



Detection of a Type-1 X-ray thermonuclear burst from GX 3+1 through *AstroSat*

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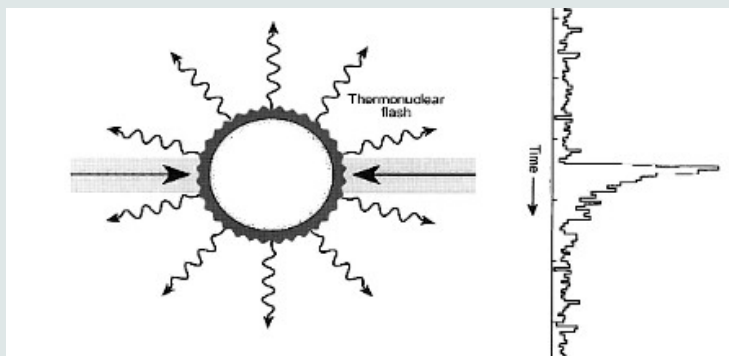
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I. THE SOURCE

1. GX 3+1 (Atoll source) - Observed on April 29-30, 2018 by *AstroSat*'s LAXPC* and SXT** onboard.
2. Mass transfer onto the Neutron Star (NS) from the companion star through Roche-Lobe overflow.
3. Ignition of H/He on NS surface produces flash type rapid Bursts.

A Schematic illustration of a Thermonuclear burst model from a Neutron Star with its corresponding light curve¹.



II. THE MOTIVATION

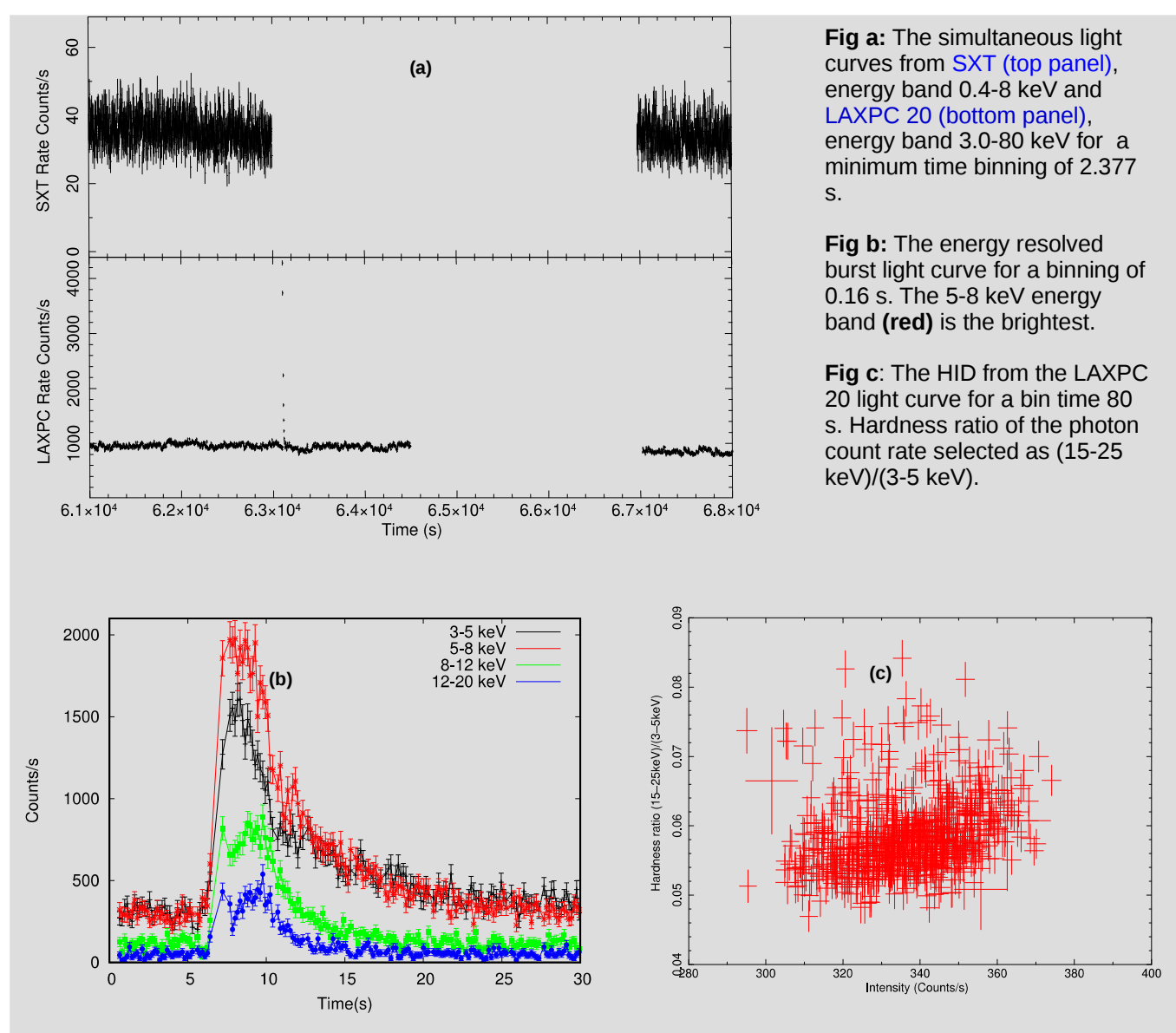
1. No *AstroSat* report published yet on GX 3+1.
2. GX 3+1 is known to display rapid bursts.
3. Burst phenomena is helpful in determining NS properties
4. Instruments *AstroSat*/SXT can observe soft X-rays (0.3-8 keV) and *AstroSat*/LAXPC has a microsecond time resolution to observe rapid bursts

METHODS

- Downloaded the relevant level 1 archival data sets from *AstroBrowse*. The response and background files used for SXT & LAXPC spectral fitting in *XSPEC* are made available by instrument team.
- Softwares used are - *LaxpcSoft* (v-May 19, 2018)², *SXT pipeline* (v-ASISXTlevel2-1.4b), *HeaSoft ftools* (*Xspec*, *Xronos*, *Xselect*), *SaoImage ds9*.

III. TEMPORAL ANALYSIS

- LAXPC counter 20 detects one Type-1 Flash burst. The Burst duration is ~ 15 mins- exponential decay of the count rate
- SXT misses the burst time by ~2 mins for unknown reasons.
- The Hardness vs Intensity Diagram (HID) suggests the **soft Banana State**. A gentle positive correlation is seen in the HID.
- The Burst is resolved into different energy bands. The 5-8 keV band is the brightest



4. THE SPECTRAL ANALYSIS

- SXT (0.8-8 keV) and LAXPC 20 (4-25 keV) spectra are divided into the **Preburst** (~ 840 s) and **Burst region** (~ 17 s).
- Model **TBABS(NTHCOMP+DISKBB+GAUSSIAN)** to fit the preburst (fig. d).
- The same model + **BLACKBODY** overfits the burst spectra. Hence remodelling is done with two models as follows, in 4-16 keV energy band
 - a) **M-1: TBABS(CUTOFFPL+BBODYRAD)** (fig. e).
 - b) **M-2: TBABS(NTHCOMP+BBODYRAD)** (fig. f)
- We find that the removal of **DISKBB** makes it a better fit.

NTHCOMP

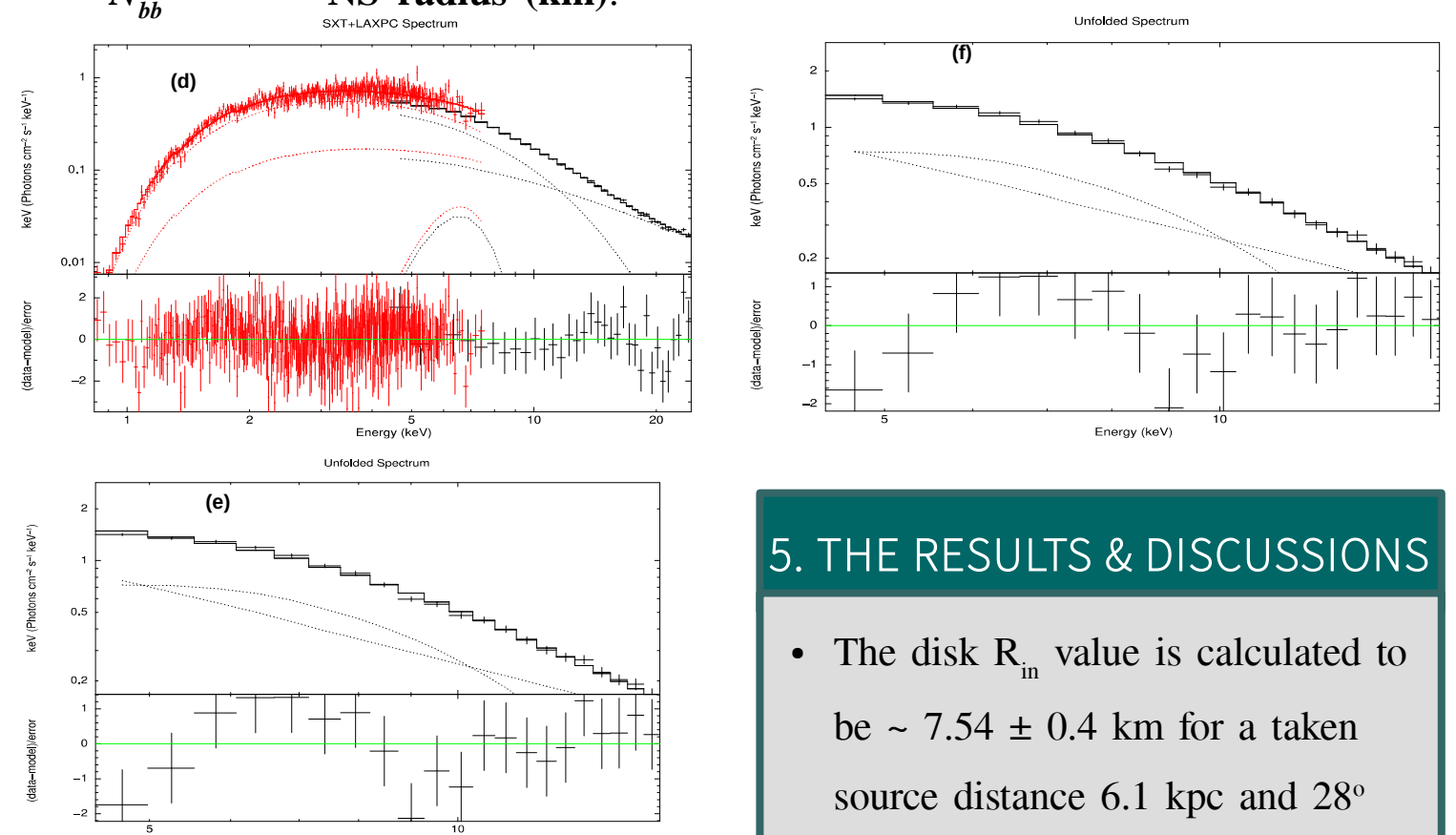
- Thermal Comptonizing Coroneae expressed in terms of Electron temperature kT_e and Spectral Index Gamma Γ .
- Comptonized soft photons from outer disk.
- kT_e kept frozen at the maximum (1000 keV).

DISKBB

- Multicolored accretion disk expressed in terms of inner disk temperature kT_{in} and Normalisation N_d .
- $N_d \longrightarrow$ **Apparent Inner Disk Radius r_{in}** .
- r_{in} times the spectral hardening factor \longrightarrow **Realistic radius R_{in} (km)**.

BBODYRAD

- A blackbody spectrum expressed in terms of the temperature kT_{bb} and a Normalization N_{bb} proportional to the surface area.
- $N_{bb} \longrightarrow$ **NS radius (km)**.



6. Comparison with Published GX 3+1 reports

- The Neutral Hydrogen column attains a value 1.4 in 10^{22} cm^{-2} units which is consistent with [den. Hartog, et al. \(2003\)](#).
- Joint fit (fig. d) obtains a $\Gamma = 2.5 \pm 0.3$ consistent with ~2.7 reported in [Pintore, et al. \(2015\)](#).
- The N_d value 16.16 ± 1.6 is close to [Ludlam, et al. \(2019\)](#) for a *NuSTAR* data.
- The NS radius values consistent with [Kuulkers & van der Klis \(2000\)](#). Their reported value was 4.5 km for a source distance 5 kpc.

5. THE RESULTS & DISCUSSIONS

- The disk R_{in} value is calculated to be $\sim 7.54 \pm 0.4$ km for a taken source distance 6.1 kpc and 28° disk inclination.
- Inner disk blackbody temperature obtained is 2.06 ± 0.1 keV.
- The blackbody temperature kT_{bb} obtained = 1.61 ± 0.04 keV which is close to 2 keV, confirming the Type-1 status of the burst.
- The calculated NS radius values are 6.7 ± 0.3 and 6.8 ± 0.3 km respectively for M-1 and M-2.
- LAXPC flux_{uabs} is higher than the SXT flux (from preburst fit).

References

1. "Astrophysical explosions in stellar systems", Maurizio Falanga, Lec-07
2. Antia H.-M., et al., 2017, *ApJS*, 231, 10