Neutron Star Astrophysics at the Crossroads: Magnetars and the Multimessenger Revolution
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X-ray dim isolated neutron star candidates from the eROSITA All-Sky Survey

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Abstract. After 2 years of continuous observations, the eROSITA All-Sky Survey bears the potential to build a complete sample of X-ray dim isolated neutron stars (XDINS). Making use of their soft X-ray emission and large X-ray-to-optical flux ratios, we selected a sample of ~ 100 candidates detected down to a limiting flux of $\sim 10^{-13}$ erg s^{-1} cm^{-2} (0.2-2 keV). Follow-up observations of the best candidates will rule out possible contaminants. Updated source catalogues and screening algorithms will further improve our efficiency to identify new XDINS.

Keywords. stars: neutron, surveys, pulsars: general

1. Introduction

The known population of X-ray dim isolated neutron stars (XDINS) is comprised of seven, nearby and middle-aged, purely thermally emitting, neutron stars. In comparison to rotation powered pulsars, the sources show higher magnetic field strengths and thermal luminosities, suggesting a possible evolutionary connection with magnetars (Viganò et al. 2013). Locally, XDINS seem to be as common as ordinary pulsars (Keane & Kramer 2008). To investigate possible evolutionary links between the different subgroups and the galactic birthrate, it is necessary to expand the known population.

Due to their emission characteristics, XDINS are best observed at soft X-ray energies. Since their discovery in the ROSAT era, additional candidates were proposed (see Rigoselli et al. 2022; and references therein). As these searches are based on surveys that cover limited sky areas, the resulting candidate samples are incomplete. The ongoing eROSITA All-Sky Survey (eRASS) (Predehl et al. 2021) will enable a complete all-sky search, with the final source catalogue detecting ~ 90 XDINS (Pires et al. 2017). At the current survey sensitivity, ~ 25 are bright enough to have already been detected. We have thus started a dedicated search for XDINS, using the observations spanning the first two years of the mission.

2. Selection criteria

Similarly to Pires et al. (2009) and Rigoselli et al. (2022), possible candidates can be selected based on cuts in X-ray colour space (Fig. 1). To distinguish XDINS from other soft X-ray emitters (cataclysmic variables, stars), we remove sources with too low X-ray-to-optical flux ratio (f_X/f_{opt}) values. At the X-ray flux level of our search, 10^{-13} erg s^{-1} cm^{-2} (0.2-2 keV band), no optical counterpart is expected in public photometric catalogues. We thus used the ARCHES tool (Pineau et al. 2017) to cross-match with those catalogues and selected candidates with matching probabilities below 50%

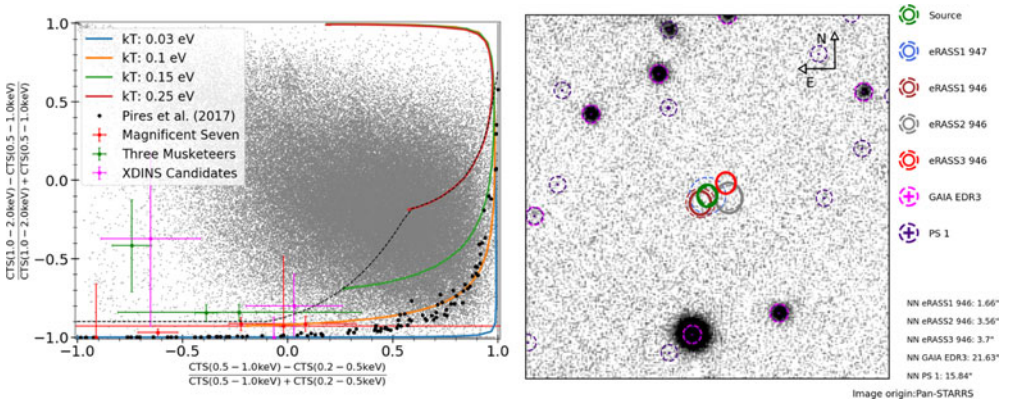

Figure 1. *Left.* X-ray colour diagram indicating the 3 candidates (magenta), the applied cut (black dashed) based on the distribution of absorbed blackbodies of different temperature and N_H values (lines), the known XDINS (green) and the simulated XDINS from Pires et al. (2017) (black dots) *Right:* Optical finding chart presenting a XDINS candidate selected from the eRASS.

(Fig. 1). We also removed candidates that are either close to bright stars and galaxies, located in crowded fields or contained in the SIMBAD (Høg et al. 2000) database.

3. Preliminary results and outlook

Applying the selection criteria, we obtain an initial sample of ~ 100 candidates. For 3 objects (fluxes within $1.5 - 3 \times 10^{-13}$ erg s^{-1} cm^{-2}; 0.2-2 keV), we initiated optical and X-ray follow-up observations with the Large Binocular Telescope and XMM-Newton respectively. The goals are to attain a more accurate X-ray sky position, increase the f_X/f_{opt} limit (> 300) and better determine the spectrum. Candidates surviving this first round of follow-up are promising targets for dedicated deeper observations to investigate the evolutionary state of the neutron star (e.g. detect the spin period, absorption features, additional thermal and non-thermal components). Forthcoming improvements in our methods and in the source catalogues (e.g. a higher energy resolution of the soft eROSITA energy band, incremental exposures) will enable promising candidates to be proposed.

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