Isolated neutron stars in the Galaxy: from magnetars to antimagnetars

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Using the model with decaying magnetic fields it is possible to describe with one smooth (log-gaussian) initial magnetic field distribution three types of isolated neutron stars: radiopulsar, magnetars, and cooling close-by compact objects. The same model is used here to make predictions for old accreting isolated neutron stars. It is shown that using the updated field distribution we predict a significant fraction of isolated neutron stars at the stage of accretion despite long subsonic propeller stage.

1. INTRODUCTION

In last ∼10–15 years astrophysics of isolated neutron stars (NSs) became one of hot topics partly because of an increasing flow of new astonishing observational results, partly due to its importance for physics, as NSs are unique natural laboratories to study matter under extreme conditions: high density, high magnetic fields, strong gravity, etc.

It came out that young NSs can appear as sources of different nature (see a brief review in [1]). The reason for drastic differences between different types of young NSs is not yet understood. Very often it is assumed *ad hoc* that distributions of initial parameters of different subpopulations are formed independently, and in population models distributions are given "by hand". However, recently it was shown that three subpopulations (close-by cooling NSs, magnetars, and radiopulsars) can be described in the unique model in the framework of decaying magnetic field [2].

In [2] the authors derived the initial distribution of magnetic fields which successfully describes three subpopulations of isolated NSs, using the population synthesis technique [3].

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It is a log-gaussian distribution with $< \log(B_0/[G]) >\sim 13.25$ and $\sigma_{\log B_0} \sim 0.6$. The field values refer to the dipolar field on the magnetic pole of a star. Here we present population synthesis studies of old evolved isolated NSs with the same initial field distribution to calculate the number of these objects which can reach the stage of accretion from the interstellar medium.

2. ISOLATED ACCRETORS

Here we briefly present the results published in [4]. We update the approach by [5] using a more detailed description of evolutionary stages [6] and applying the magnetic field distribution from [2]. The aim is to estimate the number of accreting isolated neutron stars with the new model.

The magnetic field in the model used in [2] decays relatively rapidly, on a time scale much shorter than the lifetime of the Galaxy. So, as the initial field in our calculations we use already decayed fields. I.e., we take the "optimal" distribution from [2], decay it down to the saturation values, and use it as an input for our calculations on the time scale of several billion years. The shape of this distribution can be seen in Fig. 1.

We obtain that despite the fact that we include a subsonic propeller stage (which postpones the appearance of a source at the accretor stage) the fraction of NSs at the stage of accretion is increased in comparison with the results by [5]. The increase in the relative number of accretors is due to presence of isolated NSs with large initial magnetic fields. This is illustrated in the Fig. 1. We show there contributions of isolated NSs with different initial magnetic fields to the population of accretors. Note, that the scale is logarithmic in both axes. Isolated NSs with initial fields $< 3 \times 10^{12}$ G are more numerous than those with $10^{13} < B <$(2–3) $\times 10^{13}$ G. However, the latter produce nearly one order of magnitude more accretors. Still, many (about 1/2) of NSs with the largest initial field considered here do not produce any accretors as they become Georotators due to large spatial velocities.

In the solar neighborhood ($R_{\rm solar} < 2$ kpc and $|z| < 0.5$ kpc) we predict $\sim$ 35–40% of accretors and slightly more ($\sim$ 40–45%) subsonic propellers with only $\sim$ 18–20% of Ejectors. Contributions of others stages are neglegible. In total, in the solar proximity ($R_{\rm solar} < 2$ kpc and $|z| < 0.5$ kpc) there are 0.33% of all NSs. This gives us, for the total number of NSs in the Galaxy $N_{\rm NS} = 10^9$, the number density in the solar neighborhood $n_0 \approx 3 \times 10^{-4}$ pc^{-3}, in good correspondence with earlier studies.

After the first of the “Magnificent Seven” (close-by cooling isolated NSs) have been discovered [7], several authors proposed and discussed that they can be accreting isolated NSs [7–9]. Though, it appeared that it is not so. The “Magnificent Seven” are young NSs with relatively large fields. Probably, they are related to evolved magnetars [2]. Here we demonstrate that in future the “Magnificent Seven” and similar sources are expected to become accreting isolated NSs if their magnetic fields do not decay significantly. Even a relatively long stage of subsonic propeller [10] cannot prevent accretion. This is a good news for observers. Probably, telescopes like eROSITA aboard Spektr-RG will be able to detect accreting isolated NS soon. However, the question of the accretion efficiency is still on the list [11].

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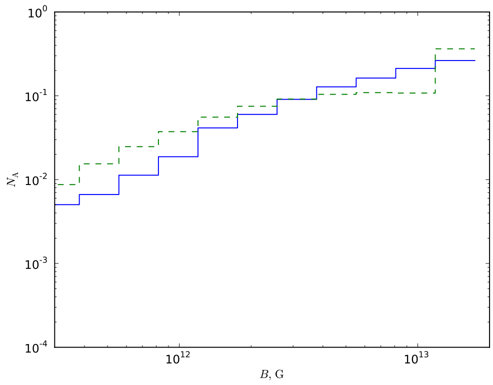

Figure 1. Results of our simulation. B is the initial magnetic field on pole, N_A is a fraction of stars in distribution. Solid line shows the contribution to the number of accretors by NSs with different initial fields. Dashed line shows the dipolar magnetic field distribution after fields decayed down to saturation values.

FIGURE CAPTIONS

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