Transient sources at the highest angular resolution

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(MPIfR)

12th EVN Symposium- Cagliari 2014

Transient sources at the highest angular resolution

- Generality

-Transients in stellar binary sistems

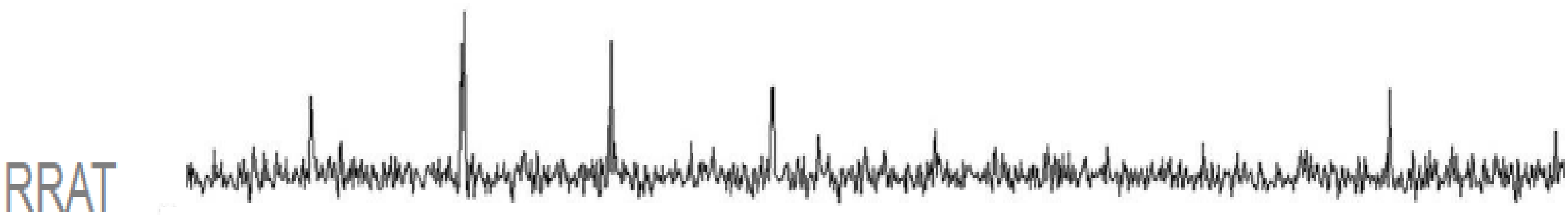
-X-ray binary LSI+61303

“Fast” radio transients

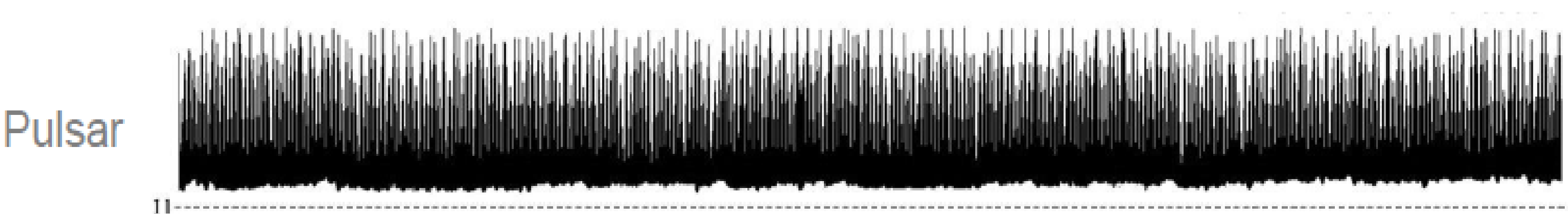
Variable on timescales of ns-minutes

“Fast” transients

typically discovered in time-series data.



Rotating radio transient (RRAT)
a class of neutron stars emitting more sporadically than pulsars



McLaughlin, M. A. et al. (2006)

“Fast” radio transients

Variable on timescales of ns-minutes

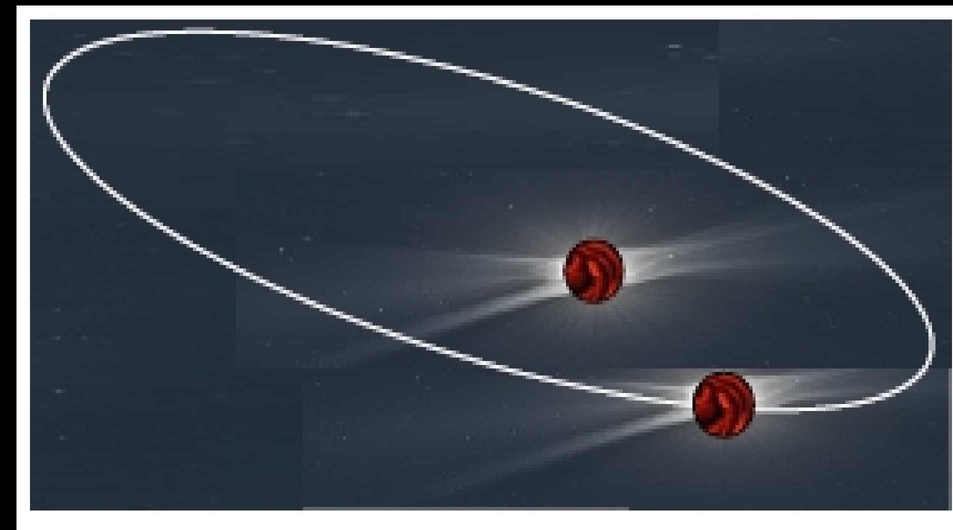
“Slow” radio transients

Variable on timescales of seconds-years

TRANSIENTS IN BINARY SYSTEMS:

I. Transients in a young-stellar system:

The pre-main sequence binary system V773 Tau A



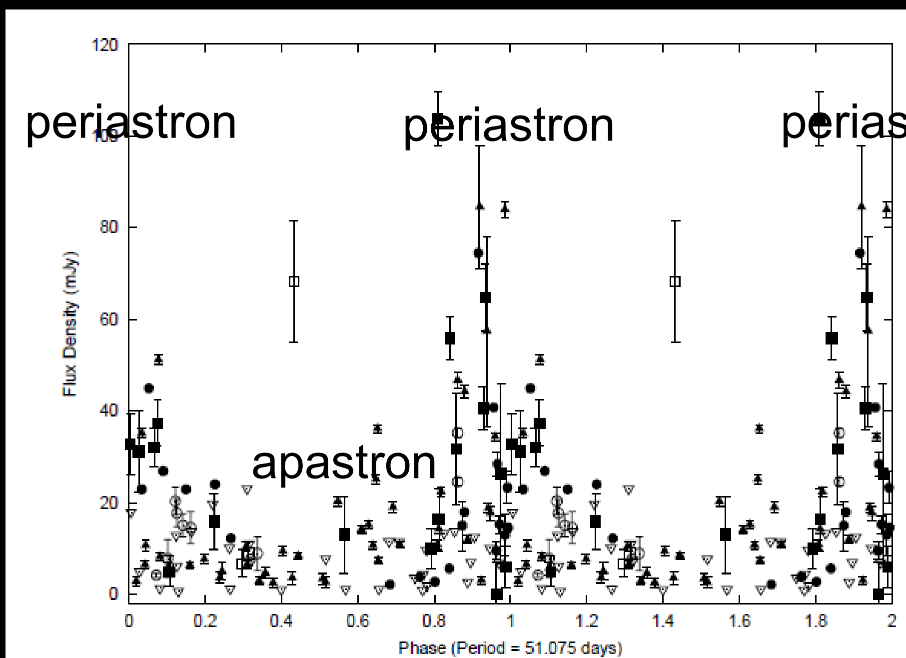
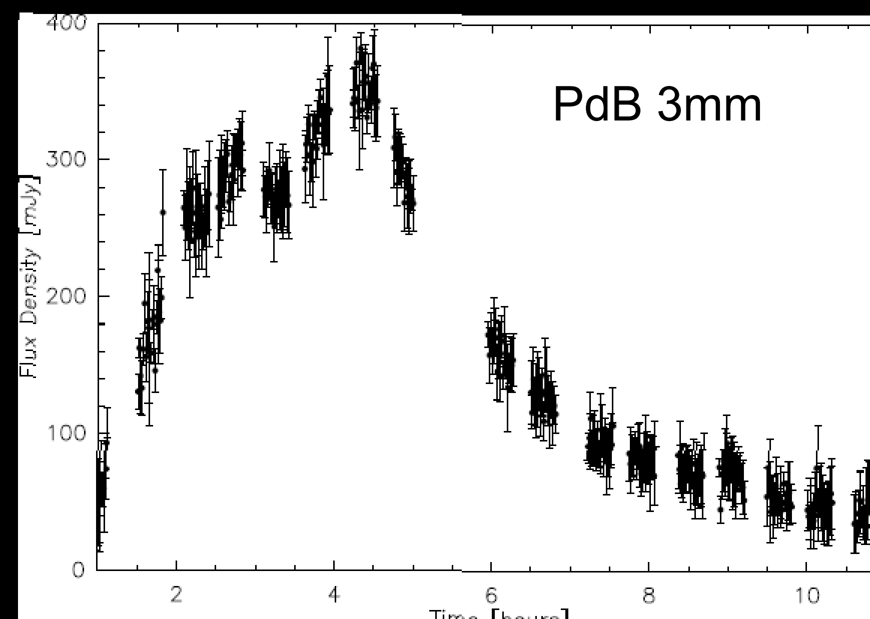
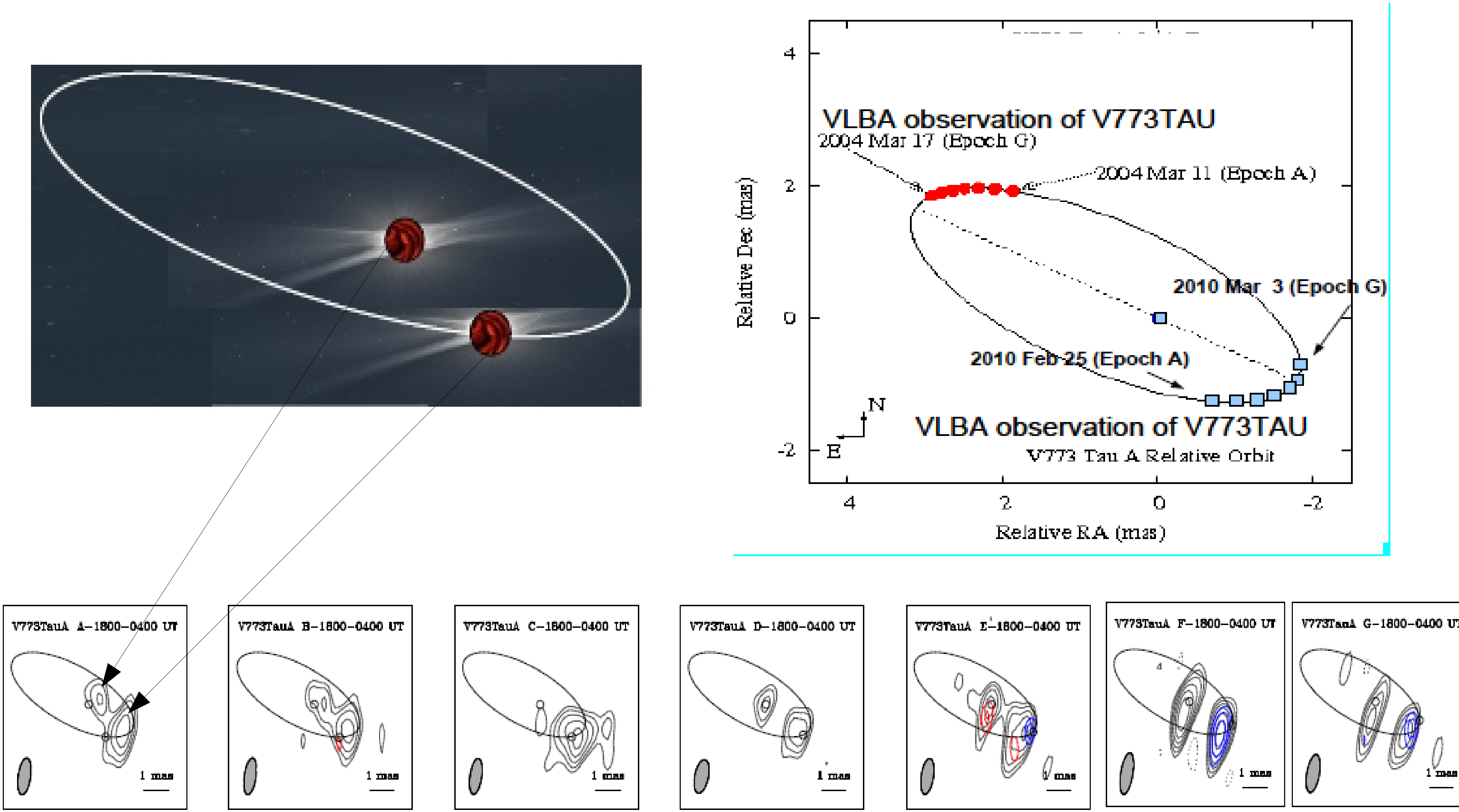


Fig. 2. Radio observations of V773 Tau folded with the orbital period of 51.075 days. Phase 0 (1, 2) refers to the passage at periastron.

Massi, Menten, Neidhöfer 2002



Massi, Forbrich, Menten et al., 2006



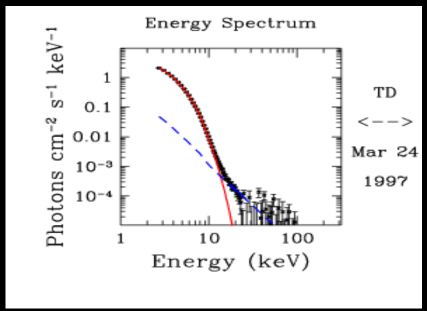
Massi, M.; Ros, E.; Boboltz, D.; Menten, K. M.; Neidhöfer, J.; Torricelli-Ciamponi, G.; Kerp, J. 2013

TRANSIENTS IN BINARY SYSTEMS:

X-RAY BINARIES

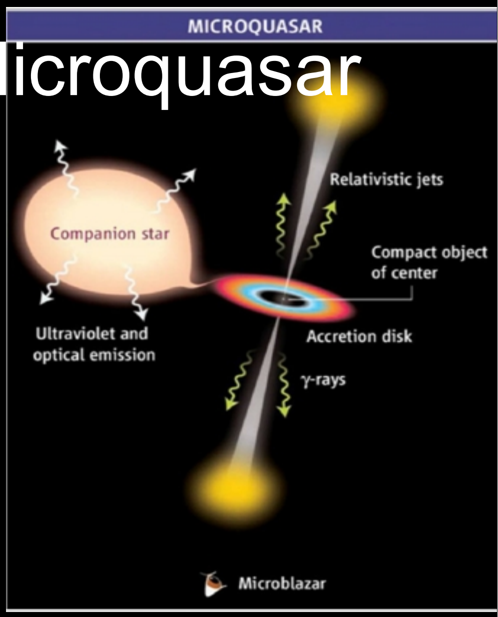
BXRB

Thermal /Soft
X-ray **State**

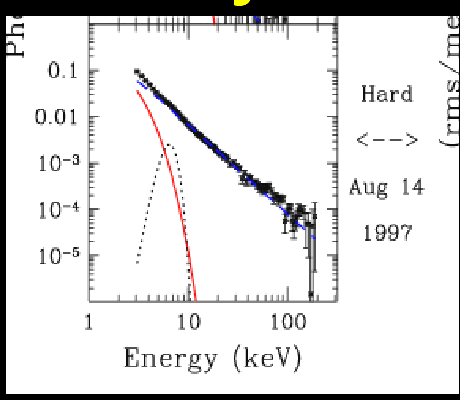


Energy spectrum

Microquasar



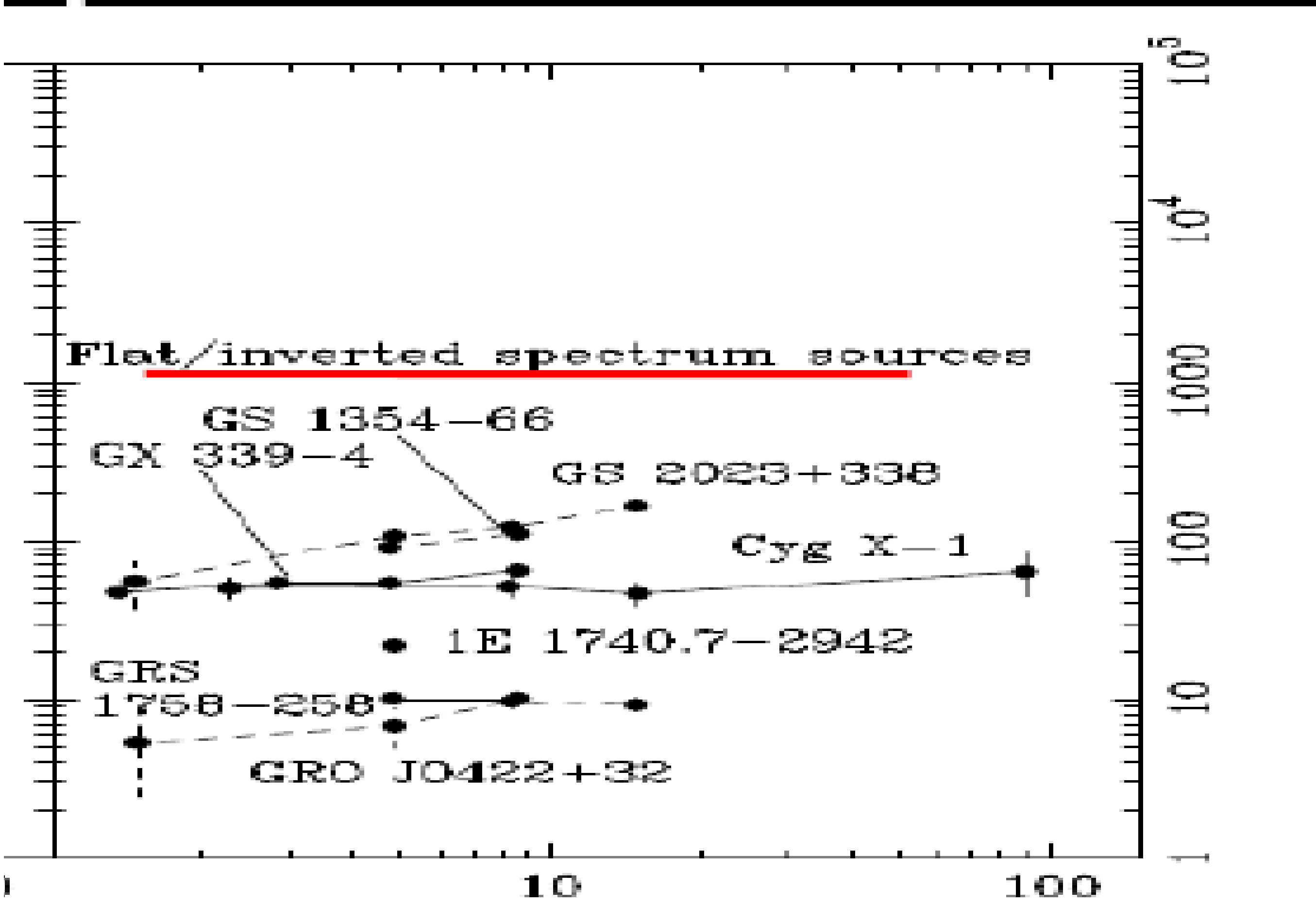
Hard X-ray State



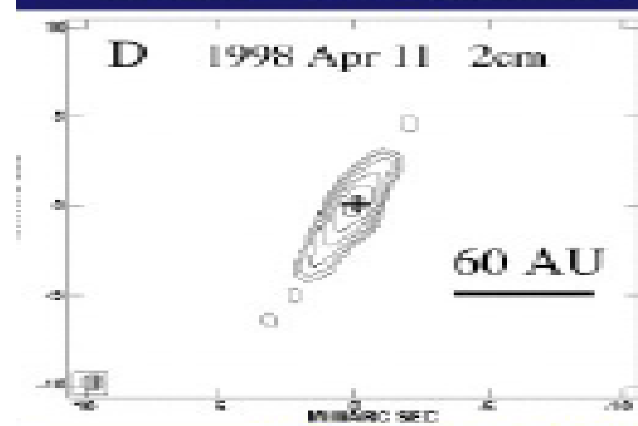
Radio Jet

flat radio spectrum

STEADY JETS



GRS 1915+105

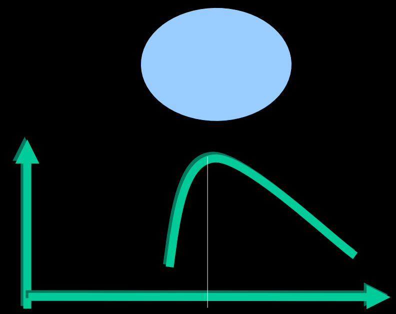


Dhawan et al. 2000

Fender et al. 2001, 2004, 2006

flat radio spectrum

Synchrotron sources: Spectrum of a uniform source

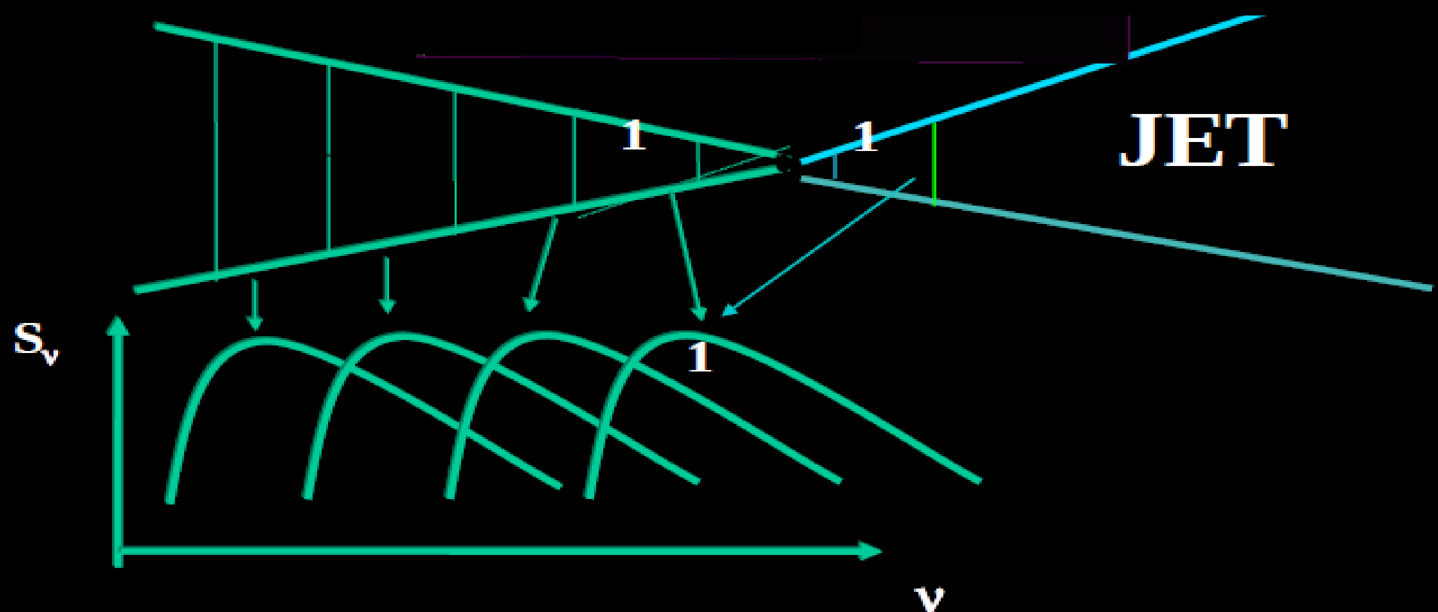


Flat Spectrum in a jet: Composite spectrum

Blandford & Konigl 1979; Kaiser 2006;

in a jet the plasma conditions are changing along the flow

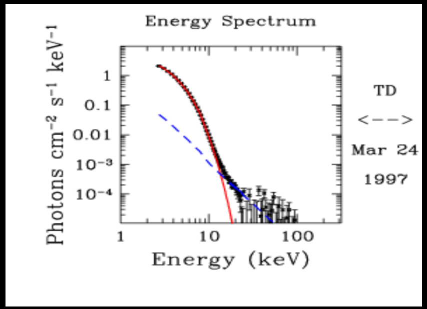
different parts of the jet can contribute with spectra peaking at different frequencies.



TRANSIENT

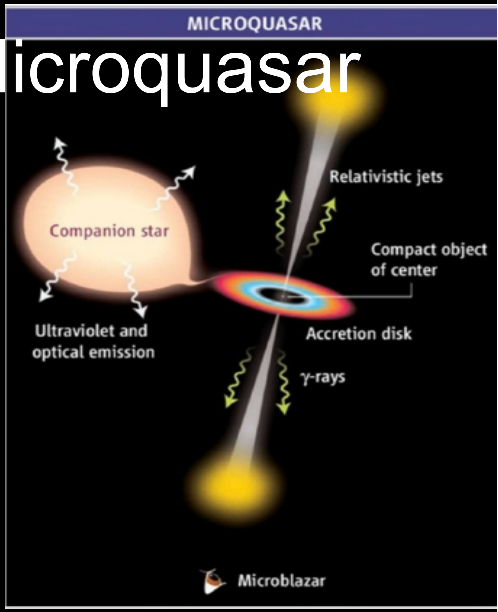
BXRB

Thermal /Soft X-ray State

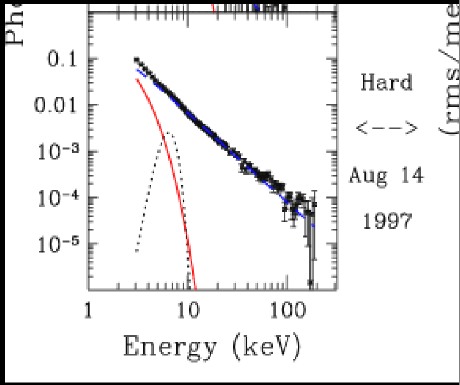


Energy spectrum

Microquasar

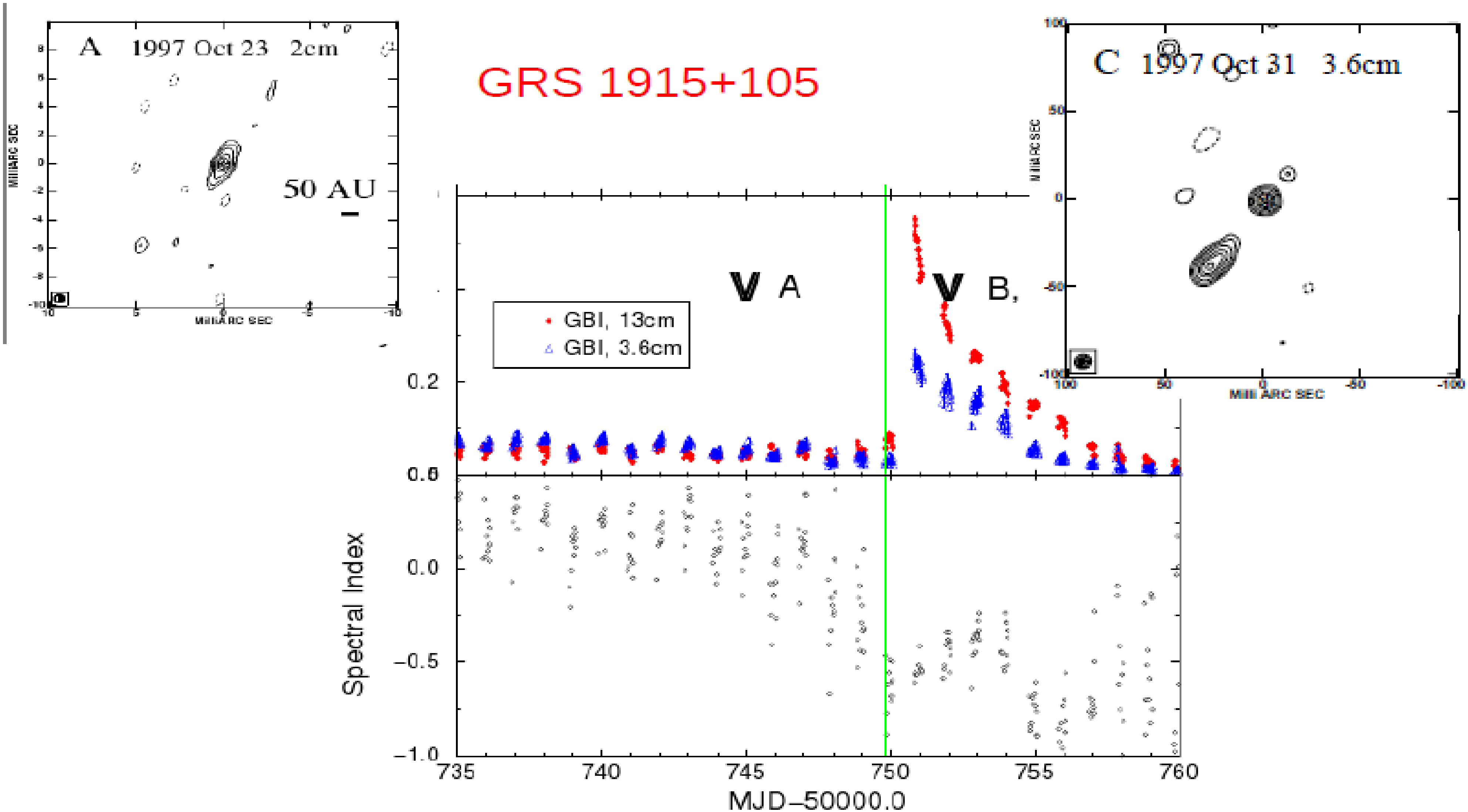


Hard X-ray State



Radio Jet

flat radio spectrum



Dhawan, Mirabel and Rodriguez 2000

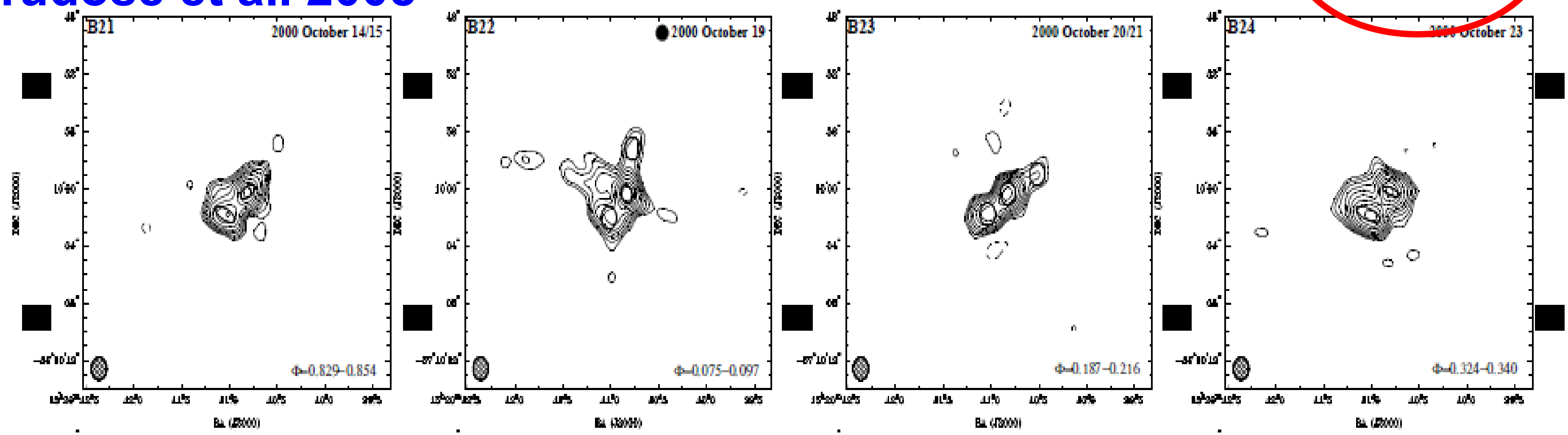
Miller-Jones et al. 2012: H1743-322

The onset of the radio flare may not always be a good diagnostic of the moment of ejection; there is a delay due to the time taken for internal shocks to form in the outflow

ACCRETING LOW B (< 10 ^{8} G) NEUTRON STARS

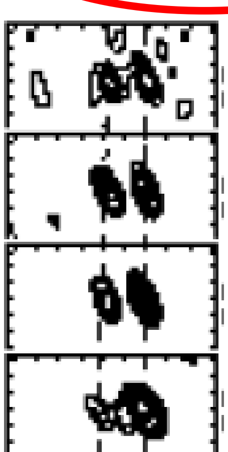
Radio imaging Circinus X-1 9

Tudose et al. 2008

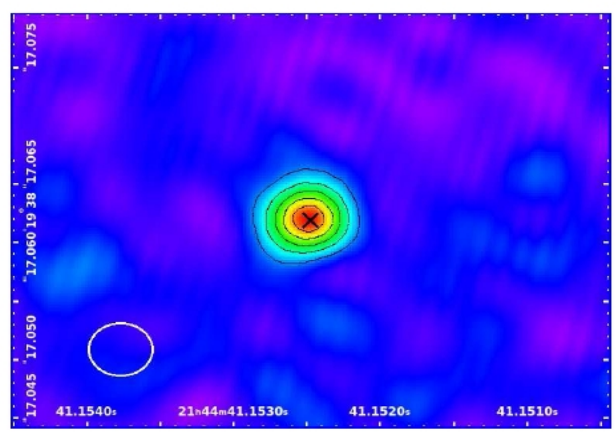


Fomalont et al 2001

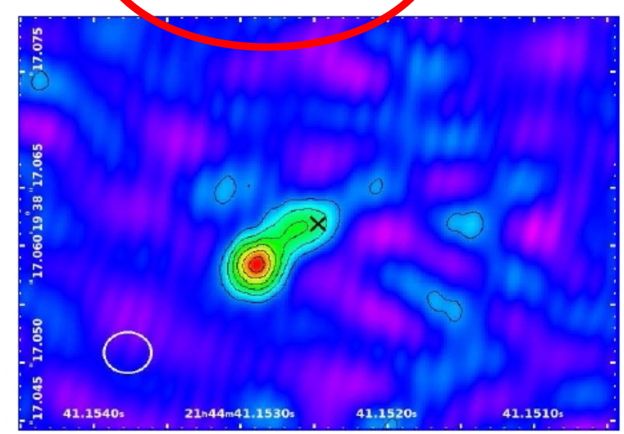
Sco X-1



Spencer et al. 2013

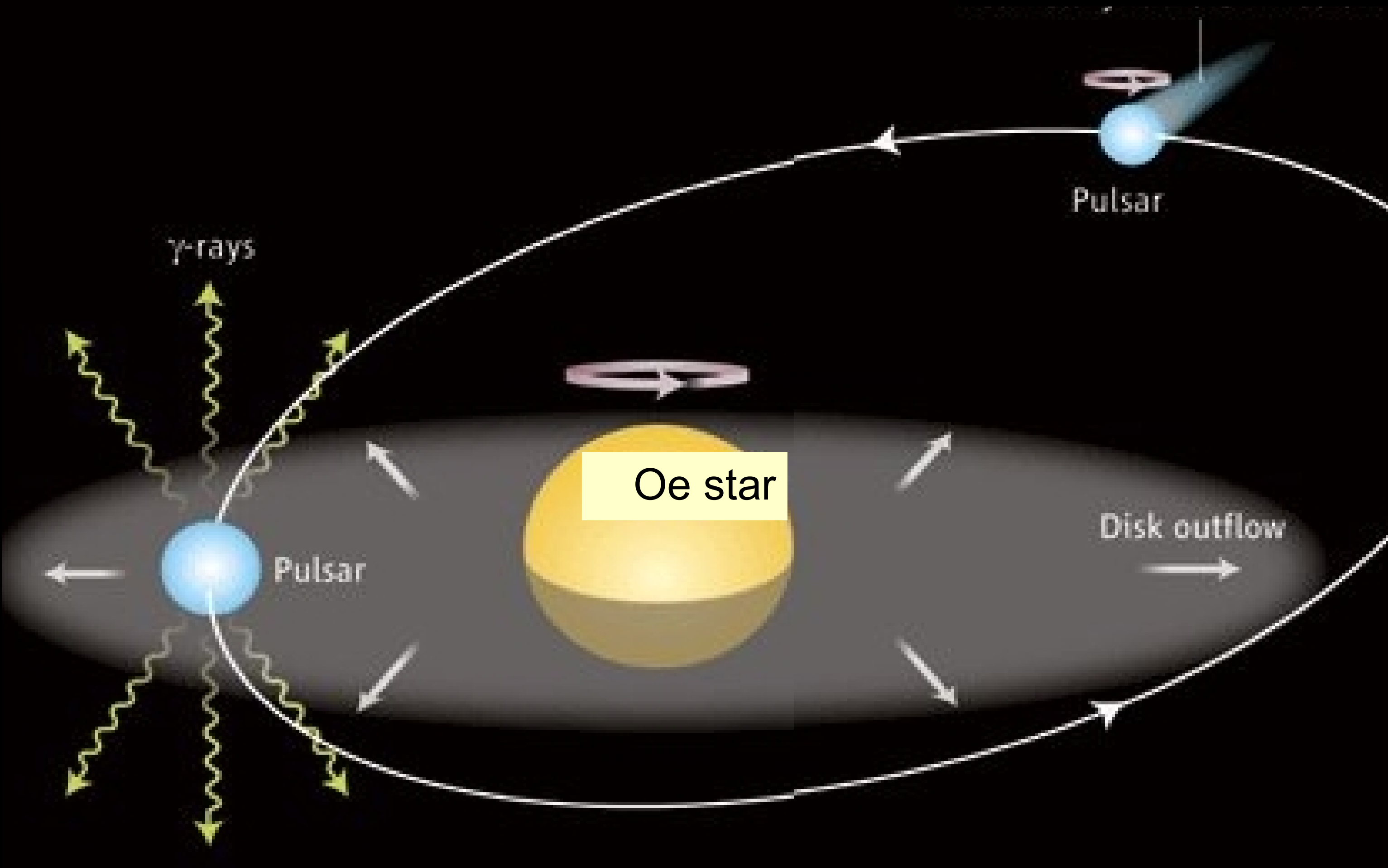


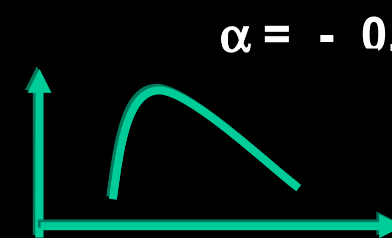
Cygnus X-2

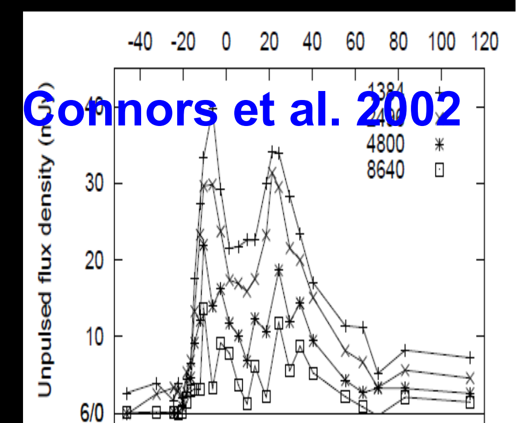


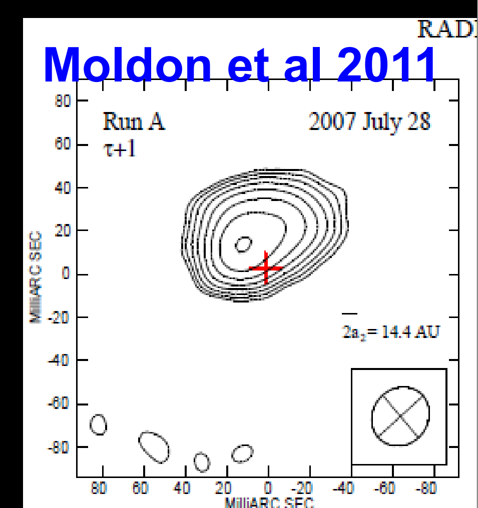
NON-ACCRETING YOUNG PULSAR : B> 10 ^{12} G, fast rotation (msec)

PSR B1259-63



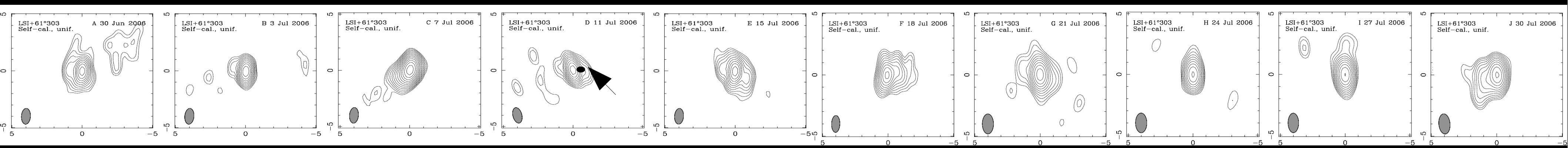


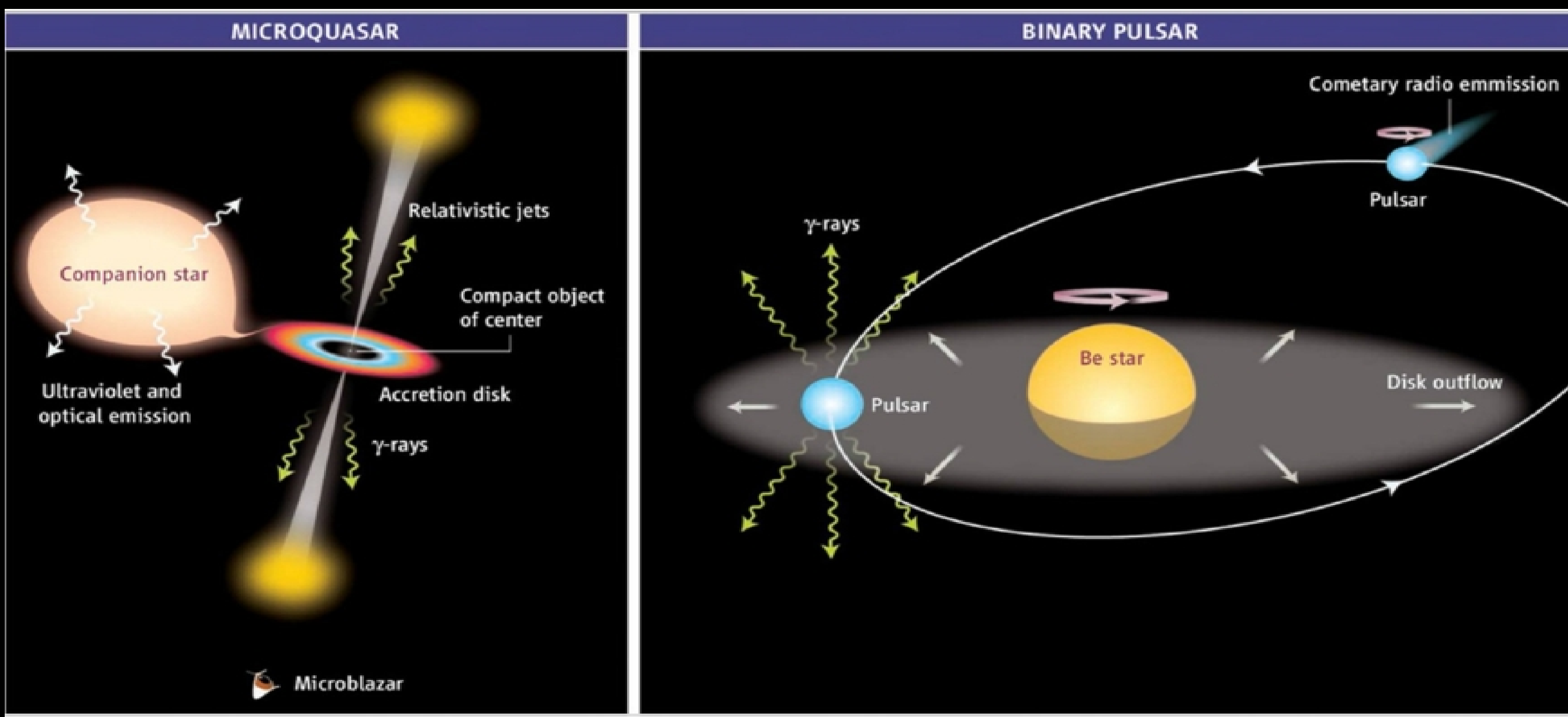




Transient around periastron

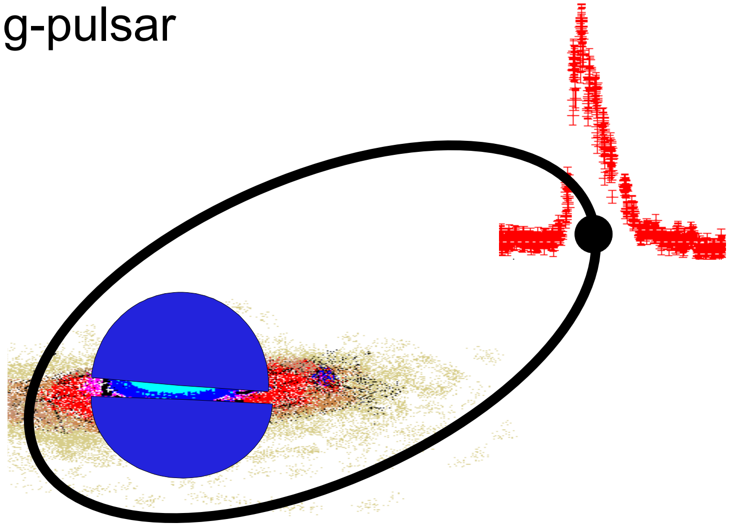
The gamma-ray binary LS I +61 303



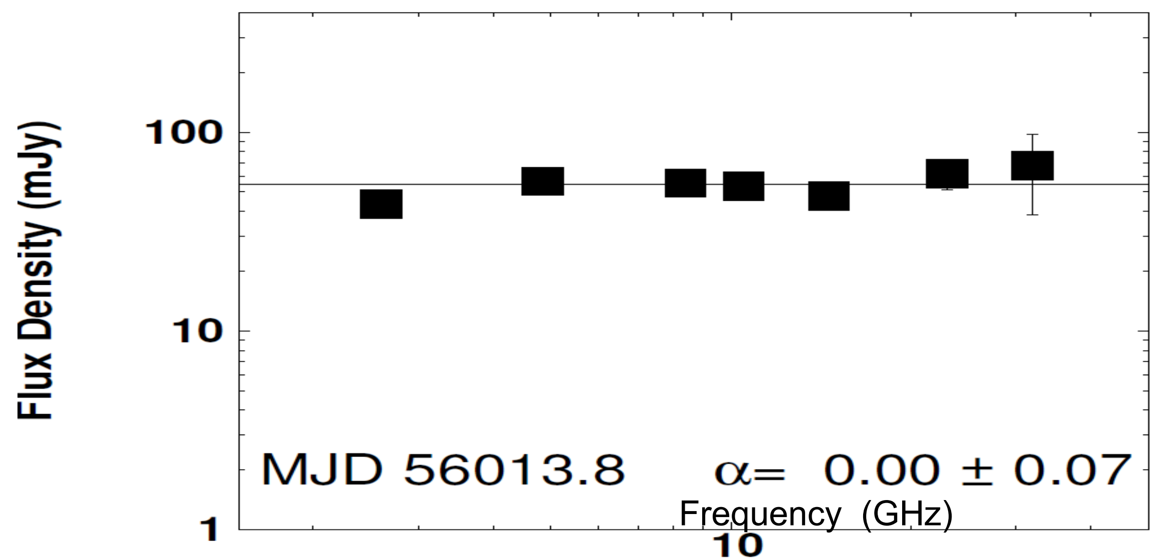


P_1 =26.496 +/- 0.008 d

There are periodic (P1) radio outbursts towards **apastron** and not towards periastron as for the young-pulsar

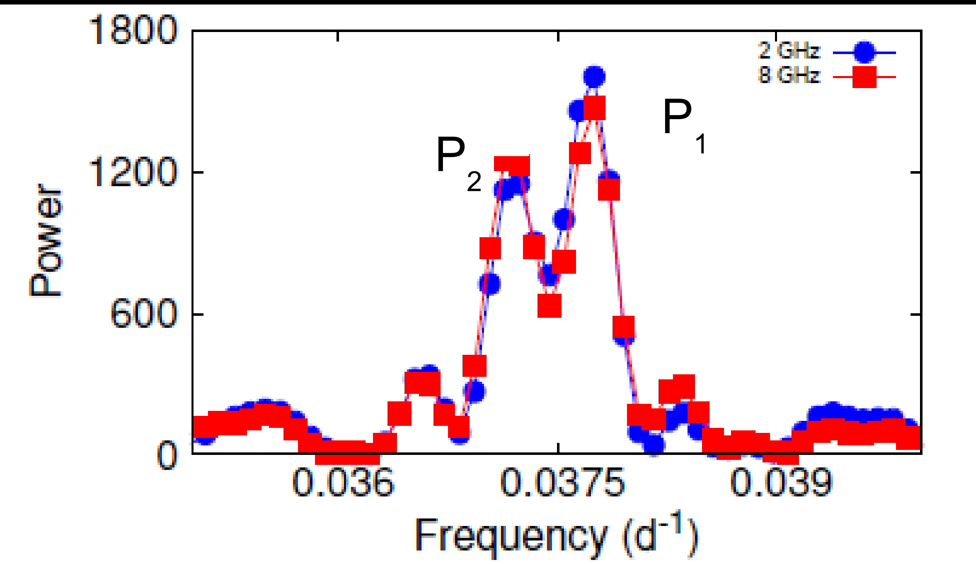


the radio spectrum is **flat**.revealing the presence of a jet



Zimmermann 2013 http://hss.ulb.uni-bonn.de/2013/3317/3317.htm
Zimmermann, Fuhrmann, Massi (2014 A&A to be sub.)

Radio: GBI



Massi &Jaron A&A 2013

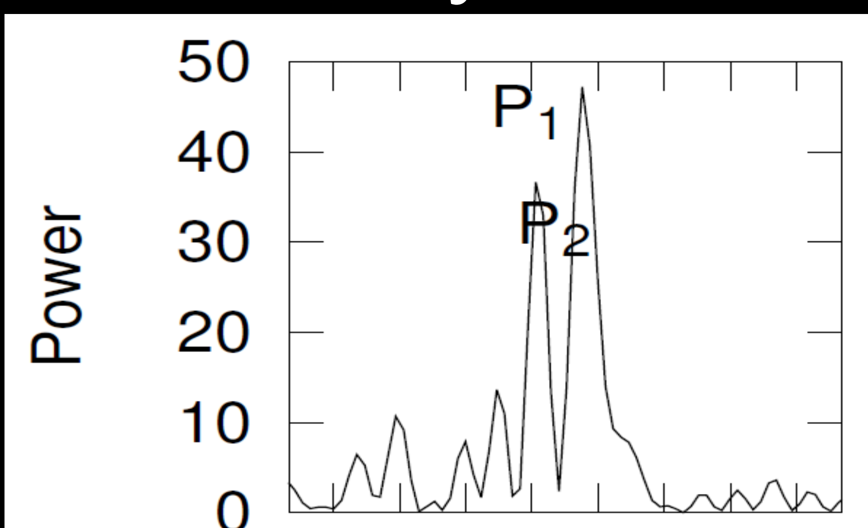
- Two periodicities:

$$P_1 = 26.49 \pm 0.07\,\mathrm{d}$$
$$P_2 = 26.92 \pm 0.07\,\mathrm{d}$$

P_1 periodical outburst (Gregory 2002)

P_2 precession of the radio jet from VLBA astrometry (27-28 d) (Massi, Ros, Zimmermann 2012)

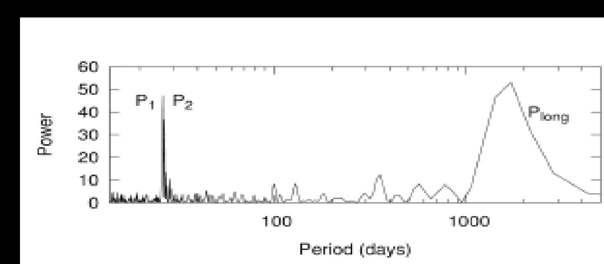
Gamma-rays: Fermi-LAT



P_1 = 26.48 +/- 0.08 d

P_2= 26.99 +/- 0.08

Jaron & Massi A&A accepted

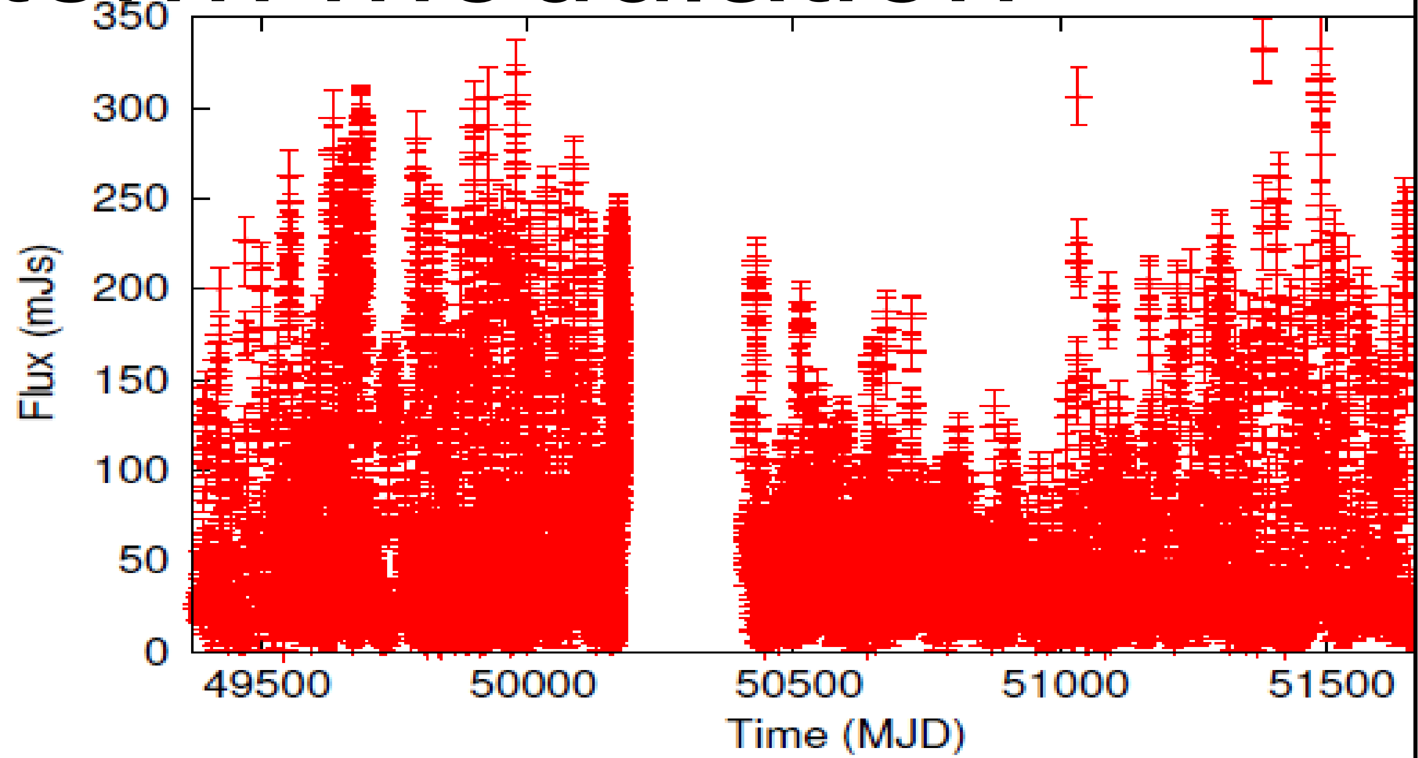


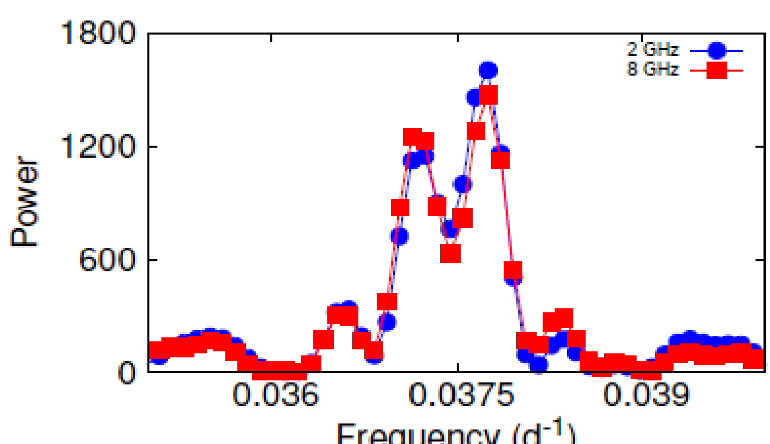
Long-term modulation

P_3 = 1667 +/-   8 d

Amplitude of the outburst changes with a long-term period of **1667 d** (~4.6 yr)

Gregory 2002,
Gregory & Neish 2002





$$P_{\mathrm{beat}} = \frac{1}{\nu_1 - \nu_2} = 1667 \pm 393\ \mathrm{d}$$

Does the long-term modulation result from the **beat** of P1 and P2 ?

The Model

Massi & Torricelli-Ciamponi 2014

$$S_{\mathrm{model1}}(t) = S_{\mathrm{a}}(t)(\delta_{\mathrm{a}}(t))^{k-\alpha} + S_{\mathrm{r}}(t)(\delta_{\mathrm{r}}(t))^{k-\alpha}$$

Kaiser (2006) **Conical jet**

$$\kappa = \kappa_0 l^{-a_3}$$

The number density of the relativistic electrons $N_{\mathrm{rel}} = \kappa E^{-p}$,

$$B = B_0 l^{-a_2}$$

$$S_{\mathrm{a}} = \int_1^L r_0 x_0 I_{\nu_{\mathrm{a}}}(\eta, l) \frac{\sin(\eta - \xi)}{D^2} l \mathrm{d}l$$

$$I_\nu(\eta, l) = \int_0^{\tau_{\mathrm{end}}(l)} \frac{J_\nu}{\chi_\nu} e^{-\tau'/\cos\eta} \mathrm{d}\left[\frac{\tau'}{\cos\eta}\right]$$

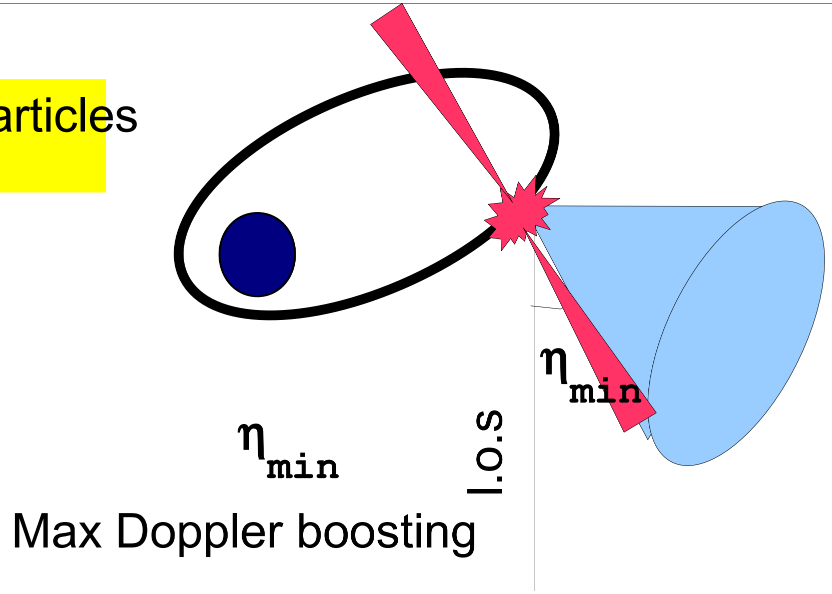
$$J_0 = 2.3\ 10^{-25}(1.3\ 10^{37})^{(p-1)/2} a(p) B_0^{(p+1)/2} \kappa_0$$

$$\chi_0 = 3.4\ 10^{-9}(3.5\ 10^{18})^p b(p) B_0^{(p+2)/2} \kappa_0.$$

Precessing jet with periodical variations of emitting particles

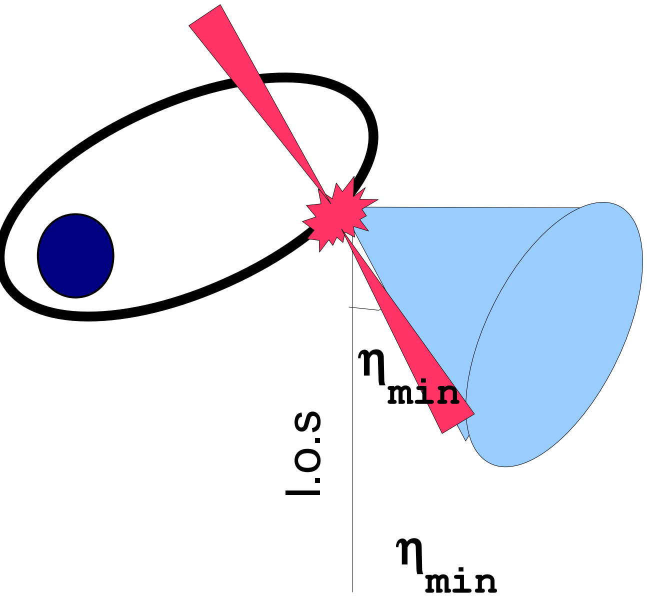
P1 (o r b i t a l)

P2 (precession)

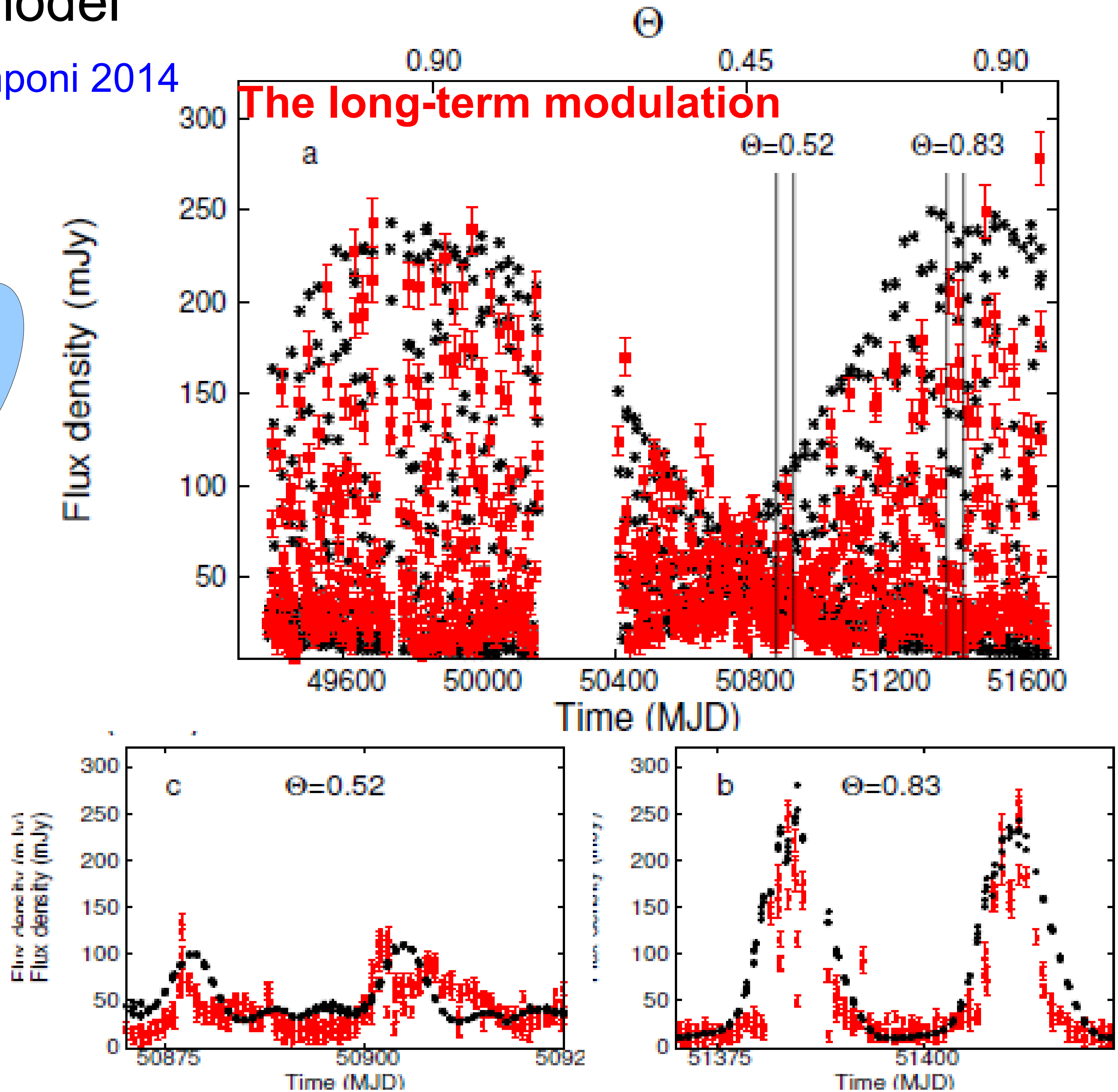


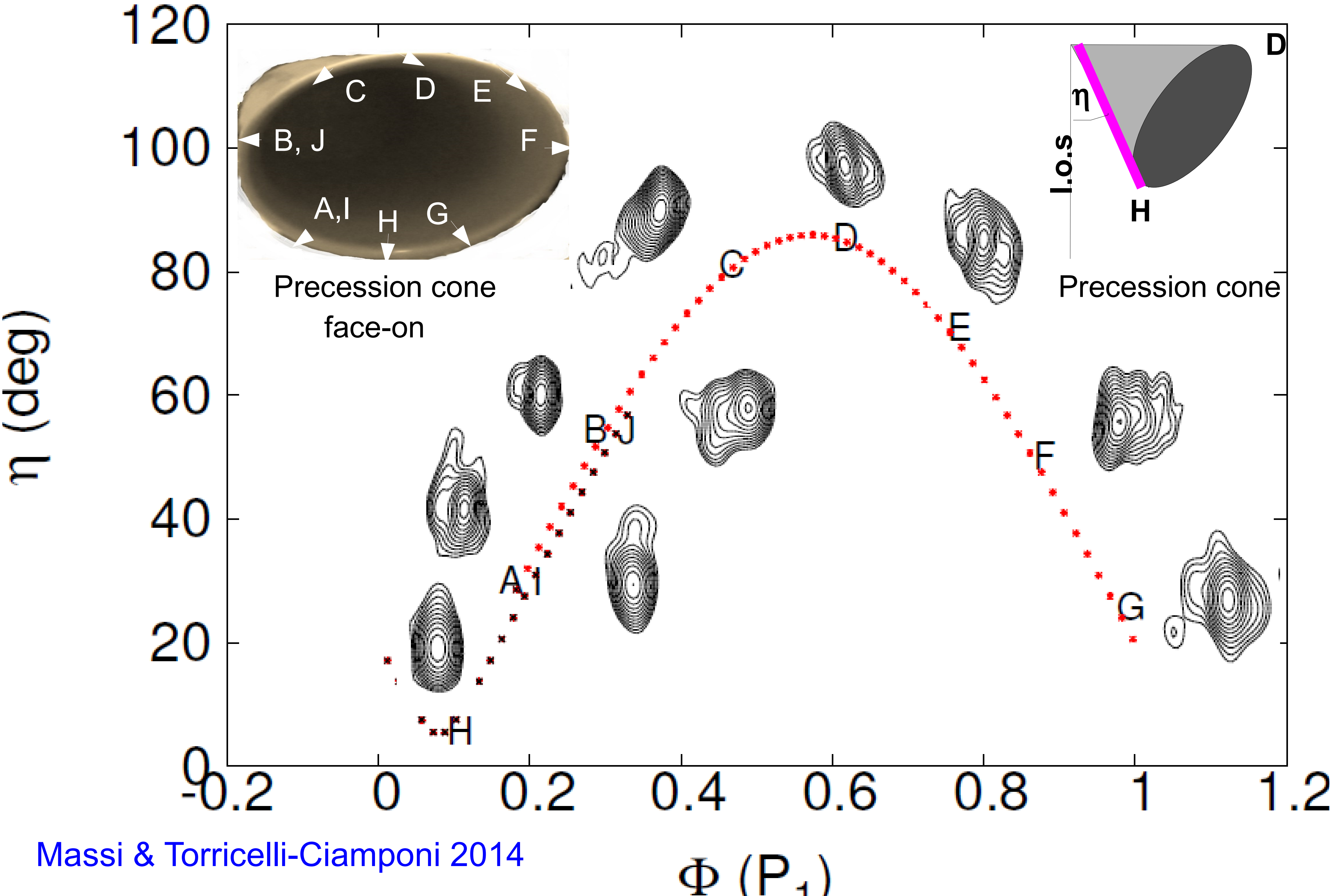
Precessing Jet model

Massi & Torricelli-Ciamponi 2014



Max Doppler boosting





Massi & Torricelli-Ciamponi 2014

Results: the rapid rotation in position angles of VLBA maps

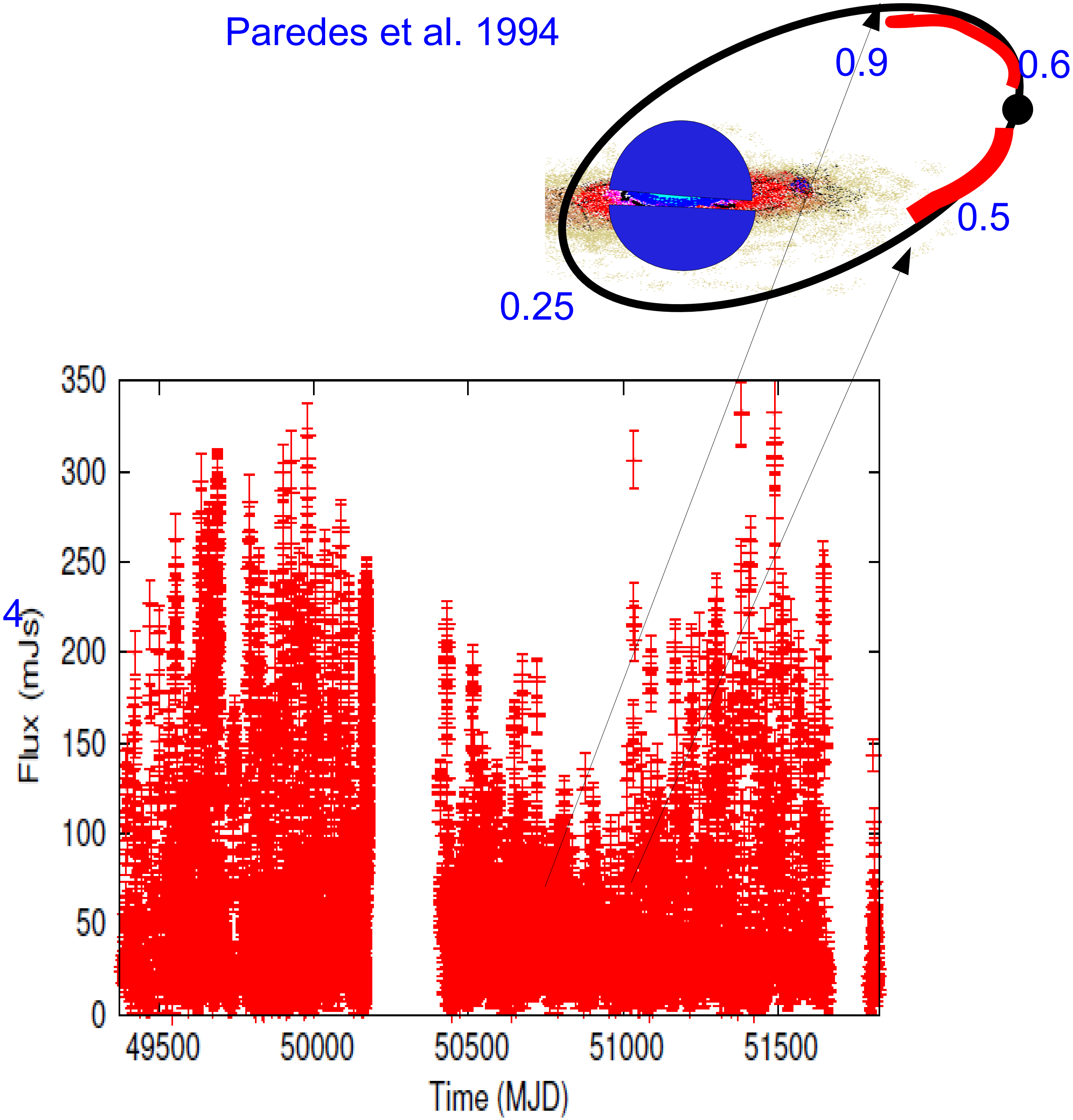
Transient sources at the highest angular resolution

1. Generality:
   Fast transients and slow transients

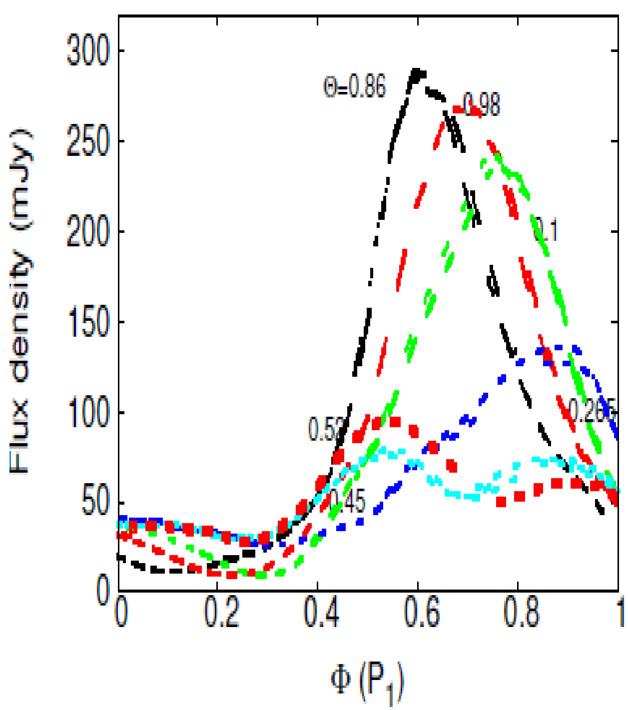
2. Slow transients in binary sistems :
   2.1 Transients in a young-stellar system
   2.2 Transients in X-ray binaries

3. The gamma-ray binary   LSI+61303
   3.1. Radio spectral index analysis: Flat-spectrum
   3.2. Timing analysis: P1, P2 in radio and Gamma-ray data
   3.3. Modeling: Precessing (P2), periodically (P1) refilled jet

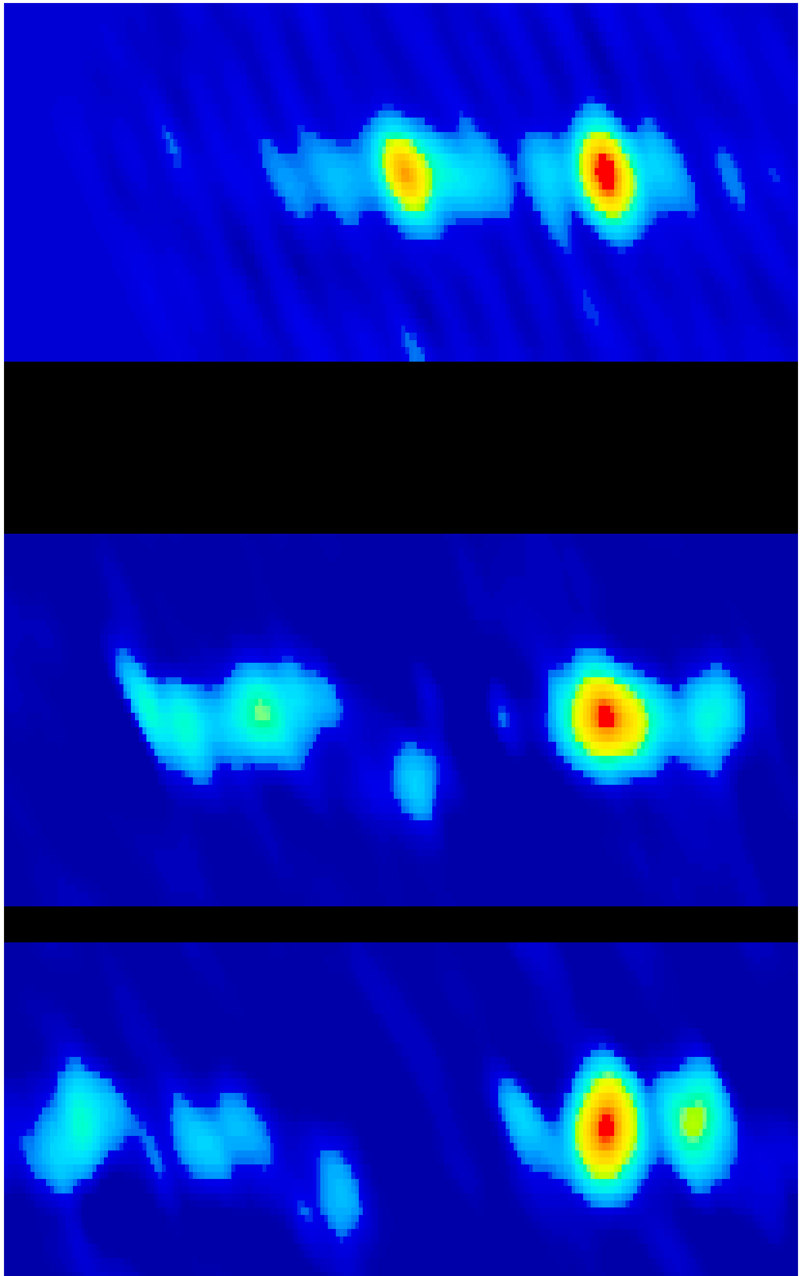
THANK YOU !



Massi & Torricelli-Ciamponi 2014

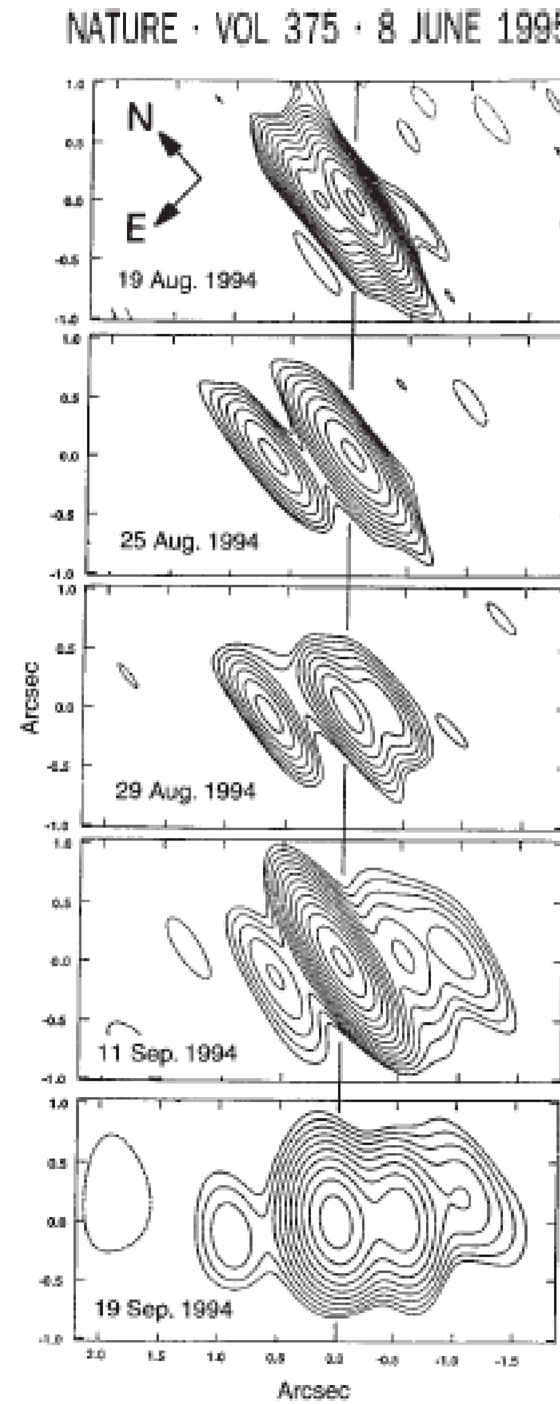


GRO J1655 – 40 Hjellming and Rupen 1995



Precession: Jets are rotating about the jet axis with a period of 3.0 ± 0.2 d

Orbital period 2.62 ± 0.02d (Baylyn et al. 1995)



Radio images: R. Hjellming and R. Rupen, NRAO.

FIG. 2.— *Swift*-BAT positional error circles over-imposed to the *Chandra* image of the field (smoothed with a Gaussian function with a FWHM of 3″). Cyan, green and yellow circles report on the best position derived by Barthelmy et al. (2008), and our analysis using the T90 and the T(tot) of the burst (see text for details), respectively. The source within the red circle is the *Chandra* source discussed in §2.3.

A magnetar-like short burst detected by the Burst Alert Telescope (BAT; Barthelmy et al. 2005) onboard Swift

Two sources within the positional error circle

their #12 of Table 3). Thus, formally we can not exclude that the faint X-ray source detected by *Chandra* at the limit of the 1σ positional uncertainty of the burst (see Fig. 2) might be the magnetar responsible for the short burst observed by *Swift*-BAT, hence independent from LS I +61°303: Assuming a thermal spectrum of ~ 0.3 keV, typical of a magnetar in quiescence (see Rea & Esposito 2011 for a review), and an absorption column density of $9 \times 10^{21}\,\mathrm{cm}^{-2}$ (relative to the whole Galactic value in the direction of the source, from the HI maps from Dickey & Lockman (1990)) we derived a 0.3–10 keV observed flux of $\sim 6.1 \times 10^{-15}\,\mathrm{erg\,s^{-1}\,cm^{-2}}$. Assuming the source is located at the end of the Milky Way, at 10 kpc distance, the corresponding luminosity would be $\sim 2.7 \times 10^{32}\,\mathrm{erg\,s^{-1}}$, consistent with it being a magnetar in quiescence. Given that the number of TeV binaries is a hand-