The Galactic Center Pulsar, SGR J1745-29

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Revealing a high magnetic field around the supermassive black hole at the centre of the Galaxy

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The Angular Broadening of the Galactic Center Pulsar SGR 1745-29: A New Constraint on the Scattering Medium

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Pulse Broadening Measurements from the Galactic Center Pulsar J1745–2900

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Using Pulsars to Measure Spacetime Around Sgr A*

Black Hole Mass

Black Hole Spin

\[ \chi = 0.9997 \pm 0.0010 \]

Liu et al 2012
Galactic Center Magnetar Discovery

X-Ray Burst

Degenaar et al. 2013
Kennea et al. 2013

X-ray Localization: 3” to Sgr A*

Rea et al. 2013

X-ray Pulsations

SGR J1745-29

Mori et al. 2013
Radio Detection

- **Period**
  \[ P = 3.76354676(2) \text{ s} \]
- **Period derivative** (spindown)
  \[ \frac{P}{P\text{dot}} = 6.82(3) \times 10^{-12} \]
- **Magnetic field**
  \[ B \sim 10^{14} \text{ G} \]
- **Spin-down age**
  \[ \sim 9000 \text{ yrs} \]
- **Dispersion Measure**
  \[ DM = 1778 \pm 3 \text{ cm}^{-3} \text{ pc} \]
- **Flux**
  \[ \sim 0.2 \text{ mJy} \]
- **Spectrum**
  \[ \sim \text{flat} \]
- **Only 4 radio magnetars known** – chance alignment is \[ 10^{-8} \]

*Eatough et al. 2013*
*Shannon and Johnston 2013*
Dispersion in the Galactic Center

NE 2001 Model
Deneva et al. 2009
Rotation Measure

\[ RM = -66960 \pm 50 \text{ rad m}^{-2} \]

\[ \text{RM}_{\text{pulsar}} \sim 0.1 \text{ RM}_{\text{SgrA*}} \]

Eatough, HF, et al. (2013)
Galactic RM of diffuse gas

5 GHz (VLA)

Law et al. (2011)
RM of Galactic Center Sources

Size of symbol $\propto$ RM (1100 to $-2200$ rad m$^{-2}$)
Cross = negative, circle = positive

Law et al. (2011)
RM and DM from hot gas

- Inferred densities at scales of 0.06, 0.15 and 40 pc roughly follow $r^{-1}$ law.
- $DM \sim n_e r \sim 10^2 \text{ cm}^{-3} \text{ pc}$
- $RM \sim B n_e r$ 
  $\Rightarrow B \propto RM \sim 8 \text{ mG}$
- Equipartition: $B \sim 2.5 \text{ mG}$
  $\Rightarrow$ Sgr A* accretes from a highly magnetized hot gas

Based on Baganoff et al. (2003), Muno et al. (2004)
Angular Broadening of the Pulsar

Also agreement in pa~80 deg

Bower et al. 2013
Individual Pulses are Highly Variable

Bower et al. 2013

**EVLA 8.7 GHz**
Figure 2.— Multi-frequency integrated pulse profiles. The blue curve is the measured profile. The red, green and black lines are the best fitted profile $P_{\text{obs}}(t)$, best-fit Gaussian profile $P_g(t)$ and the scattering filter $P_{\text{BFF}}$ respectively.

Figure 3.— Measurements of the scattering broadening timescale ($\tau$) and intrinsic pulse width ($\sigma$) of PSR J1745–2900 from 1.2 to 18.95 GHz together with the 1-σ errorbar. Left panel: The measured pulse scattering timescales $\tau$ as a function of observing frequency $\nu$. The +, ◦, and * denotes the data from Effelsberg, Nançay, and Jodrell Bank respectively. The purple squares are from Effelsberg single pulse data. The inset in the bottom left shows a zoomed region for 1 to 2 GHz. The red solid line is a simultaneous fit for the pulse broadening timescale and spectral index, which yields a scattering timescale at 1 GHz of $\tau_{1\text{GHz}} = 1.3 \pm 0.2$ s and power-law index of $-3.8 \pm 0.2$. The black dashed line is a fit fixing the power index to $-4$, which gives $\tau_{1\text{GHz}} = 1.4 \pm 0.1$ s. Right panel: The best-fit Gaussian width of each average profile as a function of frequency. The measurement between 2 and 20 GHz may suggest that the jitter-dominated time scale may vary in frequency, but the large scatter in the 1 to 2 GHz intrinsic width makes it difficult to draw firm conclusions.
A New Distance for the GC Scattering Screen

Alternate Solution:
Uniform Distribution of scatterers between GC & Sun

Bower et al. 2013
$\sim5.5$ kpc
Does a Scattering Screen at Large Distances Make Sense?

- NGC 6334B & Cyg X-3 have similar scattering sizes and non-local scattering screens
- 50 pc diameter screen associated with HII regions or GMC surfaces can provide the scattering
- Missing extragalactic background sources?
- Apparent peak of OH/IR masers around Sgr A*?
- Patchiness?
  - Scale ~5’ from G359.87+0.18

Lazio, Cordes 1998

Distance from SgrA* [pc]

van Langevelde 1992
Where are the GC pulsars?

GC Pulsar search does not require high frequencies!

~1000 pulsars with periods <100y expected (Liu et al 2012)

Macquart et al 2012
Astrometry

- 4 astrometric detections
- Accuracy ~0.3 mas/epoch
- Velocity accuracy @ GC ~100 km/s [2 months data]
  - → ~10 km/s in 1 year
- Where is it going? Where did it come from?
  - Characteristic velocity ~390 km/s
  - Escape velocity ~600 km/s
  - T_SgrA* < 1000y
  - Acceleration ~ 1 km/s/y
Conclusions

• First true GC pulsar discovered
  – Highest DM, RM, SM of any known pulsar
  – X-ray absorption consistent with GC location
  – Too unstable for precision timing tests

• Important probe of the Sgr A* environment
  – Sgr A* accretes from hot gas with high and ordered B-fields
  – Motion of the pulsar could provide length scales for ISM structures

• Scattering must originate at large distances
  – Resolves long-standing mystery --- but creates new ones

• Proper motion to come ... (tracing back to origin?)
  – Sgr A* orbit \(\sim 10^3\) yrs – likely too long for precision GR tests

• Where are the other GC pulsars?
  – Can easily detect ordinary pulsars at few GHz
  – Can detect MSPs at \(>10\) GHz