

A different nature between the radio AXPs in comparison to the others SGRs/AXPs

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1 Introduction

SGRs/AXPs are considered a subclass of pulsars powered by magnetic energy and not by rotation, as normal radio pulsars. They are understood as strongly magnetized neutron star [1, 2], with large periods of rotation $P \sim (2 - 12)$ s, and large spin-down, with typical $\dot{P} \sim (10^{-13} - 10^{-10})$ s/s in contrast to $\dot{P} \sim 10^{-15}$ s for ordinary pulsars. Their persistent X-ray luminosity, as well as the bursts and flares typical of these sources, are instead believed to be powered by the decay of their ultrastrong magnetic field (see Mereghetti 2008 for review [3]). SGRs/AXPs typically have a larger X-ray luminosity that can not be explained by their spin-down luminosity ($L_X > \dot{E}_{\text{rot}}$), unlike rotation-powered pulsars. However, the recent discovery of radio-pulsed emission in four of this class of sources, where the spin-down rotational energy lost \dot{E}_{rot} is larger than the X-ray luminosity L_X during the quiescent state - as in normal pulsars - opens the question of the nature of these radio sources in comparison to the others of this class.

According to the fundamental plane for magnetars [4], four over a total of about 20 SGRs/AXPs should have radio-pulsed emission: XTE J1810-197, 1E 1547.0-5408, PSR J1622-4950, and SGR 1627-41. Basically, the magnetar radio activity or inactivity can be predicted from the knowledge of the star's rotational period, its time derivative, and the quiescent X-ray luminosity. However, no radio emission has been detected in SGR 1627-47 yet because they are unfavorably affected by distance, scattering, or lack of sensitive observations at the time their pulsed radio emission was possibly expected to be brighter (see N. Rea et al. 2012 for details [4]).

More recently, was reported the discovery of 3.76 s pulsations from the new burst source at the Galactic center using data obtained with the *NuSTAR* Observatory. The SGR J174529 is the fourth magnetar detected in radio wavelengths, very similar

to the others radio SGRs/AXPs. Also *Swift* satellite has observed the sudden turn-on of a new radio source near Sgr A*. This result, combined with the detection of a short hard X-ray burst from a position consistent with the new radio SGR, suggests that this source is in fact a new SGR in the Galactic Center. Then, the combination of a magnetar-like burst, periodicity and spectrum led to the identification of the transient as a likely new magnetar in outburst (see the recent works about this new SGR in Ref. [5, 6]).

The radio emission of these sources has several properties that are common among them, but different from the others SGRs/AXPs: loud radio (transient radio emission different of the radio pulsar emission), low quiescent X-ray luminosity L_X (decreasing with time) that can be explained from the spin-down rotational energy loss \dot{E}_{rot} of a neutron star, as normal rotation-powered pulsar. However, models not invoking neutron stars to describe SGRs/AXPs have also been discussed, in particular the white dwarf (WD) pulsar model [7, 8, 9, 10]. As pointed out in Malheiro et al. 2012 [7], the X-ray efficiency $\eta_X = L_X/\dot{E}_{\text{rot}}$ for these radio AXPs, seems to be too small comparing to the others SGRs/AXPs when interpreted as magnetized white dwarfs. However, as neutron star pulsars these radio AXPs have $\eta_X \sim (10^{-2} - 10^{-1})$, a little bit larger than the values of normal pulsars (where $\eta_X \sim (10^{-3} - 10^{-4})$). This can be understood due to their large magnetic dipole momentum $m \sim 10^{32}$ emu, giving support for their neutron star interpretation. Following the previous work in Ref. [12], we suggest that the radio sources are rotation-powered neutron star pulsars $L_X \simeq k\dot{E}_{\text{rot}}^n$ ($L_X < \dot{E}_{\text{rot}}^{NS}$), in contrast to the others that are rotation-powered magnetized white dwarfs. In our understanding the large steady X-ray luminosity seen for almost all the no-radio SGRs/AXPs, can be explained as coming from a large spin-down energy lost of a massive white dwarf with a much large magnetic dipole moment of $10^{34} \leq m \leq 10^{36}$ emu consistent with the range observed for isolated and very magnetic WDs (see Coelho & Malheiro 2012 [11] for discussions), indicating a different nature between these sources and the radio SGRs/AXPs. These radio sources have large magnetic fields and seem to be very similar to the high-B pulsars recently found [13, 14], as already pointed out in the fundamental plane for radio magnetars [4] (see Fig. 1 of this contribution). However, we should emphasize that even if the radio SGRs/AXPs are strong magnetized neutron stars, they are not magnetars in the sense that their steady luminosity is not originated by the magnetic energy, but from the rotational energy as normal pulsars.

2 Results and Discussions

Recently, Rea et al. (2012) try to understand magnetar radio emissions from an phenomenological point of view. They proposed that magnetars are radio-loud if and only if their quiescent X-ray luminosities are smaller than their rotational energy loss.

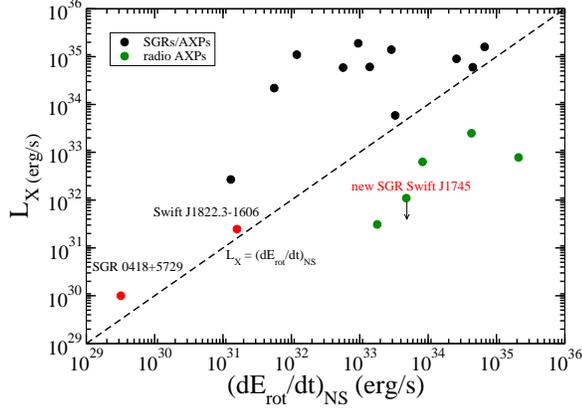


Figure 1: X-ray luminosity L_X versus the loss of rotational energy \dot{E}_{rot} , describing SGRs and AXP as neutron stars. The red points correspond to recent discoveries of SGR 0418+5729 and Swift J1822.3-1606 with low magnetic field.

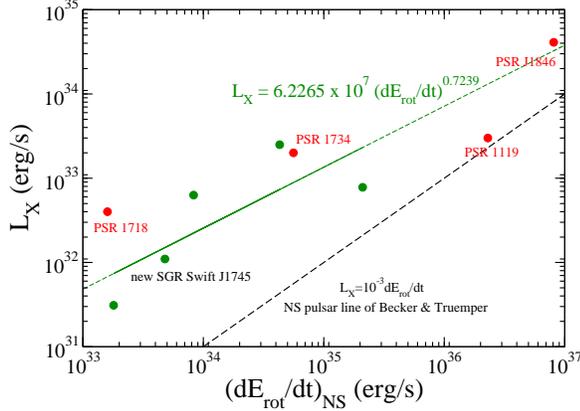


Figure 2: X-ray luminosity L_X versus the loss of rotational energy \dot{E}_{rot} for the four AXP that show radio-pulsed emission, together with some high-B pulsars. A linear log-log relation between L_X and \dot{E}_{rot} is found for the radio AXP, $L_X \propto \dot{E}_{\text{rot}}^{0.7239}$ (green dashed-line), very similar to the X-ray NS pulsar line of Becker & Trümper[15] (see McGill SGR/AXP online catalog - June, 18, 2013 at www.physics.mcgill.ca/~pulsar/magnetar/main.html). For pulsar data, see Olausen et al. 2010 [14], and references therein).

In Fig. 1, we see a large steady X-ray luminosity (and almost constant as a function of \dot{E}_{rot}) for almost all the no-radio SGRs/AXPs (black circle points - high \dot{E}_{rot} and high L_X - except for the CXO J1647 with a rotational period of $P = 10.61$ s, an upper limit of the first time derivative of the rotational period $\dot{P} < 4 \times 10^{-12}$ s/s, and an X-ray luminosity of $L_X = 4.5 \times 10^{32}$ erg/s), indicating a different nature among these sources and the radio SGRs/AXPs (green square points - high \dot{E}_{rot} and low L_X). These radio sources are in fact ordinary pulsars, with their steady X-ray luminosity that can be well explained within the neutron star model, and with magnetic fields close to the ones of high-B radio pulsars for that are entirely rotation-powered (see Fig. 2). We show that the radio SGRs/AXPs obey a linear log-log relation between L_X and \dot{E}_{rot} , $\log L_X = \log(6.2265 \times 10^7) + 0.7239 \log \dot{E}_{\text{rot}}$, very similar to the one satisfied by X-ray and gamma-ray neutron star pulsars[15, 16, 17, 18, 19], suggesting their neutron star nature. Furthermore, Fig. 2 shows that almost all the high-B pulsars are also near the line found for the radio AXPs. In contrast, for almost all the others SGRs/AXPs, $\log L_X$ does not vary too much as function of $\log \dot{E}_{\text{rot}}$, a phenomenology not shared by X-ray neutron star pulsars, suggesting a different nature for these sources.

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