AM CVn stars

a source of information about accretion disc physics

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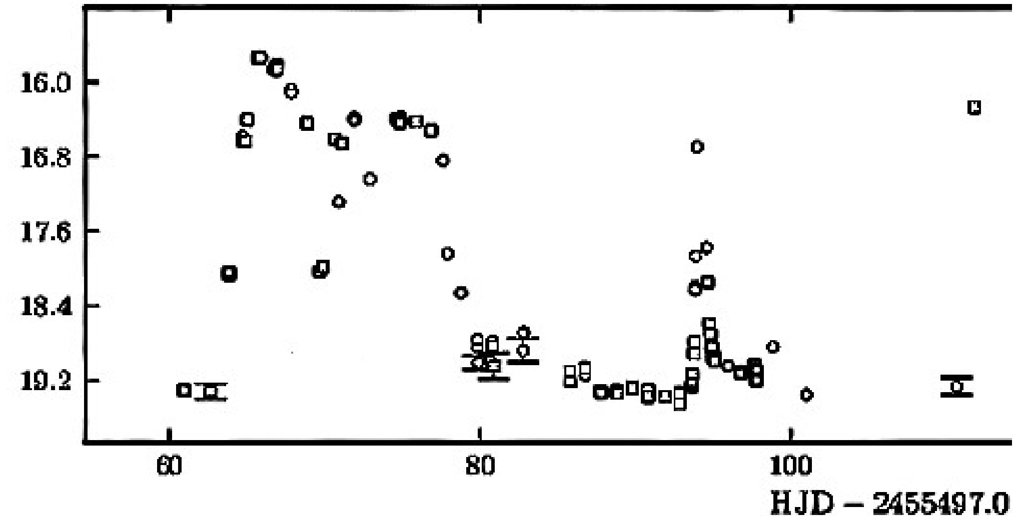
3rd AM CVn workskop, Warwick

Introduction

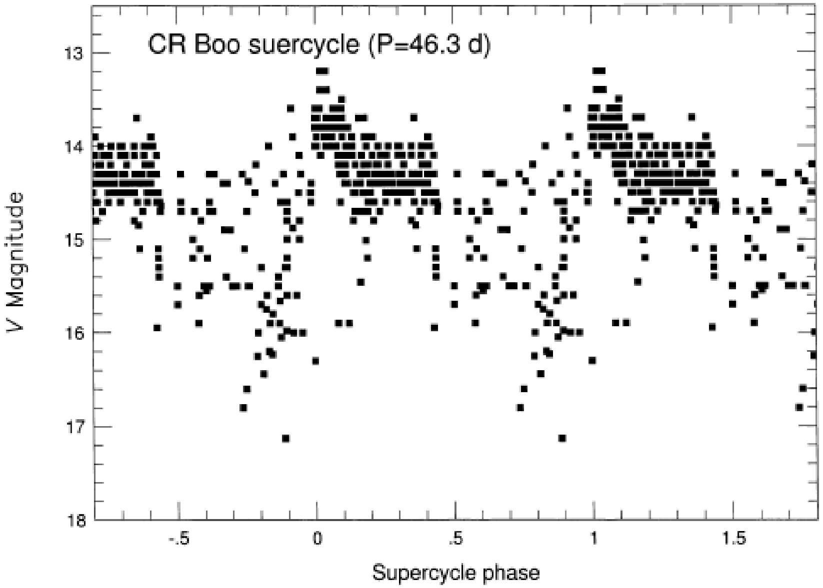
- Discs in AM CVn stars :
  - small
  - helium dominated
- Light curves characteristic features:
  - normal outbursts: *PTF1J0719, KL Dra , CR Boo (?), V803 Cen (?)*
  - superoutbursts (all ?)
  - cycling states, standstills (e.g. *CR Boo, V803 Cen)*
  - dips (e.g. *KL Dra, PTF1J0719)*
- 3 „tools” for investigation of AM CVn stars

Properties of outbursting AM CVns

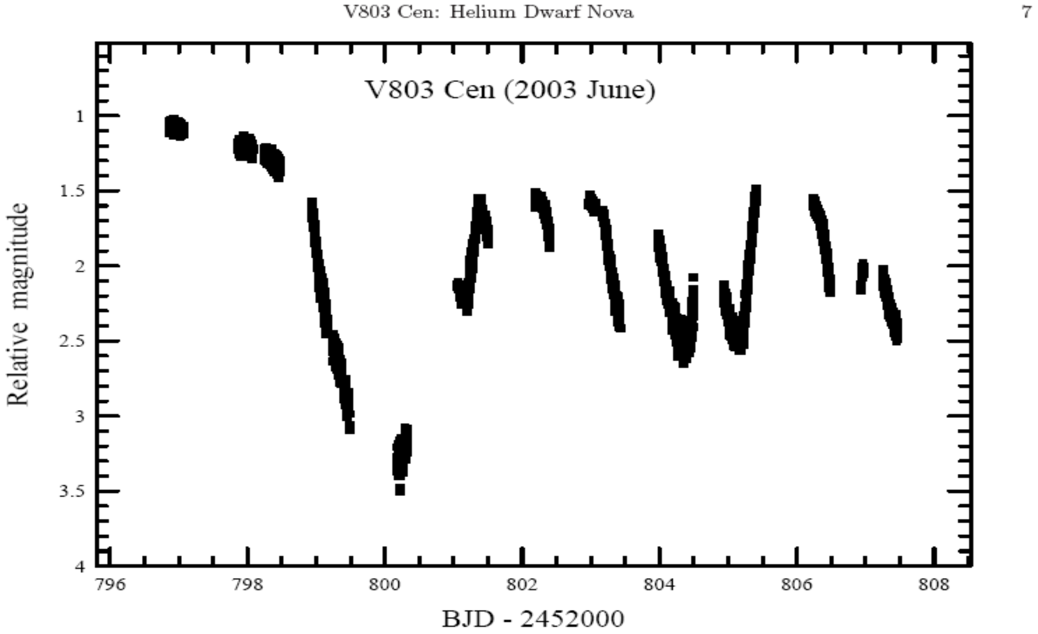
PTF1J0719+4858



Levitan et al. (2011)

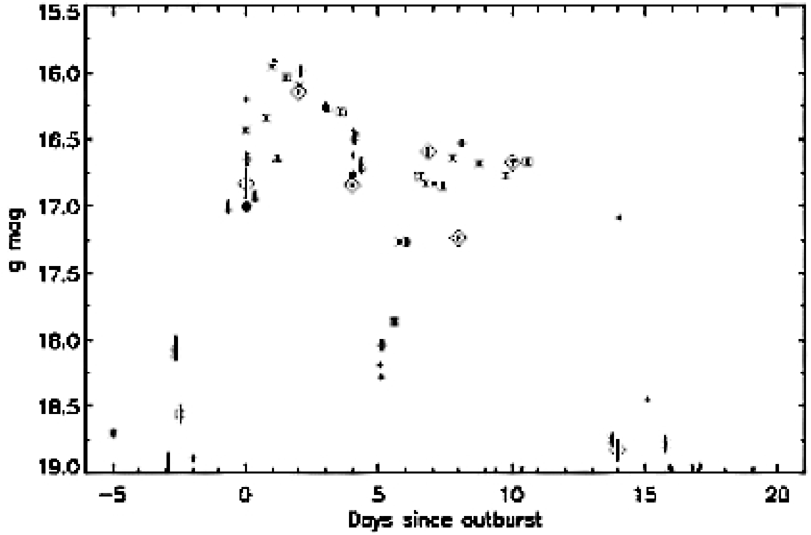


Kato et al. (2000)



Kato et al. (2004)

KL Dra



Ramsay et al. (2011)

The Disc Instability Model

- Normal oubursts of Dwarf Novae → the thermal-viscous instability in the disc :

  the change in opacities is induced by the partial ionization of the dominant chemical element in the disc

- The outward angular momentum transport in the disc →

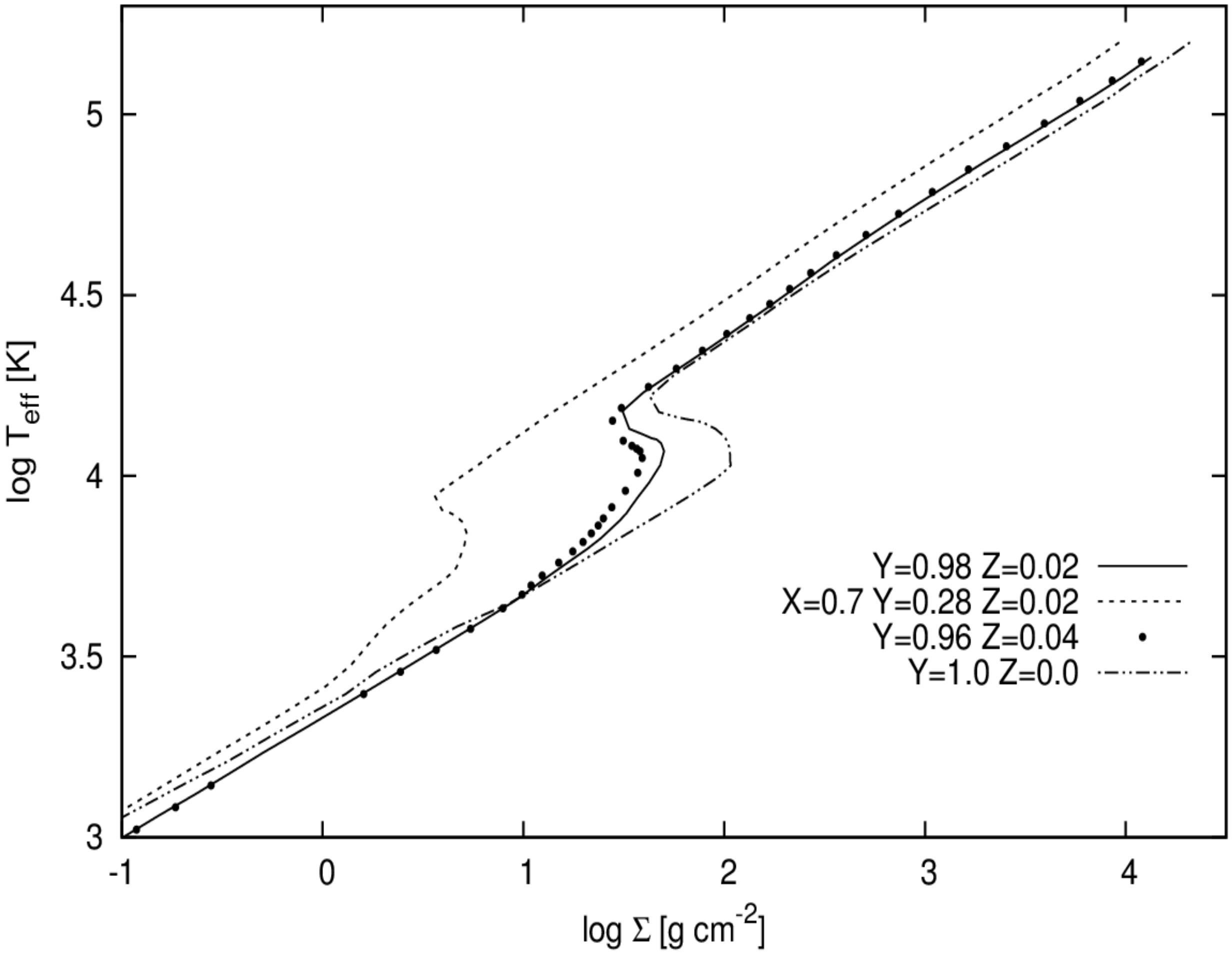
  α - parameter (Shakura-Sunyaev 1973)

- α is different for the disc in a hot and a cold state :

$$\alpha_h \neq \alpha_c$$

- The geometrically thin disc → allows decoupling of disc vertical structure and disc time evolution equations

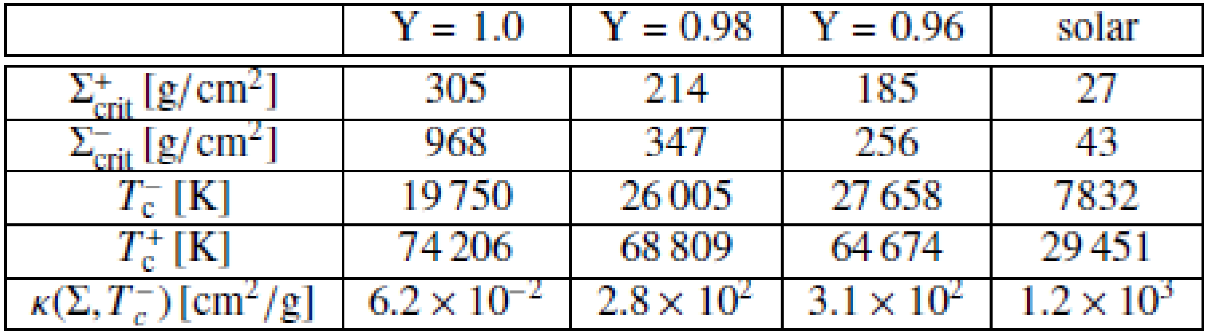
Disc Instability Model for AM CVns



- S-curve - solutions of the disc local vertical structure equations :

$$T_c\left(T_{eff}\right)\ \&\,\Sigma$$

for which given ring is in thermal equilibrium



	Y = 1.0	Y = 0.98	Y = 0.96	solar
$\Sigma^{+}_{\rm crit}$ [g/cm^2]	305	214	185	27
$\Sigma^{-}_{\rm crit}$ [g/cm^2]	968	347	256	43
$T^{-}_{\rm c}$ [K]	19 750	26 005	27 658	7832
$T^{+}_{\rm c}$ [K]	74 206	68 809	64 674	29 451
$\kappa(\Sigma, T^{-}_{c})$ [cm^2/g]	6.2×10^{-2}	2.8×10^{2}	3.1×10^{2}	1.2×10^{3}

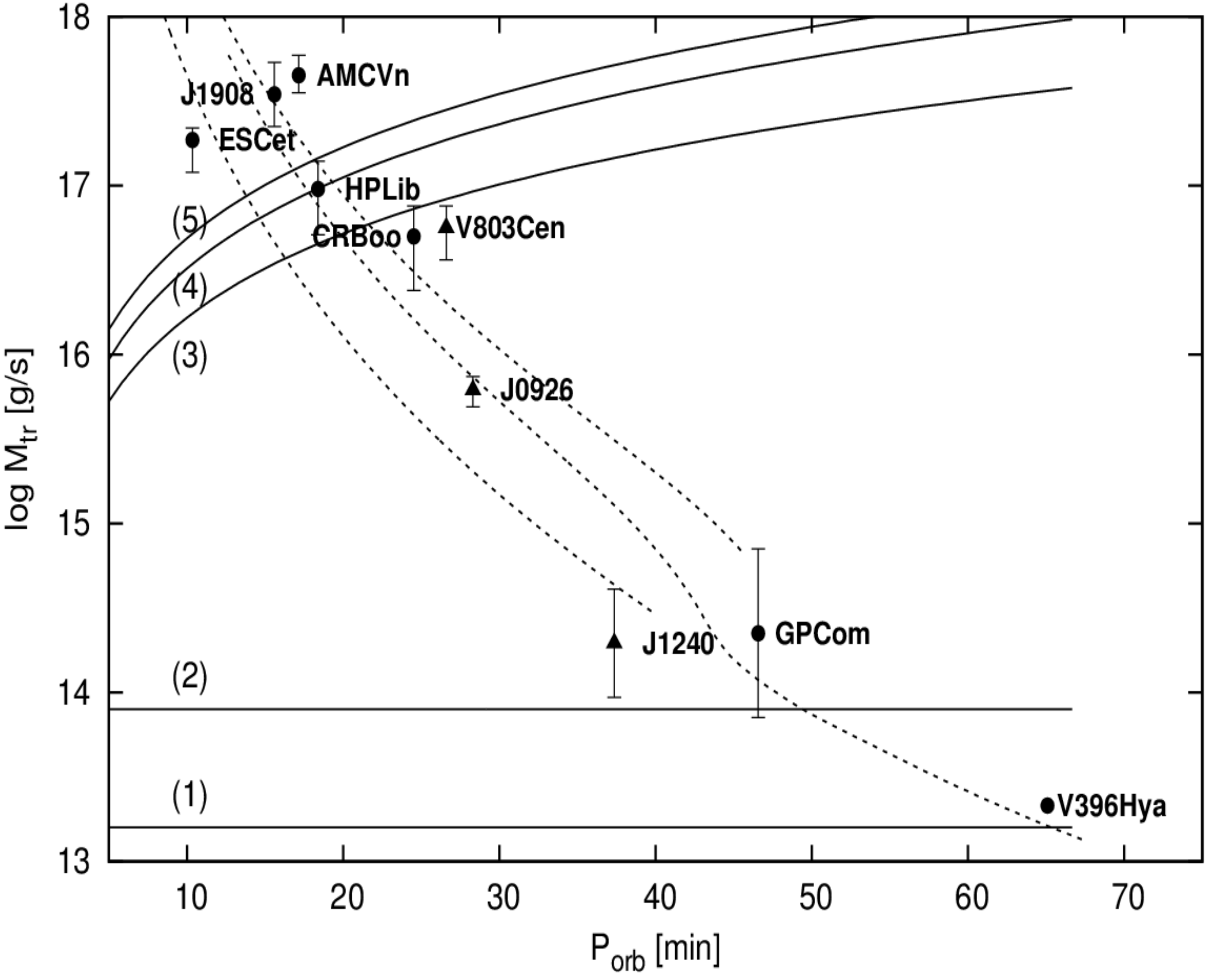
- Ionization temperatures :

$T_{HeII} \sim 28\,558\ K$ $\quad$ $T_{HeIII} \sim 63\,153\ K$

$T_{NIV} \sim 47\,448\ K$ $\quad$ $T_{CV} \sim 68\,303\ K$

$$T_{OV} \sim 82\,000\ K$$

Disc Instability Model for AM CVns



(1) M1=0.6 Msun, Y=1.0

(2) M1=1.0 Msun, Y=1.0

(3) M1=1.0 Msun, Y=0.96

(4) M1=0.6 Msun, Y=1.0

(5) M1=1.0 Msun, Y=1.0

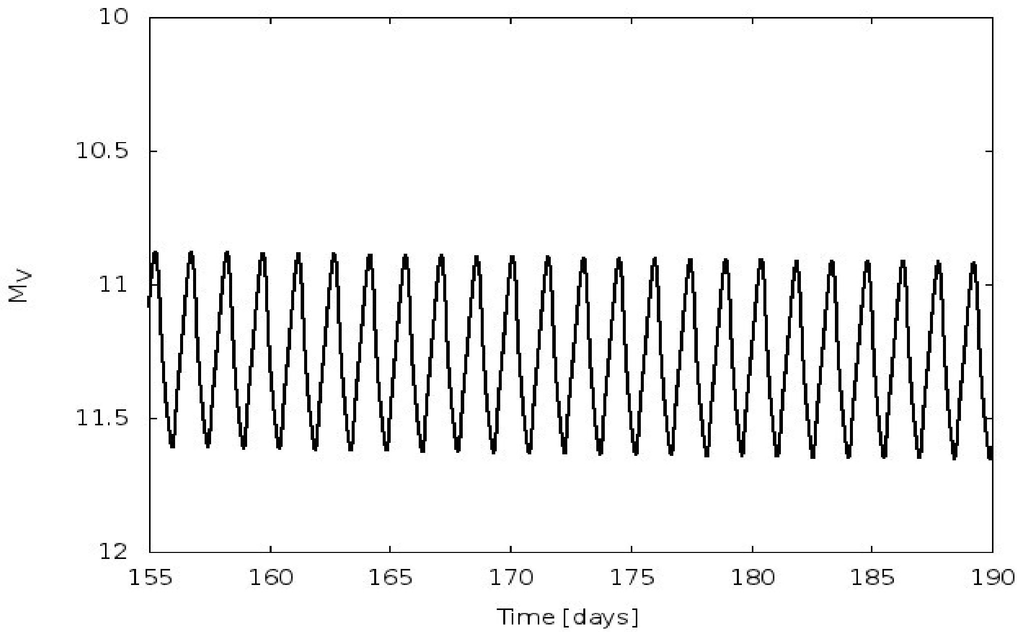
- Higher M1 - Higher Mcrit (+/-)
- Higher Z - Lower Mcrit (+/-)

Standard DIM - light curves

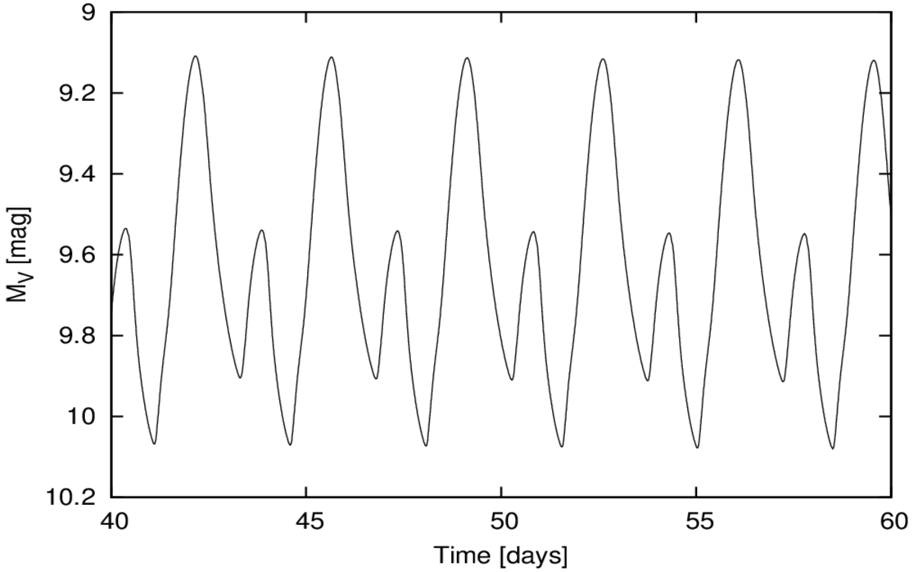
Parameters of the models :

- α_c and α_h
- mass transfer rate
- primary mass
- mean size of the disc
- chemical composition

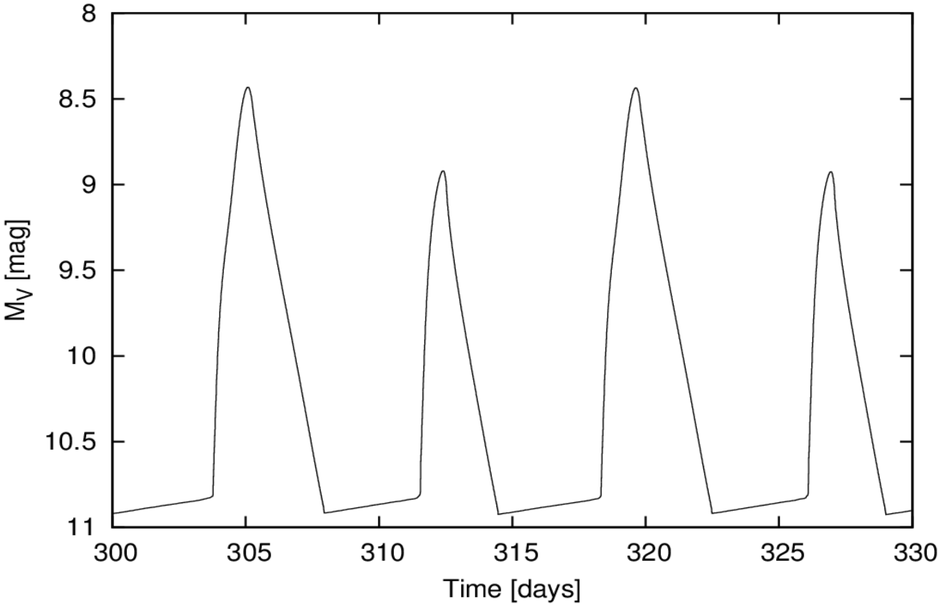
X=0.7 Y=0.28 Z=0.02 $\alpha_c = \alpha_h = 0.1$



Y=0.98 Z=0.02 $\alpha_c = \alpha_h = 0.1$



Y=1.0 Z=0.0 $\alpha_c = \alpha_h = 0.1$



Superoutbursts

Additional effects :

- heating by the bright spot
- irradiation of the disc by the primary WD
- truncation of the inner radius by the weak magnetic field or evaporation

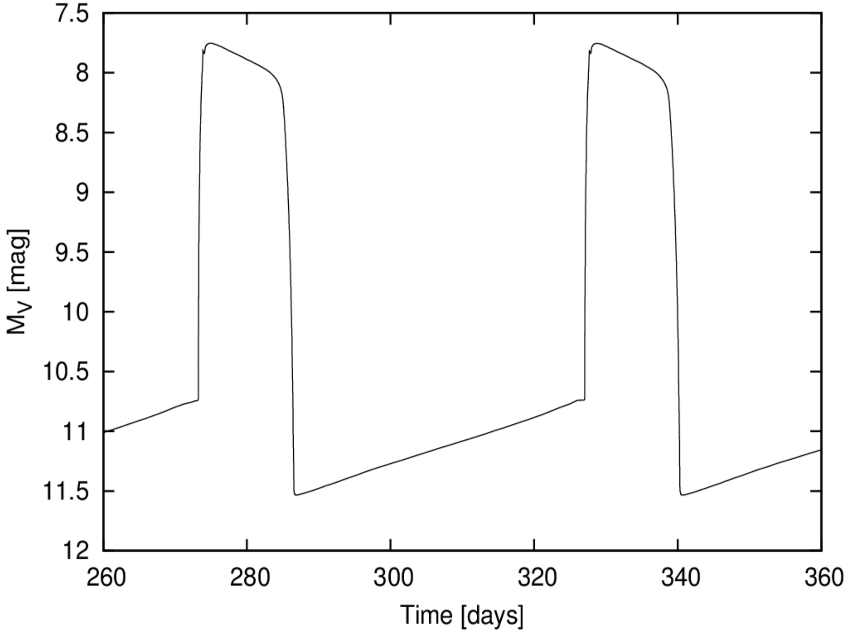
Still impossible to obtain:

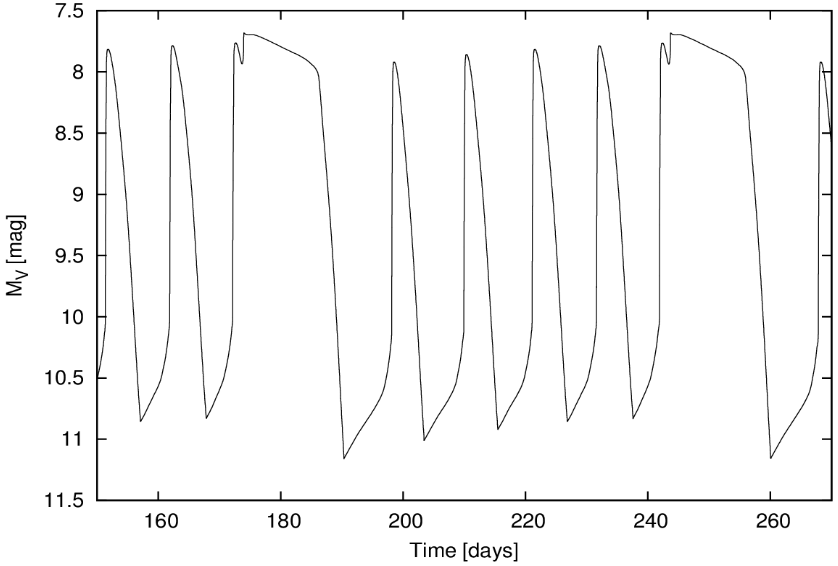
superoutbursts, dips and cycling state

The enhanced mass transfer model (EMT):

Superoutbursts are due to the major enhancement of the mass transfer rate

$\dot{M}_{tr} = max(\dot{M}_{0,tr}, \gamma \dot{M}_{acc})$ (Hameury et al. 2000)





Dips, cyclings, standstills

Prescriptions for changing $\dot{M}_{tr}$

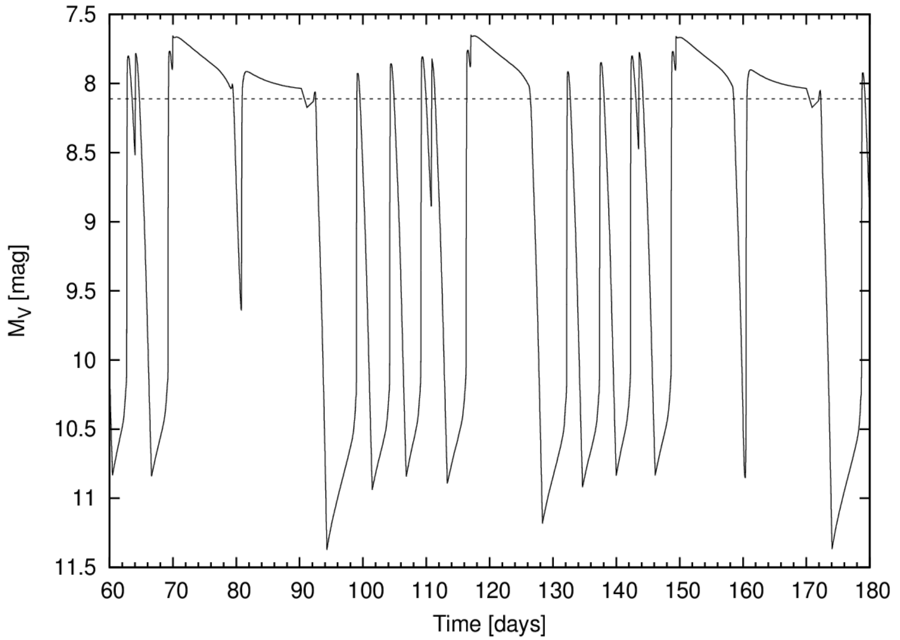
1. „Z Cam” - type modulation

(Buat-Menard et al. 2001)

$$\Delta \dot{M} / \langle \dot{M} \rangle = 40\% \qquad t = 10 + k \cdot 70 \text{ days}$$

$$\dot{M}_{\rm tr} = \max(\dot{M}_{0,\rm tr}, \gamma \dot{M}_{\rm acc})$$

2. $\dot{M}_{\rm tr} = \max(\dot{M}_{0,\rm tr}(1 + A \sin(C + \pi t/\tau), (\gamma \dot{M}_{\rm acc})))$



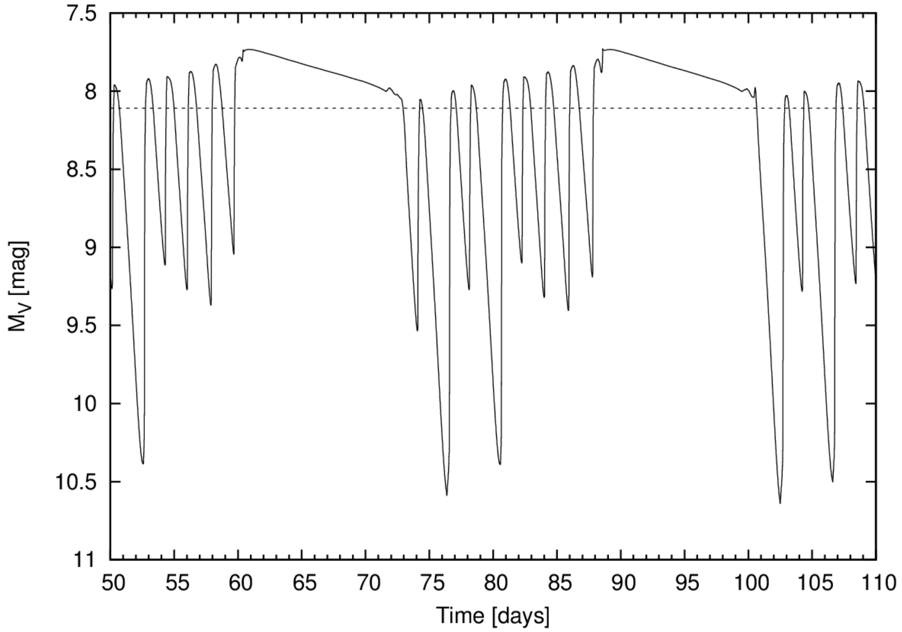
Physical mechanisms (?) :

1. Indirect irradiation of the secondary due to the outburst itself

(Smak, Viallet&Hameury 2008)

2. Direct irradiation - warped disc

(Smak 2009)



Additional „tools”

1. *Outburst amplitude - recurrence time* relation

(*Kukarkin-Parenago relation*)

$$A_n = (0.7 \pm 0.43) + (1.9 \pm 0.22) \log T_n$$

(Warner 2003)

Can be derived in the framework of DIM :

$$A_n \sim \log T_n + C\left(M_{tr}, R_d, \alpha_h, \alpha_c^{-1}, M_1, R_1\right)$$

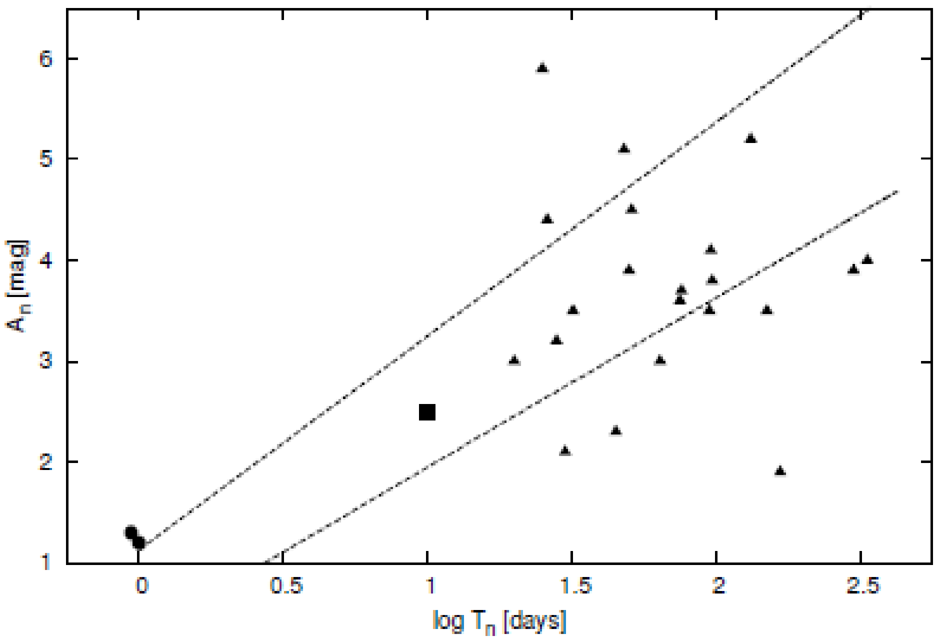
- estimation of mass transfer rates
- estimation of primary mass

2. Decay rate from the outburst

$$\tau_{dec} \sim \alpha_h^{-1} R_d M_1$$

- α_h for AM CVns: ~ 0.2 (?)

3. Both constrain α_c



Summary

1. DIM with modulations of the enhancement of mass transfer rate:

superoutbursts, normal outbursts, dips during superoutbursts , cycling state

2. Three methods to investigate AM Cvn stars :

- decay rate from the outburst → α_h (with known M1, Porb)
- Kukarkin-Parenago relation → α_c (Mtr ?)
- comparison between model light curves and real light curves →

chemical composition, missing physics ?

3. The observations which we need:

- possibly detailed light curves
- M1 and/or Mtr estimated
- information about chemical composition