Dwarf novae

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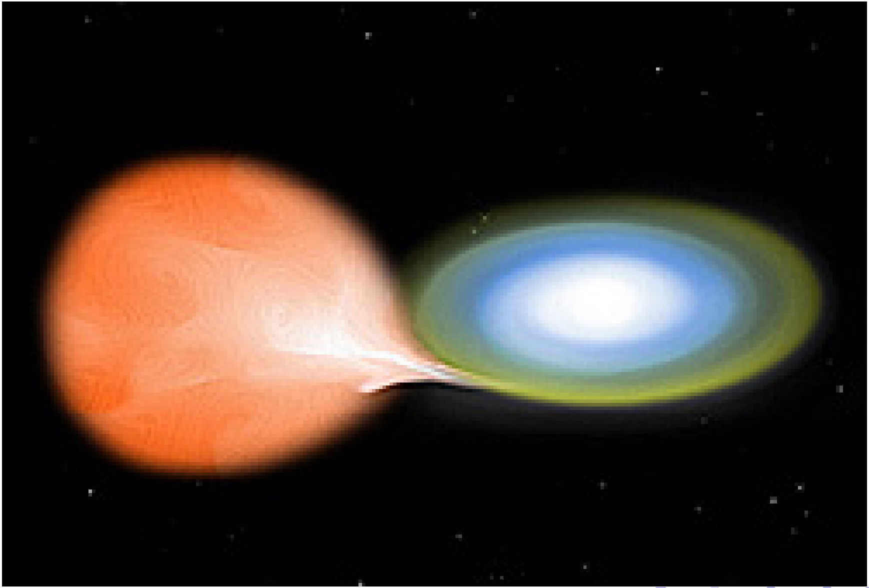
- How to explain observations of dwarf noave:
  - Mass transfer variation from the companion
  - Viscosity variations in accretion disc
- Discussion

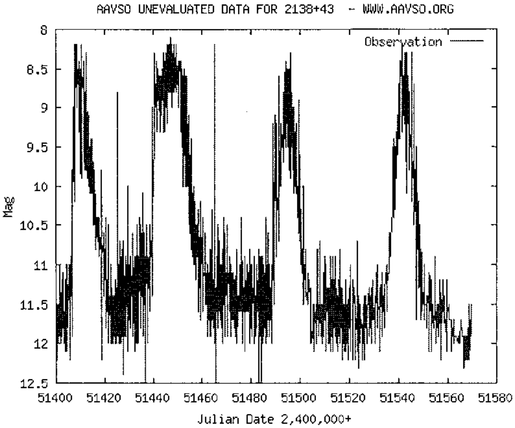
Introduction

- 2 types of cataclysmic variable stars:
  - Classical novae
  - Dwarf novae
- In both: Irregularly increase in brightness by a large factor, then drop back down to a quiescent state.
- Difference: Dwarf novae are much smaller in amplitude, and recur at intervals of weeks to months (only 1 outburst in classical novae).

Introduction



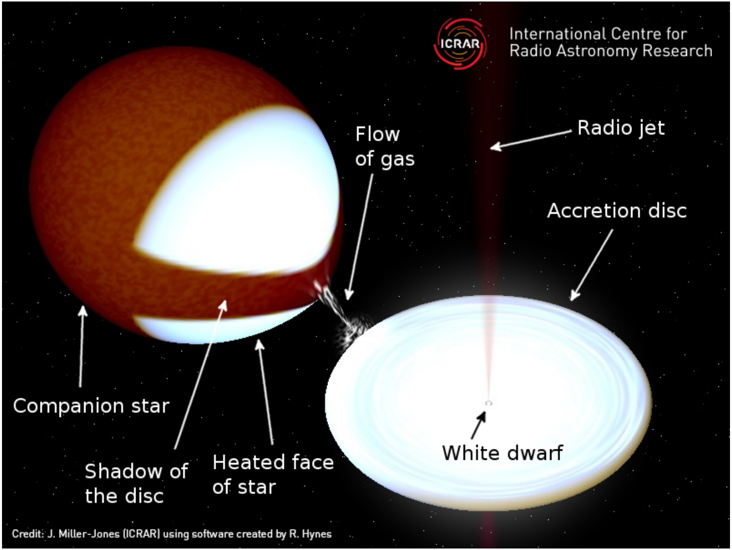
Introduction



Introduction

- What is powering the novae?
- Classical novae: Runaway thermonuclear burning (RTB) of the accreted material on the white dwarf.
- Dwarf novae:
  - RTB cannot provide recurrence times of less than about 10^4 yr.
  - Variable mass transfer rate from the companion star.
  - Variable mass transfer rate due the changes in accretion disc (instabilities).

Introduction



Variable mass transfer model (companion)

- Viscous timescale depends on the surface density gradient.
- In the beginning of the outburst, the disc tries to reach a steady state corresponding to the new, high accretion rate.
- This evolution proceeds on the viscous timescale $t_{\mathrm{visc}} \propto \frac{l^2}{\nu}$, $l << R$, corresponding to the steep density gradients in the disc caused by the sudden influx of mass.
- Rapid rise in luminosity (flat top, slow decay).
- Decay with longer time scale $\frac{R^2}{\nu}$, given by the more even density distribution after the injected matter is accreted.

Variable mass transfer model (companion)

- Numerical modeling shows that $\alpha \approx 0.1 - 1$ produce the observed duration of the burst.
- However, a few problems:
  - Basic cause of the instability in the companion star remains obscure. Some systems with similar companion show no dwarf novae bursts.
  - Disc has been observed to shrink in quiescence, rather than returning to a steady state.
  - The observed decay is not exponential, but faster.

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Variable accrection disc viscosity

- Back to the S-curve.
- Limit-cycle behaviour expected if the disc contains regions of partial ionization.

Variable accrection disc viscosity

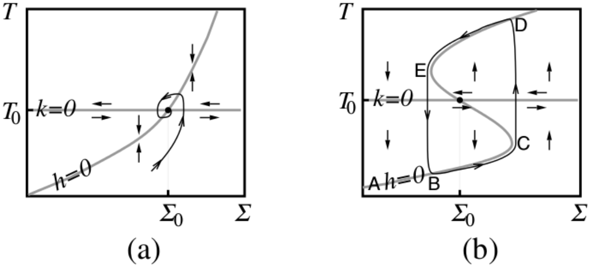


Fig. 5.12. Phase plane in the vicinity of a fixed point, indicated by a solid dot at the intersection of the two critical curves $h = 0$ and $k = 0$: (a) stable fixed point; (b) unstable fixed point and stable limit cycle.

Variable accrection disc viscosity

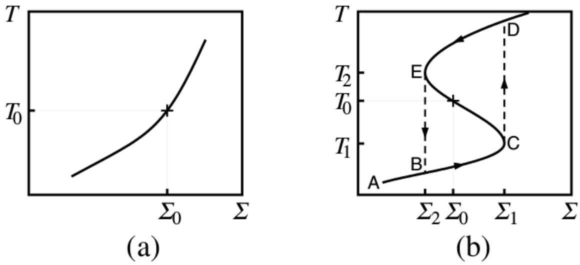


Fig. 5.14. Effective temperature–surface density diagrams with (a) a unique, stable steady solution (T_0, Σ_0), and (b) a case where limit-cycle behaviour occurs as the steady solution (T_0, Σ_0) lies on a region of the curve with $\partial T/\partial\Sigma < 0$.

Variable accrection disc viscosity

- Alternating long-lived (low viscosity) states of low $\dot{M}$ and short-lived (high viscosity) states of high $\dot{M}$, with rapid (thermal timescale) transitions between them.
- Considered so far a purely local instability at a fixed value of R.
- A domino effect needed to trigger instability in the adjacent annuli.

Variable accrection disc viscosity

- In quiescence $\Sigma(R, t)$ is between

$$\Sigma_{\max} = 11.4 R_{10}^{1.05} M_1^{-0.35} \alpha_c^{-0.86} \text{ g cm}^{-2},$$

$$\Sigma_{\min} = 8.25 R_{10}^{1.05} M_1^{-0.35} \alpha_h^{-0.8} \text{ g cm}^{-2},$$

- Outburst is triggered when $\Sigma > \Sigma_{\max}$ at some R.
- At $\Sigma_{\max}$, a transition to the hot state, and steep Σ and T gradients cause mass and heat to diffuse to adjacent annuli stimulating them to same transition.
- Leads to the propagation of heating fronts both inwards and outwards from the initial instability.

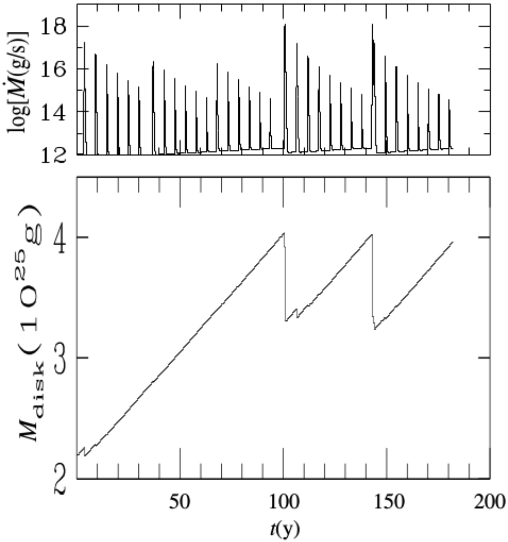
Heating and cooling fronts

- Heating front (HR)
  - Inward-moving with $v_{\mathrm{h}} \approx \alpha c_{\mathrm{s}}$
  - An outward-moving front slower, because the front moves into matter at higher density, from which it cannot readily remove angular momentum.
  - Matter flows inwards because of enhanced viscosity
- Cooling front (CR)
  - Forms when Σ decreases below Σ_{min} in the outer part of the disc.
  - Moves inward with $v_{\mathrm{c}} = 0.1\, v_{\mathrm{h}}$. Mass flows outwards.
  - Disc returns to cool quiescent state

Consequences for observations

- Rise to maximum corresponds to the time taken by the HR to travel across the disc.
- The decline time to the inward motion of the CR.
- The time at maximum depends on the point when(/if) the HR first encounters $\Sigma_{\min}(R)$.
- Observed duration and brightness can only be obtained by using the freedom to manipulate the effective value of the α parameter.

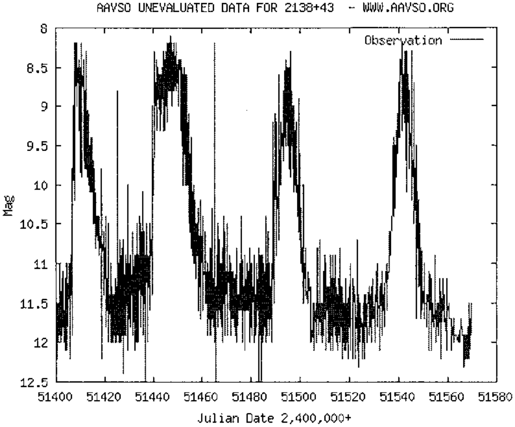
Variations in disc mass



A and B type dwarf novae (DWN)

- DWN outbursts dived in 2 classes depending on $\dot{M}$ from the companion:
- type A
    - High $\dot{M}$, a rapid rise and a slower decay, short intervals between bursts.
    - Outside-in outbursts
- type B
    - Low $\dot{M}$, slower rise than in type A, and more symmetrical.
    - Inside-out outbursts, since viscosity has time increase Σ over Σ_{max} close to disc center.
    - May alternate between narrow and wide outbursts

Type B?



AAVSO UNEVALUATED DATA FOR 2138+43 - WWW.AAVSO.ORG
Observation
Mag
8
8.5
9
9.5
10
10.5
11
11.5
12
12.5
51400
51420
51440
51460
51480
51500
51520
51540
51560
51580
Julian Date 2,400,000+

Comparison with observations

- The instability picture is successful in some areas, but also some problems exist:
  - Correlation between $\dot{M}$ and t_{rec} sometimes in contradiction with the other indicators of DWN outburst type (SS Cygni).
  - "UV delay": Shorter wavelengths delayed more than predicted. Central hole?

Conclusions

- How to explain observations of dwarf noave:
- 1) Mass transfer variation from the companion
- 2) Viscosity variations in accretion disc
- Second model is favourited.
- It satisfies the fundamental requirement of correctly predicting the occurrence of outbursts (if and only if the disc contains ionization zones).
- Needed also a viscosity mechanism for turning local thermal-viscous instabilities into global ones ($\alpha_{\mathrm{h}} \sim 10\alpha_{\mathrm{c}} \sim 0.1$).

The End