INTEGRAL observations of long X-ray bursts

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July 14, 2011

NS-11, St. Petersburg
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More or less long bursts

X-ray burst durations

Distribution of all (MINBAR*) X-ray bursts as a function of their exponential decay time

Current investigations of the various types of thermonuclear bursts aim to draw a consistent picture of the ignition and burning processes in relation with the accretion regime of the neutron stars.

More or less long bursts

Distribution of all (MINBAR*) X-ray bursts as a function of their exponential decay time

Ordinary He bursts

Short bursts $\approx 5000$

H/He bursts

Intermediate long bursts: duration $> 12$ min
From 14 sources

Unusual long* bursts
From 11 sources

Superbursts
From 11 sources

INTEGRAL

JEM-X:
100 cm$^2$ @ 10 keV
3-25 keV
FoV: 5°, 3’ reso.

IBIS:
1000 cm$^2$ @ 20 keV
18 keV – 10 MeV
FoV ≈ 12°

SPI:
20 keV – 8 MeV
2.2 keV @ 1.3 MeV
FoV ≈ 15°
The Galactic Center region as seen by JEM-X

INTEGRAL long bursts
The Galactic Center region as seen by JEM-X

94 X-ray bursters known to date; \( \approx 2/3 \) located in the Galactic Bulge region
Example of burst detections in JEM-X detector light curve
Long burst from IGR J17254-3257

KP484_DETDE_LC30s ScWs 41–43 [3–10 keV]

1st October 2006

slew!
Long burst from IGR J17254-3257

Chenevez et al., 2007
Long burst from IGR J17254-3257
1st October 2006

15 20 25 30 35 40 45

TIME (d)

15 2465.26 2465.27 2465.28 2465.29 2465.3 2465.31 2465.32

RATE (count/s)

GX 354−0

Count Rate (3–20 keV)

Time (s)

ScW 41 ScW 42

Burst 2

Chenevez et al., 2007

20 22 24 26 28 30 32 34 36

 Counts (3–10 keV)

INTEGRAL long bursts
Different lasting bursts from IGR J17254-3257 can be explained by a transition between two slightly different accretion rates. The short event is a mixed H/He burst triggered by a weak H flash, while the long burst is the result of the burning of a large He pile produced by steady H burning at a slightly higher accretion rate.
SLX 1737-282

3/4 bursts in INTEGRAL; all intermediate long!

(Falanga, Chenevez, et al., 2008)
SLX 1737-282
Time-resolved spectral analyses

March 2004
April 2005
April 2007

Burst 1
Burst 2
Burst 3

Time (s)

L_{bol} (10^{38} \text{ erg s}^{-1})

kT_{bb} (\text{keV})

R_{bb} (\text{km})

χ^2_{red}

INTEGRAL long bursts
The time resolved spectral analysis reveals variations in the temperature and inferred blackbody radius that are consistent with expansion and contraction of the neutron star photosphere. The luminosity reaches the Eddington limit, allowing us to derive the distance to the source: \( d \approx 7.5 \text{ kpc} \).
SLX 1735-269
The first long burst detected by INTEGRAL

15 September 2003

Long rise

Large radius expansion followed by contraction.

Soft precursor

Progressive hardening

1st interpretation was mix burning of H/He (Molkov et al. (2005). In ‘t Zand et al. (2007) classified the source as UCXB candidate. ⇒ Pure He burning.
The peculiar long burst from GX 3+1 on August 31, 2004

(Chenevez et al., 2006)
The peculiar long burst from GX 3+1 on August 31, 2004

Two-phases burst

(Chenevez et al., 2006)
The peculiar long burst from GX 3+1 on August 31, 2004

Relation with accretion rate

Long term persistent flux of GX 3+1

An aborted superburst due to the premature ignition of a carbon layer triggered by an He detonation could also be considered.

NS-11, St. Petersburg
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INTEGRAL long bursts

Jérôme Chenevez, DTU Space, Technical University of Denmark
The monitoring of long X-ray bursts with INTEGRAL/JEM-X has led to the discovery of six intermediate bursts longer than \( \approx 15 \) minutes: \( \frac{1}{3} \) of the total population, and \( \frac{1}{2} \) of the bursts, which occurred in the same period.

### Intermediate long X-ray bursts observed with INTEGRAL

<table>
<thead>
<tr>
<th>Source</th>
<th>Date</th>
<th>( T_b ) (s)</th>
<th>( \tau ) (s)</th>
<th>( E_b ) (erg)</th>
<th>Acc. Rate* (g/cm(^2)/s)</th>
<th>Burning</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>GX 3+1</td>
<td>20040831</td>
<td>1800</td>
<td>131</td>
<td>( 2 \cdot 10^{40} )</td>
<td>10000</td>
<td>He / H</td>
<td>Chenevez et al., 2006</td>
</tr>
<tr>
<td>IGR J17254-3257</td>
<td>20061001</td>
<td>900</td>
<td>216</td>
<td>( 2 \cdot 10^{40} )</td>
<td>400</td>
<td>(H(\Rightarrow)He)</td>
<td>Chenevez et al., 2007</td>
</tr>
<tr>
<td>SLX 1737-282</td>
<td>20040309</td>
<td>1500</td>
<td>275</td>
<td>( 0.7 \cdot 10^{41} )</td>
<td>800</td>
<td>He</td>
<td>Falanga, Chenevez et al., 2008</td>
</tr>
<tr>
<td></td>
<td>20050411</td>
<td>1800</td>
<td>323</td>
<td>( 1.2 \cdot 10^{41} )</td>
<td></td>
<td>He</td>
<td></td>
</tr>
<tr>
<td></td>
<td>20070402</td>
<td>( \sim 900 )</td>
<td>281</td>
<td>( 1.0 \cdot 10^{41} )</td>
<td></td>
<td>He</td>
<td></td>
</tr>
<tr>
<td>SLX 1735-269</td>
<td>20030915</td>
<td>2000</td>
<td>400</td>
<td>( 2 \cdot 10^{41} )</td>
<td>1500</td>
<td>He</td>
<td>Molkov et al., 2005</td>
</tr>
</tbody>
</table>

*Eddington mass accretion rate per unit area: \( m_{Edd} \approx 10^5 \text{g cm}^{-2}\text{s}^{-1} \)

(UCXB: in ‘t Zand et al, 2007)
To-date last observed superburst
SAX J1753.0-2853 on February 13th

Chenevez et al., ATel 3183

The superburst peak reaches similar count-rate as previous PRE bursts from this source, and is consistent with a shock-triggered He flash precursor as seen in other superbursts (Weinberg & Bildsten, 2007).

Chenevez et al., in prep.
**To-date last observed superburst**
SAX J1753.0-2853 on February 13th

Precursor →

Intermediate long burst!

Chenevez et al., *in prep.*
An exceptional sequence of events:

1. ATel 3162: "Fermi LAT detection of an outburst from the Galactic center region"≈20s GeV burst 3 days prior to the superburst.

2. ATel 3163: "Swift/XRT detects SAX J1747.0-2853 in outburst"Associates this source with the origin of the LAT burst.

3a. ATel 3172*: "INTEGRAL sees continuing activity from SAX J1747.0-2853"Reports only on strong X-ray flaring activity!

3b. ATel 3183*: "First superburst observed by INTEGRAL, from SAX J1747.0-2853"Superburst preceded by an intermediately long burst.

4. ATel 3217: "SAX J1747.0-2853: 'normal' thermonuclear bursts resumed"Burst quenching time upper limit of 25 days (as expected).

To-date last observed superburst
SAX J1753.0-2853 on February 13th
Summary

• First superburst observed from SAX J1753.0-2853 – *early* in outburst

• 2\textsuperscript{nd} superburst so far from a (normal) X-ray *transient* (4U1608-52 in 2005)

• 2\textsuperscript{nd} shorter quenching time (4U 0614+09 : 19 days)

• Photospheric Radius Expansion (TBC)

• Peculiar start of the outburst with a GeV event

• **First observation of a firestarter** (right heating / C supply conditions?)

• Need theoretical explanation from numerical simulations

To-date last observed superburst
SAX J1753.0-2853 on February 13\textsuperscript{th}
Most intermediate bursts are observed from low luminosity sources and are interpreted as long pure He bursts. If no H is accreted, they are consistent with the burning of a slowly accreted, thick He layer, in Ultra Compact X-ray Binaries (UCXB) where the donor star is probably a degenerated helium white dwarf.

Of special interest are bursters showing events with very different durations, thus allowing us to study transitions between different nuclear burning regimes.

Depending on the actual accretion rate, either the burning of a large amount of H-rich material is triggered by an He flash, or a thick sedimented column of He is triggered by weak H ignition.

Relation with superbursts…?