Hard X-ray emission from Eta Carinae

Jean-Christophe Leyder
Institut d’Astrophysique et de Géophysique de Liège

Roland Walter (ISDC) & Gregor Rauw (IAGL)
Outline

- High-energy emission from colliding-wind binaries
- A few words on Eta Carinae
- INTEGRAL observations of Eta Carinae
- Future prospects
Hard X-ray and γ-ray emission from colliding-wind binaries

- Colliding-wind binaries
  - Hydrodynamical shock
  - Acceleration of particles
  - Relativistic electrons

- Early-type stars
  - Huge UV radiation field

- Inverse Compton scattering
  - Hard X-rays and soft gamma-rays

Bell 1978, Pittard & Dougherty 2006
Known for its eruption in 1843 (Viotti 1995), Eta Carinae has a mass-loss rate of $10^{-3} - 10^{-4} M_\odot/\text{year}$. Optical, infrared, and X-ray observations have been conducted by Damineli et al. (2000), Whitelock et al. (2004), and Corcoran (2005), respectively. The nebula is shown in this image from NASA, ESA, UCB, STScI/AURA 2007.
Eta Carinae

• Known for its eruption in 1843 (Viotti 1995)
• Mass-loss rate of $10^{-3} - 10^{-4} \, M_\oplus/\text{year}$
• Period of 5.5 years in:
  □ optical observations (Damineli et al. 2000)
  □ infrared observations (Whitelock et al. 2004)
  □ X-ray observations (Corcoran 2005)
Eta Carinae

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**Fig. 1.**

*PCU2 L1 net counts
Colliding wind lightcurve (Pittard et al. 1998)*

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<table>
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<tr>
<th>Orbital Phase</th>
<th>Net PCU2 L1 counts s⁻¹</th>
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<td>2.0</td>
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<td>2.5</td>
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*Corcoran et al. 2001a.* The lightcurve (Fig. 1) contains re-...

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*Pittard & Corcoran 2005*
Eta Carinae as a colliding-wind binary

- Binary system made of:
  - a Luminous Blue Variable
  - a less extreme (O or WR) star (Iping et al. 2005)

- High eccentricity (0.9) (Corcoran et al. 2001)

- X-ray spectrum $\Rightarrow$ Colliding-wind binary (Corcoran 2005)
BeppoSAX observations

4 observations with PDS (Viotti et al. 2004):

- High-energy excess (13-20 keV) at $\Phi = 0.83, 1.37, 1.46$

- No excess at $\Phi = 1.05$
  
  ... but this needs confirmation...

- High-energy tail up to 50 keV (June 2000)
INTEGRAL observations:

- 1131 pointings, i.e. 3.3 Ms
  Effective exposure time of 1.1 Ms
- 3 sources in the PDS field
  - Eta Carinae (22-100 keV): significance = 7.3
    luminosity = 7E33 erg/s
  - Anomalous X-ray Pulsar 1E 1048.1-5937
  - IGR J10447-6027

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INTEGRAL observations: spectrum

- Up to 100 keV
- \texttt{wabs*mekal} \ (kT = 5.1 \text{ keV}, \text{NH} = 4.3\text{E22})
- \texttt{powerlaw} \Rightarrow \text{photon index of} \ 1 \pm 0.4
INTEGRAL observations:

- Spectrum up to 100 keV
- $wabs \times mekal$ ($kT = 5.1$ keV, $NH = 4.3E22$)
- Powerlaw: photon index $\gamma = 1 \pm 0.4$

BeppoSAX

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- $wabs \times mekal$ ($kT = 5.1$ keV, $NH = 4.3E22$)
- Powerlaw $\Rightarrow$ photon index $\gamma = 1 \pm 0.4$
INTEGRAL observations: mechanism

- High-energy non-thermal emission from a colliding-wind binary

- Inverse Compton scattering of UV or optical photons by high-energy electrons accelerated in the collision zone \(\text{(Benaglia & Romero 2003)}\)

- Total power in stellar wind interactions

\[
L = \frac{1}{2} \dot{\Theta} M \nu^2
\]

\[
L_1 + L_2 \simeq 10^{37} \text{erg/s}
\]

\(\text{(Pittard & Stevens 2002)}\)
INTEGRAL observations: variability?

- 3 major periods of observations:
  - $\Phi = 1.99-2.01; 122$ ks; significance = $---$
  - $\Phi = 2.16-2.19; 717$ ks; significance = $6.2$
  - $\Phi = 2.35-2.37; 180$ ks; significance = $3.3$

- X-ray lightcurve
INTEGRAL observations:

Colliding-wind binary

⇒ Increase in column density
⇒ Decrease in plasma emission measure
Future prospects

- Systematic search for:
  - Wolf-Rayet stars
  - non-thermal radio emitting early-type stars
  - O-type stars (magnitude $V < 8$)
- Variability?