Gamma-rays and positrons from colliding wind binaries

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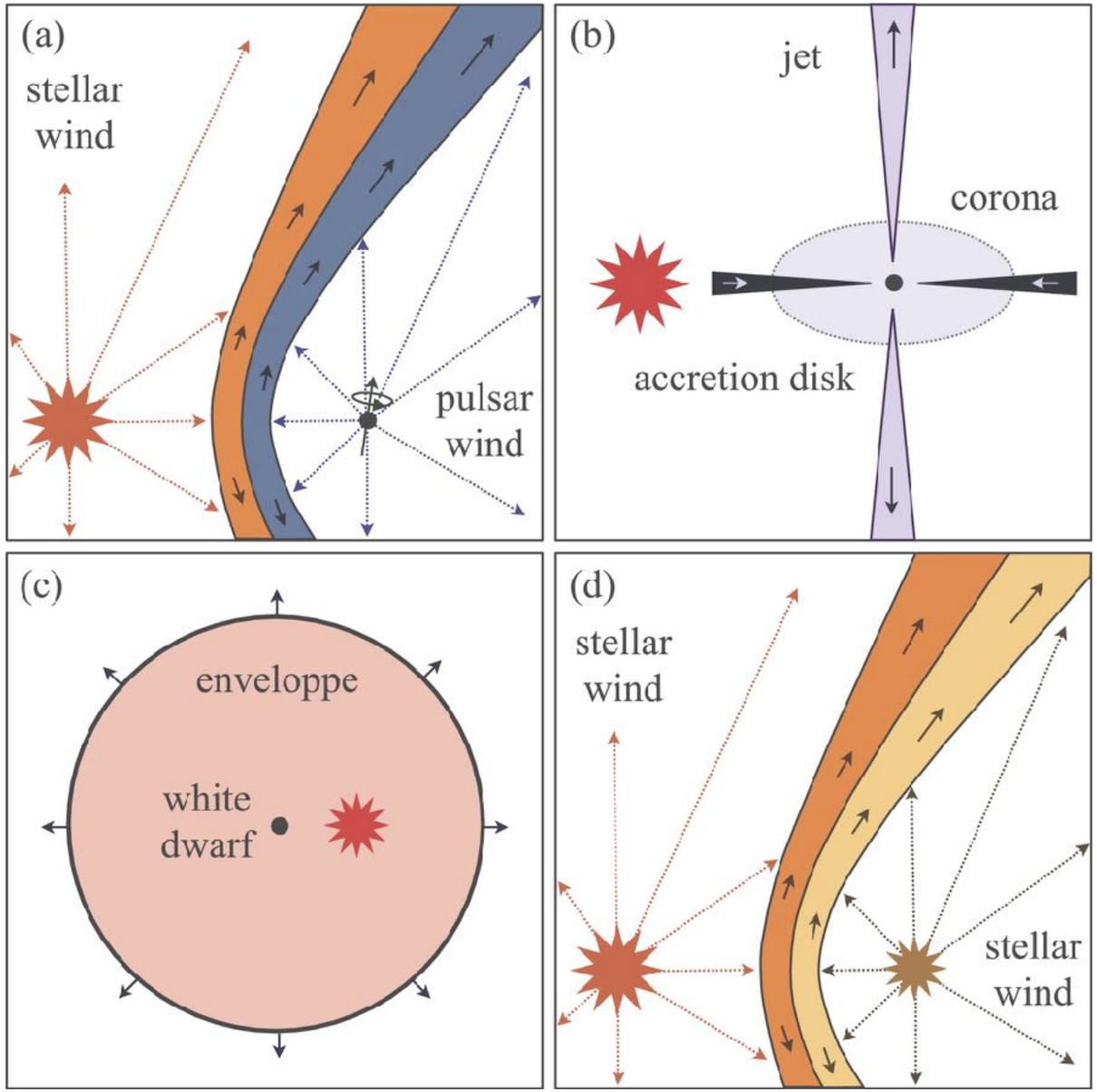
γ-ray binaries



Types of γ-ray binaries:

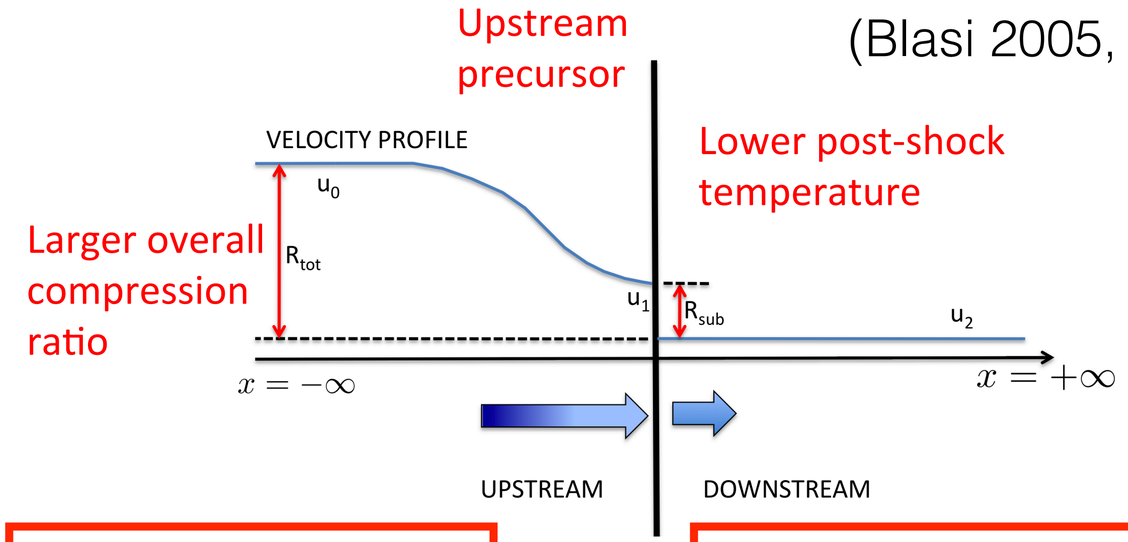
a) massive star + pulsar

b) micro quasar

c) Nova + WD

d) CWB

(Blasi 2005, 2013)



Leptonic

IC on UV/OPT

up to ~GeV

OR

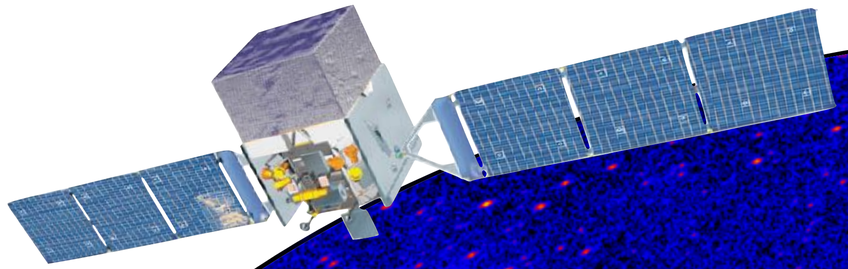
Hadronic

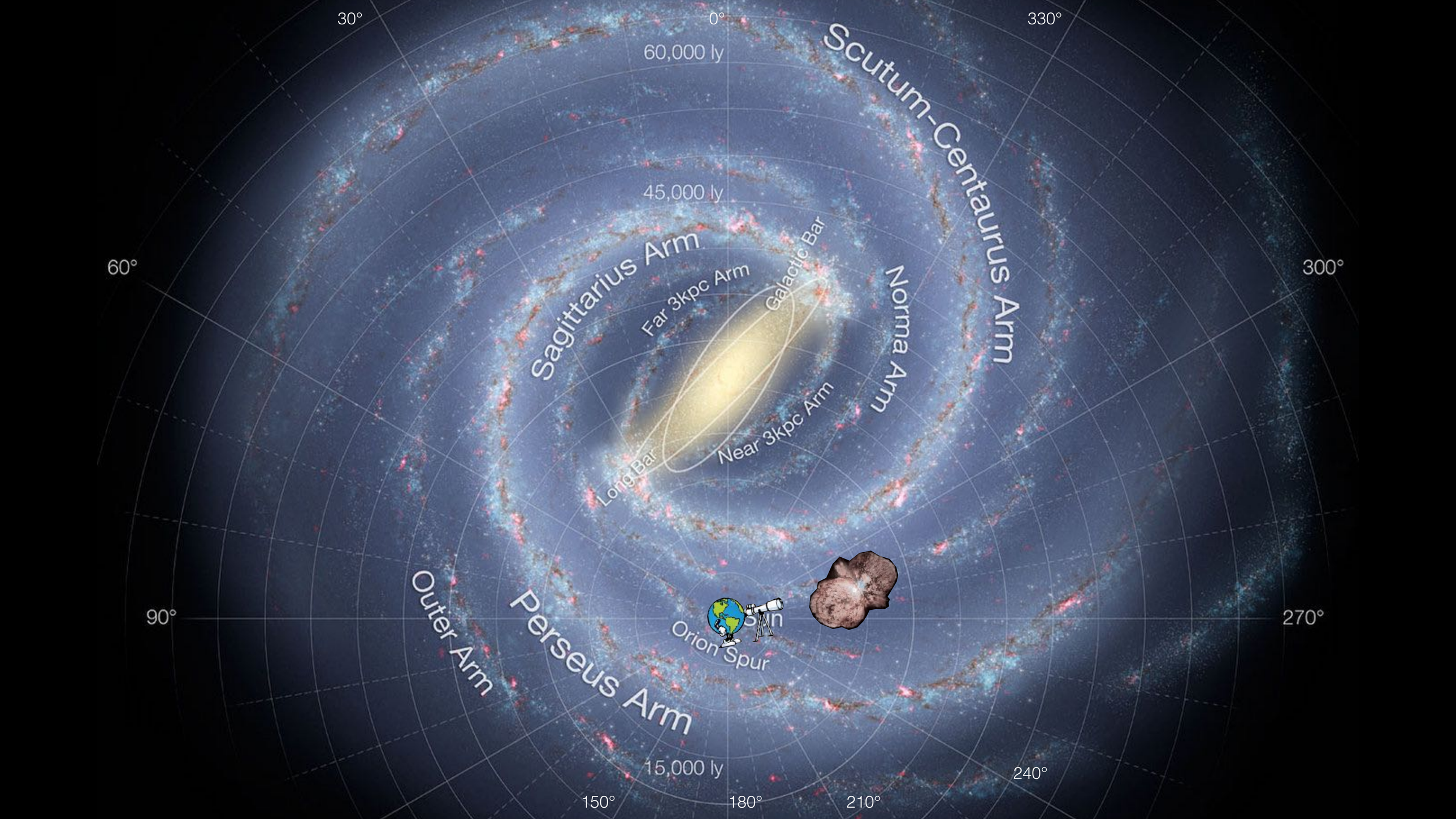
pp —> π_0

higher energies

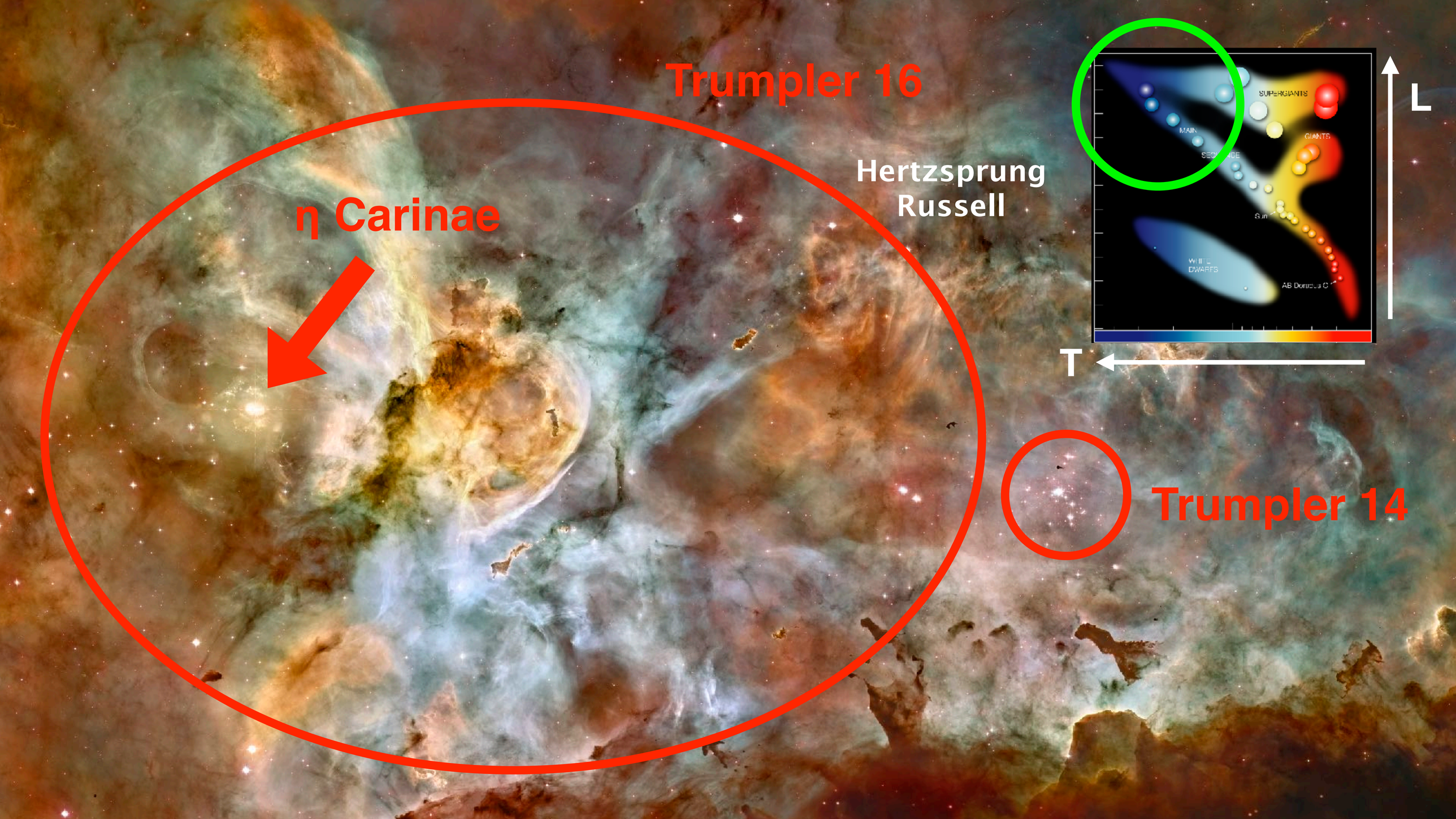
(Eichler & Usov 1993; Benaglia & Romero 2003; Pittard & Dougherty 2006; Reimer et al. 2006; De Becker 2007)

Fermi-LAT countmap

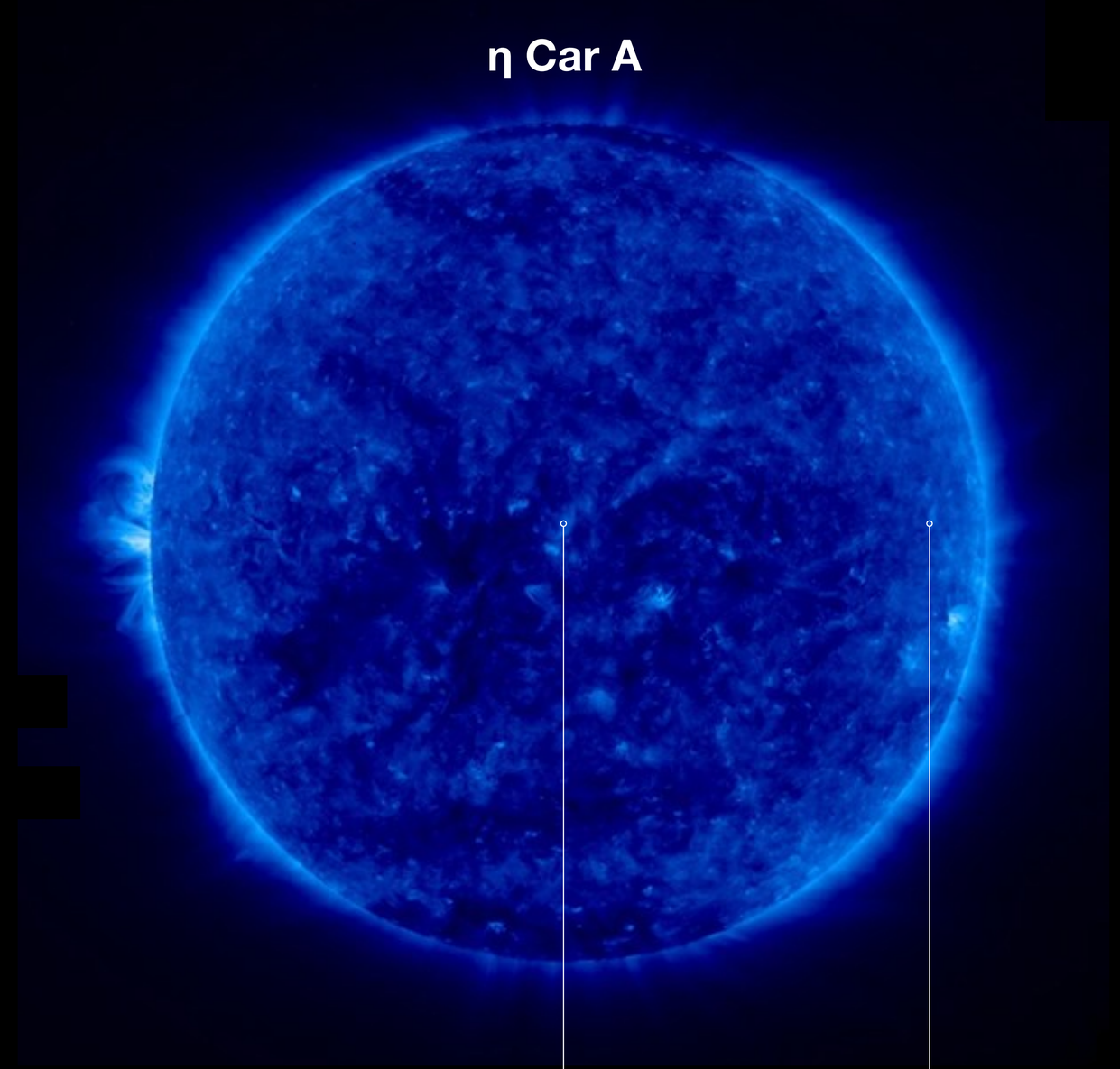


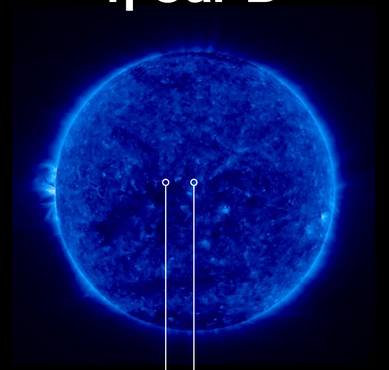

30°
0°
330°
60,000 ly
Scutum-Centaurus Arm
45,000 ly
60°
300°
Sagittarius Arm
Far 3kpc Arm
Galactic Bar
Norma Arm
Near 3kpc Arm
Long Bar
90°
270°
Outer Arm
Perseus Arm
Sun
Orion Spur
15,000 ly
240°
150°
180°
210°


0.1°
WR 22
CTA
PSF@1TeV


Trumpler 16
η Carinae
Hertzsprung
Russell
SUPERGIANTS
GIANTS
Sun
WHITE
DWARFS
L
T
Trumpler 14

η Carinae vs. Solar system





Sun

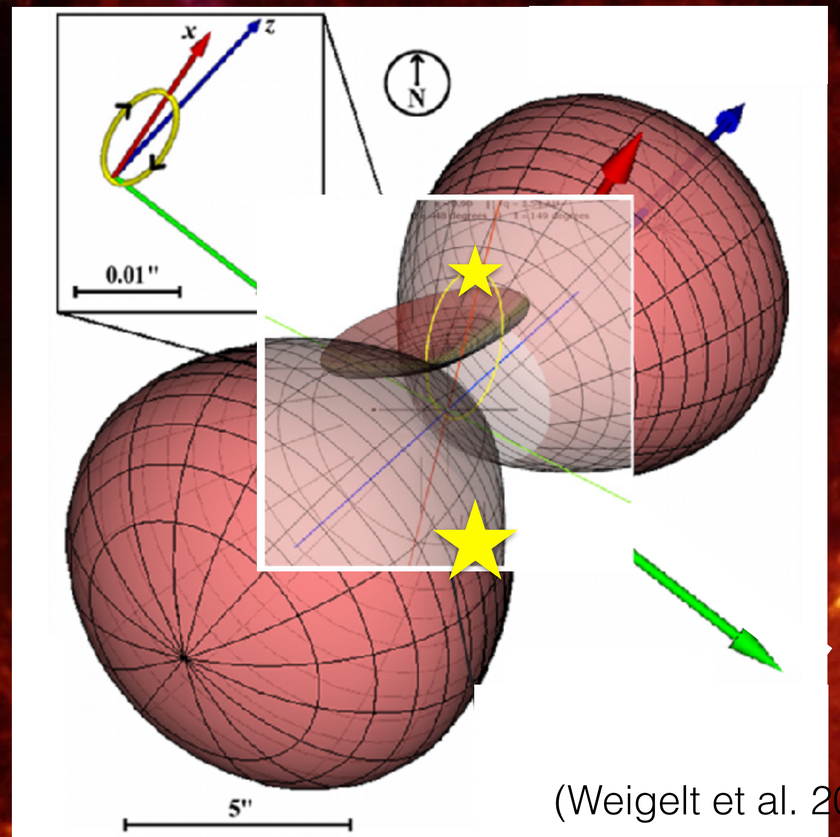
Mercury

Venus

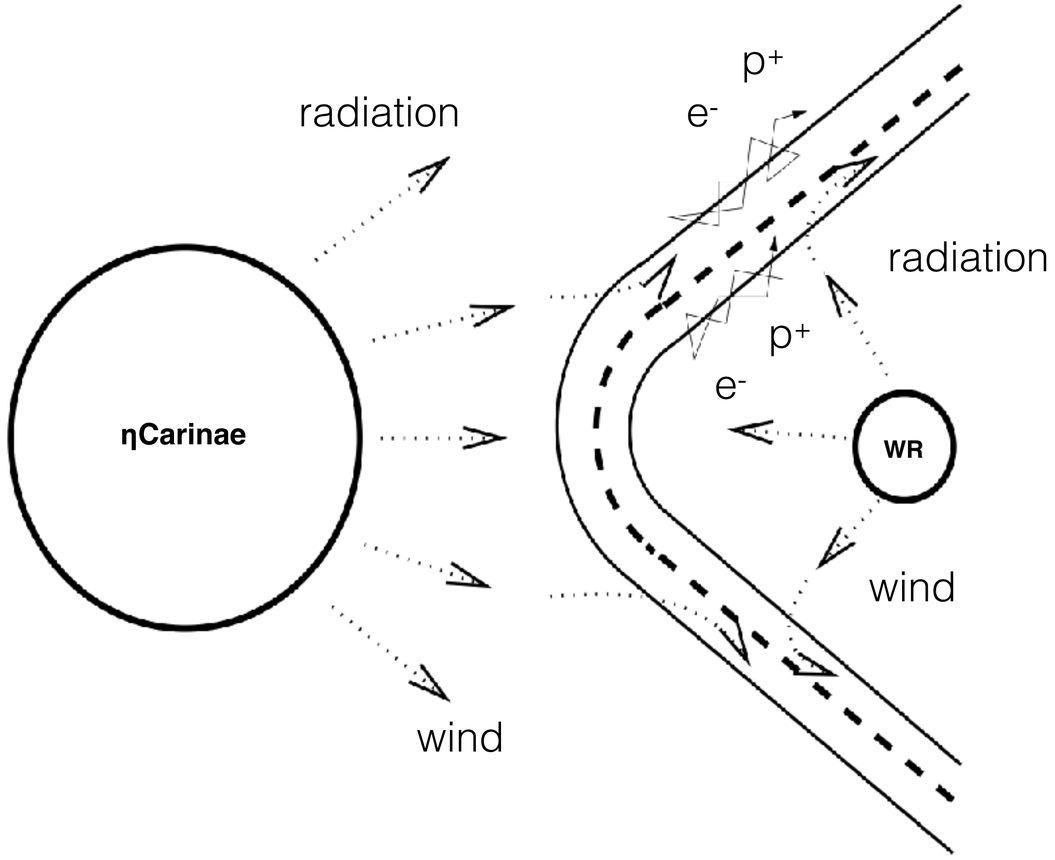
Earth

Mars

Who is η Carinae?



(Weigelt et al. 2016)

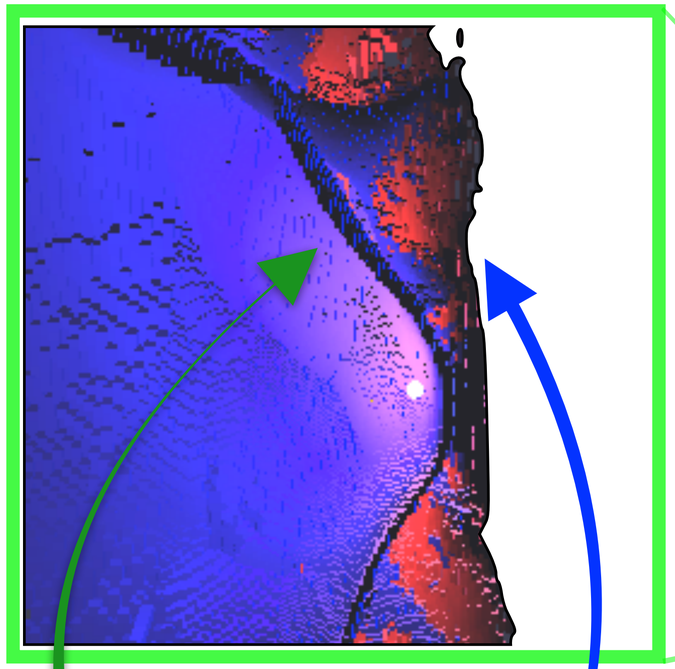


$$\eta = \frac{\dot{M}_{OB} V_{OB}^{\infty}}{\dot{M}_{WR} V_{WR}^{\infty}}$$

$$r_{WR} = \frac{1}{1+\sqrt{\eta}} D \qquad r_{OB} = \frac{\sqrt{\eta}}{1+\sqrt{\eta}} D$$

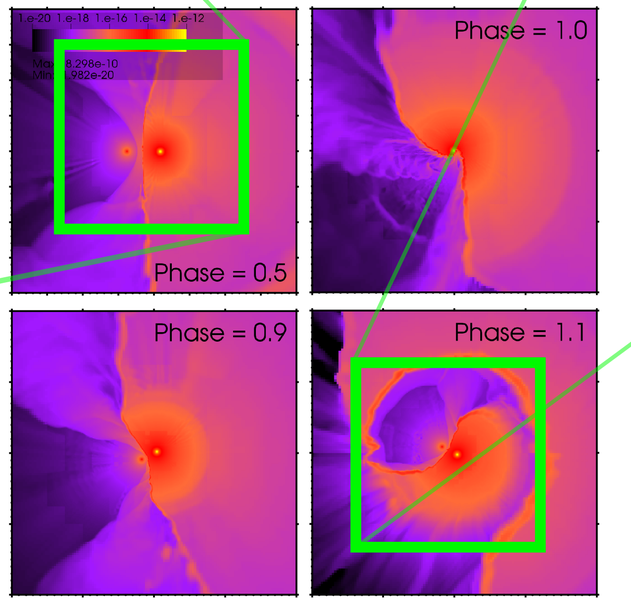
3D hydro simulations

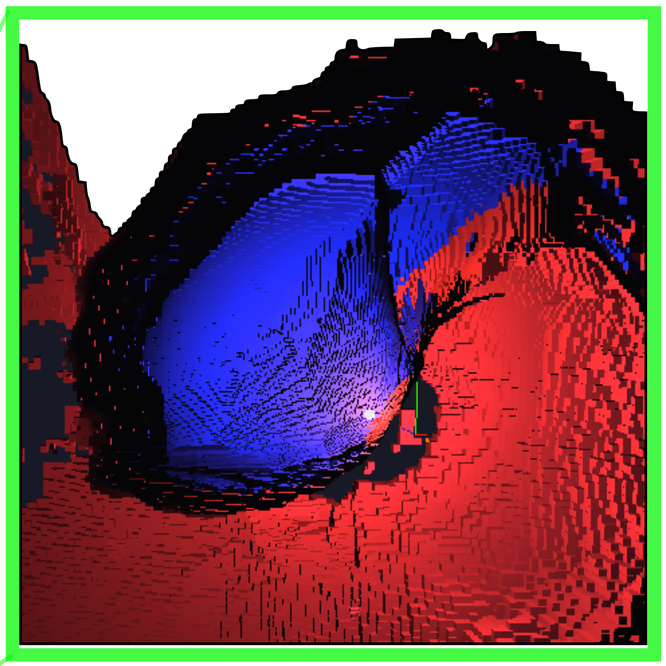
APASTRON



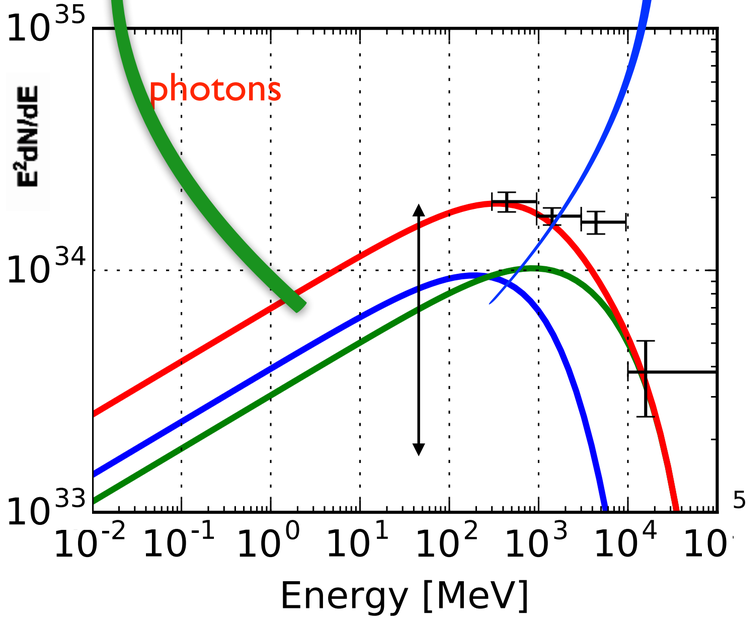
Parameter	Primary	Secondary
M ($M_\odot$)	120	30
R_* ($R_\odot$)	100	20
T_{cs} (K)	25,800	30,000
L_* ($10^6 L_\odot$)	4	0.3
k	0.30	0.50
α	0.52	0.68
$\dot{M}$ ($M_\odot\,yr^{-1}$)	4.8×10^{-4}	1.4×10^{-5}
v_∞ ($km\,s^{-1}$)	500	3000
B (G)	500	

(Parkin et al, 2011)





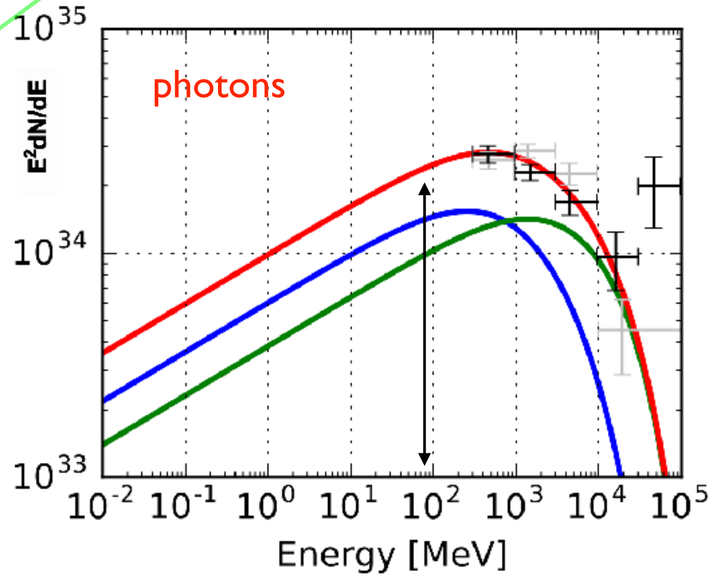
PERIASTRON



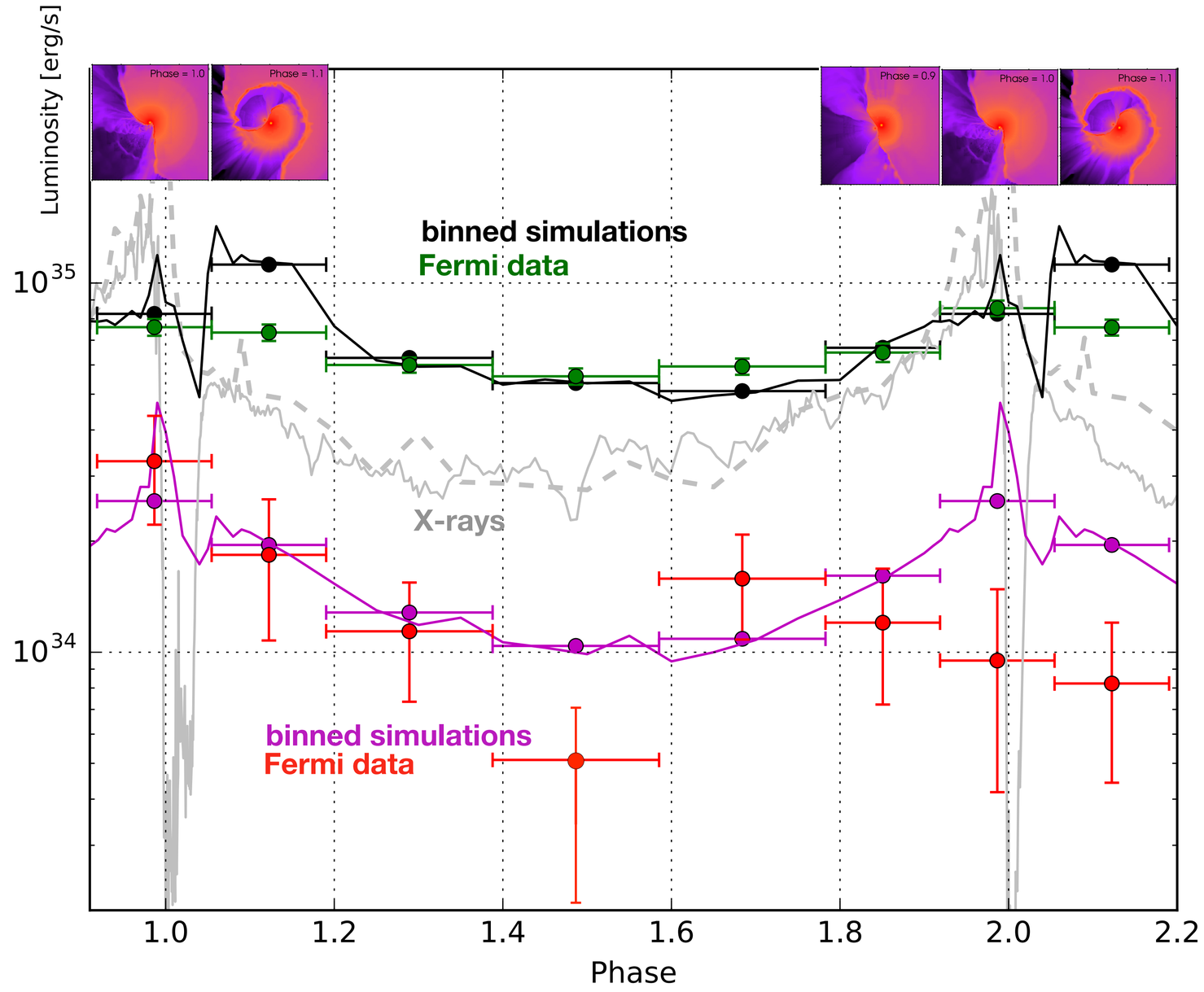
e⁻ spectrum

smooth IC spectrum

(MB and R. Walter, 2017 A&A)



η Carinae γ-ray light curve



0.3 - 10 GeV

10 - 300 GeV

L(therm)~ρ²

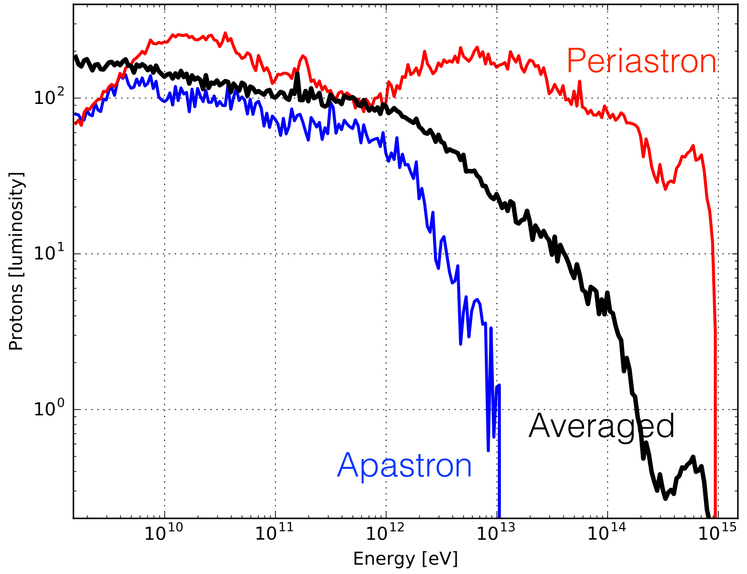
L(IC)~ρ
i.e. electrons

L(π₀)~ρ²
i.e. hadrons

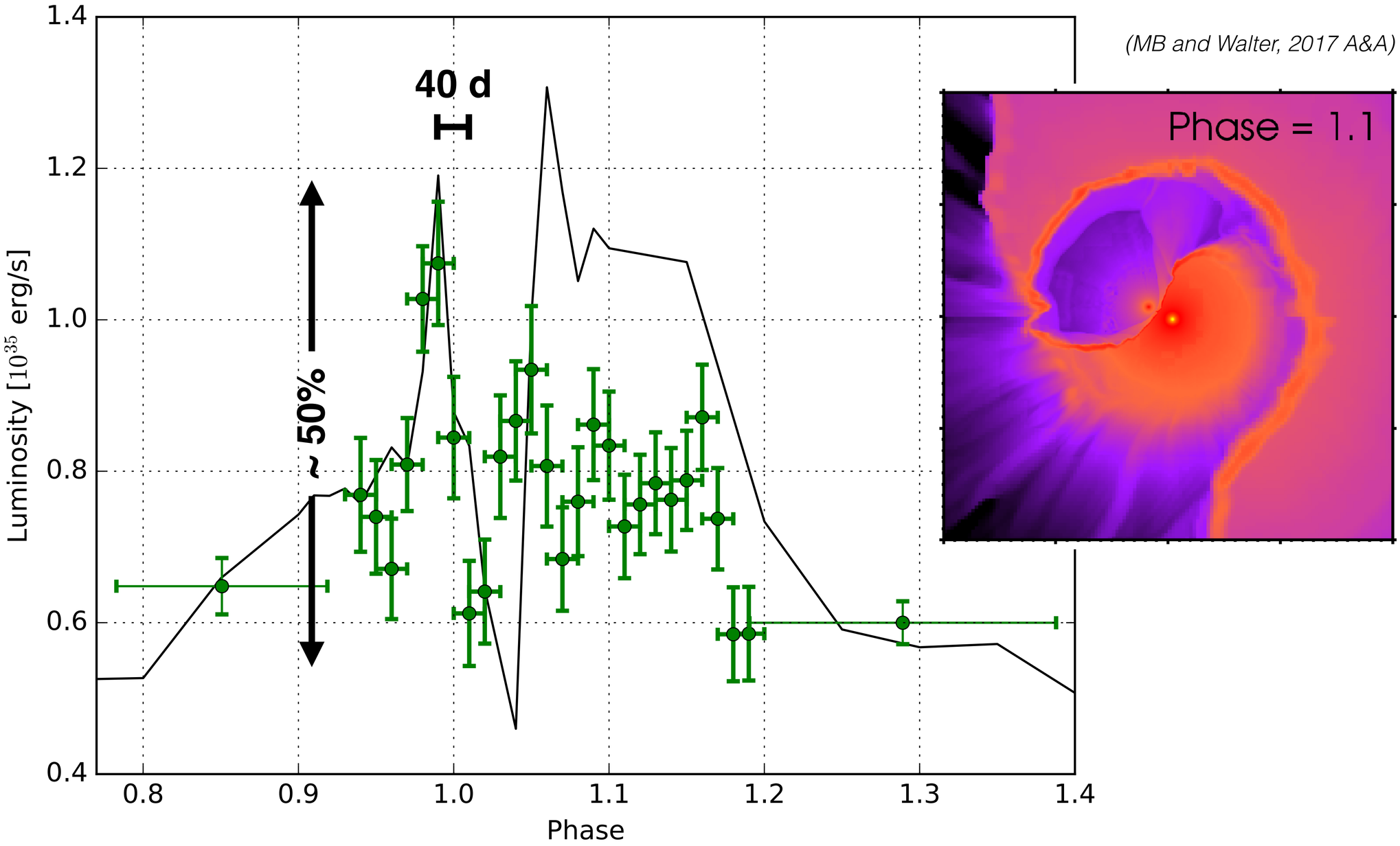
(MB and Walter, 2017 A&A)

$$\gamma_{\max,\mathrm{e}} \approx \sqrt{\frac{B_{1\mathrm{G}} R^2_{10^{14}\,\mathrm{cm}}}{L_{5\times10^6\,L_\odot}}} V_{10^3\,\mathrm{km\,s^{-1}}} \times 3 \times 10^4$$

$$\gamma_{max,p} = \frac{4\pi R^2 e B V^3}{\sigma_{pp}\delta \dot{M} c^3} \propto \frac{1}{R}$$

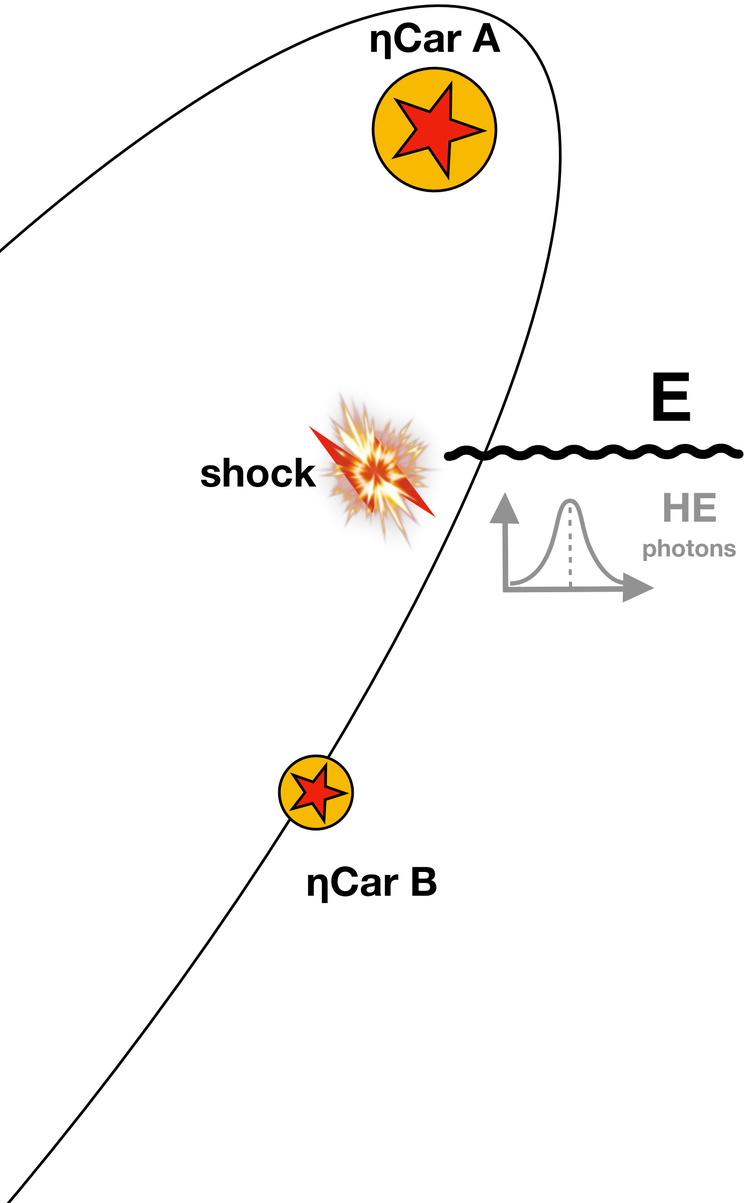


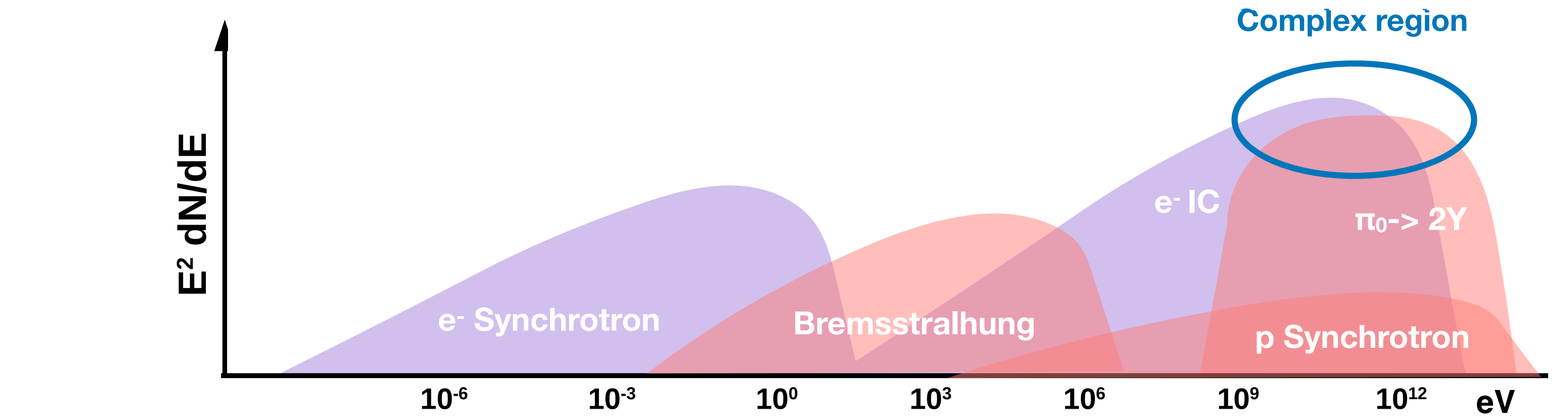
Low Energy light curve



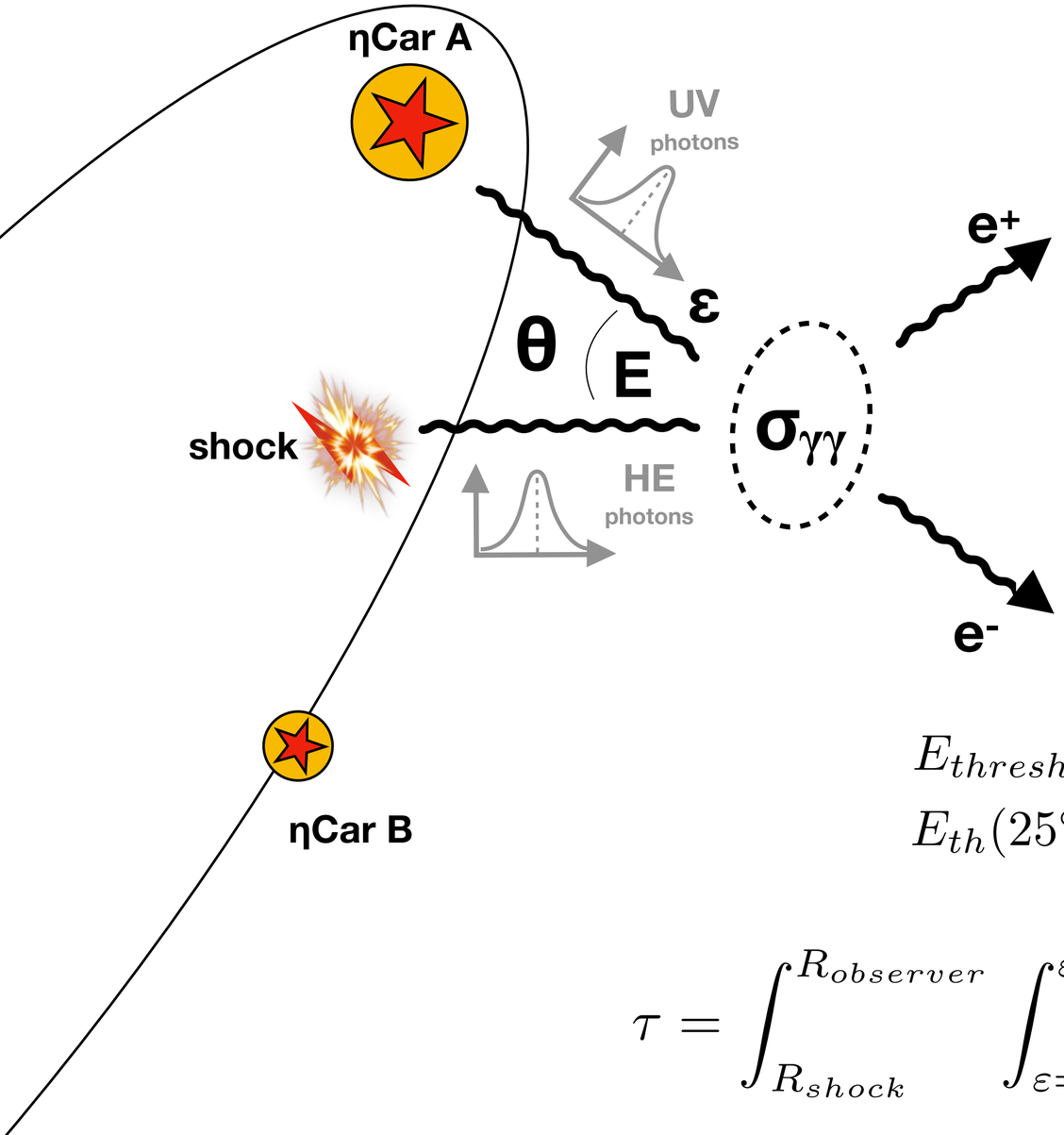
(MB and Walter, 2017 A&A)

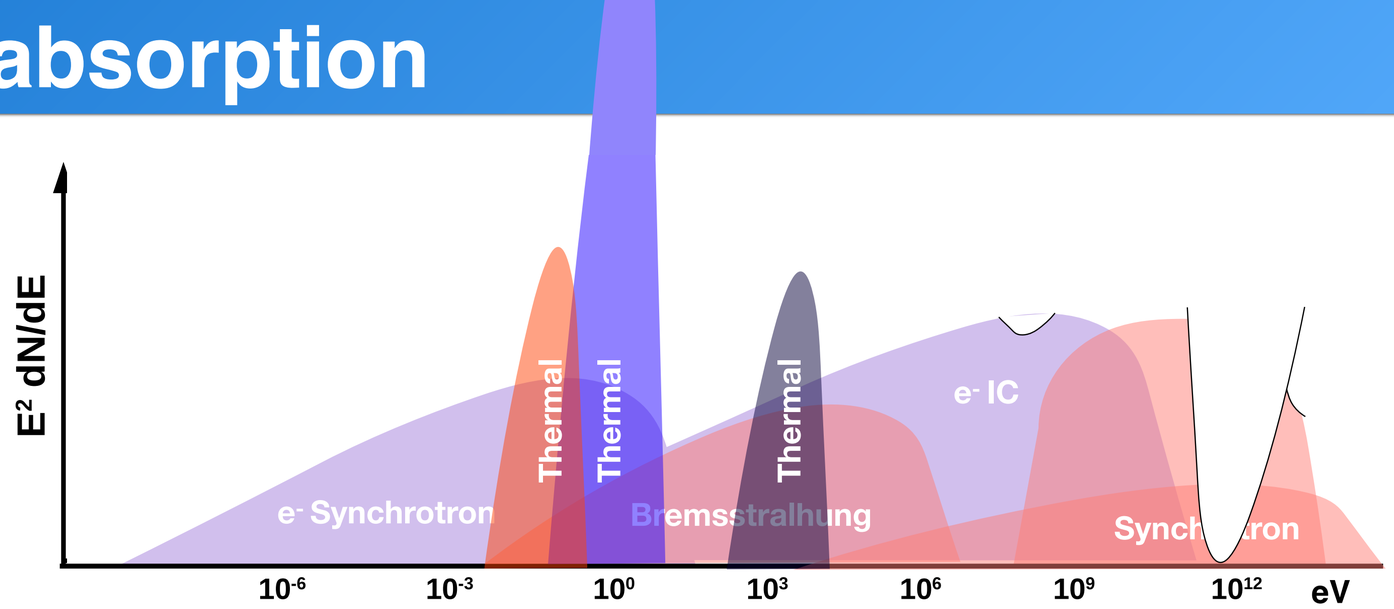
γ-γ absorption

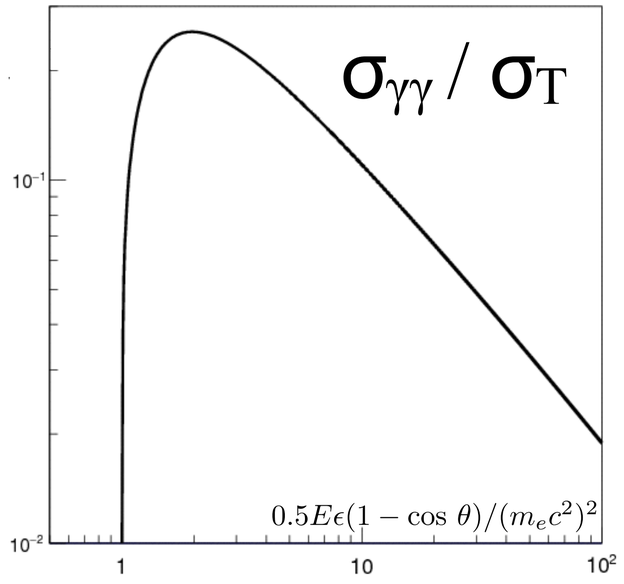




γ-γ absorption







$$E_{threshold} = 0.52/\epsilon_{\rm eV}(1-\cos\theta)\ {\rm TeV}$$

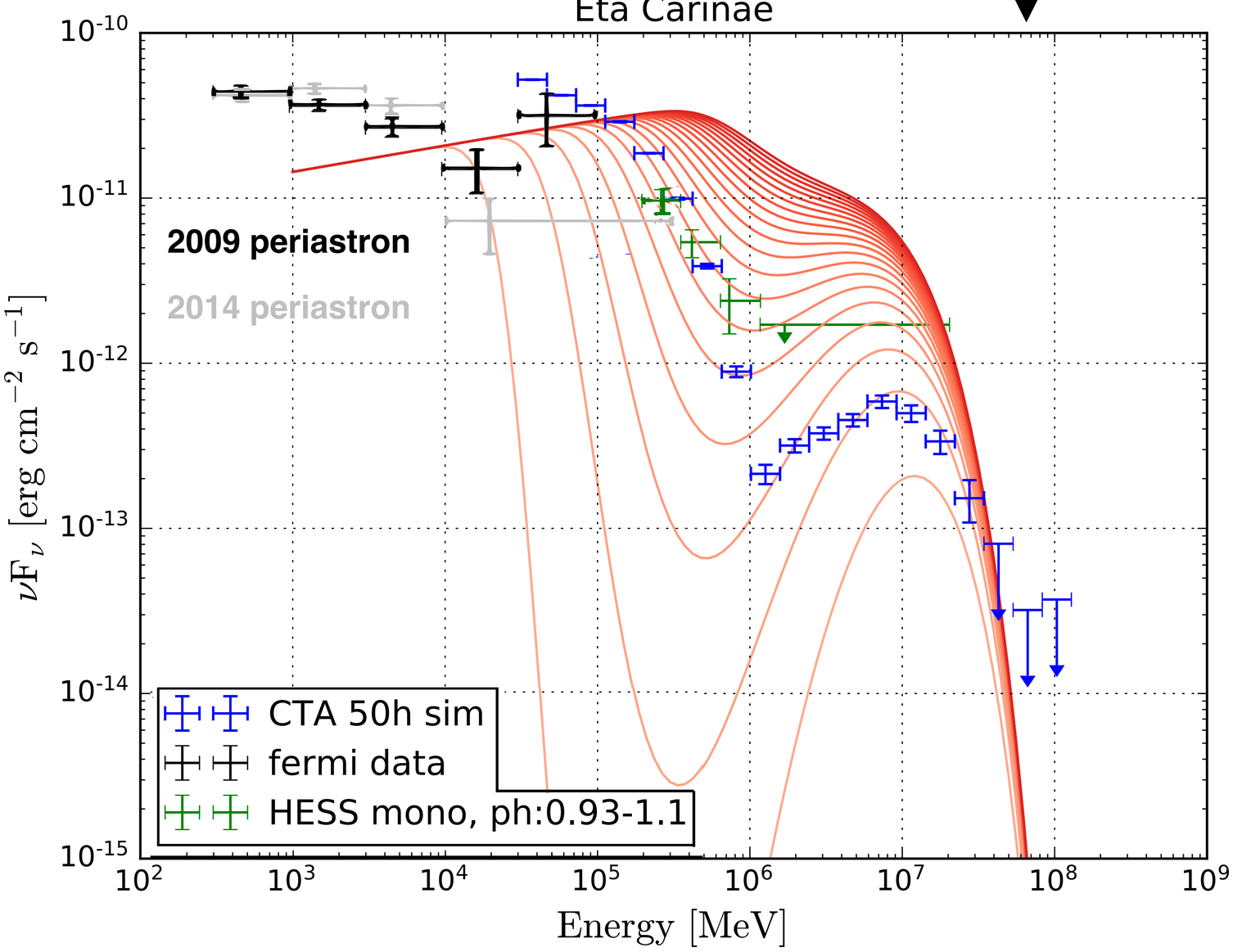
$$E_{th}(25^\circ) \sim 10 \times E_{th}({\rm head-on})$$

$$\tau = \int_{R_{shock}}^{R_{observer}} \int_{\varepsilon=0}^{\varepsilon=\infty} \int_{E=0}^{E=\infty} n(\varepsilon)\sigma_{\gamma\gamma}(\varepsilon E,\theta)\, dR\, d\varepsilon\, dE$$

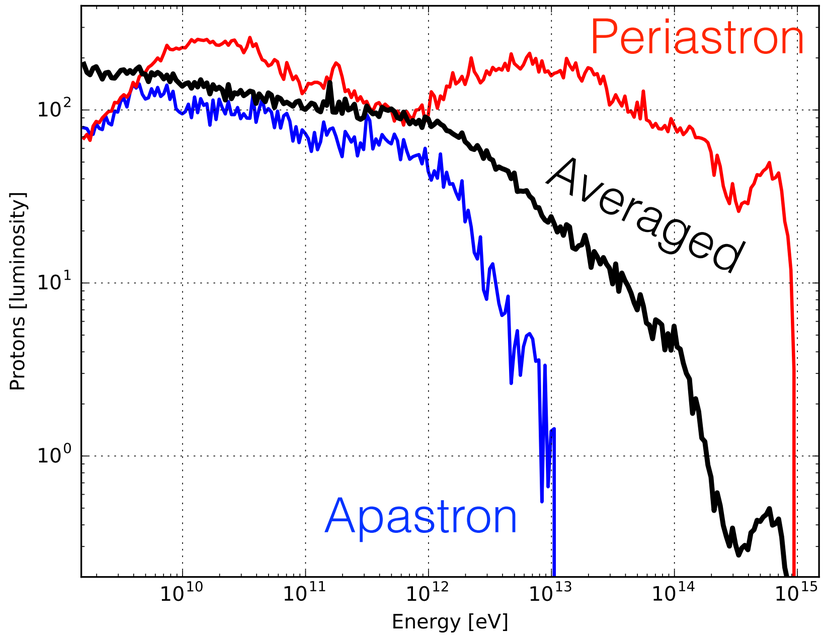
γ-γ absorption

(MB and Walter, in preparation)

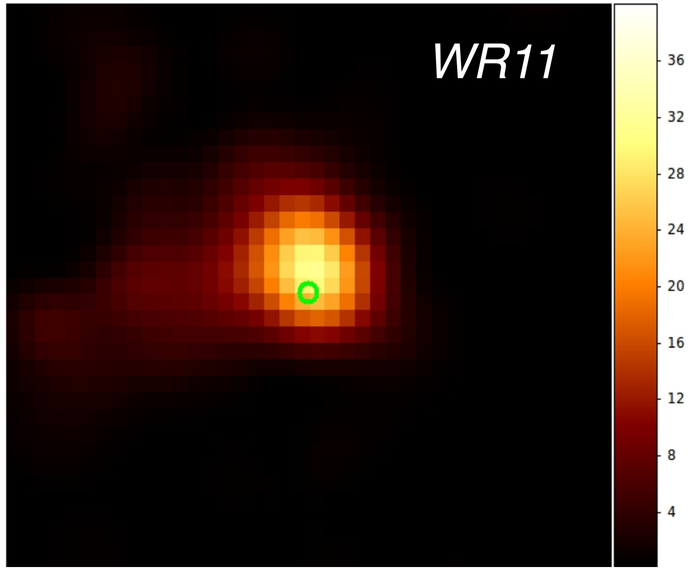
absorption peak energies varies with orbital phases

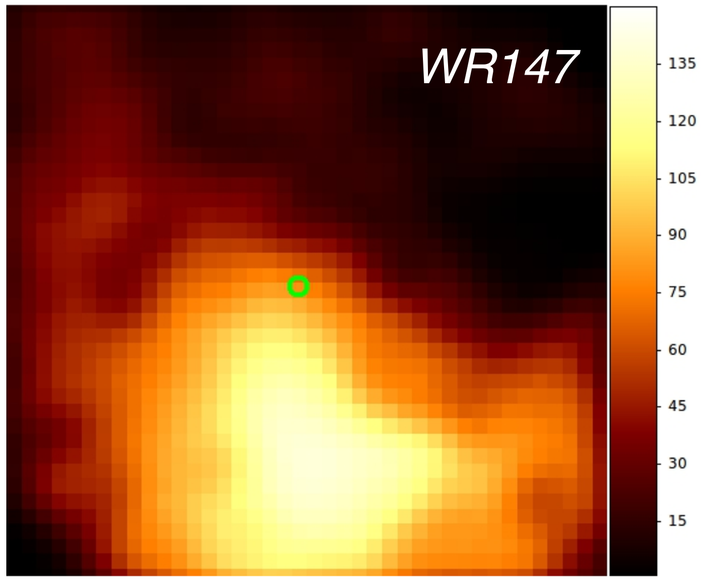


the **γ-UV** obscuration is a convolution of **UV spectrum** with spatial dependent **HE γ-ray** one, **cross section**, and geometrical **orientation**



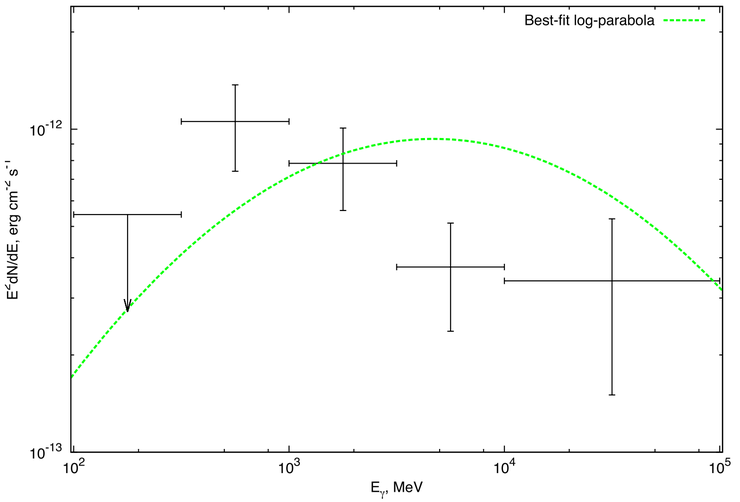
η Carinae is unique… but not alone





(Pshirkov, 2016)

Name	$l(^\circ)$	$b(^\circ)$	Distance (kpc)	TS
WR 11	262.80	−07.69	0.34	37.7
WR 70	322.34	−1.81	1.9	1.2
WR 125	54.44	+1.06	3.1	41.0
WR 137	74.33	+1.10	2.4	23.3
WR 140	80.93	+4.18	1.7	0.1
WR 146	80.56	+0.44	1.2	15.0
WR 147	79.85	−0.31	0.65	54.9

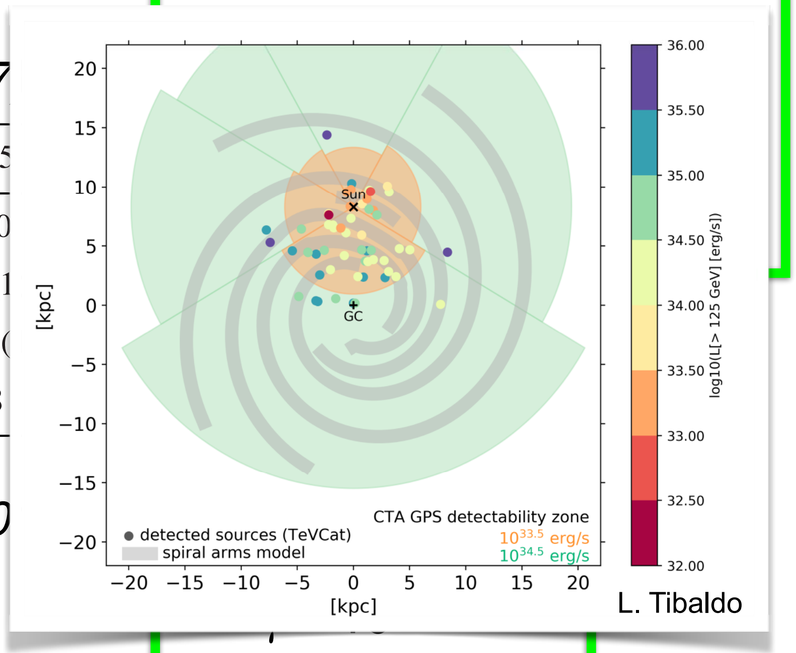


(De Marco et al., 1999) *(North at al., 2007*

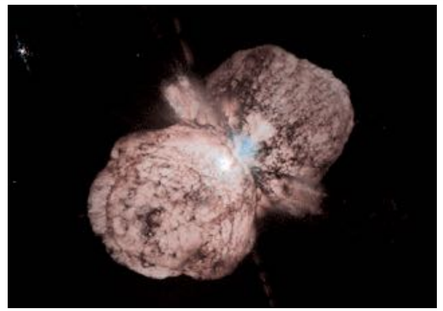
Parameter	Unit	WC8	O7.5
Mass, M	$M_\odot$	9.0	29.0
Mass-loss rate, $\dot{M}$	$10^{-7}\,M_\odot\,yr^{-1}$	80	1.8 (1
Terminal wind velocity, v^∞	$km\,s^{-1}$	1450	2500 (
Luminosity, L	$10^5\,L_\odot$	1.7	2.8

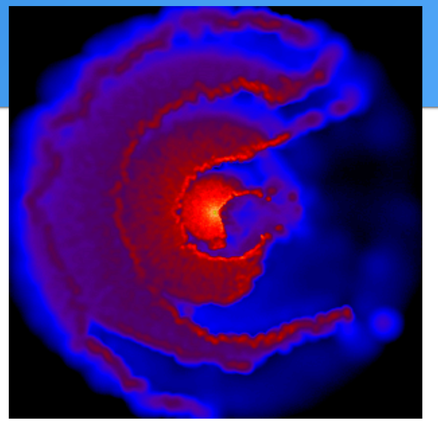
$$\eta = \frac{\dot{M}_O v_O^\infty}{\dot{M}_{WR} v_{WR}^\infty} = 0.04$$ *(De Becker & Raucq, 20*

$$L_{cwz} = \eta L_w = 2.3 \times 10^{35} ergs^{-1}$$



Energetics & Conclusion





- Thermal X-rays: 25 $L_\odot$
- Synchrotron: < 0.1 $L_\odot$
- Electron acceleration: 50 $L_\odot$
- π_0 emission: 10 $L_\odot$
- neutrino: ~ 10^{-9} GeV s^{-1} cm^{-2} (> 10 TeV)

Electrons: (γ~10^4)

- Max e^- energy match the expectation
- e^- spectral index ~ 2.25
- IC emission is unlikely at TeVs

Hadrons: (γ~10^3 ; γ~10^6 @ peri ?)

- $\pi \rightarrow \gamma$ emission matches amplitude variability
- cutoff energy ≥10^{13} eV (> middle aged SNR)
- Efficiency of particle acceleration ~1% (Spitkovsky's sim: 10%)
- Peri 2009 ≠ peri 2014 (system changed? instabilities?)

Variability is essential to deconvolve spectral energy distributions (spectral analysis @ different orbital-phases)

Few zones models
are too simplistic

Zillion-cells model necessary
(MHD, Fermi acceleration, photon propagation, …)

CTA will probe:

η Carinae could accelerate as much cosmic-rays as an average SNR

η Carinae could accelerate positrons at the same energy of the one observed by PAMELA

- **hadronic acceleration**
- **$\gamma\gamma$ absorption**
- **τ variation along the orbit**