Leibniz-Institut für
Astrophysik Potsdam

The search for X-ray dim isolated neutron stars in the SRG/eROSITA All-Sky Survey

Jan Kurpas

In collaboration with:
Axel Schwope, Adriana M. Pires, Frank Haberl

First Results from the SRG/eROSITA All-Sky Survey: From Stars to Cosmology
18.09.2024

The Magnificent Seven - a ROSAT legacy

ROSAT discovered seven X-ray dim isolated neutron stars (XDINSs)

Characteristics:
- Predominantly thermal emission
- Radio-quiet
- Nearby (within 1 kpc of sun)
- Larger magnetic field strengths, spin periods and thermal luminosities than "ordinary" RPPs

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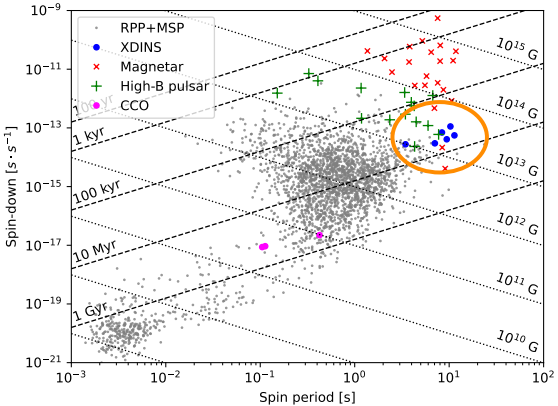
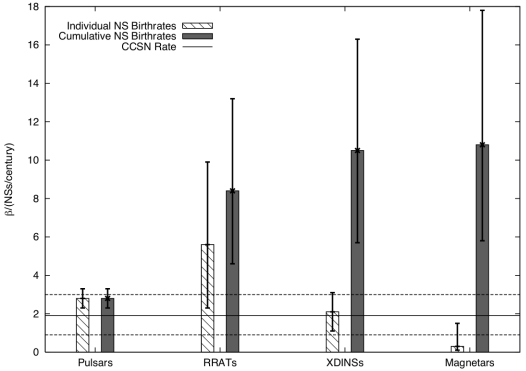
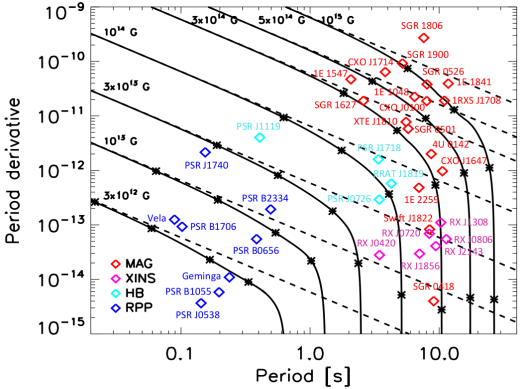


XDINS population properties



Keane, Kramer, 2008, MNRAS, 391, 2009.



Viganò, et al., 2013, MNRAS, 434, 123.

Large Galactic birthrate?
Too many INSs?

Evolutionary connection to magnetars/high-B pulsars?

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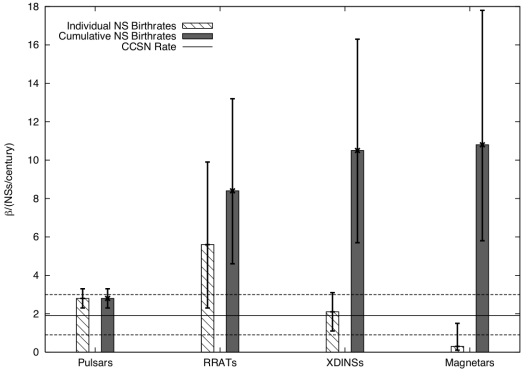

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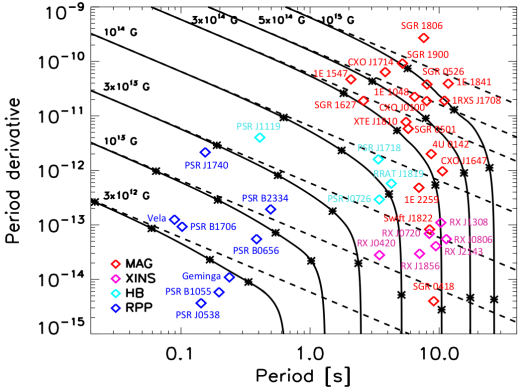

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Large Galactic birthrate?
Too many INSs?

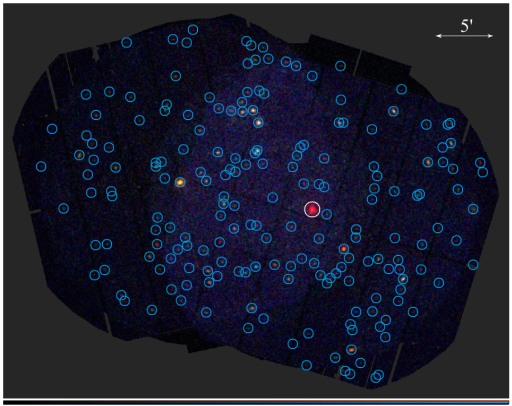
Evolutionary connection to magnetars/high-B pulsars?

The population must be increased!

The search for new XDINSs

More sources hiding in ROSAT?
- Significant source confusion!
- SWIFT+ROSAT (Rutledge+08): Calvera

Did another X-ray mission serendipitously observe an XDINS?
- Deep observations, limited sky coverage
- 5 candidates identified! (Pires+09, Rigoselli+22, Pires+22)



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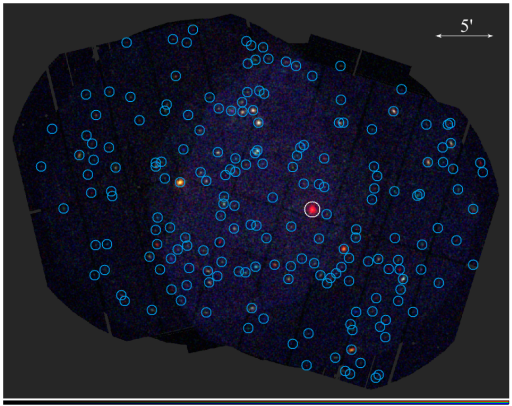

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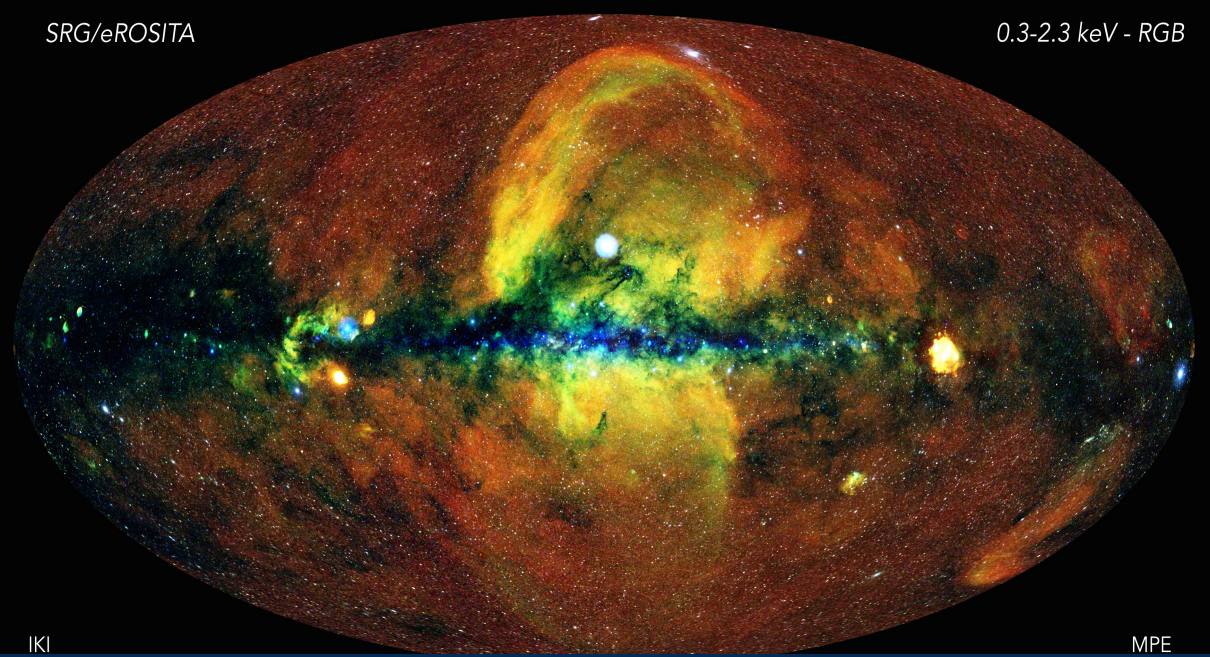
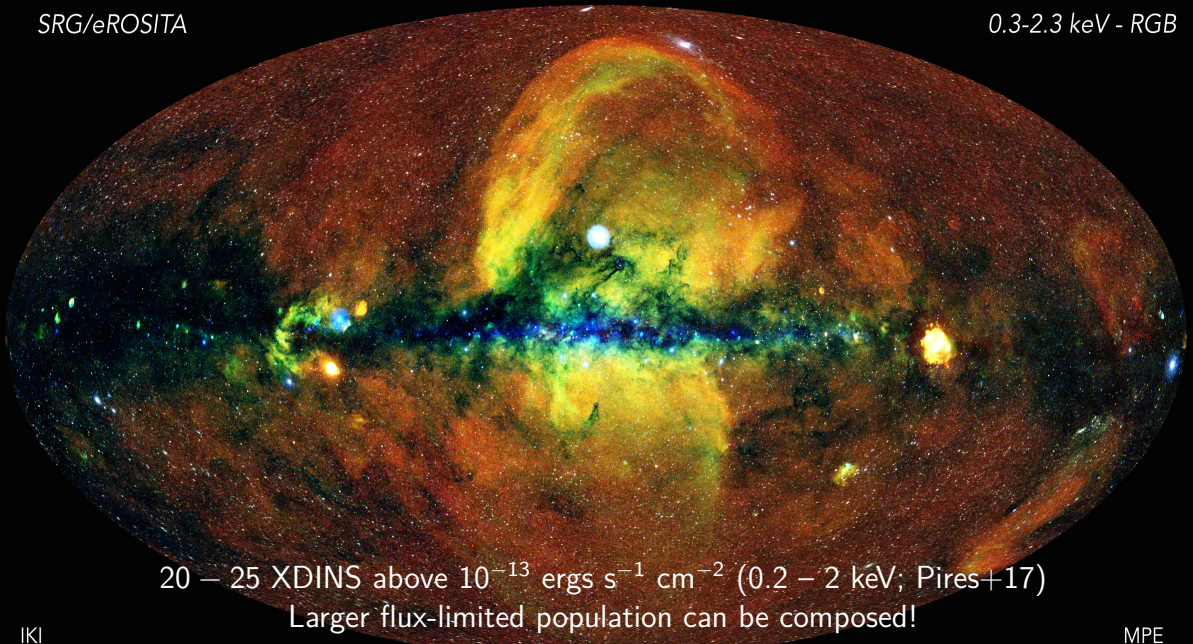
X-ray survey with "good" positional accuracy needed!

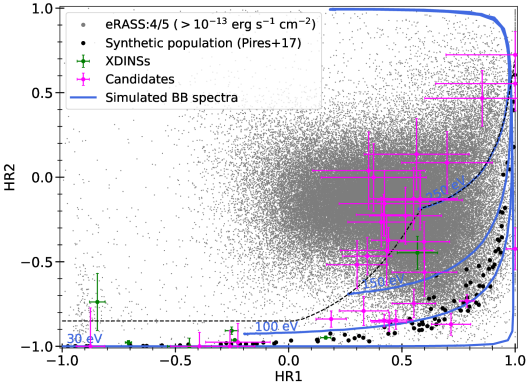

SRG/eROSITA
0.3-2.3 keV - RGB
IKI
MPE



20 – 25 XDINS above 10^{-13} ergs s^{-1} cm^{-2} (0.2 – 2 keV; Pires+17)
Larger flux-limited population can be composed!

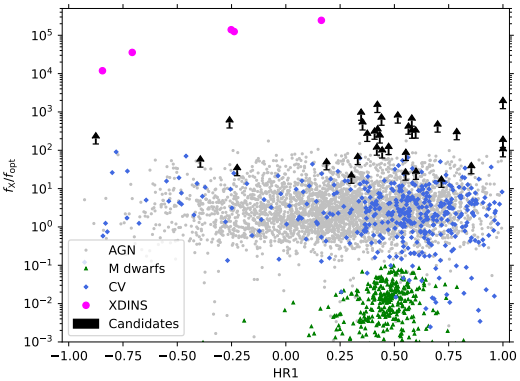
IKI MPE

Selecting the needle in the haystack



Soft blackbody-like X-ray emission

Cut in HR space



XDINSs possess $f_X/f_{\rm opt} > 10^3$

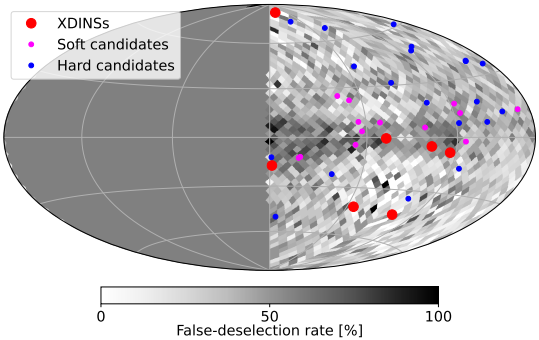
Select only eRASS sources without any optical/IR counterparts

The candidate sample and follow-up

33 candidates survive the selection
- 13 soft ($kT \lesssim 150$ eV)
- 20 harder ($kT \gtrsim 200$ eV, $\Gamma \sim 1-4$)
- 1 – 3 new XDINSs may be expected

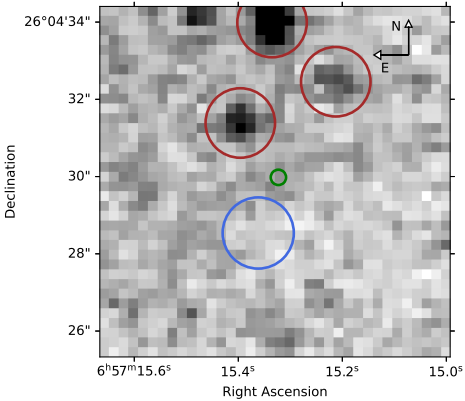
Follow-up needed to confirm INS nature!
- XMM-Newton, NICER, Chandra: spectrum, position, pulsations
- LBT, SALT and VLT: $f_{\rm x}/f_{\rm opt}$
- FAST: pulsations

Some candidates already observed
- eRASSU J065715.3+260428
- eRASSU J131716.9–402647



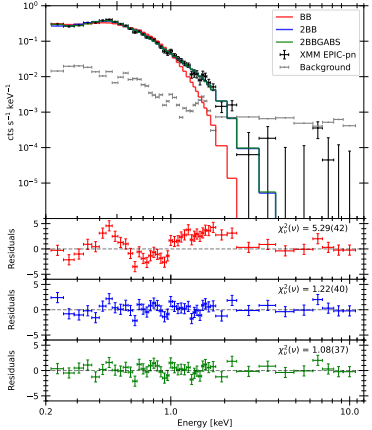
The candidate eRASSU J065715.3+260428

Targeted with XMM-Newton (67 ks), NICER (220 ks), VLT (1 h), FAST (5 h)



Magnitude limit: 27.3 mag

$f_{\rm X}/f_{\rm opt} \gtrsim 5000$



Thermal continuum + 1 feature

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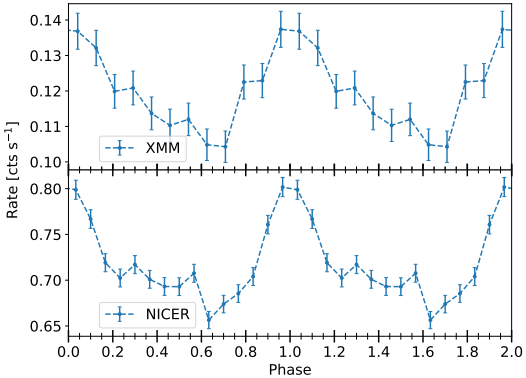
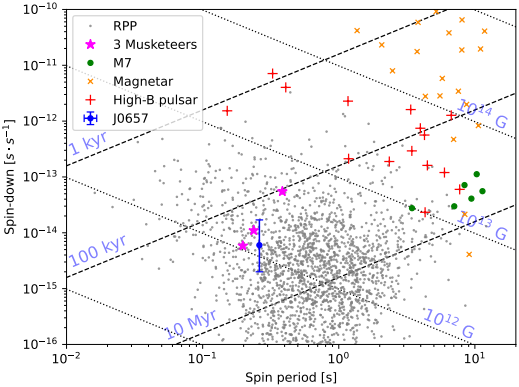


Modulation seen at X-rays

$P \approx 261$ ms, $\dot{P} = 6^{+11}_{-4} \times 10^{-15}$ s s^{-1}



$L_{\rm X}/\dot{E}_{\rm rot} < 0.01$

Undetected in FAST/Fermi LAT!

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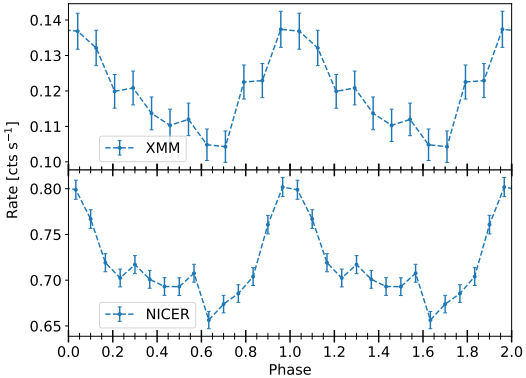

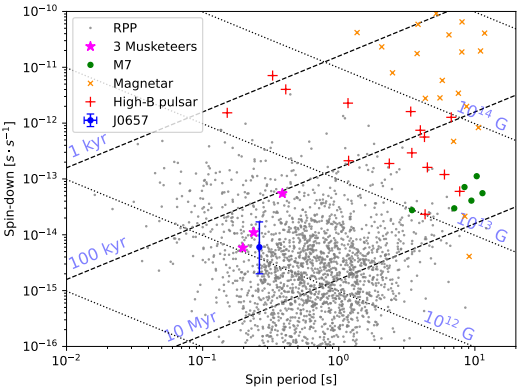

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$L_{\rm X}/\dot{E}_{\rm rot} < 0.01$

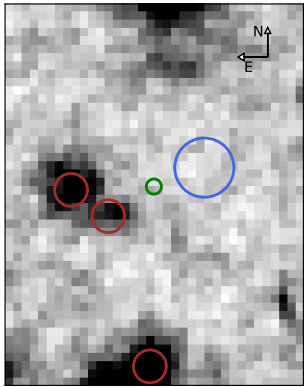
Undetected in FAST/Fermi LAT!

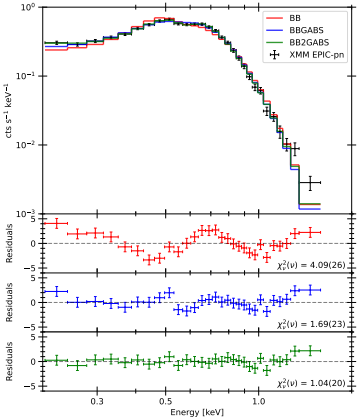
Radio/gamma-ray-quiet rotation-powered pulsar!

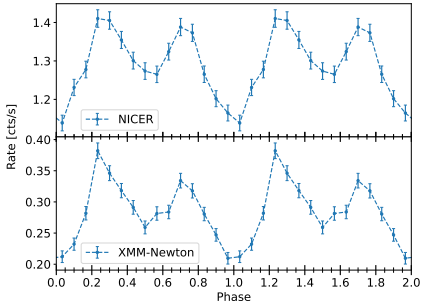
Kurpas, et al., in prep.

The candidate eRASSU J131716.9–402647

Targeted with XMM-Newton (37 ks), NICER (49 ks), and VLT (1.7 h)





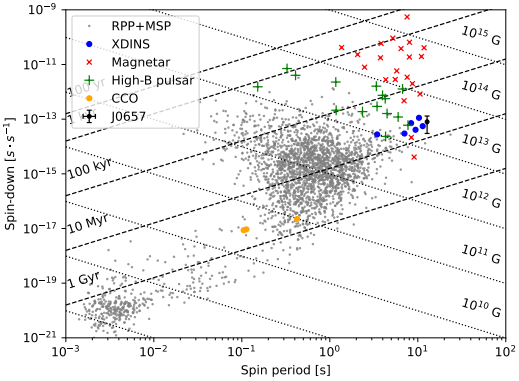


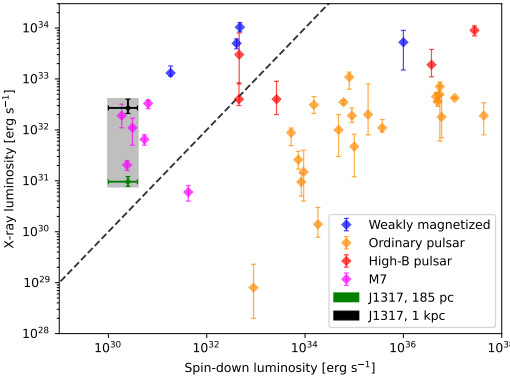
Magnitude limit: 27.5 mag
$\log(f_{\rm X}/f_{\rm opt}) \gtrsim 4$

Thermal continuum + 2 features
B-field $\sim 5 \times 10^{13}$ G

Significant modulation
$P \approx 12.76$ s,
$\dot{P} \lesssim 8 \times 10^{-11}$ s s^{-1}

A NICER timing study of eRASSU J131716.9–402647





Preliminary result (1σ)

$\dot{P} = (8 \pm 5) \times 10^{-14}$ s s^{-1}

$L_{\rm X} \gtrsim \dot{E}_{\rm rot}$

Magnetic field dominated evolution?

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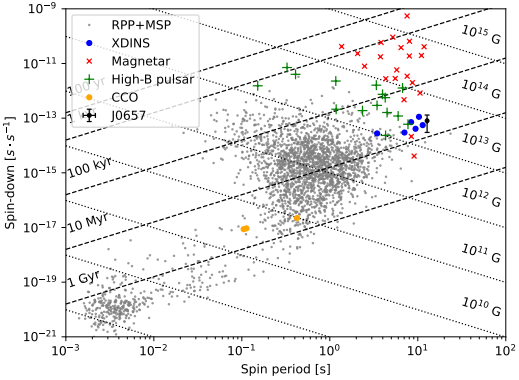

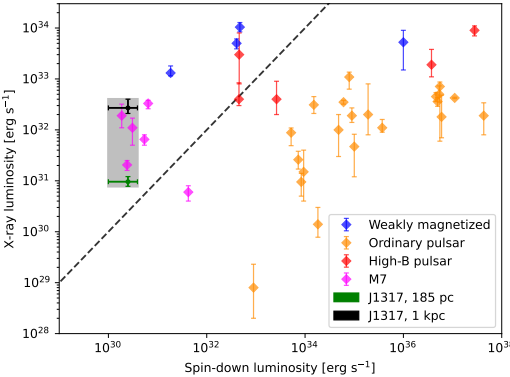

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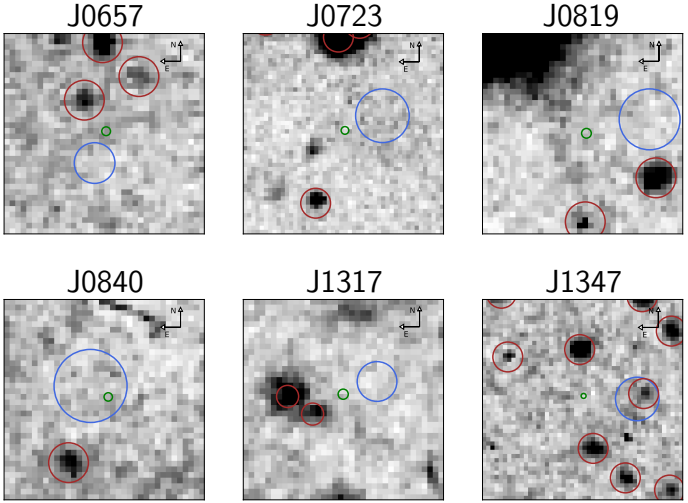
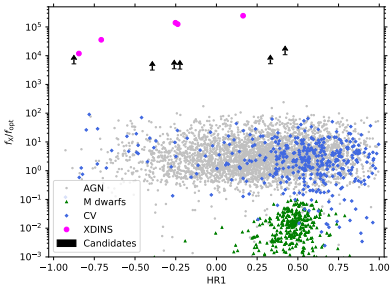
Highly magnetized INS, very similar to XDINSs

Kurpas, et al., 2024, A&A, 683, A164.

The XMM-Newton/VLT large programme

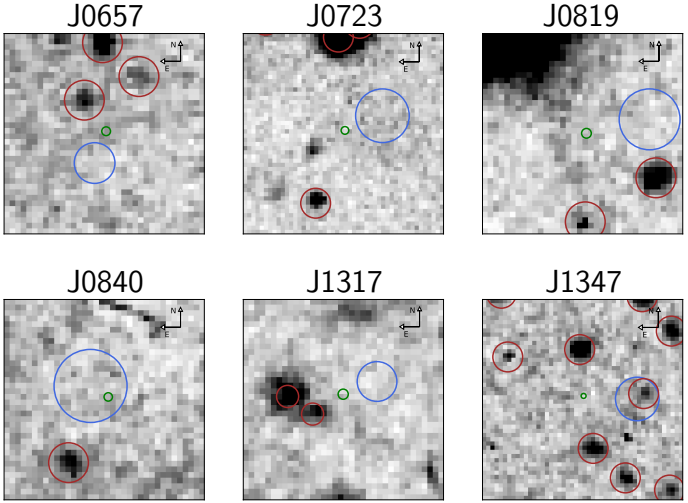


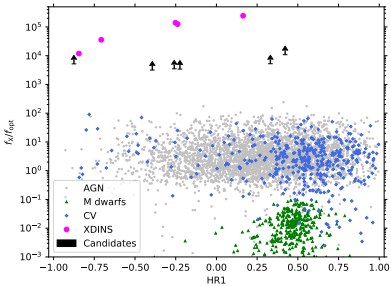


7 sources observed in AO22
- 6 new thermally emitting INSs!

Soft thermal spectra:
- $kT \sim 50 - 80$ eV

The XMM-Newton/VLT large programme





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SRG/eROSITA is increasing the (XD)INS population!

Summary

New XDINSs are ought to be hiding in the SRG/eROSITA All-Sky Survey

Identified 33 candidate objects (Kurpas, et al., 2024, A&A, 687, A251.)
- 13 soft candidates
- 20 harder sources

Follow-up campaign ongoing
- A very XDINS like source (J1317; Kurpas, et al., 2024, A&A, 683, A164)
- A new radio/gamma-ray-quiet RPP (J0657; Kurpas, et al., in prep.)
- At least 4 additional INSs discovered (Kurpas, et al., in prep.)

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To be continued ...