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A 20 cm Search for Pulsars in Globular Clusters with Arecibo and the GBT

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Abstract. We are conducting deep searches for radio pulsations at L-band ($\sim$ 20 cm) towards more than 30 globular clusters (GCs) using the 305 m Arecibo telescope in Puerto Rico and the 100 m Green Bank Telescope in West Virginia. With roughly three quarters of our search data analyzed, we have discovered 12 new millisecond pulsars (MSPs), 11 of which are in binary systems, and at least three of which eclipse. We have timing solutions for several of these systems.

1. Introduction

There are currently $\sim$ 76 MSPs known in 23 GCs. For the last two years we have been searching more than 30 GCs for MSPs with the Berkeley Caltech Pulsar Machine at the GBT and the Wideband Arecibo Pulsar Processor (WAPP) at Arecibo. The high time and frequency resolution of these data, along with newly developed search algorithms (e.g. Ransom, Cordes & Eikenberry 2003), makes us significantly more sensitive than past surveys to sub-millisecond pulsations as well as to pulsars in ultra-compact binary systems. So far we have discovered 12 new MSPs in six GCs, three of which contained no previously known MSPs.

2. New MSPs in GCs

The newly discovered pulsars are listed in Table 1, along with some of their properties. Only one of the pulsars is isolated. In an earlier survey of 11 GCs at Arecibo (Anderson 1993) seven of the 11 pulsars found were isolated (although many of these were found in stack searches). Timing observations of all our discoveries are currently underway with Arecibo and with the GBT.

In M13, given that the maximum possible cluster acceleration of 6.0×10^{-18} s^{-1} (calculated according to Phinney 1993), timing measurements of the four known pulsars show them to be old ($\tau_c > 2 \times 10^9$ yr) with very low surface magnetic fields ($B < 7 \times 10^8$ G). Similar calculations show that the spin-up of M13D constrains the M/L ratio in the core of the cluster to be > 2 $M_{\odot}/L_{\odot}$ (Ransom et al., in preparation).

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Table 1. Newly discovered MSPs.

Pulsar	P_{psr} (ms)	DM (pc cm^{-3})	P_{orbit} (hr)	$a_1 \sin(i)/c$ (lt-s)	Min M_2^a ($M_\odot$)
M30A[c]	11.02	25.1	4.18	0.23	0.10
M30B	13.0	25.1	$\gtrsim$15	?	$\gtrsim$0.2
M13C[b]	3.722	30.1	...	...	...
M13D	3.118	30.6	14.2	0.92	0.18
M5C[c]	2.484	29.3	2.08	0.057	0.038
M5D	2.988	29.3	?	?	?
M71A[c]	4.888	117	4.24	0.078	0.032
M3A	2.545	26.5	?	?	?
M3B	2.389	26.3	34.0	1.9	0.20
M3C[d]	2.166	26.5	?	?	?
M3D	5.443	26.3	?	?	?
NGC6749A	3.193	194	?	?	?

[a]With pulsar mass $M_1 = 1.4\,M_\odot$. [b]Isolated. [c]Shows eclipses. [d]Unconfirmed.

The eclipsing MSP M5C has been identified (D. Pooley, private communication) in a recent *Chandra* ACIS observation as a soft X-ray source. It is also possible that M30A has an X-ray association (Ransom et al. 2004).

At least three of the MSPs (M30A, M71A, and M5C) are in eclipsing systems. M30A and M5C show eclipse delays from an additional dispersive medium presumably created by the companion's wind.

Although M3 contains four new MSPs, they have not been consistently detected because of scintillation. For similar reasons, M30B has been detected only once, but orbital analysis of that detection shows evidence that this pulsar is in a highly relativistic and eccentric ($e \gtrsim 0.5$) binary (Ransom et al. 2004).

The newest discoveries in the list are M5D and NGC6749A. M5D was found at Arecibo with the 327 MHz Gregorian receiver. We cannot yet be certain that NGC6749A is truly associated with NGC6749. Interestingly, NGC6749 has the lowest concentration ($c = log[r_t/r_c]$) and the second lowest central luminosity density of any GC with known pulsars.

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References

Anderson, S. B. 1993, PhD thesis, California Institute of Technology

Phinney, E. S. 1993, in ASP Conf. Ser., Vol. 50, Structure and Dynamics of GCs, eds. S. G. Djorgovski, & G. Meylan, (San Francisco: ASP), p. 141

Ransom, S. M., Cordes, J. M., & Eikenberry, S. S. 2003, ApJ, 589, 911

Ransom, S. M., Stairs, I. H., Backer, D. C., Greenhill, L. J., Bassa, C. G., Hessels, J. W. T., & Kaspi, V. M. 2004, ApJ, 604, 328