Eclipse Mapping

UX UMa
HST data

Aug 94

Nov 94

CIV

λ1355

Lya

λ4381

λ2710

λ2678

 flux density (mJy)

orbital phase

orbital phase

blue

UV
UX UMa

HST data

Eclipse Mapping

Spectra for disk annuli

Hot Opaque Disk

Log brightness temperature [R]

Wavelength (Å)

P, (mJy)

2156 Å

Nov 94

Aug 94

0 5 10 1000 2000 4000 6000 8000
Dwarf Nova Outbursts

U Gem

Magnitude

1992 1993 1994

Julian Day Number

2448500 2449000 2449500
Eclipses on the Rise to Outburst

Disk much brighter during outburst
Disc Radius Variations

Disk radius increases rapidly during outburst and decreases slowly during quiescence.
Eclipses observed
with James Gregory Telescope in St. Andrews
Eclipse Mapping
Spectra on the Rise to Outburst

SS Cyg rising

Absorption lines
--> optically thick

Emission lines
--> optically thin

Wavelength (Å)

ABv

4000 5000 6000
Heating and Cooling

- **Heating**: (viscous dissipation)

\[ Q^+ = \frac{v}{2} \sum \left( R \left( \frac{d\Omega}{dR} \right) \right)^2 \quad v = \alpha c_s H \]

- **Cooling**: (radiation)

\[ Q^- = \sigma T_{\text{eff}}^4 = \sigma \int B_v(T) \left( 1 - e^{-\tau} \right) d\nu \]

- **Optical depth**:

\[ \tau_v = \int \rho \kappa_v d\ell \]

\[ I_v = B_v \left( 1 - e^{-\tau_v} \right) \]

\[ \approx B_v \quad \tau_v \gg 1 \quad T_{\text{eff}} \approx T \]

\[ \approx B_v \tau_v \quad \tau_v \ll 1 \quad T_{\text{eff}} \approx T \tau^{1/4} \]
Thermostat

$T \sim T_{\text{eff}} \tau^{1/4}$

$T_{\text{eff}} \propto R^{-3/4}$

$\tau \gg 1$  $\tau < 1$

Optically thick  Optically thin
H ionised       H partially ionised
Thermal Equilibrium S-curve and Limit Cycle

\[ T_{\text{eff}}^4 \propto \dot{M} \propto v \Sigma \]

\[ \alpha_H \sim 0.1 \]

\[ \alpha_C \sim 0.01 \]

cooling > heating

cooling < heating
Heating and Cooling Waves

Outburst triggers at small / large R for small / large Mdot

Heating wave switches disk to outburst state

Inmoving wave is faster (avalanche)

Cooling wave switches disk to quiescent state
Disk Instability Models

Luminosity

Radius

Mass

Angular momentum
Short, Long, and Slow-Rise

SS Cyg

Julian Day Number

Magnitude

2448000 2448100 2448200

Time

Outside-in heating wave

Plateau

Cooling wave

Inside-out heating wave

Slow rise

Short
Z Cam Outbursts

AS 4024

Binary Stars and Accretion Disks
Super Outbursts

Longer and brighter than normal outbursts

VW Hya
Super Humps

Photometric modulations with period a few percent longer than the orbital period.

Occur during Super Outbursts

DV UMa
Superhump Period Changes

- V1159 Ori
- IY UMa
Tides and Resonances

Disk Tide

angular momentum moves from the disk to the binary orbit.

3:1 resonance

3 cycles around the disk per orbit

Slow precession of resonant orbits

Binary Stars and Accretion Disks
Eccentric Precessing Disc

Orbit period -- few hours
Precession period -- few days
Beat period = superhump period

\[
\frac{1}{P_{SH}} = \frac{1}{P_{orb}} - \frac{1}{P_{prec}}
\]

Superhumps caused by extra tidal heating of outer disc as the eccentric bulge precesses past the companion star.
Observed Shape of Eccentric Disc

Derived from eclipse timings at different superhump phases.
Super-Cycle Models

Tidal Heating keeps disk in outburst longer when disk radius is larger.