Understanding the X-ray emission of close massive binaries: The case of WR 20a

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Galaxies meet GRBs at Cabo de Gata
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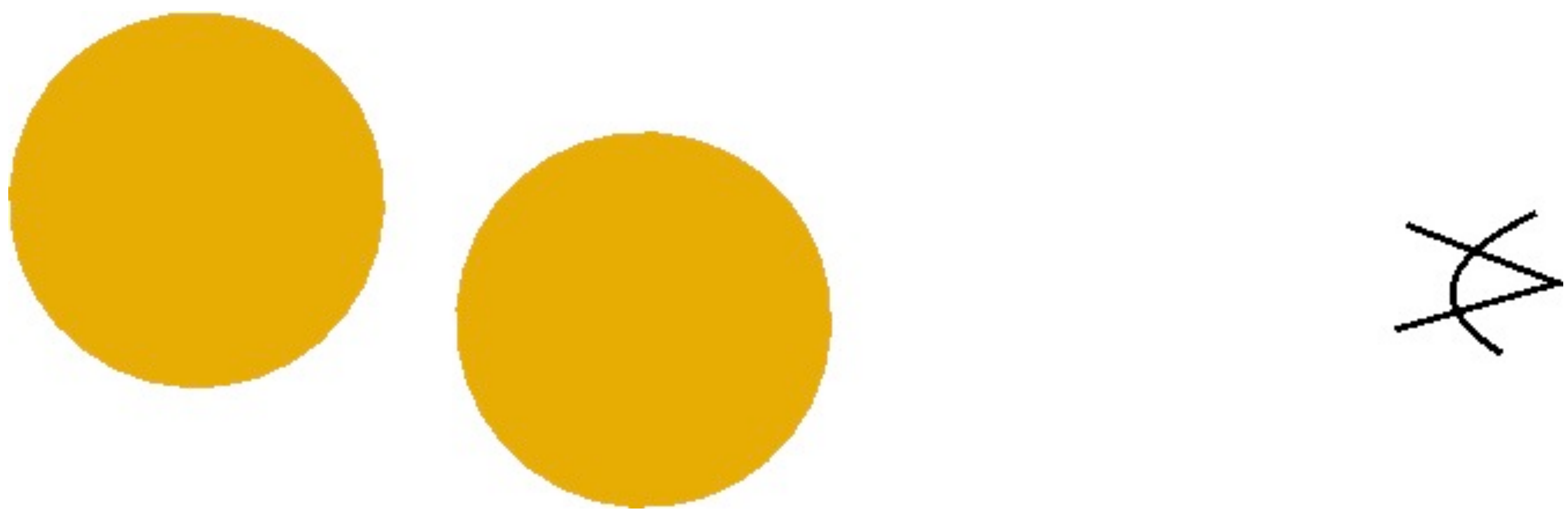
Introduction

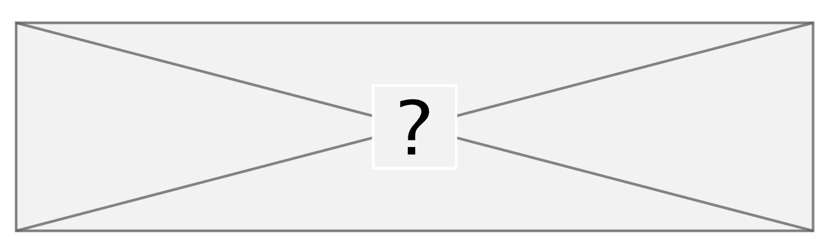
- WR stars are the progenitor systems of broad-line type Ib/c supernova and GRBs.
- WR20a could thus be representative of GRB progenitor system.
- For GRBs, understanding the wind initiation region is key as it would determine the shock break out observational properties.
- Rotation is thought to be a key ingredient, and binarity maybe essential.

WR 20a (WN6ha+WN6ha)

$$P = 3.686 \pm 0.01\,\text{days}$$
$$a = 53.0 \pm 0.7\,\mathrm{R}_\odot$$
$$i = 74^\circ.5 \pm 0^\circ.2$$

$$M = 82.7 \pm 5.5\,\mathrm{M}_\odot$$
$$\mathrm{R} = 19.3 \pm 0.5\,\mathrm{R}_\odot$$





(Rauw et al. 2005)

X-ray emission in massive stars

- Wolf-Rayet (WR) and O type stars are well known X-ray emitters.

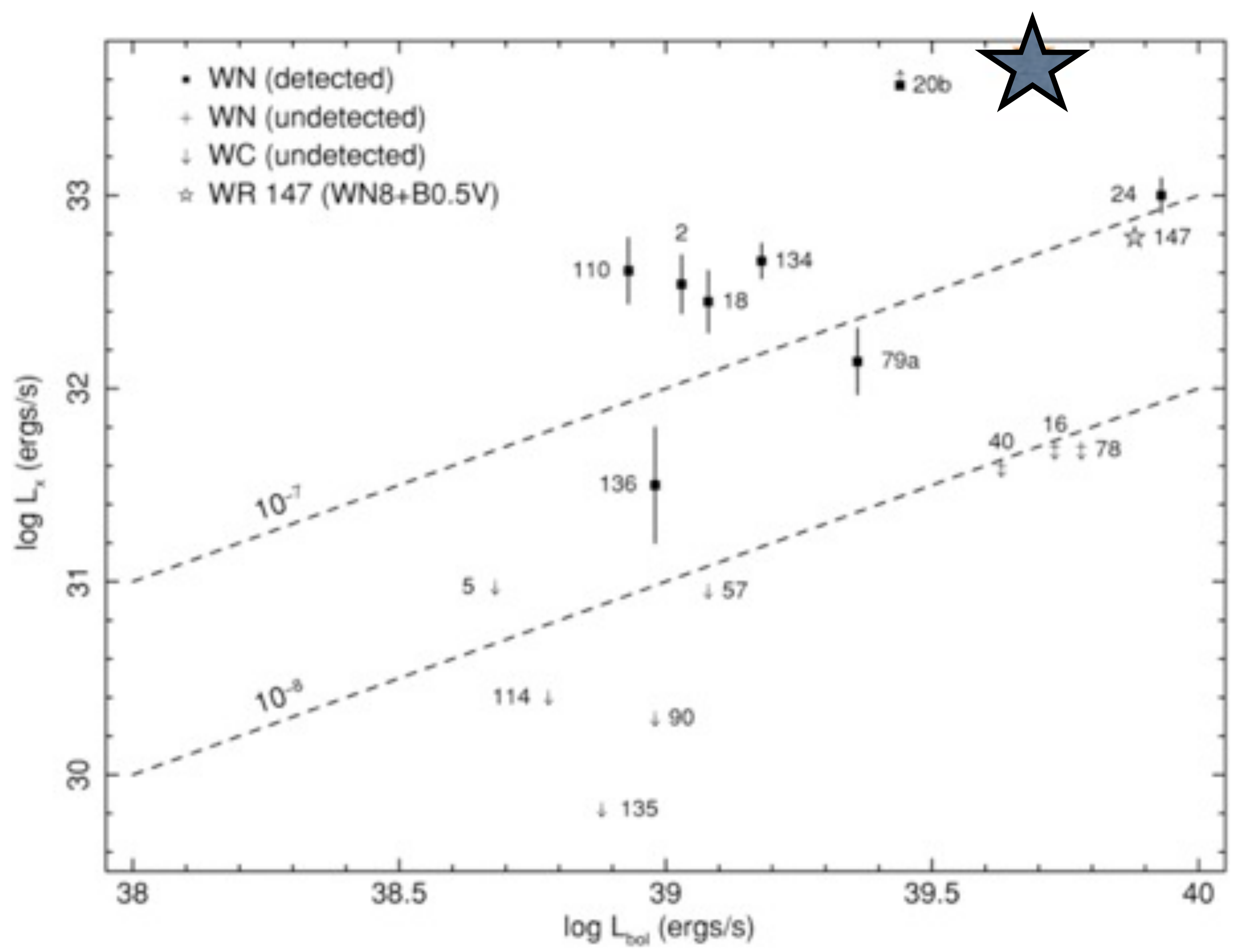
- In single stars X-rays are produced due internal wind instabilities heating the plasma up to 10 6 (<1keV) .

- O-type stars follows an empirical relation: $\log(L_X/L_{\rm bol}) \sim -6.9$

X-ray Emission from Massive Binaries (WR20a)

- Two temperature components:
  softh (0.3-0.9 keV) and hard (1.3-2keV).
- X-ray luminosity exceeding the empirical relation.

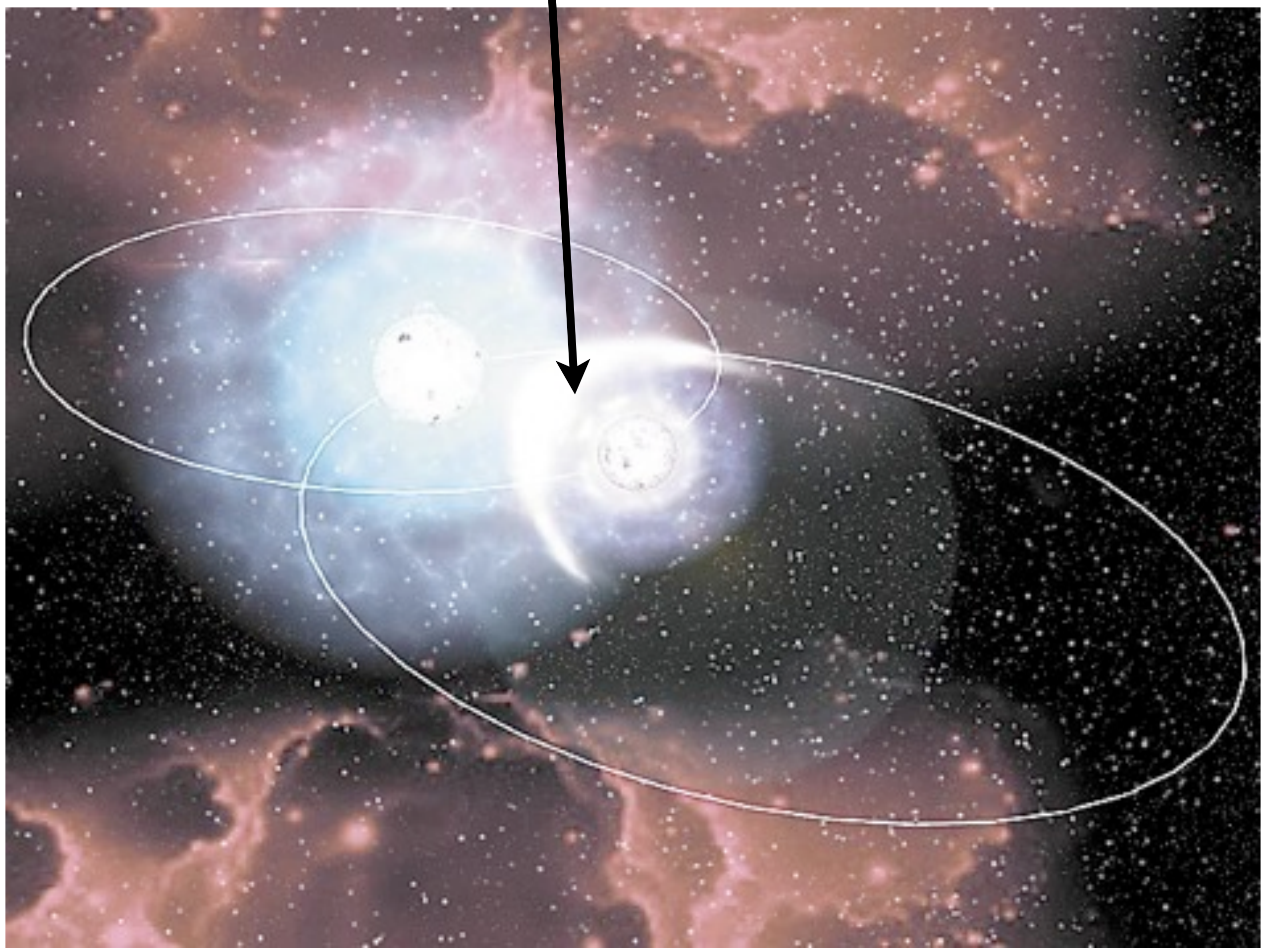
(Nazé et al. 2008)



(Skinner et al. 2010)

X-ray Emission from Massive Binaries (WR20a)

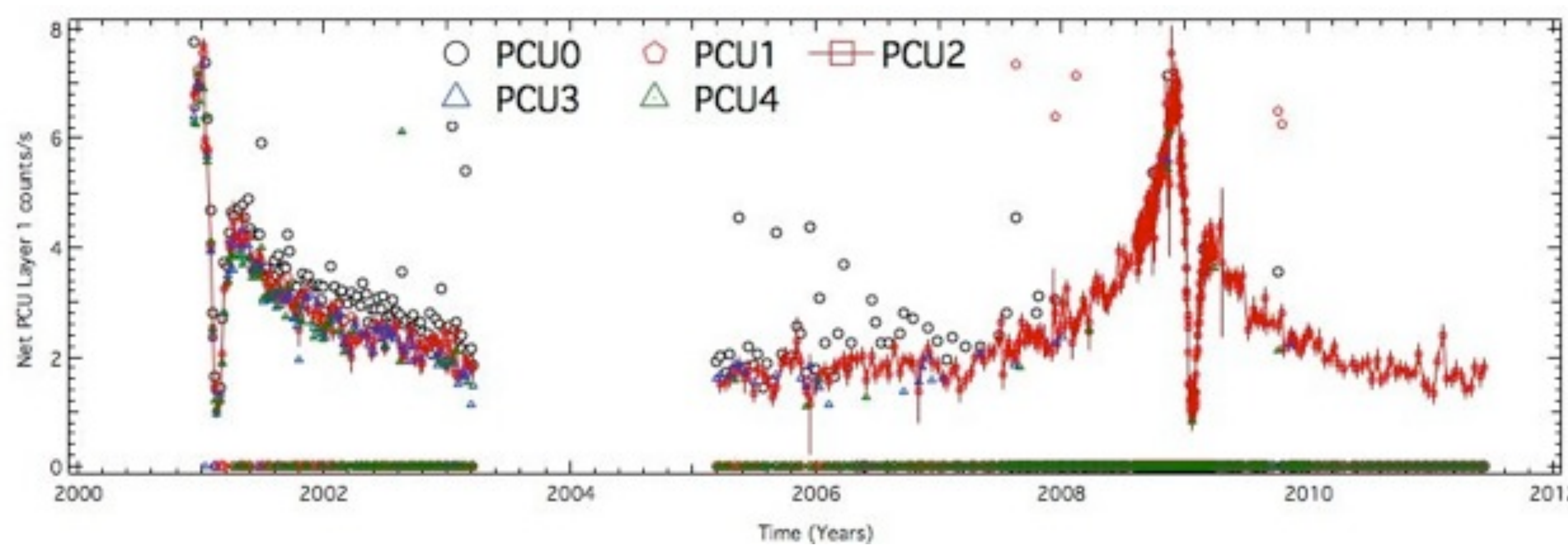
- Hard emission component produced within a Wind-wind Colliding Region (WCR).
- X-ray luminosity dominated by the WCR component.



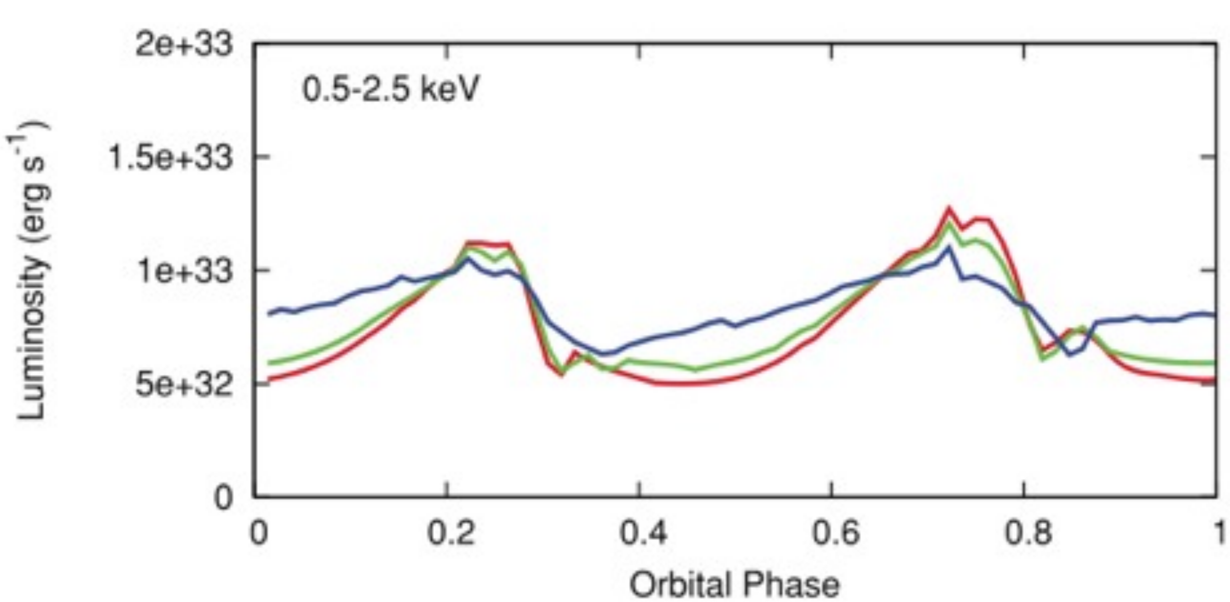
(Credit Andre Viera, IAG-USP Brazil; Pittard 2003)

Variability: Due to changes in the separation for eccentric orbit and absorption effects

Lightcurves have been constructed mostly for wide systems, e.g. WR 140:

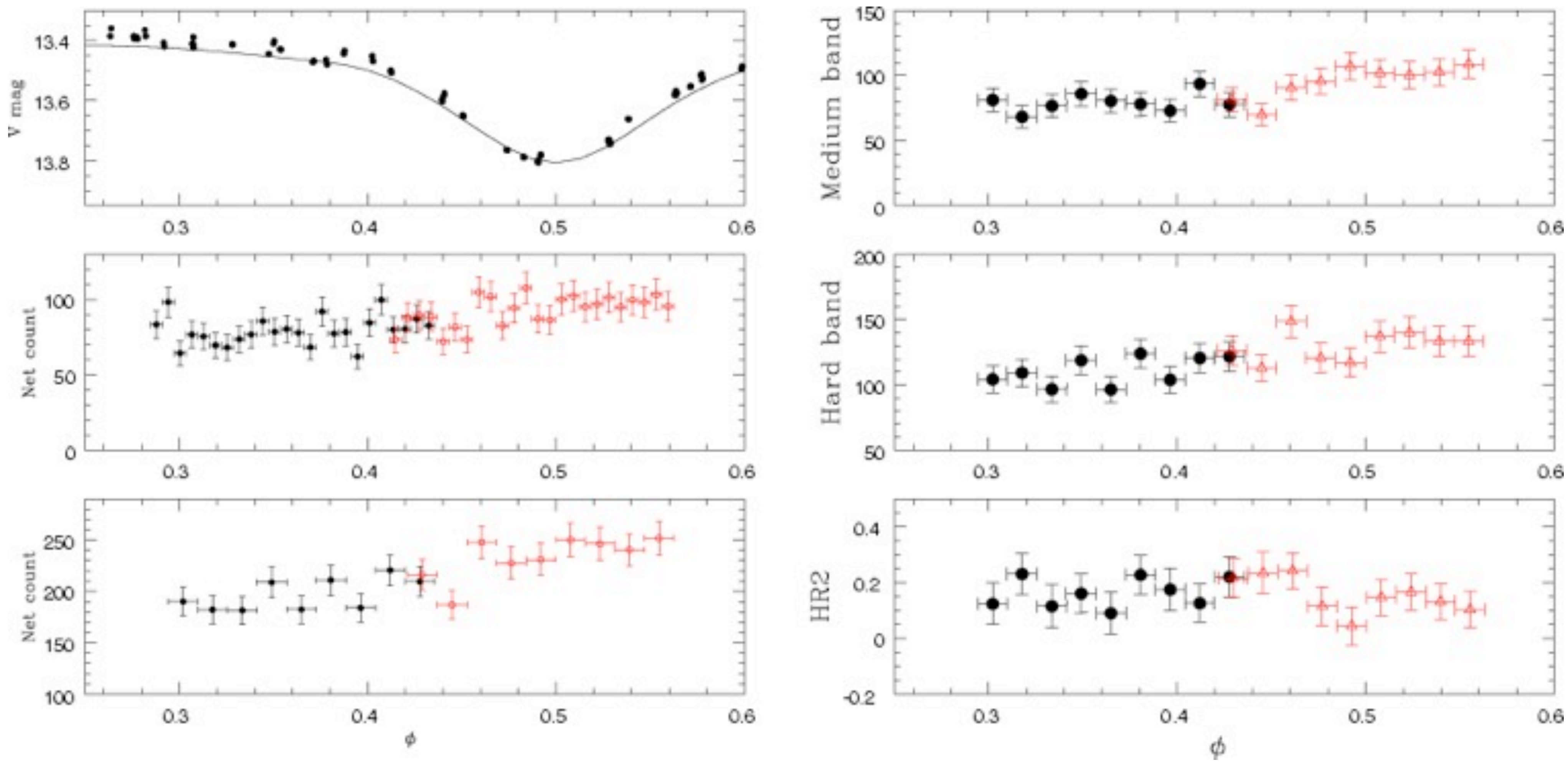


(from from http://asd.gsfc.nasa.gov)



Models for close systems predict also variability (Pittard & Parkin 2010)

X-Ray Lightcurve for WR 20a



WR 20a appears slightly more X-ray luminous and softer during the optical eclipse, opposite to what has been observed in other binary systems.

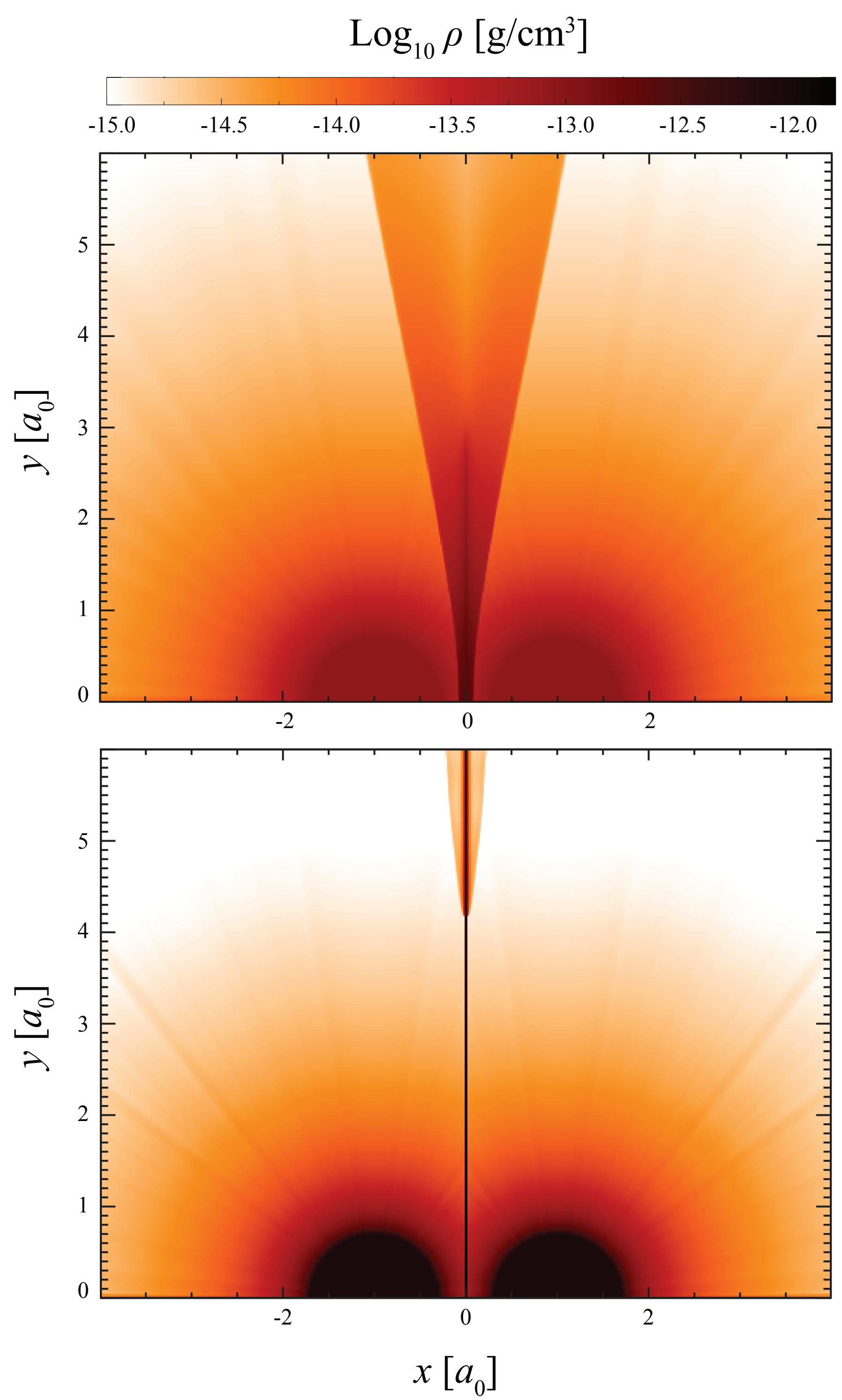
Nazé et al. (2008)

2D-HD Simulations with WR 20a parameters

PROPERTIES OF WR20A AS DERIVED BY 1: BONANOS ET AL. (2004), 2: RAUW ET AL. (2005), AND 3: NAZÉ ET AL. (2008)

Parameter	Value	Reference
Spectral Type	WN6ha+WN6ha	1
M ($M_\odot$)	$82.7 \pm 5.5 + 81.9 \pm 5.5$	1
$R_\star$ ($R_\odot$)	19.3 ± 0.5	1
$T_{\rm eff}$ (K)	$43\,000 \pm 2000$	1
$\dot{M}$ ($M_\odot\,{\rm yr}^{-1}$)	8.5×10^{-6}	1
v_∞ (${\rm km\,s}^{-1}$)	2800	1
$L_{\rm bol}$ ($L_\odot$)	$1.91 \times 10^6 (d/8\ {\rm kpc})^2$	3
L_X (${\rm erg\,s}^{-1}$)	$5.17 \times 10^{33} (d/8\ {\rm kpc})^2$	3
P (days)	3.686 ± 0.01	2
a ($R_\odot$)	53.0 ± 0.7	2
i	$74^\circ.5 \pm 2^\circ.0$	2
d (kpc)	2-8	2

Models for WR 20a



Solving :

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \ ,$$
$$\frac{\partial \rho \vec{v}}{\partial t} + \nabla \cdot (\rho \vec{v}\vec{v} + p\mathbb{I}) = f \ ,$$
$$\frac{\partial e}{\partial t} + \nabla \cdot (e+p)\vec{v} = \rho \vec{f} \cdot \vec{v} - n^2 \Lambda(T)$$

Being

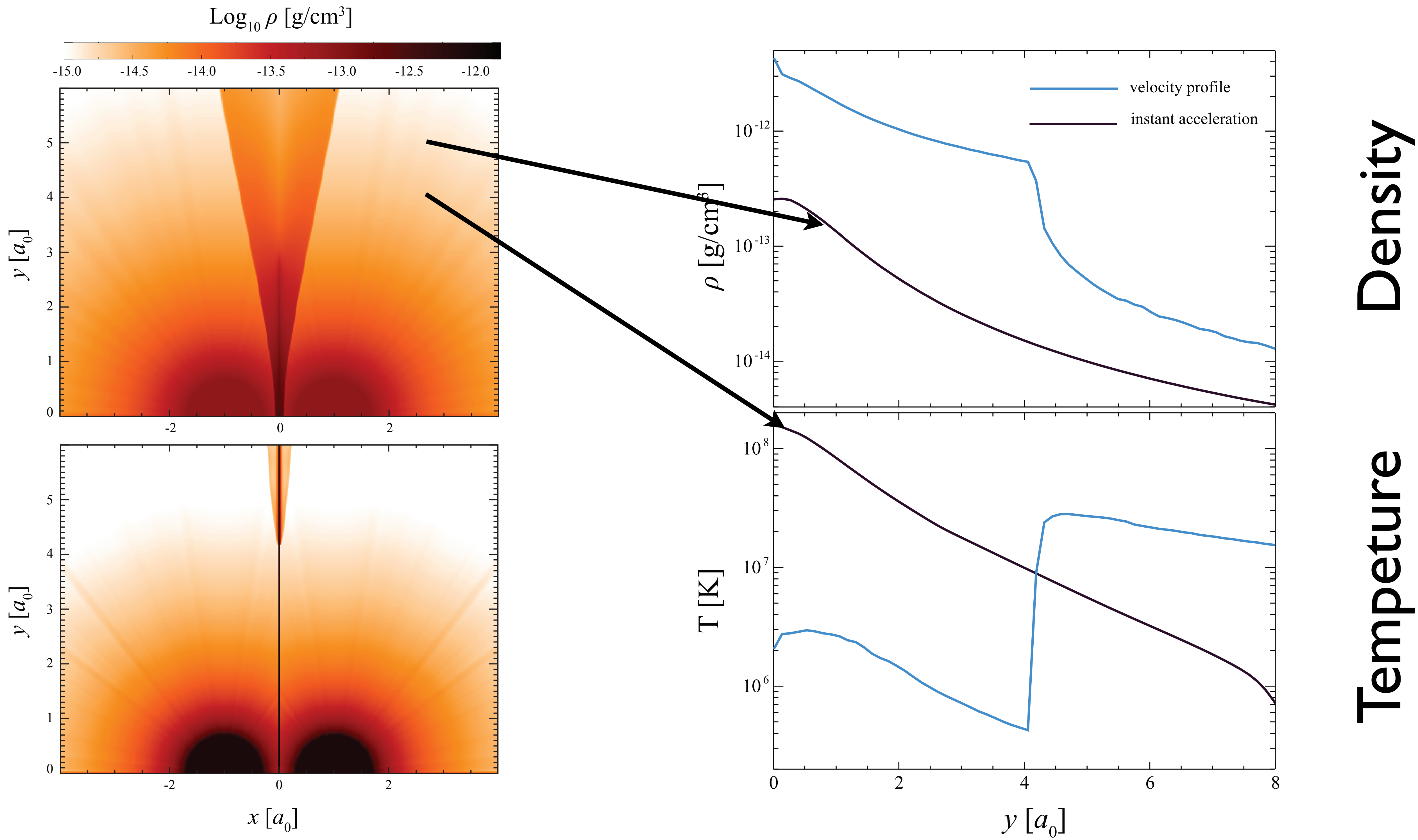
$$f = \frac{\dot{M} R_* \beta}{4\pi r^4} (v_\infty - v_0) \left(1 - \frac{R_*}{r}\right)^{\beta - 1}$$

Obtaining the velocity and density profiles

$$v(r) = v_0 + (v_\infty - v_0) \left(1 - \frac{R_*}{r}\right)^{\beta}$$
$$\rho_{\mathrm{w}}(r) = \frac{\dot{M}}{4\pi r^2 v(r)}$$

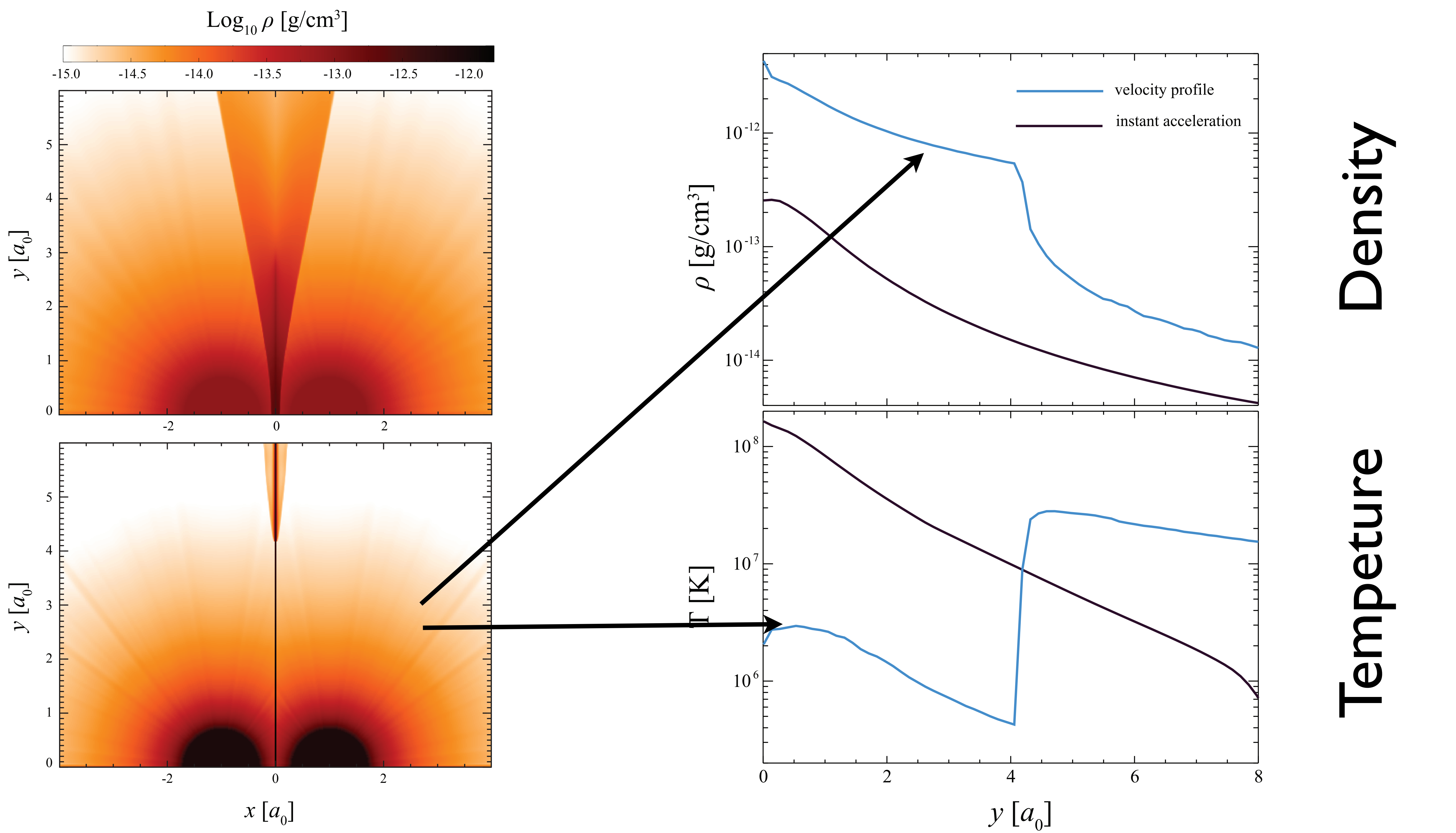
Using Mezcal code (De Colle & Raga 2006)

Density and Temperature profiles for the shocked material



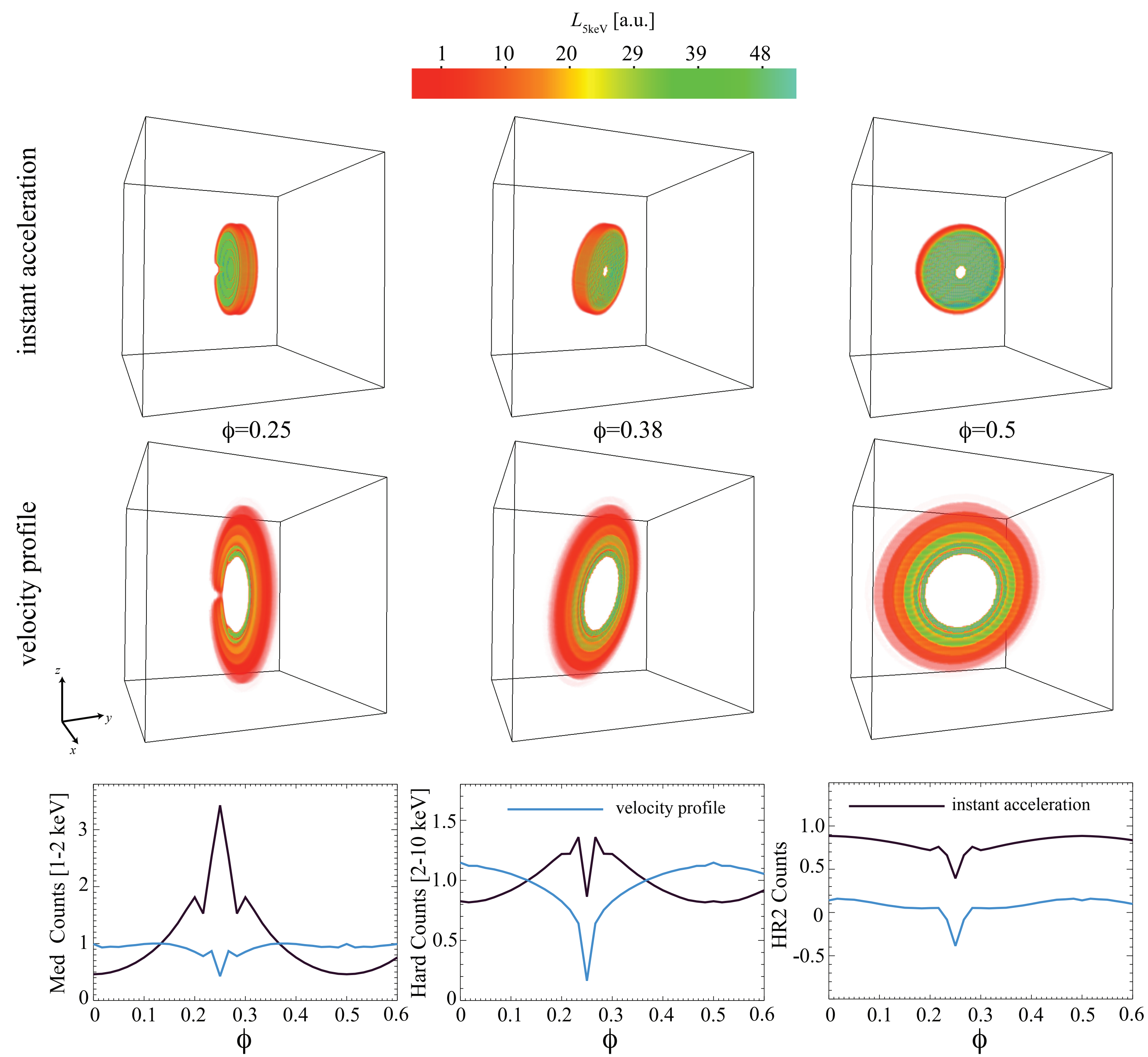
Instant acceleration model

Density and Temperature profiles for the shocked material



Velocity profile model

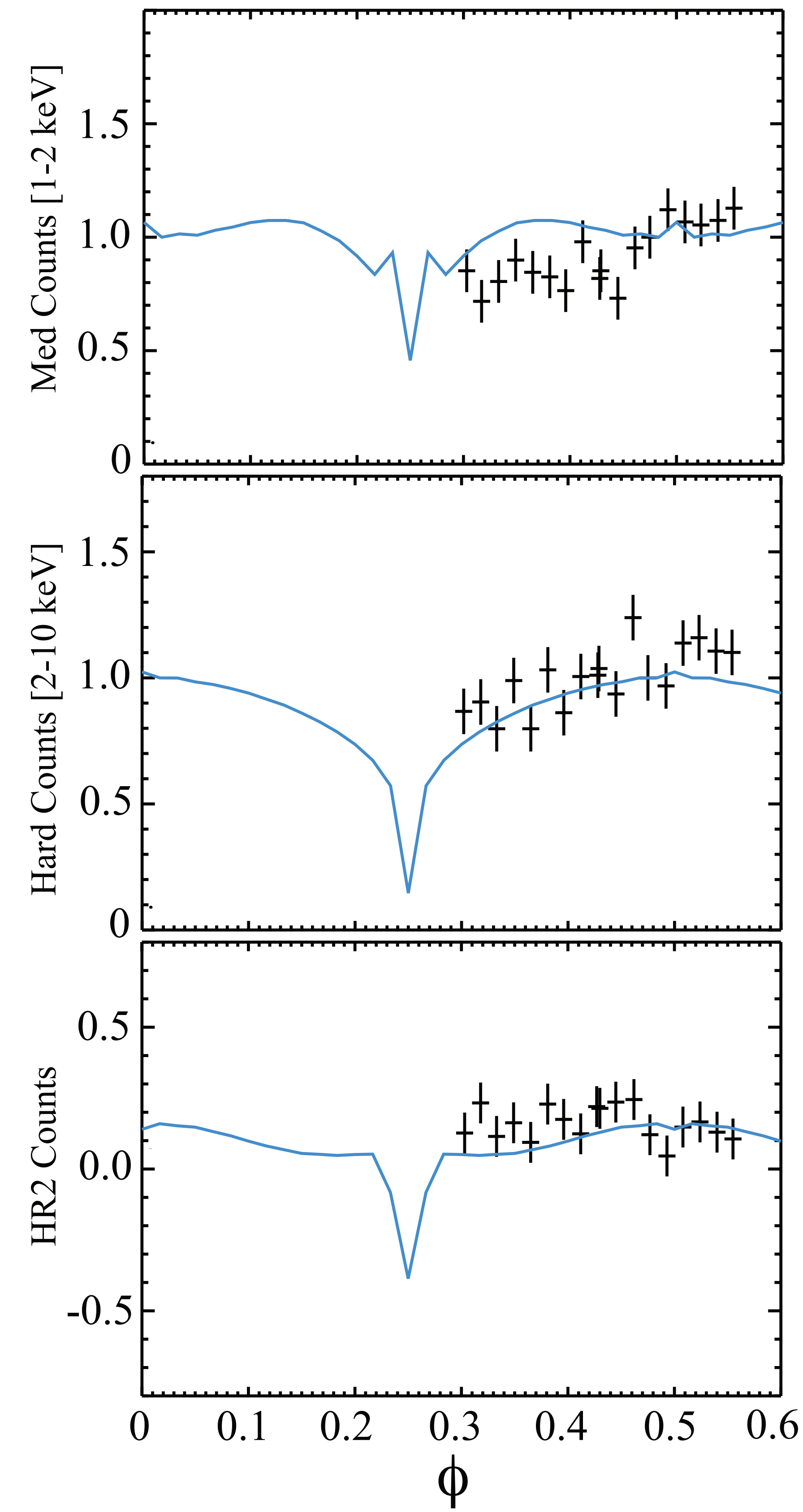
Lightcurves from Models



WR 20a

- *Velocity profile* model reproduce the LC path.

- Luminosty
  Lx = 1.86 × 1034(d/8 kpc)2 erg/s



Conclusions

- This kind of studies allow to describe the conditions of the preshock accelerating material, and hence may allow to reveal details of its acceleration process.

- Another example where extrapolate O-type star characteristics to WR does not work.

Future work

Inclusion of Coriolis effect.
Study of Instabilities.
A detailed study of the observational characteristics of WR binary stars are required.