Follow-up of isolated neutron star candidates from the eROSITA survey

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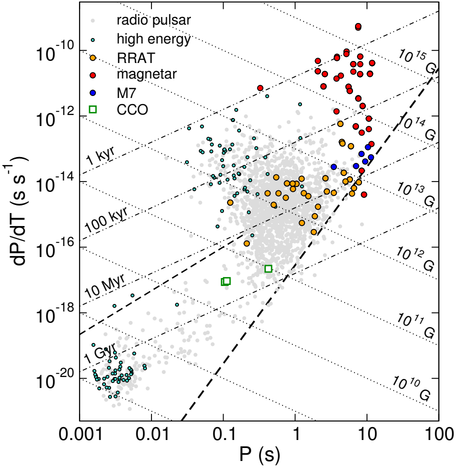
XMM-Newton: The Next Decade

AIP

Neutron stars in the Milky Way



Radio and γ-ray surveys

- rotation-powered pulsars
- millisecond (recycled) pulsars

Peculiar neutron stars

- escape detection
- challenge evolution
  - magnetars
  - the ‘Magnificent Seven’ (M7)
  - central compact objects (CCOs, a.k.a. anti-magnetars)

Radio pulsars do not tell the whole story

The magnetar-M7 connection

Strong fields at birth produce hot and long-period neutron stars due to field decay

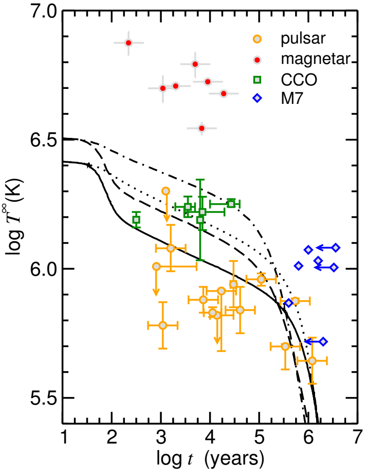
(models by Viganò, Rea, Pons, Aguilera et al.)

CCOs: different outcome of NS evolution

If the NS accretes lots of fallback debris:

- its magnetic field may be buried
- it won't spin down (no radio)
- its cooling rate is affected

(c.f. Chevalier, Muslimov & Page, Geppert, Ho, Bernal, Viganò, ...)



eROSITA to discover peculiar neutron stars

These channels are not probed by radio and γ-ray pulsars

Despite the theoretical development seen in recent years:

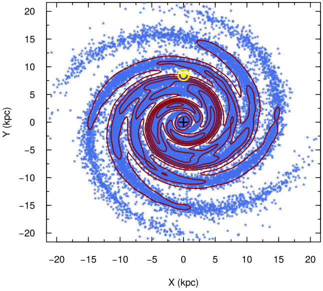
- even the state-of-the-art models are built over uncertain assumptions
  (e.g. initial field configuration, level of impurity of the crust)
- known pulsars are not sufficient to constrain models of field decay
  (Gullòn et al. 2015)
- formation and fate of CCOs:
  how common is such an episode in the Galaxy? timescale of field re-emergence?
- ...plus transients and the unknown! (faint AXPs/SGRs, old accreting neutron stars?)

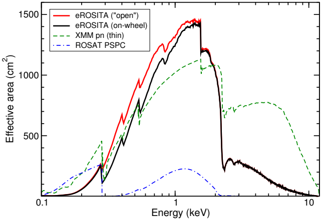
eROSITA survey – unique potential (for decades to come!) to:

- unveil radio-quiet neutron stars at fainter fluxes
- probe the population as a whole

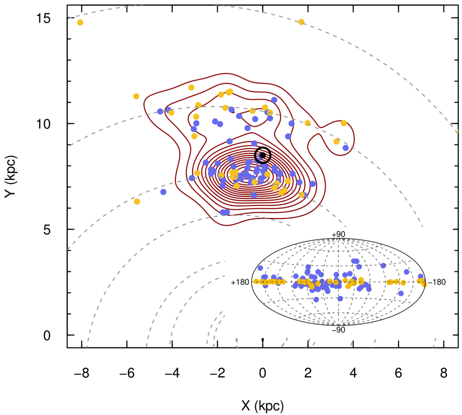
Tracking neutron stars from birth up to present time

- progenitor stars in spiral arms
- interstellar medium (analytical hydrogen layers), abundances, cross-section
- birth properties: spatial velocity, isotropical kick, constant birthrate
- motion integrated in the galactic potential
- thermal evolution: standard cooling
  (*to be included:* effects of fallback/field decay)
- isotropic blackbody emission
- eROSITA effective area and filters, averaged over FoV, survey exposure
- detection limit of 30 counts (0.2–2 keV)





eROSITA forecast



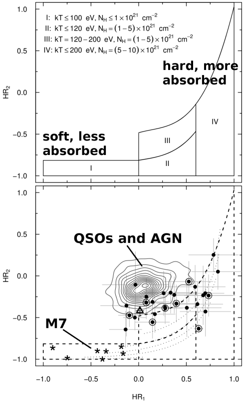
- Simulations give 85 to 100 thermally emitting neutron stars in the survey after 4 yr
- Average distances within 300 pc and 8 kpc (median 2 kpc)
- The minimum flux is $\sim 10^{-14}\,\mathrm{erg\,s^{-1}\,cm^{-2}}$
- The median flux is $\sim 3.5 \times 10^{-14}\,\mathrm{erg\,s^{-1}\,cm^{-2}}$
- 20% of the sources at intermediate flux ($\sim 10^{-13}\,\mathrm{erg\,s^{-1}\,cm^{-2}}$)

Potential for discoveries

Sources at intermediate flux can already be targeted for follow-up in the optical (VLT, LBT) and in X-rays (XMM-Newton, Chandra)

Pinpointing candidates

Cross-correlation, selection in hardness ratio, visual screening, optical follow-up

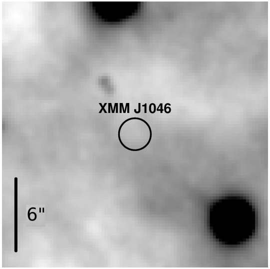


2XMMp: 30 out of 72,000

($f_X > 10^{-14}\,\mathrm{erg\,s^{-1}\,cm^{-2}}$)

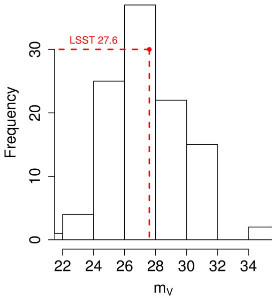
What's the limiting magnitude to rule out ordinary X-ray emitters (AGN/CV/stars)?

Discovery of a NS in Carina



$m_V > 27$ (2σ)

$\log(F_X/F_V) > 3.5$



Summary

Taking as reference our past work with the 2XMMp and the NS in Carina:
(2XMM J104608.7-594306, Pires et al. 2009, 2012, 2015)

- efficient selection of 600 candidates with $m_{\mathrm{R}} > 21 - 23$
- 5 min/target (8 m class telescope) to rule out CVs/AGN ($m_{\mathrm{V}} > 27$)

Assuming 20 neutron stars within the sample of candidates:

- 100 ks (5 ks/target) with Chandra for sub-arcsecond precision
- 2 Msec (100 ks/target) with XMM-Newton to:
  - constrain pulsations down to 15%
  - determine spectral parameters (5% kT, 15% N_{H})
  - detect spectral features or deviations from the thermal continuum

Thank you!