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Neutron Star Population Dynamics

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Abstract. We summarize our efforts at understanding the galactic neutron star (NS) population using likelihood and bayesian analyses. These include determination of the velocity distribution of young, high-magnetic field objects; the spatial, velocity, period and luminosity distributions of millisecond pulsars; and a full analysis of high-field objects including modeling of pulsars' radio beams with the implicit assumption that such objects, for fixed period and period derivative, are standard candles.

KINEMATICS OF YOUNG PULSARS

- A likelihood analysis is used that takes into account:
  1. proper motion measurements + errors;
  2. distance estimates + errors;
  3. information about radial velocities that is contained in $z = D \sin b$;
  4. multicomponent velocity models;
  5. an odds ratio is used to determine the model that best fits the data with a minimum of parameters.
- A single-gaussian model and a triple-gaussian model are disfavored by the data.
- The best fit model is a two component 3D gaussian with a single birth z scale height:
  1. component 1: $\sigma_{V1} = 175^{+20}_{-30}$ km s^{-1}.
  2. component 2: $\sigma_{V2} = 800 \pm 200$ km s^{-1}.
  3. birth scale height: $h_z = 0.13$ kpc.
- About 25% of **known** pulsars will escape the Galaxy (for escape speed = 500 km s^{-1}).
- We find no significant correlation between the 3D velocities and any combination of P and $\dot{\text{P}}$.

KINEMATICS OF MILLISECOND PULSARS

- A likelihood analysis is done on 8 MSP surveys that takes into account:
  1. MSP discoveries and non-detection survey beam areas;

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2. search sensitivity vs P, DM, ℓ, b, ν, D = distance;
3. errors on distance estimates;
4. interstellar scintillations, which modulate the intensity and yield a net *increase* in surveyed volume, by $\sim 30\%$.

- We consider power-law models for the distributions of MSPs in P and in pseudo luminosity $L_p = DS^2$.
- We consider a galactic disk-only model (plane parallel) that is exponential in z with scale height σ_z.
- We also consider disk+halo models.
- Results include:

1. MSP periods are distributed $\propto P^{-2\pm0.3}$.
2. Pseudo luminosities are distributed $\propto L_p^{-2\pm0.3}$.
3. The scale height is $\sigma_z = 0.5 \pm 0.15$ kpc
4. The scale height corresponds to an rms z velocity $\sigma_{V_z} \approx 50$ km s^{-1} and a 3D velocity ~ 90 km s^{-1}.
5. The minimum period is $P_{min} > 0.65$ ms (99% confidence).
6. The space density of MSPs at z=0 is $n_d \sim 28^{+14}_{-11}$ kpc^{-3}.
7. In a disk of radius 10 kpc, there are $10^{4.0}$ MSPs.
8. The corresponding birth rate (in 10 Gyr) is $\dot{n} \sim 10^{-6.0}$ yr^{-1}.
9. In a disk+halo model, the likelihood is maximum for a negligible halo population.

MONTE-CARLO MODELING OF THE PULSAR POPULATION

We have also undertaken a comprehensive study of the NS population that removes all selection effects, including those on the pulsar velocity distribution. We do so by performing a *forward* analysis whereby we create pulsars, search for them in pseudo surveys that have properties like those actually performed, and compare the detections with the known pulsars. Our scheme consists of: (1) integrating NS orbits in a model for the galactic potential; (2) generating pulsars at a constant birth rate; (3) modeling radio beams with core and conal components; (4) adopting a *deterministic* relationship between (true) radio luminosity and P and $\dot{P}$; (5) assuming random orientation angles between the magnetic moment, spin axis and line of sight; (6) Smearing out the intrinsic pulse shape by dispersion over a channel bandwidth and by scattering; (7) Comparing modeled and actual pulsars with a numerically derived likelihood function.

The key assumption in (4) is that radio pulsars of a given P and $\dot{P}$ are standard candles. Results of our program will be reported elsewhere.

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