Gamma-Ray Pulsars: EGRET Results and Unanswered Questions

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Outline

What Did We Learn from EGRET?

How many gamma-ray pulsars?

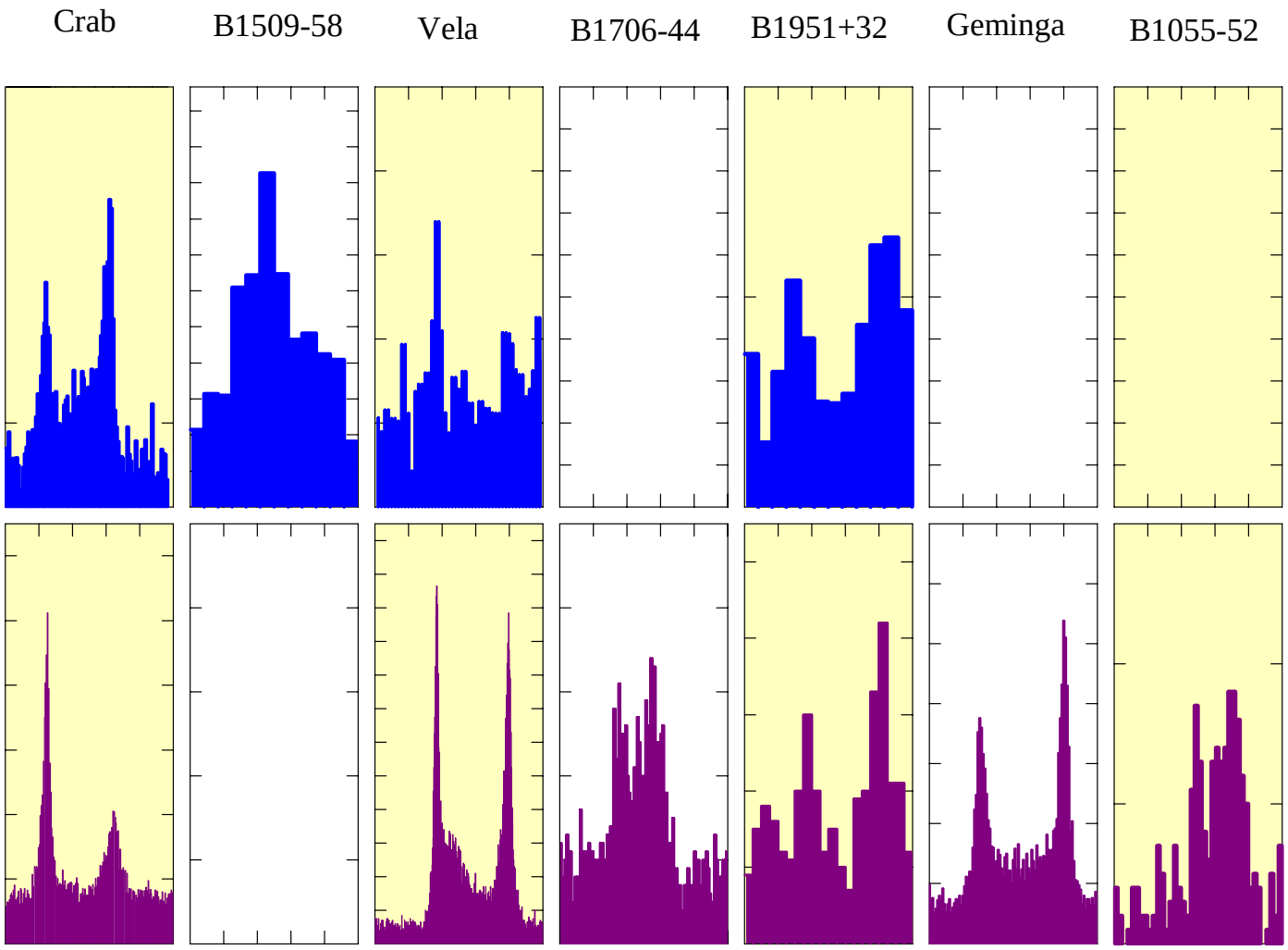
What are their characteristics?

Some Unanswered Questions

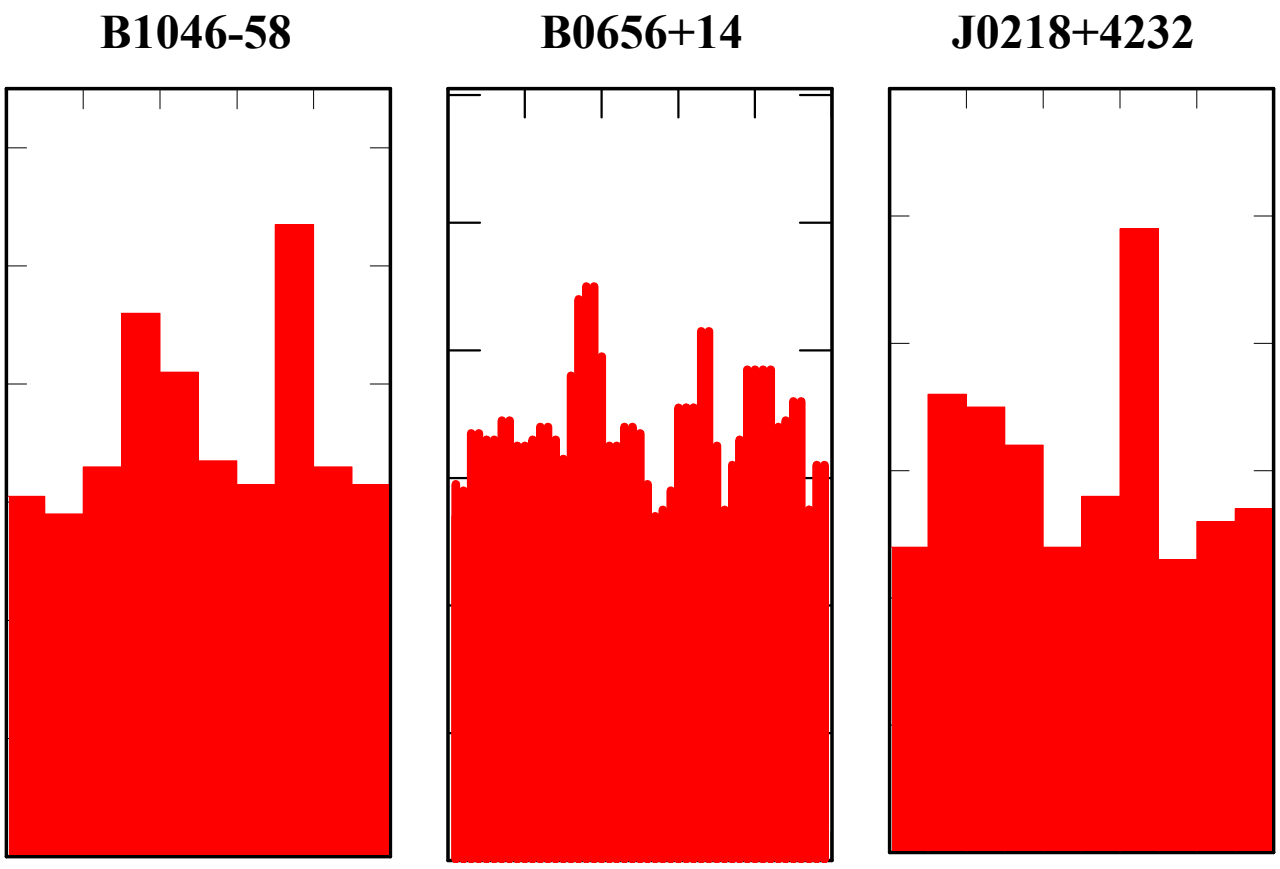
Why does each gamma-ray pulsar seem to have unique features?

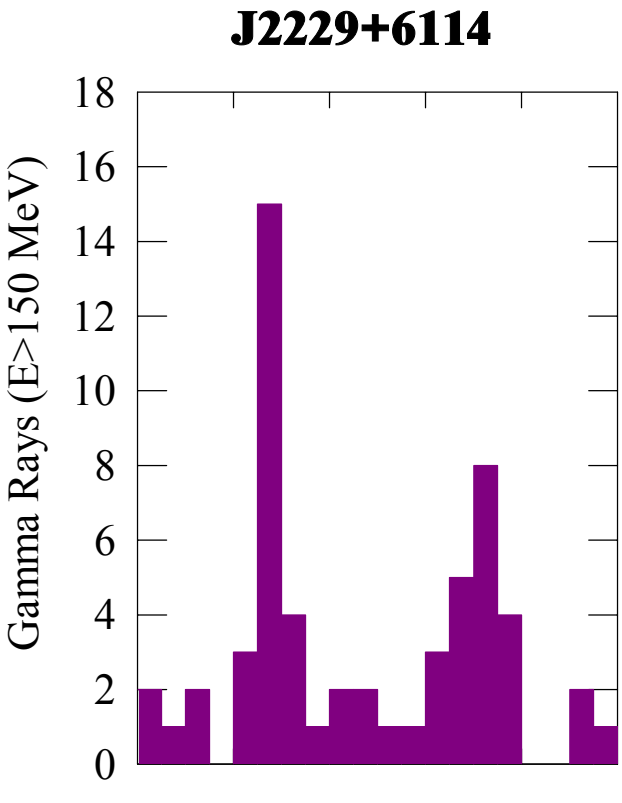
What is happening at the highest energies?

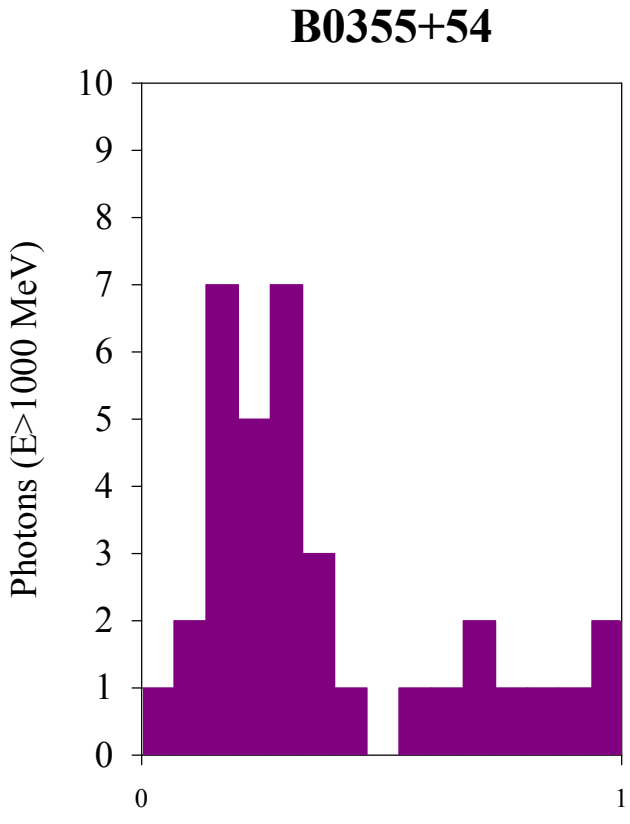
Basic theme: with so few gamma-ray pulsars, we need solid theoretical predictions to test with GLAST

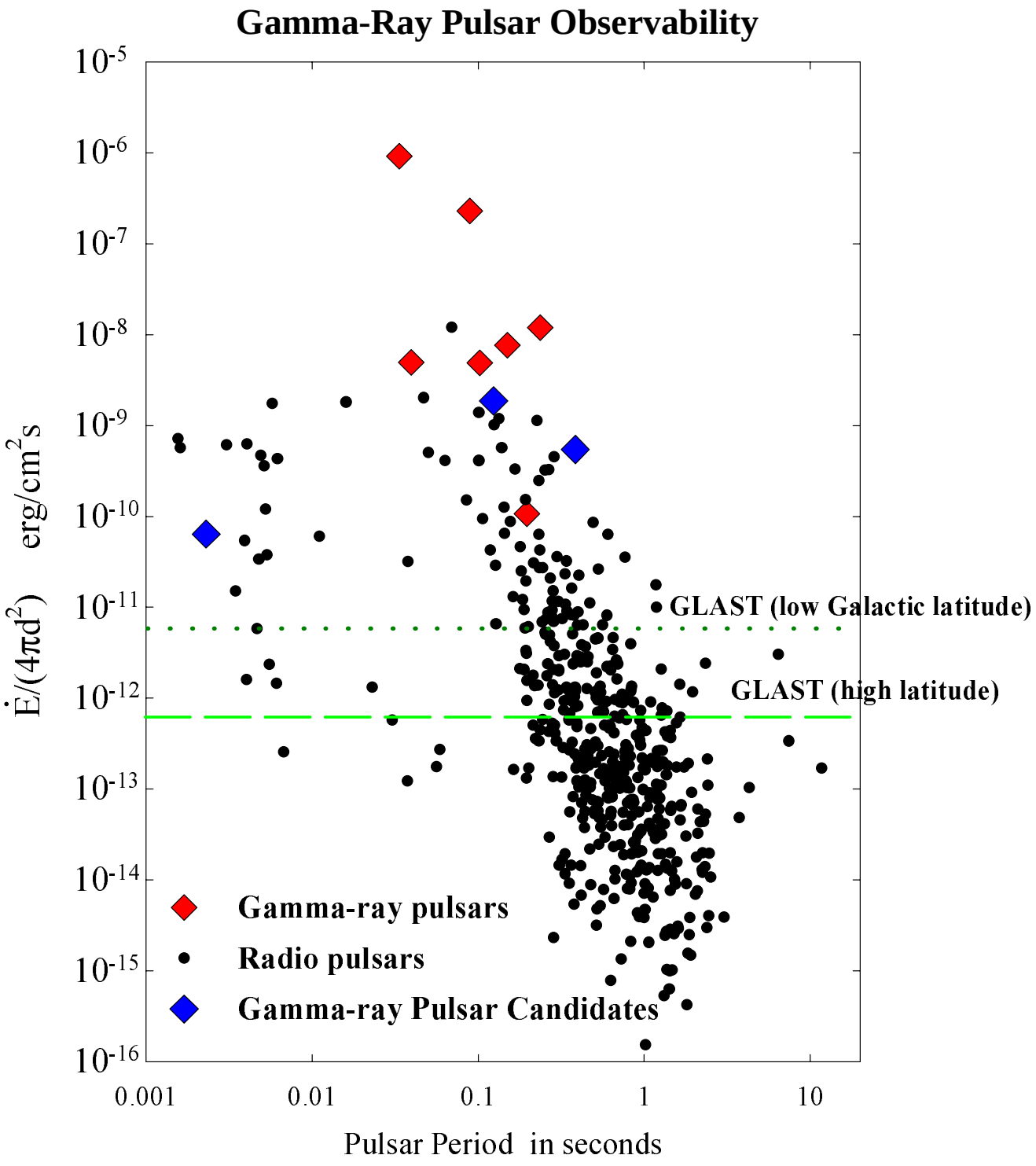

Crab
B1509-58
Vela
B1706-44
B1951+32
Geminga
B1055-52

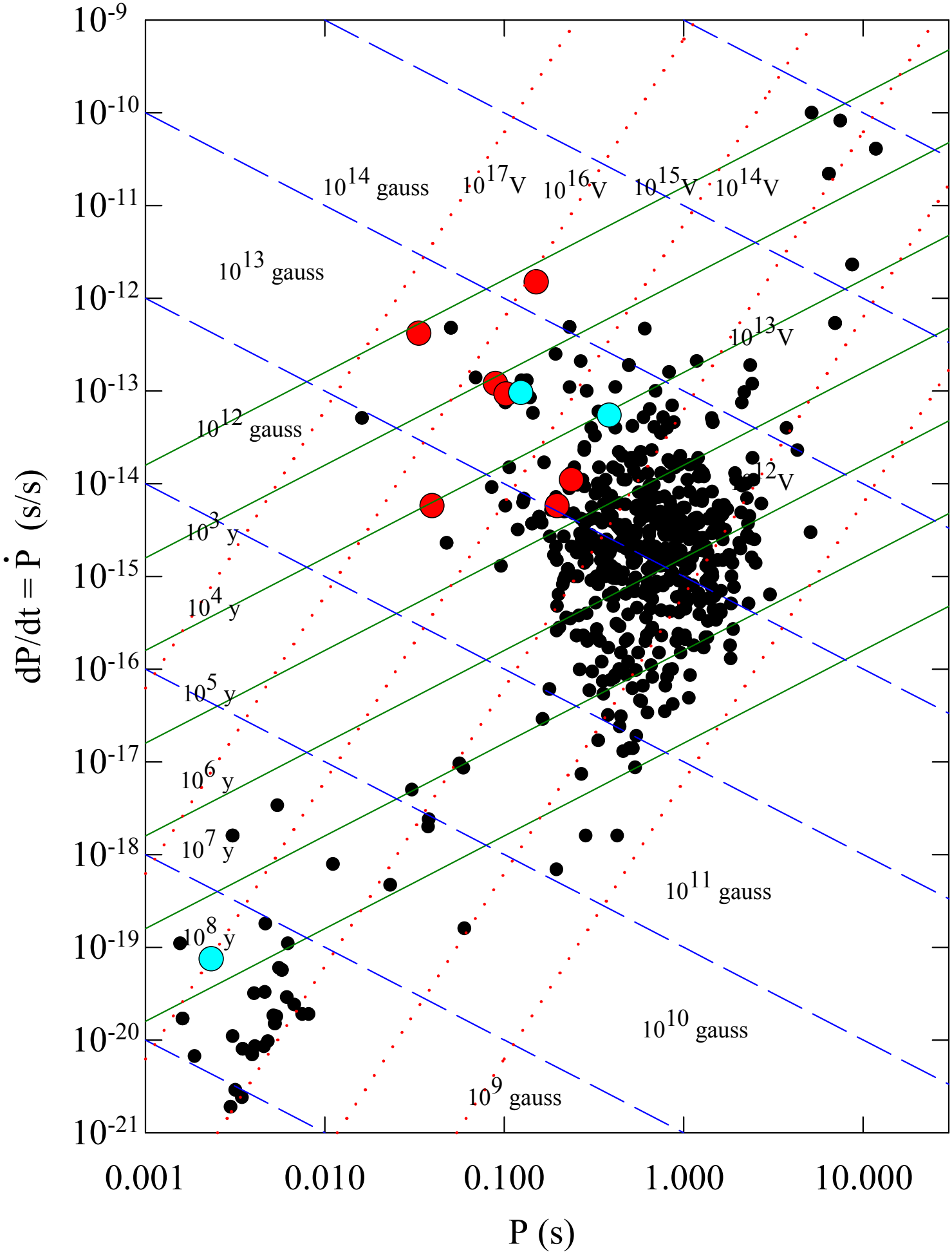
CANDIDATE PULSARS

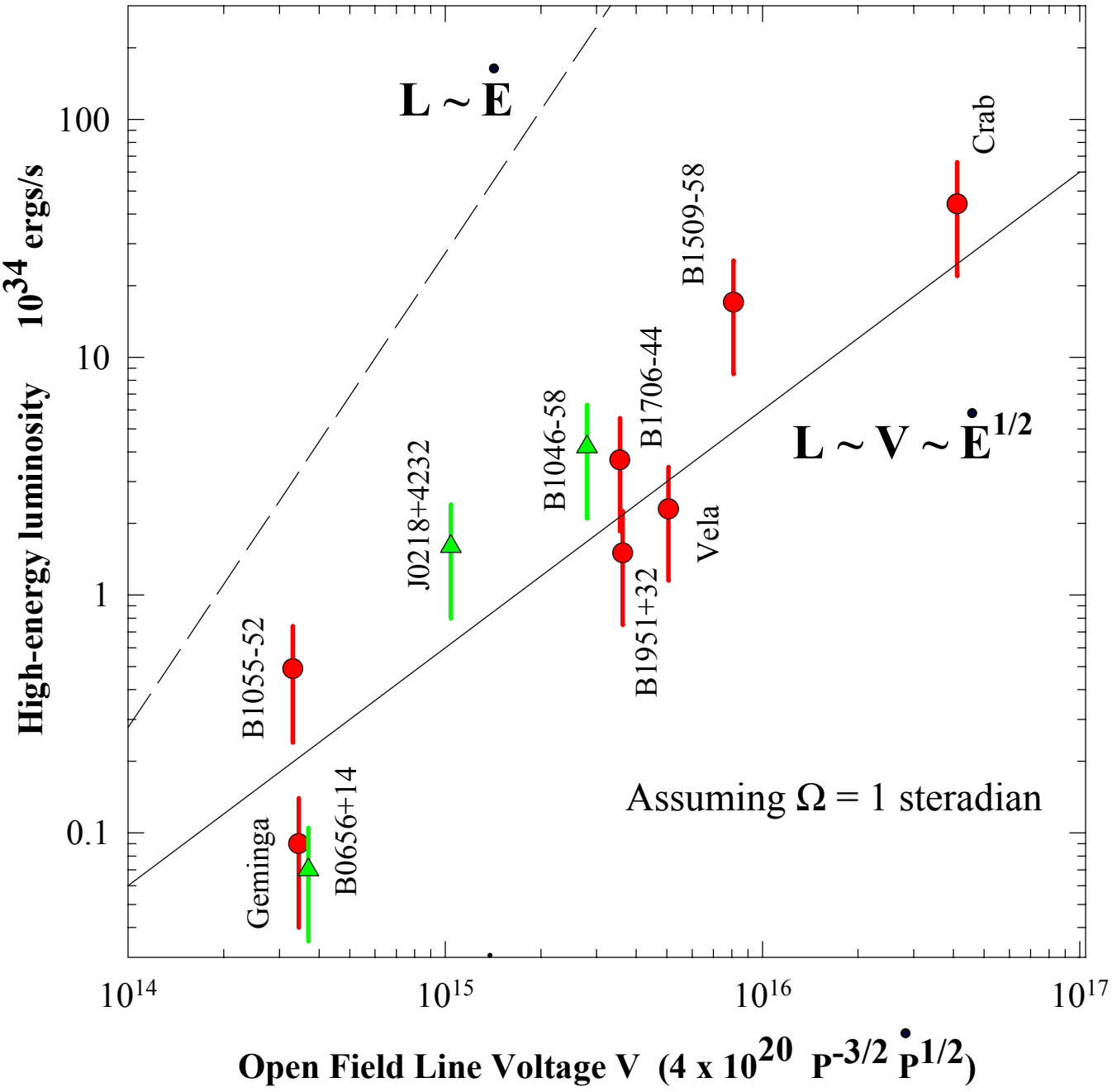


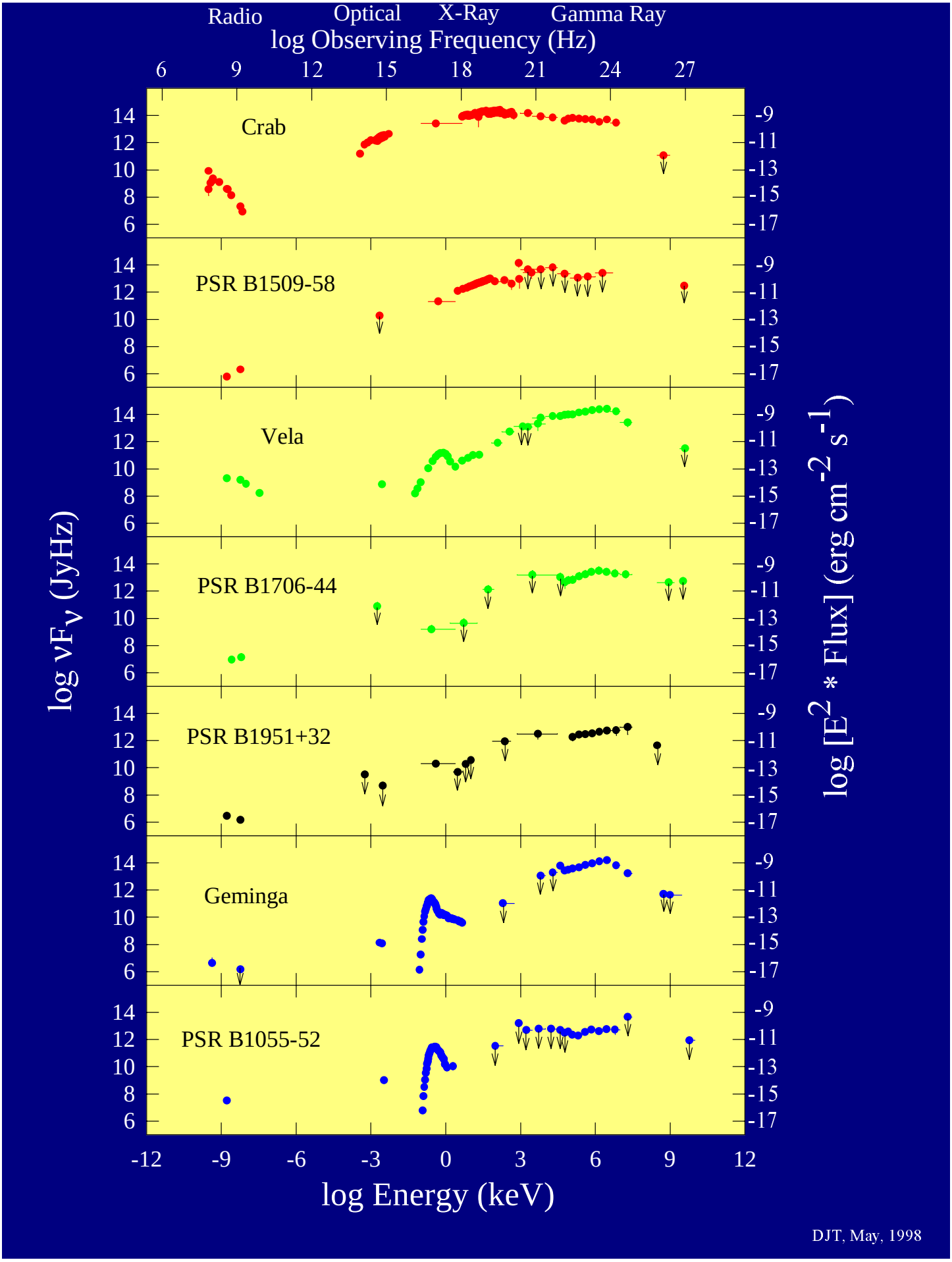





Gamma-Ray Pulsar Observability
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
$\dot{E}/(4\pi d^2)$ erg/cm^{2}s
GLAST (low Galactic latitude)
GLAST (high latitude)
Gamma-ray pulsars
Radio pulsars
Gamma-ray Pulsar Candidates
0.001
0.01
0.1
1
10
Pulsar Period in seconds

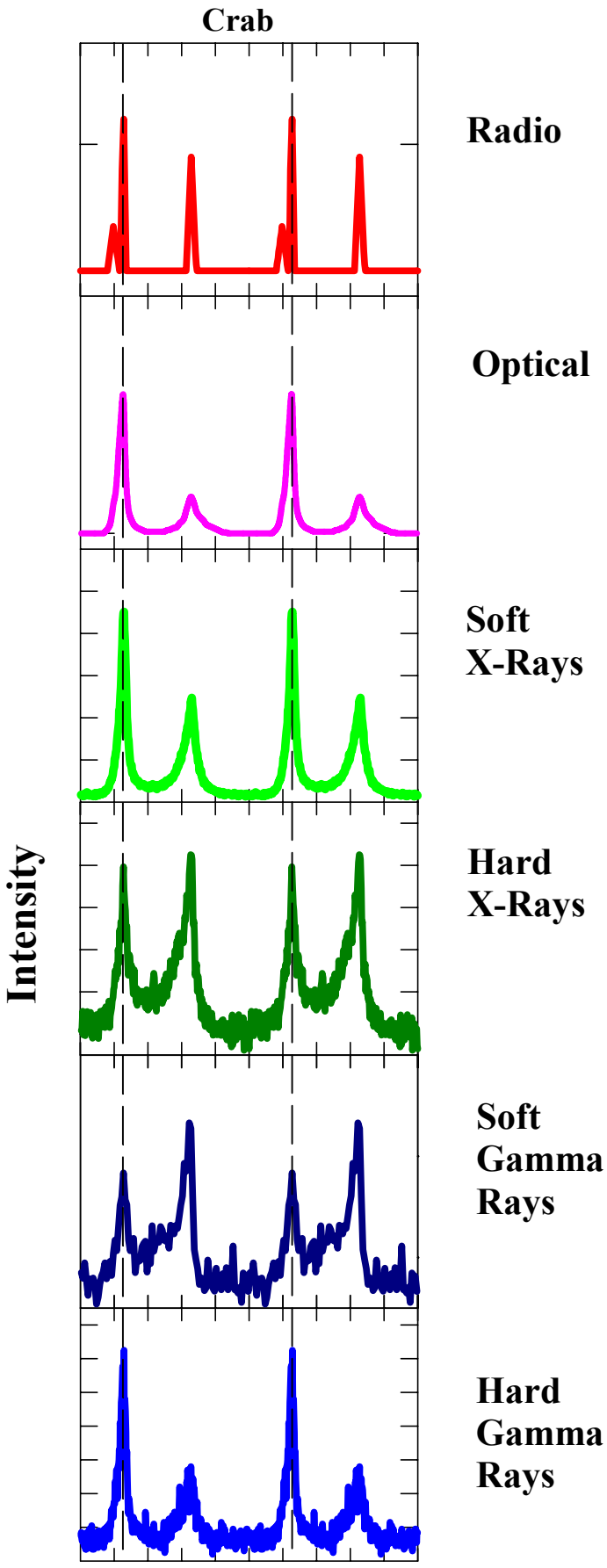

10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
10^{-19}
10^{-20}
10^{-21}
$\dot{P}$ = dP/dt (s/s)
0.001
0.010
0.100
1.000
10.000
P (s)
10^{14} gauss
10^{17}V
10^{16}V
10^{15}V
10^{14}V
10^{13} gauss
10^{13}V
10^{12} gauss
10^{12}V
10^{3} y
10^{4} y
10^{5} y
10^{6} y
10^{7} y
10^{8} y
10^{11} gauss
10^{10} gauss
10^{9} gauss

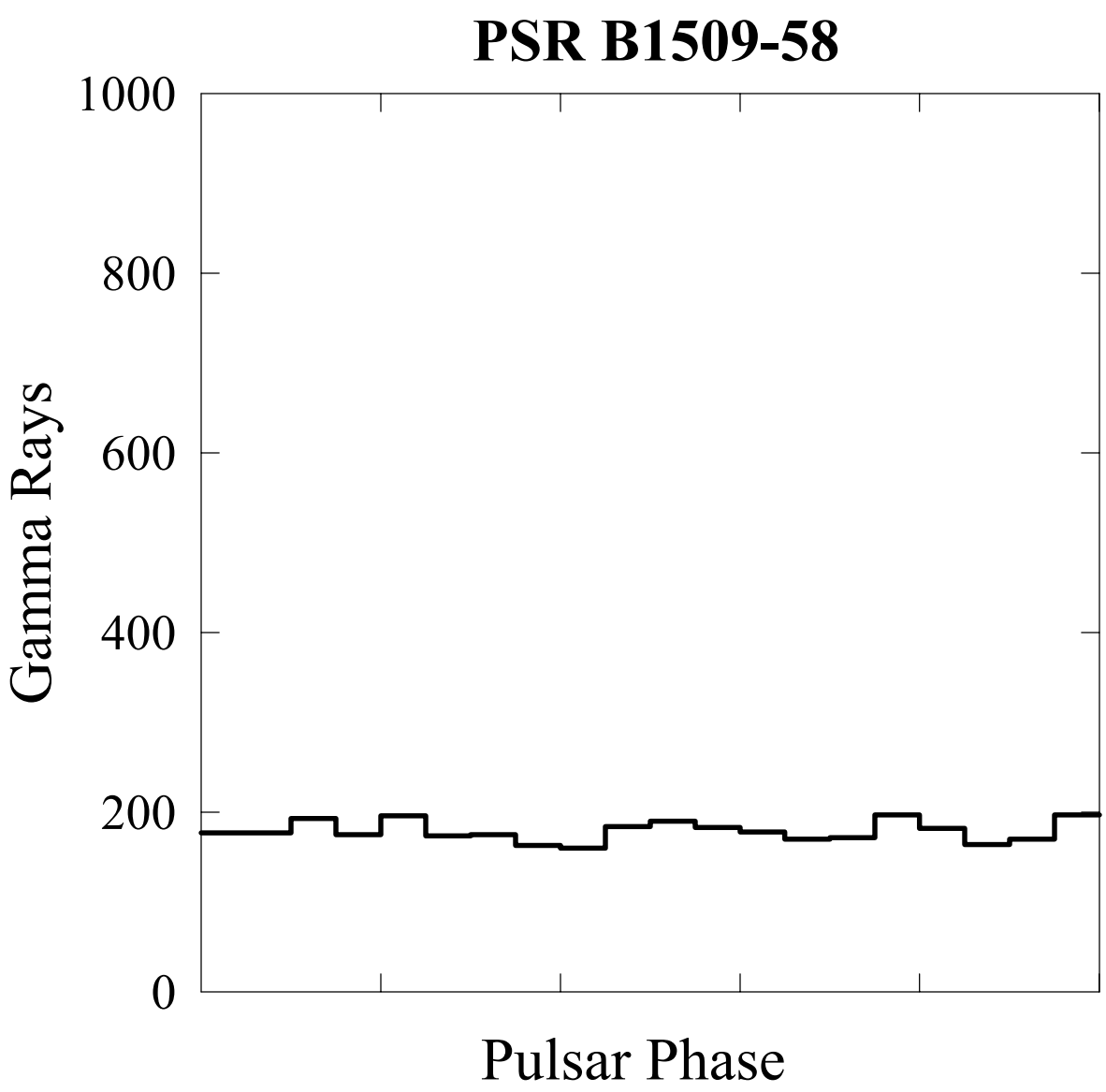

L ~ Ė
L ~ V ~ Ė^1/2
Assuming Ω = 1 steradian
Crab
B1509-58
B1706-44
B1951+32
Vela
B1046-58
J0218+4232
B1055-52
Geminga
B0656+14
100
10
1
0.1
High-energy luminosity 10^34 ergs/s
10^14
10^15
10^16
10^17
Open Field Line Voltage V (4 x 10^20 P^-3/2 Ṗ^1/2)


Radio
Optical
X-Ray
Gamma Ray
log Observing Frequency (Hz)
6
9
12
15
18
21
24
27
Crab
PSR B1509-58
Vela
PSR B1706-44
PSR B1951+32
Geminga
PSR B1055-52
log νF$_\nu$ (JyHz)
log [E^2 * Flux] (erg cm^{-2} s^{-1})
14
12
10
8
6
-9
-11
-13
-15
-17
-12
-9
-6
-3
0
3
6
9
12
log Energy (keV)
DJT, May, 1998

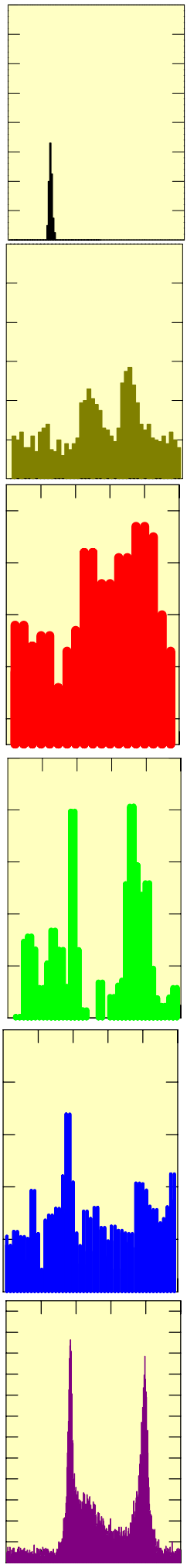
Summary of General Characteristics

- Young
- Energetic
- Fairly High Magnetic Field
- Nearby (< 3 kpc)
- Luminosity ~ open field line voltage or polar cap current
- Maximum observed power in X-ray or gamma-ray band

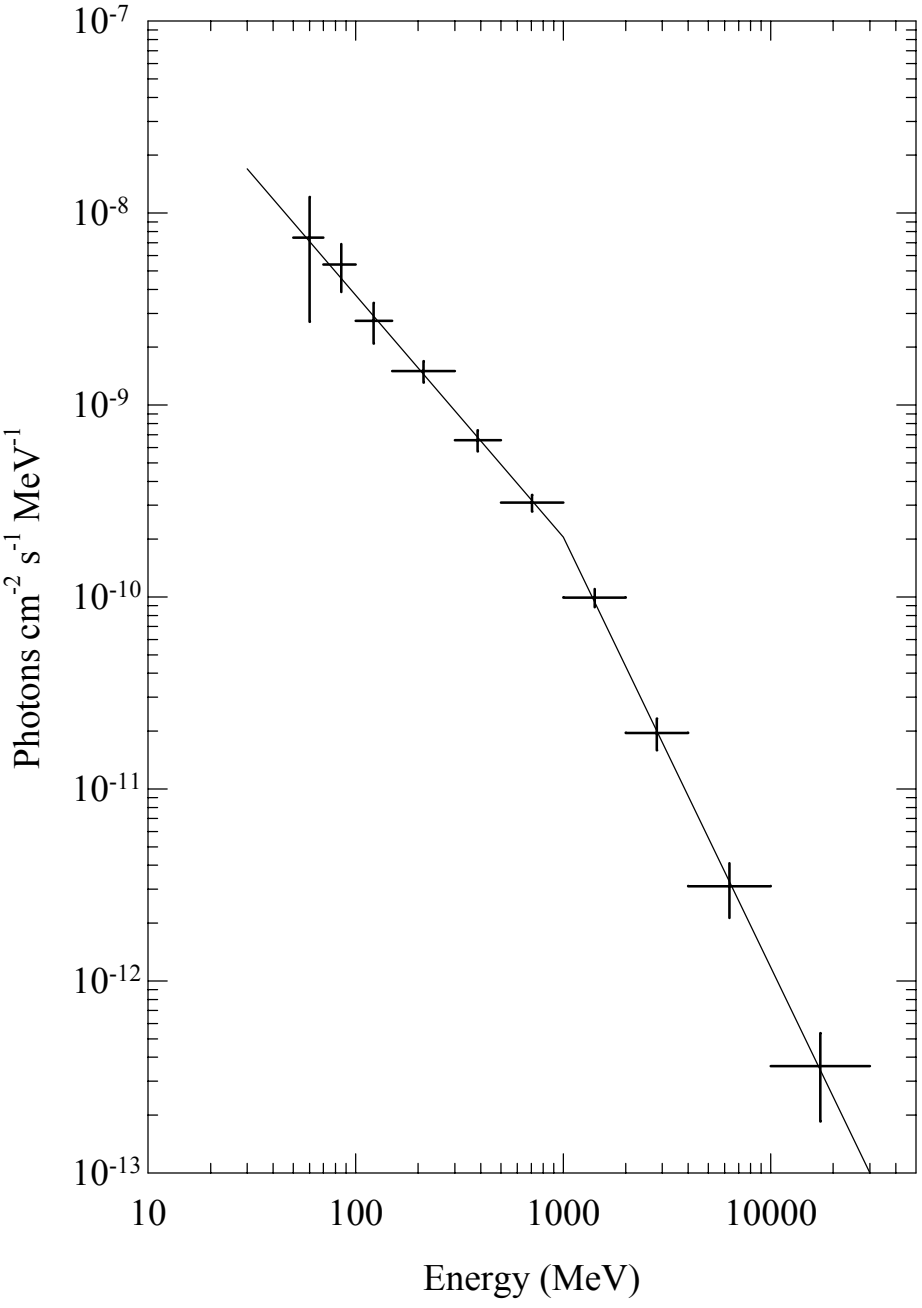

Crab
Radio
Optical
Soft
X-Rays
Hard
X-Rays
Soft
Gamma
Rays
Hard
Gamma
Rays
Intensity
Pulsar Phase -- Two Cycles shown


PSR B1509-58
1000
800
600
400
200
0
Gamma Rays
Pulsar Phase

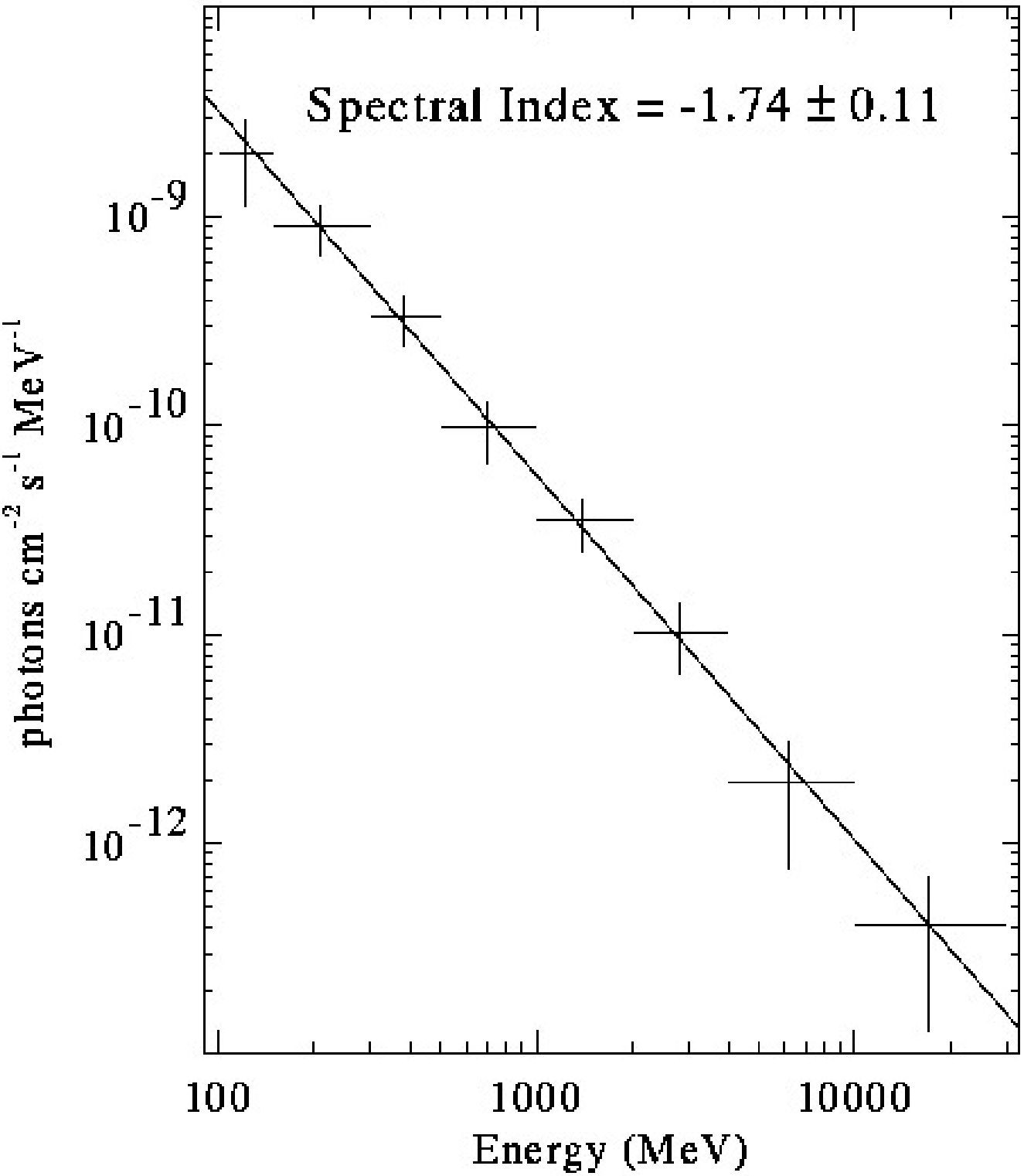
Vela

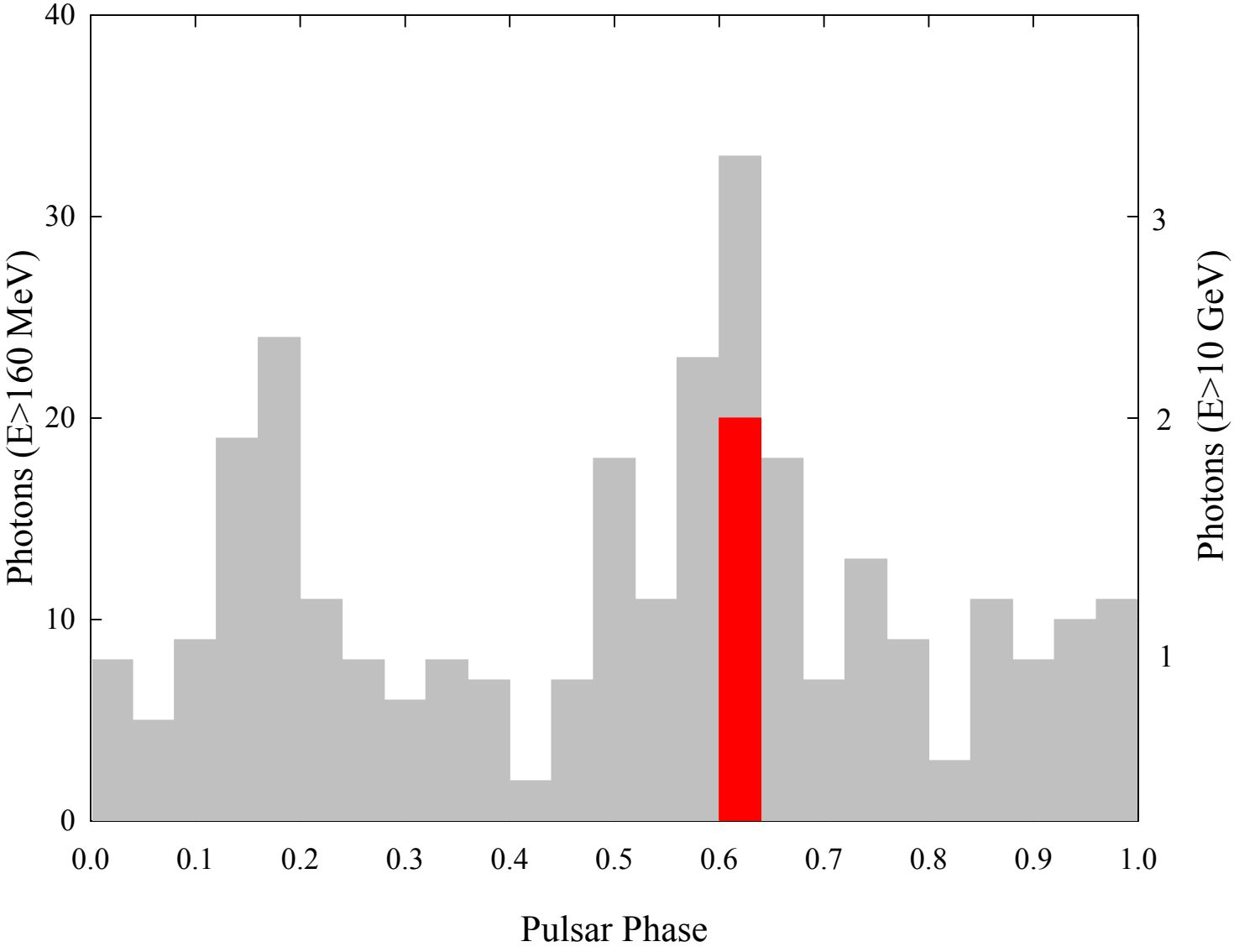

Radio
Optical
Soft X-Rays
Hard X-Rays
Soft Gamma Rays
Hard Gamma Rays

PSR B1706-44 Energy Spectrum

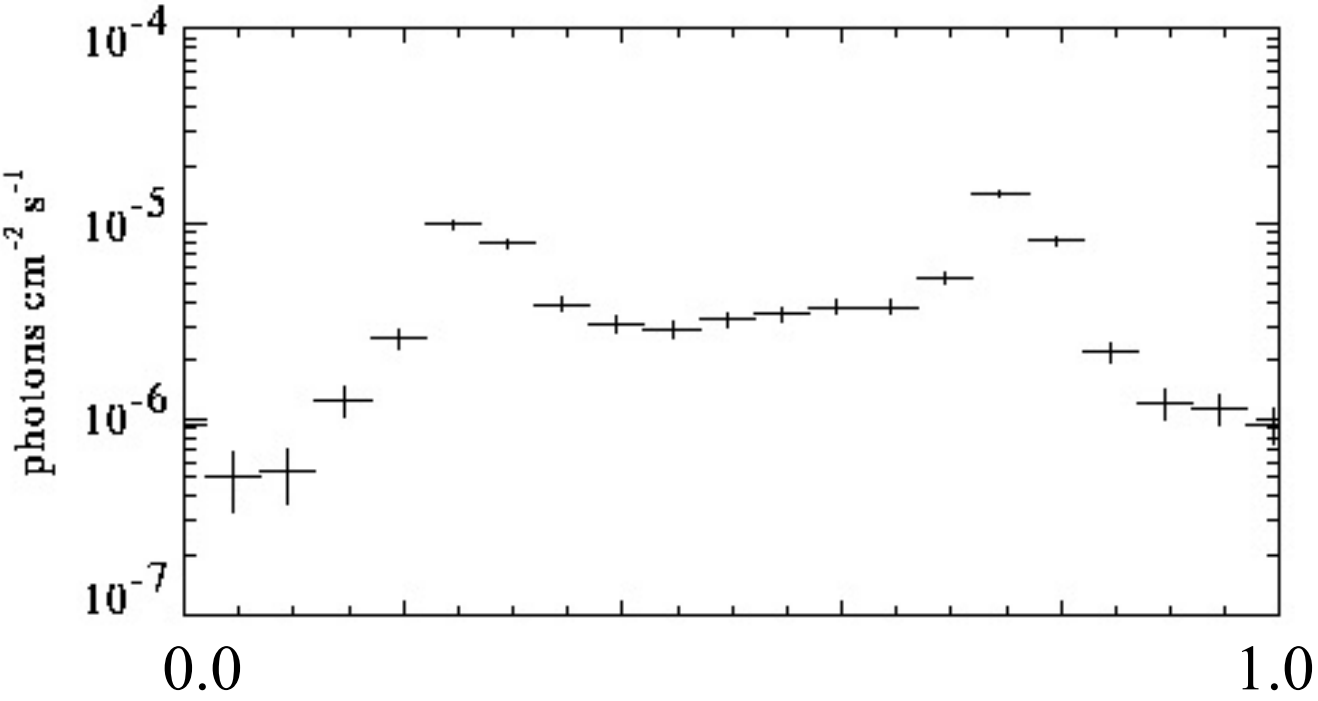


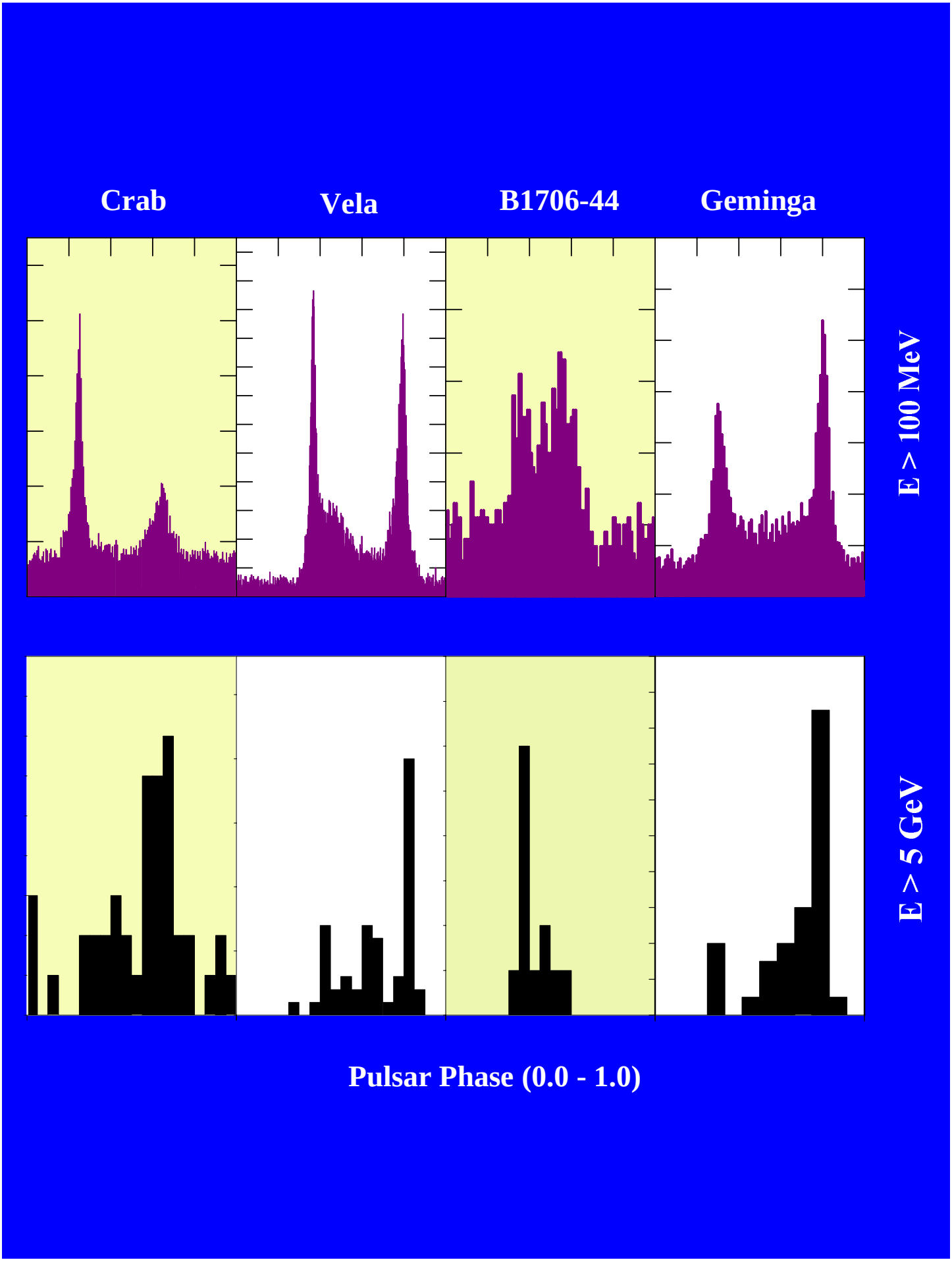
PSR B1951+32


Spectral Index = -1.74 ± 0.11
10^{-9}
10^{-10}
10^{-11}
10^{-12}
photons cm^{-2} s^{-1} MeV^{-1}
100
1000
10000
Energy (MeV)


40
30
20
10
0
Photons (E>160 MeV)
3
2
1
Photons (E>10 GeV)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Pulsar Phase

Geminga Light Curve from Phase-Resolved Maps




Crab
Vela
B1706-44
Geminga
E > 100 MeV
E > 5 GeV
Pulsar Phase (0.0 - 1.0)

Conclusion

In some ways, each gamma-ray pulsar is a "sample of one."

- •Crab - simultaneous emission across the spectrum
- •1509 - cut off at ~10 MeV
- •Vela - many different emission components
- •1706 - spectrum that breaks, not a cutoff
- •1951 - spectrum seems to extend beyond 10 GeV with no break
- •1055 - apparently high efficiency
- •Geminga - radio quiet; gamma-ray emission throughout the rotation
- •All - shift to single pulse around 5 GeV

Obviously, we need GLAST to find more pulsars.

Also important is to start the GLAST mission with specific, testable predictions for pulsars.