



Cosmic Forensics: A Study of the Pulsar Wind Nebula G359.23-0.82, The "Mouse"

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Opening Statements

- Case Background
 - Pulsars, Pulsar Wind Nebulae and The Mouse
- Fingerprinting: Collecting the Evidence
 - Reduction of Data from The Very Large Array (VLA)
- Ballistics: Where is the Mouse Going?
 - Derivative Maps and Kinematics
- Recreating the Scene of the Crime
 - Origin of the Mouse? Future?
- Closing Arguments

Case Background





Pulsars and PWNe

• Pulsars are magnetised rotating neutron stars

$$\dot{E} = \frac{d}{dt} \left(\frac{1}{2} I \omega \right) = I \omega \dot{\omega}$$

 Get pulsar wind nebula (PWN) from interaction of shocked ambient particles with magnetised wind



Crab Nebula (Hester et al. 2002)



Bow Shock PWNe

 Natal kicks from supernova (SN) explosion

 $V_{birth} \approx 300 - 1000 \text{ km/s}$



Guitar Nebula (Chatterjee & Cordes 2002)



(Vigelius, Gaensler et al. 2007)



The Mouse, PWN G359.23-0.82

- First radio observation in 1987 (Yusef-Zadeh & Bally 1987)
- X-ray detection in 1994 (Predehl & Kulkarni 1995)
- Pulsar J1747-2958 discovered in 2002 (Camilo et al. 2002)





The Arraignment

- Where is the Mouse going?
- Can we learn about the ISM?
- Can we get an independent age estimate?
- Associated with nearby SNR?

The Mouse: Radio \rightarrow X-Ray/Radio \rightarrow X-Ray



http://chandra.harvard.edu/press/04_releases/press_092304.html



FINGERPRINTING: COLLECTING THE EVIDENCE



Reduction of VLA Data

• Similar observations using hybrid BnA configuration at 1993, 1999 and 2005 epochs

• Observing frequency of 8.5 GHz

• Raw data edited, calibrated, imaged, and smoothed to uniform resolution



The Very Large Array (VLA) http://www.vla.nrao.edu/



Comparison of Epochs



- Morphology evolution
- 1999 Epoch has poor spatial frequency coverage along direction of interest
- Only consider 1993 and 2005 epochs



BALLISTICS: WHERE IS THE MOUSE GOING?



Morphology Evolution







Derivative Maps





Kinematics



Compares well with NS velocity distribution



RECREATING THE Scene of the Crime



In Situ ISM Density

• Ram pressure balance with pulsar wind:

$$\frac{\dot{E}}{4\pi (r)^2 c} = \rho V^2 = 1.37 n_0 m_H M^2 c_s^2$$

• Combine to estimate proper motion:

$$V = \frac{1525}{\sqrt{n_0}d}$$
 km/s $\mu = \frac{V}{d} = \frac{13}{\sqrt{n_0}d^2}$ mas/yr

• Using detected proper motion and $4 \le d \le 6$ kpc: $0.5 \le n_0(=1.0) \le 2.5 \ cm^{-3}$ $M \approx 60^{16}$!!



Age Estimate for J1747-2958



The Mouse at 20cm (Yusef-Zadeh & Gaensler 2005)

• Lower bound from distance travelled along tail: ~ 50 kyr

$$t > \tau_c = 25.5$$
 kyr



- Consider SNR evolution near the Mouse
- Using previous density and distance: ~ 90 kyr to cross SNR shell
- Total age of pulsar $\approx 50 + 90 = 140 \text{ kyr}$
- But do not see SNR of correct size (too small)



http://rsd-www.nrl.navy.mil/7213/lazio/GC



Future Evolution of J1747-2958?



$$\dot{\omega} = -K\omega^n$$

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- B increasing
- Similarity to Vela
- Will the Mouse become an exotic magnetar?

Using data from: http://www.atnf.csiro.au/research/pulsar/psrcat/



Closing Arguments

- Velocity consistent with neutron star population
 - First time a proper motion has been calculated for this object
- In situ measurement of ISM density from 16 kly away!
- Unlikely association with SNR G359.1-0.5
- Lower limit on age: $t \ge 140 \text{ kyr} \approx 5\tau_c$
- Magnetic field growing
 - Mouse evolving into a magnetar?
- Results to be published later this year



	Epoch 1	Epoch 2	Epoch 3
Date Observed	02 Feb 1993	08 Oct 1999	22 Jan 2005
Array Configuration	BnA	BnA	BnA
Antennas Available	27	27	25
Centre Frequency (GHz)	8.44	8.44	8.46
Bandwidth (MHz)	62.5	100	100
Polarisation Information	RR,LL	RR,LL,RL,LR	RR,LL,RL,LR
On-Source Observation Time (h)	3.12	2.98	2.72
Secondary Calibrator Reference Interval (~m)	15	17	4













