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X-ray Astronomy Group (AIP)

eROSITA follow-up of continuous gravitational waves

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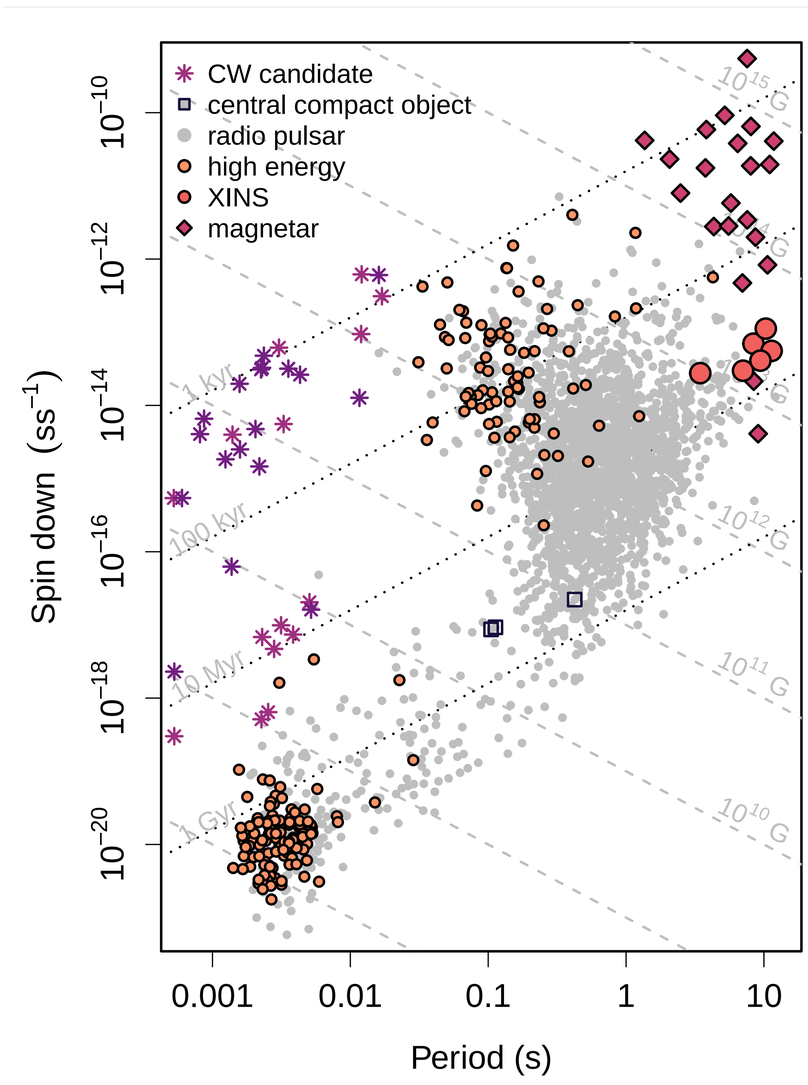
Background

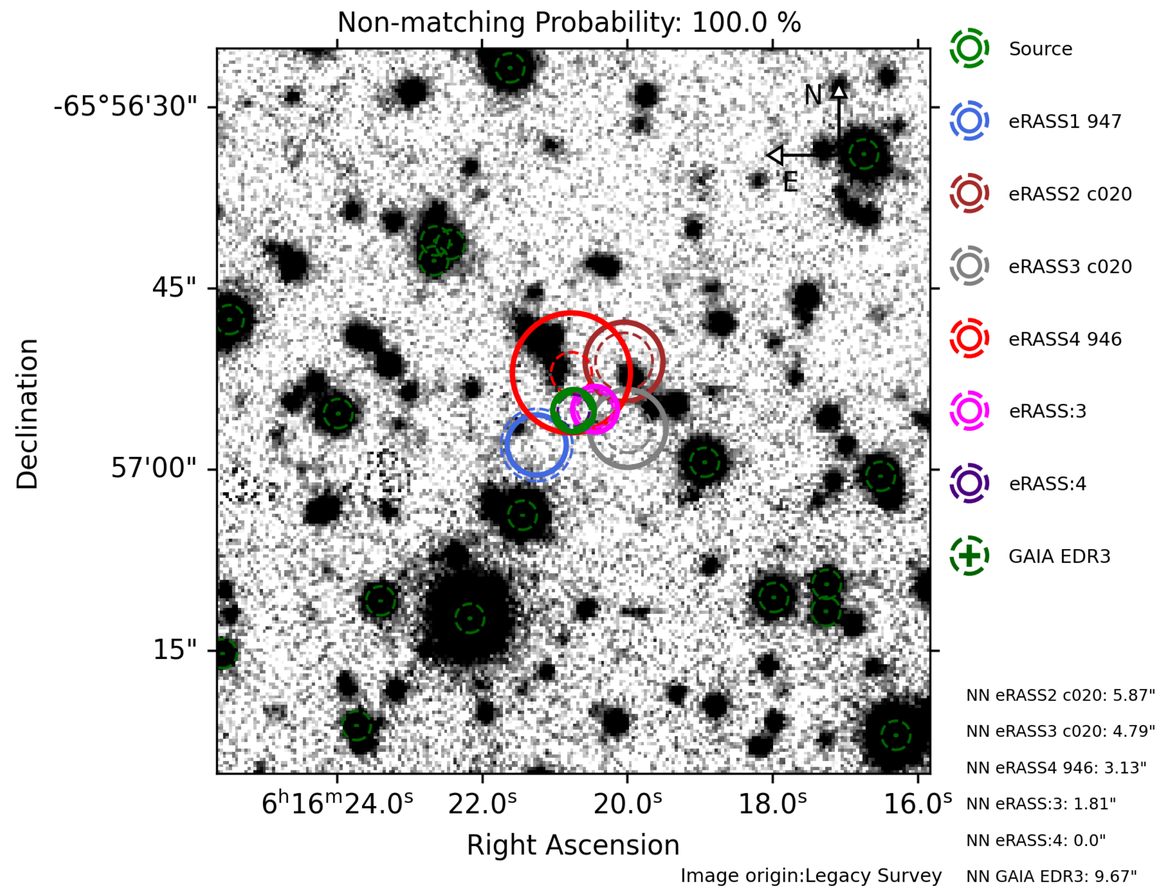
The LIGO Scientific Collaboration and Virgo Collaboration have so far announced about 50 detections of gravitational waves, all of them associated with mergers of compact objects at high redshifts. These signals are transient and bright, typically presenting a strain amplitude of 10^{-21} for most of the time. By contrast, continuous gravitational waves (CWs), a persistent though orders of magnitude weaker train of nearly monochromatic waves, have not yet been identified in the LIGO/Virgo observing runs. A spinning, slightly deformed, neutron star is one of the most promising candidate to trigger a first detection. While coherent time searches for CWs are feasible for pulsars with a precise timing solution and known sky location, blind, all-sky searches rely on semi-coherent searching methods and the shared computing power of the Einstein@Home initiative.

A search for CW counterparts with eROSITA

We investigated the sky location of 27 CW candidates from Advanced LIGO/Virgo's O1-O3 observing runs and the Einstein@Home all-sky searches, with the goal to identifying the X-ray counterpart of the spinning neutron star in the eROSITA All-Sky Survey data (eRASS:4). While the "loudest" CW emitters are expected to be young and energetic spin-powered pulsars, blind searches will put forward candidates lacking bright electromagnetic counterparts – a previously known pulsar-wind nebula or supernova remnant. This opens the interesting prospect to associate CW candidates with peculiar groups of X-ray thermally-emitting isolated neutron stars (see below) that may have evolved differently than most known neutron stars in our Galaxy.



Pulsar spin period as a function of spin-down. The diagram includes all galactic neutron stars for which both measurements are available from several multi-wavelength surveys (source: ATNF Pulsar Catalogue; ref. 1). Over-plotted in grey are lines of constant age and magnetic field intensity according to the magnetic dipole braking scenario. The position of peculiar groups of X-ray emitting isolated neutron stars (2) are highlighted (see the legend). The position of selected CW candidates from Advanced LIGO/Virgo observing runs O1-O3 are displayed as stars on the short-spin section of the diagram. The candidates displayed in purple (as opposed to magenta) are not in the footprint of the German eROSITA sky, defined west of the Galactic centre, and have not been investigated in this work.



Optical finding chart of the field of a possible X-ray counterpart of one CW candidate from the Einstein@Home searches. The inverted black and white scale show optical objects from the Legacy Survey DR9. The error circles show the position of the X-ray source as derived from individual and cumulative scans (eRASS1-4; eRASS:3, eRASS:4).

Multi-probabilistic cross-match and screening

To identify viable CW counterparts among the eROSITA detected sources we exclude those likely associated with objects catalogued in the optical/UV/IR wavelengths. Based on a multi-probabilistic cross-match (3) with eRASS:4 and GAIA EDR3, Pan-STARRS DR1, the Legacy Surveys DR9 (4-6), over half of the eRASS:4 sources located within 45 arcmin of a CW candidate are excluded. The remaining sources were then screened for counterparts using a dedicated procedure developed to identify X-ray emitting isolated neutron stars (7). About 50 previously unknown X-ray sources lacking obvious counterparts survive all the selection criteria; no extended sources have been founded among them. The optical finding chart of one such a source is shown in the figure above.

Prospects: follow-up of promising candidates

We will next investigate the X-ray emission and general properties of the X-ray sources surviving our catalogue cross-matching and screening procedures. The analysis is performed over the event lists corresponding to the target's sky tile in each eRASS1-4. Promising candidate targets will then be proposed for multi-wavelength follow-up observations with the goal to secure a neutron star identification.

References

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