Testing the Poynting-Robertson drag in thermonuclear X-ray bursts in 4U 1636-536: from archival data to NewAthena

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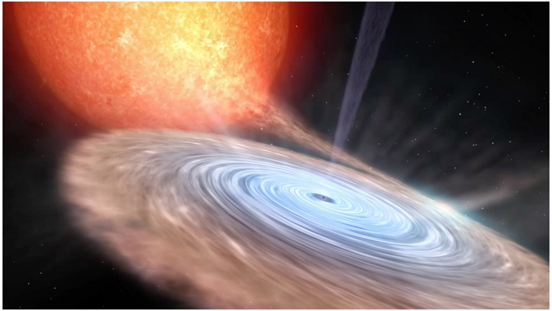
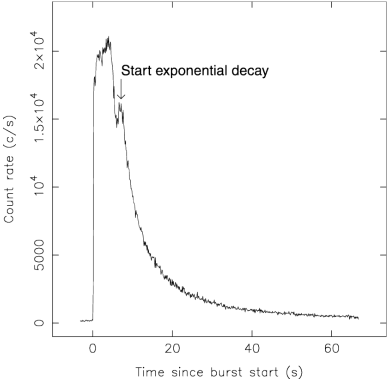
Overview

1. Introduction



X-ray binary.



Jonker et al. (2001).

1. Introduction

Does the burst affect the persistent emission?

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EVIDENCE FOR ACCRETION RATE CHANGE DURING TYPE I X-RAY BURSTS

Hauke Worpel[1,2], Duncan K. Galloway[1,2,3], and Daniel J. Price[1,2]
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Worpel et al. (2013).

- Persistent emission enhancement during bursts.
- Possible explanation: Poynting–Robertson drag.

2. Data preparation and methodology

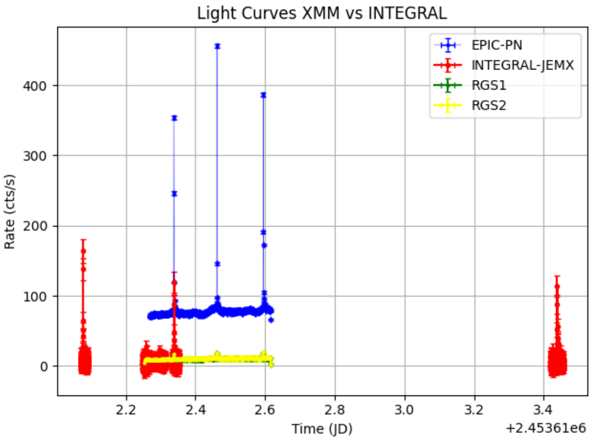
Observations and instruments

Mission	Obs ID/Rev	Start date (UTC)	End date (UTC)	Instrument	Mode	Exposure (ks)
XMM-Newton	0303250201	2005-08-29 18:04:09	2005-08-30 02:46:25	EPIC-pn	Timing	29.75
XMM-Newton	0303250201	2005-08-29 18:04:09	2005-08-30 02:46:25	RGS1/RGS2	Spectroscopy	31.3
INTEGRAL	rev. 351	2005-08-28 11:50:00	2005-08-31 01:33:00	ISGRI	Photon by photon	42.3
INTEGRAL	rev. 351	2005-08-28 11:50:00	2005-08-31 01:33:00	JEM-X	Full imaging	14

2. Data preparation and methodology

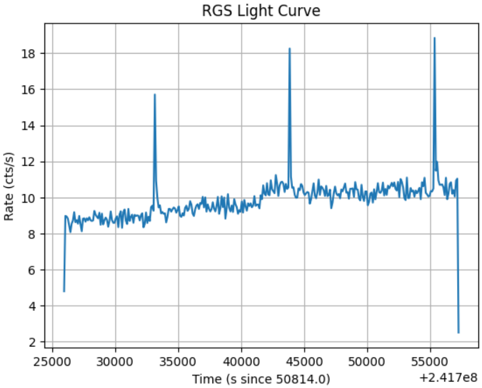
Light Curve extraction

- Light curves extracted from:
  - **XMM-Newton:** EPIC-pn, RGS1, RGS2.
  - **INTEGRAL:** JEM-X, IBIS.
- Compared light curves to identify **simultaneous X-ray bursts**.
- Only one burst was detected **simultaneously in all instruments**.

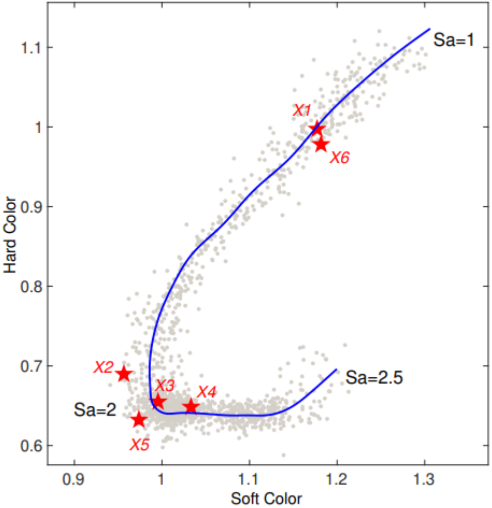


2. Data preparation and methodology

- **Gradual increase** in persistent emission seen in RGS1 (0.35–2.5 keV).
- Count rate rises from ∼8.5 to ∼11 cts/s during observation.
- Suggests **increasing accretion rate**.
- Increase in the count rate by a factor of 2 during the burst.



2. Data preparation and methodology

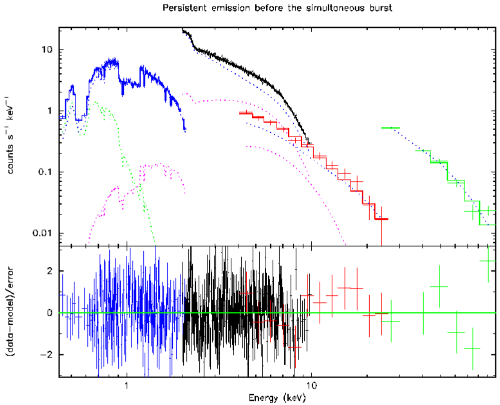


Lyu, M., et al. (2023).

2. Data preparation and methodology

Persistent emission before the simultaneous burst fit

- Fit model: `tbabs*(diskbb + bbody + relxillCp)`
- Absorption and emission lines (soft band)
- Multi-instrument fit: EPIC-pn, RGS (combined), JEM-X, IBIS



Persistent Emission Spectral Fit

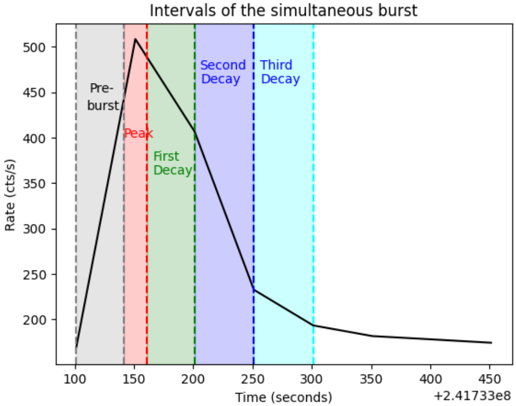
Best-fit spectral parameters

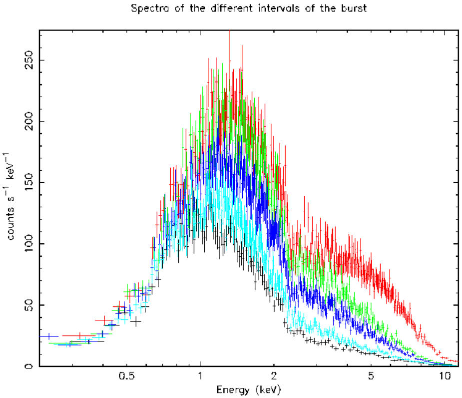
Component	Parameter	Best-fit value
TBabs	$N_{\rm H}$ (10^{22} cm^{-2})	$0.545^{+0.005}_{-0.005}$
bbody	$kT_{\rm BB}$ (keV)	$1.668^{+0.033}_{-0.032}$
	Norm.	$(1.36^{+0.03}_{-0.03}) \times 10^{-3}$
diskbb	$T_{\rm in}$ (keV)	$0.098^{+0.005}_{-0.006}$
	Norm.	$(4.63^{+1.98}_{-1.44}) \times 10^{5}$
relxillCp	Γ	$1.916^{+0.010}_{-0.010}$
	$\log \xi$	$3.308^{+0.025}_{-0.019}$
	$\log N$ (cm^{-3})	$18.973^{+0.045}_{-0.063}$
	$A_{\rm Fe}$	$1.34^{+0.50}_{-0.41}$
	$kT_{\rm e}$ (keV)	$23.6^{+2.2}_{-1.9}$
	$R_{\rm refl}$	$1.62^{+0.018}_{-0.018}$
	Norm.	$(6.19^{+0.03}_{-0.03}) \times 10^{-4}$

$$\chi^2/\mathrm{dof} = 428.82/392 = 1.09$$

2. Data preparation and methodology

- Burst divided into 5 phases: Before the burst, peak, decay 1-3.
- Only EPIC-pn used.
- Goal: track spectral evolution during burst.





2. Data preparation and methodology

Time-Resolved Burst Fitting

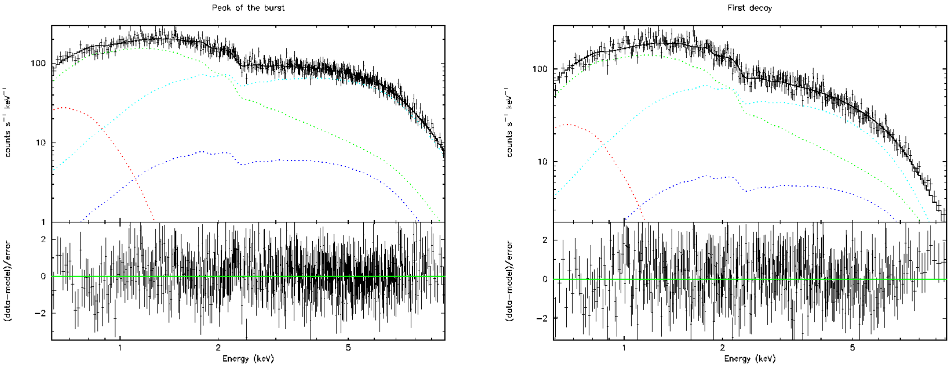
- Model: `tbabs*bbody + f`$_a$`*(persistent emission)`
- Freeze persistent emission.
- Only EPIC-pn data used.
- Evolution of kT and f_a.

3. Results

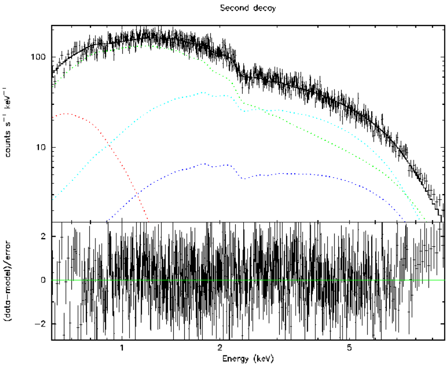
Table: Best-fit parameters for each burst interval. Uncertainties are given at the 90% confidence level.

Interval	kT_{BB} (keV)	$\mathrm{norm}_{\mathrm{BB}} \times 10^{-2}$	Persistent emission scaling factor	χ^2_ν (χ^2/dof)
Peak	$2.048^{+0.049}_{-0.047}$	$6.76^{+0.22}_{-0.21}$	$3.229^{+0.086}_{-0.087}$	0.914 (427.63/468)
Decay 1	$1.267^{+0.029}_{-0.028}$	$2.05^{+0.07}_{-0.07}$	$2.947^{+0.088}_{-0.088}$	1.182 (438.48/371)
Decay 2	$1.226^{+0.029}_{-0.028}$	$1.16^{+0.04}_{-0.04}$	$2.753^{+0.058}_{-0.058}$	1.044 (608.41/583)
Decay 3	$1.006^{+0.086}_{-0.074}$	$0.20^{+0.03}_{-0.03}$	$2.474^{+0.053}_{-0.054}$	0.982 (403.75/411)

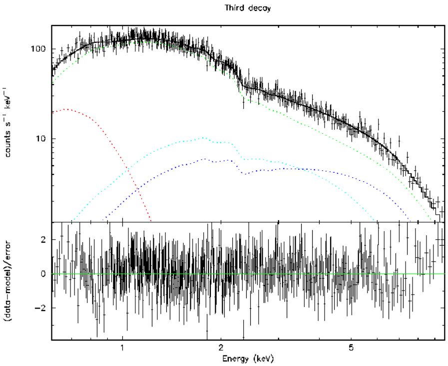
3. Results


Peak of the burst
First decay
counts s^{-1} keV^{-1}
(data−model)/error
Energy (keV)

3. Results



Second decay
counts s^{-1} keV^{-1}
100
10
(data−model)/error
2
0
−2
1
2
5
Energy (keV)



Third decay
counts s^{-1} keV^{-1}
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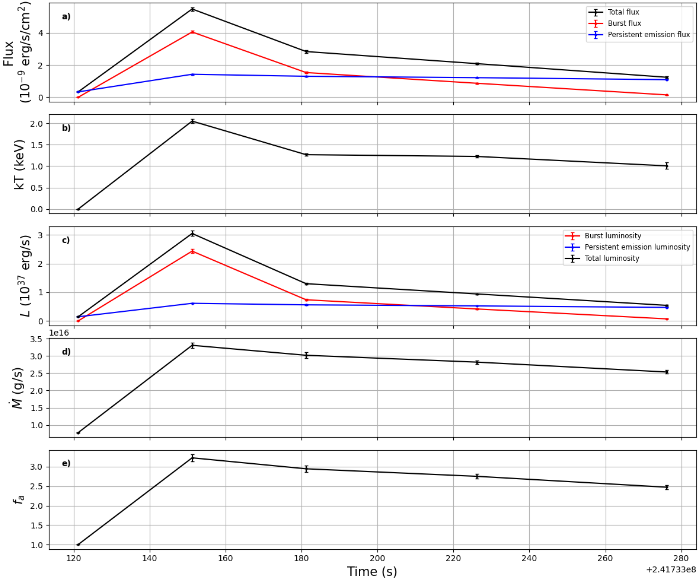
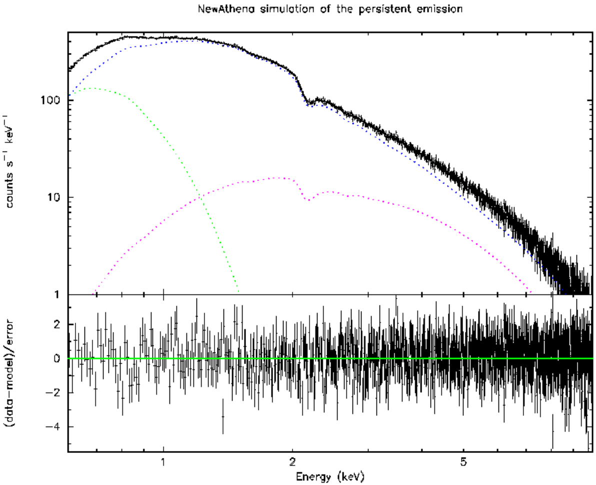
3. Results



Scaling factor of the persistent emission!!

4. NewAthena simulations



4. NewAthena simulations

Comparison of spectral parameter constraints

Parameter	XMM+INTEGRAL	NewAthena WFI
$N_{\rm H}$	0.545 ± 0.005	0.589 ± 0.001
$kT_{\rm BB}$ (keV)	$1.668^{+0.033}_{-0.032}$	1.617 ± 0.021
bbody Norm (10^{-3})	1.36 ± 0.03	1.167 ± 0.023
$T_{\rm in}$ (keV)	$0.098^{+0.005}_{-0.006}$	0.1044 ± 0.0002
diskbb Norm (10^{5})	$4.63^{+1.98}_{-1.44}$	4.99 ± 0.072
$\log \xi$	$3.308^{+0.025}_{-0.019}$	$3.304^{+0.015}_{-0.010}$
$\log N$	$18.973^{+0.045}_{-0.063}$	18.967 ± 0.018
$A_{\rm Fe}$	$1.34^{+0.50}_{-0.41}$	1.40 ± 0.11
relxillCp Norm (10^{-4})	6.19 ± 0.03	6.194 ± 0.001

Consistent best-fit values with significantly reduced uncertainties.

5. Conclusions

- One simultaneous burst analyzed in 4U 1636–536.
- Burst evolution shows:
  - $\uparrow$ Flux and blackbody temperature
  - $\uparrow$ Persistent emission ($f_a \sim 3$)
  - $\uparrow$ Accretion rate $\dot{M}$
- Consistent with burst–accretion interaction:
  - Poynting–Robertson drag
- NewAthena/WFI simulations:
  - Smaller parameter uncertainties
  - Finer time-resolved burst spectroscopy