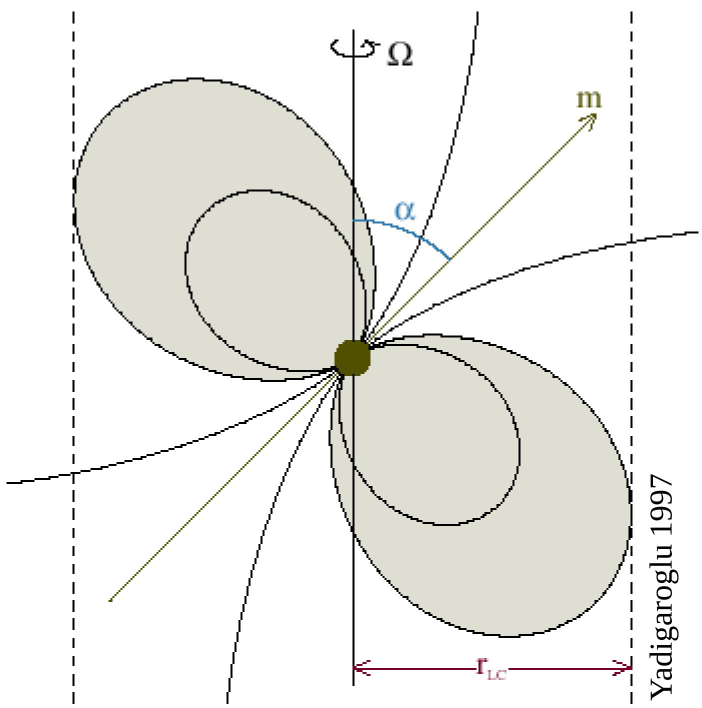
Observations of

Rotation-Powered Pulsars

in support of

GLAST



Yadigaroglu 1997

An Interdisciplinary Scientist Proposal
Stephen Thorsett
University of California, Santa Cruz

The Radio Pulsar Population

Numbers:

There are about 1350 known radio pulsars, with about 1600 expected by time of *GLAST* launch.

All-sky radio surveys give reasonably complete, flux-limited samples with fairly well-understood selection biases.

Parameters:

Radio studies give accurate source positions, and rough distances.

Timing measurements give accurate pulse phase, period, and spin-down rate.

Spin-down gives reasonable age:

$$\tau = \frac{P}{2\dot{P}}$$

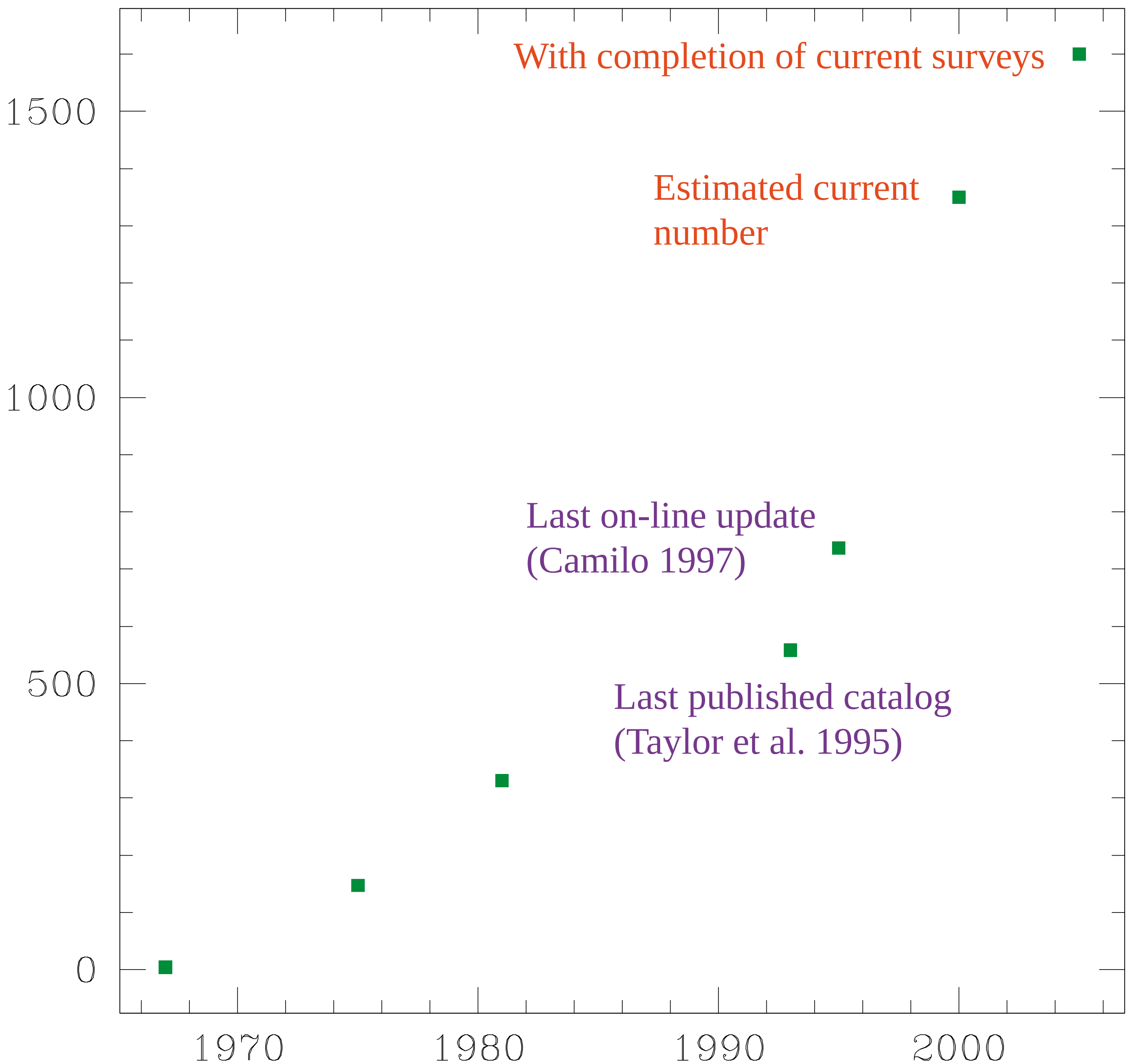
magnetic field:

$$B \approx 3.2 \times 10^{19} \sqrt{P\dot{P}}$$

and bolometric luminosity:

$$\dot{E} = I\omega\dot{\omega}$$

Radio pulsar catalogs



Gamma-Ray Pulsars

Pulsar	P s	τ yr	$\dot{E}$ erg s^{-1}	F_E erg cm^{-2}s^{-1}	d kpc	L_{HE} erg s^{-1}	η
Crab	0.033	1300	4.5×10^{38}	1.3×10^{-8}	2.0	5.0×10^{35}	0.001
B1509−58	0.150	1500	1.8×10^{37}	8.8×10^{-10}	4.4	1.6×10^{35}	0.009
Vela	0.089	11,000	7.0×10^{36}	9.9×10^{-9}	0.5	2.4×10^{34}	0.003
B1706−44	0.102	17,000	3.4×10^{36}	1.3×10^{-9}	2.4	6.9×10^{34}	0.020
B1046−58	0.124	20,000	2.0×10^{36}	2.5×10^{-10}	3.0	2.1×10^{34}	0.011
B1951+32	0.040	110,000	3.7×10^{36}	4.3×10^{-10}	2.5	2.5×10^{34}	0.007
Geminga	0.237	340,000	3.3×10^{34}	3.9×10^{-9}	0.16	9.6×10^{32}	0.029
B1055−52	0.197	530,000	3.0×10^{34}	2.9×10^{-10}	1.5	6.2×10^{33}	0.20

History:

Before EGRET, only Crab and Vela were known.

EGRET 3rd catalog added Geminga, B1055, and B1706.

B1951 and (probably) B1046 added from later analysis.

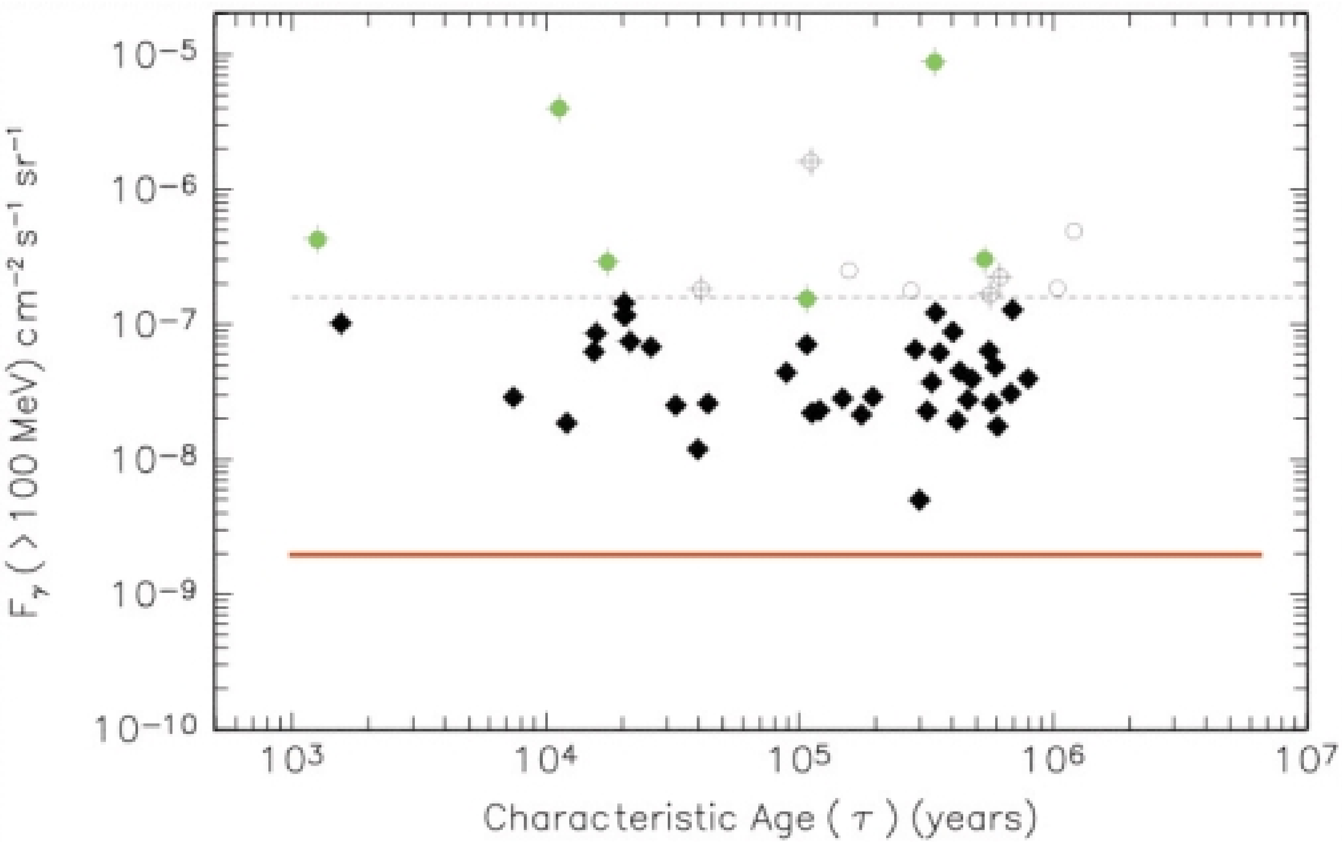
B1509 detected only up to 30 MeV.

Properties:

If ranked by $\dot{E} / d^2$ (spin-down flux at Earth), these pulsars are numbers 1, 2, 3, 4, 5, 6, 9, and 24. (Number 7 is a nearby millisecond pulsar, and 8 is a recently discovered pulsar.)

Clearly, **spin-down flux at Earth is an excellent proxy for gamma-ray luminosity**.

GLAST's Potential



Adapted from Cheng and Zhang 1998.

GLAST should detect dozens of gamma-ray pulsars, reaching well below the tip of the iceberg seen by EGRET and other earlier missions.

Emission Processes

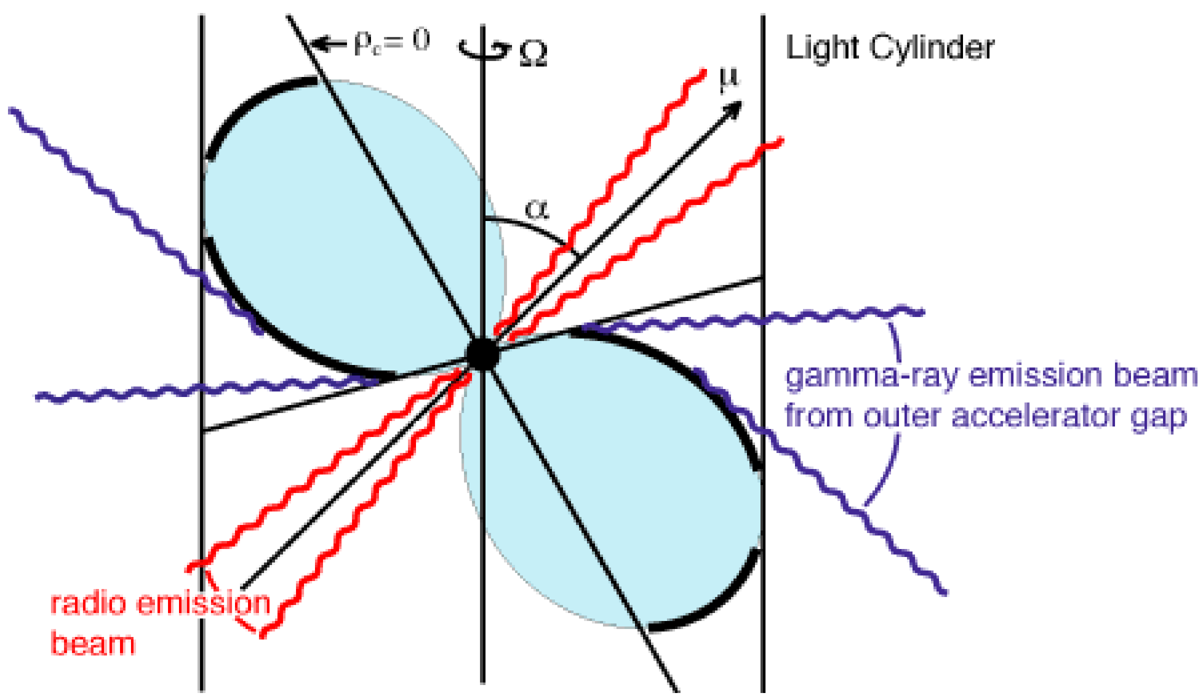
Radio is a convenient observing band, and the observed phenomenology is rich, but connection to emission physics has been elusive:

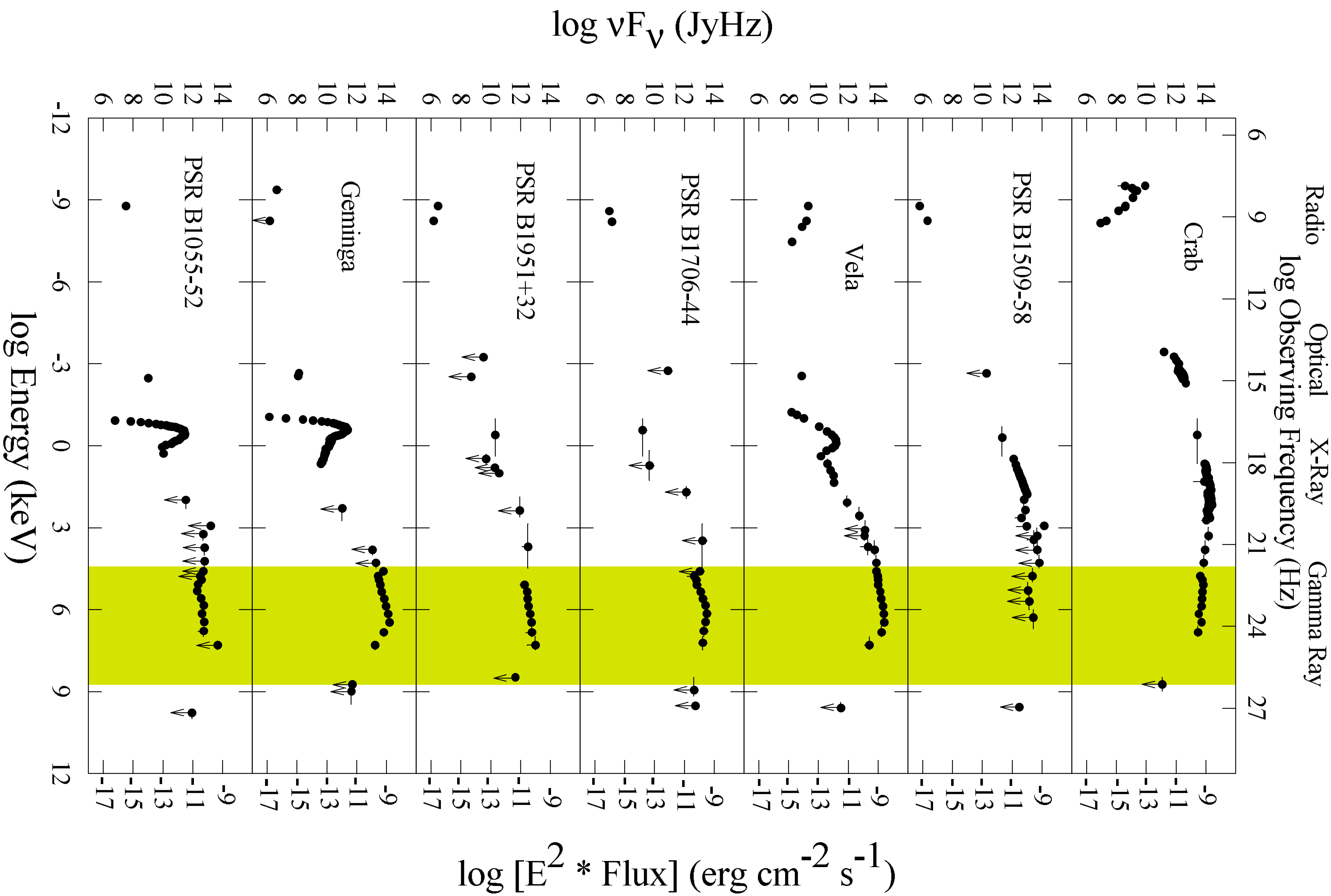
- Radio is a tiny fraction of energy budget
- Radio emission is coherent (i.e., non-linear) process

Gamma-ray band is at or near peak in pulsar spectrum, and gamma-ray emission physics is relatively straightforward (at least, it is incoherent!).

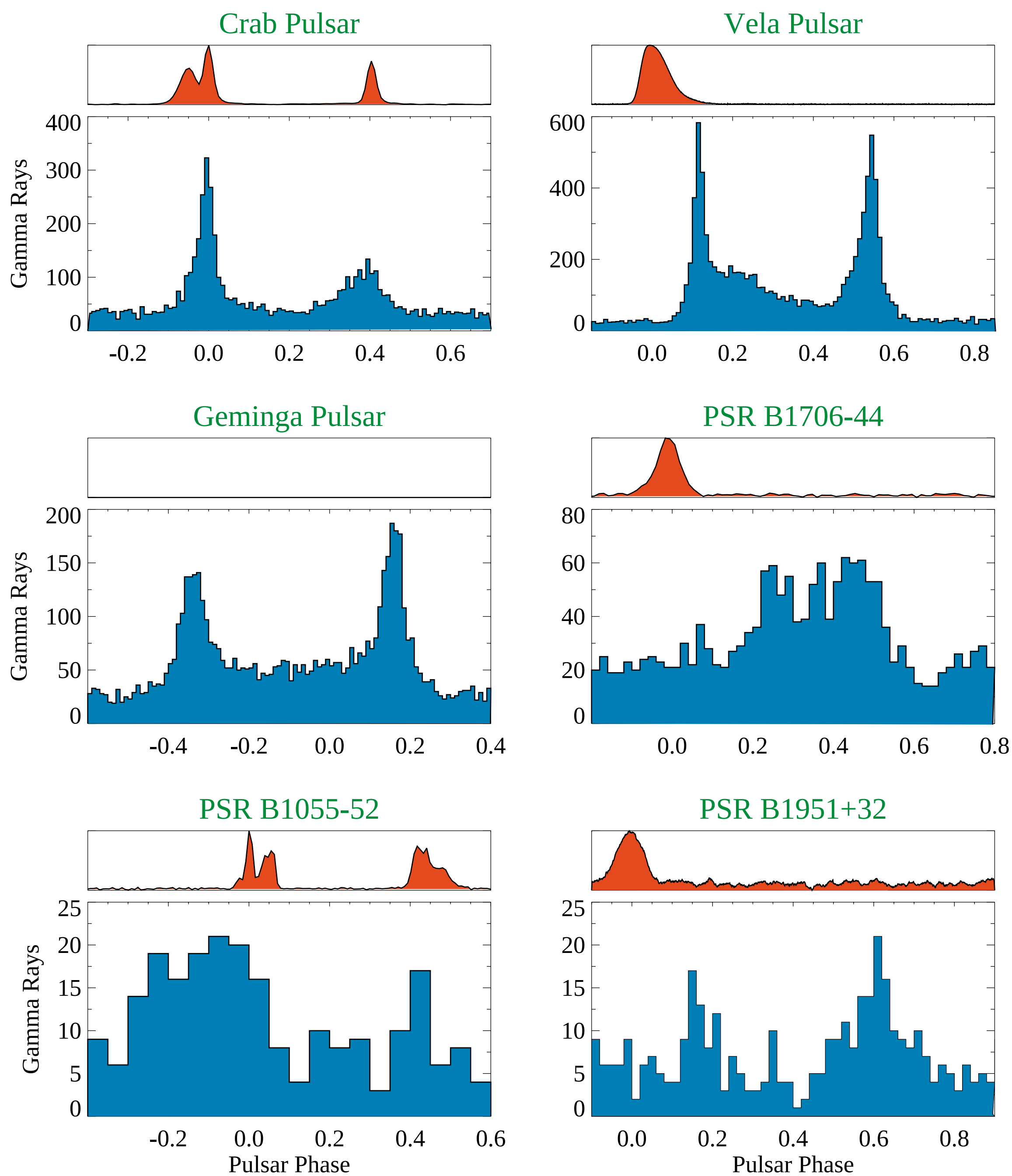
Two generic models for high-energy emission:

- Polar cap models: emission occurs in open field line region above magnetic pole (where radio emission occurs)
- Outer gap models: emission occurs in outer magnetosphere, through particle acceleration in charge-separated regions





Adapted from Thompson et al 1999



Adapted from thesis of J. M. Fierro

EGRET pulsar profiles compared with phase-aligned radio profiles

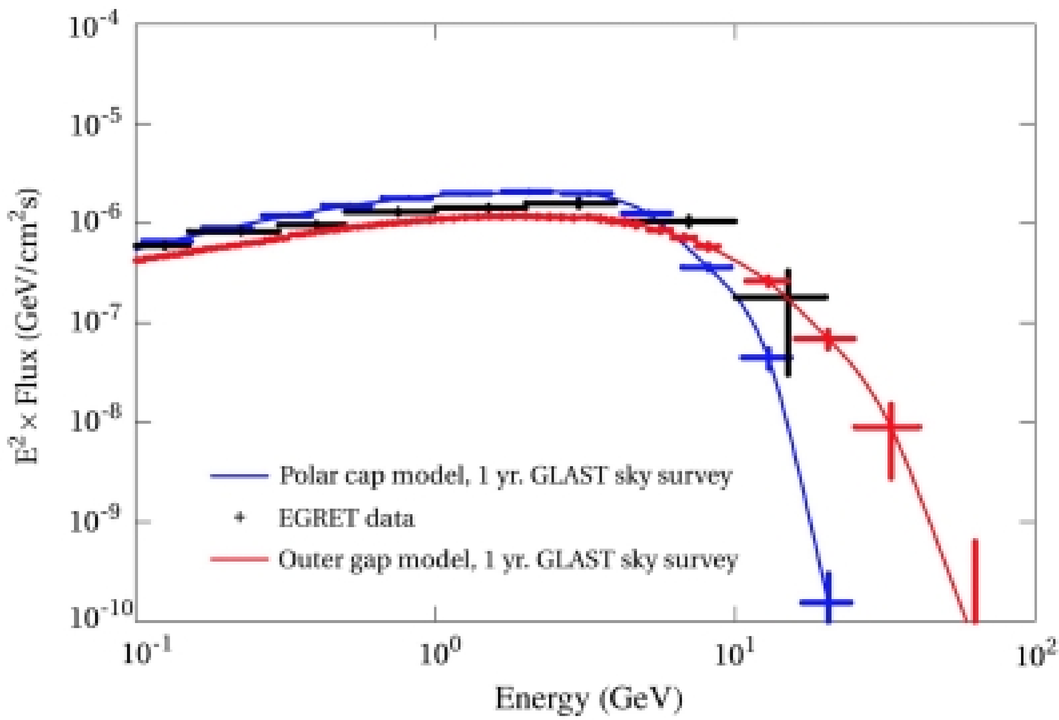
GLAST's Promise

Profile statistics:

GLAST will produce a large collection of gamma-ray lightcurves, which can be compared with radio profiles and prediction of models.

Spectra:

GLAST will test predictions of high-energy spectral breaks:



and will measure phase dependence of spectra, for detailed comparisons with models.

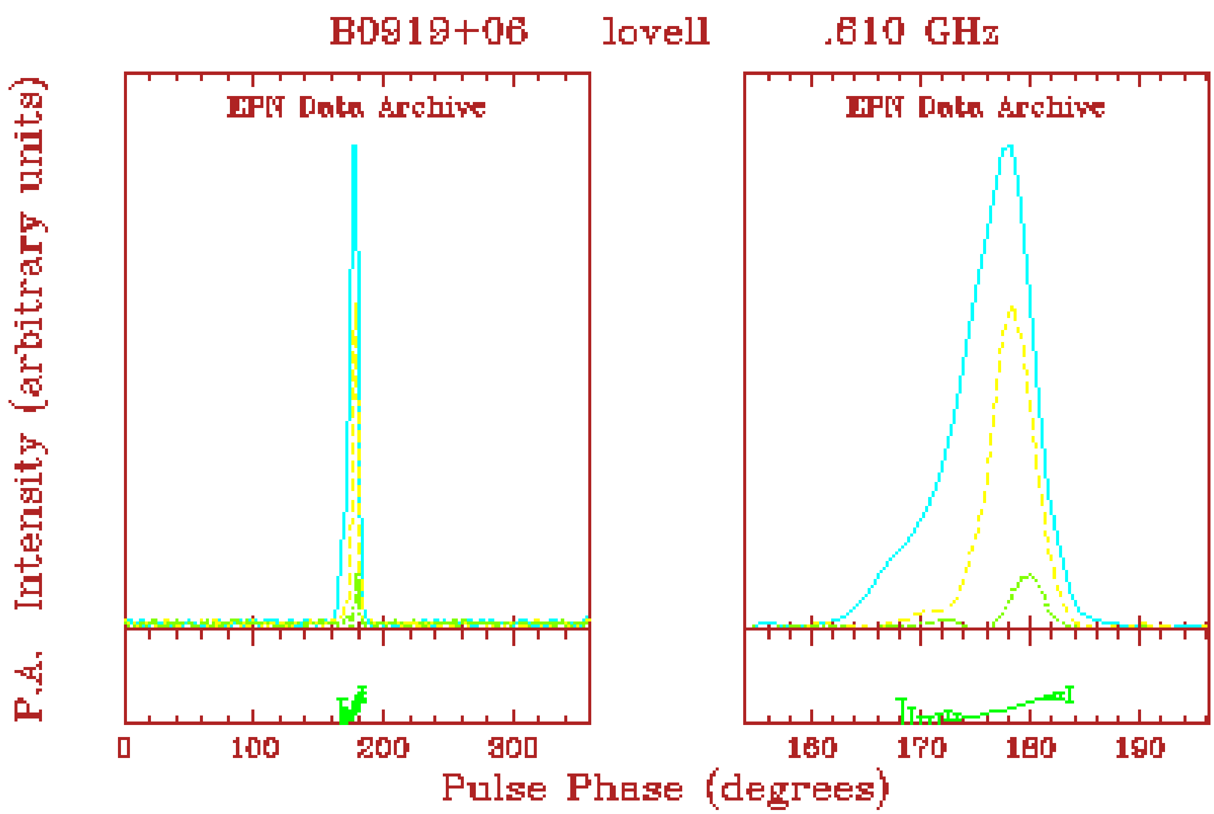
GLAST will also test, for example, Harding's prediction (in a polar cap model) that older pulsars will have higher gamma-ray efficiency.

Beaming Factors

The fraction of the sky illuminated by a pulsar beam is crucial for understanding:

- the pulsar density and birthrate
- and hence the minimum Type II SNe mass
- and testing galactic nucleosynthesis models

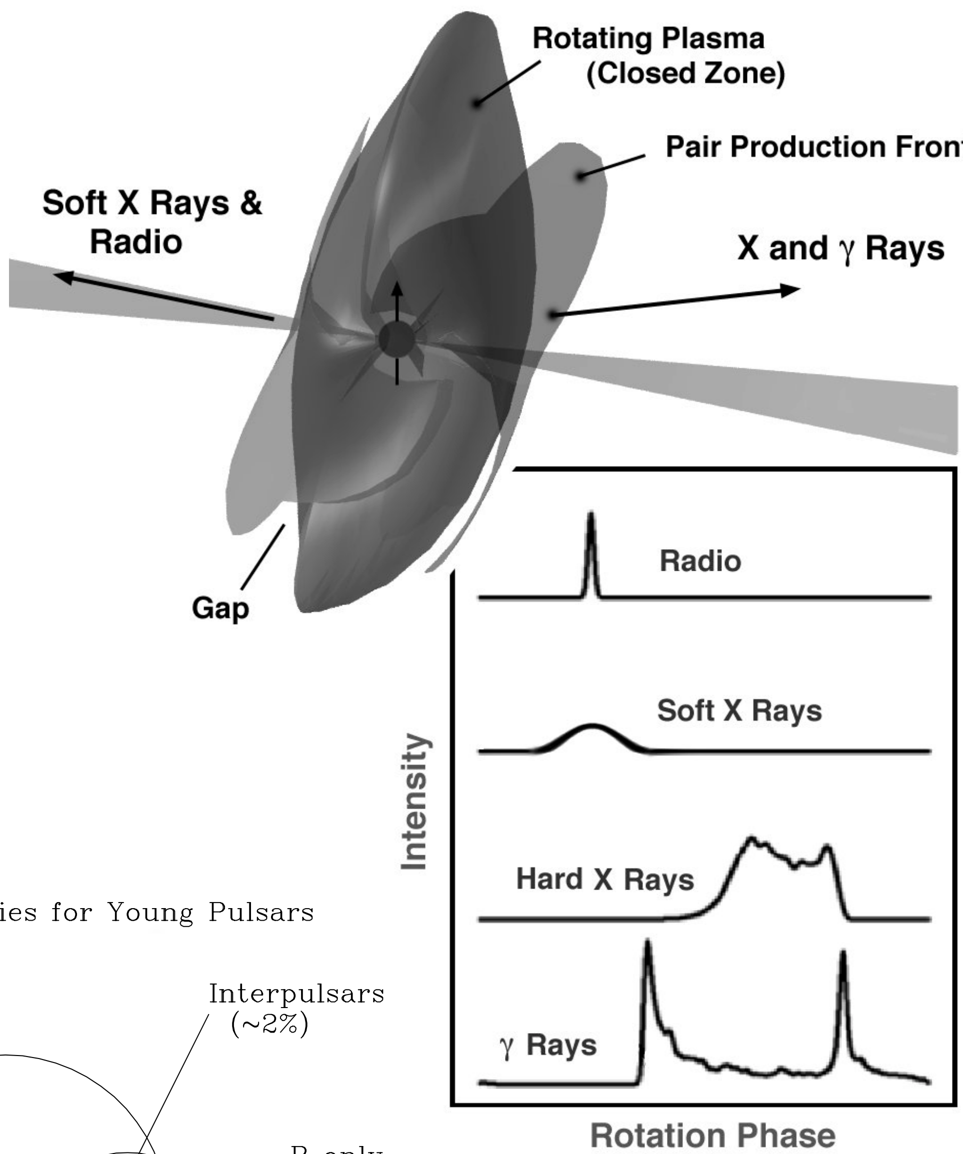
Radio pulsar beam sizes and shapes are poorly determined, but beaming factors are probably small:



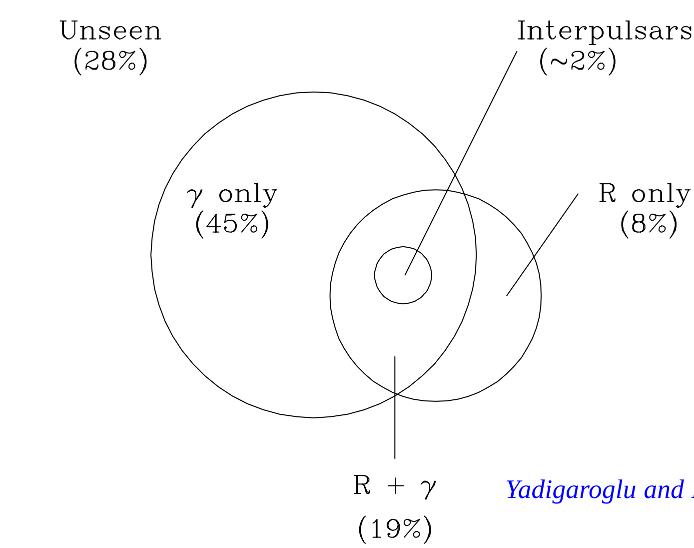
Gamma-Ray Beams

...are probably much larger than radio beams...

Theory



Detection Probablilities for Young Pulsars



Yadigaroglu and Romani 1995

Geminga (and others?)

Observations

Geminga is observed as a gamma-ray (and X-ray/optical) pulsar, but (probably) not as a radio pulsar. Outside radio beam?

Geminga is closest gamma-ray pulsar to Earth, suggesting that radio quiet pulsars may be very common.

Promise of *GLAST*

Even with *GLAST*, only the brightest sources might have enough photons to directly search for periodicities.

GLAST positions of unidentified sources can be passed to *Constellation* or other X-ray telescopes for period searches.

Comparison of large *GLAST* pulsar profile sample will allow indirect comparison of radio and gamma-ray beaming fractions.

GLAST and the Radio Pulsar Community

Pulsar parameters:

- Positions and spin parameters are needed to fold GLAST photons.
- Absolute phase measurements are needed to study profile alignment and geometry.
- Radio parameters help prioritize objects for GO observations.

Pulsar ephemerides:

- For young, noisy pulsars, contemporaneous radio observations are needed to track pulse phase and allow long-term photon folding.
- Because it is impossible to monitor all radio pulsars, radio observations must target high priority pulsars and coordinate as needed (when possible) with guest observers.

Pulsar expertise:

- Radio community has experience with absolute timekeeping at the submicrosecond levels required for GLAST.

IDS Proposal

Preflight:

- Prepare new radio pulsar catalog
- Define FITS catalog format
- Develop web query system

- Identify high priority observations to fill in catalog information
- Coordinate observations with non-US (especially southern hemisphere) observers

- SWG and E/PO activities

First post-launch year:

- Pulsar data verification activities with instrument team
- Radio observations of key pulsars for high-precision ephemerides
- Analysis of *GLAST* sky survey data, to produce high-quality phase-resolved gamma-ray spectra of the eight known gamma-ray pulsars

- Continued SWG and E/PO activities

Later years:

- Continued radio observations for ephemerides
- Coordinated radio work with GO investigators

- Continued SWG and E/PO activities