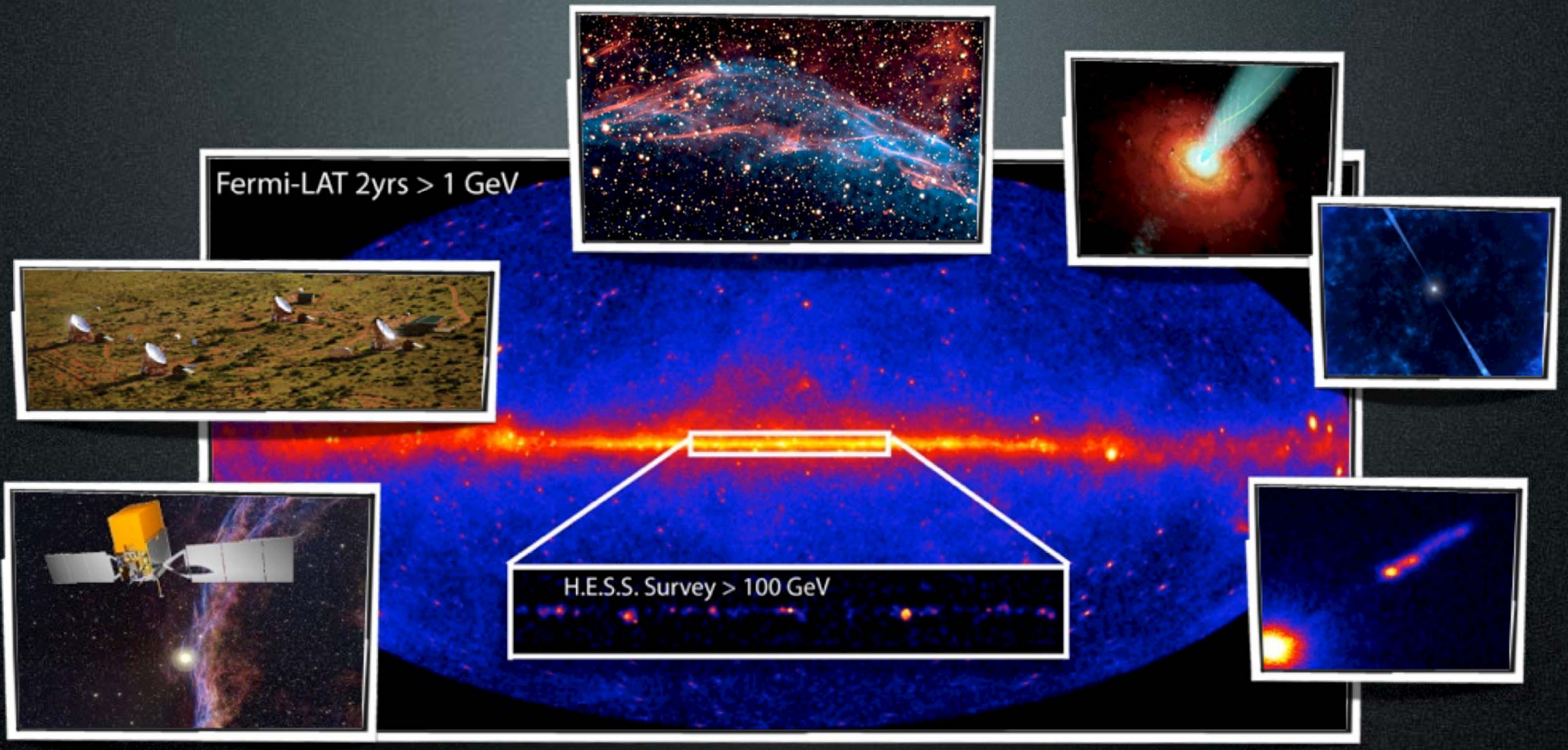


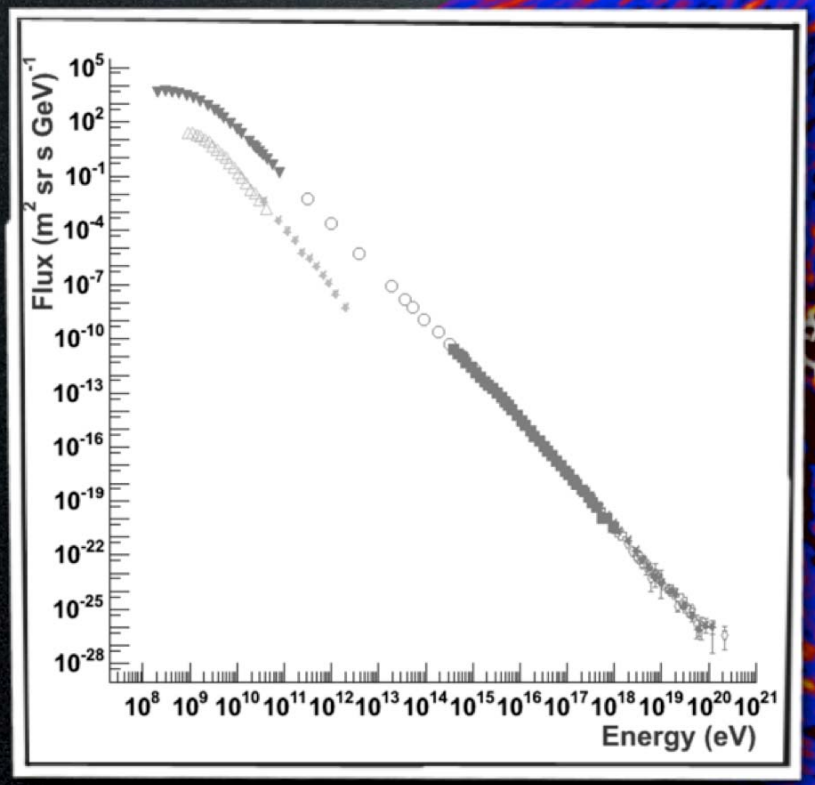
Cosmic Particles

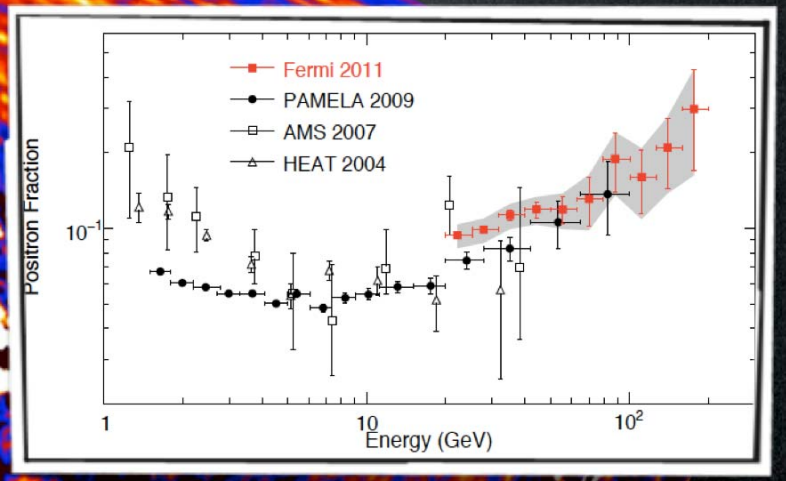
Galactic particle accelerators

Stefan Funk

KIPAC Kavli Institute for Particle Astrophysics and Cosmology

My personal motivation





- Cosmic particle acceleration and Dark Matter searches

Electrons and positrons

Electrons and Positrons

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References in the article
Citations to the Article (1027) (Citation History)
Refereed Citations to the Article
Also-Read Articles (Reads History)

Translate This Page

Title: An anomalous positron abundance in cosmic rays with energies 1.5-100GeV

Authors: Adriani, O.; Barbarino, G. C.; Bazilevskaya, G. A.; Bellotti, R.; Boezio, M.; Bogomolov, E. A.; Bonechi, L.; Bongi, M.; Bonvicini, V.; Bottai, S.; Bruno, A.; Cafagna, F.; Campana, D.; Carlson, P.; Casolino, M.; Castellini, G.; de Pascale, M. P.; de Rosa, G.; de Simone, N.; di Felice, V.; Galper, A. M.; Grishantseva, L.; Hofverberg, P.; Koldashov, S. V.; Krutkov, S. Y.; Kvashnin, A. N.; Leonov, A.; Malvezzi, V.; Marcelli, L.; Menn, W.; Mikhailov, V. V.; Mocchiutti, E.; Orsi, S.; Osteria, G.; Papini, P.; Pearce, M.; Picozza, P.; Ricci, M.; Ricciarini, S. B.; Simon, M.; Sparvoli, R.; Spillantini, P.; Stozhkov, Y. I.; Vacchi, A.; Vannuccini, E.; Vasilyev, G.; Voronov, S. A.; Yurkin, Y. T.; Zampa, G.; Zampa, N.; Zverev, V. G.

Affiliation: AA(University of Florence, Department of Physics, Via Sansone 1, I-50019 Sesto Fiorentino, Florence, Italy), AB(University of Naples

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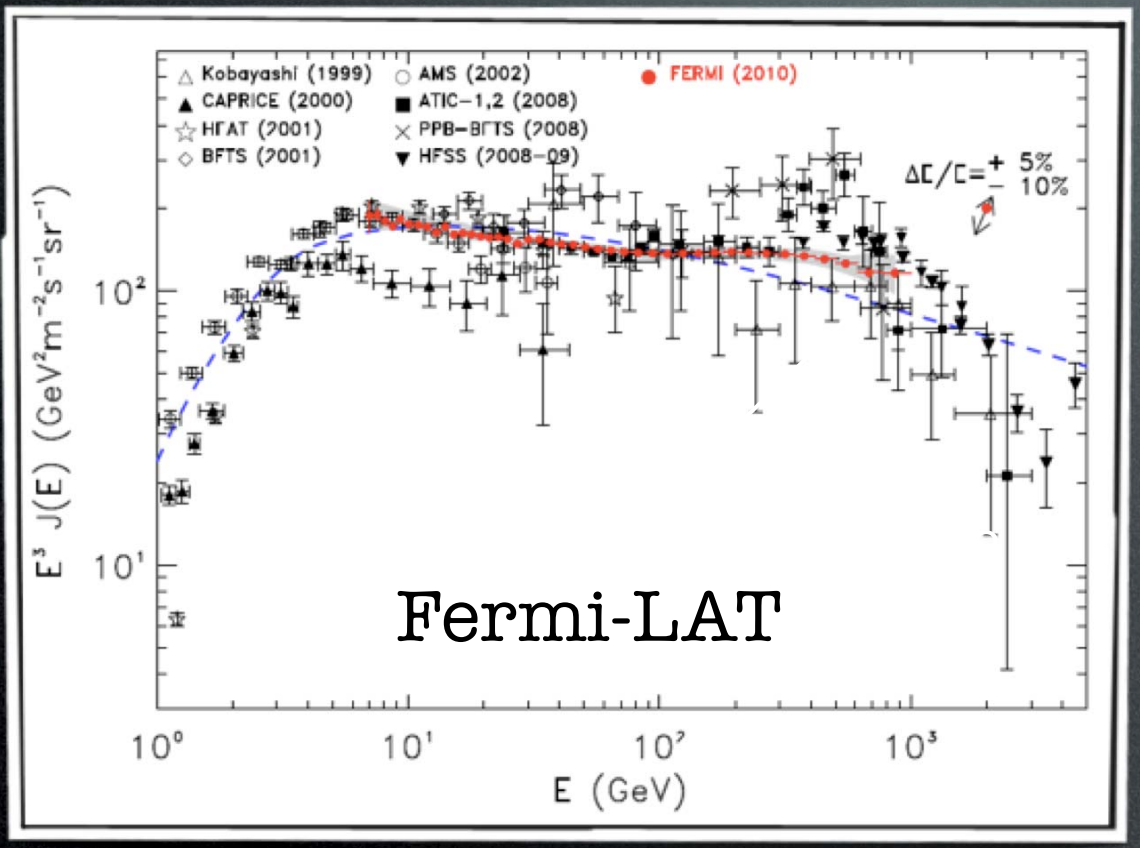
Citations to the Article (635) (Citation History)
Refereed Citations to the Article
Also-Read Articles (Reads History)

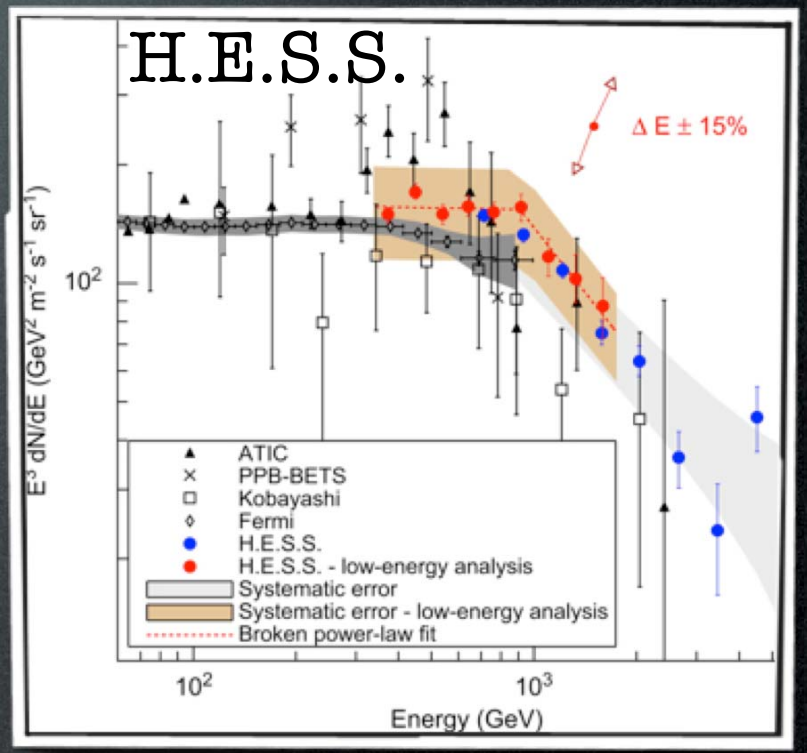
Translate This Page

Title: Measurement of the Cosmic Ray e++e- Spectrum from 20GeV to 1TeV with the Fermi Large Area Telescope

Authors: Abdo, A. A.; Ackermann, M.; Ajello, M.; Atwood, W. B.; Axelsson, M.; Baldini, L.; Ballet, J.; Barbiellini, G.; Bastieri, D.; Battelino, M.; Baughman, B. M.; Bechtol, K.; Bellazzini, R.; Berenji, B.; Blandford, R. D.; Bloom, E. D.; Bogaert, G.; Bonamente, E.; Borgland, A. W.; Bregeon, J.; Brez, A.; Brigida, M.; Bruel, P.; Burnett, T. H.; Caliandro, G. A.; Cameron, R. A.; Caraveo, P. A.; Carlson, P.; Casandjian, J. M.; Cecchi, C.; Charles, E.; Chekhtman, A.; Cheung, C. C.; Chiang, J.; Ciprini, S.; Claus, R.; Cohen-Tanugi, J.; Cominsky, L. R.; Conrad, J.; Cutini, S.; Dermer, C. D.; de Angelis, A.; de Palma, F.; Digel, S. W.; di Bernardo, G.; Do Couto E Silva, E.; Drell, P. S.; Dubois, R.; Dumora, D.; Edmonds, Y.; Farnier, C.; Favuzzi, C.; Focke, W. B.; Frailis, M.; Fukazawa, Y.; Funk, S.; Fusco, P.; Gaggero, D.; Gargano, F.; Gasparrini, D.; Gehrels, N.; Germani, S.; Giebels, B.; Giglietto, N.;

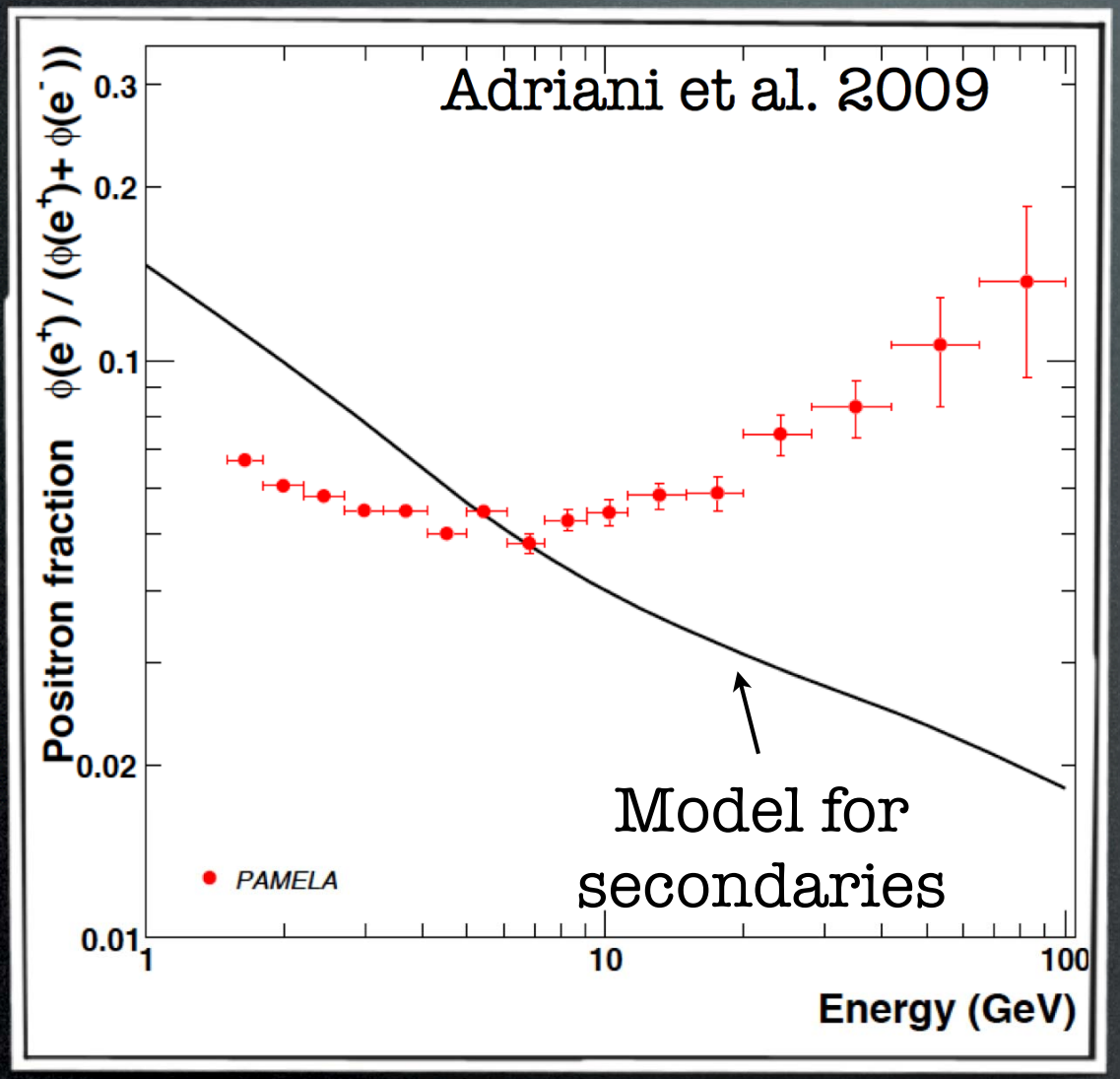
The highest-cited Fermi-LAT science paper

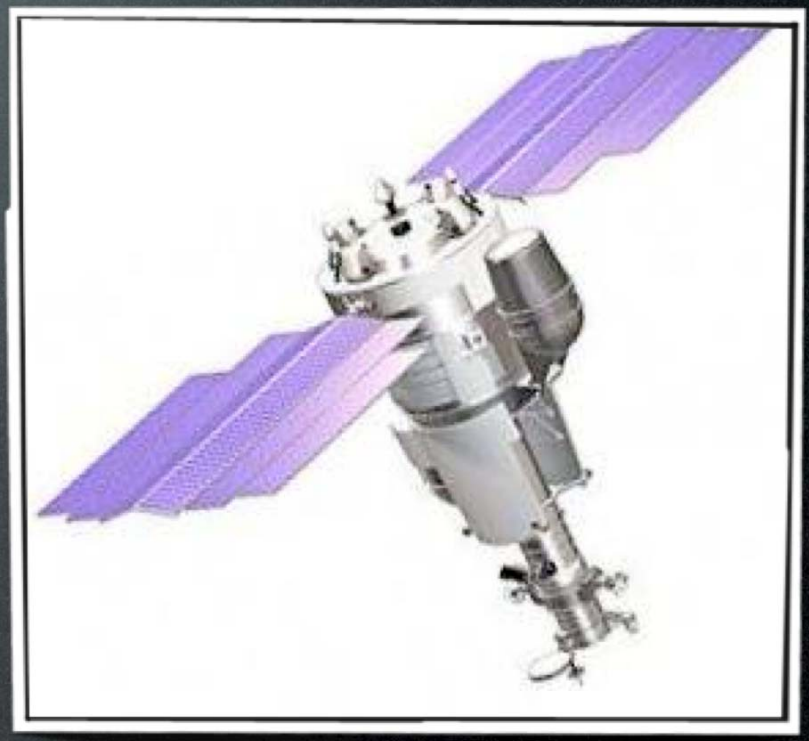




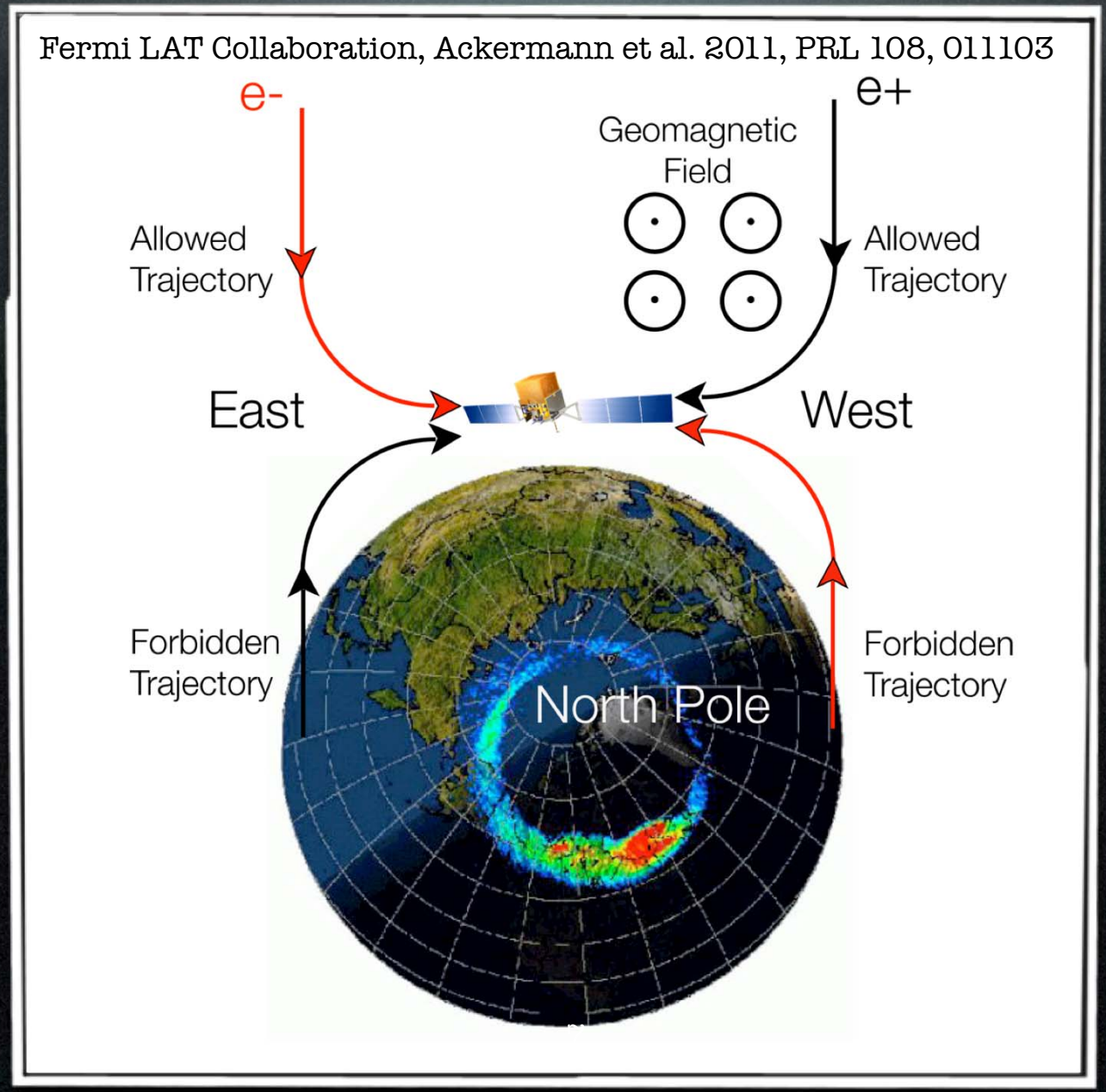
- Possibility to detect DM signatures both in gamma-rays and in charged particles

Separate positrons



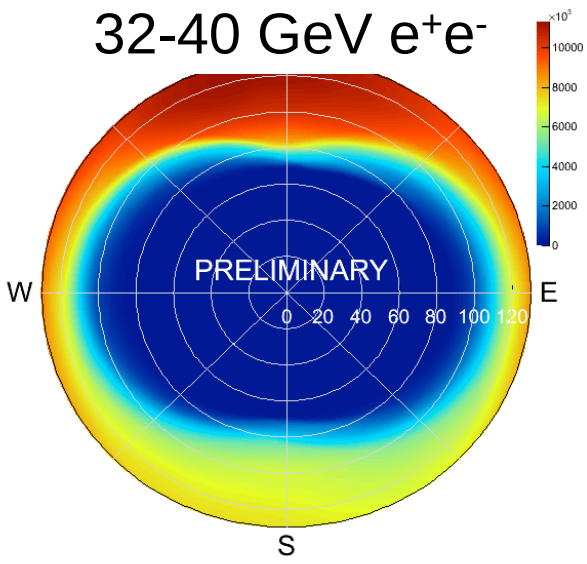


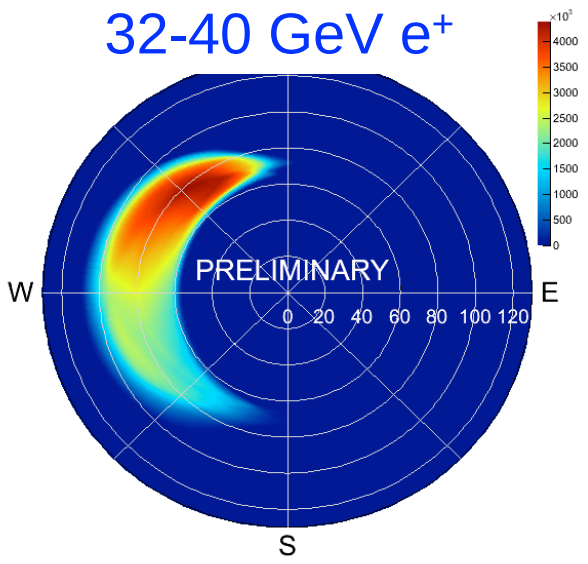
Separating Positrons with Fermi-LAT

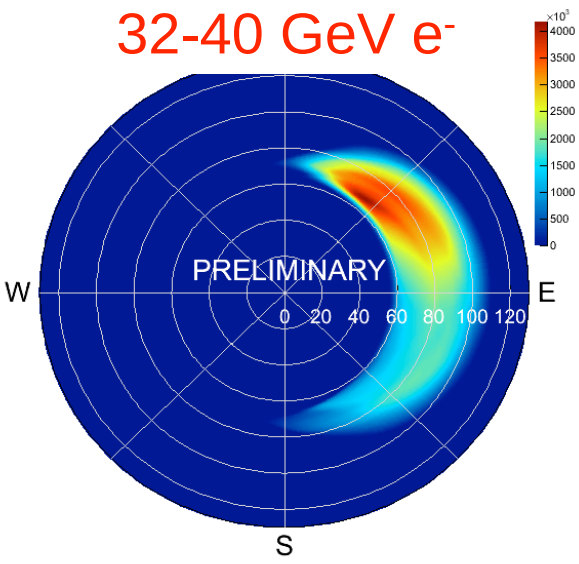


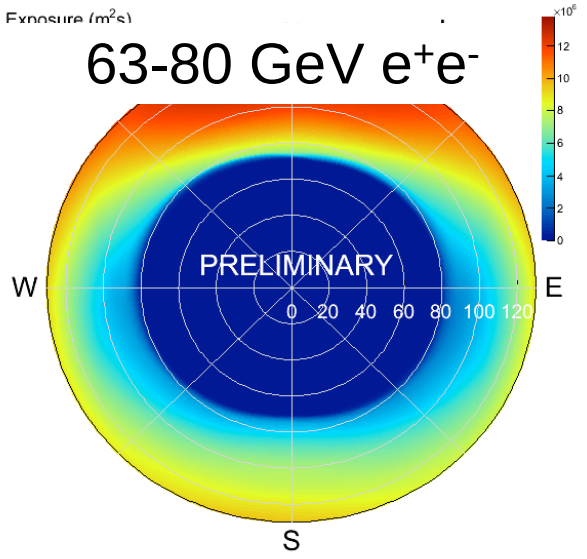
Separating Positrons with Fermi-LAT

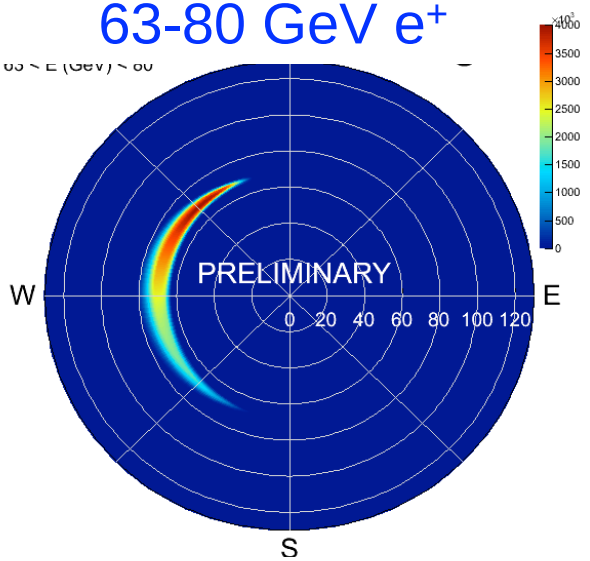
Fermi LAT Collaboration, Ackermann et al. 2011, PRL 108, 011103

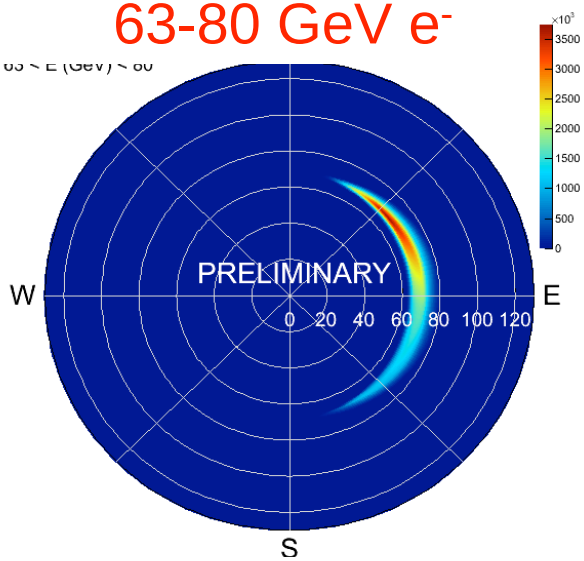




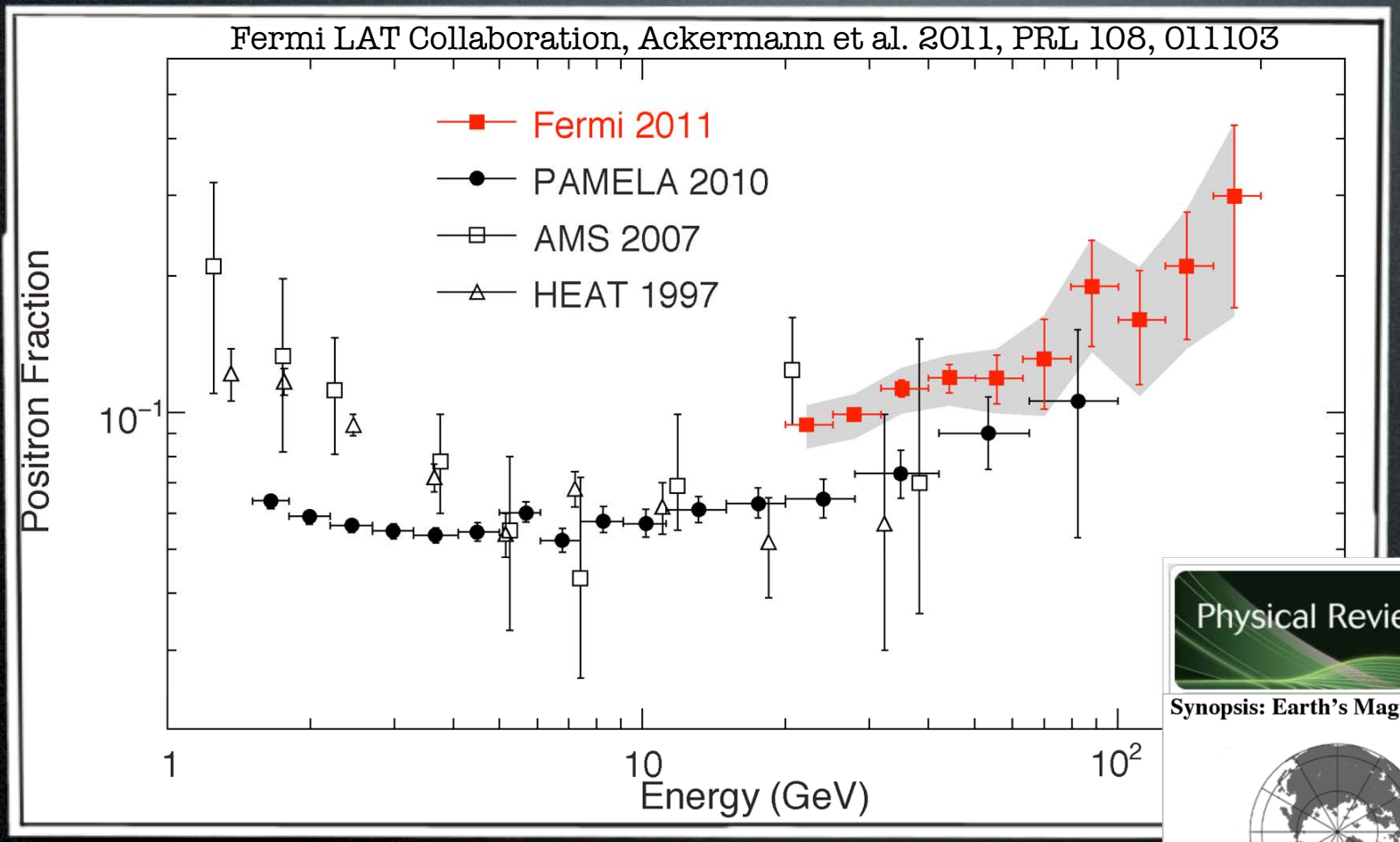


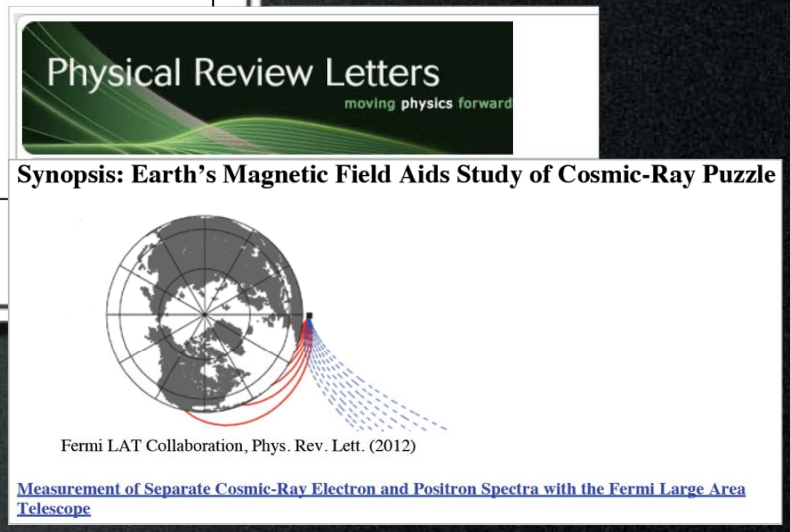






Separating Positrons with Fermi-LAT

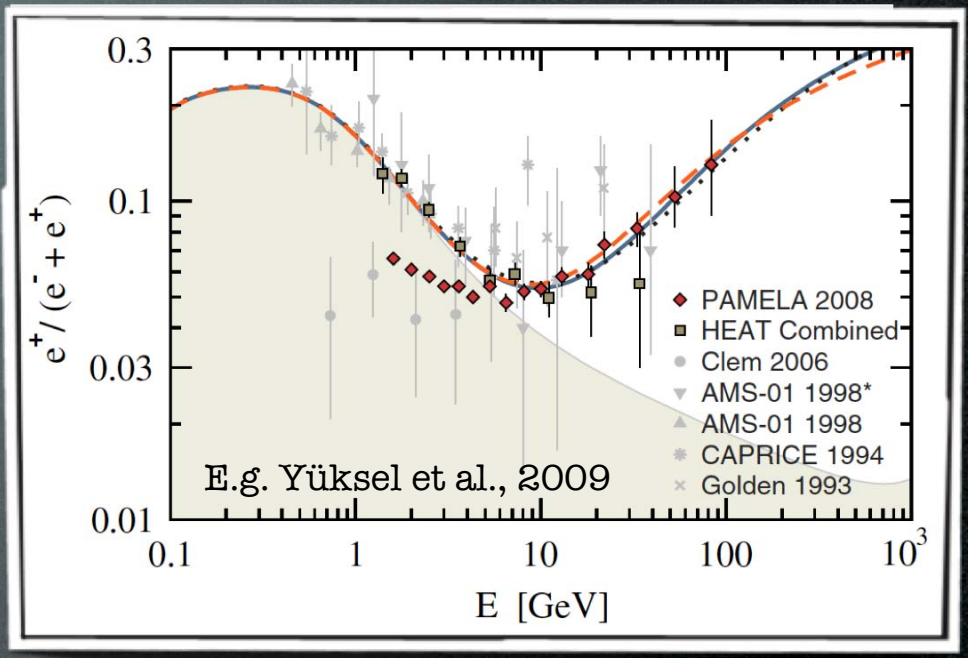




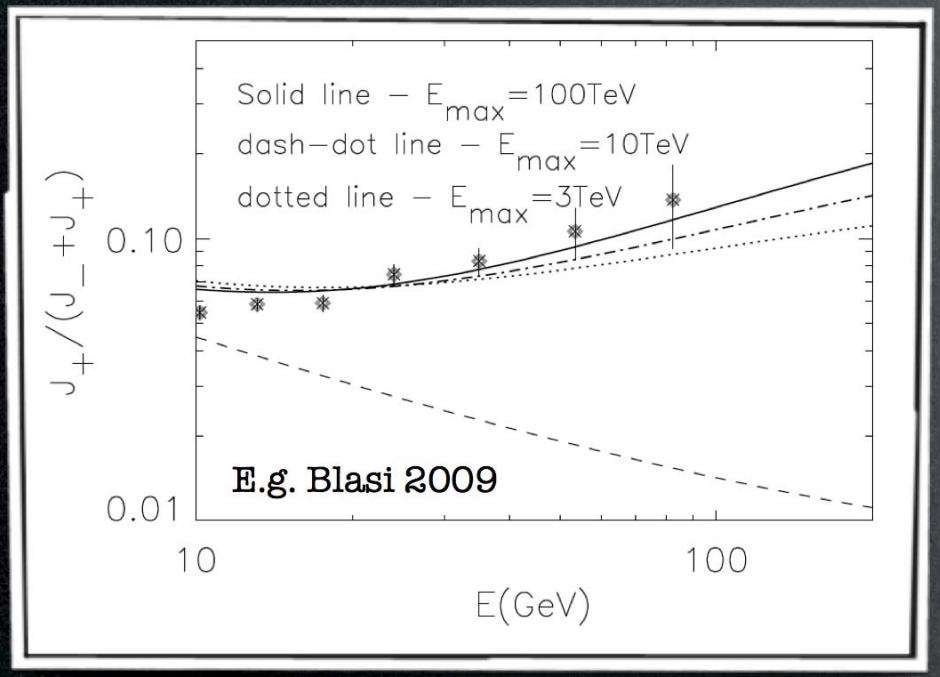
Possible sources

- Dark Matter, Pulsars, SNRs, …

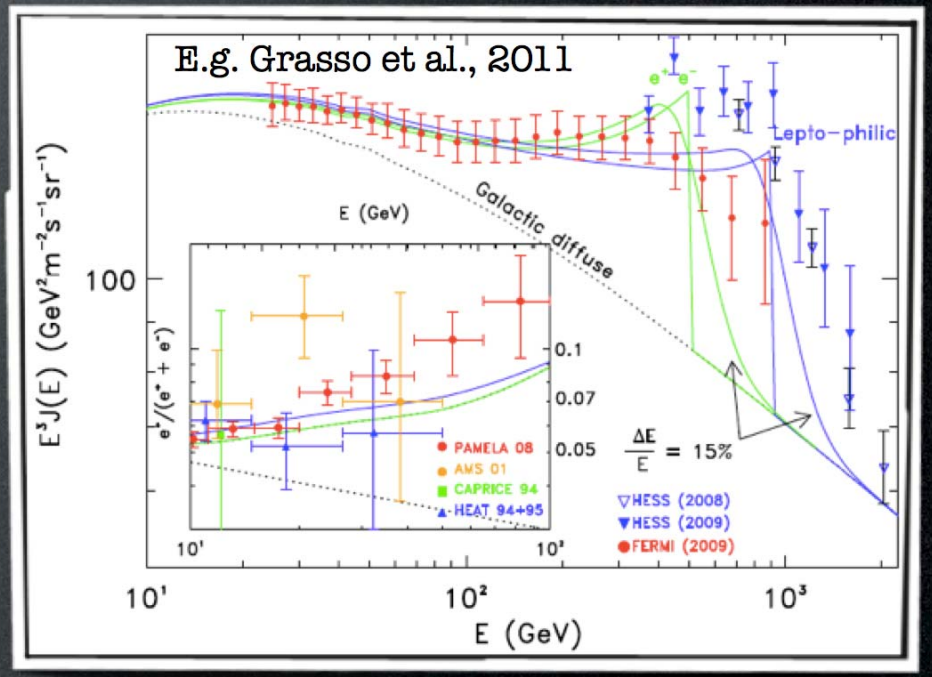
Pulsar Wind Nebulae



Supernova remnants

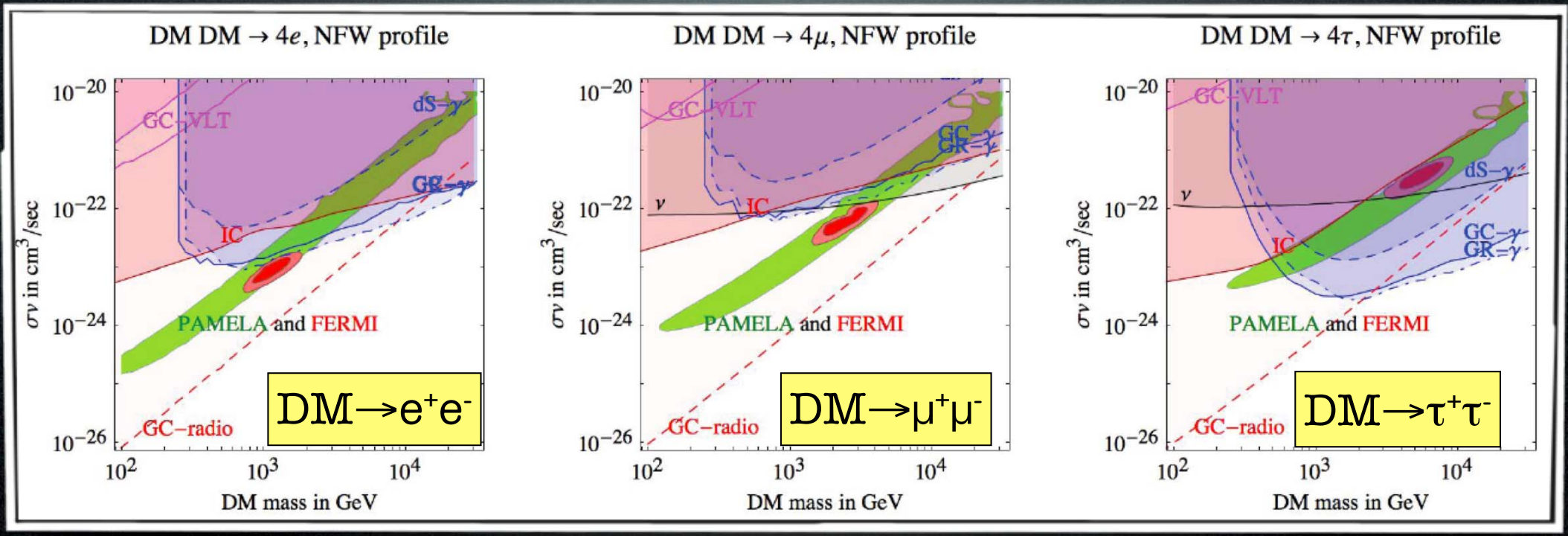


WIMPs



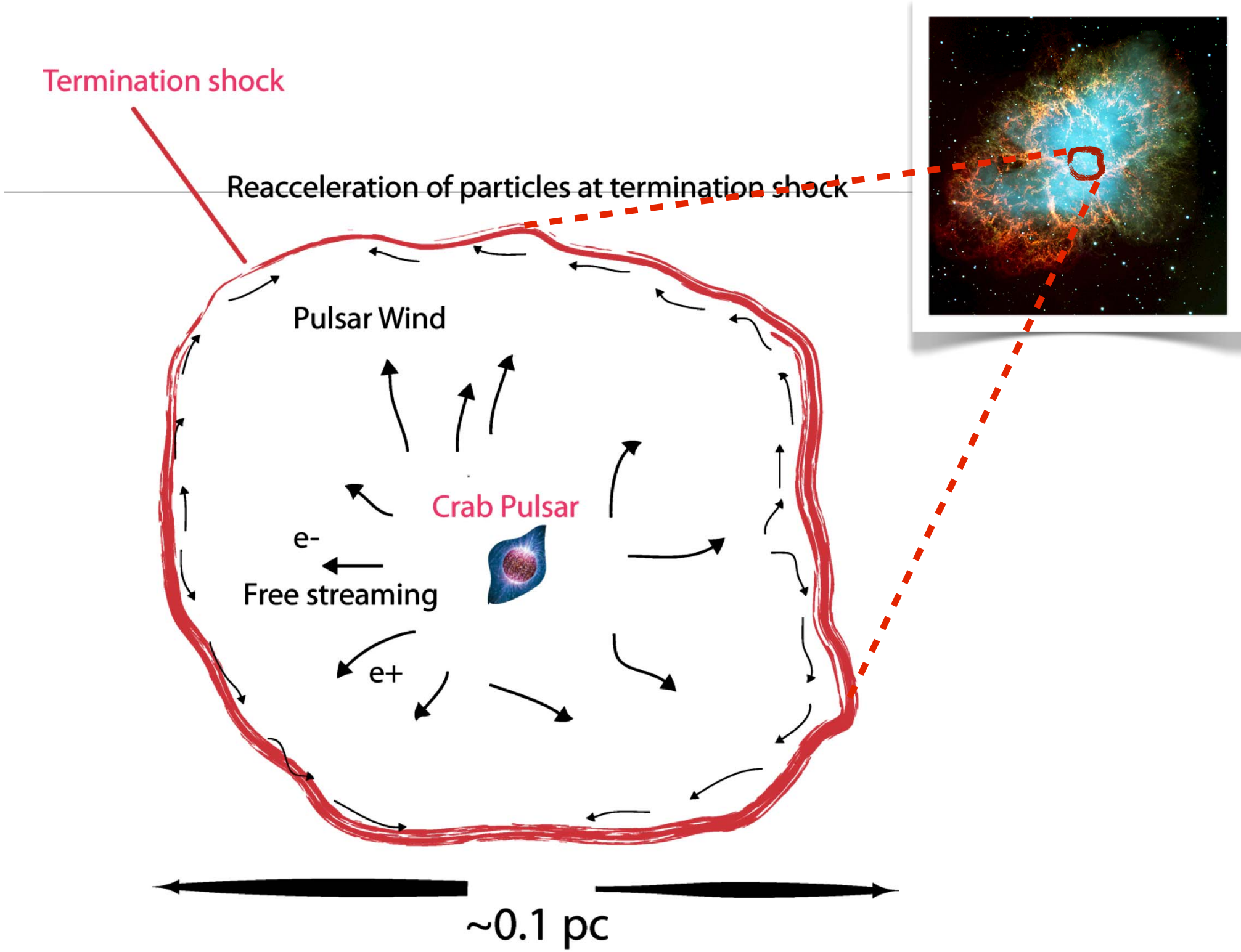
Lepto-Philic models

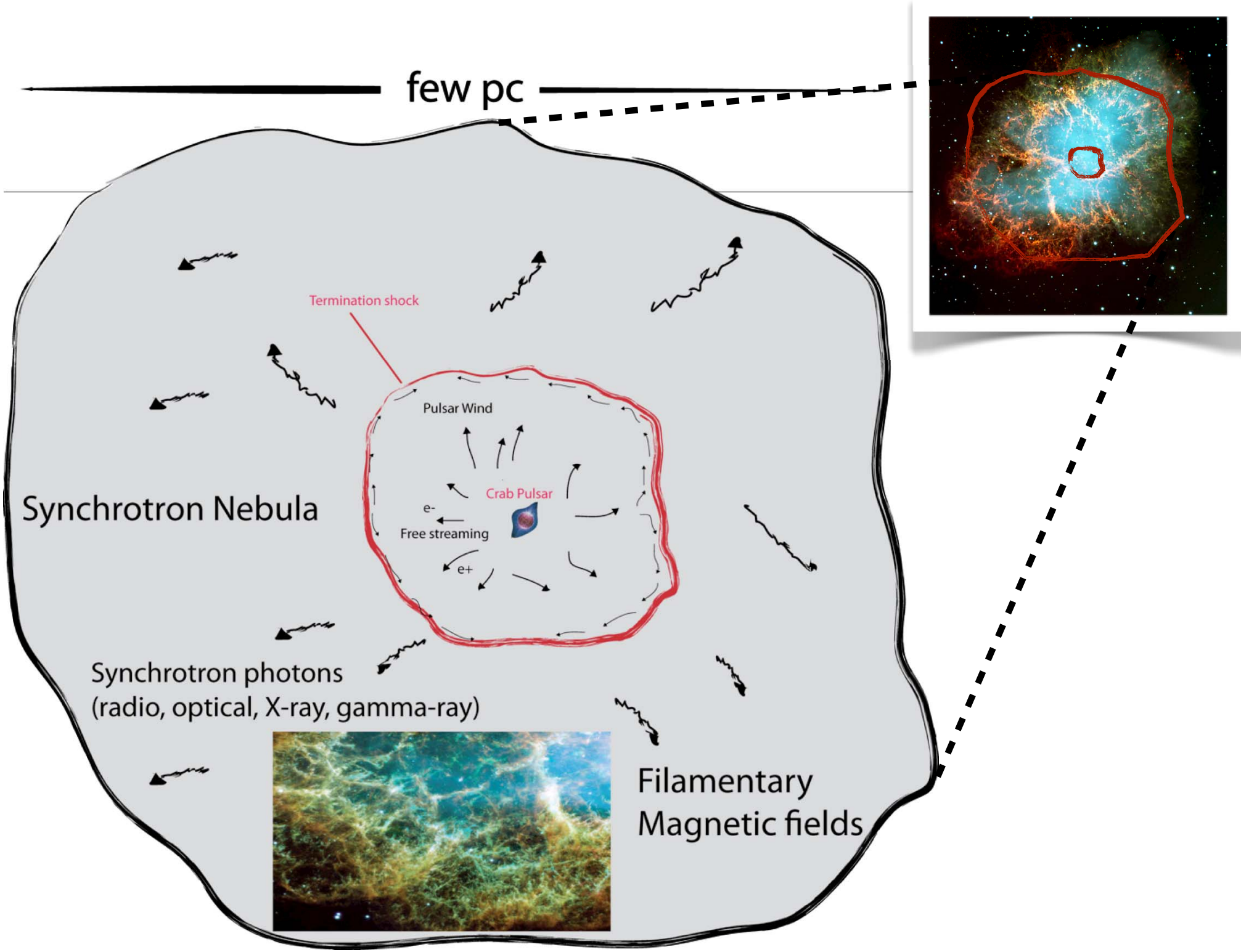
Meade et al. 2010

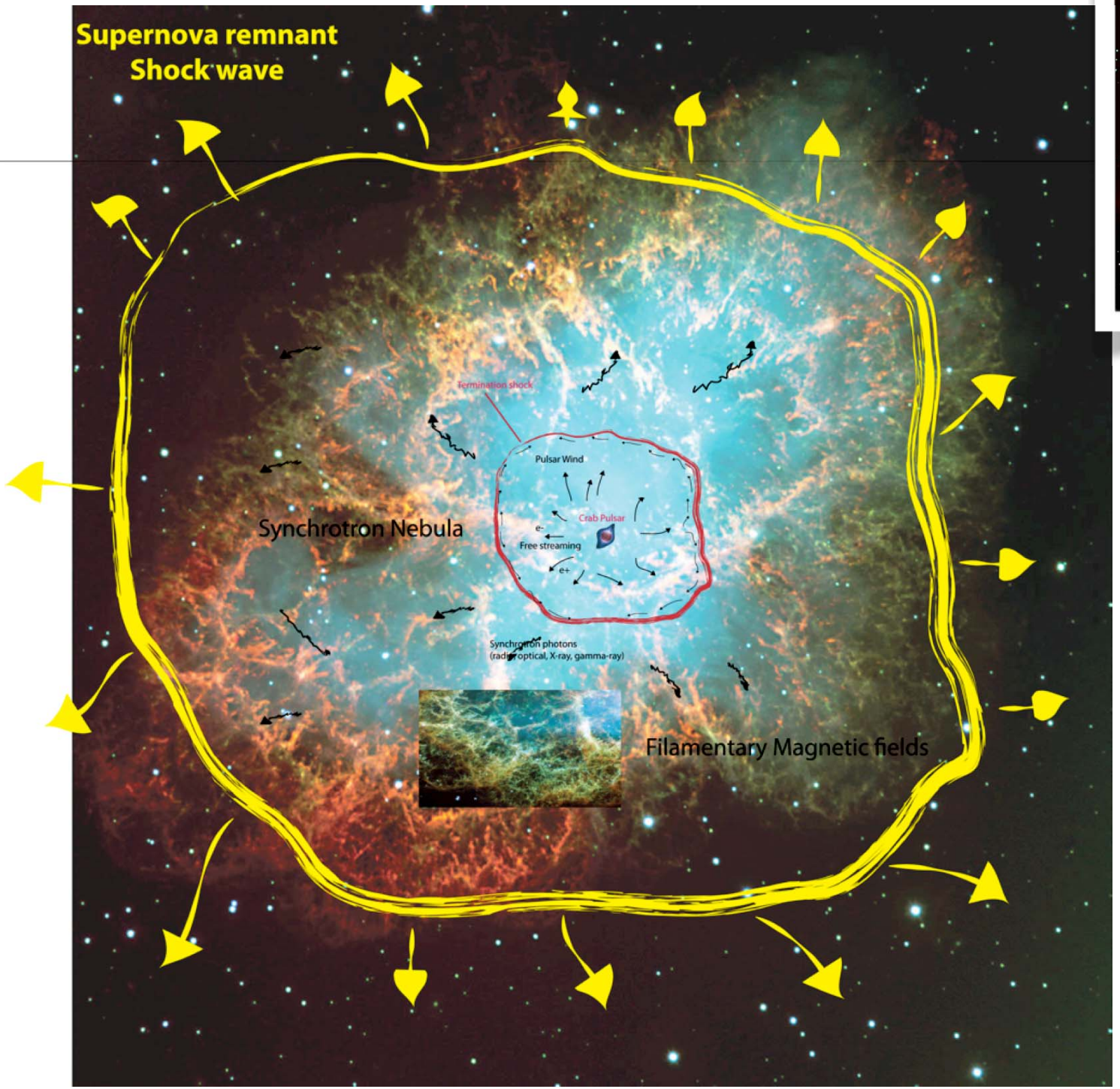


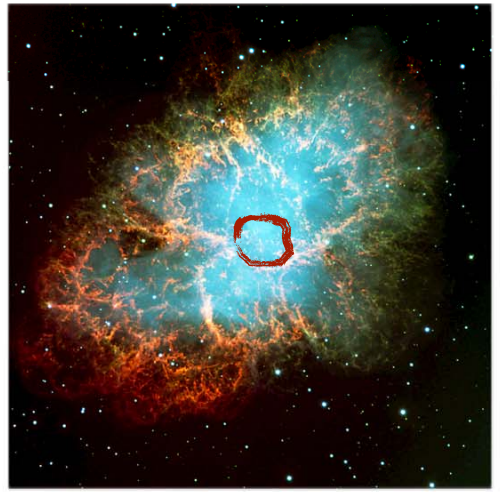
- Mostly ruled out by now ...

Pulsar Wind Nebulae


Termination shock
Reacceleration of particles at termination shock
Pulsar Wind
Crab Pulsar
e-
Free streaming
e+
~0.1 pc

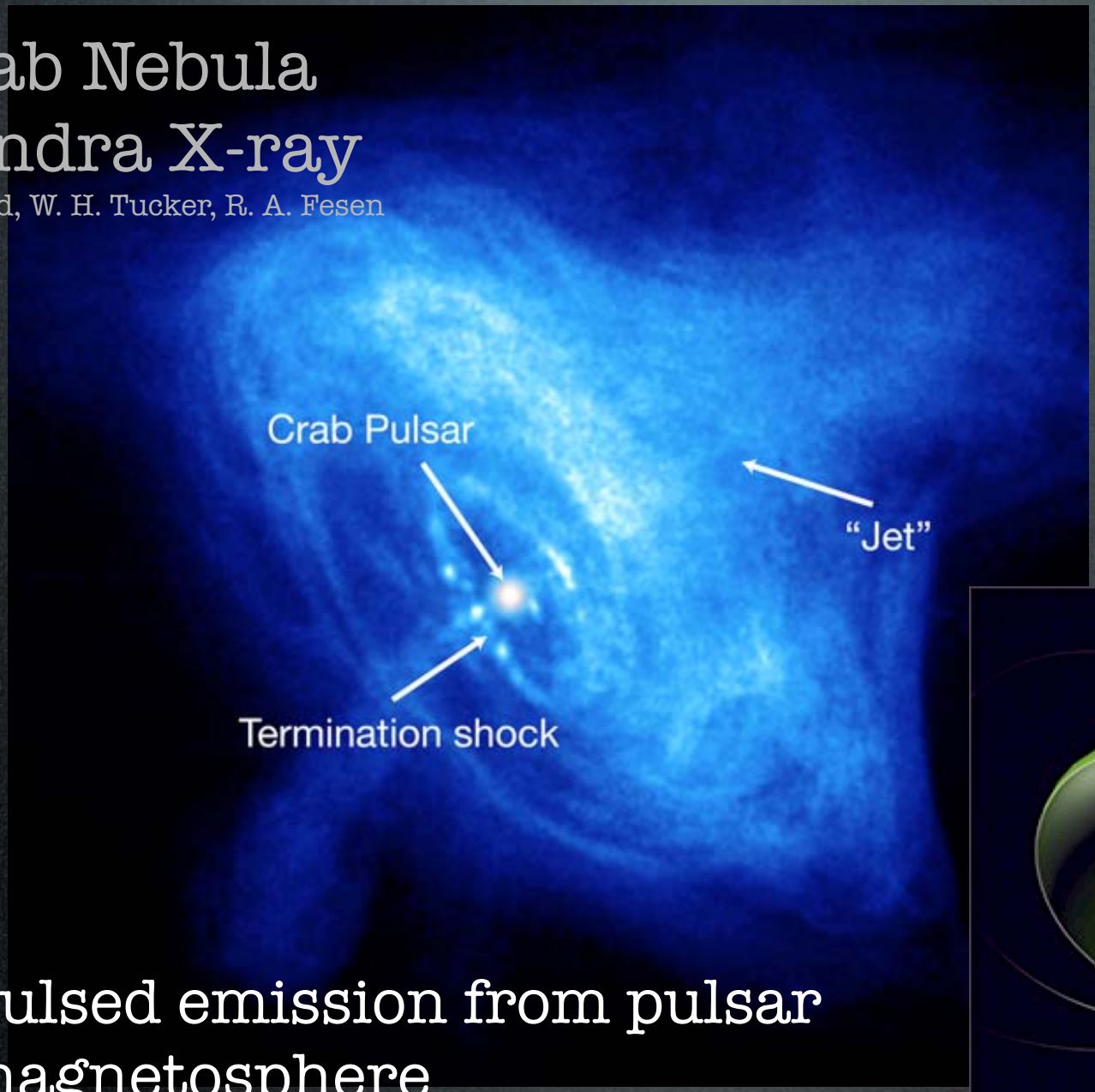

few pc
Termination shock
Pulsar Wind
Crab Pulsar
e-
Free streaming
e+
Synchrotron Nebula
Synchrotron photons
(radio, optical, X-ray, gamma-ray)
Filamentary
Magnetic fields

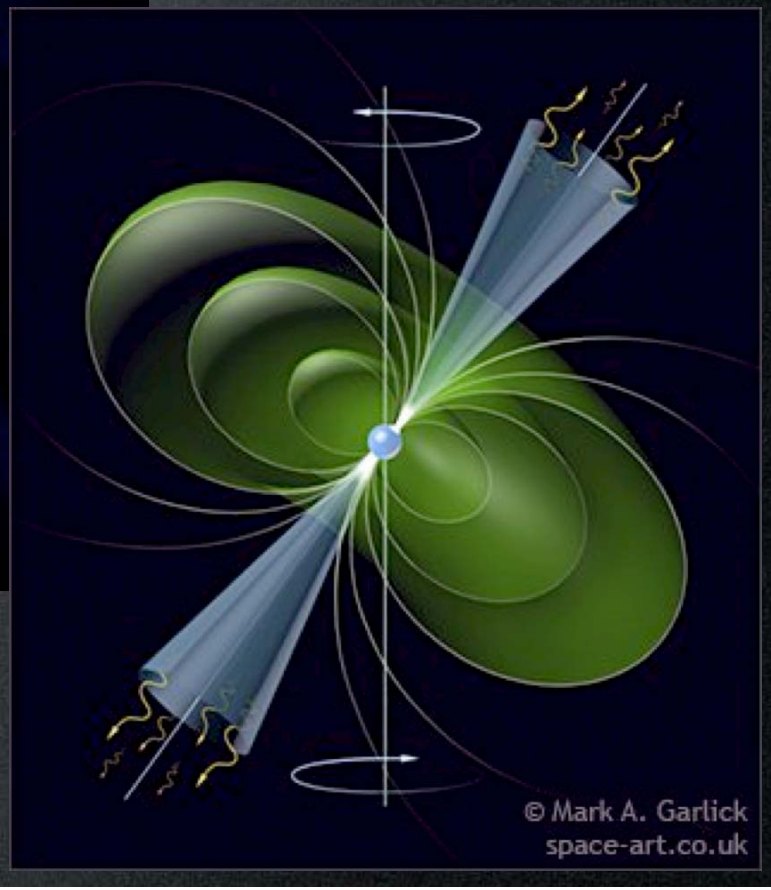

Supernova remnant
Shock wave
Termination shock
Pulsar Wind
Crab Pulsar
e-
Free streaming
e+
Synchrotron Nebula
Synchrotron photons
(radio, optical, X-ray, gamma-ray)
Filamentary Magnetic fields



Crab Nebula
Chandra X-ray

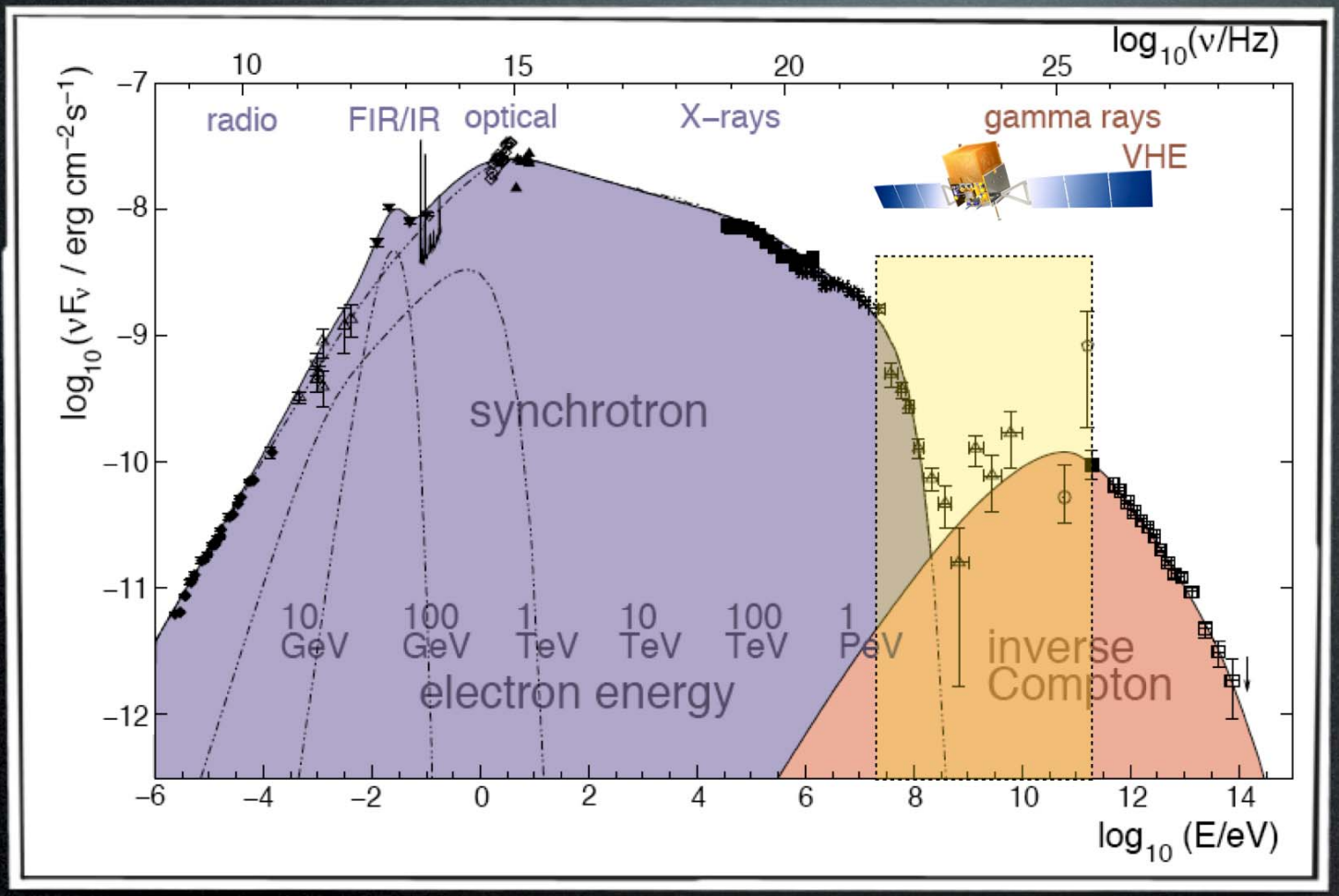
F. D. Seward, W. H. Tucker, R. A. Fesen

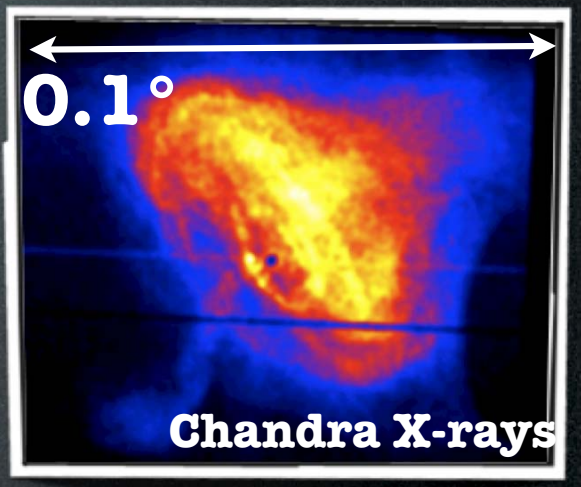


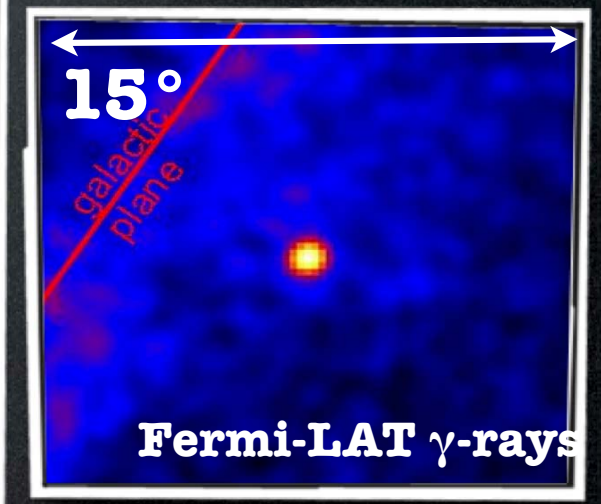


- Pulsed emission from pulsar magnetosphere
- Steady emission from extended electron nebula

The Crab Nebula

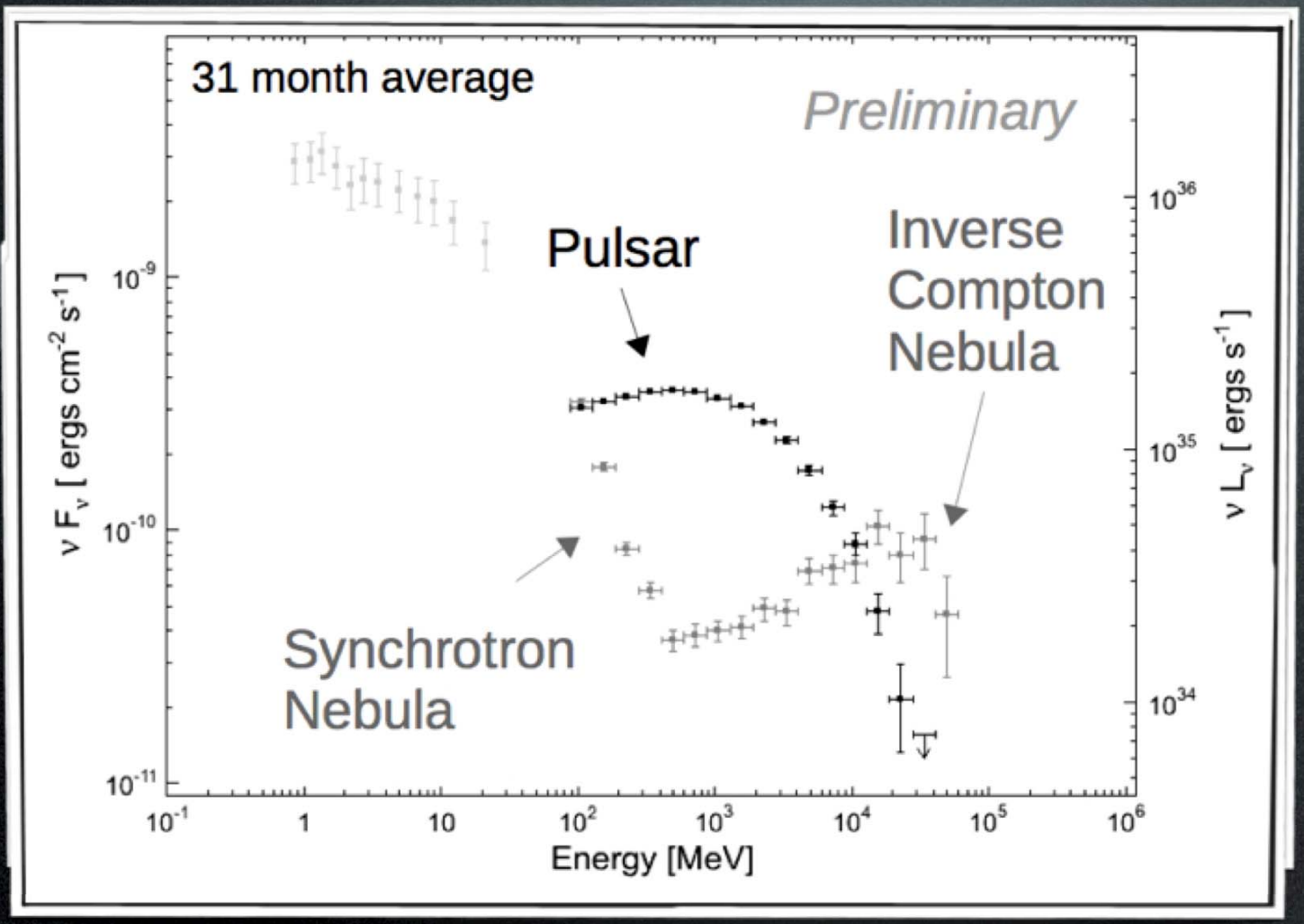


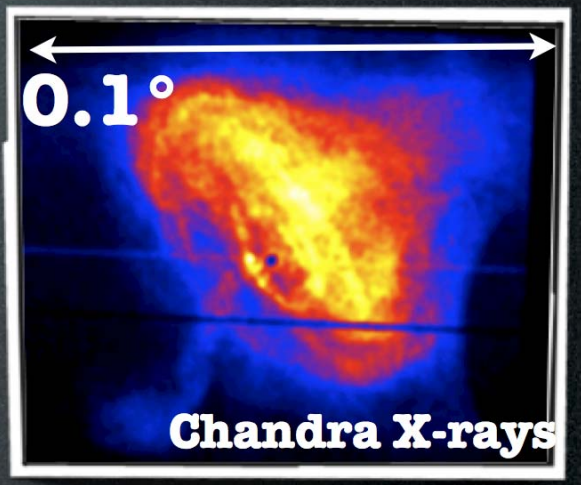


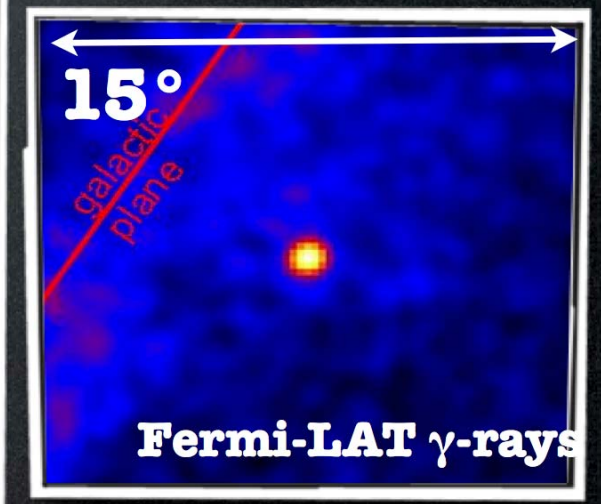


- Measure falling tail of synchrotron and rising tail of IC emission
- Emission not resolved by Fermi - need instruments such as Chandra, Hubble, ...

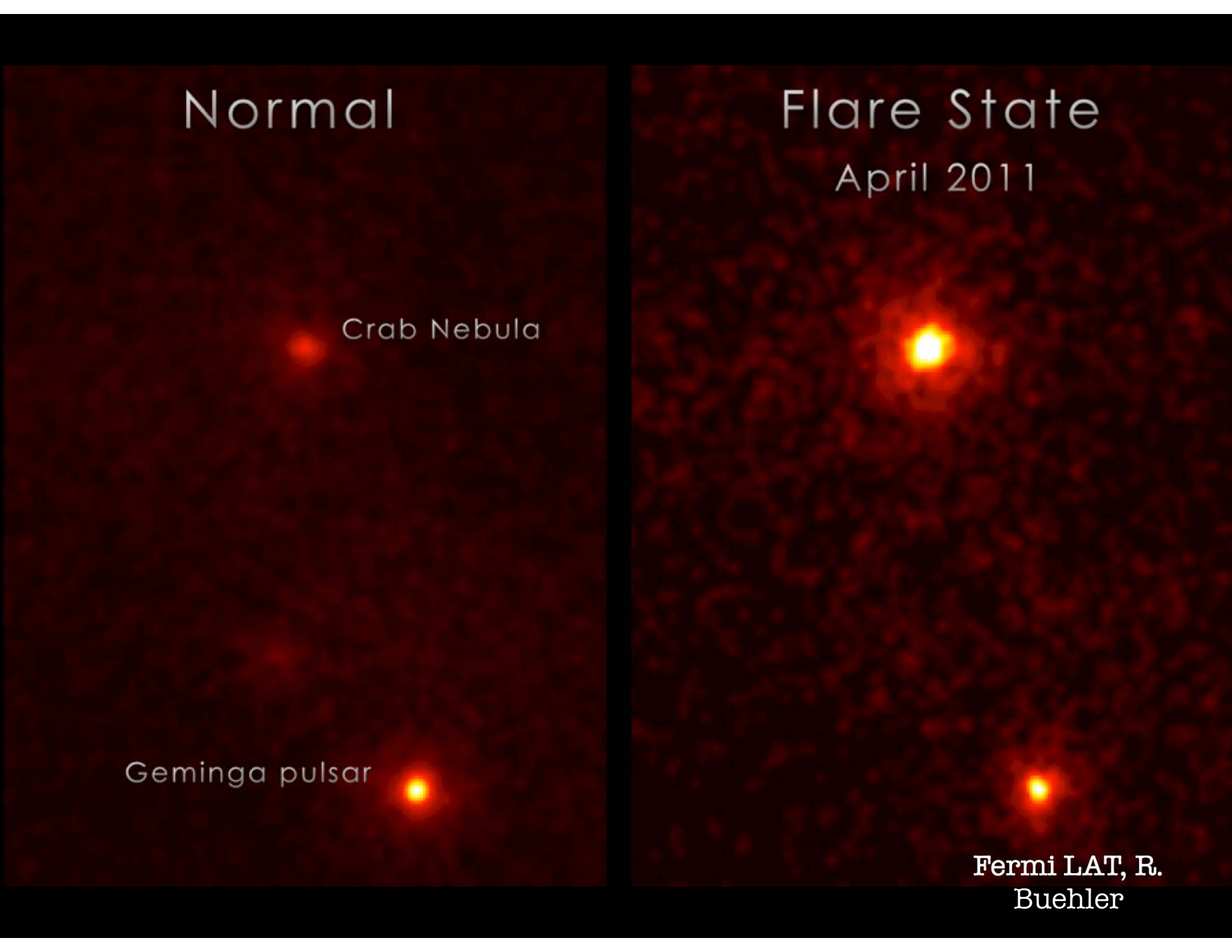
The Crab Nebula



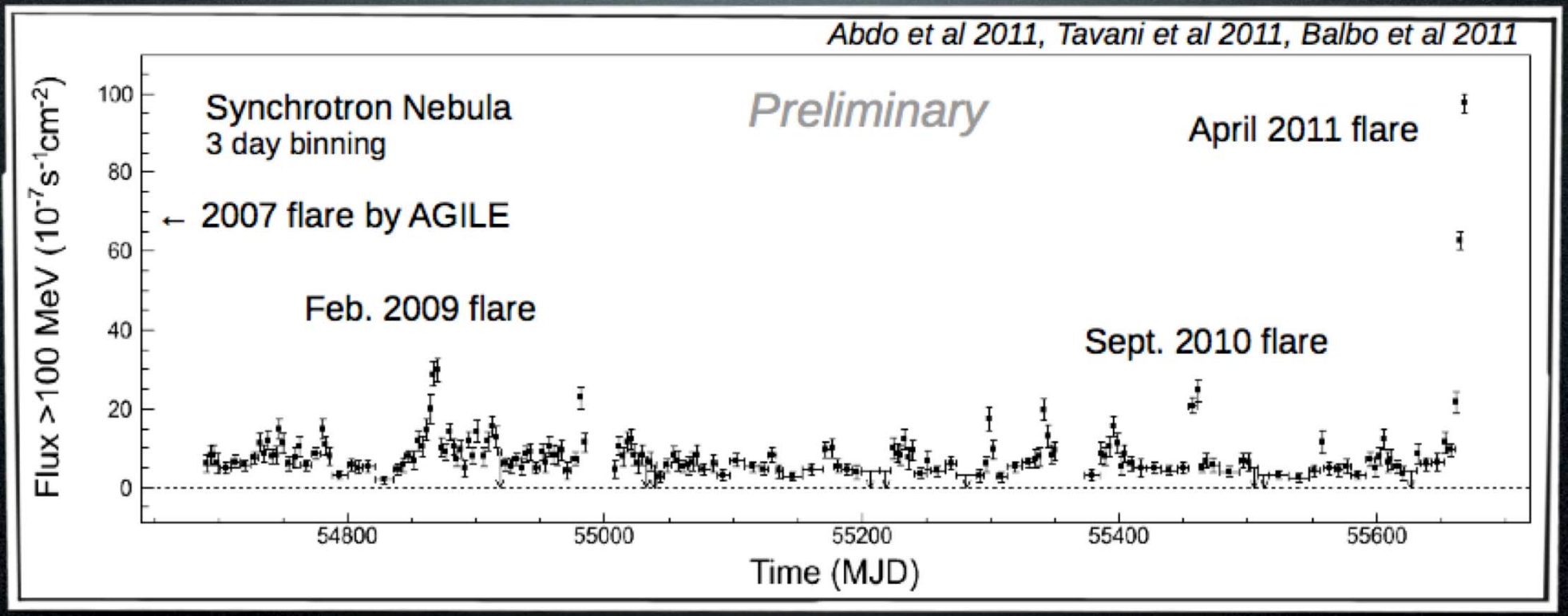




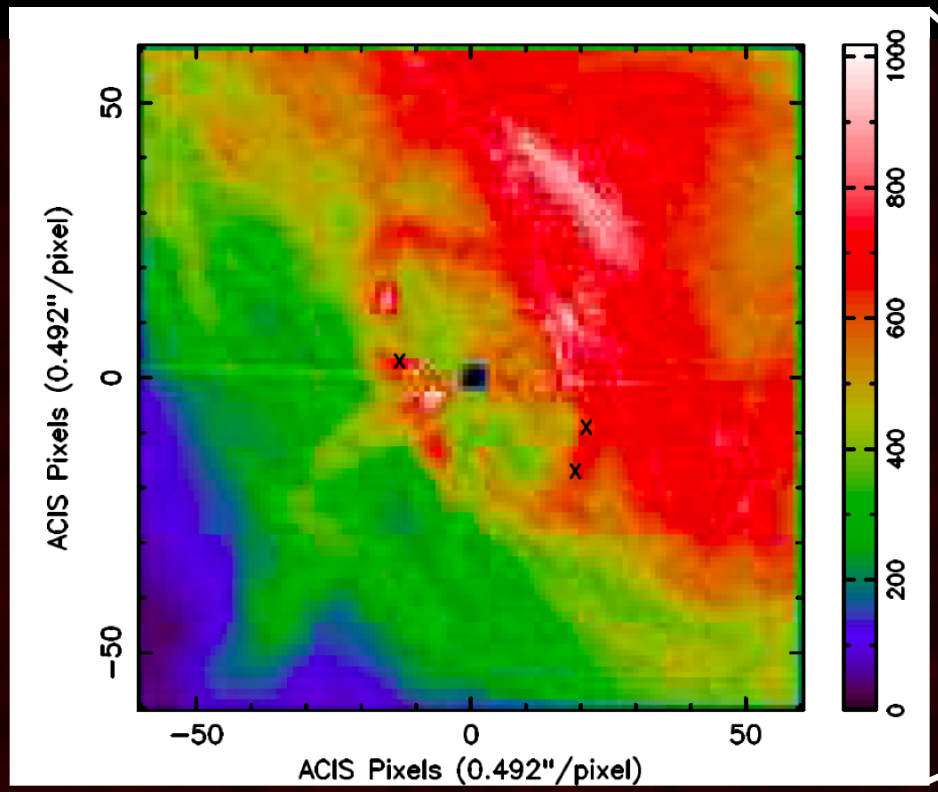
- Measure falling tail of synchrotron and rising tail of IC emission
- Emission not resolved by Fermi - need instruments such as Chandra, Hubble, ...


Normal
Crab Nebula
Geminga pulsar
Flare State
April 2011
Fermi LAT, R. Buehler

Synchrotron part light-curve



- Three major flares since start of the mission (one additional observed by AGILE)
- During April flare: Crab Nebula brightest source on the GeV gamma-ray sky (!)



Flare State

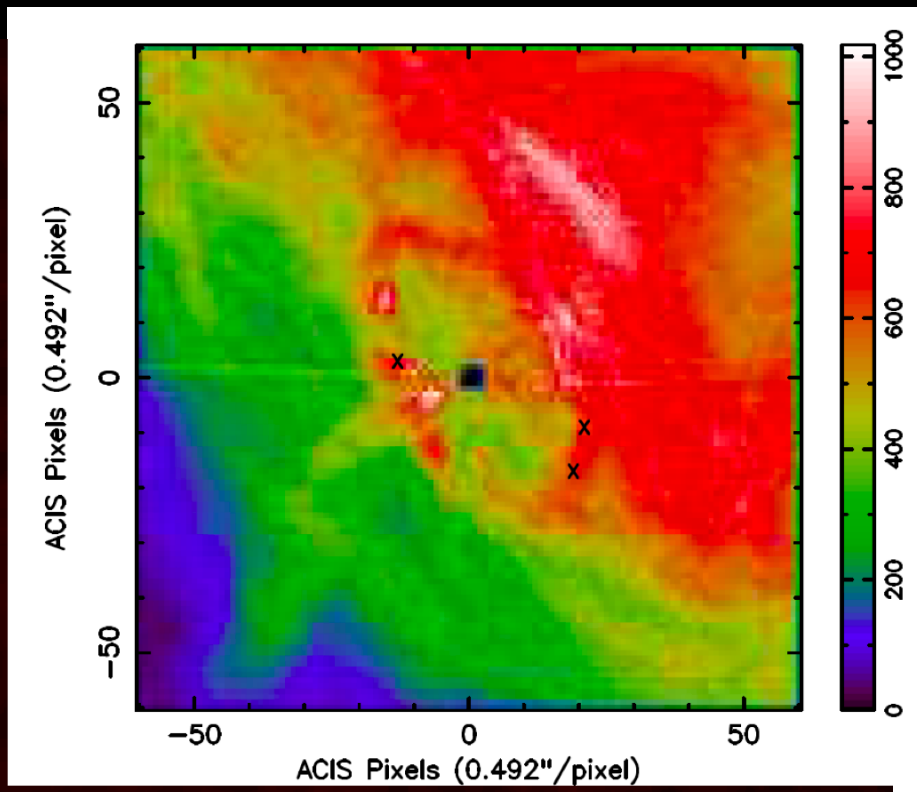
April 2011

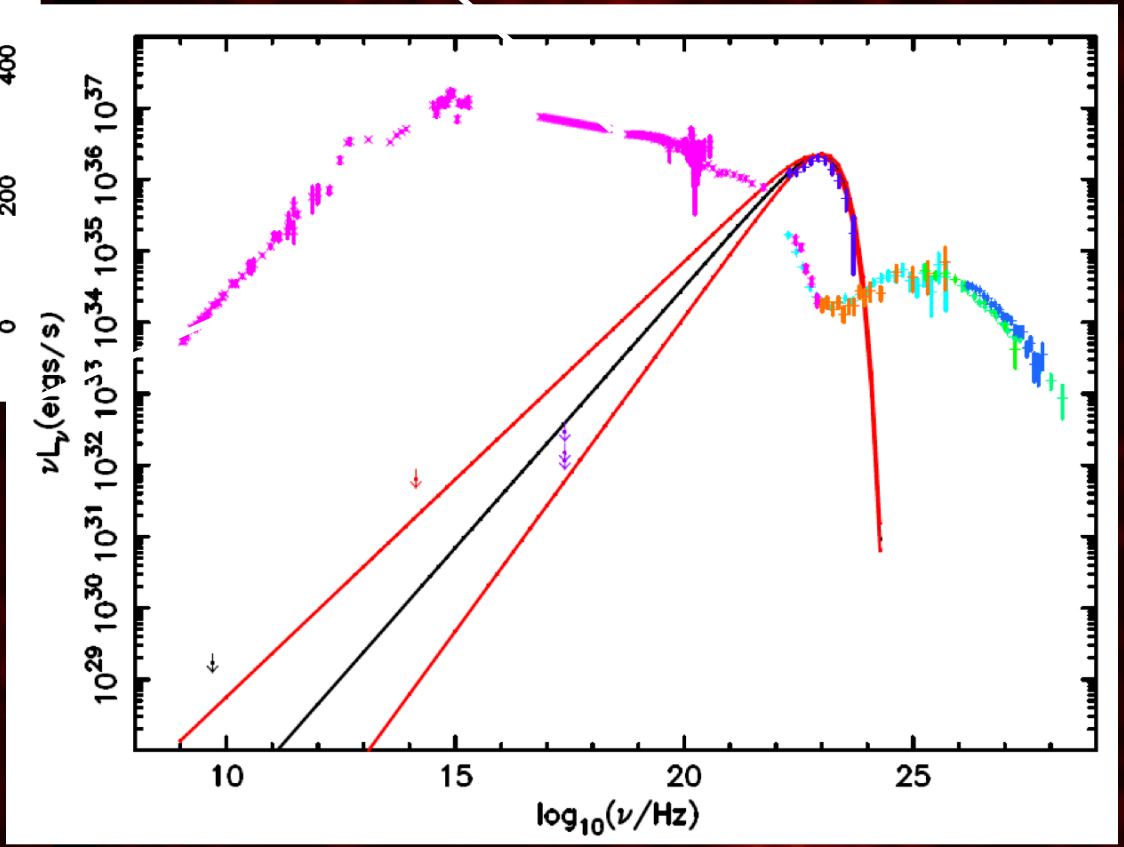
Geminga pulsar

Fermi LAT, R. Buehler

Flare State

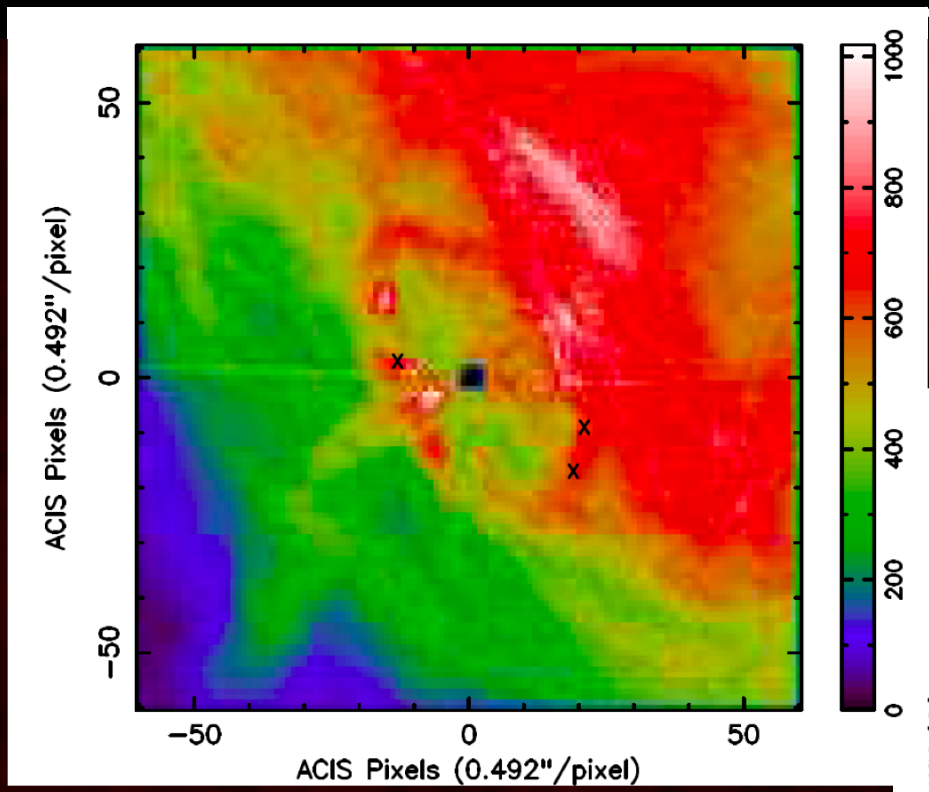
April 2011





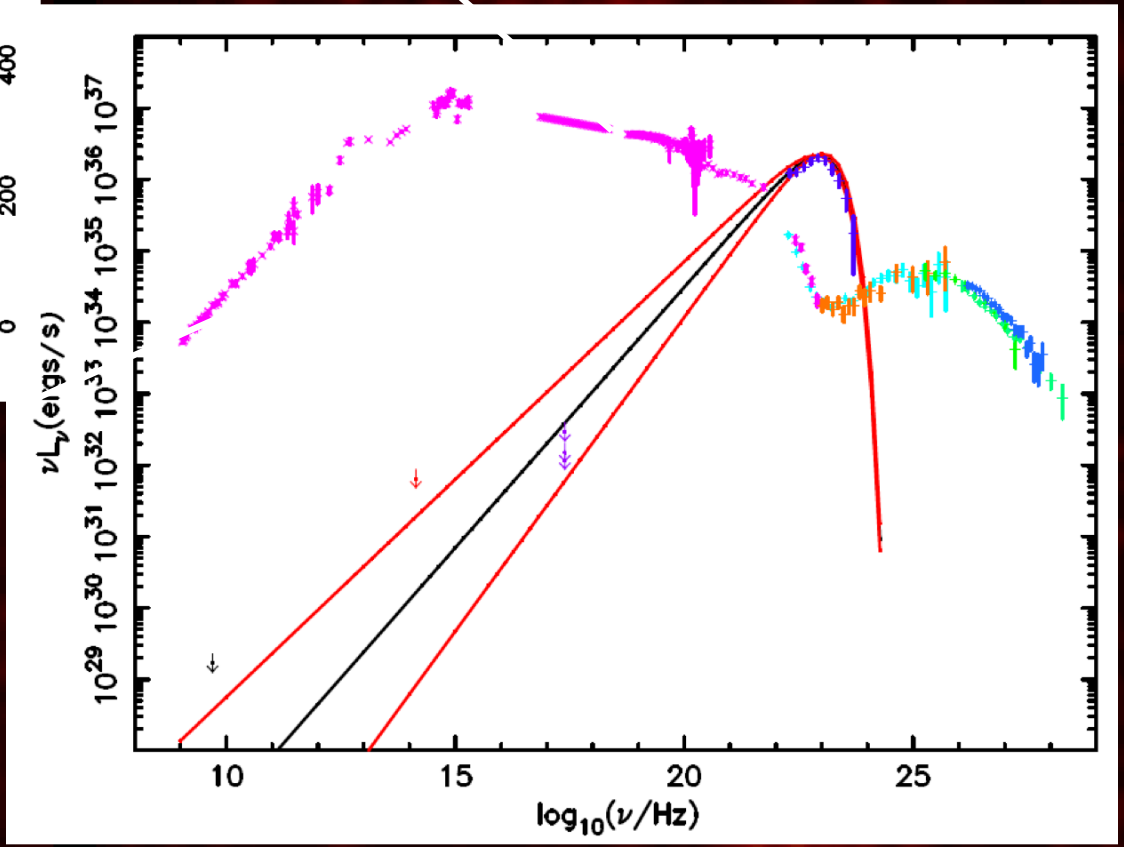
Geminga pulsar

Fermi LAT, R. Buehler



Flare State

April 2011

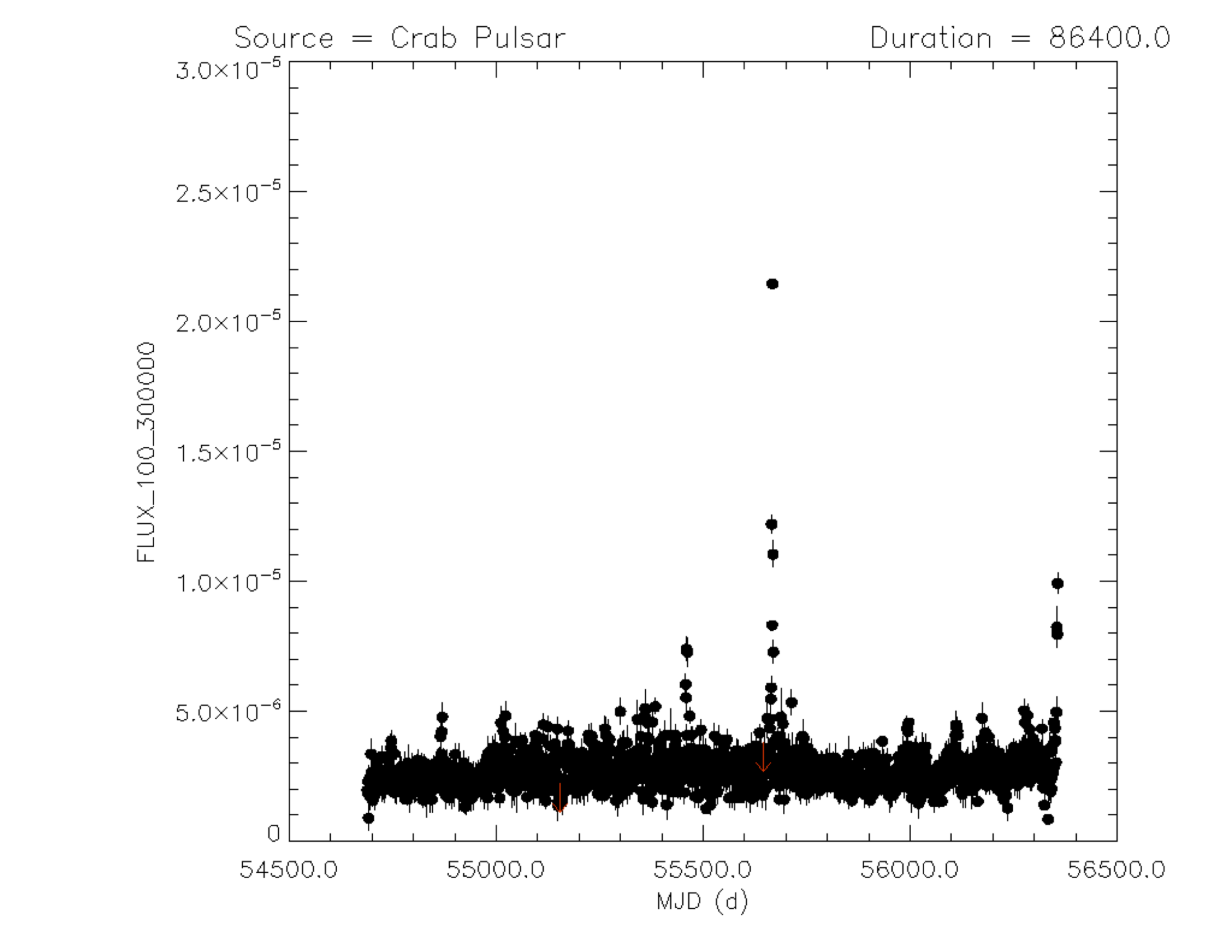


Geminga pulsar

similar flares predicted

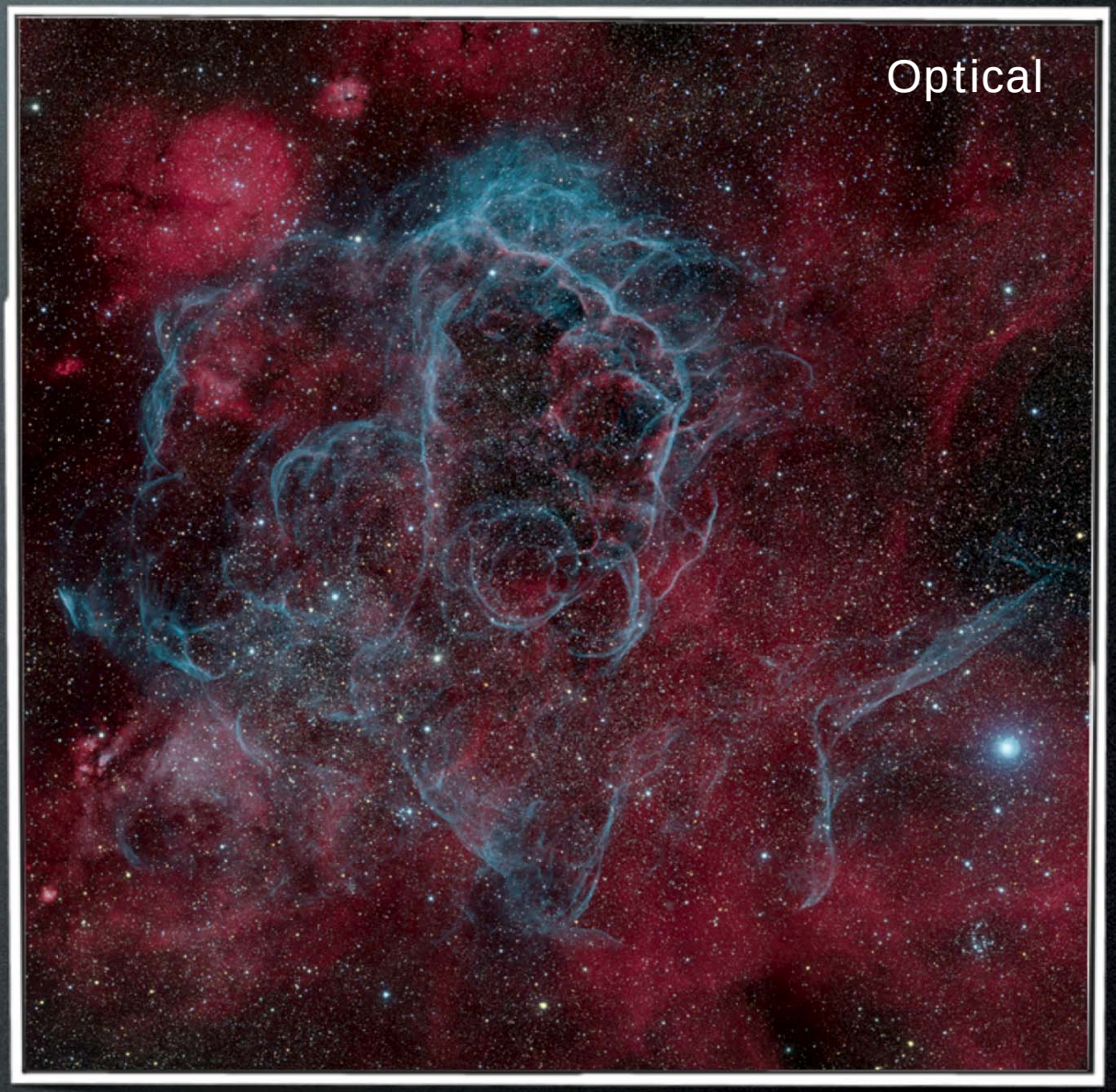
in 100 TeV range might be detectable with HAWC or CTA

Fermi LAT, R. Buehler


Source = Crab Pulsar
Duration = 86400.0
FLUX_100_300000
3.0×10⁻⁵
2.5×10⁻⁵
2.0×10⁻⁵
1.5×10⁻⁵
1.0×10⁻⁵
5.0×10⁻⁶
0
54500.0
55000.0
55500.0
56000.0
56500.0
MJD (d)

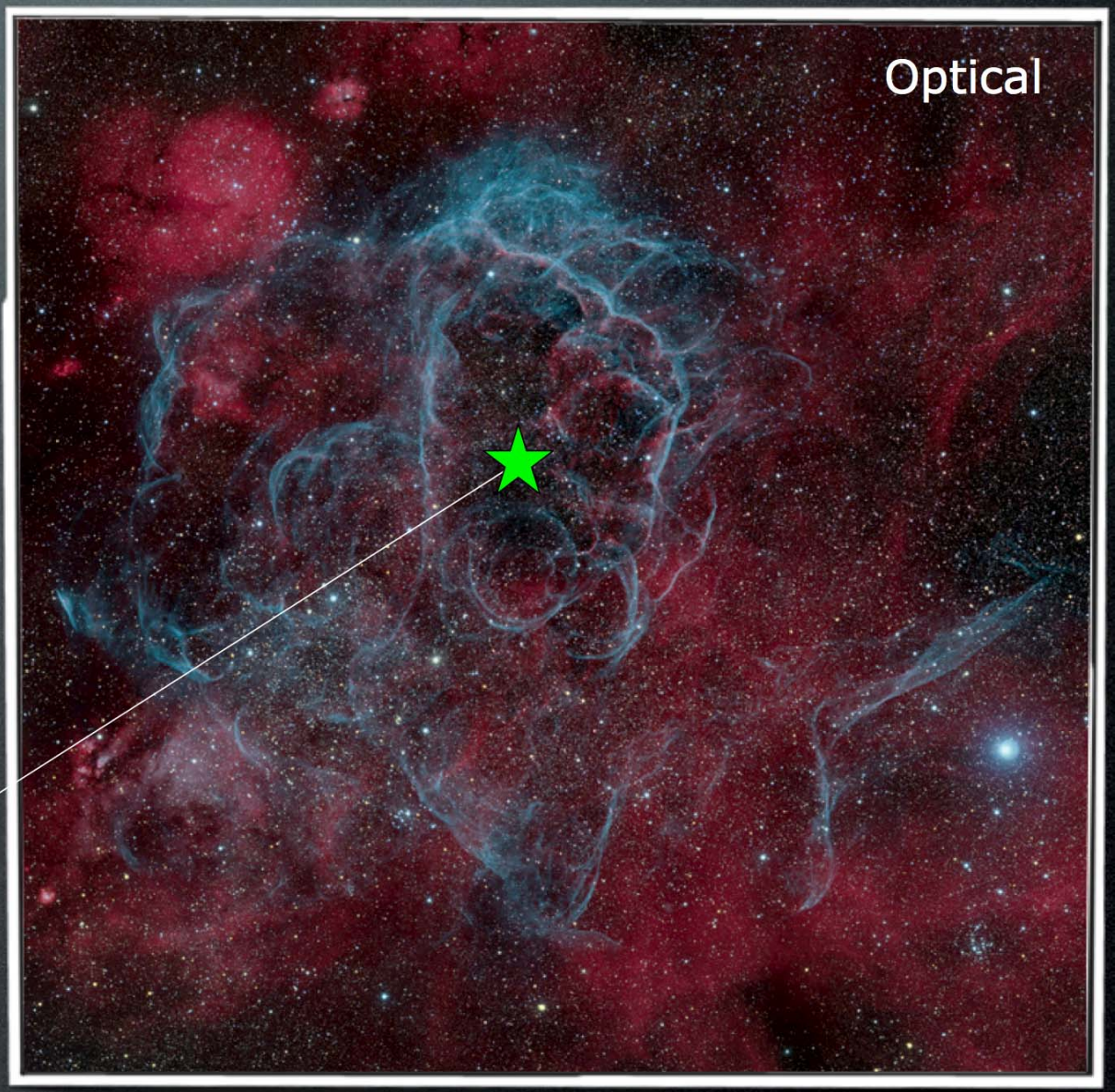
Escape from Vela X

- Vela SNR
  - Very nearby (290 pc) supernova explosion 10,000 years ago



Escape from Vela X

- Vela SNR
  - Very nearby (290 pc) supernova explosion



Escape from Vela X

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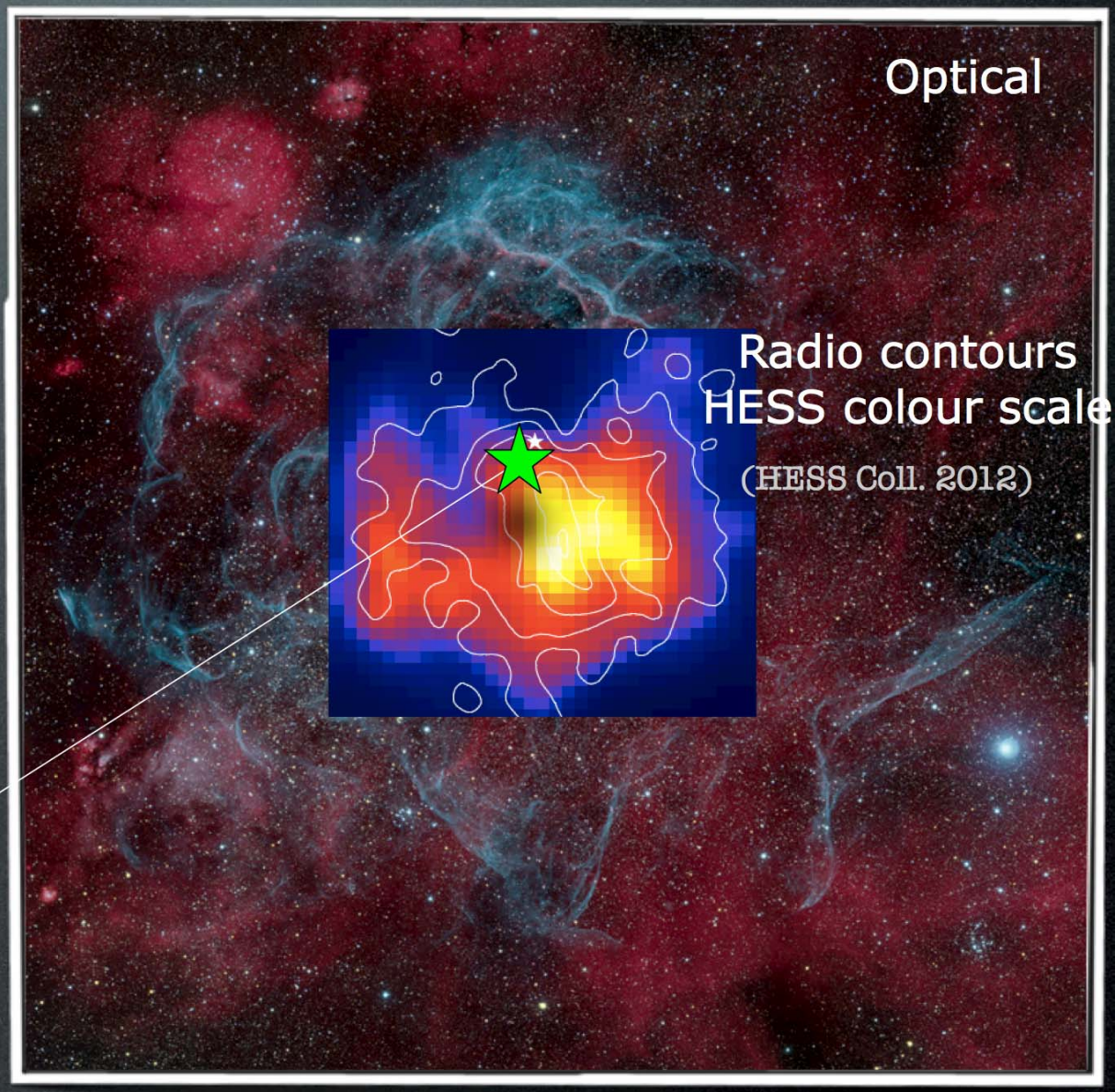


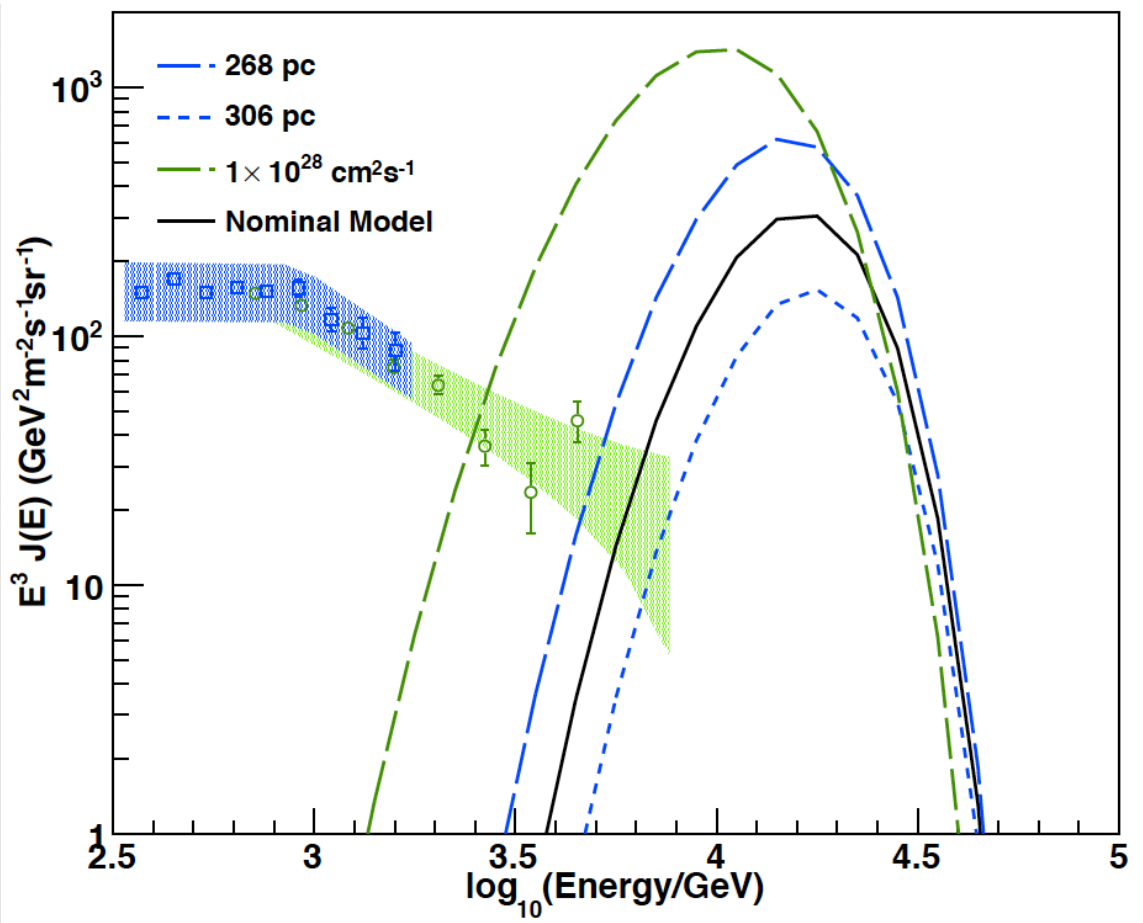
Escape from Vela X

- Model which matches the GeV-TeV gamma-ray spectrum
  - Predicts contribution to local CR electron spectrum

The Astrophysical Journal Letters, 743:L7 (5pp), 2011 December 10 doi:10.1088/2041-8205/743/1/L7

ESCAPE FROM VELA X

J. A. Hinton[1], S. Funk[2], R. D. Parsons[3], and S. Ohm[1,3]
[1] Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK
[2] Kavli Institute for Particle Astrophysics and Cosmology, SLAC, 2575 Sand Hill Road, Menlo Park, CA 94025, USA; funk@slac.stanford.edu
[3] School of Physics & Astronomy, University of Leeds, Leeds LS2 9JT, UK
Received 2011 October 17; accepted 2011 November 1; published 2011 November 16



Escape from Vela X

- Model which matches the GeV-TeV gamma-ray spectrum
  - Predicts contribution to local CR electron spectrum
- CTA will
  - A) beautifully measure gamma-ray emission, morphology, spectrum
  - B) measure the electrons lost from Vela X arriving at the Earth (diffuse)

The Astrophysical Journal Letters, 743:L7 (5pp), 2011 December 10 doi:10.1088/2041-8205/743/1/L7

ESCAPE FROM VELA X

J. A. Hinton[1], S. Funk[2], R. D. Parsons[3], and S. Ohm[1,3]
[1] Department of Physics and Astronomy, University of Leicester, Leicester LE1 7RH, UK
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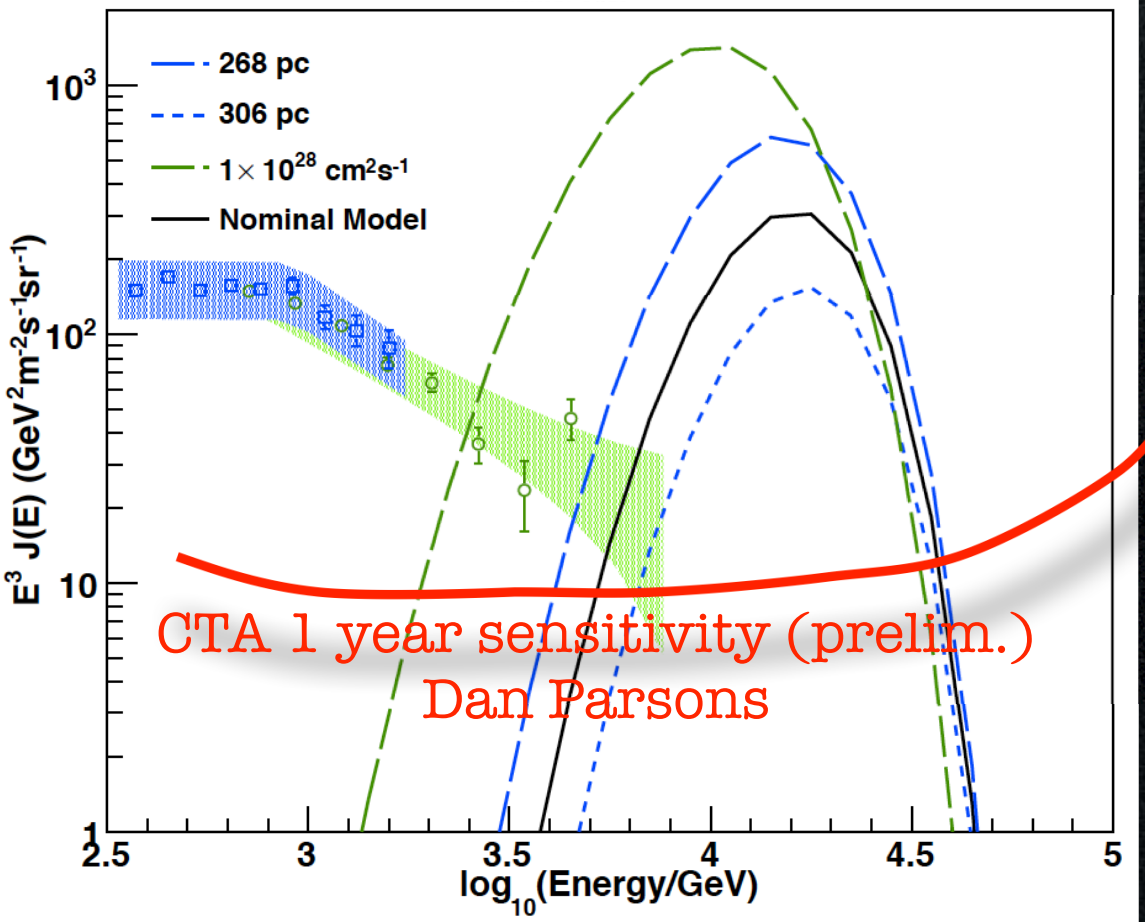
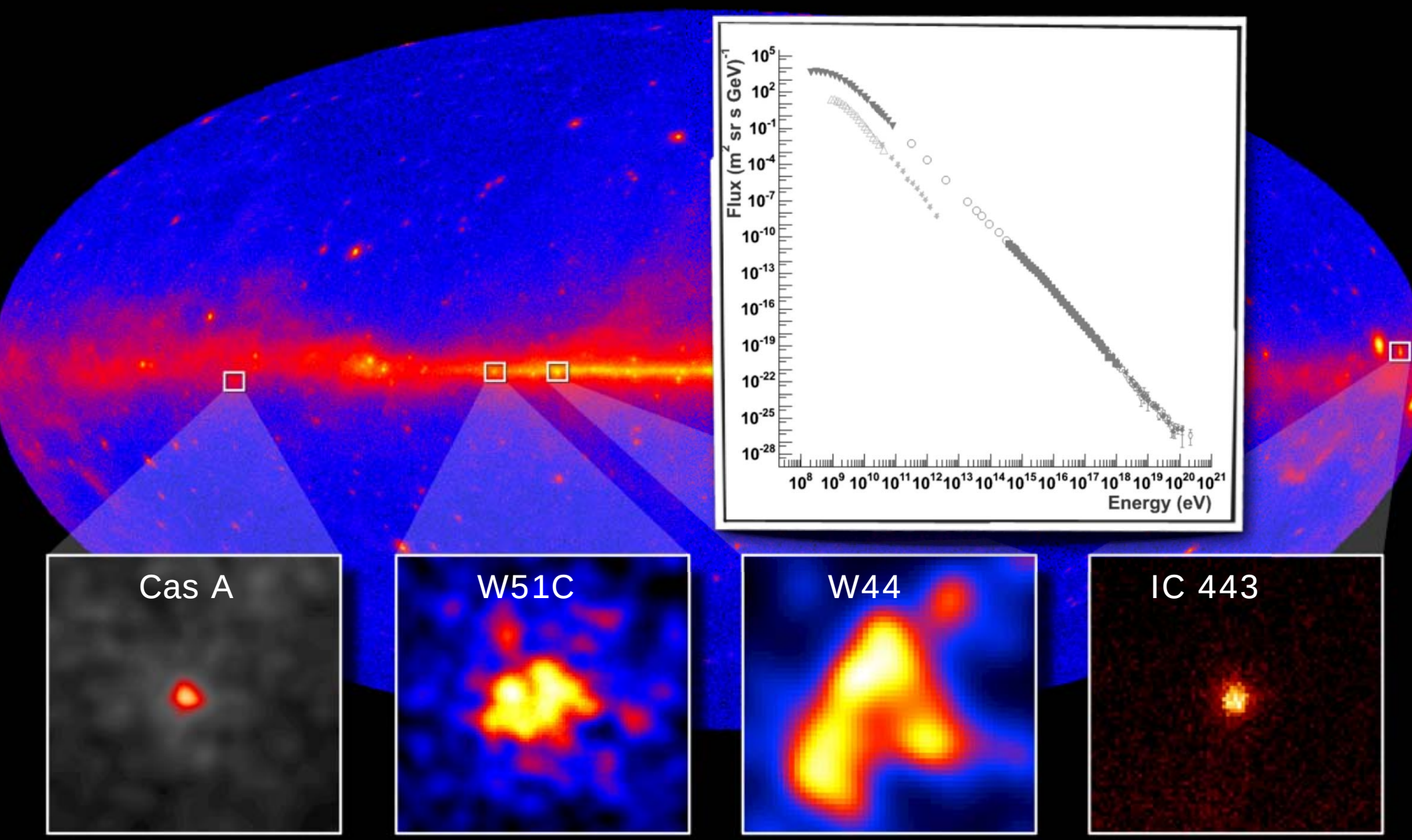
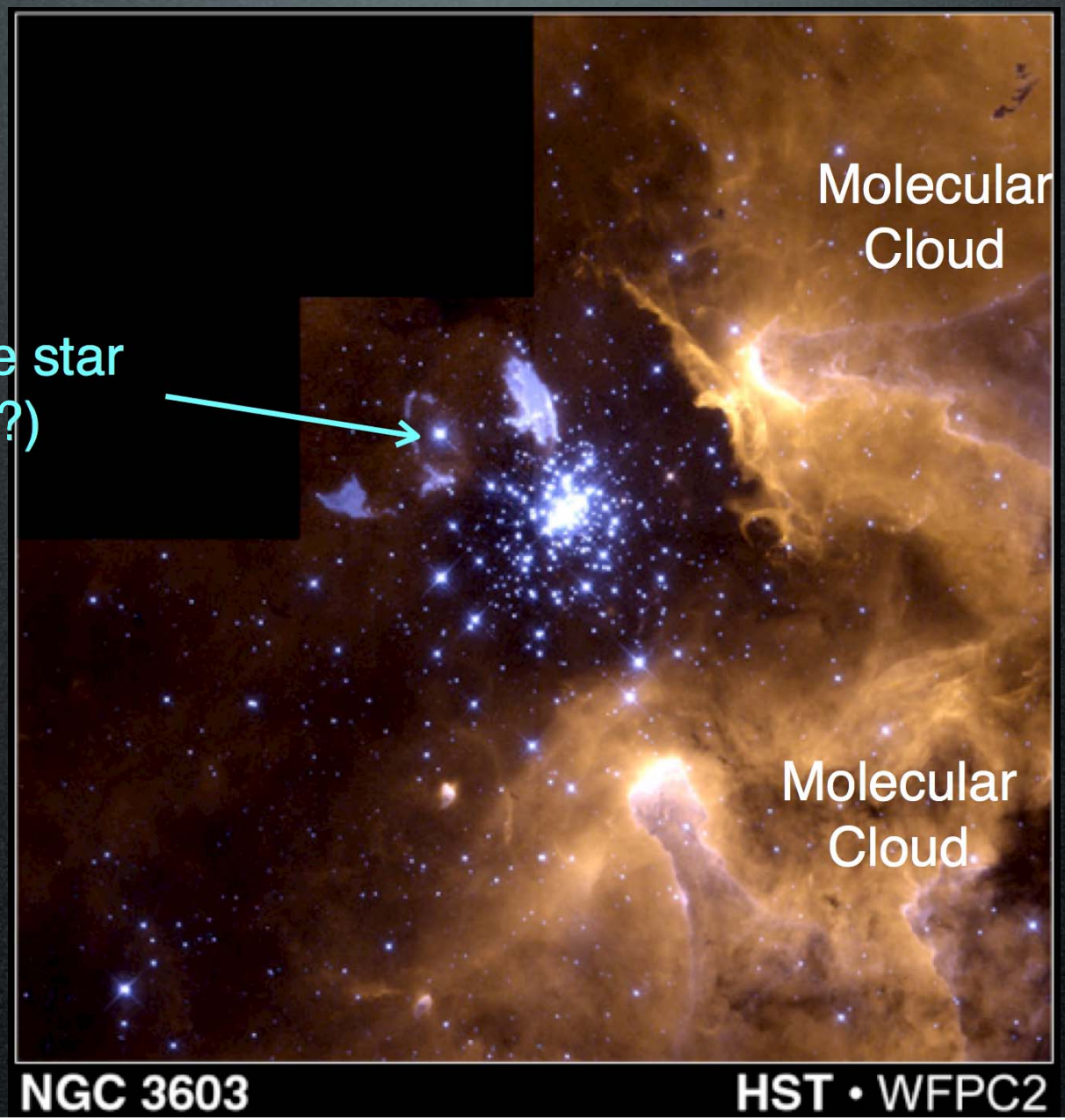


Supernova remnants

Supernova remnants

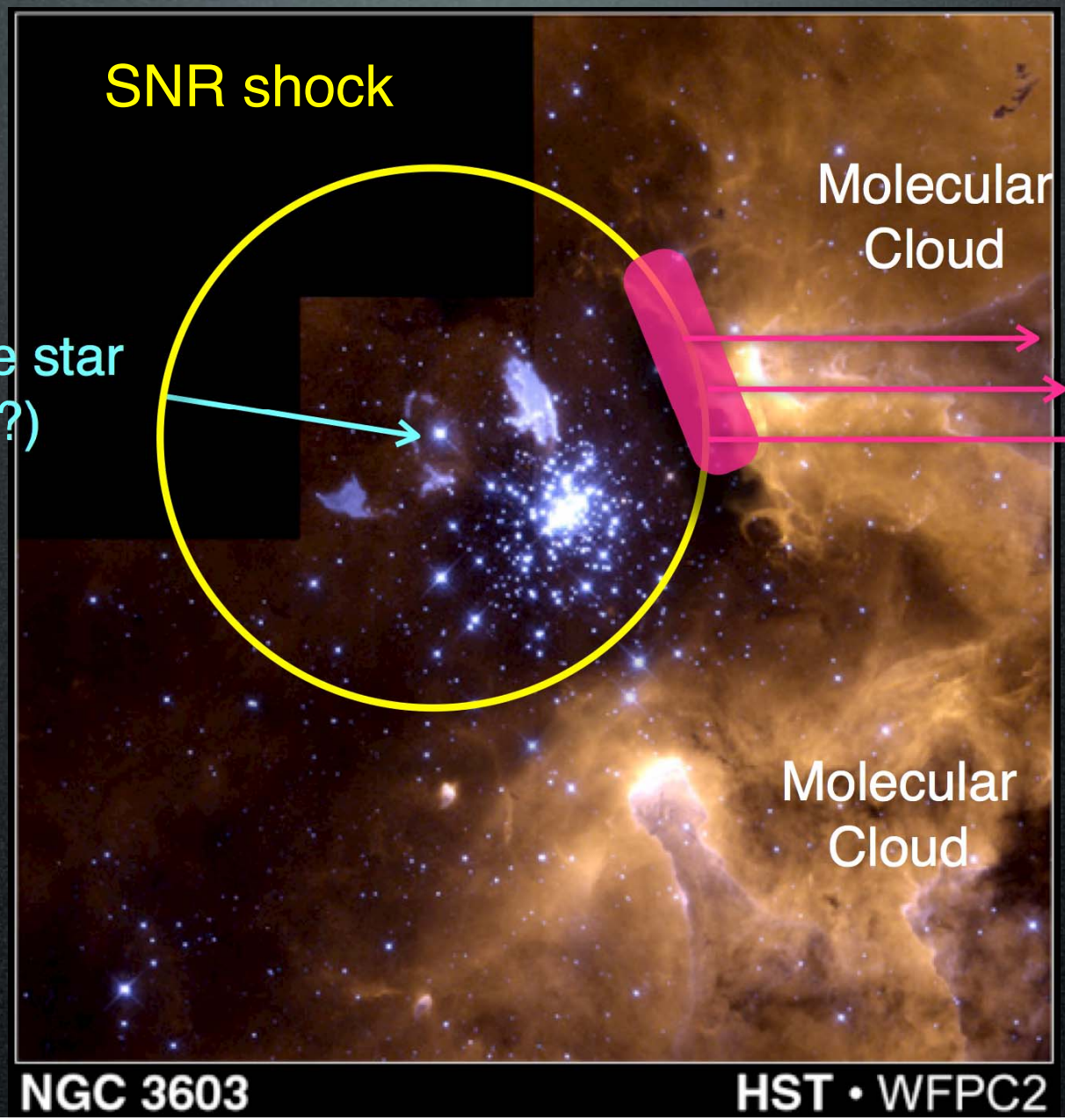


The General Idea



Evolved massive star (about to die?)

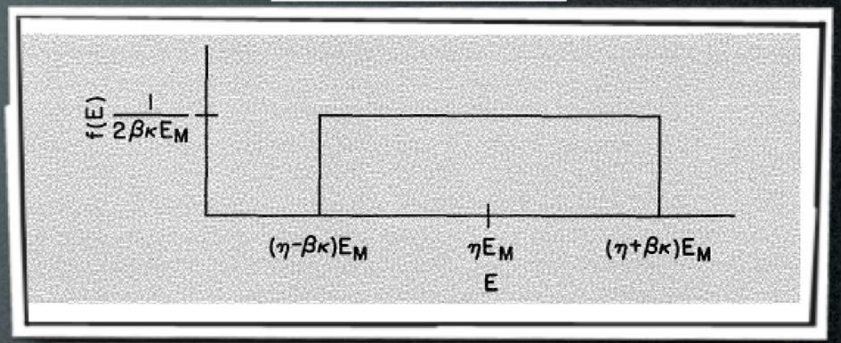
The General Idea



The π^0-decay bump

- Neutral pion-decay: in the rest-frame of the pion, the two γ rays have 67.5 MeV each (i.e. a line)
- Transforming into the lab-frame smears the line but keeps it symmetric about 67.5 MeV (in dN/dE)
- Transforming to E^2 dN/dE destroys symmetry and generates the "bump"

Stecker, 1971



Dermer, 1986

dN/dE

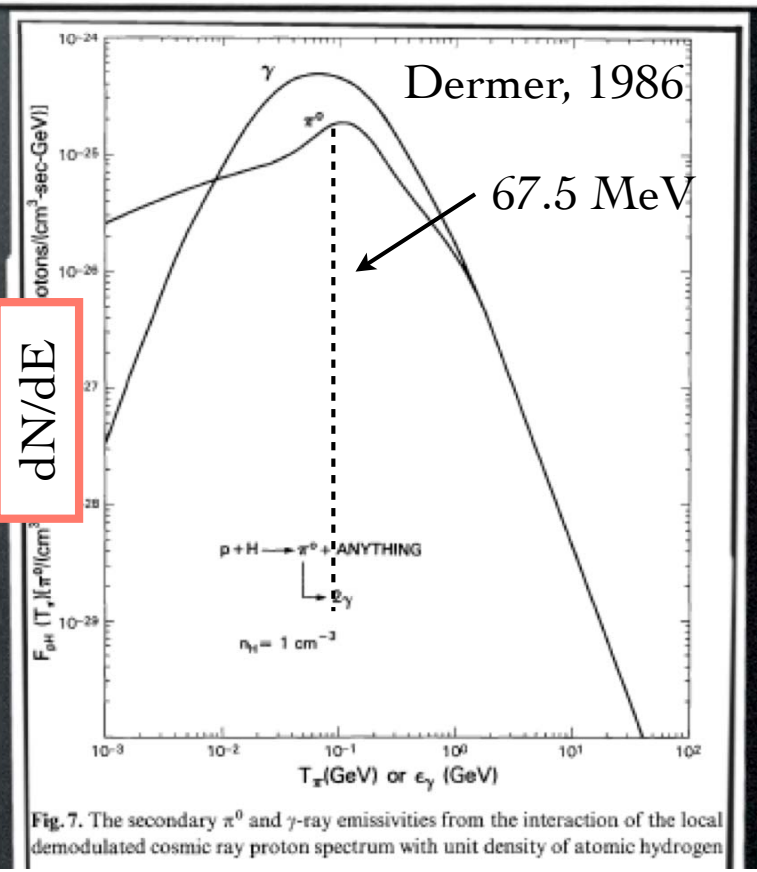
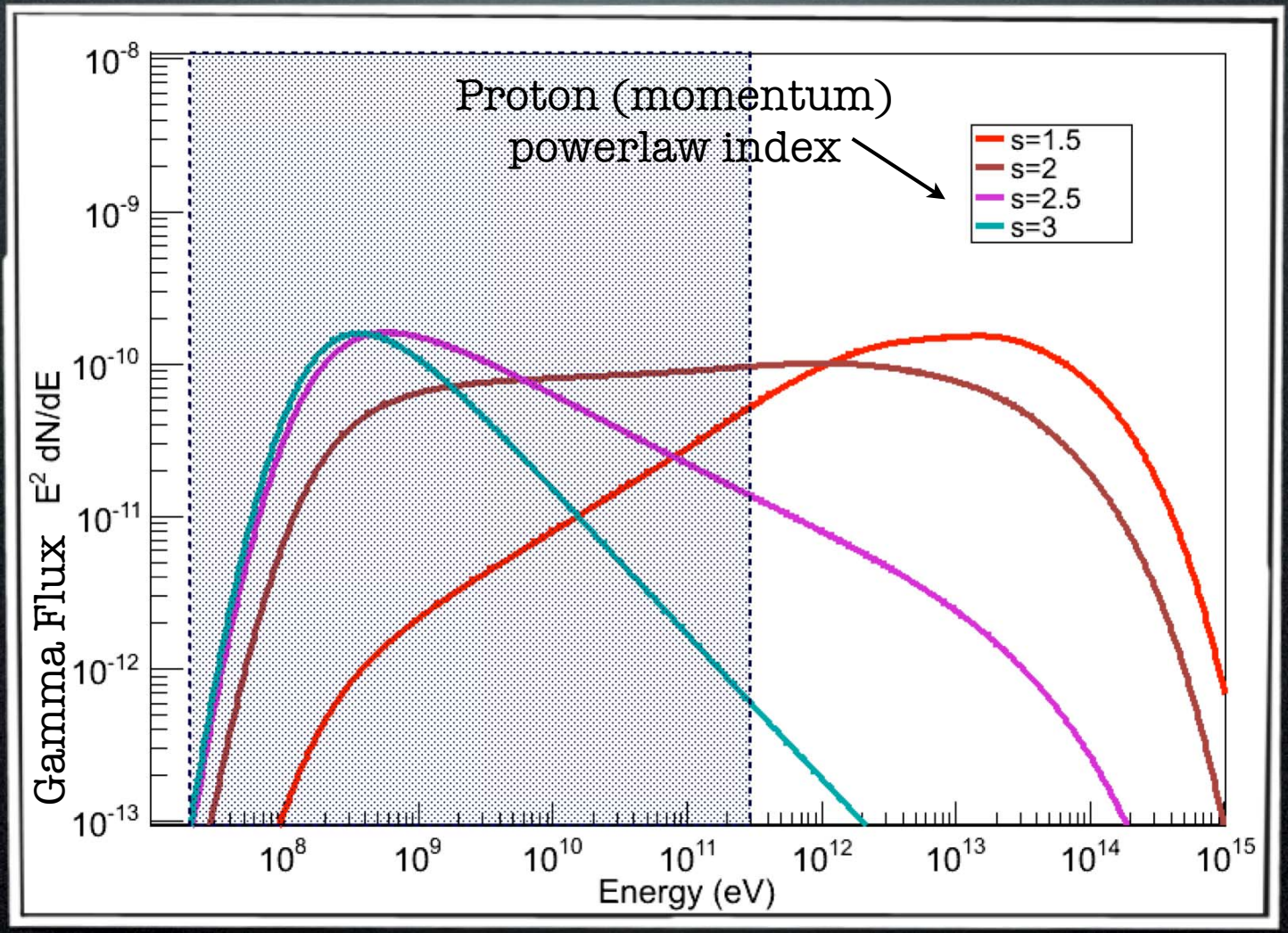


Fig. 7. The secondary π^0 and γ-ray emissivities from the interaction of the local demodulated cosmic ray proton spectrum with unit density of atomic hydrogen

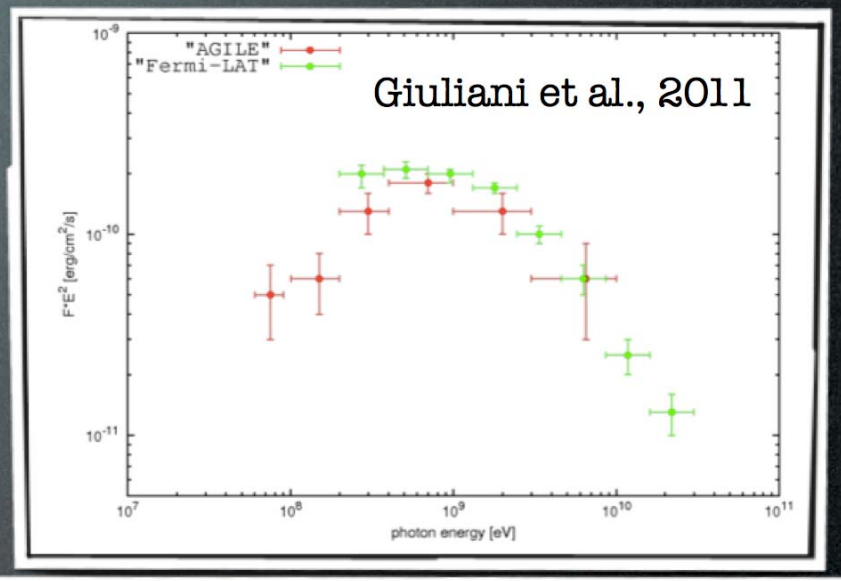
The π^0-decay bump

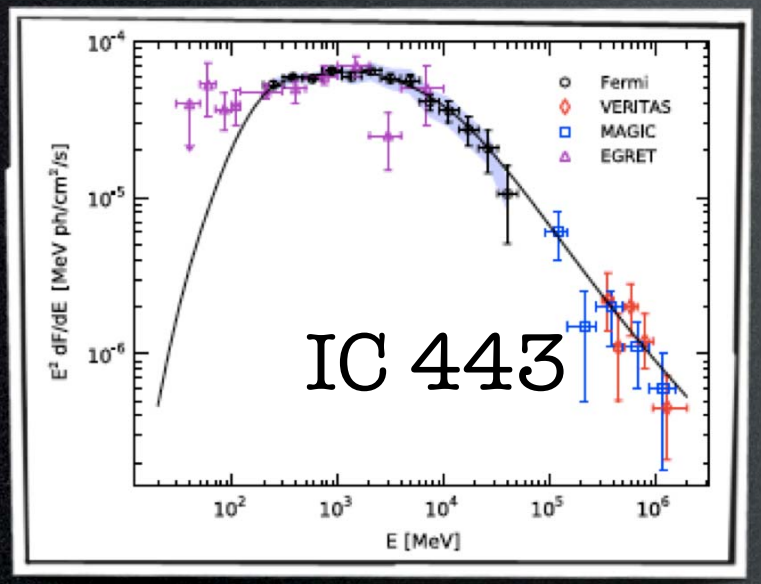


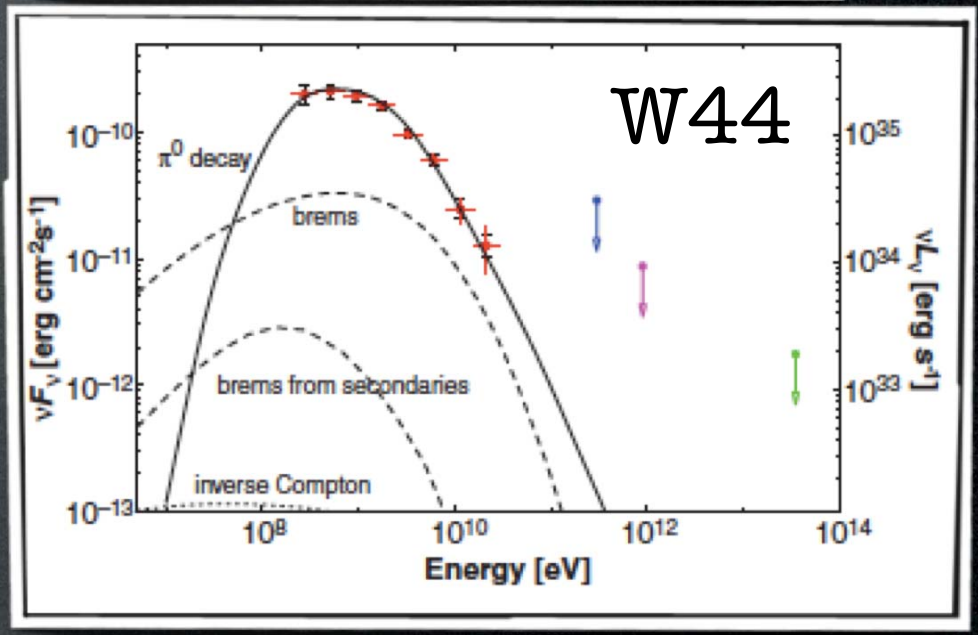
- The only smoking gun feature beyond neutrinos

Earlier observations

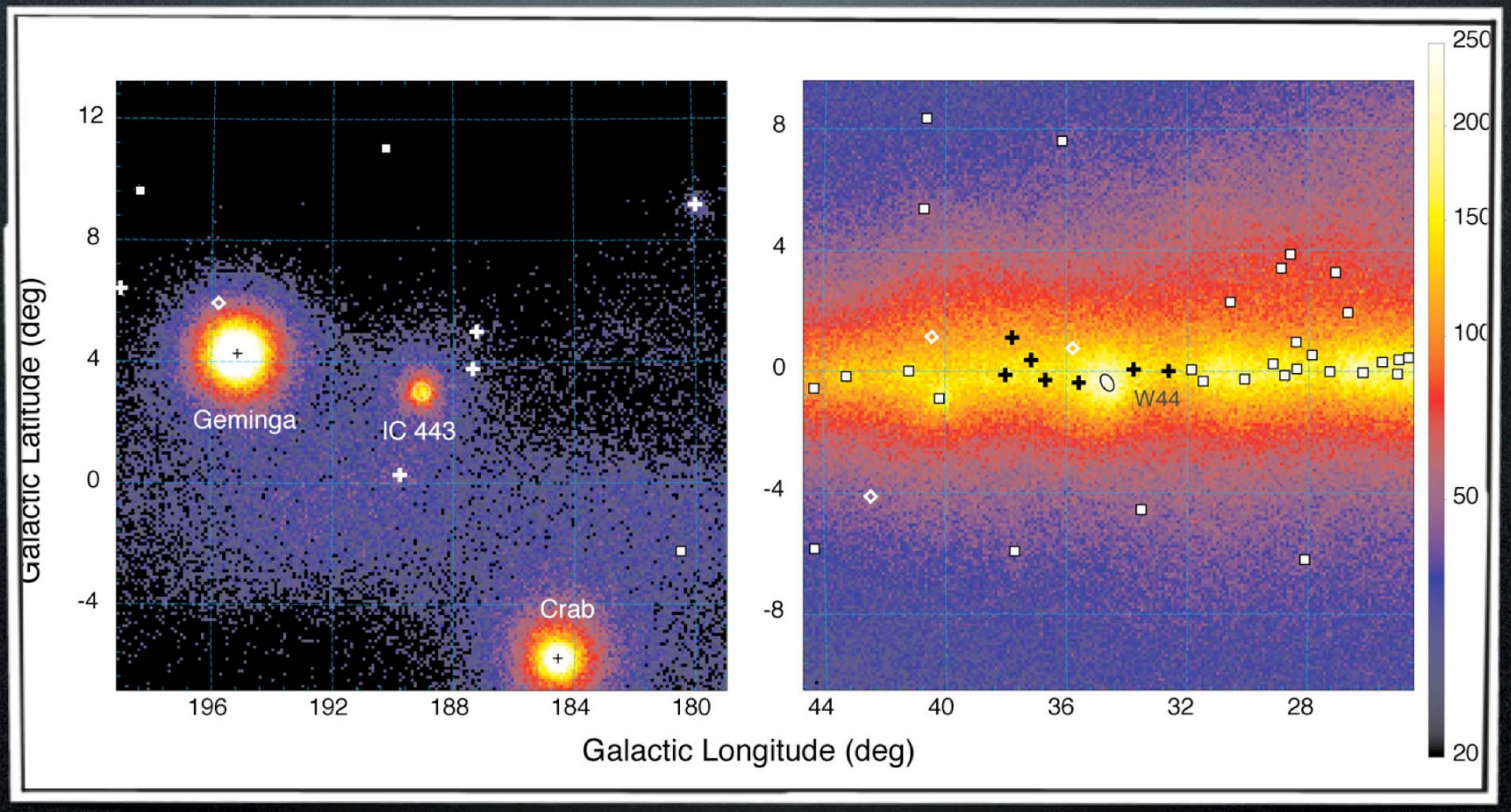
- Seen with EGRET in the Galactic diffuse
- AGILE detection of drop in γ-ray emission in W44
- Earlier Fermi-LAT analyses started at 200 MeV (rapidly changing effective area)





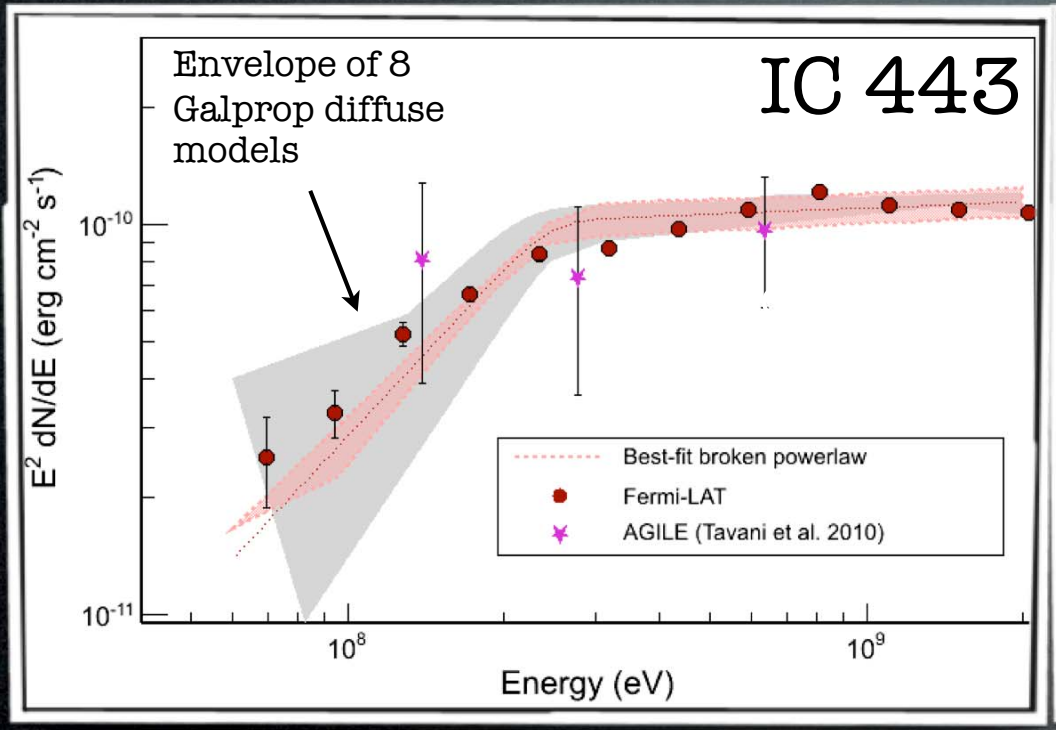


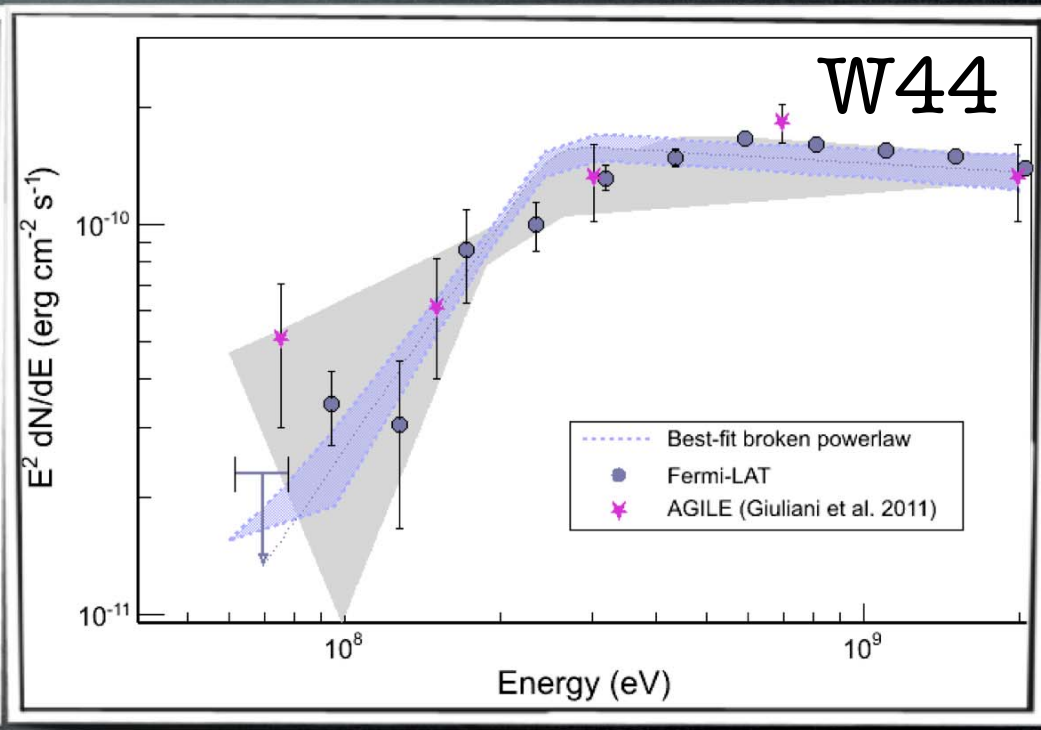
The best candidates



- IC 443 and W44 are the two brightest SNRs in the Fermi-LAT range

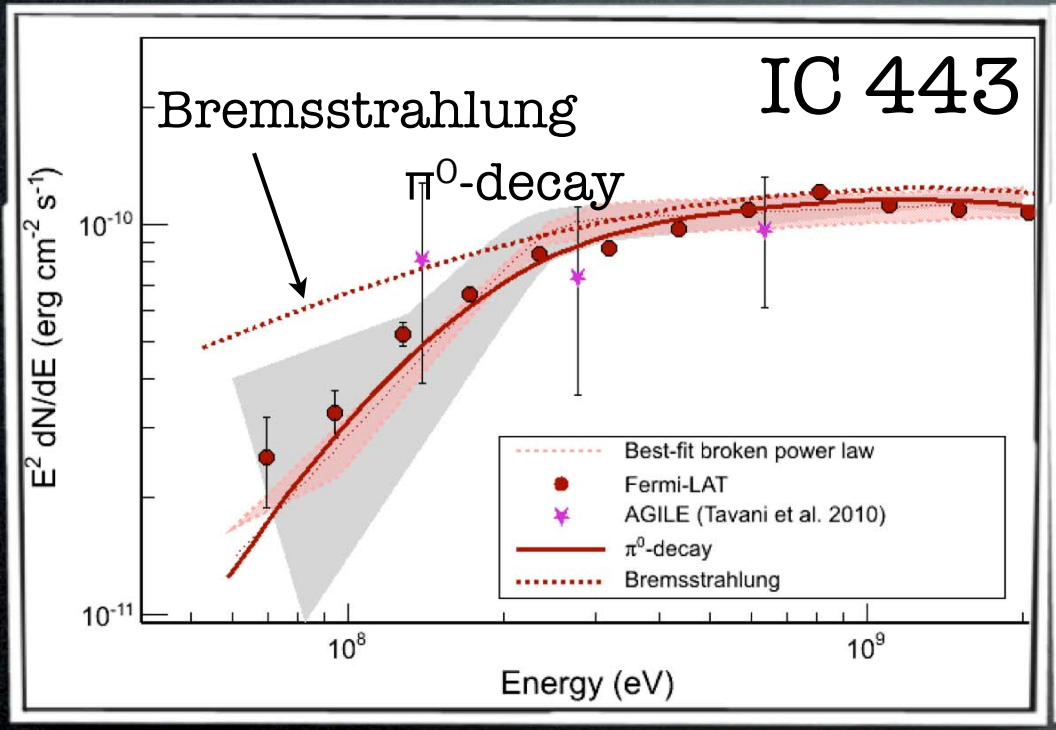
Clear detection of pion-bump

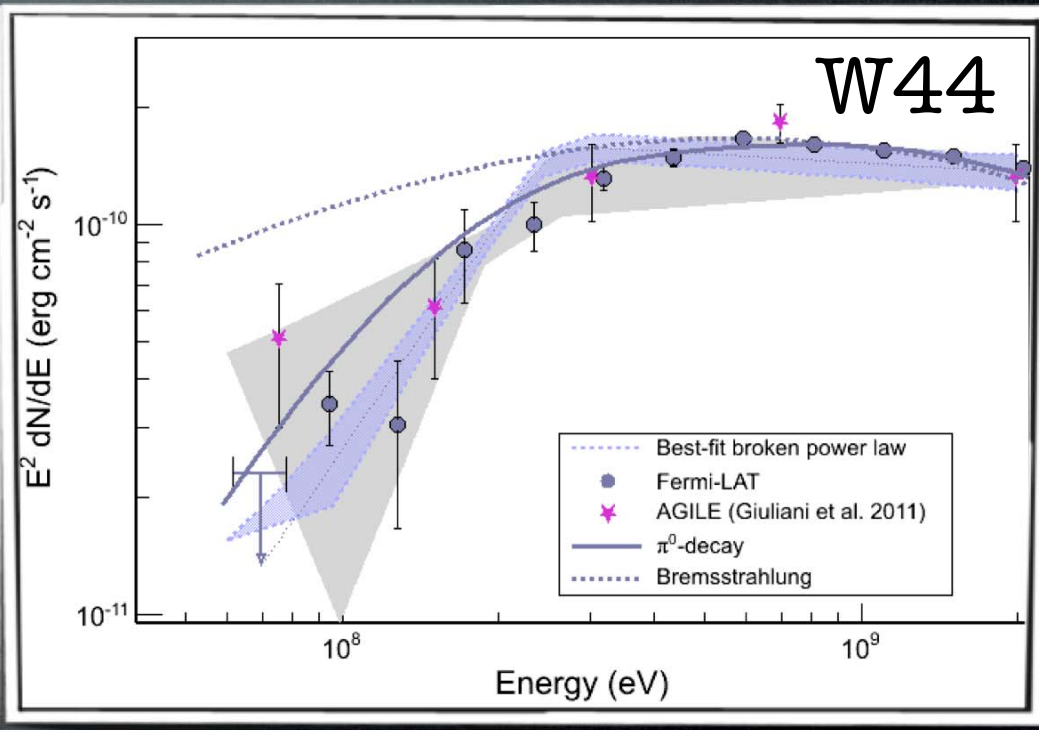




- Clear indication of a low-energy “turnover”

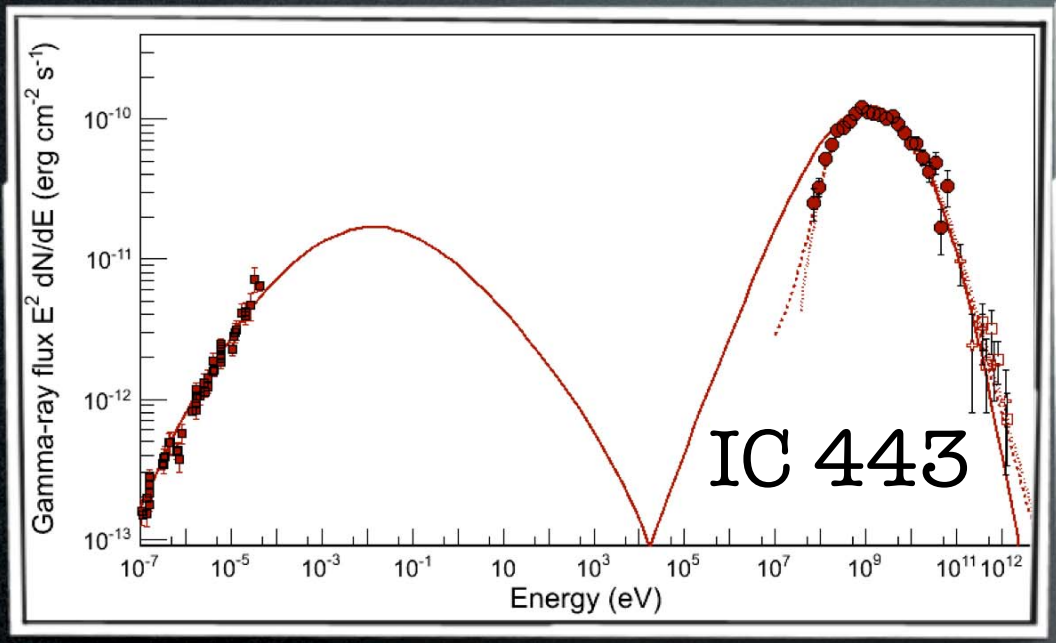
Clear detection of pion-bump

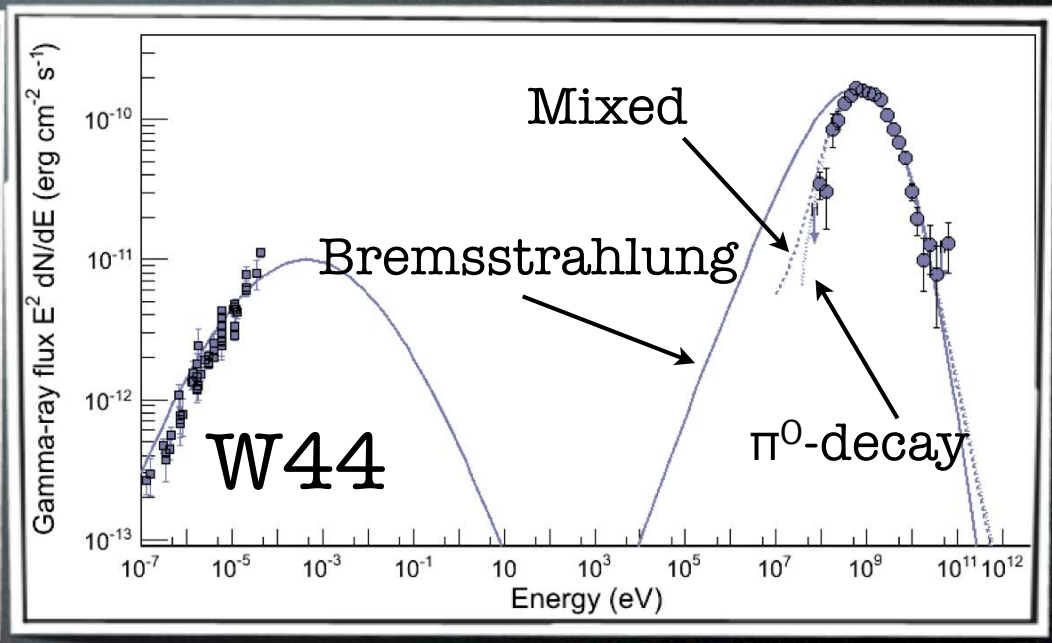




- Turnover matches what is expected from pion-decay
- Best-fit Bremsstrahlung model shows less steep decline

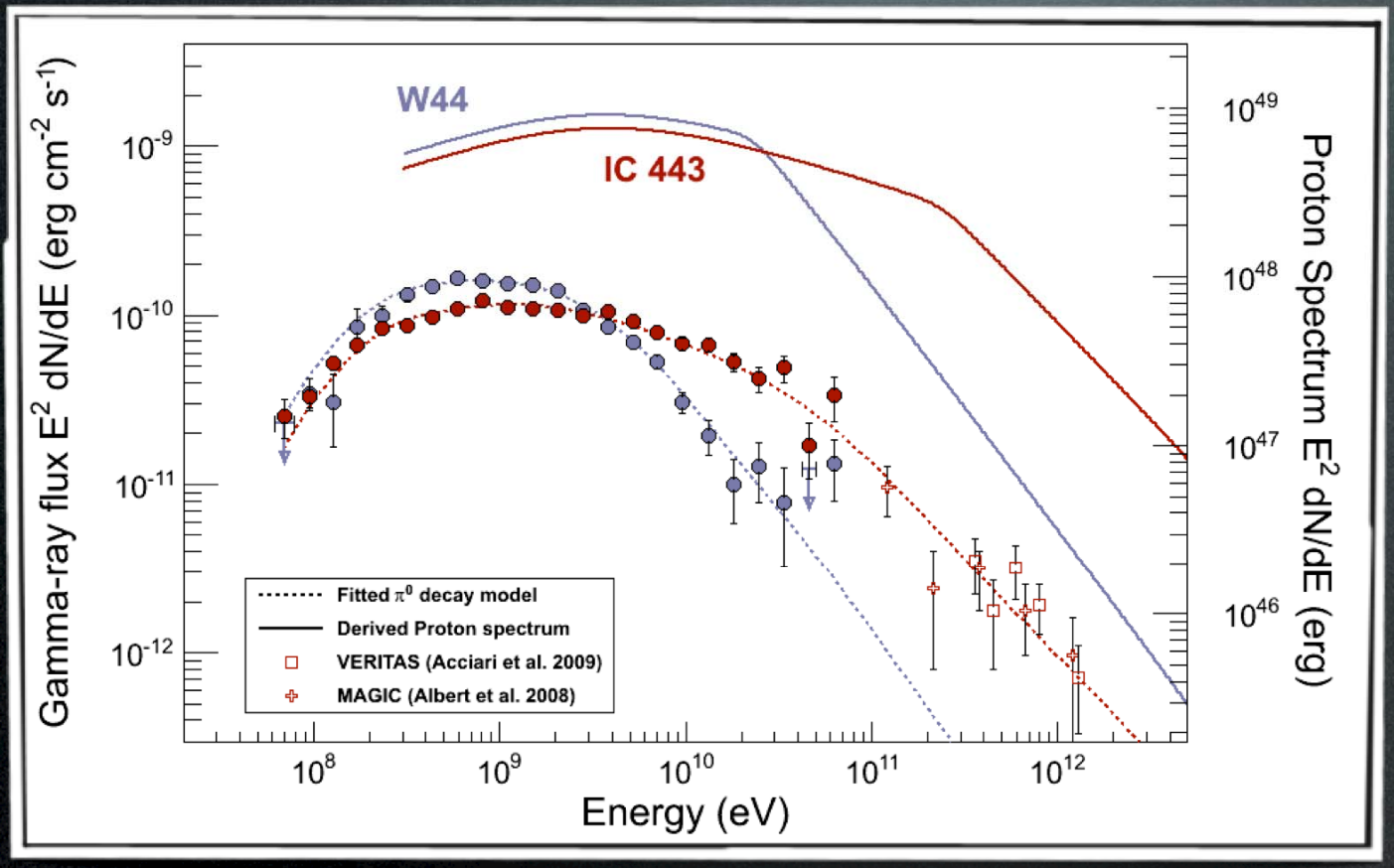
Ruling out leptonic scenarios





- Inverse Compton scenario: energetically completely disfavored (need factor 100 higher radiation fields). Also shape not consistent with IC
- Bremsstrahlung (solid): adjust B-field, total number of electrons and density to match observed emission. Spectra < 200 MeV inconsistent.
- Mixed model: Ratio electrons/protons: K_{ep}= 0.01 (dN/dp @ p=1GeVc^{-1})

Resulting Proton spectrum



$$\frac{dN_p}{dp} \propto p^{-s_1}\left[1+\left(\frac{p}{p_{\rm br}}\right)^{\frac{s_2-s_1}{\beta}}\right]^{-\beta}$$

- s_1 = 2.36±0.05, s_2 = 3.1±0.1 (3.5±0.1) p_{br} =239±74 (22±8) GeV c^{-1} (for IC 443)
- Below the break: proton spectrum softer than electron spectrum ($s_{1,e}$ = 1.72)
- Reason for high-energy break not fully understood
- CR efficiency 1-4%. Strongly depends on assumed density

Summary

- Whatever your interest in the high-energy sky, you have to understand particle acceleration - this is the prevalent signal
- Foreground for Dark Matter studies
- Can study the acceleration of Cosmic ray (protons and electrons) in astrophysical sources
- VERITAS, CTA, IceCube, and HAWC are expected to make significant progress on these issues in the next decade.