AGILE & Fermi Observations of PSR B1509-58

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on behalf of the
AGILE Team & AGILE Pulsar Working Group

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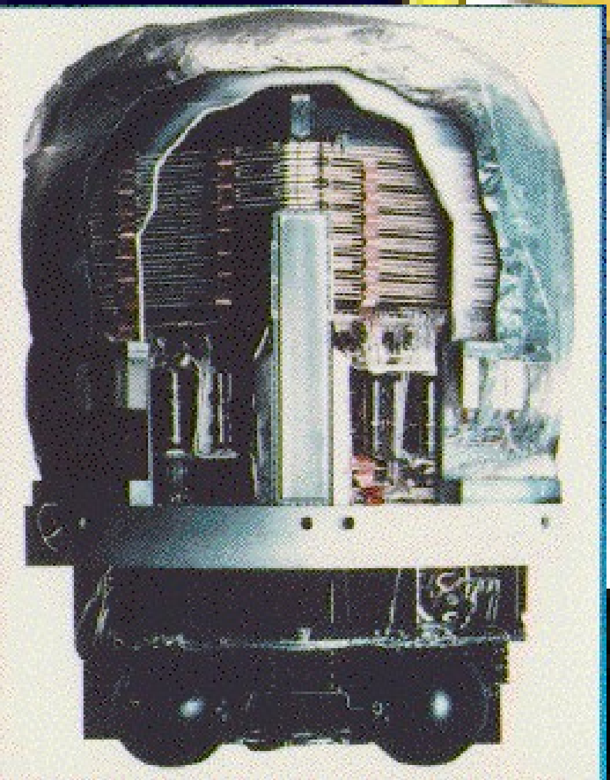
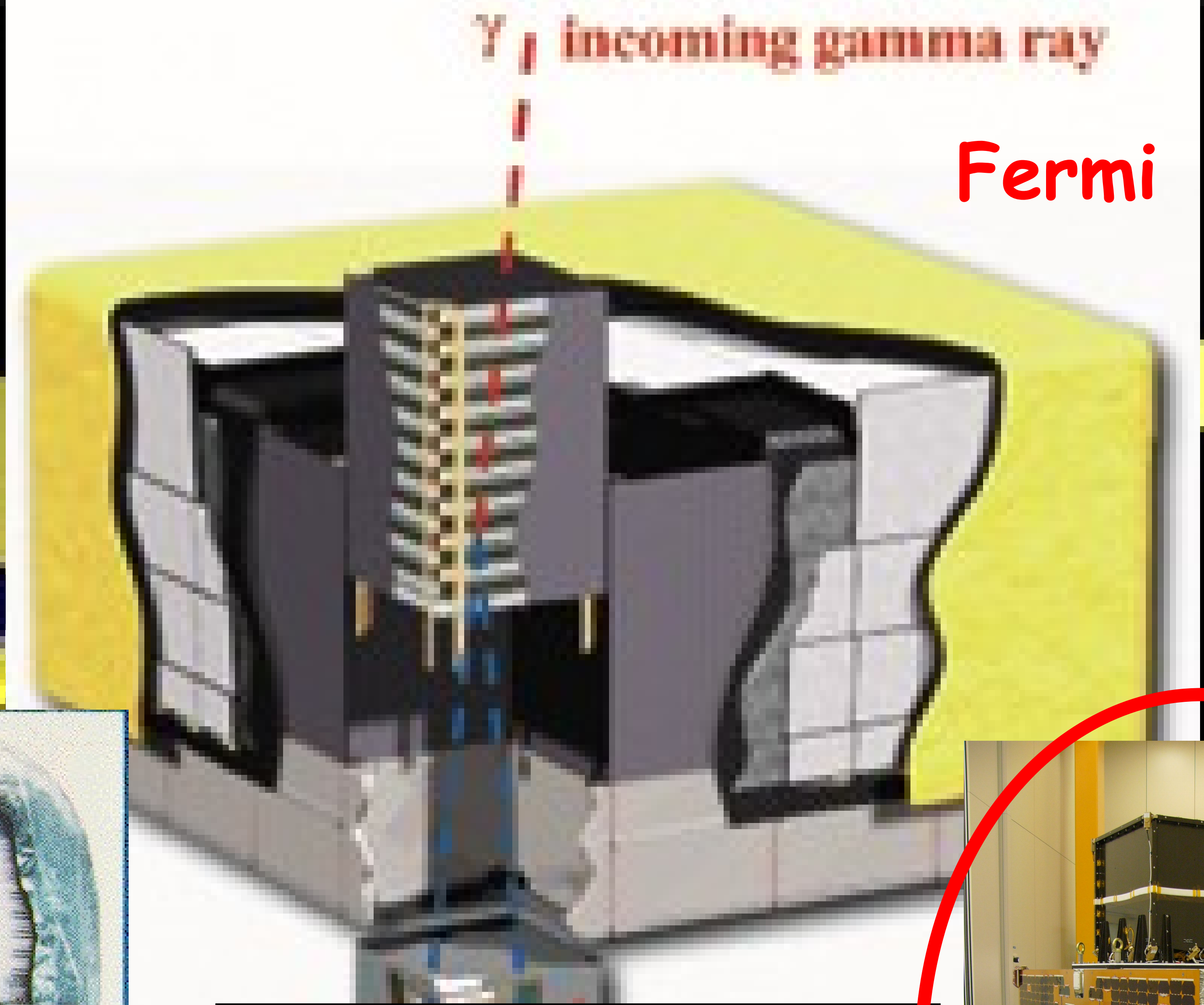
EGRET

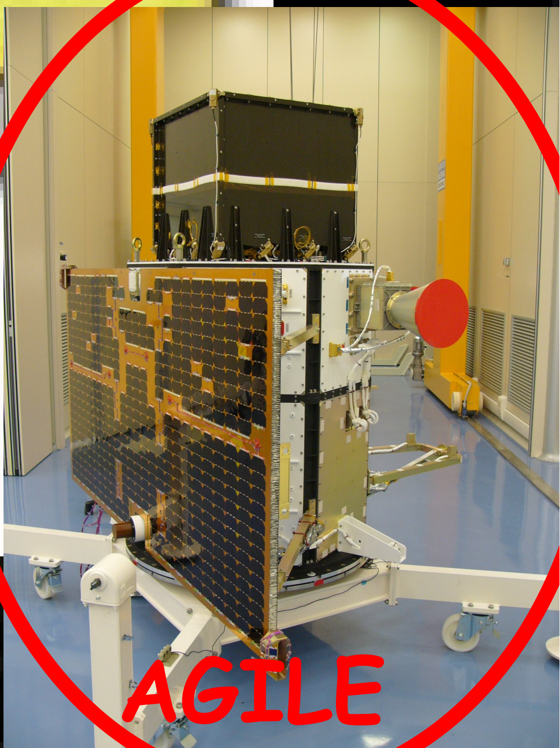


Fermi



>0.5 GeV Fermi sensitivity much better than AGILE.

at 100 MeV (and below) AGILE sensitivity is competitive.



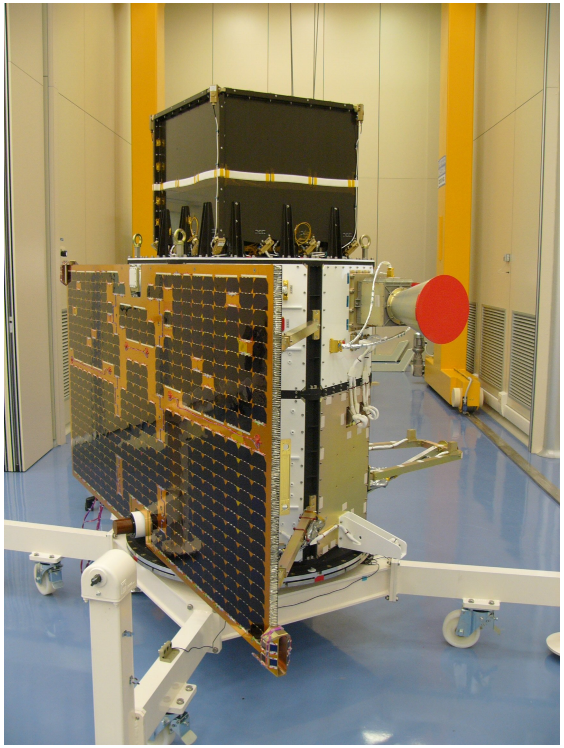
AGILE

AGILE

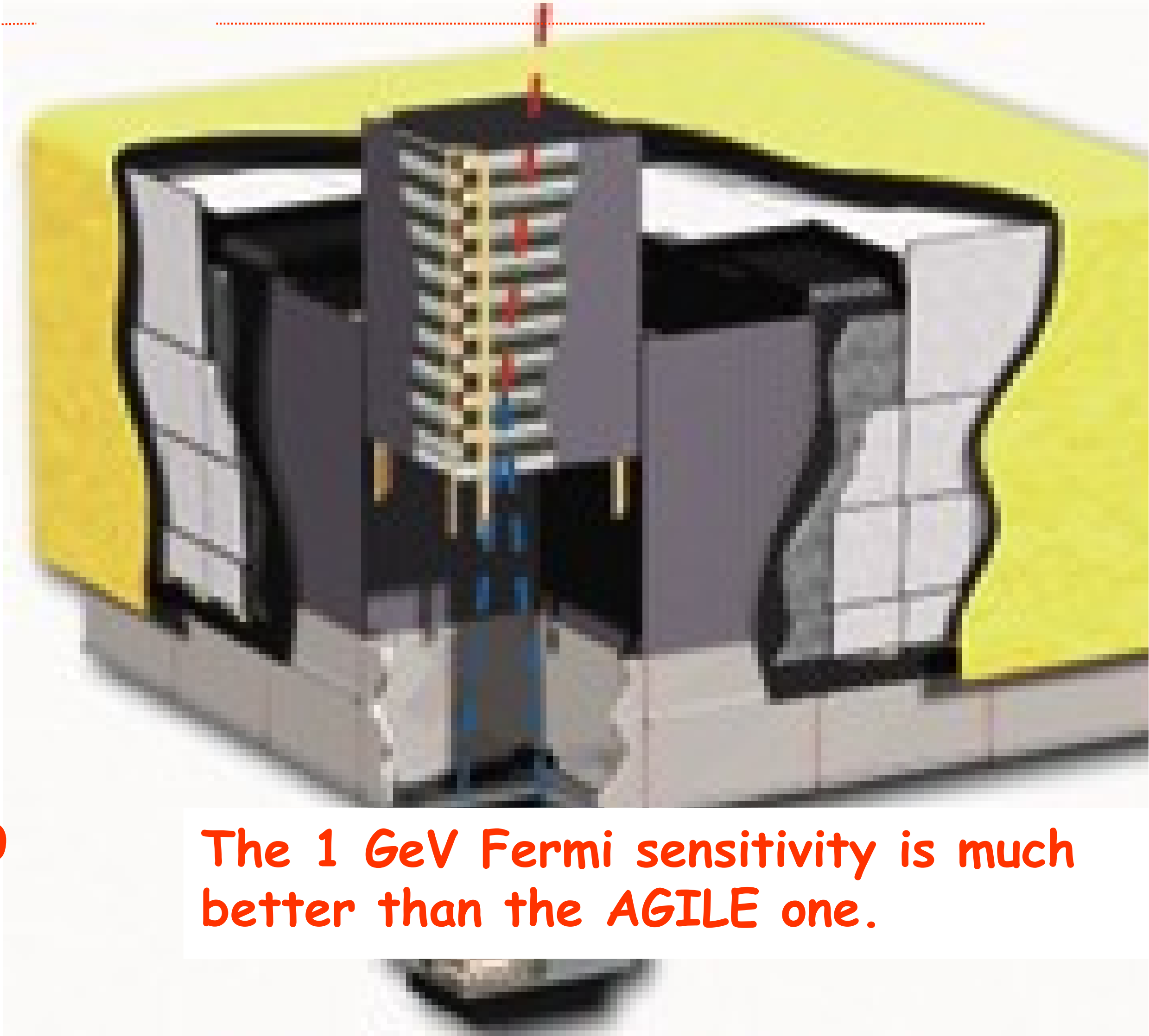
Fermi

20 MeV - 50 GeV

20 MeV - **300 GeV**

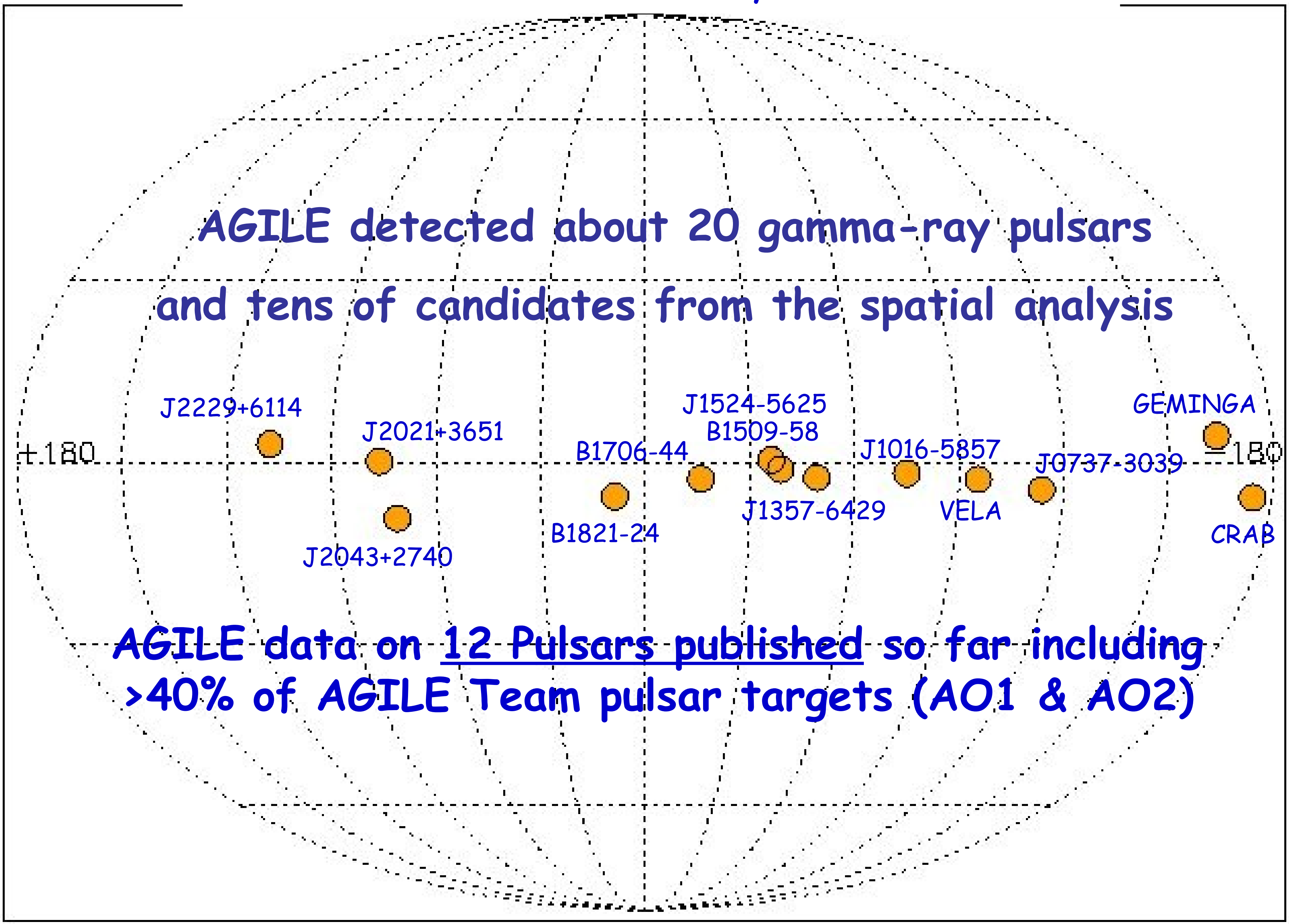


In the 30-100 MeV AGILE sensitivity is competitive (500 cm^2 eff. Area for timing).

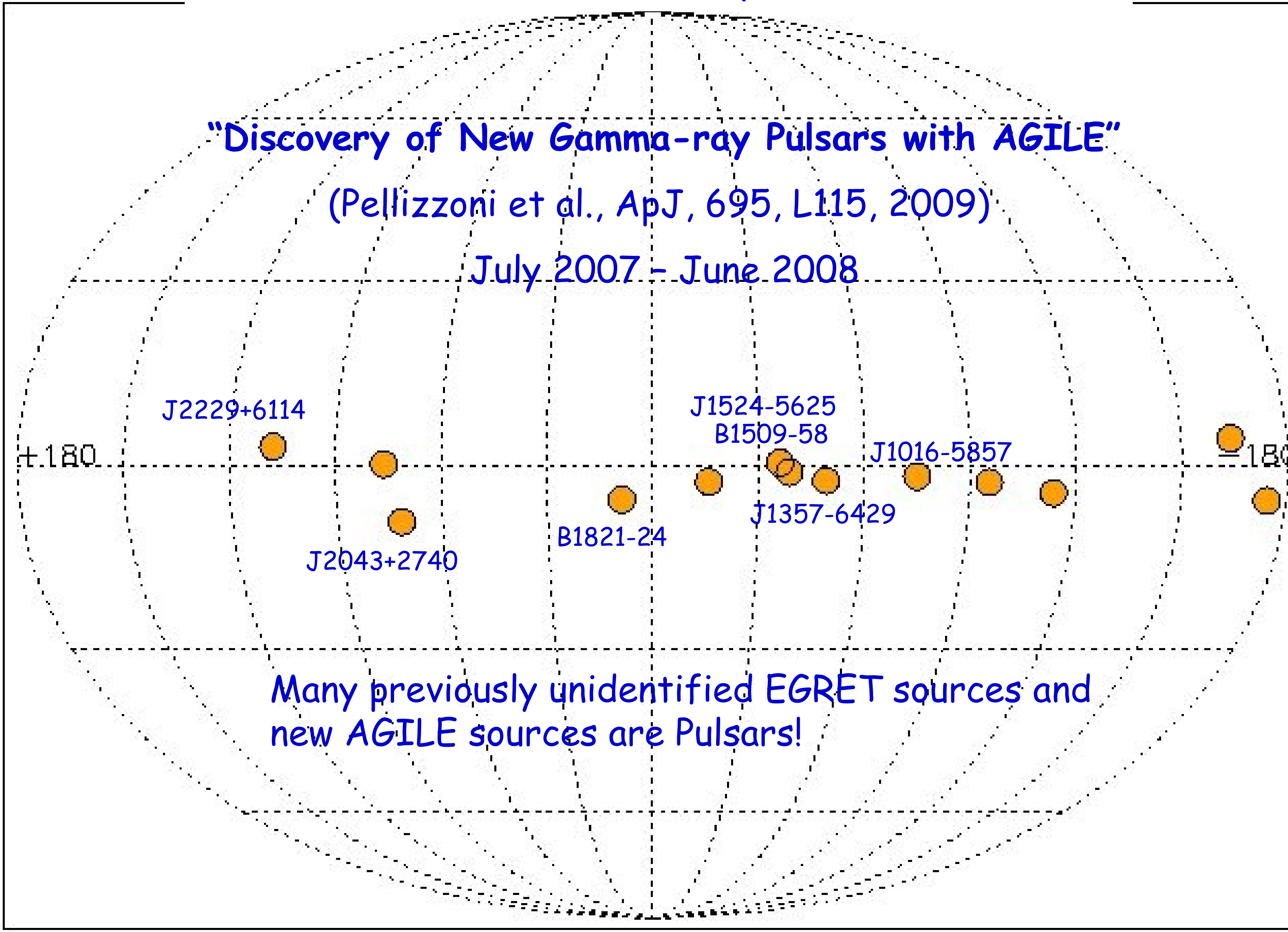


The 1 GeV Fermi sensitivity is much better than the AGILE one.

AGILE Pulsars… three years after…



AGILE Pulsars… two years after…



"Discovery of New Gamma-ray Pulsars with AGILE"

(Pellizzoni et al., ApJ, 695, L115, 2009)

July 2007 – June 2008

Many previously unidentified EGRET sources and new AGILE sources are Pulsars!

AGILE Pulsars… two years after…

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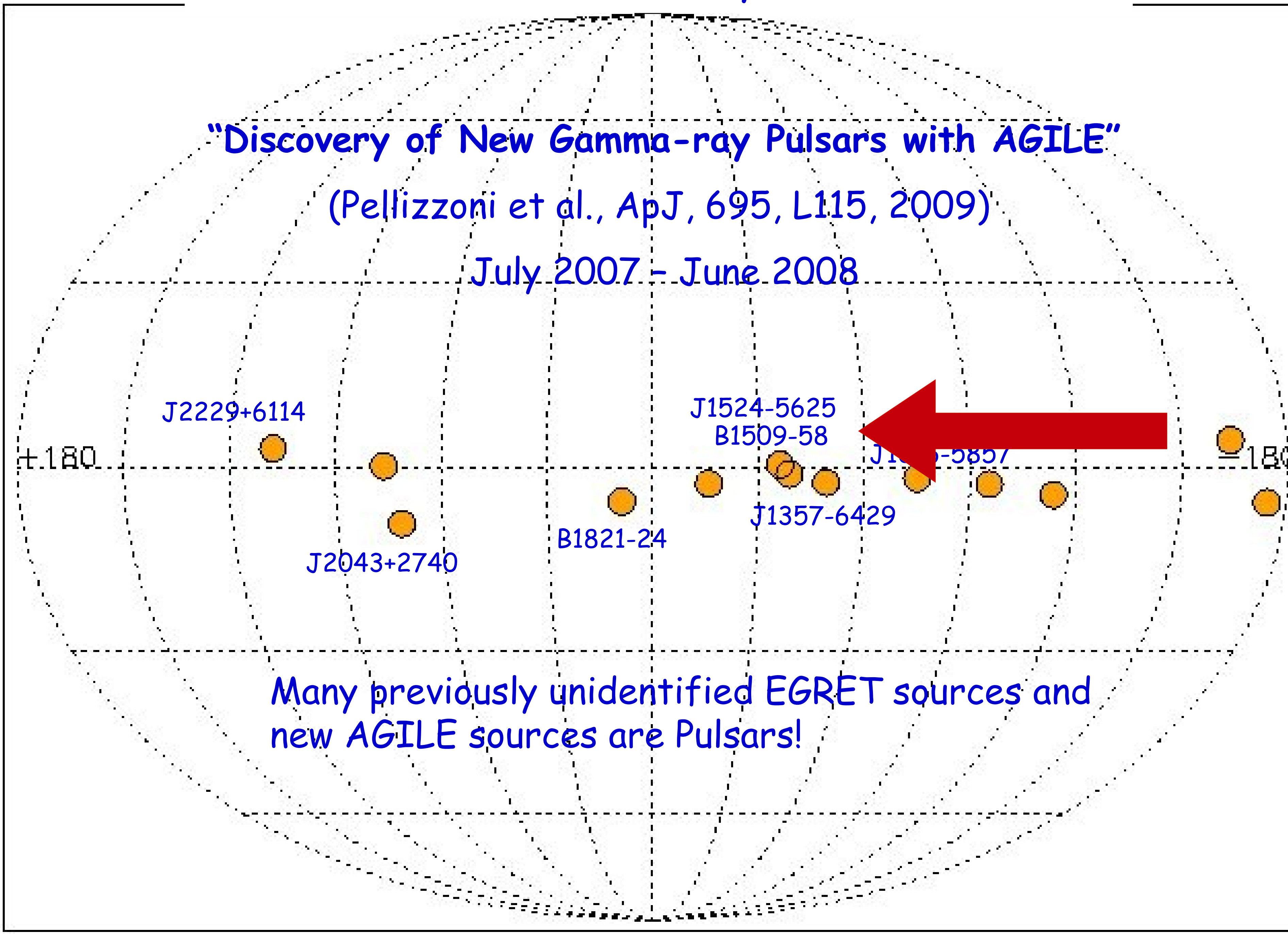

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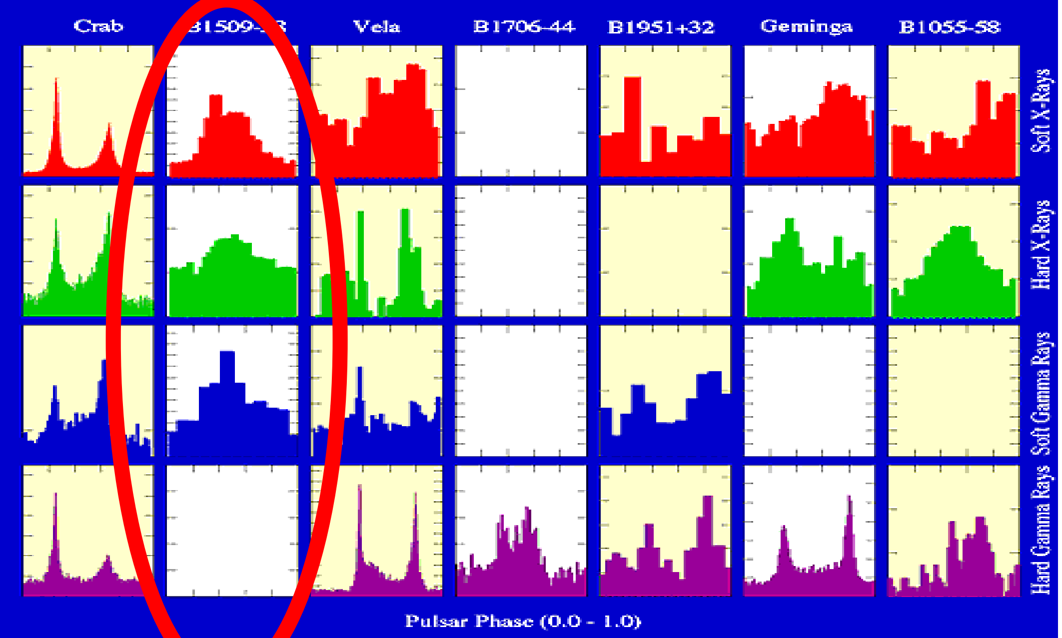
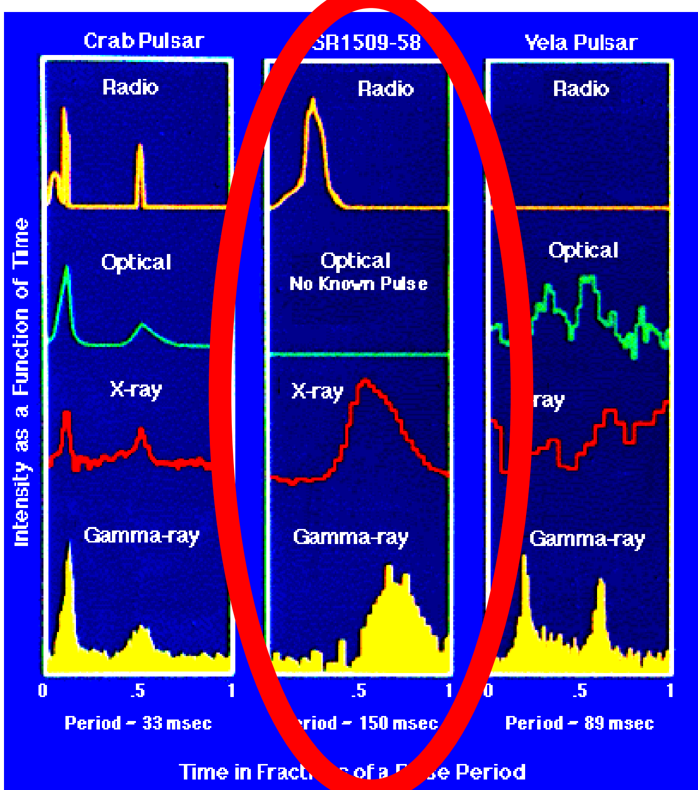




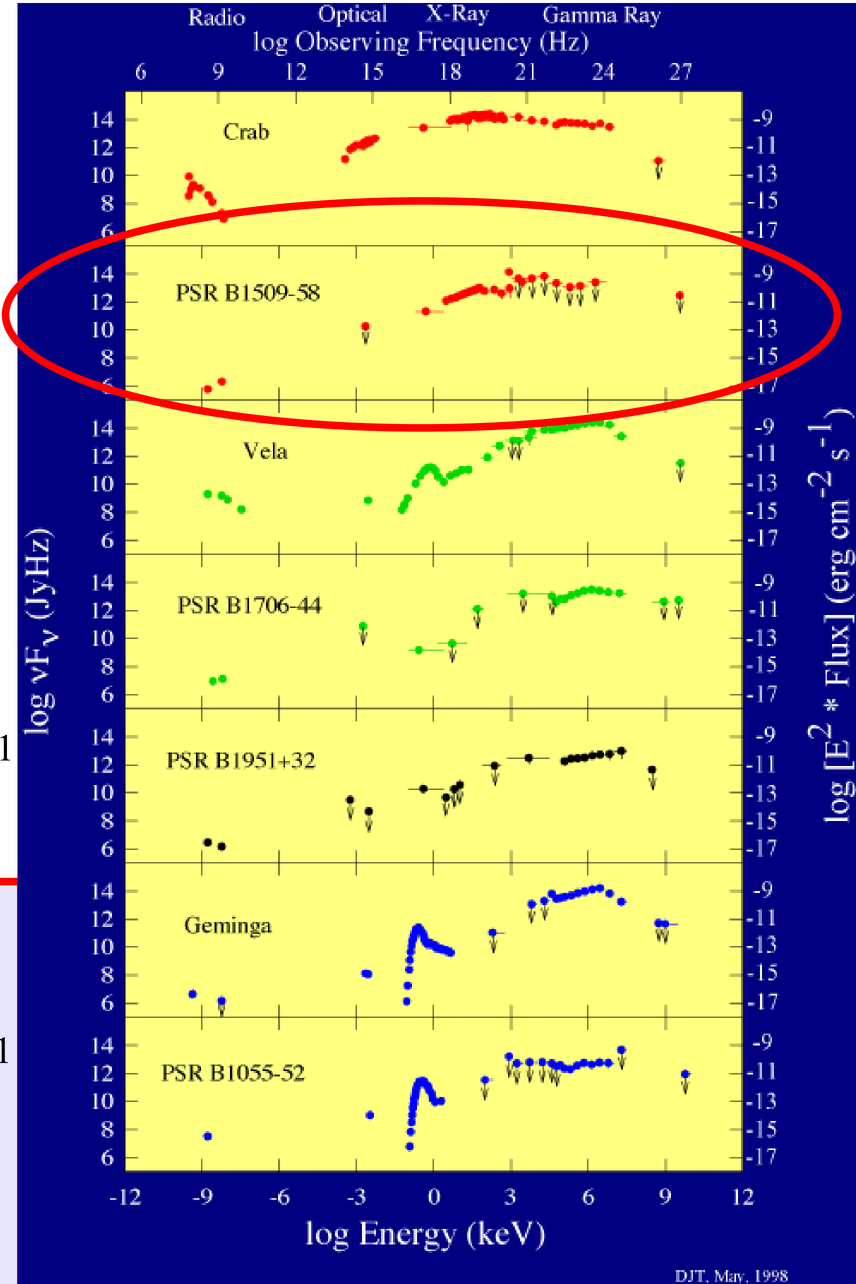
$$P \simeq 150\, ms$$

$$\dot{P} \simeq 1.53 \times 10^{-12}\, s\, s^{-1}$$

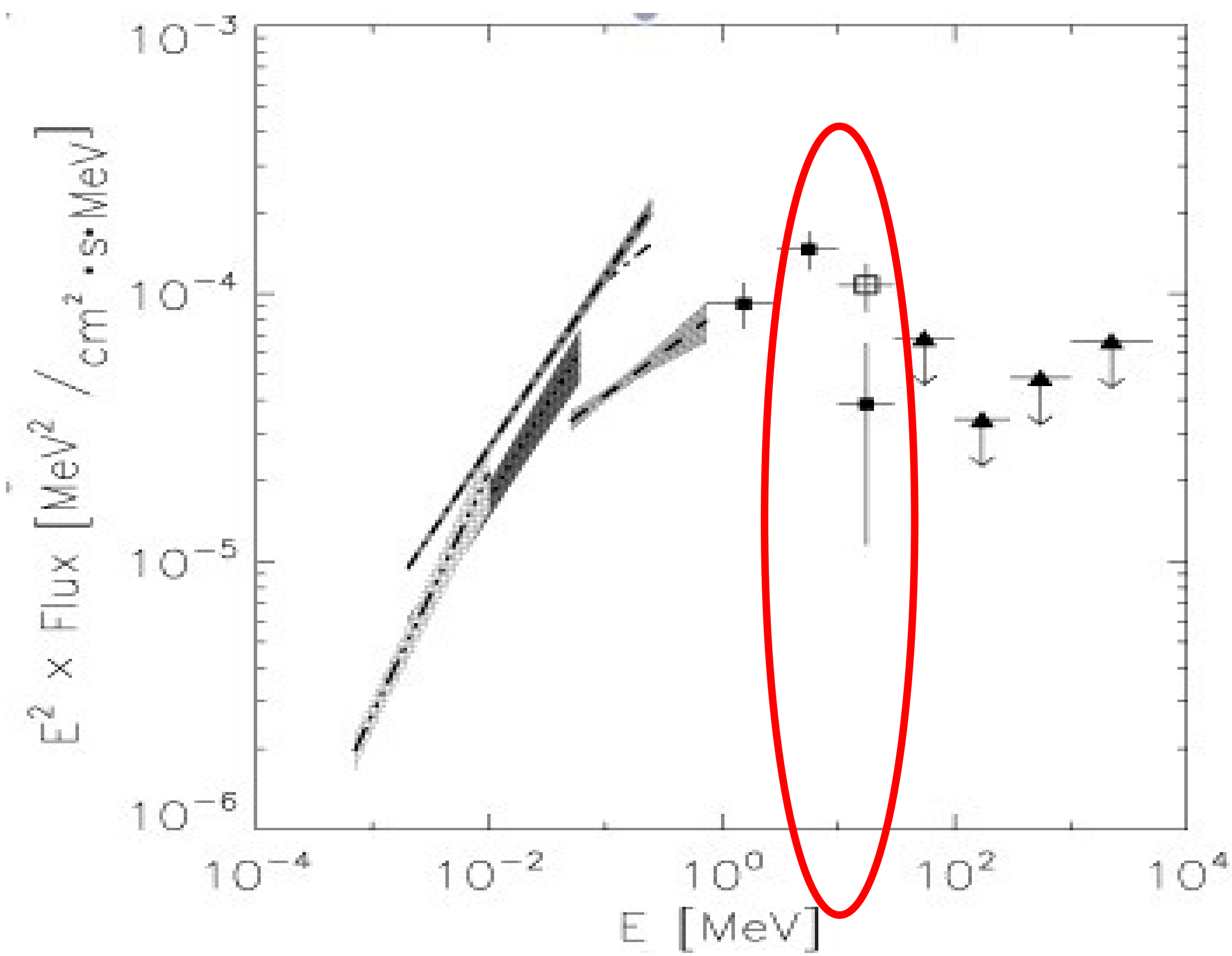
$$\tau_{sd} \approx 1570\, yrs$$

$$\dot{E} \approx 1.8 \times 10^{37}\, erg\, s^{-1}$$

$$B \approx 3.1 \times 10^{13}\, G$$

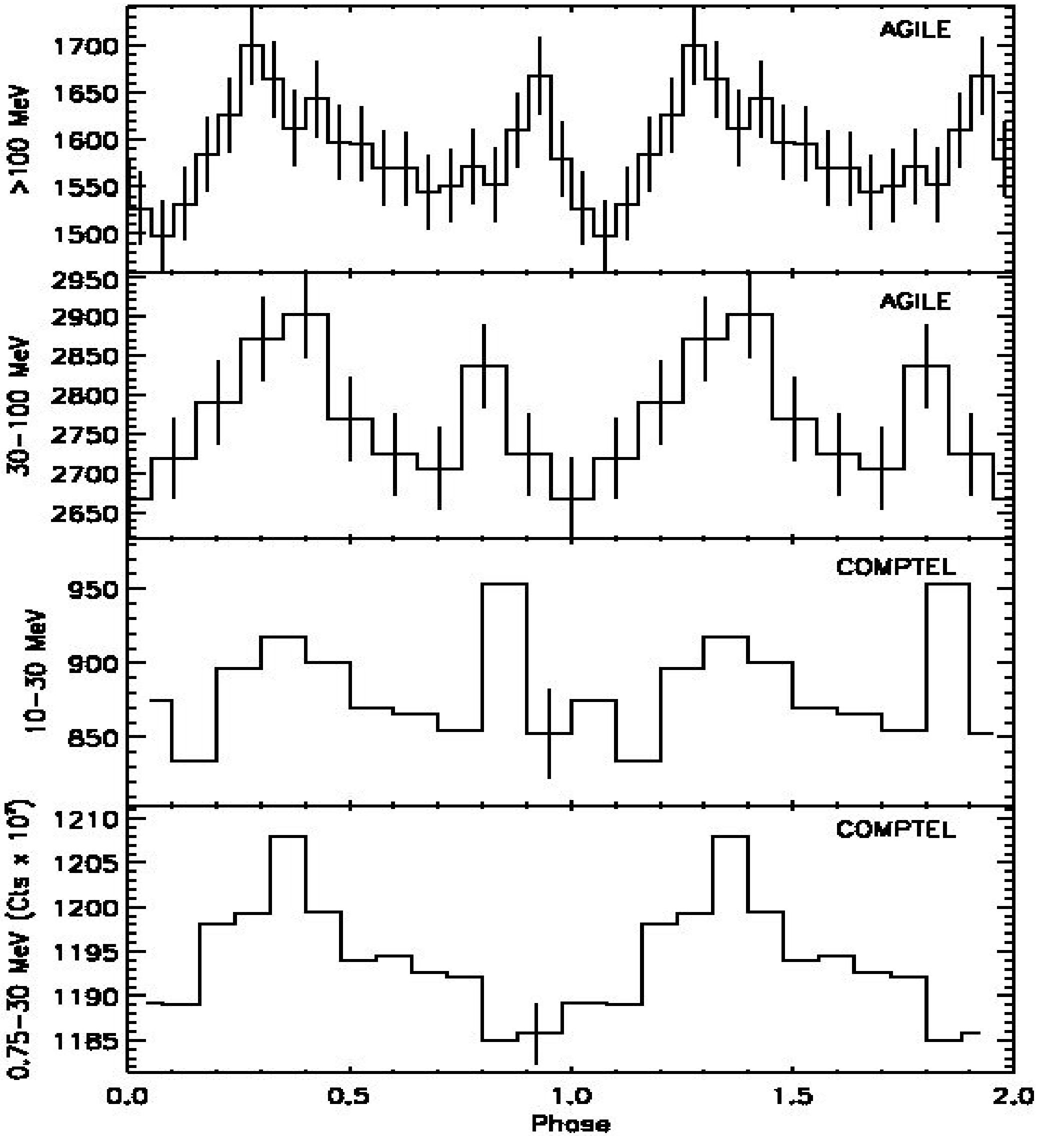


PSR B1509-58 with Comptel



Kuiper et al. 1999

PSR B1509-58 with AGILE (1)



Pellizzoni et al. ApJ, 695, L115, 2009

Pilia et al. ApJ, 723, 707, 2010

Detection of PSR B1509−58 and its pulsar wind nebula in MSH 15−52 using *Fermi* - LAT 5

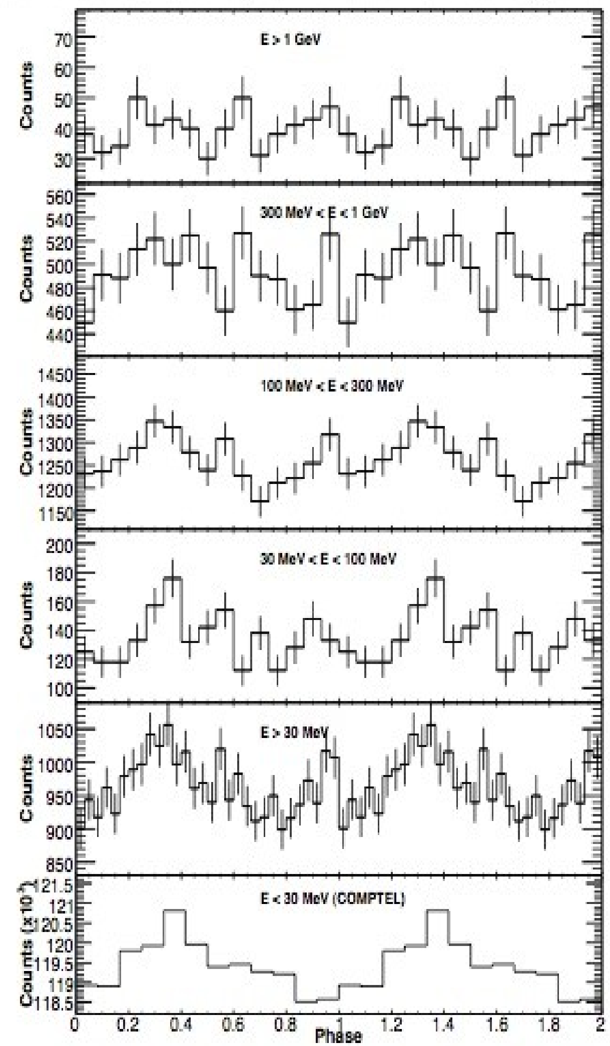
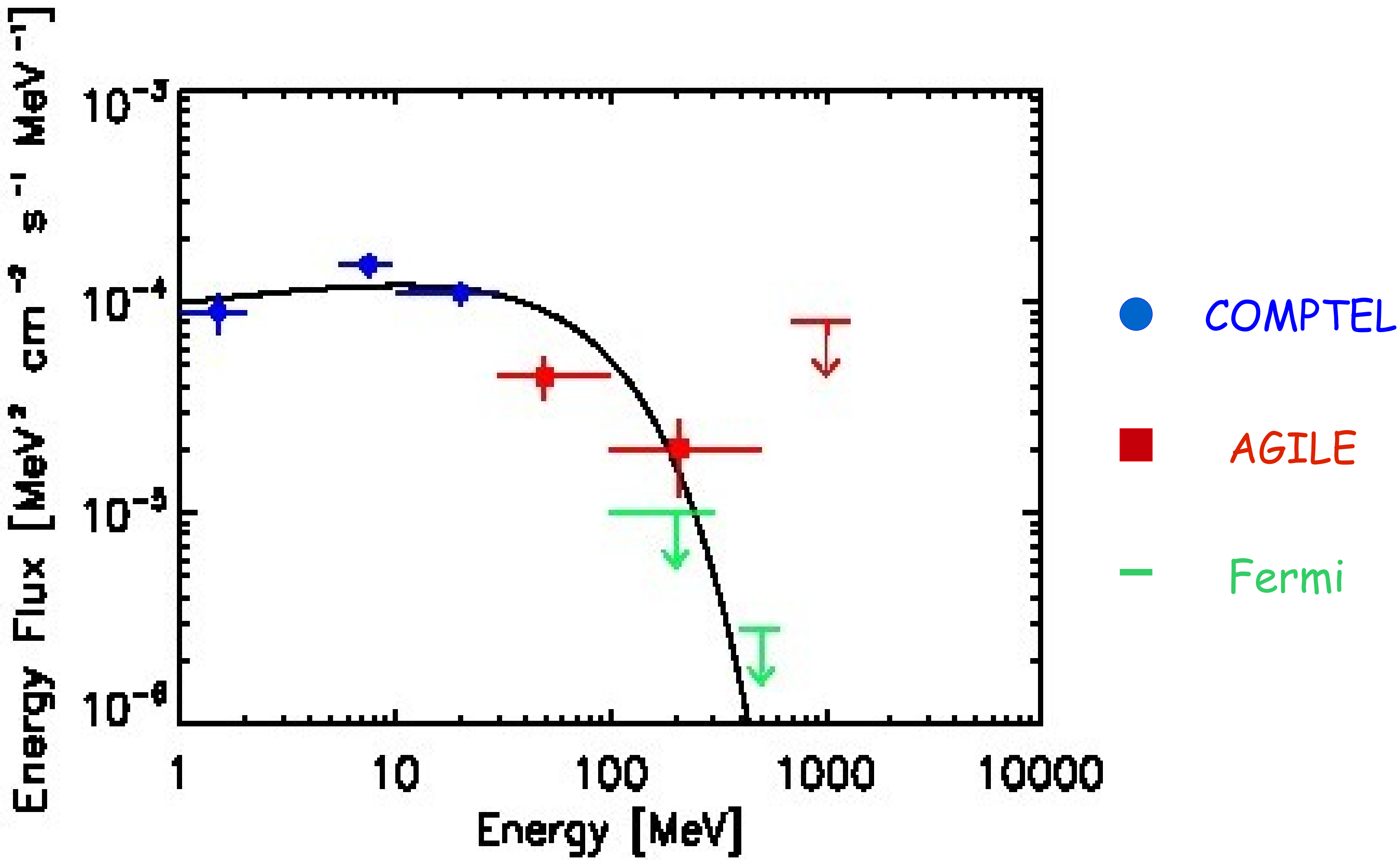


Fig. 2.— Light curves of the pulsar PSR B1509−58 in different energy bands within a circular region of energy-dependent radius. From bottom to the top: COMPTEL (0.75 – 30 MeV; Kuiper et al. 1999) and LAT profiles in 30 MeV–300 GeV, 30 MeV–100 MeV, 100 MeV–300 MeV, 300 MeV–1 GeV, 1 GeV–300 GeV energy bands are presented. Two cycles are shown.

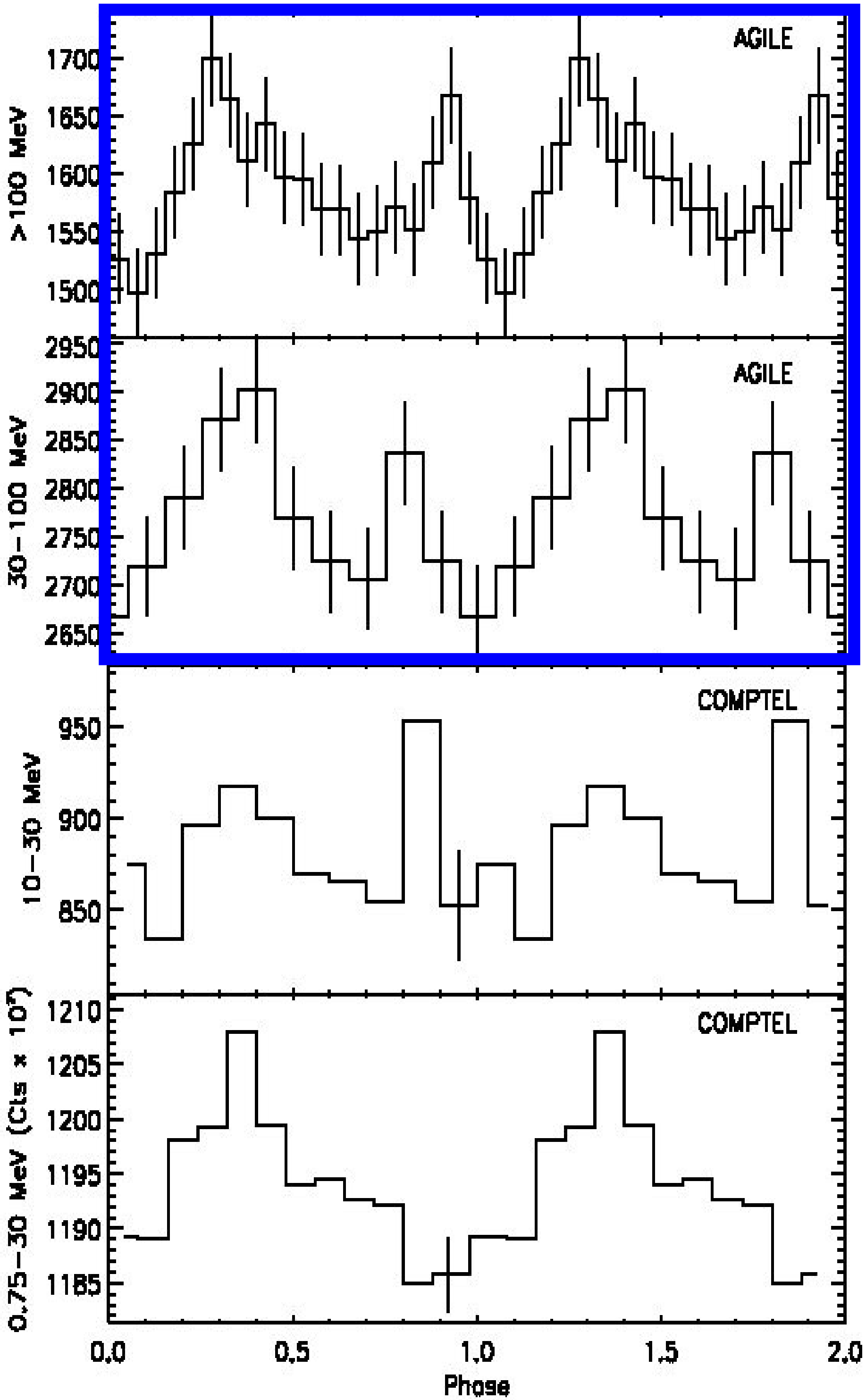
Abdo et al., ApJ, 714, 927, 2010

PSR B1509-58 with AGILE (2)



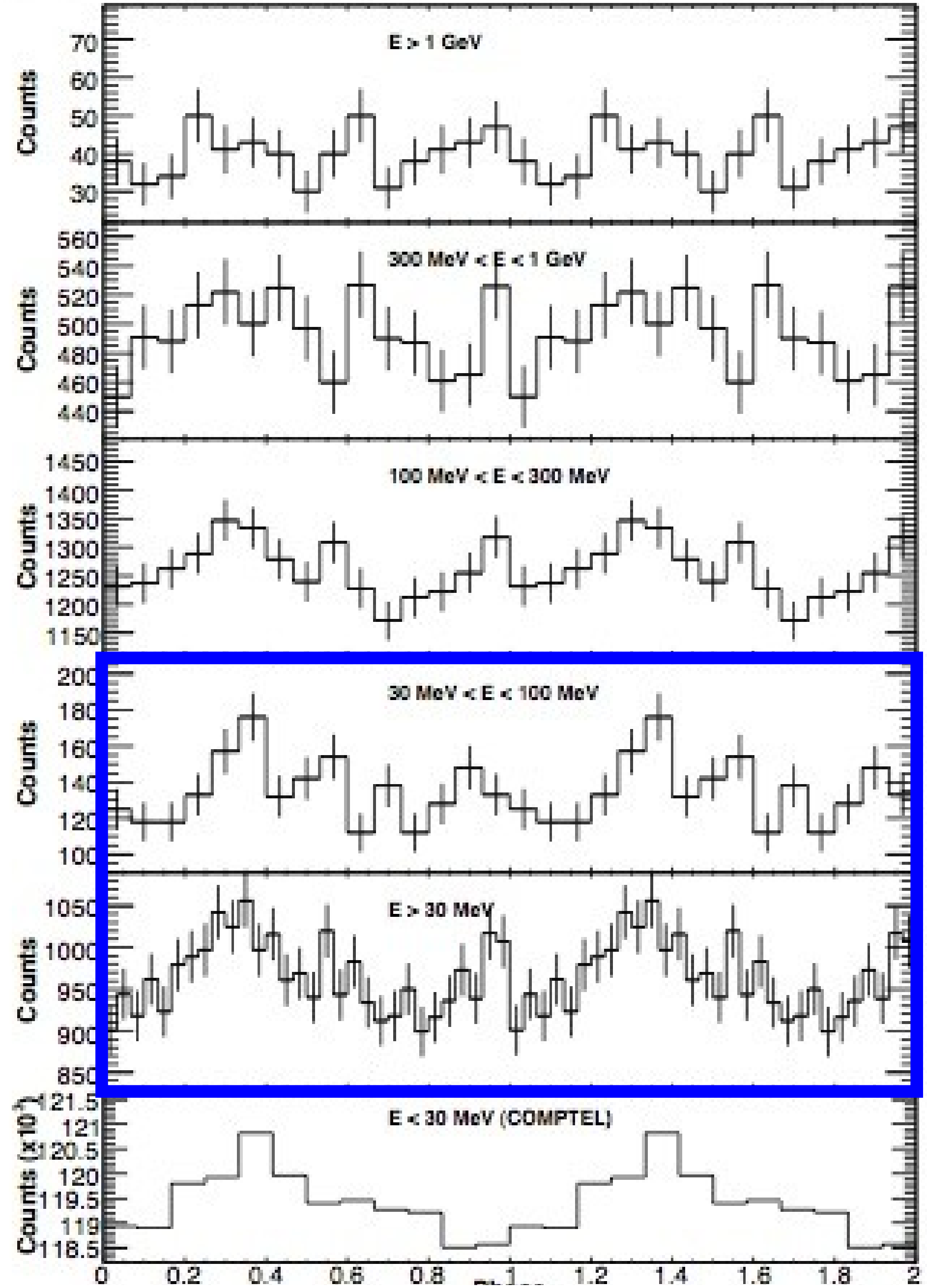
Pilia et al. 2010

The “soft” γ-pulsar B1509-58



AGILE (Pilia et al. 2010)

Detection of PSR B1509−58 and its pulsar wind nebula in MSH 15−52 using *Fermi* - LAT



Fermi (Abdo et al. 2010)

ight curves of the pulsar PSR B1509−58 in different energy bands within a circular region of energy-dependent radi

Polar Cap - Photon Splitting

Harding, Baring & Gonthier 1997

- Third order QED process

- Forbidden in vacuum

- For $B \leqslant B_{cr}$ ($B_{B1509} = 3.1 \times 10^{13}\,G$) it takes place BEFORE the threshold for pair production

- $\gamma \rightarrow \gamma\,\gamma$ so that high energy emission (> some GeVs) is inhibited

Modelling the Soft Spectrum of PSR B1509-58

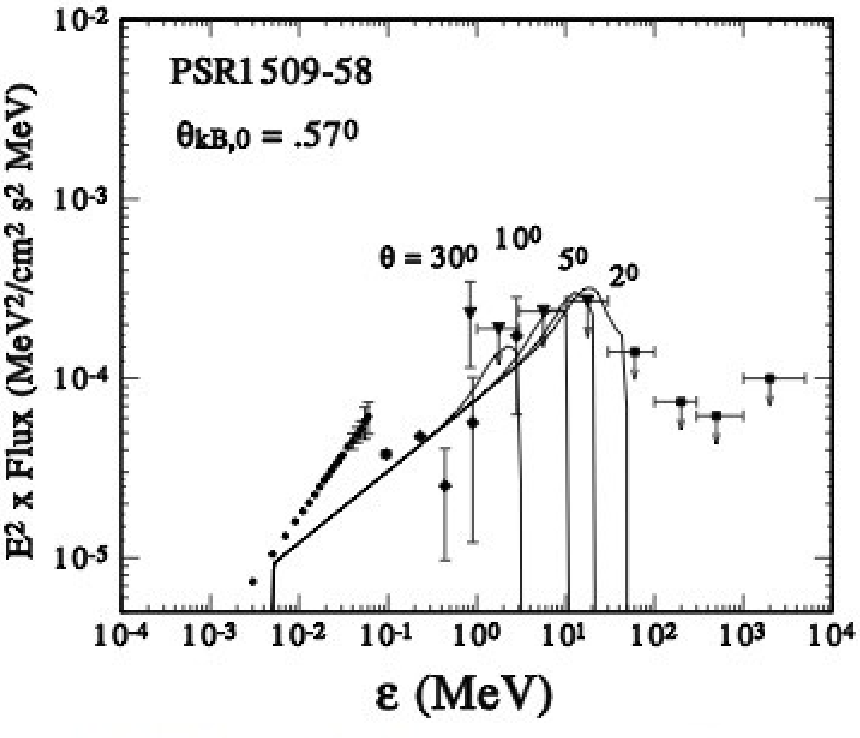


FIG. 12.—Same as Fig. 11, for the model spectra of Fig. 8

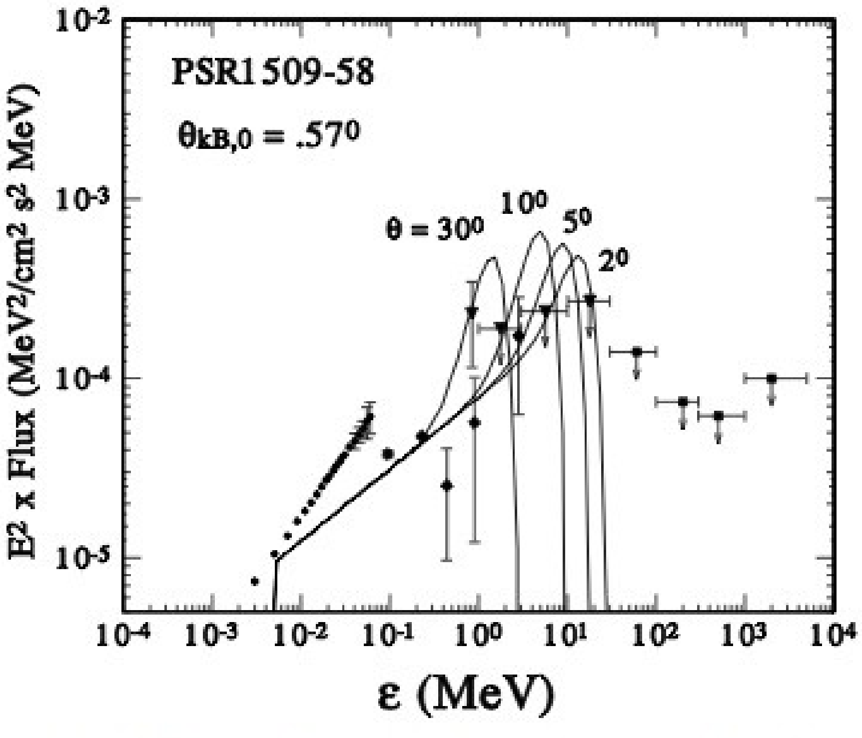


FIG. 14.—Same as Fig. 13, for the model spectra of Fig. 10

Harding, Baring & Gonthier 1997

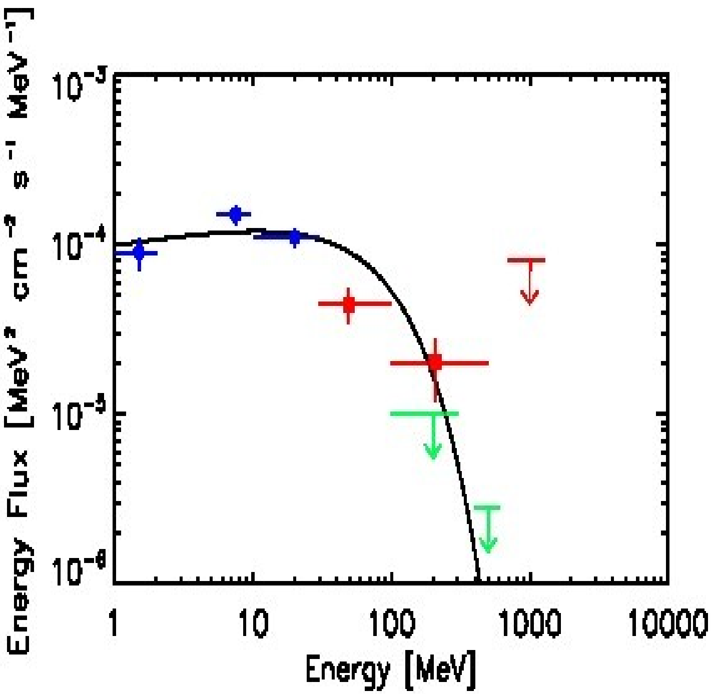
Photon Splitting - Pair Production

$$F(E) \propto E^{-\alpha} \exp[-(E/E_C)]$$
$$\alpha = 1.87 \pm 0.09$$

$$\epsilon_{esc}^{sat} \simeq 0.077 (B' \sin\theta_{kB}, 0)^{-6/5}$$

$$B' = B/B_{cr}$$

θ_{kB} = angle between the photon momentum and the magnetic field vectors

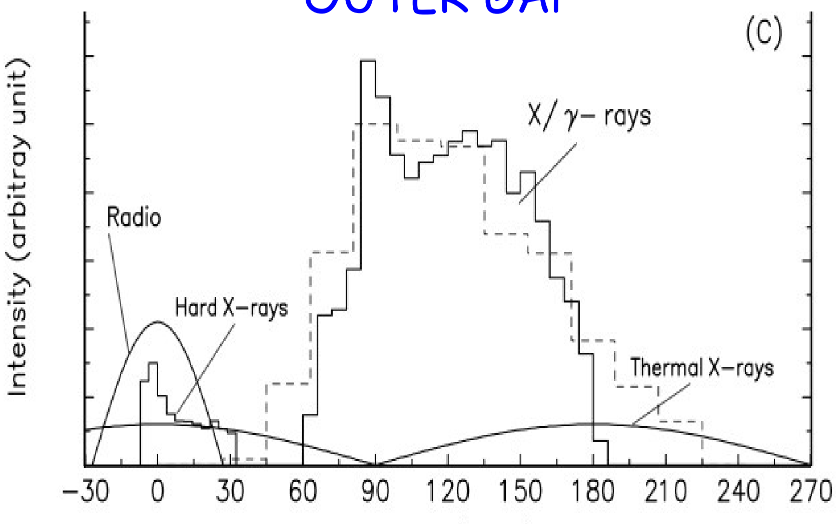


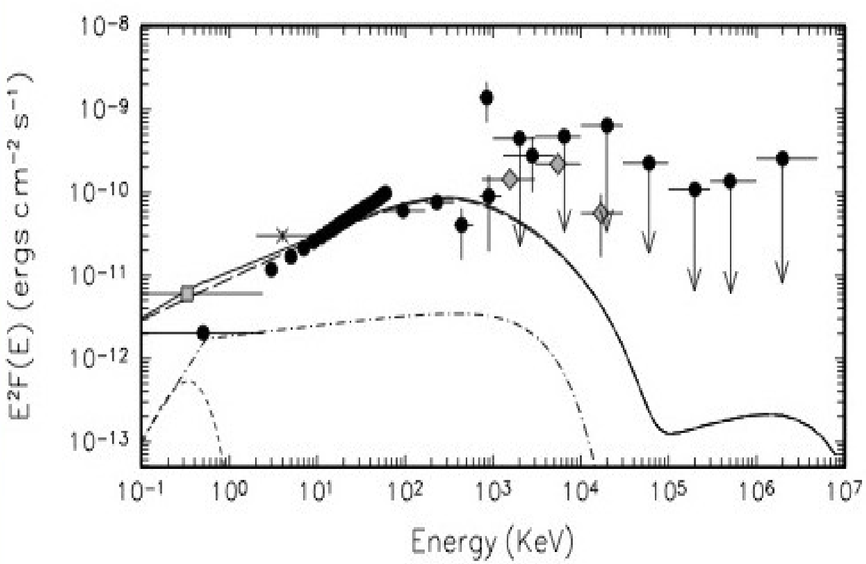
Pilia et al. 2010

- Given the observed cutoff energy ($E_C = 81 \pm 20\ MeV$), the corresponding magnetic field is $B' = 0.3$. This implies emission at height $h \simeq 1.3\ R_{NS}$ above the PC, where the pair production ensues.

Alternative scenarios

OUTER GAP





Zhang & Cheng 2000

$\alpha \approx 60°$ $\zeta \approx 75°$

TWO POLE CAUSTIC GAP

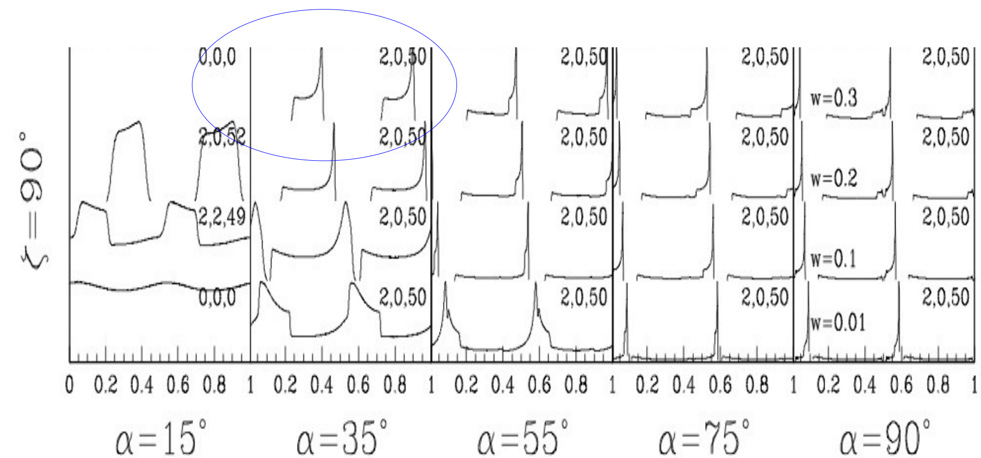


FIG. 9.— Collection of sample light curves for the TPC model. Four select w (values in bottom right panel) are shown for each panel; the radio pole has closest approach at phase=0. The values for the number of all peaks, the number of broad peaks and the maximum peak separation (in %) are indicated by each curve. Intensities are normalized to pulse maximum.

Watters et al. 2009

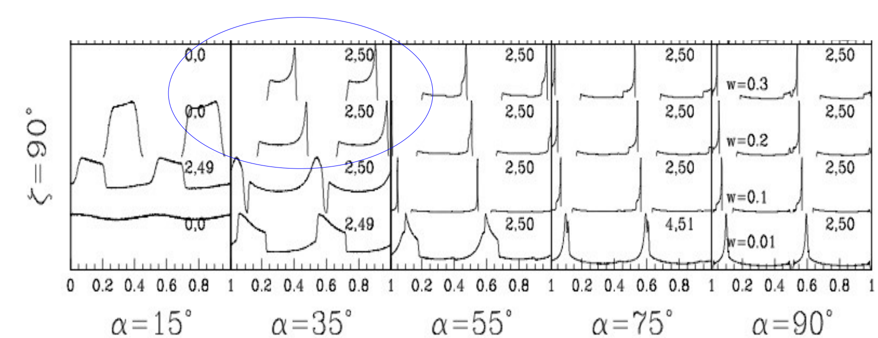


FIG. 14.— Light curves for the Two Pole Caustic (TPC) model. Each panel shows curves for four values of the gap width w. The curves are labeled with the number of major peaks and the peak separation, in percent.

Romani & Watters 2010

$\alpha \approx 35°$ $\zeta \approx 90°$

Geometry Constraints

OUTER GAP		TWO POLE CAUSTIC GAP	
$\alpha \approx 60°$	$\zeta \approx 75°$	$\alpha \approx 35°$	$\zeta \approx 90°$

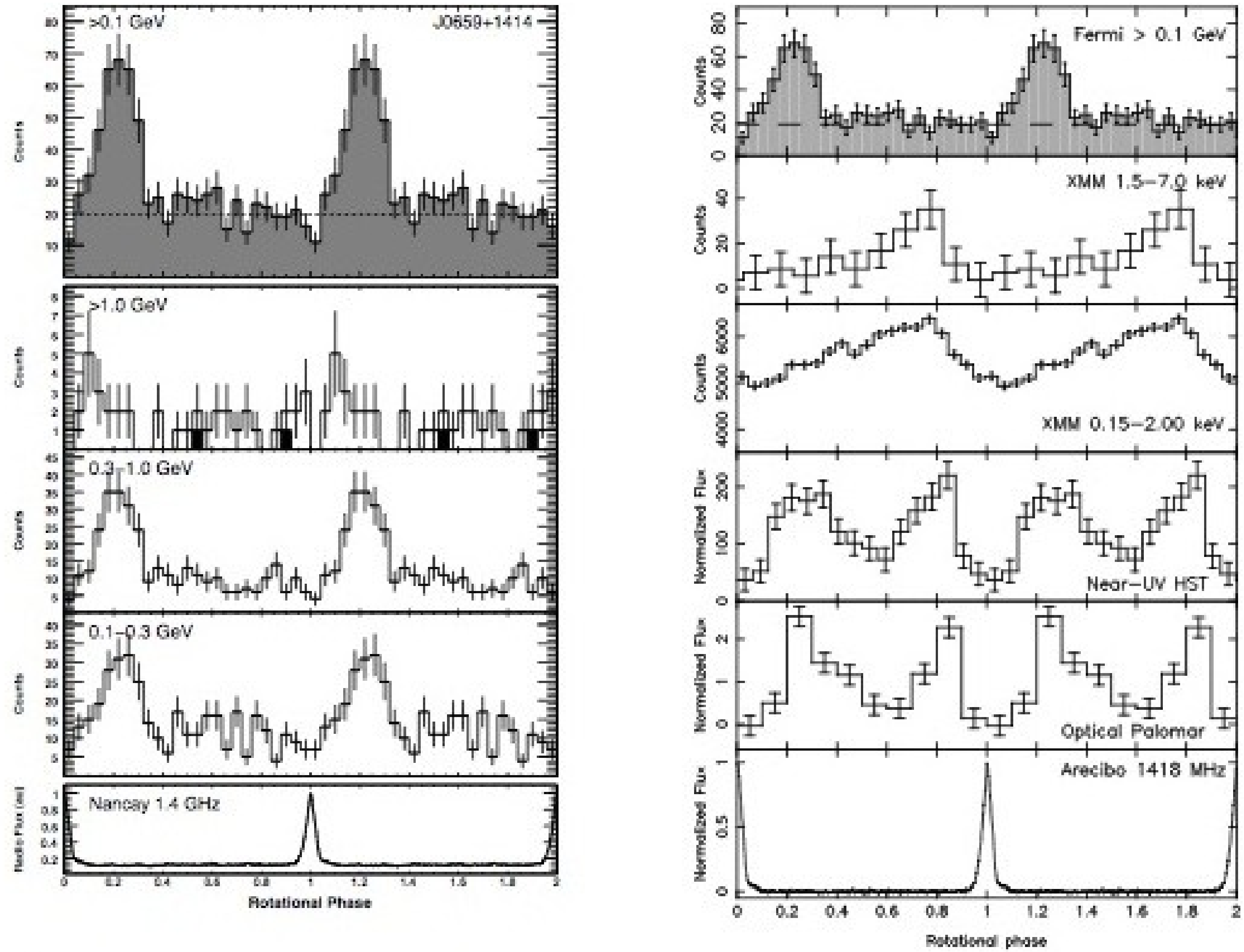
α = magnetic inclination
ζ = viewing angle

- $\alpha < 60°$ at the 3σ confidence level (Crawford et al. 2001)

- If $\zeta > 70°$ (Melatos 1997) then $\alpha > 30°$ at the 3σ level

- For these values, however, the Melatos model for the spin down of an oblique rotator predicts a braking index $n > 2.86$ slightly inconsistent with the observed value $n = 2.839(3)$ (Livingstone et al. 2005)

A Similar Case: PSR B0656+14



$$E_C = 700\ MeV$$

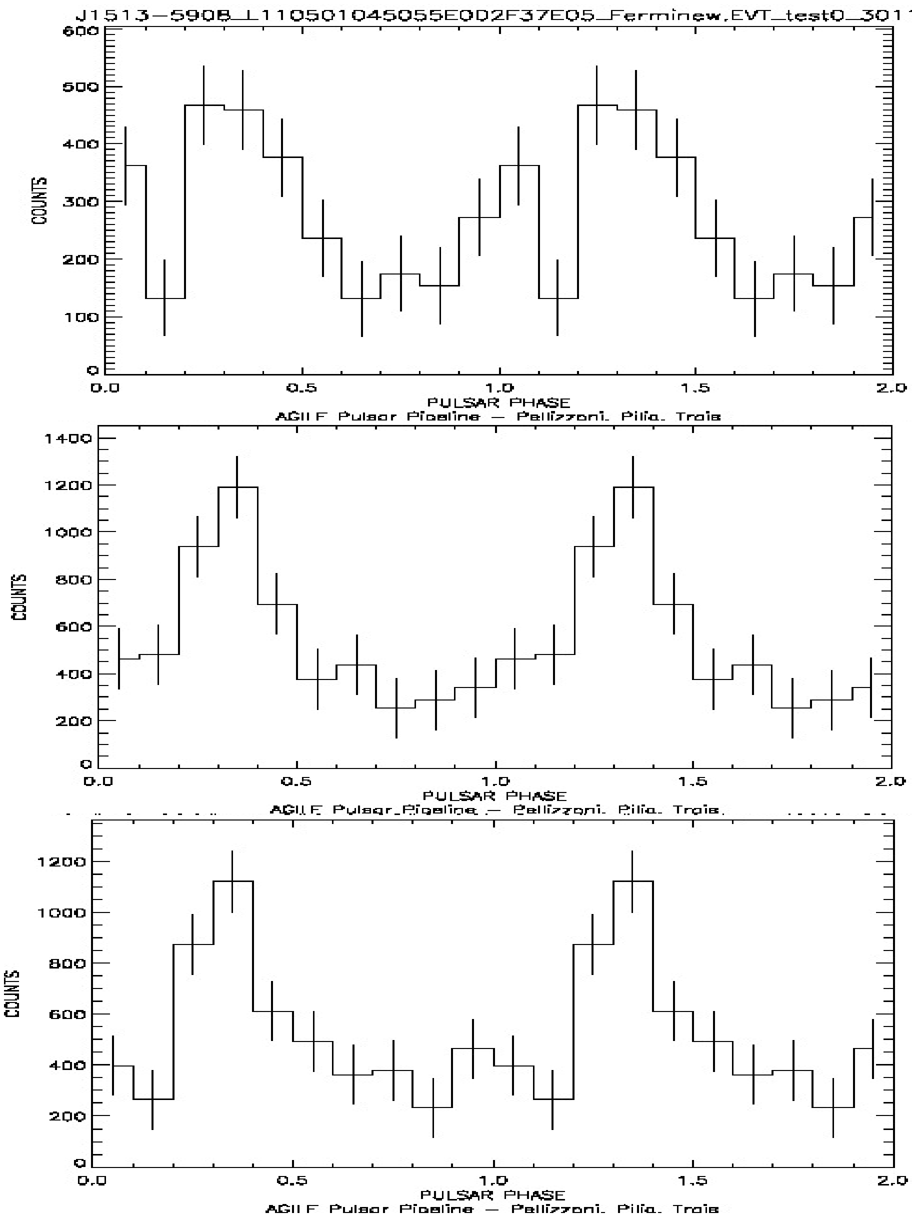
Weltevrede et al. 2010

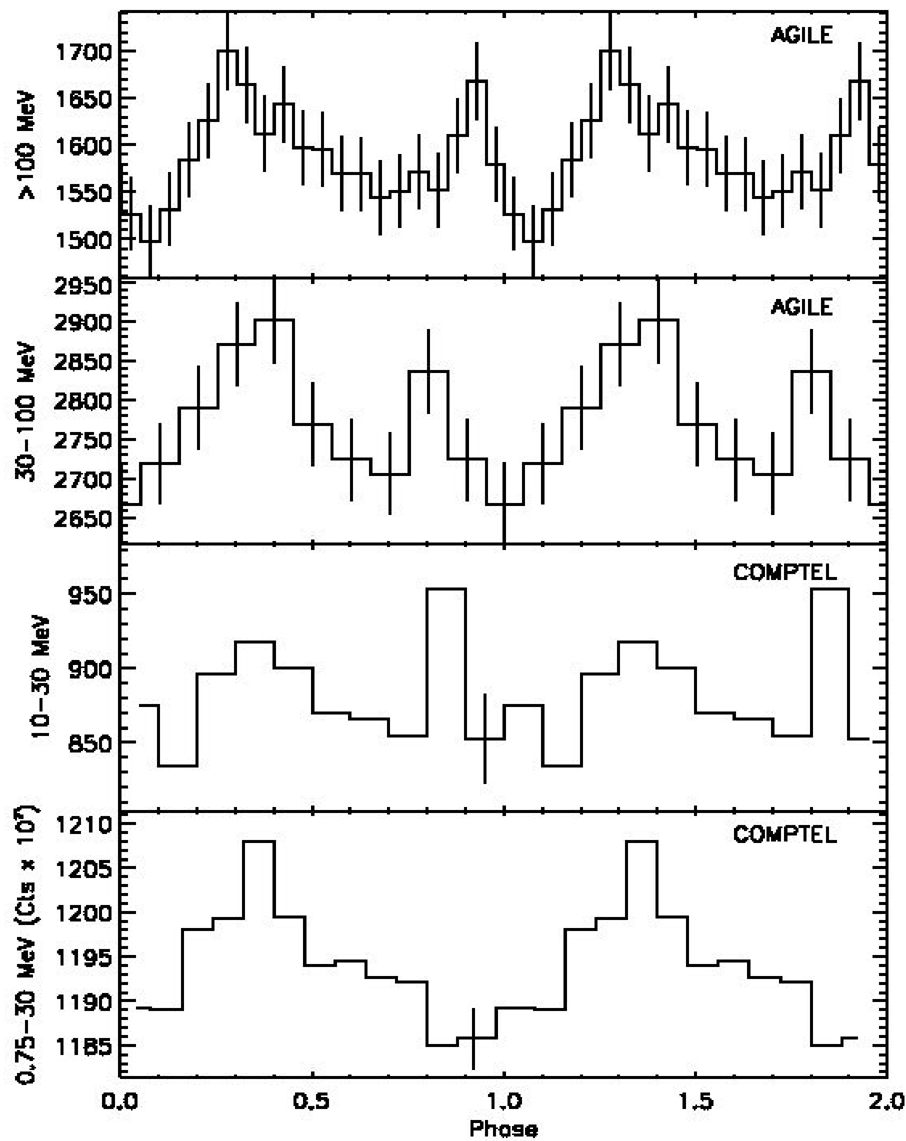
New Results from Fermi

E < 150 MeV

E < 300 MeV

E < 500 MeV





Summary

- AGILE firmly confirmed the detection of gamma-ray pulsation from PSR B1509-58 with good significance (5 sigma)

- The observed lightcurve shows two peaks which lag the radio peak of 0.39(2) and 0.94(3).
The profile is single peaked up to energies E = 10 MeV, where Comptel detected the presence of a second peak.

- The detection of pulsed emission by AGILE at E > 30 MeV, confirms the presence of a strong spectral break, with a cutoff at E~100 MeV.

Conclusions

Our observations are compatible with emission from the polar cap regions powered by photon splitting cascades.

This likely inerpretation could represent the first physical measurement ever made related to the QED photon splitting process.

The fact that PC emission at HE appears rare might be explained by the requirement that a number of conditions concur to have low magnetospere emission, e.g. an aligned geometry and high magnetic fields.

New class of “soft” gamma-ray pulsars?

Thank You!

For information and collaborations, please contact us:

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