Transient sources at the highest angular resolution

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Transient sources at the highest angular resolution

- Generality

- Transients in stellar binary systems

- 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
TRANSIENTS IN BINARY SYSTEMS:
X-RAY BINARIES

BXRB

**Thermal /Soft X-ray State**

Energy spectrum

**Hard X-ray State**

Radio Jet

flat radio spectrum

Flat/inverted spectrum sources

GS 1354-66
GX 339-4
GS 2023+338
Cyg X-1

GRO J0422+32

GRS
1750-258

Dhawan et al. 2000

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

Microquasar

BXRB

Thermal /Soft X-ray State

Energy spectrum

Hard X-ray State

Radio Jet

flat radio spectrum
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

Tudose et al. 2008

Radio imaging Circinus X-1

Spencer et al. 2013

Cygnus X-2

Fomalont et al. 2001

Sco X-1
NON-ACCRETING YOUNG PULSAR: $B > 10^{12}$ G, fast rotation (msec)

PSR B1259-63

Transient around periastron

$\alpha = -0.7$

Connors et al. 2002

Moldon et al. 2011
The gamma-ray binary LS I +61 303
$P_1 = 26.496 \pm 0.008$ 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

Two periodicities:

\[ P_1 = 26.49 \pm 0.07 \text{ d} \]
\[ P_2 = 26.92 \pm 0.07 \text{ d} \]

\( P_1 \) periodical outburst (Gregory 2002)

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

Massi & Jaron A&A 2013

Gamma-rays: Fermi-LAT

\[ P_1 = 26.48 \pm 0.08 \text{ d} \]
\[ P_2 = 26.99 \pm 0.08 \]

Jaron & Massi A&A accepted
Amplitude of the outburst changes with a long-term period of $1667 \text{ d} \ (\sim 4.6 \text{ yr})$

Gregory 2002, Gregory & Neish 2002

Does the long-term modulation result from the beat of $P_1$ and $P_2$?
The Model
Massi & Torricelli-Ciamponi 2014

\[ S_{\text{model}}(t) = S_a(t)(\delta_a(t))^{k-\alpha} + S_r(t)(\delta_r(t))^{k-\alpha} \]

Kaiser (2006)
The number density of the relativistic electrons
\[ N_{\text{rel}} = \kappa E^{-p} \]

Conical jet

\[ I_{\nu}(\eta, l) = \int_{0}^{\tau_{\text{end}}(l)} \frac{J_{\nu}}{\chi_{\nu}} e^{-\tau'/\cos \eta} d \left[ \frac{\tau'}{\cos \eta} \right] \]

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

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

Precessing jet with periodical variations of emitting particles

\( P_1 \) (orbital)

\( P_2 \) (precession)

Max Doppler boosting

\[ \eta_{\text{min}} \]

I.O.S.
Precessing Jet model

Massi & Torricelli-Ciamponi 2014

The long-term modulation

Max Doppler boosting
Results: the rapid rotation in position angles of VLBA maps

Massi & Torricelli-Ciamponi 2014
1. **Generality:**
   Fast transients and slow transients

2. **Slow transients in binary systems:**
   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!**
During the maximum of the long-term modulation, the peak of the outburst occurs at orbital phase ~0.6. Afterwards, there is a gradual shift to longer orbital phases (~0.9). After the minimum, the outburst reappears at orbital phase ~0.5.

Paredes et al. 1994

Massi & Torricelli-Ciamponi 2014
Precession: Jets are rotating about the jet axis with a period of $3.0 \pm 0.2$ d

Orbital period $2.62 \pm 0.02$ d (Bay lyn et al. 1995)

Radio images: R. Hjellming and R. Rupen, NRAO.
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 \( \sim 0.3 \) keV, typical of a magnetar in quiescence (see Rea & Esposito 2011 for a review), and an absorption column density of \( 9 \times 10^{21} \) 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 \( \sim 6.1 \times 10^{-15} \) 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 \( \sim 2.7 \times 10^{32} \) erg s\(^{-1} \), consistent with it being a magnetar in quiescence. Given that the number of TeV binaries is a handful while no one so far exists in the Galaxy that has...