The True Colors of Supergiant Fast X-ray Transients: the Swift View

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C. Guidorzi (Uni-Fe), et al...

Swift Mission Conference: Celebrating 5 years
SFXTs Properties:

• discovered/rediscovered by INTEGRAL:
  TRANSIENTS: sporadic and SHORT flares peaking at $10^{36}-10^{37}$ erg s$^{-1}$ lasting a few hours (as observed with IBIS/ISGRI, Sguera et al. 2005, 2006)

• association with OB supergiant companions
  => new class of High Mass X-ray Binaries

• flare X-ray spectrum similar to accreting NS

• a few SFXTs are X-ray pulsars:
  
<table>
<thead>
<tr>
<th>Source</th>
<th>Pspin (s)</th>
<th>Instrument</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>AX J1841.0-0536</td>
<td>~ 4.7</td>
<td>ASCA</td>
<td>(Bamba et al. 2001)</td>
</tr>
<tr>
<td>IGR J18483-0311</td>
<td>~ 21</td>
<td>INTEGRAL</td>
<td>(Sguera et al. 2007)</td>
</tr>
<tr>
<td>IGR J16465-4507</td>
<td>~ 228</td>
<td>INTEGRAL</td>
<td>(Lutovinov et al. 2005)</td>
</tr>
<tr>
<td>IGR J11215-5952</td>
<td>~ 187</td>
<td>RXTE</td>
<td>(Swank et al. 2007)</td>
</tr>
</tbody>
</table>

• high dynamic range (3-5 orders of magnitude)
  $L_{\text{max}}=10^{36}-10^{37}$ erg s$^{-1}$, $L_{\text{min}}=L_{\text{quiesc}}=10^{32}$ erg s$^{-1}$, soft spectrum, likely thermal

• Orbital periods 3-165 days
Swift observations of the 5\textsuperscript{th} outburst: IGR J11215-5952 Feb 2007

- Below detectability
  \[ L(1-10) = 3.7 \times 10^{33} \text{ erg s}^{-1} \]

- Slow rise

- Outburst (1 day)
  Feb 09: CR increase by \(~10\) in \(<1.5\) h
  by \(~65\) in \(17\) h
  \[ L(1-10) = 1.1 \times 10^{36} \text{ erg s}^{-1} \]

- Decline phase (5 d)

- Down to (15 d)
  \[ L(1-10) = 1.2 \times 10^{33} \text{ erg s}^{-1} \]

SFXT \( L_x \sim 10^{36} \text{ erg s}^{-1} \)
Dynamic range \(\sim 10^3\)

(hard spectrum)
**Swift observations of the 5th outburst:**

IGR J11215-5952 Feb 2007

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**SFXT Lx \sim 10^{36} \text{ erg s}^{-1}
Dynamic range \sim 10^3 (hard spectrum)**
The properties of all the observed outbursts are similar. The true orbital period is \( P_{\text{orb}} = 164.6 \text{ days} \) (Romano et al. 2009b)

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SFXTs properties: open questions

Duration of the outbursts?
Broad band truly simultaneous spectra:
really similar to X-ray pulsars?

Long term properties?
How much time spent in outbursts vs quiescence?
Are they still in accretion when they are
not in bright flaring activity?

Orbital and spin periods? Neutron star magnetic field?
**Swift**: the 1st panchromatic, sensitive, long-term monitoring campaign

Sample of 4 confirmed SFXTs:
XTE J1739-302 (prototype)
IGR J17544-2619 (prototype)
IGR J16479-4514 (triggered BAT in 2005)
AX J1841.0-0536 (pulsar)

2 or 3 obs /source/week, 1 ks each
• catch “almost” every outbursts,
• monitor the onset of a new outburst to follow the whole outburst duration
• monitor long term properties (first time) and the quiescent level

1st year: 2007 Oct
330 XRT observ.
363 kiloseconds
(Romano, et al 2009c)
MNRAS,399,2021

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**Swift/XRT light curves**

(a) IGR J16479–4514

(b) XTE J1739–302

2007-10-26 to 2008-11-15

variability

1E36 erg s\(^{-1}\)

both 4 orders of magnitude
Swift/XRT light curves

(c) IGR J17544–2619

(d) IGR J18410–0535

Flares: 4 orders of magnitude

No outbursts: 2 orders of magnitude
SFXT Inactivity Duty Cycle

XRT provides casual sampling of the light curve at a resolution $\sim 4d$
- BAT-detected outburst,
- intermediate state (firm detection excluding outbursts),
- non detections (detections with a significance below $3\sigma$).

$$IDC = \frac{\Delta T_\Sigma}{\Delta T_{\text{tot}} (1 - P_{\text{short}})} ,$$

<table>
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<tr>
<th>Source</th>
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<tr>
<td>IGR J16479-4514</td>
<td>17%</td>
</tr>
<tr>
<td>AX J1841.0-0536</td>
<td>28%</td>
</tr>
<tr>
<td>XTE J1739-302</td>
<td>39%</td>
</tr>
<tr>
<td>IGR J17544-2619</td>
<td>55%</td>
</tr>
</tbody>
</table>

Accreting matter most of the time

Time a source spends UNdetected down to a flux $1-3 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$
$\Delta T_\Sigma =$ total expo($>900s$) where $3\sigma$UL only obtained;
$\Delta T_{\text{tot}} =$ total expo; $P_{\text{short}} =$%(expo < 900s)
Out of outburst emission spectroscopy

The lowest luminosity level we could monitor with Swift:
$L_X = 6 \times 10^{32}$ erg s$^{-1}$ in XTE J1739-302 and $L_X = 3 \times 10^{32}$ erg s$^{-1}$ in IGR J17544-2619
Out of outburst emission spectroscopy

Black-body radii < 1km!!!
<< $R_{\text{NS}}$

polar cap accretion?

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UVOT light curves

(a) XTE J1739−302

(b) uvw1

(c) uvw2

(d) XRT Count rate

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Outburst panchromatic light curves

(a) IGR J16479–4514

Count rate

0.01 0.1 1 10

MJD
Outburst panchromatic light curves

The X-ray emission is highly variable and spans almost 4 orders of magnitude in count rate

(Romano et al. 2008)
Comparison of 7 SFXTs light curves

>8 days of monitoring with Swift/XRT

Common features:
- outburst length > hours
- multiple peaked structure
- dynamic range ~ 3 oom

2005 Aug 30
Sidoli et al. 2008

2007 Feb 09
Romano et al. 2007

2008 Aug 13
Sidoli et al. 2009b

2008 Mar 31
Sidoli et al. 2009a

2008 Jul 05
Romano et al. 2009a

2009 May 6
Sidoli et al. 2009c

2009 Jun 11- Jul 8
Romano et al. 2009d
## Outburst emission spectroscopy

<table>
<thead>
<tr>
<th>Source</th>
<th>$N_H (10^{22})$</th>
<th>$\Gamma$</th>
<th>$E_{\text{cut}}$</th>
<th>$E_{\text{fold}}$</th>
<th>$L_x (0.5-10 \text{ keV})$</th>
<th>$L_x (0.5-100 \text{ keV})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IGR J16479–4514</td>
<td>$6.2 \pm 0.5$</td>
<td>$1.1 \pm 0.2$</td>
<td>$6.6 \pm 0.9$</td>
<td>$15.3 \pm 2.5$</td>
<td>$28.2 \times 10^{36}$</td>
<td>$57.3 \times 10^{36}$</td>
</tr>
<tr>
<td>IGR J17544–2619</td>
<td>$1.1 \pm 0.2$</td>
<td>$0.75 \pm 0.1$</td>
<td>$18 \pm 2$</td>
<td>$4 \pm 2$</td>
<td>$1.9 \times 10^{36}$</td>
<td>$5 \times 10^{36}$</td>
</tr>
<tr>
<td>IGR J1739–302</td>
<td>$12.5 \pm 3$</td>
<td>$1.4 \pm 0.7$</td>
<td>$6 \pm 6$</td>
<td>$16 \pm 10$</td>
<td>$1.9 \times 10^{36}$</td>
<td>$3 \times 10^{36}$</td>
</tr>
</tbody>
</table>

(Romano et al. 2008)

(Sidoli et al., 2009a)
Outburst emission spectroscopy


same spectral shape but higher column density during the flare than in the low level activity
variable absorbing column density during the flare was observed in XTE J1739–302 for the first time

(Sidoli et al. 2009b)

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Status of the SFXT Project

2009 November 3:

IGRJ16479-4514 144 obs/161 ks
XTE J1739-302 184 obs/206 ks
IGRJ17544-2619 142 obs/143 ks
AX1841.0-0536 88 obs/96 ks (2008 only)

Total Exposure 606 ks

558 observations

(Romano et al. 2010, in prep.)
Summary

Only panchromatic experiment that can catch outbursts since their early stages (~100s):
- true length of outbursts

Monitoring program:
non-serendipitous study in all intensity states
• different kinds of outbursts
• inactivity duty cycle
• intensity-based spectroscopy

http://www.ifc.inaf.it/sfxt/