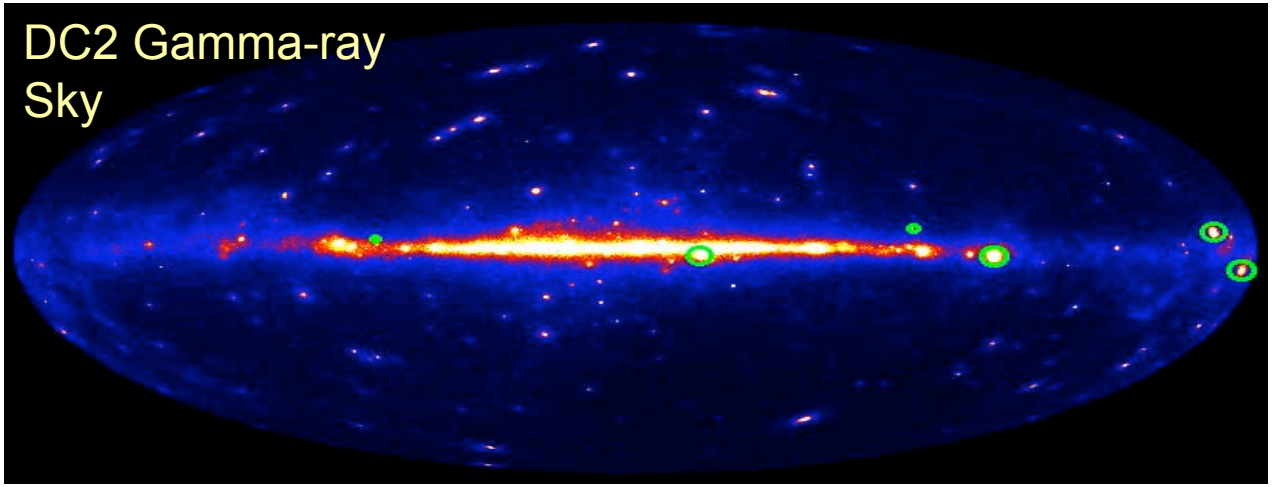


GeV Emission from Pulsars

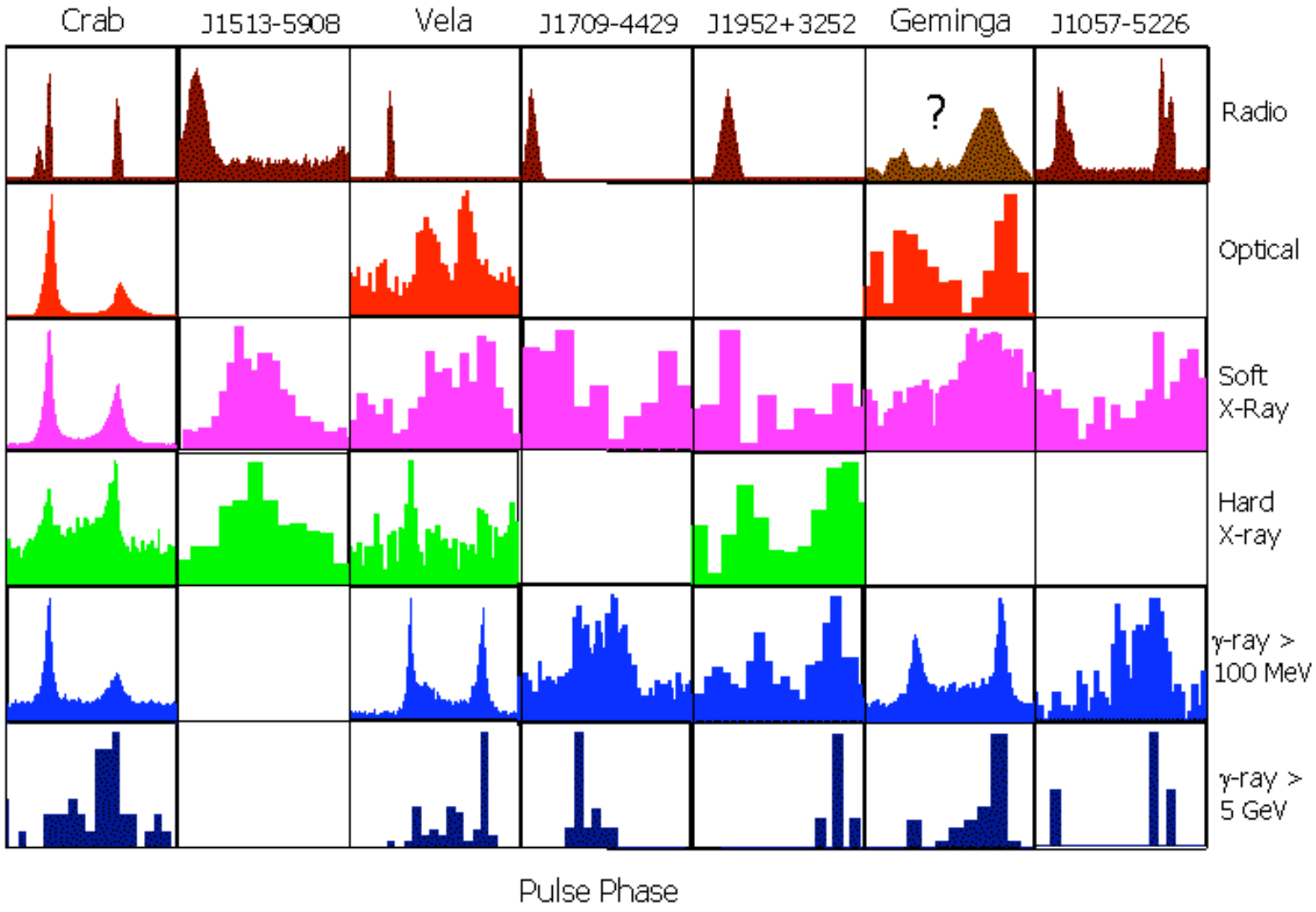
Zaven Arzoumanian
CRESST/GSFC

[channeling Alice Harding, Dave Thompson,
and others]

Why do we care?

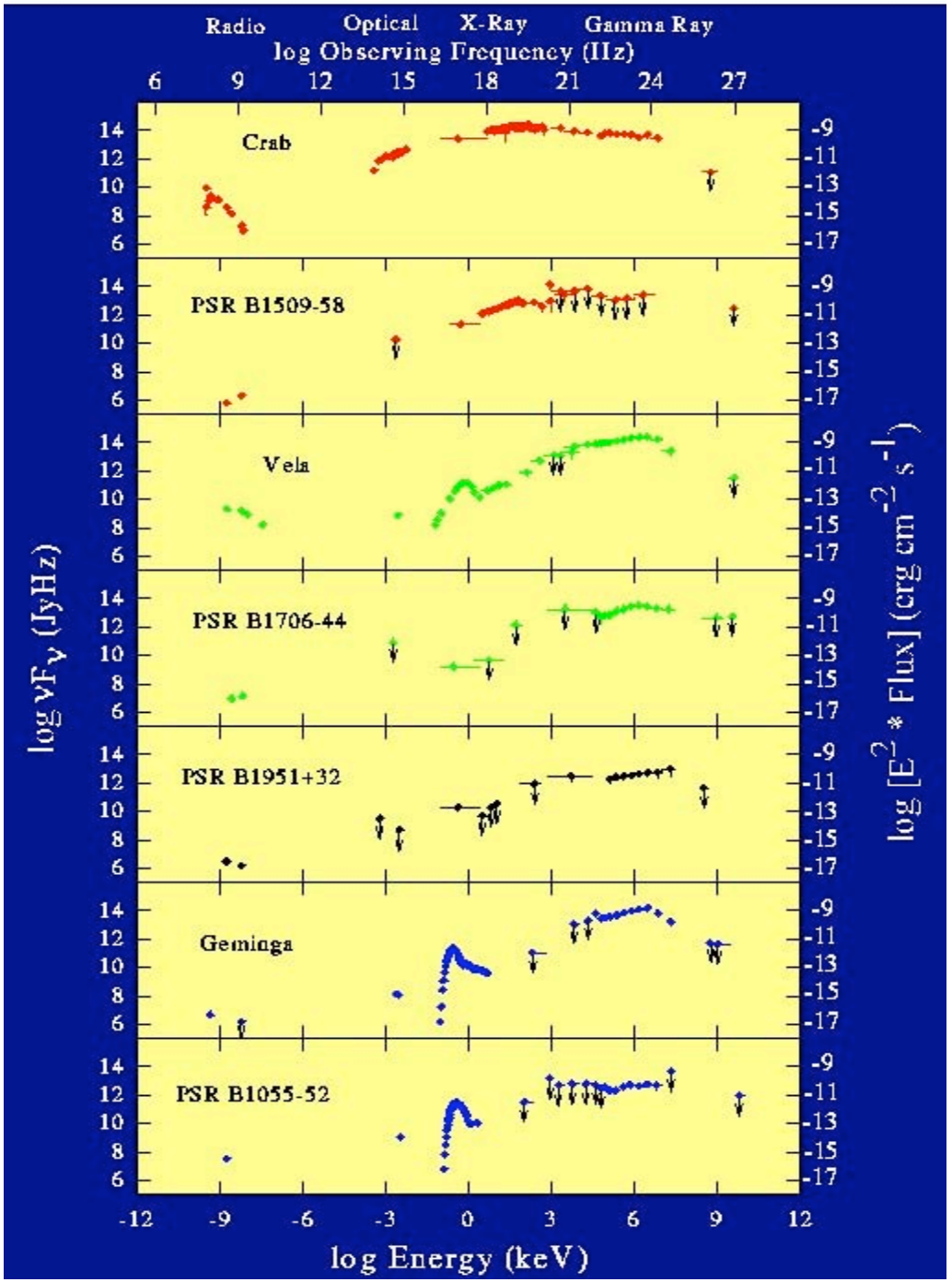
- Gamma-rays trace properties of the highest-energy particles ⇒ probe the acceleration mechanism. In most cases, *lion's share of luminosity is in gamma-rays*. Particles go on to sculpt the surrounding medium.
- Explore how particles interact with the extreme environment: strong magnetic and electric fields, frame-dragging gravity, high currents, etc.
- What roles do neutron star properties (temperature, magnetic configuration) and viewing geometry (light-bending, aberration) play in the observed radiation?
- *Handful of pulsed detections by EGRET have had an inordinate impact on our understanding of neutron star magnetospheres.*

Multiwavelength profiles of γ-ray pulsars

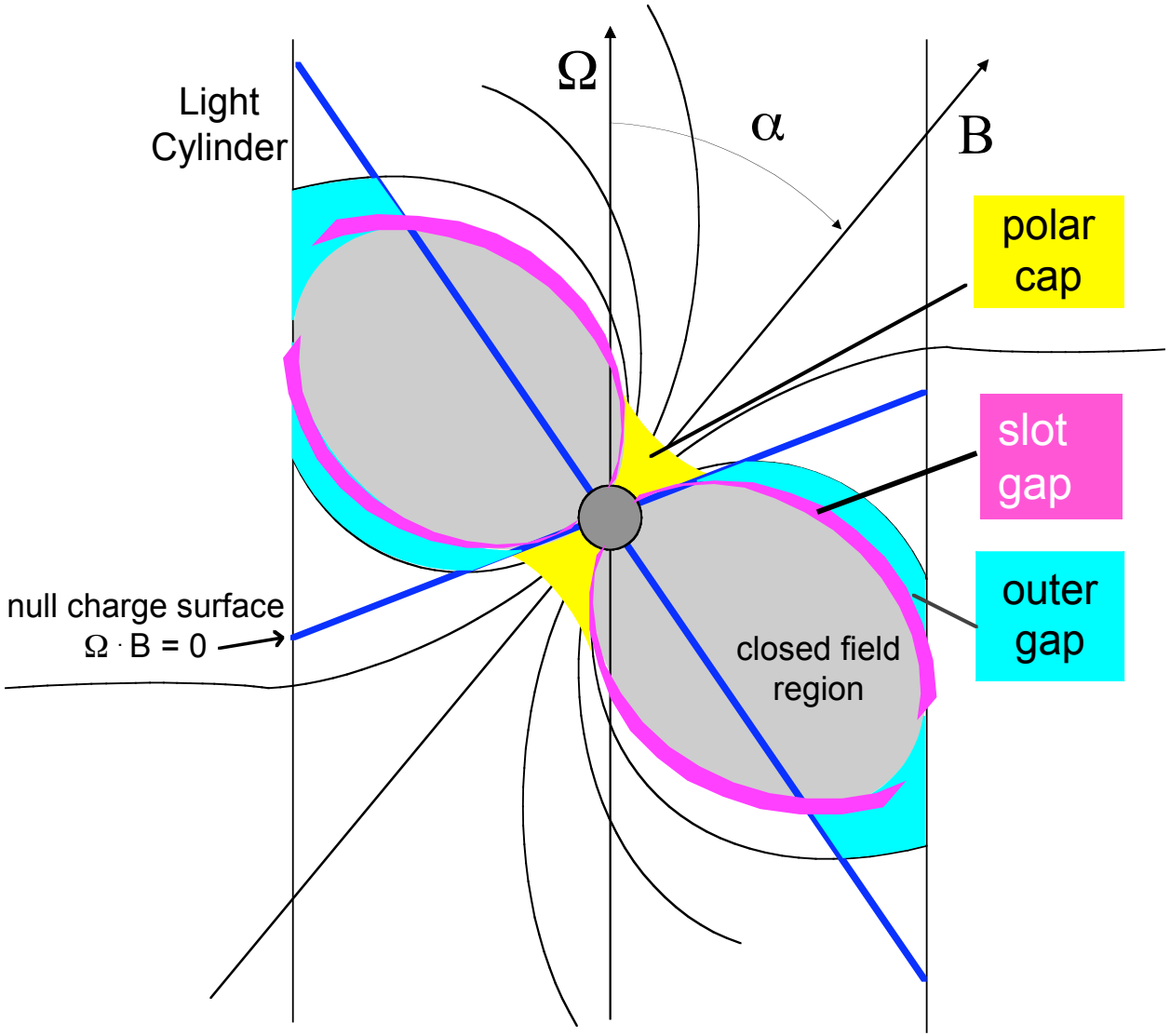


Broad-band spectra

- Power peaked in γ-rays
- No pulsations detected above 20 GeV
- High-energy turnover
- Increase in hardness with age
- Thermal component appears in older pulsars



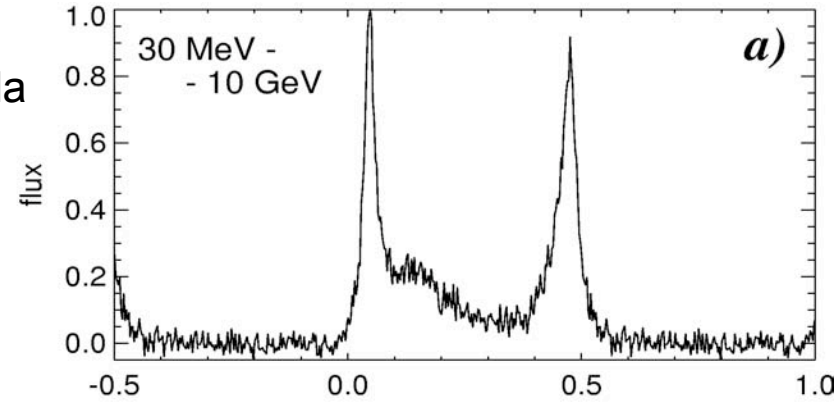
High-energy emission models



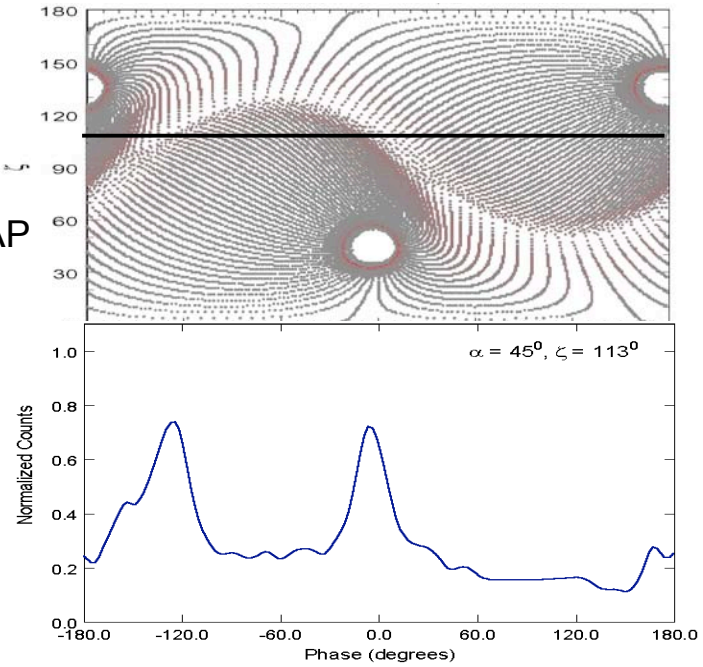
- Different processes can accelerate particles in the magnetosphere
- Pair-creation cascades, interactions with thermal surface photons likely
- Different beaming solid angles, spectral properties

Model light-curves

Vela

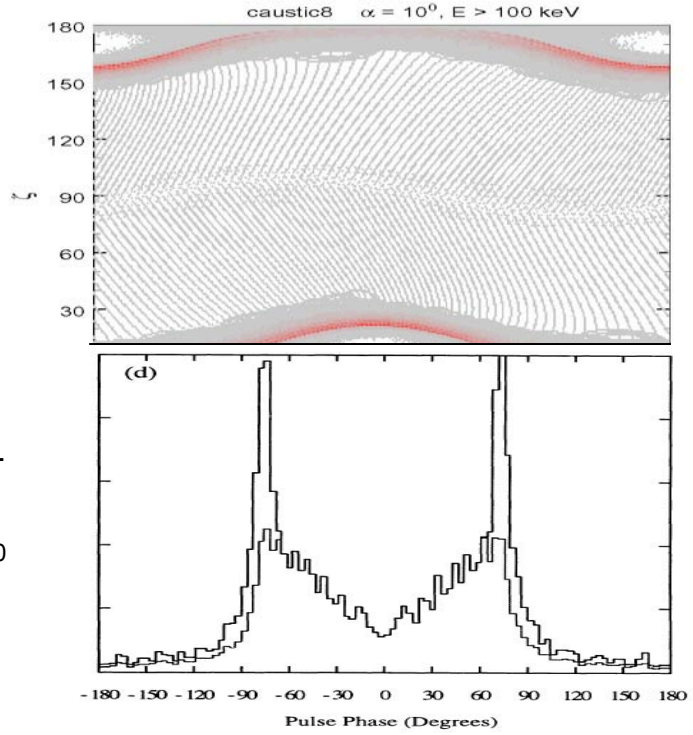


SLOT GAP MODEL
$\alpha = 45^0$,
$\zeta_{obs} = 113^0$

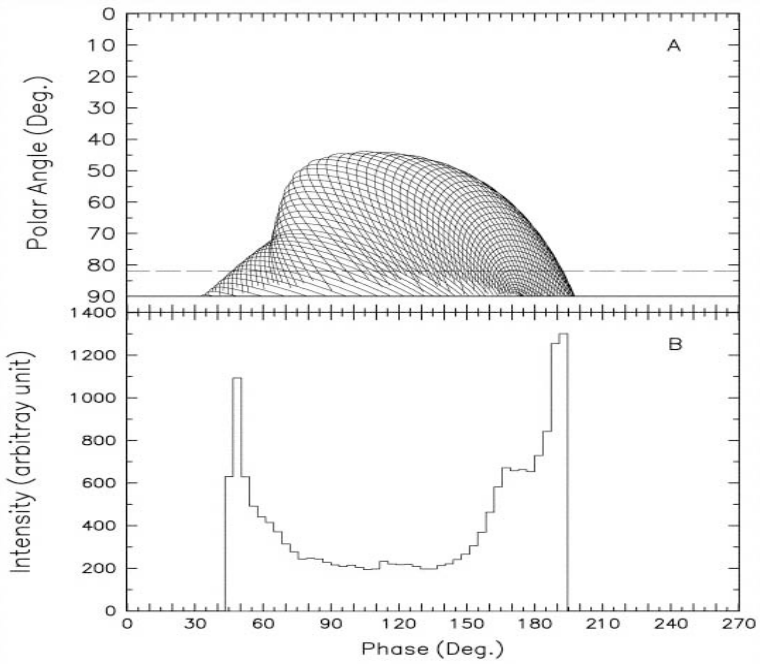


POLAR CAP MODEL

$\alpha = 10^0$,
$\zeta_{obs} = 16^0$



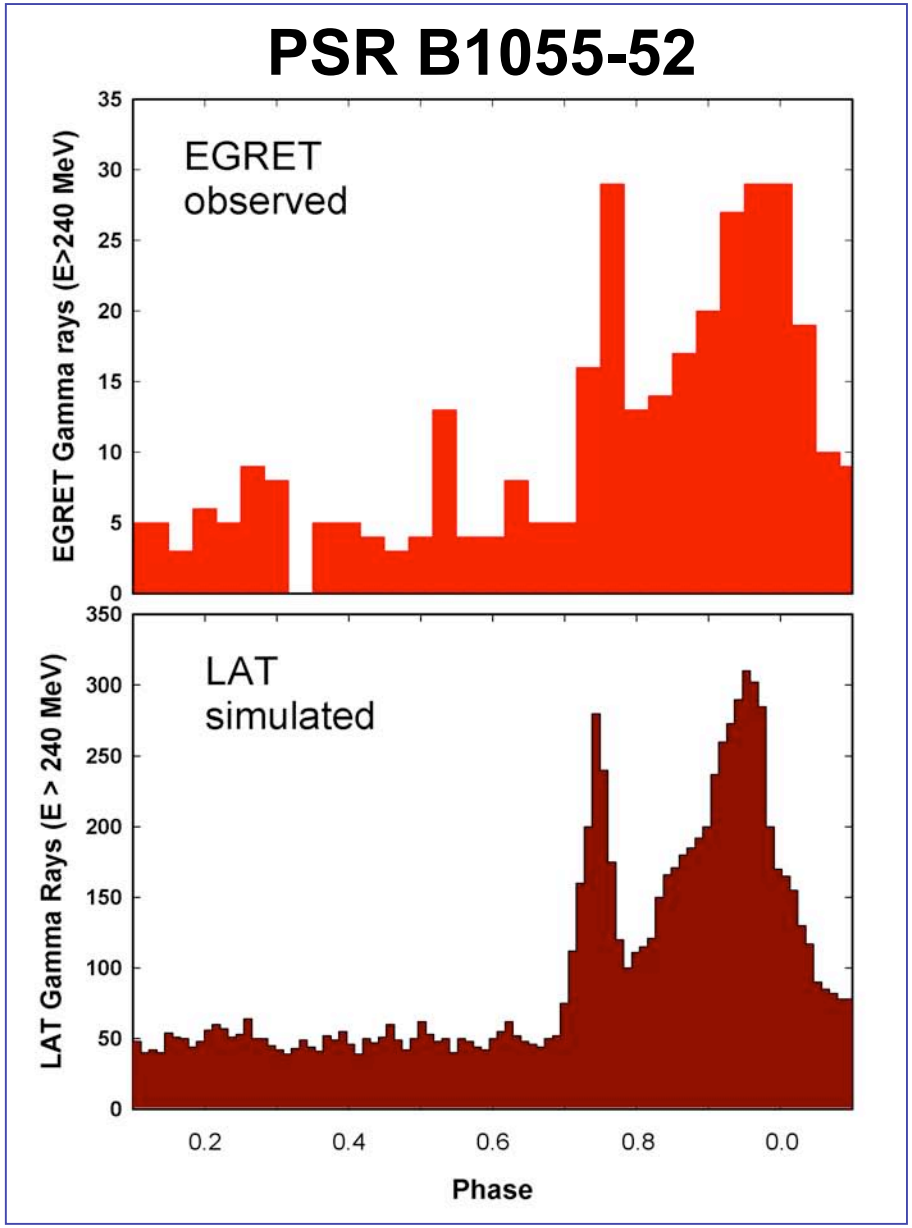
OUTER GAP MODEL
$\alpha = 65^0$,
$\zeta_{obs} = 82^0$



Pulse Profiles

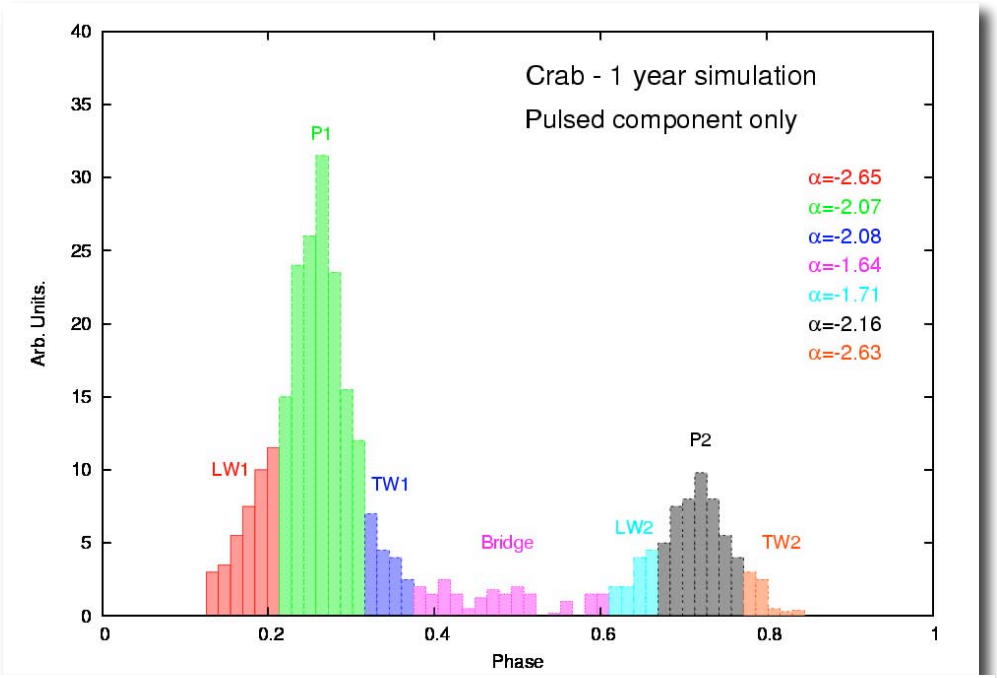
Photon-counting limited: EGRET provided insufficient statistics to compare models. In 2 years, LAT will provide 25-30 times as many photons.

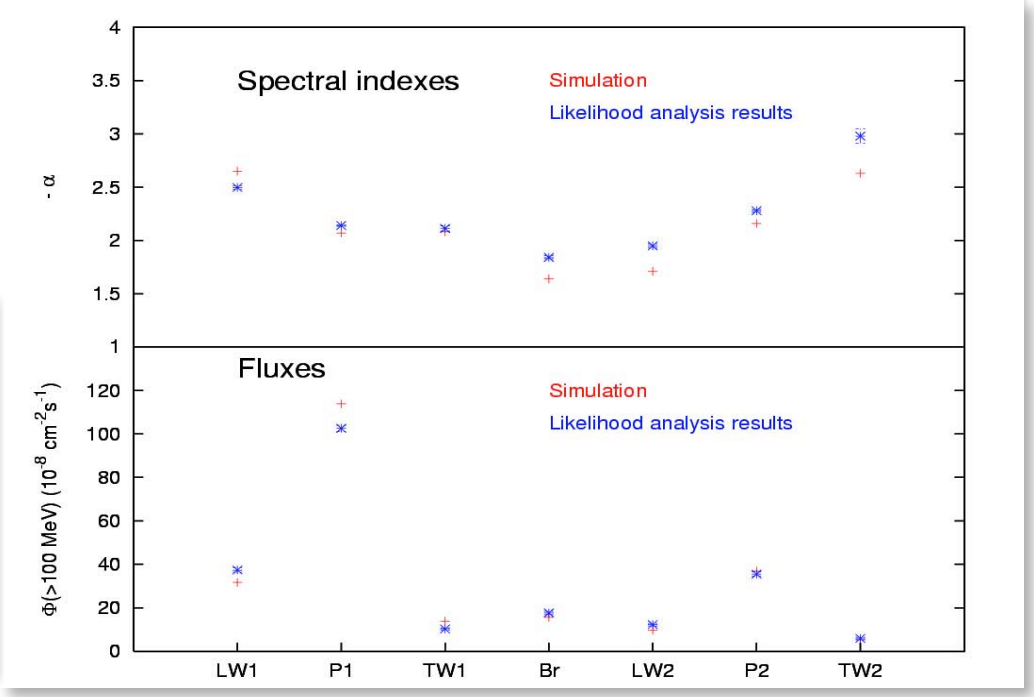
- Pulse shapes, peak separations, phase relations to other wave-lengths test models
- Sensitive to possible microstructure and off-pulse emission
- Probe to 5 times greater distances



Phase-resolved spectroscopy

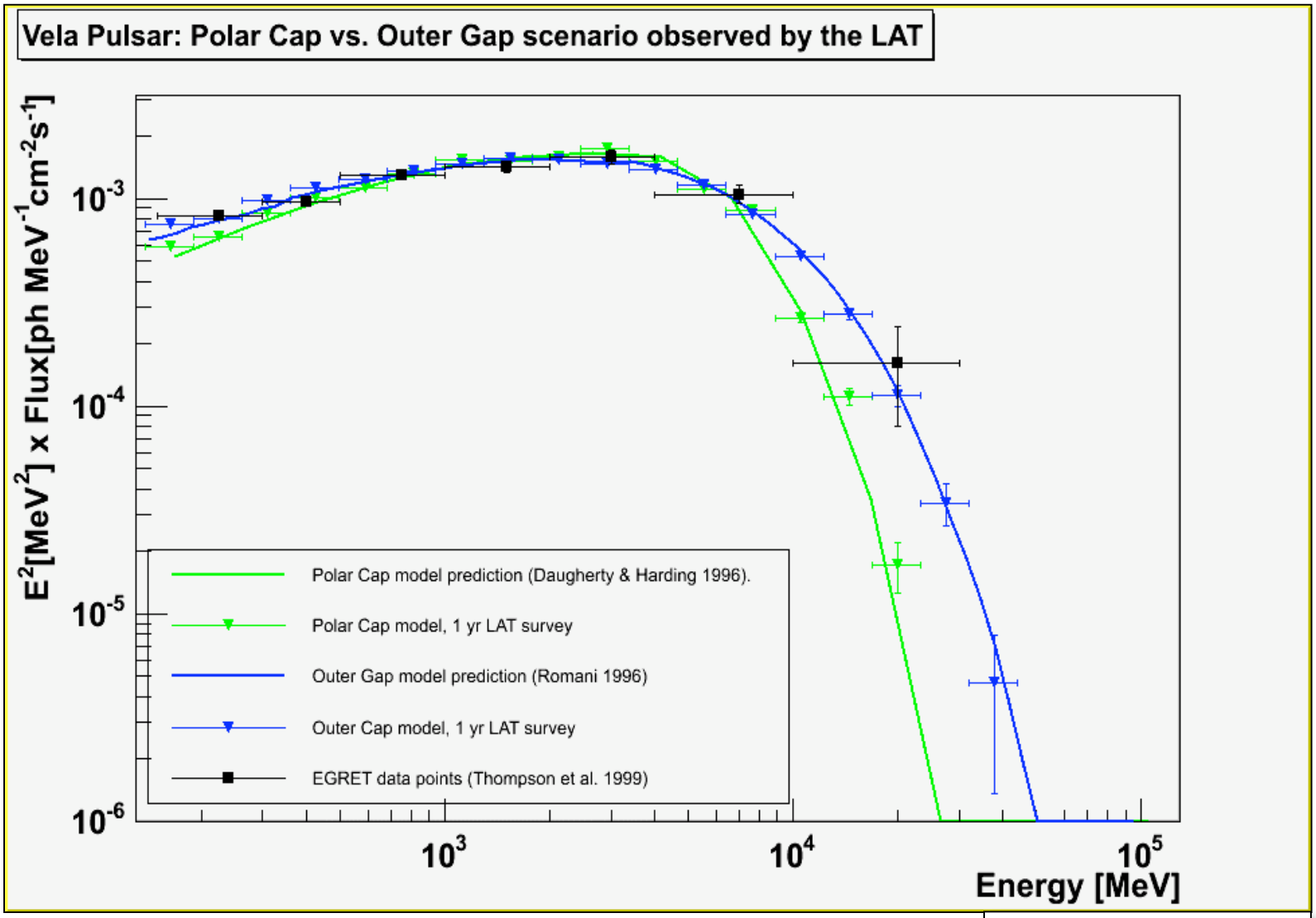
Measurement of spectral properties as a function of pulse phase (currently limited by large uncertainties) will provide important diagnostics of emission physics.





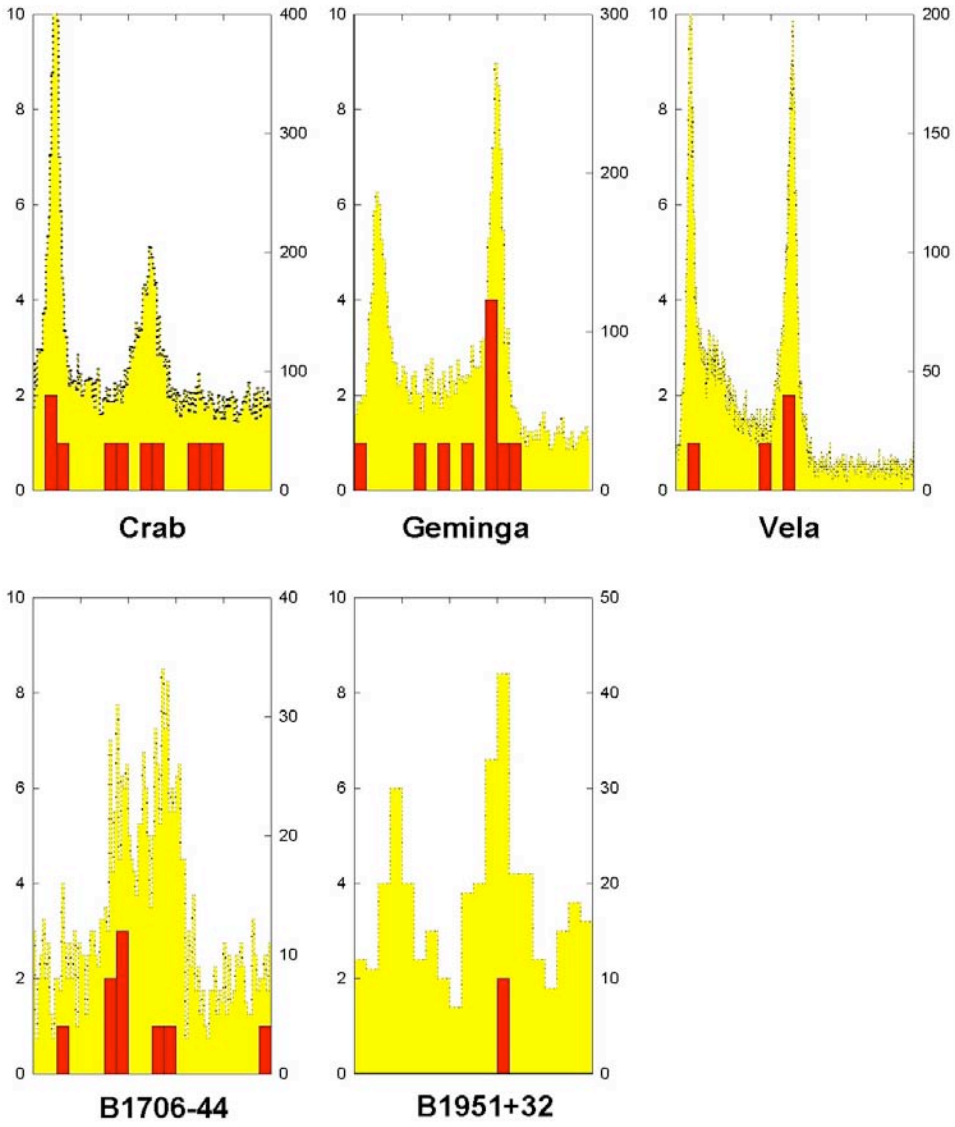
One year LAT simulation of the Crab pulsar, including sky background, and spectral indices in various phase ranges. *Top:* Input profile. *Bottom:* Results from a likelihood analysis for the spectral index and flux in the same phase ranges. *(Courtesy T. Reposeur)*

Spectral Cutoffs



Courtesy M. Razzano

Pulsars at GeV energies

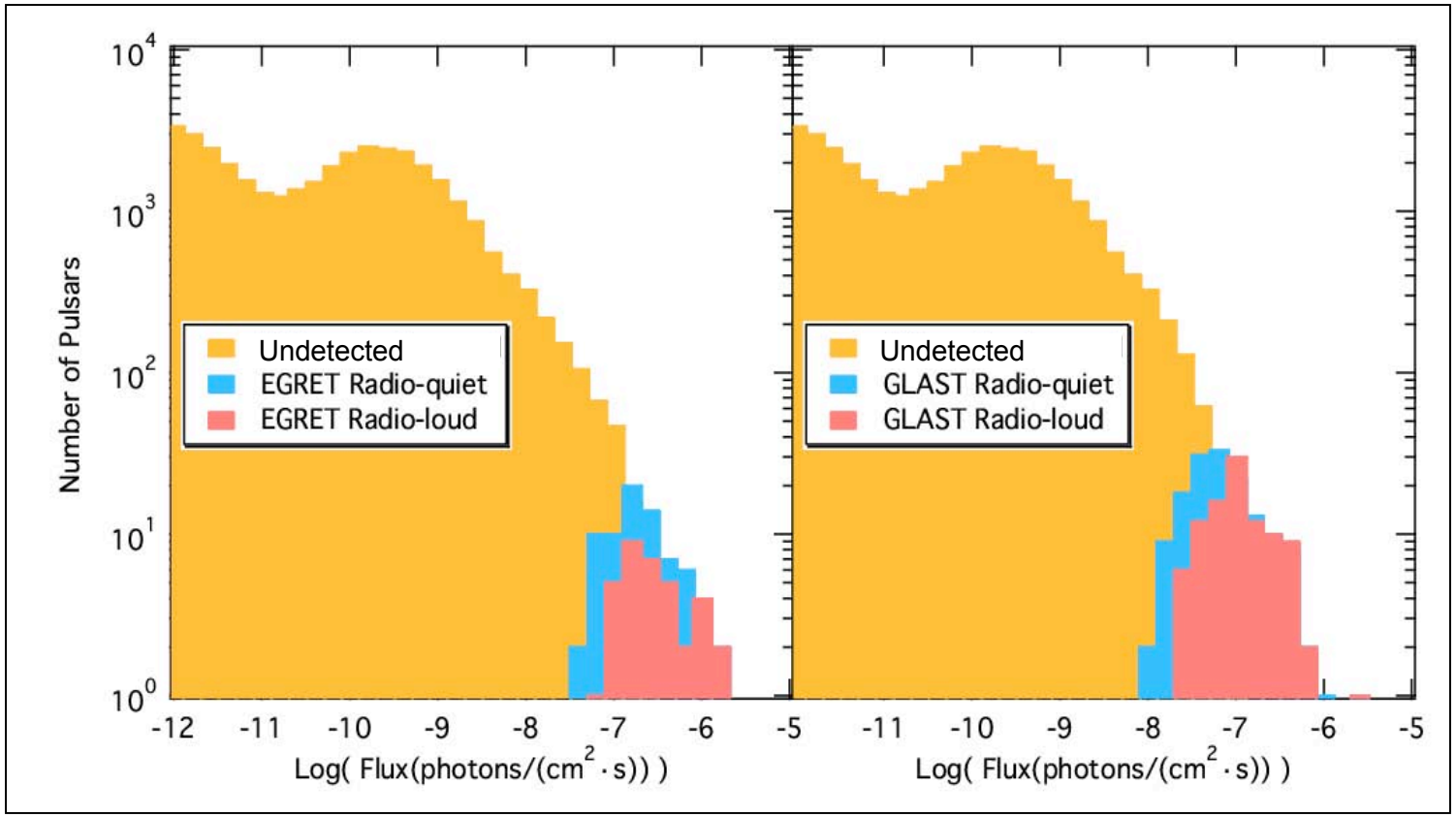


No pulsed emission seen at TeV energies. Spectral gap between EGRET and Cerenkov telescopes is important for constraining emission models. GLAST will close this gap.

Above 10 GeV, LAT is at least 100 times more sensitive than EGRET.

Instead of the handful of photons seen by EGRET (red bars), LAT will see hundreds of photons at these energies.

How many pulsars will GLAST detect?



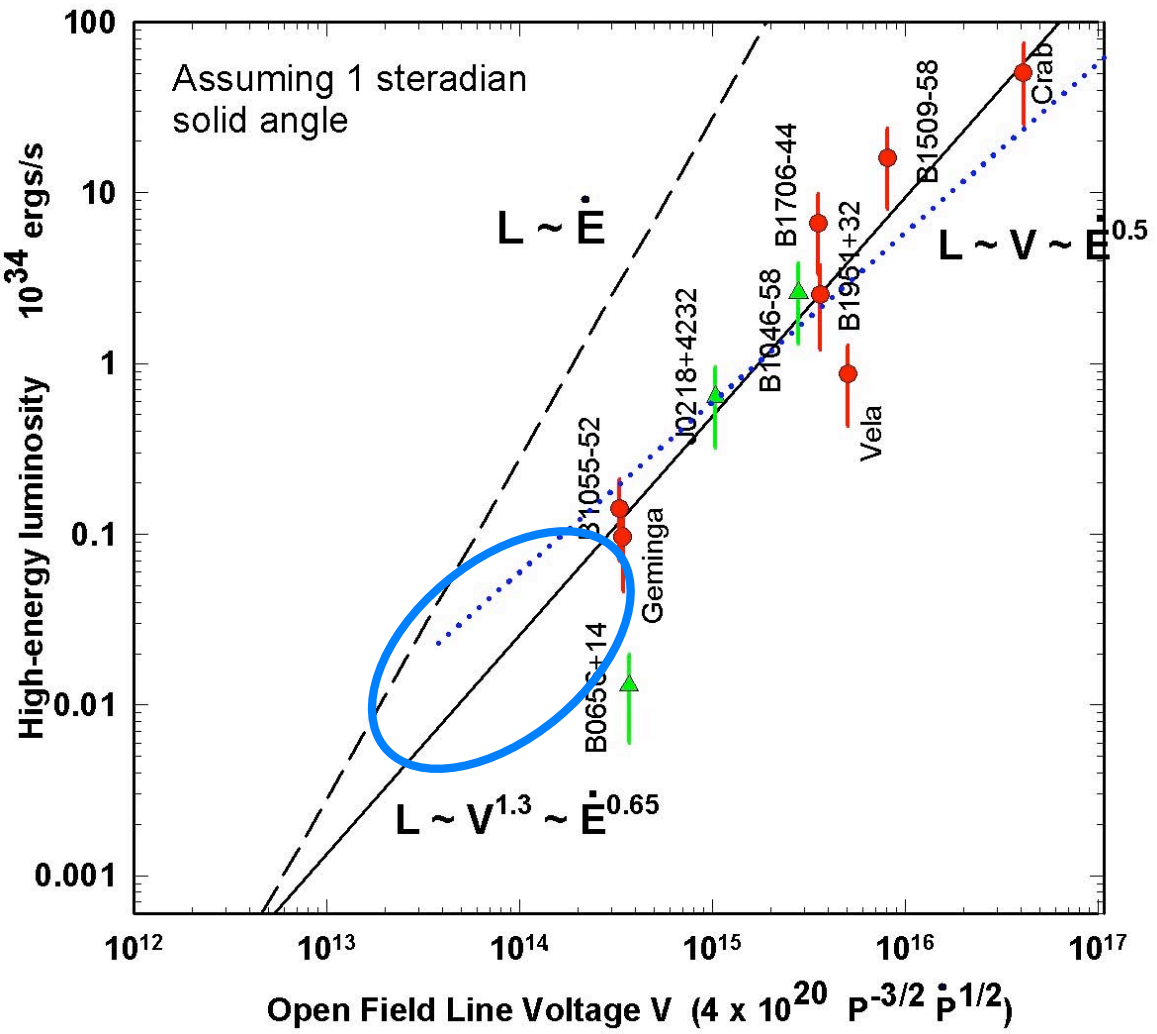
Population synthesis predicts several hundred in 1 year.
Relative numbers of radio-loud/quiet are model-sensitive.
LAT will allow blind periodicity searches of brightest unID-ed EGRET sources.

Luminosity vs. Voltage

Does trend measured by EGRET hold for other pulsars?

What happens as observed luminosity approaches total spin-down luminosity?

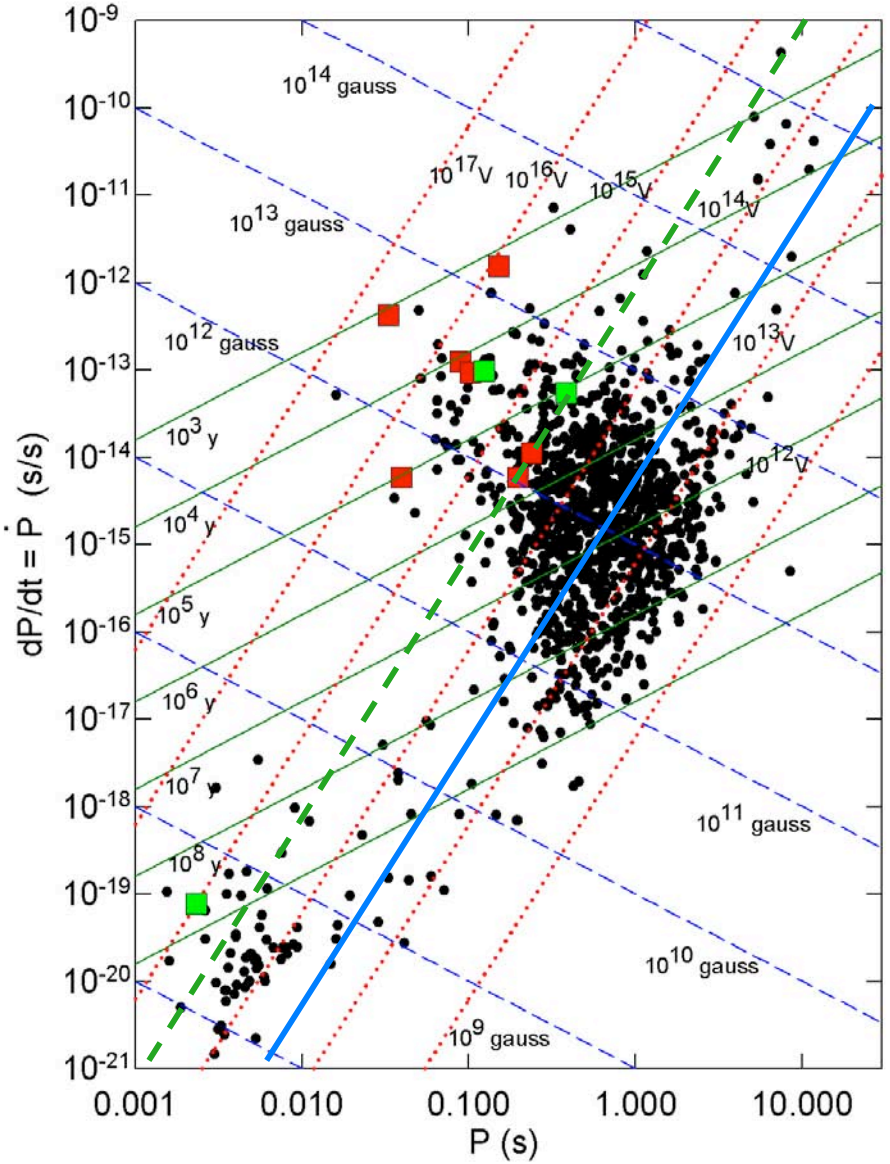
- ● High-confidence gamma-ray pulsars
- ▲ Lower-confidence gamma-ray pulsars



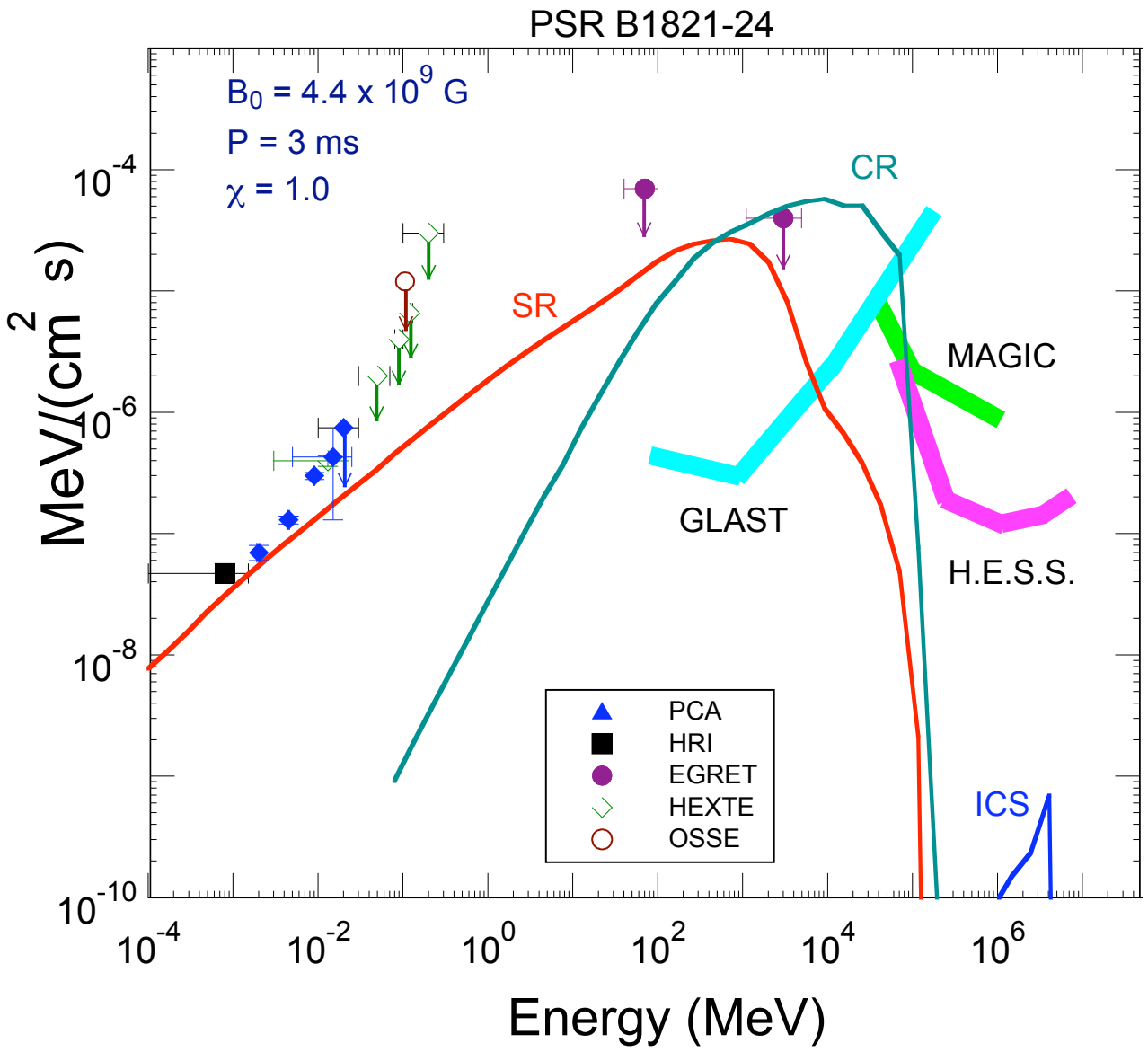
Pulsar Population

With LAT sensitivity, detection threshold moves well into the bulk of the pulsar population.

In particular, millisecond pulsars now lie almost entirely to the left of the line, in the potentially observable region, if this trend remains valid.

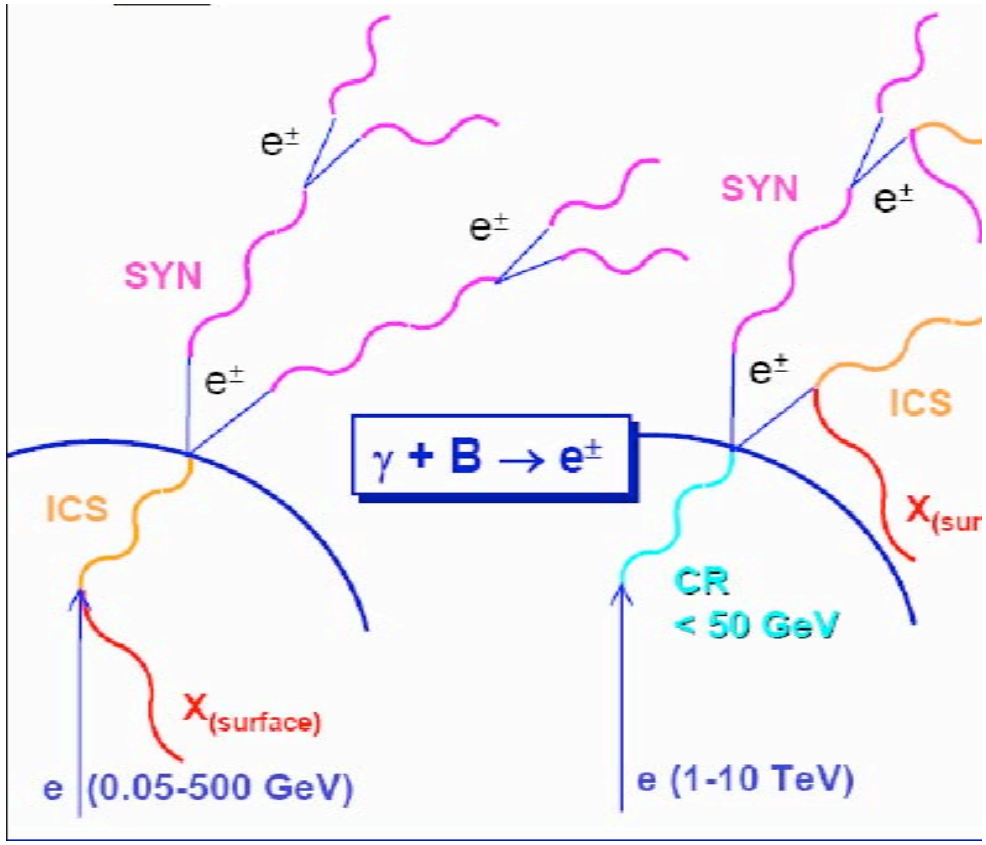


B1821-24: screened acceleration

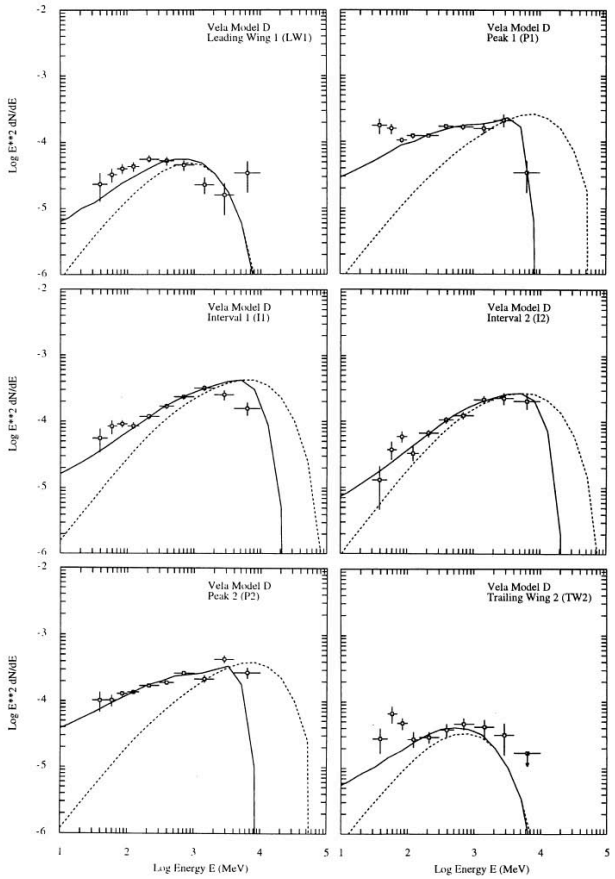


Polar cap models

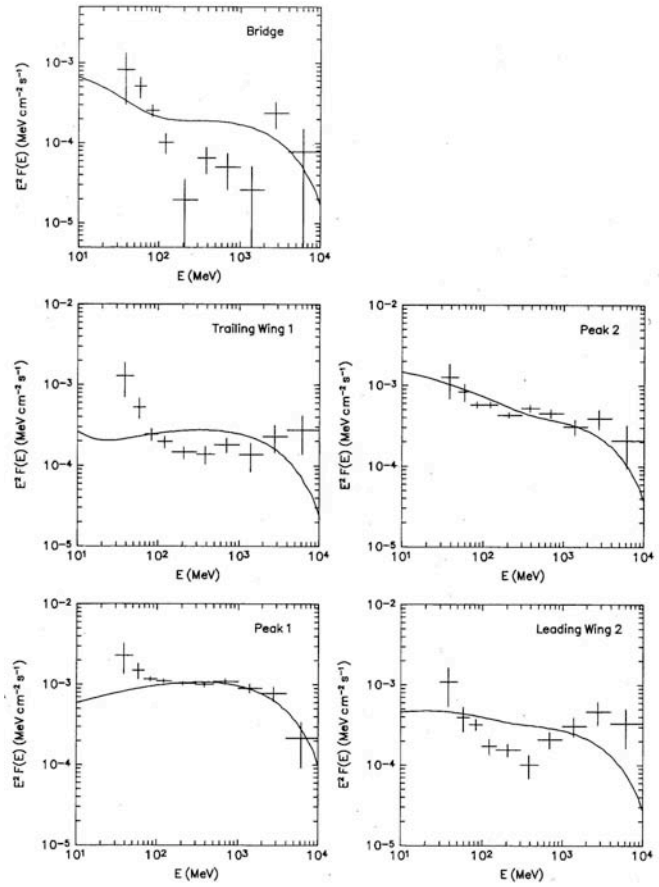
•Different processes can accelerate charged
particles above NS surface, depending on the
temperature of the NS surface (Space Charge
Limited Flow if T > Ti or Vacuum gap if viceversa);
•Accelerated charges initiate cascade at few
stellar radii above polar caps;
•The Curvature Radiation-induced cascades
are more stable and much important for highenergy
emission; IC is not stable;
•Gamma-ray absorption from magnetic-field induced pair production
•Recent update based on high-altitude Slot Gaps (1983)
Model predictions:
•Sharp cutoff (super-exponential due to photon absorption);
•Cutoff energy decreases with increasing B;
•Luminosity proportional to the current outflow from poles;
•Radio Quiet pulsars >> Radio Loud pulsars;



LAT Pulsar Science: Phase-Resolved Spectra

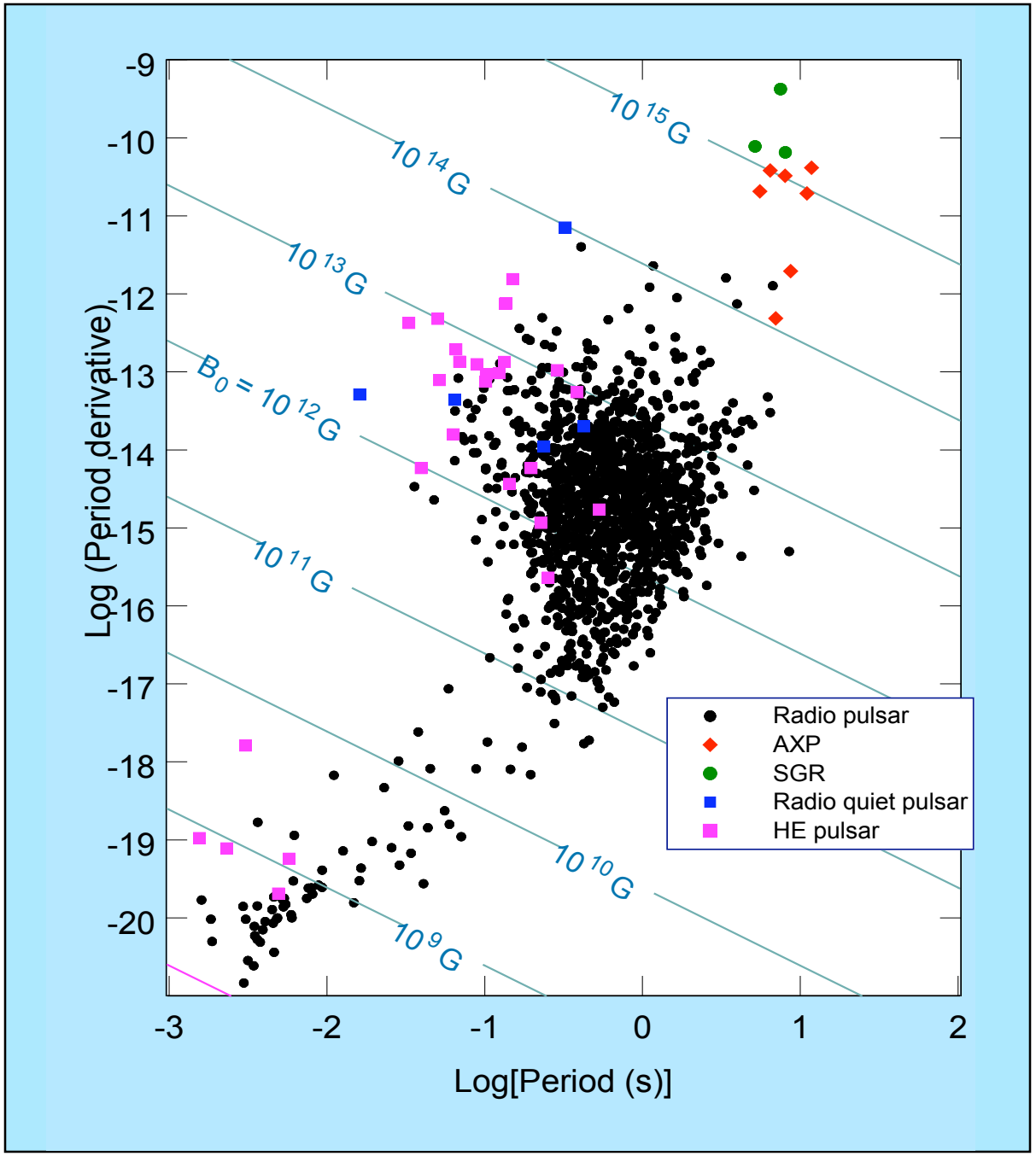


Left: Polar Cap model for Vela (Daugherty & Harding, 1996)
Right: Outer Gap model for Crab (Cheng, 2004)



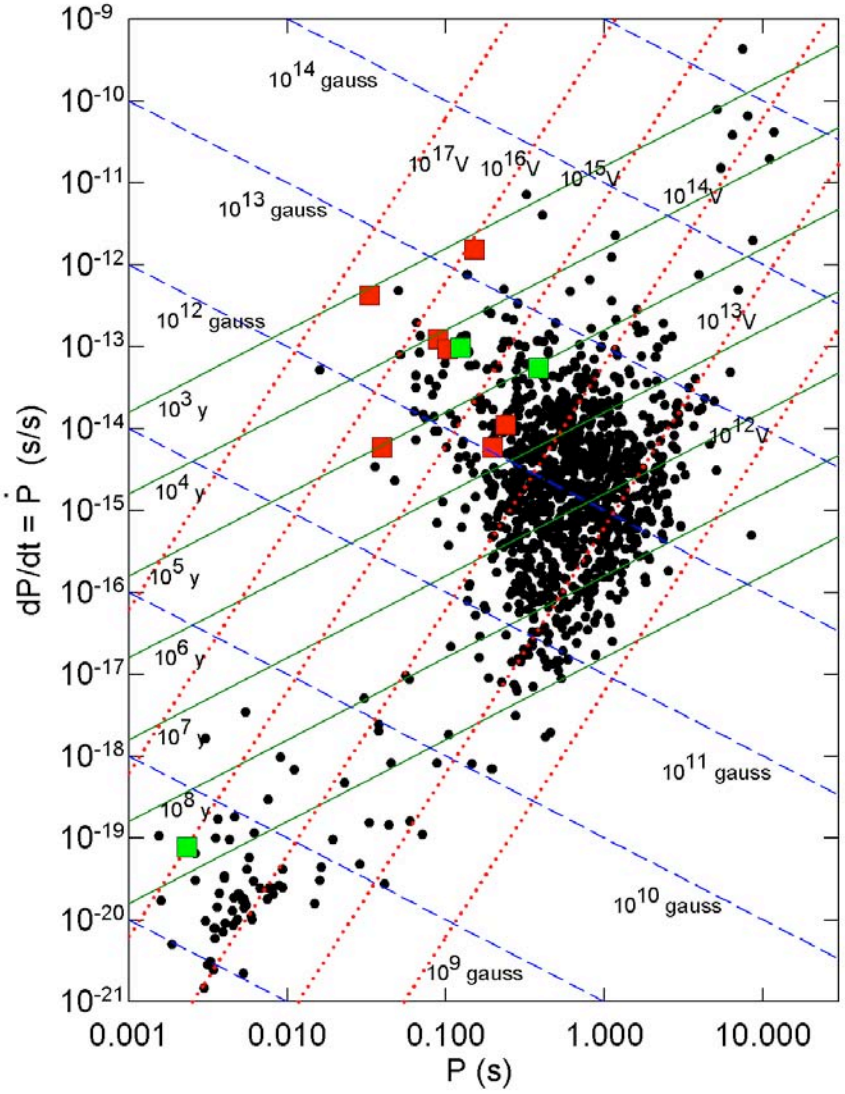
Models have calculated phase-resolved spectra for some gamma-ray pulsars. Comparison with the data is largely limited by the data uncertainties.

LAT will provide high-quality phase-resolved spectra for the bright pulsars, with error bars smaller than these by about a factor of five.

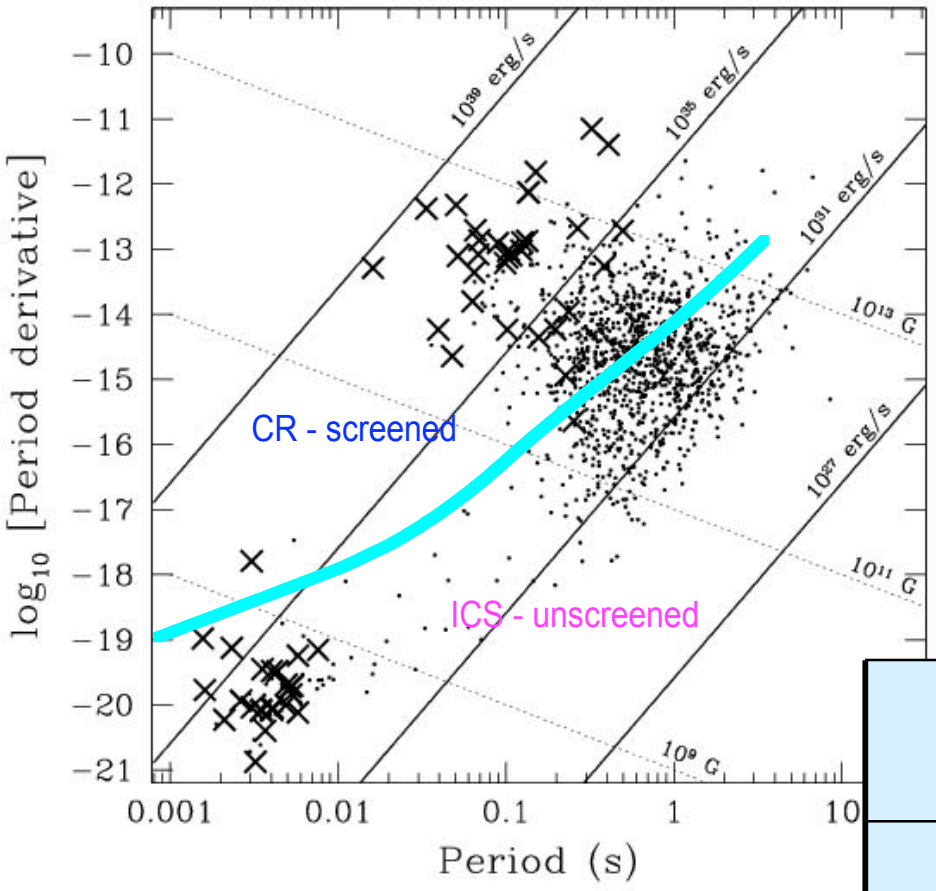


observations

- ~1700 radio pulsars
- ~10 γ-ray pulsars
- ~30 X-ray pulsars
- 7 AXPs
- 5 SGRs



Detections of MSPs at high energy



Most MSPs have unscreened acceleration

	Radio	X-ray pulsed	X-ray steady	γ-ray
Normal pulsars	1400	16	12	8
Millisecond pulsars	>100	6	20	1