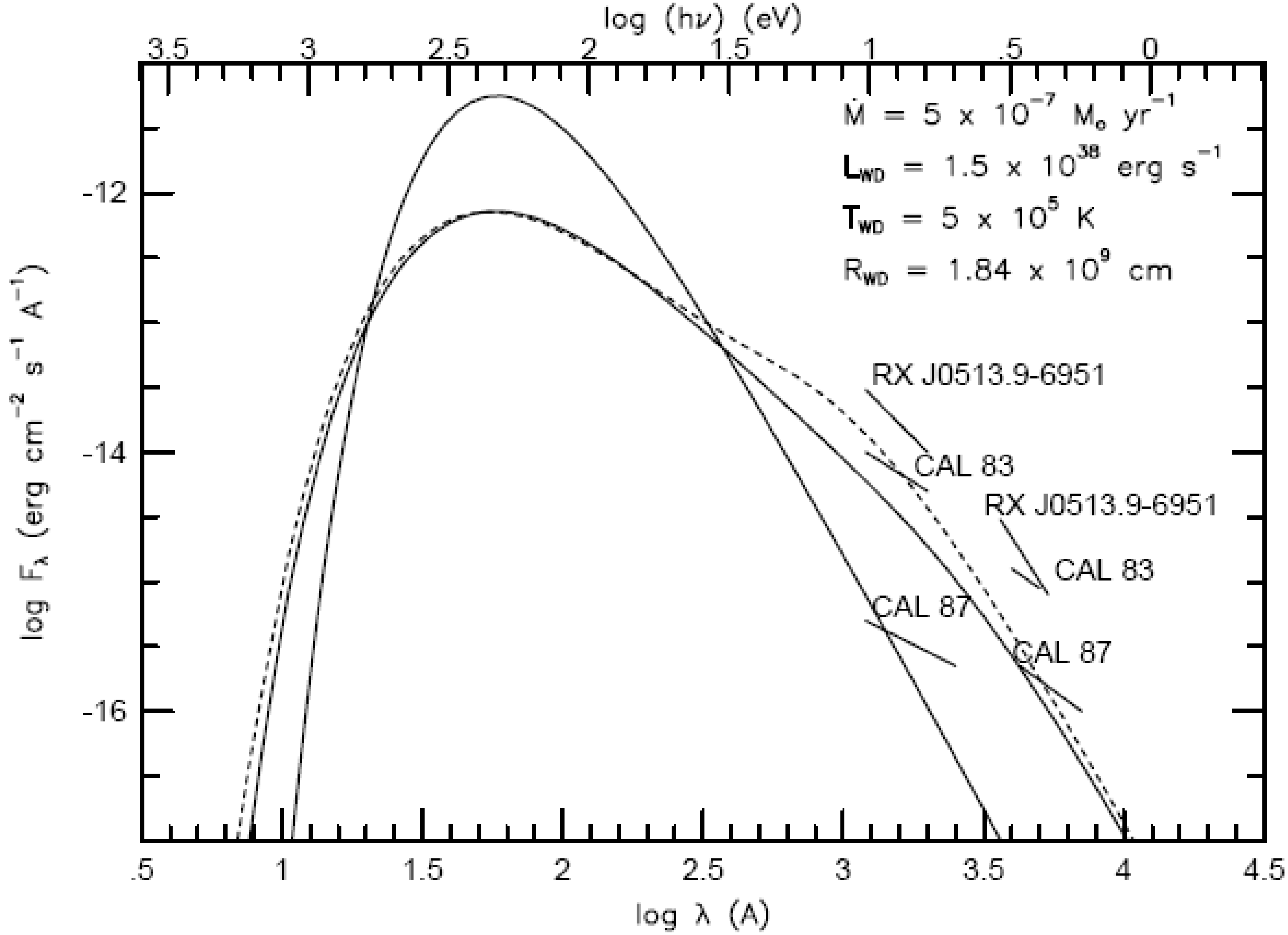
Accretion discs in Superluminous Supersoft Sources

It is widely believed they should be different from discs in CVs because of:

1. Very high accretion rates
2. Strong (X-ray) irradiation by a burning white dwarf
3. Observation suggest “obscuring wall” at the outer disc rim and “flaring”

Robert Popham, Rosanne Di Stefano



WD + irradiated, flared accretion disc

1.

SSSS

Mass-transfer rate ~10^{-7} Msun/year ~ 6.3×10^{18} g/s

DN

$$\dot{M}_{max} \approx 7.8 \times 10^{16} \left(\frac{\alpha_{hot}}{0.2}\right)^{0.01} P_{hr}^{1.79} \mathrm{~g~s^{-1}}$$

~ 2×10^{18} g/s (P_{orb}= 6 hr)

L_{acc} ~ 10^{36} erg/s ~ 0.01 L_{Edd}

...but what is κ ?

Advection of heat important?
(slim discs?)

$$q_{ad} = \frac{2}{3} f^{-1} \left(\frac{H}{R}\right)^2 Q^+$$

Radial flux

$$q_{th} = \left(\frac{H}{R}\right) Q^-$$

But in SSSS $(H/R)^2 < 0.004$

2.

Equations for irradiated discs (Dubus et al.)

$$\frac{\partial \Sigma}{\partial t} = -\frac{1}{r}\frac{\partial}{\partial r}(r\Sigma v_r) + \frac{1}{2\pi r}\frac{\partial \dot{M}_{ext}}{\partial r} \qquad (1)$$

and

$$\frac{\partial \Sigma j_K}{\partial t} = -\frac{1}{r}\frac{\partial}{\partial r}(r\Sigma j_K v_r) + \frac{1}{r}\frac{\partial}{\partial r}\left(-\frac{3}{2}r^2\Sigma\nu\Omega_K\right) + \frac{j_2}{2\pi r}\frac{\partial \dot{M}_{ext}}{\partial r} - \frac{1}{2\pi r}\mathcal{T}_{tid}(r) \qquad (2)$$

$$\frac{\partial T_c}{\partial t} = \frac{2(Q^+ - Q^- + (1/2)Q_i + J)}{C_p\Sigma} - \frac{\Re T_c}{\mu C_p}\frac{1}{r}\frac{\partial (r v_r)}{\partial r} - v_r\frac{\partial T_c}{\partial r} \qquad (3)$$

$$Q^+ = \frac{9}{8}\nu\Sigma\Omega_K^2 \qquad Q^- = \sigma T_{eff}^4$$

$$\frac{\mathrm{d}P}{\mathrm{d}z} = -\rho g_z = -\rho \Omega_K^2 z$$

$$\nabla_{\mathrm{rad}} = \frac{\kappa_R P F_z}{4 P_{\mathrm{rad}} c g_z}$$

$$\frac{\mathrm{d}\varsigma}{\mathrm{d}z} = 2\rho$$

$$\frac{\mathrm{d}\ln T}{\mathrm{d}z} = \nabla \frac{\mathrm{d}\ln P}{\mathrm{d}z}$$

$$\frac{\mathrm{d}F_z}{\mathrm{d}z} = \frac{3}{2}\alpha\Omega_K P + \frac{\mathrm{d}F_t}{\mathrm{d}z}$$

Surface boundary condition

$$T^4(\tau_s) = T_{\mathrm{eff}}^4 + T_{\mathrm{irr}}^4$$

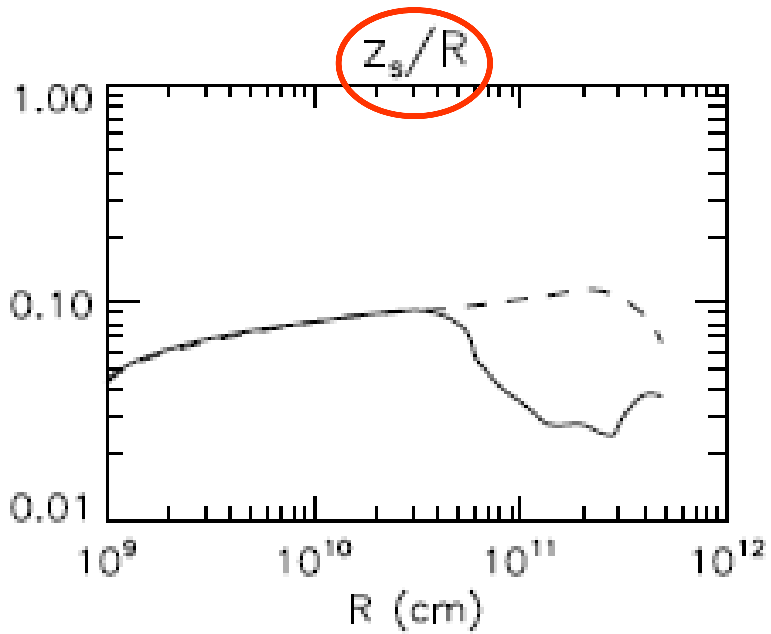
For $\tau_{\mathrm{tot}} \gg 1$, the temperature at the disc midplane

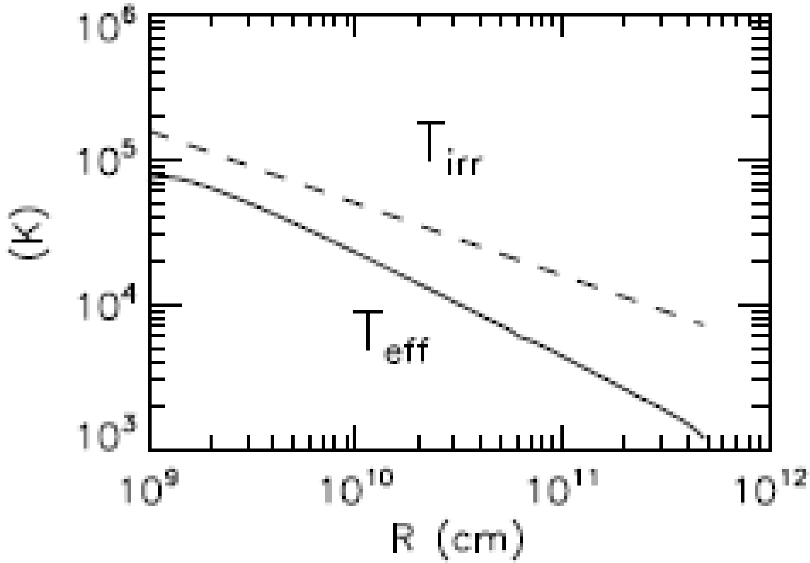
$$T_c^4 \equiv T^4(\tau_{\mathrm{tot}}) = \frac{3}{8}\tau_{\mathrm{tot}} T_{\mathrm{eff}}^4 + T_{\mathrm{irr}}^4$$

For the vertical structure to be dominated by irradiation:

$$\frac{F_{\mathrm{irr}}}{\tau_{\mathrm{tot}}} = \frac{\sigma T_{\mathrm{irr}}^4}{\tau_{\mathrm{tot}}} \gg F_{\mathrm{vis}}$$

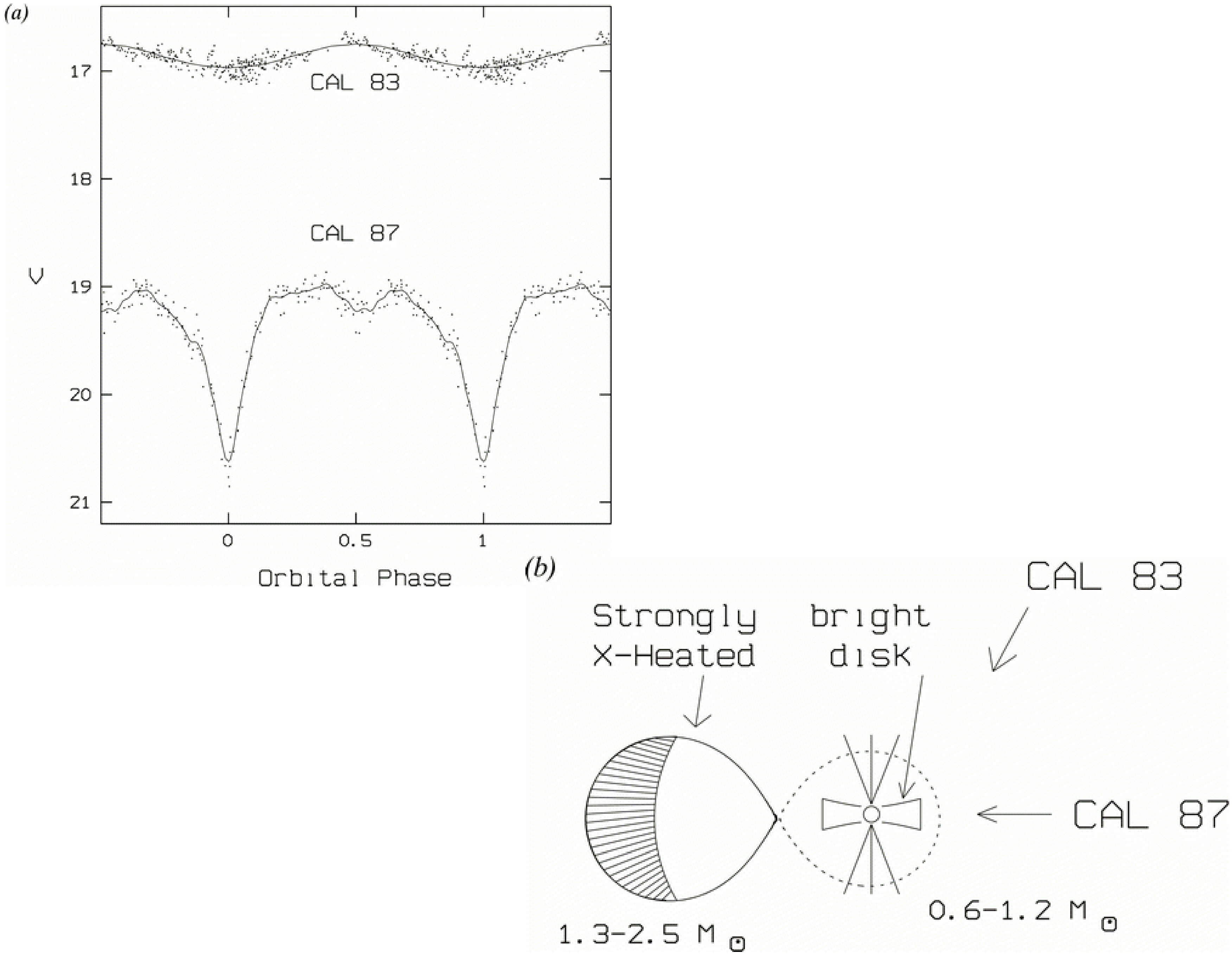
Disc's shape



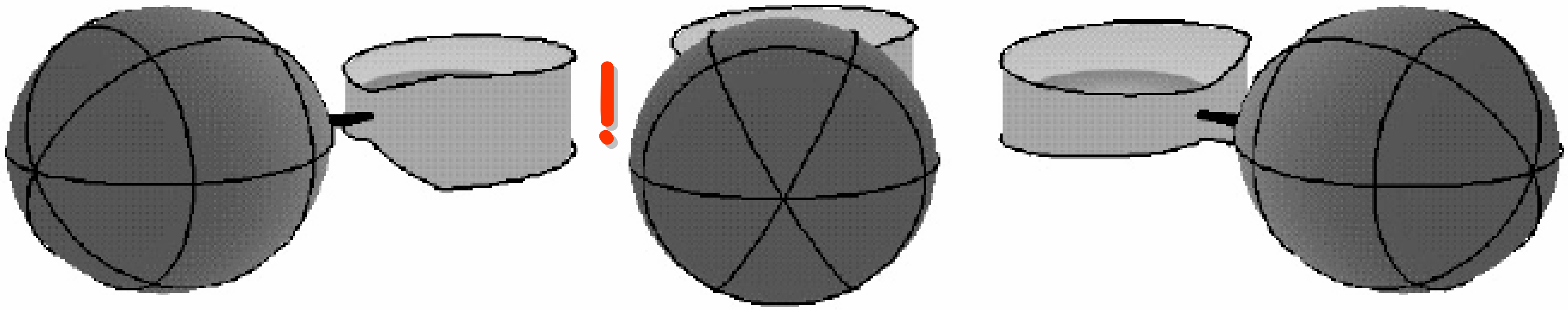


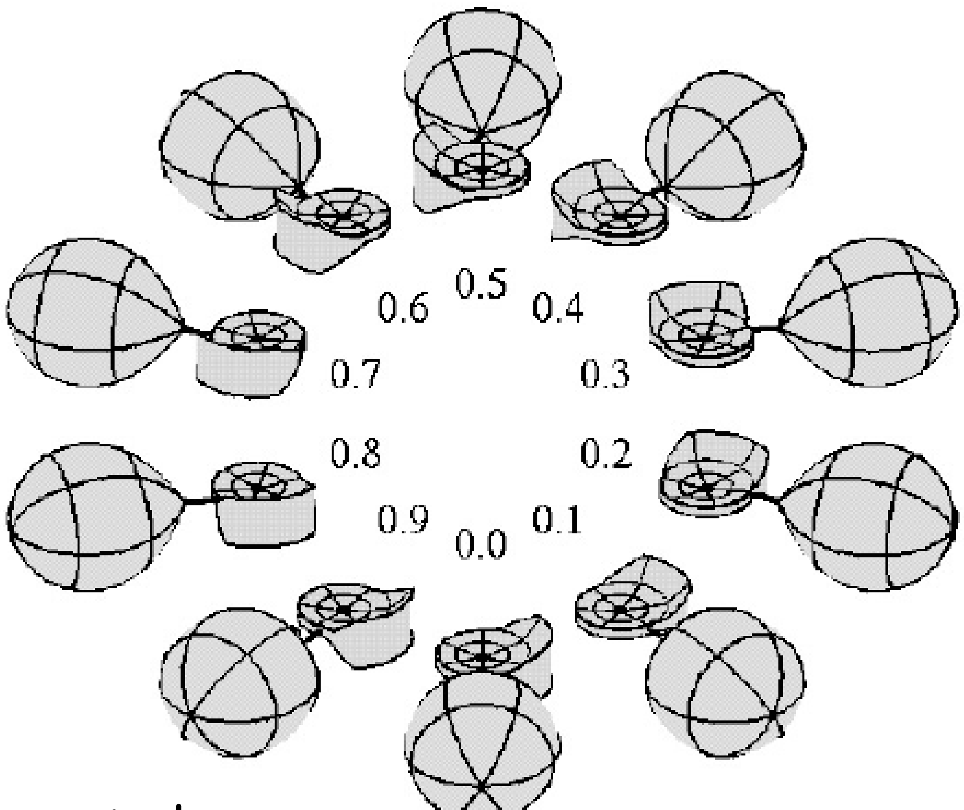
Accretion rate: 1×10^{18} g/s

…but this is for a point source, near the WD this is not a valid approximation.


(a)
17
18
19
20
21
V
CAL 83
CAL 87
0
0.5
1
Orbital Phase
(b)
CAL 83
Strongly
X-Heated
bright
disk
CAL 87
1.3–2.5 M ⊙
0.6–1.2 M ⊙

CAL 87

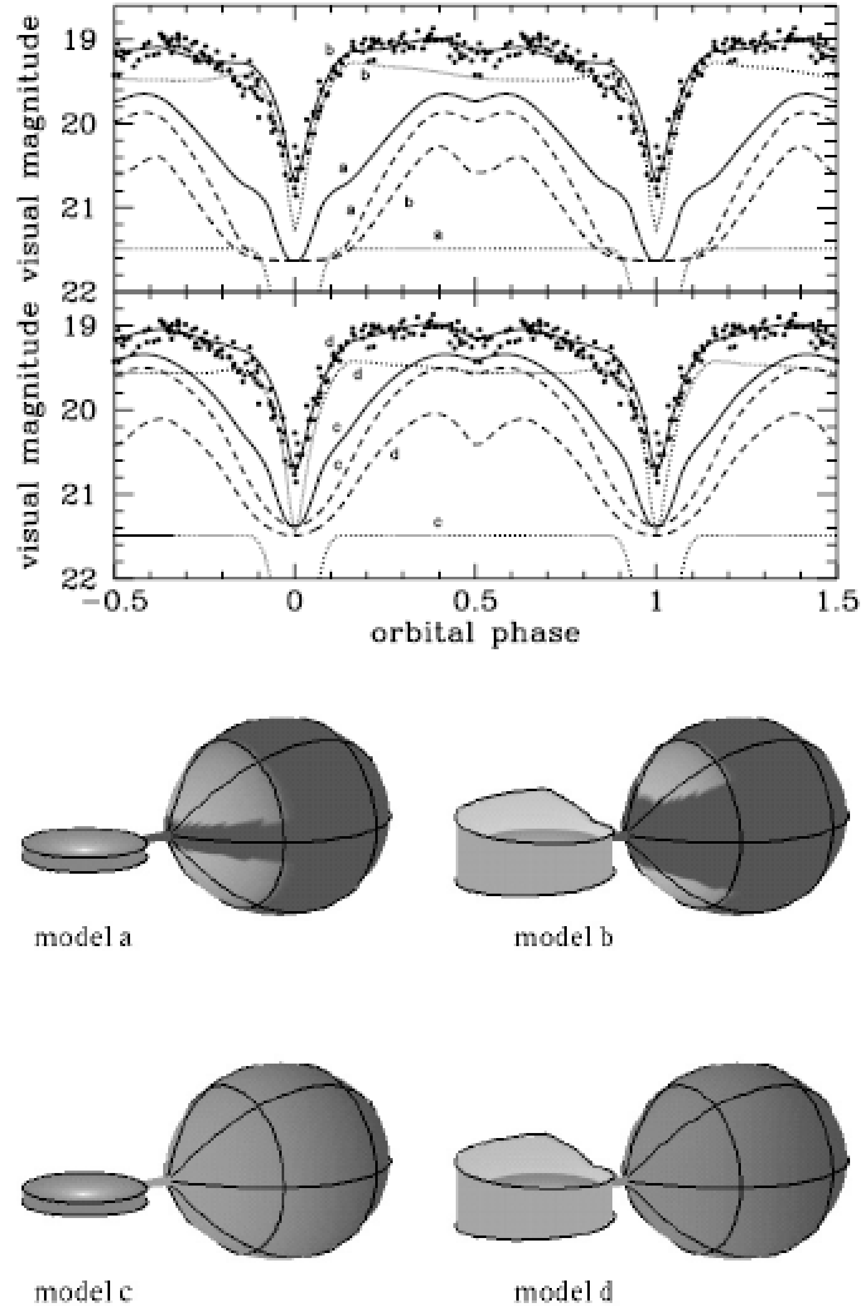




RX J0019

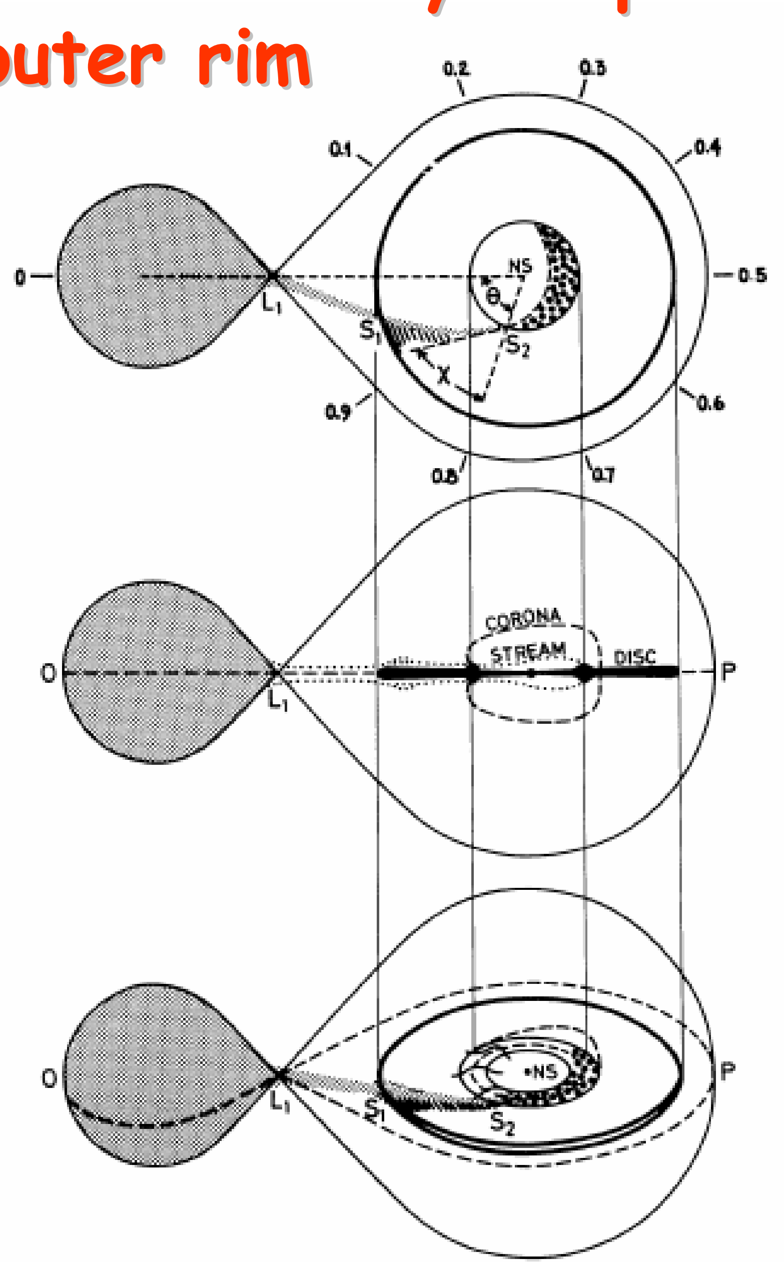
Meyer-Hofmeister et al.

Inspiration: LMXBs



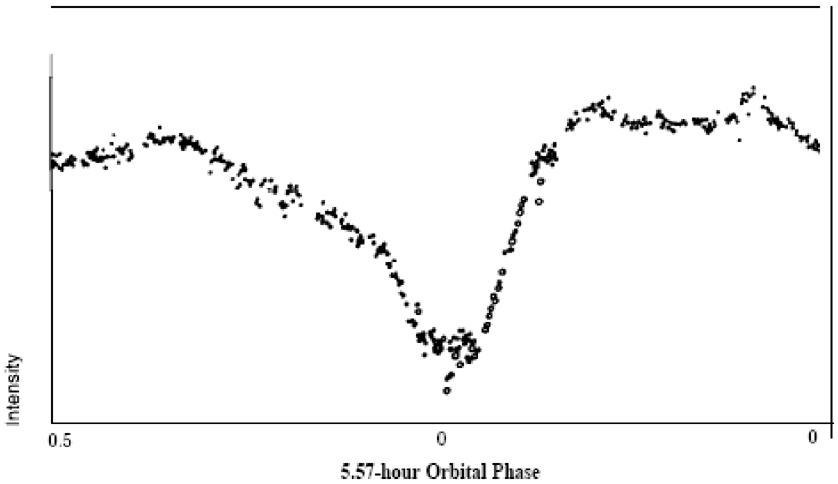
Schandl et al.

Alternative to skyscrapers at the disc outer rim

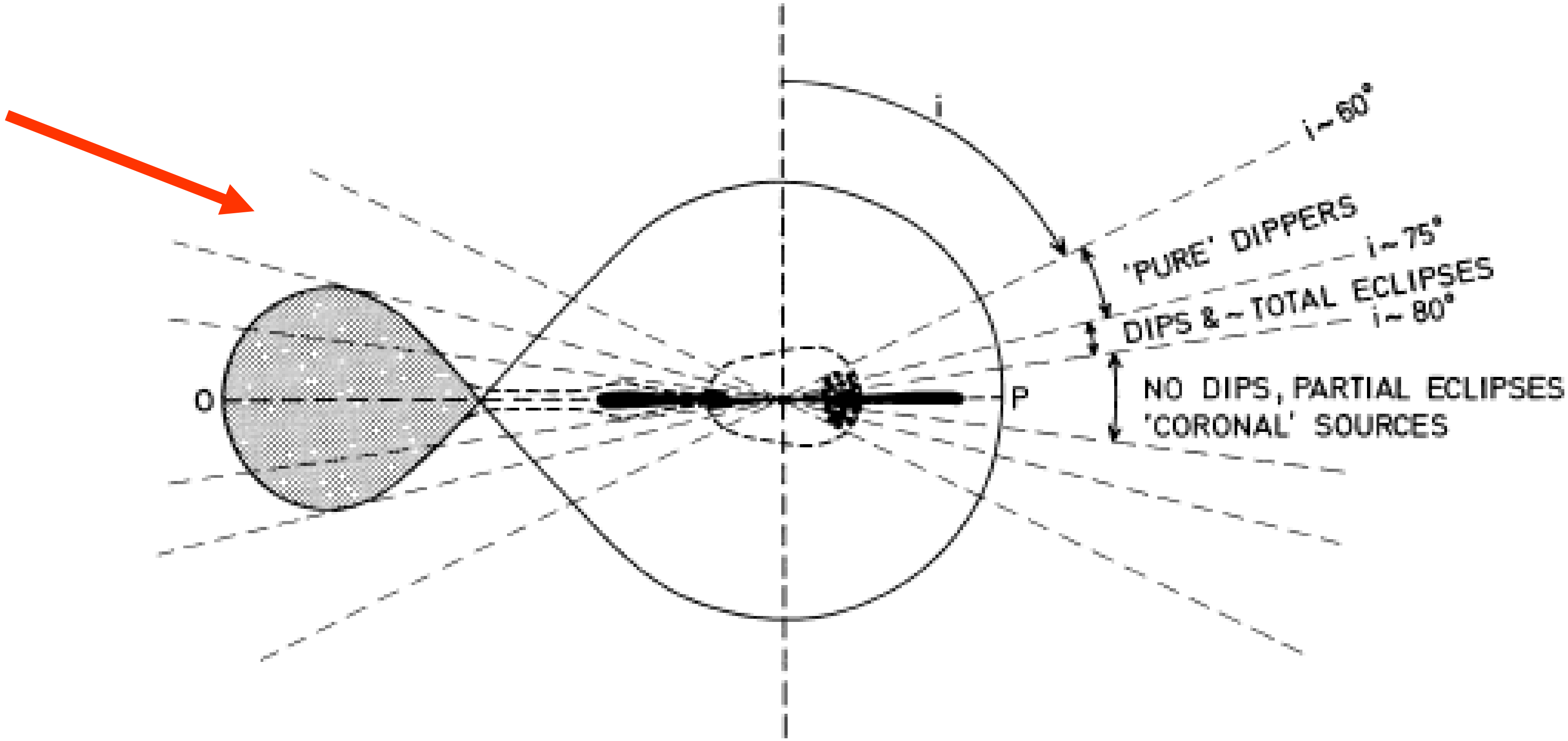


LMXBs

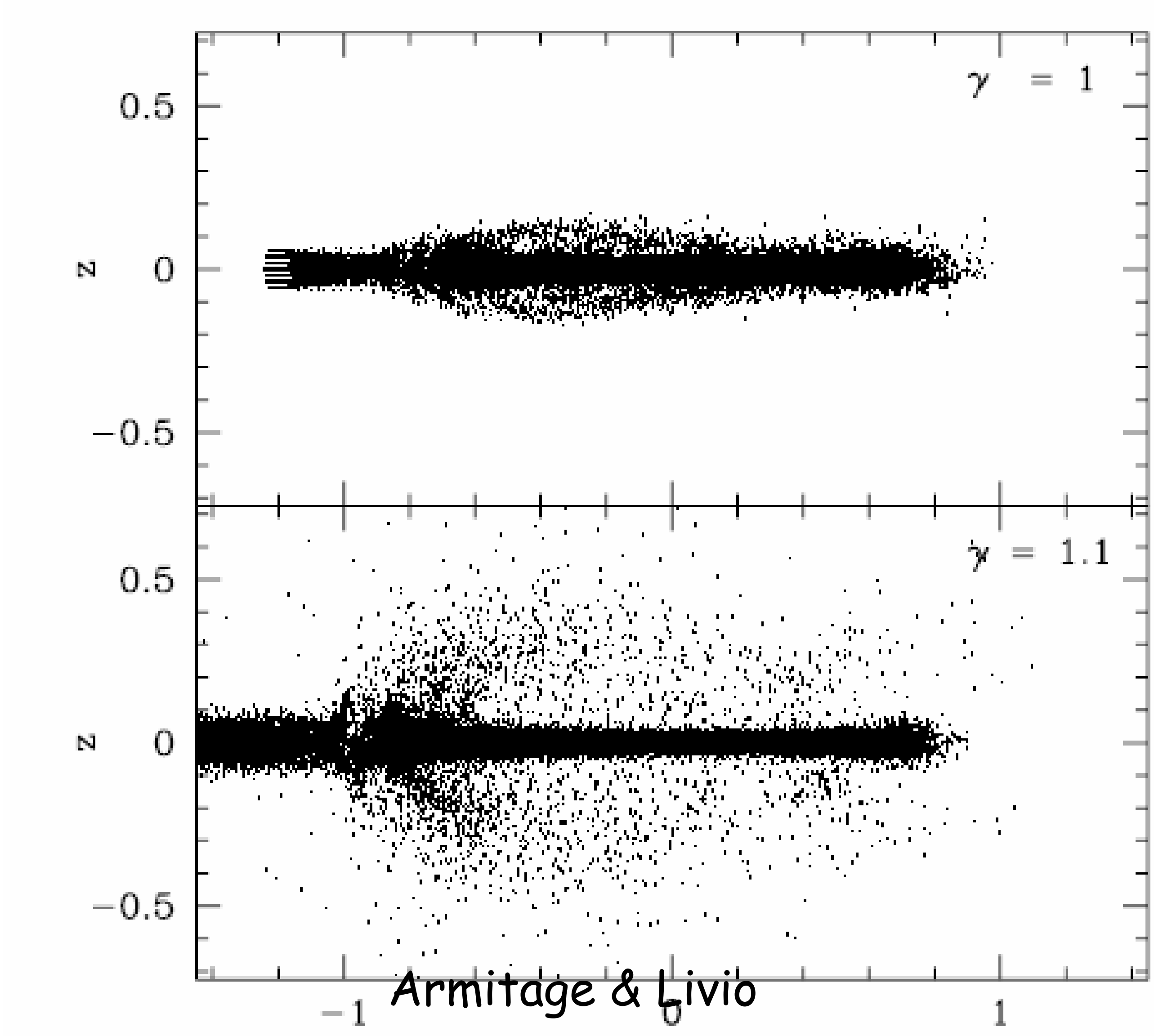
Frank, King & Lasota



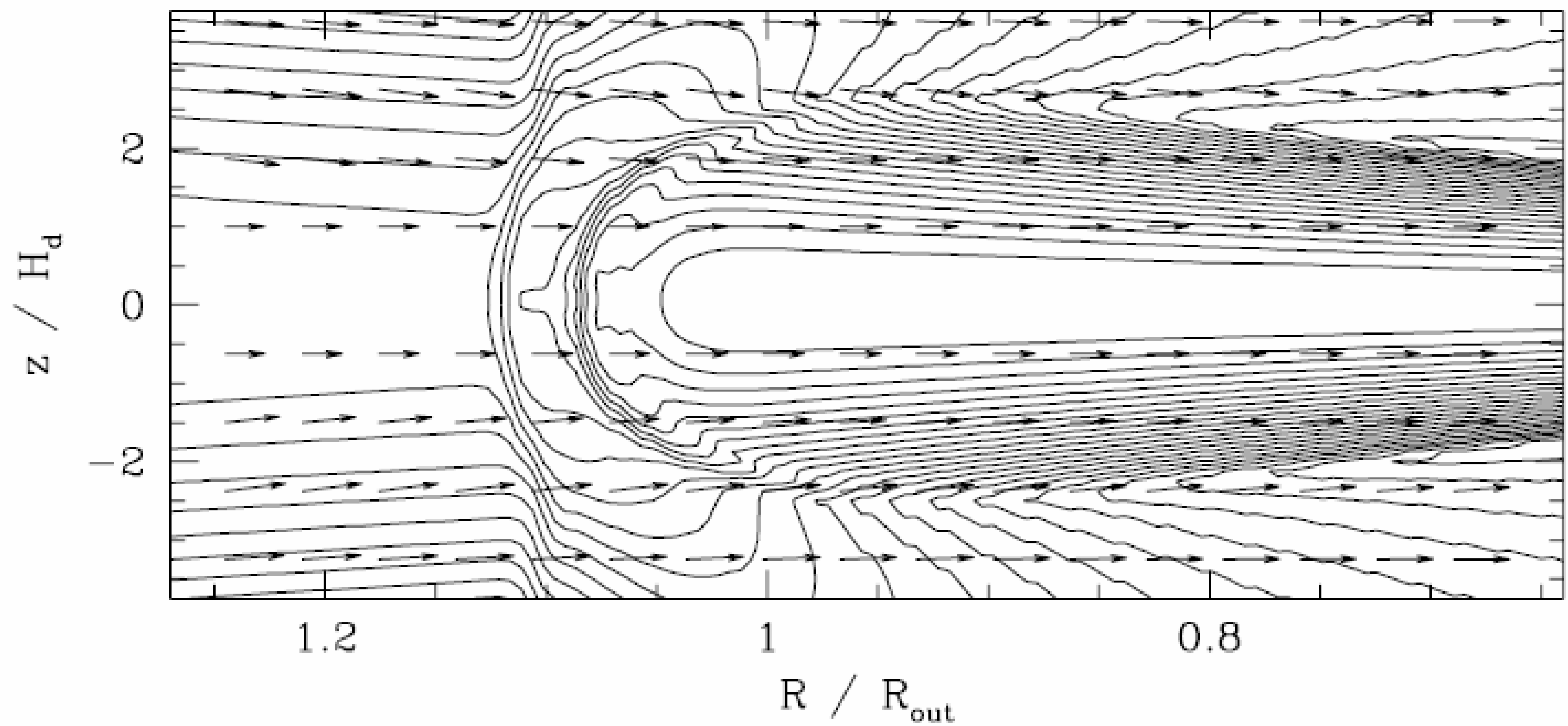
Would this work for SSSS ?



Simulations of the stream-disc interaction



Armitage & Livio



But according to T. Marsh & Co. in **quiescent** U Gem: no sign of overflow but **H/R ~0.15 - 0.25** !!!

Conclusions:

1. SSSS discs can be (and will be) treated with the present thin-disc " technology"
2. Outer rim problem non-trivial & controversial
3. Big problem: **WINDS** from discs