VLBI observations of microquasars: the case of Cygnus X-3

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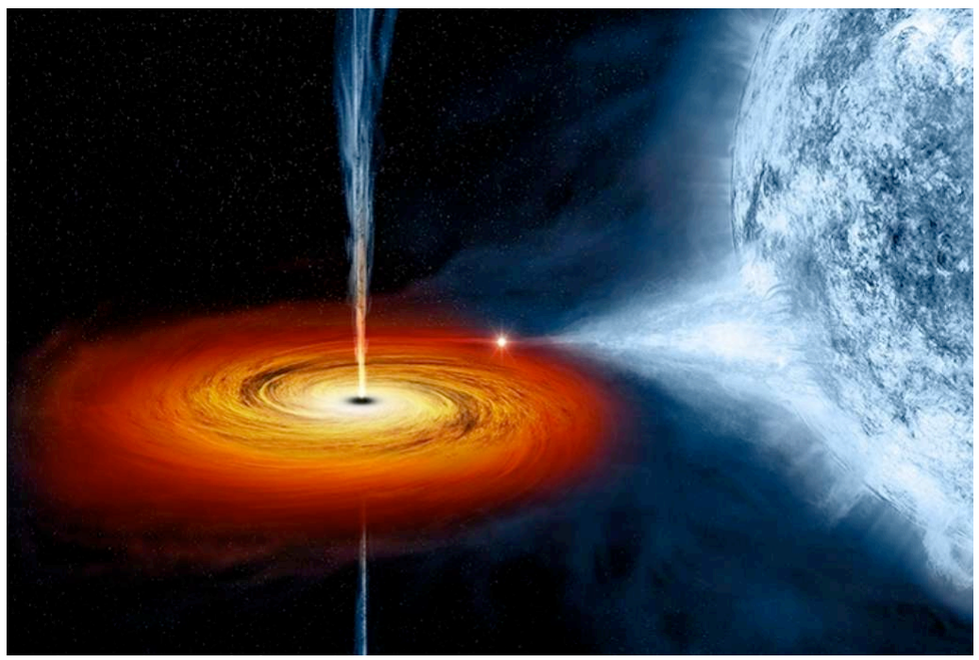
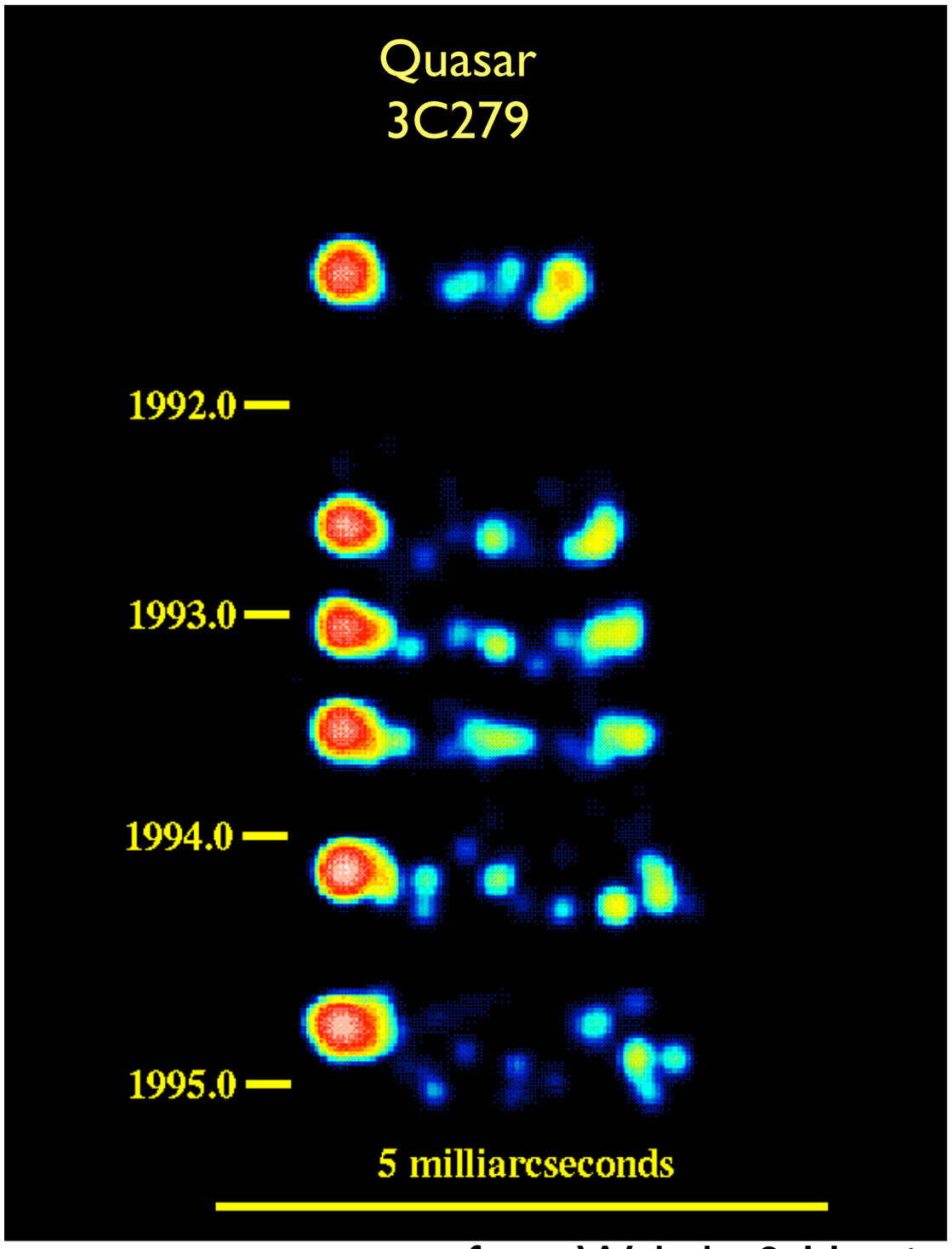
In collaboration with:

M. Giroletti, A. Pellizzoni, S. Righini, V. Tudose,
G. Surcis, C. Migoni, A. Melis et al.



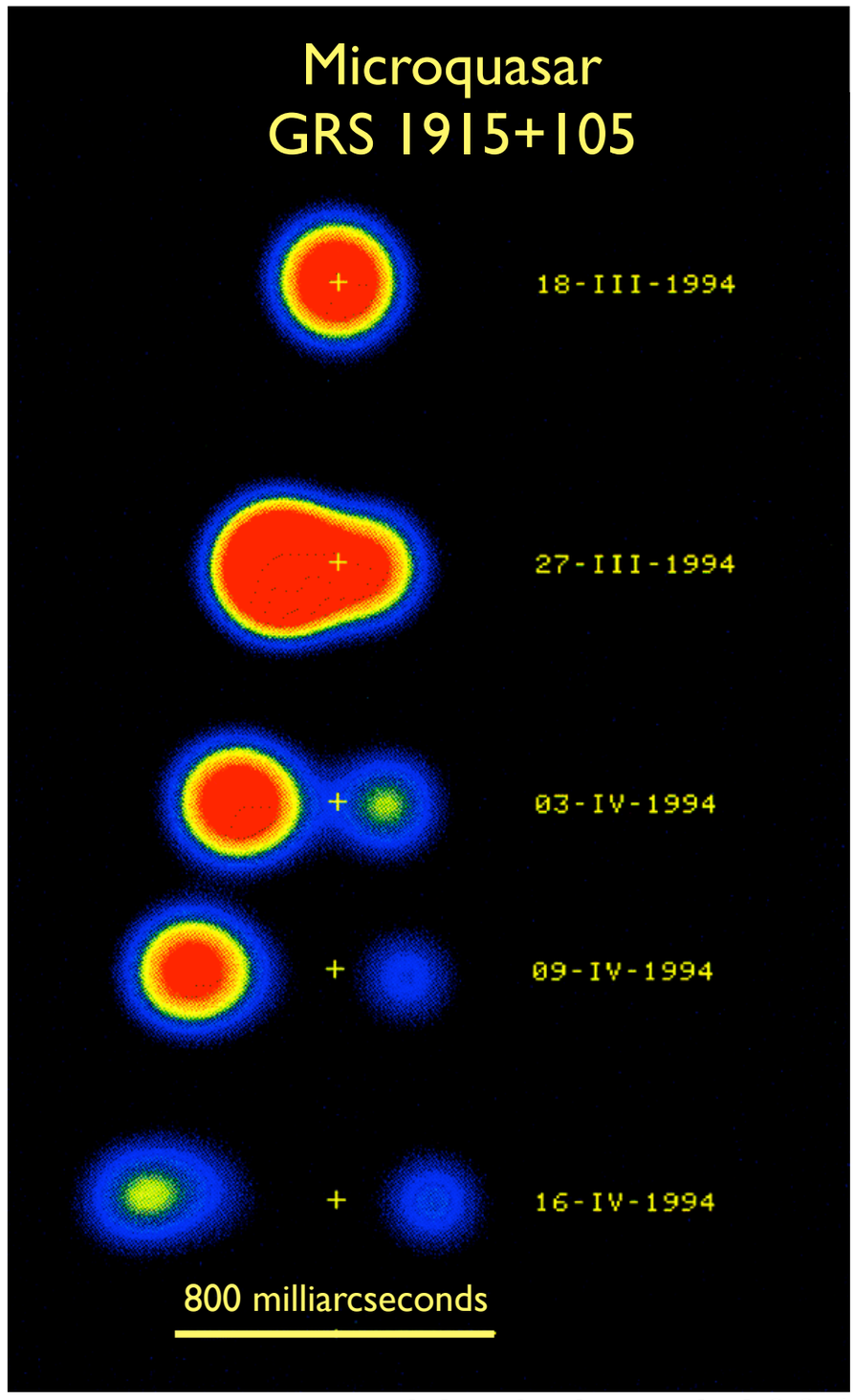
Relativistic jets in quasars and microquasars

VLBI at 1.3 cm



from Wehrle & Unwin

VLA at 3.5 cm

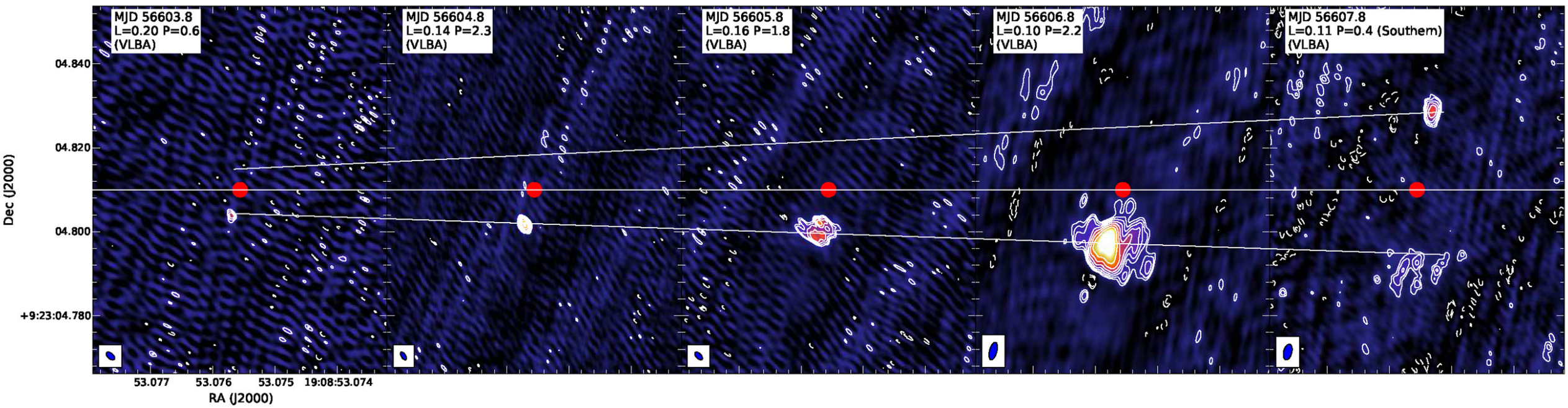


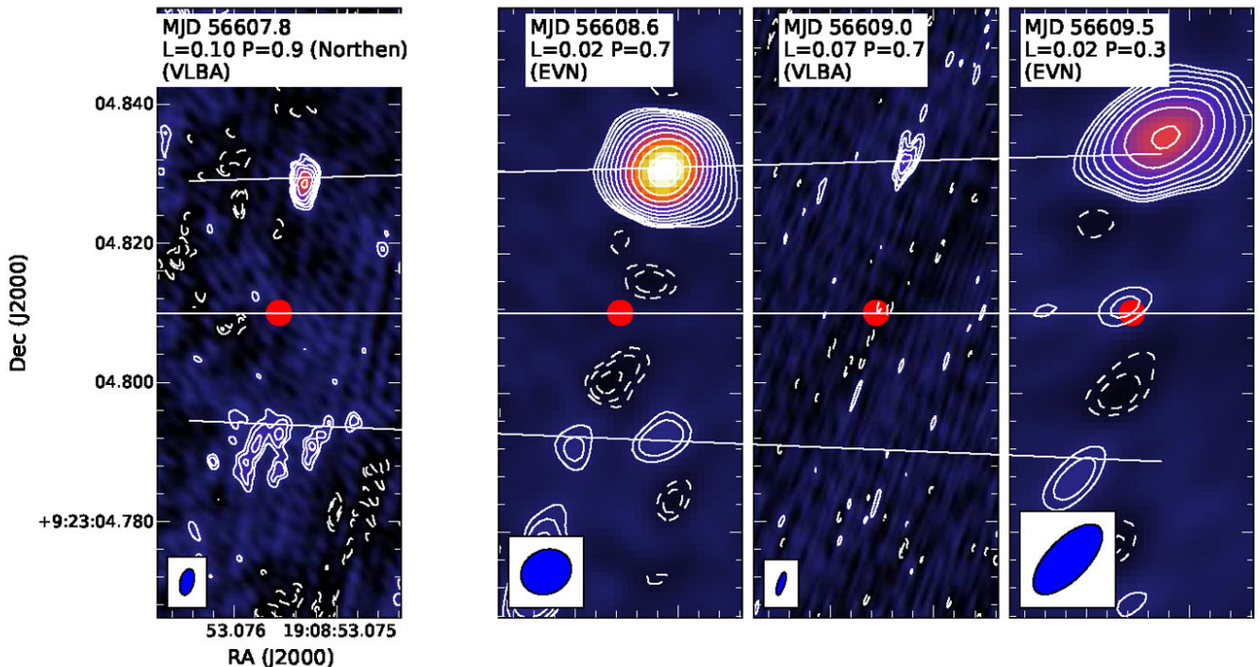
Mirabel et al. 1994

Resolved, expanding jets in XTE J1908+094

* Joint e-EVN/VLBA observations over 7 days during the 2013 outburst

* Moving jet knots: evolving morphology, impacting unusually dense ISM





Rushton et al. 2017

Why observing microquasars with VLBI ?

* Microquasars : accretion-ejection processes on human timescales

* Ideal laboratories to study :

  - link between accretion and ejection
  - jet launching
  - jet evolution in real time
  - particle acceleration to relativistic energies
  - interaction with ISM

* VLBI provides morphology, speed, direction of jets

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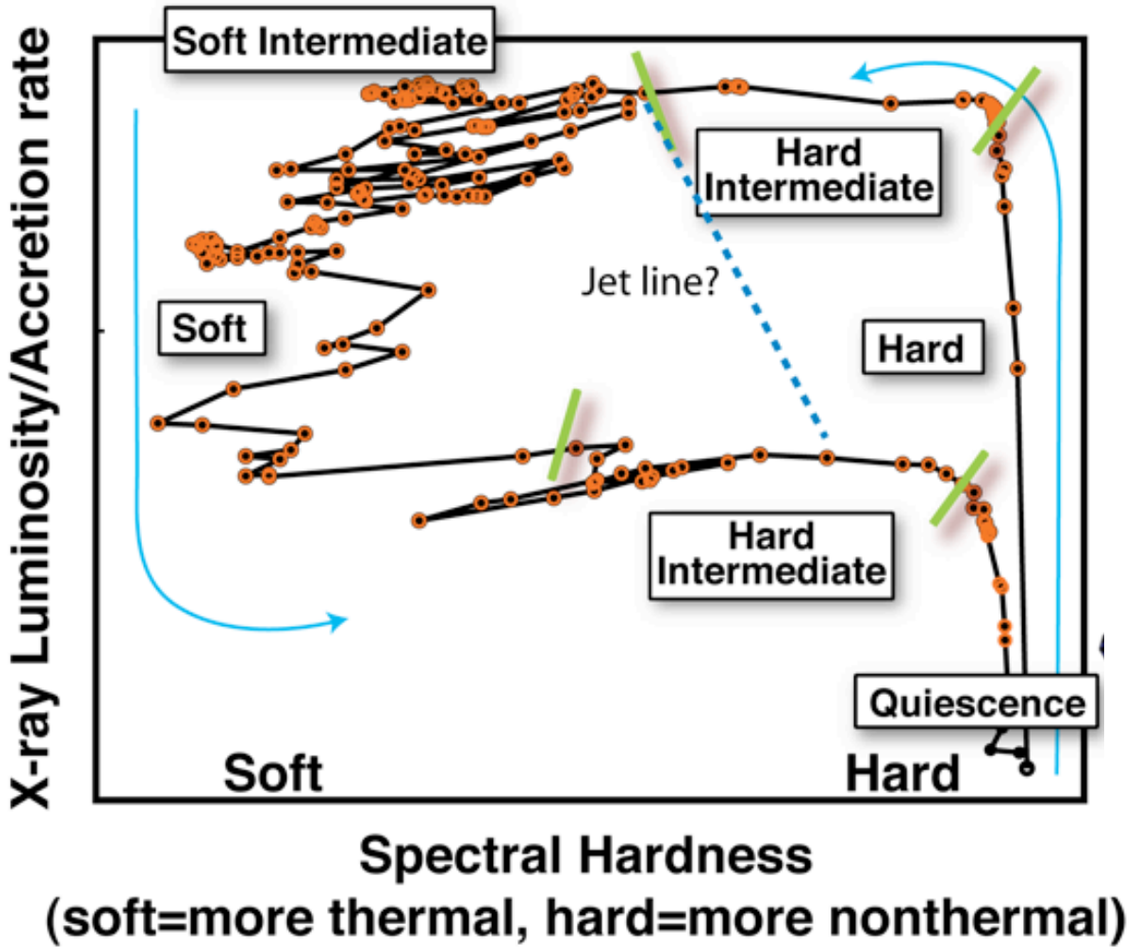
When observing microquasars with VLBI ?

The typical evolution of microquasars during outbursts

* Inner accretion-flow variability :
  => X-ray state changes



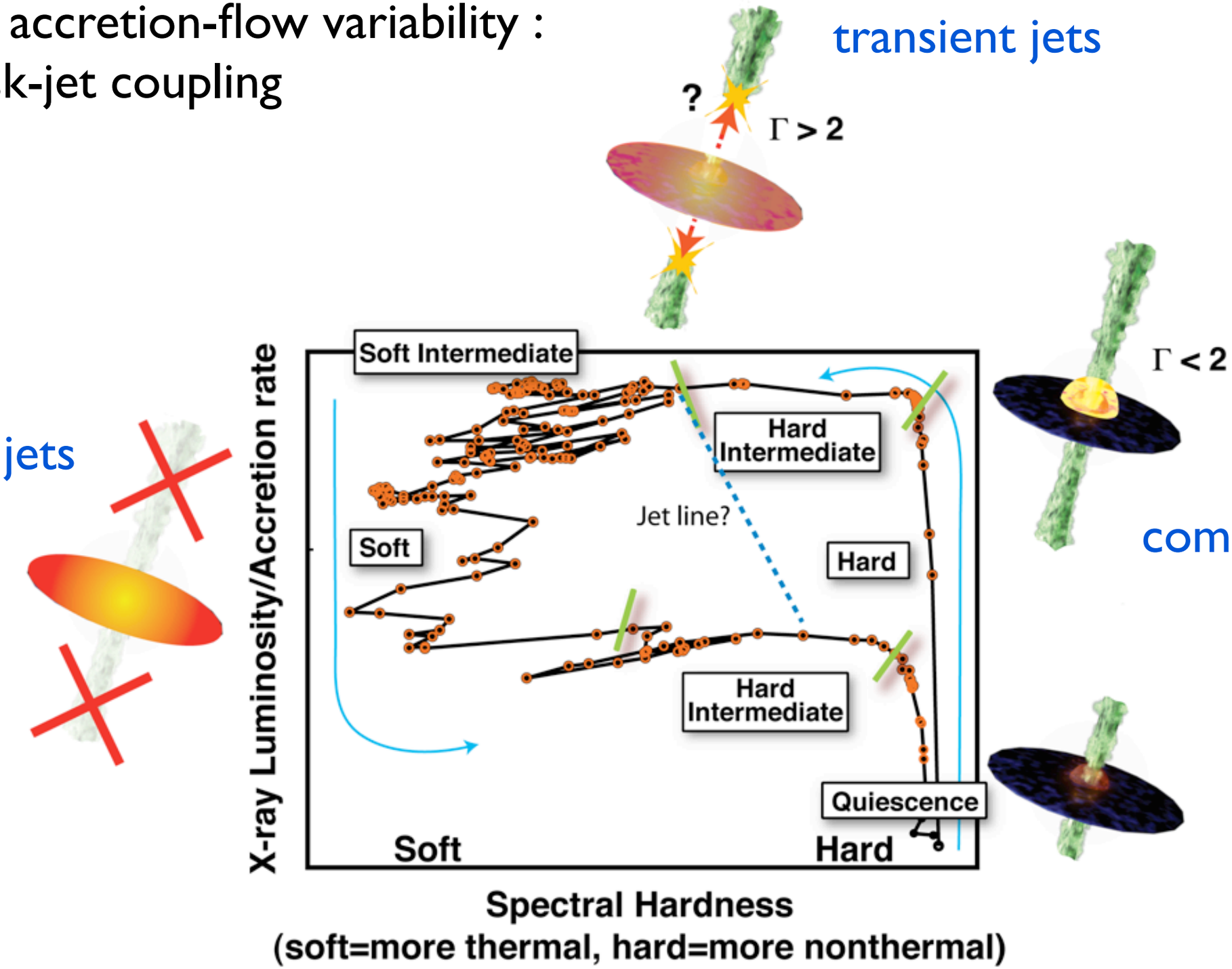
The typical evolution of microquasars during outbursts

* Inner accretion-flow variability :
  => disk-jet coupling

transient jets

quenched jets

compact jets



The particular case of Cygnus X-3

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

* Short orbital period: 4.8 hr, distance 7.4 kpc

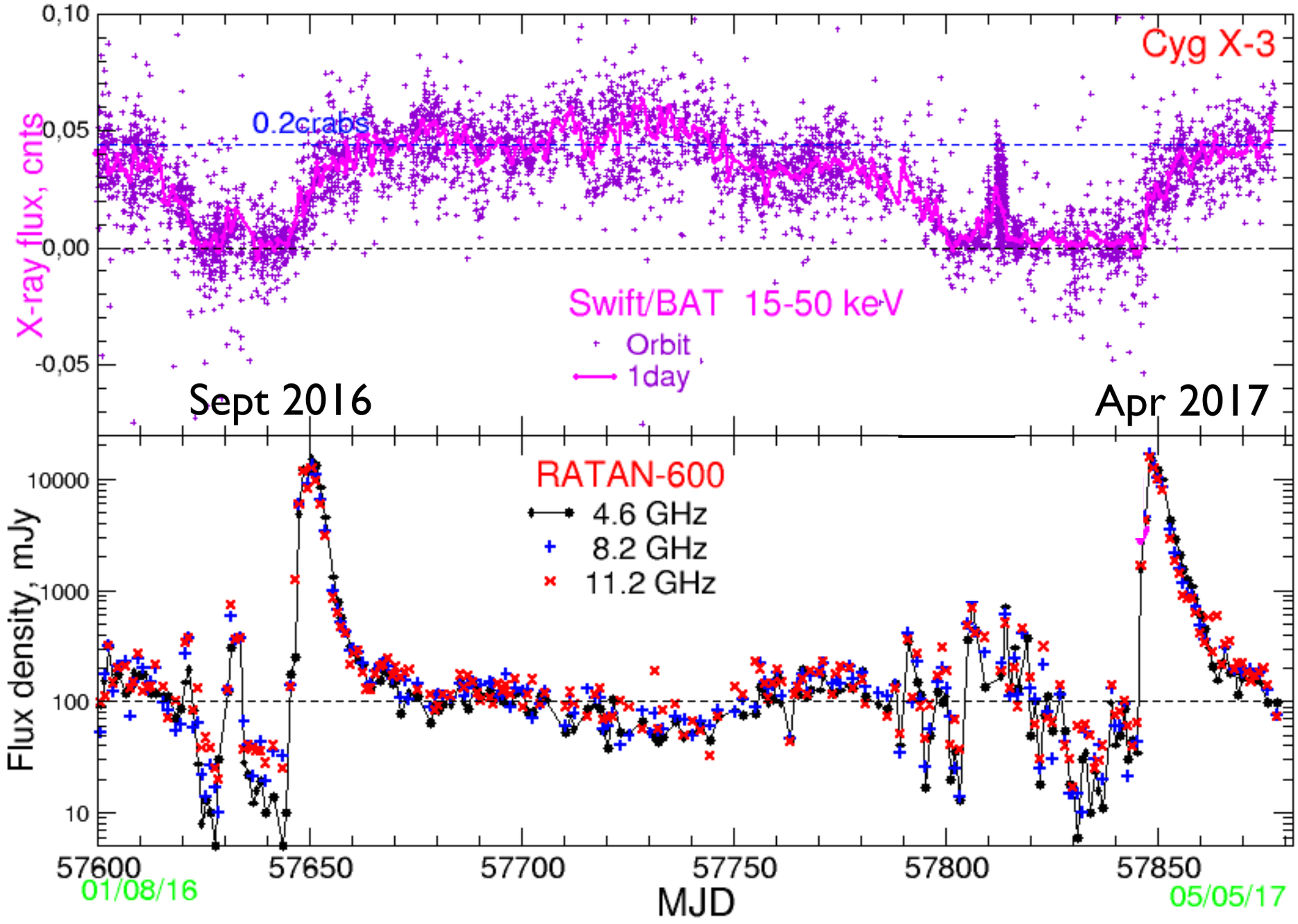
* The brightest X-ray binary in radio :

=> Giant radio flares of 10-20 Jy after quenched radio state (< 30 mJy)

=> Transition from the hypersoft X-ray state to a harder state

Radio and X-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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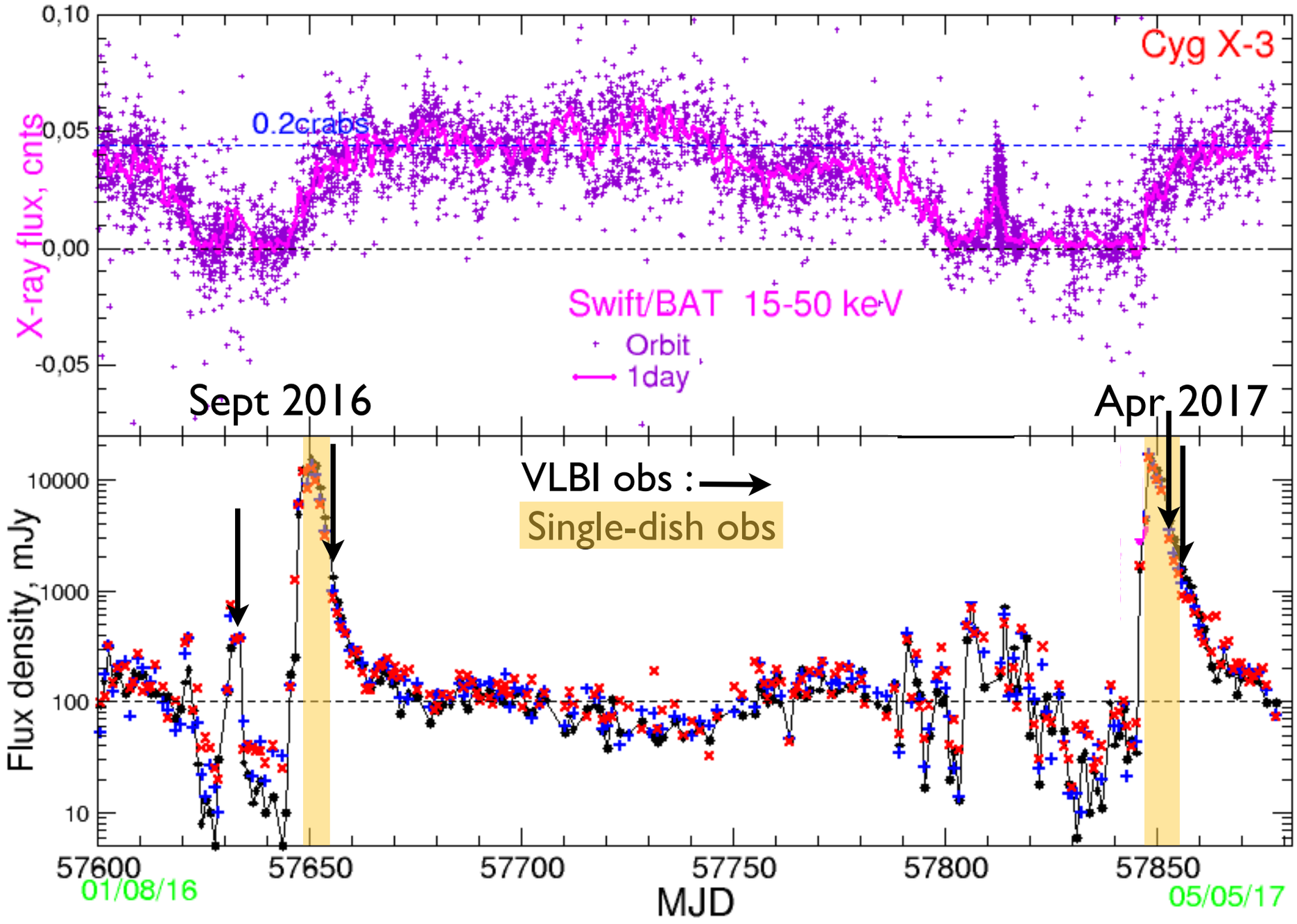


The giant radio flare in Sept 2016

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

=> Comparison between mini and giant flares

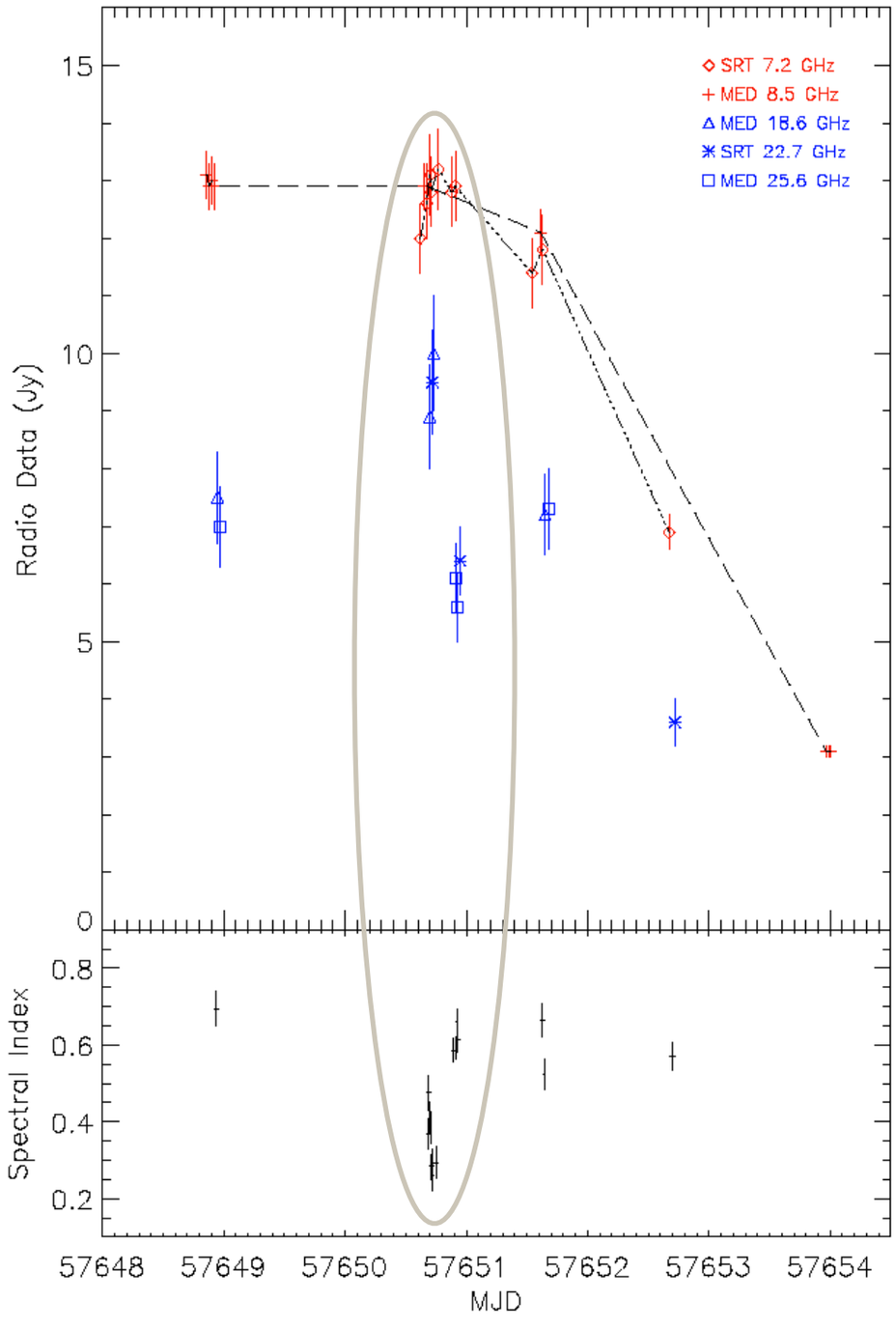
* Single-dish observations with SRT and Medicina at 7.2, 8.5, 18.6, 22.7, 25.6 GHz

=> Monitoring of the giant flare over 6 days

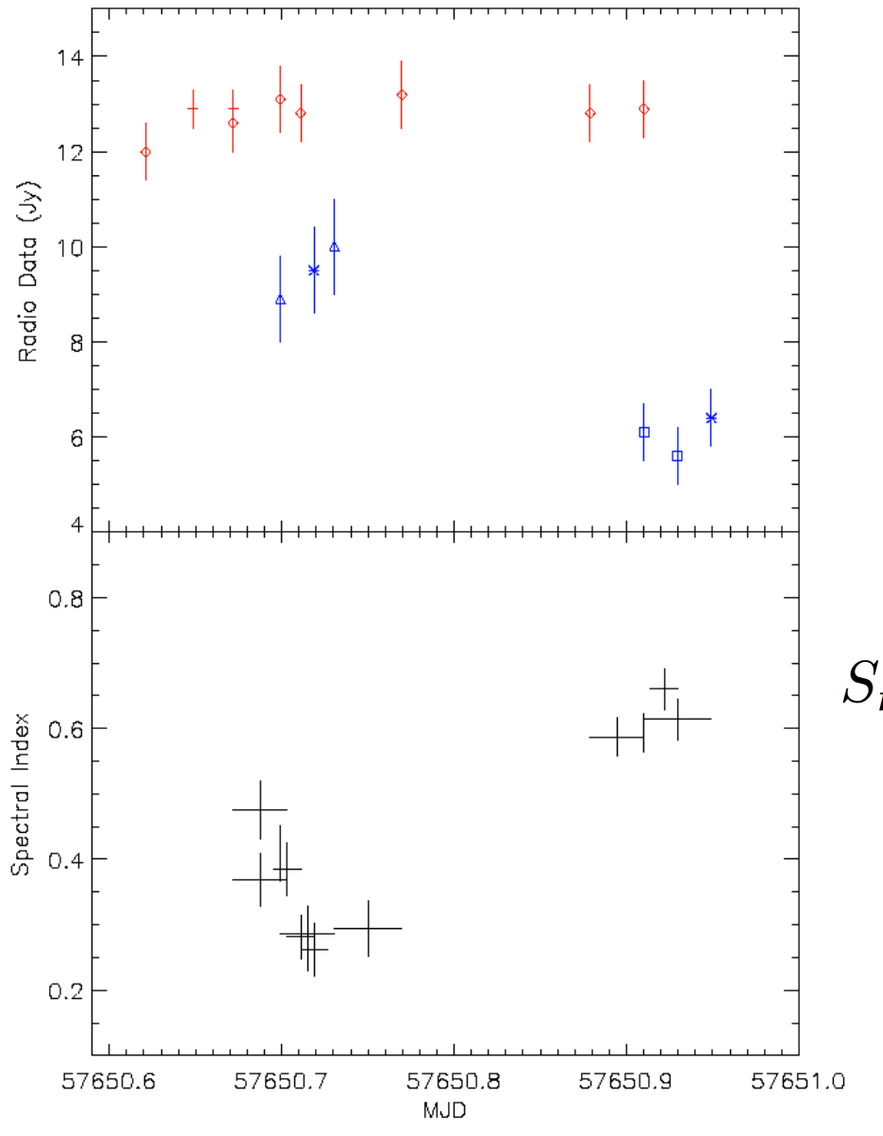
Credits: S. Loru

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!

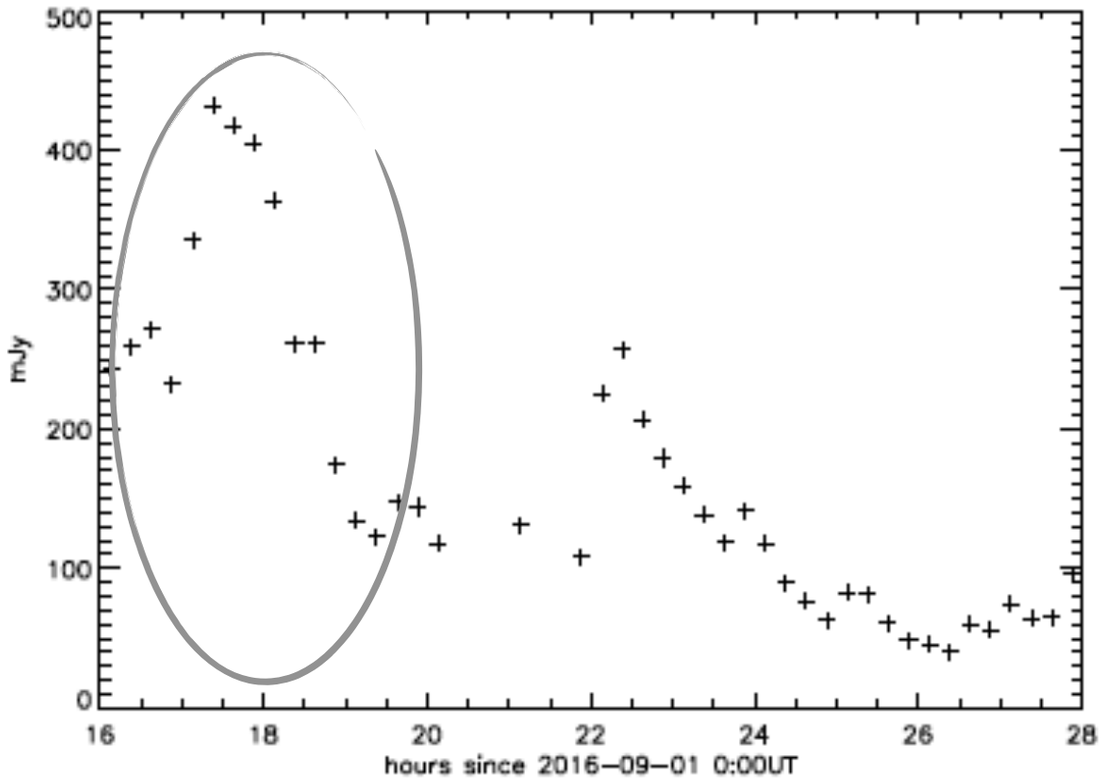


$$S_\nu \propto \nu^{-\alpha}$$

Egron et al. 2017

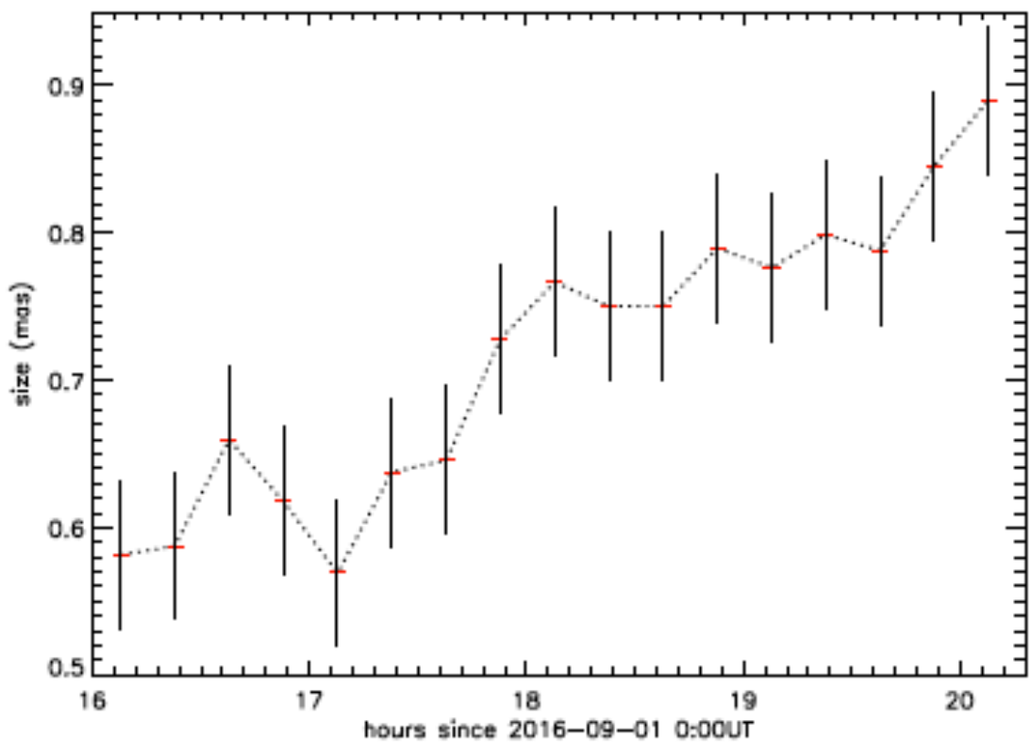
VLBI observations during the mini-flare

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



Egron et al. 2017

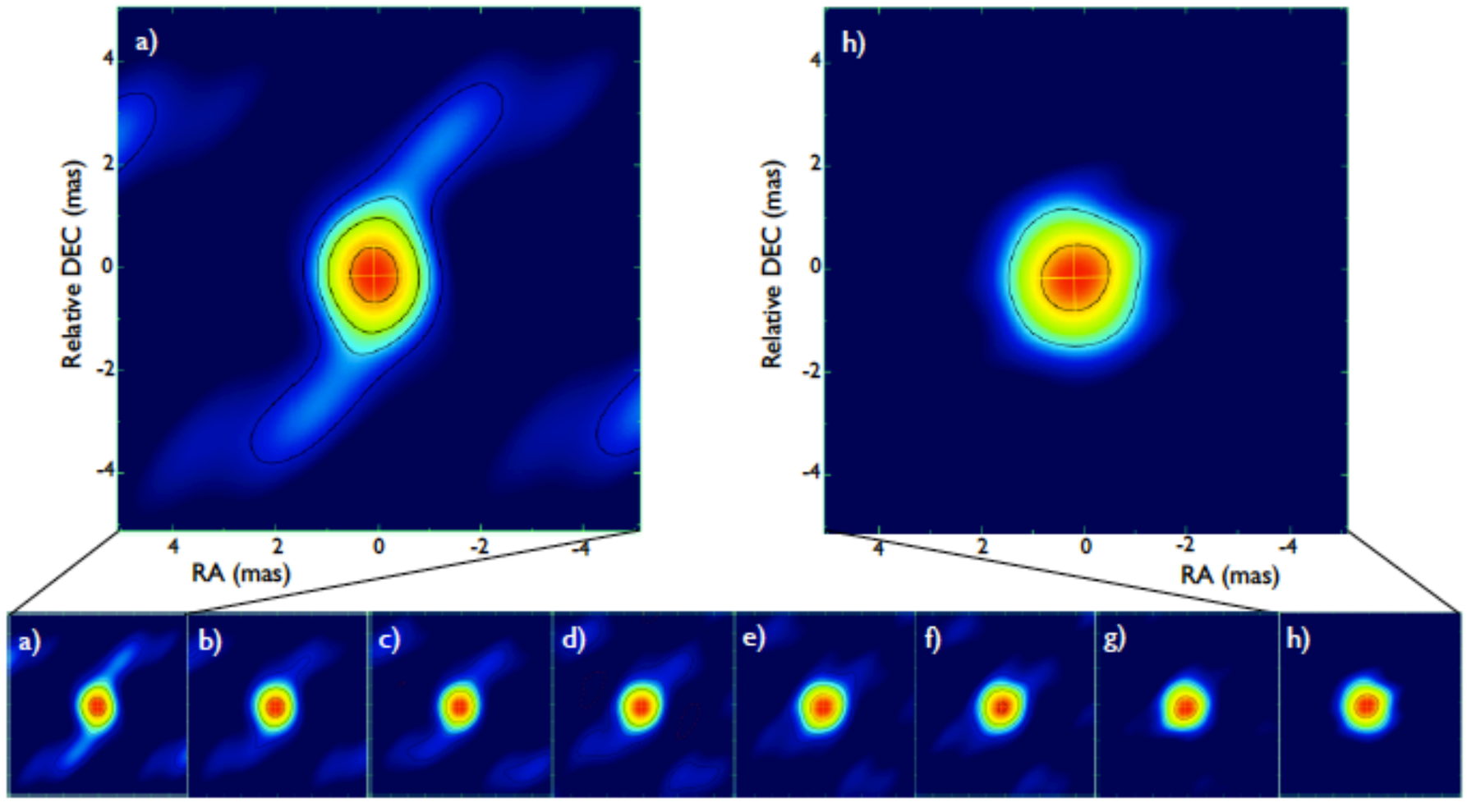
* Radius in mas of the emitting component
=> expansion of the region from 0.6 to 0.9



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 : compact jets



Egron et al. 2017

VLBI obs at the end of the 2016 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.

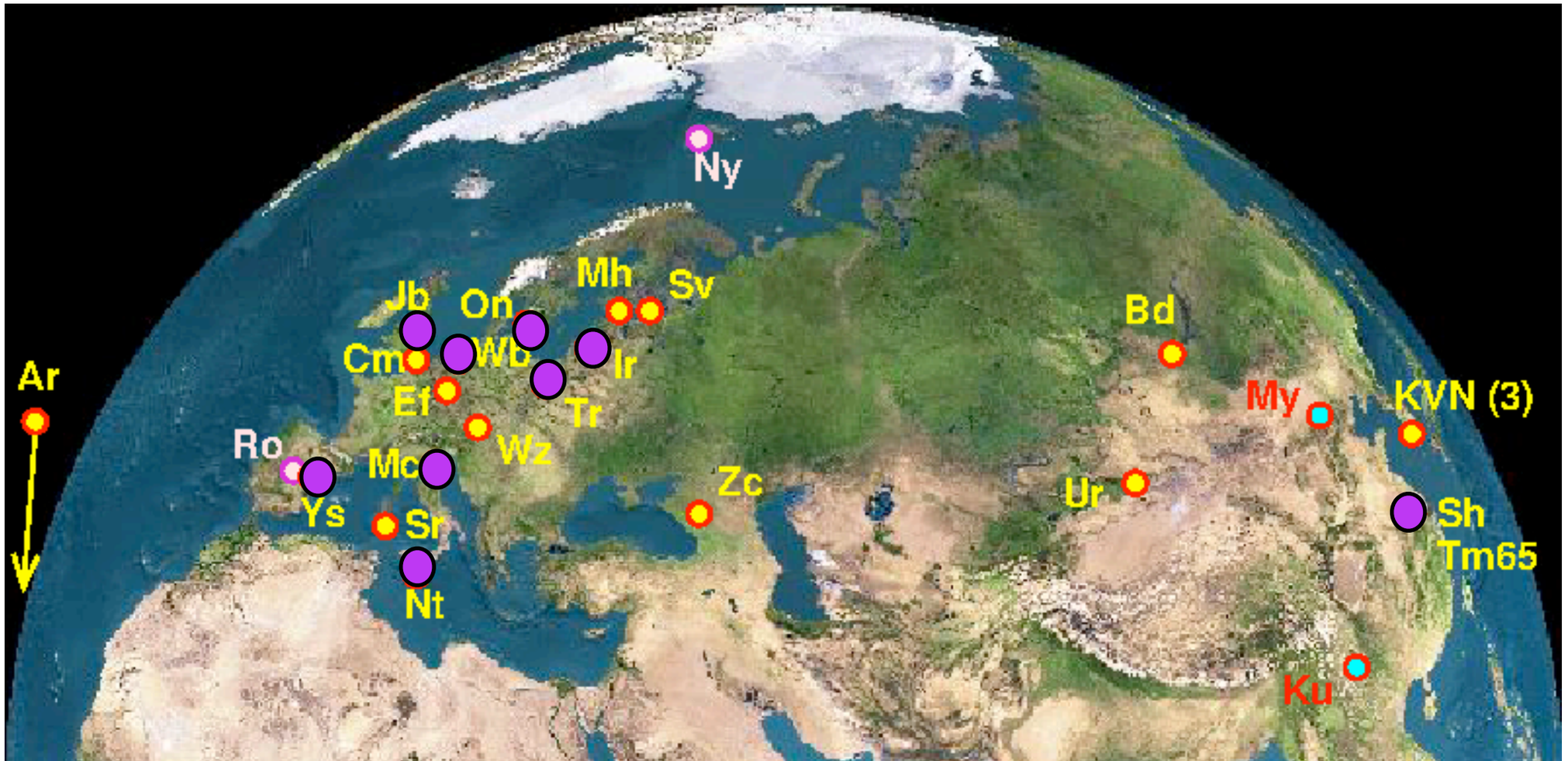
* Source strongly resolved out
  => different jet morphology w.r.t. the mini-flare

* Beam area = 0.88 mas^2
  Assuming a two sided ejection, jet extended over 30 mas
  => jet speed > 0.3c

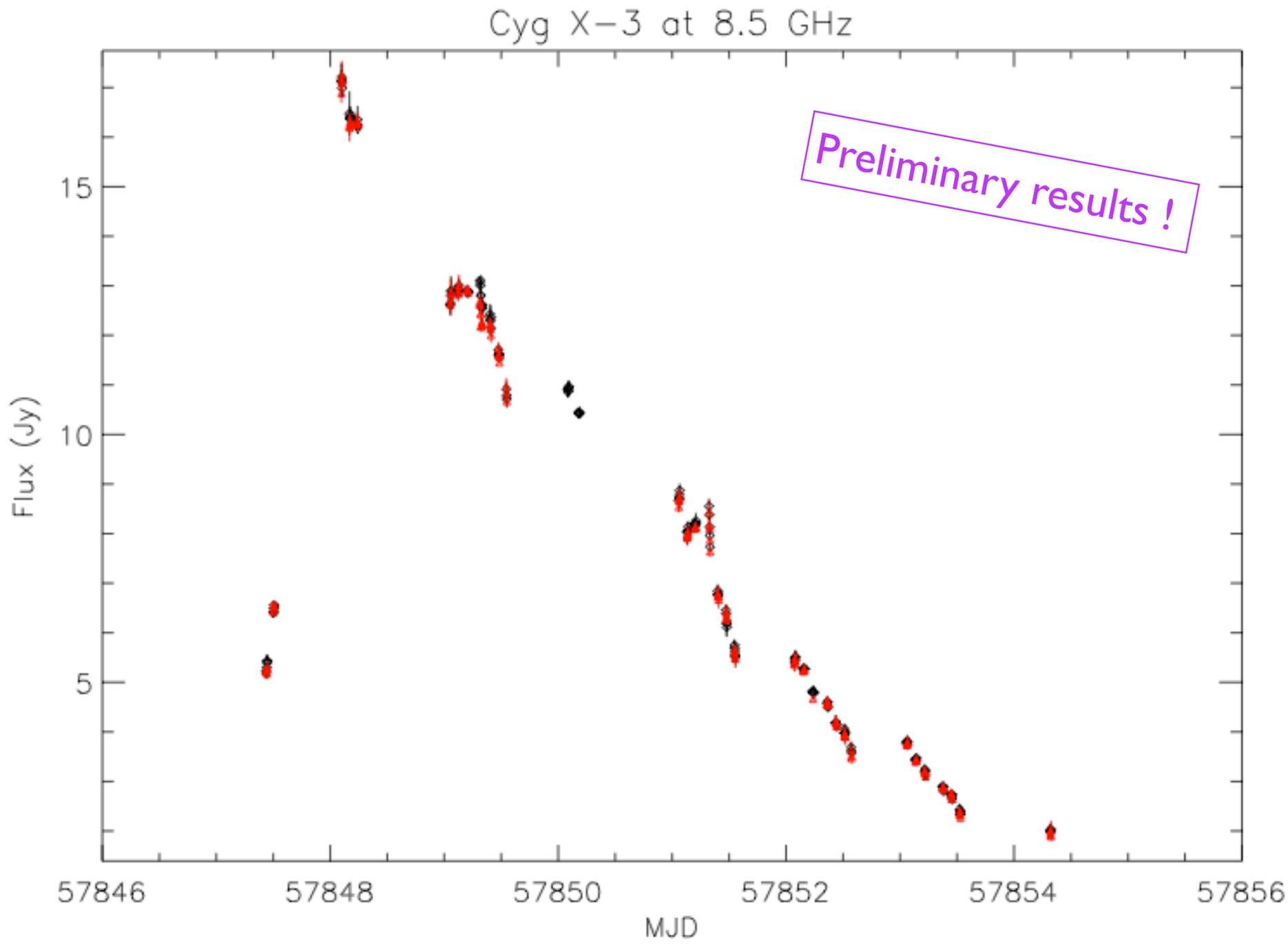
The giant radio flare in April 2017

* 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:

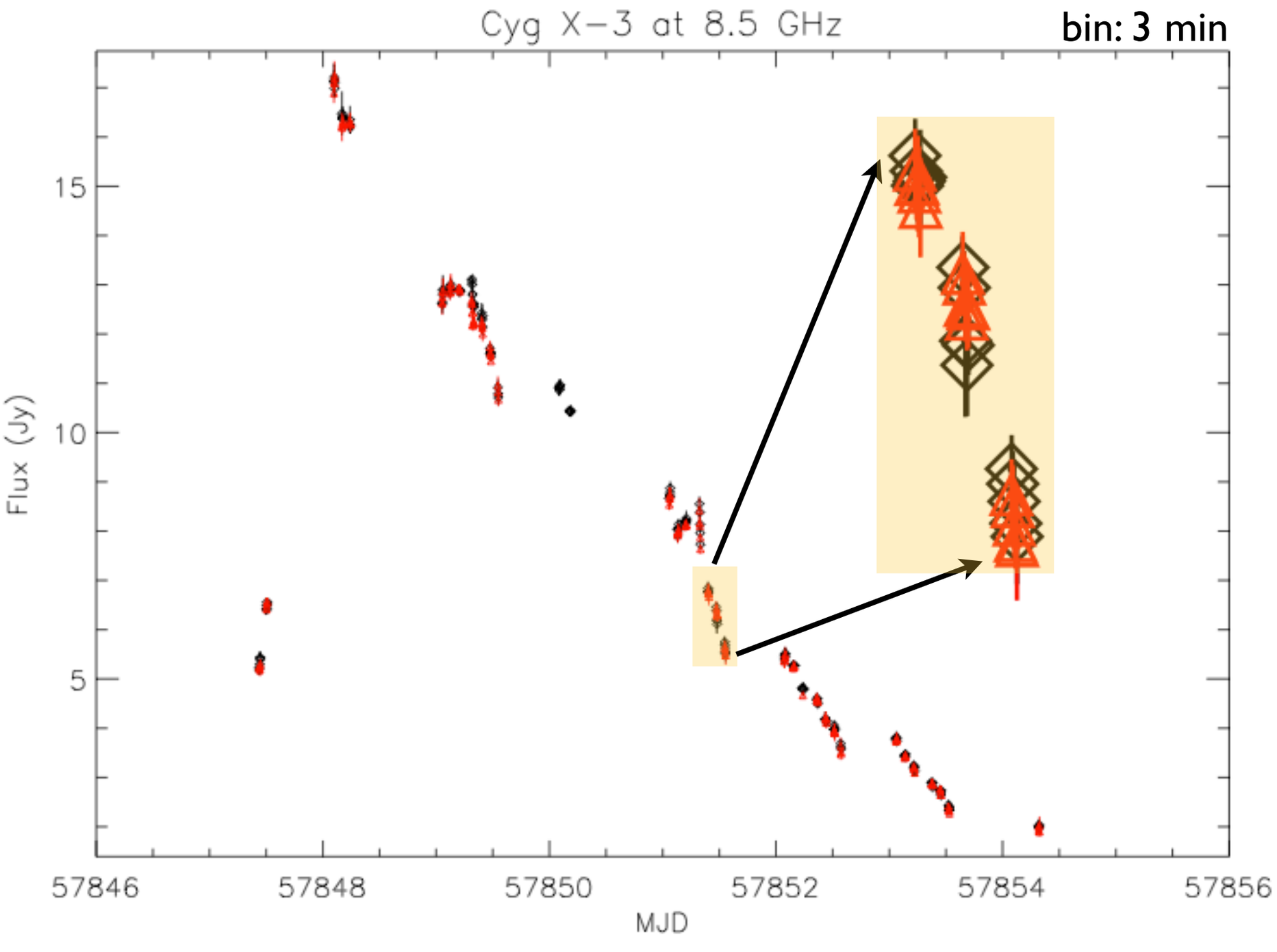


Medicina observations at 8.5 GHz



Peak reached on 5 April 2017, F =16.5 +/- 0.5 Jy at 8.5 GHz

Medicina observations at 8.5 GHz



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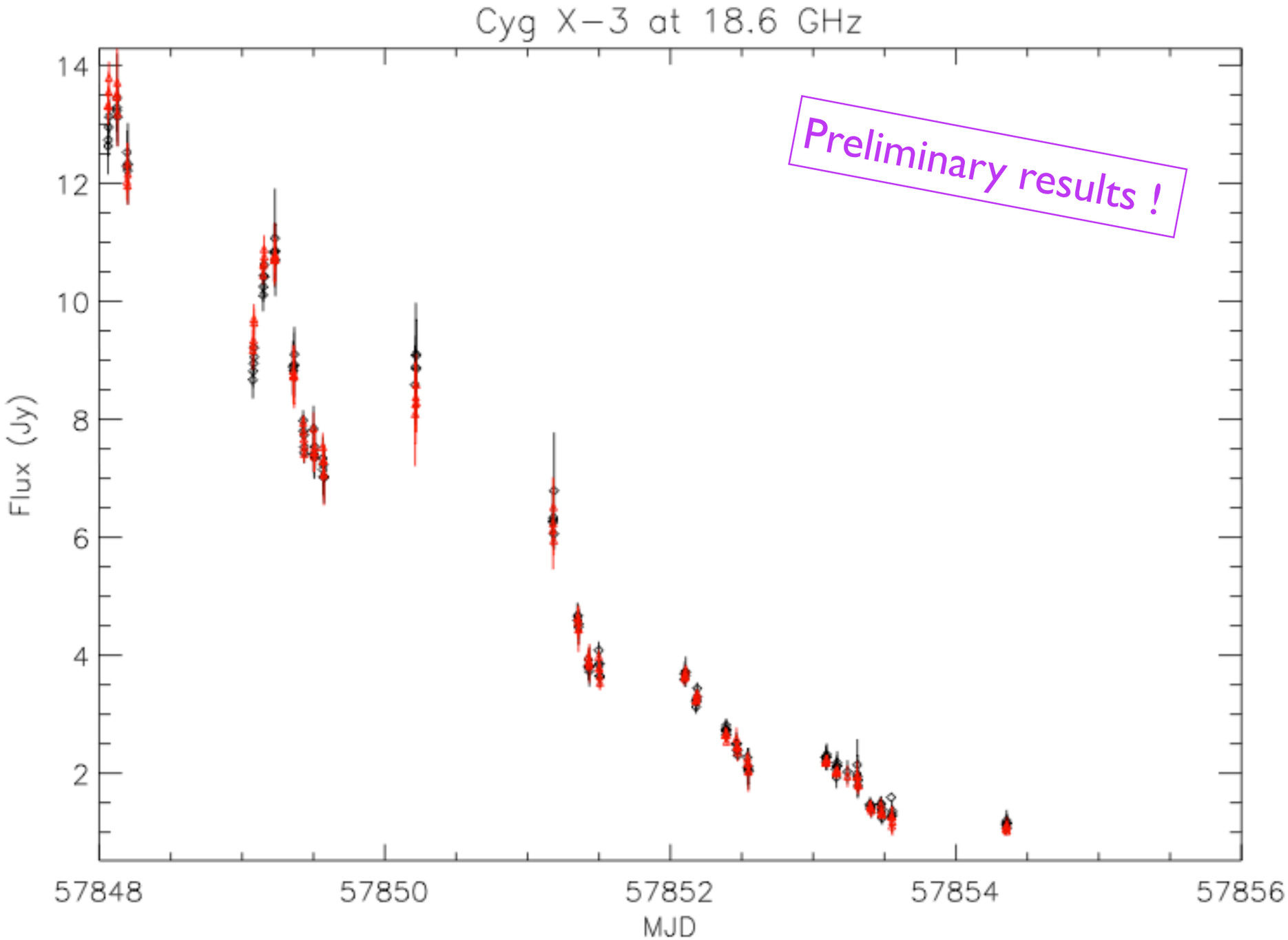
Medicina observations at 18.5 GHz

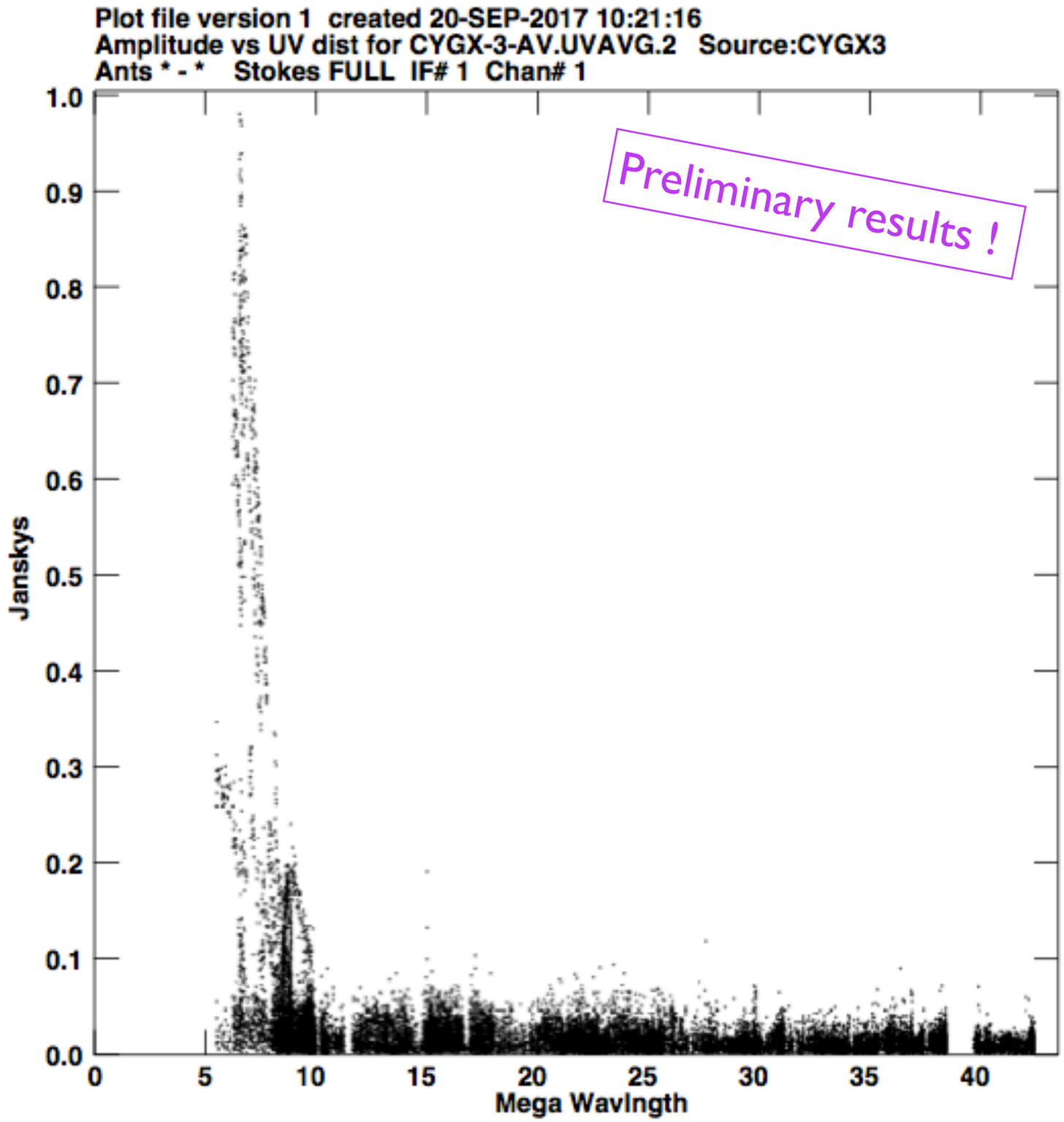


F =13 +/- 1 Jy at 18.5 GHz on 5 April 2017

e-EVN at 5 GHz on 10 April

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

  => extended structure



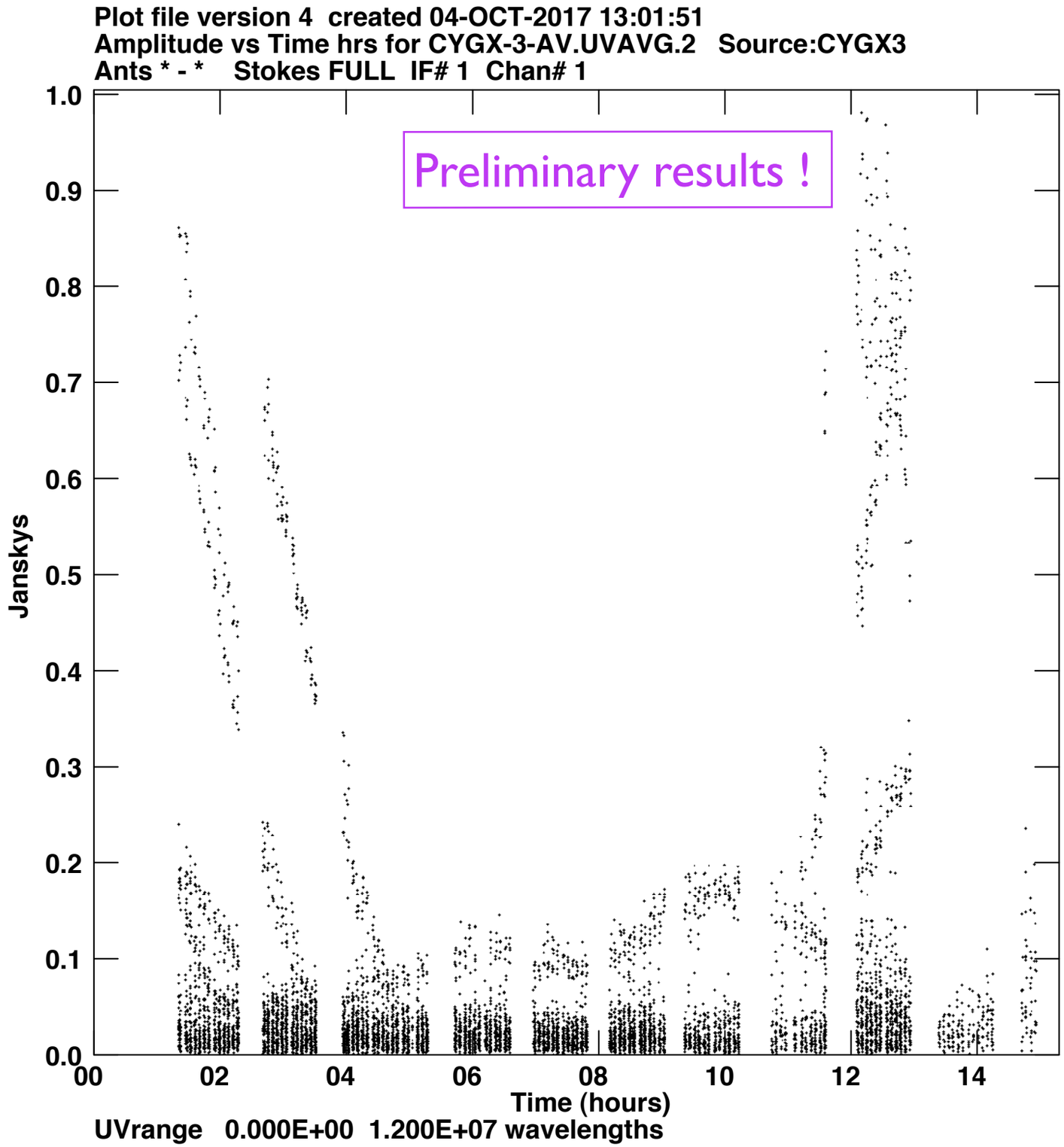
e-EVN at 5 GHz on 10 April

* Amplitude of the visibility as a function of time :

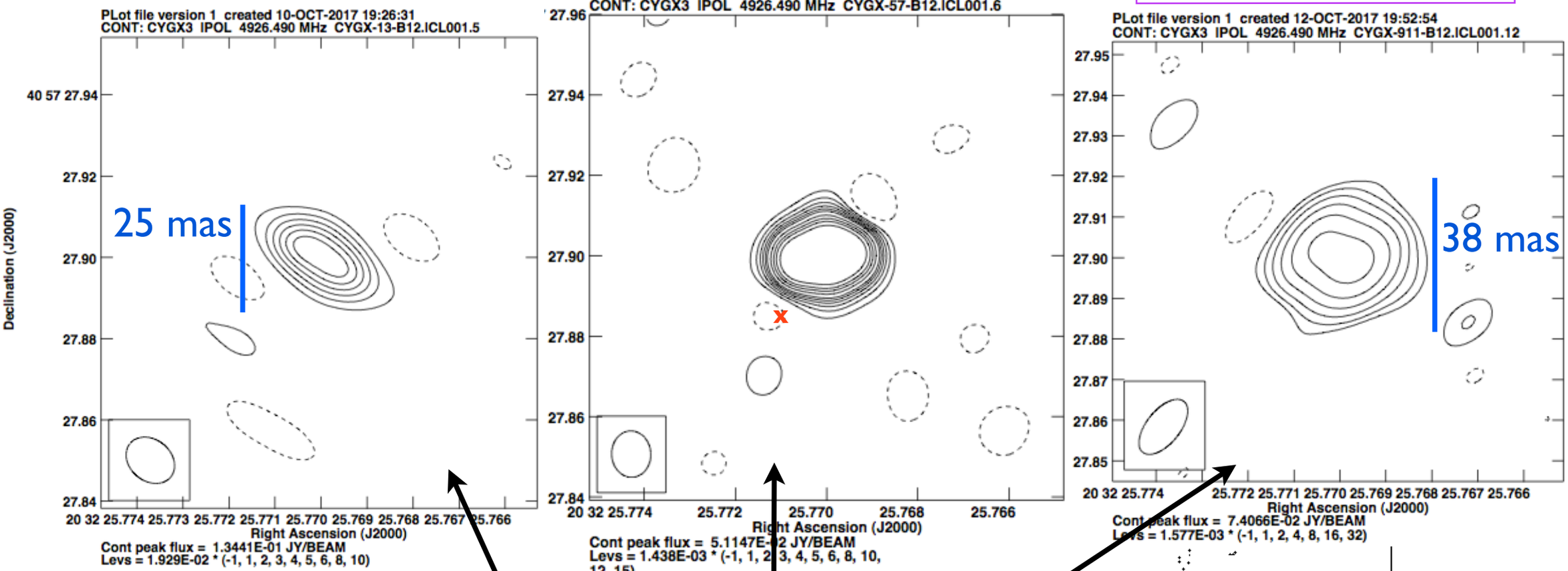
  => strong variability

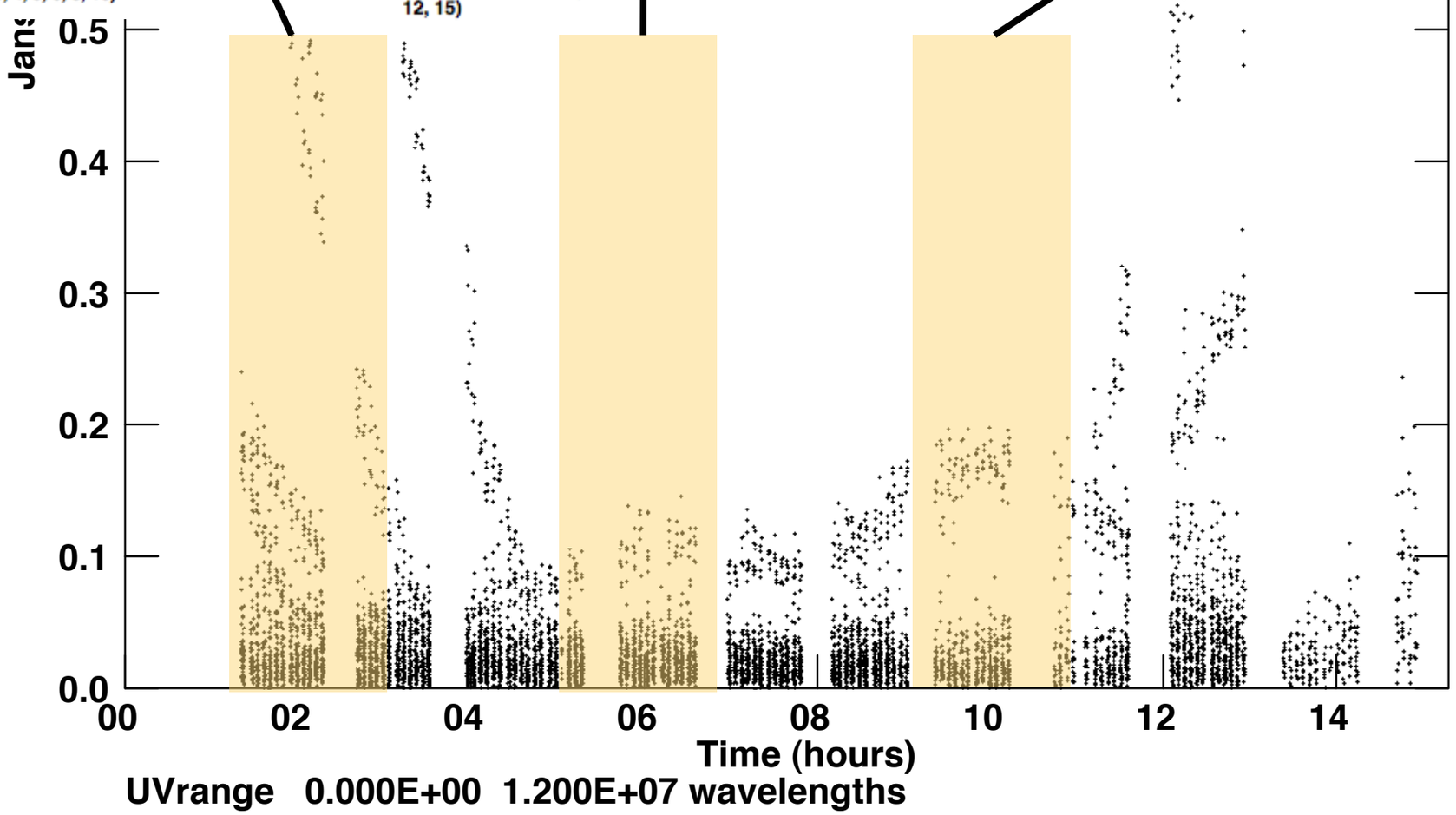
  => study on short timescales

  => short baselines (scattering)



Preliminary results !





Conclusions

* Cyg X-3 is a key source to better understand jets.

* Single-dish monitoring + VLBI observations are clearly complementary

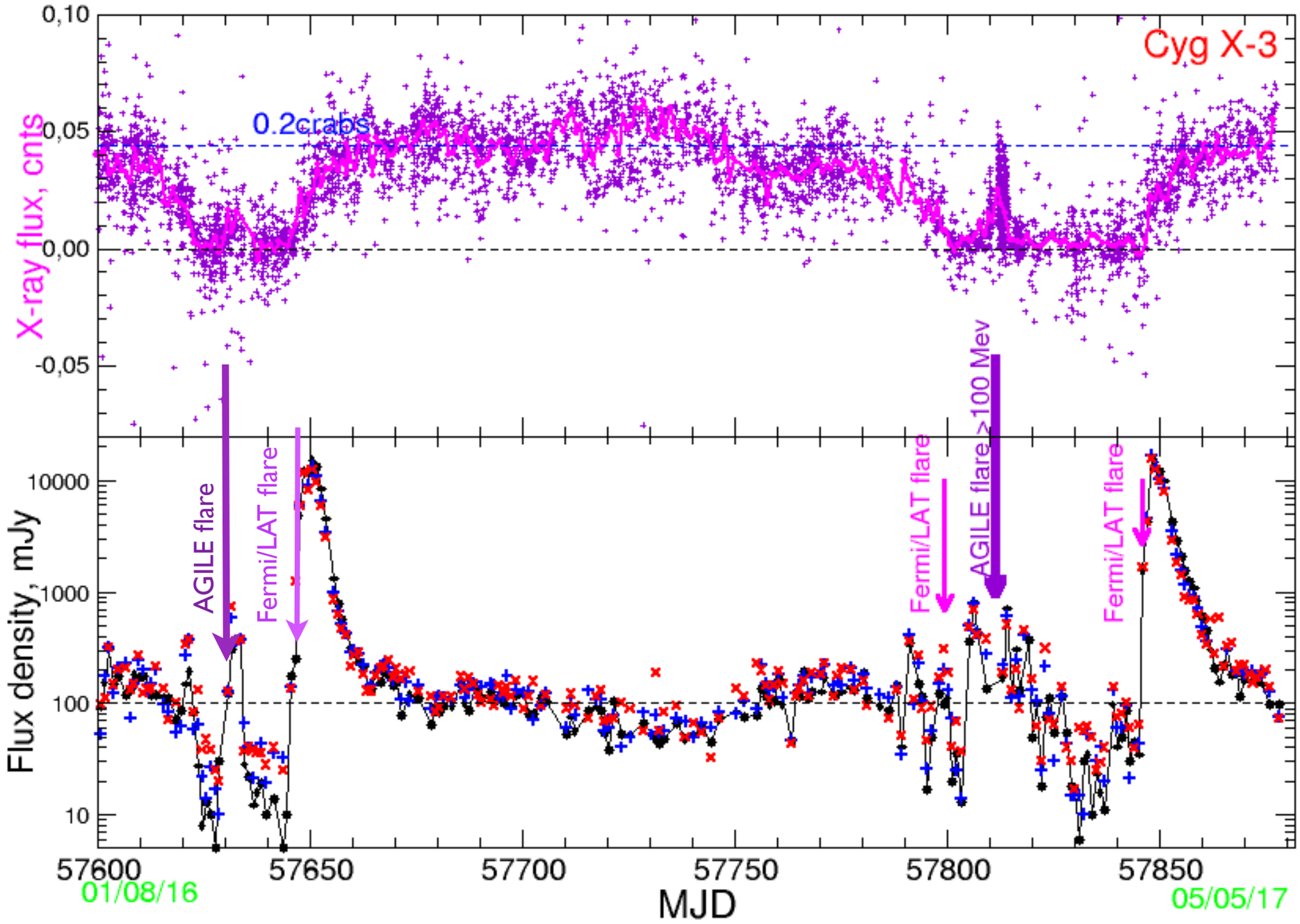
* Necessity to trigger more VLBI ToO observations of microquasars on several consecutive days

* Observations with KVN => crucial to study the jet formation and structural/spectral evolution at 22/43/86/129 GHz simultaneously.

* It would be great to have KVN, VERA, KaVA, EAVN and EATING VLBI programs dedicated to microquasars :-)

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



Calibrator J2007+4029