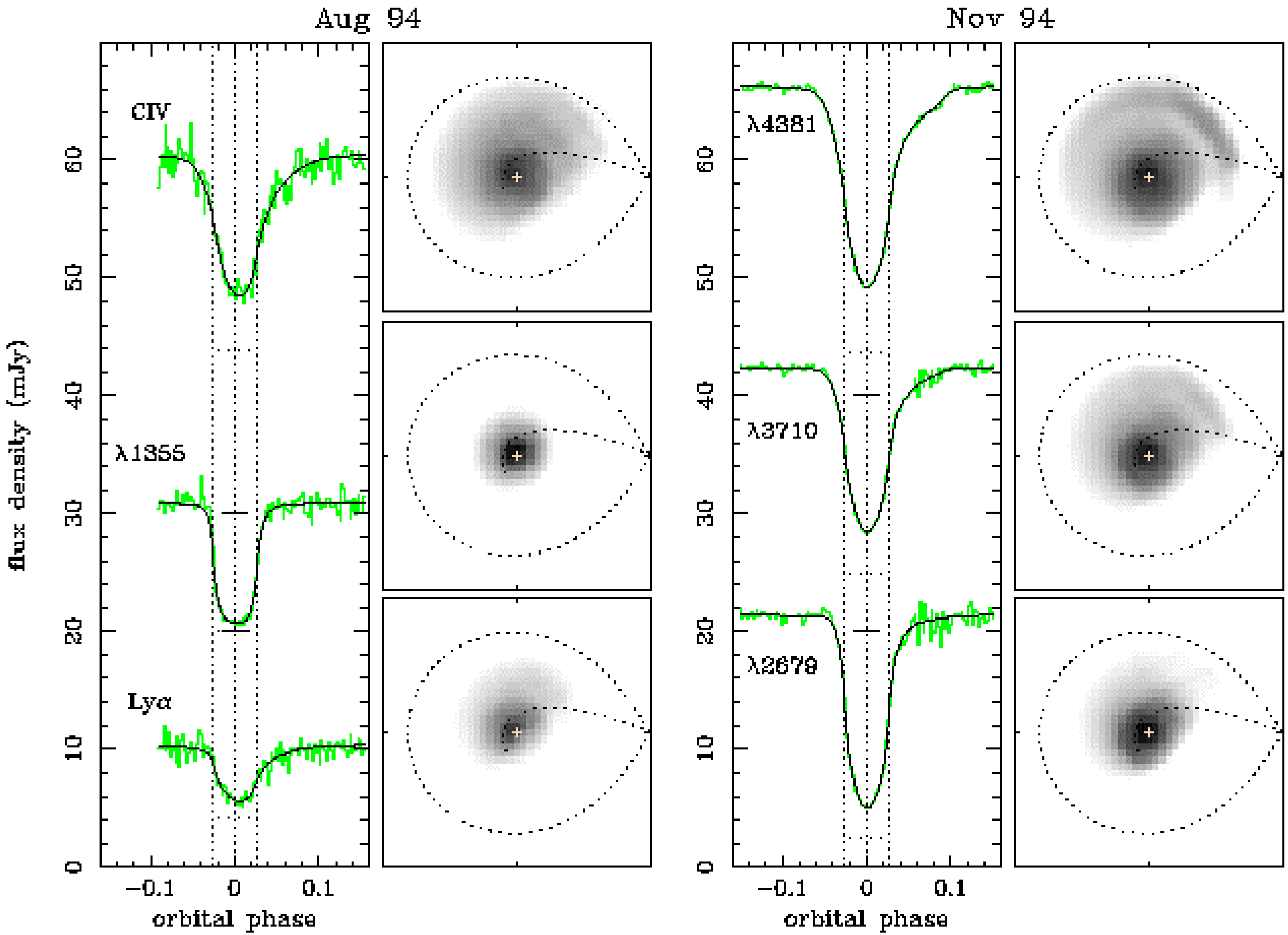
Eclipse Mapping

UX UMa

HST data



blue

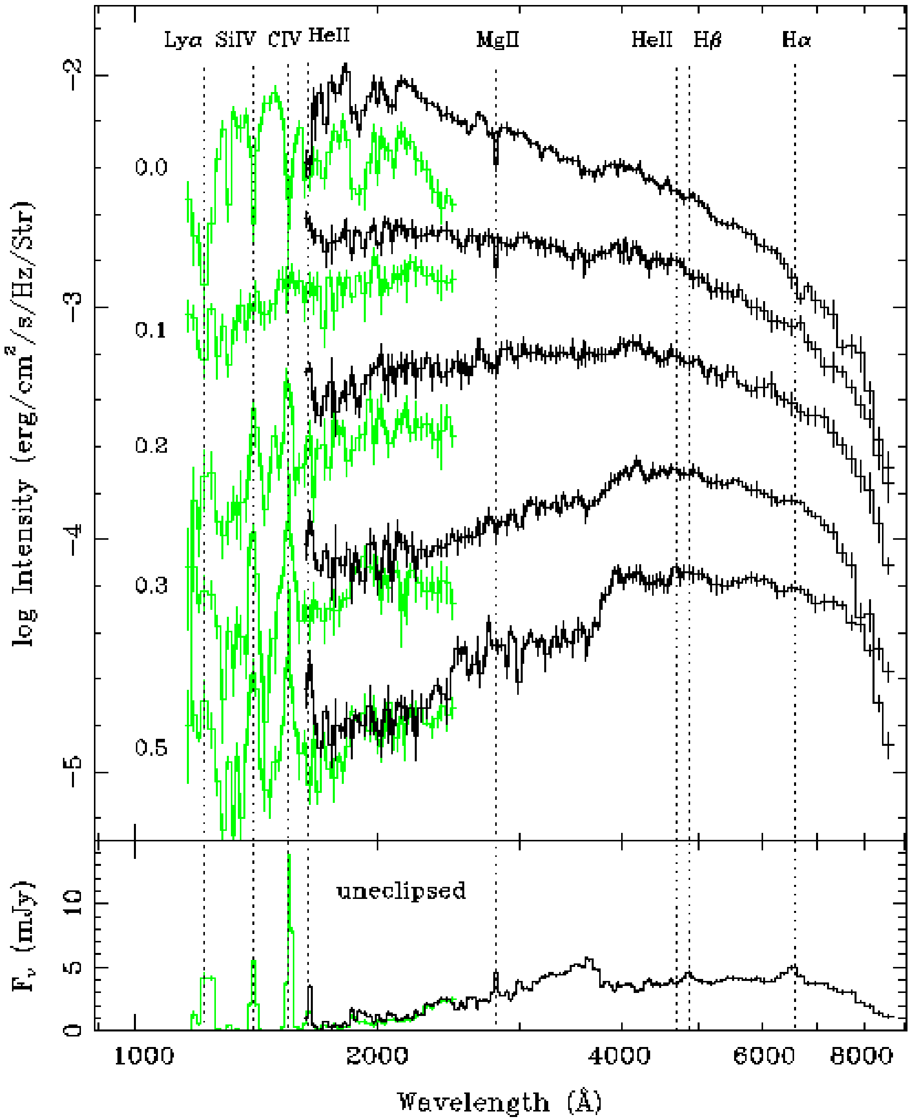
UV

Eclipse Mapping

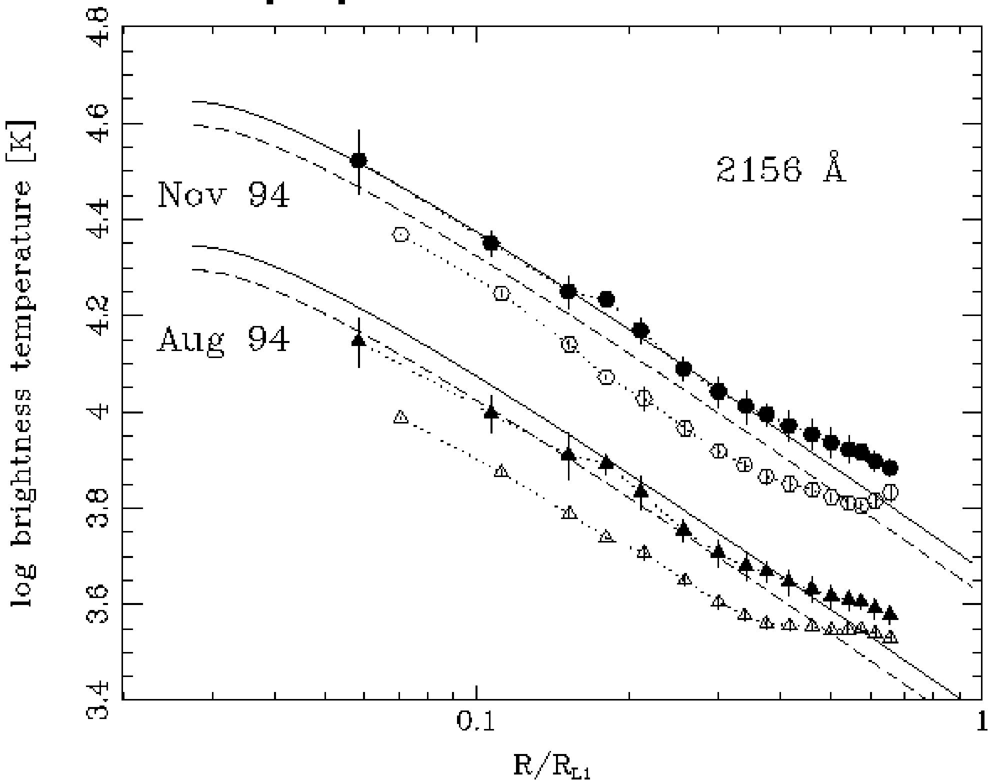
UX UMa

HST data

Spectra for disk annuli

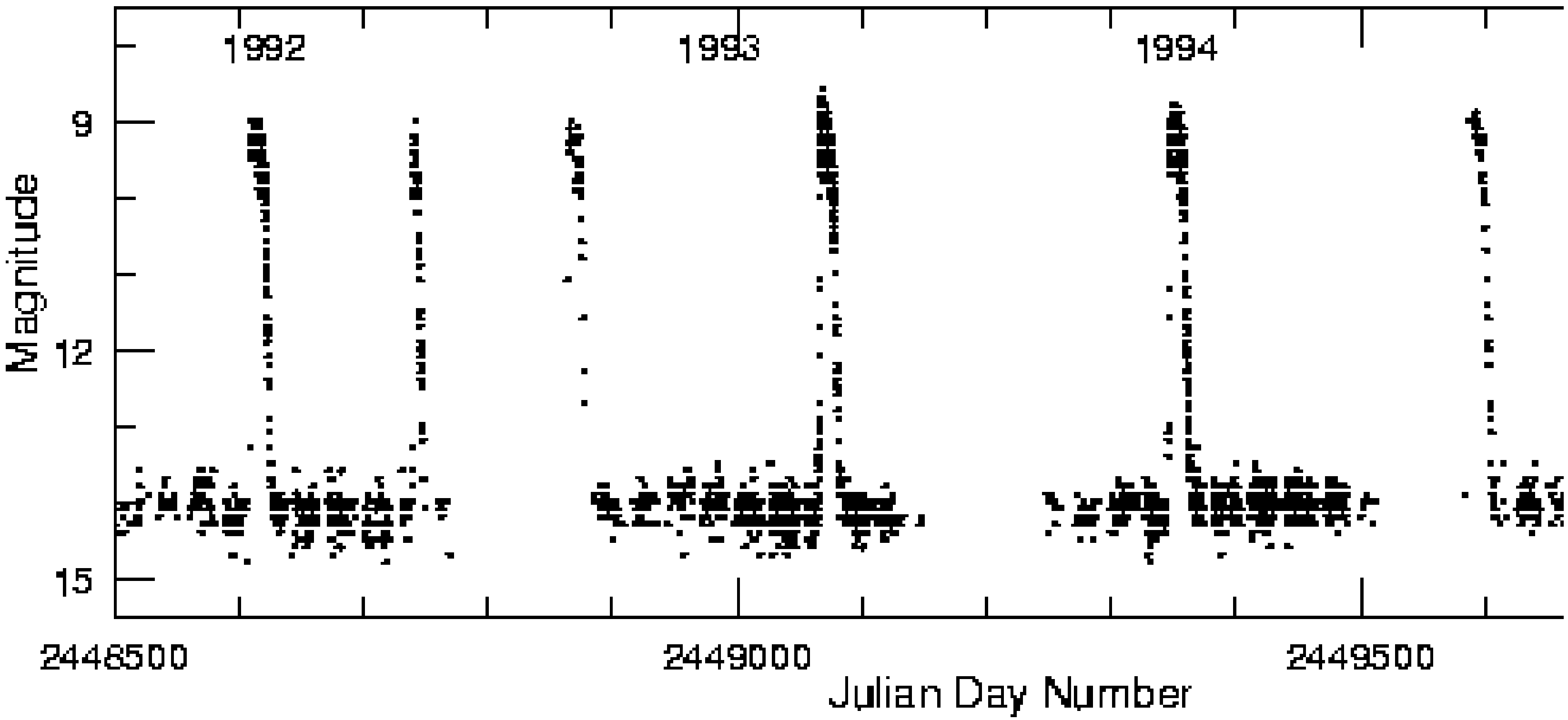


Hot Opaque Disk

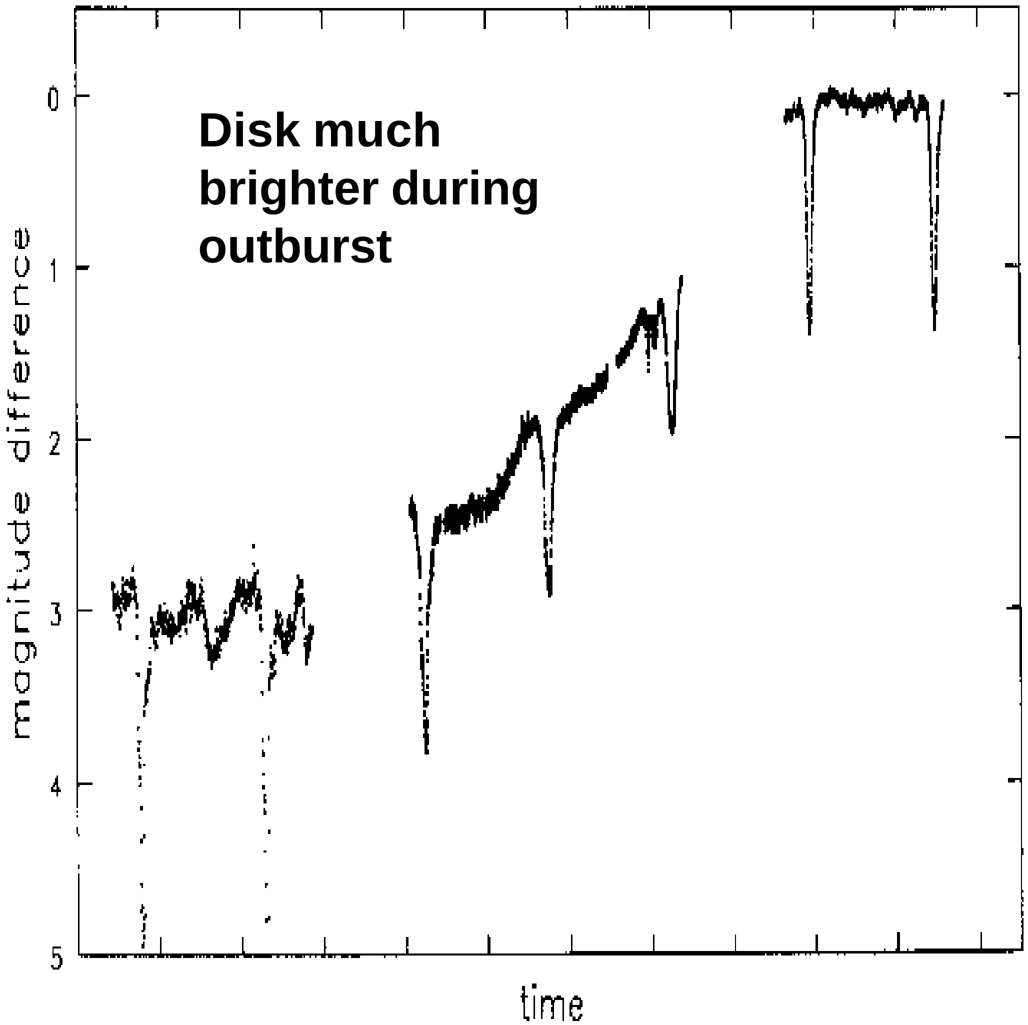


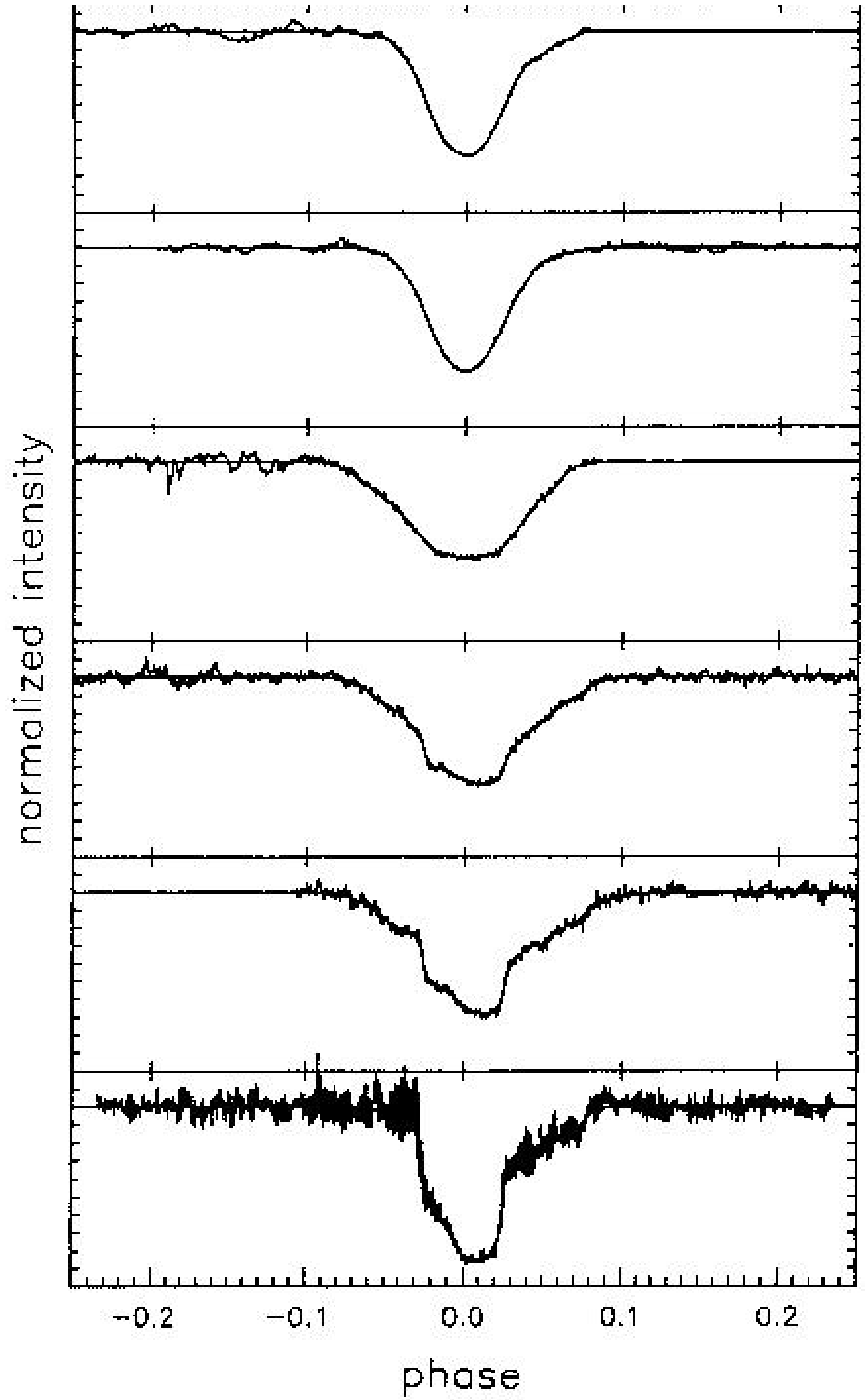
Dwarf Nova Outbursts

U Gem



Eclipses on the Rise to Outburst



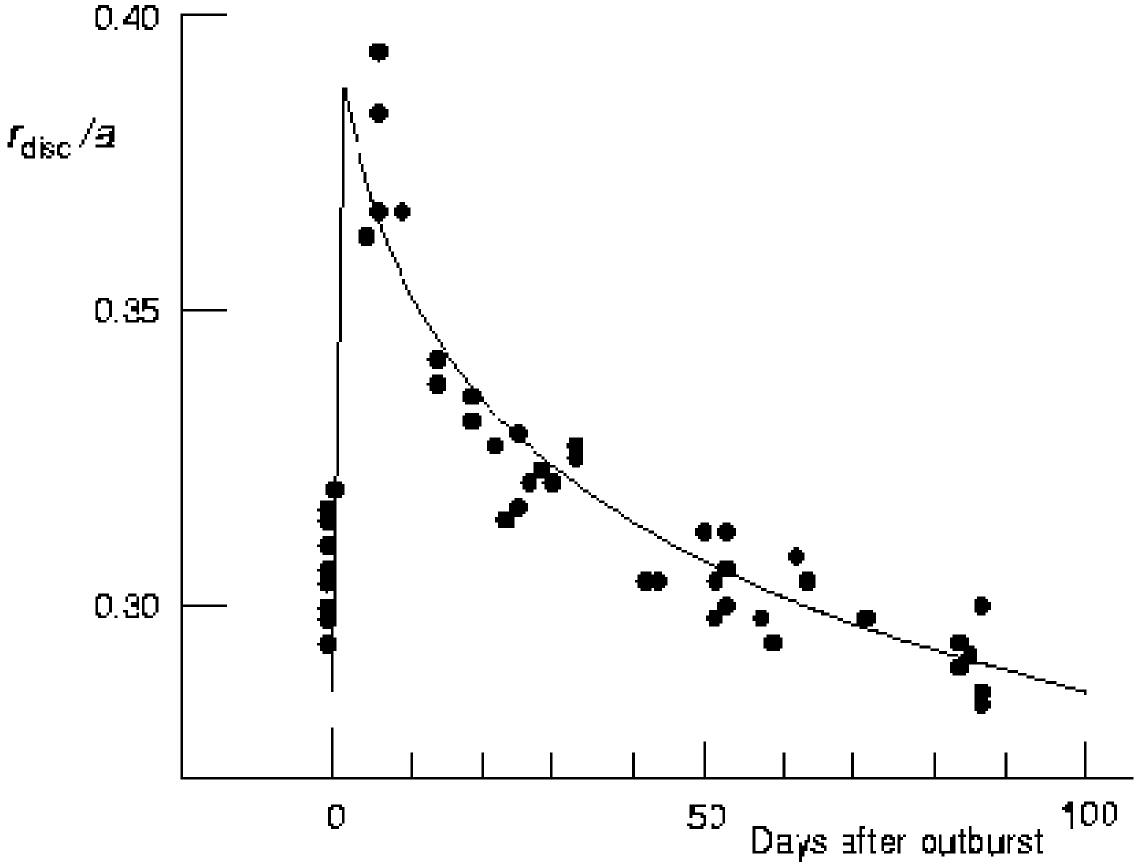


Disc Radius Variations

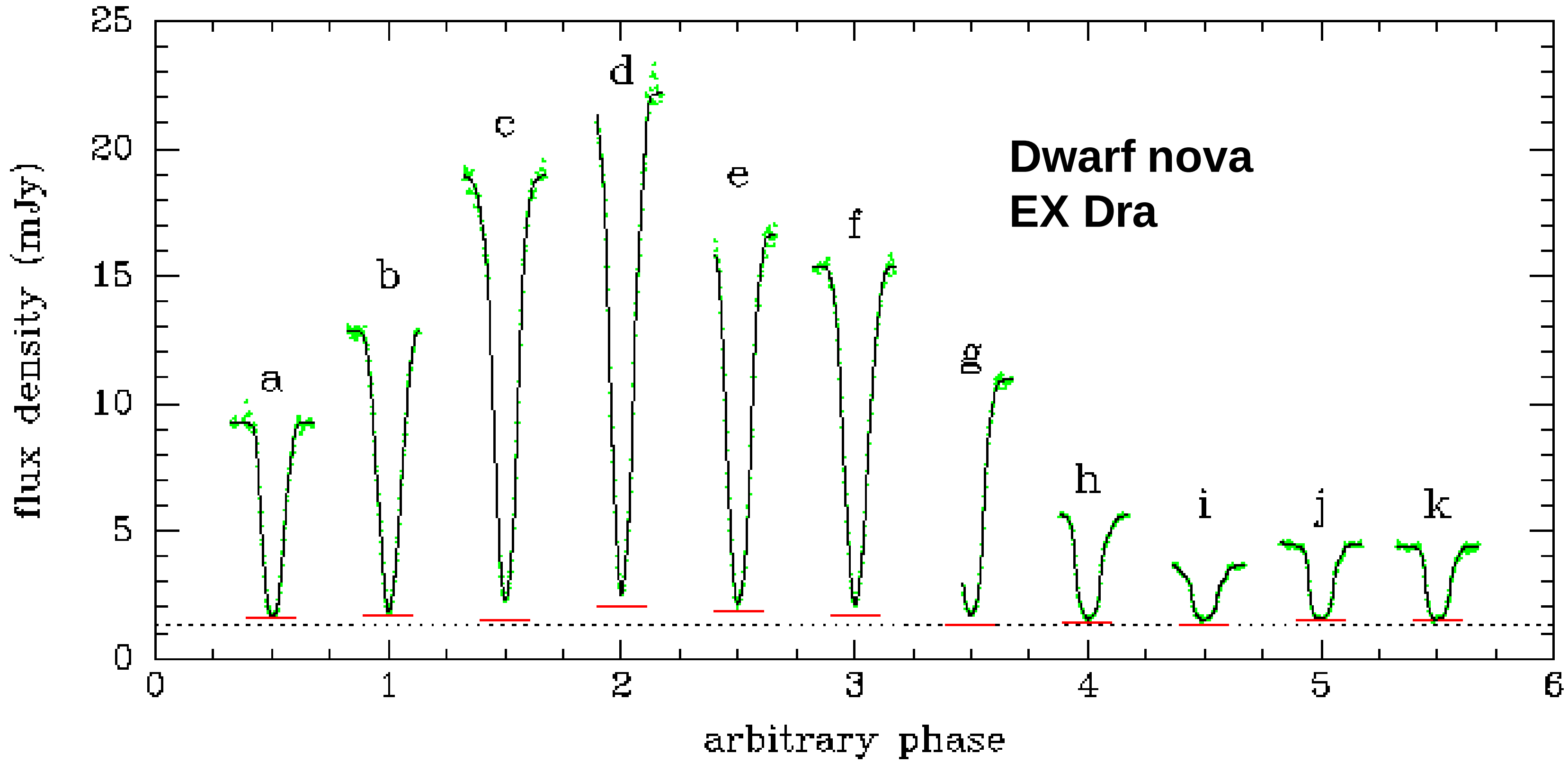
Disk radius

increases rapidly during outburst

decreases slowly during quiescence



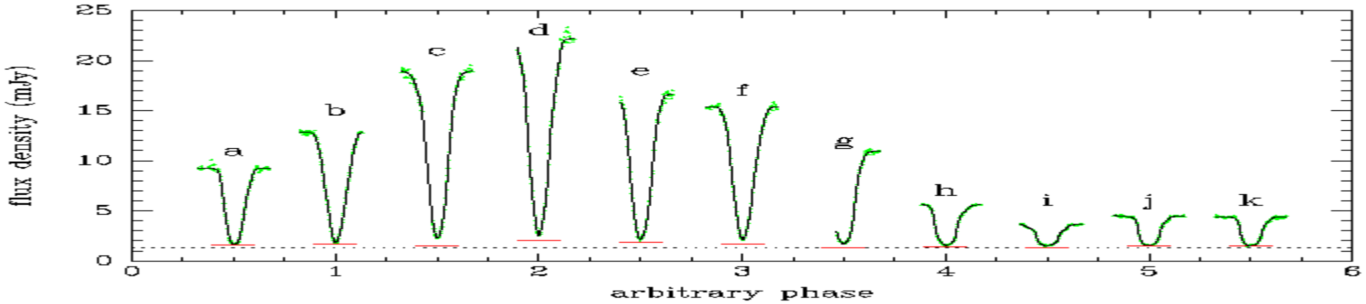
Eclipse Mapping

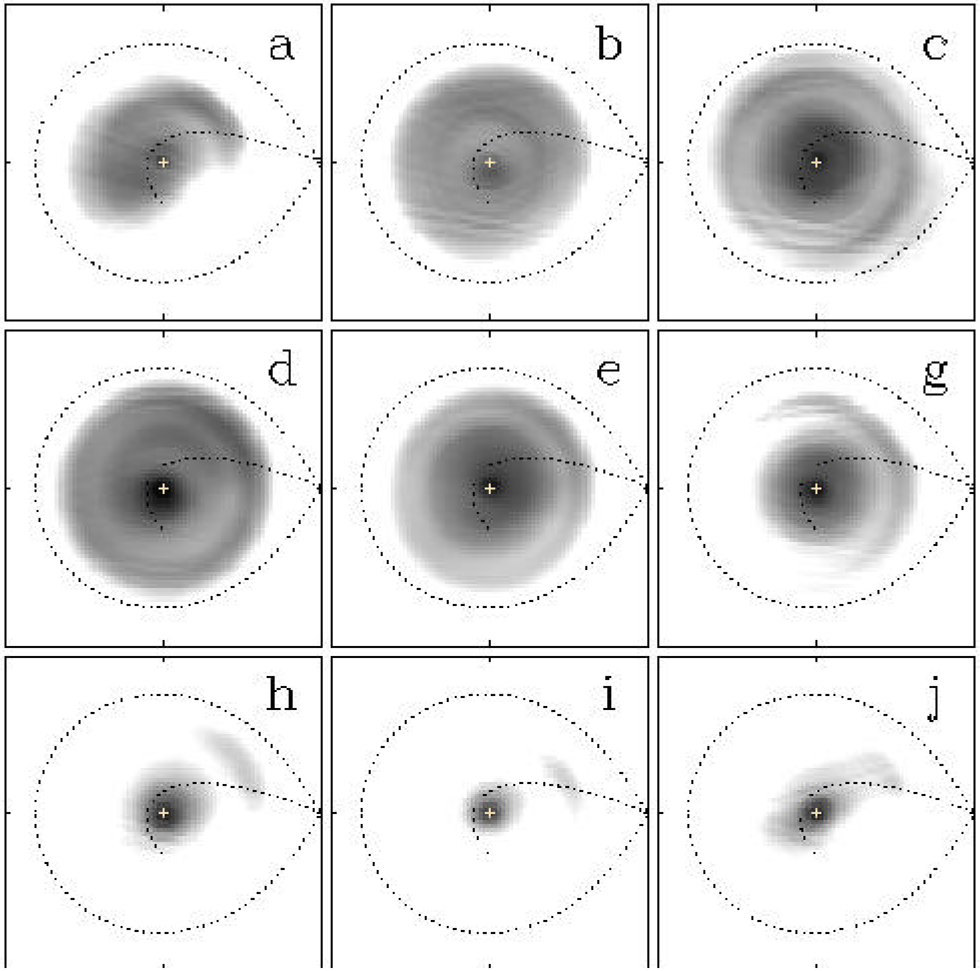


Eclipses observed

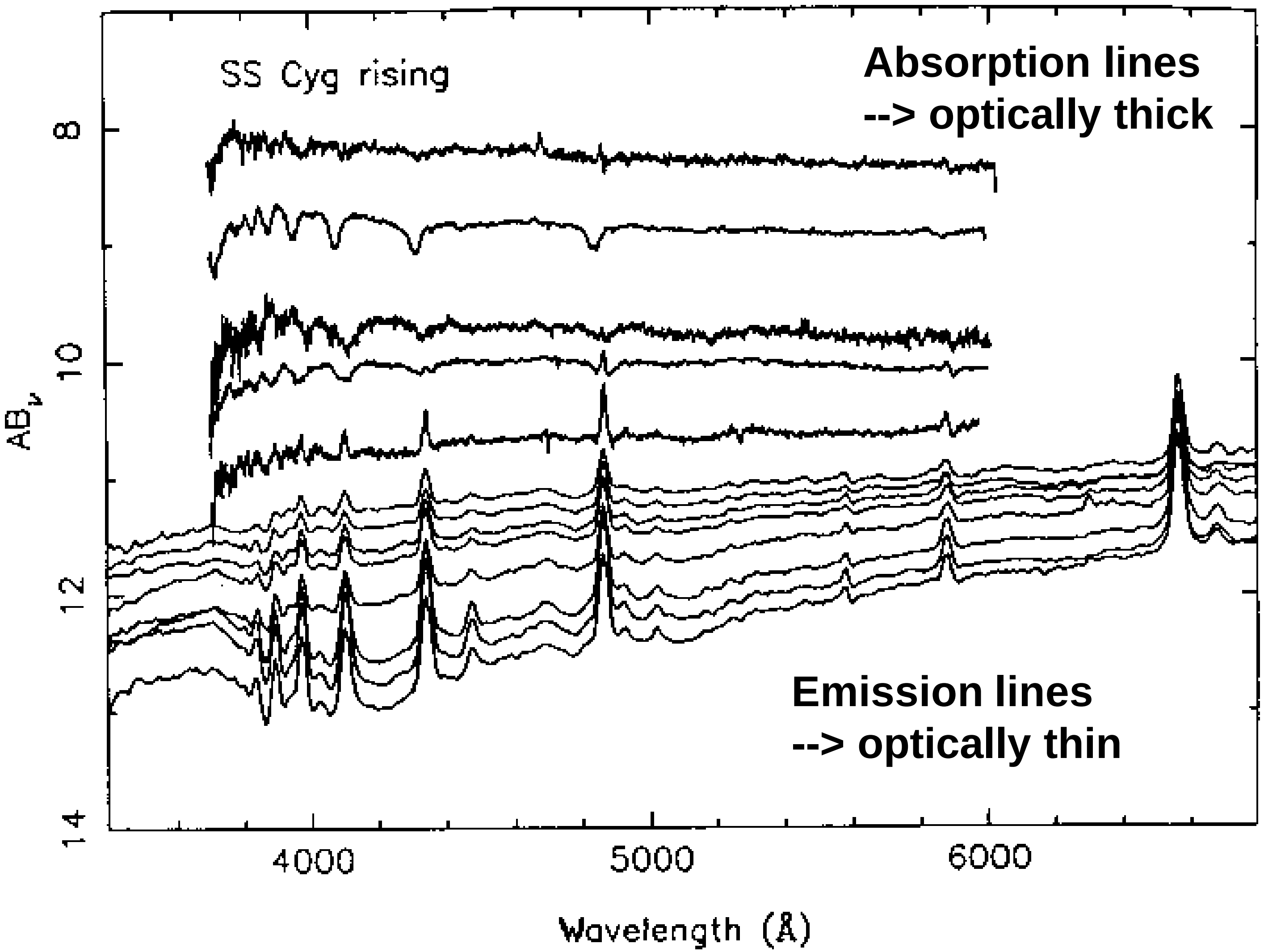
with James Gregory Telescope in St.Andrews

Eclipse Mapping





Spectra on the Rise to Outburst



Heating and Cooling

- **Heating : (viscous dissipation)**

$$Q^{+} = \frac{n\,\Sigma}{2}\left(R\,\frac{d\Omega}{dR}\right)^{2} \qquad n = a\;c_{S}\;H$$

- **Cooling : (radiation)**

$$Q^{-} = s\;T_{eff}{}^{4} = s\int B_{n}(T)\left(1-e^{-t}\right)dn$$

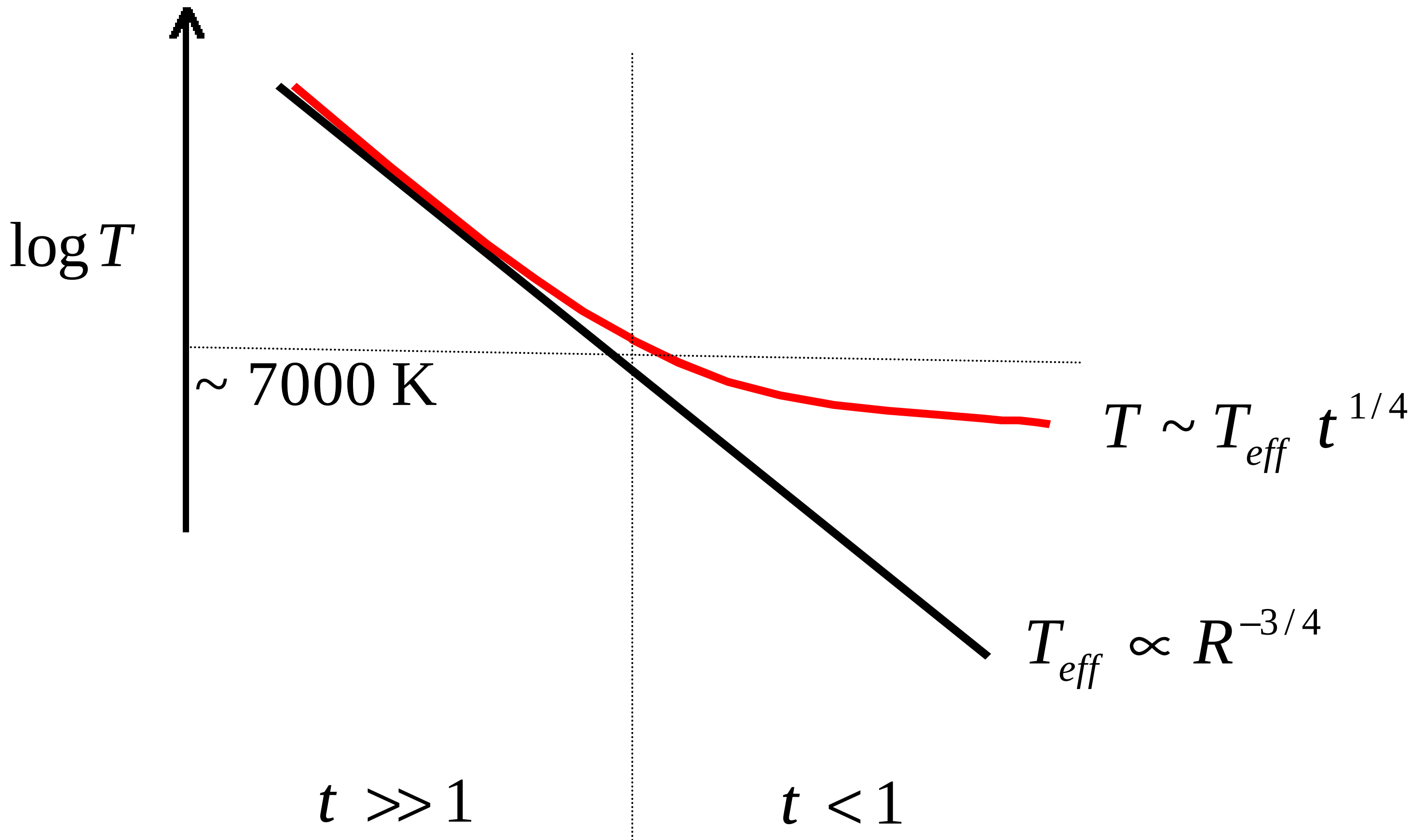
- **Optical depth :** $t_{n} = \int r\;k_{n}\;d\ell$

$$I_{n} = B_{n}\left(1-e^{-t_{n}}\right)$$

$$\approx B_{n} \qquad t_{n} \gg 1 \quad T_{eff} \approx T$$

$$\approx B_{n}\;t_{n} \qquad t_{n} \ll 1 \quad T_{eff} \approx T\;t^{1/4}$$

Thermostat



Optically thick

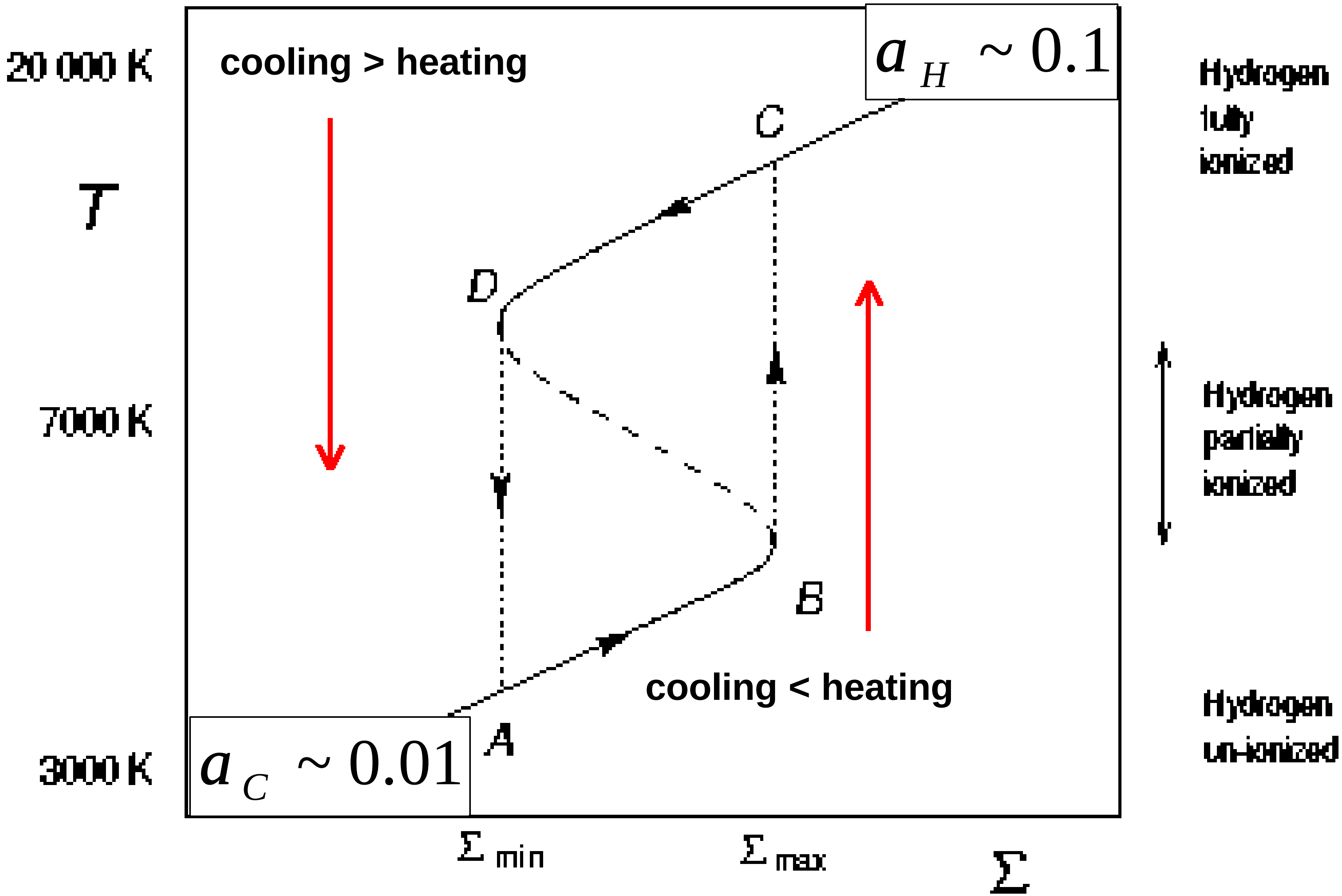
H ionised

Optically thin

H partially ionised

Thermal Equilibrium S-curve and Limit Cycle

$$T_{eff}^{\ 4} \propto \dot{M} \propto n\,\Sigma$$



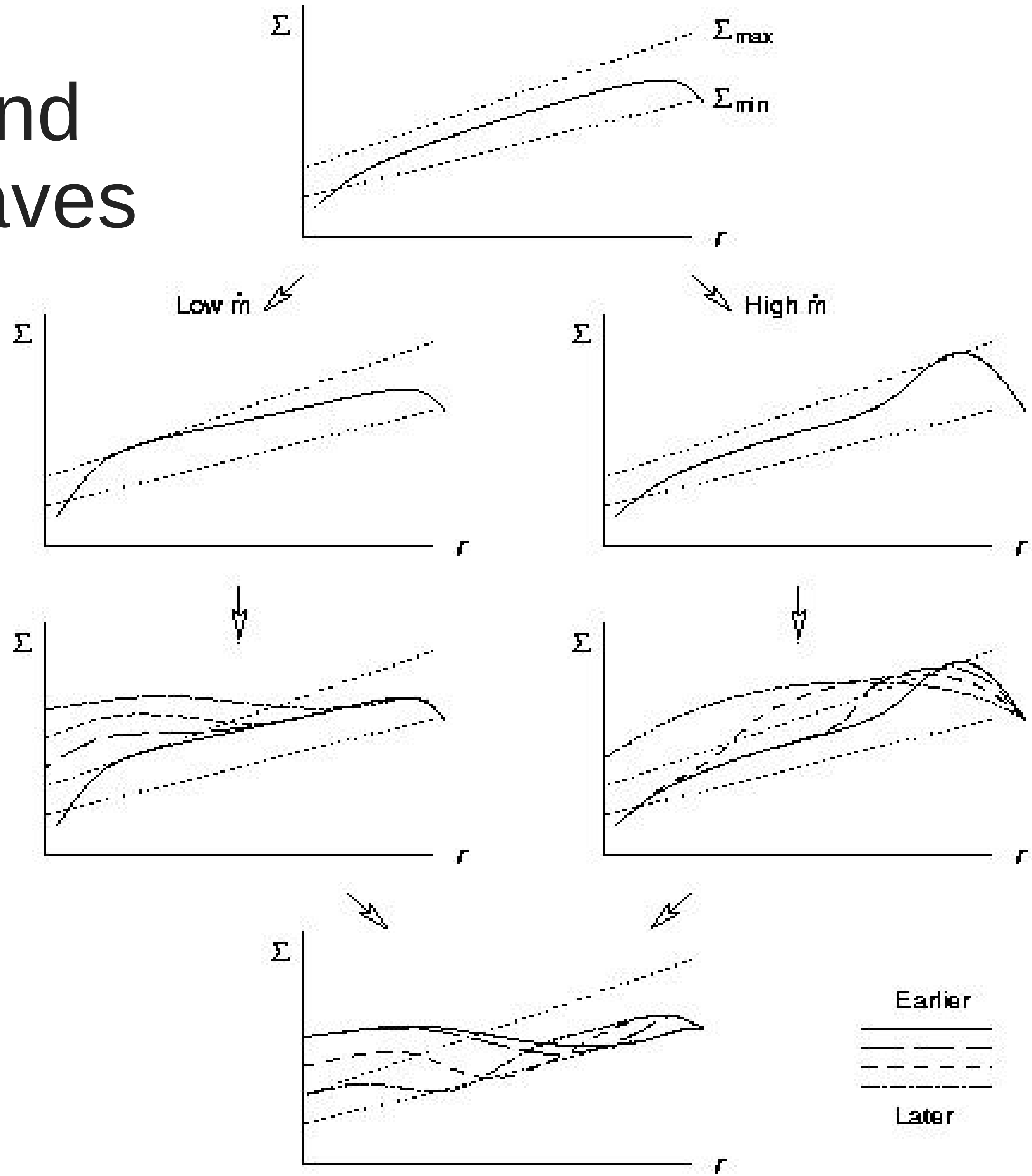
Heating and Cooling Waves

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



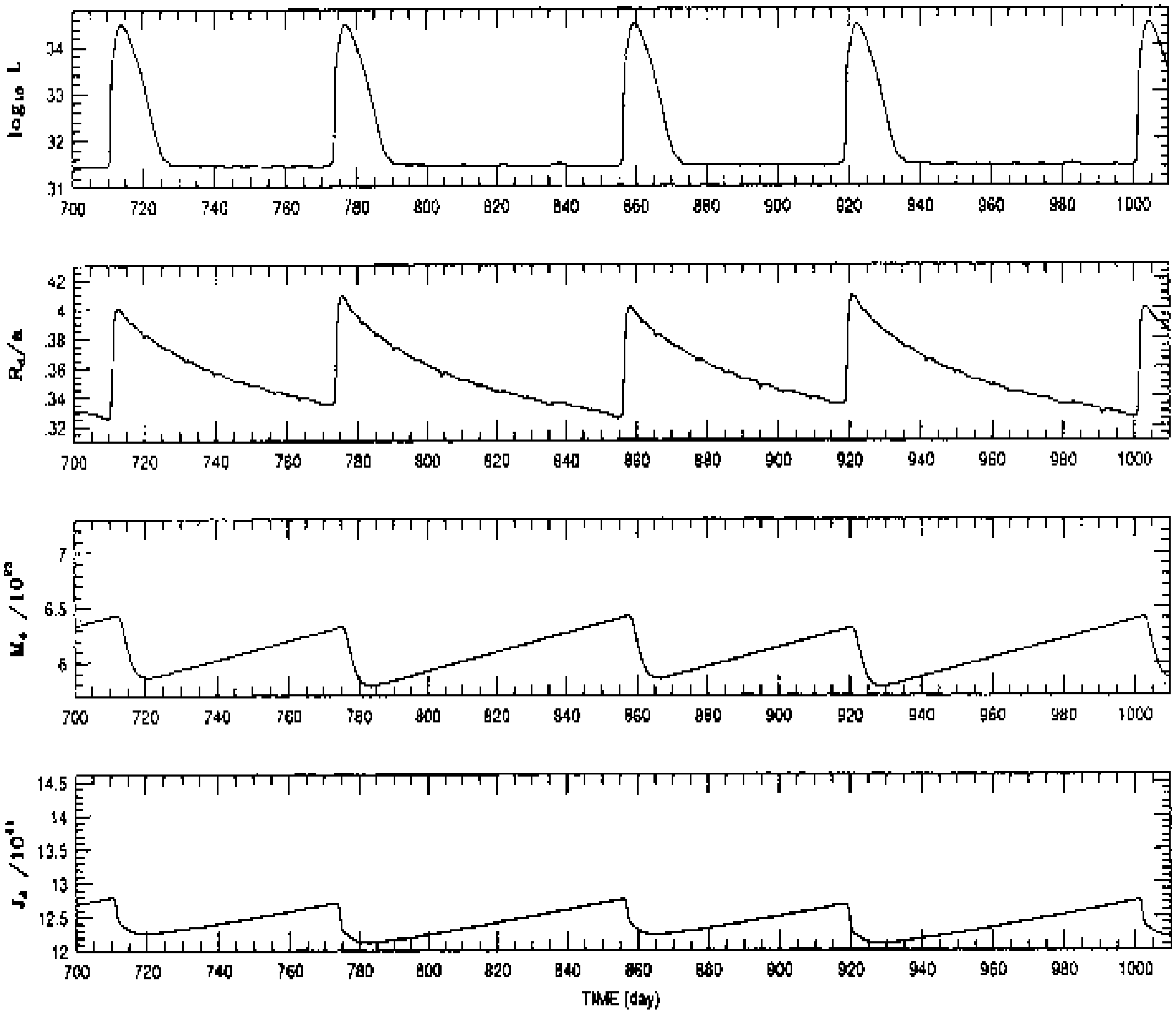
Disk Instability Models

Luminosity

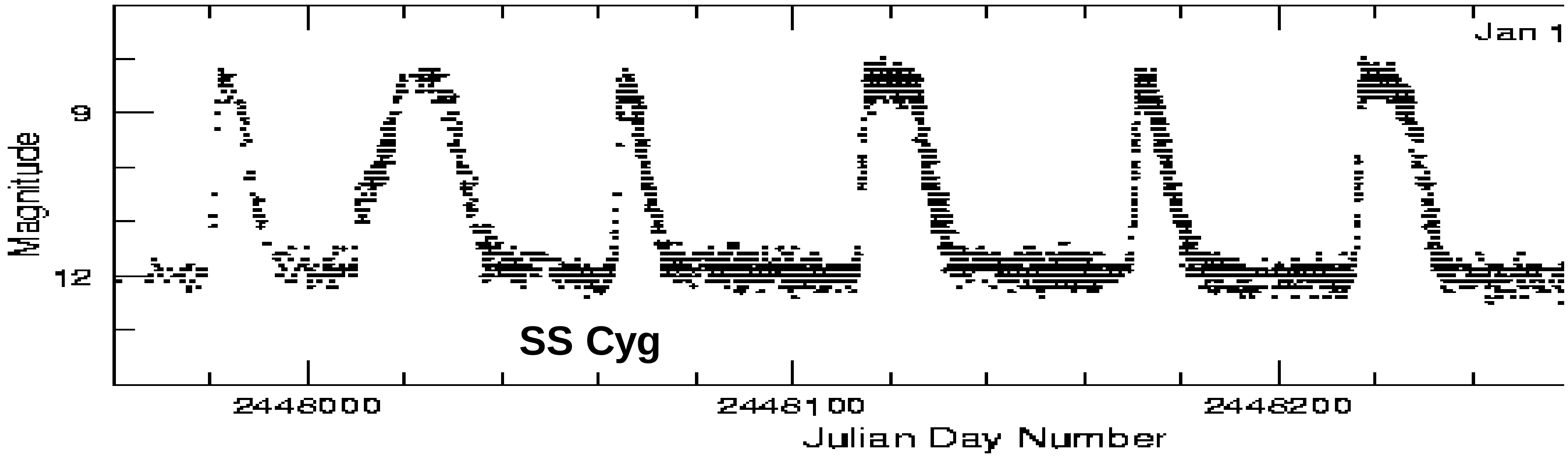
Radius

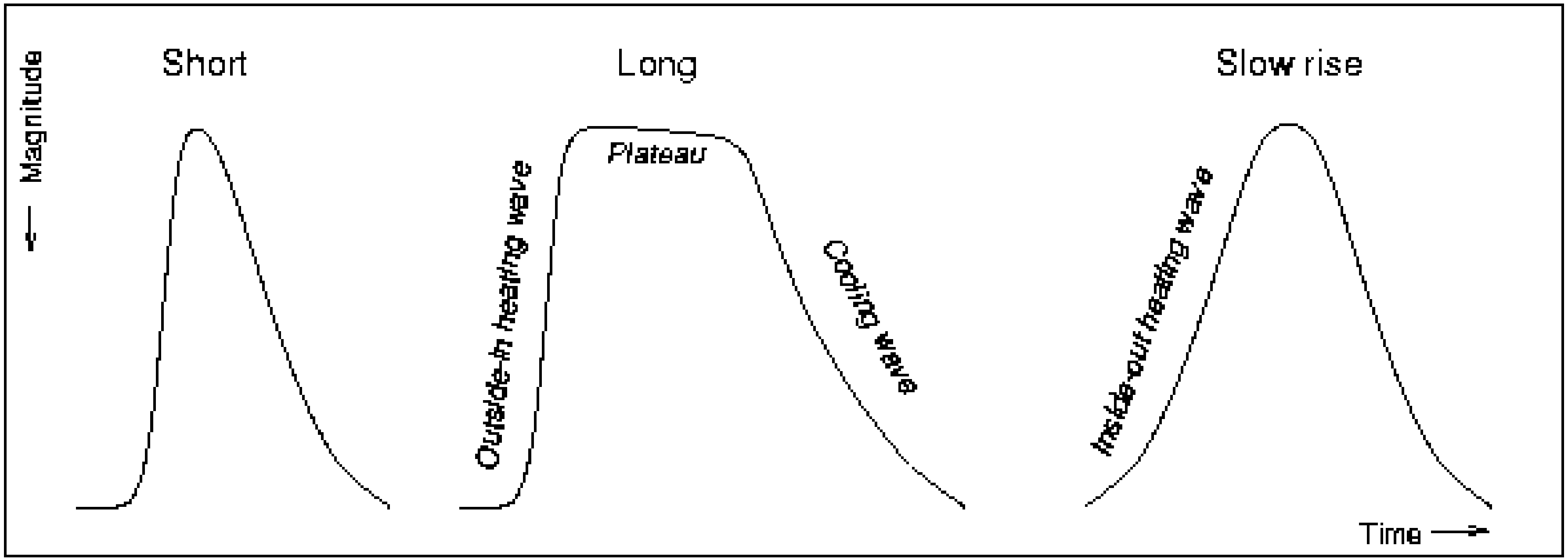
Mass

Angular momentum

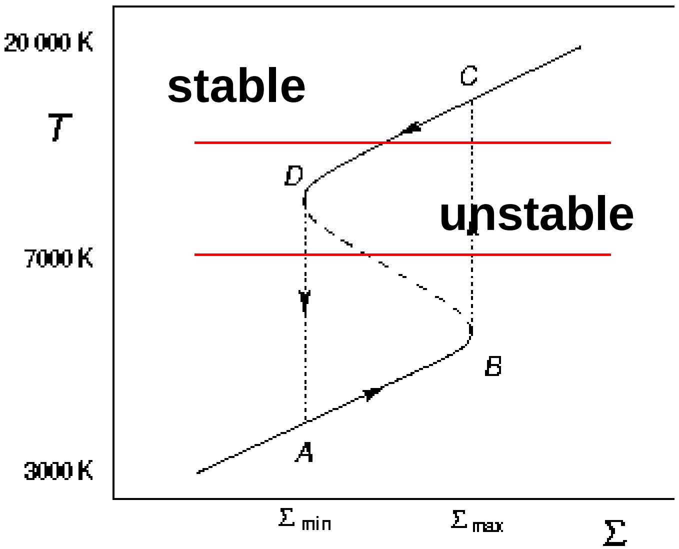


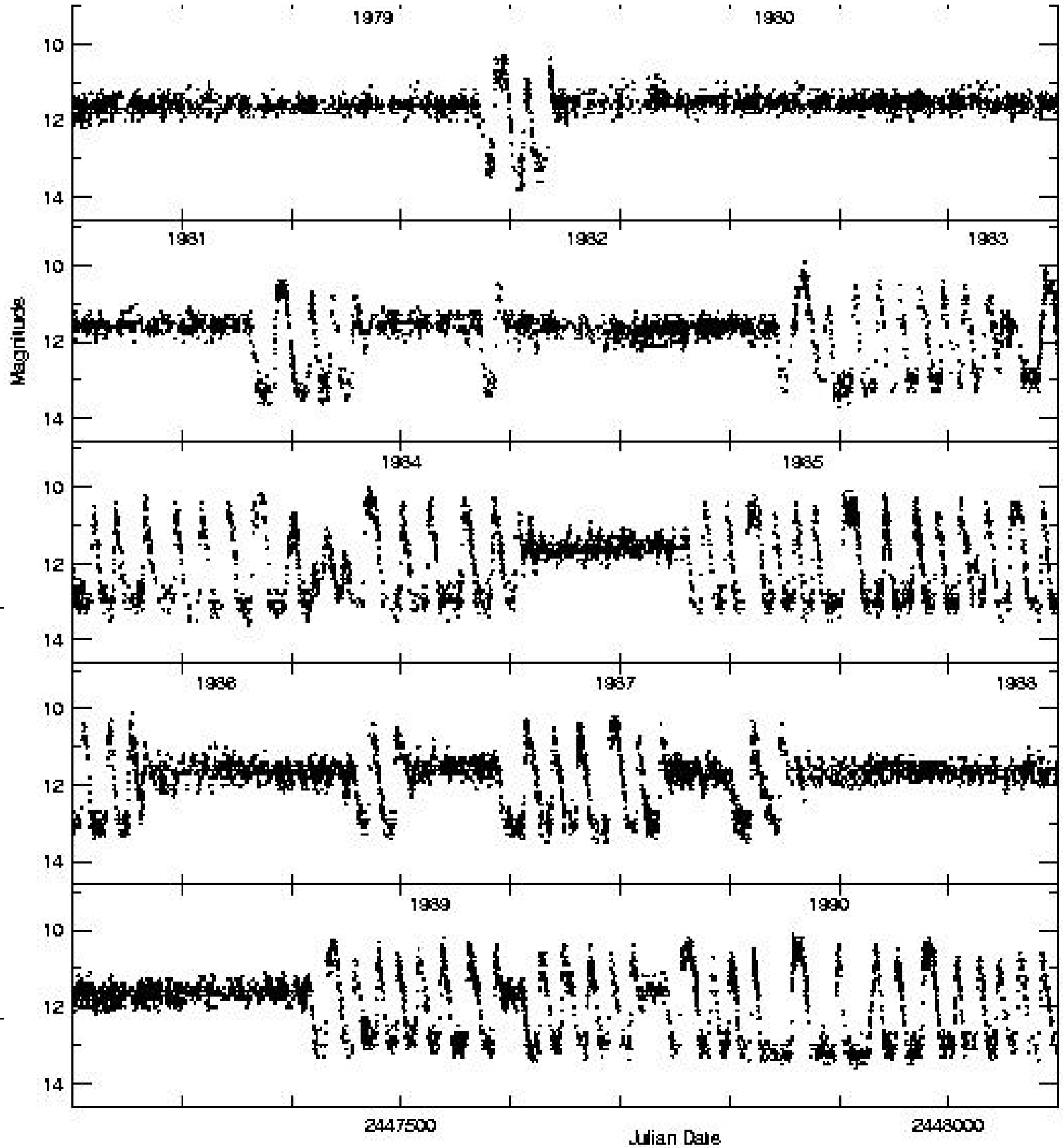
Short, Long, and Slow-Rise





Z Cam Outbursts

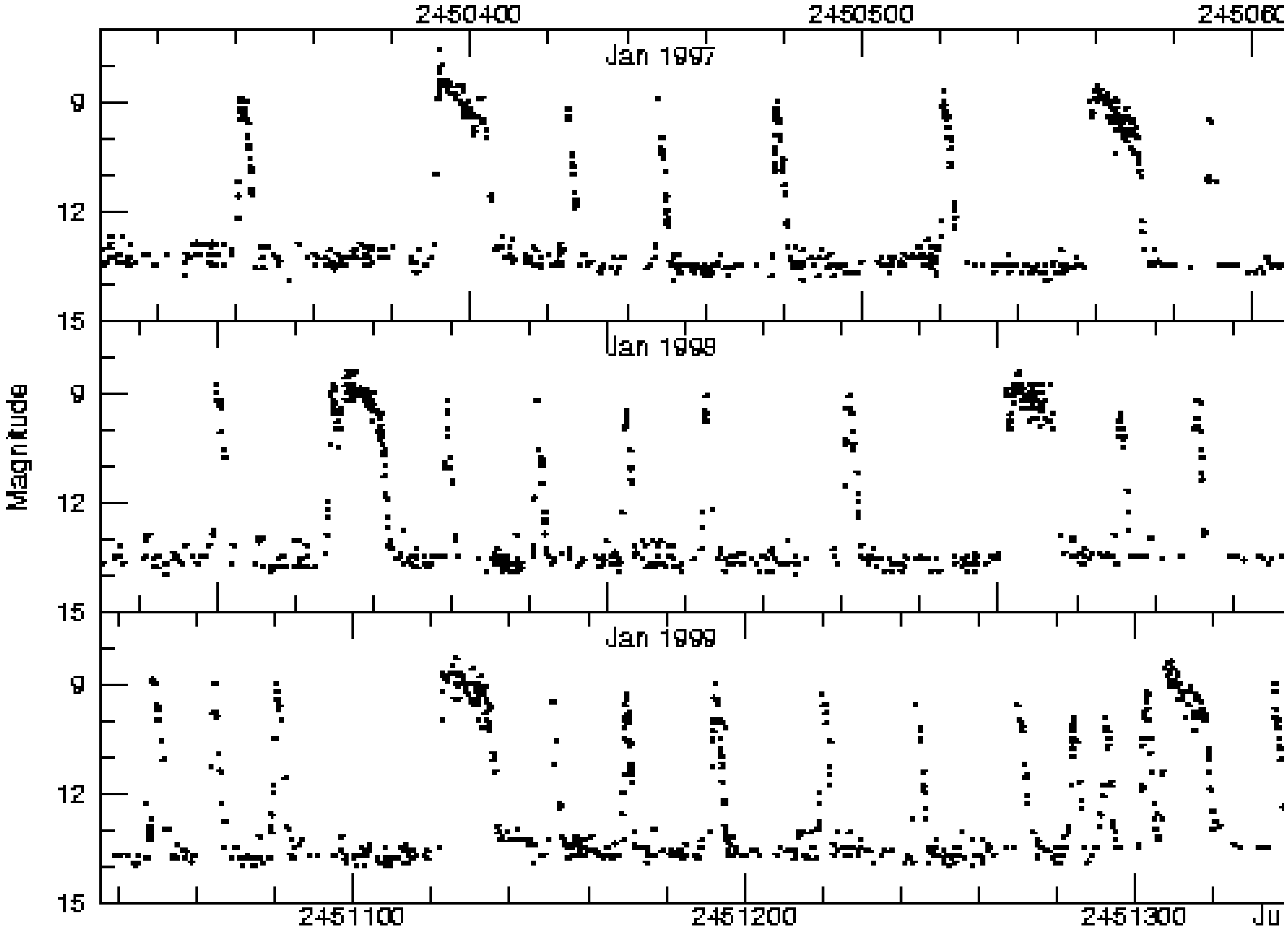




Super Outbursts

Longer and brighter

than normal outbursts

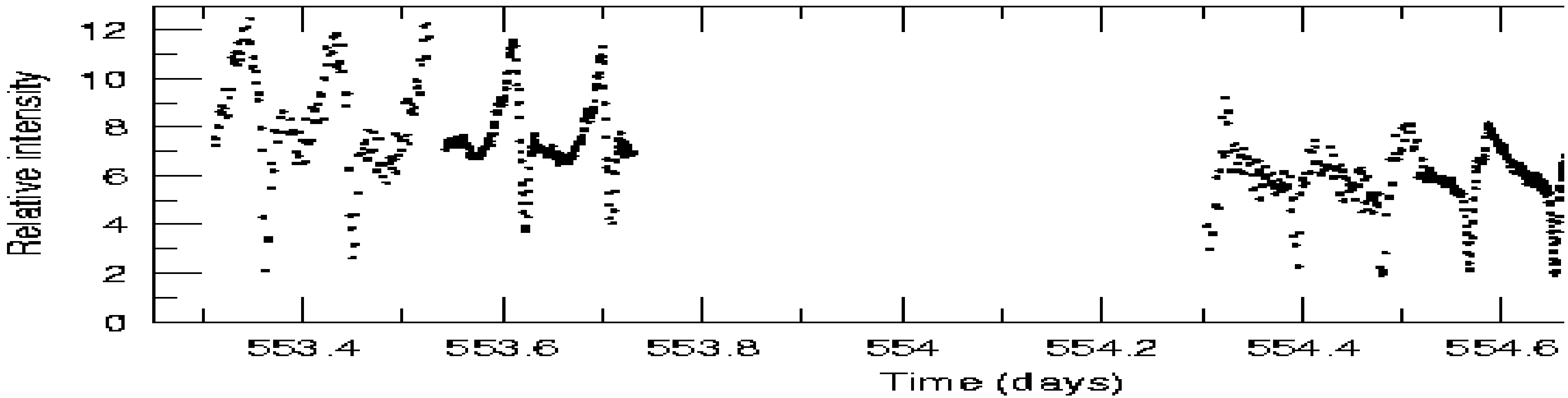


VW Hya

Super Humps

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

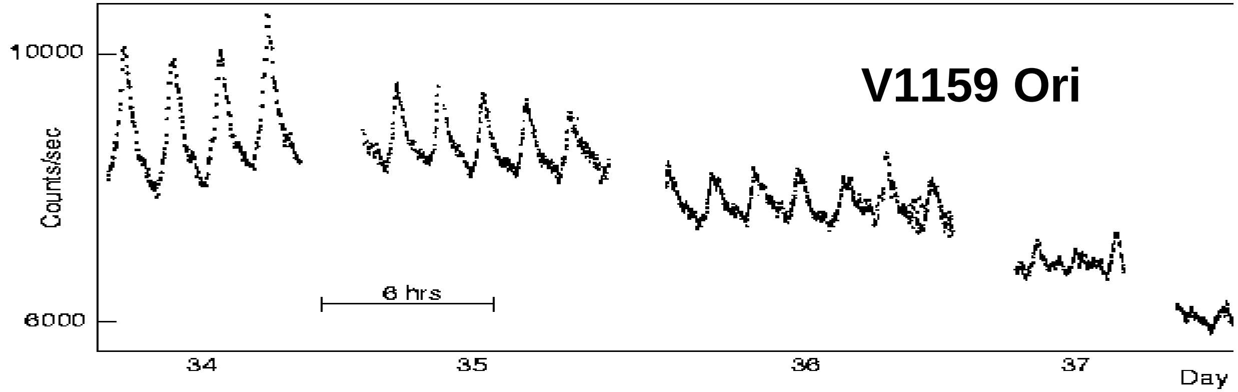
Occur during Super Outbursts

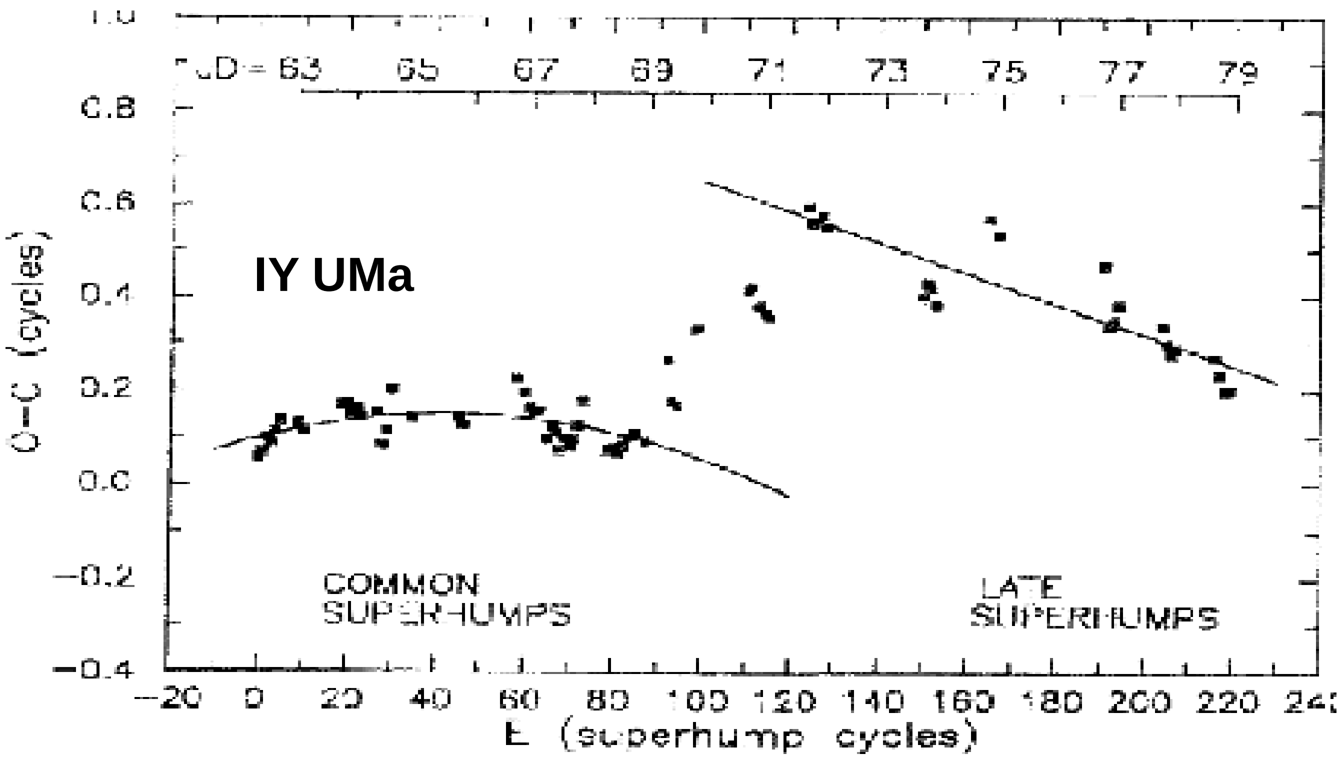


DV UMa

Superhump Period Changes

▪

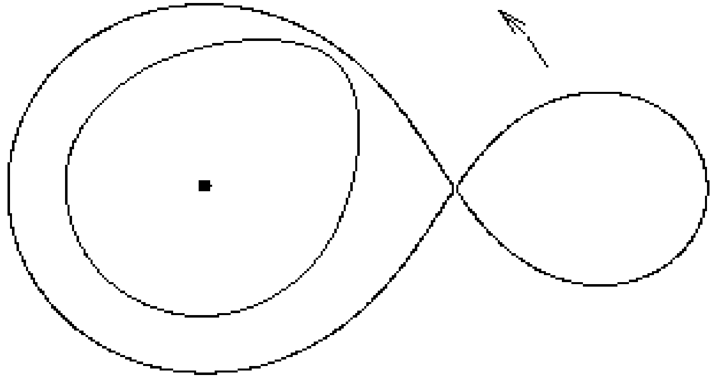




Tides and Resonances

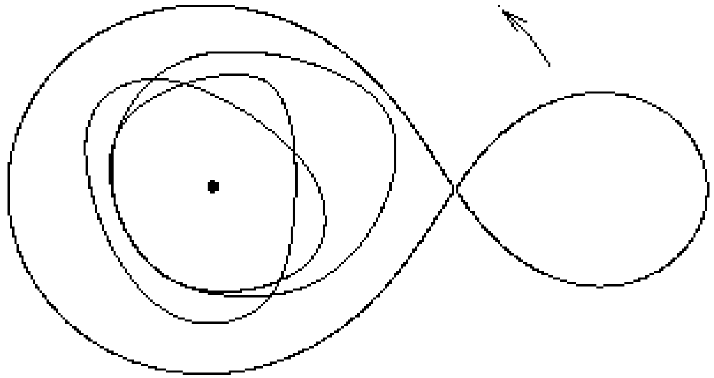
Disk Tide

angular momentum moves from the disk to the binary orbit.

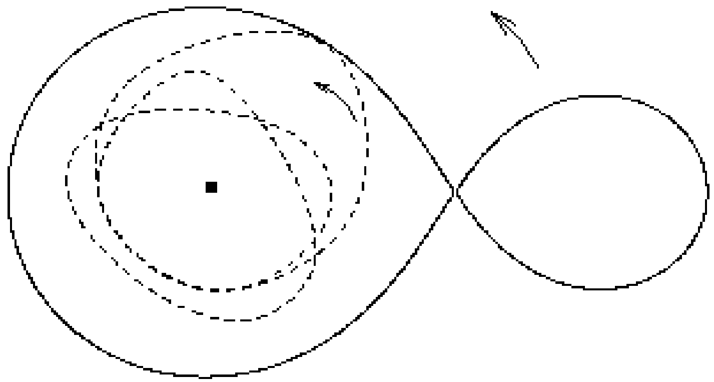


3:1 resonance

3 cycles around the disk per orbit



Slow precession of resonant orbits



Eccentric Precessing Disc

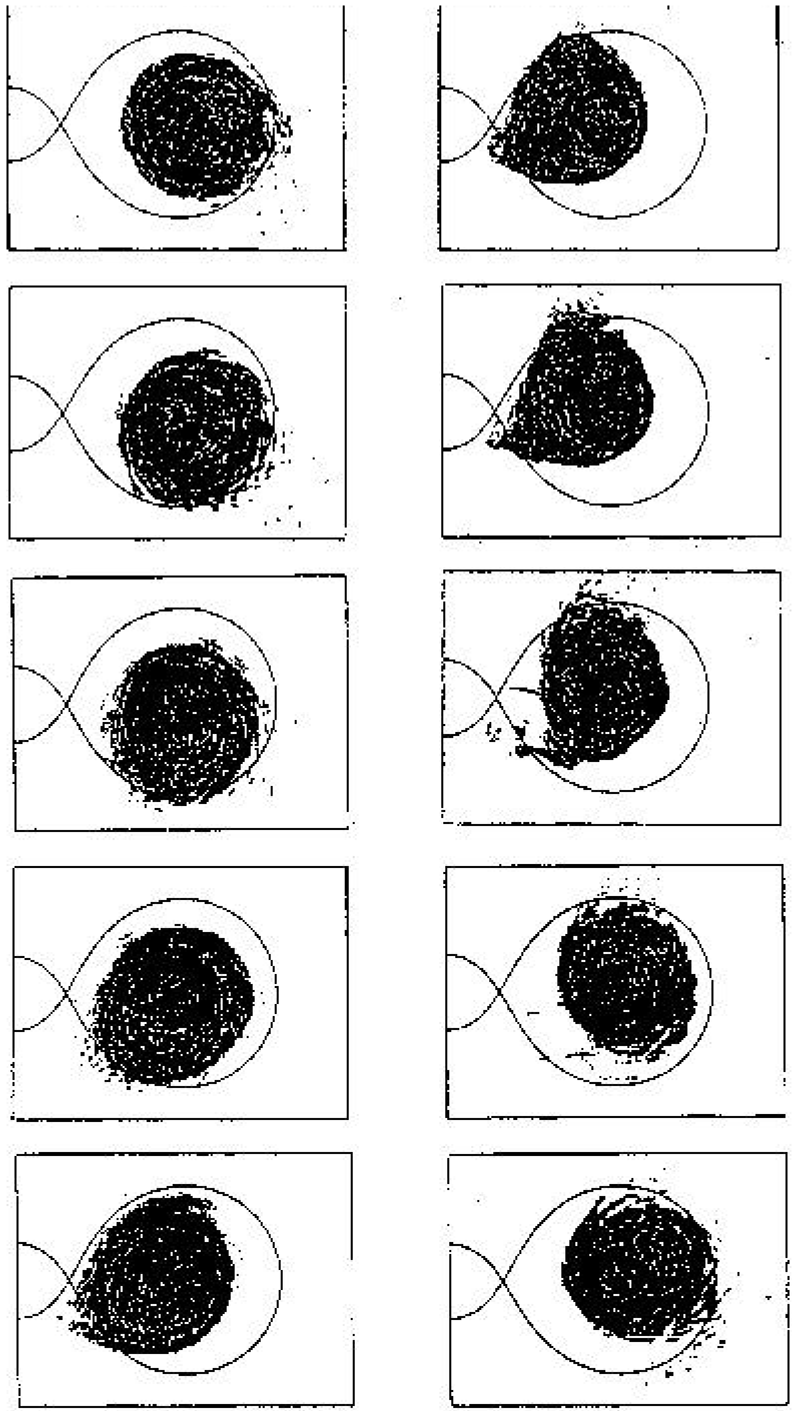
Orbit period -- few hours

Precession period -- few days

Beat period = superhump period

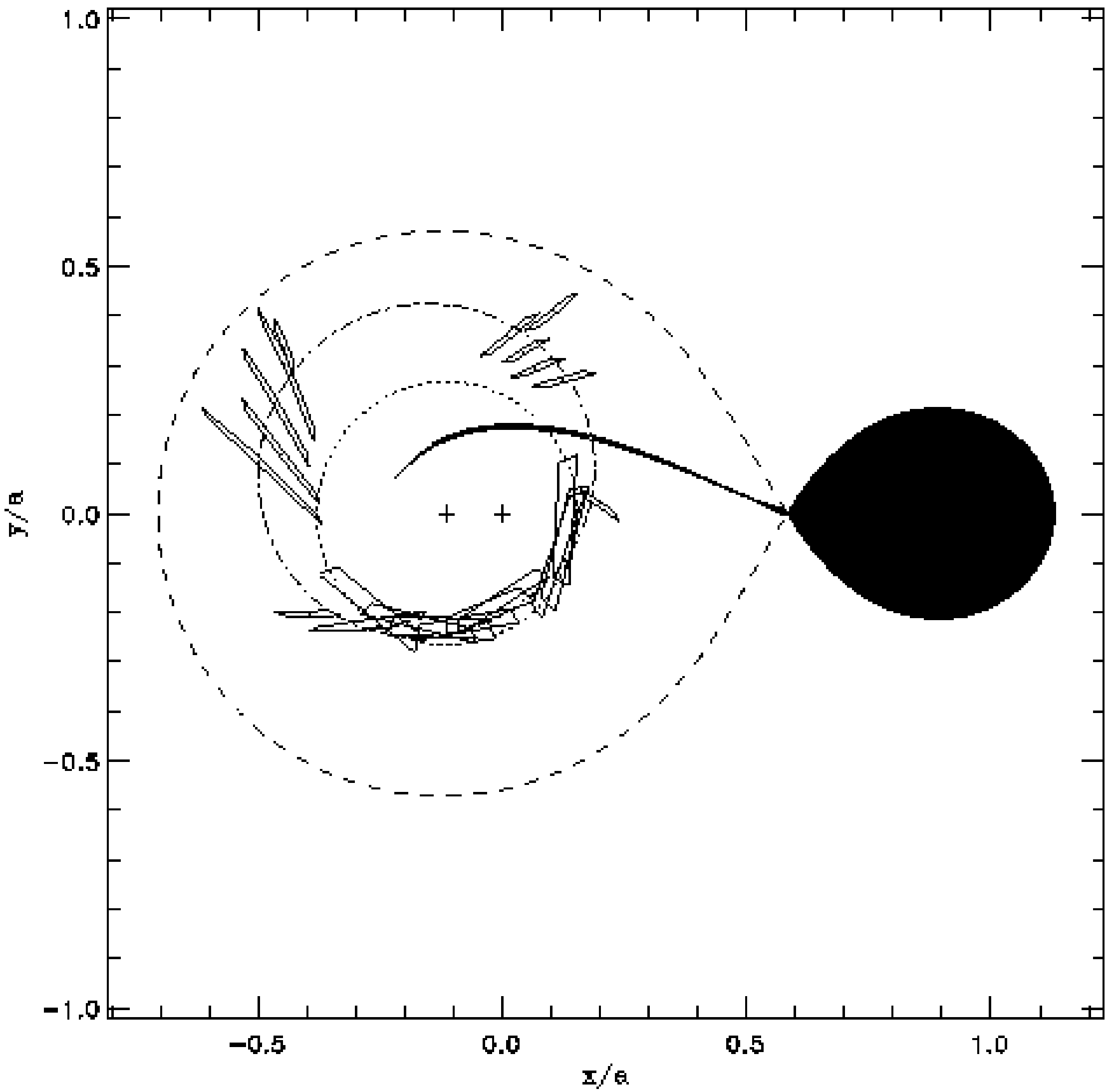
$$\frac{1}{P_{SH}} = \frac{1}{P_{orb}} - \frac{1}{P_{prec}}$$

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.



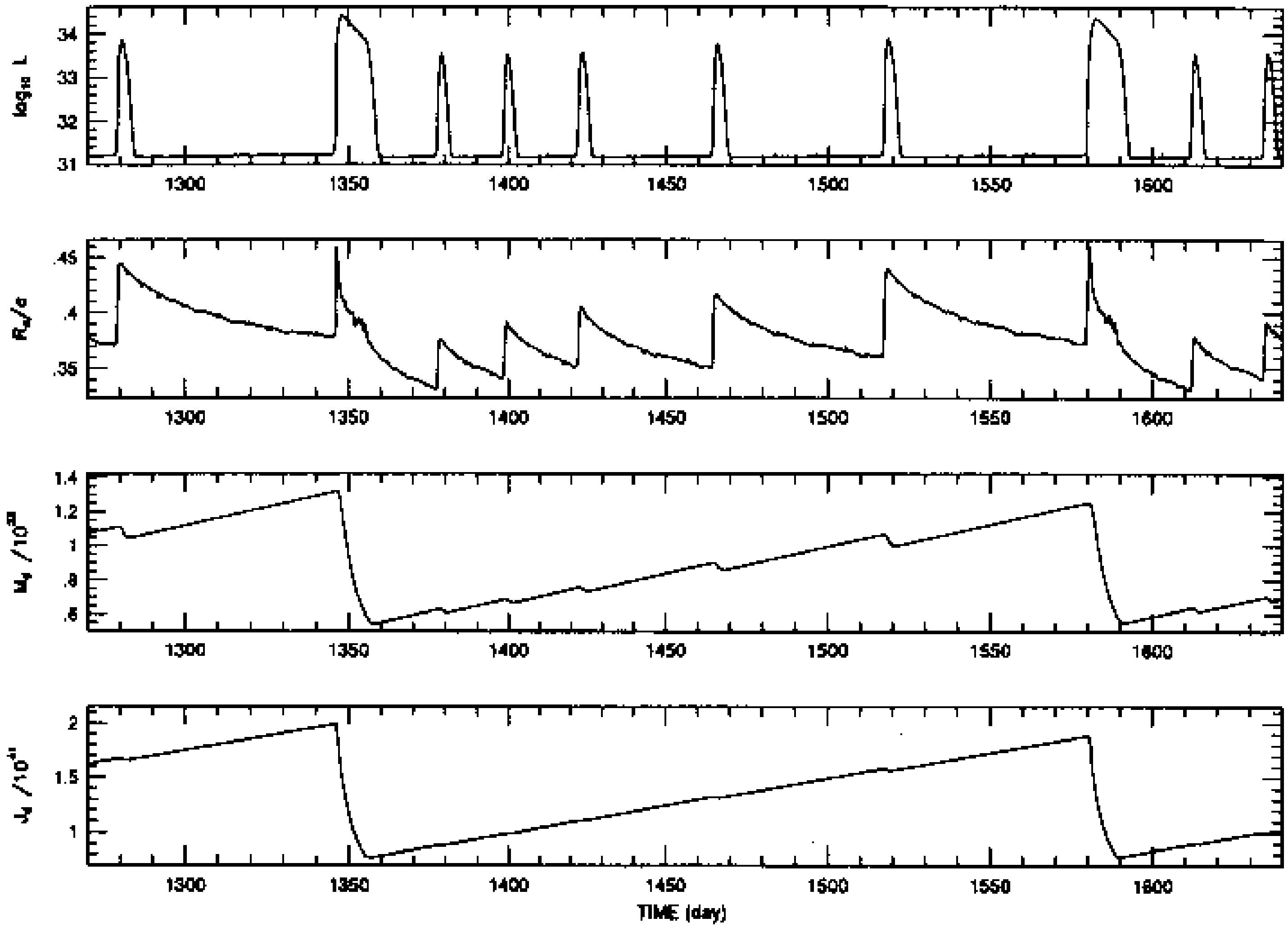
Super-Cycle Models

Luminosity

Disk radius

Disk mass

Angular momentum



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