Gamma-ray flares from the Crab Nebula

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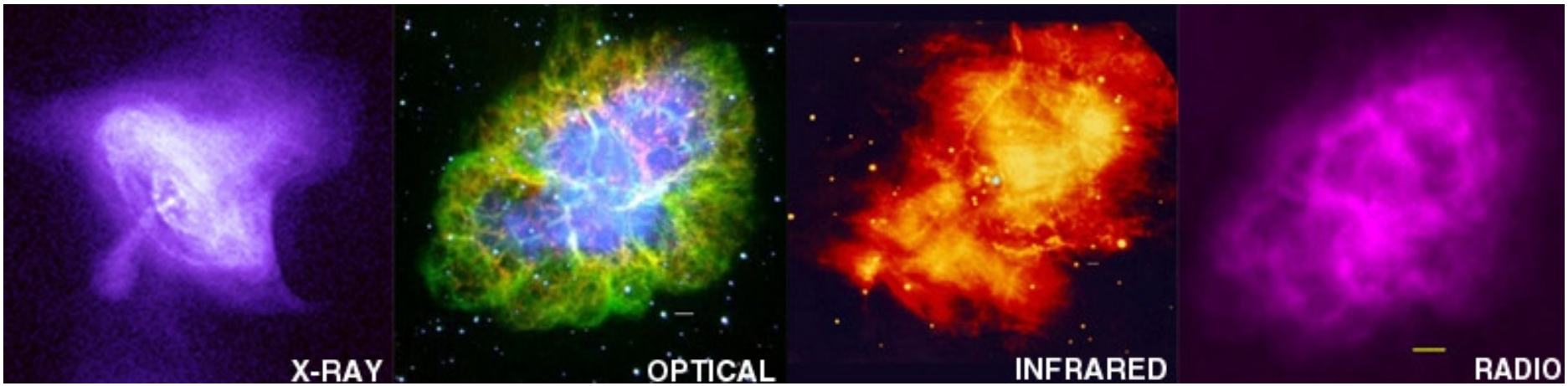
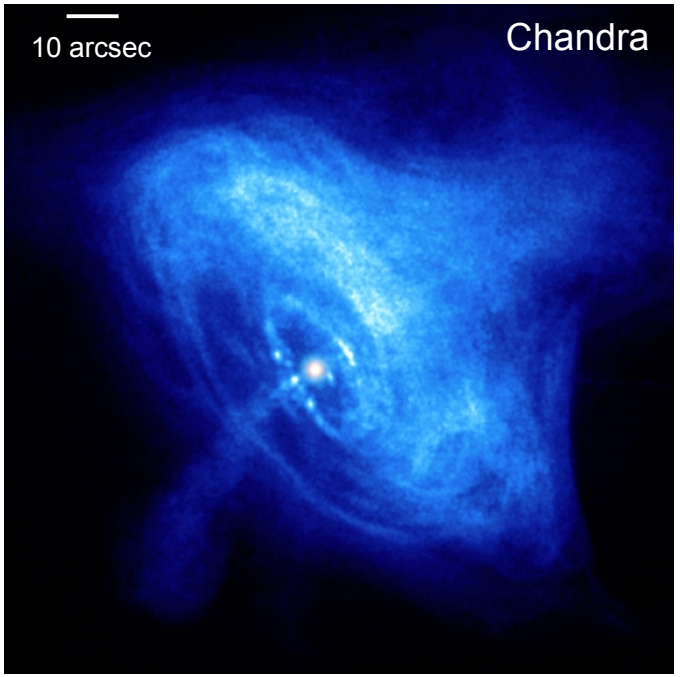
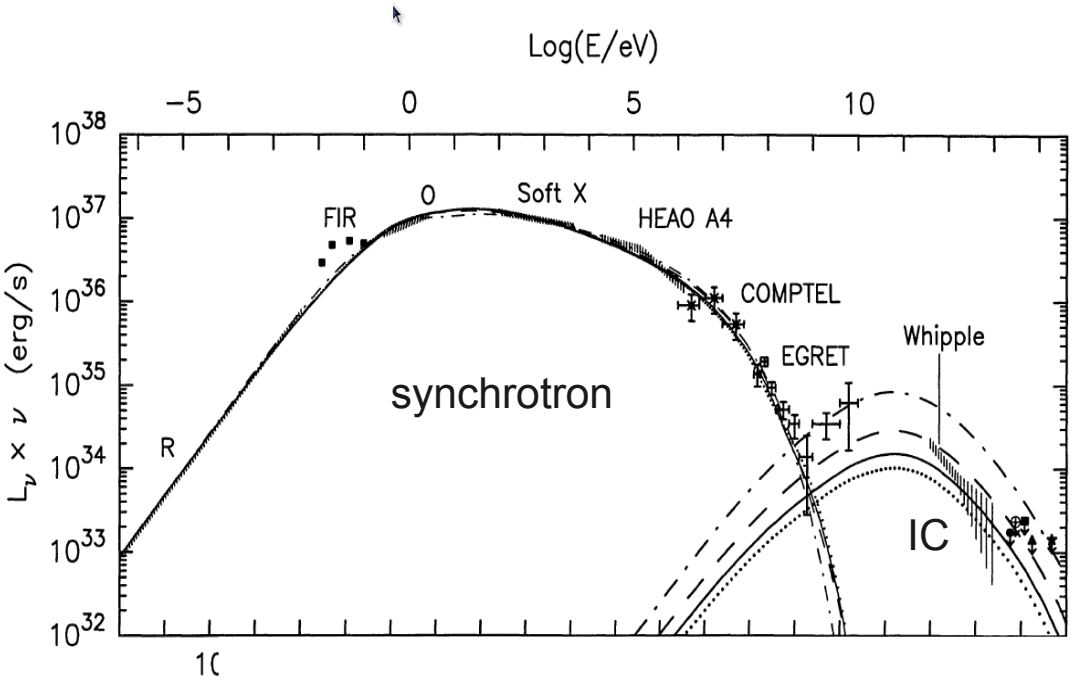


Rolf Buehler, Roger Blandford, Stefan Funk, Marco Ajello, Eric Grove, Liz Hays, Luca Mazziotta, Damien Parent *for the LAT Collaboration*

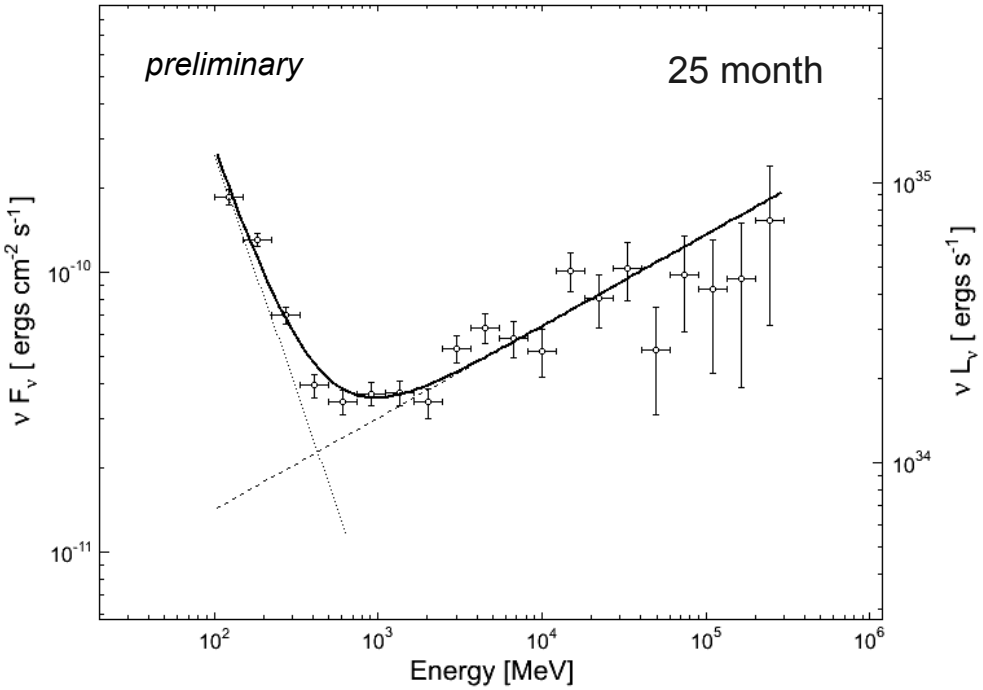
The *star* of the play

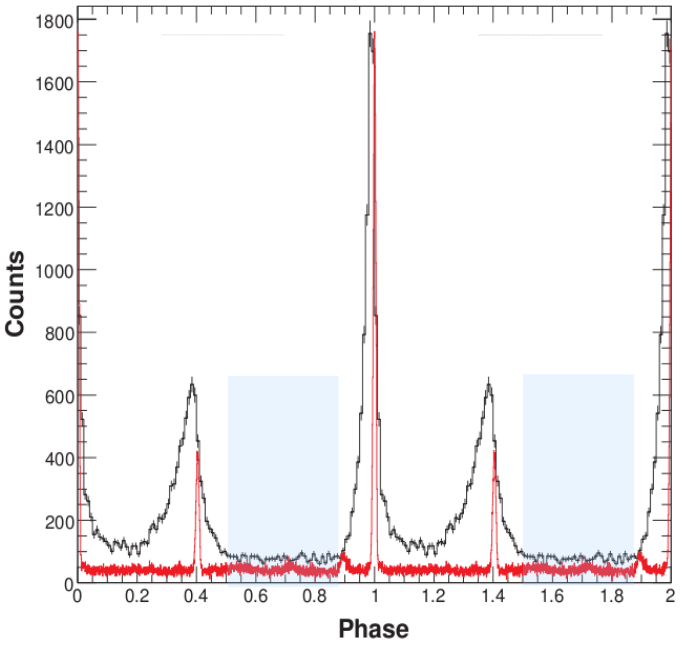




- Remnant from 1054 AD supernovae at 2 kpc
- Standard candle in X-rays and VHE
- Yearly variable in X-rays ~3.5% , 1-150 MeV on ~40%
  (Wilson-Hodge et al 2010,Munch et al. 1995, de Jager et al 1996)

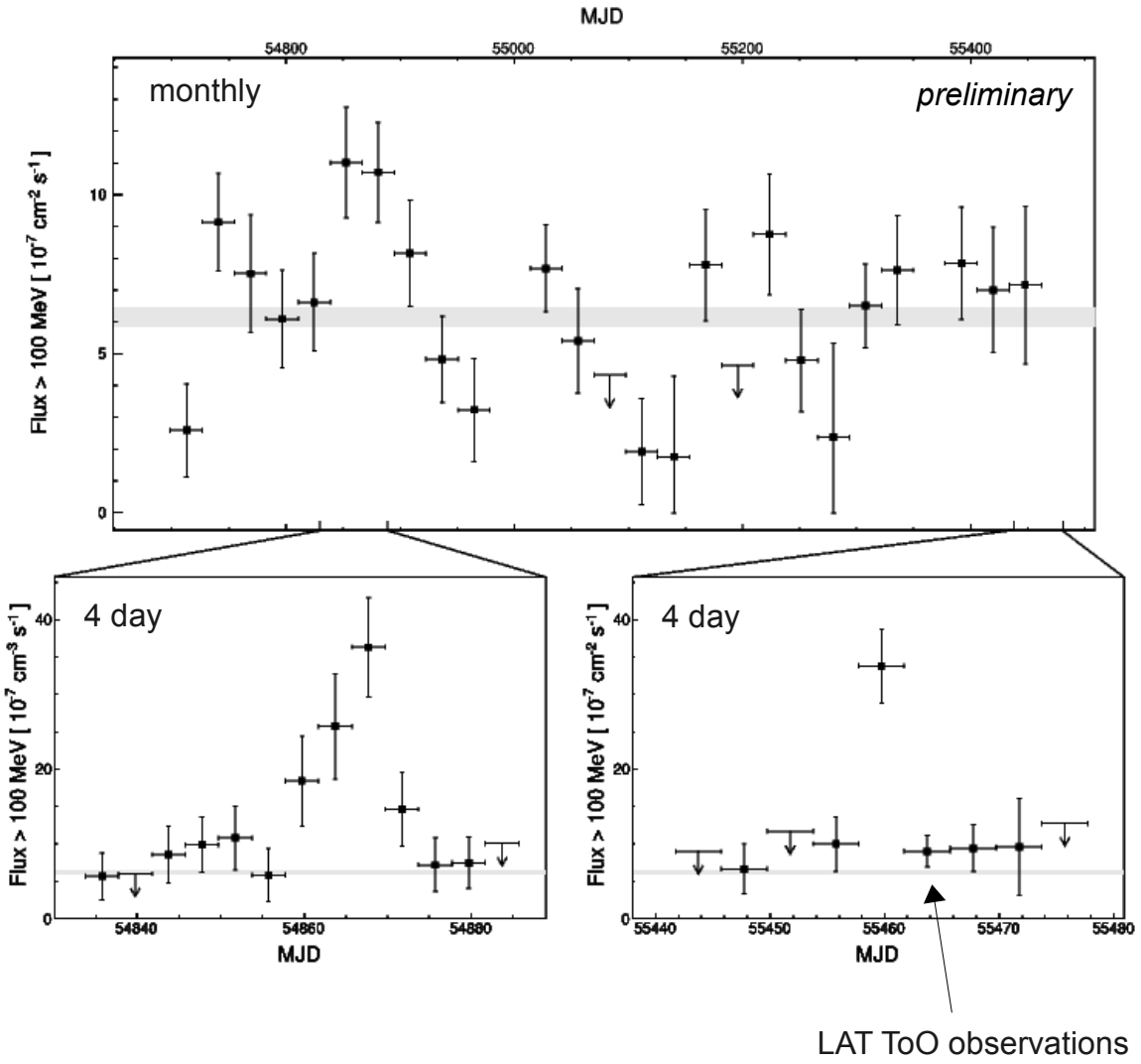
Crab with Fermi





- Fermi measures Nebula transition between components
- Measurement in Off pulse to avoid pulsar foreground

Nebula synchrotron flux



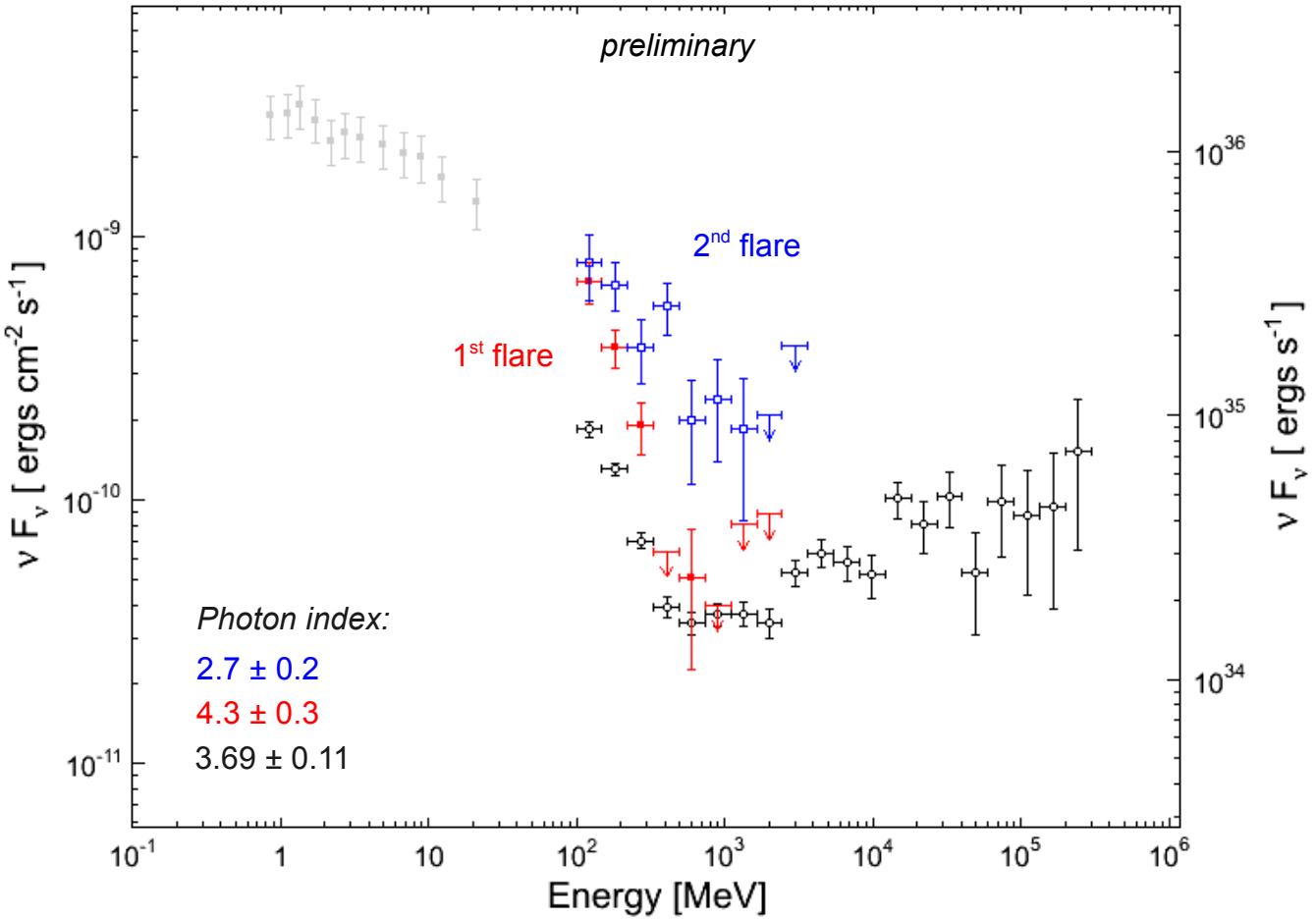
Monthly variations

Two flares:

- Flux increase of factor ~4 during ~16 days
  (26 Jan 11 to Feb. 2009)
- Flux increase of factor ~6 during ~4 days AGILE
  (18 to 22 Sep. 2010) Atel: 2855

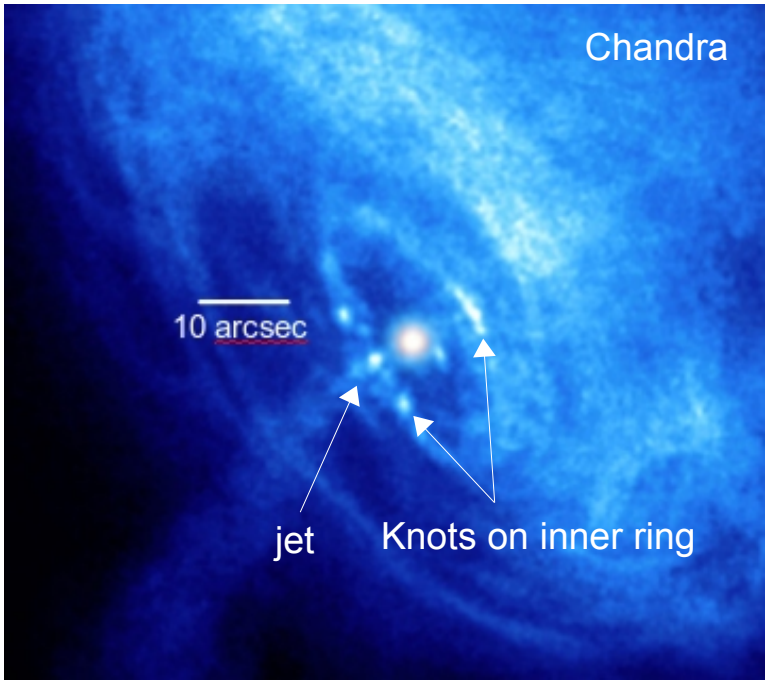
No variation (<5%) nebula IC component

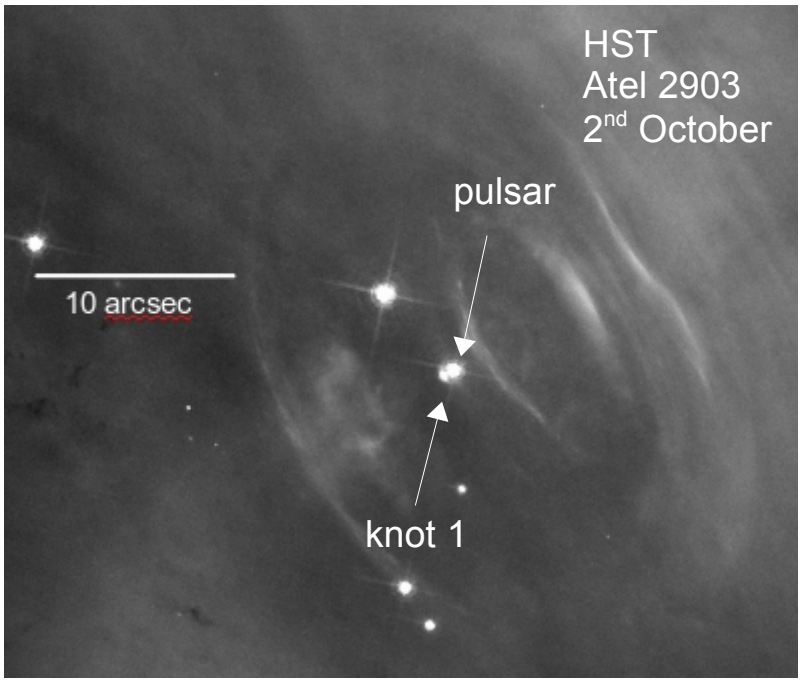
Flares spectrum



- Second flare has hard spectrum and extends >1 GeV at >3 σ
- Energy release small compared to pulsar spin down ($\sim 5 \cdot 10^{38}$ erg s^{-1})

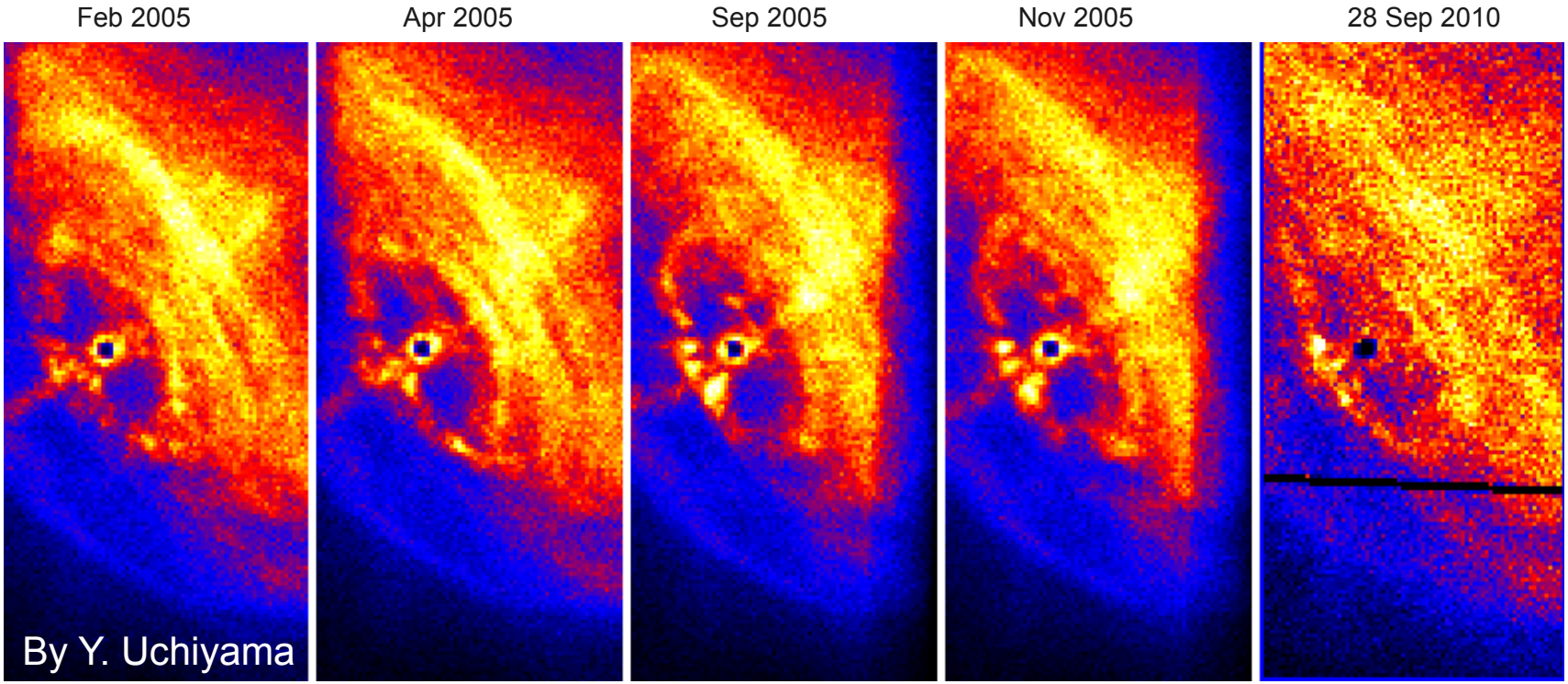
Where does it come from?





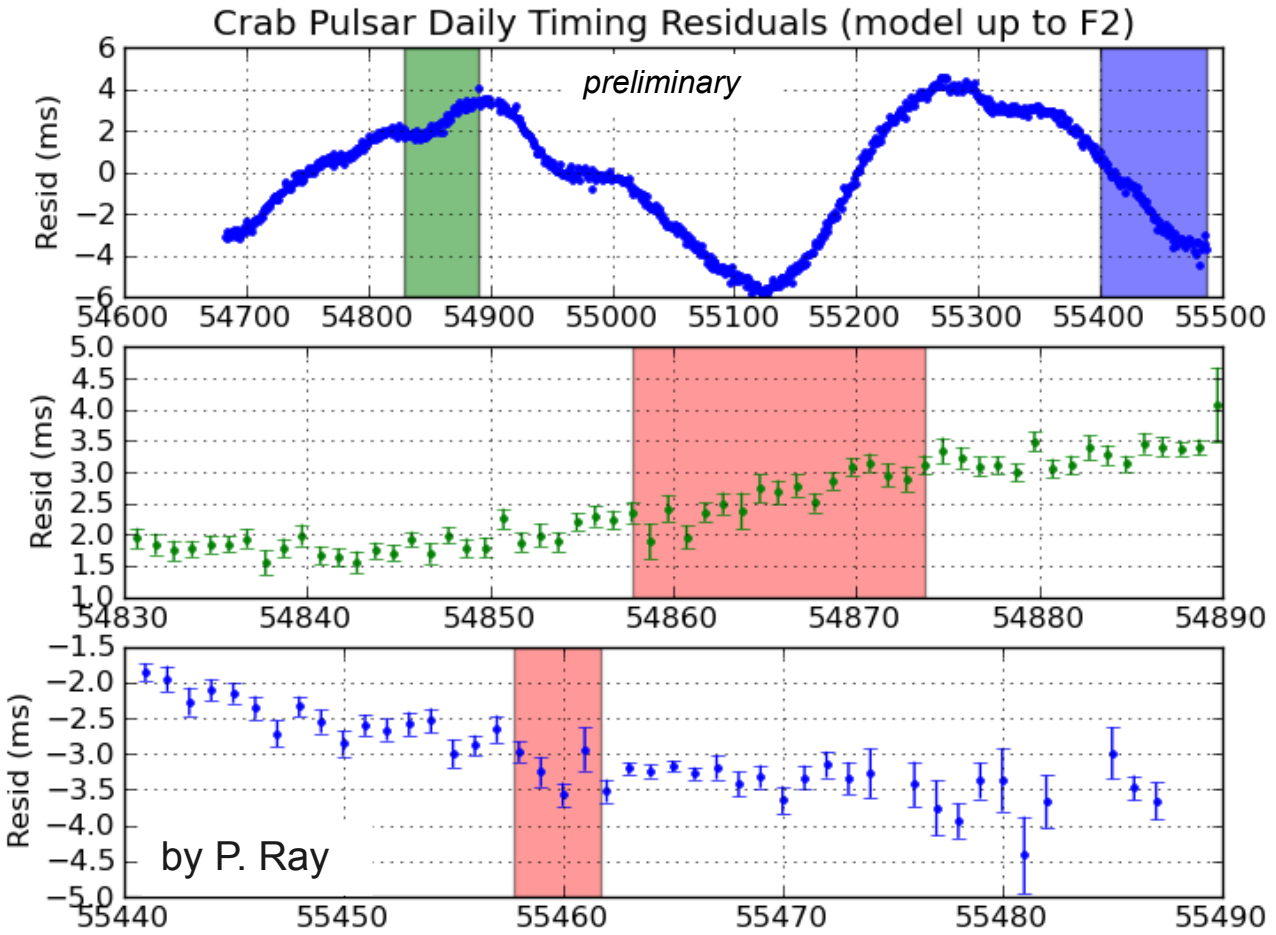
- Not resolvable with LAT localization accuracy (~2')
- Causality: $L < D \cdot t \cdot c < 4 \cdot 4\text{days} \cdot c = 0.014$ pc < 1.5"
- Structures this small only in inner nebula (<15" around pulsar)

Where does it come from?



- Nothing unusual detected in Chandra and Hubble observations after the flare (Atels: 2882, 2903)
- Future simultaneous observations may reveal location

From the pulsar ?



- Nothing unusual during the flares in the timing residual
- Pulsar light curve constant within 5%

How are particles accelerated?

Basic conclusions:

- Radiation is synchrotron emission (fast variability and SED)
- Electrons have ≥ PeV energies for magnetic field 0.2-2 mG

Highest energy particles associated to a discrete source. Difficult for diffusive shock acceleration:

$$\frac{larmor\ radius}{cooling\ length} \approx 2\times10^{-2}\varepsilon_{peak} \approx 4 \qquad \text{(for } \varepsilon_{peak} = 200 \text{ MeV)}$$

→ Acceleration might be related directly to the pulsar

DC component or mag. reconnection of striped Wind

Summary

Synchrotron component of the Crab Nebula is variable on monthly time scales in gamma-rays. Two strong flares with daily variations.

Several conclusions:

- The flare emission is *synchrotron radiation* from a *small region*, likely in the *inner Nebula*
- The acceleration of electrons to ≥ PeV poses difficulties to diffusive shock acceleration

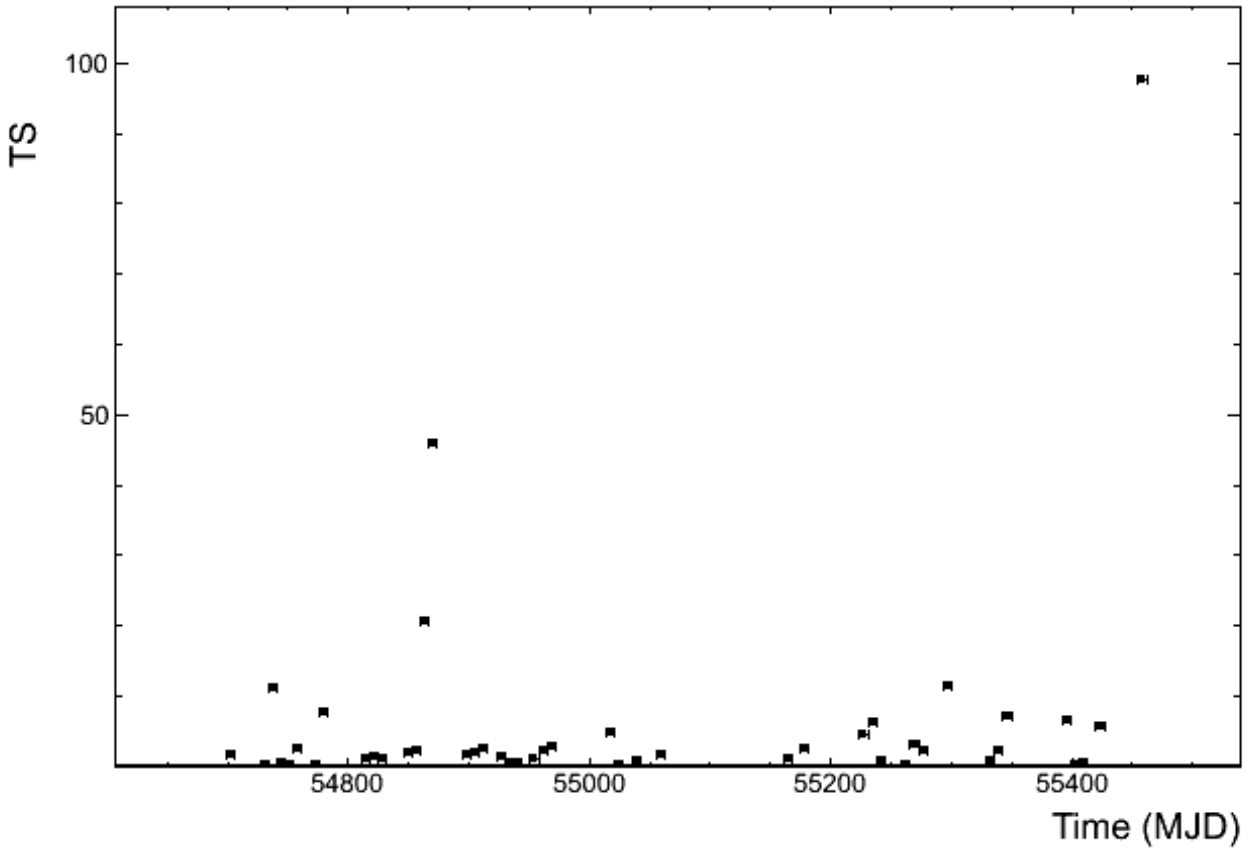
→ perhaps acceleration in the pulsar electric field

Motivates future theoretical and experimental work. Multi-wavelength observations may soon pin down the gamma-ray emission site.

Paper submitted, see astro-ph/1011.3855

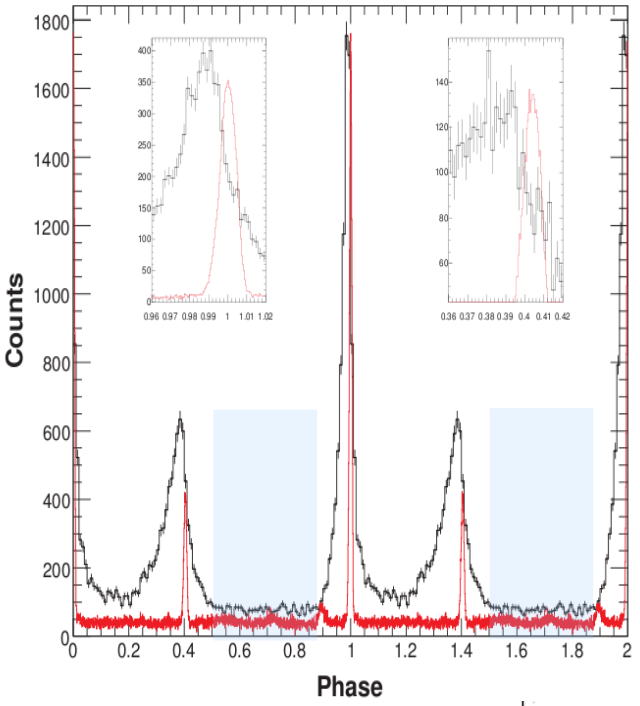
Backup slides

Weekly TS of flaring component



Crab with Fermi

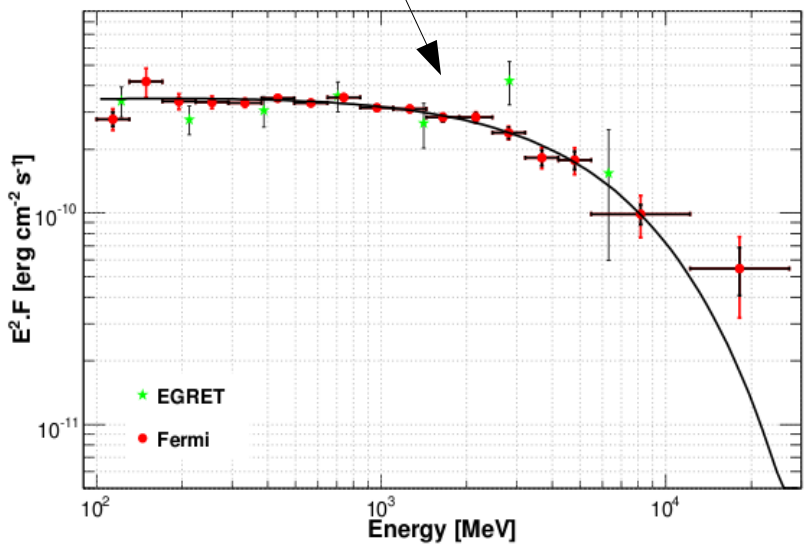
Pulsar spectrum
index=1.97 ± 0.02
with exp. cutoff
~6 GeV



Sych. index: 3.99 ± 0.12

IC index: 1.64 ± 0.05

Pulsar



Nebula