Parkes and pulsars: globular clusters, supernova remnants, and magnetars

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People: S Ransom, J Halpern, J Reynolds, J Sarkissian, D Lorimer, B Gaensler, S Johnston, R Manchester, M Kerr

Telescopes: Arecibo, GBT, Nançay, IRAM, ATCA, LBA, VLA, VLBA, Gemini, HST, Chandra, Swift, XMM, Fermi, HESS
“We’re proud to be a part of the operation of [the Parkes] telescope; we’ll do it for nothing.” (SKF Bearings on replacing bearings for elevation gearboxes, quoted by Jon Ables on the 30th anniversary)
“Parkes has played an important role in pulsar astronomy, making many interesting discoveries. I am sure that the next 30 years will be just as interesting.” (Dick Manchester, Parkes 30th anniversary)
Globular clusters

- First millisecond pulsar (Backer et al 1982)
- LMXBs thought to lead to MSPs
- High LMXB incidence in GCs
- Searches in GCs: MSP in M28 (Lyne et al 1987)
Globular clusters

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![Image of globular cluster with MSP at Parkes](attachment:image1.png)

MSP at Parkes (Lyne et al 1990)

![Image of VLA observation](attachment:image2.png)

VLA (Fruchter & Goss 2000)

Manchester et al 1990, 91

**nature**

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MSPs in 47 Tucanae

A BREEDING GROUND FOR MILLISECOND PULSARS
1997: 20cm multibeam receiver
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9 new MSPs
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9 new MSPs

47 Tuc C
47 Tuc D
47 Tuc E
47 Tuc F
47 Tuc G
47 Tuc H
47 Tuc I
47 Tuc J
47 Tuc N
47 Tuc O
47 Tuc R
47 Tuc S
47 Tuc V
47 Tuc W

47 Tuc R

Signal-to-noise ratio

Acceleration (m s$^{-2}$)
$n_e = 0.07 \text{ cm}^{-3}$

(Freire et al 2001)
47 Tuc


(Freire et al. 2001)
47 Tuc  Chandra (Heinke et al 2005)
HST: 47 Tuc W (Edmonds et al 2002)
Supernova remnants and pulsar wind nebulae

The Crab: nebula powered by pulsar rotational energy; a prototype?
Supernova remnants and pulsar wind nebulae

The Crab: nebula powered by pulsar rotational energy; a prototype?

Little evidence of SN ejecta; uncommonly good calorimeter; largest spin-down luminosity; radio pulses detectable at \(~\text{Mpc}(!)\)...
Supernova remnants and pulsar wind nebulae

The Crab: nebula powered by pulsar rotational energy; a prototype?

Little evidence of SN ejecta; uncommonly good calorimeter; largest spin-down luminosity; radio pulses detectable at ~Mpc (!)...  

Not a prototype! Exceptional (if enormously important)
First pulsars discovered in SNRs/PWNes at Parkes

“...that many Galactic SNRs could contain... pulsars detectable in a more sensitive search.”
Slow going with pulsar/SNR discoveries...

- None found in Galactic plane 20cm survey (Johnston et al 1992)
- None found in directed PKS, AO, JB surveys of 88 SNRs in 1990s
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PSR J1119-6127/SNR G292.0-0.5

ATCA (Crawford et al 2001)
SNR G292.0+1.8

Chandra (Hughes et al 2001, Park et al 2007)
10 hr Parkes search on Sep 5, 2001:

\[ P = 135 \text{ ms}, \quad \dot{E} = 10^{37} \text{ erg s}^{-1} \]

\[ S_{1.4} = 70 \mu\text{Jy} \]
SNR G21.5-0.9

Chandra

1 arcmin Matheson & Safi-Harb 2005

Gaensler & Slane 2006

Interstellar Material

Supernova Blast Wave and Swept-up Shell

Reverse Shock

Pulsar and Nebula

Ejecta

hot

cold

$R_w$

$R_{PWN}$
Deep searches at GMRT (Gupta et al. 2005) and Parkes:

\[ P = 61 \text{ ms}, \dot{E} \approx 10^{37} \text{ erg s}^{-1} \]
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The Mouse nebula
(bow-shock PWN)
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\[ P = 98 \text{ ms}, \quad \dot{E} \approx 10^{36} \text{ erg s}^{-1} \]

\[ M \sim 60 \]

Gaensler et al 2004
The Mouse pulsar

Discovered at Parkes
Timed at GBT
GeV pulsations with Fermi

1 deg from Galactic centre: “remove” pulsar to map central region
SNR G315.9-0.0: the Frying Pan

MOST

ATCA:
SNR G315.9-0.0: the Frying Pan

MOST

ATCA:

$P = 61 \text{ ms}, \dot{E} \approx 10^{36} \text{ erg s}^{-1}$

$\mathcal{M} \sim 200$

Ng et al 2011
3C58 (Chandra; GBT)

G0.9+0.1 (VLA/XMM; GBT)

G106.6+2.9 (Chandra; Lovell)

G54.1+0.3 (Chandra; Arecibo)

G76.9+1.0 (VLA/Chandra; GBT)

Arzoumanian et al 2011
As of 2011

1.4 GHz luminosity (mJy kpc²)

Characteristic age (yr)

3C58 (Chandra; GBT)  G0.9+0.1 (VLA/XMM; GBT)

G54.1+0.3 (Chandra; Arecibo)  G76.9+1.0 (VLA/Chandra; GBT)

Arzoumanian et al 2011
Magnetars (AXPs/SGRs)

- Occasional gigantic X-ray/gamma-ray flares
- Long periods (5-12 sec), spinning down rapidly (huge inferred B)
- Persistent and variable very large X-ray luminosity (> spin-down)
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- Powered by decay of wound-up internal B field
- Deep crustal heating, drift of B, stress, crustal deformation
- Ejection of helicity, external B twisted, currents, torque changes, heating
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No radio emission

Duncan & Thompson 1992
RXTE (Ibrahim et al 2004)

XTE J1810-197

VLA (Halpern et al 2005)
Radio pulsar!
(Parkes on 17 March 2006)
John & John, on site at Parkes, go to work making an audio magnetar detector on the fly.
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XTE J1810-197 has flat spectrum
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Clouds in West Virginia...
XTE J1810-197 has flat spectrum

Clouds in West Virginia...
Gotthelf & Halpern 2007

XTE J1810-197

VLT

Gemini

Ks=21.9
Continued variability of radio flux...
... and then it just vanished

Torque
Nançay
GBT
Parkes
1E1547.0-5408: magnetar candidate

(Gelfand & Gaensler, astro-ph 7 Jun 07)
1E1547.0-5408: magnetar candidate

(Gelfand & Gaensler, astro-ph 7 Jun 07)

P=2 sec pulsations discovered at Parkes on 8 Jun
IE1547.0-5408/PSR J1550-5418

Flat spectrum: first published results from ATCA 7mm system

Also, detected at Parkes at 22 GHz
IE1547.0-5408/PSR J1550-5418

Flat spectrum: first published results from ATCA 7mm system

Proper motion: measured with LBA (Deller et al 2012)

\[ \mu_\alpha = 3.1 \pm 0.5 \text{ mas yr}^{-1} \]
\[ \mu_\delta = -7.1 \pm 0.4 \text{ mas yr}^{-1} \]

Magnetar scatter-broadened to \(~7\) mas (even at 8 GHz!), so and contribute little: Mopra essential
NASA’s Swift observes X-ray echoes around SGR J1550–5418

Credit: NASA/Swift/Jules Halpern (Columbia Univ.)
NASA’s Swift observes X-ray flux increase!

PSR J1550-5418

4000x flux increase!
Thank you to all the staff (including receiver group in Marsfield)!

CSIRO ATNF Parkes Observatory Staff – May 2011

Brett Armstrong  Receivers
Scott Brady  Site Services
Etore Carretti  Project Scientist
Daniel Craig  Computing
Jon Crocker  Technical Services
Andrew Dean  Visitors Centre
Anne Evans  Quarters
Ilana Feain  ASKAP Scientist

Julia Hockings  Administrative Services
Chris Holingdrake  Visitors Centre Manager
Simon Hoyle  Computing
Andrew Hunt  Electronics and Servo Systems
Shirley Ingram  Quarters
Alan Laing  Electronics
Tom Loes  Site Services
Erik Lensson  Head of Engineering Operations

Matt McFarland – Electrician  Site Services Coordinator
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Margaret Marshall  Quarters
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Mal Smith  RF Systems – Site Manager
Gina Spratt  Computing
Tricia Trim  Visitors Centre
Karin Unger  Visitors Centre
Bev Wilson  Visitors Centre

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