INTEGRAL monitoring of unusually Long X-ray bursts

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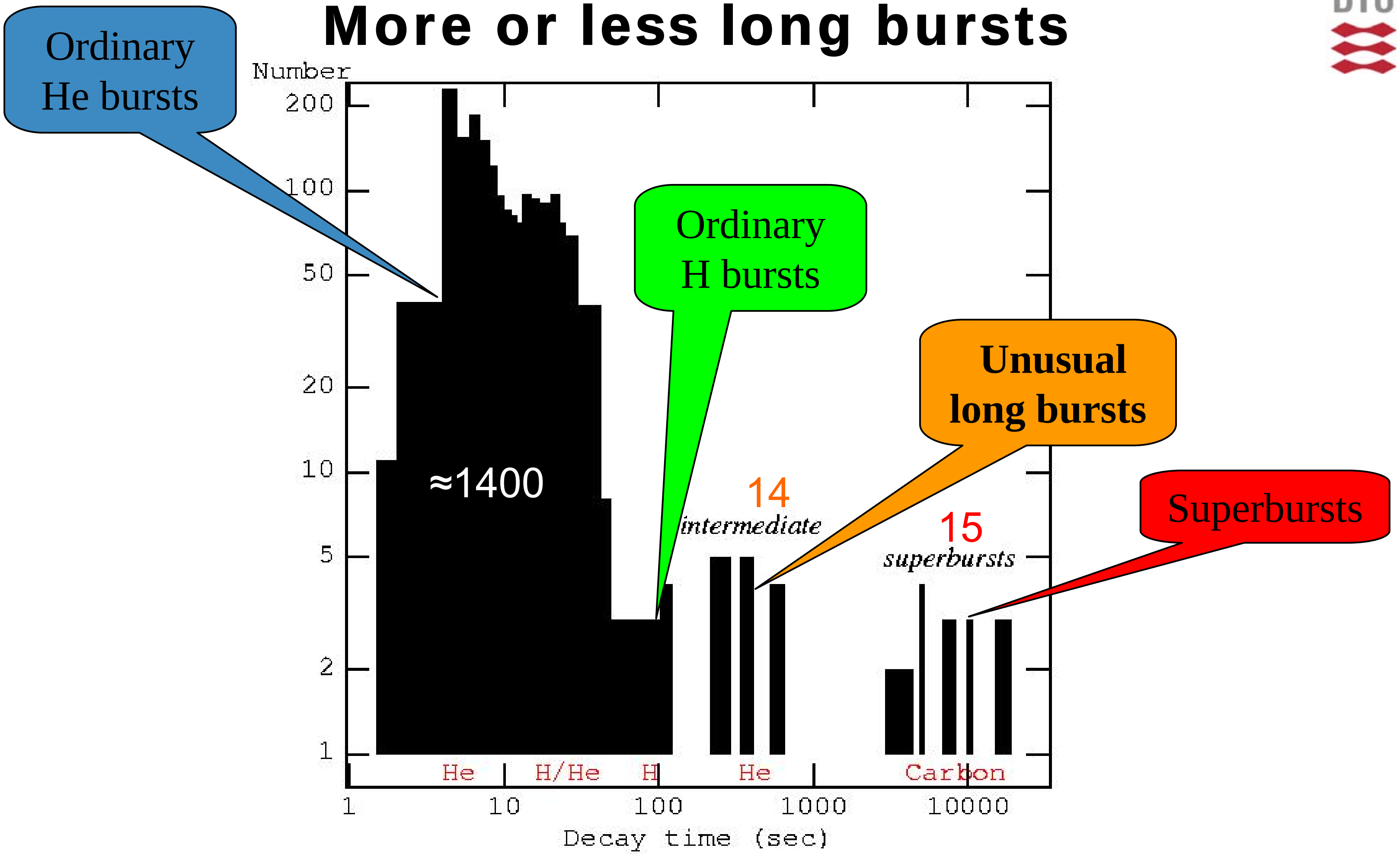
More or less long bursts



Distribution of the X-ray bursts as a function of their exponential decay time

The long term goal is to interpret the various types of thermonuclear bursts into a consistent picture of the ignition and burning processes in relation with the accretion regime of the neutron stars.

OBSERVATIONS

Intermediate long bursts

Intermediate duration (~10 min) X-ray bursts
like, e.g., GX 3+1 long X-ray burst on 31st August 2004
are rare events.
They may reveal unexplored nuclear burning physics.
It is worth monitoring unusual X-ray bursts with INTEGRAL!

Accepted Proposals

INTEGRAL Key Programmes

<u>AO 4</u> Long X-ray burst monitoring in the Galactic Centre : 23 sources

<u>AO 5</u> Long X-ray burst monitoring in the Galactic Centre : 44 sources
Long X-ray burst monitoring in the Cygnus Region : 2 sources

<u>AO 6</u> Survey of long X-ray bursts in the Galactic Centre : 48 sources
Survey of long X-ray bursts in the Galactic Disk : 10 sources
Survey of long X-ray bursts in the Cygnus region : 2 sources

Data are allocated for X-ray bursts lasting more than 10 minutes.

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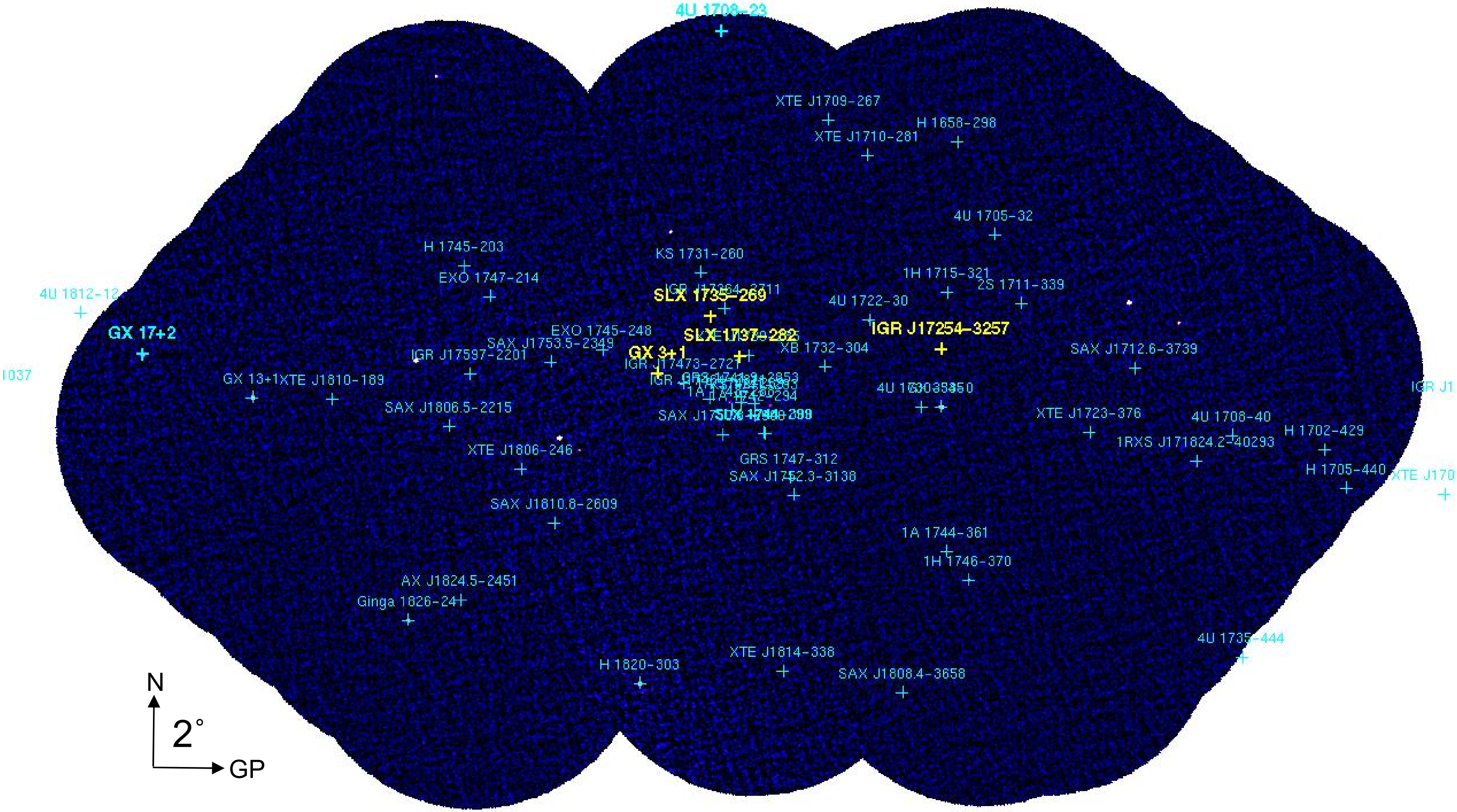
Also search for unusual long events in public data archive and core programme data.

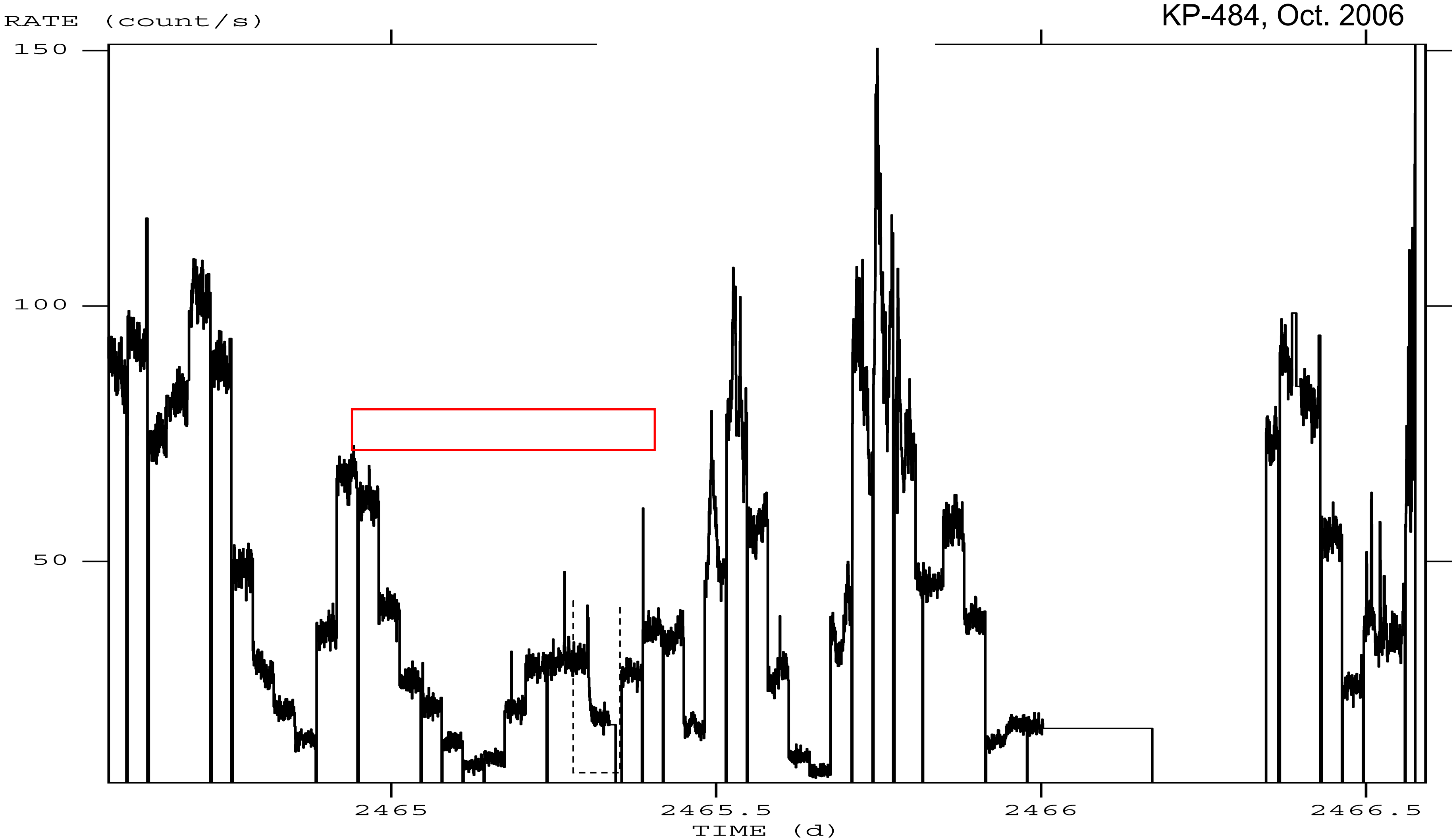
The Galactic Center region as seen by JEM-X

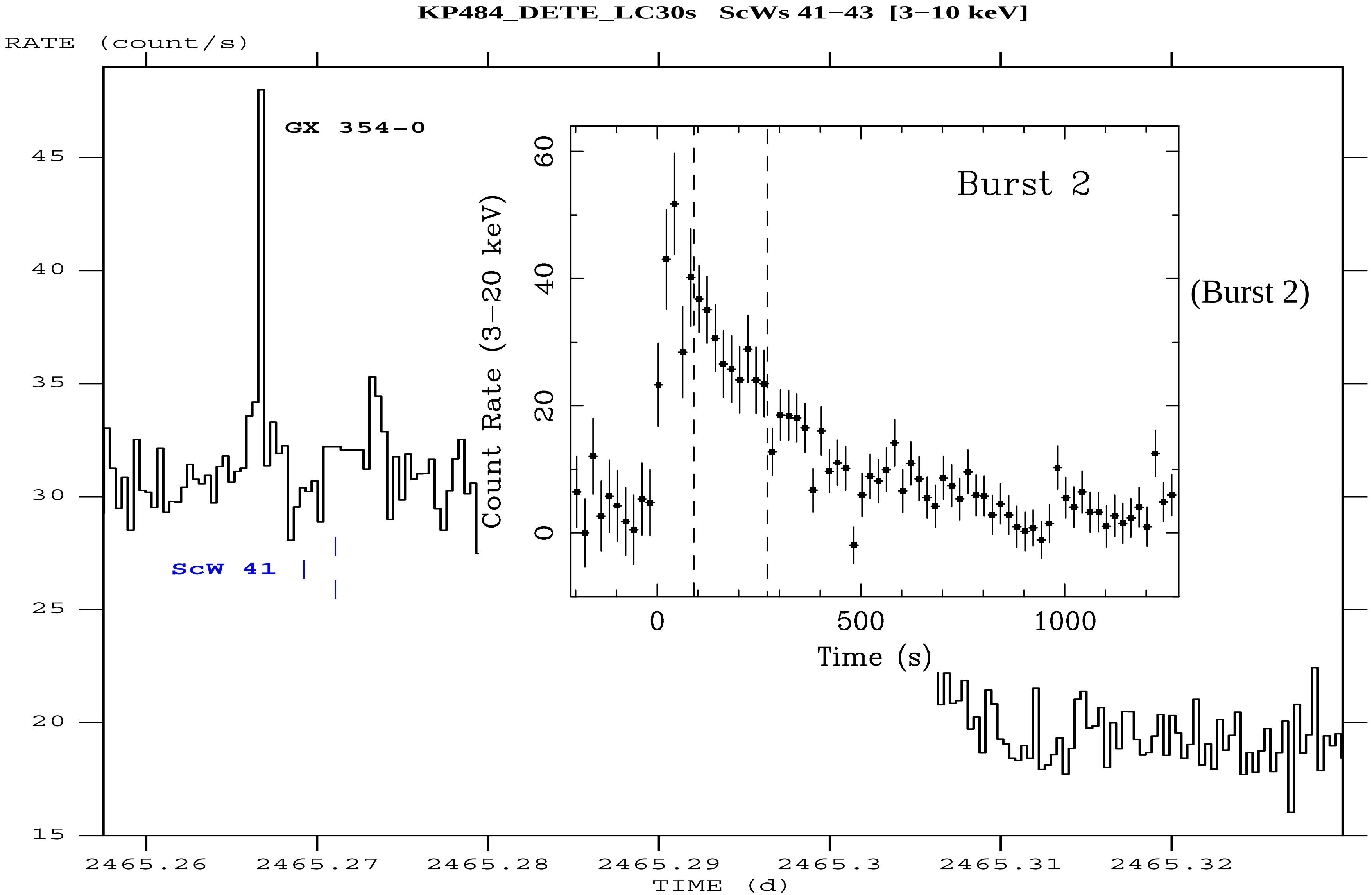


89 X-ray bursters known to date; ≈2/3 located in the Galactic Bulge region

Example 1: **X-ray burst detection in JEM-X <u>images</u>**

Example 2: **JEM-X detector <u>light curve</u> (30s bins)**

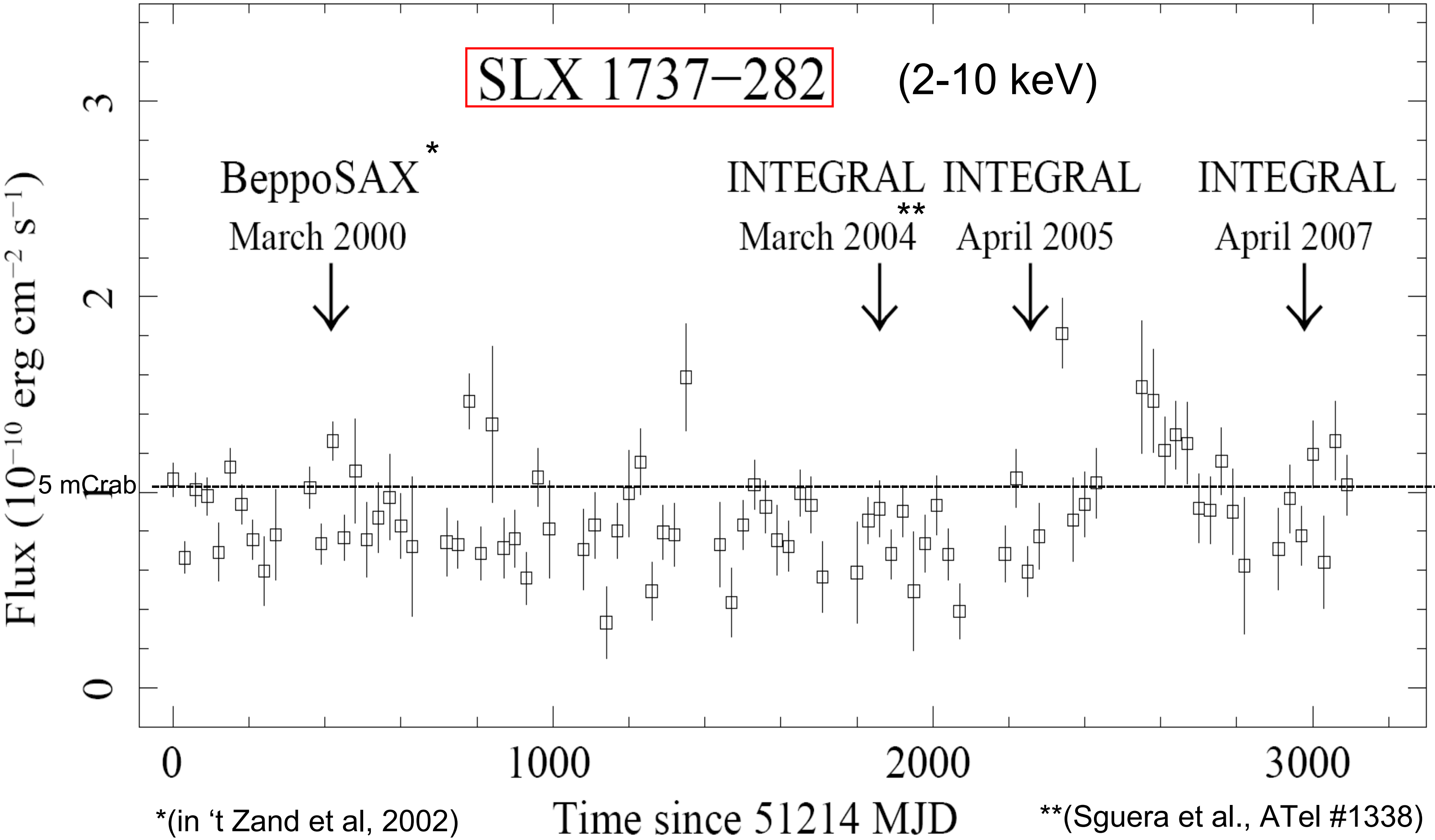



KP484_DETE_LC30s ScWs 41−43 [3−10 keV]
RATE (count/s)
45
40
35
30
25
20
15
GX 354−0
ScW 41
2465.26
2465.27
2465.28
2465.29
2465.3
2465.31
2465.32
TIME (d)
Count Rate (3−20 keV)
60
40
20
0
Burst 2
0
500
1000
Time (s)
(Burst 2)

A weak persistent, long bursting only source

RXTE/PCA

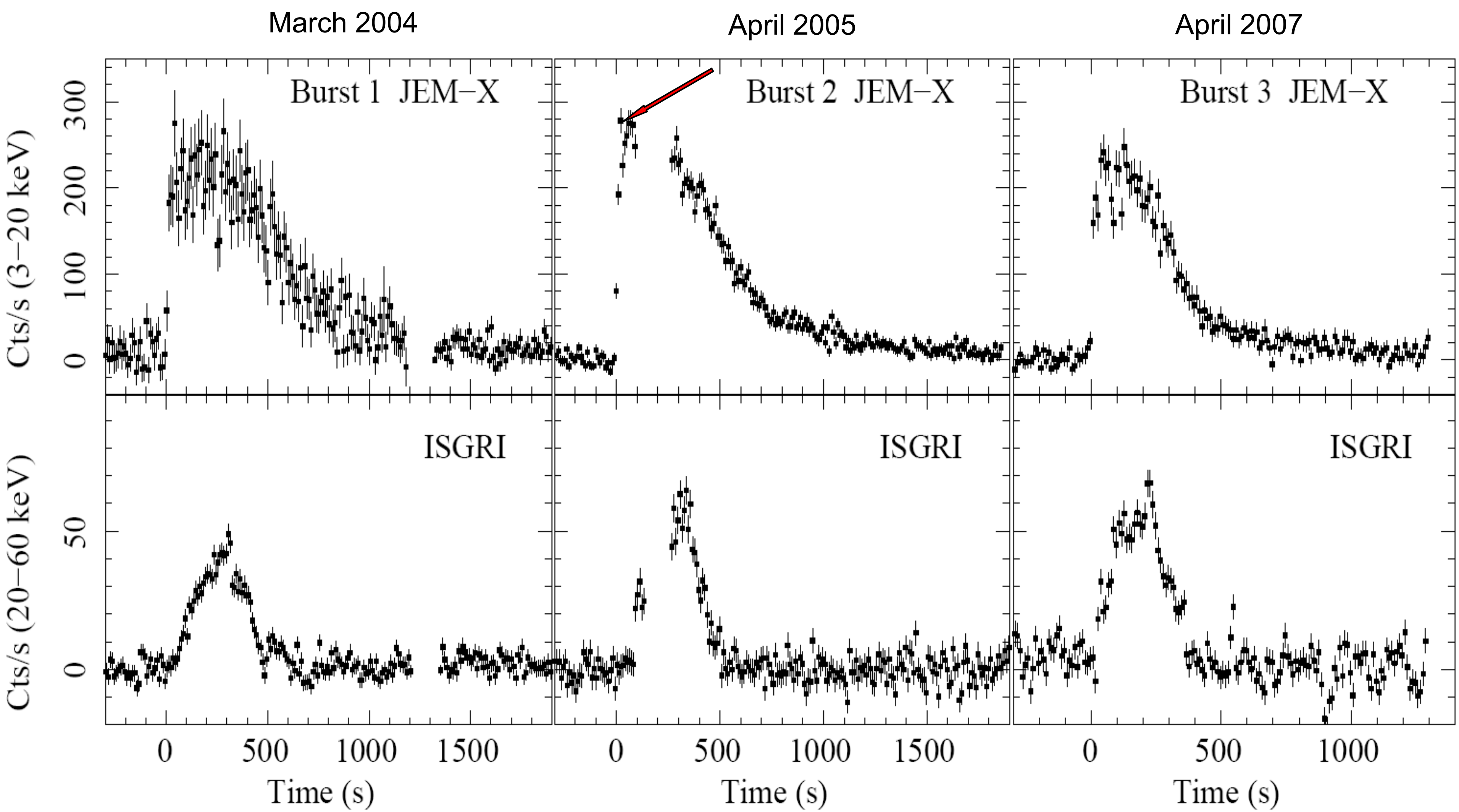
(Falanga, Chenevez et al., 2008)

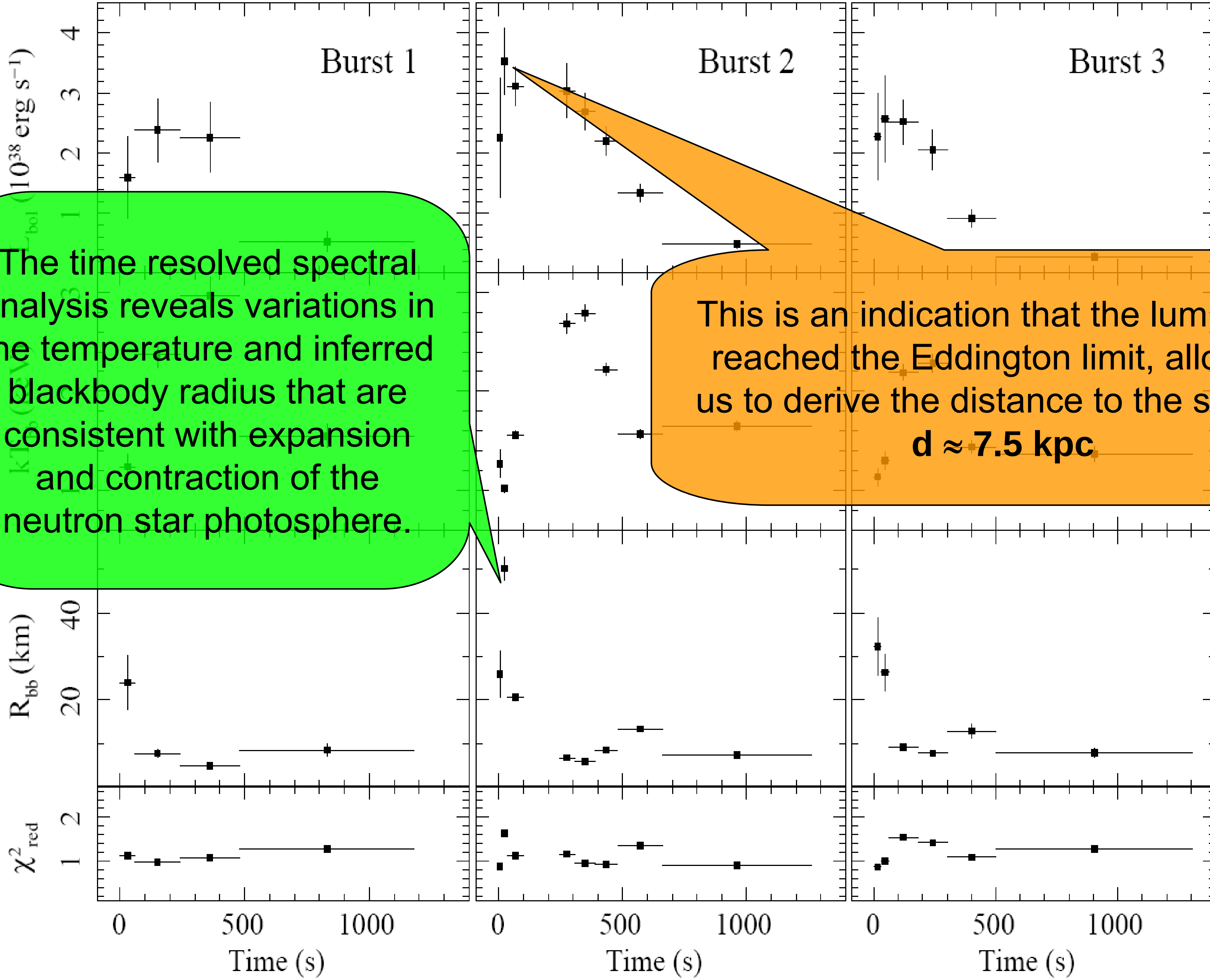


*(in 't Zand et al, 2002)

**(Sguera et al., ATel #1338)

3 bursts in INTEGRAL; all intermediate long!





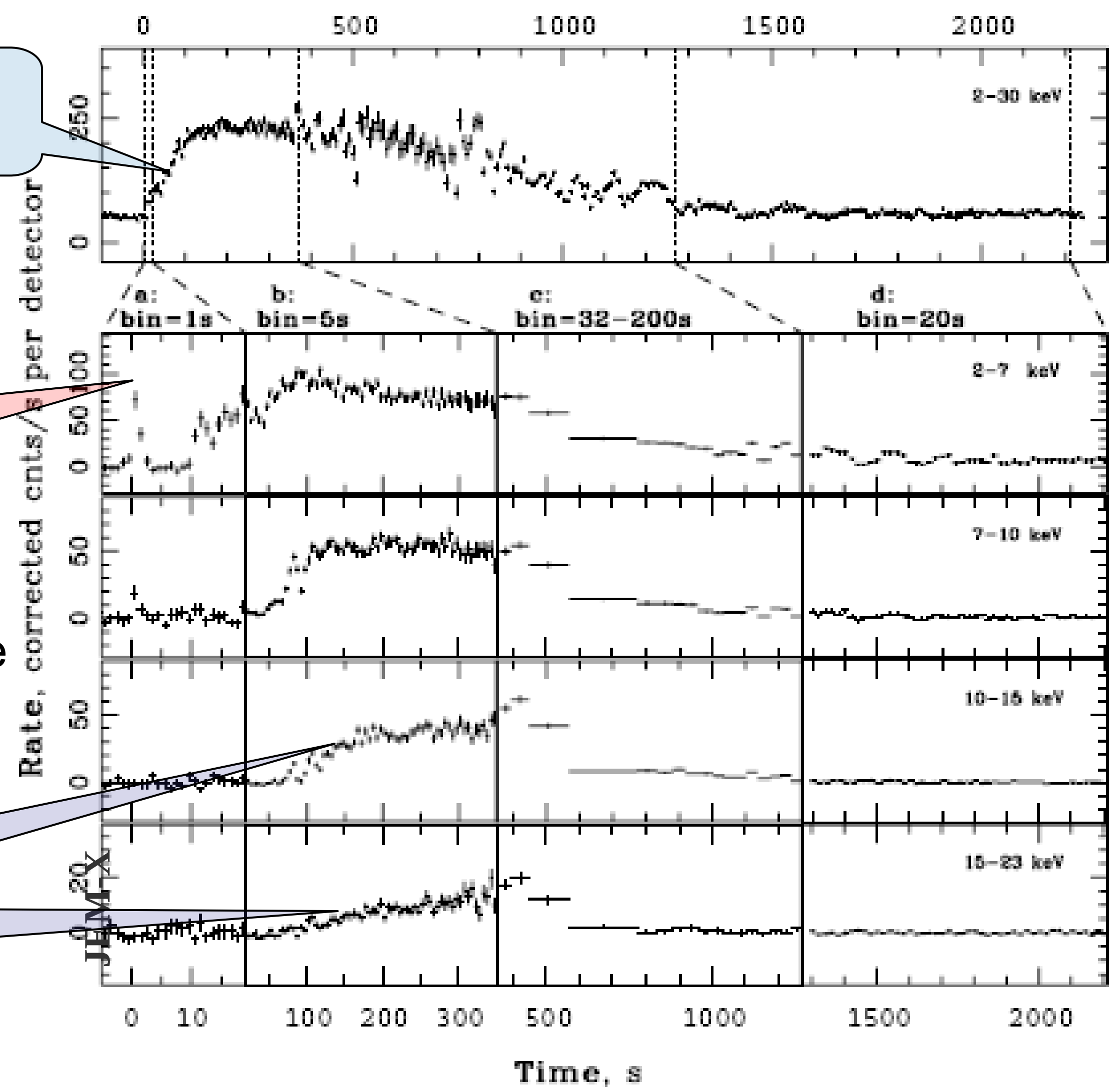
The time resolved spectral analysis reveals variations in the temperature and inferred blackbody radius that are consistent with expansion and contraction of the neutron star photosphere.

This is an indication that the luminosity reached the Eddington limit, allowing us to derive the distance to the source: **d ≈ 7.5 kpc**

SLX 1735-269

15 September 2003

S. Molkov et al.: INTEGRAL detection of a long powerful burst from SLX 1735-269 (2005)



Long rise

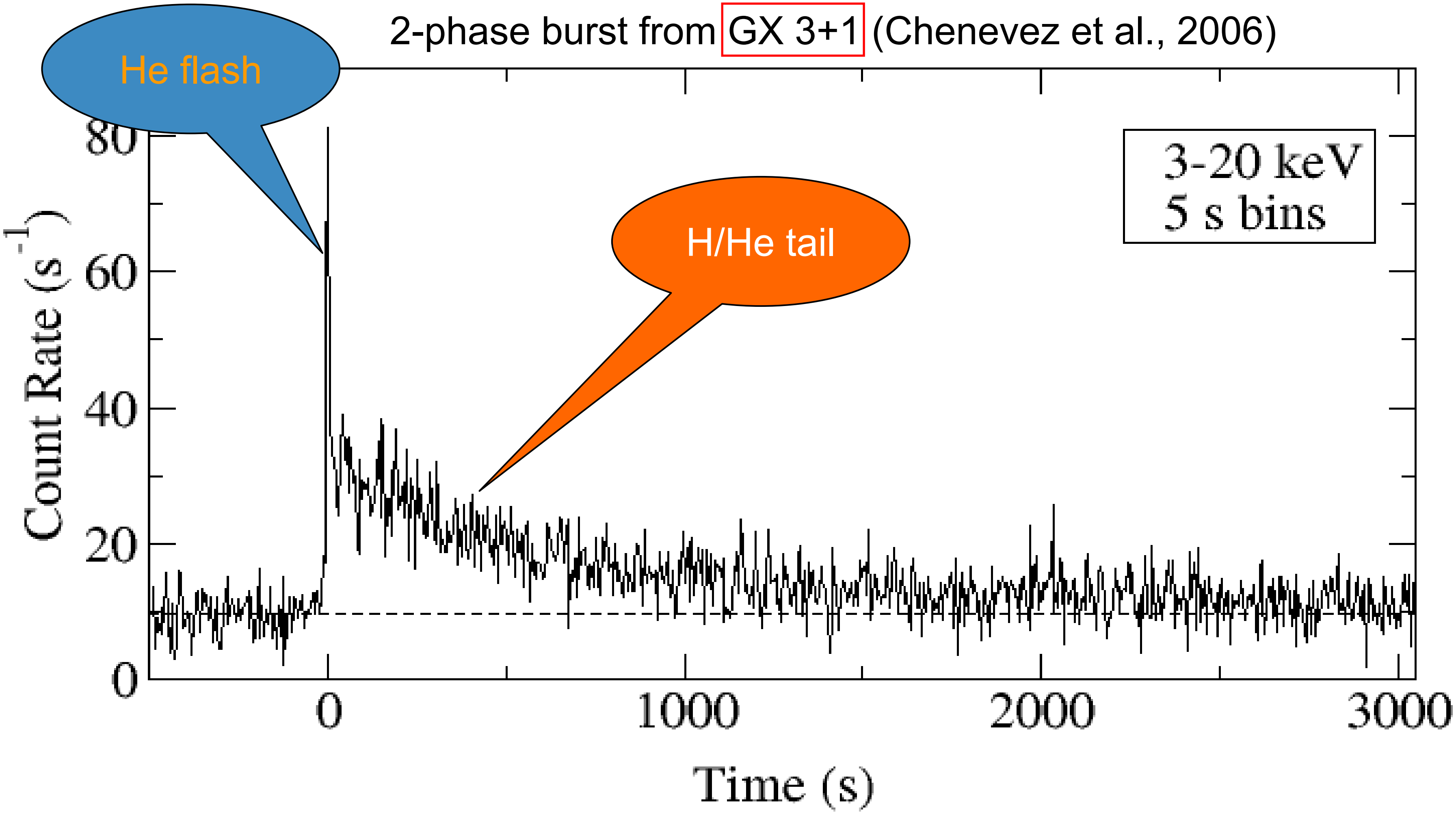
Soft precursor

Very soft emission (UV) due to cooling caused by large radius expansion followed by contraction.

Progressive hardening

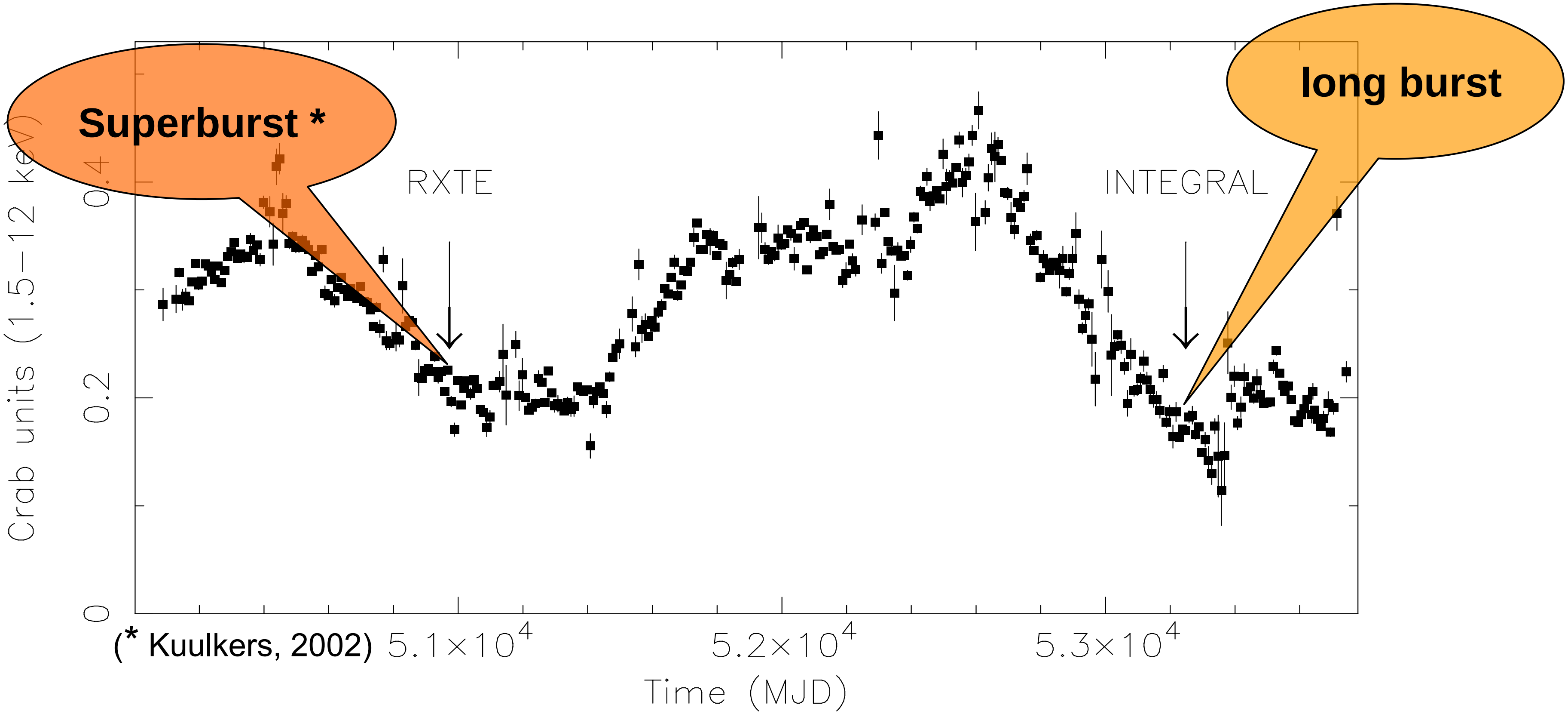
EXPLANATIONS

2-phase burst from GX 3+1 (Chenevez et al., 2006)



Relation with accretion rate

Long term persistent flux of GX 3+1

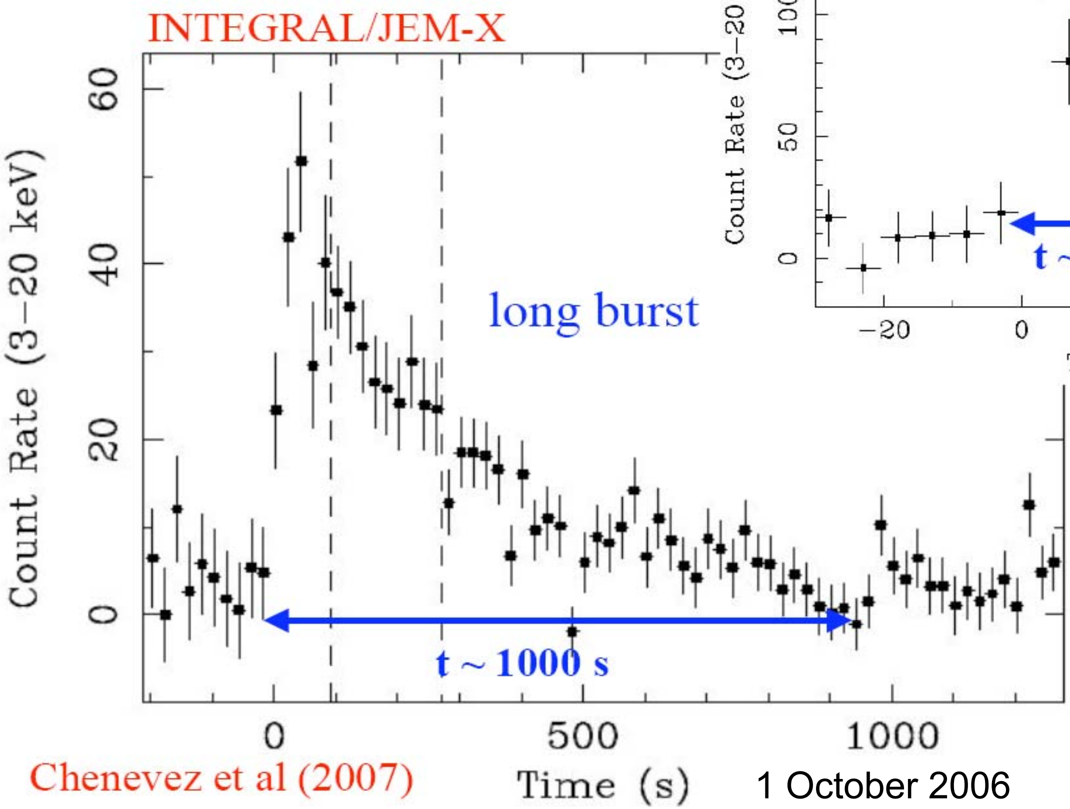


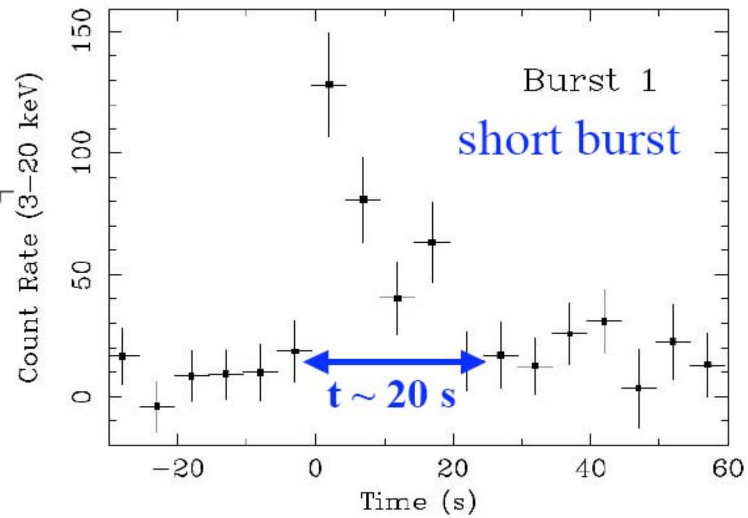
(* Kuulkers, 2002)

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

Transition between Two Regimes?

IGR J17254-3257





17 February 2004

$L \sim 0.4\%\ L_{Edd}$

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 at a slightly higher accretion rate.

PROPERTIES OF INTERMEDIATE LONG BURSTS

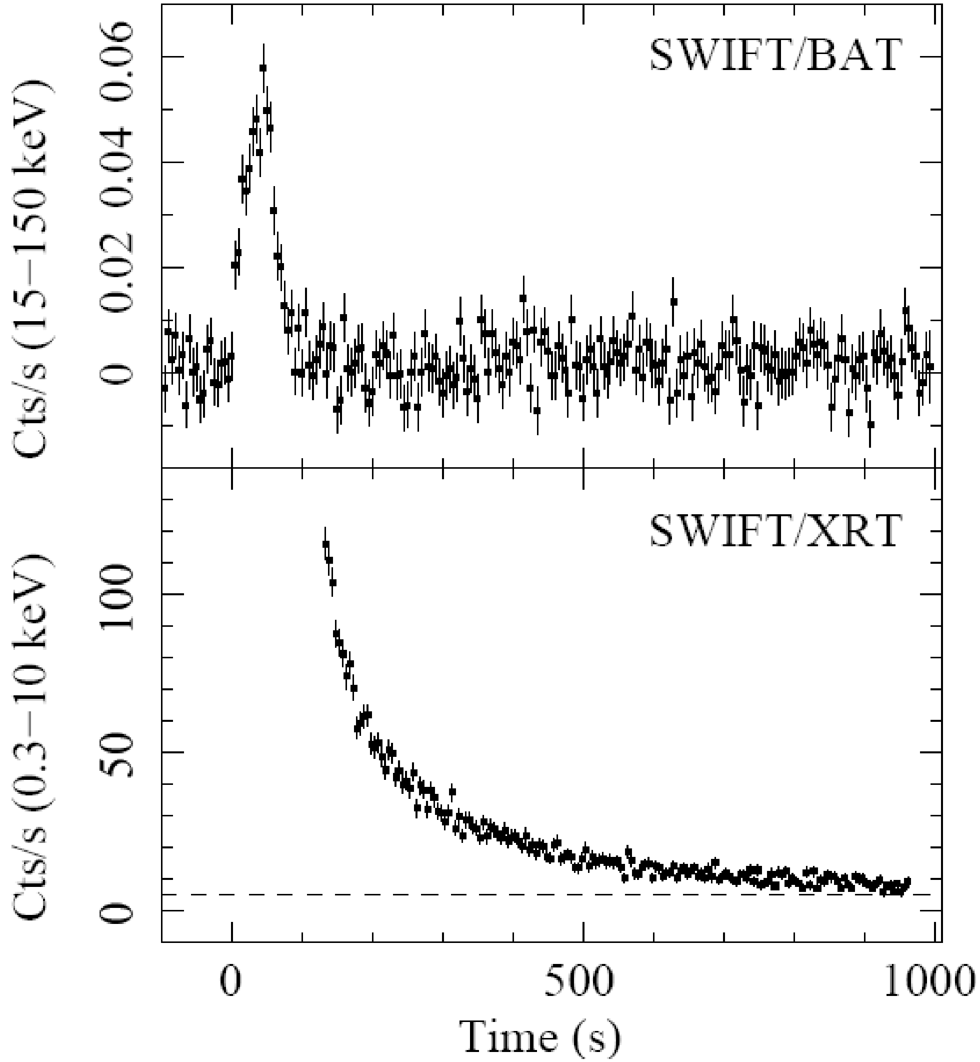
Falanga, Chenevez et al., 2008

source	SLX1737-282				SLX 1735-269	2S 0918-549	IGR J17254-3257	GX 3+1	GX 17+2	4U 1708-23
instrument	WFC	JEM-X			JEM-X	WFC	JEM-X	JEM-X	PCA	SAS-3
precursor burst	no	no	yes	no	yes	no	no	no	no	yes
duration (min)	15	25	30	20	33	40	15	30	15–30	25
$\tau_{\rm rise}$ (sec)	1	2	2	2	100	1	20	1.3	0.4–1.3	20
$\tau_{\rm exp}$ (min)	10	5.0	5.4	4.5	10	3.9	3.7	10.8	3.2–8.3	5.5
$kT_{\rm max}$ (keV)	3.0	3.0	2.8	2.3	2.9	3.0	1.6	2.3	1.8–2.4	2.5
$L^a_{\rm peak}$ (10^{38} erg s^{-1})	3.8	2.5	3.8	3.6	5.1	3.5	0.9	0.8	1.6–2.0	3.0
$E_{\rm b}$ (10^{40} erg)	19	7	12	10	20	9	2.0	2.1	5.1–7.9	9.7
$\tau \equiv {\rm E_b/L_{peak}}$ (min)	8.4	4.7	5.4	4.7	6.5	4.3	3.6	4.4	5.3–6.6	5.4
$L^b_{\rm pers}$ (%$\rm L_{Edd}$)	0.4	0.5	0.5	0.5	1.0	0.6	0.2	6.0	75–80	0.3
distance (kpc)	8	7.3	7.3	7.3	8.5	5.4	8	5	10	6
references	[1]	[2]	[2]	[2]	[3]	[4]	[5]	[6]	[7,8,9]	[10]

[a] Unabsorbed bolometric peak (black-body) luminosity.
[b] We used the bolometric unabsorbed flux from spectral fits; the observed maximum flux during radius-expansion bursts
1. in 't Zand et al. (2002), 2. this work 3. Molkov et al. (2005), (see also Suzuki & Kawai, 2005; Sguera et al., 2007b),
4. in 't Zand et al. (2005), 5. Chenevez et al. (2007), 6. Chenevez et al. (2006), 7. Tawara et al (1984), 8. Kuulkers et al. (2002),
9. Galloway et al. (2006), 10. Hoffman et al. (1978)

6/(14) intermediate long bursts published with JEM-X analysis

Last minute: long burst from XTE J1701-407 on July 17th



Falanga, Bozzo, Chenevez, *submitted*

(but also Linares et al., astro-ph/0808.3950)

SUMMARY

Our monitoring of long X-ray bursts with INTEGRAL including archive searches and near real time observations has led to the discovery of five intermediate long bursts among the 14 known in total. Of special interest are the low luminosity bursting sources allowing us to study unusual burning regimes in the context of Ultra Compact X-ray Binaries (UCXB). Bursts of very different durations from the same source can be explained by the transition between two nuclear burning regimes.

Intermediate long X-ray bursts observed with INTEGRAL

Source	Date	T_b (s) | τ (s)	E_b (erg)	Acc. Rate* (g/cm^2/s)	Burning	Reference
GX 3+1	20040831	1800 | 131	$2 \cdot 10^{40}$	10 000	He / H	Chenevez et al., 2006
IGR J17254-3257	20061001	900 | 216	$2 \cdot 10^{40}$	400	H / He	Chenevez et al., 2007
SLX 1737-282	20040309 20050411 20070402	1500 | 275 1800 | 323 ~900 | 281	$0.7 \cdot 10^{41}$ $1.2 \cdot 10^{41}$ $1.0 \cdot 10^{41}$	800	He He He	Falanga, Chenevez et al., 2008
SLX 1735-269	20030915	2000 | 400	$2 \cdot 10^{41}$	1 500	He	Molkov et al., 2005

*Eddington mass accretion rate per unit area: $\dot{m}_{Edd} \approx 10^5\,\mathrm{g\,cm^{-2}\,s^{-1}}$

CONCLUSIONS

Intermediate long bursts have generally been explained by the extended cooling of a thick layer associated with mixed H/He burning at relatively low accretion rate.

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

Long pure He bursts involving an even larger column depth are now considered, especially if no H is accreted (e.g., UCXB where the donor star is a degenerated helium white dwarf).

Relation with superbursts…?

PERSPECTIVES

X-ray bursts as probes of:

- Compact object as neutron star
- Neutron stars properties (M_{NS}, R_{NS}, T_{NS}, spin)
- Accretion rate
- Evolutionary state (H/He) of the companion

Future prospects:

- Still hope to see the first **superburst** with INTEGRAL

  Nuclear lines / photoionisation edges