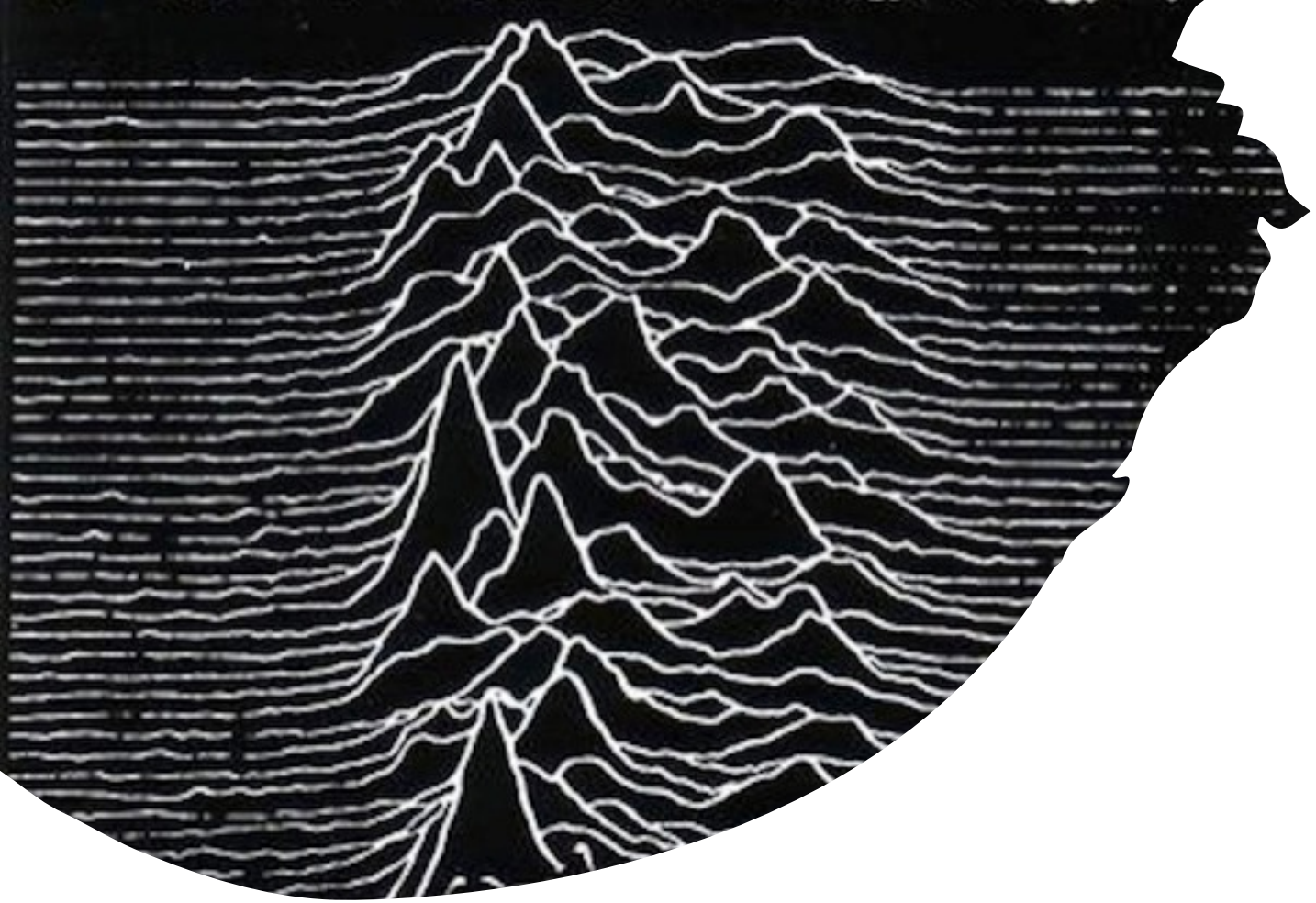


The third Pietro Baracchi conference
November 2021

Pulsars from radio to *TeV Gammas*

Shi Dai
ARC DECRA Fellow
Western Sydney University

WESTERN SYDNEY UNIVERSITY

cta cherenkov telescope array

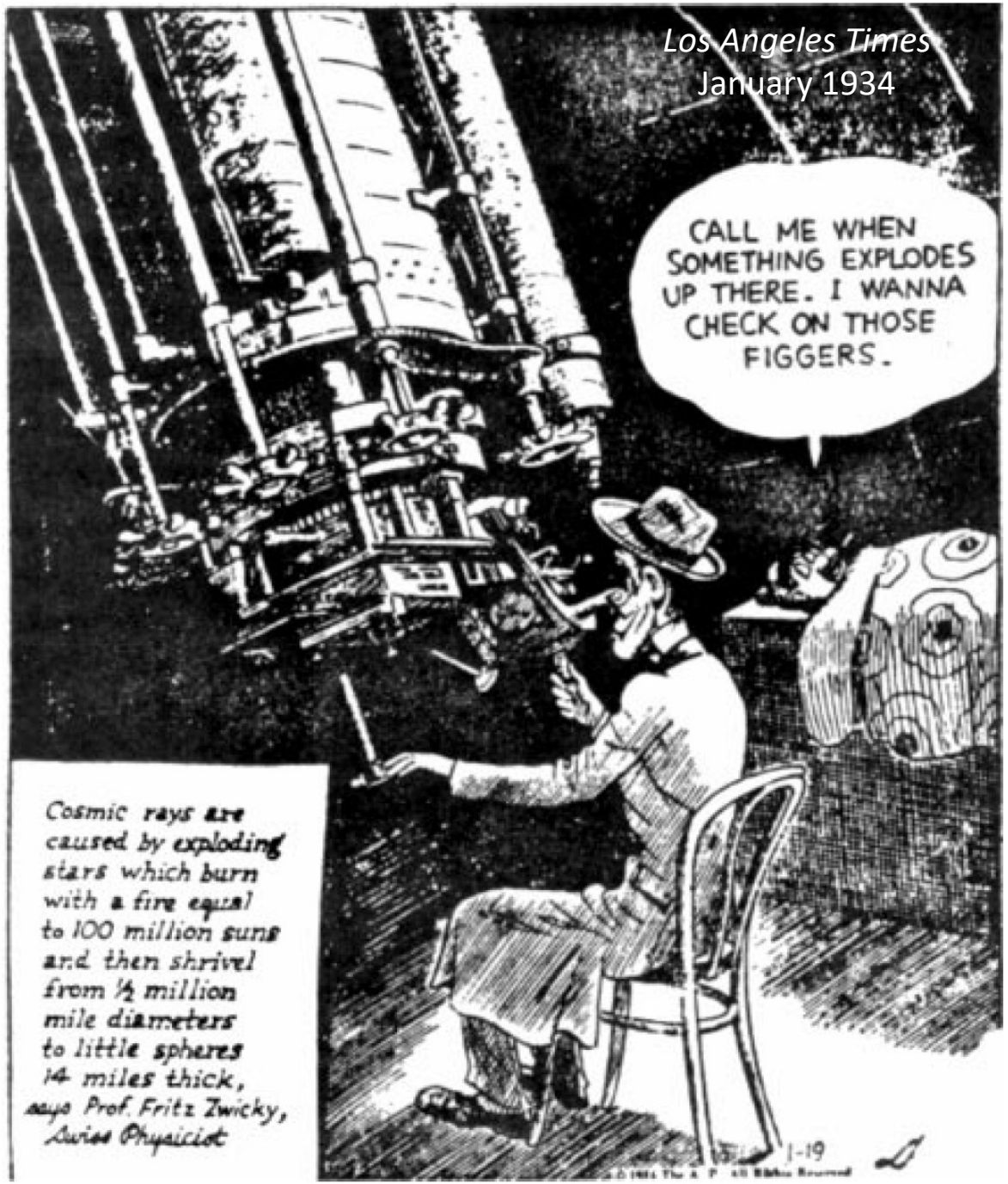
- At the American Physical Society meeting in December 1933, Walter Baade and Fritz Zwicky proposed the existence of neutron stars to explain the origin of a supernova.

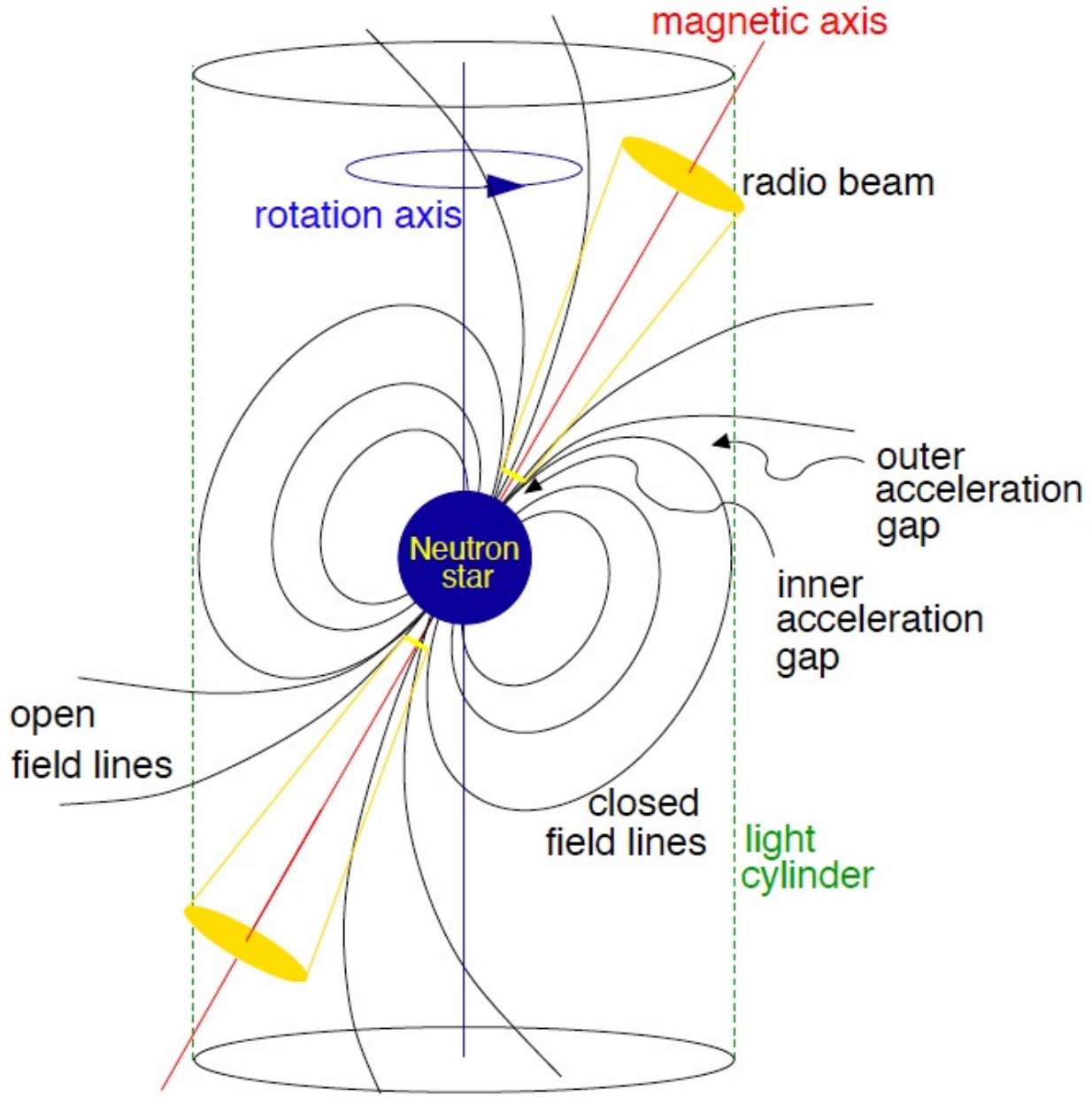
  "…… with all reserve we advance the view that supernovae represent the transition from ordinary stars into neutron stars, which in their final stages consist of closely packed neutrons."

  (Baade W, Zwicky F, 1934, Phys. Rev. 46, 76)

- Pacini (1967) first proposed that a rapidly rotating neutron star (*in a vacuum*) with a strong magnetic field emits dipole radiation.

  (Pacini, 1967, Nature, 216, 567)

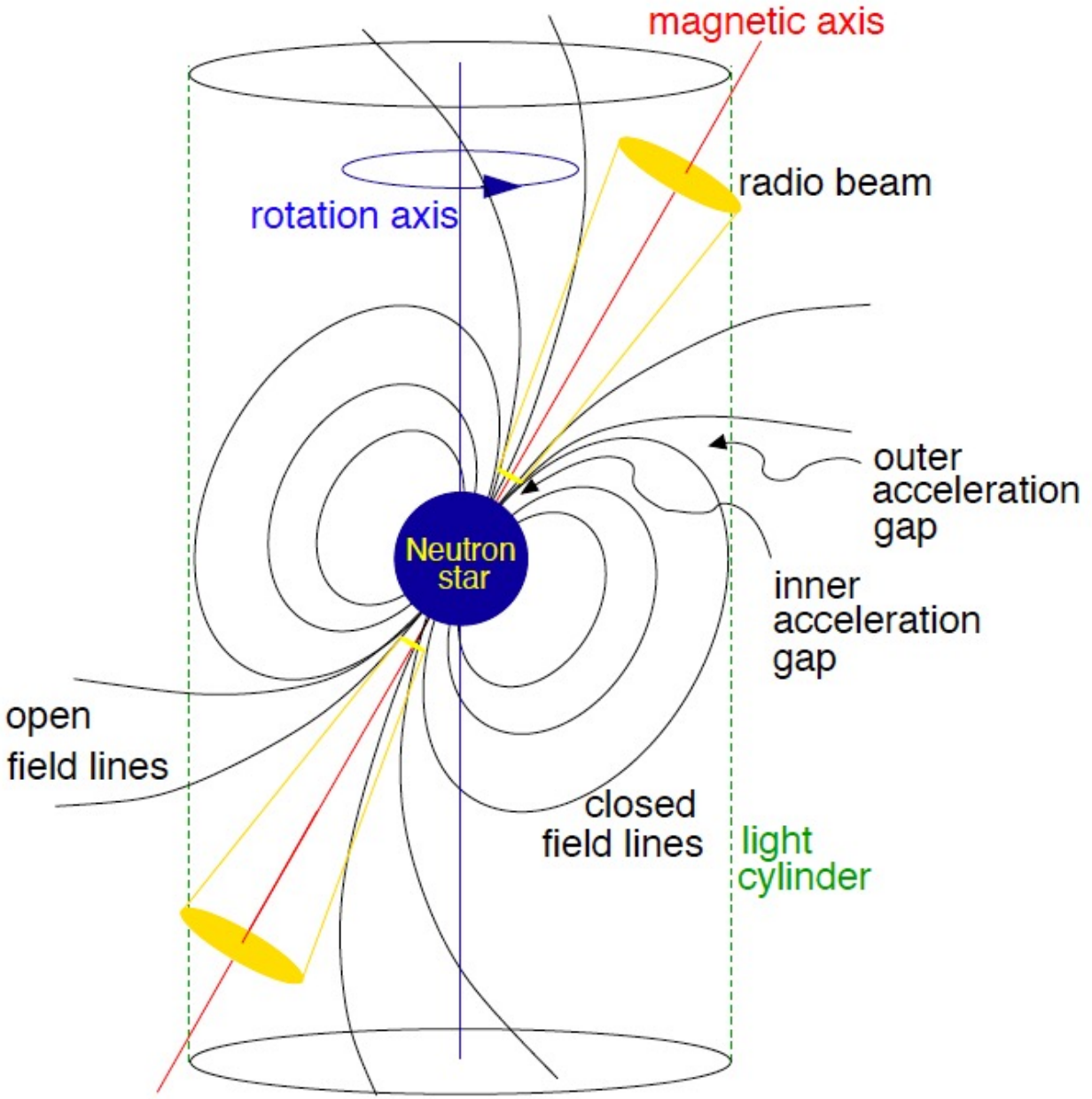




Lorimer & Kramer (2005)

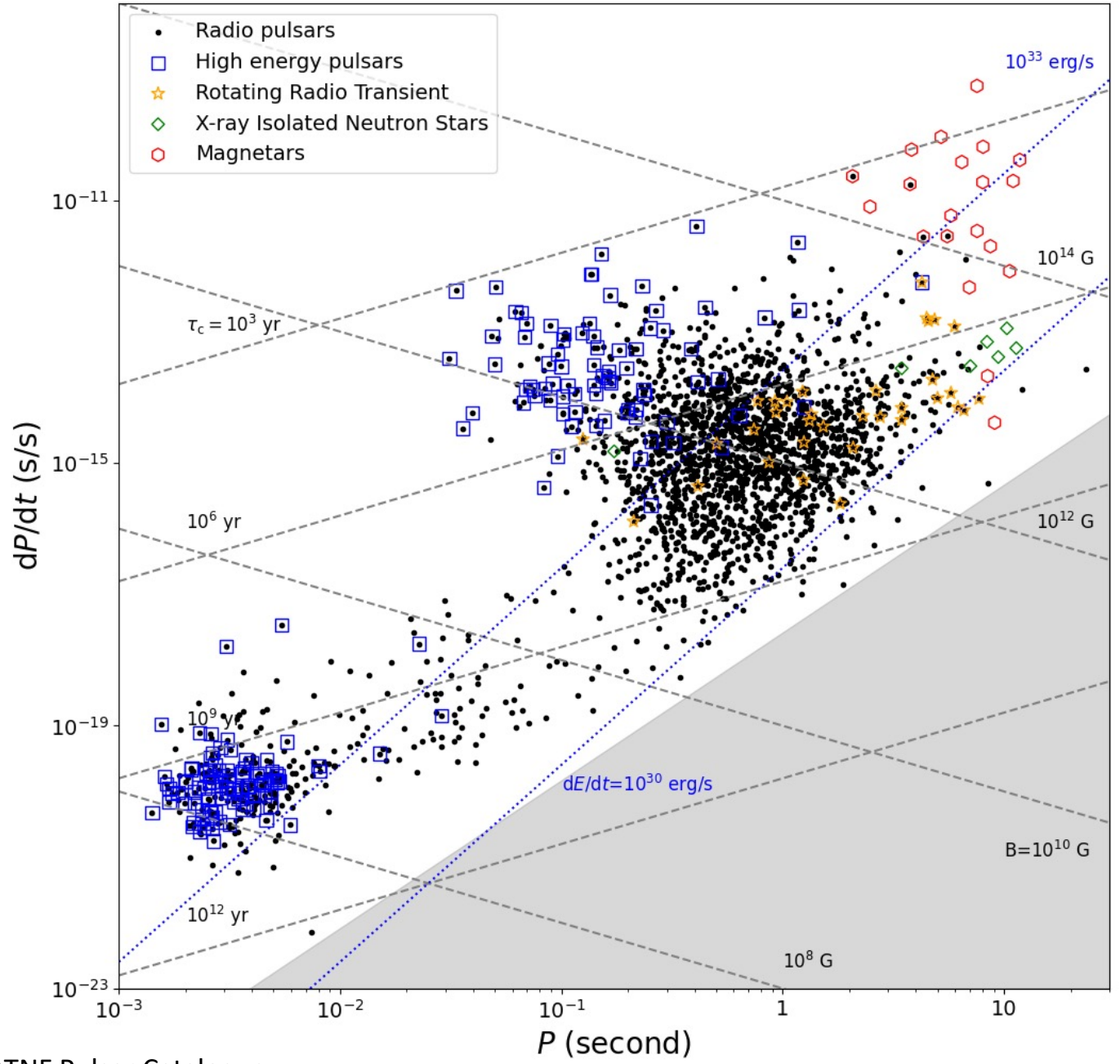
- How does the magnetosphere fill with charge?
- What is the solution of fields and currents in the magnetosphere?
- What is the energy spectrum of outflowing particles?
- What is the mechanism of the coherent radio emission?

Beskin (2016); Harding (2017)



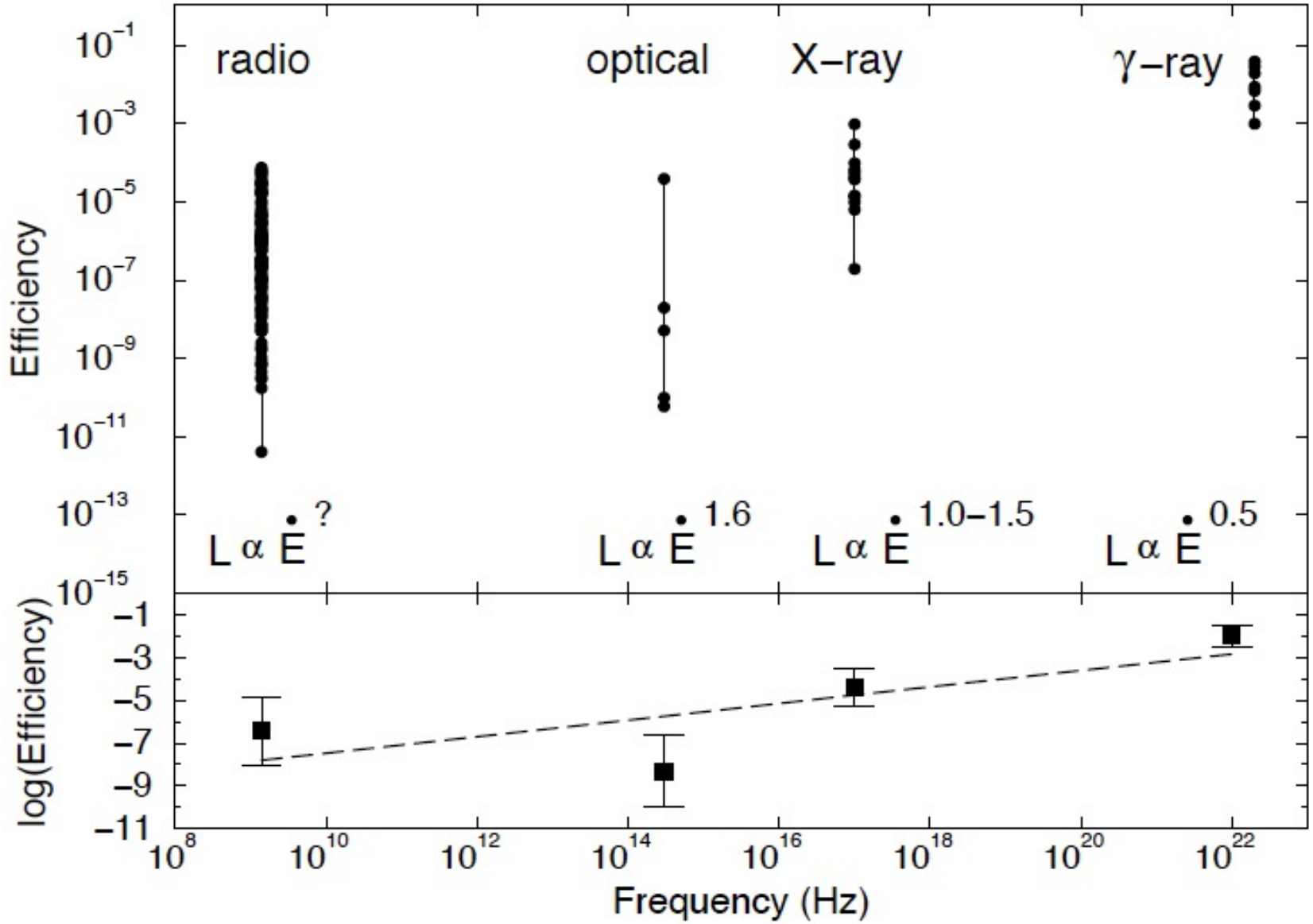
Lorimer & Kramer (2005)

- $B \propto (P \cdot \dot{P})^{1/2}$
- $Age \equiv P/2\dot{P}$

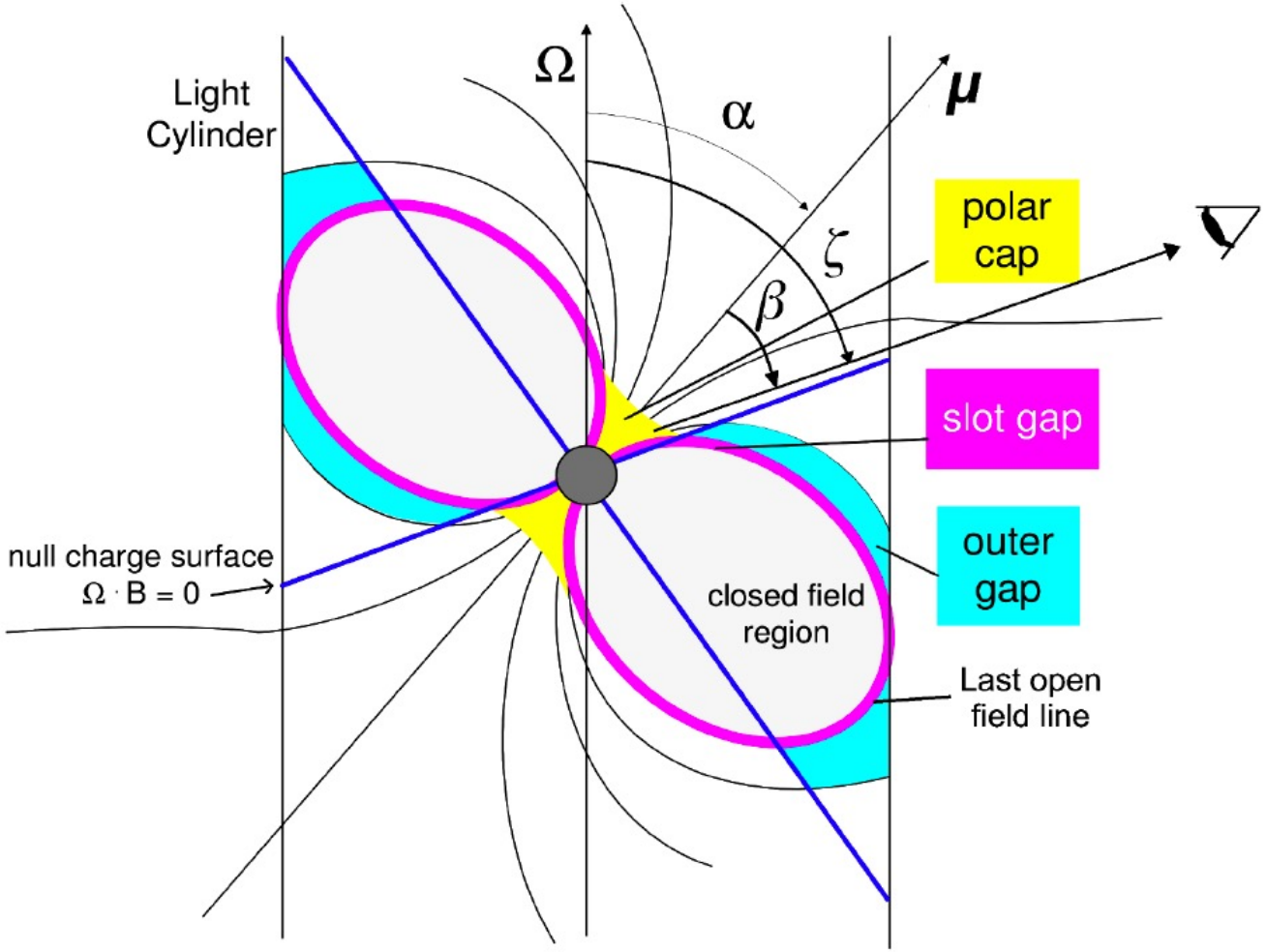


Data from the ATNF Pulsar Catalogue

	Radio (coherent)	Optical (~10 pulsars)	X-ray	Gamma-ray (>30MeV)
Young/ energetic	Steep spectrum (low frequency turnover?)	Non-thermal (e.g., Crab)	Thermal + non-thermal	Non-thermal
Middle aged	…	Thermal	Thermal + non-thermal	…
Millisecond	…	Thermal	Thermal	…
Magnetars (~30)	Flat spectrum (up to ~100GHz)	<5 magnetars	Thermal + non-thermal (some with a hard X-ray component)	*NOT detected*



Lorimer & Kramer (2005)

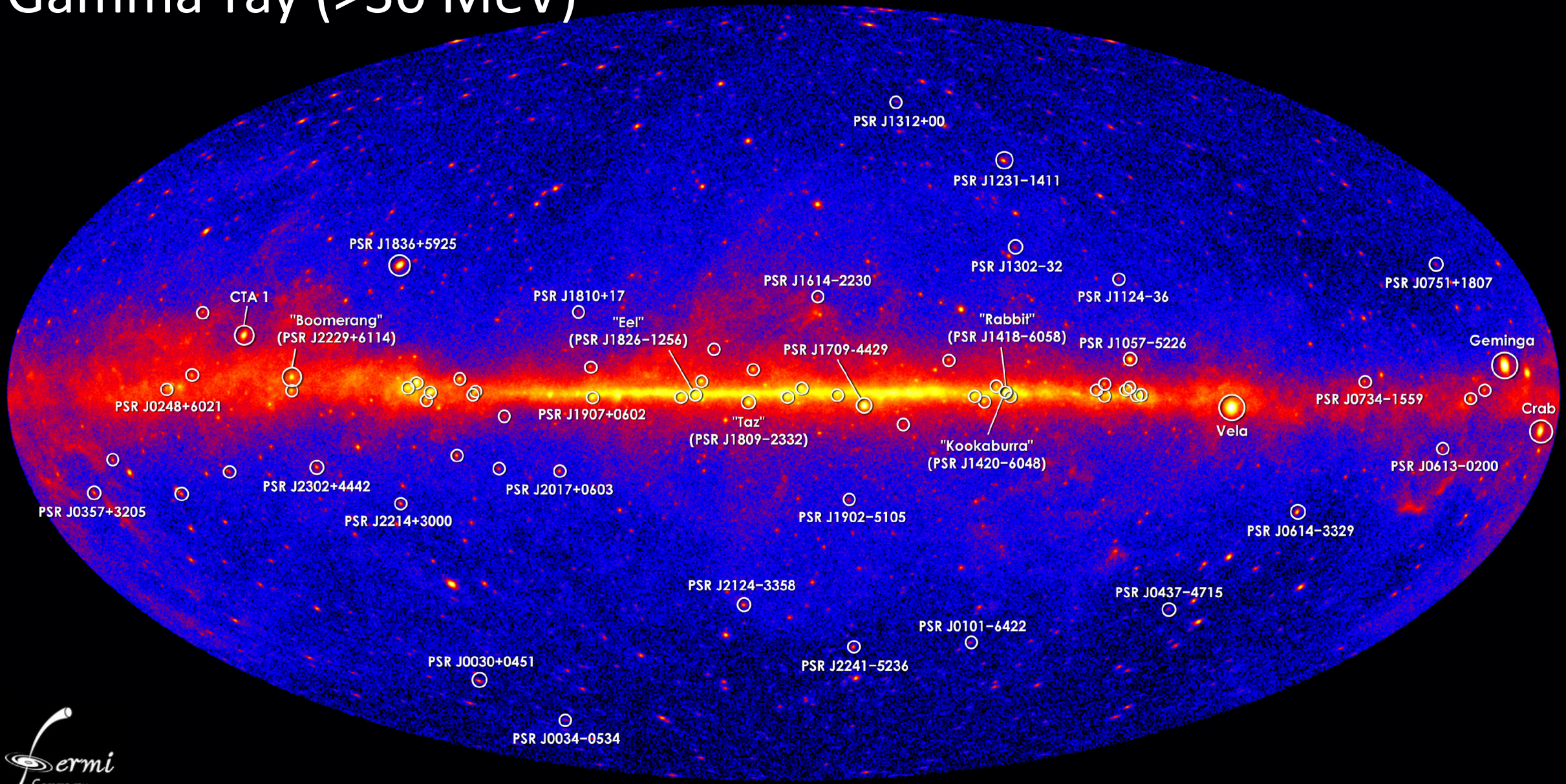


Harding (2005)

Prior to 2008

1. Acceleration region: polar cap, slot gap, outer gap?
2. Radiation mechanism: synchrotron, curvature, inverse Compton scattering?
3. Spectral cutoff: maximum electron energy, absorption?

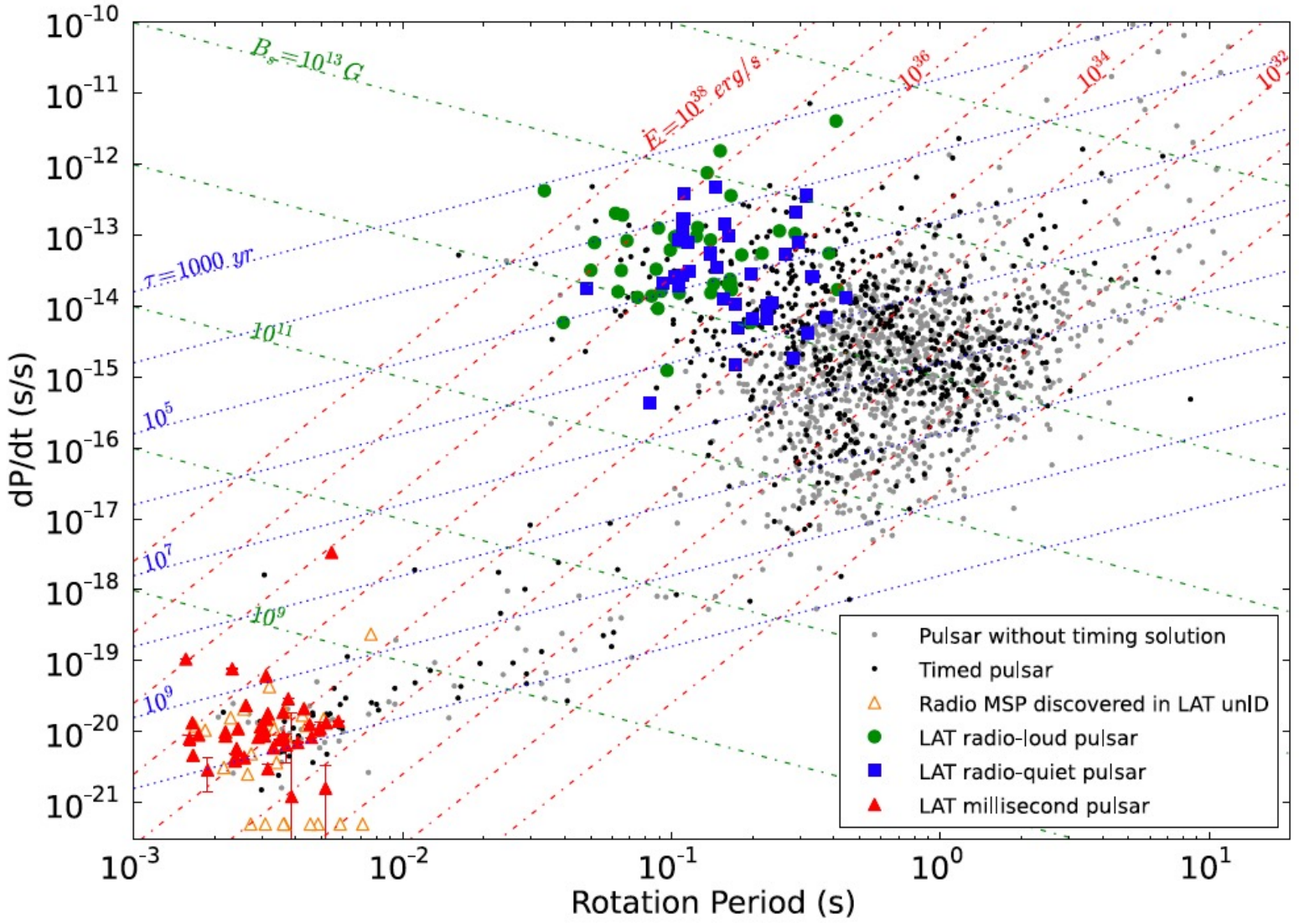
Gamma-ray (>30 MeV)



Fermi Gamma-ray Space Telescope

Credit: NASA/DOE/Fermi LAT Collaboration

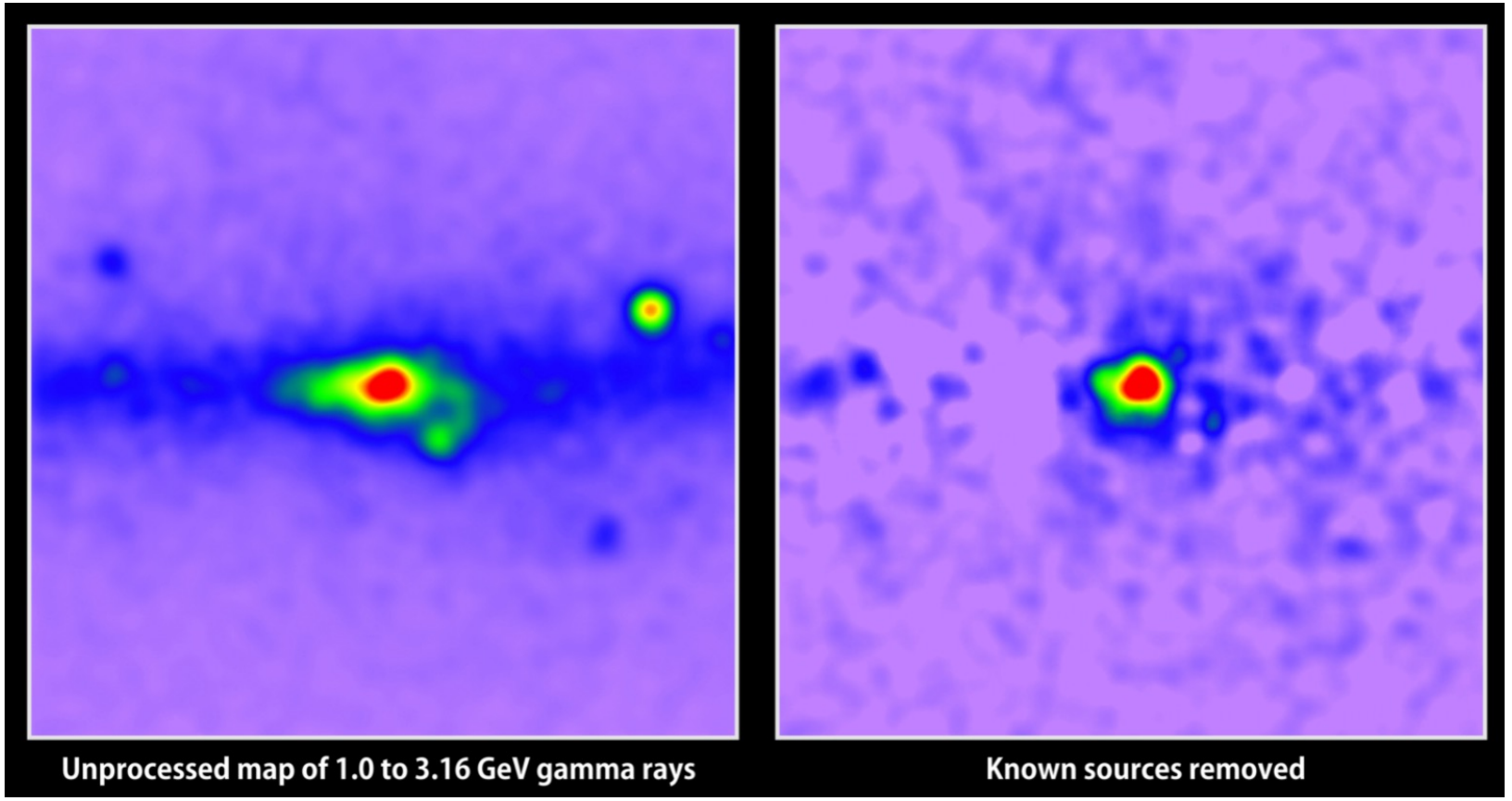
- A large fraction of the local energetic pulsars are GeV emitters.
- The gamma-ray emission accounts for a large fraction of the spin-down luminosity.



Abdo et al. (2013)

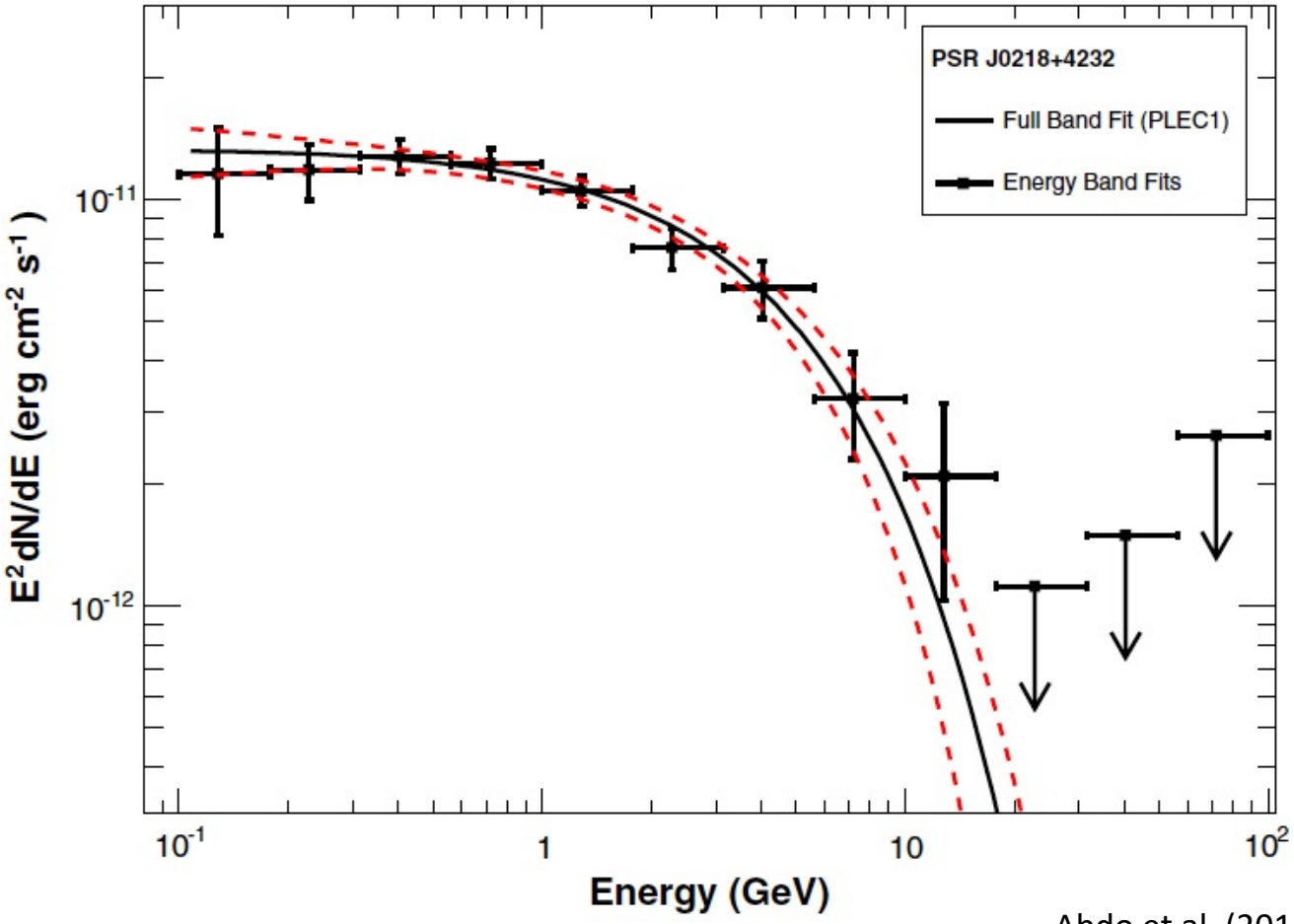
- Discovery of a population of new millisecond pulsars.
- What's the origin of gamma-ray in the Galactic Centra and globular clusters?

Galactic Centre



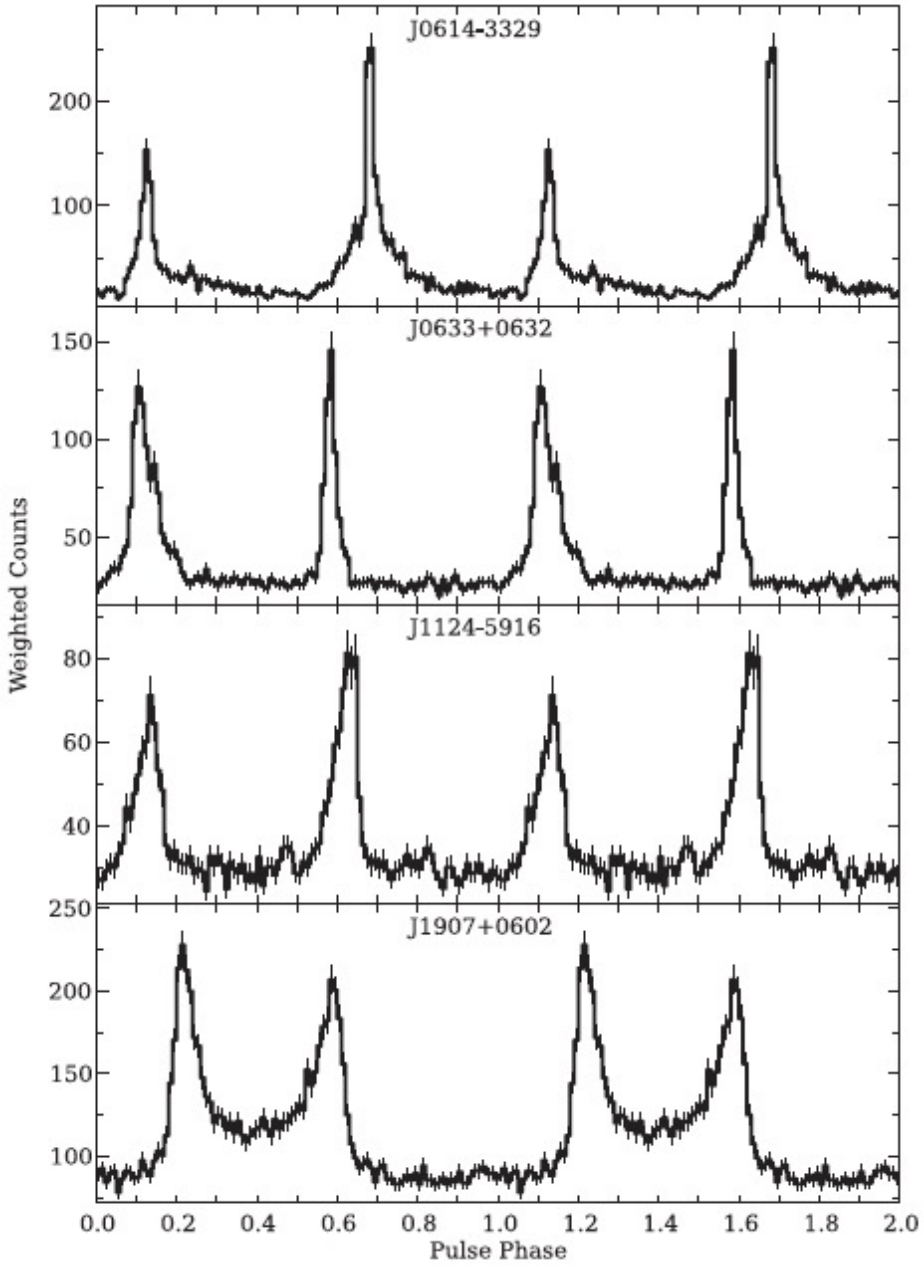
Credits: T. Linden

- The gamma-ray emission is from high-altitude emission zones (e.g., outer gap).



Abdo et al. (2013)

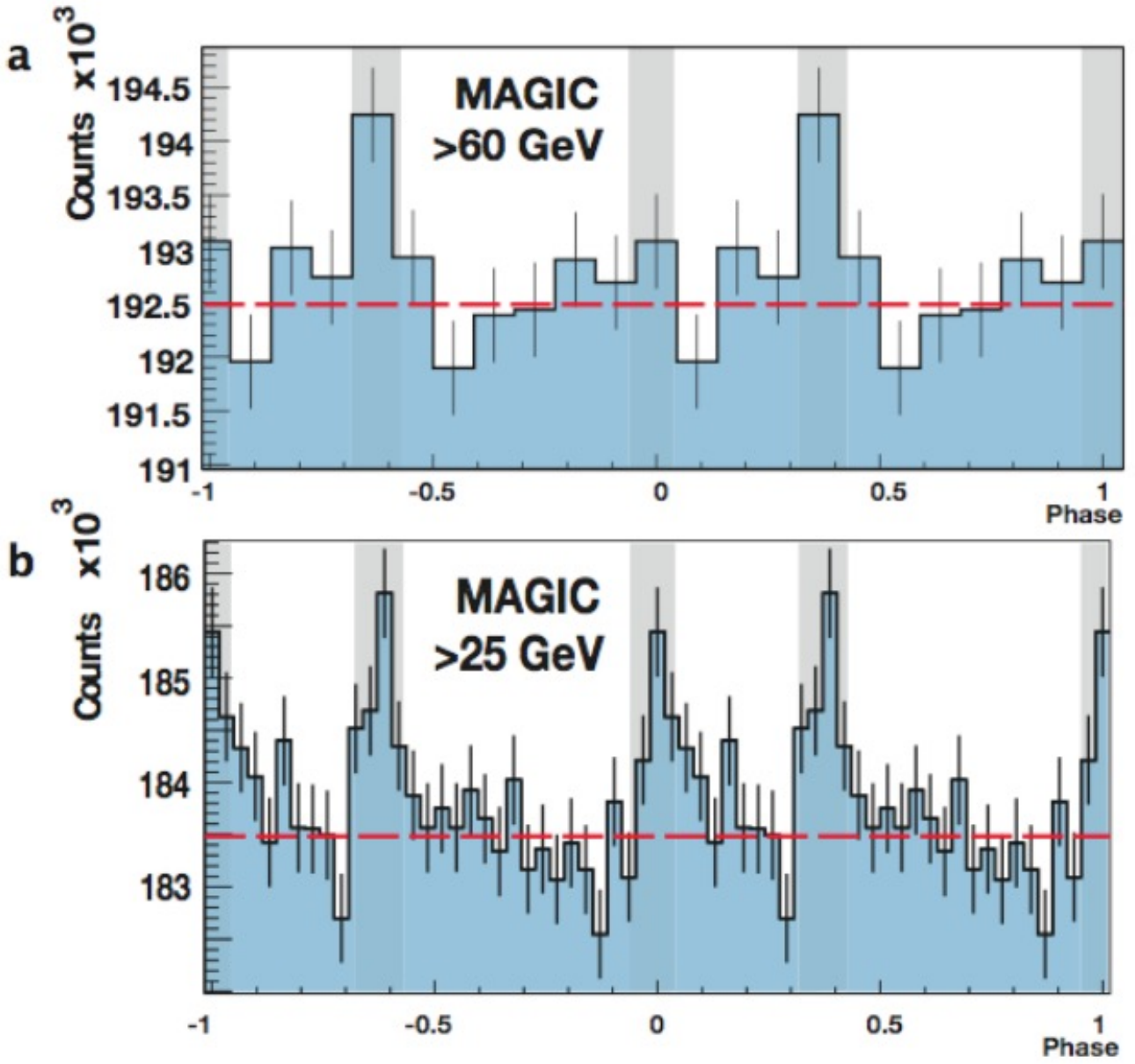
- The gamma-ray emission is distributed in a narrow gap bordering the closed field line boundary.



Abdo et al. (2013)

Gamma-ray (>10 GeV)

- Pulsed gamma-ray above 25GeV from Crab detected by **MAGIC** (Aliu et al. 2007).
- The detection strongly suggests that high energy emission is not from polar-cap region.



Aliu et al. (2007)

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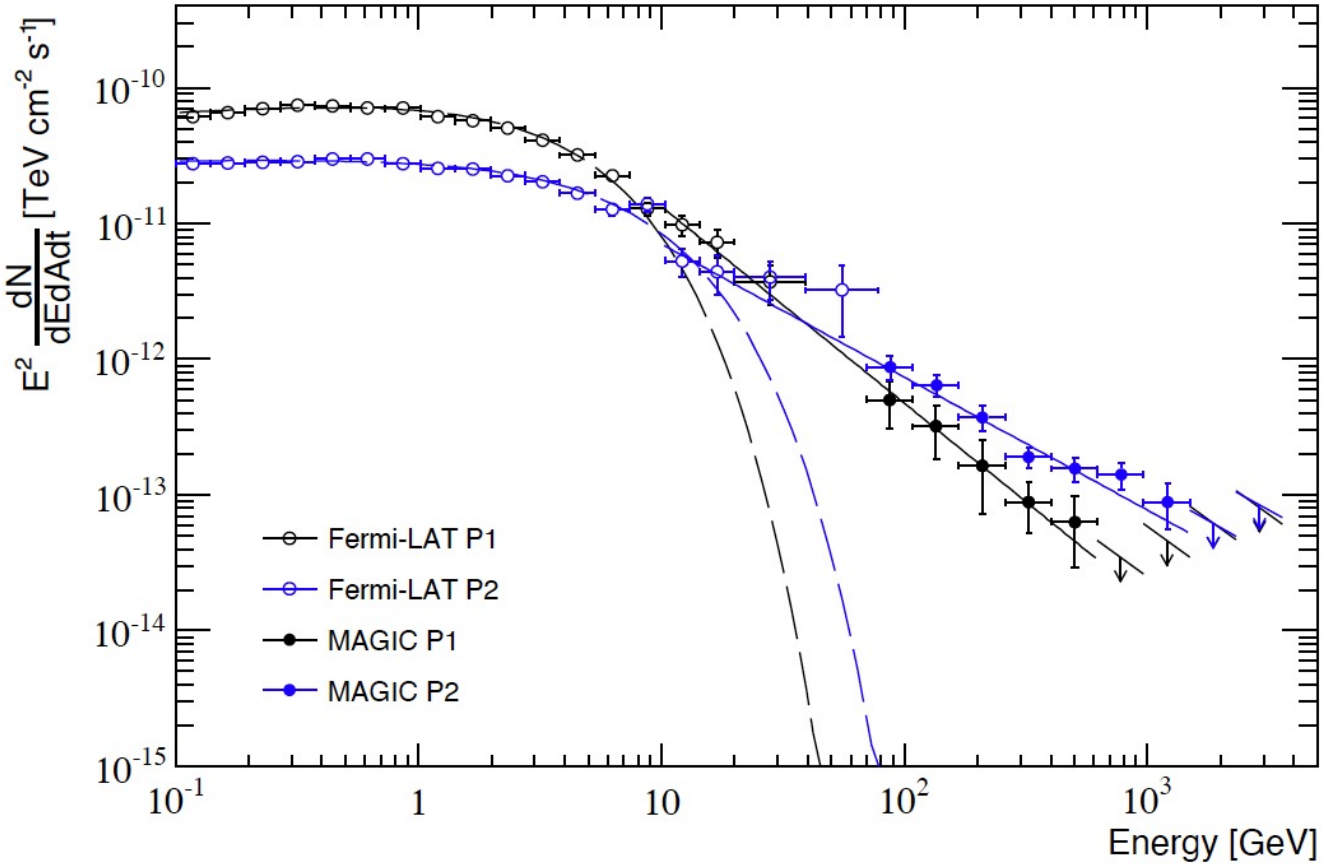
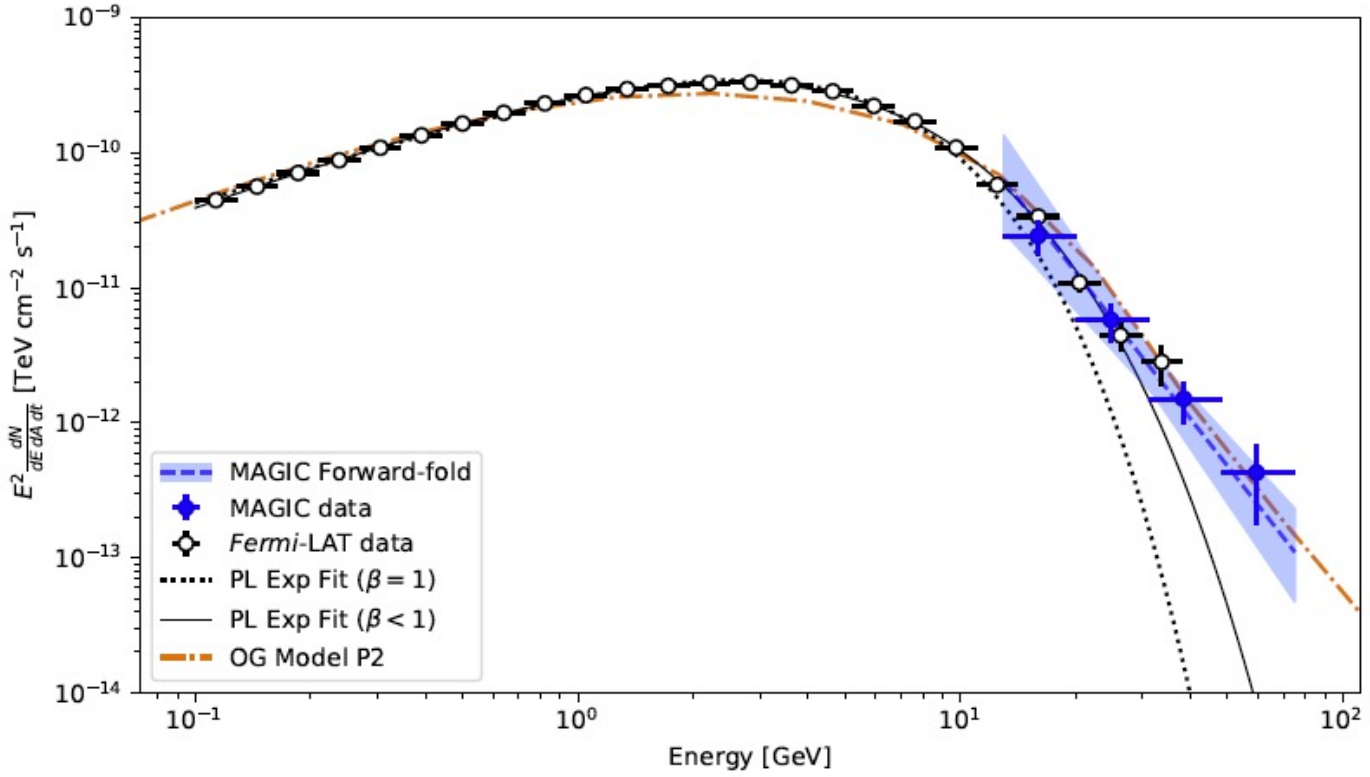


Ansoldi et al. (2016)

Towards TeV Gammas…

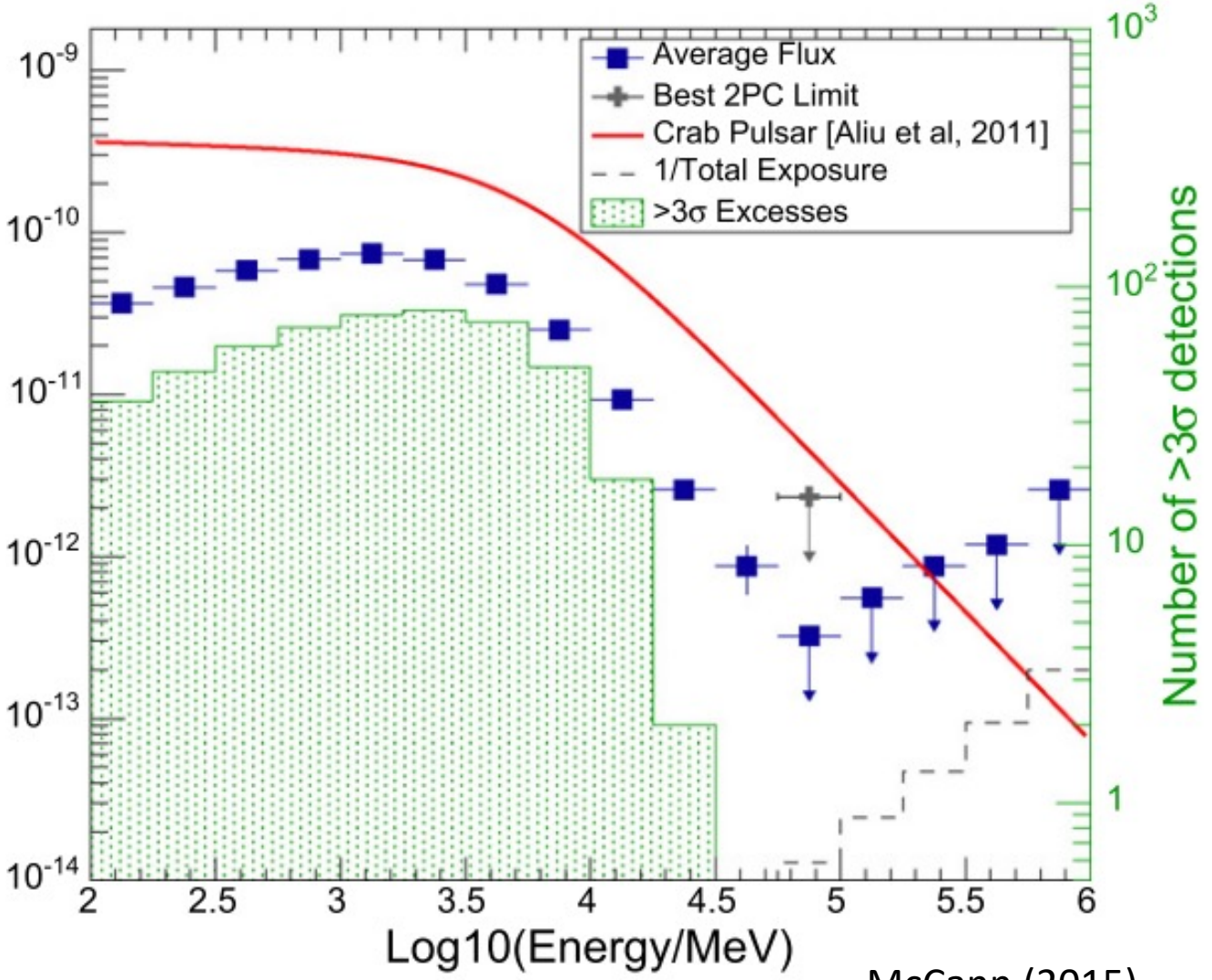
- Vela up to TeV (H.E.S.S in prep.)
- PSR B1706−44: sub-100GeV (Spir-Jacob et al. 2019)
- Geminga: up to 75GeV (Acciari et al 2020)



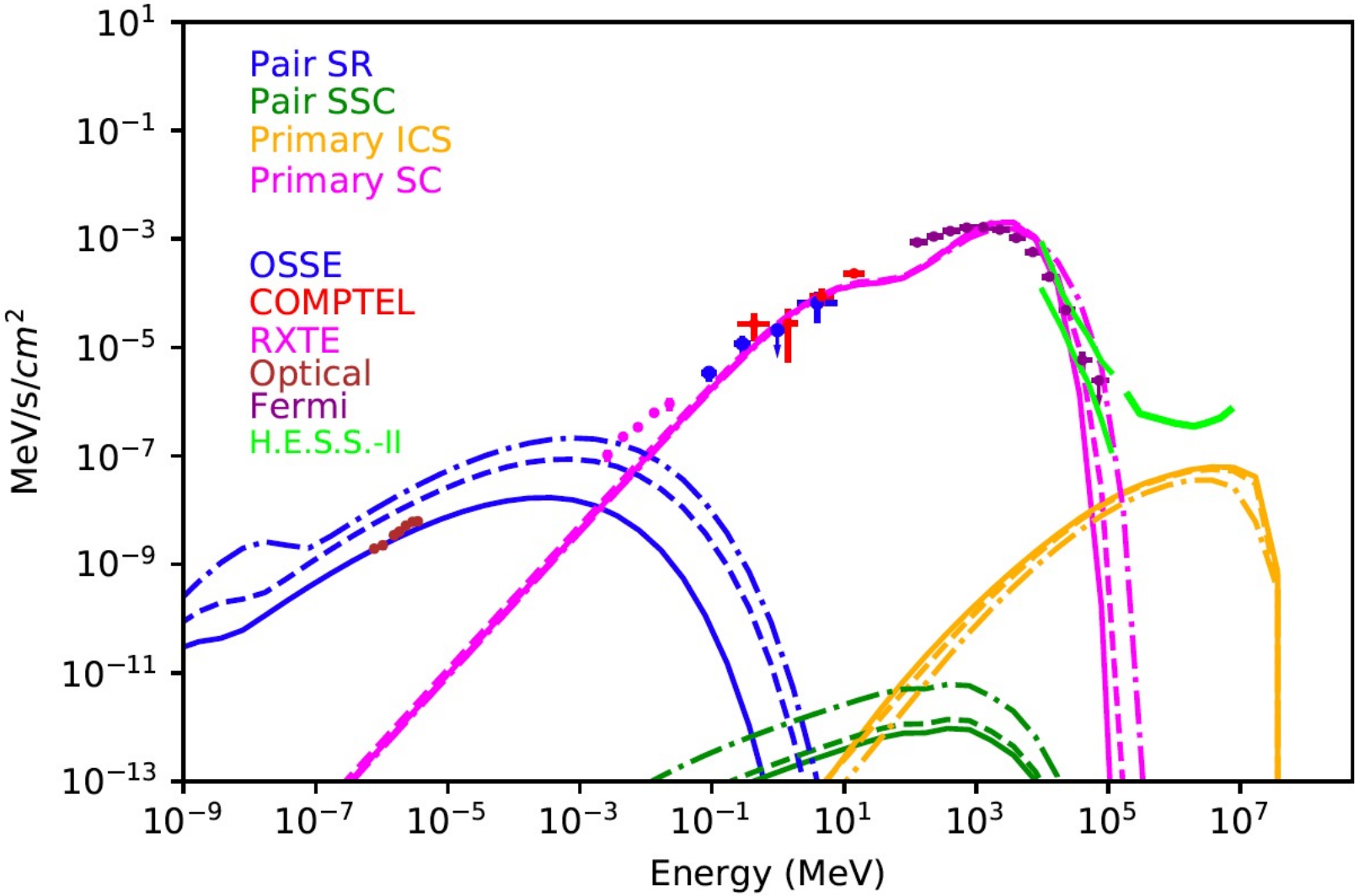
Acciari et al. (2020)

Towards TeV Gammas…

- Average emission per pulsar from a sample of 115 pulsars was limited to lie below ~7% of that of the Crab pulsar in the 56−100 GeV band and below ~30% in the 100−177 GeV band.



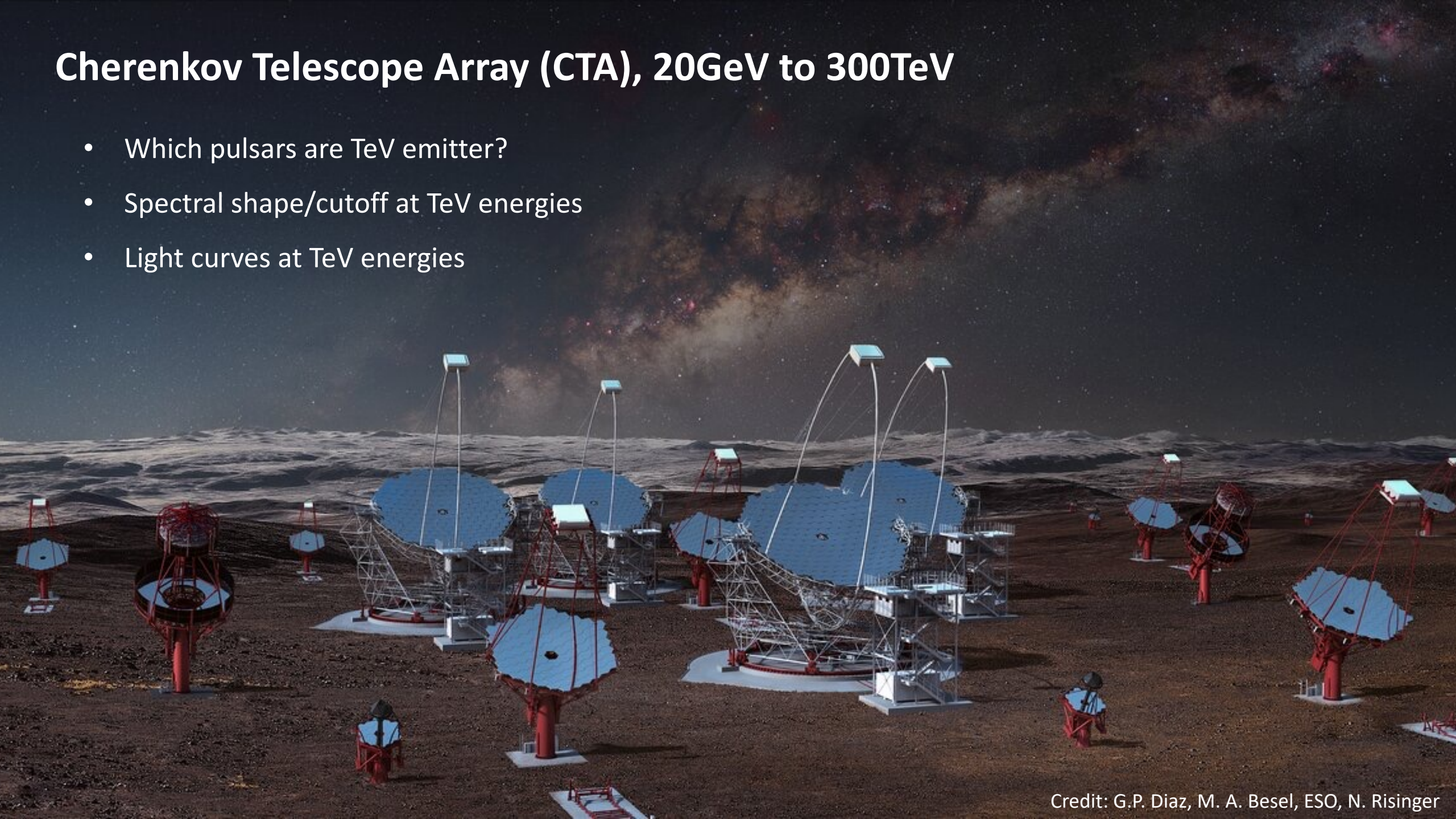
McCann (2015)



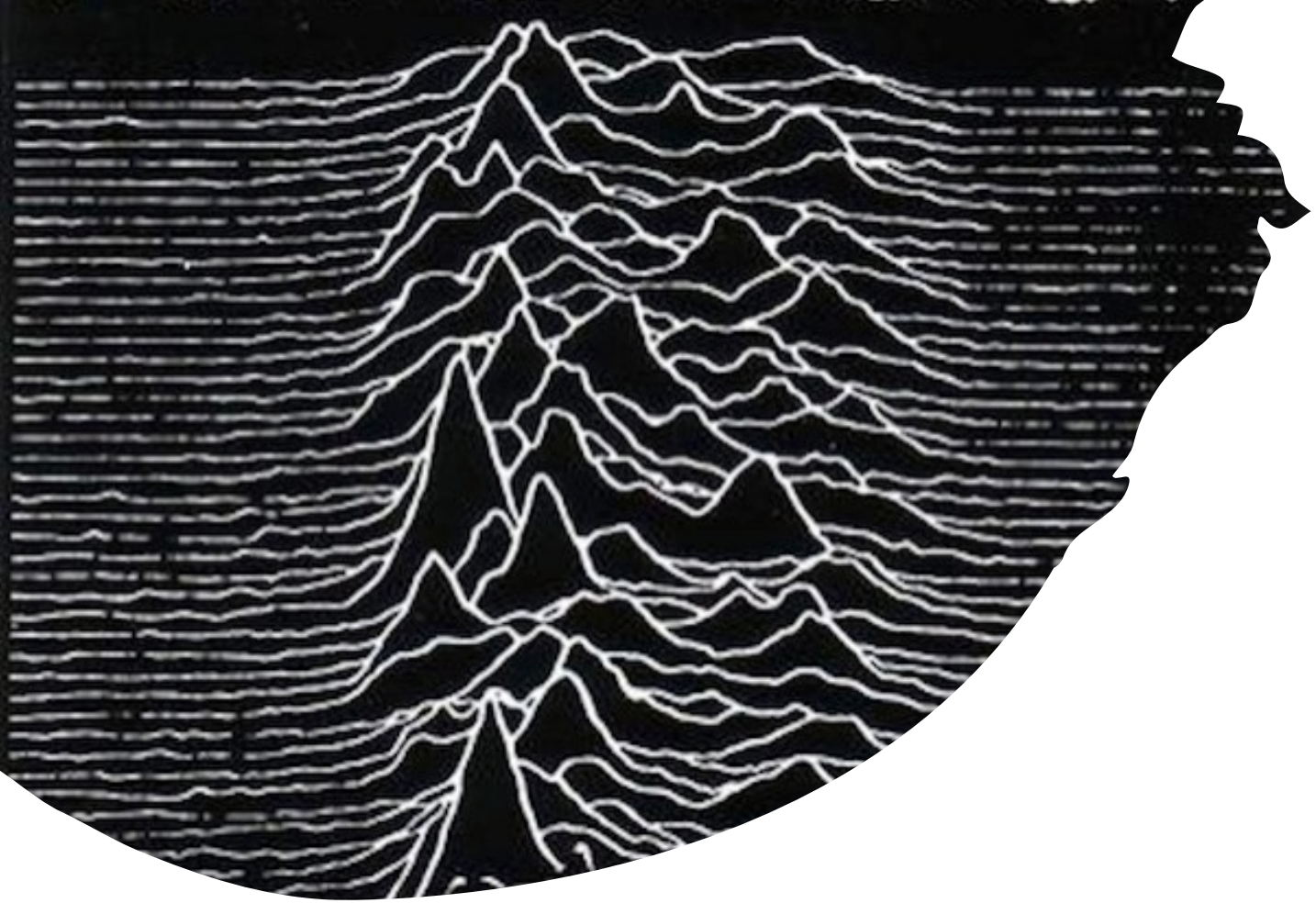
Harding et al. (2021)

Cherenkov Telescope Array (CTA), 20GeV to 300TeV

- Which pulsars are TeV emitter?
- Spectral shape/cutoff at TeV energies
- Light curves at TeV energies



Credit: G.P. Diaz, M. A. Besel, ESO, N. Risinger



- CTA will shed new light on the origin of very high energy (VHE) emission from pulsars.
- VHE emission reveals key information about the outer part of pulsar magnetosphere (close to the light cylinder), where radio giant pulses and fast radio bursts (possibly) originate.
- Understanding the VHE spectrum of pulsars (MSPs) is important for a range of astrophysics (e.g., dark matter, globular clusters, Galactic Centre).

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