Searching for the most elusive X-ray transients with *XMM-Newton*

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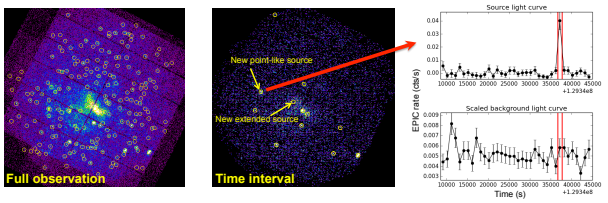
ABSTRACT

Thanks to its unprecedented grasp in the 0.2-12 keV range and more than 16 years of operations, ***XMM-Newton EPIC*** is the best instrument to discover **X-ray transient sources on timescales shorter than a few hours**. However, many transients are missed by standard analysis procedures either because they are buried in the background of the full observation or because they occurred in high particle background time intervals. In the framework of **EXTraS, an EU funded project aimed at the full exploitation of the EPIC data in the time domain**, we developed a software pipeline to perform **time-resolved source detection of EPIC archival data**, leading us to the discovery of many new transient sources. The most interesting **scientific cases** we have already identified range from flares of young stellar objects to extragalactic transients. After software optimization and a careful screening of the results, the full **transient catalogue and the software tools** necessary to extend this search to forthcoming data **will be made publicly available** through an interactive archive and a science gateway, respectively.

The software pipeline

The algorithm

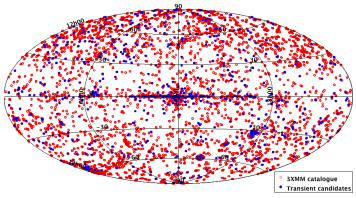
For each observation, **source detection** is performed on images integrated on short **time intervals** and results compared with the list of sources detected in the full observation, searching for **new point sources**.



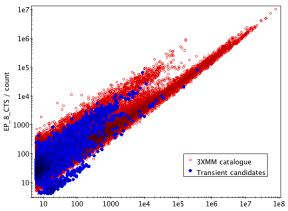
The **time intervals** are derived from a **Bayesian Blocks** (BB) analysis *(Scargle et al. 2013)* on 30"x30" partially-overlapping regions covering the full field of view, from which the brightest point sources are excised. These intervals are formed by the change points in which **the count rate varies significantly** with respect to the (time-variable) background extracted from a large nearby region. These time intervals are then selected through a **spatial clustering** algorithm, retaining only those in which the rate excess is not homogeneously distributed within the region. Finally, the spatial clustering algorithm is also applied to **1,000 s time intervals** in small regions covering the **exclusion areas around bright sources**.
After performing the **source detection with standard SAS tasks**, we consider as **transient candidates** only the new point-like sources detected within the regions from which the specific time interval was derived.

Performances and Results

The **software pipeline** has been **developed** at IUSS Pavia and **tested** on different computing facilities at INAF, CINECA and University of Leicester. Depending on the characteristics of the hardware and of the specific observation, the processing of a single observation can take from less than 1 hour to several days. The pipeline has been run on **all the observations included in the 3XMM-DR5 catalogue** *(Rosen et al. 2015)* and the results (**>2,000 transient candidates**) are currently under screening.



Sky distribution (in Galactic coordinates) of the transient candidates compared to all 3XMM point-like sources.



Detection likelihood vs. number of counts (0.2-12 keV) for transient candidates and 3XMM point sources.

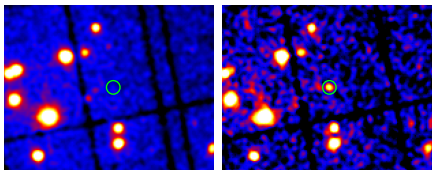
The Science Gateway

The software pipeline will be **publicly released** at the end of the EXTraS project through an **on-line portal**, from which the user will be able to run the full pipeline with customized settings and parameters on any dataset included in the XMM-Newton Science Archive. This will allow any member of the **scientific community** to **optimize** the search for X-ray transients in specific sets of observations and to **extend** this kind of analysis well beyond the EXTraS project. Moreover, the portal can be used by the **general public** (e.g., high school students during dedicated workshops) to experience an end-to-end analysis of pre-selected scientific cases.

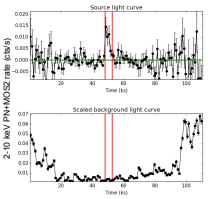
A selection of early scientific results

Flare from Young Stellar Object (YSO)

A ~4 ks X-ray flare has been detected by the EXTraS pipeline during an observation of the **Rho Ophiuchi** star forming region lasting for a full satellite orbit. Its **spectrum is very hard** (it is undetected at energies < 2 keV), indicating strong X-ray absorption from local material.



X-ray image of the Rho Ophiuchi region containing the flaring YSO (green circle) in the full observation (~110 ks, left panel) and during the flare (~4 ks, right panel).

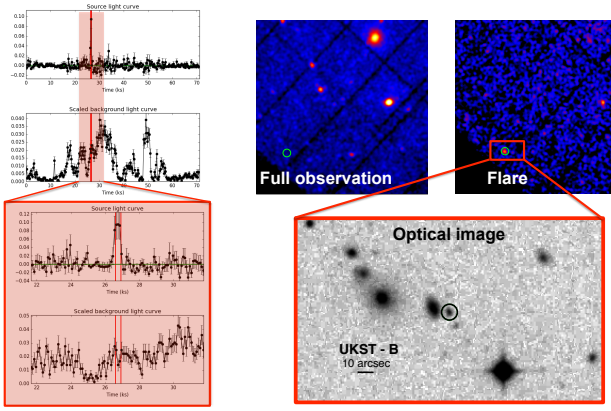


2-10 keV light-curve of the YSO (upper panel) and the background (lower panel)

This X-ray source had never been detected before and its infrared counterpart is very likely a **YSO**. These properties are similar to those of another flare from a YSO already discovered in the preliminary phases of the EXTraS project (*Pizzocaro et al. 2015*, see **poster D05**).

Extragalactic transient

A **~300 s** X-ray flare has been detected by the EXTraS pipeline during a **high Galactic latitude** pointing. This flare is positionally coincident with a blue **galaxy** of unknown redshift. An optical observation aimed at the measure of its redshift failed due to technical reasons and will be repeated when the target will be visible again.



Considering its flux, spectrum and duration, this flare would be compatible with a **supernova shock break-out** event, like the one observed by *Swift*/XRT from SN2008D (Soderberg et al. 2008), if its distance were ~500 Mpc. Such a distance is fairly consistent with the optical properties of the candidate host galaxy.

References:
Pizzocaro et al. 2016, A&A 587, A36
*Rosen et al 2015, arXiv:*1504.07051
Scargle et al. 2013, ApJ 764, 167
Soderberg et al. 2008, Nature 453, 469

The EXTraS collaboration

EXTraS is funded by EU within the FP7 Cooperation "Space" call under GA no. 607452. The project started in January 2014, with an expected duration of 36 months. Project coordinator is A. De Luca (INAF/IASF Milano). The EXTraS consortium includes:

- Istituto Nazionale di Astrofisica (INAF), Italy (coordinator)
- Istituto Universitario di Studi Superiori di Pavia (IUSS), Italy
- Istituto di Matematica Applicata e Tecnologie Informatiche (CNR-IMATI), Italy
- Max-Planck-Institut für Extraterrestrische Physik (MPE), Germany
- University of Leicester (UK)
- Erlangen Centre for Astroparticle Physics (Germany)

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