X-ray counterpart detection and γ-ray analysis of the supernova remnant G279.0+01.1 with eROSITA and Fermi-LAT

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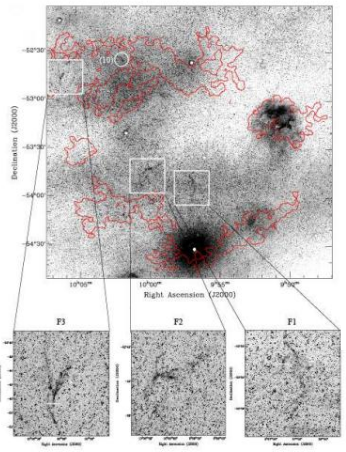
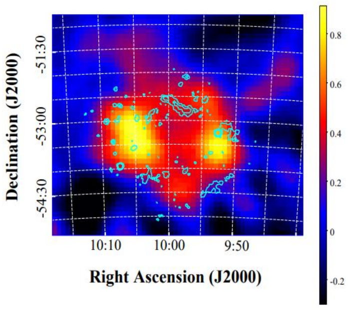
Introduction

Depending on their evolutionary state and distance from Earth, the angular sizes of Galactic SNRs can range from a few arcmin to several degrees. Only a select number of low surface brightness Earth-adjacent remnants, a few tens of hundreds of parsecs away, which are found in their most evolved state and with sizes of several degrees, have been detected. In the X-ray band particularly, even fewer findings have been reported. The improved sensitivity of the eROSITA All-Sky Survey offers a unique chance to detect such SNRs that XMM-Newton/Chandra/Suzaku and ROSAT could not have seen. The G279.0+01.1 SNR, with a ~3° apparent angular size, is a showcase example of this category that has been extensively studied across the entire electromagnetic spectrum, from radio to GeV γ-rays, except in X-rays.



SHS Hα map overlaid with PMN radio contours in red (4.85 GHz) *(Stupar & Parker 2009)*



Fermi-LAT Residual map: >5 GeV *(Araya 2020)*

A dichotomy

Old and distant scenario:

Using the statistical relation between the observed absorption in X-rays (as derived from the X-ray spectral fit) with the mean color excess *(Foight et al. 2016)*: $N_H[cm^{-2}/A_v] = 2.87(\pm 0.12)x10^{21}$ and employing the latest *Lallement et al. (2022)* optical extinction data sets one derives a:

$2.49^{+0.22}_{-0.25}$ kpc distance → consistent with the literature value (2.7 kpc). Assuming a 2.7 kpc distance a 10^6 yr age is derived using the SNR evolutionary models by *Leahy & Williams (2017)*.

"Young" and adjacent scenario:

Motivation:

- **All distance estimates reported in literature (including the above distance measurement) are based on empirical relations with substantial scatter.**
- **The soft (detected down to 0.3 keV) X-ray emission in non-equilibrium point towards small absorption indicating that the remnant could be placed at a much closer distance.**

Strategy: The shape of the remnant's X-ray spectrum (dominance of light element emission lines, i.e., O, Ne, and Mg) and the remnant's location on the Galactic Plane support a core-collapse SNR progenitor origin → potential pulsar association. But all potentially associated pulsars within 3° from the remnant's center have a ~0.4 kpc distance.

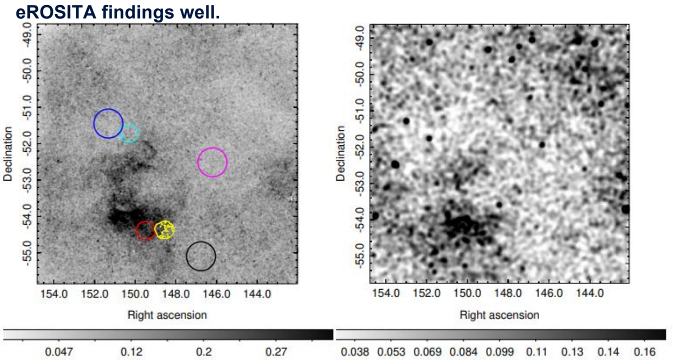
Pulsar association yields a 0.4 kpc distance and a 10^4-10^5 yr age (using *Leahy & Williams (2017)* SNR evolutionary models)

Discussion

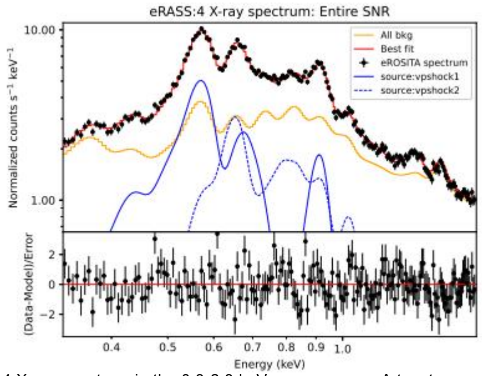
- **The X-ray emission is predominantly soft with a strong detection between 0.3-1.1 keV, no excess photons are detected above 2.0 keV. The X-ray spectra is purely thermal, exhibiting O, Ne and Mg emission lines, and is well-fitted with a two temperature thermal plasma in non-equilibrium ionization. Individual sub-regions have been inspected showing that the plasma temperature overall drops as we move from the northwestern to the southeastern part of the remnant.**
- **A refined radio size of 3° using PMN and ASKAP data is consistent with the remnant's X-ray and GeV extension. No excellent spatial correlation is found in all three energy bands. No overall spatial coindence is expected due to different particle populations (GeV electrons (radio synchrotron), Thermal X-ray plasma (ejecta and ISM heating), Hadronically induced γ-rays (π° decay)).**
- **The results obtained in this work cast some doubt on the so far prevailing interpretation that G279.0+01.1 is located at a distance of ~2.7 kpc and has an age of ~1 Myr. The remnant's observational properties (γ-ray emission and soft X-ray emission in a non-equilibrium state) + potential pulsar assoociation are better aligned with a significantly smaller distance and age.**

New findings

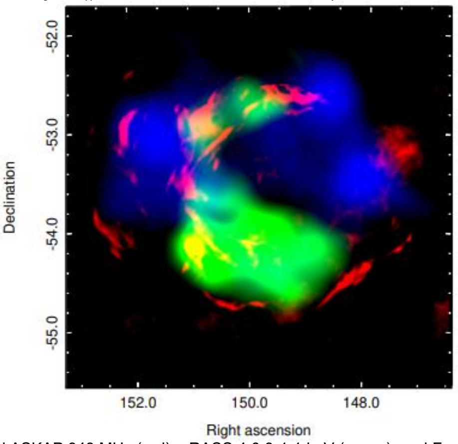
In this work, we report the first detection of the SNR G279.0+01.1 in X-rays (the X-ray emission is purely thermal and mainly confined in the 0.3-1.1 keV energy range) using eRASS data from the first four completed eROSITA All-Sky Surveys, eRASS:4. Unpublished XMM-Newton observations that cover small portions of the SNR complement eROSITA findings well.



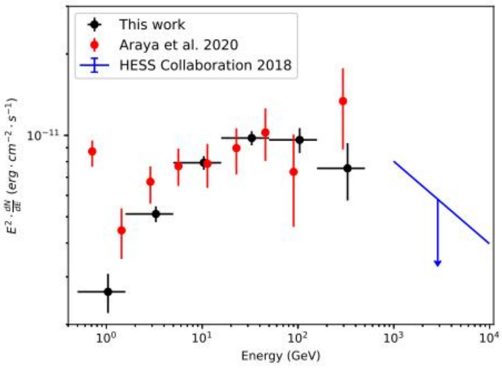
Left panel: eRASS:4 intensity sky map [counts/pixel] in the 0.3-1.1 keV energy range, with point sources removed. Red, yellow, and cyan circles mark the positions of the 0823031001, 0823030401, and 0823030301 XMM-Newton pointings, respectively. Blue, magenta, and black circles represent background control regions for spectral inspection. Right panel: ROSAT intensity sky map in the 0.4-2.4 keV energy range for comparison (an aposteriori detection following the initial detection with eROSITA).



eRASS:4 X-ray spectrum in the 0.3-2.3 keV energy range. A two-temperature thermal plasma in non-equilibrium of kT~0.3 keV and kT~0.6 keV, as well as an absorption column density of N_H~0.3 cm^{-2}, describes the SNR's spectra well.



Combined ASKAP 943 MHz (red), eRASS:4 0.3-1.1 keV (green), and Fermi-LAT >5 GeV (blue) image of the SNR.



GeV-TeV SED: Black dots correspond to the Fermi-LAT spectrum in the 0.5-500 GeV band, obtained in this work. Red and blue dots correspond to giga-electronvolt Fermi-LAT data reported in *Araya (2020)* and TeV-H.E.S.S. upper limits reported in *H. E. S. S. Collaboration et al. (2018a)*, respectively.