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A Search for Radio Transients

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Abstract. We report on the initial results of the first large scale survey for transient radio sources along the Galactic plane. This survey has revealed the existence of two new classes of transient radio sources. One is a new class of pulsars that emit radiation in short, burst like modes, with one extreme candidate being visible for only four days and then completely switching off its radio emission for approximately 30 days. It is therefore concluded that statistically many more of these objects must exist and this will have large consequences for the population estimates of pulsars in our galaxy. Another new class of sources are called Repeating Radio Transients (RRATs). Periodicities have been detected for some of these sources, an indication of their likely neutron star origin. However, the remainder of the sources emit aperiodic pulses of radiation, and although their origin is unknown, dispersion measures indicate that they are galactic in nature.

Key words. sources: transient – – stars: neutron – pulsars: new class – galactic: population estimates

1. Introduction

Transient radio sources generally indicate the occurrence of an energetic or bursting event. The emission produced ranges in timescales of the order of milliseconds, an indication of a high degree of compactness, to months, and can take the form of bursts, flares and pulses. Radio astronomy has a long history of attempts to probe the transient radio sky, culminating in many exciting discoveries, most notably the discovery of pulsars in 1967 (Hewish et al. 1968). Figure 1 shows the various regions of the transient radio sky and the sources found within them.

It is obvious from figure 1 that the largest group of known transient radio sources are pulsars. However, there exists a large number of other observed and theoretical sources of transients. Known transient sources range in their proximity to the Earth, from ultra high energy cosmic rays colliding with the Earth's atmosphere to radio flares from planets in our solar system to so called flare stars, such as UV Ceti and AD Leo. Theoretical sources of radio transients include radio pulses from γ-ray burts, annihilating black holes and possible signatures from magnetars, highly magnetized neutron stars.

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2. Sky Surveys

Since the discovery of pulsars in 1967 by the detection of single pulses, the transient radio sky has been subject to multiple surveys which have attempted to catalogue various radio sources using this method, Cordes & McLaughlin (2003):

- Staelin & Reifenstein (1968): giant pulses were discovered originating from the Crab pulsar.

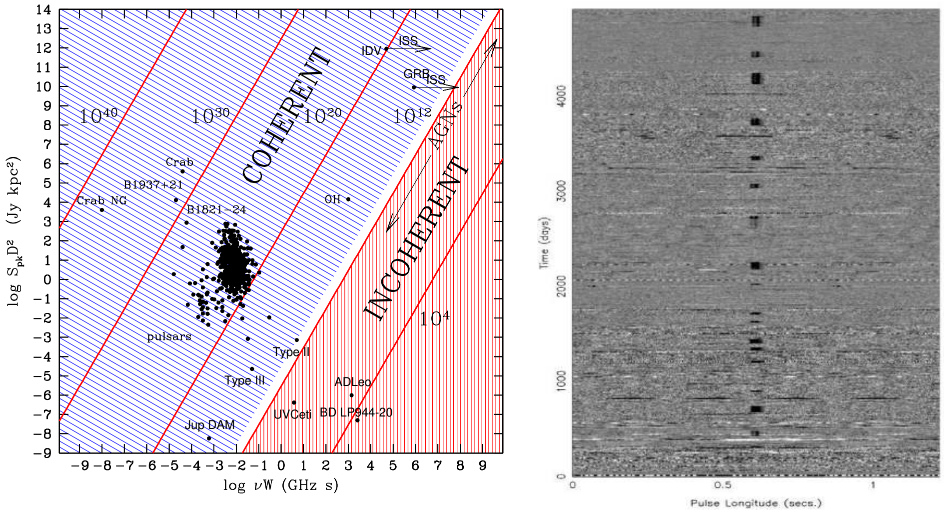

Fig. 1. The left panel, taken from Cordes et al. (2004), shows the phase space for the transient radio sky. The x-axis is the product of the emission frequency, ν, and the pulse width, W. The y-axis is the product of the observed flux density, S, and the distance squared, D^2. The diagonal lines represent constant brightness temperature (K). The right panel shows time vs. pulse longitude for pulsar B1931+24, where the 'on' states are represented by the darker regions.

- Davies & Large (1970): detected three new pulsars but searched unsuccessfully for pulsars associated with 13 supernova remnants.
- Large & Vaughan (1971): 31 pulsars were discovered using the Molongo Cross telescope in Australia.
- Nice (1999): one pulsar was discovered using the Arecibo telescope.
- Hyman et al. (2005): detected 5 bursts from radio transient source GCRT J1745–3009.
- Unsuccessful searches include that for single pulses from X-ray sources Scorpius X-1 and Cygnus X-1 (Taylor et al. 1972), radio counterparts of gravitational pulses (Hughes & Retallack 1973), pulses from the instant of a supernova explosion (Huguenin & Moore 1974) and radio bursts associated with annihilating black holes (O'Sullivan et al. 1978). There have been searches for radio pulses associated with γ-ray bursts (Cortiglioni et al. 1981) and soft γ-ray repeaters (Vaughan & Large 1989) which did not yield any results.

3. New Classes of Transient Sources

The Parkes Multibeam Pulsar Survey is the most successful pulsar survey to date, finding over 700 pulsars so far (Faulkner et al. 2004). Although this survey was designed to search for periodic signals, the data were reprocessed using a single pulse search method, resulting in the discovery of a new class of transient sources, RRATs. Another new class of sources, discussed here, were discovered during monitoring of known pulsars.

3.1. New Class of Pulsars

This new class of pulsars is characterised by a non-radiating or 'switched off' state, the duration of which greatly exceeds the radiating 'on' state. The prototype for this new class, PSR B1931+24, was discovered at Jodrell Bank whilst timing programs were being applied to a large number of known pulsars. This pulsar appears with an unexplained 40 day periodicity (Kramer et al. 2005). Another four candidates were found in the Parkes Multibeam

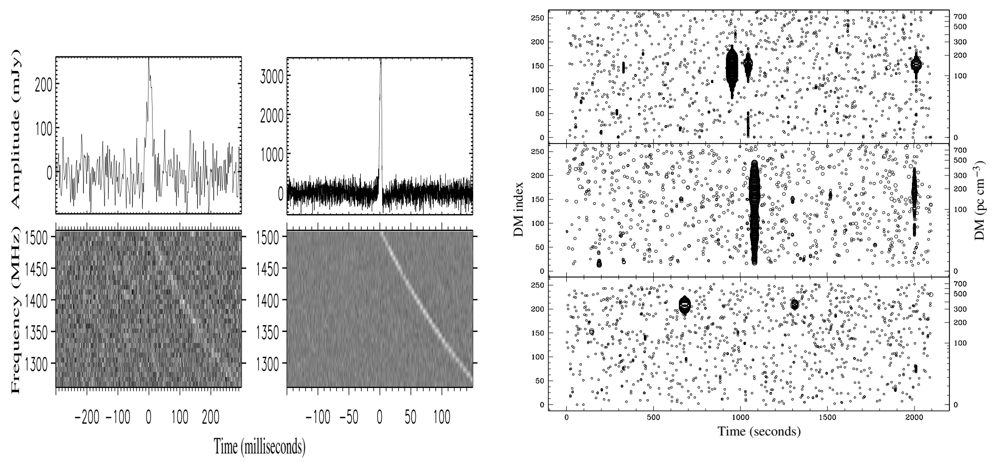

Fig. 2. The left panel shows two examples of a RRAT pulse, a strong single pulse (top) and the dedispersed time series across all frequency channels (bottom). The signal is clearly broadband and the dispersion sweep is as expected for a signal of astrophysical origin. The right panel shows DM index (left y-axis) and DM value (right y-axis) vs. time for three different RRAT detections. The size of the circle is proportional to the signal-to-noise ratio of the pulse. McLaughlin et al. (2005)

Pulsar Survey. PSR B1931+24 is only visible for about four days (see figure 1).

3.2. Repeating Radio Transients (RRATs)

RRATs are characterized by strong, sporadic bursts of radio emission at repeatable dispersion measures. Examples of some of the 12 sources found so far are shown in figure 2. Of the 12 sources, periodicities have been found for six and so are most probably rotating neutron stars. The origin of the radio emission from the other six sources remains in question.

4. Implications for Galactic Population Studies

Extrapolating from the rate of pulse emission for the detected RRATs, we infer that there must be 25 times more of these objects in the sky surveyed by the Parkes Multibeam Pulsar Survey detectable at the same sensitivity level. This implies that there exists at least 20% more neutron stars in the Galaxy than previously thought, if indeed the RRATs are neutron stars. From considerations of the 'on'/'off' periods of the new class of pulsars at least another 30% of neutron stars are missed in surveys, culminating in the conclusion that there exists at least 50% more neutron stars in the Galaxy than previously assumed. Selection effects play a major role in the detection of these objects, such as RFI and the difficulty in discriminating weak signals from terrestrial interference and noise, thus this value is a lower limit.

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