Dwarf Novae

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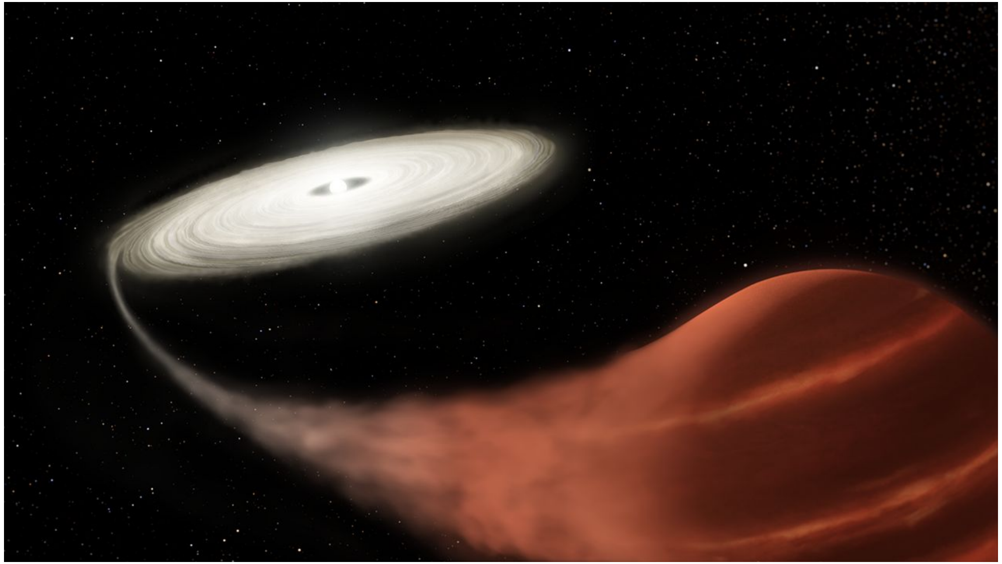
Agenda

★ The basics

★ Historical background

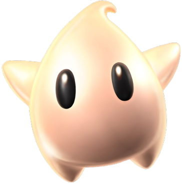
★ Current theories

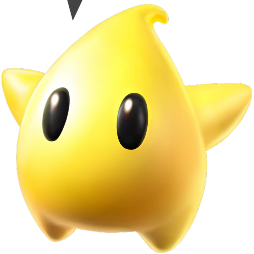
★ Observations



What Are Cataclysmic Variables?

Binary systems → white dwarf + companion star





Accretes matter

Typically main sequence

What Are Dwarf Novae?

Cataclysmic Variables

Supernovae

- ★ Single large outburst
- ★ Progenitor star 'dies'

Classical Novae

- ★ Periodic outbursts
- ★ Brightness increases by a factor of ~10^6

Dwarf Novae

- ★ Periodic outbursts
- ★ Brightness increases by a factor of ~10
- ★ Dimmer
- ★ More frequent
- ★ Different mechanism

etc...

What Are Dwarf Novae?

Outburst phase	5 to 20 days
Inactive phase	30 to 300 days
Most likely mechanisms	Instability in the accretion disk **or** Instability in mass transfer between the two stars
Why?	Understand the dynamics of accretion disks

Outburst Types

- ★ **Normal outbursts:**
  - Duration: 2–20 days
  - Magnitude: 2 to 5
  - More frequent (every 10 days ~ 10 years)

- ★ **Superoutbursts:**
  - 5–10 times **longer**
  - 0.7 magnitudes **brighter**
  - occur every few normal outbursts
  - small brightness variations→ **superhumps**

Superoutburst

Normal Outburst

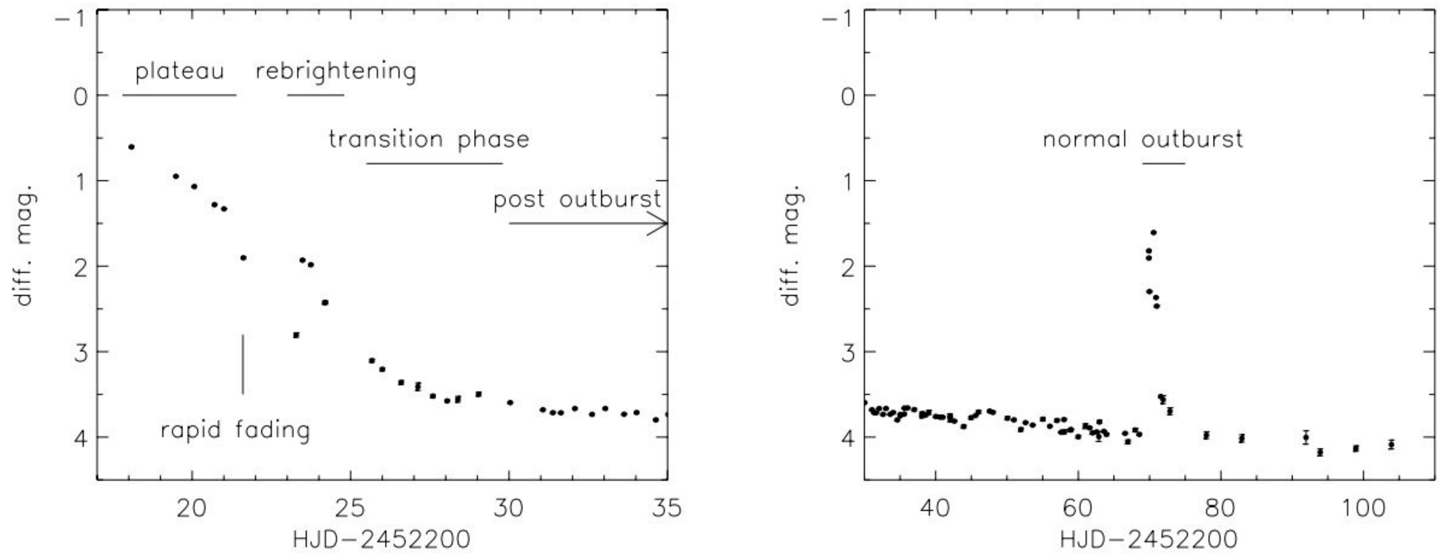


Fig. 1. Light curves of 1RXS J232953.9+062814 during and after the outburst in 2001 November. The abscissa and ordinate denote HJD and the differential magnitude, respectively. The filled circles represent the averaged magnitudes during each night. Left panel: Light curve including the superoutburst. We define four phases during this period, as shown in the panel (see the text). Right panel: Light curve during the post-outburst phase including a normal outburst.

Categorizing Dwarf Novae

CVs orbital period gap = ~1.5h to 3.35h → few observations…

Group 1

- ★ Below period gap
- ★ SU UMa category
- ★ Normal + superoutbursts

Group 2

- ★ Above period gap
- ★ Superoutbursts and superhumps are rarely observed

First Detections

U Geminorum (1855)

- ★ John Russel Hind (1823 - 1895)
- ★ First discovery – accidental!
- ★ Magnitude varied from 9 to 14 every ~100 days

SS Cygni (1896)

- ★ Ms. Louisa Wells (1862 - 1938)
- ★ 2nd discovery
- ★ Magnitude varied from 8 to 12 every ~50 days

First theories

1. Using only U Gen and SS Cyg Light Curves

★ Difficult:
- Light curves and period very different

2. Relation to Classical Novae

★ Outburst amplitude and frequency relation

3. Geometrically Variable (eclipsing) stars

★ Issue:
- CV Increase in brightness not decrease

First Theories (ctn.)

4. Changes in Temperature

★ 1948: Hinderer obtains high quality spectra – Temporal variations model

Hinderer's Model: G-type star surrounded by shell of thin gas

5. Accretion Disk With a Hot Spot

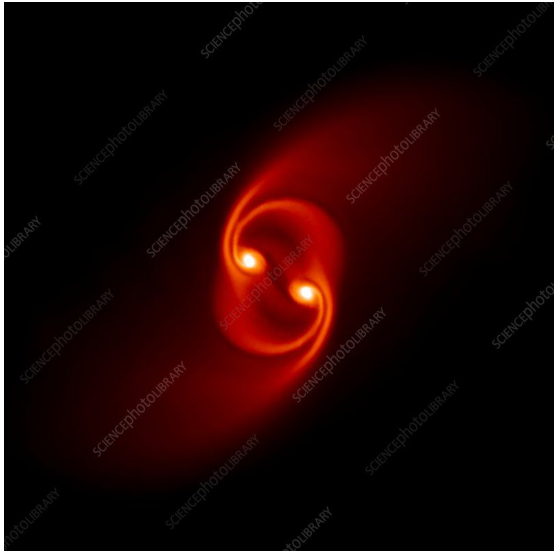
★ Similarities between UX UMa and old nova DQ Her.

★ 1956: Standard Model for Cataclysmic Variables

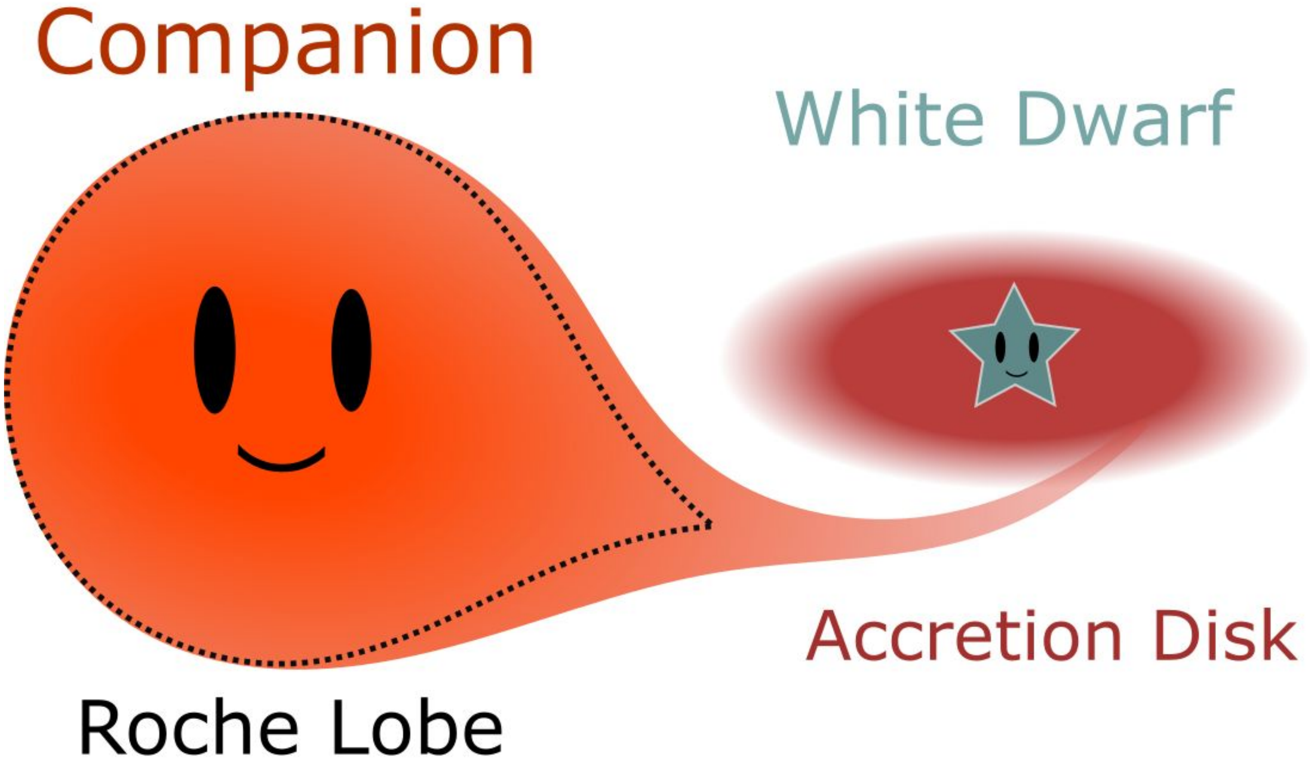
Kraft 1962 Standard Model applied to dwarf novae: They are caused by accretion disks!

Binary Star Formation

- Fragmentation Hypothesis
    - Protostar separates due to gas cloud instabilities
- Fission Hypothesis
    - Formed star separates into two



Mass Transfer Burst (MTB) or Disk Instability (DI)?

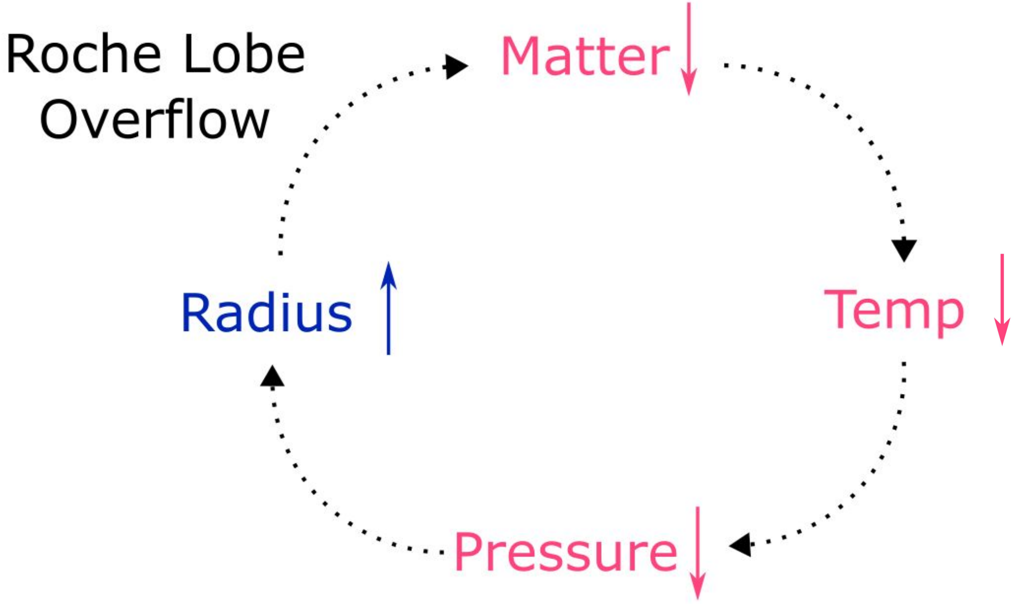


What is faster?

Mass transfer or accretion rate?

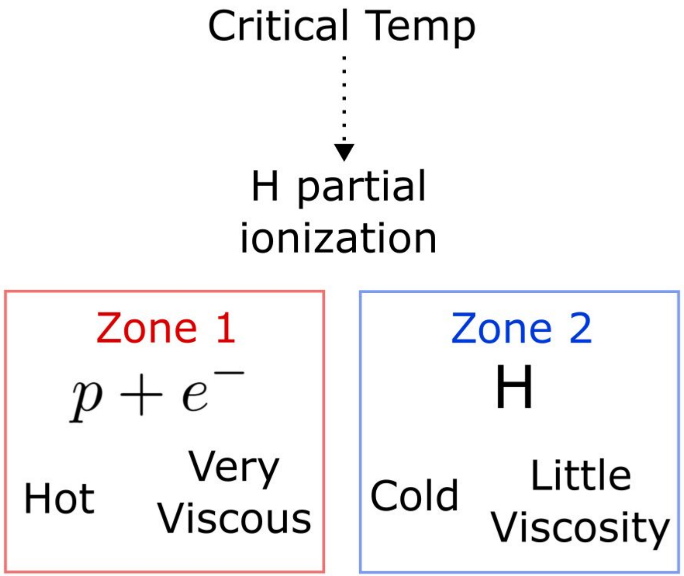
Mass Transfer Burst

- Companion Star has instability in secondary envelope



Disk Instability - 2 Origins

Thermal



Gravitational

- Resonant angular momentum transfer
- Eccentricity of disk
  - Shocks
  - Denser

Modelling Accretion Disks

DI Model → Simulate outburst cycles → Do models match observations?

- ★ Varying **viscosity parameter** α
  - 0.01 during the quiescent phase
  - 0.1 during the outburst phase
  - Needed to explain the observed cycles!
- ★ **1D modeling:** Reflares seen during outbursts that are not observed in real data
- ★ More accurate results → 3D simulations

Using telescopes

★ Detections at visible and UV wavelengths

★ Measure lower/upper limits on outburst reccurence times

★ Learn about mechanisms

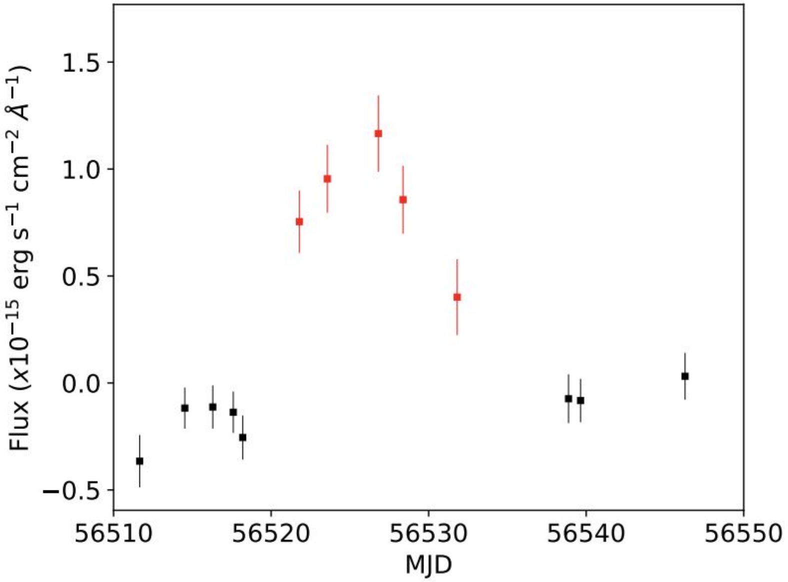


Fig. 3. Zoom of the *uvm2* light curve of SW2 during its second observed outburst in the UVOT data, showing that the source exhibited a rise and decay in brightness over a 10 day period, with a maximum duration of the outburst of 20 days. The red points show detections and the black points show non-detections.

Conclusion

- CV with dim frequent outbursts due to accretion disk
- Two Models:
  - Mass transfer burst
  - Disk instability
- Lots to discover about how they work
  - Observational data
  - Model Comparison
- Future goals: studies on the quiescent state
  - contradiction between model and observations.

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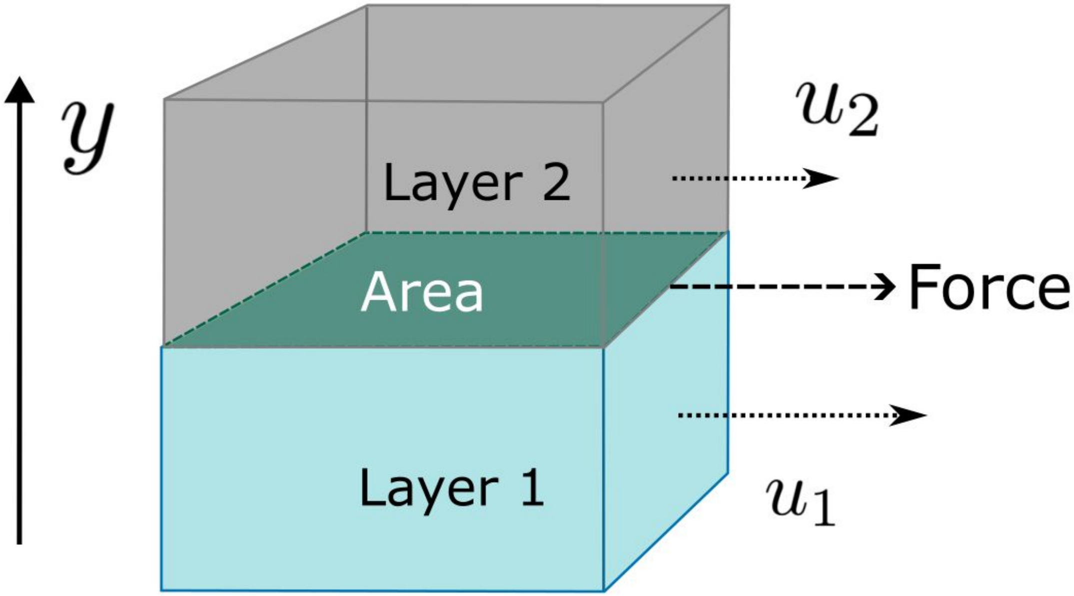
(extra) Current Theory - Preliminaries

$$\frac{\text{Force}}{\text{Area}} = \text{Viscosity}\ \frac{\Delta u}{\Delta y}$$



$$\begin{array}{c}\text{Angular}\\ \text{Momentum}\\ \text{Transfer}\end{array} \propto \text{Viscosity}$$

(extra)

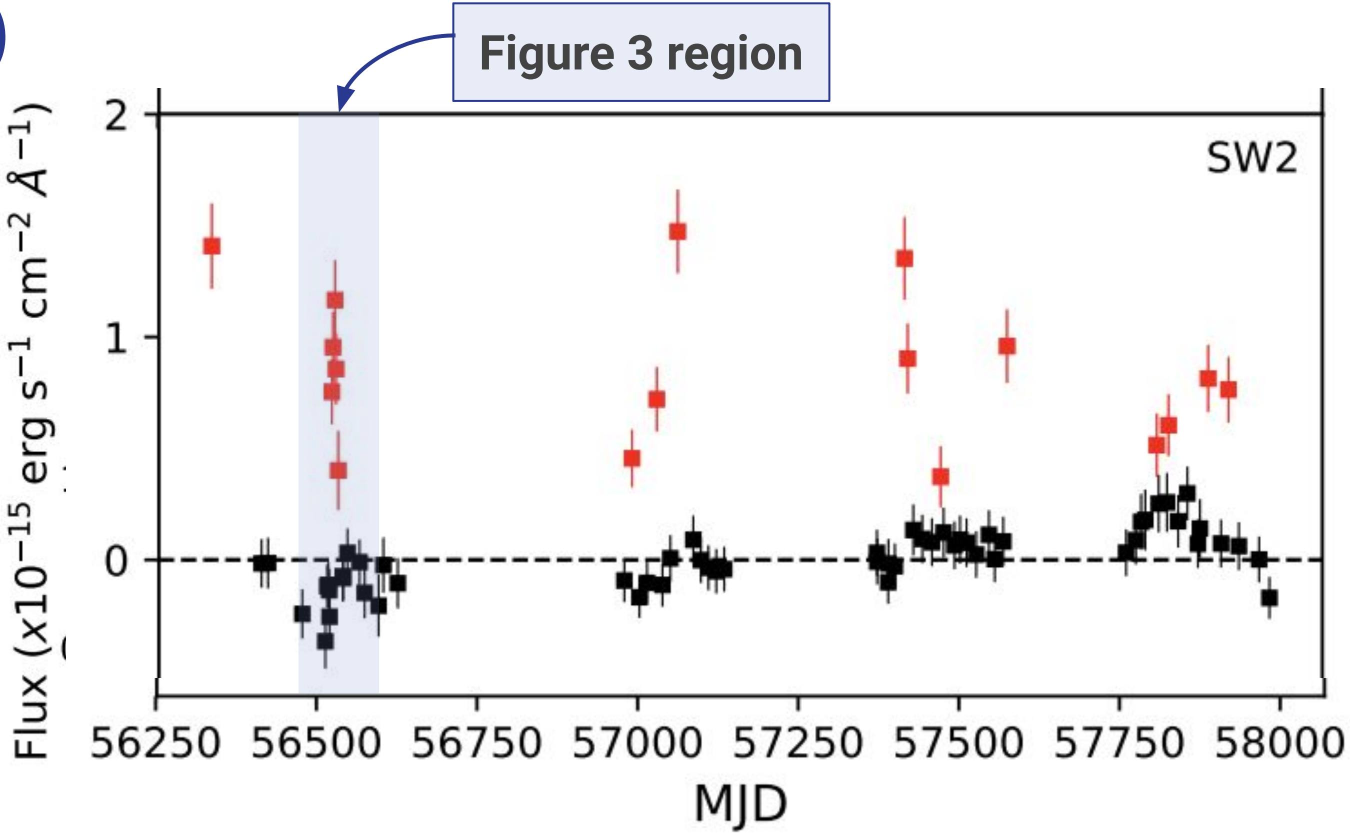


Figure 3 region
SW2
Flux (x10^{-15} erg s^{-1} cm^{-2} Å^{-1})
2
1
0
56250
56500
56750
57000
57250
57500
57750
58000
MJD