AS4024 : Binary stars and accretion discs

Time-dependence and stability of accretion discs

(2 lectures)

Dr Michael Truss

mrt2@st-andrews.ac.uk

Outline of lectures:

a) Variability from disc/binary geometry:

- Double-peaked emission lines
- Bright spot model
- Eclipses and eclipse mapping
- Dippers

b) Dwarf nova outbursts

- Thermal-viscous instability vs mass-transfer instability
- Wide/narrow and superoutbursts
- Superhumps

c) Tidal instability

- Spiral waves
- Superoutburst / superhump unified model

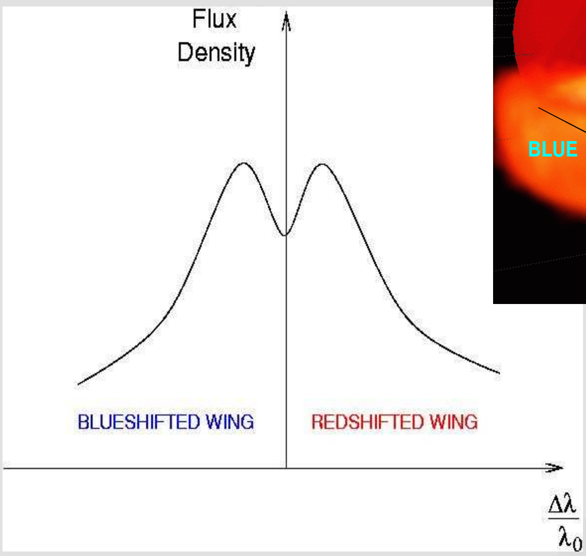
d) Magnetic fields

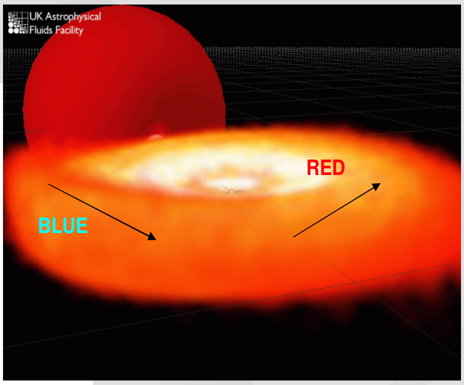
- Polars and intermediate polars
- TOADS

e) Neutron stars and black holes in binaries

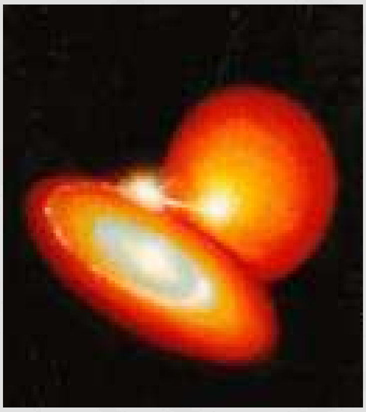
- X-ray transients

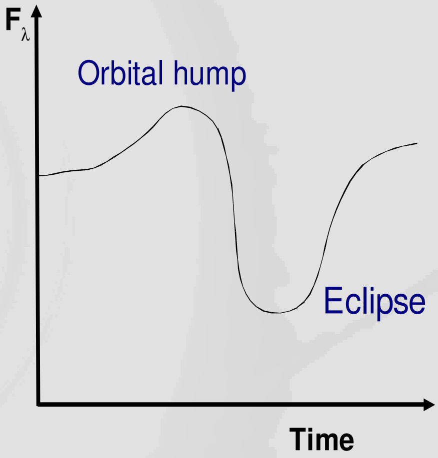
Double-peaked emission lines





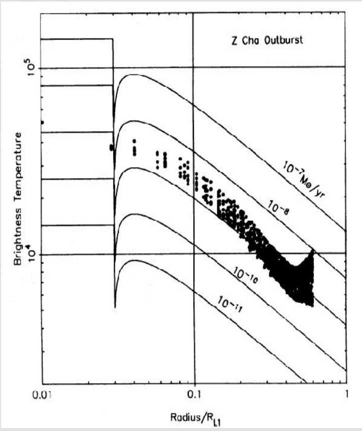
The hot-spot

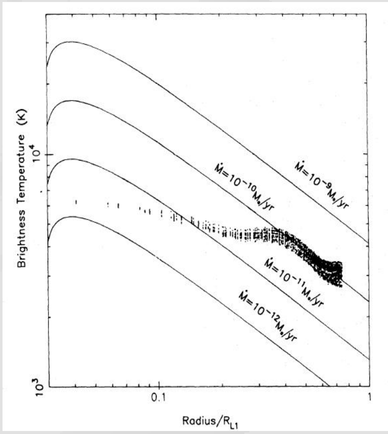




Eclipse mapping

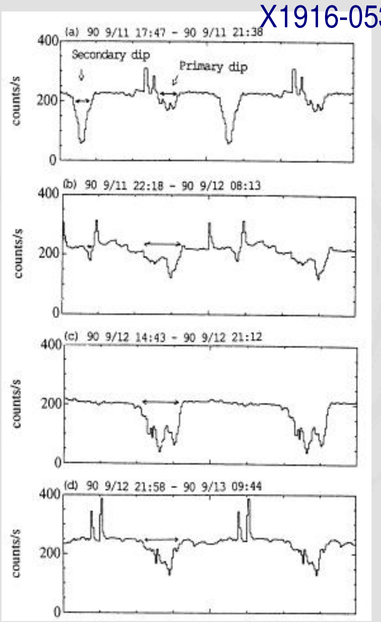
- Eclipse light curve → disc brightness distribution
- Deep, sharp eclipse of hot, short wavelength central regions
- Shallow, broad ecipse of cooler outer disc.

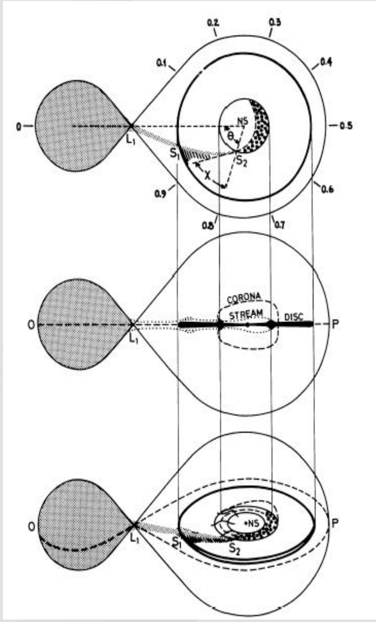




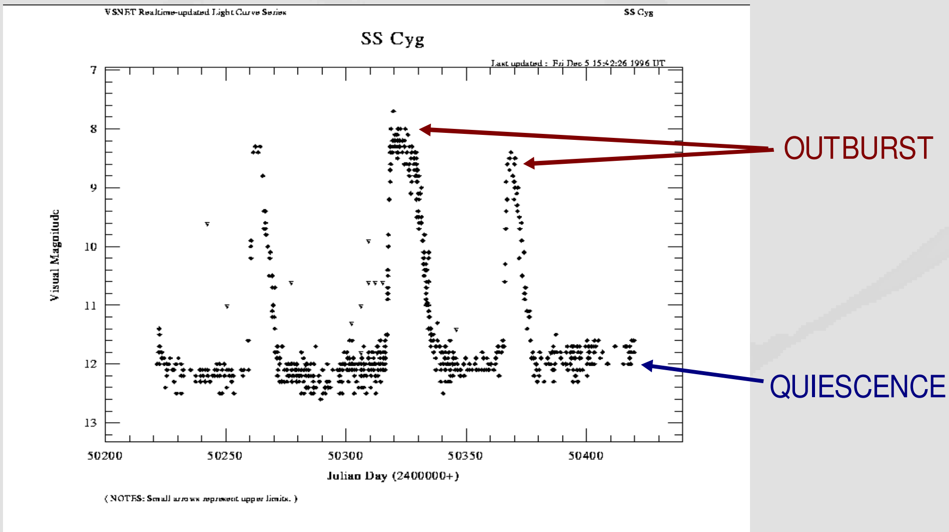
X-ray dippers

X1916-053





Dwarf nova outbursts

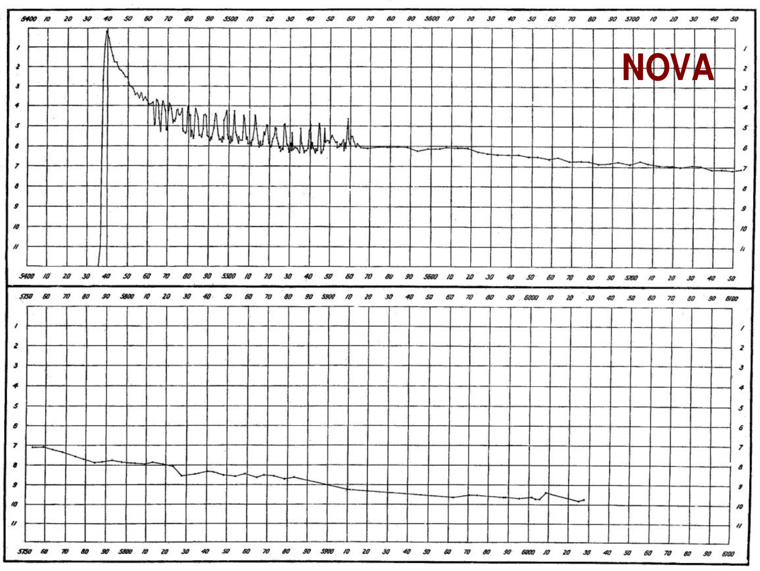


Cataclysmic Variables

- 472 known, less than half are magnetic
- Interacting binaries WD + low-mass companion
- $P_{orb} \sim 1 - 12$ h

Non magnetic	Magnetic
Novae	Polars (AM Herculis)
Nova-likes	Intermediate Polars
Dwarf Novae	

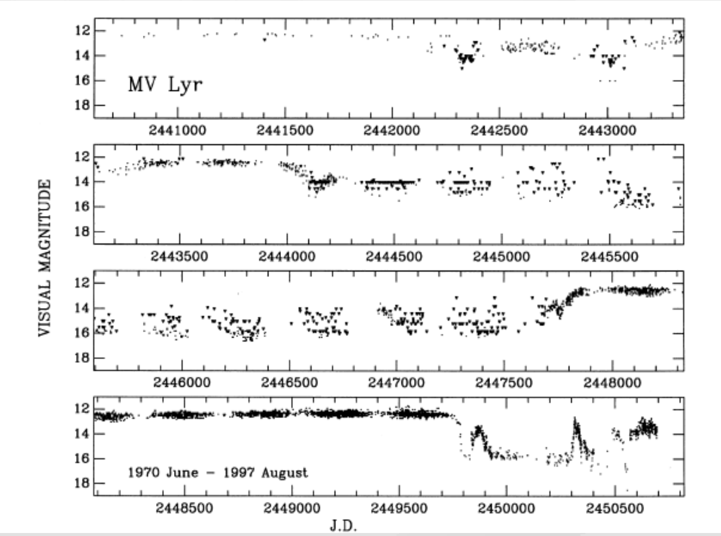
CV Zoology



Historical light curve of 0324+43 GK Persei for JD 2415435 - 2416027 (February 1901 - October 1902), taken from *Ann. Harvard Coll. Obs.*, 48, 2, 39 (1903), and showing the 1901 outburst.

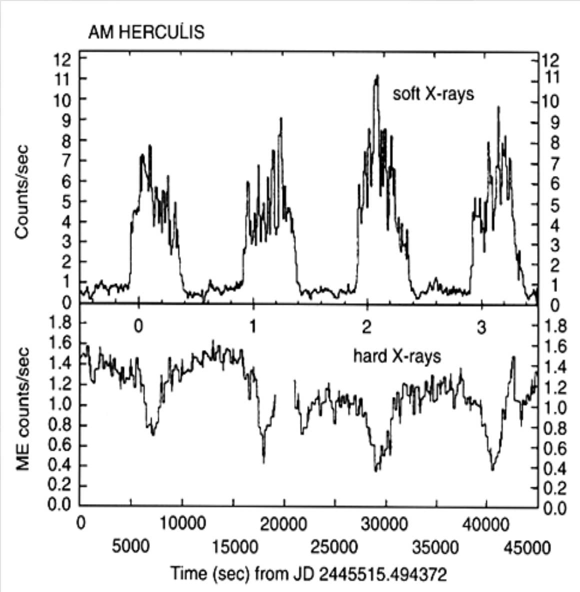
CV Zoology

NOVA-LIKE

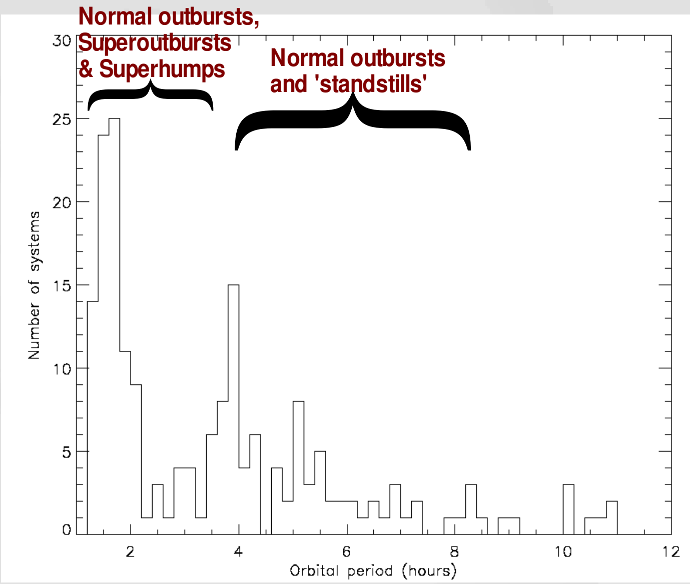


CV Zoology

AM Her



Dwarf Nova Zoology



Dwarf nova outbursts

Two theories:

1. Mass transfer instability (out of favour):

Donor has convective envelope

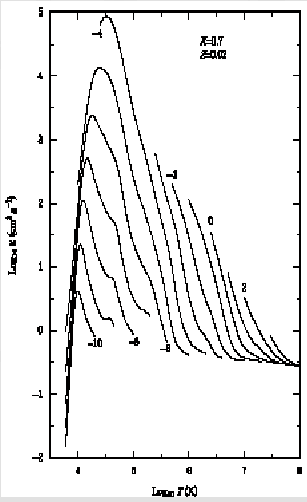
As mass is lost, radius increases

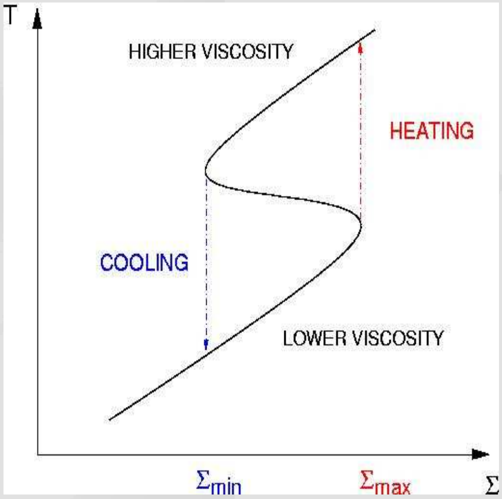
More mass is lost, envelope becomes radiative

Mass transfer steadies until envelope becomes convective again

Dwarf nova outbursts

2. Thermal-viscous disc instability





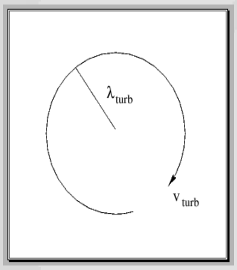
Dwarf nova outbursts

3. Viscosity

Reynolds Number Re = inertial force / viscous force

Molecular viscosity → Re ~ 10^{14} but require Re << 1 to explain outbursts ! ∴ need bigger viscosity

Shakura & Sunyaev (1973) : $\nu = \alpha c_s H$



$\lambda < H$; $v < c_s$ ∴ $\alpha < 1$

DN outburst : T(cold) = 4,000K ; T(hot) = 60,000K
α(cold) = 0.01 ; α(hot) = 0.1