PULSAR FORMATION RATES

**HOW**

First obtain estimate of total number:
- Properties of observed sample
- Modeling of PSR-survey selection effects
- Correction factors due to emission processes

Then obtain estimate of rate:
- Lifetime estimates
PULSAR FORMATION RATES

**HOW**

Earlier estimates:

- 'Scale factor' calculation: **inverse problem**

Density-weighted estimate of the number of PSRs in the Galaxy for every observed one based on $V/V_{\text{max}}$ arguments
Radio Pulsars in NS-NS binaries

NS-NS Merger Rate Estimates

Scale-factor calculations:

- Narayan et al. '91; Phinney '91;
- Curran & Lorimer '95;
- Arzoumanian et al. '99; VK et al. '01

Dominant sources of estimate uncertainties identified:

- **small-number** observed sample (2 NS-NS in Galactic field)

- PSR population dominated by **faint objects**

- Robust lower limit for the MW: 1 per Myr

- Upward correction factor for faint PSRs: ~ 1-500
Statistical "Forward" Approach  

Calculation of Rate Probability Distribution

It is possible to assign statistical significance to NS-NS rate estimates with Monte Carlo simulations

Kim, VK, Lorimer '03

- Choose PSR space & luminosity distribution
- Populate Galaxy with \( N_{\text{tot}} \) "1913+16-like" pulsars
- Simulate PSR survey detection and produce observed samples
- Distribution of \( N_{\text{obs}} \) for a given \( N_{\text{tot}} \) : Poisson
- Calculate \( P \left( I; N_{\text{tot}} \right) \) for best-fitting Poisson distribution
- Derive \( P \left( N_{\text{tot}} \right) \) (Bayesian analysis) and \( P \left( R_{1913} \right) \)
- Repeat for 1534+12 and derive \( P \left( R_{\text{tot}} \right) \)
Distribution of number of objects $N_{obs}$ in observed samples:
Poisson

$$\mathbb{P}(N_{obs} ; \lambda) = \frac{\lambda^{N_{obs}} \exp(-\lambda)}{N_{obs}!}$$

Likelihood of current sample:
$$\mathbb{P}(1 ; \lambda) = \lambda \exp(-\lambda)$$
The mean of the Poisson distribution $<N_{obs}>$ is linearly proportional to the total number of PSRs in the Galaxy:

$$\lambda = <N_{obs}> = \alpha N_{tot}$$

Using Bayes' theorem we calculate the probability distribution:

$$P(N_{tot}) = \alpha^2 N_{tot} \exp(-\alpha N_{tot})$$

and the most likely value is:

$$N_{peak} = 1/\alpha$$
Using the probability distribution we can calculate the most likely rate $R_{\text{peak}}$ as well as the ranges of rates at various confidence levels.
Dependence of most likely coalescence rate on the PSR LF parameters:

$L \sim L^{-p}$, $L > L_{\text{min}}$

$R_{\text{peak}}$ is mostly insensitive to the spatial distribution parameters
Current expectations for most likely advanced (initial) LIGO detection rates of NS-NS inspiral events

rate at peak probability

$$R_{\text{det}} \quad 4-100$$

(1/yr) \quad (1-25) \times 10^{-3}
Radio Pulsars in NS-WD binaries

NS-WD Merger Rate Estimates

3 binary pulsars with lifetimes comparable or shorter than a Hubble time are known in the Galaxy:

- PSR J0751+1807
- PSR J1757-5322 (Lundgren et al. '95)
- PSR J1141-6545 (Edwards & Bailes '01)
  (Kaspi et al. '00)

PSR J1141-6545 is very young with a pulsar lifetime of only ~10 Myr: it dominates the NS-WD rate by far!
NS-WD Coalescence Rate

Peak Rate:

~30 per Myr

without any beaming correction
For the future ...

- Include model distributions for pulse profiles and binary orbit characteristics
- Apply rate constraints on population synthesis models
- Obtain number estimates for pulsars in globular clusters