

The spectacular giant radio flares of Cygnus X-3

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In collaboration with:

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M. Cadolle Bel, E. Kalemci, T. Belloni, V. Grindberg et al.

Cyg X-3: a very peculiar source

- * HMXB, probably a black hole wind-fed by a Wolf-Rayet star
- * Short orbital period: 4.8 hr, distance 7.4 kpc
- * The brightest X-ray binary in radio
- * Giant radio flares of 10-20 Jy (e.g. Miller-Jones+04, Corbel+12)
- * First microquasar firmly detected in gamma-rays with AGILE (Tavani+09) and Fermi (Fermi/LAT collab.+09)

X-ray and radio states

- * Canonical X-ray states + hypersoft state (Szosteck+04, Hjalmarsdotter+09)
- * Radio states : quiescence, quenched jet, minor/major/giant flares

Hypersoft X-ray state :

- Soft X-ray emission very high
- Hard X-ray emission extremely low
- Quenched radio state (< 30 mJy)

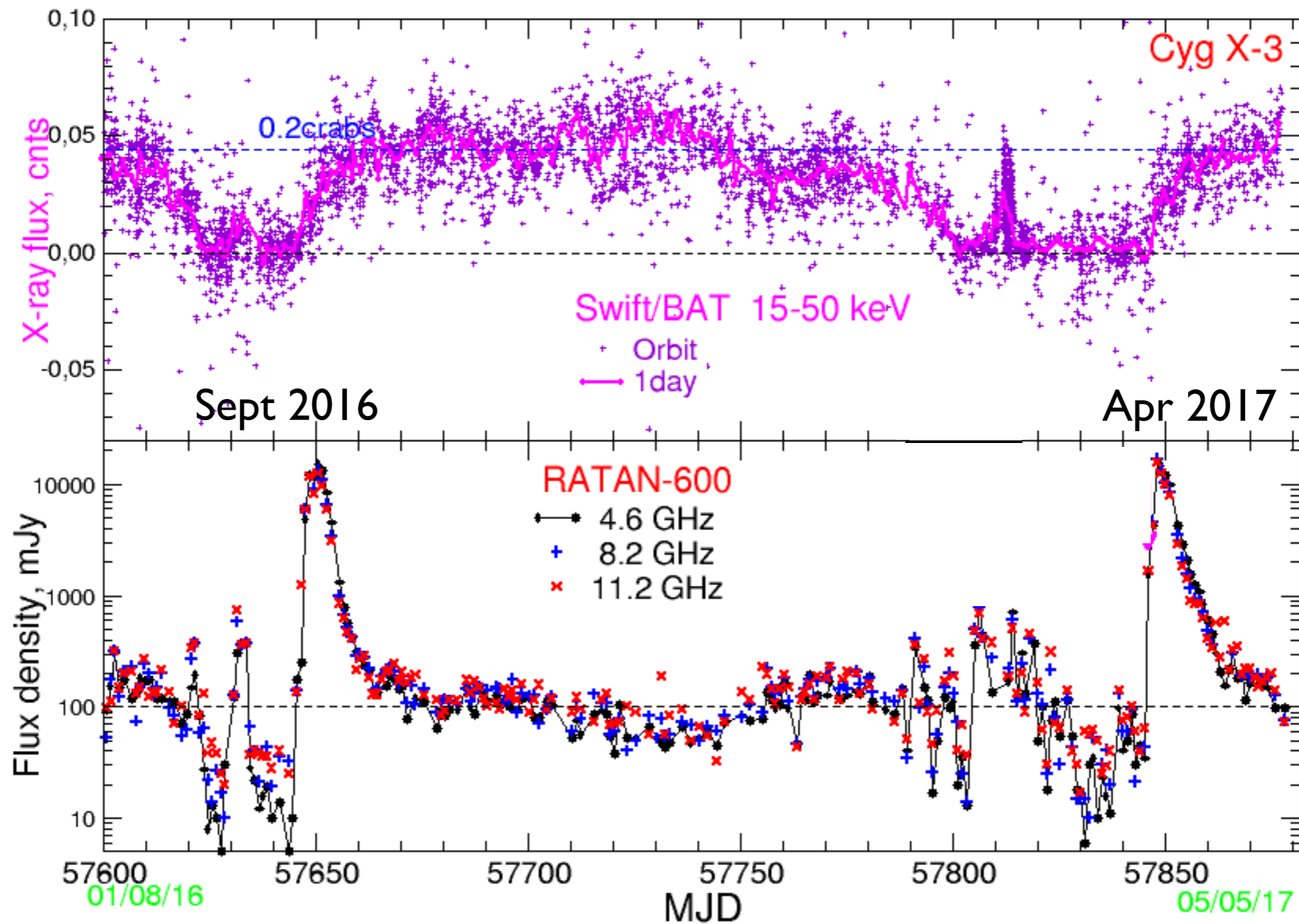
=>

Giant radio flare > 10 Jy

- Transition to harder X-ray state
- Inversion of the X-ray behavior

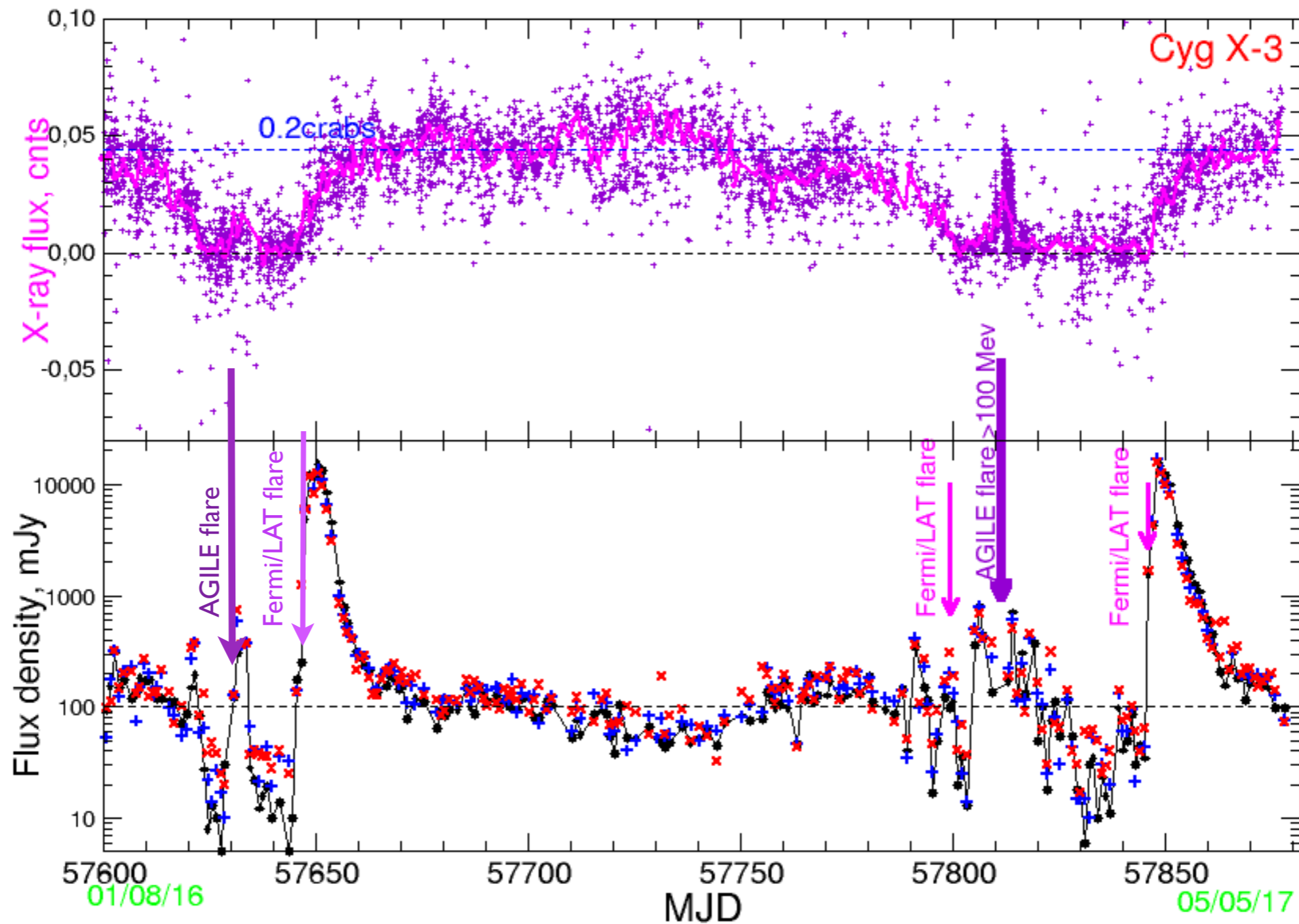
Radio and X-ray connections

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



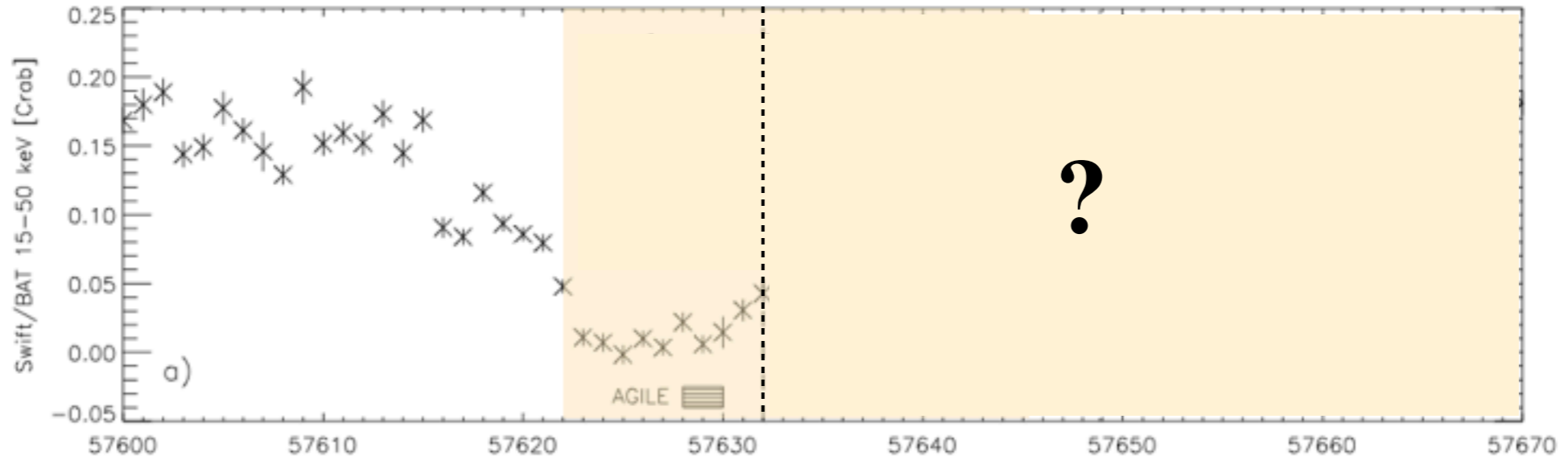
Radio, X-ray and gamma-ray connections

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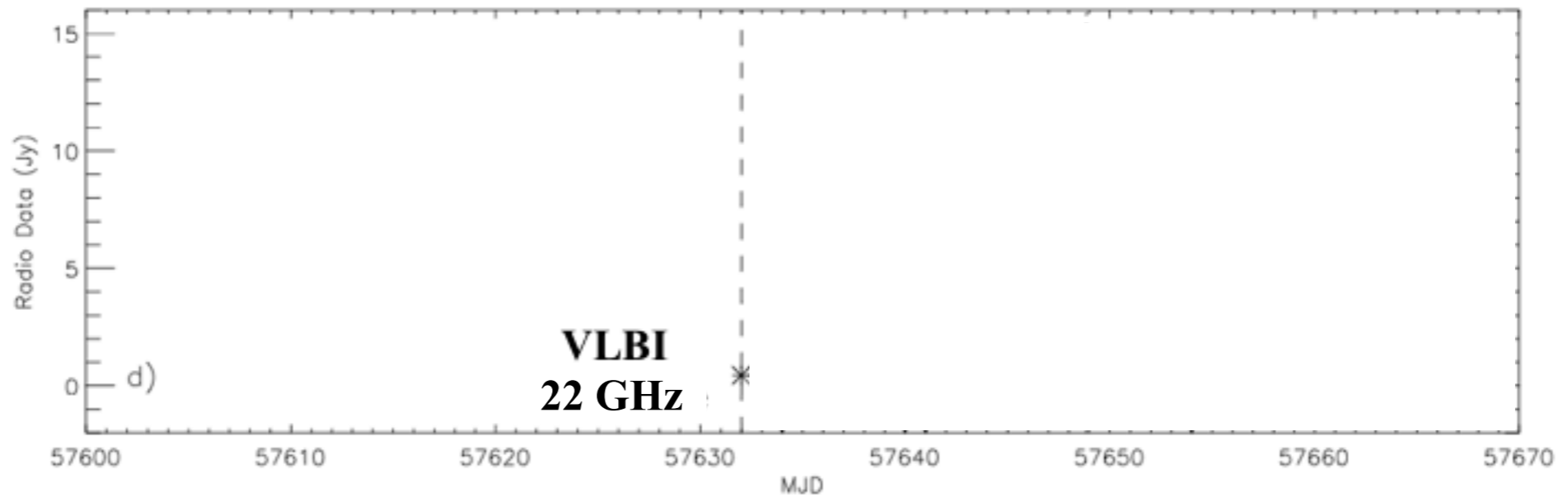


The giant flare in September 2016

Swift/BAT
(15-50 keV)

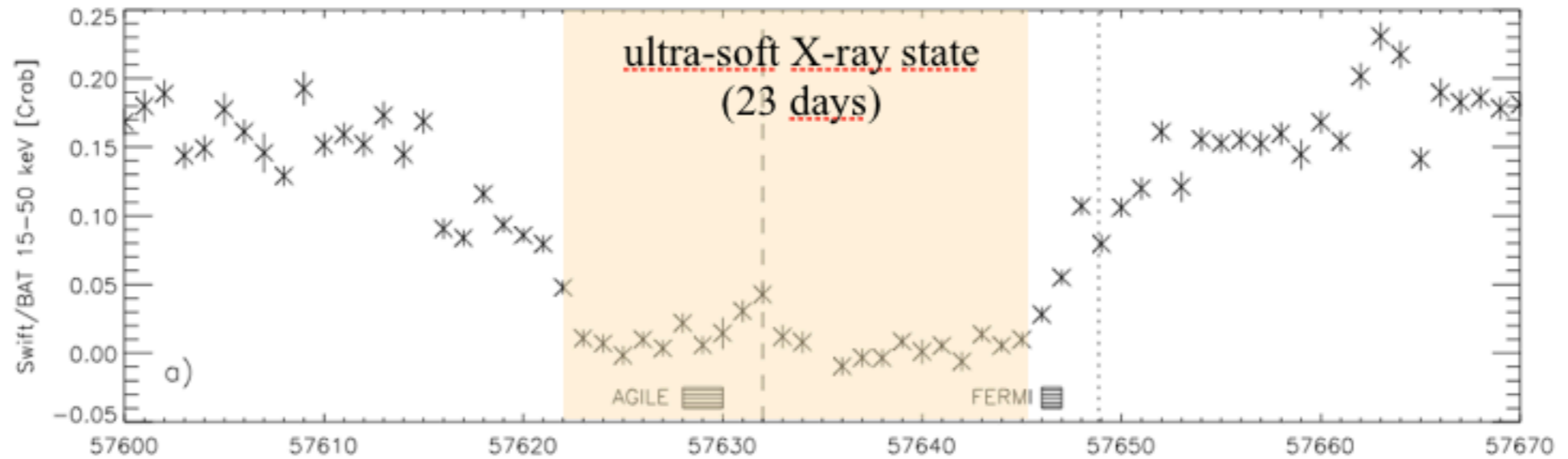


ToO Radio
observations

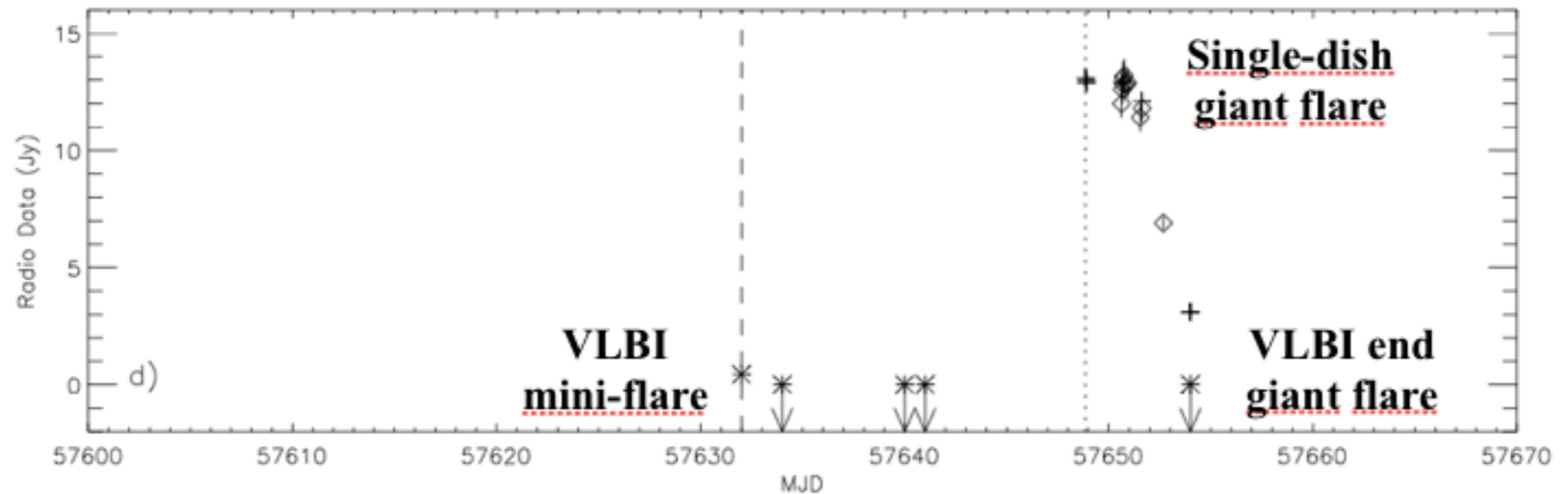


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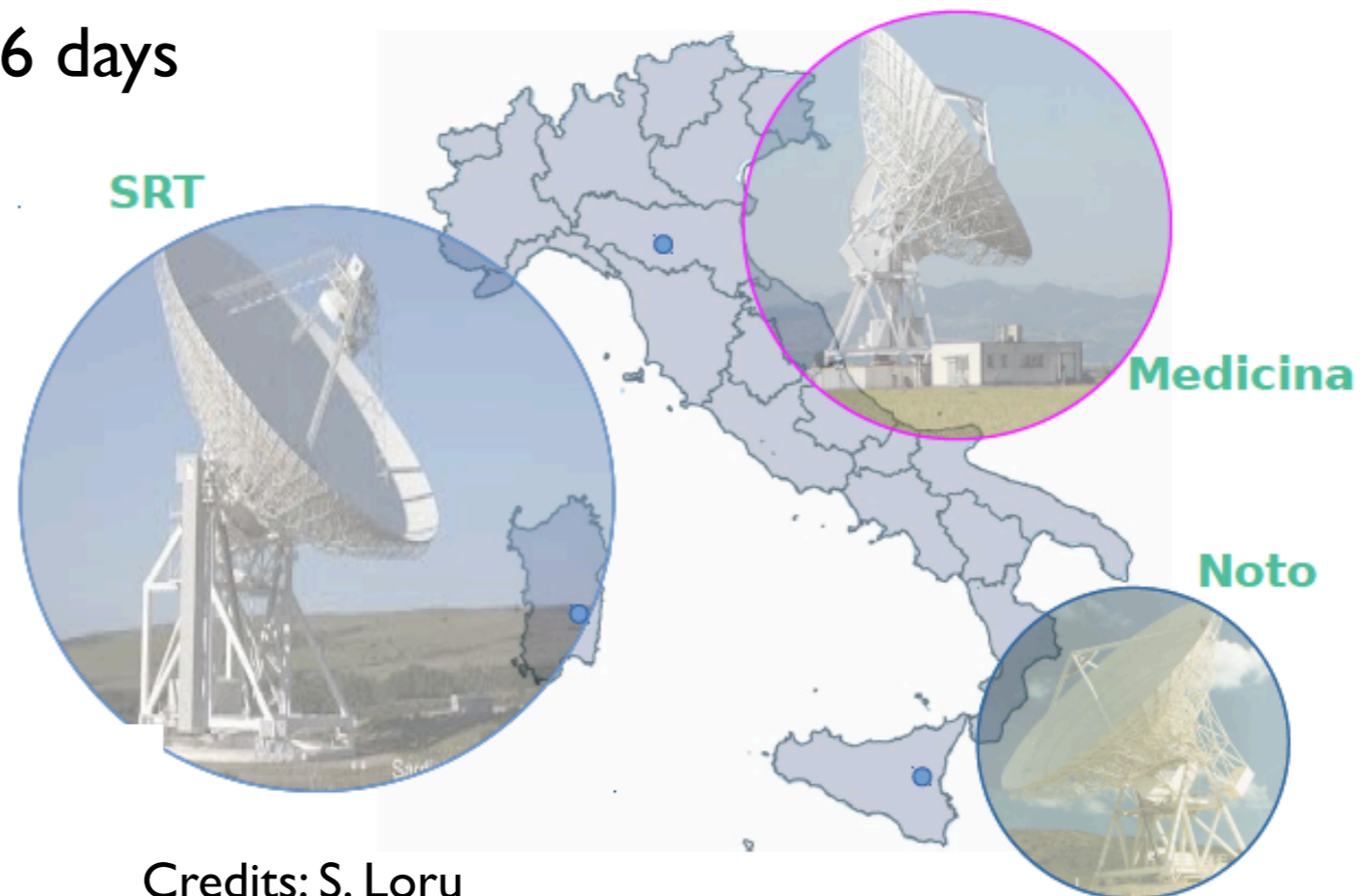
What is happening in Cyg X-3 during the mini and giant radio flares ?

* VLBI observations at 22 GHz : SRT, Medicina, Noto, Torun, Yebes, Onsala

=> Comparison between mini and giant flares

* Single-dish observations with SRT and Medicina at 7.2, 8.5, 18.6, 22.7, 25.6 GHz

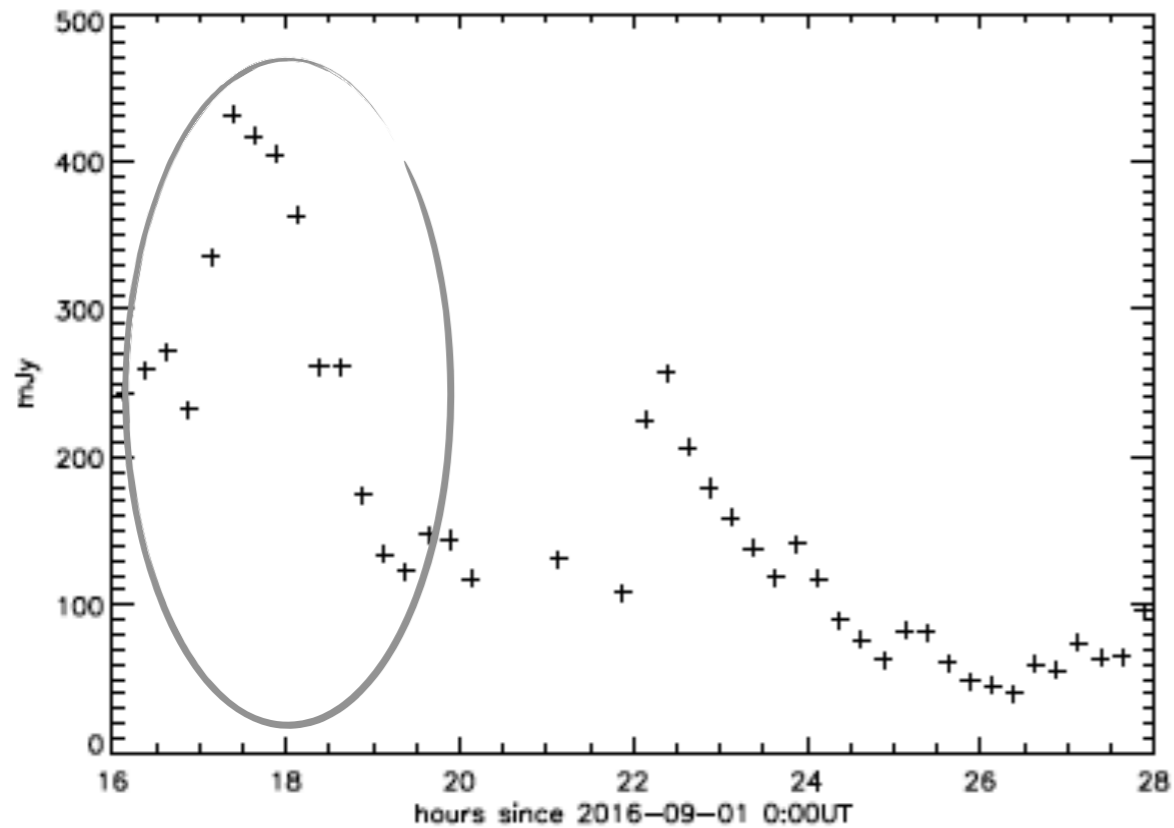
=> Monitoring of the giant flare over 6 days



Credits: S. Loru

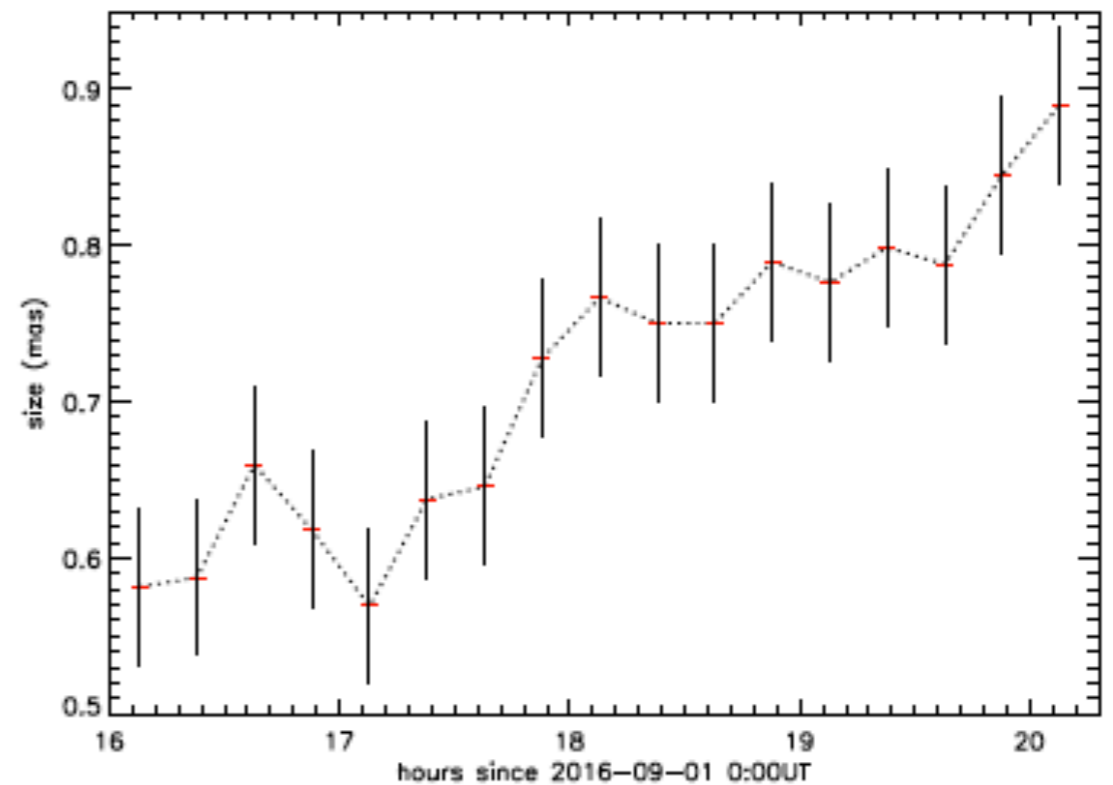
VLBI observations during the mini-flare

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



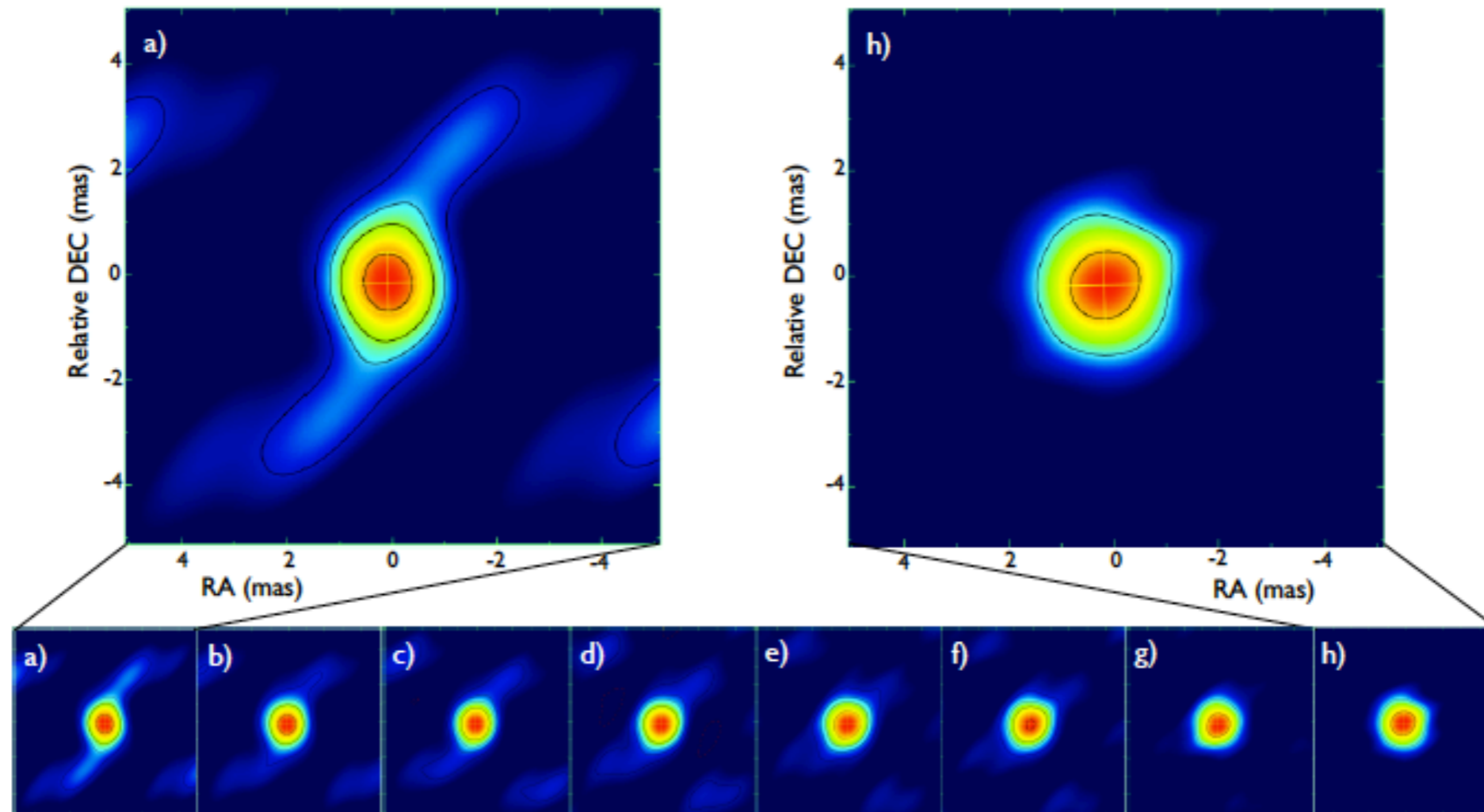
Egron+17

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



VLBI observations during 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

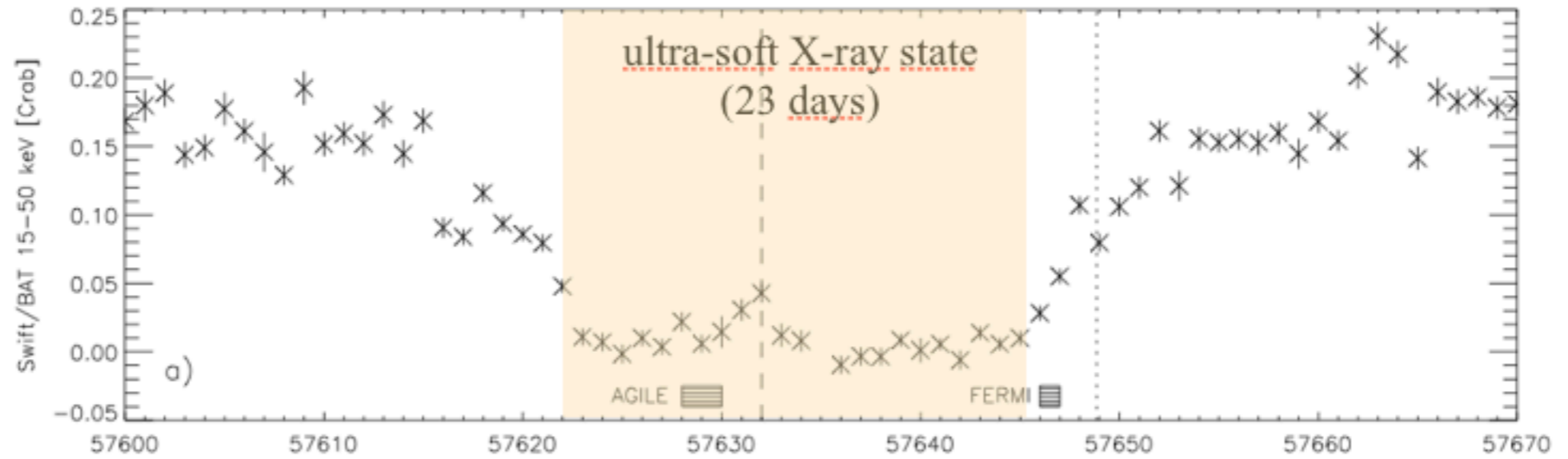


VLBI obs at the end of the giant flare

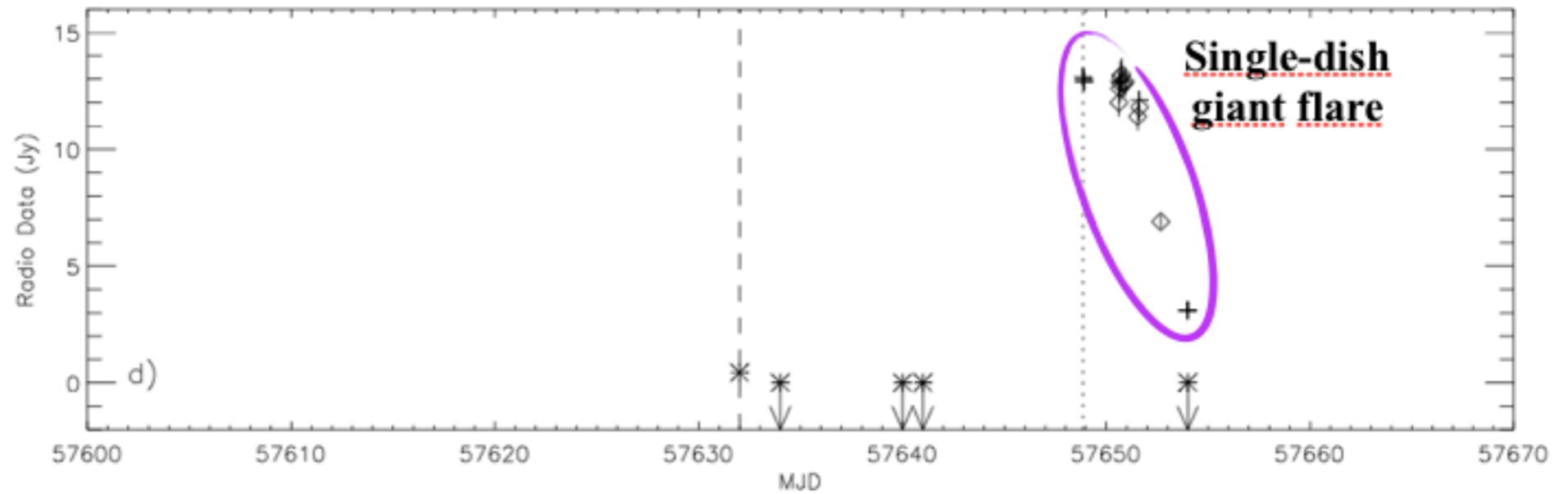
- * No VLBI detection on 23 Sept at 22 GHz whereas $F = 1.4$ Jy
Without SRT, 5-sigma sensitivity of 20 mJy/beam.
- * Source strongly resolved out
=> different jet morphology w.r.t. the mini-flare
- * Beam area = 0.88 mas^2
Assuming a two sided ejection, jet extended over 30 mas
=> jet speed $> 0.3c$

What about the single-dish observations?

Swift/BAT
(15-50 keV)

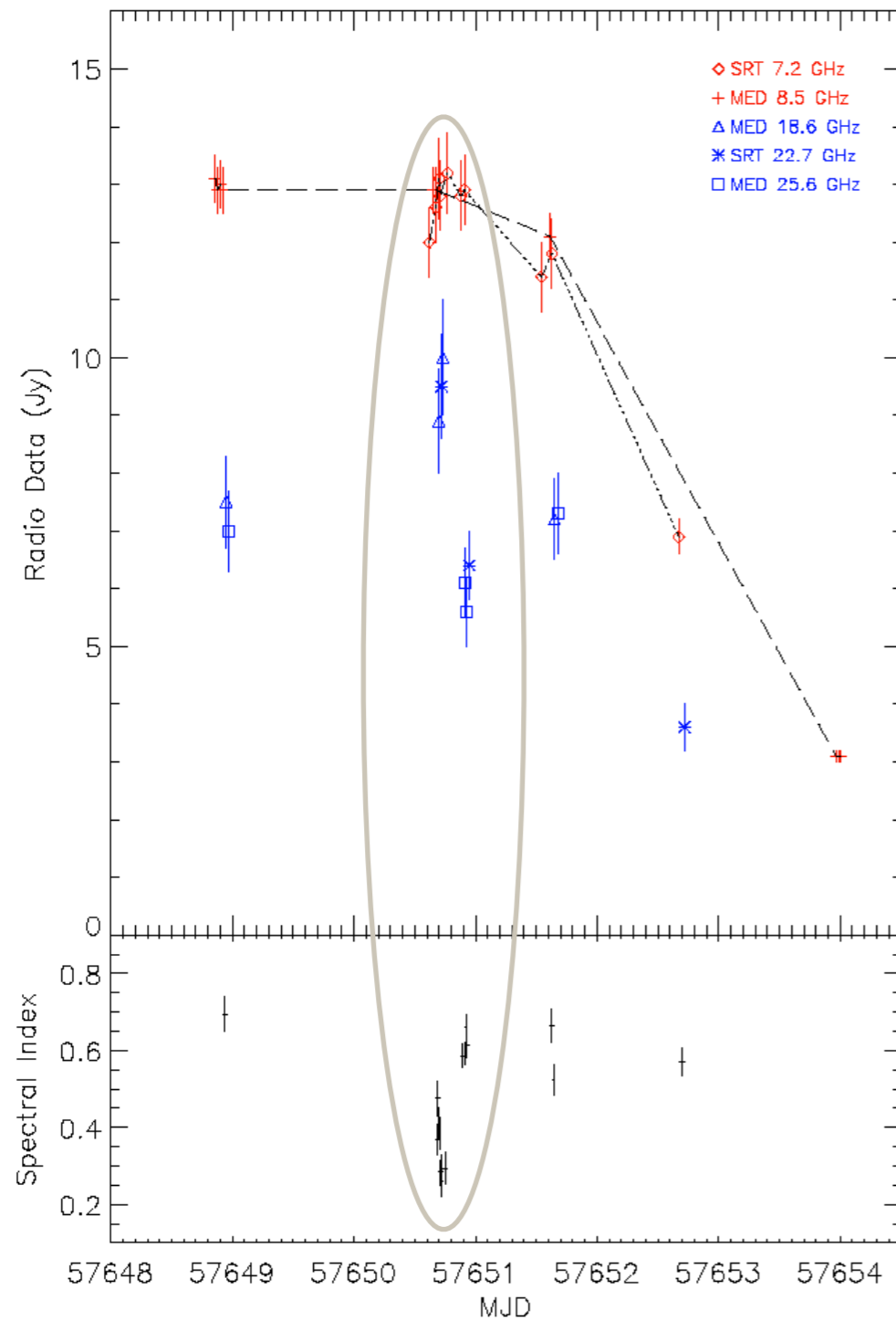


ToO Radio
observations



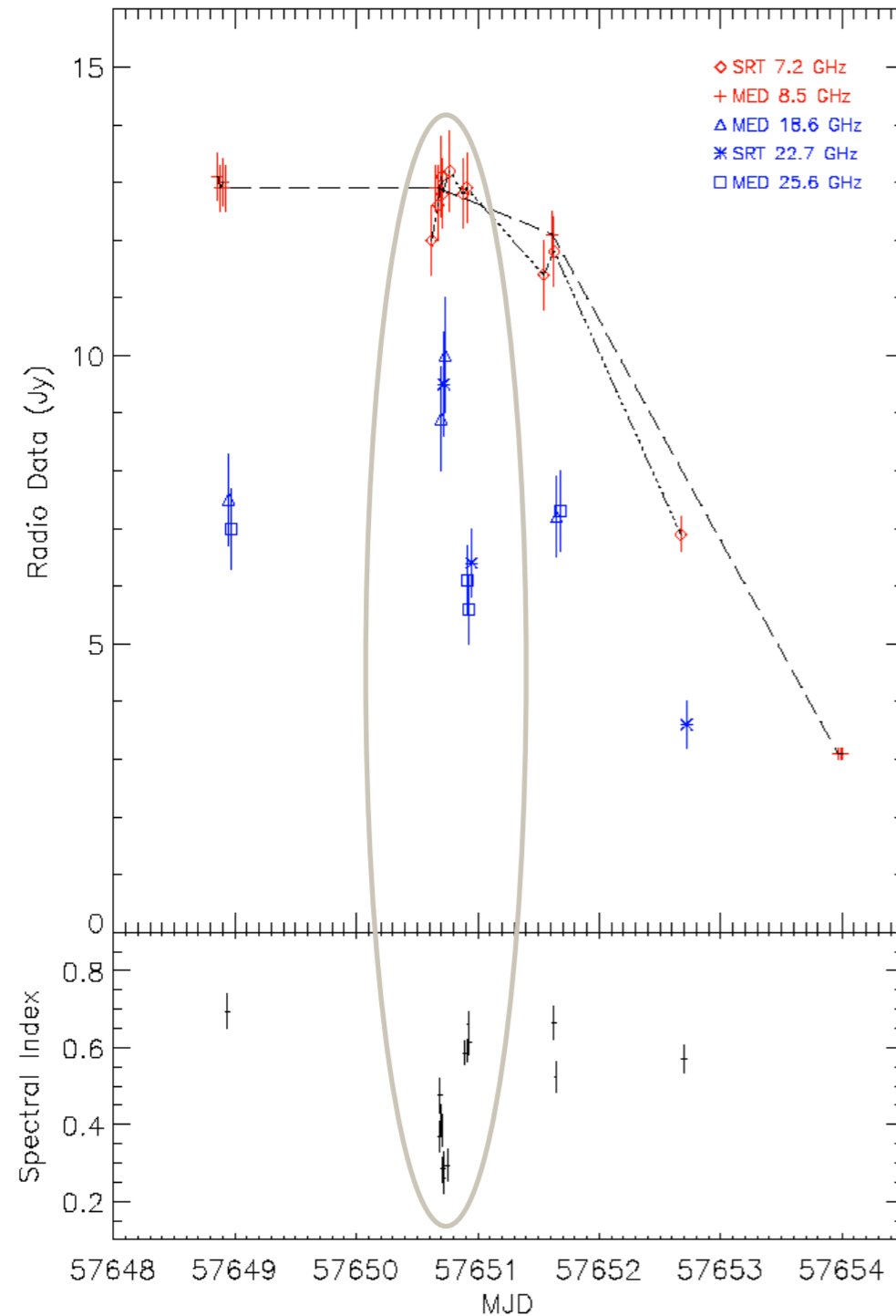
SRT and Medicina observations

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

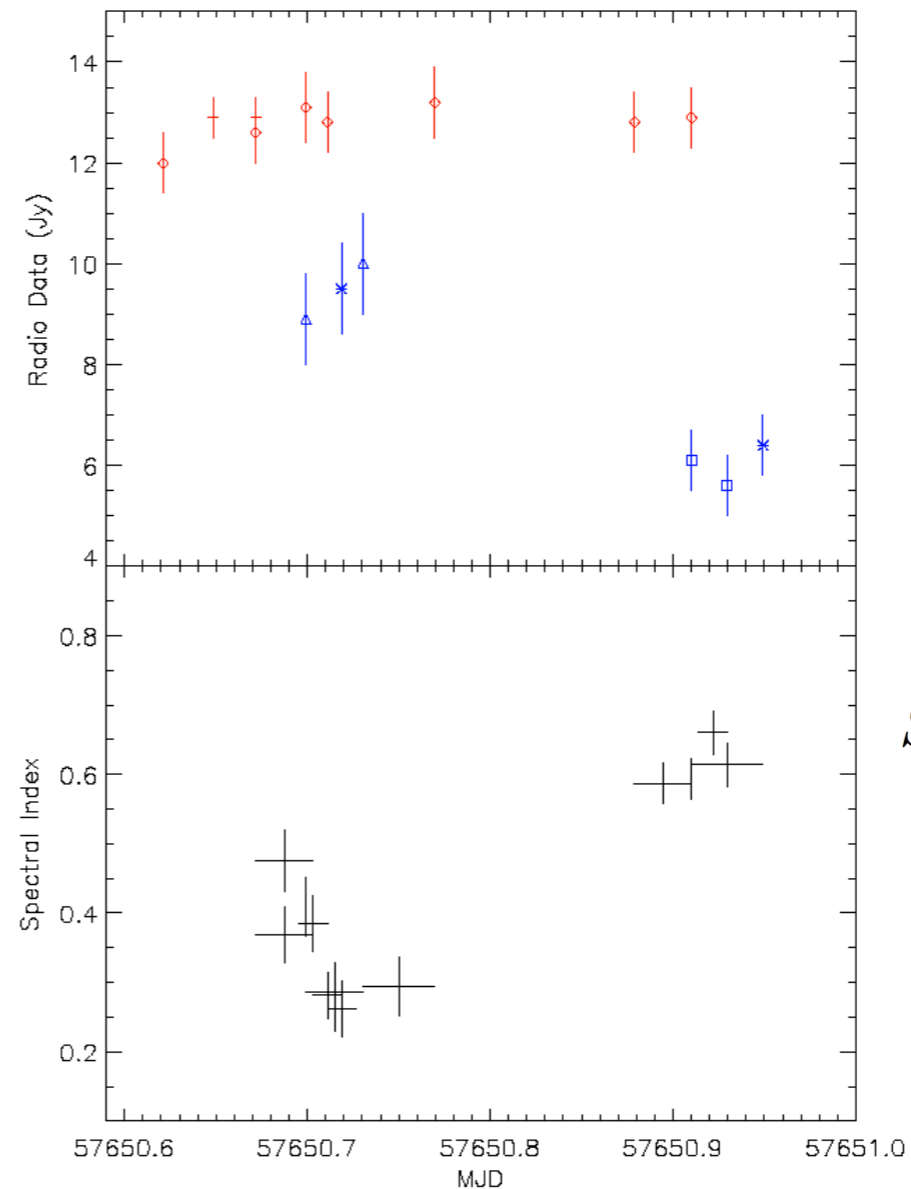


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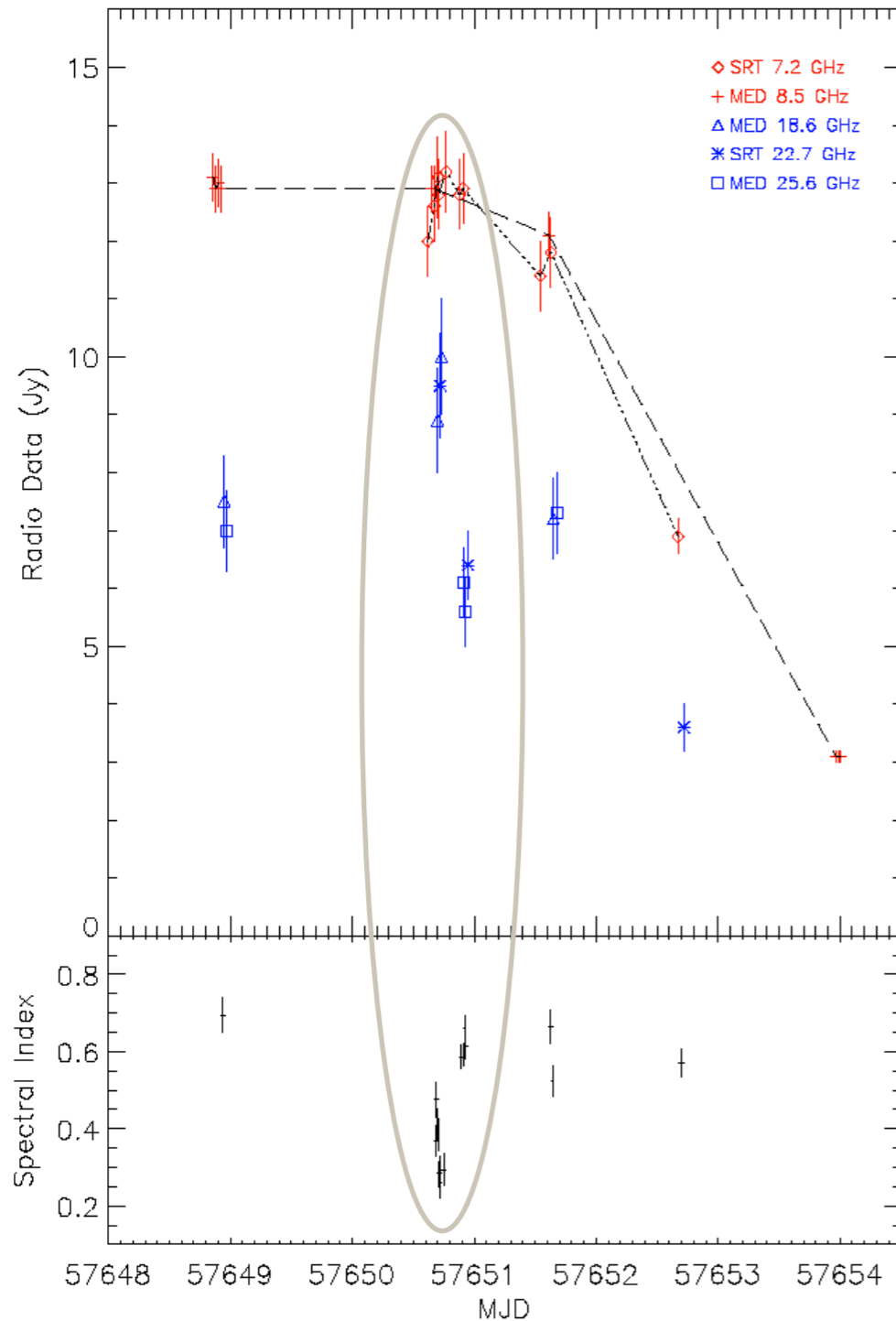
=> Clear spectral index change at the peak of the flare on 5 hrs!



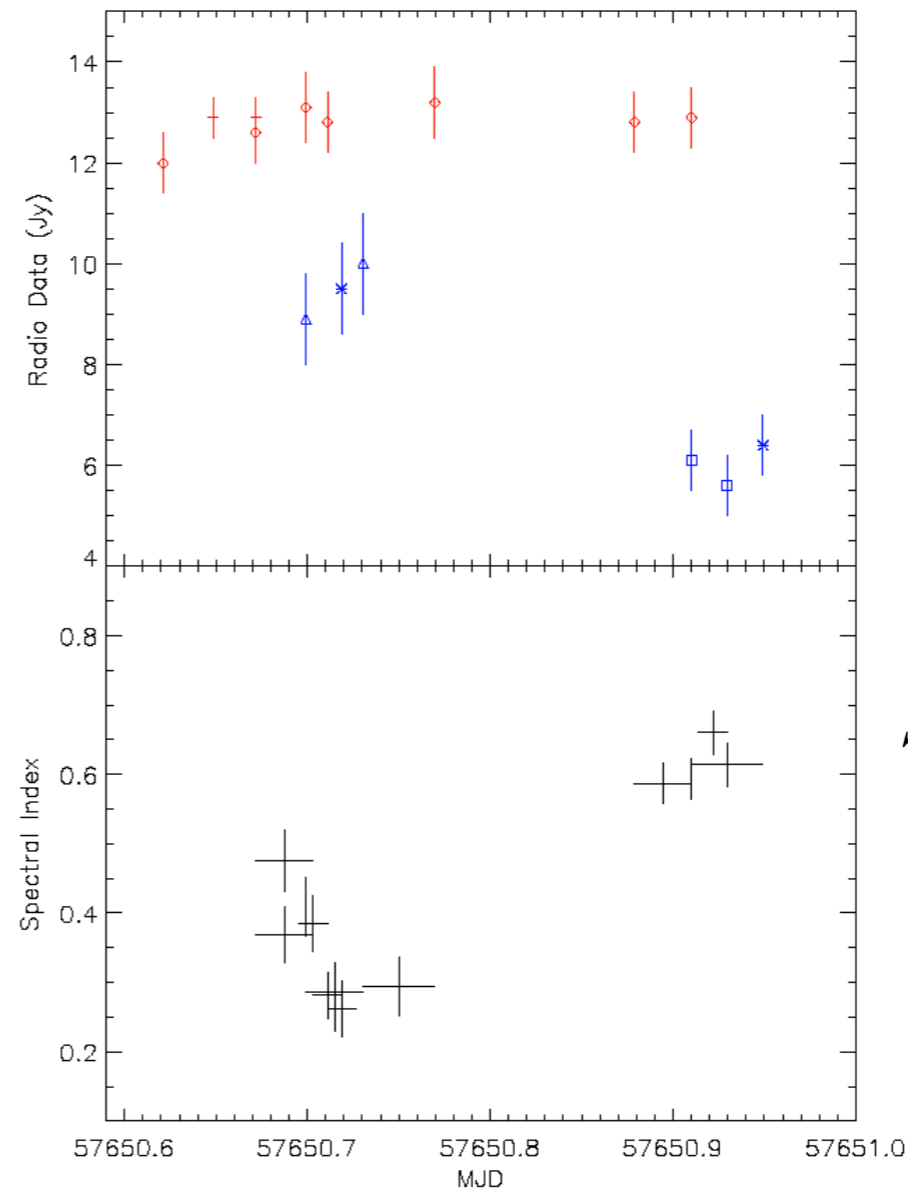
$$S_\nu \propto \nu^{-\alpha}$$

SRT and Medicina observations

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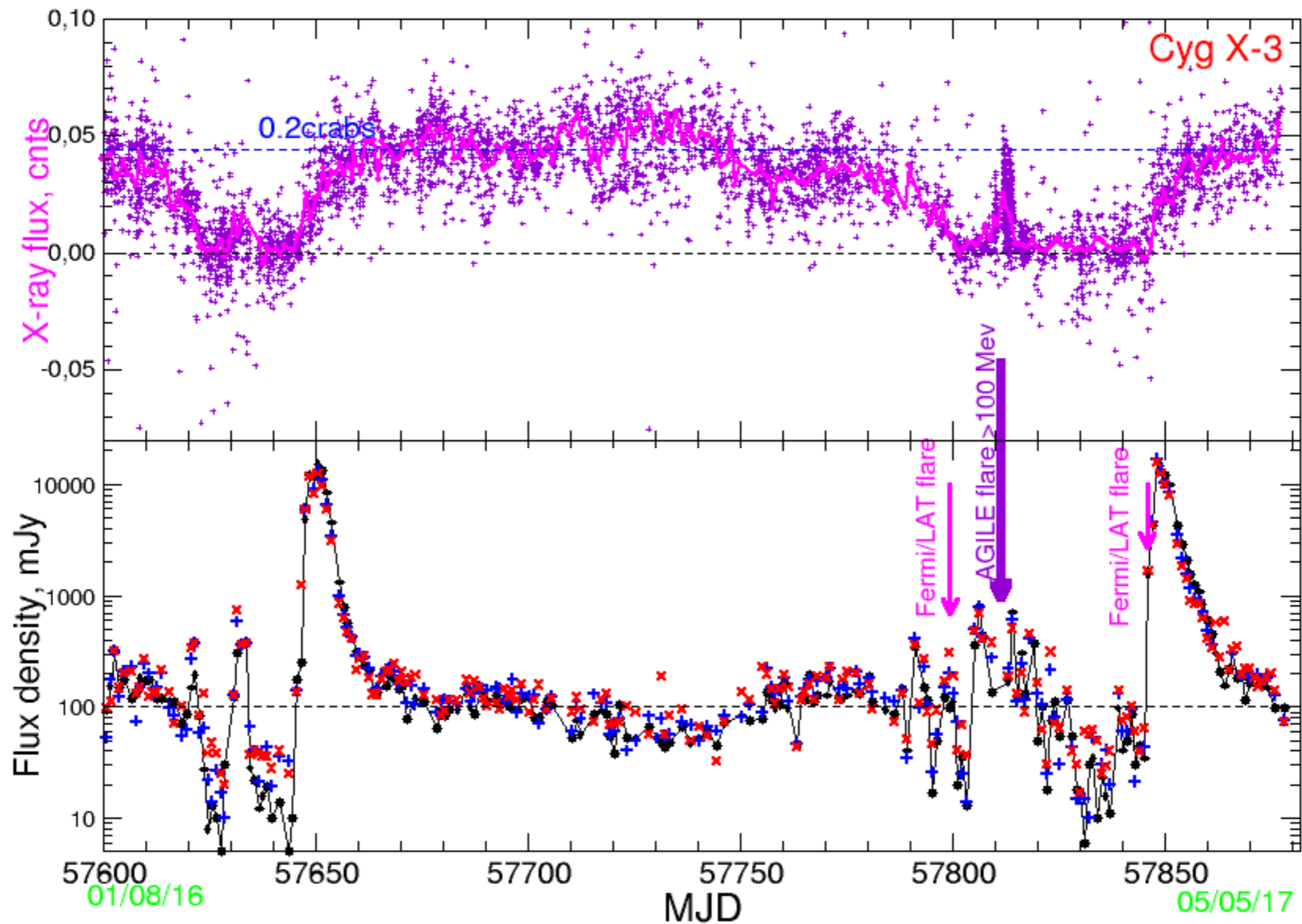
=> Evolution from optically thick to optically thin plasmons in expansion moving outward from the core



$$S_\nu \propto \nu^{-\alpha}$$

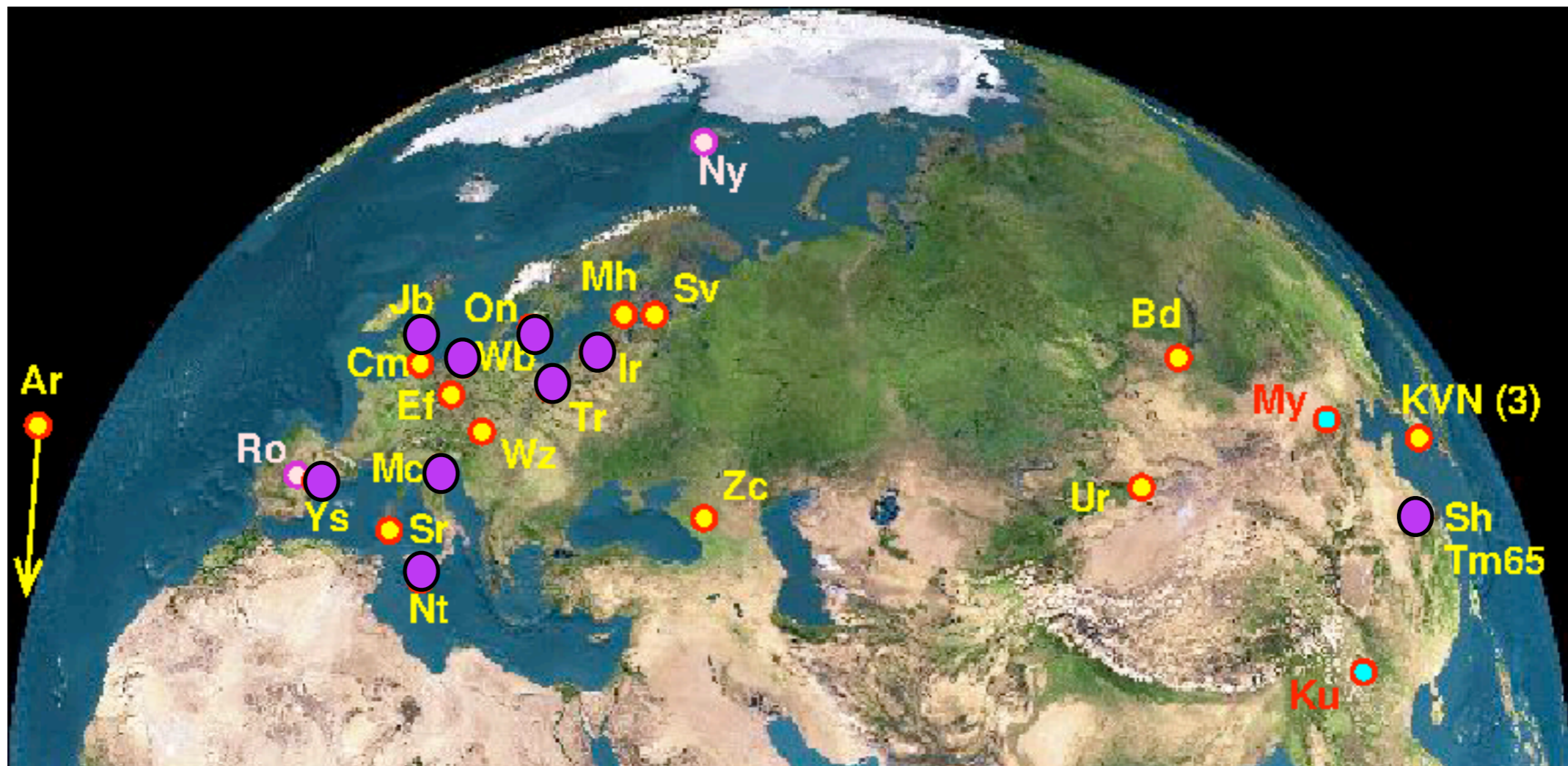
The giant flare in April 2017

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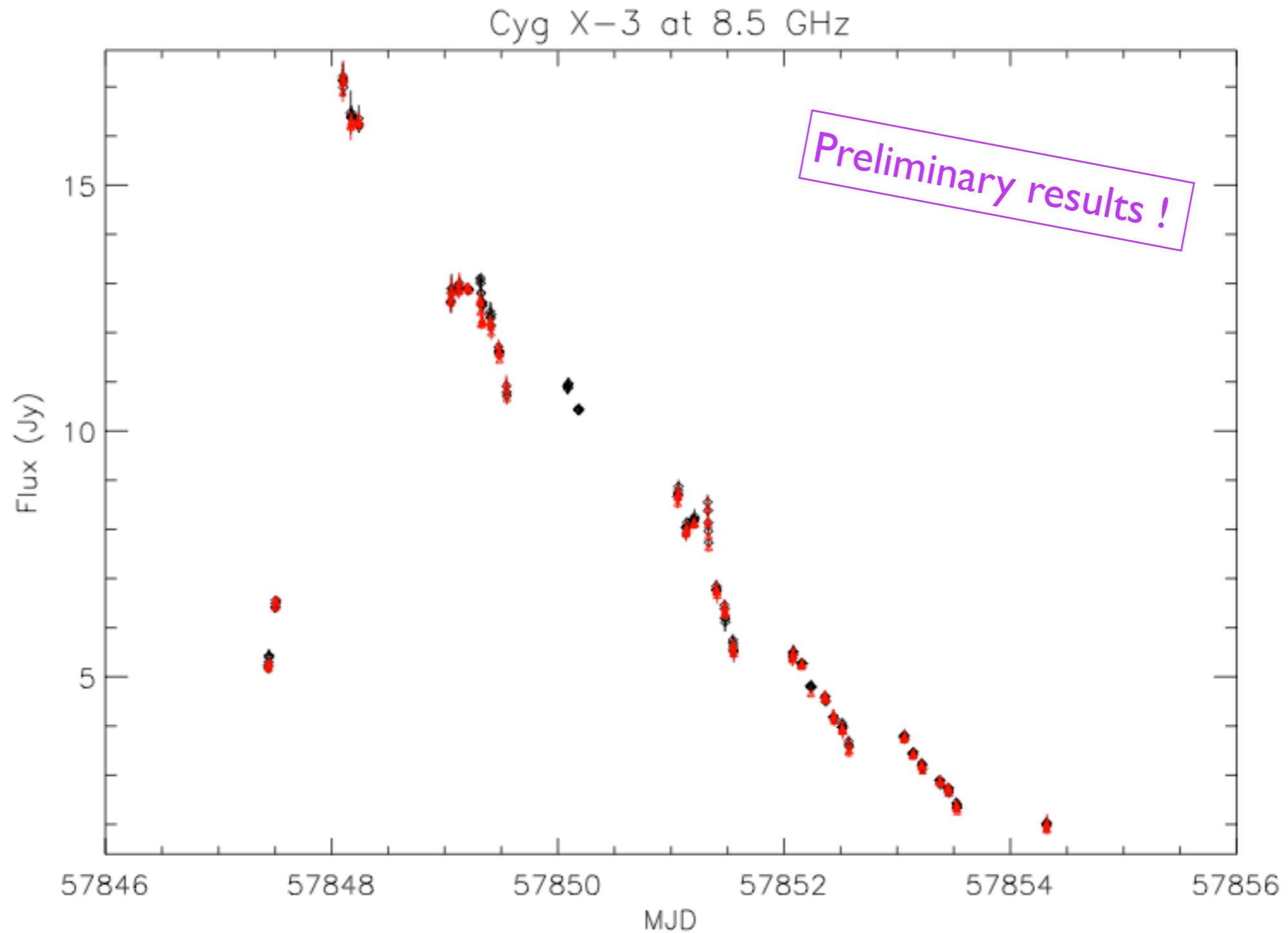


Radio observations in April 2017

- * 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 10 and 13 April for 15 hrs each: ●

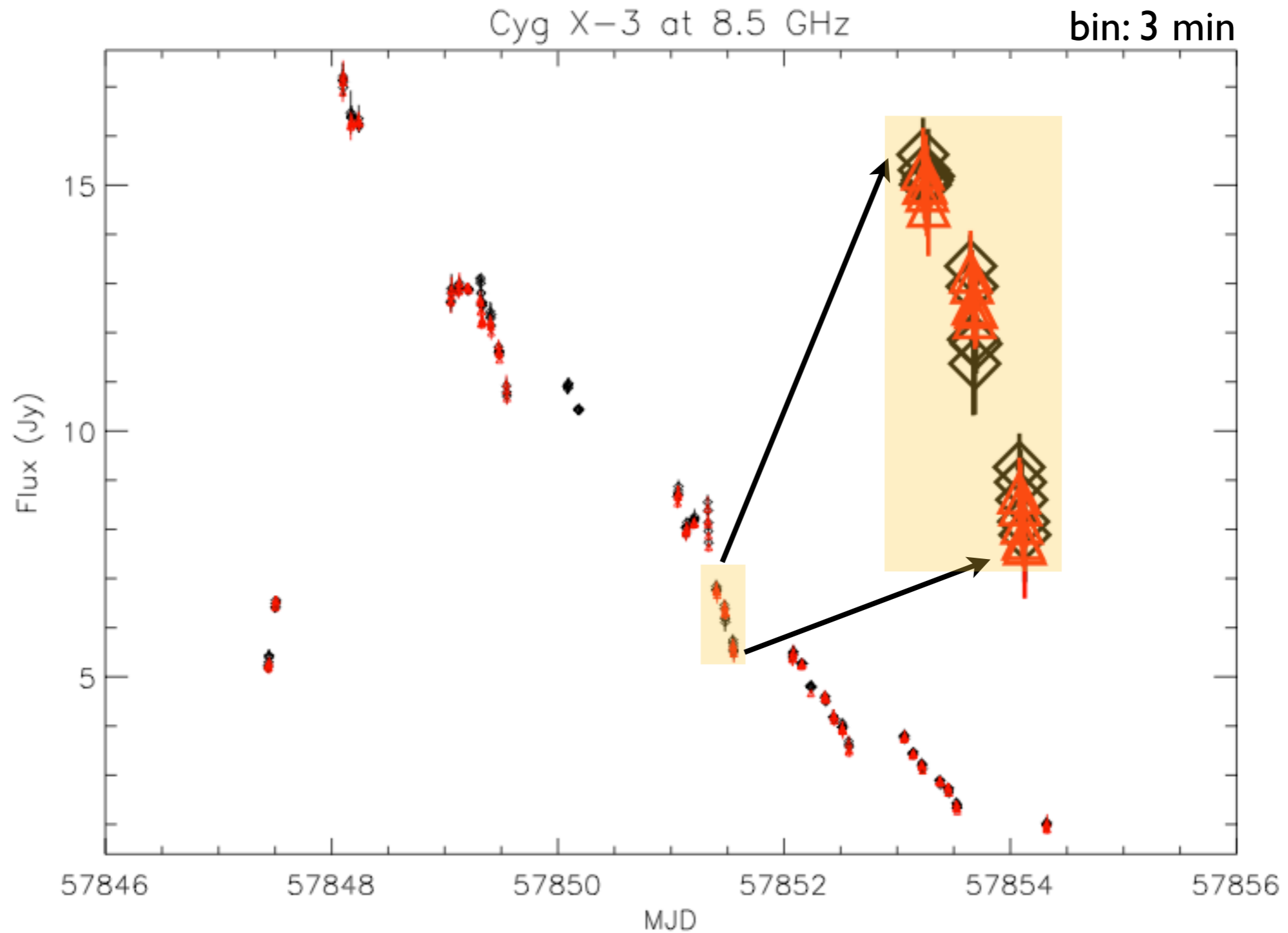


Medicina observations at 8.5 GHz



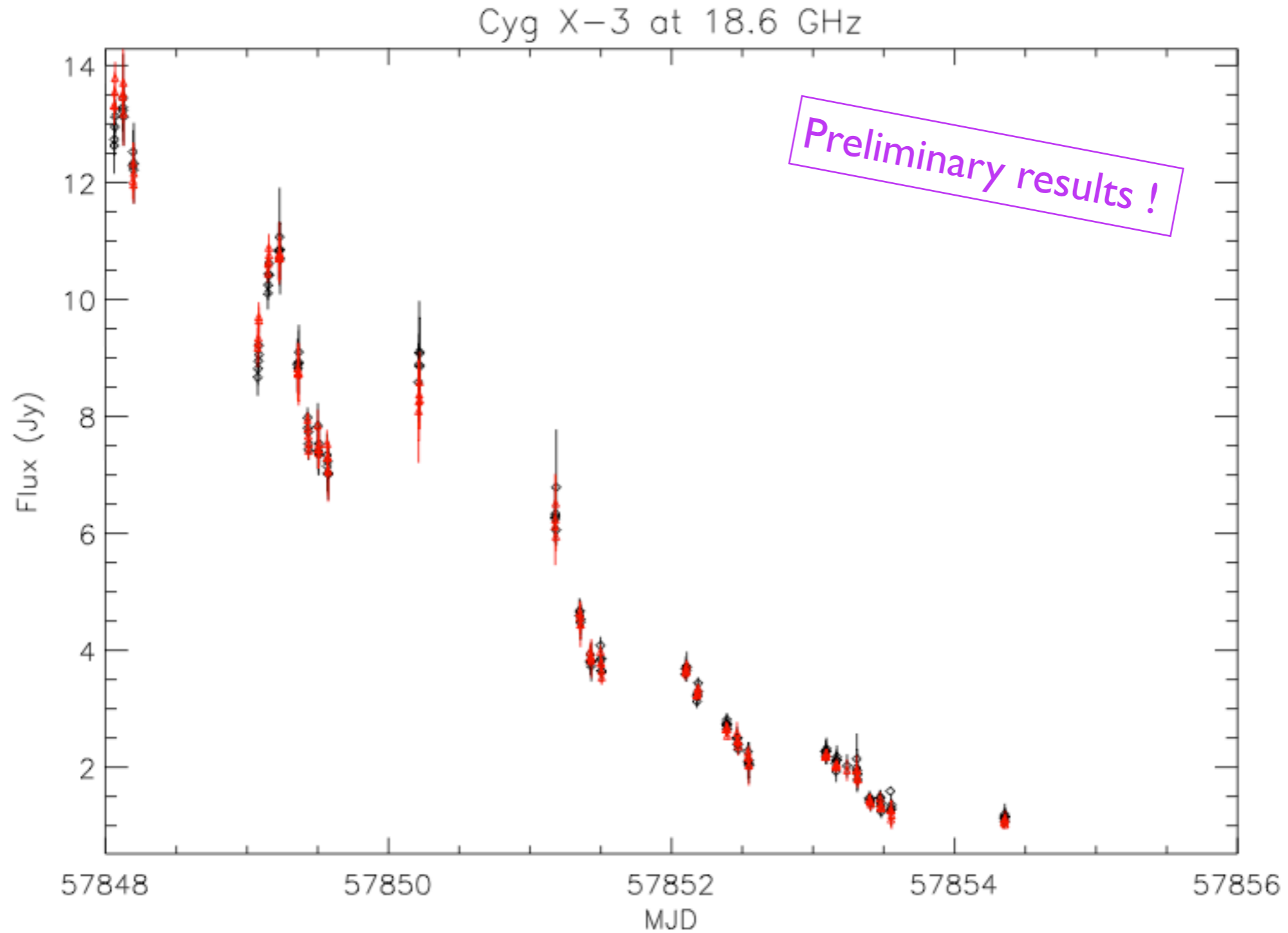
Peak reached on 5 April 2017, $F = 16.5 \pm 0.5$ Jy at 8.5 GHz

Medicina observations at 8.5 GHz



Peak reached on 5 April 2017, $F = 16.5 \pm 0.5$ Jy at 8.5 GHz

Medicina observations at 18.5 GHz

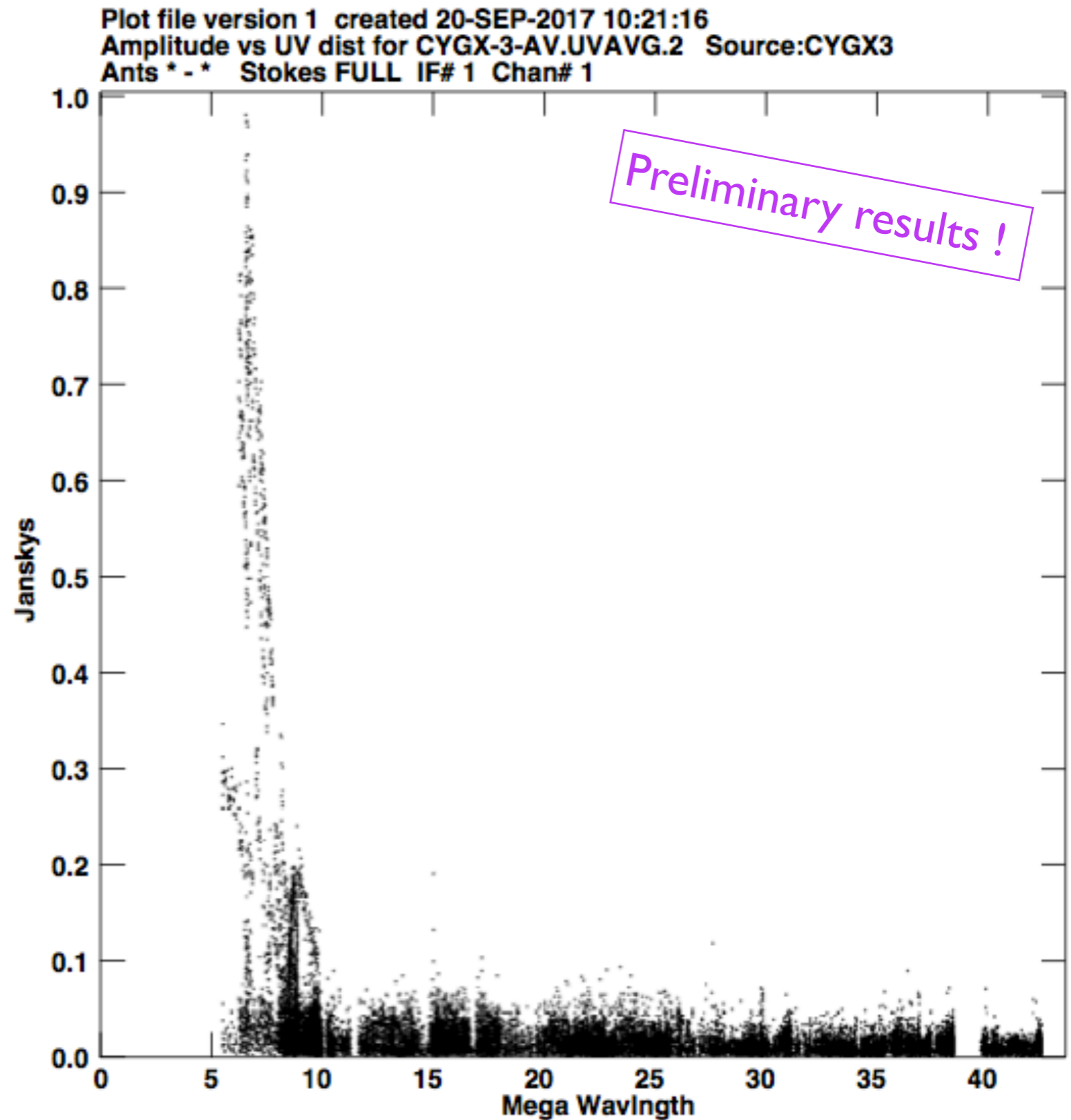


$F = 13 \pm 1$ Jy at 18.5 GHz on 5 April 2017

VLBI observations at 5 GHz on 10 April

* Amplitude of the visibility as a function of the baseline length :

=> extended structure

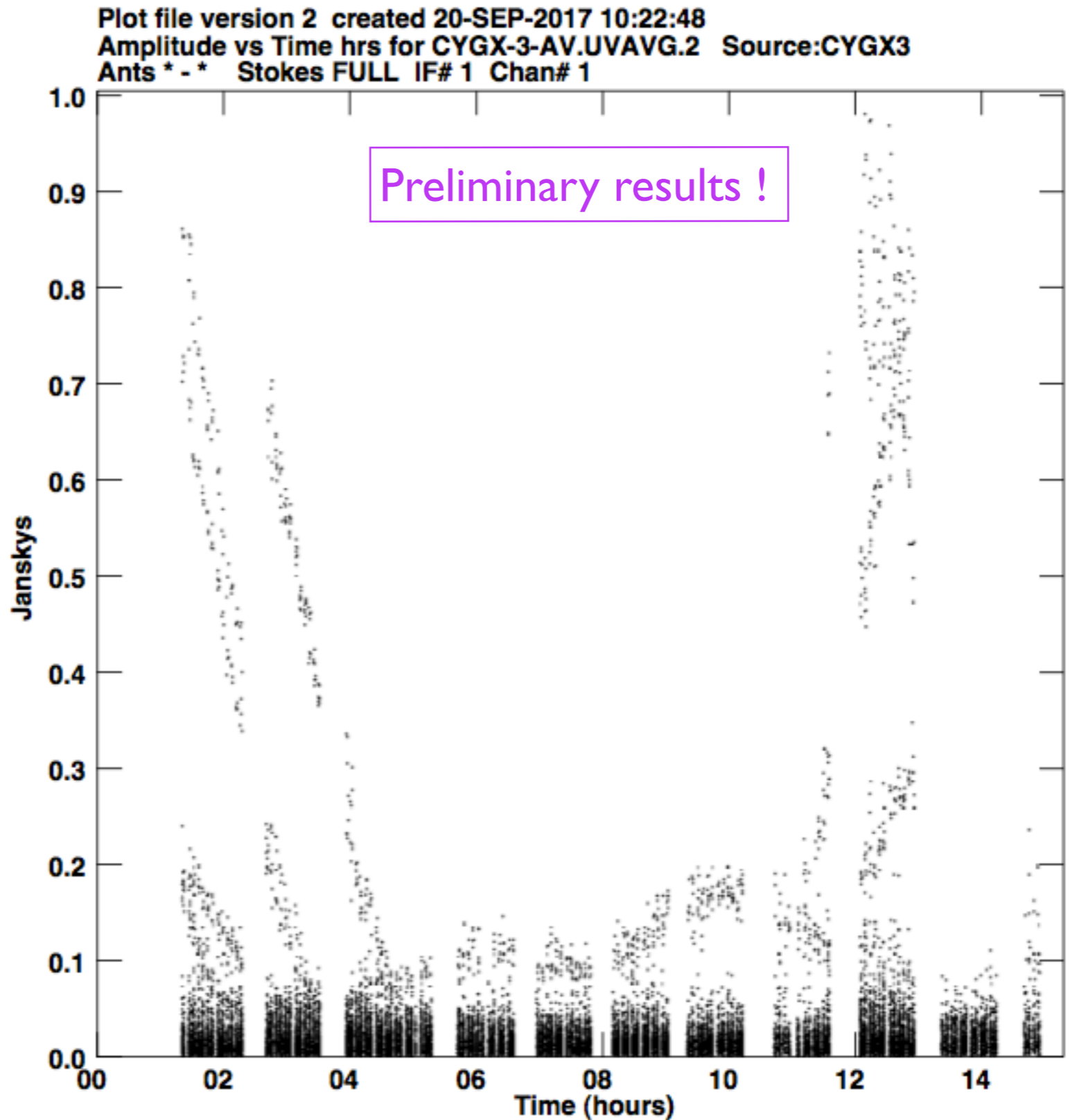


VLBI observations at 5 GHz on 10 April

* Amplitude of the visibility as a function of time :

=> strong variability

=> study on short time scales



Conclusions

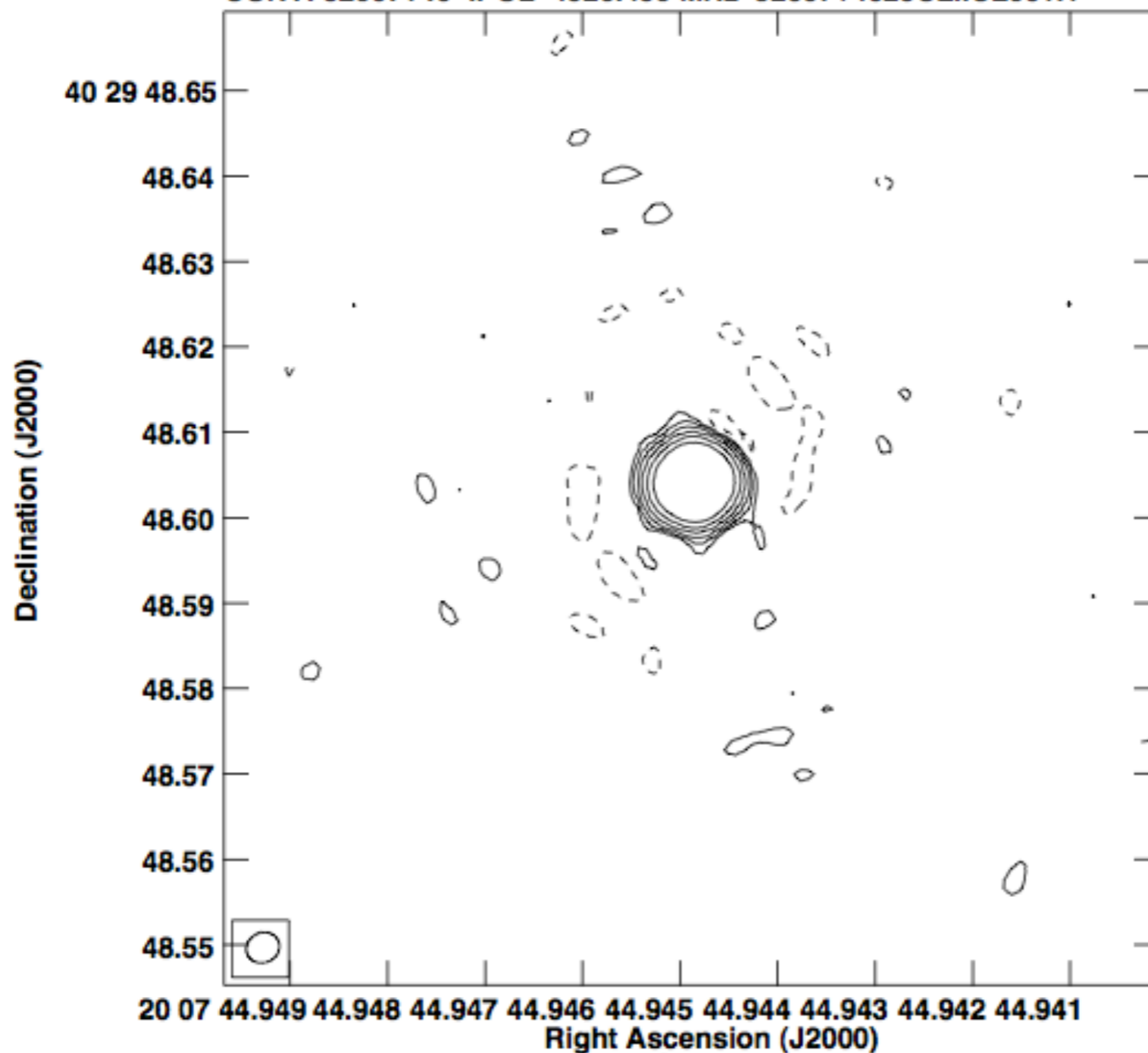
- * Rare, fascinating and complex case of giant radio flares in Cyg X-3
- * Mini radio flare in 2016: ejection close to the core, associated with a slight increase of the size of the emitting component
- * Giant radio flares in 2016 and 2017: transition from the hypersoft to a harder X-ray state, jet extended, with emission of blobs of plasma at the peak of the radio flux in 2016
- * Why do we observe such giant flares in Cyg X-3 ?
What is the disk - jet connection during giant flares ?
What is the role of the strong wind from the companion star ?
- * Use the Italian antennas in single dish and/or VLBI !

Thanks!



Calibrator J2007+4029

Plot file version 1 created 22-SEP-2017 18:00:14
CONT: J2007+40 IPOL 4926.490 MHz J2007+4029CL.ICL001.1



Cont peak flux = 9.9139E-01 JY/BEAM
Levs = 3.186E-03 * (-1, 1, 2, 4, 8, 16, 32)