Science with the EXTraS Project: Exploring the X-ray Transient and variable Sky.

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Abstract The EXTraS project ("Exploring the X-ray Transient and variable Sky") will characterise the temporal behaviour of the largest ever sample of objects in the soft X-ray range (0.1-12 keV) with a complex, systematic and consistent analysis of all data collected by the European Photon Imaging Camera (EPIC) instrument onboard the ESA XMM-Newton X-ray observatory since its launch. We will search for, and characterize variability (both periodic and aperiodic) in hundreds of thousands of sources spanning more than nine orders of magnitude in time scale and six orders of magnitude in flux. We will also search for fast transients, missed by standard image analysis. Our analysis will be completed by multiwavelength characterization of new discoveries and phenomenological classification of variable sources. All results and products will be made available to the community in a public archive, serving as a reference for a broad range of astrophysical investigations.

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1 The EXTraS project: aim, implementation.

The EXTraS project ("Exploring the X-ray Transient and variable Sky") will systematically explore the temporal domain information stored in the database collected by the European Photon Imaging Camera (EPIC, [11, 13]) onboard the ESA XMM-Newton observatory. EPIC is the most powerful tool to study faint X-ray sources in the 0.1-12 keV range. Indeed, the Serendipitous Source Catalogue based on EPIC data (see e.g. [14]), listing more than 540,000 detections in its most recent release (3XMM), is the largest catalogue of X-ray sources ever compiled. However, time-domain information in such data, although very rich, remained mostly unused. EXTraS will release to the community a full temporal characterization (both aperiodic and periodic variability) of hundreds of thousand of sources with flux spanning from 10^{-9} to 10^{-15} erg cm^{-2} s^{-1} (0.2-10 keV), on time scales ranging from ~ 0.1s to ~ 10 years. EXTraS will also search for short-duration transients, not included in 3XMM, and will also perform a phenomenological classification of all sources based on their temporal and spectral properties. The different lines of temporal analysis implemented within the project are described in more detail in [3].
The project has received funding within the EU-FP7 framework (grant agreement n. 607452) and is carried out by a collaboration including INAF (Italy), IUSS (Italy), CNR/IMATI (Italy), University of Leicester (UK), MPE (Germany) and ECAP (Germany). More information, updates on the project as well as a full list of contacts can be found by visiting the project web site at www.extras-fp7.eu.

2 An (incomplete) overview of Science with EXTraS.

The extremely broad range of variability timescales and luminosities investigated by EXTraS is shown in Figure. 1. The scientific discovery space is very large and we trust that EXTraS results will have a great impact in many areas of astrophysics and cosmology. The blind nature of our search will allow astronomers to measure (or give strong limits on) the intrinsic occurrence rate of different transient events and to perform population studies. Withouth demanding completeness, we include below a list of science cases that will benefit of our results (see also caption to Fig. 1).
Flaring stars: constraining, on a statistical basis, the duration, duty cycle and amount of energy released in flares of different stellar groups. Indeed, as an interesting first result of EXTraS, we may mention the unexpected detection of a flare from a *very young protostar* (Pizzocaro et al., in preparation)
Cataclysmic variables and Novae: unveiling periodicities and bursts in about 100 known sources; searching for new systems.
Low-mass X-ray binaries (LMXBs): probing e.g. the properties of bursting LMXBs [10] – in particular, for the poorly known "burst only sources". Bursts from M31, the closest spiral galaxy, can also be detected[5].
High-Mass X-ray Binaries (HMXBs): constraining e.g. the census of Supergiant Fast X-ray Transients [8], which is crucial to unveil the evolutionary path and for-

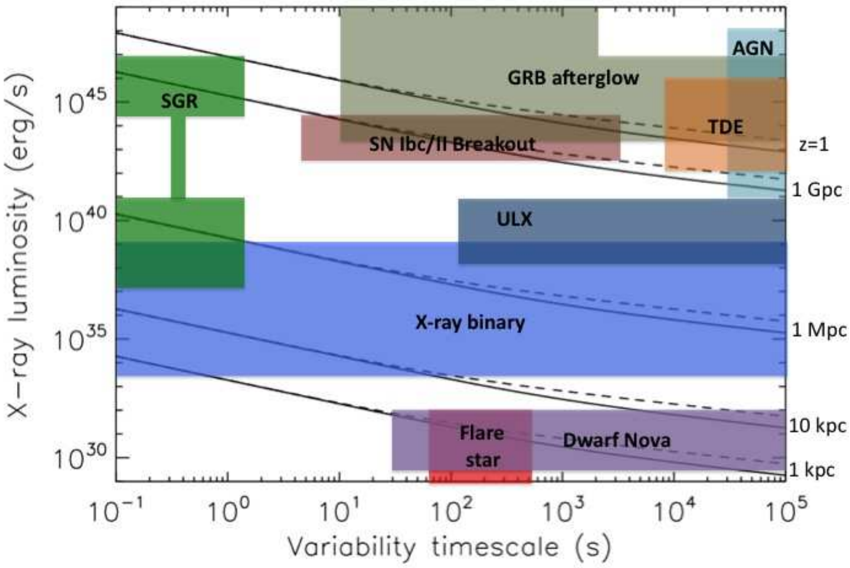

Fig. 1 Peak X-ray luminosity of different source populations as a function of their characteristic variability time scale (adapted from [7]). Diagonal lines mark the approximate EXTraS 0.5-2 keV sensitivities (at 4σ confidence, EPIC/pn camera only) for various source distances. Solid lines are computed using the nominal detector background; dashed lines are computed adopting a factor 10 higher background count rate, to show the effect of time periods with enhanced particle background. Even assuming a very conservative 6.5σ sensitivity level (a factor 2–5 higher flux than in the figure), implying an essentially null contamination from spurious detections, we can expect a very rich harvest of variable sources, based on the equivalent sky coverage of EPIC data and on previous observational results and theoretical models. Among such sources, several hundreds of flares from a broad population of stars and pre-stars; 3-300 and 0.3-30 bursts from persistent and transient LMXBs, respectively, in the Galactic Center region; 3-5 SFXTs active in bright flaring and 40-75 sources in an intermediate state of flaring; several new magnetars; a few Tidal disruption Events up to z$\sim 5-6$; up to a dozen Low-luminosity GRBs up to z$\sim$ 2; about ten supernova shock break-out events up to z$\sim$ 0.1; moreover, it can be estimated that about 100 "Fast radio burst" should have occurred within the field of an ongoing EPIC pointed observation.

mation rate of massive stars.

Isolated Neutron Stars: constraining e.g. the population of magnetars [6] and its relation to the overall population of Neutron Stars (NS), which will also impact on our comprehension of the short GRBs.

ULtraluminous X-ray Sources: assessing accretion physics in these poorly understood sources [4] by e.g. searching for, and unveiling, source "states"; systematically searching for bursts and periodicities (orbital, or rotational)

Tidal Disruption Events (TDEs): constraining their poorly known statistics (even the case of no detections would be interesting) and their physics [1].

Gamma-Ray Bursts (GRBs): constraining the rate of Low-Luminosity GRBs (e.g. [2]), possibly up to high redshift, and their progenitors; no detections would set the strongest available constraint on their population.
Supernovae: inferring a measure of the Supernova (SN) rate independent from optical surveys by detecting SN shock breakout events [9]; no detections would set important constraints on the poorly known underlying physics.
Active Galactic Nuclei (AGN): measuring the mass of ~ 100 AGNs, based on their variability properties; calibrating the variability-luminosity relation locally; characterizing the variability of Blazars, their duty-cycle on short timescales and deriving constraints on particle injection/acceleration, magnetic field, BH mass.
Rare events: ranging from galactic events (e.g. tidal disruption events of minor bodies falling onto NSs or BHs) to cosmic ones (e.g. orphan afterglows of GRB seen off-axis, GRBs from the first very massive stars); constraining the high energy properties of the puzzling "Fast radio bursts" [12].
Totally unexpected discoveries can be also foreseen, as has always been the case when a new region in parameter space has been explored.

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