The giant radio flares of Cyg X-3: the link with the gamma-ray emission

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In collaboration with:

Cyg X-3: a very peculiar source

* HMXB, probably a black hole wind-fed by a Wolf-Rayet star

* The brightest X-ray binary in radio (relativistic plasma ejection)

* Giant radio flares of 10-20 Jy at the end of the ultra-soft X-ray state/quenched radio state (Koljonen +10)

* First microquasar firmly detected in gamma-rays with AGILE (Tavani +09) and Fermi/LAT (Fermi/LAT collab. +09)
Radio, X-ray and gamma-ray connections

Radio, X-ray and gamma-ray connections

The giant flare of September 2016

- Swift/BAT (15-50 keV)
- ToO Radio observations
- ultra-soft X-ray state (23 days)
- Single-dish giant flare
- VLBI mini-flare
- VLBI end giant flare
The giant flare of September 2016

Swift/BAT (15-50 keV)

ToO Radio observations

ultra-soft X-ray state (23 days)

Single-dish giant flare
SRT and Medicina observations

* Multi-frequency observations at 7.2, 8.5, 18.6, 22.7 and 25.6 GHz

=> Clear spectral index change at the peak of the flare on 5 hrs!

Egron et al. submitted to MNRAS
SRT and Medicina observations

* Multi-frequency observations at 7.2, 8.5, 18.6, 22.7 and 25.6 GHz

=> Evolution from optically thick to optically thin plasmons in expansion moving outward from the core
The giant flare of September 2016

ToO Radio observations

Swift/BAT (15-50 keV)

ultra-soft X-ray state (23 days)

Single-dish giant flare

VLBI mini-flare

VLBI end giant flare
VLBI observations of the mini-flare

* Phases and amplitudes for the different baselines

=> variation of the flux on a few hours at 22 GHz
VLBI observations of the mini-flare

*VLBI light curve obtained on 1 Sept 2016
  => peak of 450 mJy at 22 GHz

* Radius in mas of the emitting component
  => expansion of the region from 0.6 to 0.9

Egron et al.
submitted to MNRAS
VLBI observations of the mini-flare

* Evolution of the size of the emitting component during the 4 first hrs
  => expansion at the velocity 0.06-0.09c assuming d = 7-9 kpc

* Short radio flare close to the core of the source
The giant flare of September 2016

- **Swift/BAT (15-50 keV)**
- **ToO Radio observations**
- **ultra-soft X-ray state (23 days)**
- **VLBI end giant flare**
VLBI obs at the end of the giant flare

* No VLBI detection on 23 Sept at 22 GHz whereas $F = 1.4 \text{ Jy}$

* Source strongly resolved out
  => different jet morphology w.r.t. the mini-flare

* Beam area = 0.88 mas$^2$
  Assuming a two sided ejection, jet extended over 30 mas
  => jet speed $> 0.3c$
Radio and gamma-ray connections

* Mini-flare 2016
  - Radio emission close to the core
  - AGILE detection before the mini radio flare (ATel Piano +16)
    \[ F = (4.0 \pm 1.4) \times 10^{-6} \text{ photons/cm}^2/\text{s} \text{ (on 28-29-30 Aug)} \]

* Giant flare 2016
  - Relativistic jets in expansion
  - Fermi/LAT detection at the onset of the giant flare (ATel Loh +16)
    \[ F = (2.2 \pm 0.4) \text{ then } (2.8 \pm 0.4) \times 10^{-6} \text{ photons cm}^2/\text{s} \text{ (on 15-16 Sept)} \]

=> Particle acceleration (shocks at different distances along the jet or magnetic reconnection) closer to the core consistent with a brighter gamma-ray emission (Dubus +10; Corbel +12)
The 2017 giant flare episode

* 14 Feb : gamma-ray flare detection with Fermi/LAT (ATel Loh)
* 25 Feb : radio quenched observed with the RATAN-600 (ATel Trushkin)
* 27 Feb - 1 March : AGILE detection (ATel Piano)
* 15-16 March : AGILE detection (ATel Piano)
* 3 April : Fermi/LAT detection (ATel Loh)
* 3 April : beginning giant radio flare F > 1.5 Jy (Trushkin)
Radio, X-ray and gamma-ray observations

First results of the 2017 giant flare

* Medicina ToO observations for 8 consecutive days from 4 April
  => 8.5, 18.6 and 24.1 GHz
  => long sessions from 3 to 13 hrs per day

* 2 runs e-EVN triggered at 5 GHz on 9 and 13 April for 15 hrs each
  => participation of Noto and Medicina (2nd run)
Medicina observations at 8.5 GHz

* Peak reached on 5 April 2017
* $F = 16.5 \pm 0.5$ Jy at 8.5 GHz
* $F = 13 \pm 1$ Jy at 24.1 GHz

Preliminary results!
VLBI observations at 5 GHz

*Amplitude of the visibility in function of the baseline length
=> extended structure

Preliminary results!
VLBI observations at 5 GHz

* Phases and amplitudes for the baseline Noto-Yebes:
  => variation of the flux on small timescale

Preliminary results!
Conclusions

* Clear correlations between X-ray state, gamma-ray emission and giant radio flares

* Mini radio flare (2016) close to the core
  Giant radio flares occur further downstream and start in the ultra-soft X-ray state

* Gamma-ray emissions above 100 MeV:
  - During soft spectral X-ray states and rapid spectral transitions
  - Anti-correlation with hard X-rays
  - Precede radio flares, when moving into/out of quenched state
  - Associated with rapid variation from jets (shock-in-jet model)

  => in agreement with Tavani +09; Bulgarelli +12; Corbel +12; Piano +12

* Link between accretion, ejection and gamma-ray emission still complicated...
First high-resolution images of SNRs with SRT…

Egron, Pellizzoni,... Cardillo, Giuliani et al. Accepted for publication to MNRAS