Searching for Radio Pulsations in AXPs

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Abstract: To investigate the physical nature of the Anomalous X-ray Pulsars and their relations with the rotational powered radio pulsars, observations of four southern AXPs, obtained at 1.4 GHz using the multibeam receiver of the Parkes radio telescope, have been performed. No pulsed emission with periodicity matching the X-ray ephemeris have been found in the observed targets down to a limit of ~ 0.1 mJy. A blind search has also been performed on all the 13 beams of the multibeam receiver (the central beam being pointed on the target AXP), leading to the serendipitous discovery of the new radio pulsar J1712-3943.

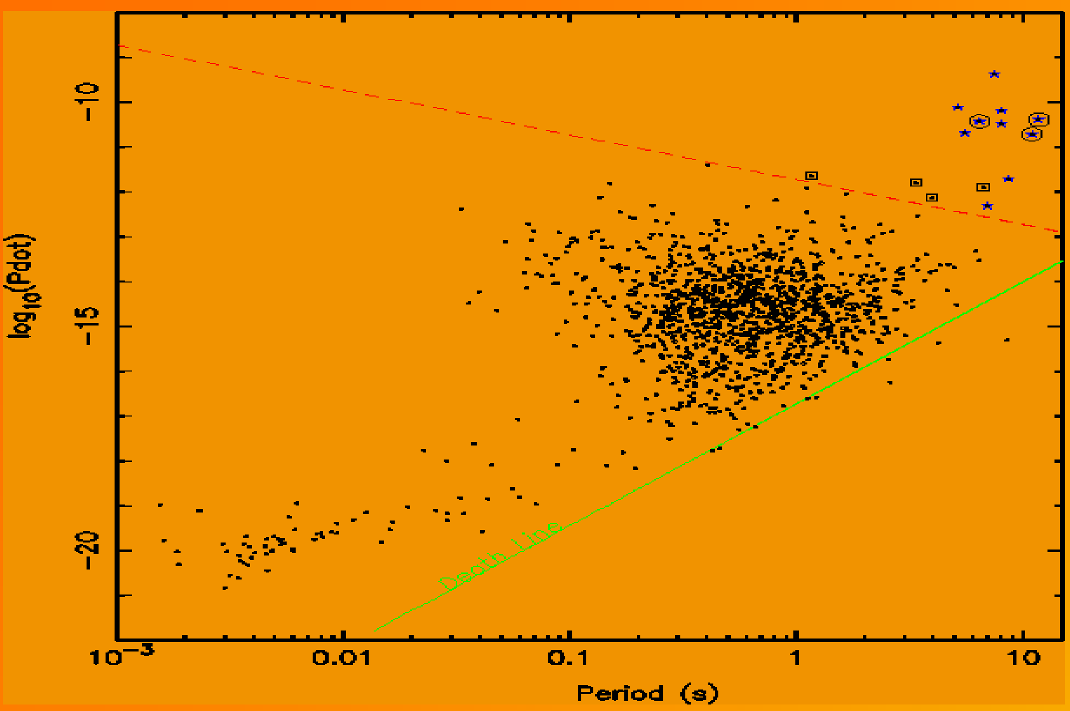

Figure 1: P – $\dot{P}$ diagram. Dots are the Galactic field pulsars; the ones enclosed in a square have dipole magnetic fields above the quantum critical field (B_{cr}=4.4 x 10^{13}). Stars are AXPs and SGR; those surrounded by a circle are the ones we observed at Parkes.

Introduction: in the last two decades, a significant amount of observational and theoretical effort has been dedicated towards the understanding of an "unsual" class of X-ray pulsars, namely the Anomalous X-Ray pulsars (AXPs) and the Soft Gamma-Ray Repeaters (SGRs). These relatively bright X-ray sources were soon recognized as a distinct class of neutron stars with respect to the well known radio pulsars or X-ray binary populations. In particular, they are not pulsating in the radio band, their rotational energy loss is not sufficient to power alone the observed X-ray luminosity, and there is no evidence for a companion star.

Assuming these sources being isolated X-ray pulsars with purely dipole magnetic losses, their inferred magnetic fields are extremely high (B~10^{14}-10^{15} Gauss), by this mean they are called magnetars (Duncan & Thompson 1992; Thompson & Duncan 1993, 1995). In the magnetar scenario the energy resevoir powering the X-ray emission is hence the decay of such ultra-strong magnetic fields.

Up to now, the search for radio counterparts of AXPs and SGRs have given negative results both to timing and interferometry searches, but revealed in a few cases reliable associations with SNRs (Gaensler et al. 2000, 2001). In some peculiar circumstances, however, radio counterparts for some magnetars were revealed: a) as a consequence of SGRs' Giant Flares, a radio outburst were detected, which slowly faded with a timescale of weeks after the impulsive event (Frail et al. 1999; Cameron et al. 2005; Gaensler et al. 2005); b) during the outburst of the only confirmed transient AXP, XTE J1810-197, Very Large Array observations revealed a point source of flux density 4.5+/-0.5 mJy at 1.4 GHz (Halpern et al. 2005).

A further incentive for doing deep searches for radio pulsations from magnetars came in the last few years with the discovery of radio pulsars with dipole magnetic fields in the magnetar range (Camilo et al. 2000; see Figure 1). For the magnetars, infact, the radio emission was thought to be inhibited by such strong fields, but the discovery of these highly magnetic pulsars challanges this theory.

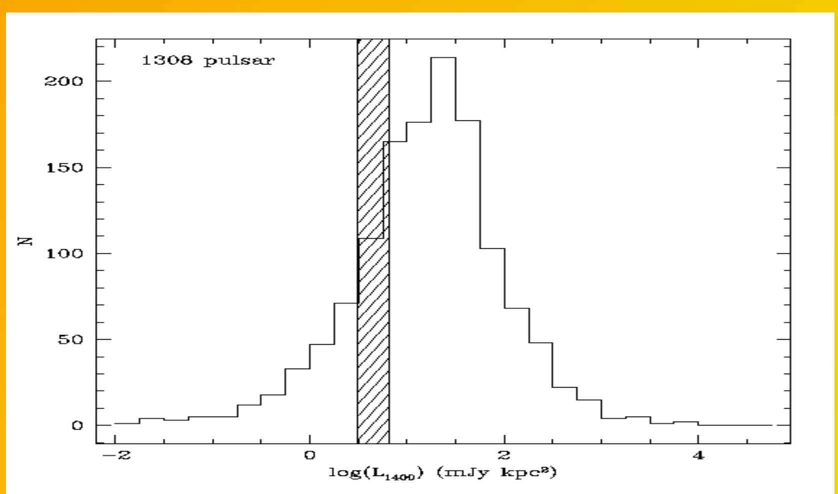

Figure 2: Luminosity distribution for the known radio pulsars. The shaded region indicates the upper limits obtained in this search.

Observations and Data Analysis: the observations of the four AXPs of our sample (see Table 1) have been performed in September 1999 using the 20-cm multibeam receiver of the Parkes Radio Telescope. All the 13 beams of the receiver have been used during the observations to search for serendipitous sources in the vicinity of our main targets. The total 288 MHz bandwidth has been splitted into 96 channels each 3 MHz wide in order to mitigate the effect of the ISM. Each source has been observed twice for about 2.8 hours each time.

Data from the central beam of the multibeam receiver (pointed on the AXPs) have been analysed using the programme `pdm`: the code takes in input a period P and a dispersion measure DM and folds the time series according to a number of trial values around the input ones, searching for the combination of P and DM for which the signal-to-noise ratio S/N is maximised. The period range searched for each source has been obtained from the X-ray ephemeris and their errors (see Table 1). A number of trial DM values, ranging from 0 up to the value giving a maximum broadening of the pulse of 10% of the period, has been explored.

The observations relative to all the 13 beams have been subsequently analysed with the blind search code `pmsearch` (an FFT based code; see Manchester et al. 2001) to search for possible radio counterparts of the AXPs pulsating at a different period with respect to the one measured in X-rays and to search for new radio pulsars in the vicinity of our main targets.

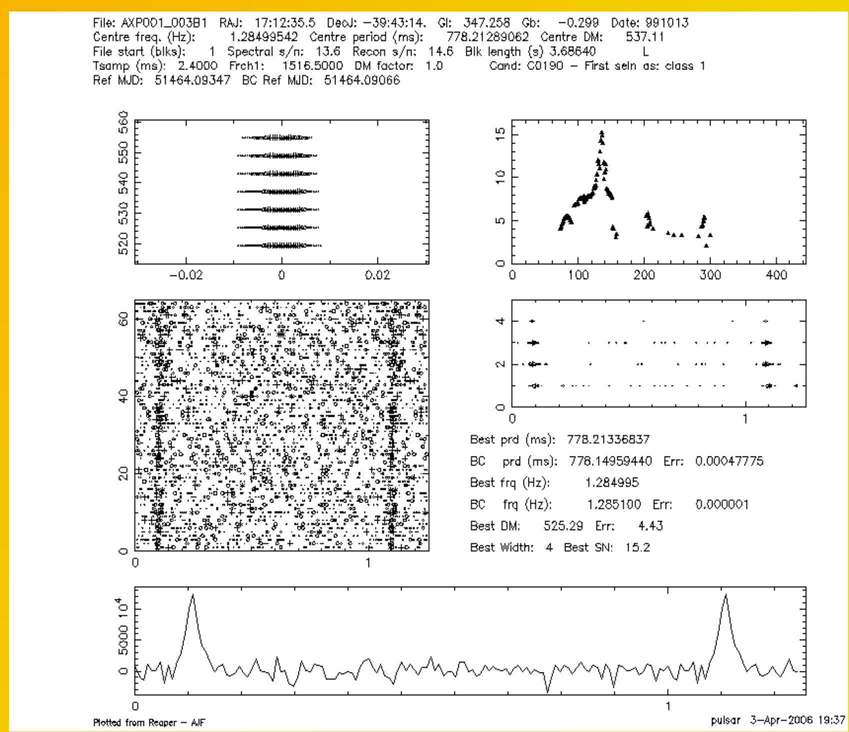

Figure 3: Discovery plot for the new pulsar J1712-3943.

Name	P (s)	$\dot{P}$	B (G)	Dist (kpc)	Flux limit (mjy)
1E 10481-.5937	6.4	3.3 x 10^{-11}	4.7 x 10^{-14}	5	0.17
1RXS J170849-400910	11.0	1.9 x 10^{-11}	4.6 x 10^{-14}	8	0.10
1E 1841-045	11.8	4.1 x 10^{-11}	6.0 x 10^{-14}	7	0.10
AX J1845-0258	7.0	-	-	8	0.09

Table 1: main parameters for the sample of AXPs observed. From left to right the source name, period and period derivative derived from X-ray observations, inferred dipolar magnetic field and distance. The last column is the upper limit on the flux at 1.4 GHz obtained in this work.

Conclusions: no radio pulsation with periodicity matching the X-ray ephemeris has been found in our sample of AXPs down to a limit of ~0.1 mJy (Table 1). Given the high distance of these sources with respect to the bulk of the known radio pulsars, the lack of detection could be simply due to a selection effect: the upper limit on the radio luminosity for our targets is infact only slighly lower than the median of the distribution in luminosity of the known radio pulsars (Figure 2). Deeper observations are hence required in order to asses the link between rotational powered radio pulsars and AXPs.

The blind search for radio pulsations in the proximity of the four AXPs studied resulted in the serendipitous discovery of the new pulsar J1712-3943 having spin period P=778.15 ms and DM=530 (Figure 3) and in the detection of 17 previously known pulsars.