Searching for fast transients in XMM-Newton data

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1. Introduction

- Compact objects are the most variable sources in the sky [1].
- Searching for X-ray variability on the shortest possible timescales

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Identification of new and rare compact objects

2. Objectives

- Develop code to detect faint variable sources in XMM-Newton data, complementary to existing variability tests (χ^2, Kolmogorov-Smirnov).
- Identify new and rare compact objects, for instance: Distant type-I X-ray bursts, short γ-ray bursts at high redshift, gravitational wave events, possible X-ray counterparts to fast radio bursts, etc.

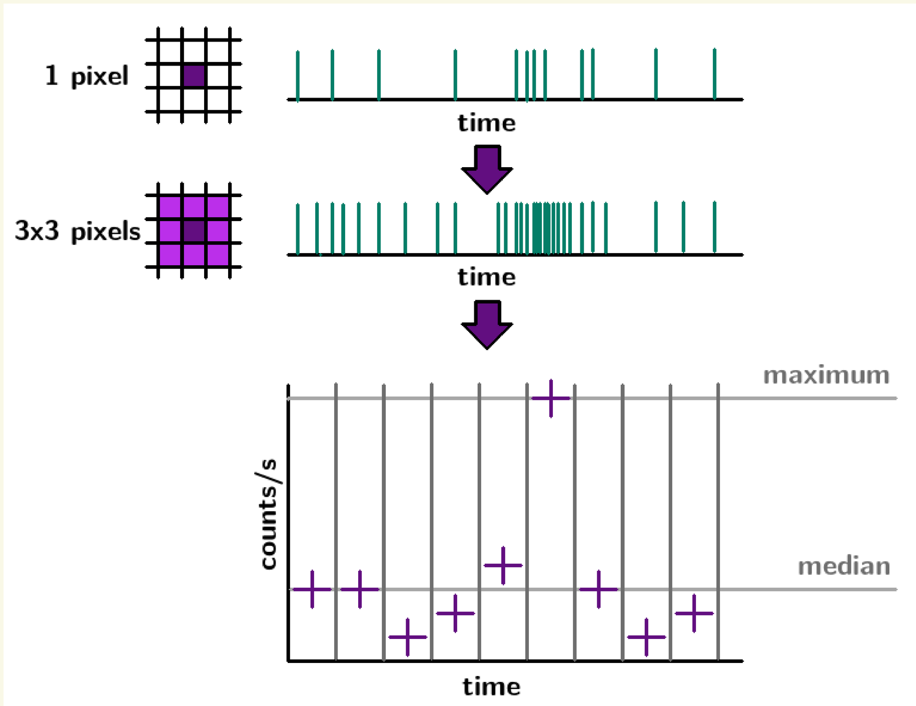
3. Method

Algorithm to detect variable sources from XMM-Newton's EPIC-pn observations, filtered in an energy range between 0.2 and 12 keV. Based on a pre-existing code (Variabilitectron) [2], modified and improved (code available online [3]).

Variability computation

- Observations binned into short time windows.
- Count photons detected per pixel and per time window.
- For each pixel, sum of the photons in a 3×3 square around the central pixel.
- Computation of the median counts per pixel over the time windows.

$$Variability = \begin{cases} (max(counts) - median)/median & \text{if } median \neq 0 \\ max(counts) & \text{if } median = 0 \end{cases}$$



Detection of the variable sources

- Sliding boxes of size $|b|^2$, sum of variability per box.
- Variable area if variability_box > detection_level × $|b|^2$ × median
- Position of the variable source = central (x,y) coordinates of the variable area.

4. Results

Algorithm tested on 9 observations of M31 with different time windows. Analysis of the lightcurve of the detected variable sources with the Science Analysis System (SAS). The blue dot corresponds to the location of the detected source.

Known variable sources

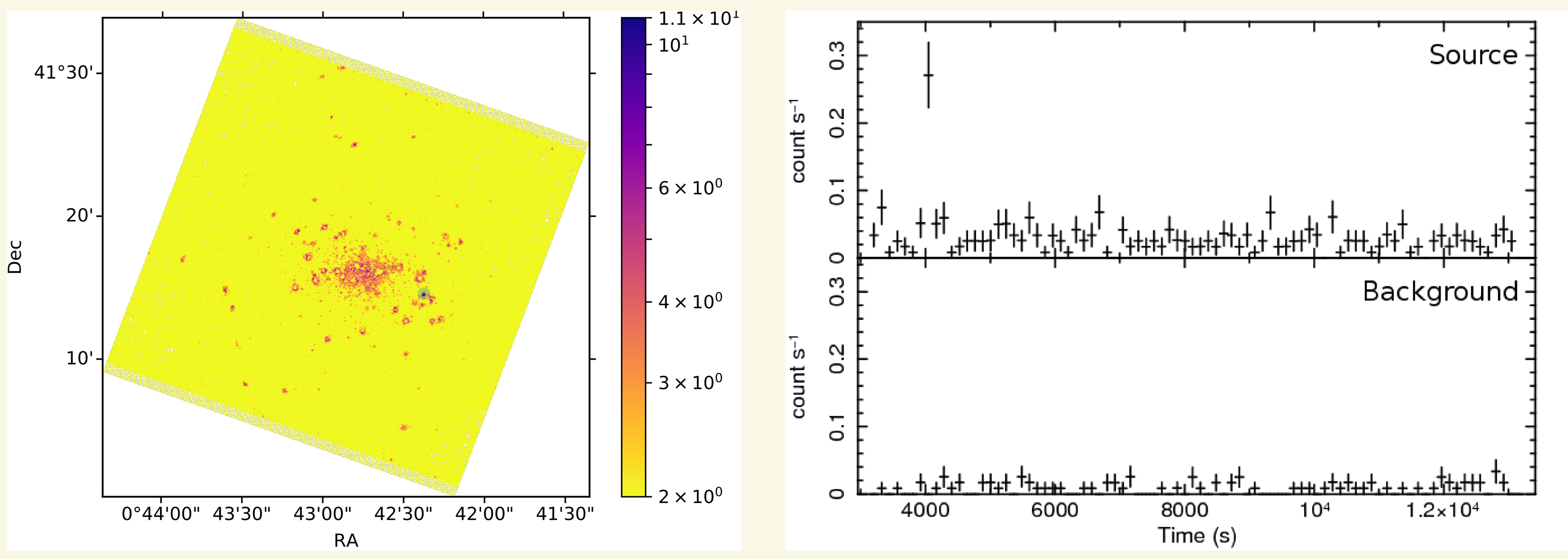


Figure: Left: Variability of the observation 0381_0112570101. Input parameters: box size = 5, detection level = 10, time window = 40s. **Right**: Light curve of the source: type-I X-ray burst [4]

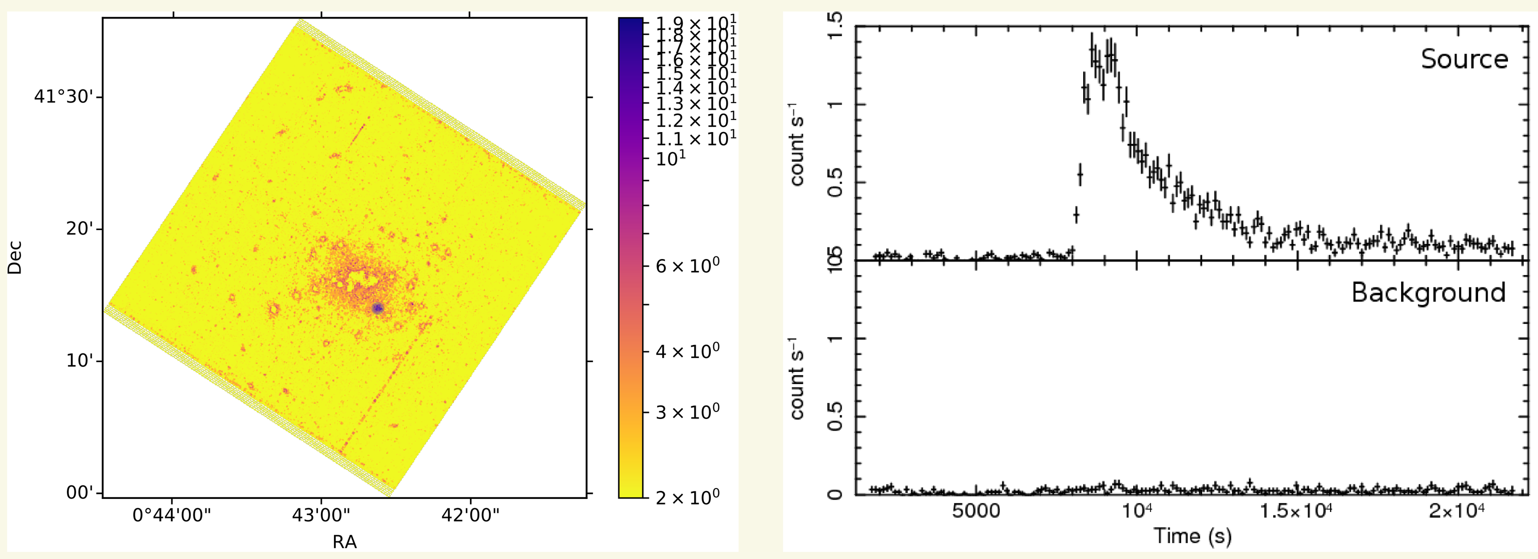


Figure: Left: Variability of the observation 1490_0505720501. box size = 5, detection level = 10, time window = 100s. **Right**: Light curve of the source: stellar flare

Unknown variable sources

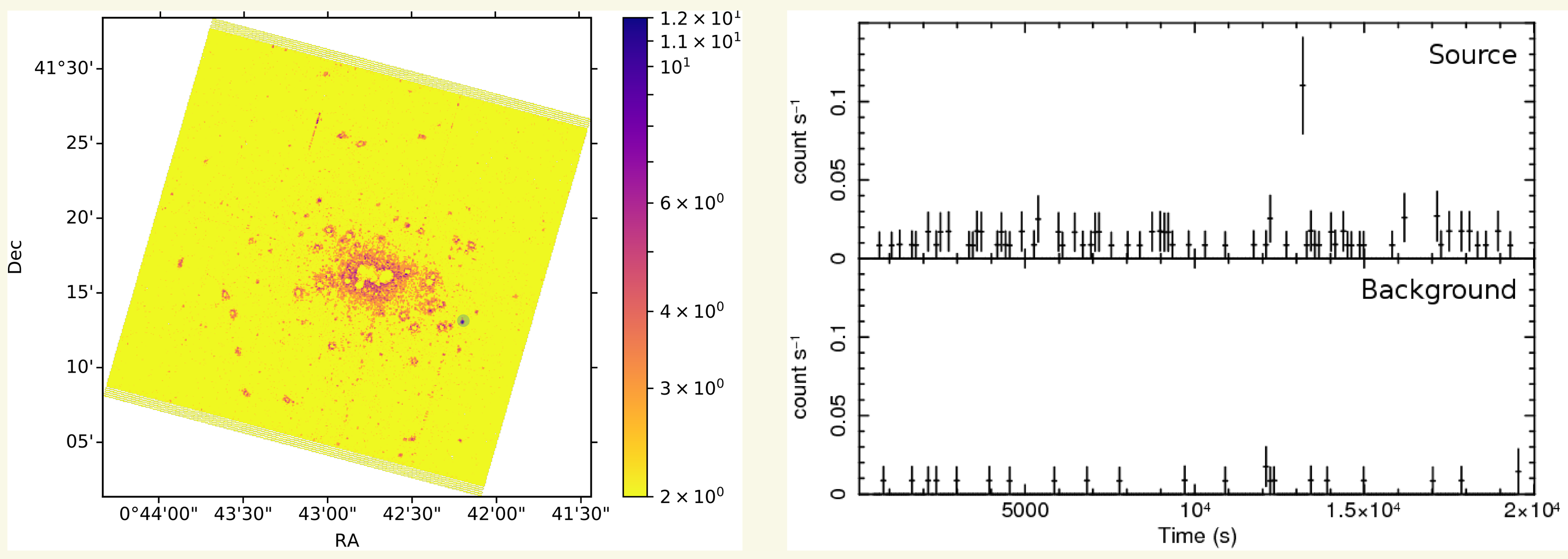


Figure: Left: Variability of the observation 2207_0674210201. box size = 5, detection level = 10, time window = 40s. **Right**: Light curve.

Type-I X-ray burst	This observation	Typical values
Duration (s)	~120	~20-500
Persistent luminosity ($L_{Eddington}$)	~0.01	~0.01-0.2 [4]
Peak luminosity ($L_{Eddington}$)	1	1
Power-law index	$1.95^{+1.23}_{-0.72}$	~1.4-2.1 [5]

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Consistent with type I X-ray bursters detected in low mass X-ray binaries (LMXBs)

Analysis of a set of observations

To test the robustness of the algorithm, we measure the χ^2 and Kolmogorov-Smirnov probability of constancy with the SAS and lcstats (ftools). Classification of the detected sources into different categories. The faint sources presenting a burst cannot be detected by XMM-Newton's automatic pipeline (too low number of counts).

Catalogue	Observations	Detections	Variable	Non variable	Bad pixels	Other
DR7	381	138	49	11	11	64 (11 obs.)
DR8	375	111	50	12	24	25 (10 obs.)

Table: Characteristics of the sources detected with time window=100s and detection level=10.

5. Conclusion

- X-ray variability is a powerful tool to detect compact objects.
- Variabilitectron is able to detect faint sources varying in the timescale of the chosen time window. Complementary to existing variability tests (χ^2, Kolmogorov-Smirnov).
- Large amount of XMM-Newton observations (~10000): lots of data to be exploited.

6. Future work

- Improve the robustness of the detections by eliminating bad pixels from search region, restricting energy range searched to ~0.5-12 keV to avoid low energy noise.
- Apply the algorithm to all existing XMM-Newton observations.
- Adapt code for other X-ray observatories, e.g. Chandra, Swift or SVOM.

References

[1] Lin, D., Webb, N. A., & Barret, D. 2012, 756, 27

[2] Wojtowicz D. *Variabilitectron.pdf*, 2017.

[3] https://framagit.org/inespm/variabilitectron

[4] Pietsch, W. & Haberl, F. 2005, 430, L45

[5] Kaaret, P., Feng, H. & Roberts, T. P. 2017.