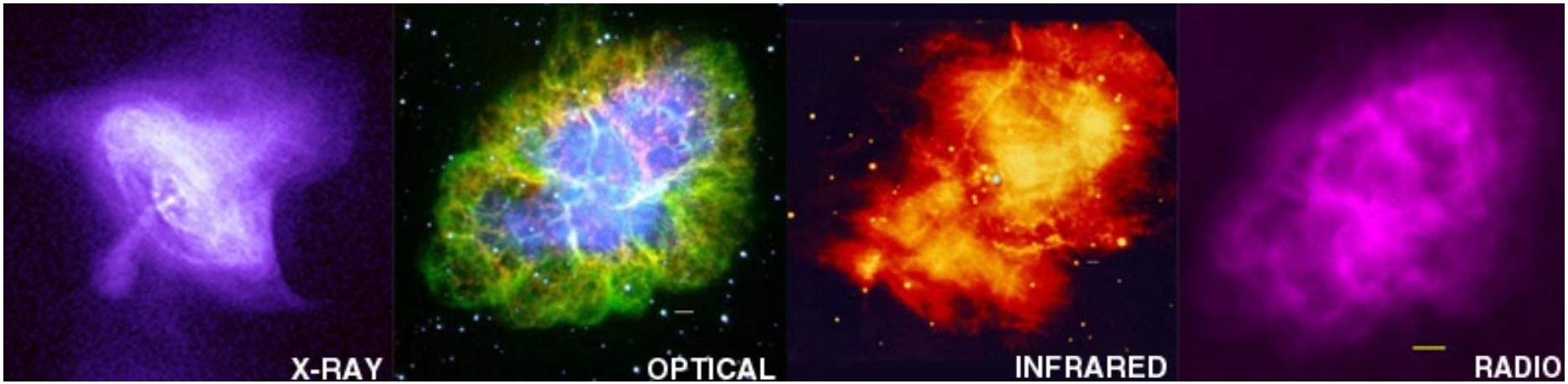
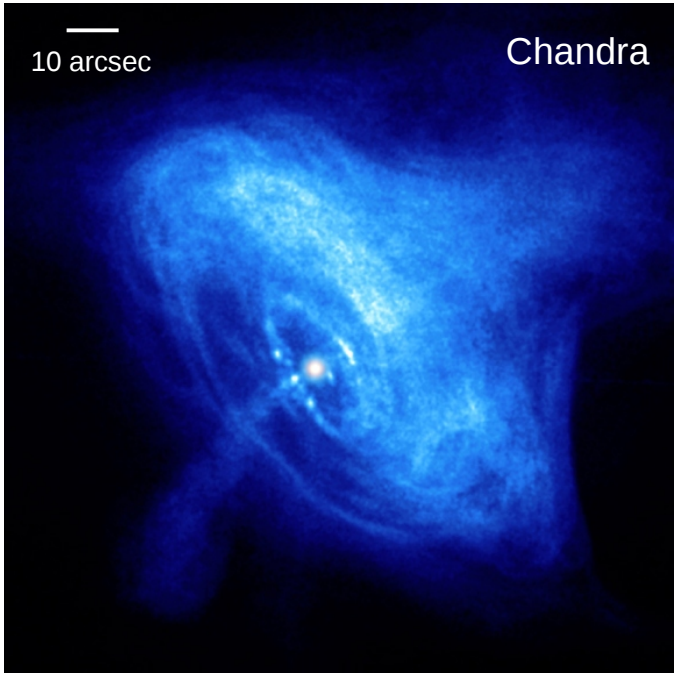
The flaring Crab

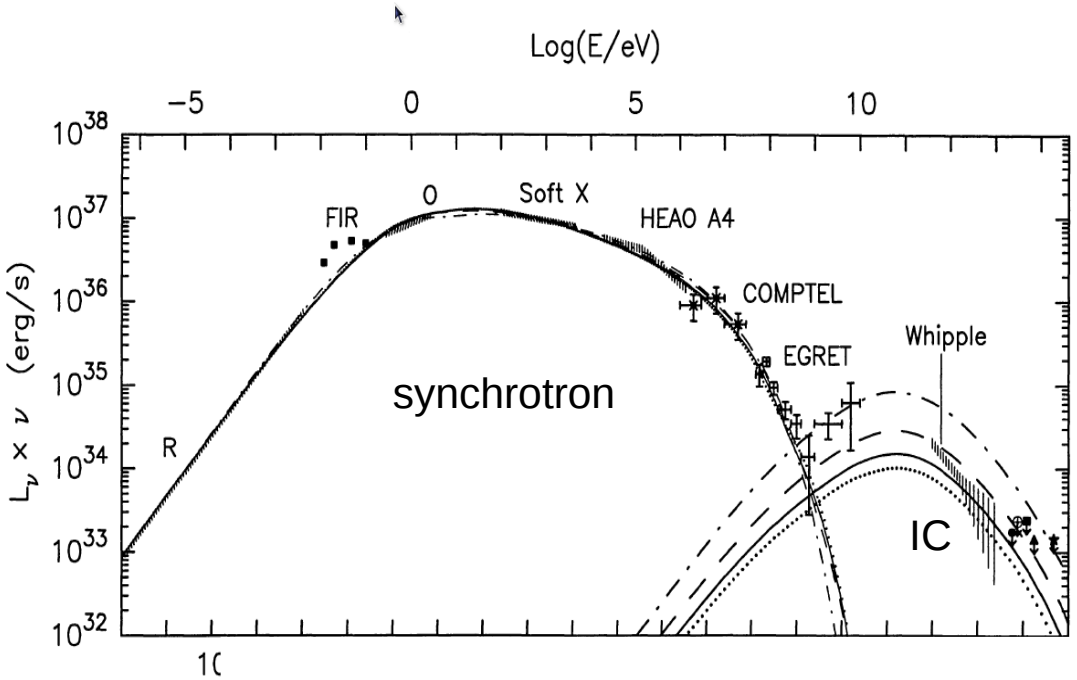
Fermi Symposium • Rome 11 May 2011



R. Buehler *for the LAT collaboration* and A. Tennant, E. Costa, D. Horns,
C. Ferrigno, A. Lobanov, M. Weisskopf

The *star* of the play



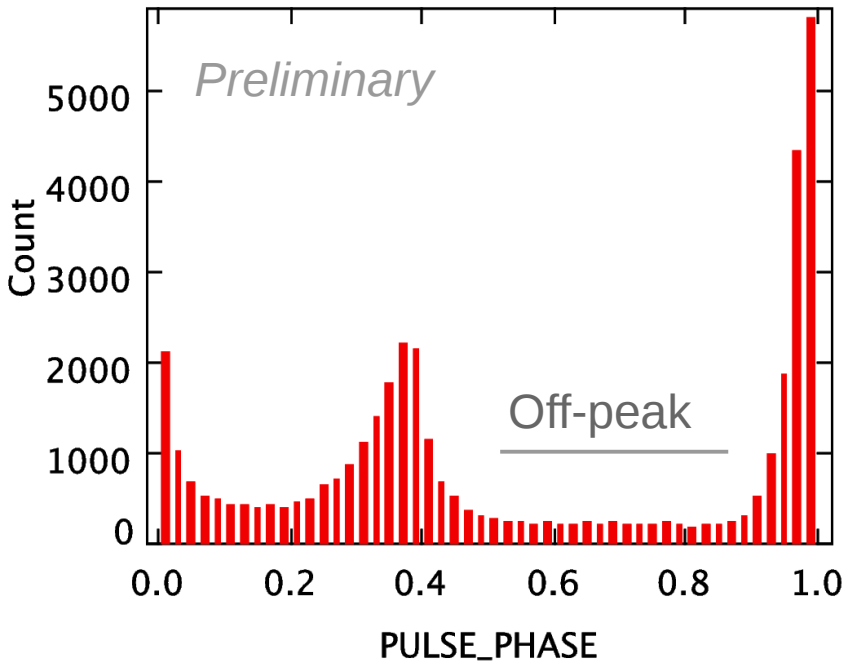


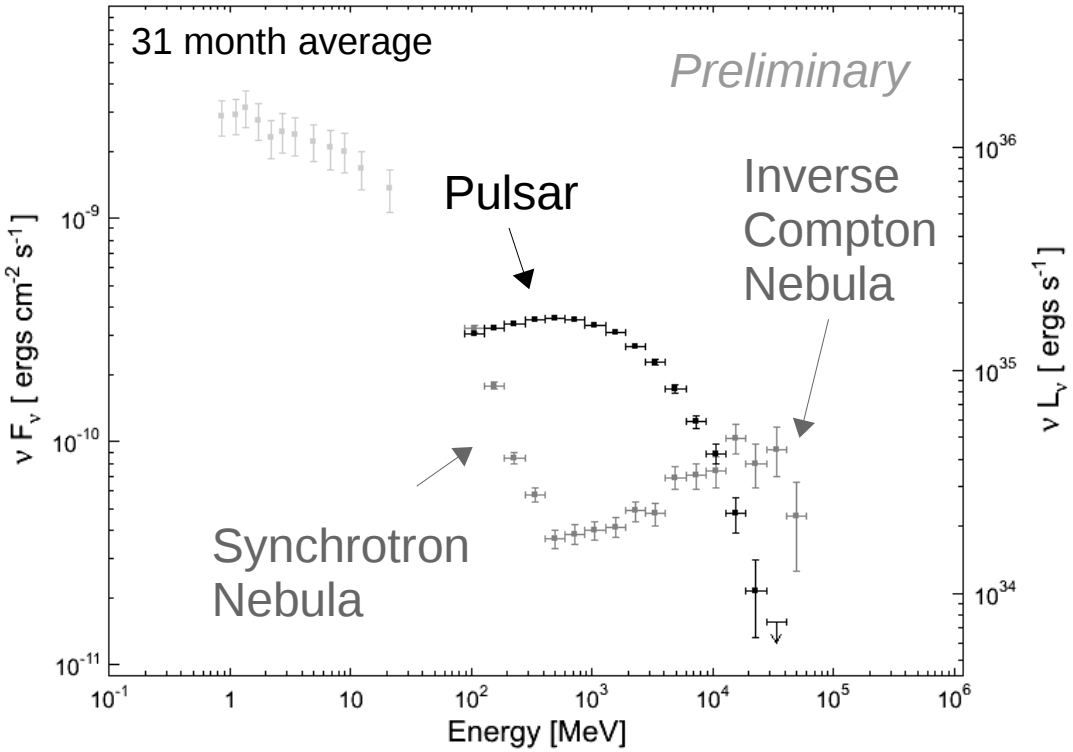
- Remnant from 1054 AD supernovae at 2 kpc
- Standard reference in X-rays and VHE
- Yearly variable in X-rays ~3.5% , 1-150 MeV ~40%

(Munch et al. 1995
de Jager et al 1996)

See talk by Colleen Hodge tomorrow

Introduction to Crab with Fermi

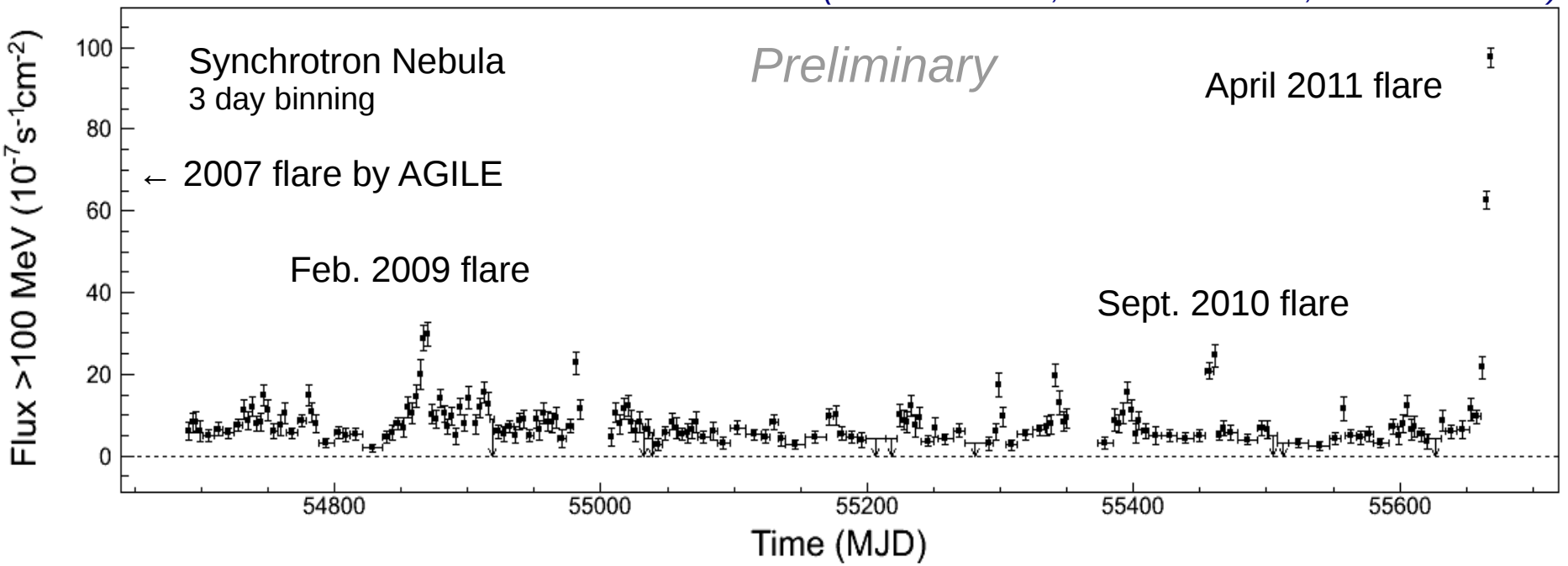




Complicated region with pulsar and nebula on top of each other

Three day Crab synchcrotron curve

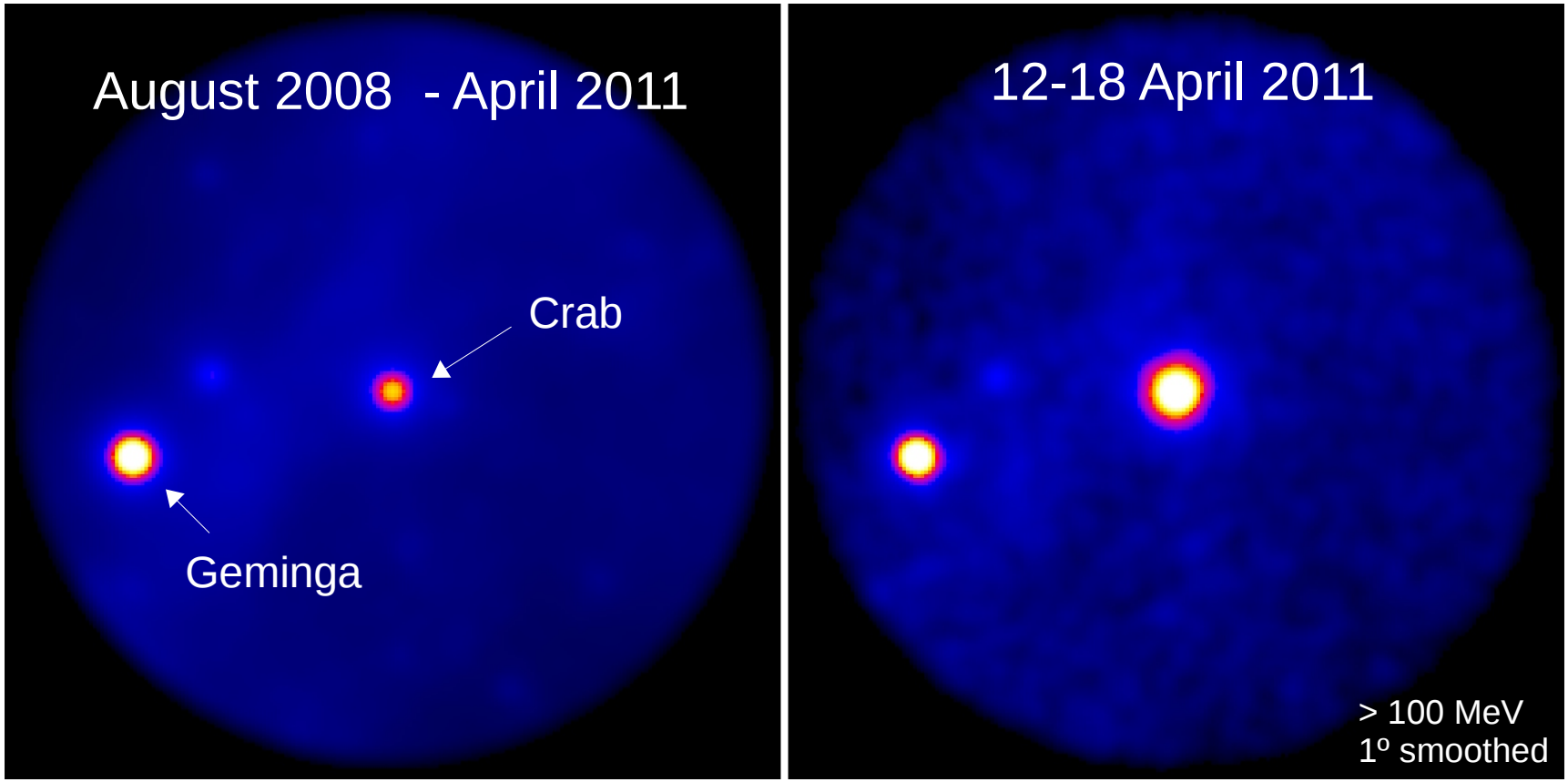
(Abdo et al 2011, Tavani et al 2011, Balbo et al 2011)



Average flux ~6 10^{-7} ph/cm^2/s above 100 MeV, whith three flares as extremes of persistent variability. Flux increase by ~5 during 2009 and 2010 flares.

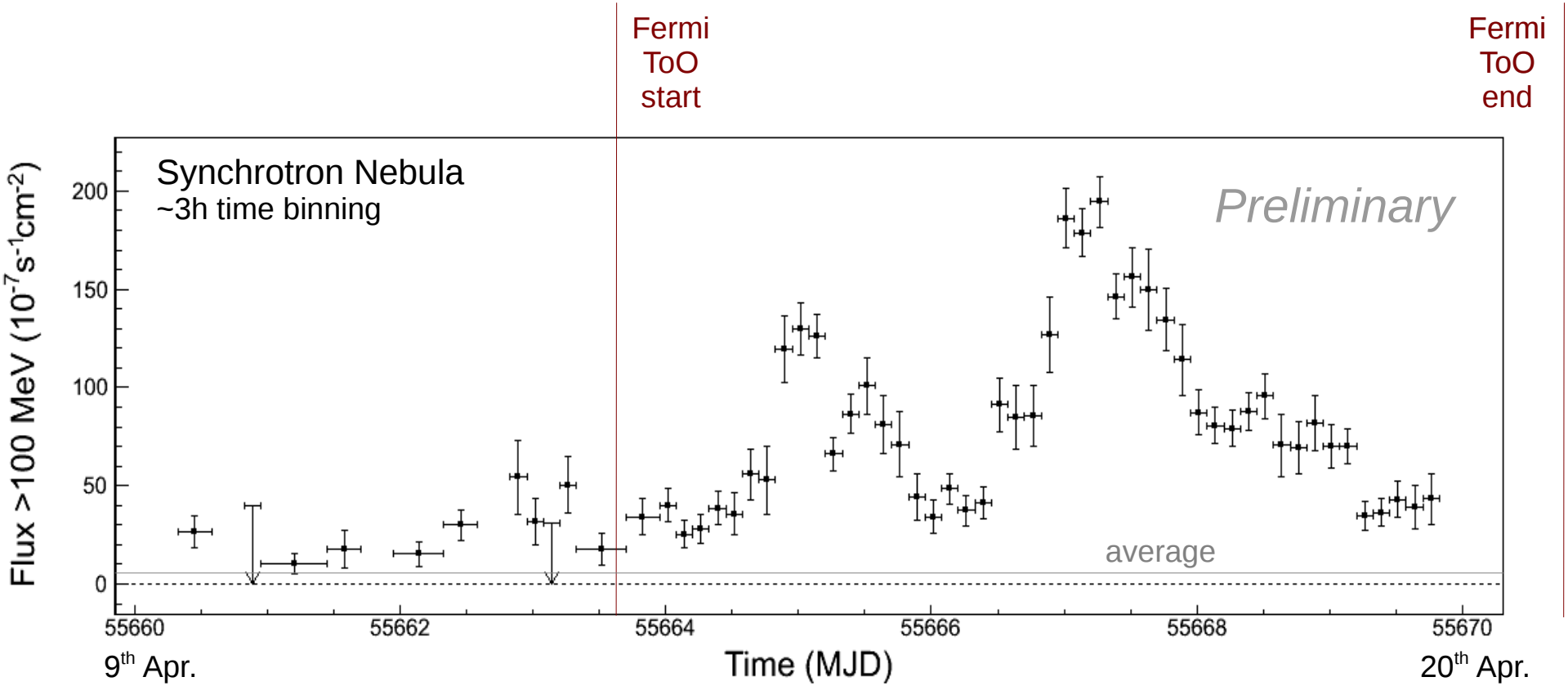
See poster by Liz Hays

The 2011 outburst



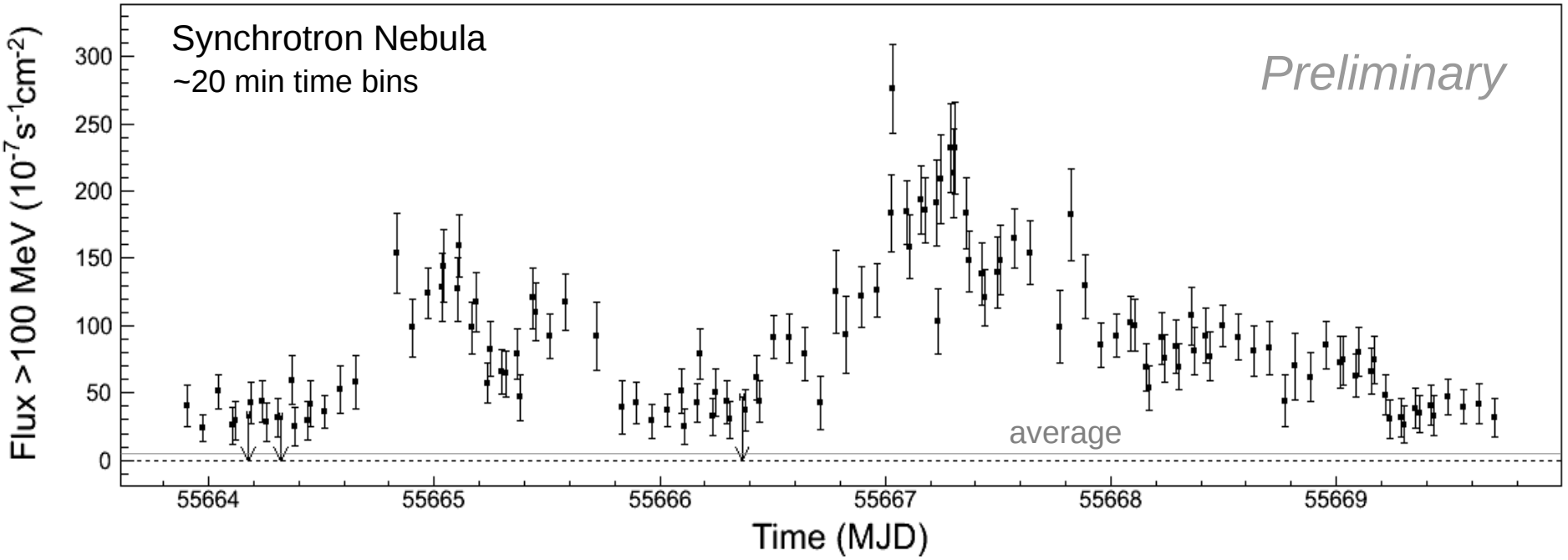
During the flare, the Crab was the brightest source in the gamma-ray sky

2011 flare in 3 hours binning



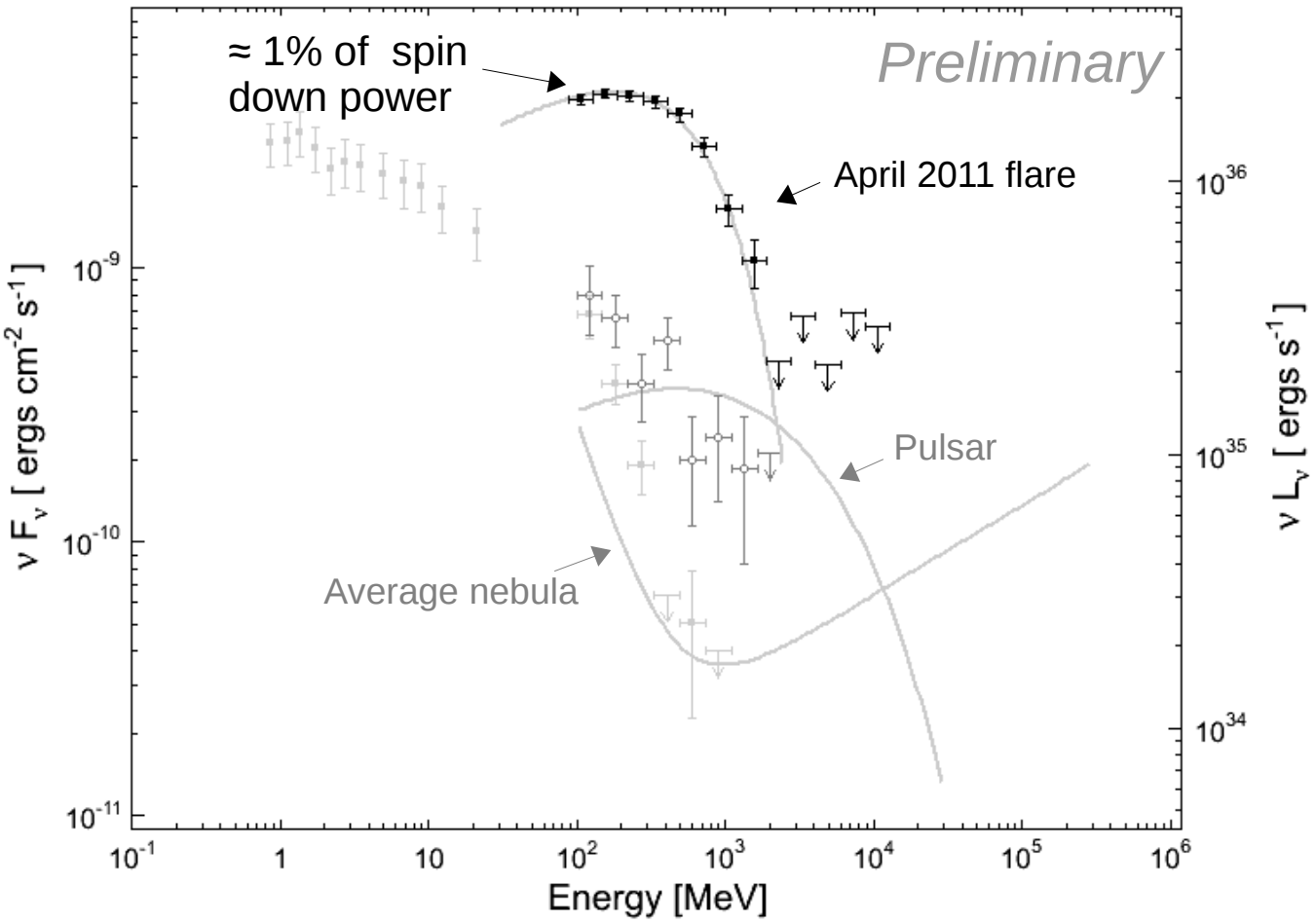
Synchrotron nebula increased by factor ~30 during very good Fermi and Chandra coverage

2011 flare in ~20 min. binning



Fast variability (~1h)

Nebula 2011 flare spectrum

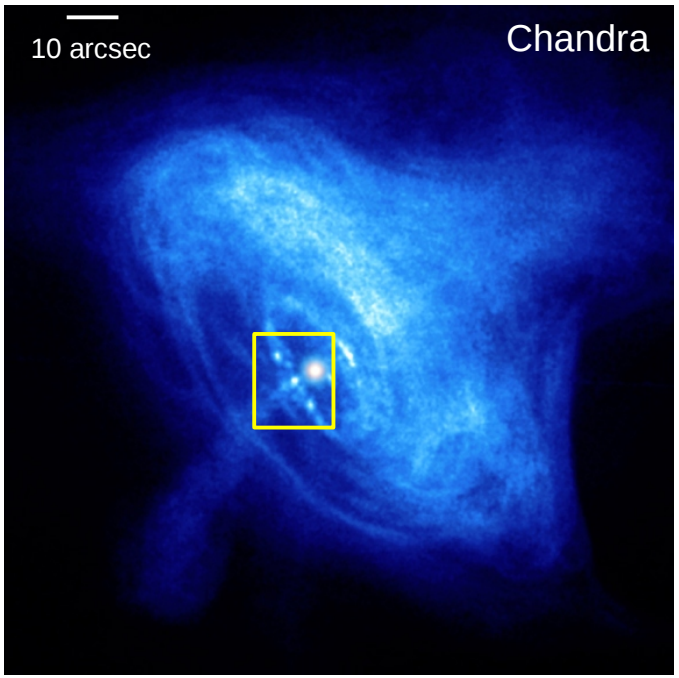


New spectral component of power law of index 1.6 and exponential cutoff at 580 MeV (Pulsar like, but no sign of pulsation in flare photons)

Chandra monitoring

After September 2010 flare, monitoring and flare ToO program led by Martin Weisskopf put in place with Fermi and AGILE.

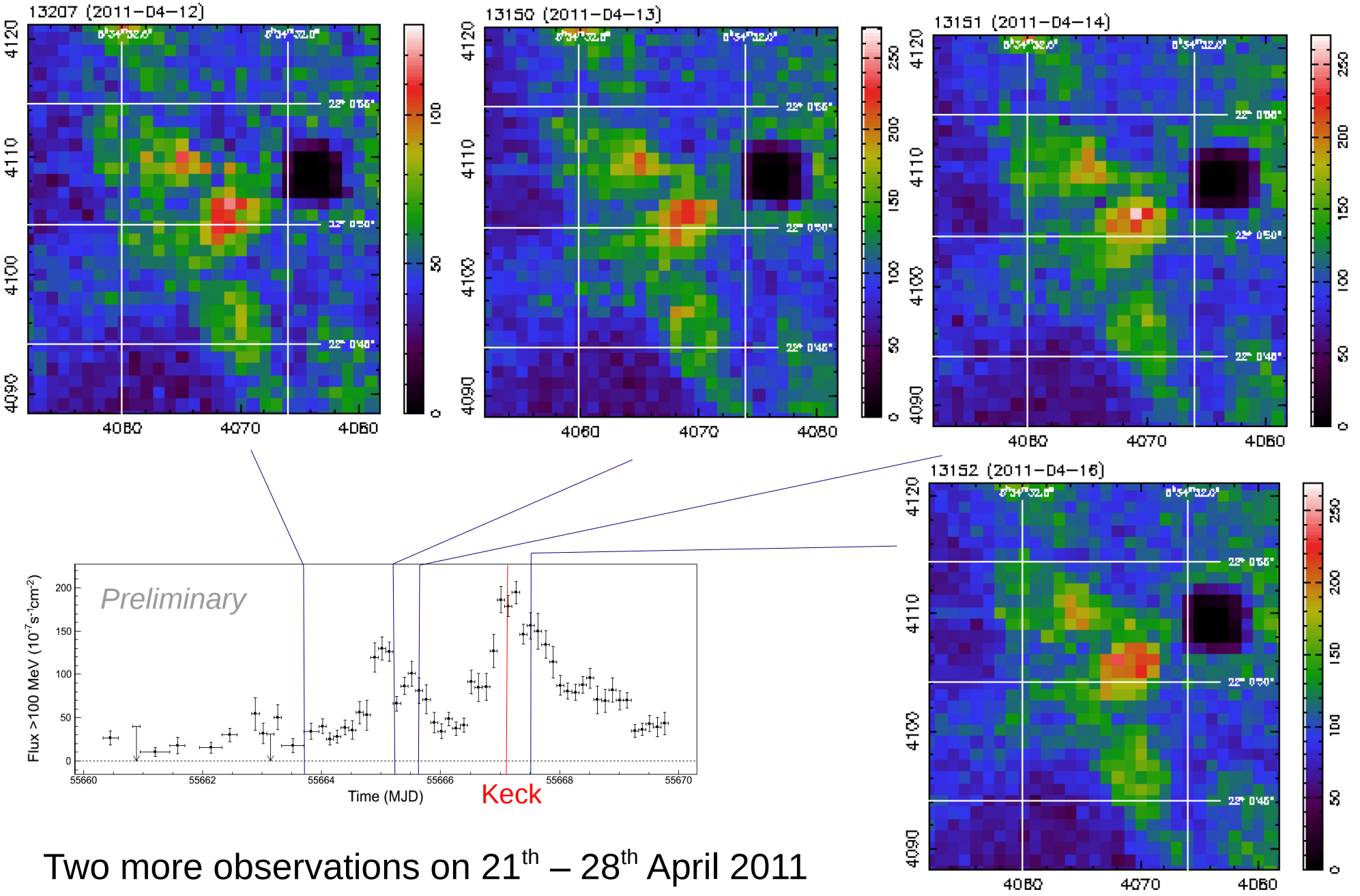
- Monthly snapshot of 5 ks
- ToO of 5 10 ks snapshots triggered on recent flare



The following results produce by *Allyn Tennant*, as part of a team consisting of:

R. Blandford, R. Buehler, P. Caraveo, E. Costa, D. Horns, C. Ferrigno, S. Funk, R. Mignani, A. Lobanov, A.De Luca, M. Tavani, A. Tennant, Y. Uchiyama and M. Weisskopf

Chandra during the 2011 flare

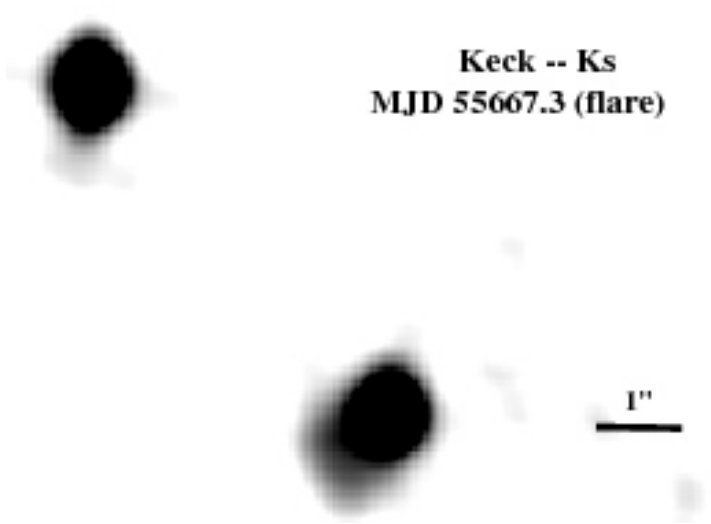


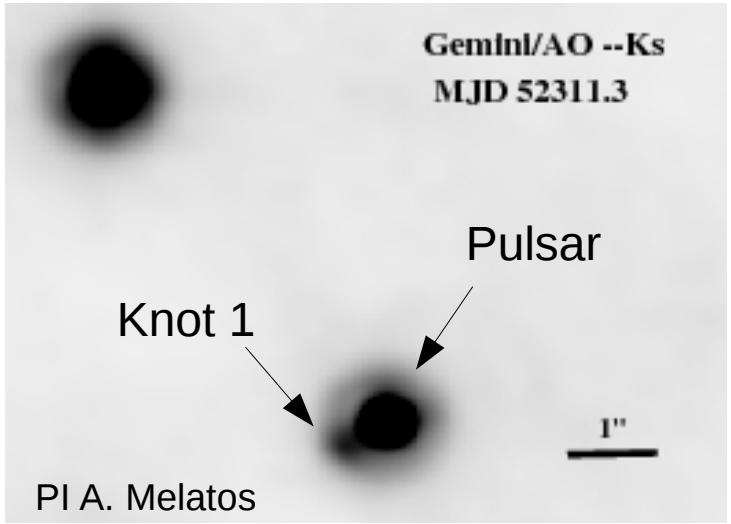
Two more observations on 21th – 28th April 2011

Optical and radio observations

Keck observations of Hai Fu analyzed by Roger Romani

(Thanks J. Graham, C. Max)





- No strong variation of knot 1 (<20%) or the pulsar in the optical. No strong shift in knot 1 position.
- EVLA observations on 15th and 18th April thanks to T. Cheung and G. Taylor give upper limits on radio flux.

→ Flare component with hard spectral rise


And here, poor fool! with all my lore I
stand, no wiser than before..

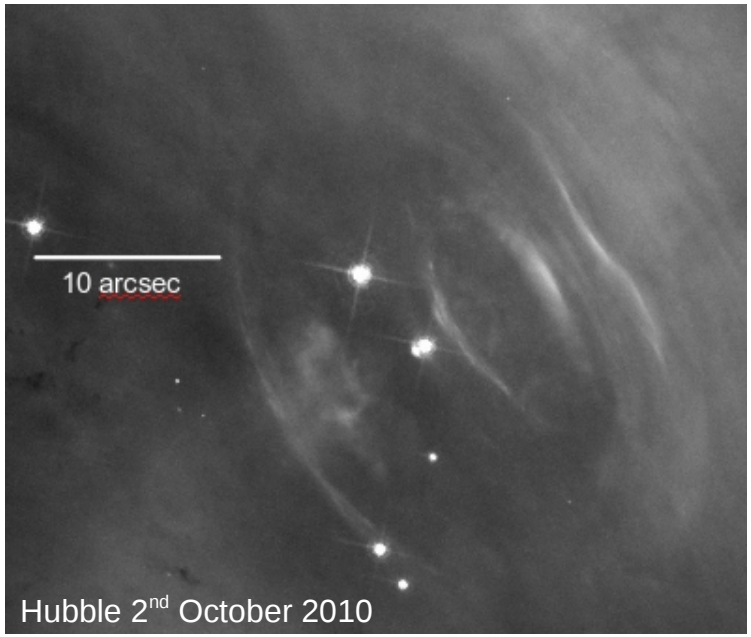
Not true..

- Flare from hard new SED component peaking at ~500 MeV with “pulsar like” spectrum
- No correlations with any waveband found yet → hard spectrum
- Significant synchrotron emission >1GeV and fast acceleration very difficult for shock acceleration → Acceleration via magnetic reconnection in striped Wind or in DC-pulsar potential?

- Compact emission region < 0.0004 pc ~ 0.04" (for D<4) → Inner nebula

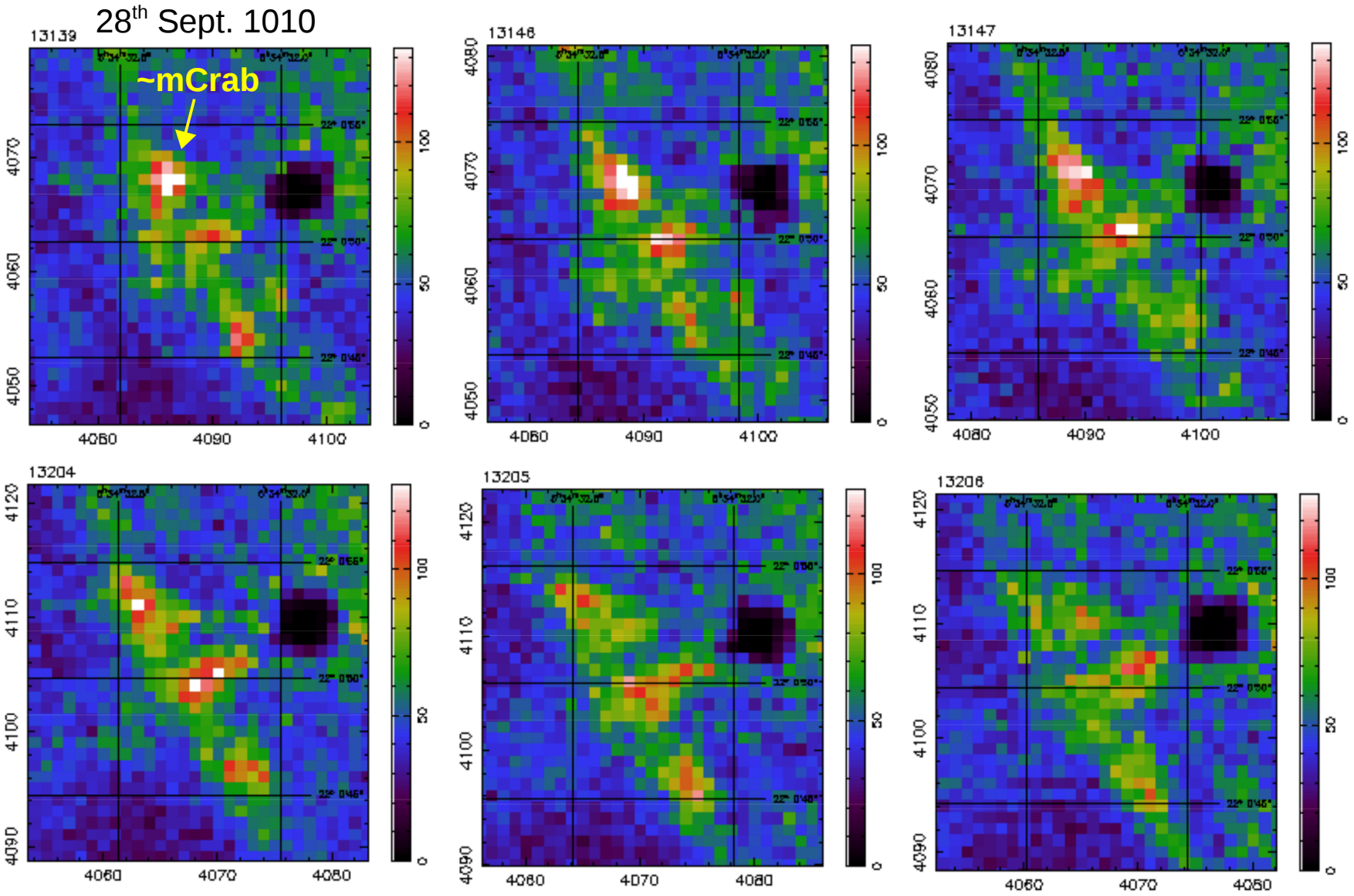
↓

Emission from very close (<0.1 pc) of the pulsar?



Backup slides

Chandra after the 2010 flare

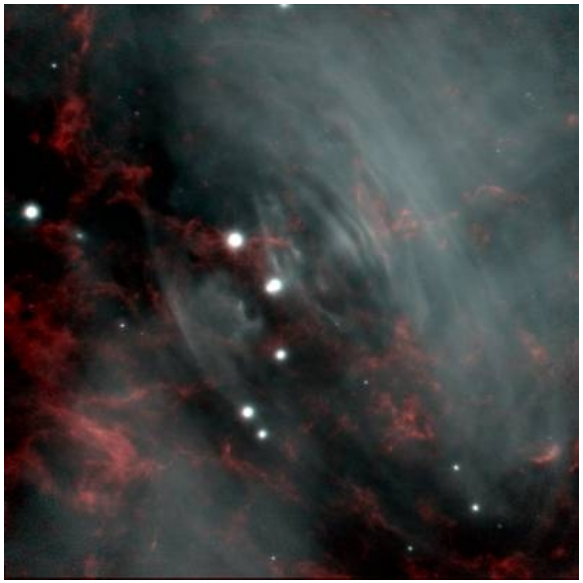


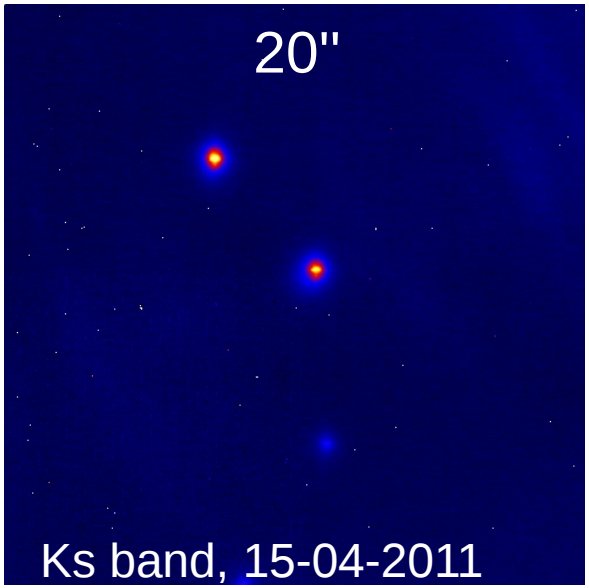
6 days after September 2010 flare, followed by ~monthly images

Other MW observations

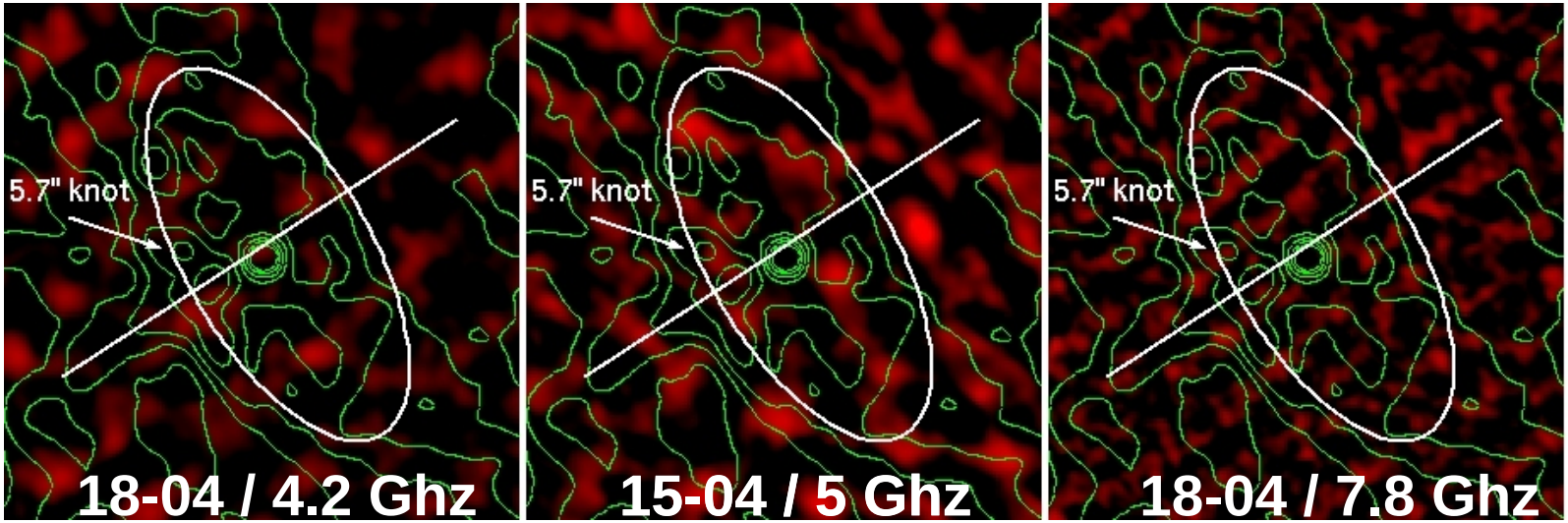
Thanks to James Graham, Clair Max, Hai Fu

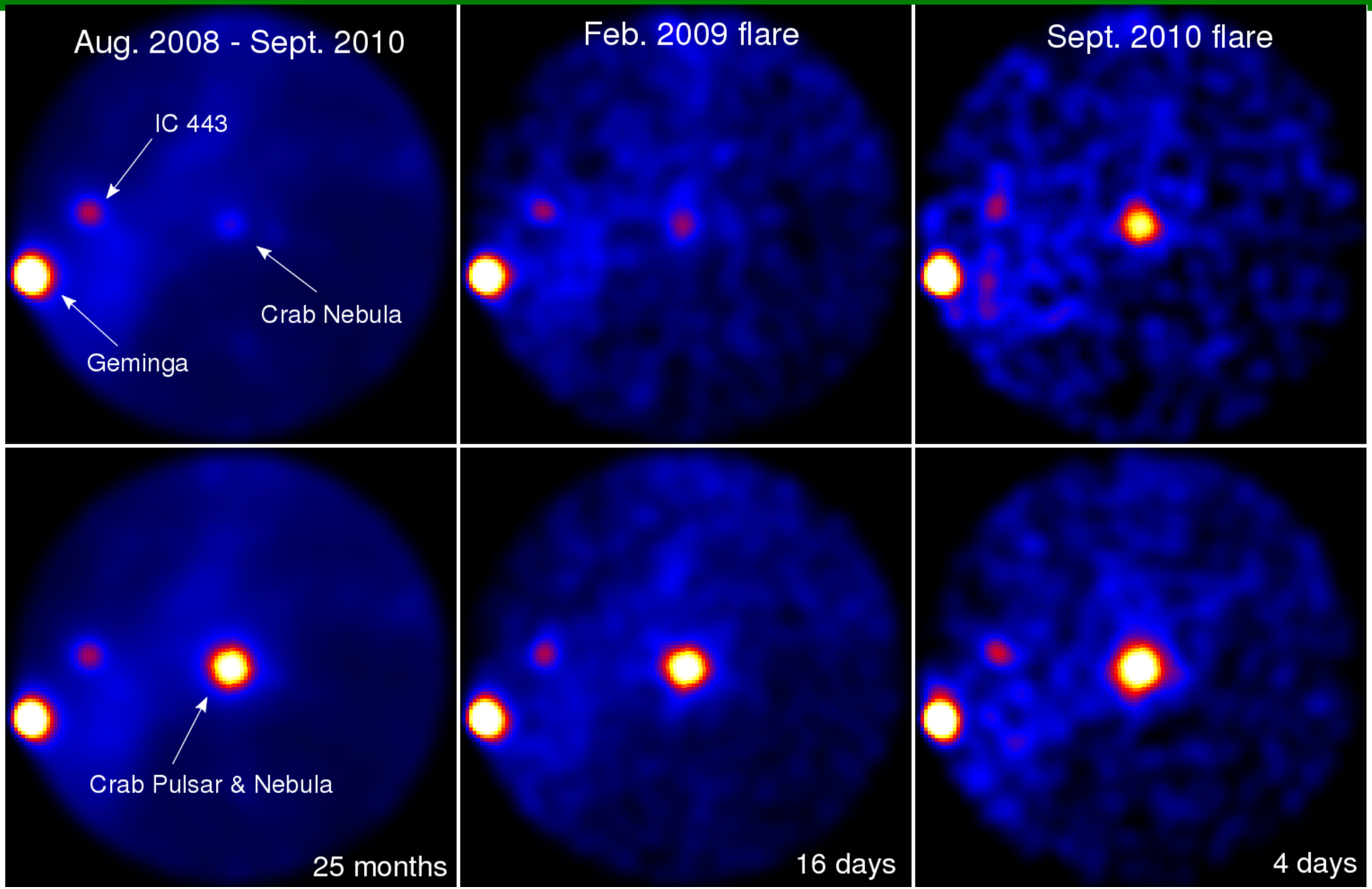
Keck



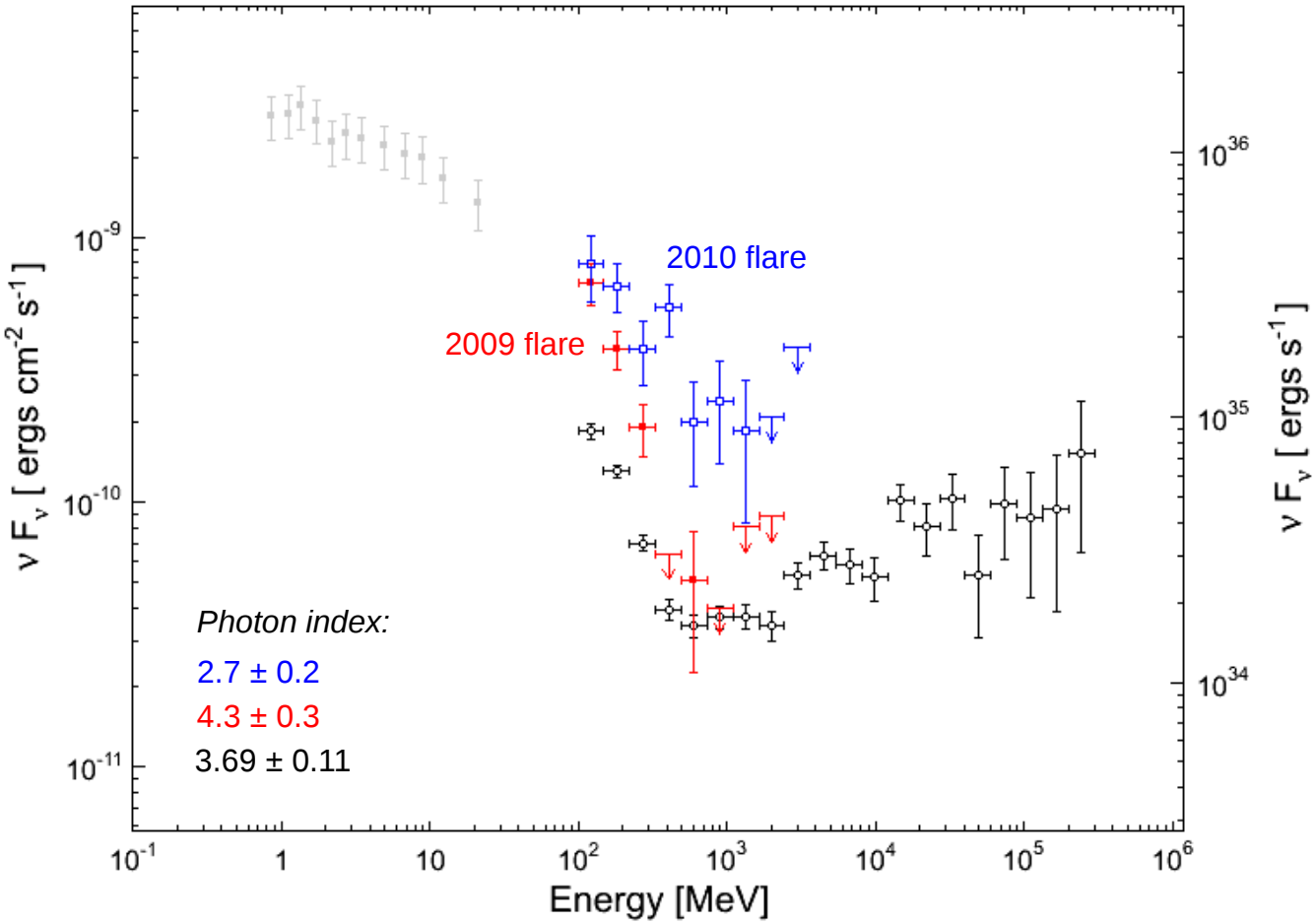


EVLA provided by Teddy Cheung and Greg Taylor



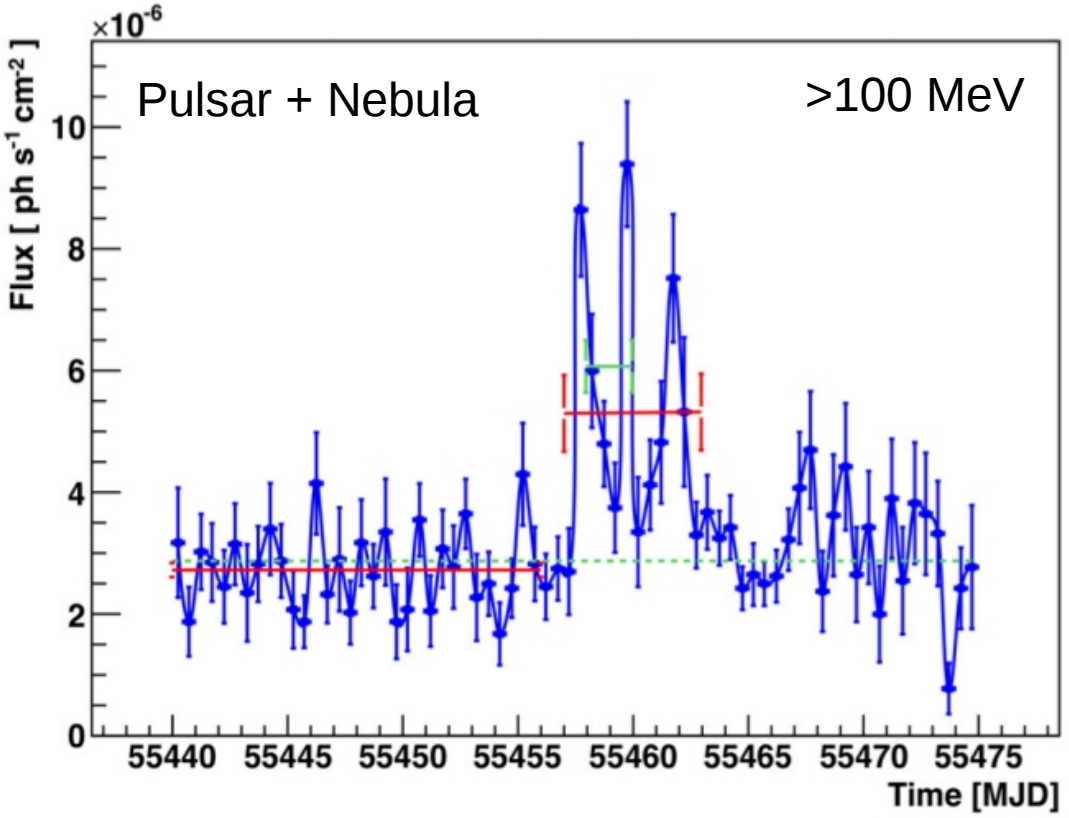

Aug. 2008 - Sept. 2010
IC 443
Crab Nebula
Geminga
Feb. 2009 flare
Sept. 2010 flare
Crab Pulsar & Nebula
25 months
16 days
4 days

2009 and 2010 flares spectrum



Second flare has hard synchrotron spectrum and extends >1 GeV

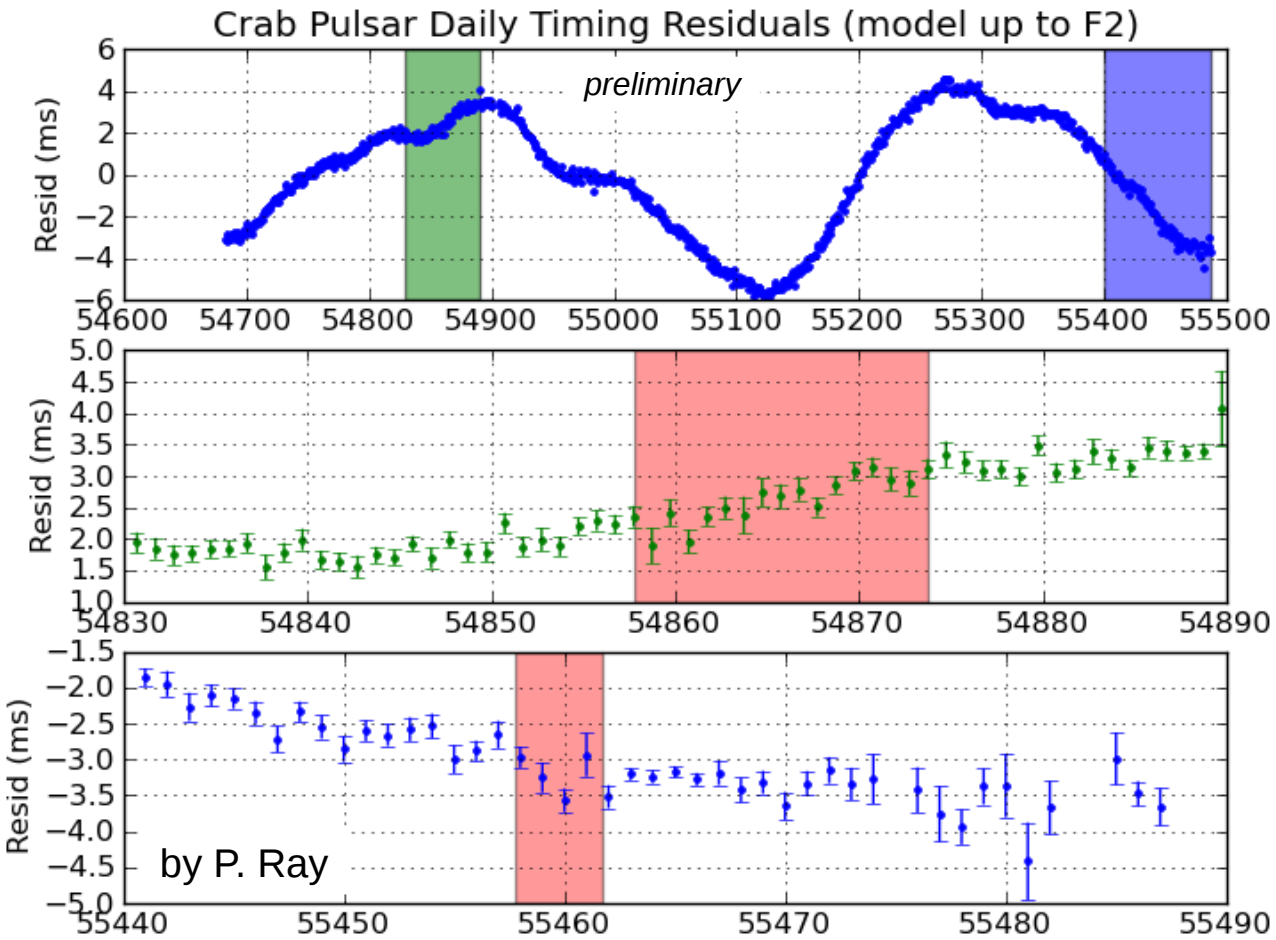
Short term variability during 2010 flare



Balbo et al 2011: September 2010 flare is composed of three rapid (~12h) flares

(Under power-law assumption for Pulsar+synch. And IC Nebula. Pulsar assumed to be stable)

Pulsed emission



Nothing unusual during the flares in the timing residual

How are particles accelerated?

Synchrotron emission above 1 GeV $\longrightarrow$ $\varepsilon_{peak} \propto E^2 B \gtrapprox 200\,MeV$

$$\frac{larmor\,radius}{cooling\,length} \propto \frac{E\,B^{-1}}{E^{-1}\,B^{-2}} \propto E^2 B \rightarrow \frac{larmor\,radius}{cooling\,length} \approx 2\times10^{-2}\,\varepsilon_{peak} \gtrapprox 4$$

Problem for diffusive shock acceleration (DSA)

Caveats: possibly **two zone** model or **Doppler boosting**, *but:*

- Particles don't travel far → sudden jump of B needed
- Doppler boosting in Crab would need to be >4

PIC simulations show that DSA appears not to work here

(Sironi, Spitkovki 2009)

→ Acceleration likely related directly to the pulsar DC component or mag. reconnection of striped Wind..