Yet MORE PM Survey Discoveries....?

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Abstract.

The Parkes Multibeam (PM) survey has found nearly 50% of the >1400 known pulsars and detected 20% of the pulsars in binary systems (75% within the survey area), few of these are millisecond pulsars with orbits of less than one day. It is known that the normal search techniques used in the PM Survey have selected against finding binary pulsars, due to the long integration times used. The relative performance of the search techniques used and the improvements made prior to the complete reprocessing of the data currently being undertaken are discussed. The processing is being done on COBRA - the new supercomputer at Jodrell Bank. The results of the reprocessing, as well as adding more solitary pulsars, will give more confidence on the population and types of binaries in the Galactic plane. However, it can be shown that for millisecond pulsars in binary orbits of between 20min and a few hours, the search techniques are still relatively insensitive.

1. Introduction

The Parkes Multibeam Survey (PM Survey) has discovered nearly half the known pulsars. Observations started in 1997 and completed in 2002. The PM survey used the 13-beam receiver at the 64-metre Parkes Radio Telescope and covered a strip along the Galactic plane with \(|b| < 5^\circ\) and \(l = 260^\circ\) to \(l = 50^\circ\). The observations were carried out with a 0.25ms sampling time, collecting \(2^{23}\) samples, in an approximately 35-min observation. The nominal limiting flux density is about 0.2mJy, for dispersion measures (DM) of less than 300 cm\(^{-3}\)pc. (Further details of the PM system can be found in Manchester et al. (2001)). There are approximately 2670 pointings, each of 13 beams, making a total of 34,710 integrations. The data are stored on some 154 DLT tapes for off-line processing.

Since the start of the survey, improved search techniques have been implemented and there has been some changes to the interference filters used. Consequently, there are more pulsars expected to be discovered using the ex-
existing data. With the increased computing power now available, particularly in the form of beowulf clusters such as Cobra at Jodrell Bank, it has been decided to reprocess the entire data set.

2. Binary Pulsar Discoveries

There have been 73 binary pulsars discovered, of which 15 have been discovered or re-detected in the PM survey (there are 19 known in the survey area). There is a large number, 25, which have been discovered in searches of Globular Clusters (GC). The reasons for being so many GC binary pulsars discovered is that as well as having a lot of stars in a restricted space, so stars often “capture” each other, the whole of the GC is in a narrow range of dispersion measures. It is, therefore, feasible to use more computationally expensive acceleration searches. This illustrates the benefit of using improved acceleration search algorithms with long integrations as discussed in Friere (2000) and Camilo et al. (2000).

The plot, in figure 1, of pulsar periods and orbits for these systems highlights that PM binary pulsars may have some selection effects. There are four binary pulsars which are within the PM survey area and not reported as detected. Two of the undetected pulsars B1855+09 and B1913+16 have flux levels of 4mJy (DM 13.3) and 0.7mJy (DM 169) respectively at 1400MHz, well above the minimum detectability levels. The other two do not have flux levels recorded for 1400MHz, but have DM’s and periods where the PM survey is reasonably sensitive.

Considering B1913+16, for example, it is a pulsar with a period of 59ms, but with a fast orbital period of 7.7hours. The full FFT would suffer significant smearing of upto 10 Fourier bins, thus limiting sensitivity.

Also, it can be seen that, apart from B1744-24A (a pulsar in GC Terzian 5) and J1141-6545 which are both very bright, there are no pulsars detected with orbits of less than 1 day, which could be partially due to selection effects. There are no binary pulsars with periods of less than 9-ms, however, there is a group

![Figure 1. All binary pulsars, showing the relationship between pulsar period and binary orbit.](image-url)
with medium-long periods (50-500ms) and long orbits (>230 days), these can be detected using non-accelerated searches. There is a clear possibility of finding further binary pulsars in the PM data.

3. PM Reprocessing Search algorithms

The PM survey has used a long integration of 35 mins for high sensitivity. However, the integration time makes it insensitive to fast binary pulsars due to smearing of received power across a number of Fourier bins. The processing to date has almost all only used a frequency domain search of the full data set for each observation. Consequently, the search has had the predicted sensitivities only for solitary pulsars up to about 2-sec period. The reprocessing of the data includes searches for accelerated (binary) pulsars, long period pulsars and single pulses - looking for “Giant Pulses” at a particular DM (McLaughlin 2001).

- **Frequency Domain Search** - Most pulsars found have periods of one second or less and are effectively searched for using the frequency domain. This is due to the great efficiency of the FFT algorithm at separating many different frequencies concurrently.

  This is the same search as performed previously, using the full length FFT. However, improvements in the “birdie filters” means that less of the spectrum is removed.

- **Time Domain Search** - Long period pulsars (> 2 sec period) are most sensitively searched for using a time domain search, efficiently done by using a Fast Folding Algorithm (FFA) (Staelin 1969). This is because at low frequencies the separation of periods becomes relatively coarse using an FFT. By only searching a limited period range the FFA is reasonably efficient computationally.

- **Linear Acceleration Search** - An efficient technique to search for linearly accelerating pulsars has been written and tested (e.g. Anderson 1992), but has not been used on large quantities of data. Known as a “stack search”, this operates by the relative shifting and summing of independent partial FFT’s of the data (in this case 16 segments). It is very efficient in that many accelerations can be tested with only one set of transformed segments. Its limitations are that there is a loss of approximately 20% in sensitivity (see tests later and Anderson 1992) over a fully coherent search and only pulsars which are in orbits long enough to be accelerating linearly over the time of the observation, will have the maximum sensitivity.

- **Phase Acceleration Search** - This approach searches for periodicities in the variations of the observed pulsar period, using the frequency domain - an FFT of an FFT (Ransom 2001). This is capable of identifying pulsars which have completed more than 1.5 orbits over the period of the observation. In the PM survey these would be very fast binaries, having orbits less than 20-mins. Such binaries do have been detected in X-rays, for example X1820-303 (Stella, Priedorsky & White 1987, which has a 685-sec orbit.)
Figure 2. Sensitivity to pulsars in binary orbits for the phase acceleration, “stack” linear accl. searches and unaccelerated searches. In each case the pulsar is in a circular orbit with a period of 10ms. The sampling time is .25ms and has a 35min integration. Note the difference in sensitivity for starting at different phase angles of the orbit. For reference, the sensitivity to an isolated pulsar is 215 for a non-accel. search and 168 for a linear accl. search.

4. Search algorithm testing

Figure 2 shows the sensitivity of the search algorithms to simulated pulsars with various parameters. Although the segmented search significantly increases sensitivity to relatively fast binaries, it can clearly be seen that there is still a region of low sensitivity for binary pulsars between 20min and 6 hours.

5. Cobra Reprocessing

Reprocessing of data at Jodrell Bank will be on Cobra - a cluster of 91 processor boards incorporating 182 processors. A full tape takes approximately 1 day to process, while using 100 processors. It is anticipated that a significant number of new pulsars will be discovered in the PM Survey data; most will be normal solitary pulsars, however, there may be some really exciting objects.

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