Time-dependent modelling of the non-thermal emission in Eta Carinae

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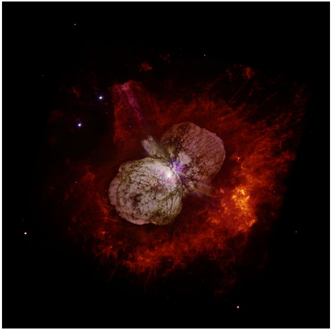
Variable Galactic Gamma-ray Sources
Heidelberg 4–6 May 2015

- Distance 2.3 kpc
- Period 5.54 yr
- Last periastron: May 2014
- Eccentricity: $e \simeq 0.9$
- Semimajor axis: 16.16 AU
- Separation at periastron: 1.66 AU

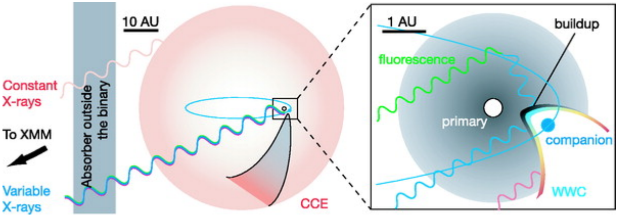


Primary star

- Luminous Blue Variable (LBV)
- $M \sim 120 M_\odot$
- $\dot{M} \sim 5 \times 10^{-4} M_\odot/\mathrm{yr}$
- $v_{w,\infty} = 500 km\, s^{-1}$

Secondary star

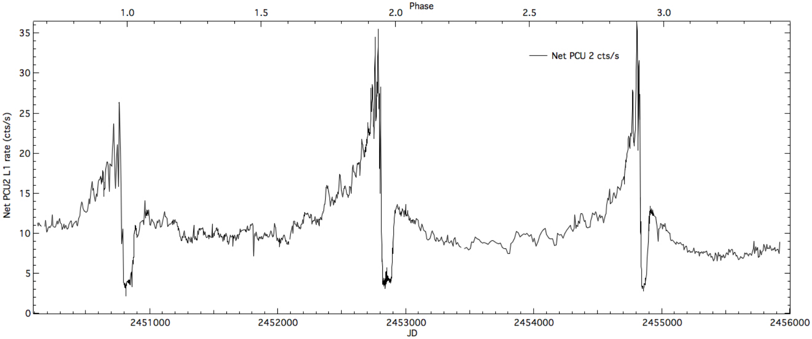
- O or WR
- $M \sim 30 M_\odot$
- $\dot{M} \sim 10^{-5} M_\odot/\mathrm{yr}$
- $v_{w,\infty} = 3000 km\, s^{-1}$



X-ray model

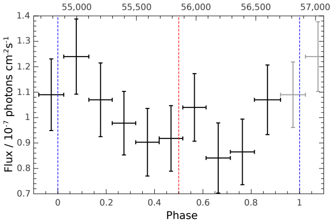
- Hamaguchi et al. 2007:
- A low temperature ($T \sim 1$ keV) steady emitter enveloping the binary (CCE)
- Hot ($T \sim 4$ keV), variable emission from the wind-wind collision region (WWCR)

RXTE PCU lightcurve

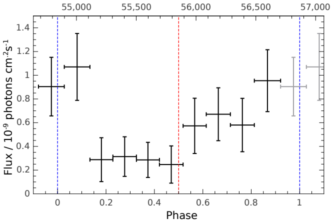


The GeV view of Eta Carinae: Flux variability

- Recent results from Reitberger et al. (2015)
- Slow decrease in flux after periastron
- No evidence for wind collision region collapse!



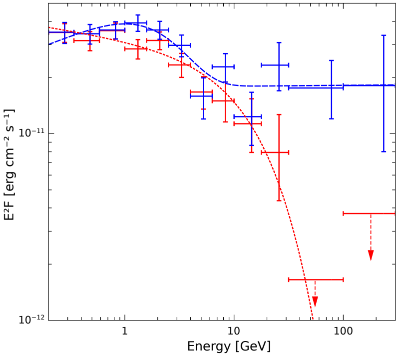
0.2 to 10 GeV



10 to 300 GeV

Two spectral components:

- 1 GeV< E <10 GeV: Power law with a cutoff at
  - periastron: $E_c = 1.6 \pm 1$ GeV
  - apastron: $E_c = 17 \pm 6$ GeV
- $E > 10$ GeV: Hard powerlaw with $\Gamma = 2.0 \pm 0.1$ during periastron.



Periastron Apastron

Proposed scenarios for GeV phenomenology

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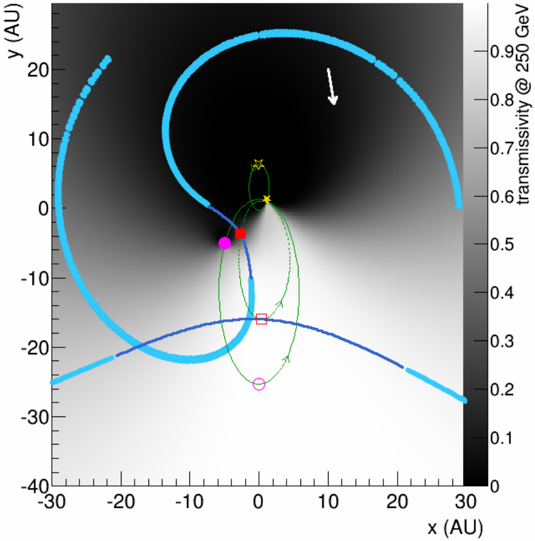
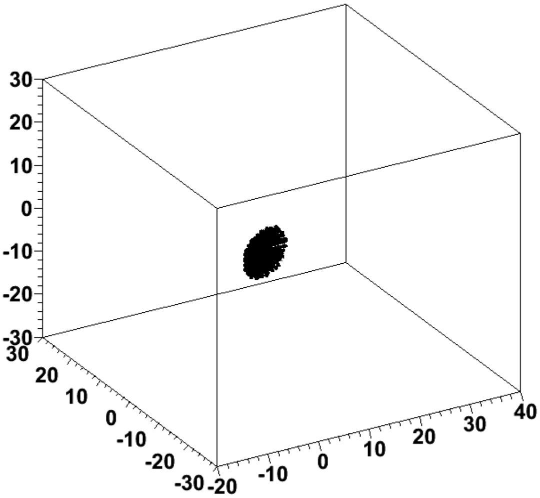
  - Acceleration of electrons to few tens of GeV requires super Bohm acceleration around periastron
  - No time dependence or particle distribution evolution considered

A time dependent particle acceleration, evolution and radiation model of η Car

Ohm, S., Zabalza, V., Hinton, J.A. & Parkin, E.R., 2015,
On the origin of γ-ray emission in η Carina
MNRAS, 449, L132 arXiv:1502.04056

- Analytical description based on Parkin & Pittard (2008).
- 82x100 Bins are followed as they move outwards on the shock cap and then shoot out ballistically.




30
20
10
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-30
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10
20
30
40

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$$\chi = \frac{t_{\rm cool}}{t_{\rm esc}} \simeq \frac{v_3^4 d_{12}}{\dot{M}_7}$$

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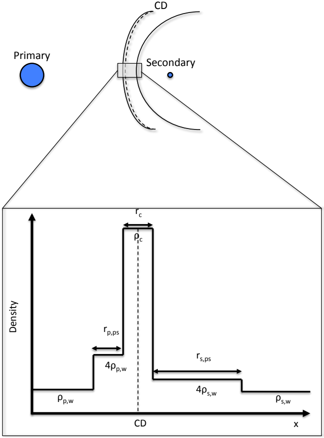
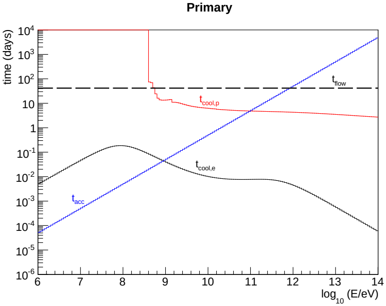


$\varphi = 0.05$



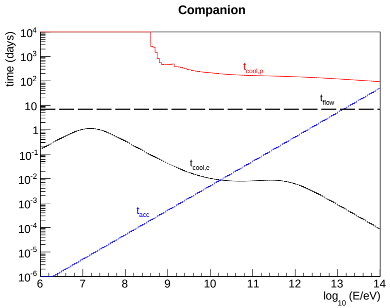
$t_{cool,p}$, $t_{cool,e}$, t_{acc}

t_{flow}: – – –

For each time step and shock cap bin:

- Compute steady state spectrum from pp or Sync+IC+Bremss losses for protons and electrons, respectively, assuming $\eta_{acc} = 10$.
- $E^{p}_{max} \approx 100$ GeV

$\varphi = 0.05$



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t_{flow}: – – –

- The secondary post-shock density is low enough that protons do not interact during their flow along the shock cap → not a steady state.
- Maximum energy is set by the total time the particles remain in the shock before they flow away.

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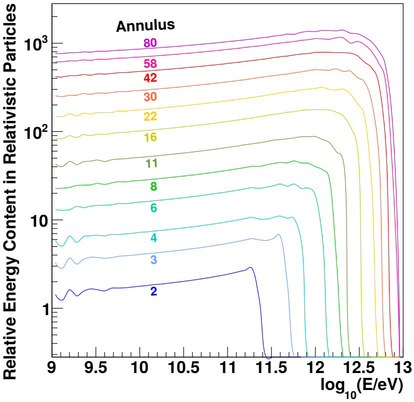
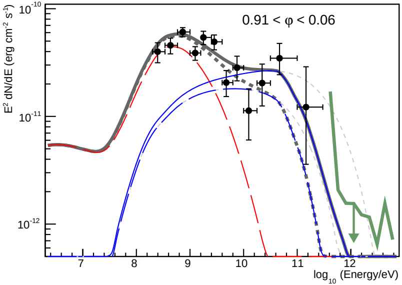
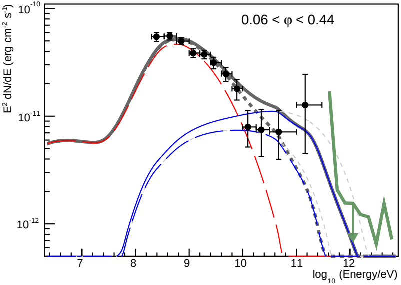
- When a given bin reaches the edge of the shock cap, the two shock layers mix within 10^{11} cm and radiate.

Acceleration: CR Shock modification

- In the outer part of the shock-cap, ram pressure is low, and cosmic ray pressure at the shock is high.
- We apply nonlinear modification to acceleration scheme following Berezhko & Ellison (1999).

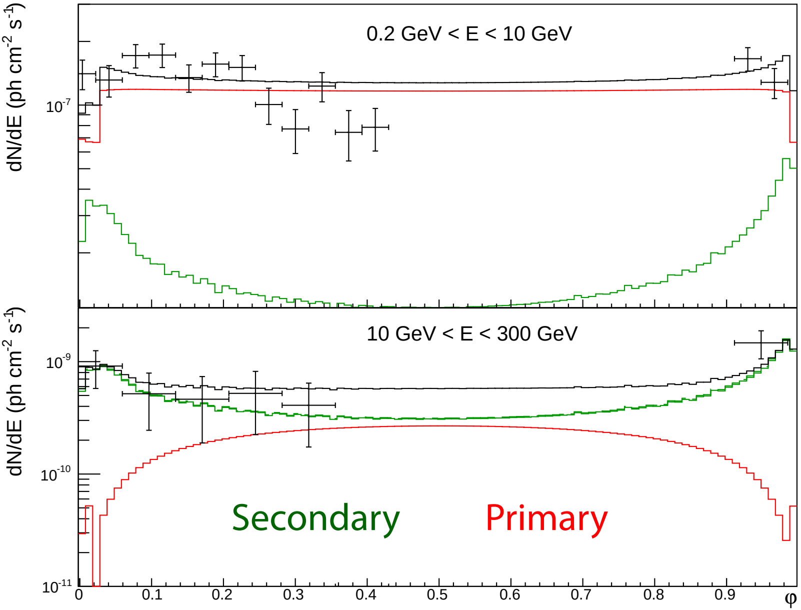






10 months around periastron

5 to 28 months after periastron


0.2 GeV < E < 10 GeV
dN/dE (ph cm-2 s-1)
10-7
10 GeV < E < 300 GeV
10-9
10-10
10-11
Secondary
Primary
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
φ

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- Where are all the other gamma-ray emitting wind colliding binaries?
- Looking forward to the observational results during the 2014 May periastron: NuSTAR, Fermi, HESS-II.

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