integration of null pulses) is continuously present during the null state. Finally, the astonishing morphological similarity of the on-states and their very similar timescales and repetition rates are unique among nulling pulsars.

The above emission characteristics of PSR J1752+23 make it exceptional among the pulsar population. Since neither the timing nor pulse profile morphology data indicate any pulse arrival time and/or pulse shape variability that could be due to orbital motion or precessional beam wobble of the pulsar, it appears most natural to assume that its unusual properties are related to the pulse emission mechanism. As these properties may provide new, useful constraints on the emission process, observations of PSR J1752+23 will be continued, including polarization measurements and simultaneous observations at multiple frequencies to achieve a possibly complete phenomenological description of this fascinating object.

A New Binary Millisecond Pulsar in a Globular Cluster

After analyzing 1.5 TB of L-band WAPP search data taken on 10 globular clusters this past summer, Scott Ransom (McGill/MIT), Ingrid Stairs (NRAO), Jason Hessels (McGill), Vicky Kaspi (McGill), & Dunc Lorimer (JBO) report a new binary millisecond pulsar (MSP) in M71 — the first pulsar discovered in this cluster. This brings the total of new MSPs discovered by this project to four (two new pulsars in M13 and one in M5 were detailed in Newsletter No. 34). M71A is an eclipsing 4.8-ms system (see Fig. 17) in a 4.2-hr orbit around a very low-mass companion ($\gtrsim 0.03\ M_\odot$) — typical of the burgeoning class of eclipsing binary MSPs.

Observations in Aug 2002 showed that the new MSP discovered in M5 (M5C) also undergoes eclipses, with an orbital period of 2.1 hr, and has a companion with a mass $\gtrsim 0.04\ M_\odot$. Additionally, an orbital solution was found for the new MSP, M13D, giving an orbital period of 14 hr, and a more massive companion ($\gtrsim 0.17\ M_\odot$). Scott et al. are

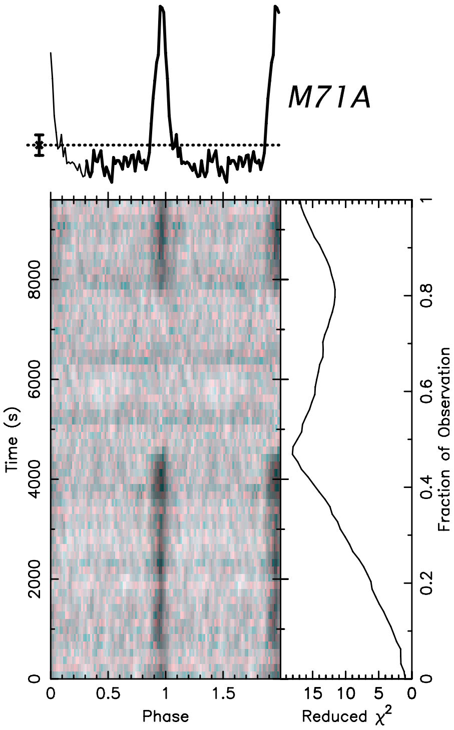

Figure 17: (Top) Two cycles of the average pulse profile of the new eclipsing MSP in globular cluster M71. The grey-scale beneath the profile shows the duration and intensity of the pulsar signal in time. An eclipse is clearly visible. The 1.4-GHz WAPP data were obtained in June 2001. (Courtesy: Scott Ransom)

currently making regular timing observations using the WAPP, which also allows them to search for new pulsars that may become visible due to scintillation.

Finally, together with Paulo Freire (NAIC), an additional 1.5 TB of search data have recently been taken on 12 other globular clusters. After processing, they will have searched all globular clusters visible from Arecibo and within 50 kpc with unprecedented L-band sensitivity. They expect to find several more MSPs in the process.

A Distant Gamma-Ray Pulsar?

Mallory Roberts (McGill/MIT), Jason Hessels (McGill), Scott Ransom, Vicky Kaspi (McGill/MIT), Paulo Freire (NAIC), Fronefield Crawford (Haverford) & Dunc Lorimer (JBO) report the discovery of a young pulsar in the error box of a high energy γ-ray source known since the days of the *COS B* satellite. Most of the sources observed by *COS B* and *EGRET* have been reluctant to reveal their identities, despite many efforts to find low-energy counterparts. The large positional uncertainty of γ-ray sources in the energy range 100 MeV – 10 GeV, which can be greater than 1° across, is a major stumbling block in this endeavor. This team approached this problem by targeting potential hard X-ray counterparts to these sources, discovered by Roberts, Romani & Kawai (2001) in an *ASCA* survey of *EGRET* error boxes.

Recently, Mallory et al. observed two of these X-ray sources, AX J1907.4+0549 & AX J2021.1+3651, from Arecibo using the WAPP at 1.4 GHz. This has resulted in the discovery of a young (characteristic age 17 kyr), energetic (spin-down luminosity 3.4×10^{36} ergs s^{-1}), 104-ms pulsar in the direction of AX J2021.1+3651 with a 1425-MHz flux of only ~0.1mJy. The pulse profile of PSR J2021+3651 is shown in Fig. 18. Given the rarity of such young, energetic pulsars, and the small size of the Arecibo beam (FWHM ~ 3.3′ at 1.4 GHz), an association with the X-ray source is highly probable. Furthermore, PSR J2021+3651 lies in the error box of the hard-spectrum, low-variability, γ-ray source, 3EG J2021+3716 (also known as GEV J2020+3658 & 2CG 075+00). This association, along with the high inferred spin-down luminosity of the pulsar, strongly suggests that PSR J2021+3651 emits pulsed γ–rays, a very exciting pros-

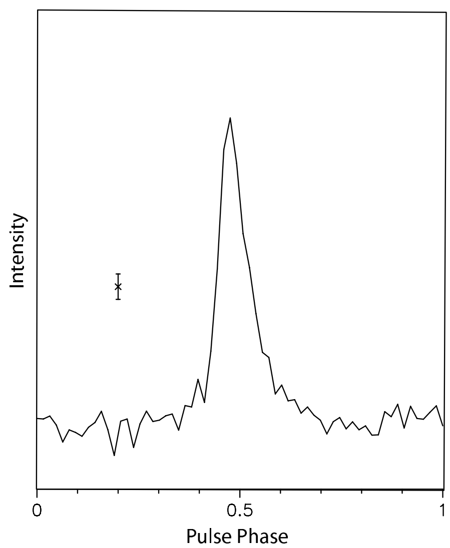

Figure 18: The 1.4-GHz pulse profile of PSR J2021+3651. The error bar shows the 1σ uncertainty. (Coertesy Jason Hessels)

pect as there are currently only a handful of confirmed γ-ray pulsars.

The DM of PSR J2021+3651 is 371 pc cm^{-3}, by far the highest known in the Galactic longitude range 55° < l < 80°. Using the new Cordes & Lazio (2002) electron model of the Galaxy, this DM corresponds to a distance of ~12 kpc, putting it at the far edge of the outer spiral arm. Such a large distance implies that, if PSR J2021+3651 is the low-energy counterpart to GeV J2020+3658, it is extremely efficient at producing γ-rays. Planned X-ray and infrared studies of PSR J2021+3651 may be able to further constrain the distance to the pulsar.

Planned timing observations of PSR J2021+3651 over the course of the next year, will allow an accurate determination of the position, which, combined with an approved *Chandra* observation, will be a definitive test of the association of the pulsar and the X-ray source.

Pulsars in the Galaxy, M33?

Maura McLaughlin (JBO) & Jim Cordes (Cornell) have completed their search for isolated, dispersed radio pulses from the spiral galaxy M33. This was undertaken in the hope of detecting Crab-like objects emitting "giant" pulses, or pulses with 100 – 1000 times mean pulse strengths. The search resulted in the detection of several pulses at high DM which are consistent with signatures of astrophysical origin and may well be pulses from extra-galactic pulsars. Sadly, because of the difficulty in distinguishing astrophysical signals from terrestrial RFI, it is not currently possible to ascertain the origin of the pulses. However, the results of the search, available at http://www.jb.man.ac.uk/~mclaughl/M33, should be very useful for planning future single-pulse searches with the Arecibo feed-array, which will allow anti-coincidence tests, and with the SKA, whose sensitivity and field of view will revolutionize our understanding of the transient radio sky.

Timing the PSR J2016+1947 Binary System

The binary pulsar PSR J2016+1947 was found in 1990 in an intermediate galactic latitude search using the Arecibo 430-MHz line feed. The pulsar (period = 64.94 ms; DM = 34 cm^{-3} pc) was confirmed in Dec 1997, and observed from the end of 1997 to that of 1999. Due to its very long orbital period, and a lack of coverage for about half of the orbit, it has been very difficult to determine its timing parameters. The best timing solution, still marred by possible rotation count ambiguities, yields an orbital period of ~635 days, and an eccentricity of ~0.0015. Due to a large gap in observations in 1998, it is not clear whether there is genuine phase connection, and a second full orbit must be observed to clarify this. A companion mass of 0.29 $M_\odot$ was derived assuming a pulsar mass of 1.35 $M_\odot$ and an inclination of 90°. The pulse profile of PSR J2016+1947 is quite narrow, and it is detected with high signal-to-noise even in 3-min integrations. Given the object's low DM, the prospects for high-precision timing are good, especially given imminent Arecibo capabilities such as the new L-band receiver and the ability to observe pulsars with a 400-MHz total bandwidth via 4 WAPPs.

The PSR J2016+1947 system promises to excel as a tool to test the Strong Equivalence Principle (SEP), the basic foundation of General Relativity (GR). This principle requires the universality of free fall, even for objects that have very significant gravitational self-energies. Thus, both PSR J2016+1947, with its very large (negative) self-gravitation energy of about 15% of the total mass (depending on the equation of state for cold matter at high densities), and the white dwarf companion, with its negligible self-gravitational energy, should fall in the Galactic gravitational field with the same acceleration. However, if the assumption of SEP is wrong, as postulated in many alternative gravitational theories, (i.e., if $|\Delta| = |1 - m_I/m_G| \neq 0$, where m_I and m_G are the inertial and gravitational masses of the pulsar), the accelerations for the pulsar and the white dwarf will be different. The effect will be similar to that of a neutral atom under a strong electric field, which causes different accelerations on the nucleus and electrons, with the net effect of a polarization of the atom. In atomic physics, this is known as the "Stark" effect, the resulting polarization is more intense as the electrons are further from the nucleus. The equivalent gravitational "Nordtvedt" effect on a MSP/white-dwarf binary produces an increase in the eccentricity of the system, and this too becomes more pronounced for wider orbits.

The timing project being made by Paulo Freire (NAIC), Stuart Anderson (Caltech), José Navarro (Schlumberger) & Rick Jenet (Caltech) is aimed at confirming the eccentricity and characteristic age of PSR J2016+1947. If these are confirmed, then the figure-of-merit for a Stark test, P_B^2/e (Arzoumanian, Ph.D. thesis, Princeton), is 5 times higher for PSR J2016+1947 than for any other system with known eccentricity and large characteristic age. Using all the binary systems that pass this criterion, a value of $|\Delta| < 0.004$ was obtained (Wex, A&A, 317, 976). This could improve by a factor of 5 using the PSR J2016+1947 system.

The Lunar Laser Ranging (LLR) experiment tests SEP violation in the weak field limit, predicted (among others) by the Brans-Dicke theory. The test now being carried out at Arecibo is qualitatively different as it probes the strong field regime, it can impose, among all known gravitational tests, the most stringent constraints on the tensor-bi-scalar theories of gravitation (Esposito-Farése, Pulsar Timing, *GR & the Internal Structure of Neutron Stars, 13*). These are among the very few viable alternatives to GR, and predict virtually the same results in the weak-field limit probed by Solar System tests like LLR. Only when strong fields are involved do differences in behavior like SEP violation become, in principle, observable.