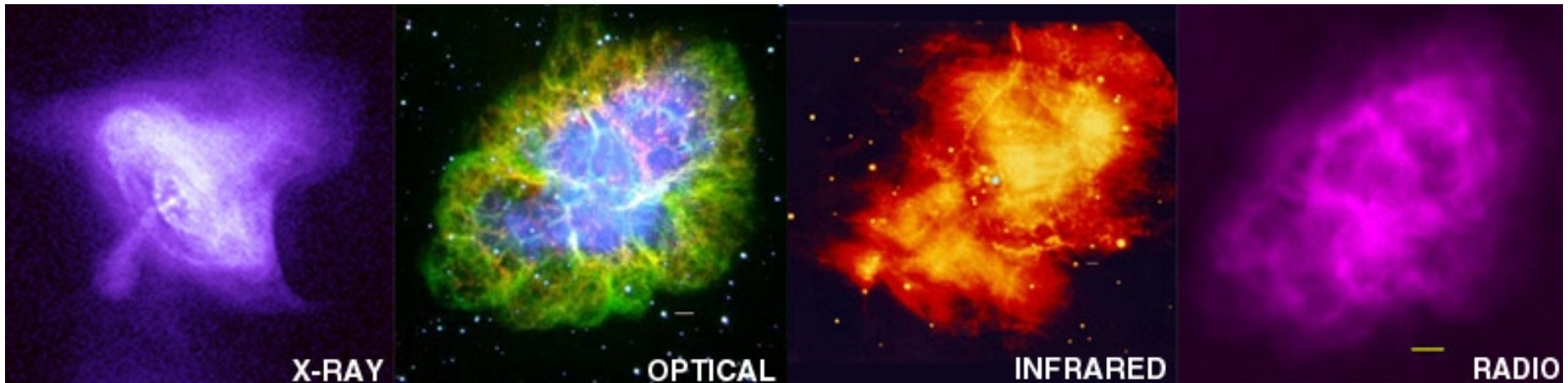


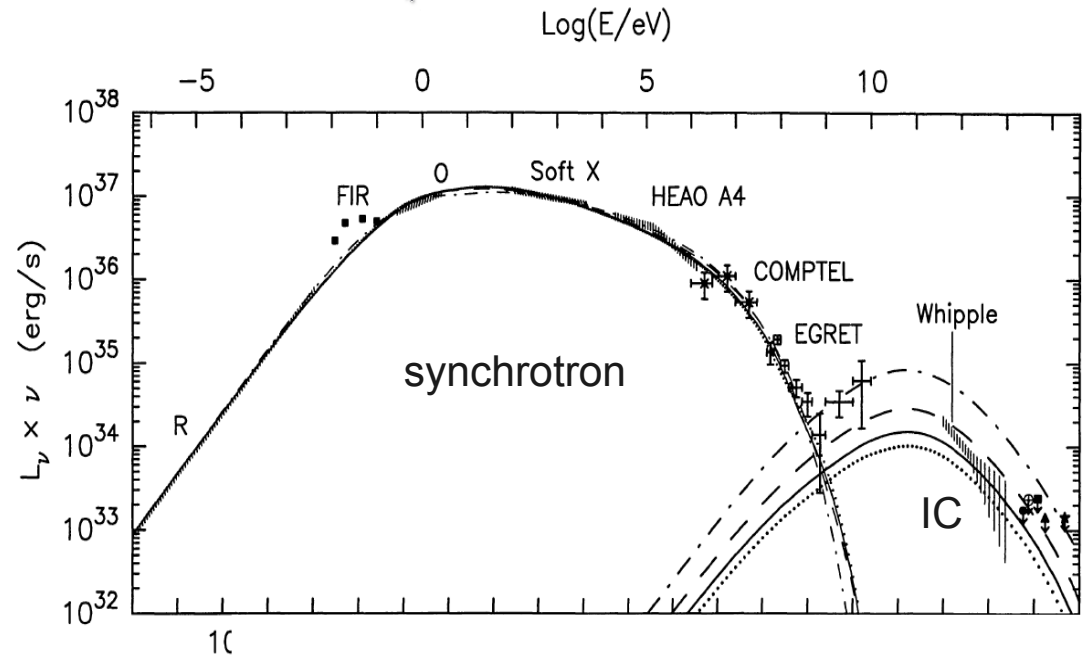
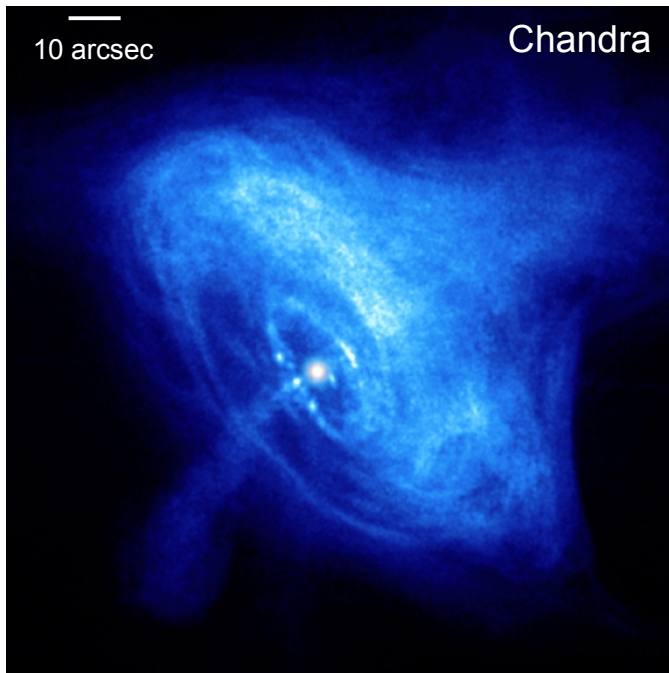
Gamma-ray flares from the Crab Nebula

Variable Galactic Gamma-ray Sources • Heidelberg 1 December 2010



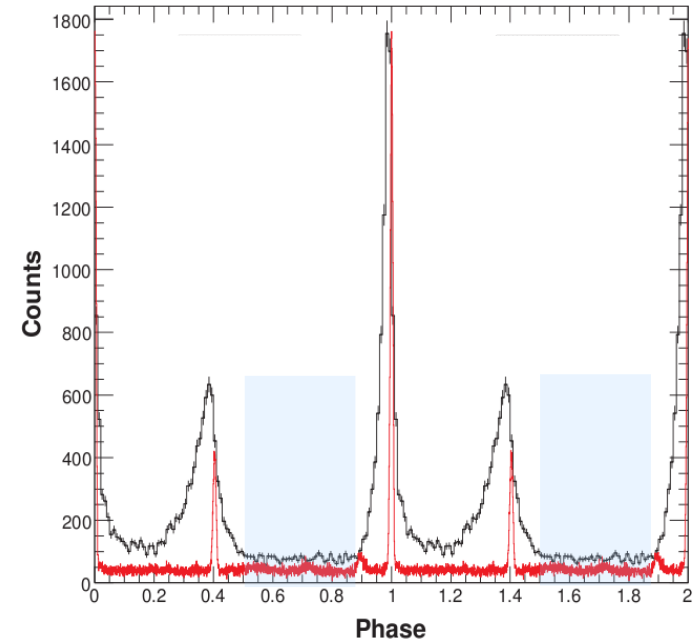
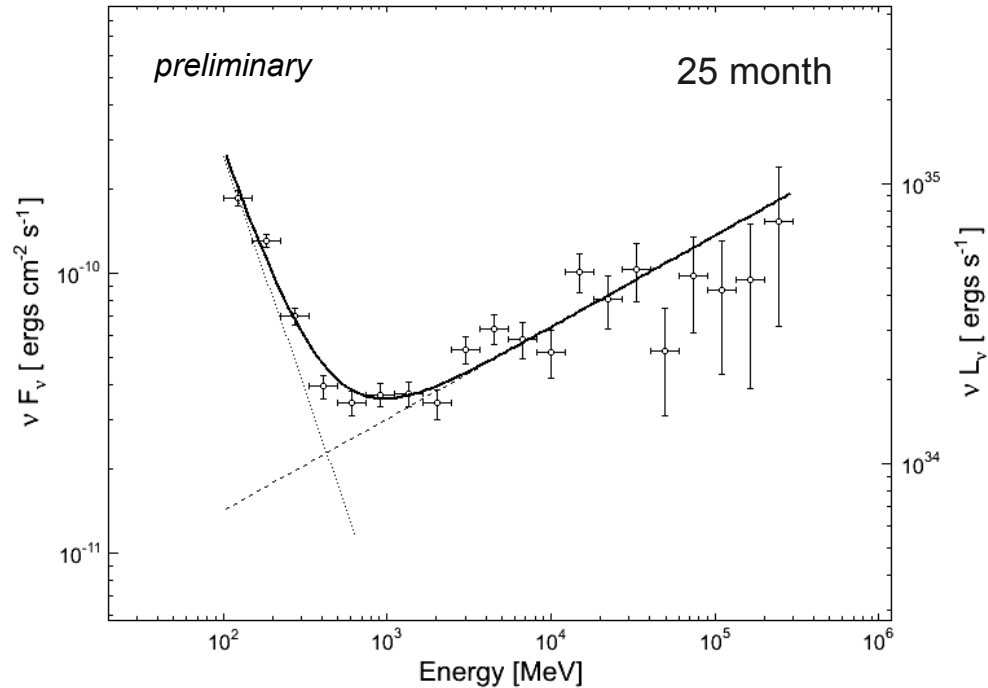
Rolf Buehler for the LAT Collaboration

The *star* of the play



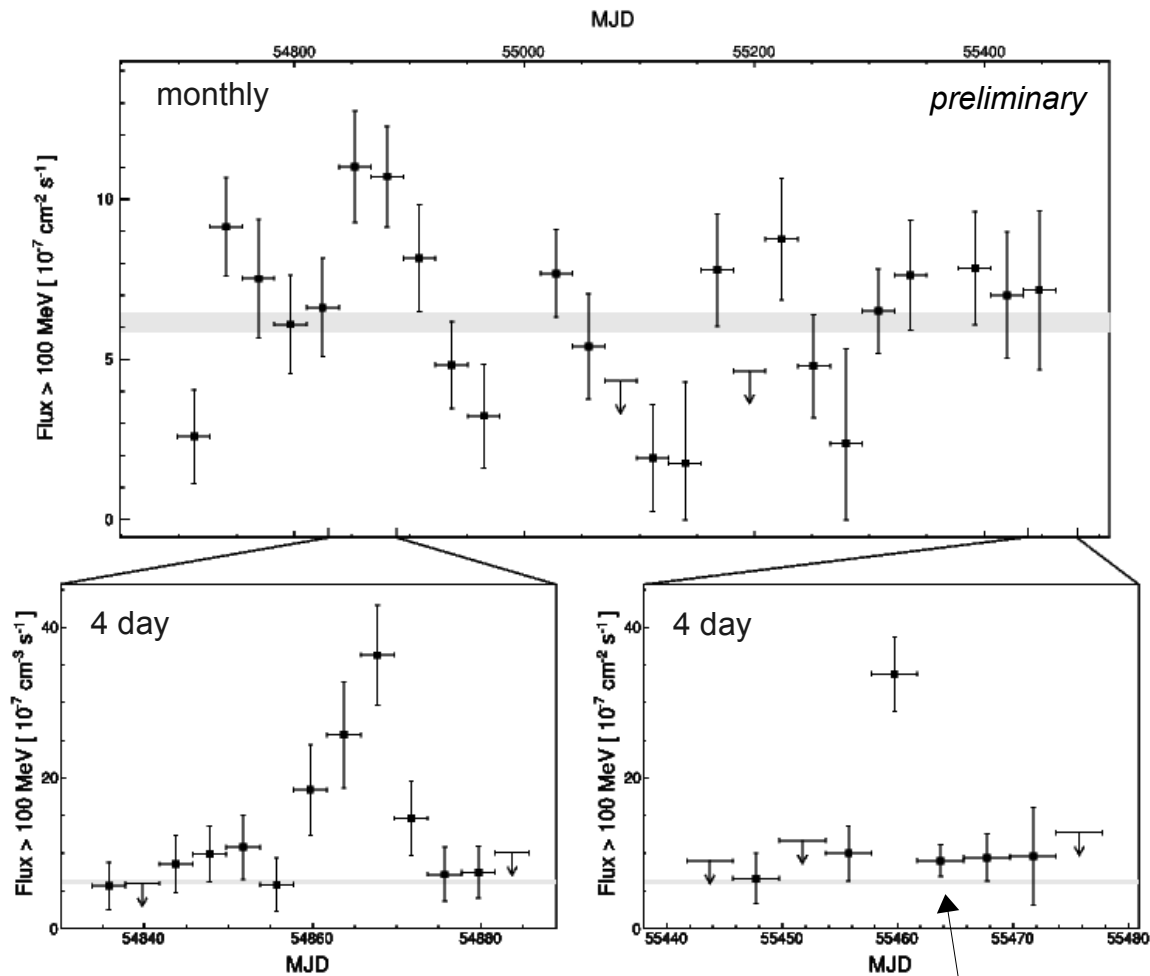
- Remnant from 1054 AD supernovae at 2 kpc
- Standard candle in X-rays and VHE
- Yearly variable in X-rays $\sim 3.5\%$, 1-150 MeV on $\sim 40\%$
(Wilson-Hodge et al 2010, Munch et al. 1995, de Jager et al 1996)

Crab with Fermi



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

Nebula synchrotron flux



Monthly variations

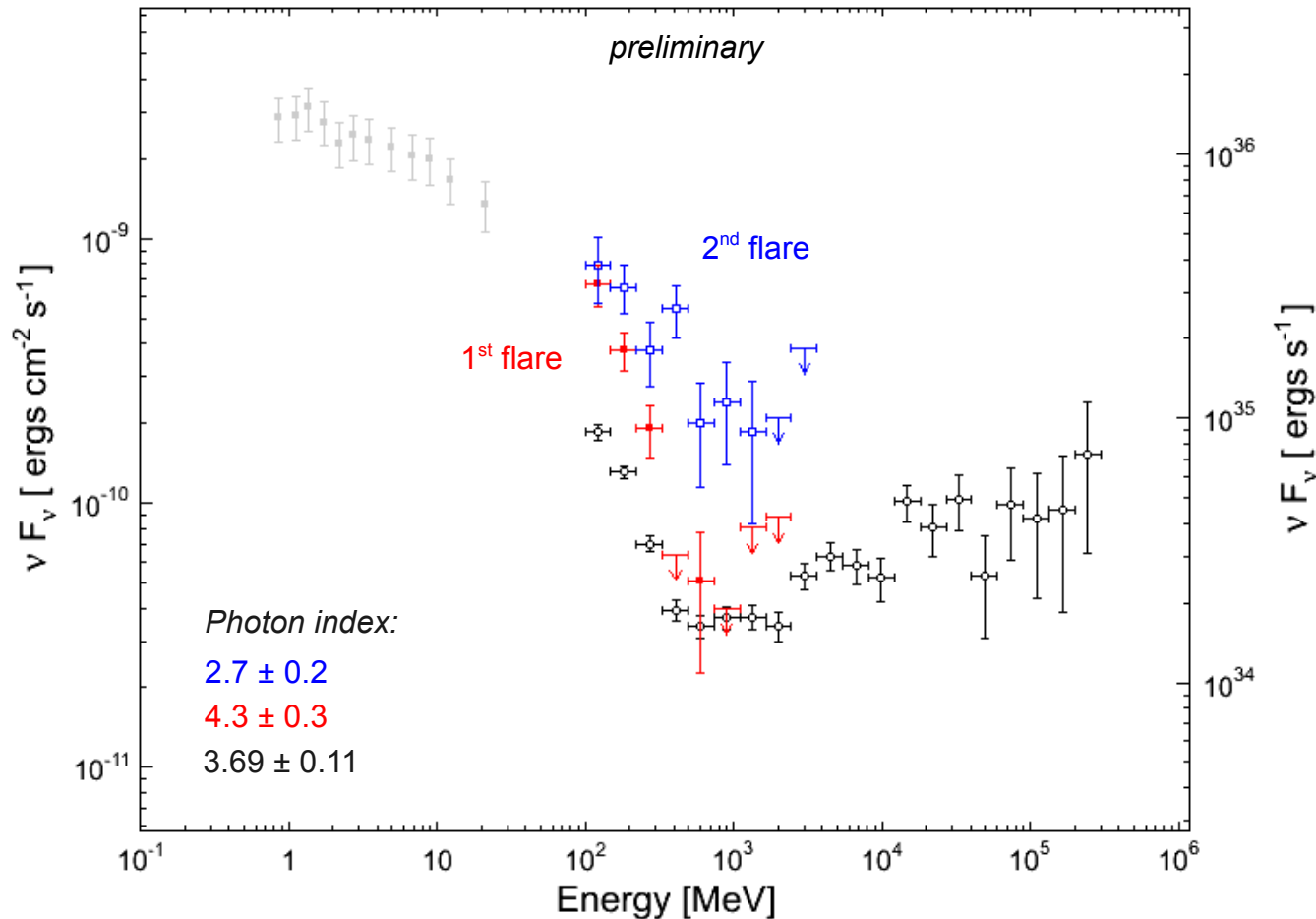
Two flares:

- 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%) in pulsed emission and nebula IC component

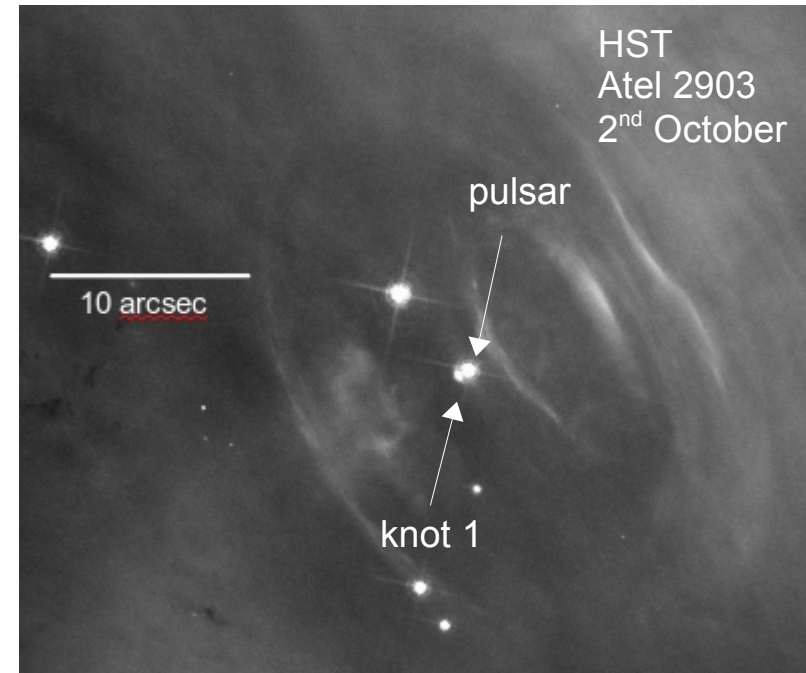
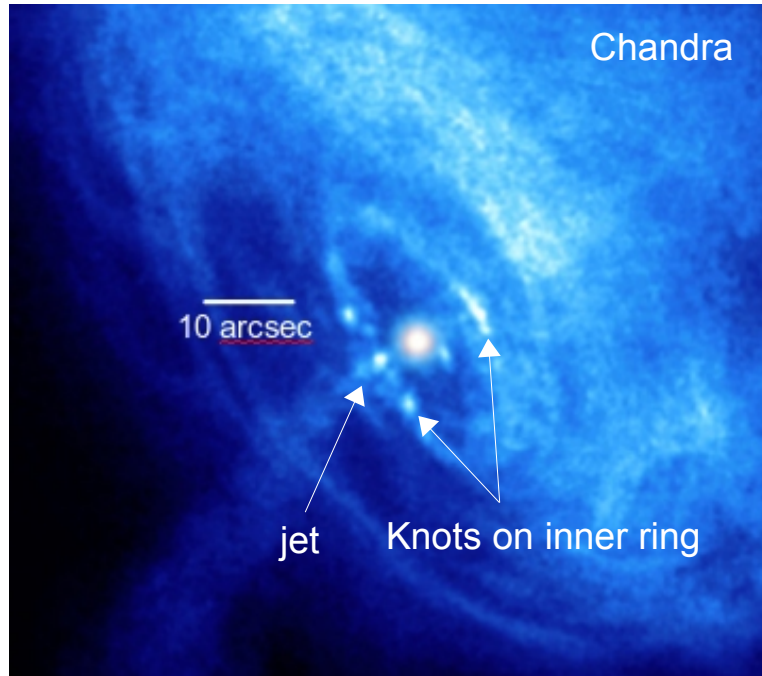
LAT ToO observations

Flares spectrum



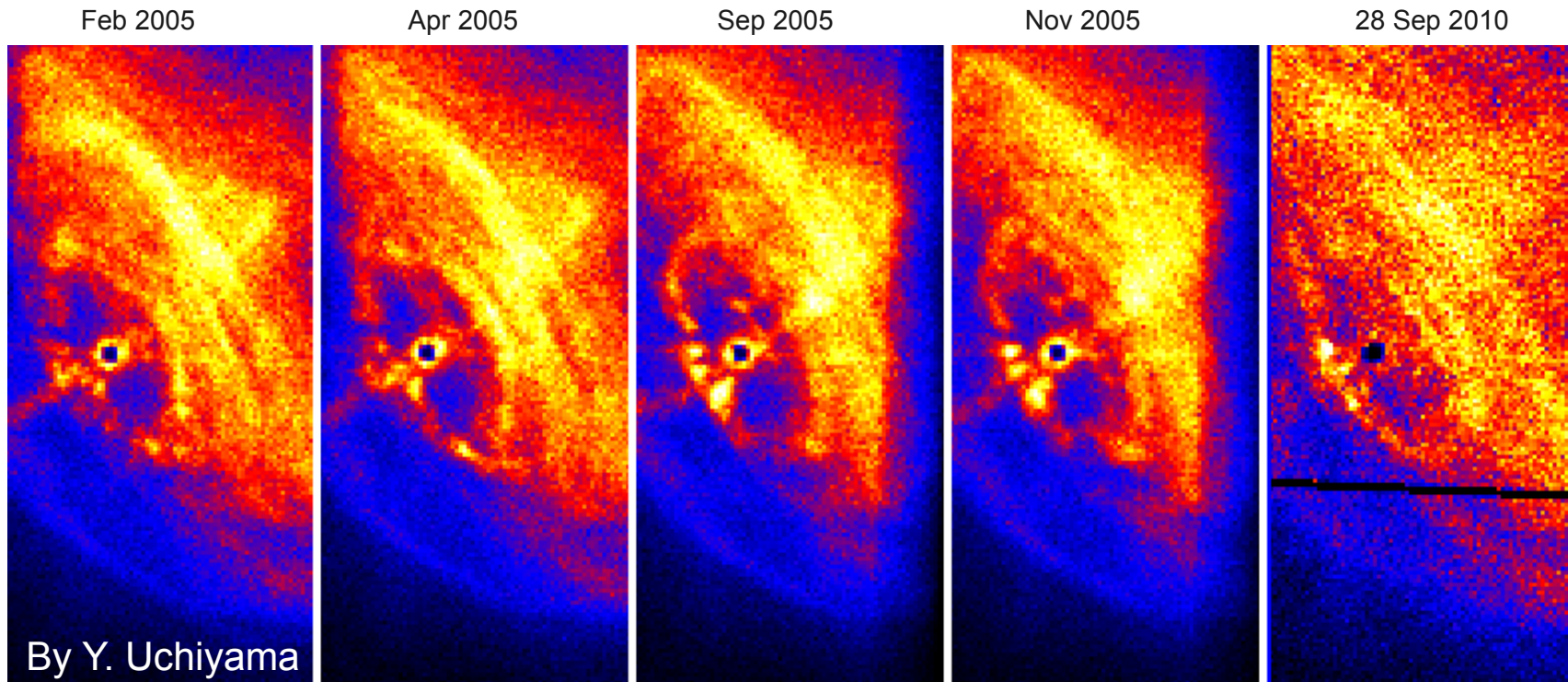
- Second flare has hard spectrum and extends >1 GeV at >3 σ
- Energy release small compared to pulsar spin down ($\sim 5 \cdot 10^{38}$ erg s⁻¹)

Where does it come from?



- Not resolvable with LAT localization accuracy ($\sim 2'$)
- Causality: $L < D \cdot t \cdot c < 4 \cdot 4\text{days} \cdot c = 0.014 \text{ pc} < 1.5''$
- 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

How are particles accelerated?

Basic conclusions:

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

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

$$\frac{\textit{larmor radius}}{\textit{cooling length}} \approx 2 \times 10^{-2} \varepsilon_{peak} \approx 4 \quad (\text{for } \varepsilon_{peak} = 200 \text{ MeV})$$

→ Acceleration might be related directly to the pulsar

DC component or mag. reconnection of striped Wind

Summary

The high energy tail of the synchrotron component of the Crab Nebula is variable on monthly time scales. Two strong flares were detected on timescales of a few days.

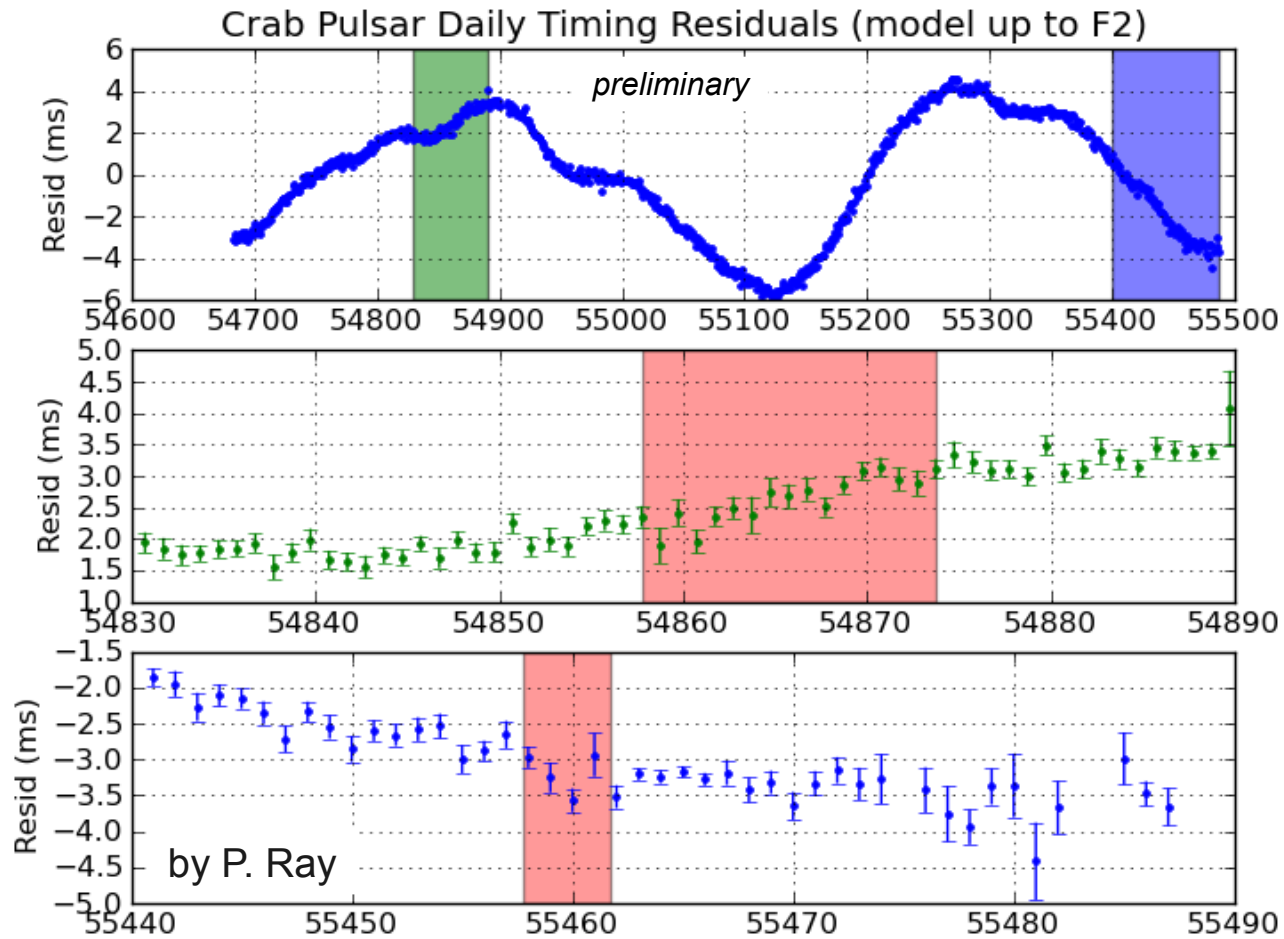
Several conclusions can be drawn:

- The flare emission is synchrotron radiation from a small region, likely in the inner Nebula
- The acceleration of electrons to \geq PeV poses severe 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.

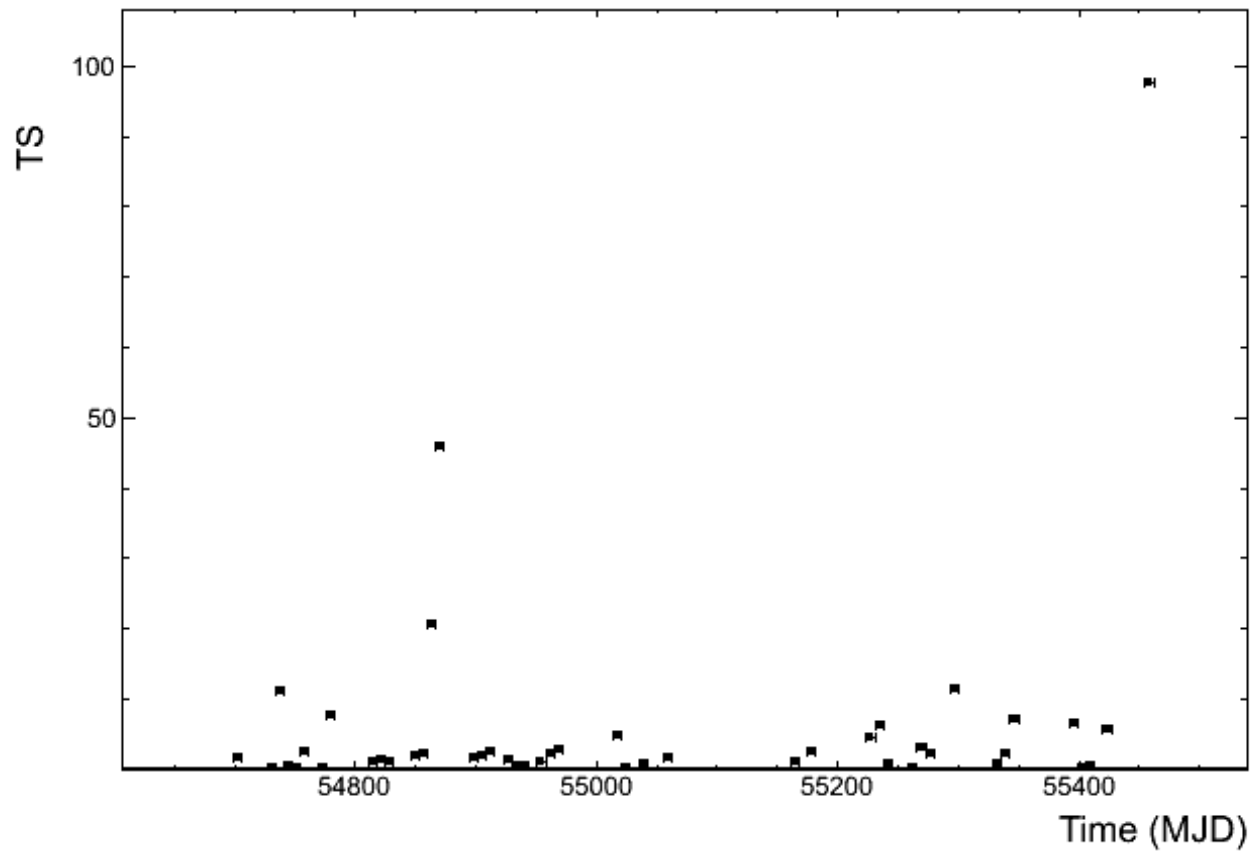
Backup slides

Pulsed emission



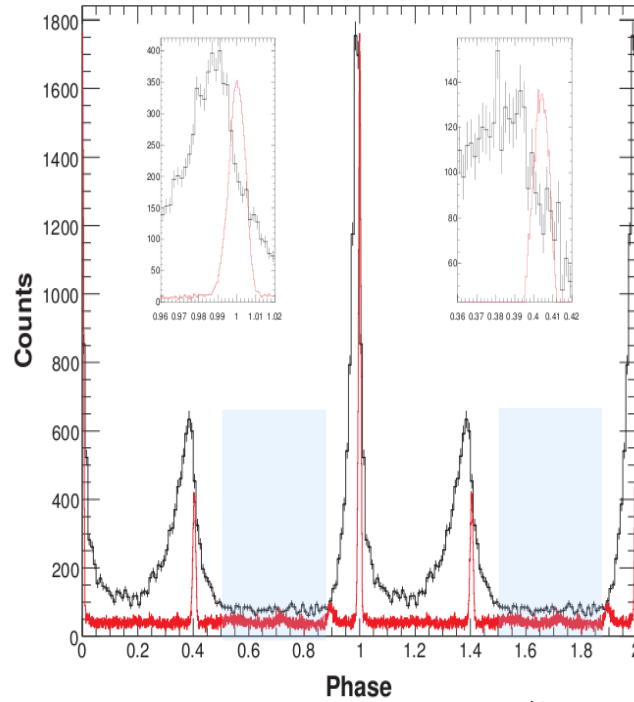
Nothing unusual during the flares in the timing residual

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

