The Galactic Millisecond Pulsar Population

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Goal: to understand the birth, life and death of neutron stars in as many environments as possible

- Radio pulsars as probes
  - The current sample and some of the surveys
  - Selection effects and modeling techniques
  - Older results concerning normal pulsars
- The millisecond pulsar population
  - New analysis with “old” Parkes multibeam surveys
- Open questions
The radio pulsar tally (N>2000)

Key developments

- Low-noise receivers
- Multibeam systems
- Data acquisition systems
- High performance computing
- Interference excision
- Multiple analyses
Parkes multibeam surveys (pre-HTRU)

- **Galactic plane survey** → 800+ new pulsars
  Manchester et al. 2001

- **High latitude survey** → Double pulsar
  Burgay et al. 2006

- **Perseus arm surveys** → Outer galaxy
  Burgay et al. 2012

- **Swinburne intermediate latitude** → Recycled
  Edwards et al. 2001

- **Swinburne high latitude** → 1909-3744
  Jacoby et al. 2009

- **Magellanic Cloud surveys** → 20+ pulsars
  Manchester et al. 2006
Pulsar sample is heavily biased

\[ S = \frac{L}{4\pi d^2} \]

\( S \rightarrow \) Flux density
\( L \rightarrow \) Luminosity
\( d \rightarrow \) Distance
Monte Carlo approach to problem

Rotation Curve

Neutron star properties...
\( V_0, P(t), B(t), L(t) \)

The Galaxy

Interstellar medium model

Pulsar surveys \( \rightarrow S_{\text{min}} \)

Model sample \( \rightarrow \) True sample
"Snapshot model" results

Lorimer et al. 2006

http://psrpop.phys.wvu.edu
“Time evolution” model results

- Random luminosities don’t produce good results. Need $L = f(P, P_{dot})$
- Final distribution appears to be log-normal

Faucher-Giguere & Kaspi 2006
Ridley & Lorimer 2010
Landmark papers in MSP statistics

- Sample of three MSPs → Birthrate problem!
  Kulkarni & Narayan 1988
- High latitude surveys → Isotropic population
  Johnston & Bailes 1991
- Evolutionary simulations → P-Pdot distributions
  Rathnasree 1993
- Spindown studies → Ages, spin-up lines
  Camilo et al. 1994
- Parkes/Arecibo 70cm surveys → Local population
  Lorimer 1995
- Likelihood analyses → Population distributions
  Cordes & Chernoff 1997
The Galactic MSP tally

http://astro.phys.wvu.edu/GalacticMSPs

2001 → 33 sources

2012 → 175+(23?) sources

Galactic MSPs currently outnumber their counterparts in globular clusters!
Still finding MSPs in PMPS! (#26 confirmed yesterday)


The Galactic MSP population

Results from pre-HTRU surveys (based on a sample of 57 MSPs)

“Standard model” has:

• ~32,000 potentially observable MSPs
• Period distribution peaking at ~5ms
• Log-normal luminosity function
• 500 pc scale height (exponential)
• 7.5 kpc scale length (Gaussian)
## A plethora of population models

<table>
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<tr>
<th>Model</th>
<th>Modifications</th>
<th>log(QKS)</th>
<th>RChi-sq</th>
<th>N_{Galaxy}</th>
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<td>CC97-pdist</td>
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<tr>
<td>I</td>
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</tbody>
</table>

**Strategy:** Investigate impacts of changes to “optimal model” → better understand uncertainties
Model E - 100 pc scale height
Model D - cc97 period distrib.
Model C - uniform disk

Pulsar survey

Number of detections

PM PH PA SI SH

DM (pc/cc)

Period (ms)

Galactic latitude (degrees)

Galactic longitude (degrees)
Model A – current best effort
Some open questions

• In general, what about:
  – magnetic field decay?
  – intermittency?
  – Scintillation?

• For MSPs, what about:
  – Binary evolution
    • Synthesis code + Selection effects
  – Binary subclasses
  – Fraction isolated (~20% observed)
  – Modeling Fermi sample and other surveys