2 YEARS ANALYSIS OF GEMINGA WITH FERMI-LAT

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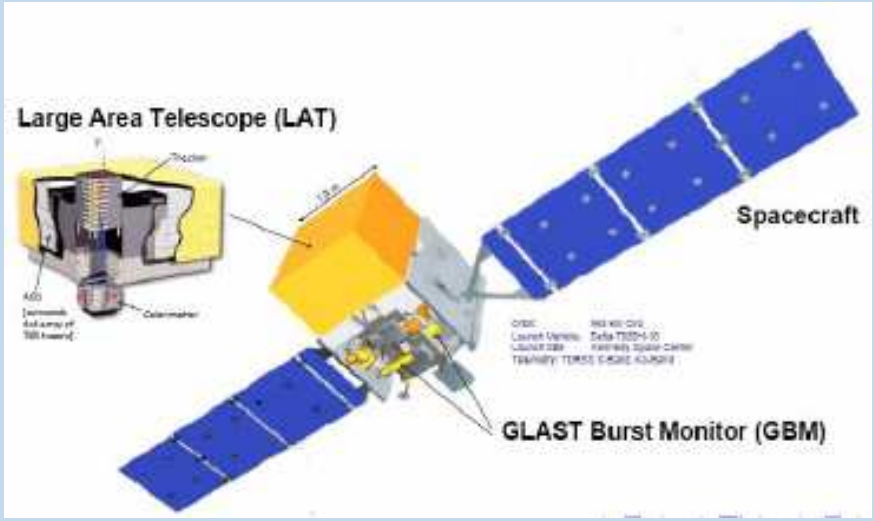
FERMI SPACECRAFT

- 2008, June 11
  Cape Canaveral
- LAT: 20 MeV-300 GeV



LAT vs EGRET

- Effective area: 6 times better
- Sensitivity: 50 times higher
- Angular resolution: 3 times better
- Much better energetic resolution
- Observed sources: 2233 vs 271
- Observed pulsars: >80 vs 7

FERMI PULSARS

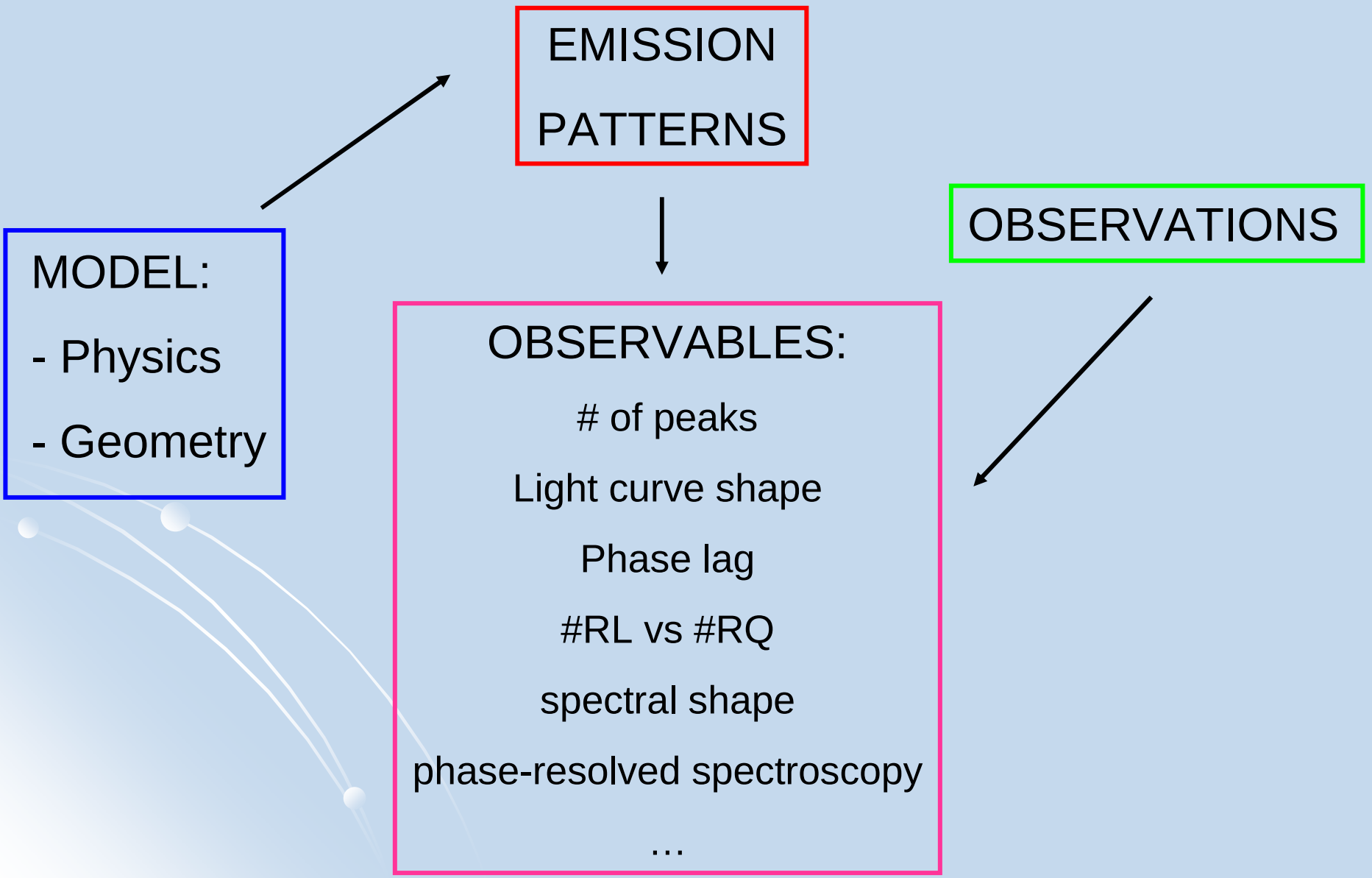
- Gamma-rays efficiency: 10 %
- Radio efficiency: 10^{-7}-10^{-6}

- 2 populations of non-recycled rotation-powered pulsars: radio-loud and radio-quiet

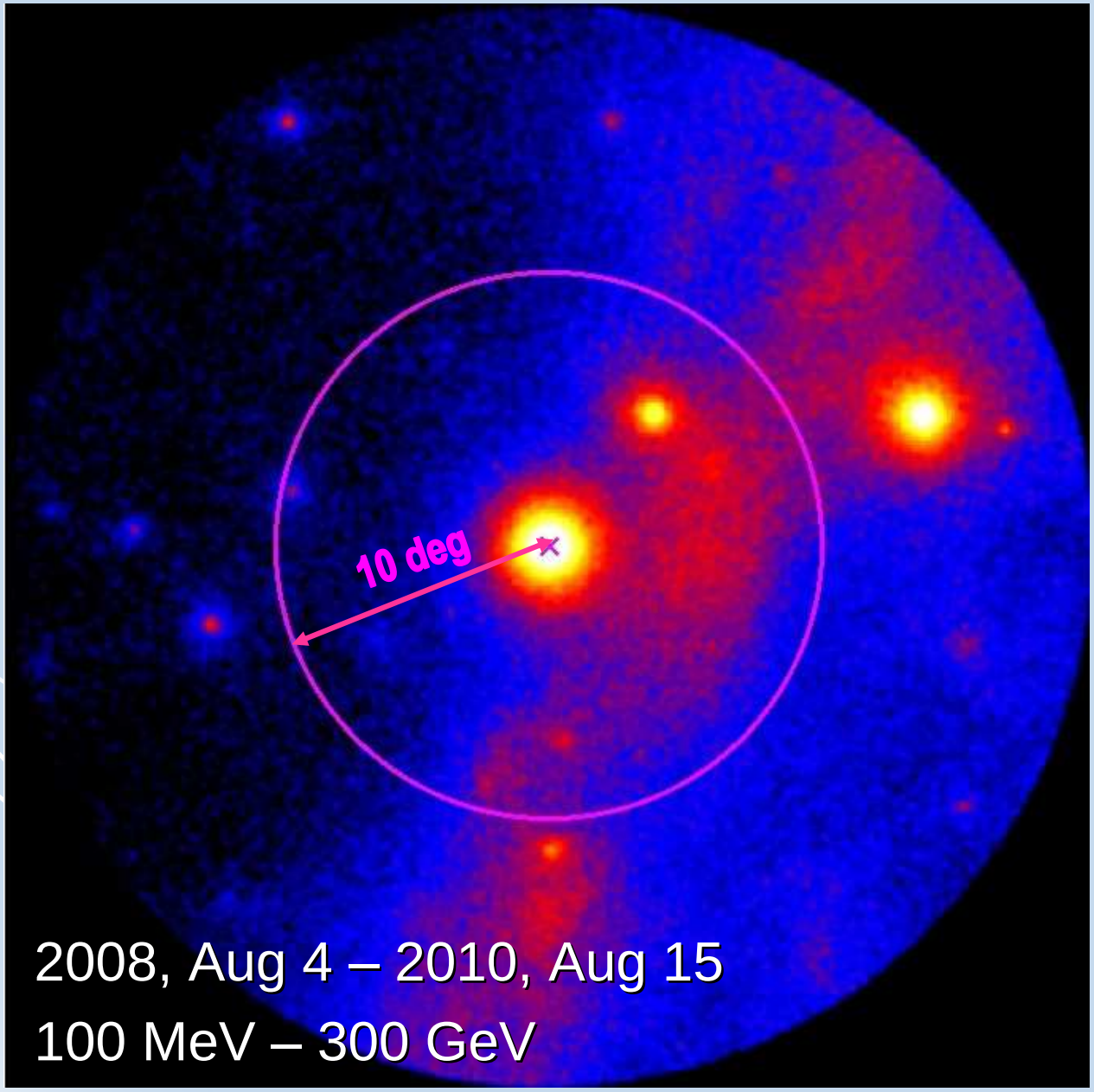
- Spectral shape: power law + exp. Cutoff
- Cutoff energy: 1-5 GeV

- Gamma-rays emission from the outer magnetosphere

OBSERVATIONAL CONSTRAINTS



DATA SET

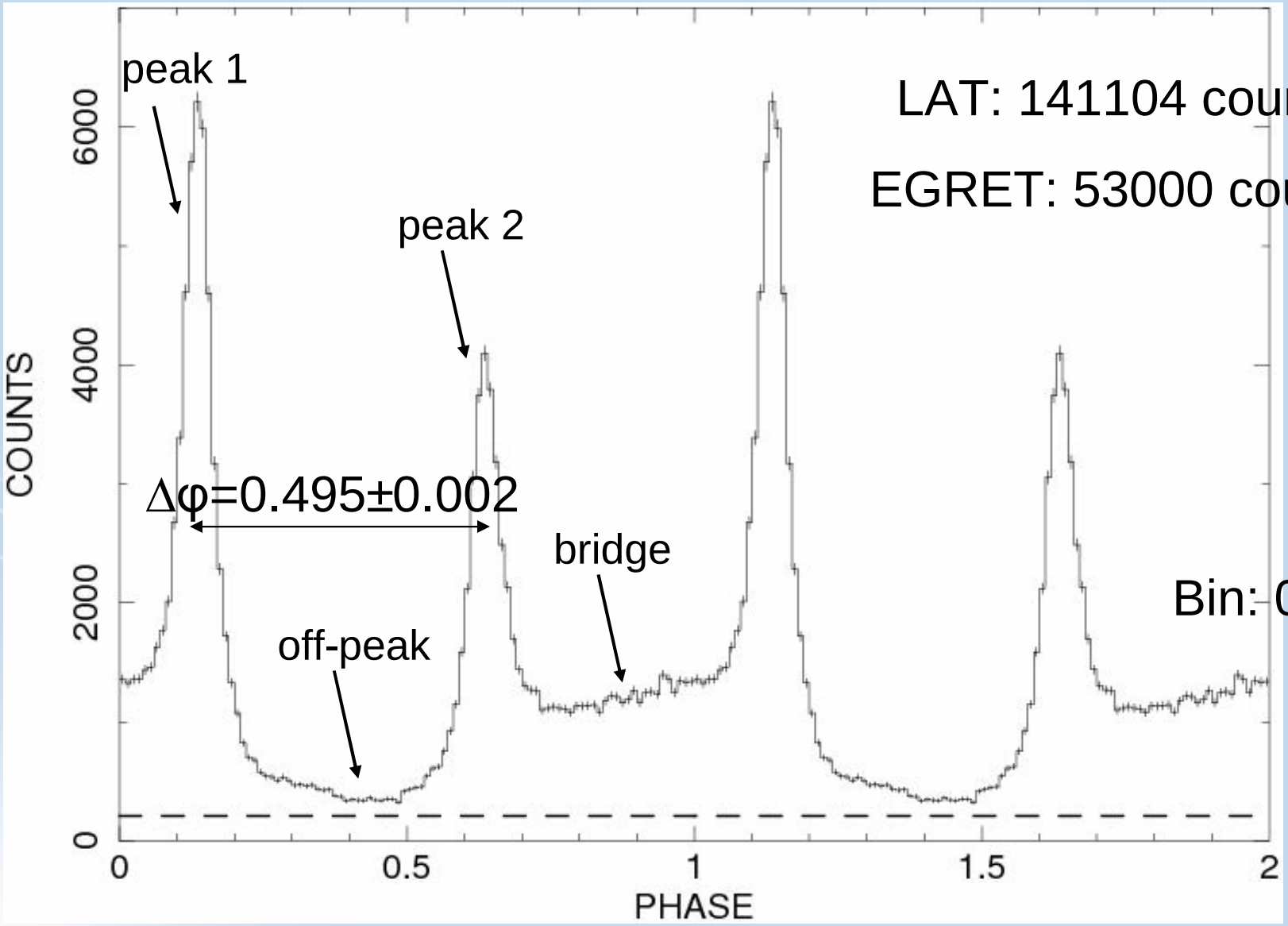


PERFORMED ANALYSIS

- Study of the light curve in different energy ranges
- Phase-averaged spectral analysis
- Phase-resolved spectral analysis
- Search for a pulsar wind nebula (PWN)

LIGHT CURVE

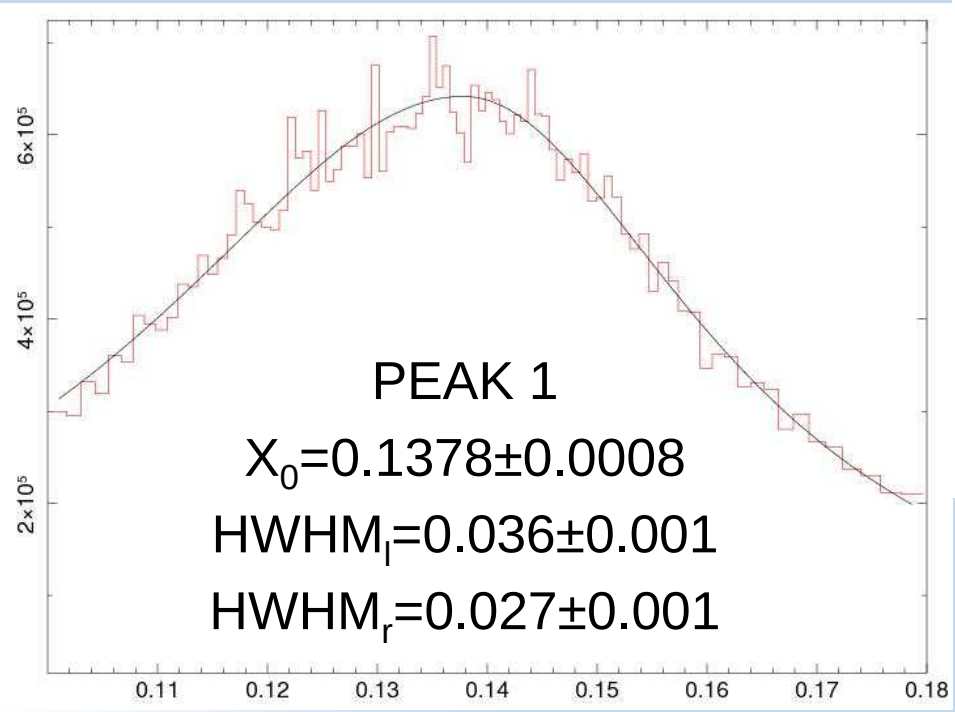
Energy dependent PSF ➡ θ≤max{1.3, 1.6 – 3 log (Energy(GeV))}

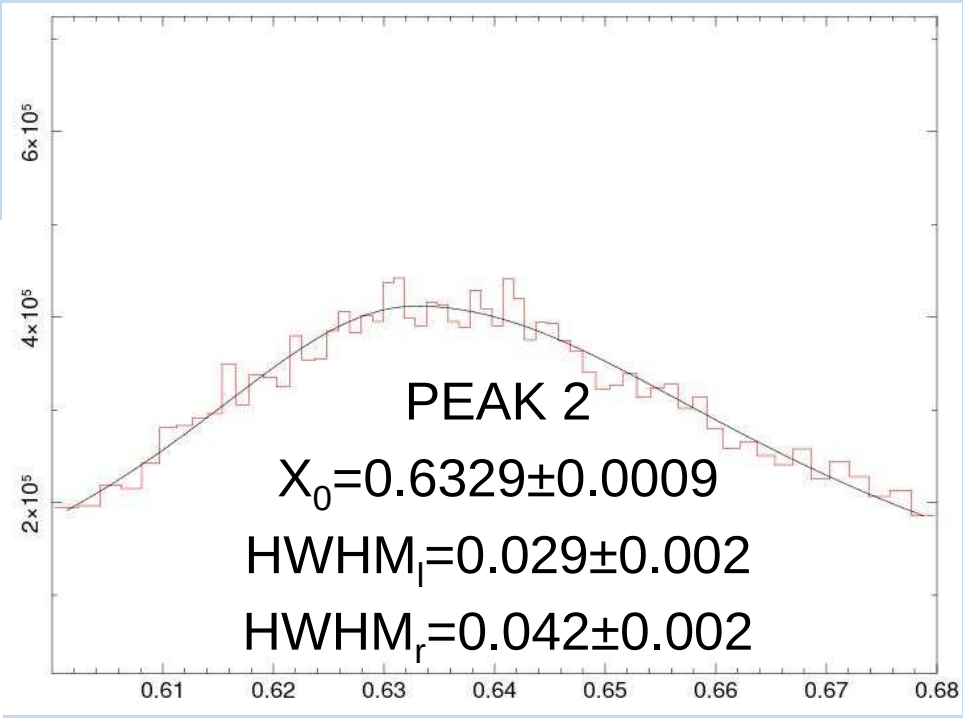


PEAKS ASIMMETRY

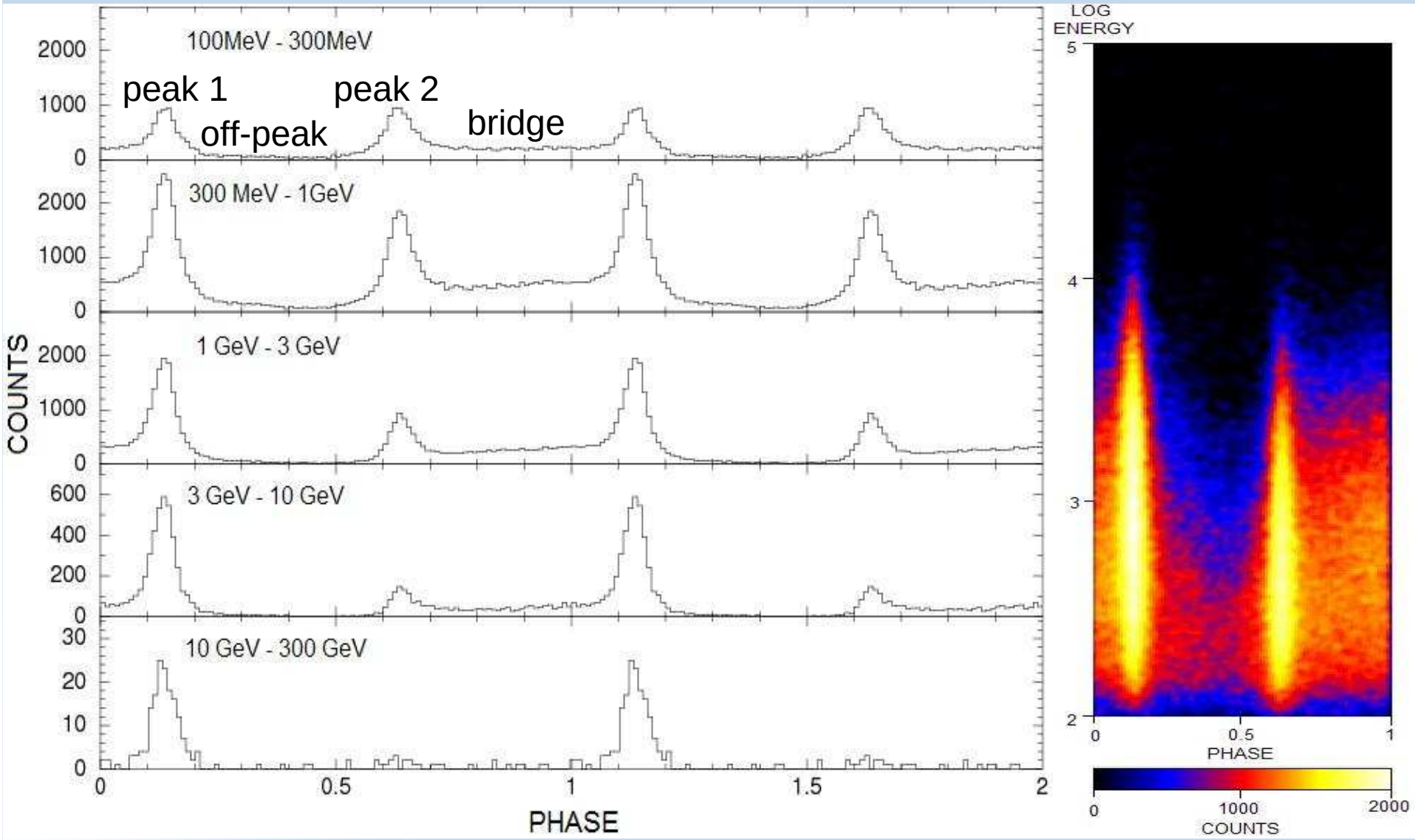
- Best fit functions:

  asymmetric Lorentzian





LC EVOLUTION WITH ENERGY



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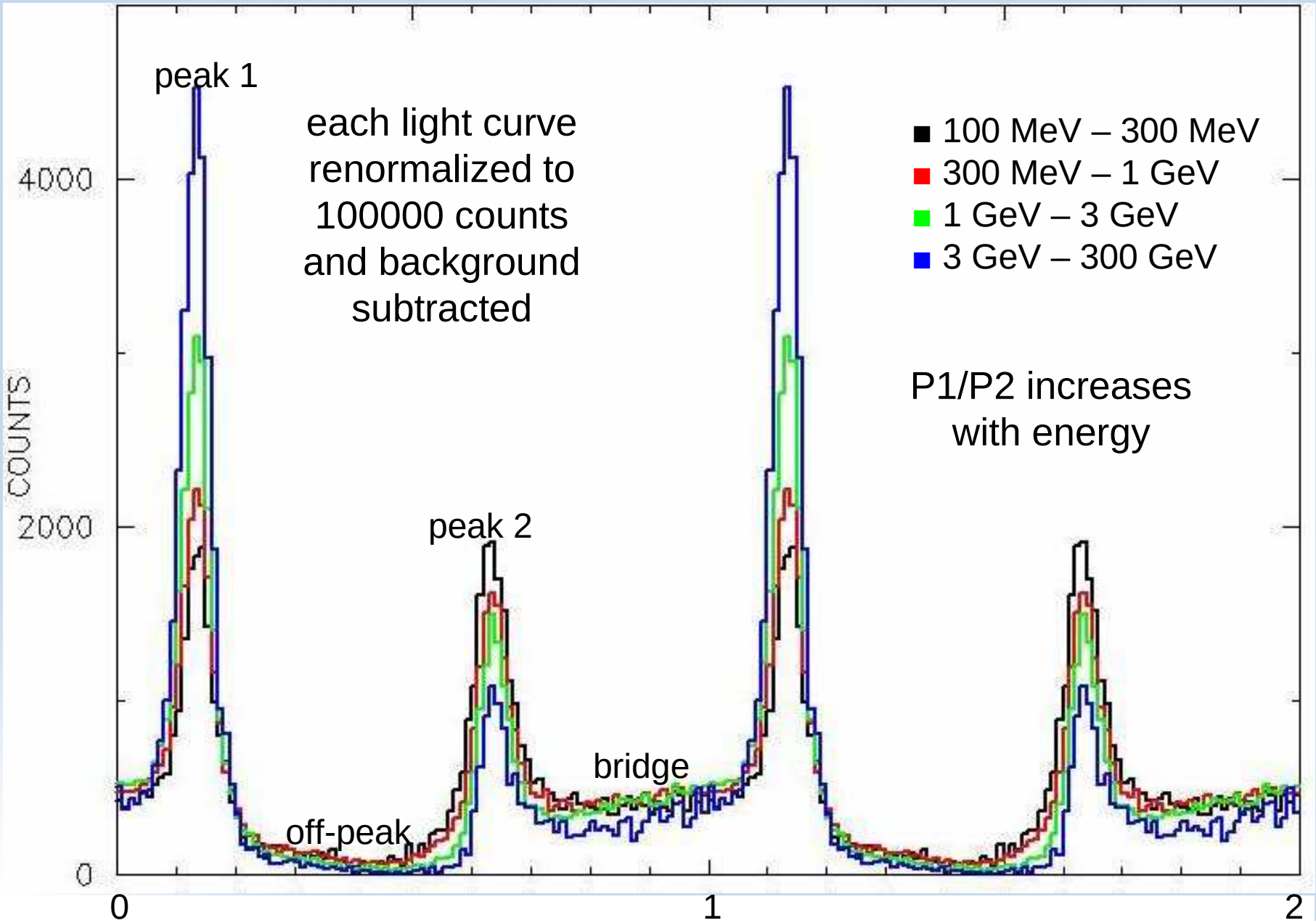


SPECTRAL ANALYSIS

- 10° region of interest (ROI)
- 20° source region

- Non-pulsar sources: power law
- Pulsar sources: power law + exp cutoff
- Spectral parameters fixed except normalizations (1FGL, 1st psr catalogue)

- Maximum likelihood method
- Different models tested for Geminga:
  - Power law
  - Power law + exponential cutoff
  - Power law + super exponential cutoff

PHASE-AVERAGED SPECTROSCOPY

	Exp. cutoff	Super-exp. cutoff	Super-exp. cutoff
K^*	1.20 ± 0.01	1.45 ± 0.06	0.771 ± 0.003
γ	1.31 ± 0.01	1.22 ± 0.02	1.58 ± 0.01
$E_{cutoff}^\bullet$	2424 ± 28	1819 ± 118	4972 ± 39
b	1	0.87 ± 0.02	2

* 10^{-9} ph cm^{-2} s^{-1} MeV^{-1}

$^\bullet$ MeV

$$\frac{dN}{dE} = K(E(\mathrm{GeV}))^{-\gamma} \exp\left[-\left(\frac{E}{E_{cutoff}}\right)^b\right]$$

$$N = (4.17 \pm 0.03) \times 10^{-6}\ \mathrm{ph\ cm^{-2}\ s^{-1}}$$

$$F = (4.10 \pm 0.03) \times 10^{-9}\ \mathrm{erg\ cm^{-2}\ s^{-1}}$$

CONSTRAINTS ON EMISSION MODEL

- Absence of radio emission
- Geometrical constraints from the X-rays
- $r \geq (\varepsilon_{max} B_{12}/1.76\ \mathrm{GeV})^{2/7} P^{-1/7} R_*$

  $\varepsilon_{max} \sim 18$ GeV $\longrightarrow$ $r_{min} \geq 2.7\ R_*$

EMISSION FROM THE OUTER MAGNETOSPHERE

$$L_\gamma = 4\pi f_\Omega F_{obs} D^2$$

$D \sim 250$ pc, $F_{obs} \sim 4.1 \cdot 10^{-9}$ erg s^{-1}cm^{-2}

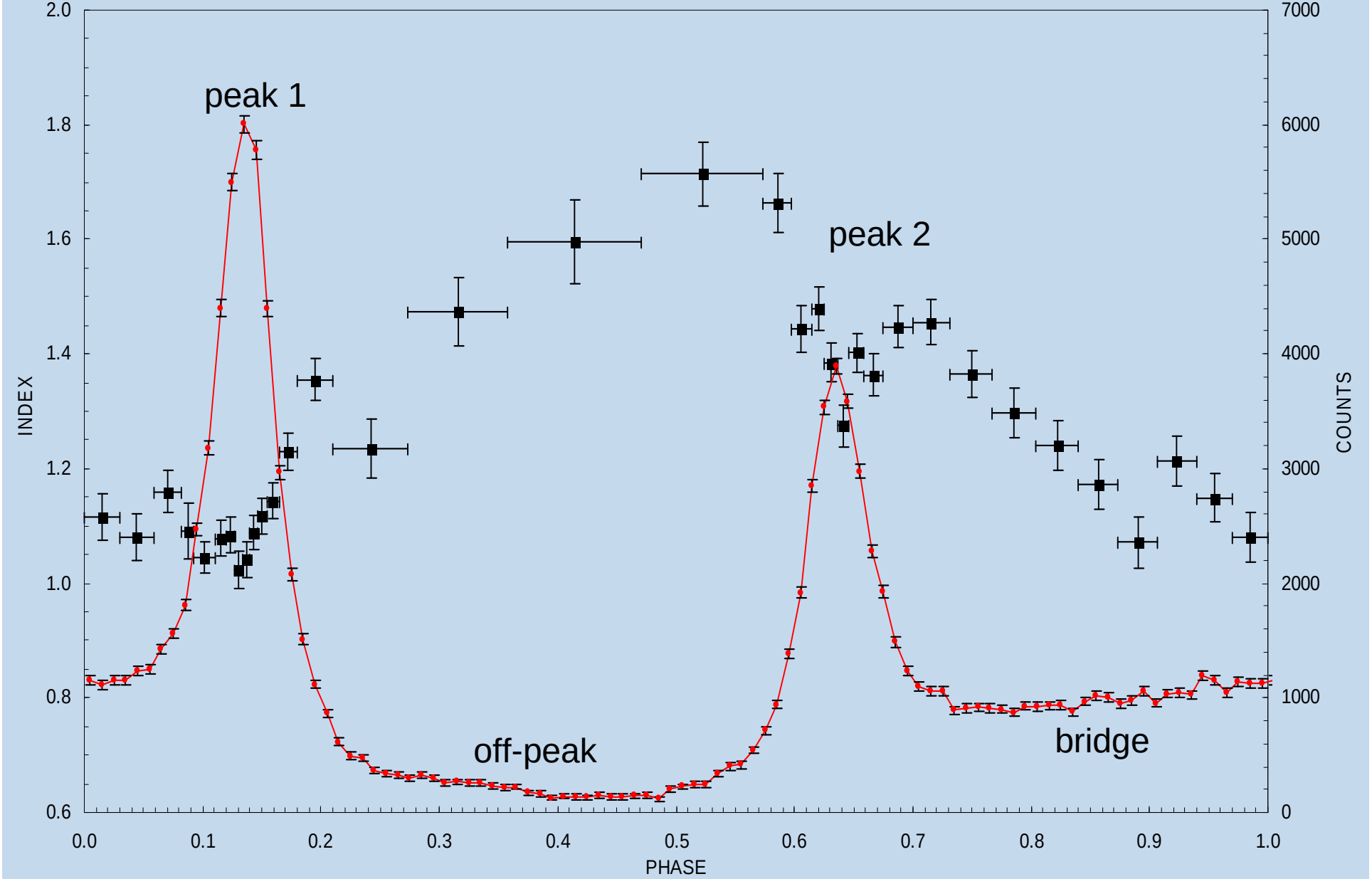
$f_\Omega \sim 0.1\text{-}0.15$ (OG model)

$$L_\gamma = 4.6 \cdot 10^{33} \text{ erg s}^{-1}$$

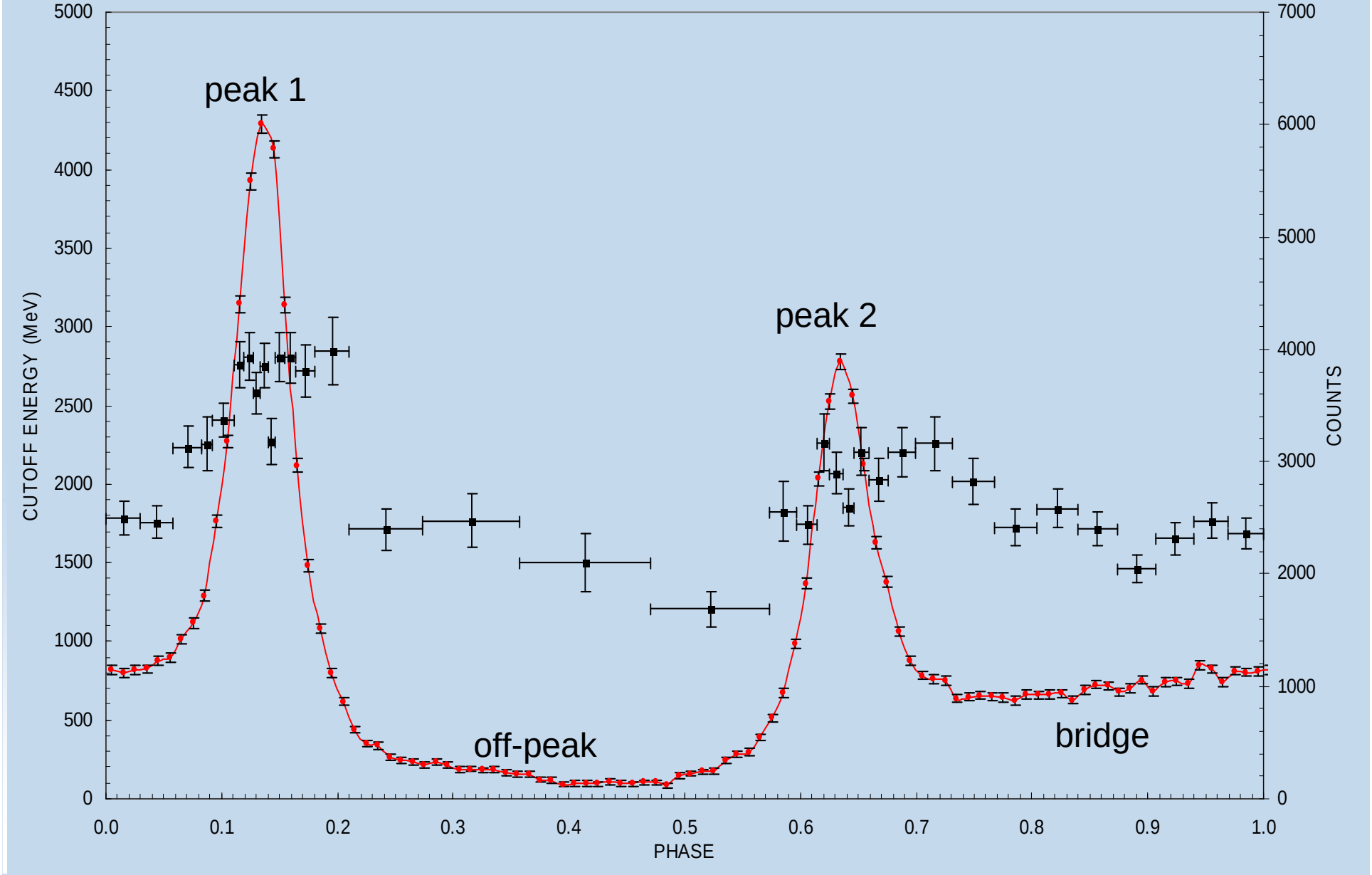
PHASE-RESOLVED SPECTROSCOPY

- 35 bins, 4031 counts each
- Power law + exp cutoff
- Emission from the pulsar in each bin
- Big variations of the spectral parameters through the period

SPECTRAL INDEX



CUTOFF ENERGY



PWN SEARCH

- PSR: pl + exp cutoff
- PWN: power law

$$TS_{cutoff} = -2\ln\left(\frac{L_{max,pl}}{L_{max,cutoff}}\right)$$

1. Analysis of the off-peak emission
   - 100 MeV < E < 300 GeV
   - 0.36 < φ < 0.47

2. Analysis of the emission over the cutoff
   - 2.5 GeV < E < 300 GeV
   - 0 < φ < 1

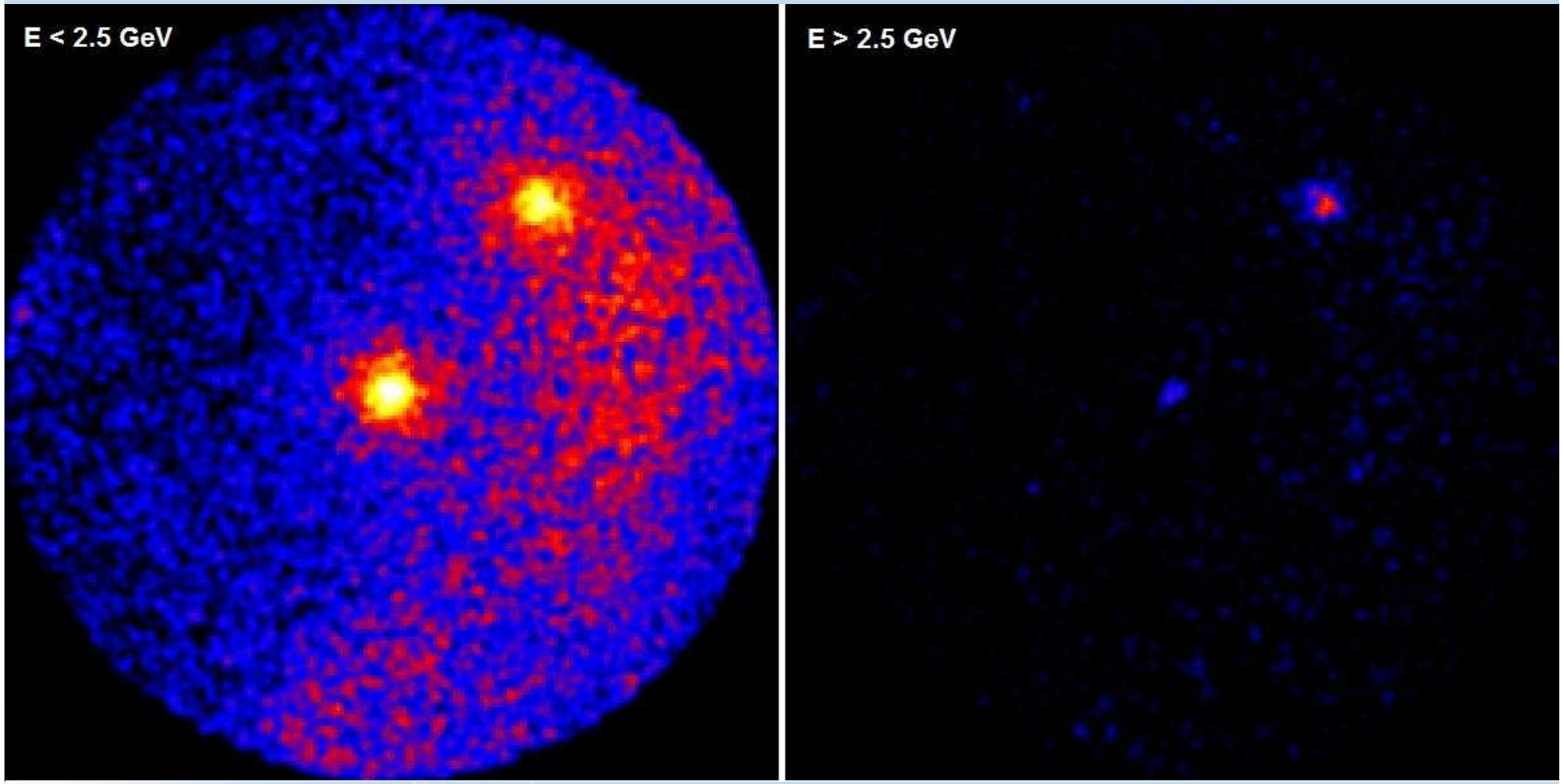
1) OFF-PEAK EMISSION

Power law	
γ	2.26 ± 0.03
N (10^{-7} ph cm^{-2} s^{-1})	9.79 ± 0.34
Power law exp. cutoff	
γ	1.60 ± 0.07
E_{cutoff} (MeV)	1502 ± 186
N (10^{-7} ph cm^{-2} s^{-1})	7.48 ± 0.37

$TS_{cutoff} = 151$

Pwn rejected at 12.3 σ

1) OFF-PEAK EMISSION



2) EMISSION OVER THE CUTOFF

Power law	
γ	3.64 ± 0.03
N (10^{-7} ph cm^{-2} s^{-1})	1.09 ± 0.01
Power law exp. cutoff	
γ	1.48 ± 0.12
E_{cutoff} (MeV)	2752 ± 149
N (10^{-7} ph cm^{-2} s^{-1})	1.09 ± 0.02

$TS_{cutoff} = 164$

Pwn rejected at 12.8 σ