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eROSITA expectations for thermally emitting isolated neutron stars

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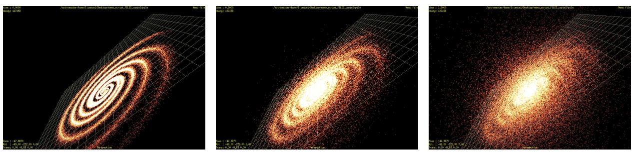
Background and motivation

The observed population of neutron stars is dominated by radio pulsars. In recent years, however, different observational manifestations of isolated neutron stars (INSs) have been discovered, which include *magnetars*, *X-ray dim INSs* (XDINS) and *rotating radio transients*. Relative to canonical radio pulsars, these objects display diverse (and mostly unpredicted) properties. While currently fewer in number, they might represent a considerable fraction of the neutron stars in the Galaxy. In particular, it is remarkable that XDINS – a homogeneous group of seven nearby, radio-quiet, cooling INSs, with higher magnetic field and higher thermal X-ray luminosity than normal pulsars – are all detected in the very local Solar vicinity. Is this fact an anomaly caused by the Sun's current location near regions of active stellar formation of the Gould Belt or is it really meaning that radio surveys do miss a large population of INSs, at least as large as that of standard radio pulsars? To answer these questions, an X-ray survey at soft energies and faint fluxes as well as population modeling in the Galactic scale are needed.

Population synthesis of thermal INSs

We developed a model for the Galactic population of thermally emitting INSs in which they are created from a progenitor population of massive stars distributed in the spiral arms of the Galactic disk; after receiving a kick velocity – exponentially distributed with mean $v_{3d} = 380\,\mathrm{km\,s^{-1}}$ (Faucher-Giguère & Kaspi 2006, ApJ 643, 332) – their evolution in the Galactic potential is followed while they cool down emitting soft X-rays. For the gravitational potential, the contributions of the disk, bulge and halo are considered, also taking into account spiral wave perturbations on the exponential disk (Patsis et al. 1991 A&A 243, 373).

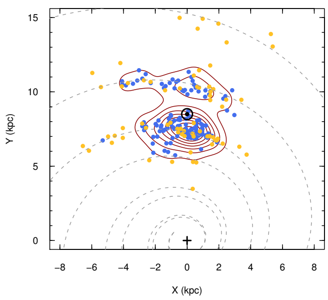


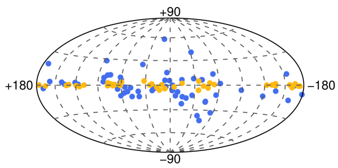
Spatial evolution of the neutron stars in the Galactic potential.

The INSs emit as isotropic blackbodies and cool down assuming standard curves for hadronic matter (e.g. Yakovlev & Pethick 2004, ARA&A 42, 169). The expected source count rates are then computed in the eROSITA detector, considering the absorption by the interstellar material. An analytical description based on layers of hydrogen in both atomic and molecular form (Dickey & Lockman, ARA&A 28, 215), was applied and the absorption cross-section of Morrison & McCammon (1983, ApJ 270, 119) was adopted. To compute count rates, we used the on-axis eROSITA response (version `iv`) and assumed a mean exposure of 2 ks after four years of survey. Assuming that the population of cooling INSs is in a steady state, we adopted a constant birthrate (of 2.1/century; Gill & Heyl 2007, MNRAS, 381, 52) during the Galaxy's lifetime relevant for cooling, roughly the last 10 Myr. For simplicity, all neutron stars are created with the same mass and radius.

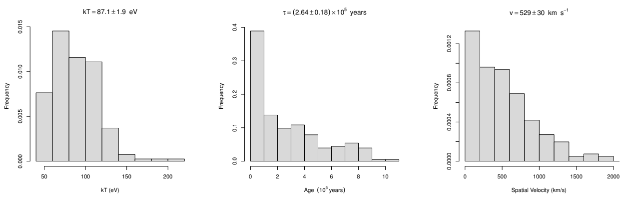
Results and perspectives

The current version of our model predicts a number of ~ 100 to 200 new X-ray thermally emitting isolated neutron stars to be discovered, after 4 yr of eROSITA survey. This corresponds to a significant increase in the number of currently known objects of up to an order of magnitude.



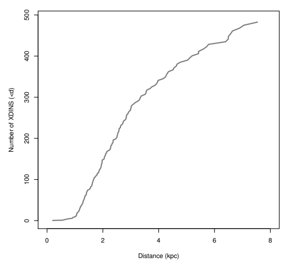


We show the expected spatial distribution of eROSITA-detected INSs (left). The detection limit is assumed to be 20 counts, roughly corresponding to a detection likelihood greater than 10 (G. Lamer, priv. comm.). Blue symbols are neutron stars with $kT < 100$ eV while orange symbols are those with higher kT. On top, the projected distribution on the Galactic plane is shown, with the centroid of the modeled spiral arms. The Sun's location is marked in black while a cross at $X, Y = (0, 0)$ shows the Galactic center. The lower plot is a Hammer-Aitoff projection in galactic coordinates of these objects.



Temperature, age and 3-D velocity distributions of the detected INSs.

Cumulative distribution of thermally emitting INSs as a function of distance from the Sun, as expected after 4 yr of eROSITA survey. Although preliminary, the current version of our model has provided us with a sense of how these sources are born and evolve in the Milky Way and what are the main sources of uncertainty involved.



We aim at developing our model further in order to compare its theoretical expectations with results from eROSITA. The planned main improvements are the inclusion of a more realistic description of the absorbing interstellar material (in collaboration with Bettina Posselt, Penn State University) and a distribution of neutron star masses and cooling rates, including effects of crustal heating by magnetic field decay. Our final goals are to derive reliable birthrate estimates, constrain properties of XDINS at greater distances and investigate their relation with other neutron star populations.