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

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Sardinia Radio Telescope

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NATIONAL INSTITUTE FOR ASTROPHYSICS

Cyg X-3: a very peculiar source

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

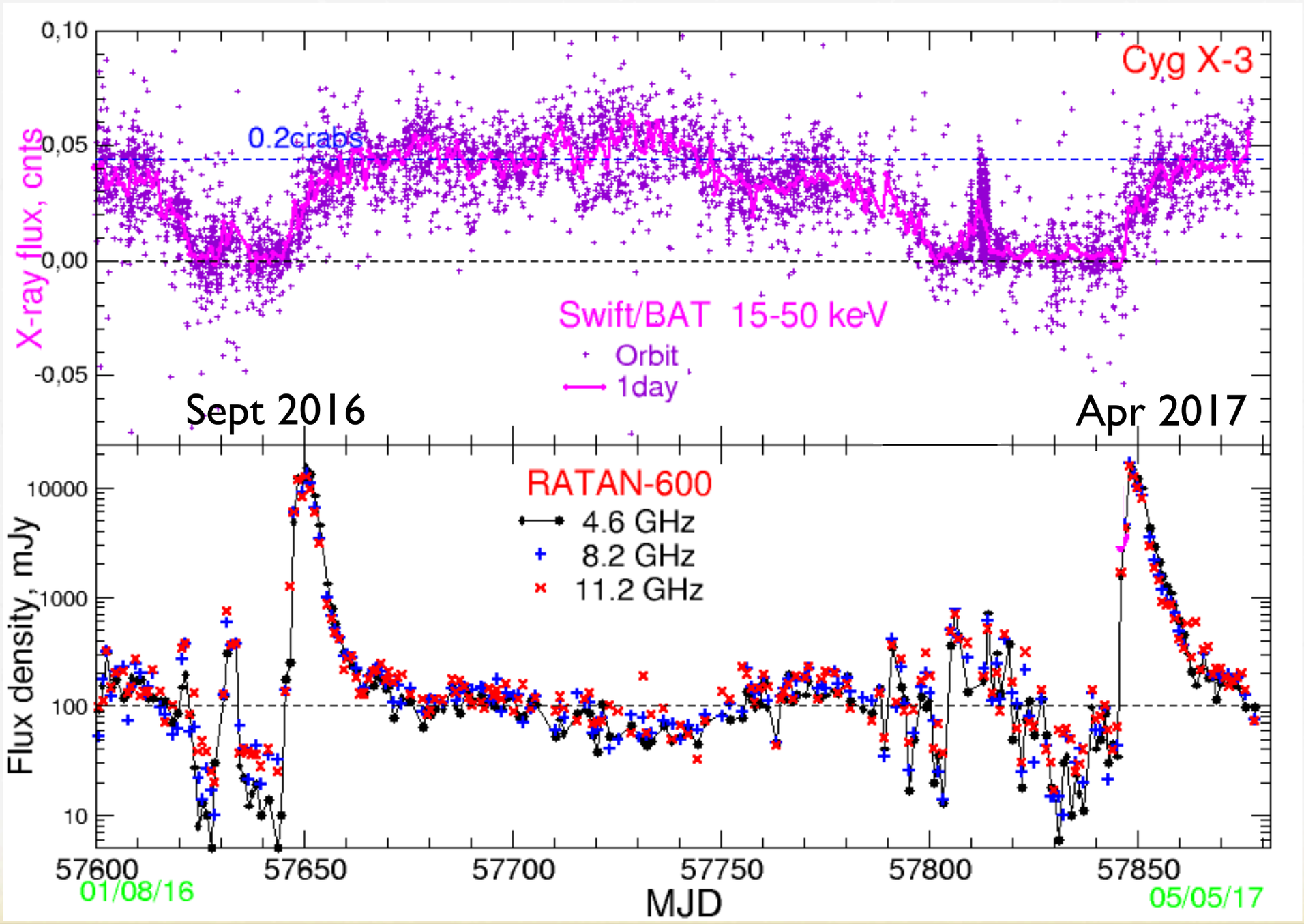
* The brightest X-ray binary in radio (relativistic plasma ejection)

* 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

S. Trushkin: http://www.sao.ru/hq/lran/XB/CygX-3/CygX-3_lc_rat_sw_2016-17f.png



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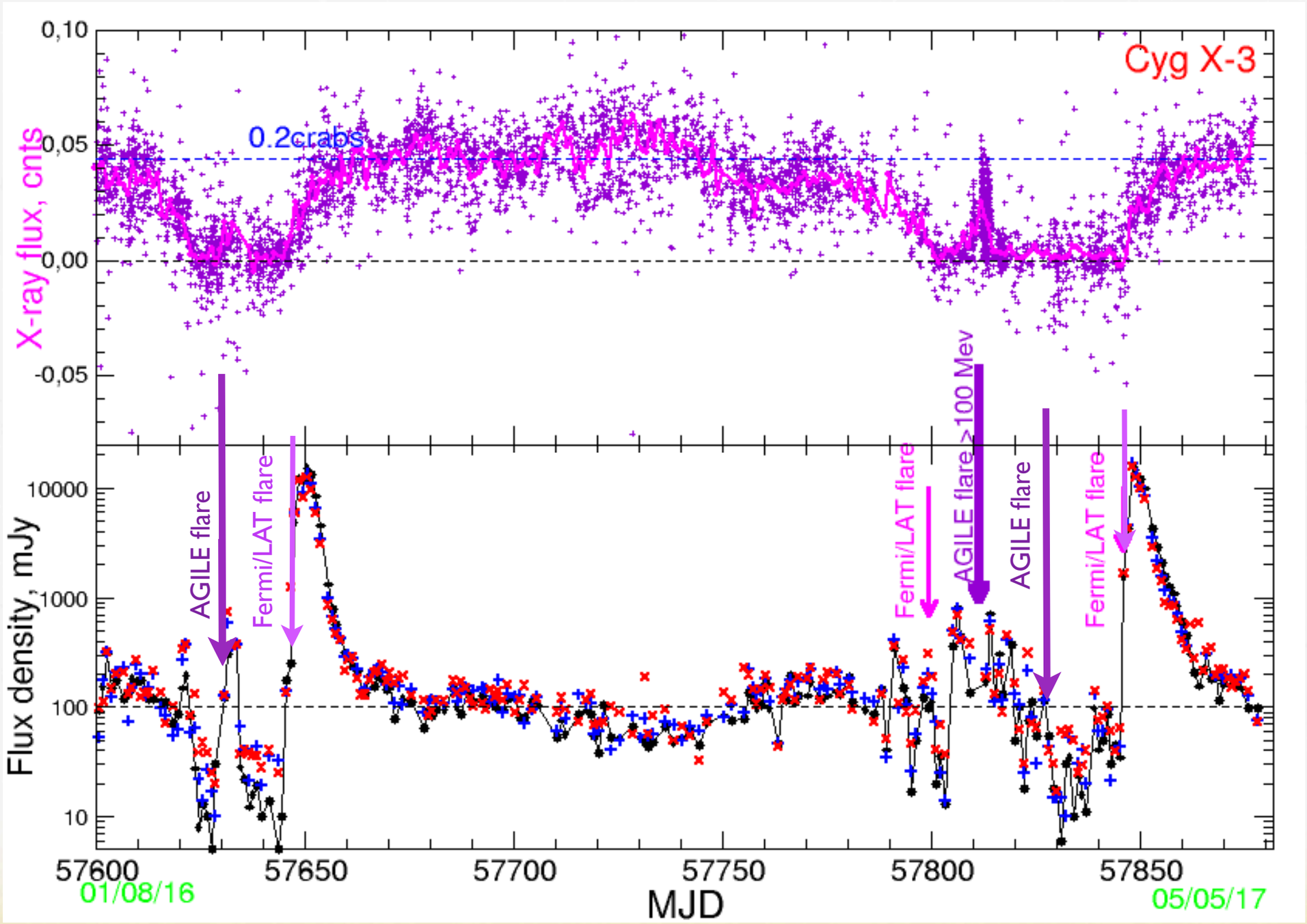
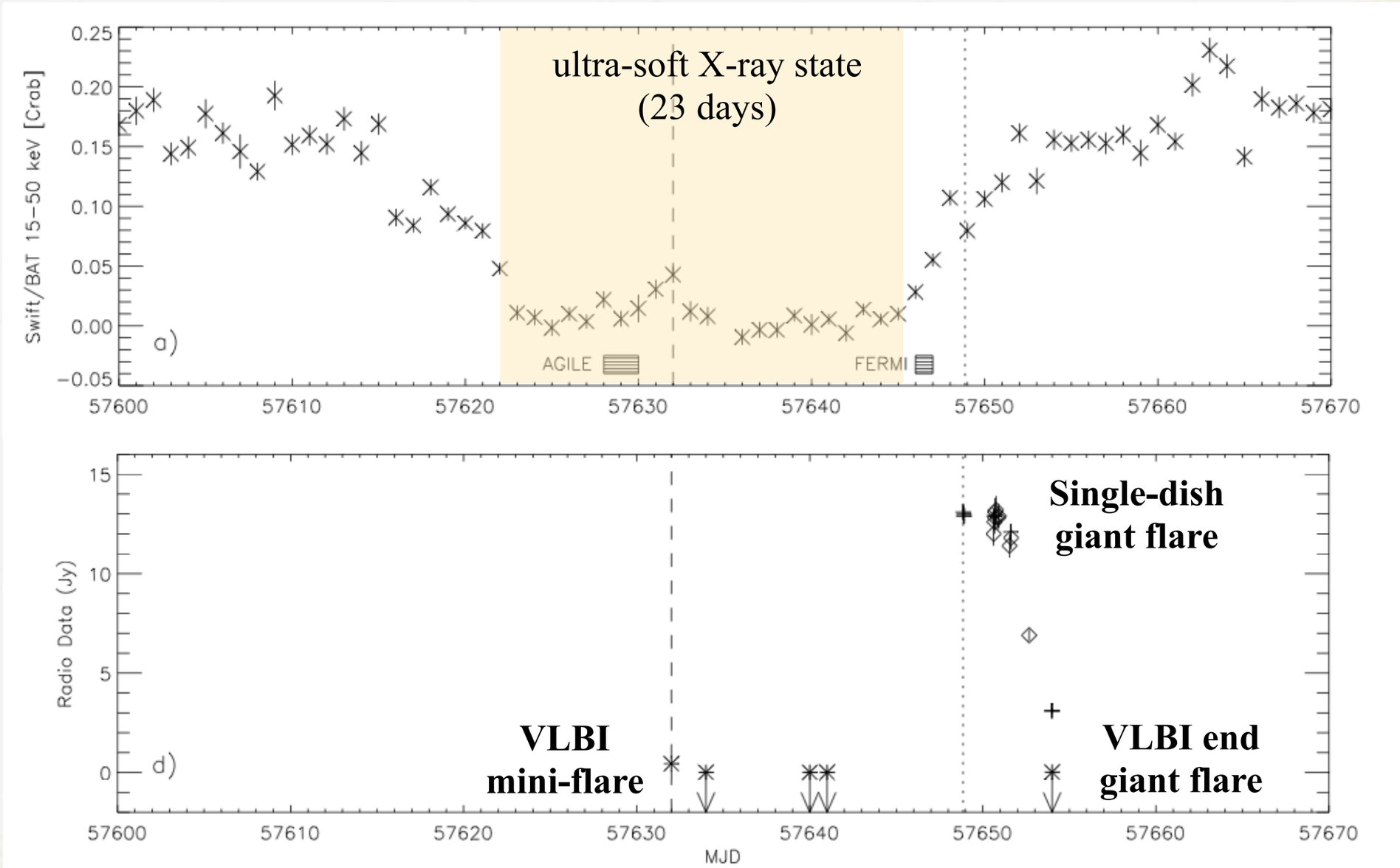


The giant flare of September 2016

Swift/BAT
(15-50 keV)

ToO Radio
observations



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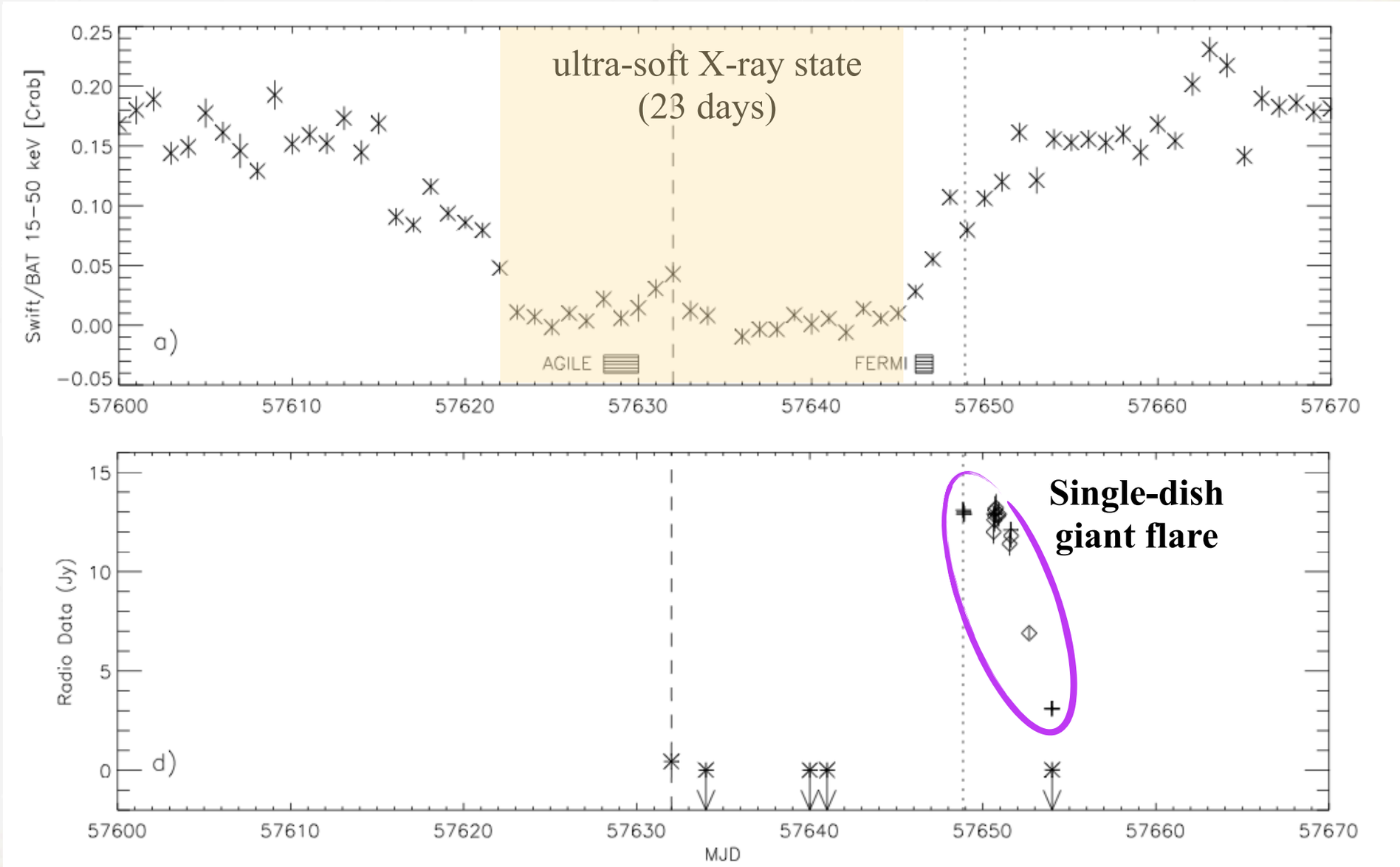
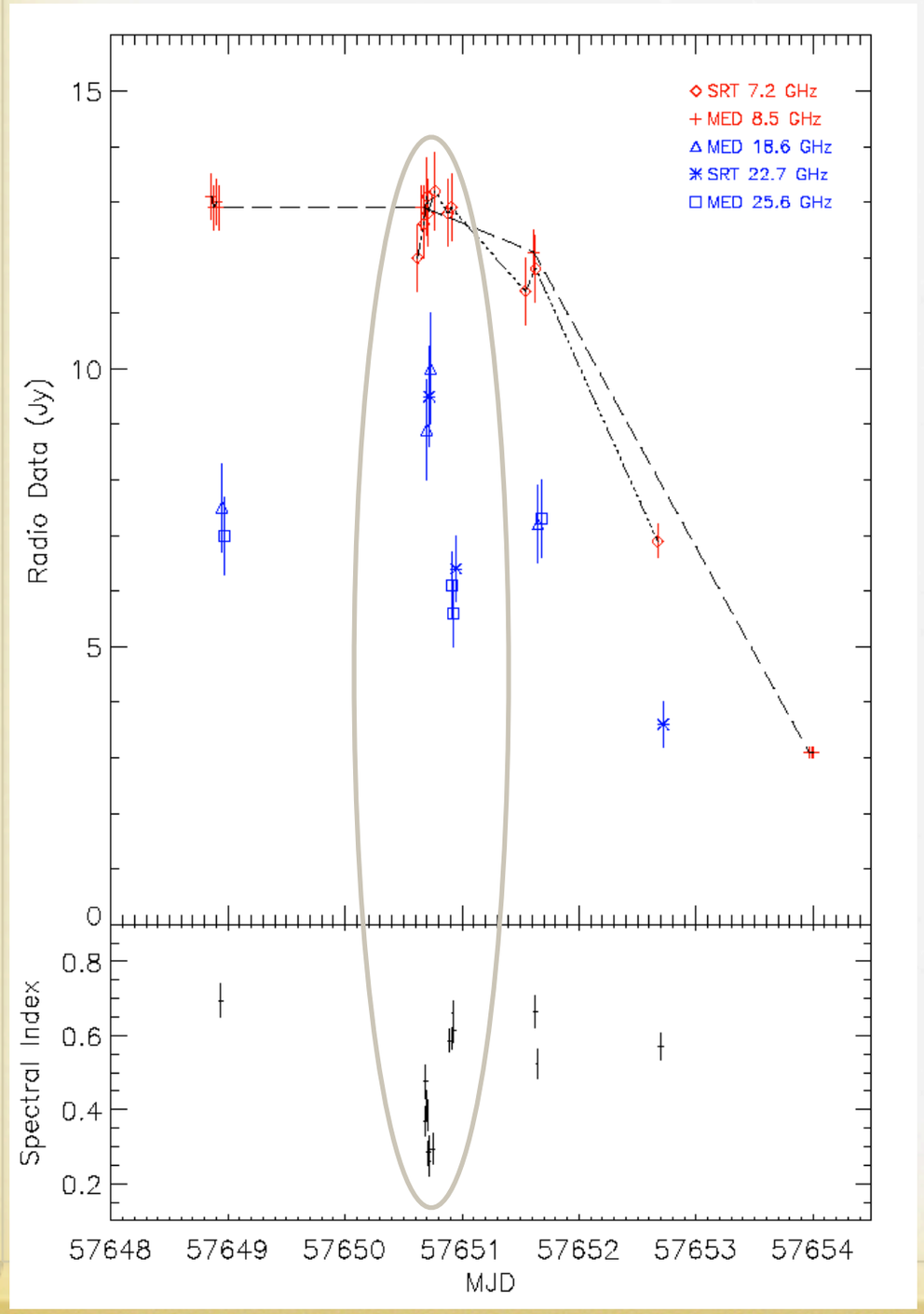
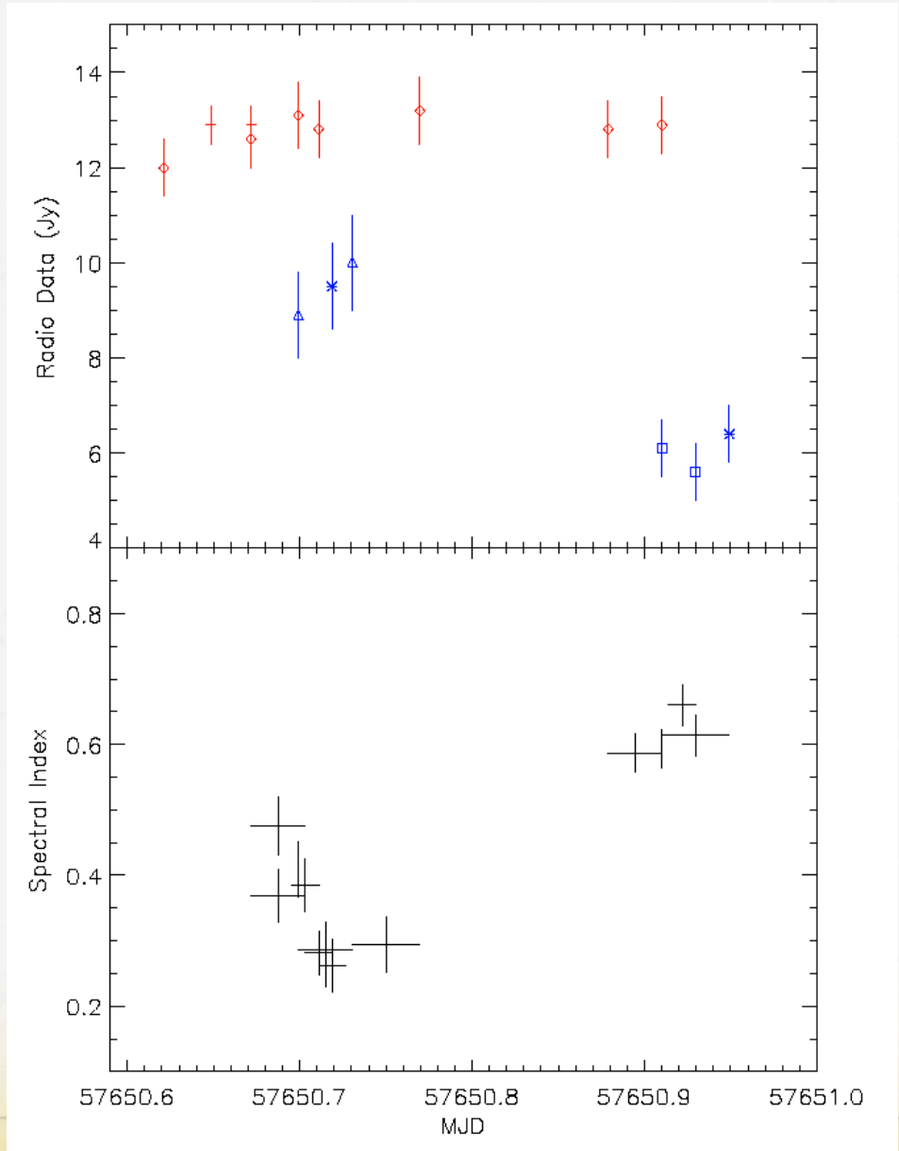


SRT and Medicina observations

* 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

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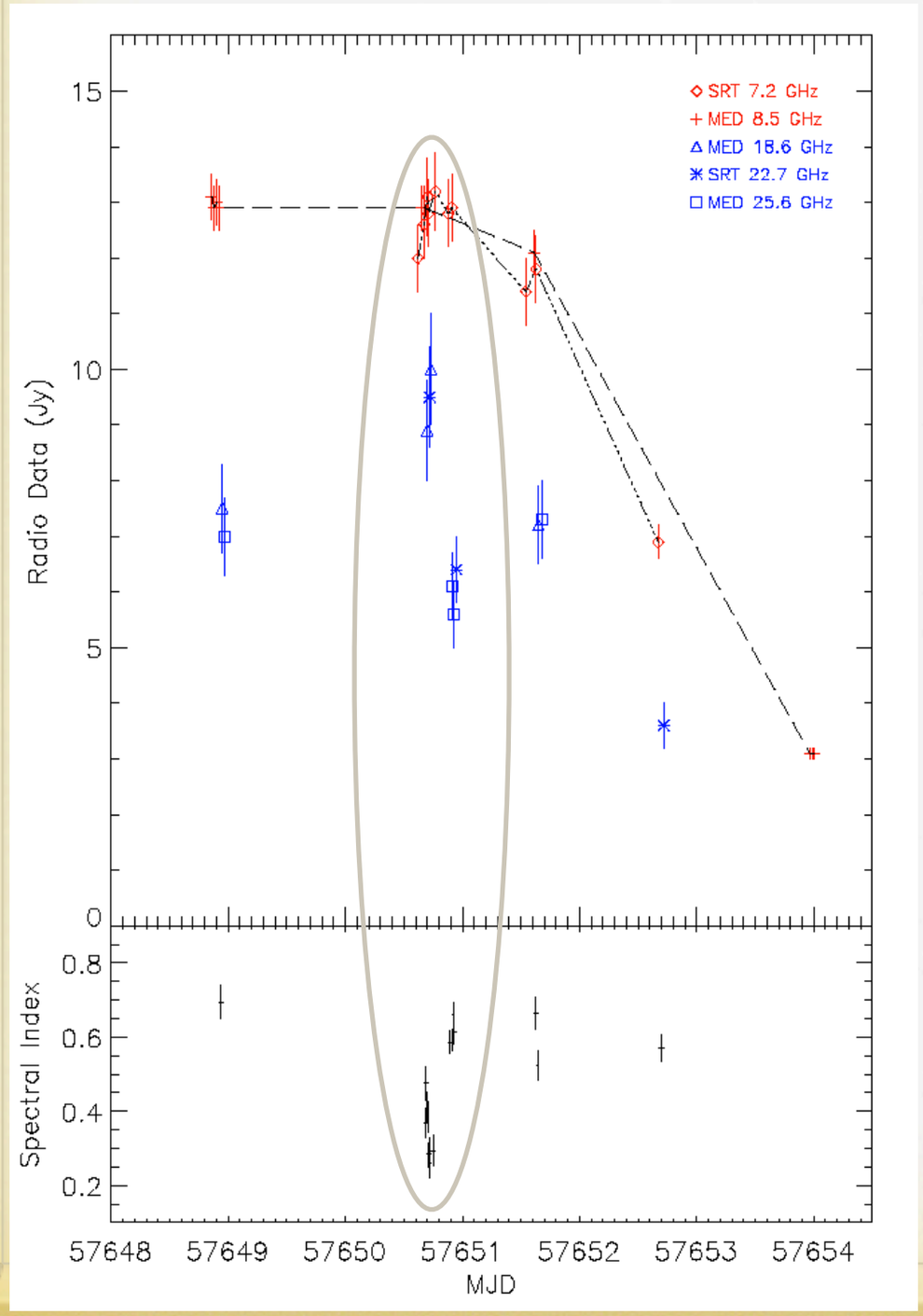
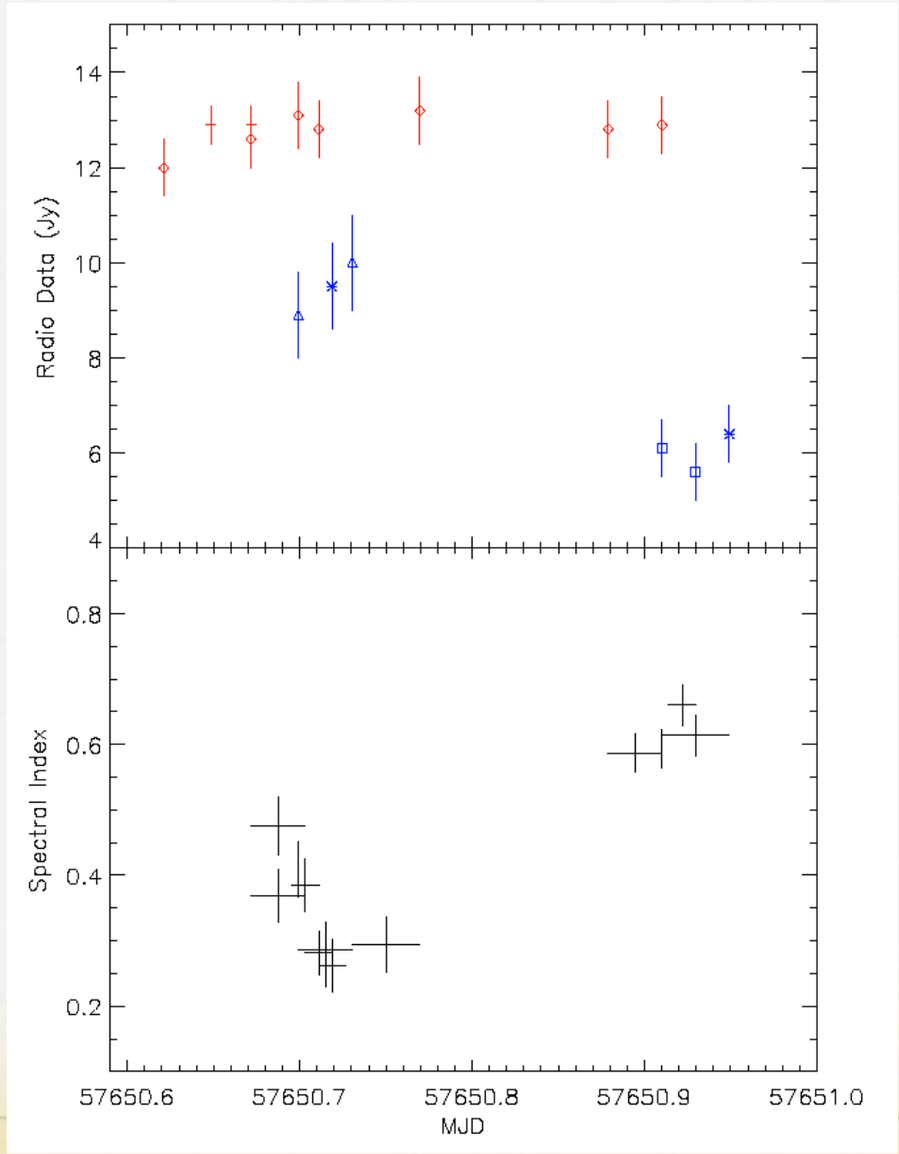


=> Evolution from optically thick to optically thin plasmons in expansion moving outward from the core



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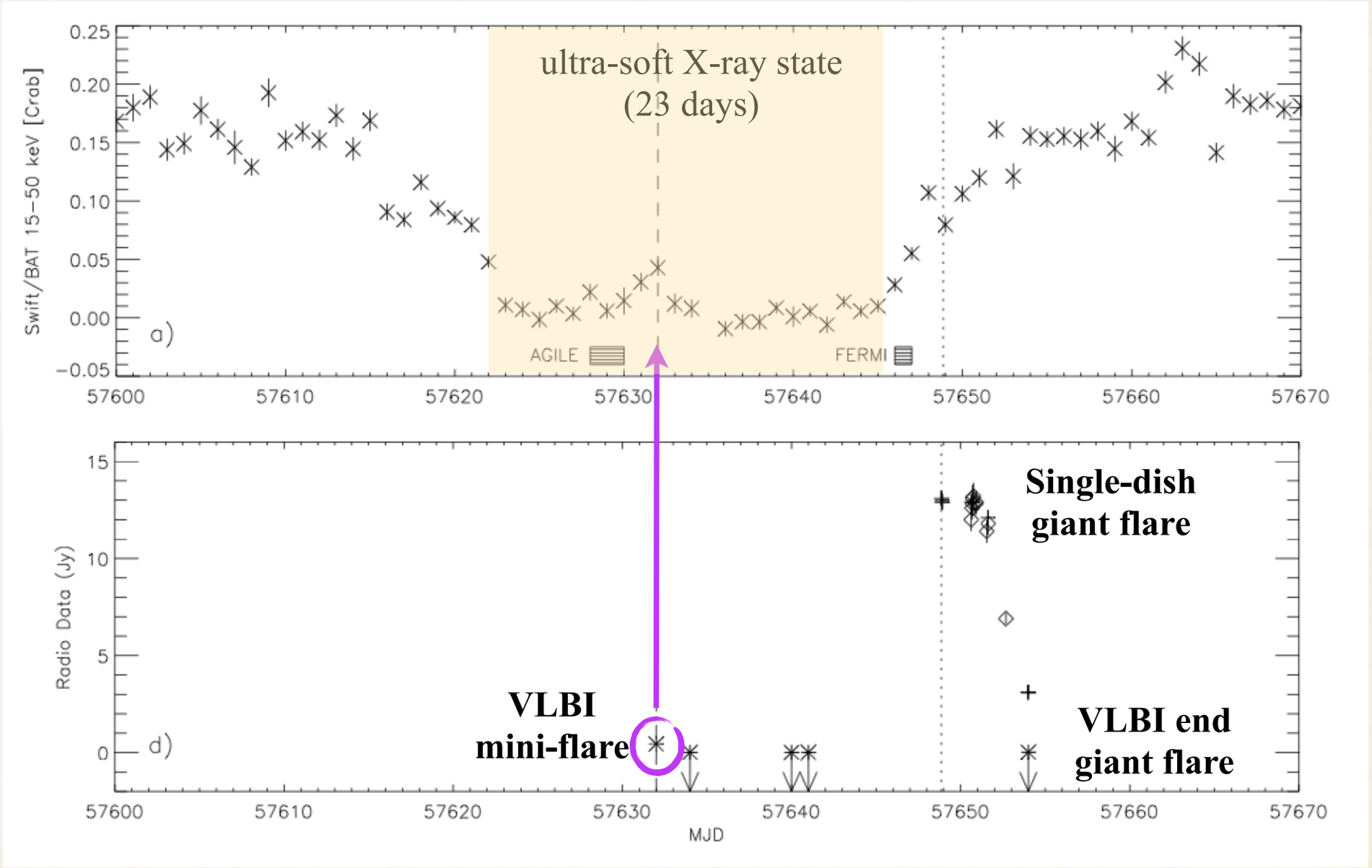
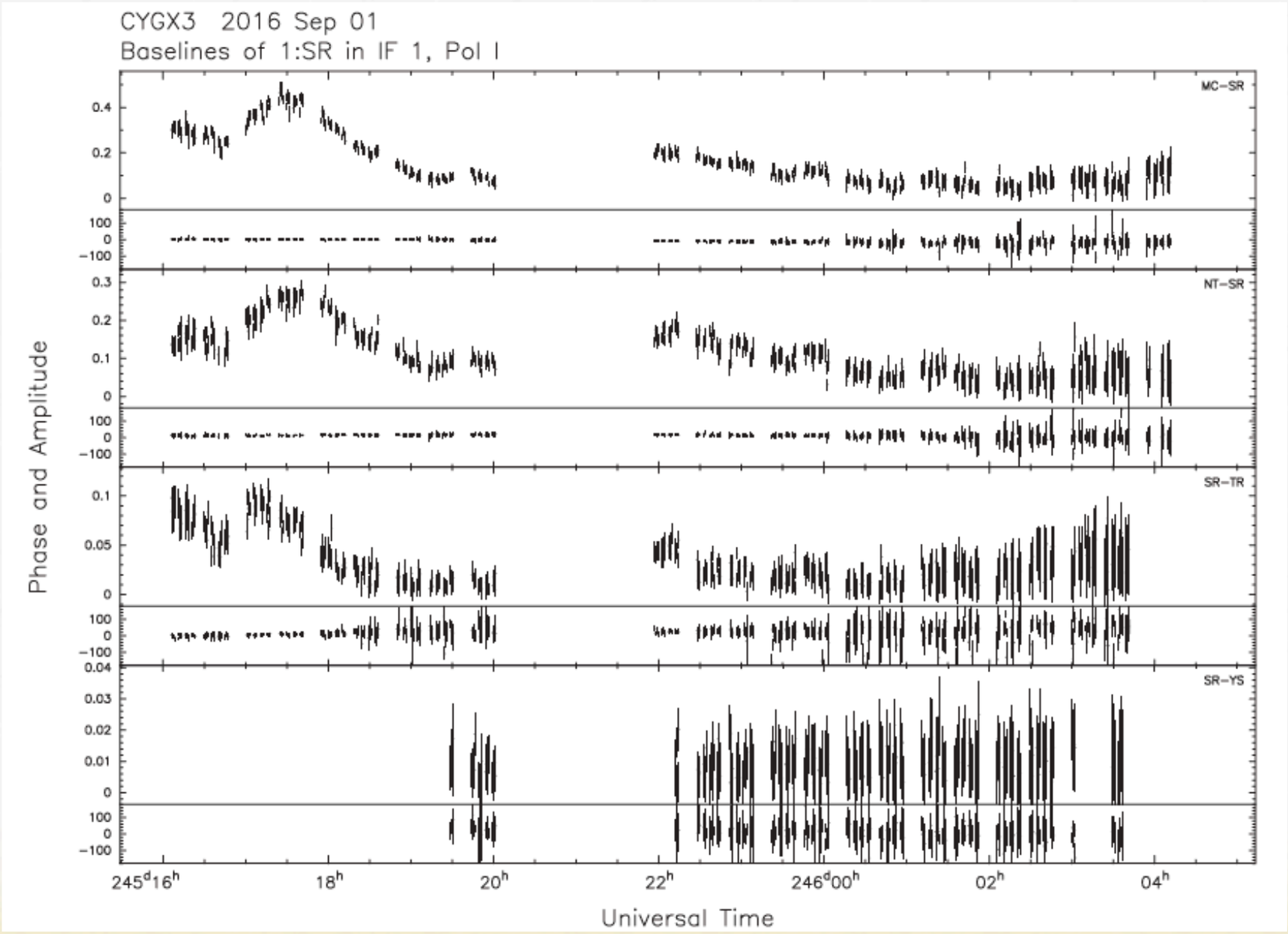


VLBI observations of the mini-flare

* Phases and amplitudes for the different baselines

  => variation of the flux on a few hours at 22 GHz



SRT/Medicina

SRT/Noto

SRT/Torun

SRT/Yebes

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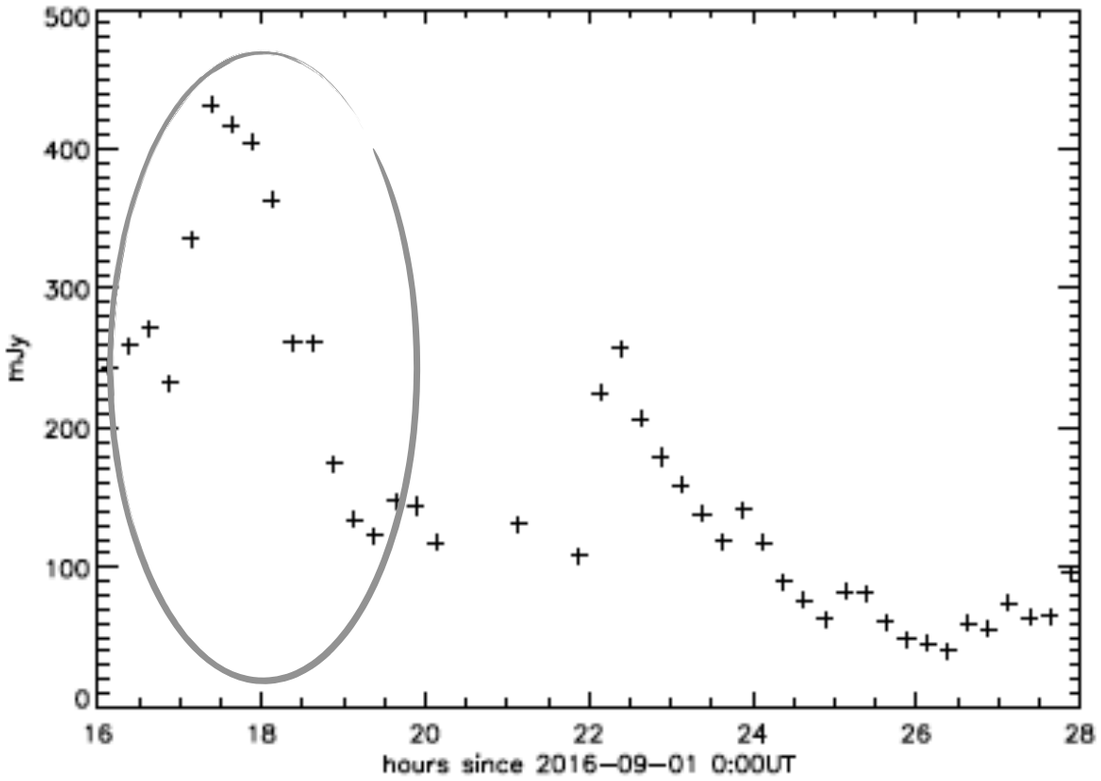
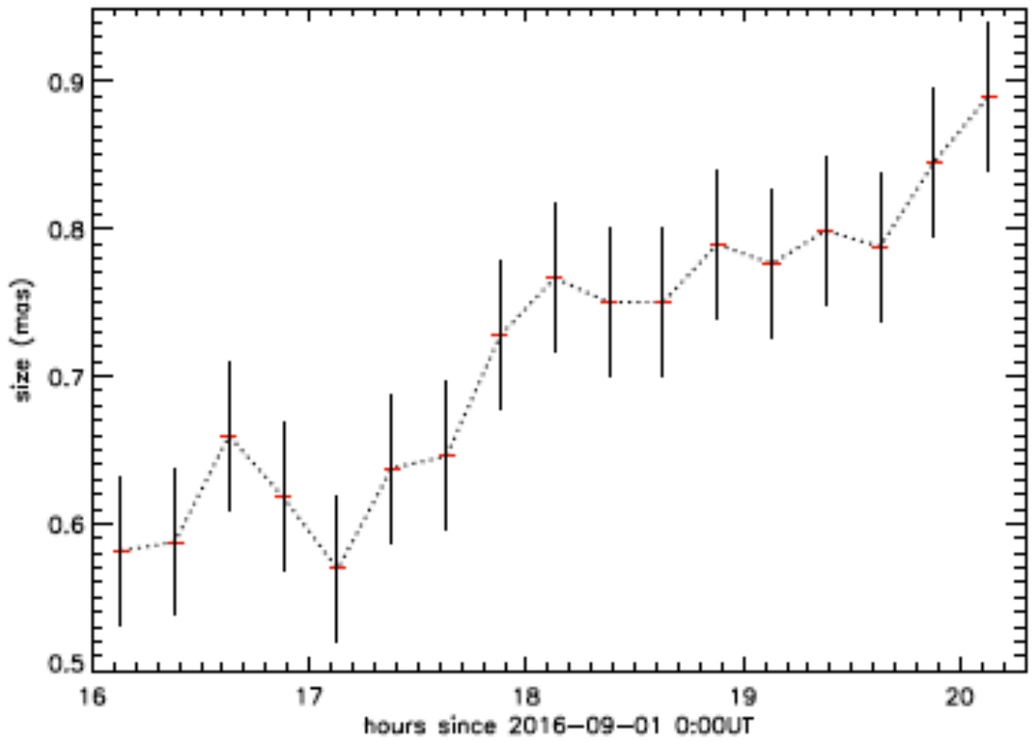
VLBI observations of the mini-flare

*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



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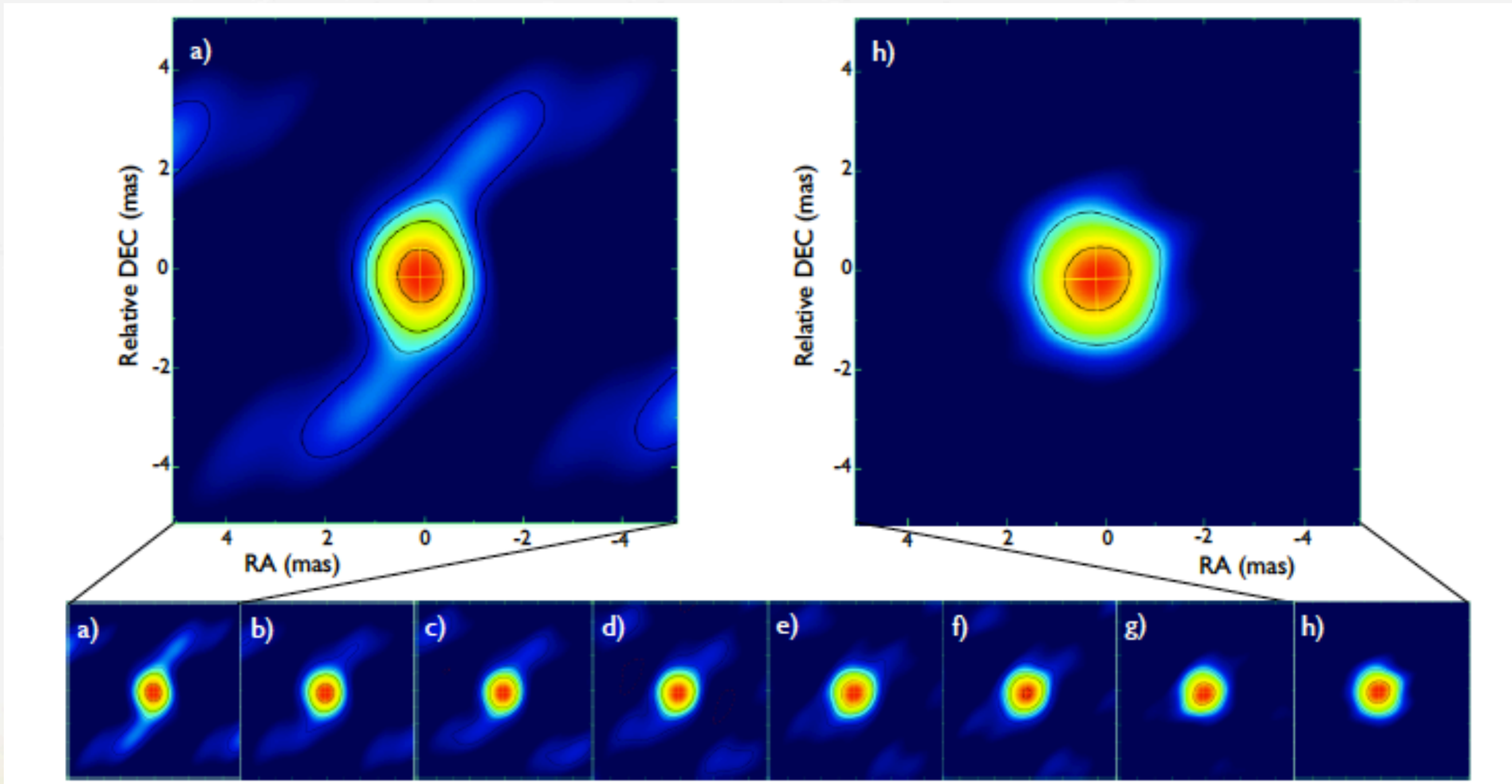
submitted to MNRAS

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



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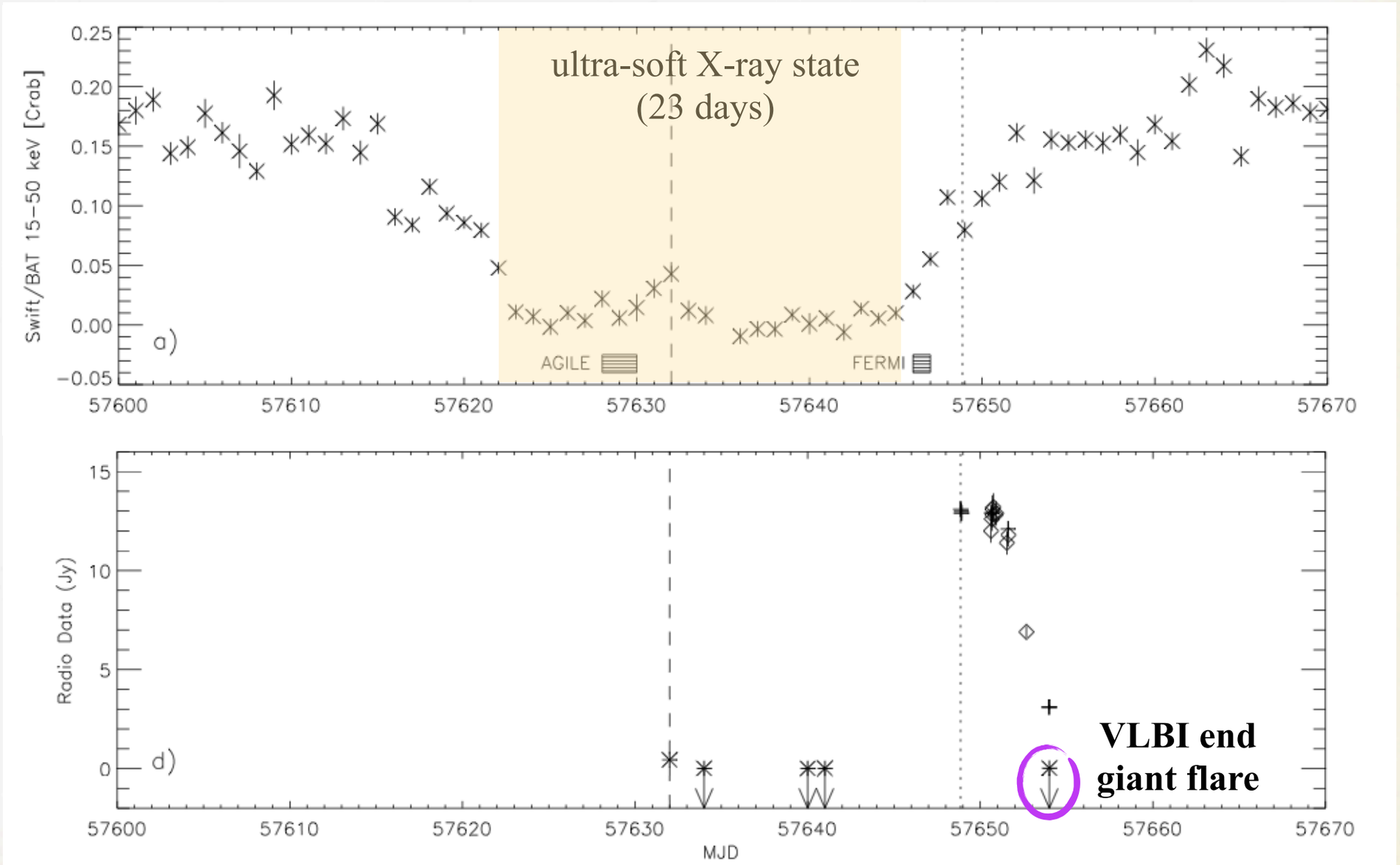

VLBI obs at the end of the giant flare

* No VLBI detection on 23 Sept at 22 GHz whereas F = 1.4 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 +/- 1.4) x 10^-6 photons/cm^2/s (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+/-0.4) then (2.8+/-0.4) x 10^-6 photons cm^-2 s^-1 (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

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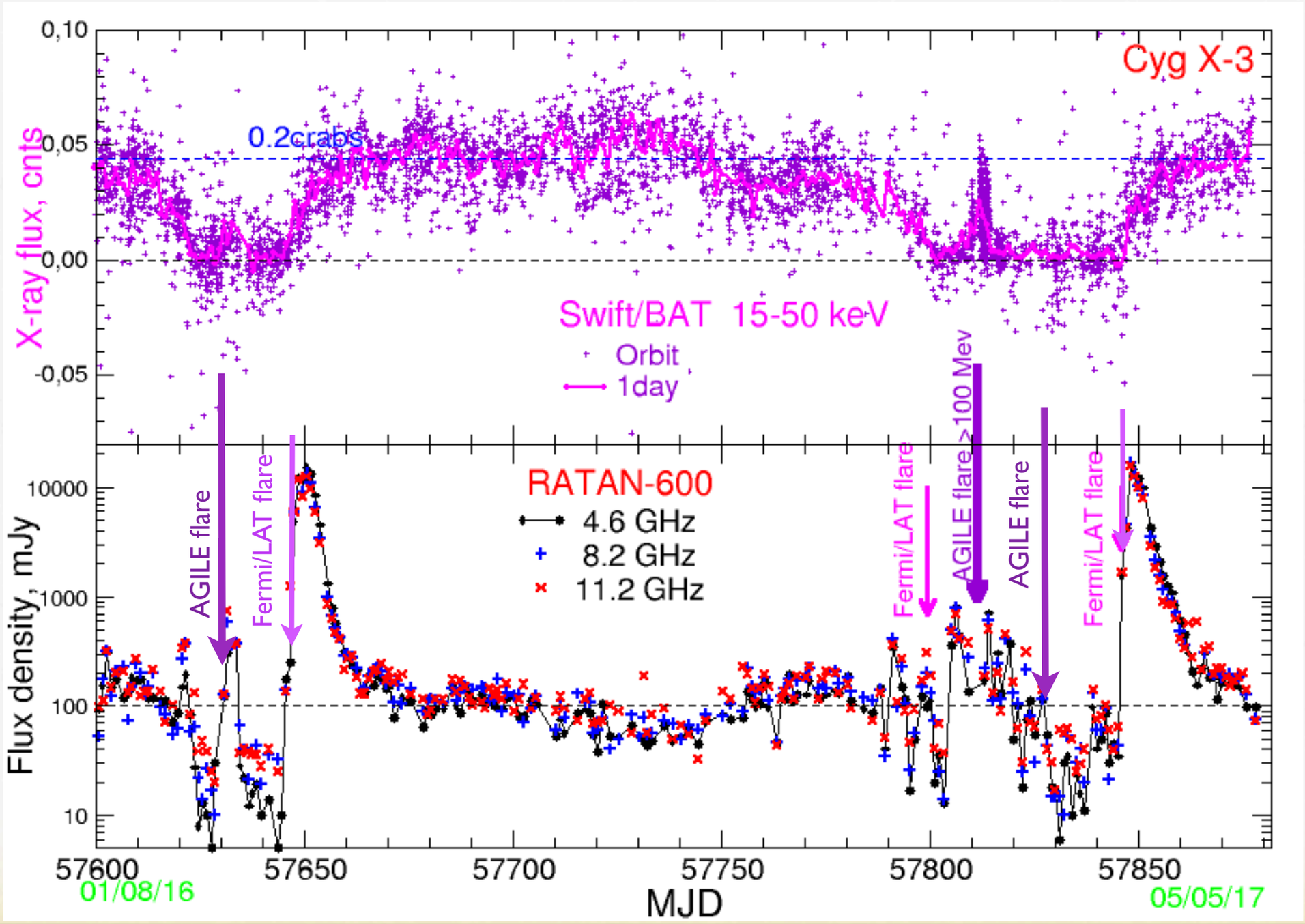
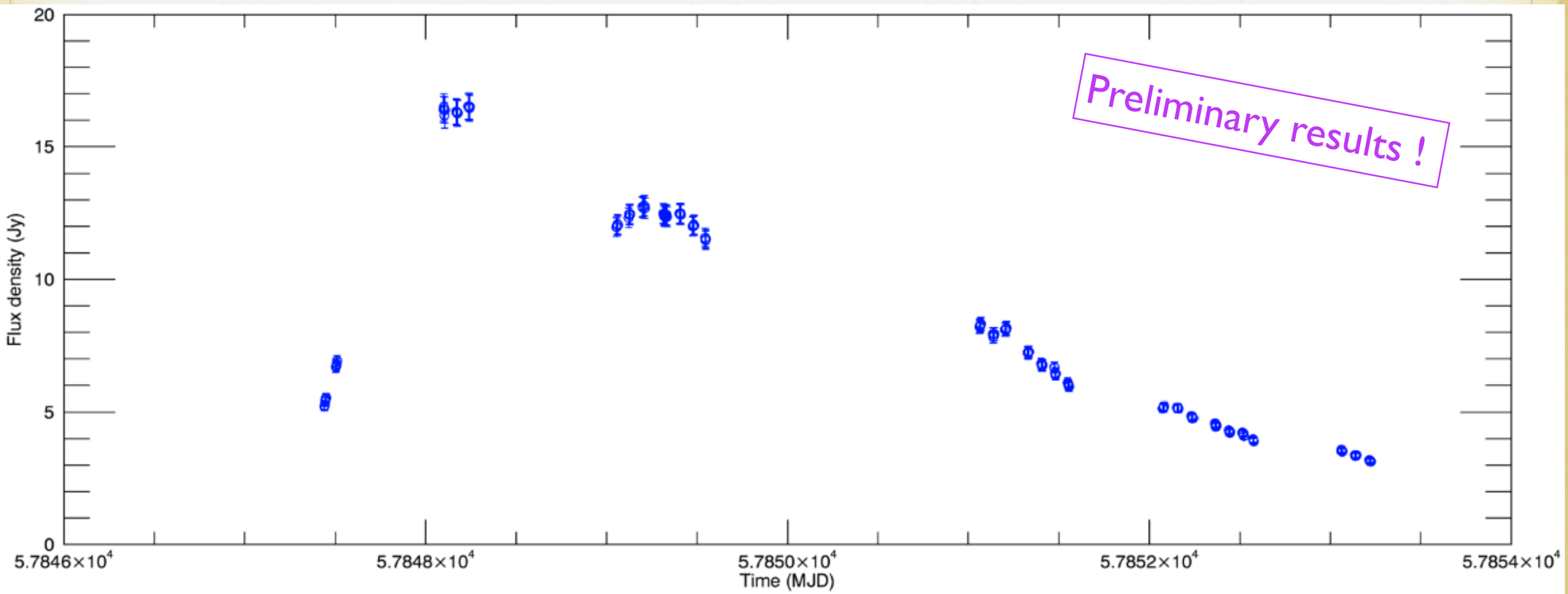


First results of the 2017 giant flare

* 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



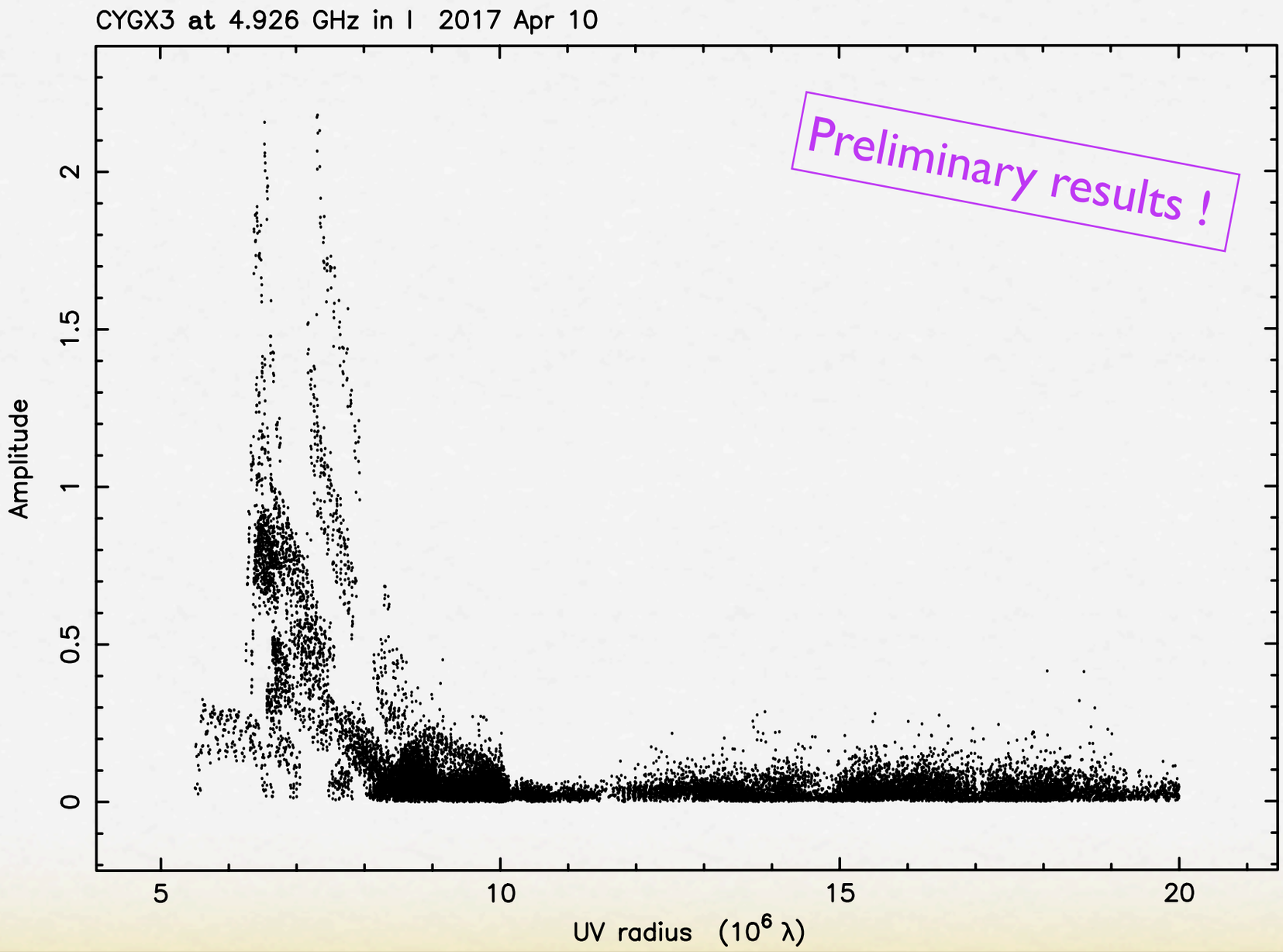
* Peak reached on 5 April 2017
* F =16.5 +/- 0.5 Jy at 8.5 GHz
* F = 13 +/- 1 Jy at 24.1 GHz

} Spectral index changes ?

VLBI observations at 5 GHz

* Amplitude of the visibility in function of the baseline length

  => extended structure

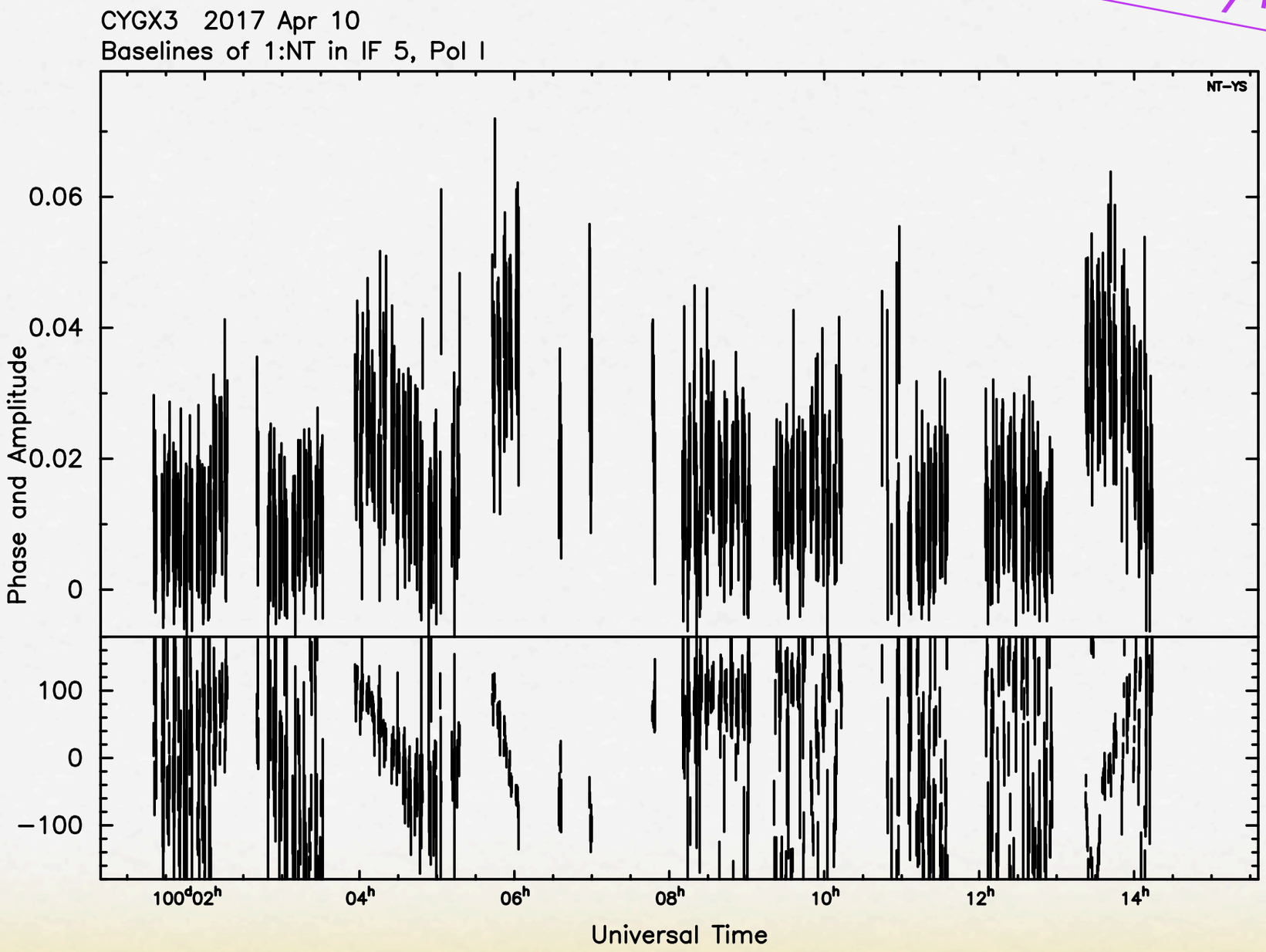


VLBI observations at 5 GHz

* Phases and amplitudes for the baseline Noto-Yebes :

=> variation of the flux on small timescale

Preliminary results !



Conclusions

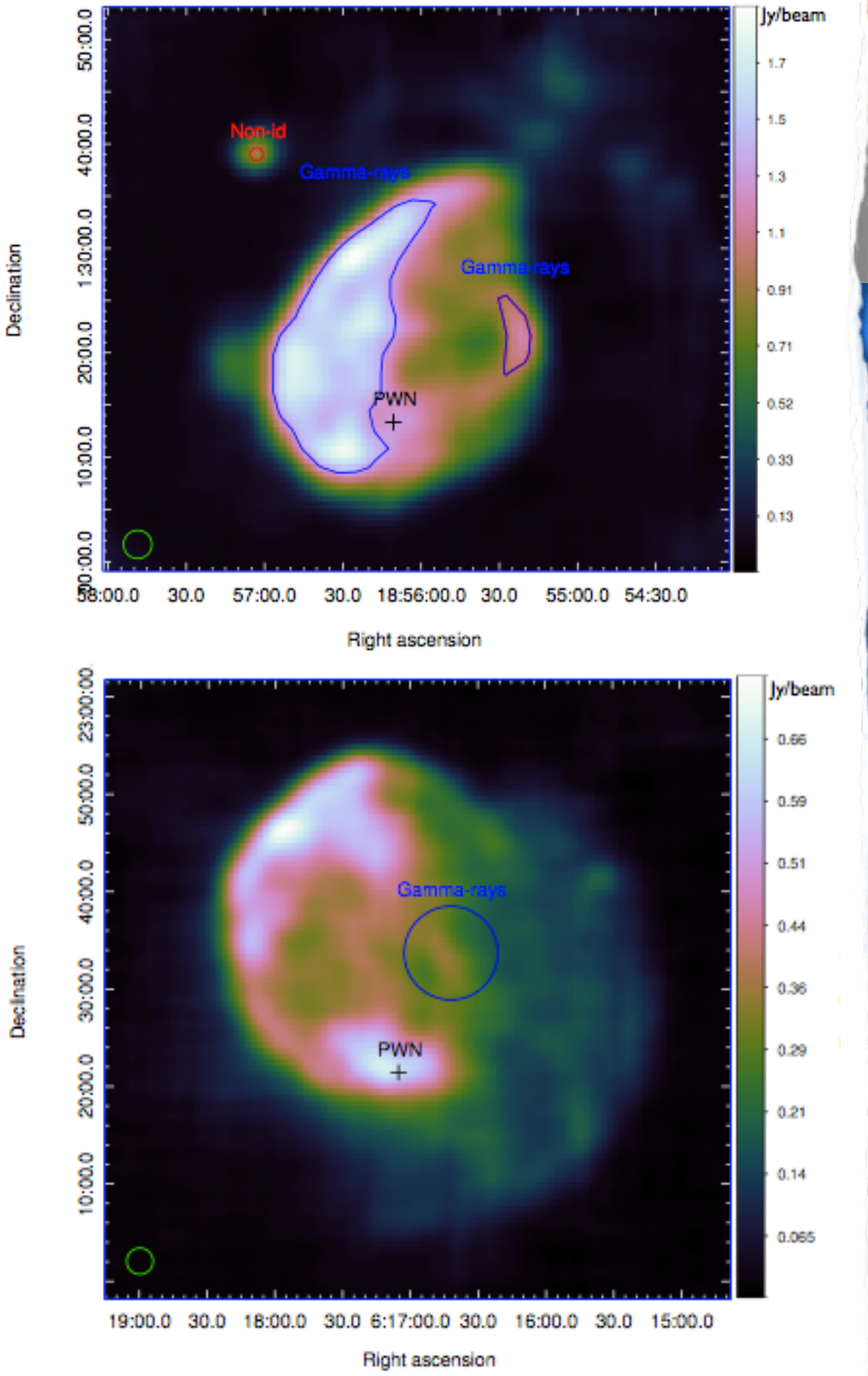
* Clear correlations between X-ray state, gamma-ray emission and giant radio flares

* 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