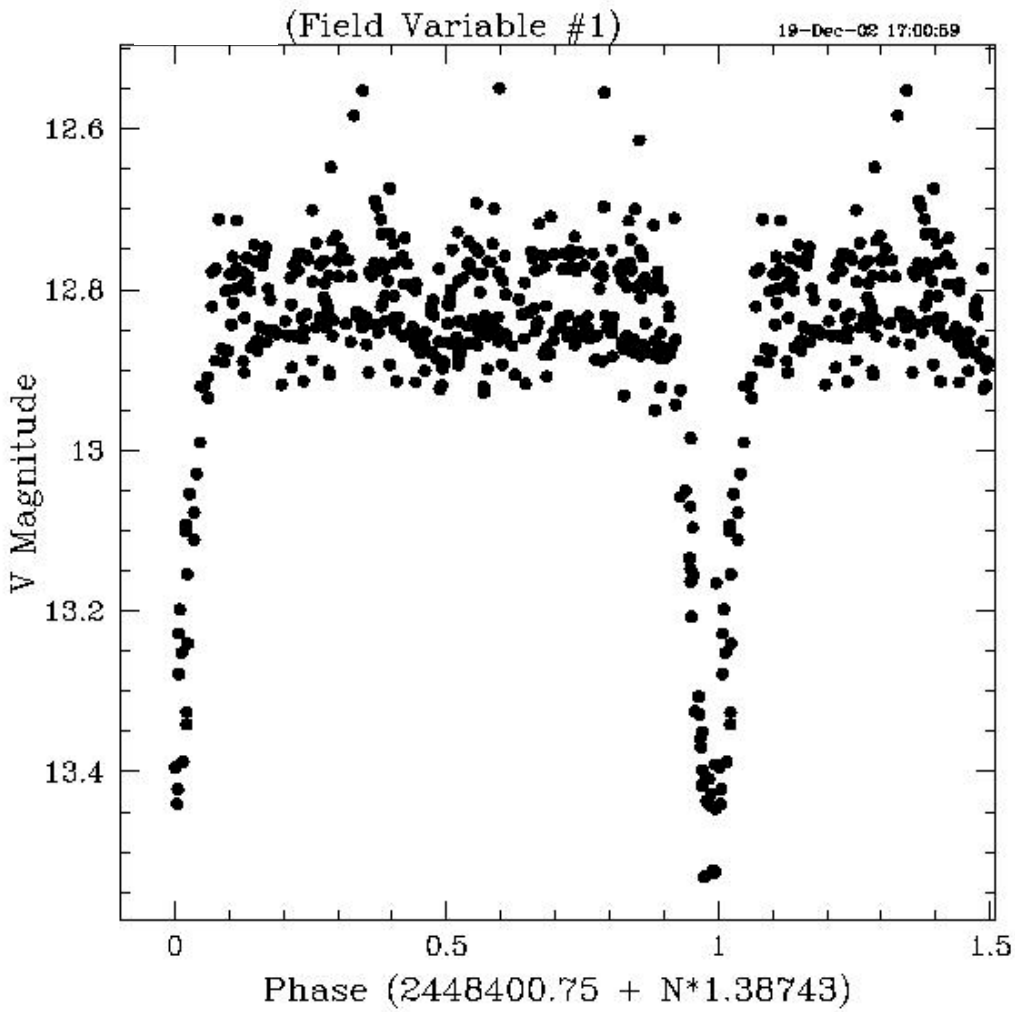
Why Not You?!

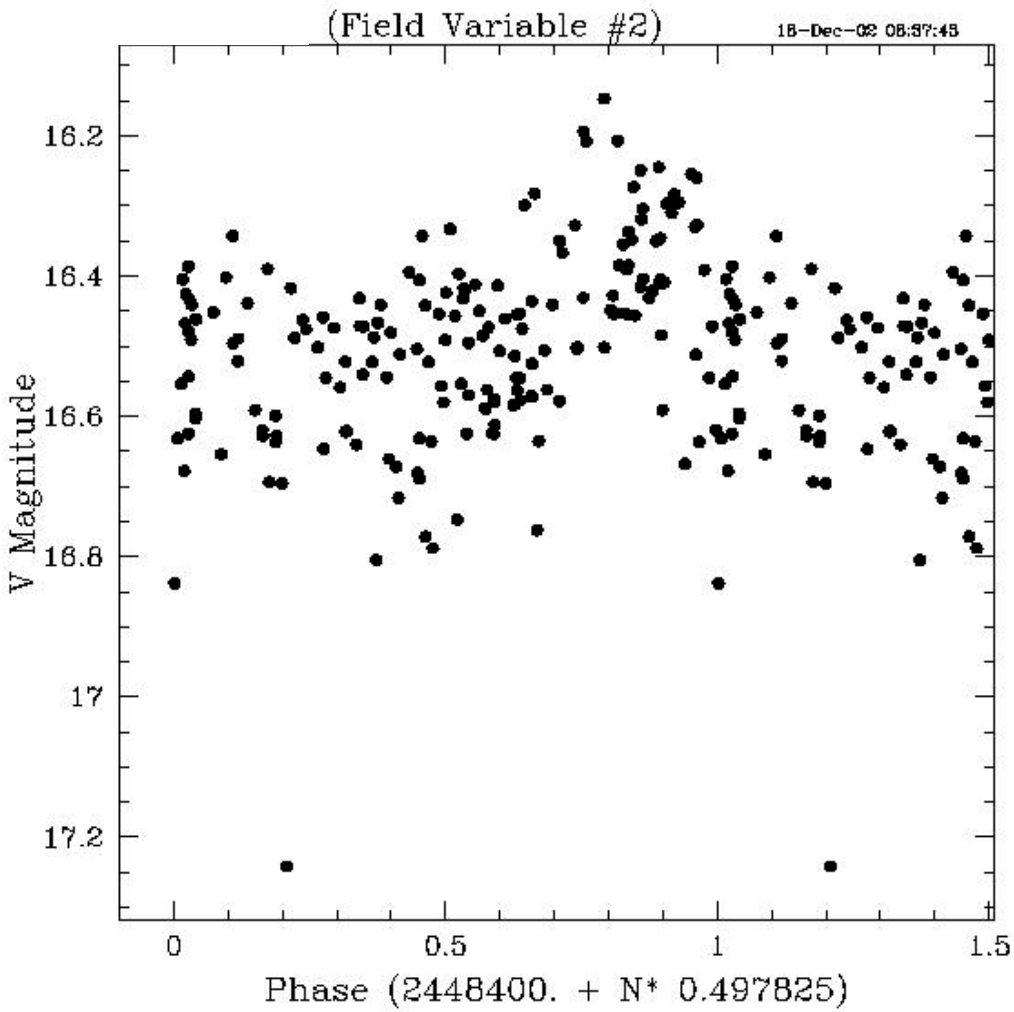

(Field Variable #1)
18-Dec-02 06:10:58
V Magnitude
12.6
12.8
13
13.2
13.4
13.6
0
0.5
1
1.5
Phase (2448403.1 + N*7.4846)


(Field Variable #2)
18-Dec-02 10:39:48
12.6
12.8
13
13.2
13.4
13.6
V Magnitude
0
0.5
1
1.5
Phase (2448600.3 + N*0.584972)

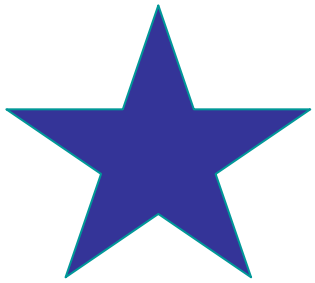

(Field Variable #1)
18-Dec-02 06:56:46
16.2
16.4
16.6
16.8
17
17.2
V Magnitude
0
0.5
1
1.5
Phase (2448409. + N*12.774)

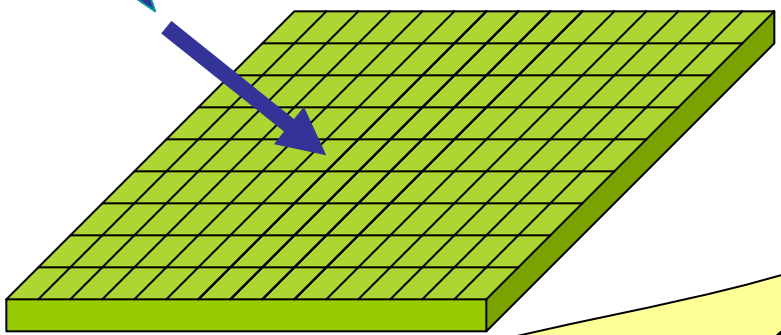

Star number
12.2
12.4
12.6
V Magnitude
0
0.5
1
1.5
PHASE (2448400.00000 + 38.900000000 *E)


(Field Variable #1)
19-Dec-02 17:00:59
12.6
12.8
13
13.2
13.4
V Magnitude
0
0.5
1
1.5
Phase (2448400.75 + N*1.38743)

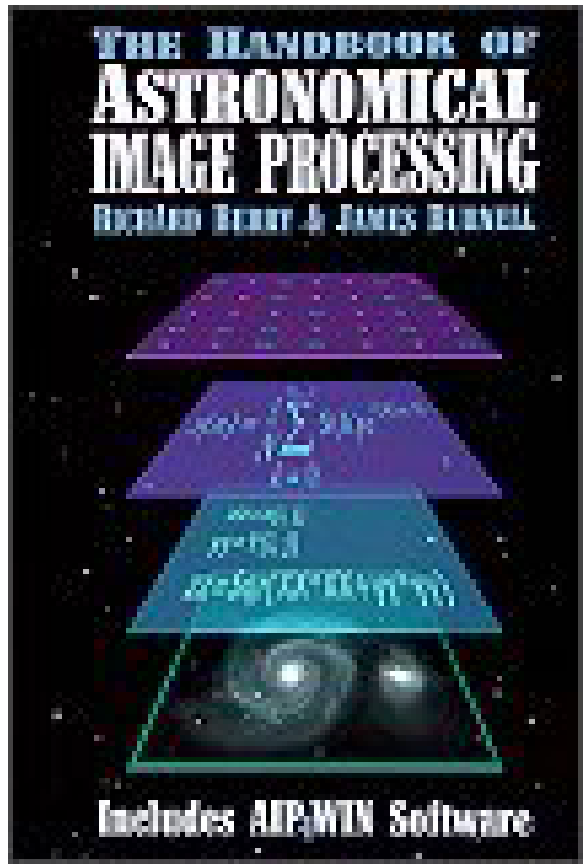

(Field Variable #2)
16-Dec-02 05:57:45
16.2
16.4
16.6
16.8
17
17.2
V Magnitude
0
0.5
1
1.5
Phase (2448400. + N* 0.497825)

Photometry With AIP4WIN





CCD Photometry



Helpful Tools

ALADIN: Finding Chart Tool

http://aladin.u-strasbg.fr/AladinJava?frame=downloading

AIP4WIN: CCD Photometry Book and Software

CCDSoft: Software Bisque CCD Image Acquisition and Photometry

AVE: Light curve plotting and period analysis tools

http://usuarios.lycos.es/rbarbera/AVE/AveInternational.htm

Cataclysmic Variable Catalogue Online

http://icarus.stsci.edu/~downes/cvcat/

Tutorial on CVs

http://cosmos.atu.edu/observatory/CVs

Tutorial on Photometry and CCDs

http://cosmos.atu.edu/observatory/CCDs

What Why Where? (WWW)

- CBA Arkansas (ATU Observatory)
  - http://cosmos.atu.edu