NEUTRON STAR POPULATION IN THE GALACTIC CENTER REGION

A POTENTIAL SOURCE OF POLARIZED X-RAY EMISSION

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We analyse the emission properties of the population of neutron stars that is expected to be present in the innermost parts of the Galactic center. A part of the population of isolated neutron stars propagates supersonically through denser ionized streams of the Minispiral (Sgr A West), forming bow shocks where particles are accelerated and are expected to produce polarized X-ray synchrotron signal. Another source of the synchrotron emission is an elongated magnetosphere and tail. We investigate whether the polarized X-ray emission from Galactic center neutron star bow shocks will be potentially detectable in the framework of future X-ray polarimeters. A special case is a detected young neutron star - magnetar SGRJ1745-2900 - that has undergone a series of outbursts with a peak X-ray luminosity of the order of $10^{35}\,\mathrm{erg\,s^{-1}}$ (1-10 keV). Apart from an intrinsic X-ray emission, the X-ray emission from neutron star outbursts may be scattered by molecular clouds in the Central Molecular Zone by Thomson scattering, which is another potential source of polarized X-ray emission.

Neutron star population near the Galactic center

The Galactic center region is a very complex region, which hosts the **supermassive black hole** of ~ $4\times10^6\,M_\odot$ which is associated with the compact radio source Sgr A*. Infrared observations revealed a very dense nuclear star cluster (NSC) that consists of both **late-type** and **early-type** stellar populations (Buchholz et al., 2009), see Fig. 1. Multi-wavelength observations ranging from infrared L-band up to the radio domain dissected the structure of the **gaseous-dusty multiphase medium**, which consists of both non-thermal (Sgr A East) and thermal components (Sgr A West – the minispiral). Since the thermal streamers of the minispiral and the NSC occupy the innermost parsec, the rate of interaction between the gaseous clumps and stars is expected to be non-negligible. The geometry of the minispiral is highly non-spherical, thus the geometrical distribution of encounters is expected to produce the net polarization of the total signal, see Fig. 2.

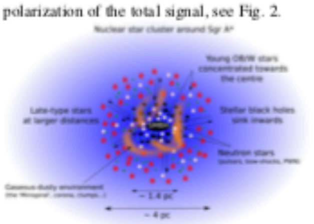

Figure 1: Illustration of the nuclear star cluster around Sgr A*. The main components are late-type stars whose abundance appears to decrease towards Sgr A*, early-type stars concentrated towards the centre (Buchholz et al., 2009), and hypothetical stellar remnants. These components are expected to propagate through gaseous-dusty environment and to interact with denser regions.

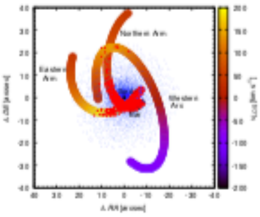

Figure 2: Interaction of the population of neutron stars with the minispiral streamers. Blue dots represent the whole population of 10^4 neutron stars around Sgr A*, while red dots stand for the neutron stars that interact with the minispiral. The calculation was performed for a broken power-law profile with a declining density towards the center.

The presence of supersonic objects may be revealed by the presence of bow shocks. The end-products of the stellar evolution that are still observationally unexplored in the Galactic center region – in particular **neutron stars** – could be revealed via bow shocks, see Fig. 3 for illustration. The method of searching for neutron-star bow shocks in particular in the X-ray and radio domains could thus be complementary to standard radio pulse searches, which have yielded a low number of detections in the Galactic centre despite sufficient sensitivity (Fig. 4).

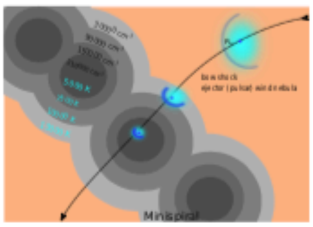

Figure 3: Illustration of the neutron star–minispiral interaction. Density and temperature values within each clump are indicated.

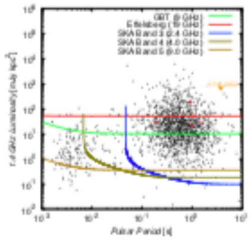

Figure 4: The comparison of the 1.4 GHz luminosities of known pulsars (Manchester et al., 2005) with the detection limits for the current (GBT and Effelsberg radiotelescope) and future surveys (SKA – Square Kilometer Array).

Distribution of interaction modes of neutron stars

Using the properties of the ambient medium and the distribution of neutron stars in terms of the magnetic dipole intensity and their rotational period, we assess the distribution of the interaction modes (**accretor, propeller, and ejector**) in the innermost parsec of the Galactic center (Zajacek et al., 2015). We consider three types of the spatial power-law distribution of neutron stars, see Figs. 5 and 6, which affect mainly the rate of the interaction with the minispiral–in the range of 1–10%. The ejector regime is prevalent for both the interarm and the minispiral region, see Figs. 7 and 8. However, it is even more prevalent for the interarm region due to lower ambient pressure. The distribution of the interaction modes in the period-magnetic intensity plane is depicted in Fig. 9 for both the interarm and the minispiral region. A shift is apparent between the interarm and the minispiral region: for the fixed value of the period, the propeller and the accretor regimes occur for larger magnetic intensities in the minispiral region.

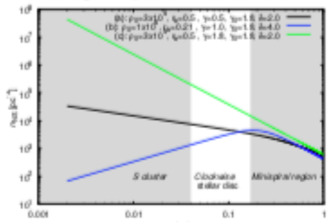

Figure 5: Profiles of number density for different parameters, see the legend.

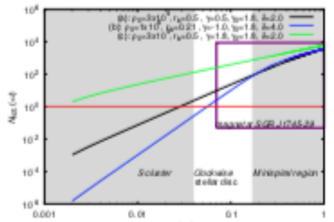

Figure 6: Calculated number of neutron stars within a sphere of radius r centred at Sgr A*.

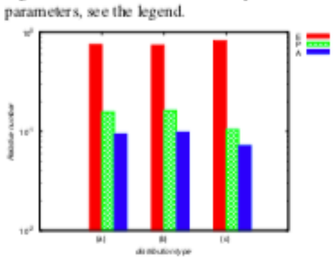

Figure 7: Distribution of the interaction modes for the interarm region.

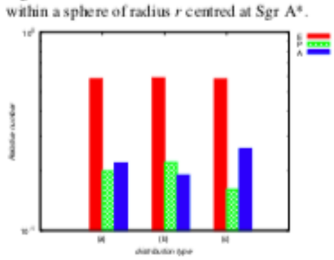

Figure 8: Distribution of the interaction modes for the minispiral region.

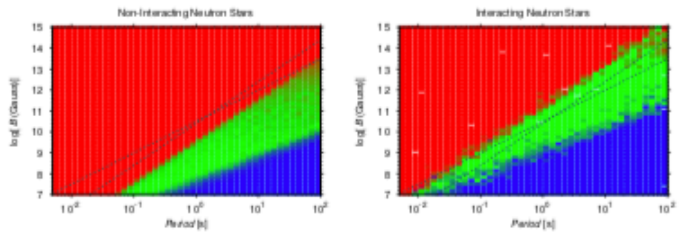

Figure 9: Distribution of interaction modes (E, P, A) in the period-magnetic intensity plane. The left panel represents the modes of neutron stars that are located outside the minispiral and the right panel stands for neutron stars that pass through the minispiral. The calculation was performed for 200 000 neutron stars spatially distributed according to (a).

Observability of bow-shock nebulae

The observability of bow-shock structures is given by the angular scale and the flux density that is above the sensitivity threshold at given wavelength. The bow-shock angular scale is given by the standoff distance $R_0=\sqrt{\dot{E}/(4\pi c(1+\alpha)\rho_a v_{\rm rel}^2)}$, where $\dot{E}=I\Omega\dot{\Omega}$ is the spin-down power. In the Figure below, we plot simulated size distribution of bow-shock nebulae for the spatial distribution (b).

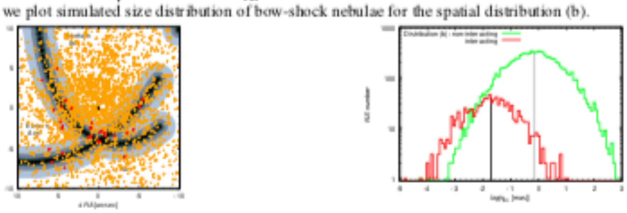

Figure 10: Size distribution of the bow shocks created by the shocked wind of relativistic particles generated by the ejector mode: **Left:** Angular sizes in comparison with the minispiral arms. **Right:** Distribution of sizes calculated for the non-interacting neutron stars and those interacting with the denser minispiral streamers. Calculation was performed for the broken-power law distribution of neutron stars with the break radius of 0.21 pc and decreasing density towards the center.

In addition, we estimate the X-ray luminosities of neutron star nebulae $L_X(1-10\,\mathrm{keV})$ using the relation $\log L_X=(33.42\pm0.20)+(1.27\pm0.17)\log(\dot{E}/10^{36})$ (Kawai et al., 1998).

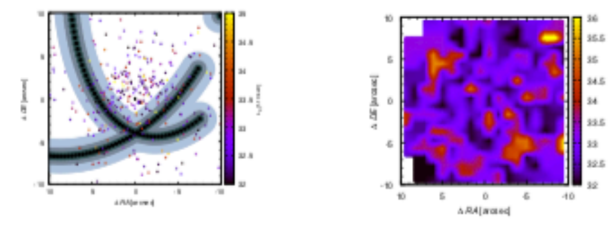

Figure 11: Estimated X-ray luminosities (1-10 keV) for neutron star nebulae. **Left:** Selected nebulae more luminous than $10^{32}\,\mathrm{erg\,s^{-1}}$. **Right:** Distribution of luminosities on a grid of 40×40 smoothed by a gaussian kernel of 0.1″.

References

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