Periodic X-ray bursts from accreting neutron star LMXBs

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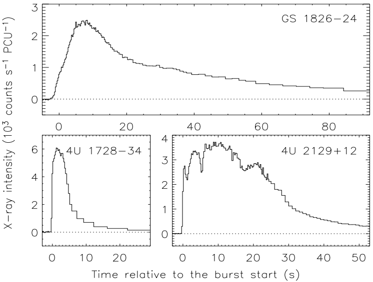
Bursts

Type I

- Due to unstable thermonuclear ignition of accreted matter
- Sharp rise and exponential decay of intensity
- Blackbody spectra with 0.5-3 KeV temperature
- Cooling observed during decay
- Duration 10-100 s
- Typical luminosity $\sim 10^{39}$ ergs/s



Galloway et al. 2006

Bursts

Goals

- Well-defined emission spectra can help to constrain the radius
- Photospheric Radius Expansion (PRE) bursts can be used to estimate distances
- Flame spreading and burning physics
- Burst oscillation physics

Factors affecting burst behavior

- Fuel composition
- Mass accretion rate
- Magnetic field
- Initial conditions (set by previous bursts or other stellar processes)

Burning regimes

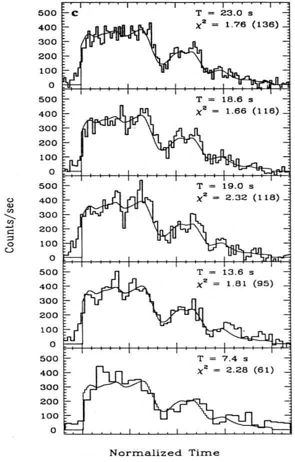
Increasing accretion rate ↓

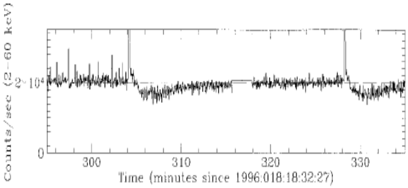
- Unstable H burning
- Stable H burning
- Unstable He burning
- Mixed H/He ignition
- Stable He burning

Bursts

Type II

Due to spasmodic accretion onto neutron star originating from accretion disc instability (usually in a series)

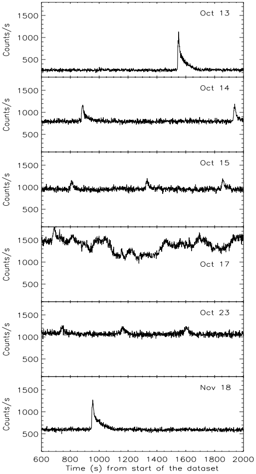




Tan et al. 1991
Lewin et al. 1996

- Low Mass X-ray Binary (LMXB) in 21 hr orbit [Strohmayer et al. 2010, Papitto et al. 2011]
- 11 Hz pulsar [Strohmayer et al. 2010, Papitto et al. 2011]
- In the globular cluster Terzan 5
- $\sim$ 400 bursts [Motta et al. 2011, Chakraborty et al. 2011a, Linares et al. 2011]
- Burst oscillation [Cavecchi et al 2010]
- mHz Quasi Periodic oscillation (QPO) [Linares et al. 2012]
- atoll-Z transition [Altamirano et al 2010b, Chakraborty 2011b]
- Accretion disc wind [Miller et al. 2011]

The bursts and their peculiar nature



Chakraborty et al. 2011a

Aims

- Understanding the unique nature and origin (type-I/ type-II) of these bursts
- Origin of mHz QPOs
- Variation of burst properties with spectral states and consequently with accretion

$$\alpha = \frac{Gravitational\ energy\ released\ in\ mass\ accretion}{Energy\ emitted\ in\ bursts}$$
$$= F_p t_{rec} / E_b$$

If bursts are thermonuclear

$$\alpha = (Q_{grav}/Q_{nuc}) * (1+z)$$
$$= 44(\frac{M}{1.4M\odot})(\frac{R}{10Km})^{-1}(\frac{Q_{nuc}}{4.4MeVnucleon^{-1}})^{-1}$$

Burst properties

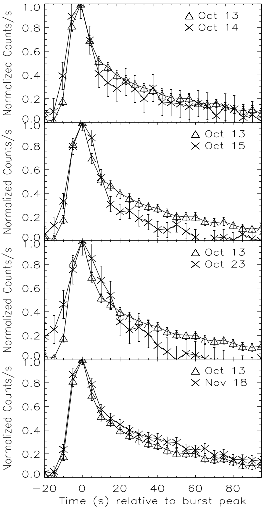
Burst spectra: absorbed blackbody
Continuum spectra: absorbed blackbody+powerlaw

Table: Properties (with 90% errors) of burst and non-burst emissions during the 2010 outburst of IGR J17480–2446.

Date	Time range	Non-burst flux	Burst peak flux	τ	T_{int}	Burst fluence	Ratio of fluences	No. of bursts
Oct 13	00:12:32-01:05:10	$2.58^{+0.01}_{-0.02}$	$9.89^{+0.73}_{-0.78}$	120	-	$26.70^{+0.52}_{-0.54}$	-	1
Oct 14	04:28:01-05:24:09	$8.62^{+0.04}_{-0.04}$	$5.36^{+0.48}_{-0.56}$	105	1034	$15.35^{+0.61}_{-0.67}$	$58.11^{+2.32}_{-2.55}$	3
Oct 15	10:24:32-11:06:11	$10.65^{+0.04}_{-0.04}$	$2.73^{+0.02}_{-0.23}$	72	512	$6.60^{+0.22}_{-0.29}$	$82.62^{+2.76}_{-3.59}$	5
Oct 23	03:26:40-04:14:09	$11.81^{+0.05}_{-0.06}$	$2.70^{+0.29}_{-0.39}$	56	434	$6.72^{+0.37}_{-0.44}$	$76.38^{+4.25}_{-4.99}$	6
Oct 26	08:19:28-09:15:11	$10.55^{+0.04}_{-0.05}$	$4.21^{+0.27}_{-0.31}$	60	722	$11.21^{+0.31}_{-0.35}$	$67.94^{+1.92}_{-2.15}$	5
Oct 31	09:05:20-10:02:10	$9.54^{+0.04}_{-0.04}$	$4.18^{+0.38}_{-0.42}$	90	1016	$10.31^{+0.37}_{-0.42}$	$93.96^{+3.43}_{-3.81}$	3
Nov 05	06:43:28-07:40:10	$8.92^{+0.04}_{-0.04}$	$4.56^{+0.41}_{-0.46}$	100	1273	$12.50^{+0.35}_{-0.38}$	$90.83^{+2.58}_{-2.82}$	3
Nov 08	05:17:20-06:14:10	$8.35^{+0.04}_{-0.04}$	$4.92^{+0.54}_{-0.60}$	120	1488	$17.62^{+0.42}_{-0.46}$	$70.48^{+1.72}_{-1.85}$	2
Nov 15	03:32:32-04:29:09	$7.26^{+0.03}_{-0.03}$	$7.65^{+0.59}_{-0.63}$	130	2137	$26.85^{+0.55}_{-0.59}$	$57.80^{+1.20}_{-1.30}$	2
Nov 18	02:06:24-03:03:11	$6.62^{+0.02}_{-0.02}$	$9.17^{+0.61}_{-0.65}$	135	2391	$36.41^{+0.65}_{-0.70}$	$43.49^{+0.79}_{-0.85}$	2

Chakraborty et al 2011a

Comparison of the profiles of bursts on various days



Chakraborty et al 2011a

IGR J17480-2446

Bursts are indeed thermonuclear!!

Because of its shape, presence of temperature cooling and also burst oscillations the Oct. 13 burst is confirmed to be a thermonuclear one

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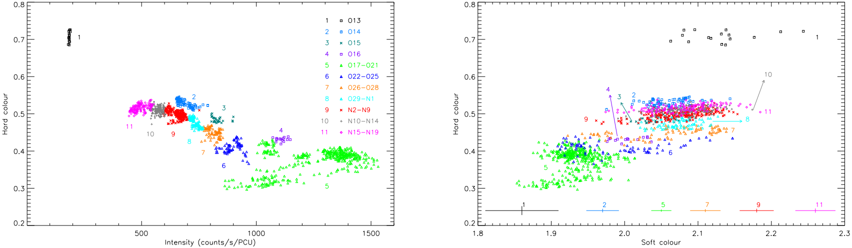
- Burst peak flux, fluence and recurrence time decrease with increase of persistent flux

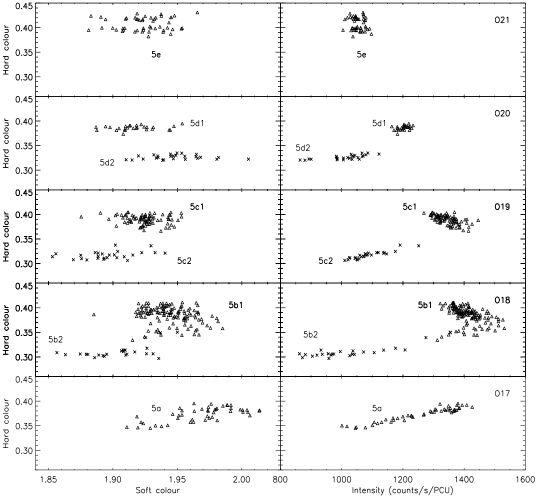
HID & CD



- Banana state of 'C' like curve in HID
- Hysteresis observed in HID
- Diagonal track in CD
- Both SC and HC decreased with intensity

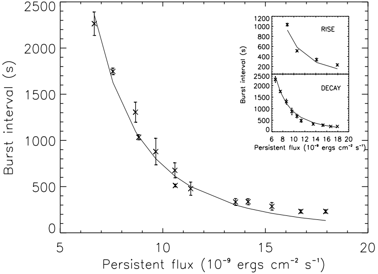
Chakraborty et al 2011b

The zoomed-in outburst peak (seg. 5): Z tracks

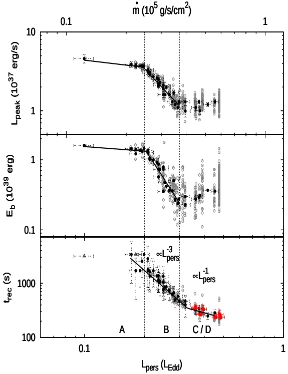


Chakraborty et al. 2011b

Variation with accretion rate



Chakraborty et al. 2011b



Linares et al. 2012

The periodicity high function of persistent emission

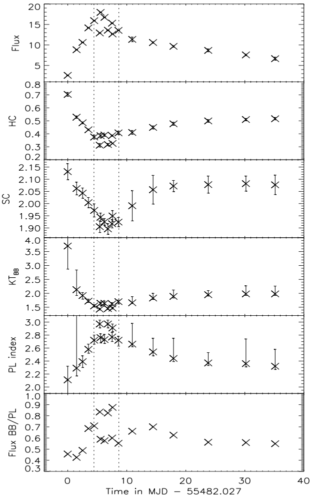
Setting in of different burning regimes at different accretion rate

Summary

- Periodic bursts with the shortest recurrence time observed till date
- Bursts are proved to be thermonuclear which confirms mHz QPO model of quasi stable thermonuclear burning
- Shows thermonuclear bursts with no cooling
- Showed atoll to Z transition and back, and the Z regime corresponded to the mHz QPOs
- Burst properties were found to be correlated with spectral states
- Burst recurrence smooth function of accretion rate and its behaviour indicated different burning regimes at the different accretion rates

Thank you

Variation of spectral parameters throughout the outburst



Chakraborty et al. 2011b