A giant radio flare from Cygnus X-3 with associated gamma-ray emission

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+
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Gamma-ray binaries

- 5 gamma-ray binaries known, emit most of their power above 100 MeV
- Massive star + compact object
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See talks of:
- Richard Dubois “Long Term Fermi LAT Observations of LS I+61 303 and LS 5039”
- Robin Corbet “Periodic Emission from The Gamma-ray Binary 1FGL J1018.6-5856”
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• Question: Where are the particles accelerated to VHE?
  - Shocked pulsar wind (PSR B1259-63)
  - Jet
Microquasars

• Produce relativistic jets
• Long time candidates for gamma-ray sources
• Cyg X-1 detected in VHE gamma-rays by MAGIC (Albert et al. 2007)
• No VHE gamma-ray emission from GRS 1915-105 (HESS Coll. 2009)
• Cyg X-3 detected by Fermi-LAT and Agile
Microquasars

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• Question: What makes Cyg X-3 special?
Cygnus X-3

- It has a powerful jet
- One of the brightest binaries in radio
- High mass companion (WR star)
- Short orbital period 4.8 hr
- Gamma-rays orbitally modulated
- Gamma-rays produced during jet ejection, but when exactly and where?
Cygnus X-3

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7-12 Jan 2012, 219th AAS, Texas, Anna Szostek
Multi-wavelength monitoring
21 September, 2010 - 8 June 2011

Cygnus X-3

X-ray
15-50 keV
3-5 keV

gamma-ray
>100 MeV

radio
11 & 15 GHz
Multi-wavelength monitoring
21 September, 2010 - 8 June 2011

Cygnus X-3

X-ray 15-50 keV
X-ray 3-5 keV
Gamma-ray >100 MeV
Radio 11 & 15 GHz

quenched state
Multi-wavelength monitoring
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Cygnus X-3
X-ray 15-50 keV
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major radio flare

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Cygnus X-3

- **X-ray**
  - 15-50 keV
  - 3-5 keV

- **Gamma-ray**
  - >100 MeV

- **Radio**
  - 11 & 15 GHz
Gamma-ray activity in period 1

X-ray
15-50 keV

gamma-ray
>100 MeV

radio
11 & 15 GHz
Gamma-ray activity in period 1

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Cygnus X-3
Gamma-ray activity in period 1

X-ray
15-50 keV
0.02 cts/cm²/s

Gamma-ray
>100 MeV

Radio
11 & 15 GHz

Cygnus X-3
Gamma-ray activity in period 1

X-ray
15-50 keV
0.02 cts/cm²/s

gamma-ray
>100 MeV
0.3 Jy

radio
11 & 15 GHz

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Cygnus X-3
Relation between flare onset and gamma-ray trigger in period 2

gamma-ray >100 MeV

delayed radio 11 & 15 GHz
X-ray hardness ratio & RXTE spectra (arrows)
Relation between flare onset and gamma-ray trigger in period 2

gamma-ray >100 MeV

radio
11 & 15 GHz

X-ray
hardness ratio & RXTE spectra (arrows)
Relation between flare onset and gamma-ray trigger in period 2

Gamma-rays before flare peak

Flare peak

Gamma-rays >100 MeV

radio
11 & 15 GHz

X-ray hardness ratio & RXTE spectra (arrows)
Relation between flare onset and gamma-ray trigger in period 2

Gamma-rays before flare peak

Flare peak

Onset of the flare here?

gamma-ray >100 MeV

radio 11 & 15 GHz

X-ray hardness ratio & RXTE spectra (arrows)
Relation between flare onset and gamma-ray trigger in period 2

Gamma-rays before flare peak

Flare peak

Onset of the flare here?

Non-thermal component in spectrum

gamma-ray >100 MeV

- AMI
- OVRO
- RATAN (11 GHz)

- Energy (keV)
- Flux Density (Jy)
- LAT Flux

- Onset of flare here?
- Non-thermal component in spectrum

- MJD 55639.0
- MJD 55641.0
- MJD 55642.0
- MJD 55643.0
- MJD 55646.0
- MJD 55649.8

- \( E_{\gamma} \) (keV cm\(^{-2}\) s\(^{-1}\))
Relation between flare onset and gamma-ray trigger in period 2

Is gamma-ray trigger before or after onset of the flare?

Gamma-rays before flare peak

Flare peak

Onset of the flare here?

Non-thermal component in spectrum

gamma-ray >100 MeV

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Relation between flare onset and gamma-ray trigger in period 2

Is gamma-ray trigger before or after onset of the flare?

Simultaneous rise
radio + non-thermal X-ray + gamma-ray

Gamma-rays
before flare peak

Flare peak

Onset of the flare here?

Non-thermal component in spectrum

gamma-ray
>100 MeV
ISM absorption
Partial absorber
Iron line feature

Hybrid thermal/non-thermal Comptonization model (eqpair, Coppi 1992, 1999)

Extrapolation of spectrum 3 10-50 keV to GeV band, is several orders of magnitude lower than LAT flux.
X-ray spectra (RXTE)

ISM absorption
Partial absorber
Iron line feature
Hybrid thermal/non-thermal Comptonization model (eqpair, Coppi 1992, 1999)
Extrapolation of spectrum 3 10-50 keV to GeV band, is several orders of magnitude lower than LAT flux.

hard X-rays and gamma-rays can NOT be parts of the same powerlaw component
• Soft X-ray state: 3-5 keV at RXTE/ASM above 3 cts/s

• Low level of hard X-ray emission: Swift/BAT below 0.02 cts/cm²/s

• Rapid radio emission from relativistic jet: 15 GHz above 0.2-0.4 Jy. Major flares are not necessary!
Possible scenario

- Shock forms at various distances along the jet (Lindfors et al. 2007; Miller-Jones et al. 2009)

- Transition **IN/OUT** of the ultrasoft X-ray state signal a **decrease/increase** in jet efficiency with non-thermal region moving **CLOSER/FURTHER** from the compact object

- Gamma-ray emission is most efficient at “sweet-spot” bounded by strong pair production on thermal X-rays and declining seed photon density for inverse Compton scattering (Cerutti et al. 2011; Sitarek & Bednarek 2011)

- Detections prior to and after the quenched state when shock moves through this region