Neutron Stars and Pulsars: Challenges and Opportunities after 80 years
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Do magnetars really exist?

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Abstract. It is shown that there are neither necessary nor sufficient properties to provide unambiguous evidence for including any object in the AXP/SGR class.

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1. Expected properties of AXPs and SGRs

To answer the question in the title we must discuss some specific properties of anomalous X-ray pulsars (AXPs) and soft gamma-ray repeaters (SGRs). These sources are believed to be strongly magnetized neutron stars (magnetars) and can be described by some additional characteristics. These are:

1. the supercritical dipole magnetic field $B > B_{cr} = \frac{2\pi m^2 c^3}{eh} = 4.41 \times 10^{13}$ G,
2. low losses of the rotational energy comparing with their X-ray luminosities:
$$L_x > \frac{dE}{dt} = \frac{4\pi I dP/dt}{p^3},$$
3. the bursting behaviour,
4. the black body plus power-law X-ray spectrum,
5. the erratic radio pulse behaviour,
6. they are young objects connecting with SNRs,
7. they have very long periods.

Let us consider these properties one by one.

1) Some years ago SGR0418+5729 was discovered, with $P = 9.1$ sec (Rea, Esposito & Turolla 2010). The upper limit of dP/dt gives $B = 6.4 \times 10^{19}(PdP/dt)^{1/2} < 7.5 \times 10^{12}$ G. This object showed two bursts at $8 - 200$ keV during 20 minutes with energies 4×10^{37} and 2×10^{37} ergs (the border between AXPs and SGRs).

Recently SGR 1822-1606 has been detected (Rea, Izrael & Esposito 2008). Its surface magnetic field is equal to 2.8×10^{13} G and less than B_{cr} as for SGR0418+5729.

So, a high surface dipolar magnetic field is not necessarily required for magnetar-like activity. There are, on the other hand, 19 radio pulsars with $B_s > B_{cr}$ (Manchester *et al.* 2005). Hence superstrong magnetic fields are not sufficient for the appearance of an AXP/SGR.

2) The young radio pulsar PSR J1846-0258 in SNR Kes 75 ($\tau = 884$ years) with $P = 326$ msec shows X-ray bursts and strong variations of times of arrivals, i.e. it is similar to AXP/SGR . However its losses of rotation energy $dE/dt = 8.1 \times 10^{36}$ erg/sec are quite enough to provide X-ray luminosity $L_x = 4.1 \times 10^{34}$ erg/sec.

3) The bursting behaviour is the common characteristic of all anomalous pulsars. However normal radio pulsars demonstrate variations at all frequencies and at all time intervals (from nanoseconds up to several years) as well. Moreover giant radio bursts of one of subpulses are detected in a number of them (see, for example, Malofeev, Malov & Shchegoleva 1998) and even giant pulses are observed in some pulsars (Soglasnov, Popov & Bartel 2004; Popov, Kuz'min & Ul'yanov 2006).

Strong variability of intensity and spectral changes of components of individual pulses in AXP/XTE J1810-197 do not differ in principle from the behaviour of normal radio pulsars. Their individual pulses have not only very different intensity but their spectral indices often changes sign at low frequencies (Kuzmin, Malofeev & Shitov 1978). Thus anomalous pulsars differ from radio ones by values of parameters and by the character of their variability only.

4) Such a sum is believed typical for spectra of AXP/SGRs. However several dozens of normal radio pulsars emit thermal and non-thermal radiation also. Sometimes (as in the Crab pulsar PSR B0531+21) total spectra have very complicated form.

5) There are radio pulsars (for example, Geminga - Malofeev & Malov 1997) showing changes in intensities and forms of pulses and even in phases of pulse appearances.

6) About 20 normal radio pulsars are observed in SNRs but they do not belong to the class of AXP/SGR.

7) SGR J1627-41 has the short interval between subsequent observed pulses $P = 2.6$ sec. On the other hand some normal radio pulsars have periods of order of several seconds (Manchester *et al.* 2005).

2. Two additional arguments against the magnetar model

1. In the popular model of magneto-rotational explosion of supernova (Ardeljan, Bisnovatyi-Kogan & Moiseenko 2005) it is shown that magnetic fields of order of 10^{16} G may only exist in a new born neutron star for 1 sec.

2. The detailed calculations show that magnetic plasmas ejected from a neutron star emit neutrino radiation mainly. Electromagnetic radiation will be essential if magnetic fields in the magnetosphere $B > 10^{16}$ G (Gvozdev, Ognev & Osokina 2011).

3. Conclusions and discussion

1. There are no necessary and sufficient properties to provide unambiguous evidence for including an object in the AXP/SGR class.

2. It is not necessary to use the magnetar model for the description of observed characteristics of AXPs and SGRs. There is the alternative model: the drift model with the suggestion on drift waves in the vicinity of the light cylinder (Malov & Machabeli 2006). Neutron stars with rather short rotation periods ($P < 1$ sec) and surface magnetic fields of order of 10^{12} G are believed to be the central bodies of AXPs/SGRs in this model.

The specific characteristic of such objects is a small angle β between the rotation axis of the neutron star and its magnetic moment. Indeed in those cases when radio emission of AXPs has been detected and their polarization parameters have been measured estimations give rather small values of angles β.

The radio emission of two AXPs: J1810-197 (Janssen *et al.* 2007) and 1E 1547.0-5408 (Camilo *et al.* 2008) has shown that the variations of the polarization position angles in these objects are small. The maximum derivative of the position angle ϕ with longitude Φ is given by

$$C = \left(\frac{d\phi}{d\Phi}\right)_{max} = \frac{\sin\beta}{\sin(\zeta - \beta)} \leqslant 1.$$

Here, ζ is the angle between the rotational axis of the neutron star and the line of sight toward the observer . Thus, $\zeta - \beta$ is the minimum angular distance at which the line of sight intersects the radiation cone. Setting the angular radius of this cone to be 10°, we conclude that the angle β should be less than 10° in J1810-197. The detection of an interpulse in the AXP XTE J1810-197 that is offset from the main pulse by a distance other than 180° (it is approximately 240° – cf. Serylak, Stappers & Weltevrede 2008), may also directly reflect the smallness of β for this object.

For PSR J1642-4950 we obtain $\beta = 15.6°$ (Malov 2012). Hence, this object is also a nearly aligned rotator, and it is justified to apply our drift model to it.

If $\beta = 15.6°$, the boundary of the magnetosphere is at a distance of the order of $4r_{LC}$, where r_{LC} is the radius of the light cylinder. This makes possible the formation of appreciable pitch angles and the generation of synchrotron emission, since the ratio of the magnetic energy to plasma energy becomes less than unity. The estimates for such a case give for AXPs/SGRs values of rotation periods $P = 16 - 250$ msec and magnetic fields at the neutron star surface $B_s = 3.4 \times 10^{11} - 4.6 \times 10^{12}$ G (Malov 2010).

In the drift model the cyclotron instability can develop near the light cylinder, resulting in the generation of radio emission. It is expected that all this emission will be generated in a very narrow layer and that it will be much more intense at low frequencies (of the order of 100 MHz) than at higher frequencies (Malov 2012).

The main problem of all models is the difficulty in explaining the energetics of power gamma-ray bursts in SGRs. Apparently, it is necessary to invoke sources of energy within the neutron star. These may cause episodic ejections of plasma in the magnetosphere and releasing of its energy, for example, as a result of nuclear reactions (Malov 2012).

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