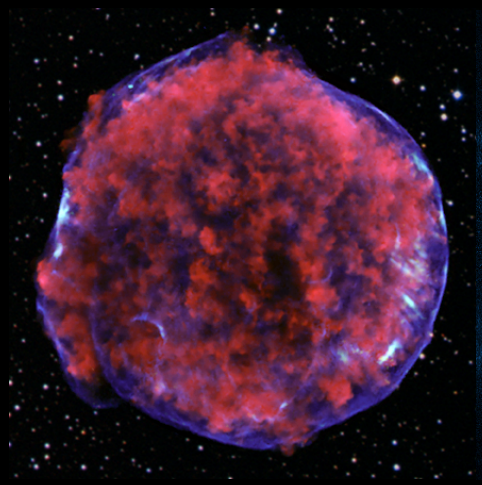
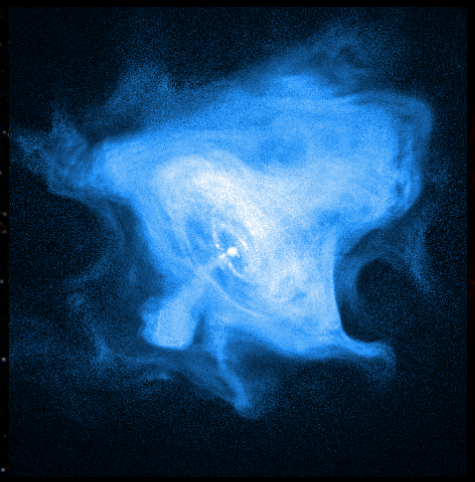
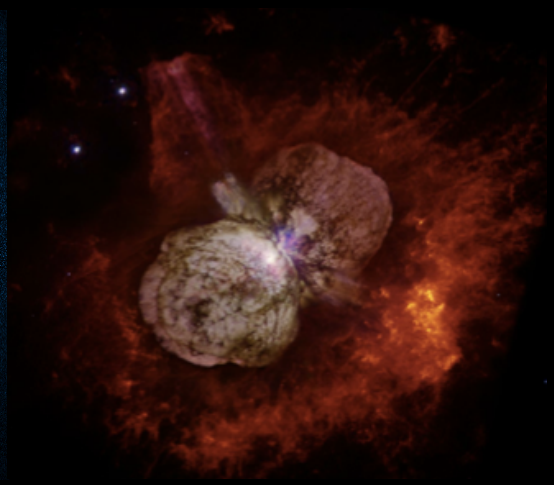




Galactic

News & Progress

Jim Hinton

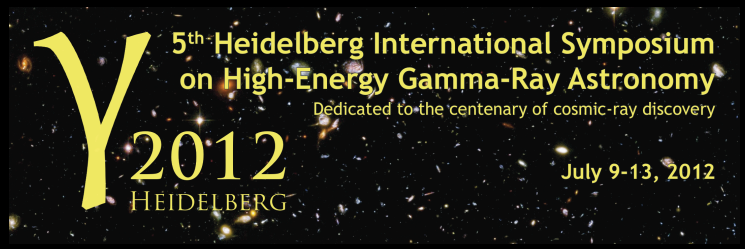
University of Leicester

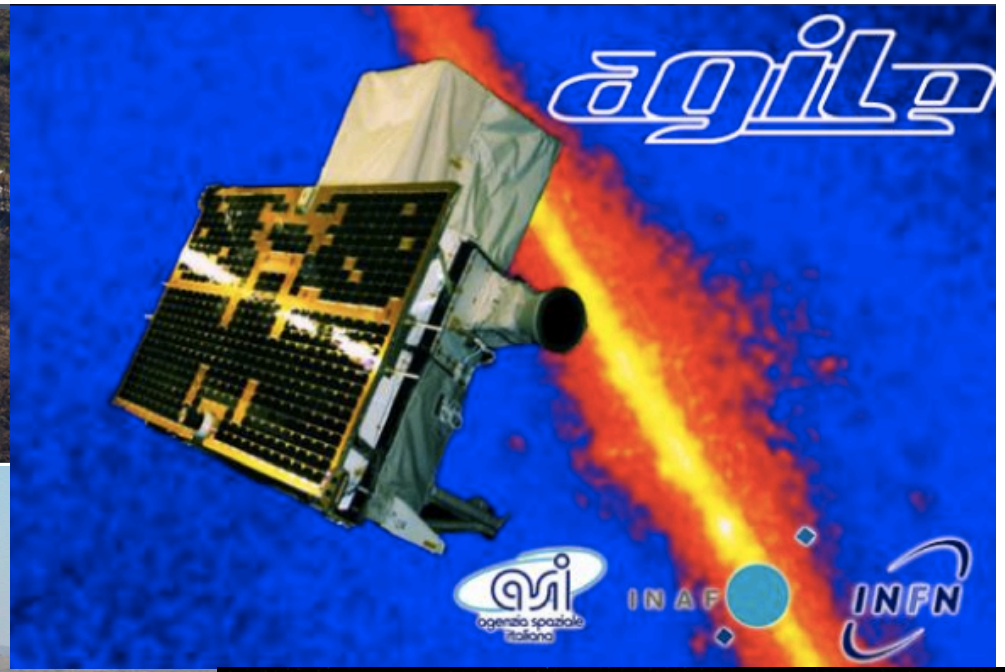
Galactic γ-ray Astronomy

University of Leicester

- Arguably the major topic of this meeting
  - a lot of progress both observationally and theoretically since HDGS 2008
- This talk = Biased overview
  - observational focus
  - will skip binaries
  - Contents
    - Some general remarks
    - Supernova remnants
    - Pulsars and PWN
    - Everything else
      - briefly

	Talks	Posters
SNR	18	18
Pulsars +PWN	11	19
Binaries	6	16
Other	18	10
Total	**53**	**63**

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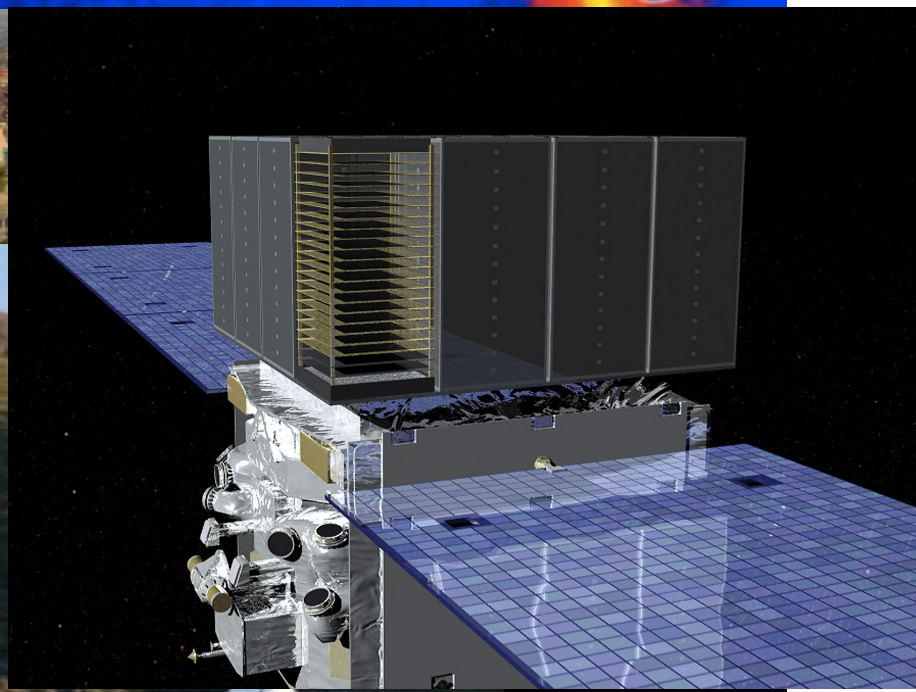
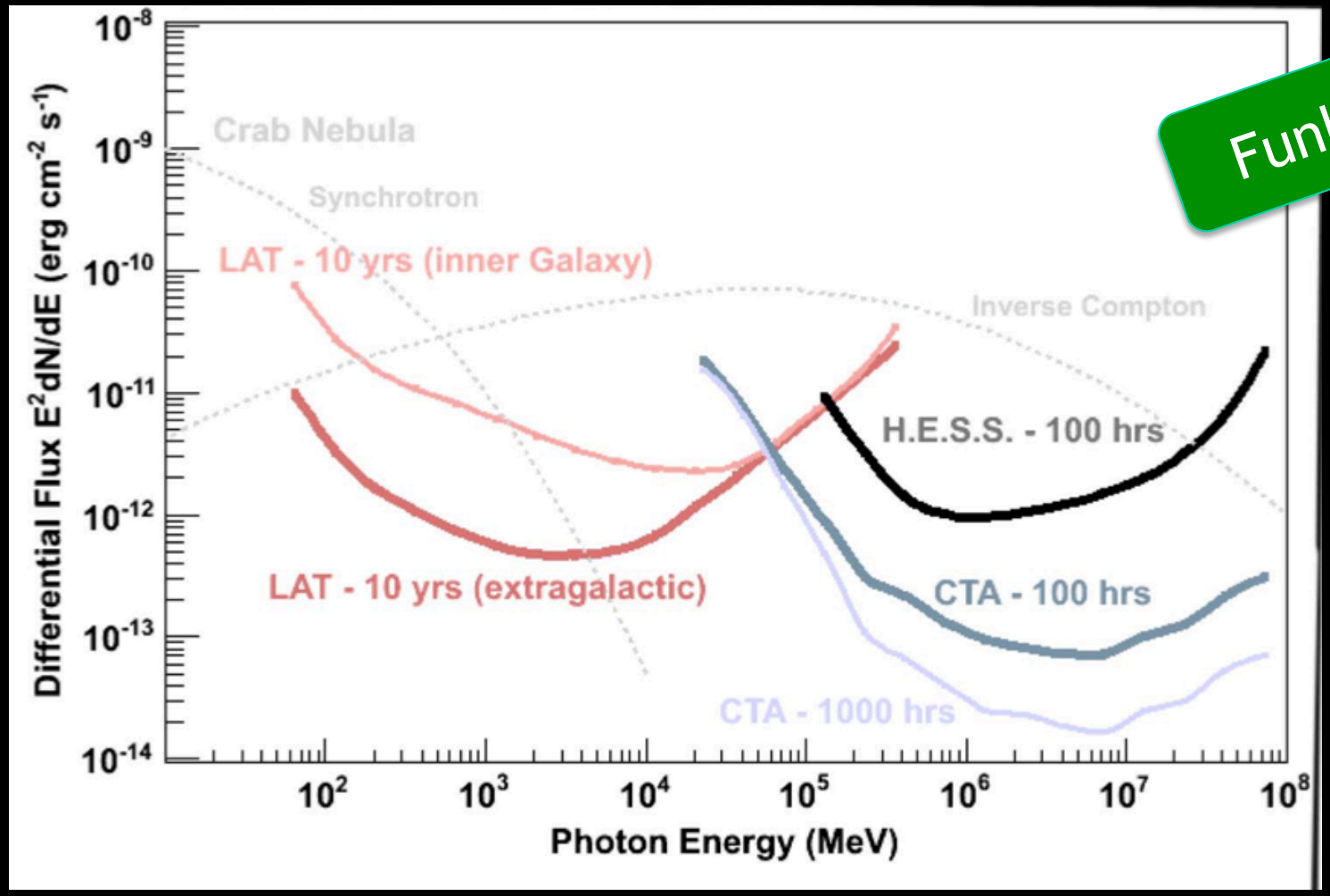
INFN

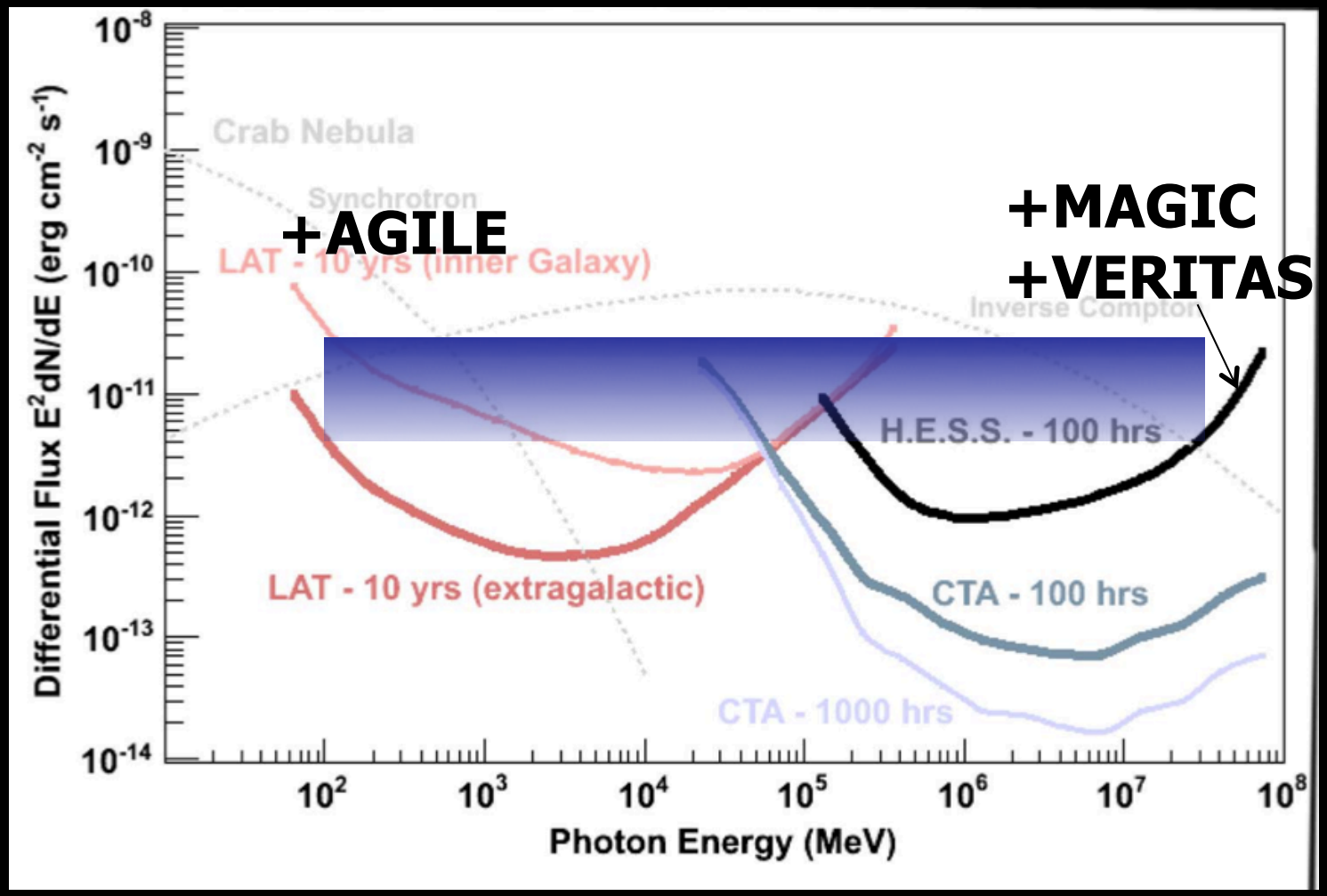


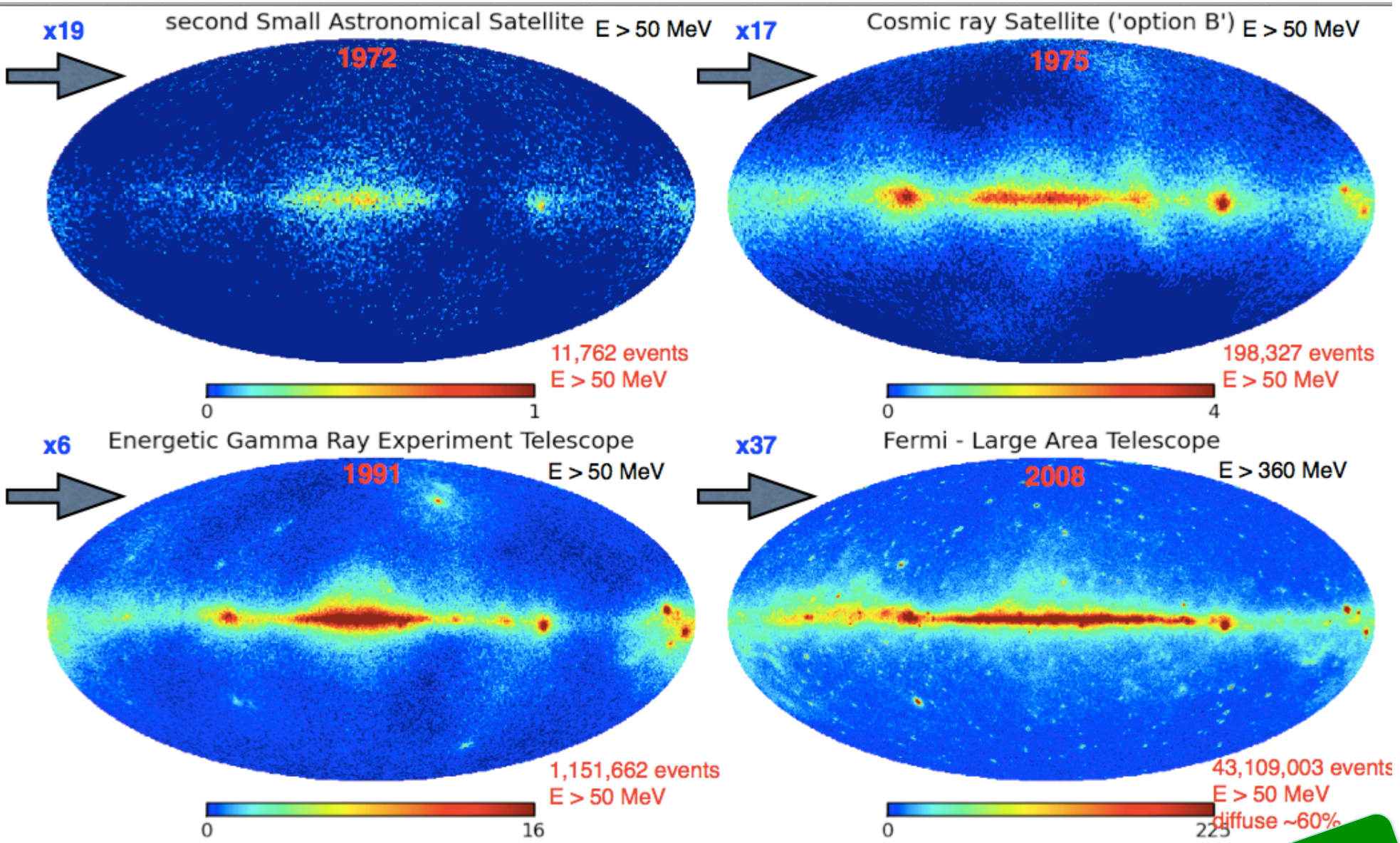
Instruments



Funk

Instruments





NASA High Energy Astrophysics Science Archive Research Center (HEASARC)

Casandjian

4 years of Fermi

University of Leicester

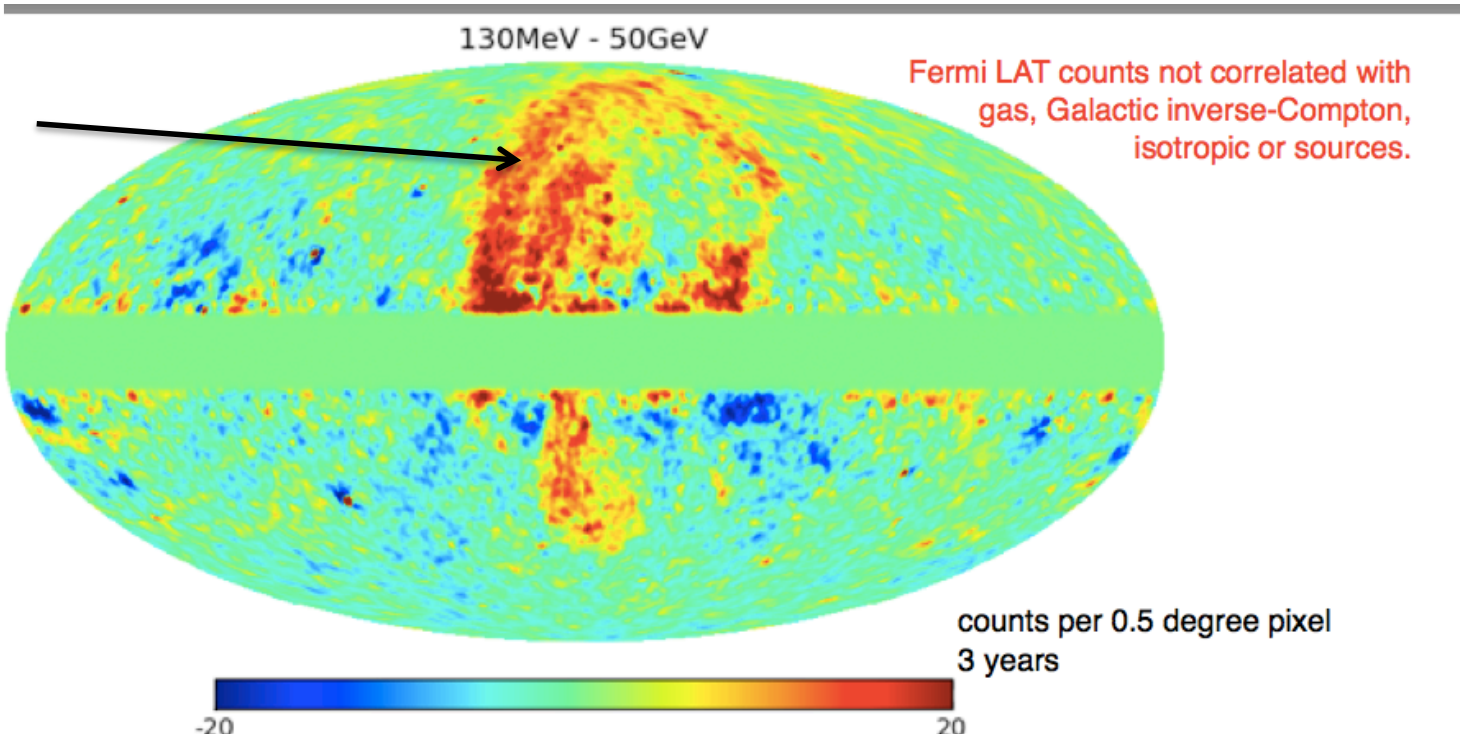
- 1873 sources
- 517 above 10 GeV
- >200 likely Galactic
  - ~120 pulsars
  - ~40 SNR candidates

Table 6. LAT 2FGL Source Classes

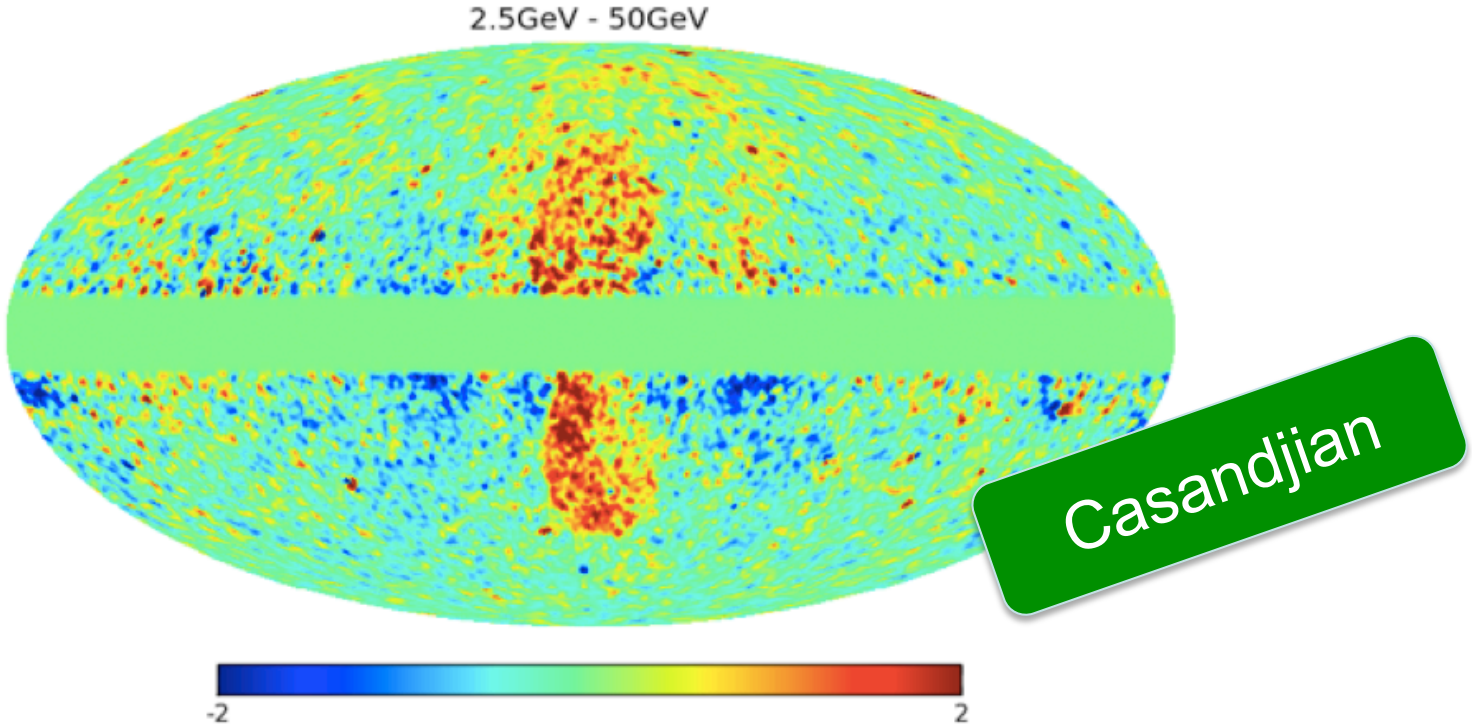
Description	Identified Designator	Identified Number	Associated Designator	Associated Number
Pulsar, identified by pulsations	PSR	83	...	...
Pulsar, no pulsations seen in LAT yet	...	...	psr	25
Pulsar wind nebula	PWN	3	pwn	0
Supernova remnant	SNR	6	snr	4
Supernova remnant / Pulsar wind nebula	...	...	†	58
Globular cluster	GLC	0	glc	11
High-mass binary	HMB	4	hmb	0
Nova	NOV	1	nov	0
BL Lac type of blazar	BZB	7	bzb	429
FSRQ type of blazar	BZQ	17	bzq	353
Non-blazar active galaxy	AGN	1	agn	10
Radio galaxy	RDG	2	rdg	10
Seyfert galaxy	SEY	1	sey	5
Active galaxy of uncertain type	AGU	0	agu	257
Normal galaxy (or part)	GAL	2	gal	4
Starburst galaxy	SBG	0	sbg	4
Class uncertain	...	...	...	1
Unassociated	...	...	...	575
Total	...	127	...	1746

Saz Parkinson

Loop I



Fermi bubble



Casandjian

Lar

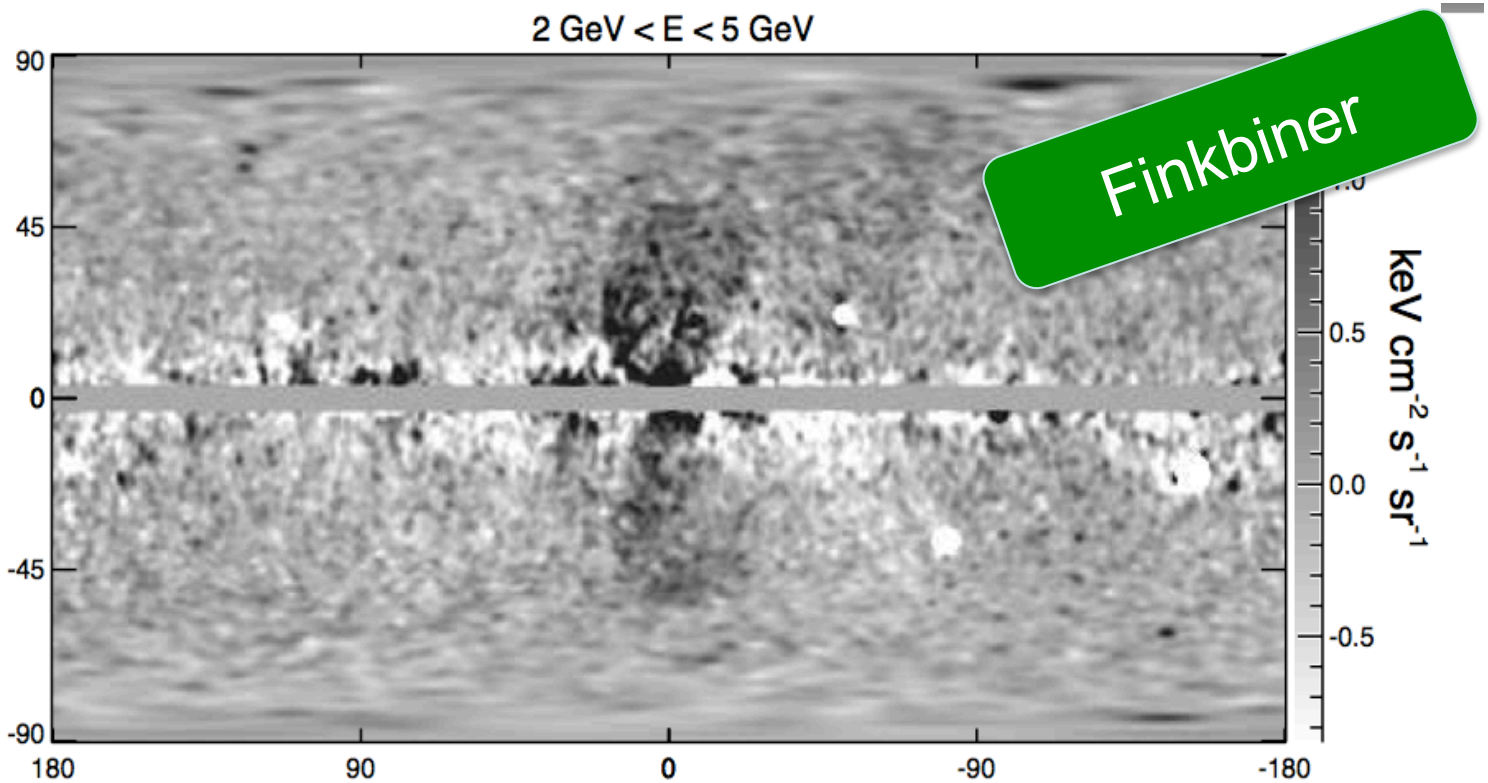
" A exc
associat
southern

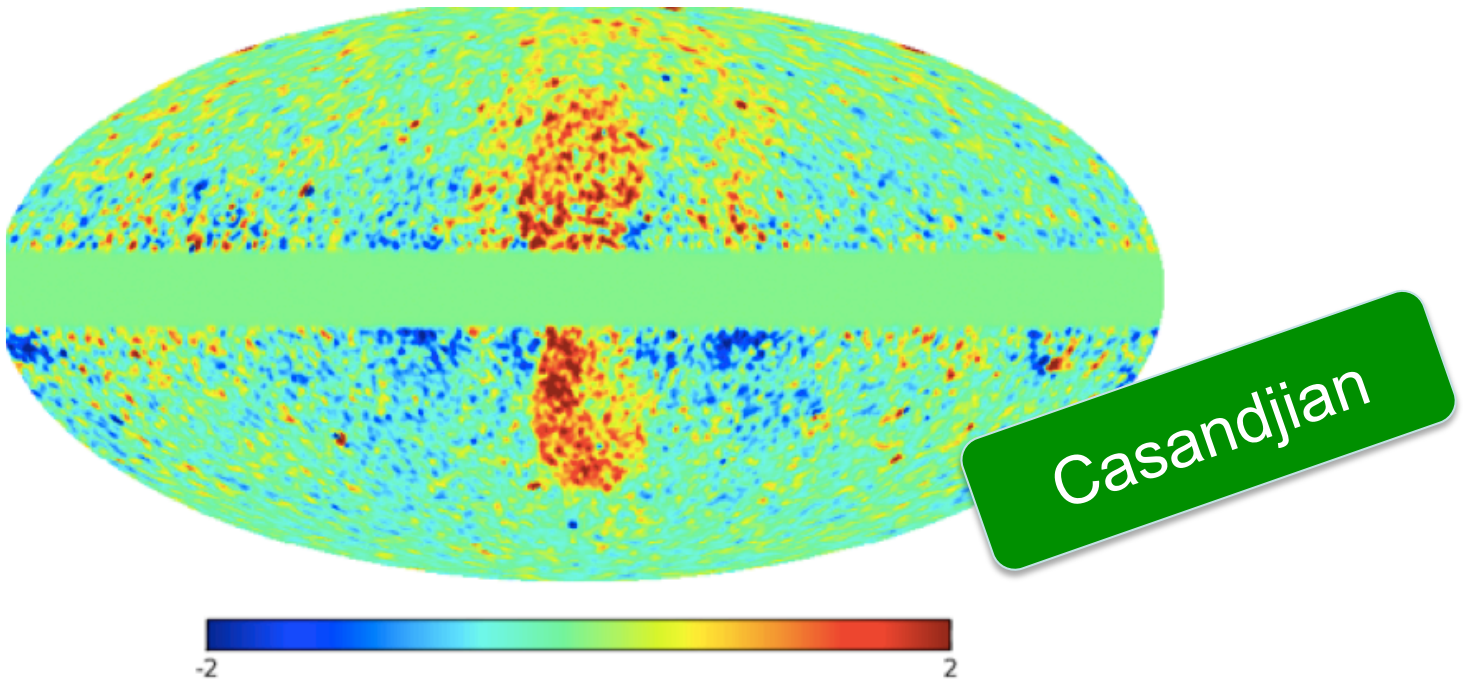
Casandjia
2009 Ferr

Full desc
Su, Slaty

Evidence for substructure in bubbles: "Cocoon" and "Jets"

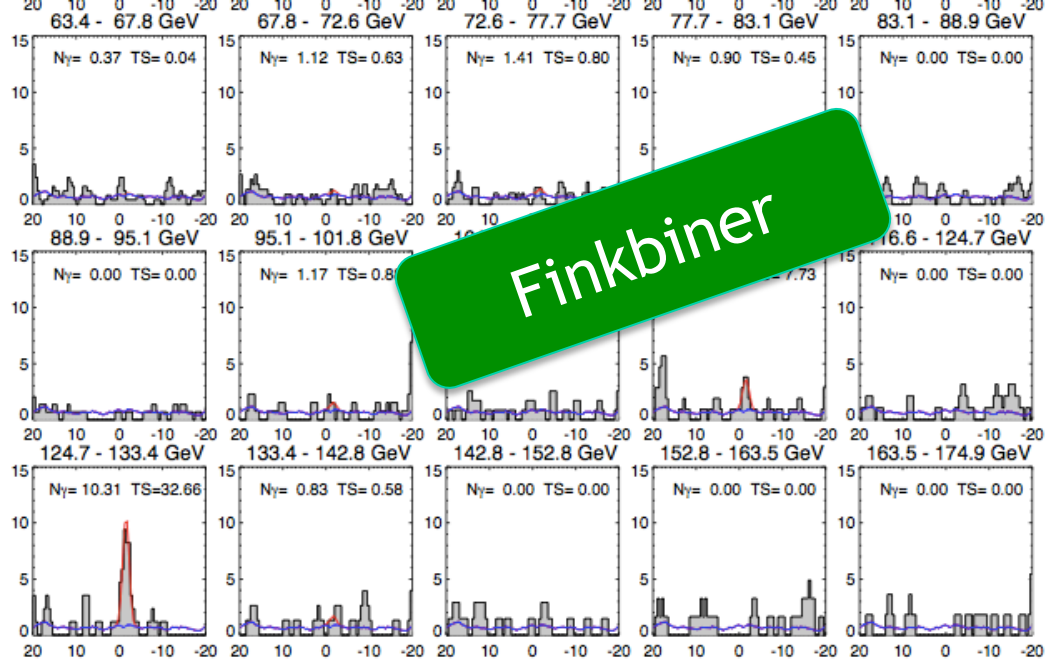
AGN origin plausible but CMZ possibility remains



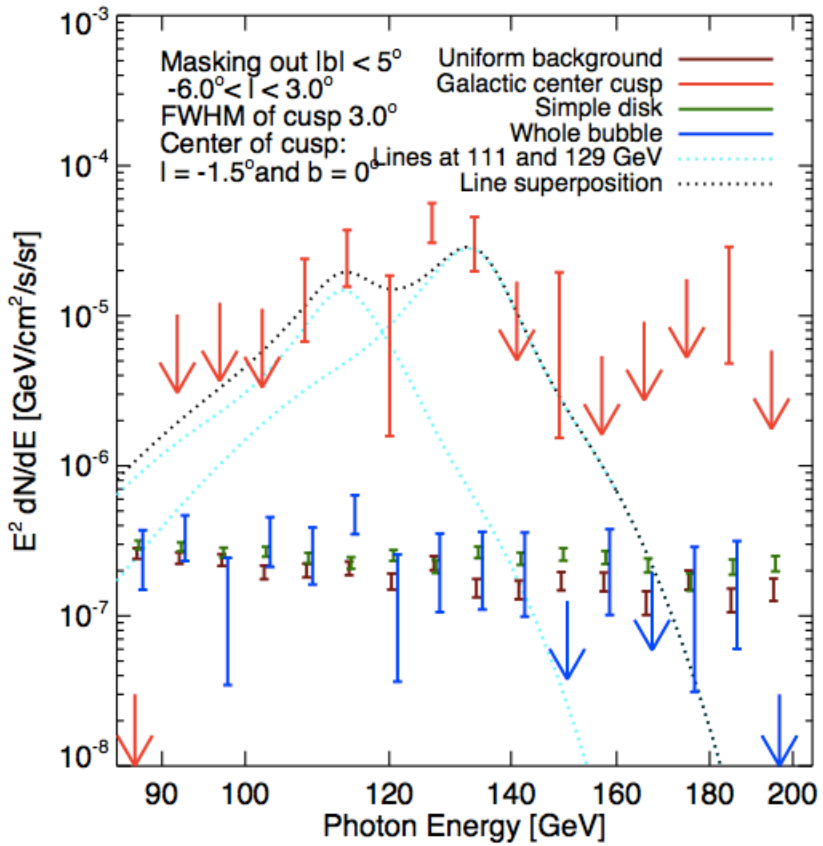


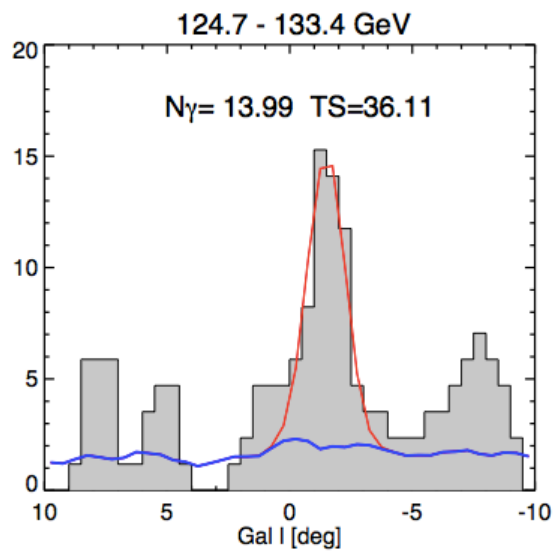
Lines?

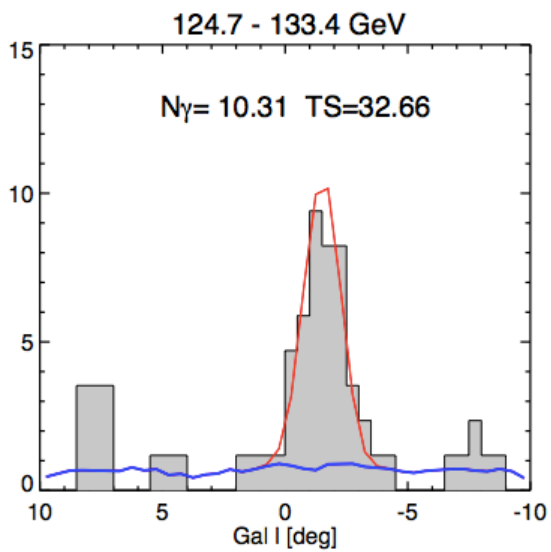
- Strongly peaked emission 1.5° offset from the GC
  - astrophysical accelerators?
    - e.g. pulsar winds
      - Aharonian et al 2012

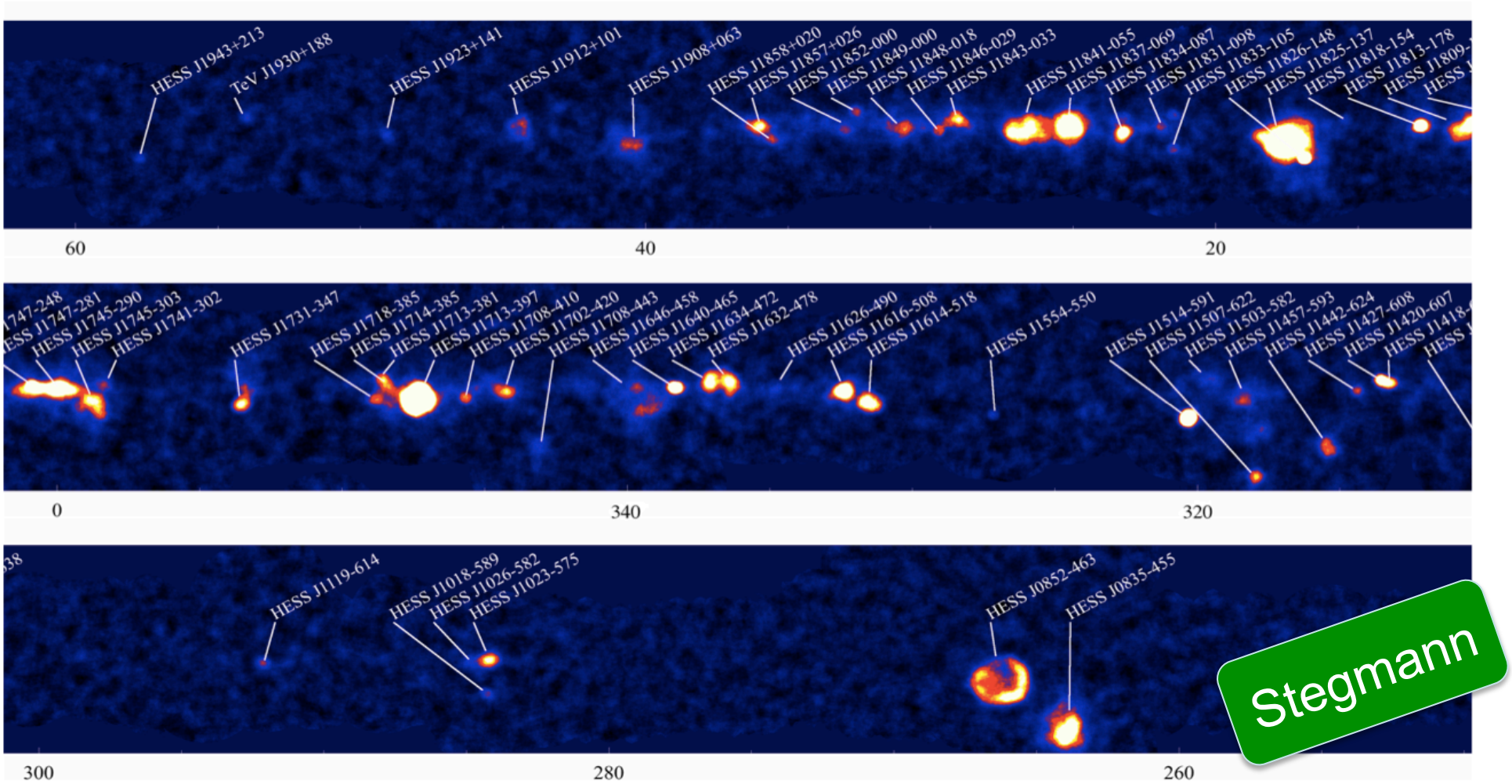


Finkbiner

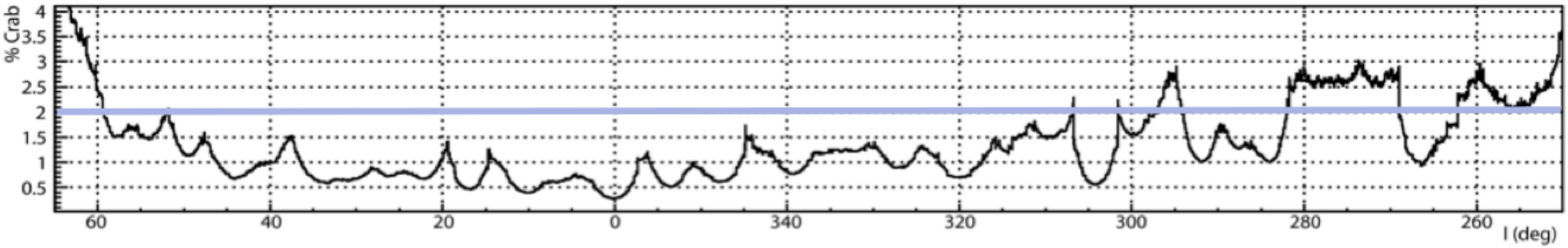


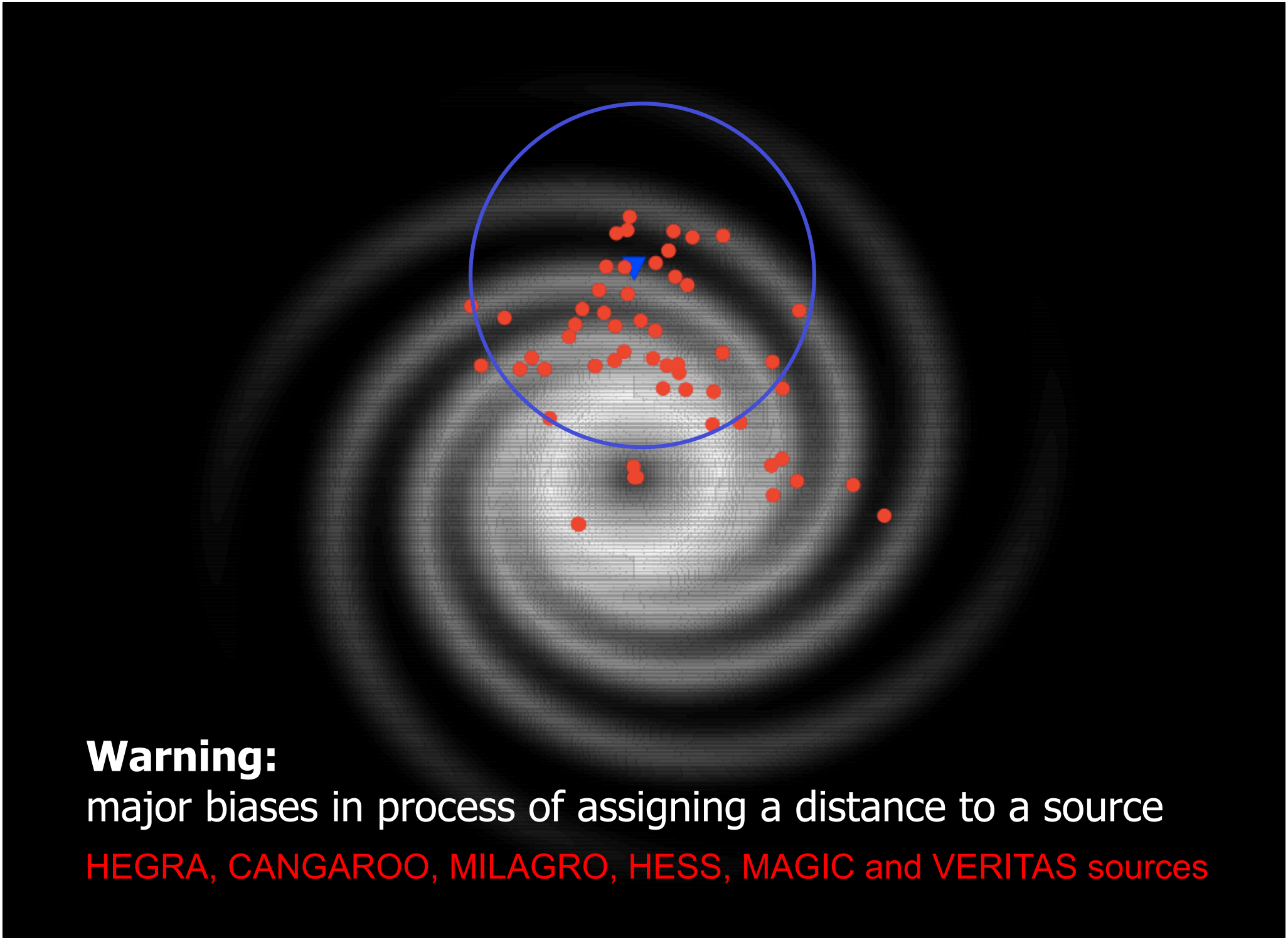






Sensitivity at b=-0.3°, assuming a spectral index of 2.5, detection level 5σ pre-trials

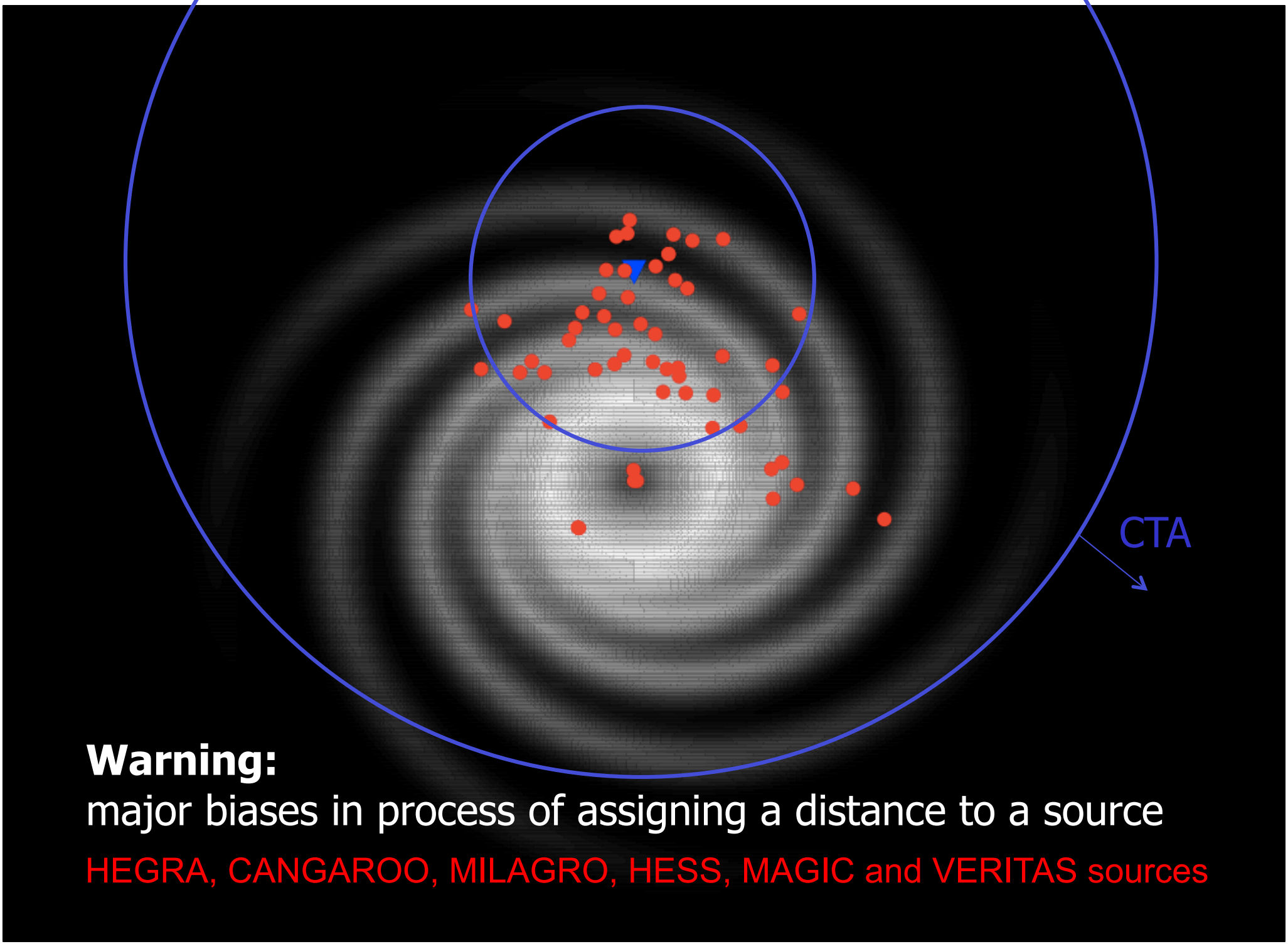




Warning:

major biases in process of assigning a distance to a source

HEGRA, CANGAROO, MILAGRO, HESS, MAGIC and VERITAS sources



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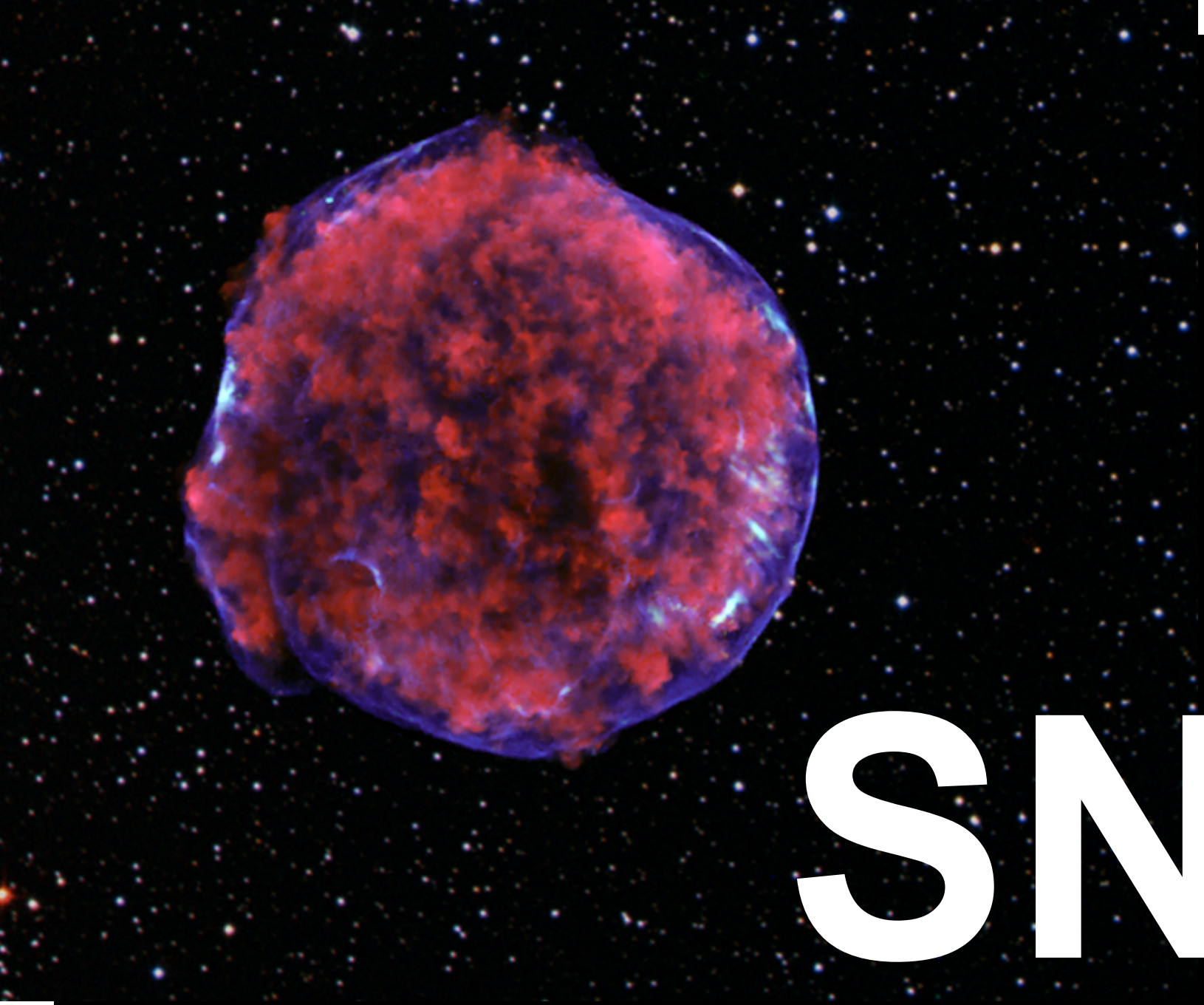
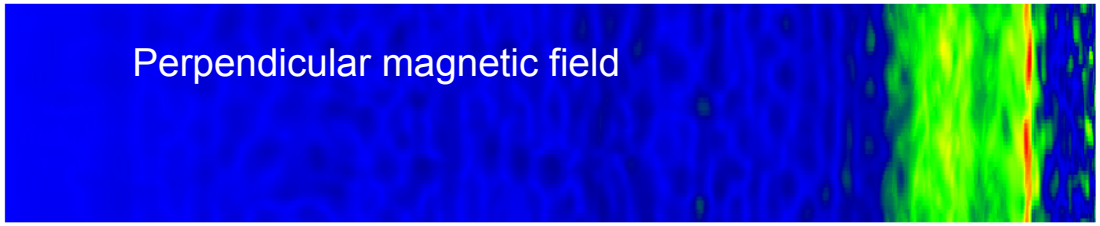


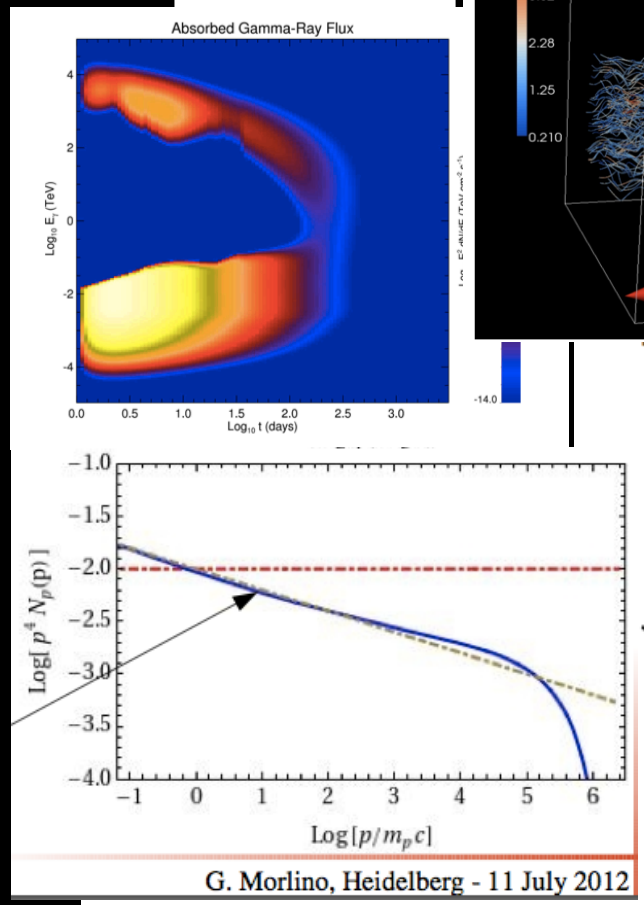
SNR

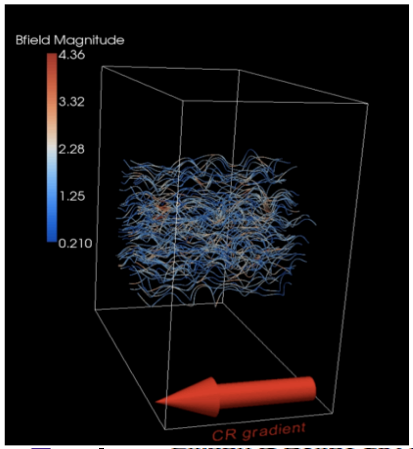
SNR Theory

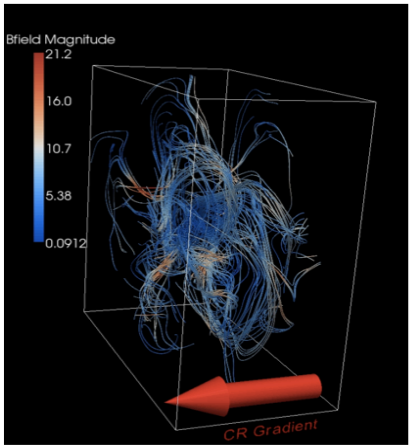
- Bell
- Renaud
- Ksenofontov
- Kachelriss
- Bykov
- Ellison
- Malkov
- Caprioli
- Reville
- Dwarkadas
- Morlino

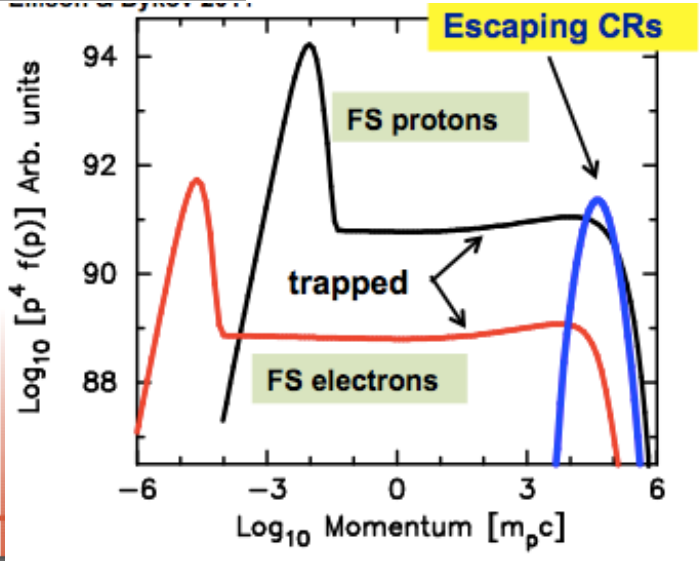
+Posters







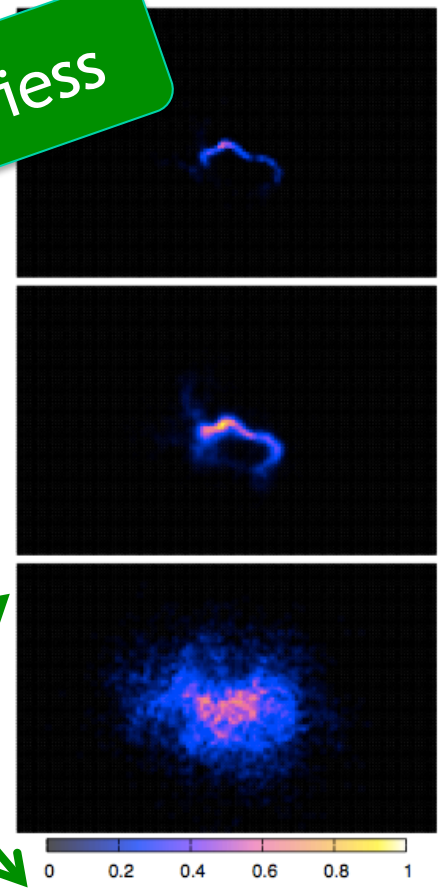


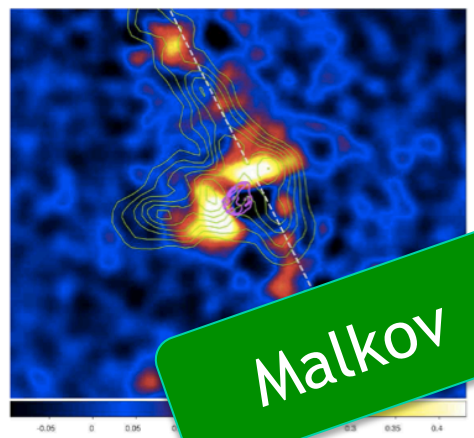


SNR Theory

- Topics/Trends
  - Magnetic field amplification
    - strongly supported by observations
    - developing understanding of how it works
  - Escape
    - expectations of anisotropy
      - ordered fields
      - large scale components of turbulent fields
    - no consensus on speed or spectrum
  - Maximum acceleration energy
    - (Very) young SNRs strongly favoured for PeV particle acceleration
  - Reconnection?
    - well maybe, DSA still firm favourite

Kachelriess





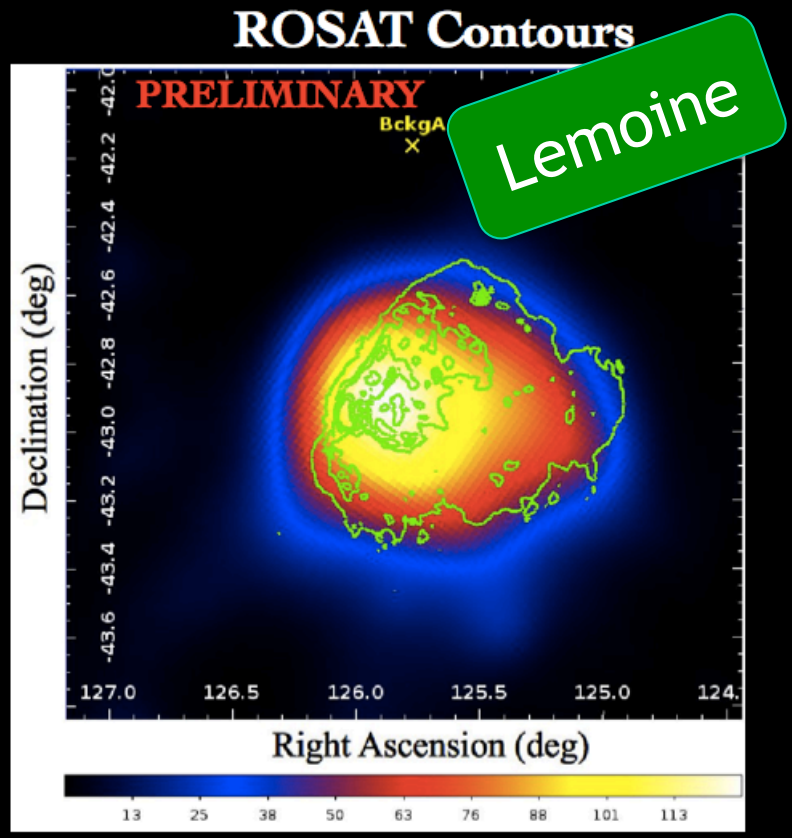
Malkov

Fermi-LAT γ-image of SNR W44, *Uchiyama et al 2012*

SNRs at GeV

- Status 2008 = EGRET
  - ~0 unambiguous detections of Supernova Remnants
- Fermi
  - 2FGL: 78 associations (but expect 45% by chance…)
  - SNR catalogue: 52/278 radio SNRs have coincident GeV emission
    - 12 identified SNR (extended)
    - 6 new extended candidates
    - 14 "SNR-like" point-source associations

Giordano



Lemoine

e.g. Puppis A
4000 years old (Sedov)
30 pc, n~4cm^{-3}
GeV Radius: 0.38±0.04°

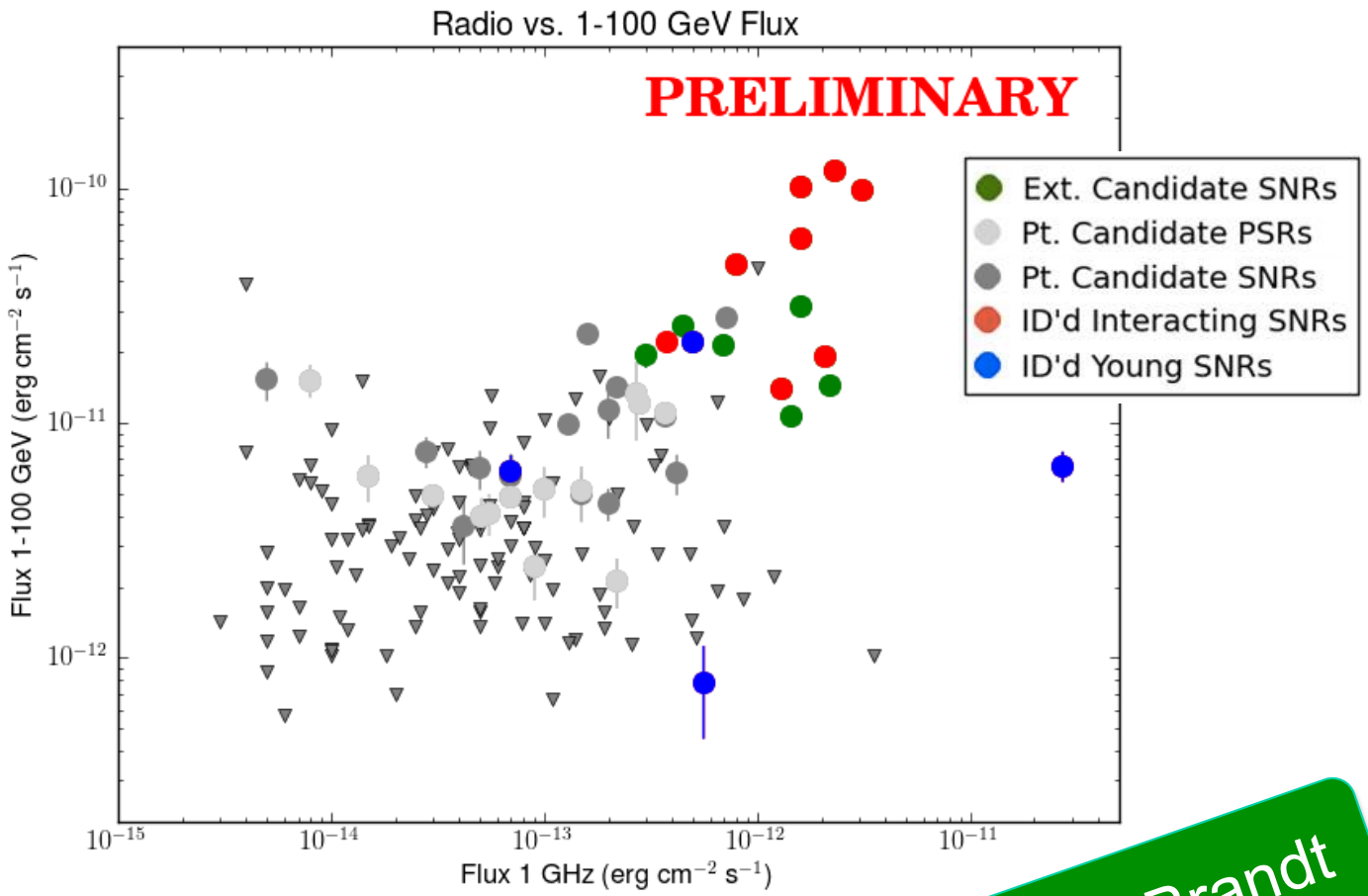
Preliminary results I
SNRs Radio vs GeV Flux

Remnants known to be interacting with large molecular clouds show a good correlation

Young seems to be more out-liers

PSRs contamination is under investigation (MW data)

New Candidates



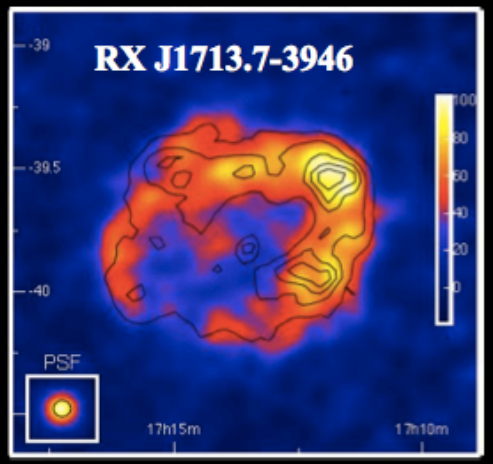
Giordano + Brandt

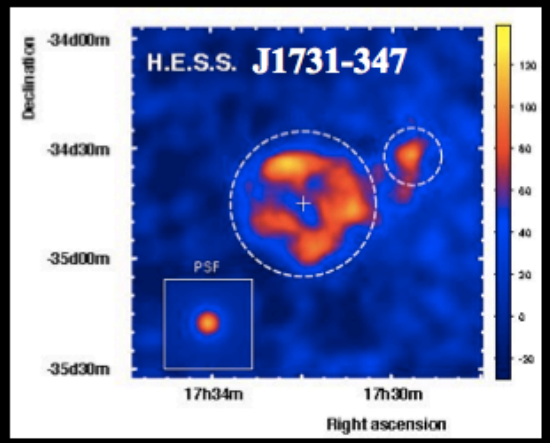
TeV Shells at GeV

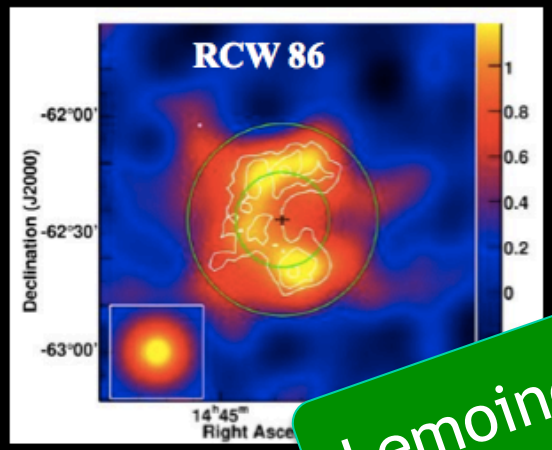
University of Leicester

A hadronic scenario requires hard proton spectral index in all TeV detected shell-type SNRs ($\Gamma \leq 1.8$)

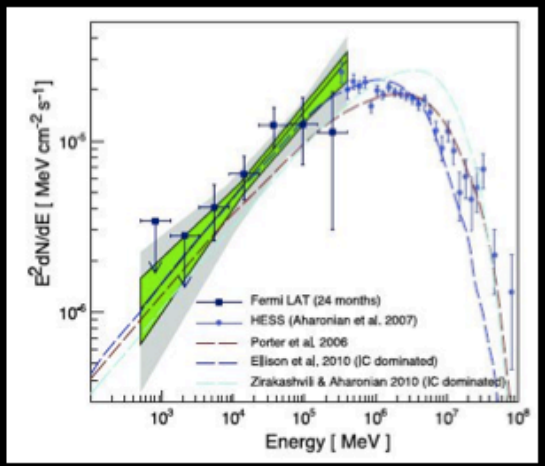
=> See Posters on RCW 86 by Renaud et al. & HESS J1731-347 by Acero et al.

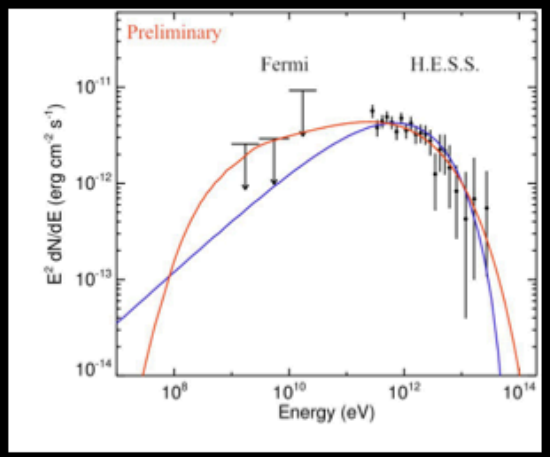


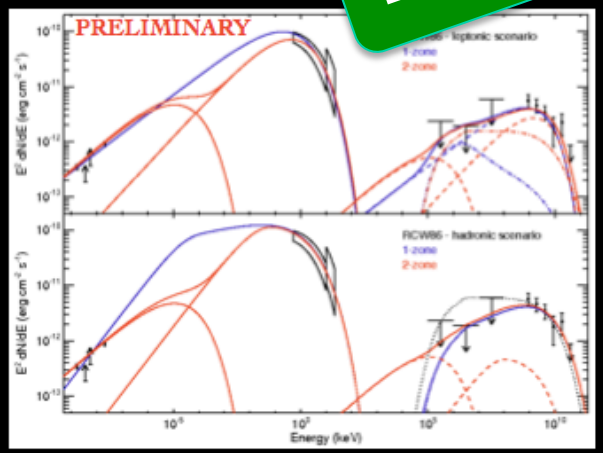




Lemoine







(selection effects?: TeV shells peak at TeV energies, large enough…)

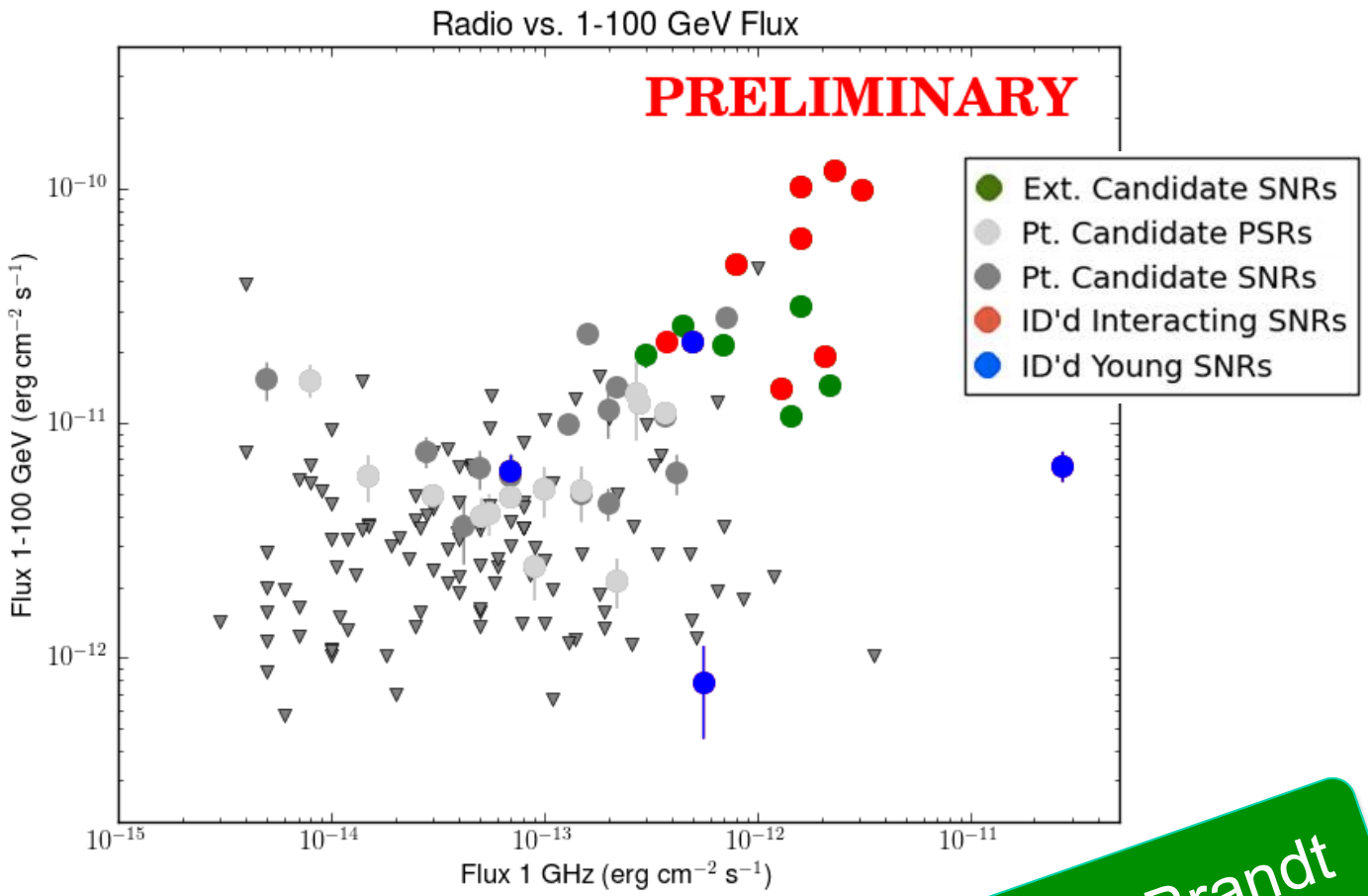
Preliminary results I
SNRs Radio vs GeV Flux

Remnants known to be interacting with large molecular clouds show a good correlation

Young seems to be more out-liers

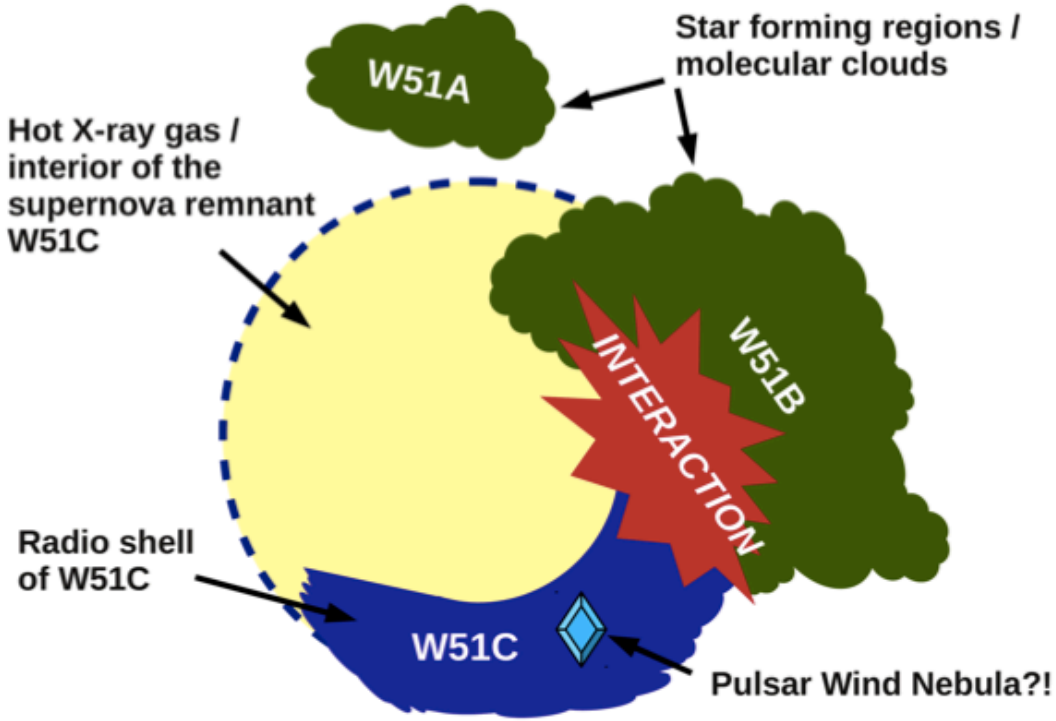
PSRs contamination is under investigation (MW data)

New Candidates



Giordano + Brandt

An illustration of the W51 complex



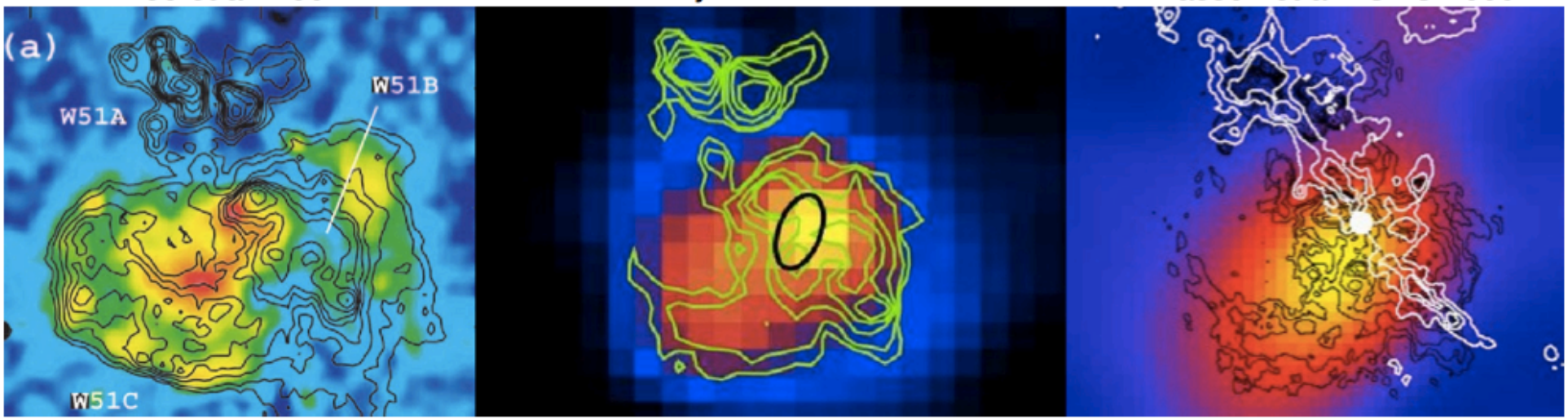
Krause

~30 ky old
@5 kpc
~0.5° diam.

ROSAT 0.7-2.5 keV
Koo et al. 2002

Fermi / LAT 2-10 GeV
Uchiyama et al. 2011

H.E.S.S. >1 TeV
Fiasson et al. ICRC 2009



GeV:

Spectrum and luminosity suggest π_0 decay origin

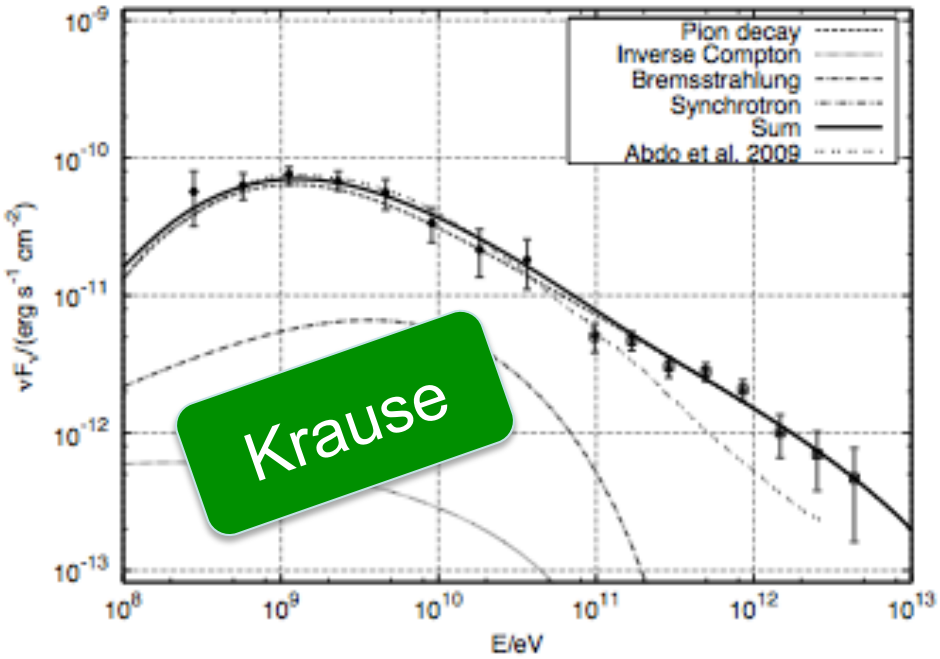
(e.g. Kinematic low-E cut-off suggested – need 100-200 MeV Fermi data to confirm)

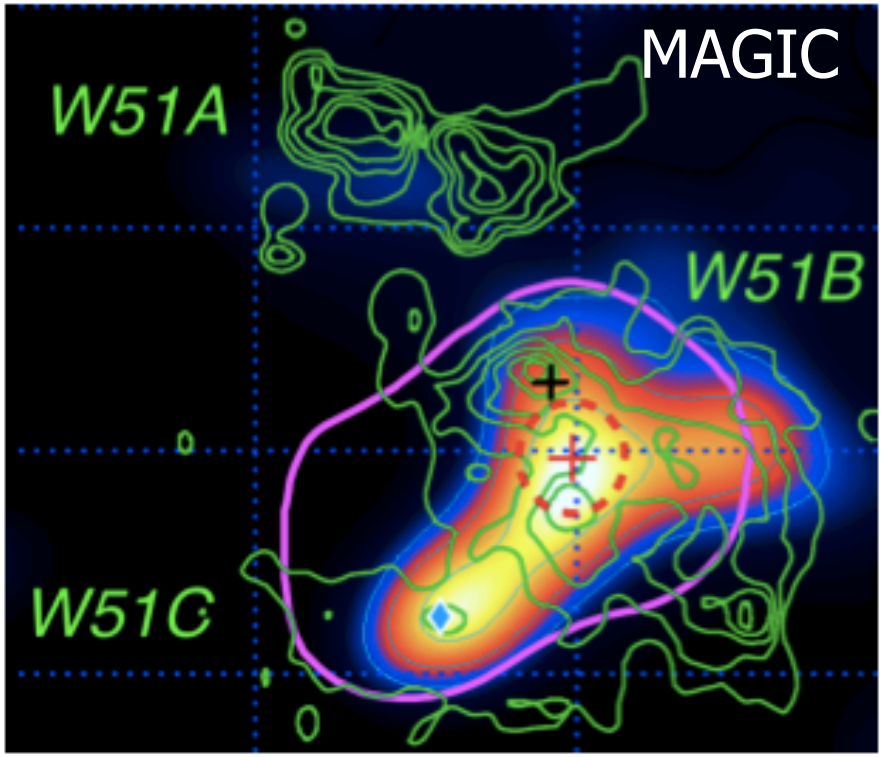
TeV:

Ongoing acceleration? - 10 TeV particles represent the "lucky few" still left?

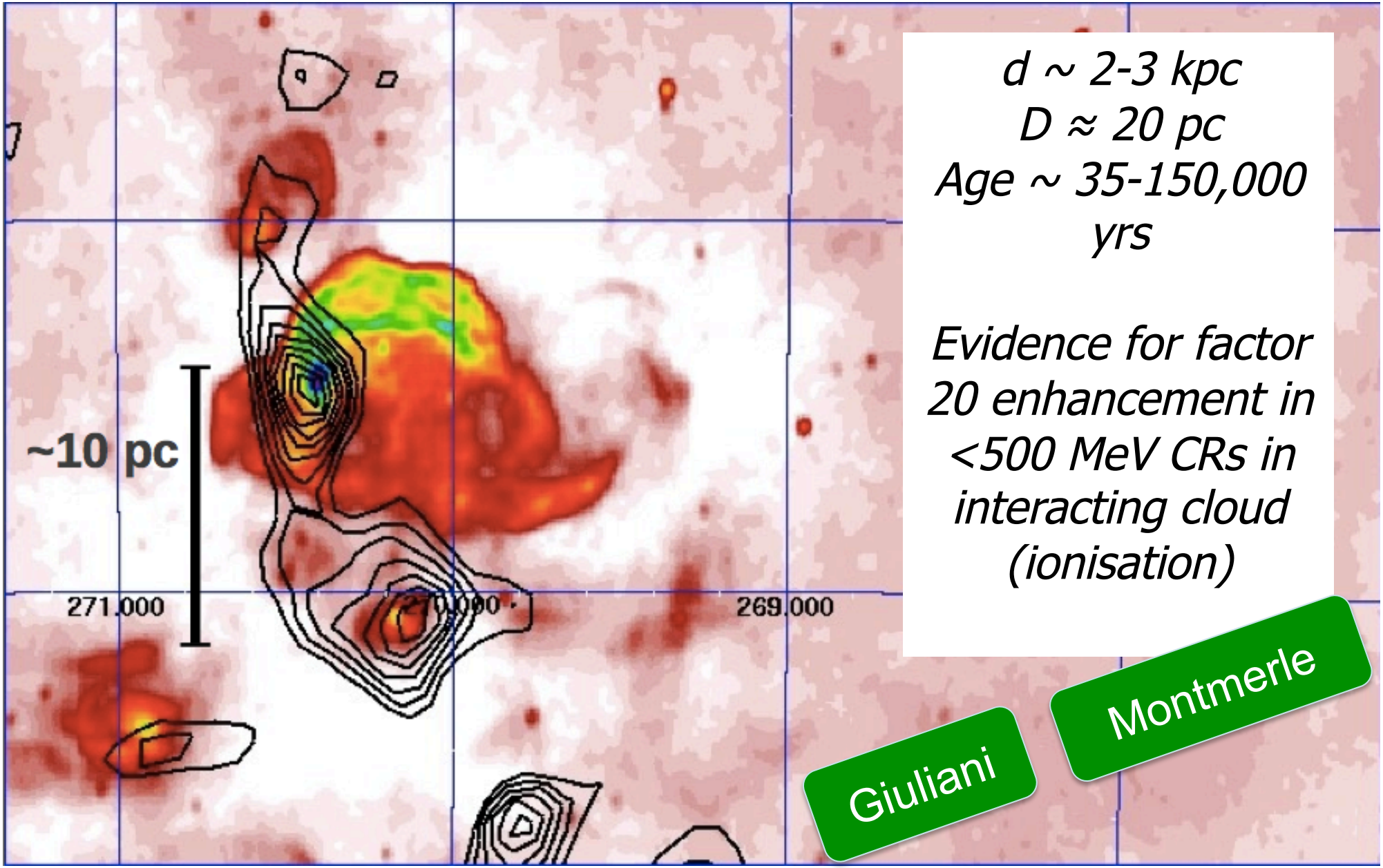
But only part of the cloud seems to be illuminated

Confinement problem, reacceleration?





W28: Another Old Interacting SNR



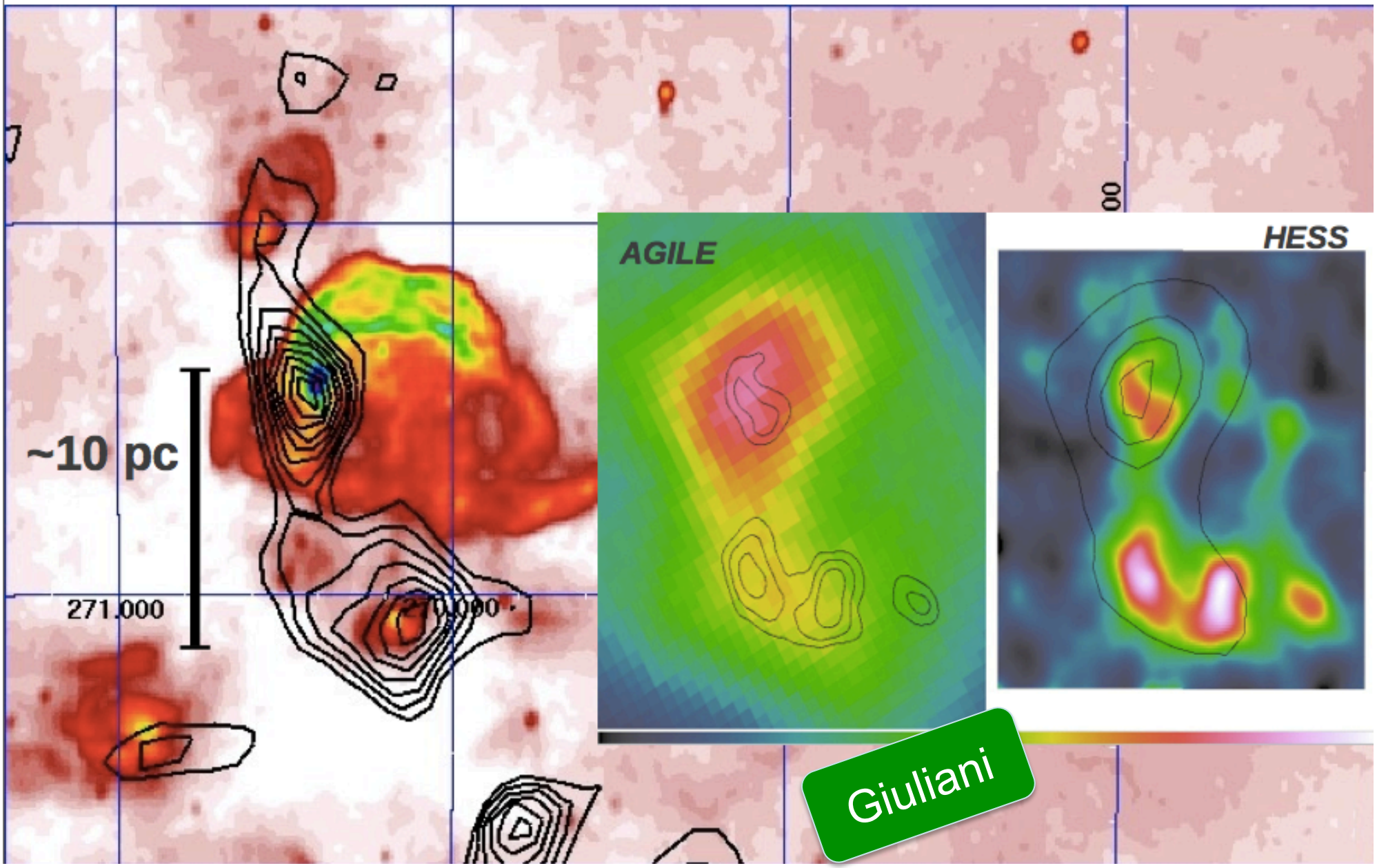
d ~ 2-3 kpc
D ≈ 20 pc
Age ~ 35-150,000 yrs

Evidence for factor 20 enhancement in <500 MeV CRs in interacting cloud (ionisation)

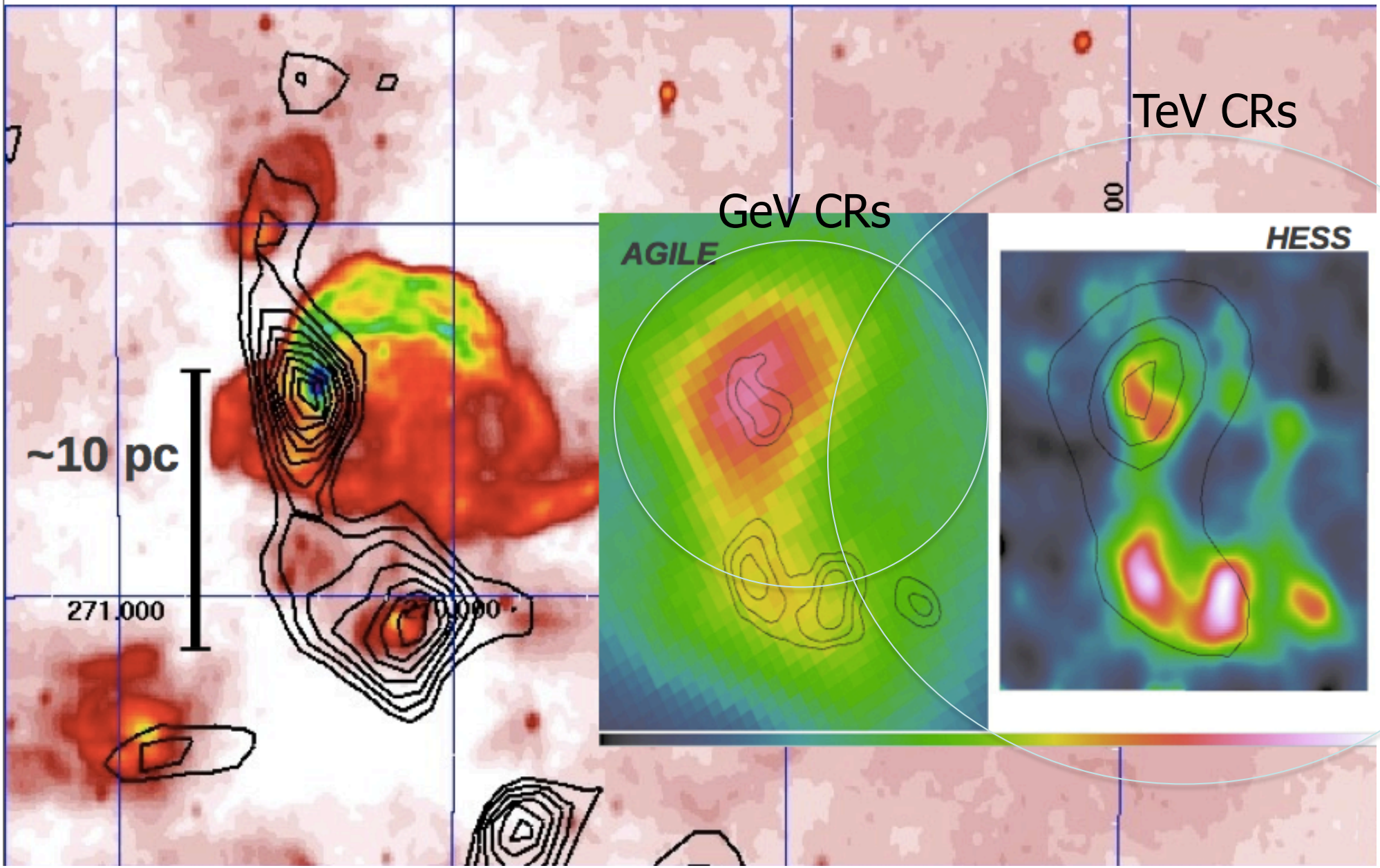
Giuliani

Montmerle

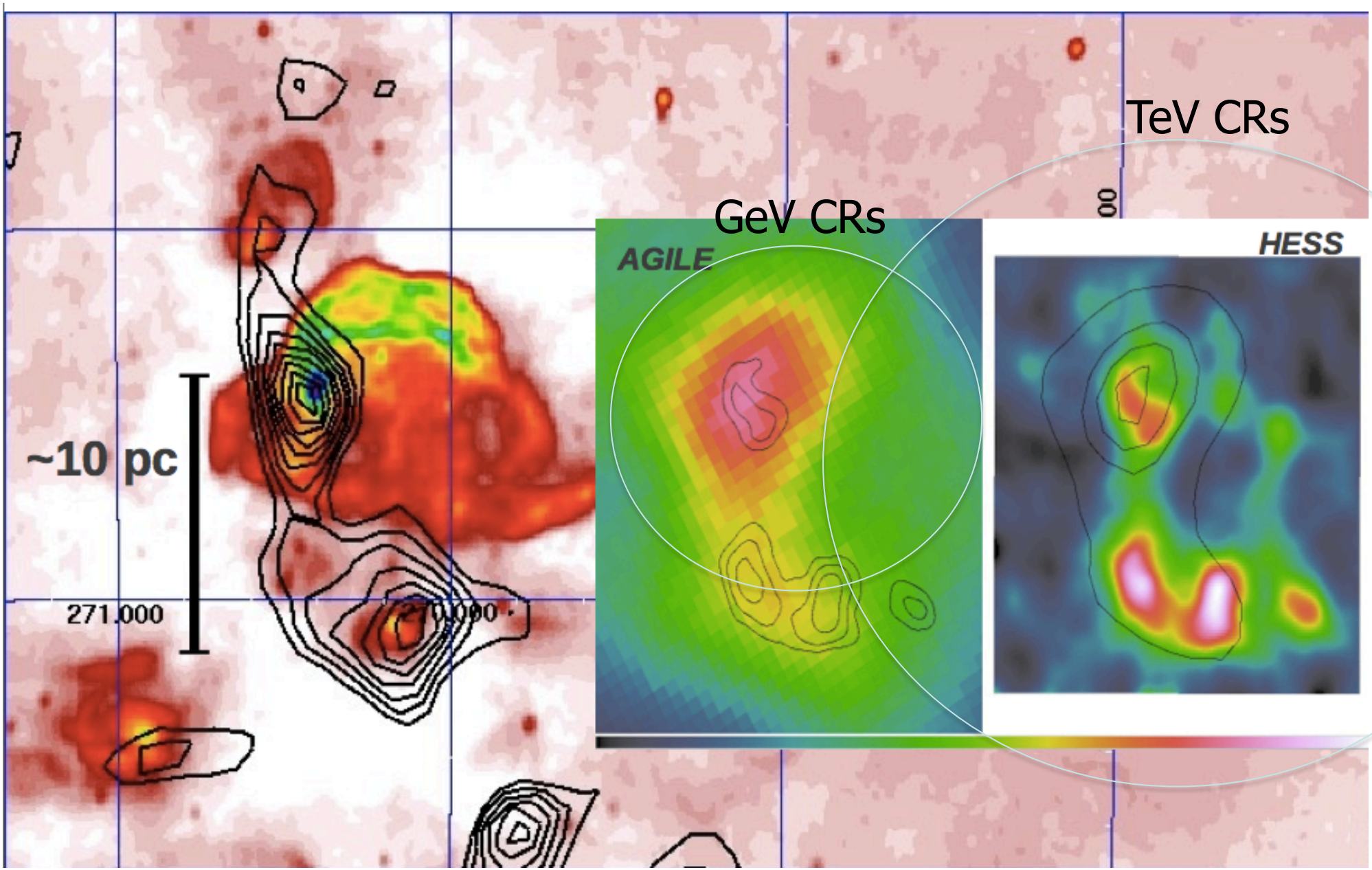
SNRs at “low” energy : diffusion of CRs (W28)

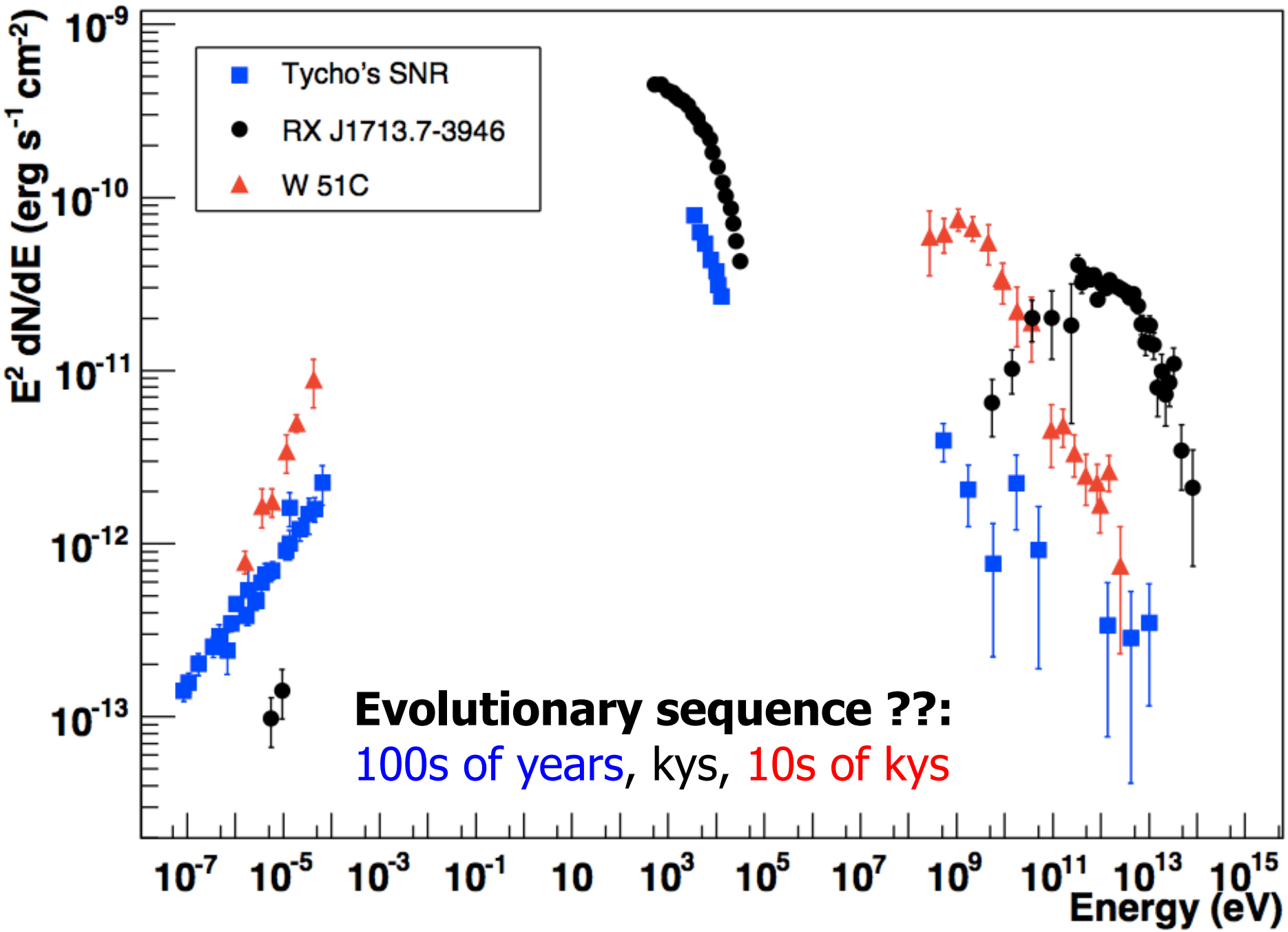


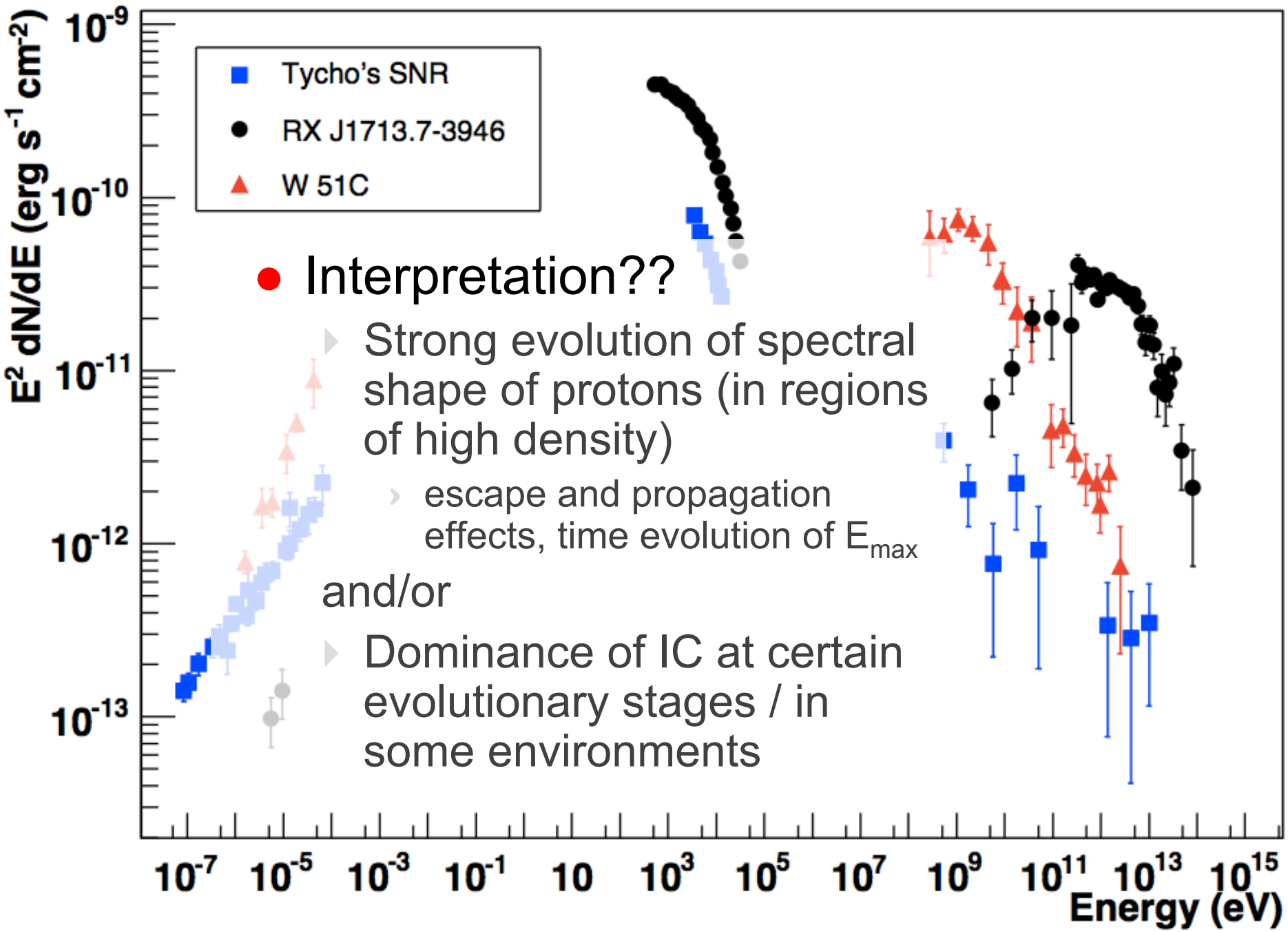
SNRs at “low” energy : diffusion of CRs (W28)



Problems: (3D) distances SNR-Clouds, Age of SNR, …




Tycho's SNR
RX J1713.7-3946
W 51C
E^2 dN/dE (erg s^{-1} cm^{-2})
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-7} 10^{-5} 10^{-3} 10^{-1} 10 10^{3} 10^{5} 10^{7} 10^{9} 10^{11} 10^{13} 10^{15}
Energy (eV)
Evolutionary sequence ??:
100s of years, kys, 10s of kys



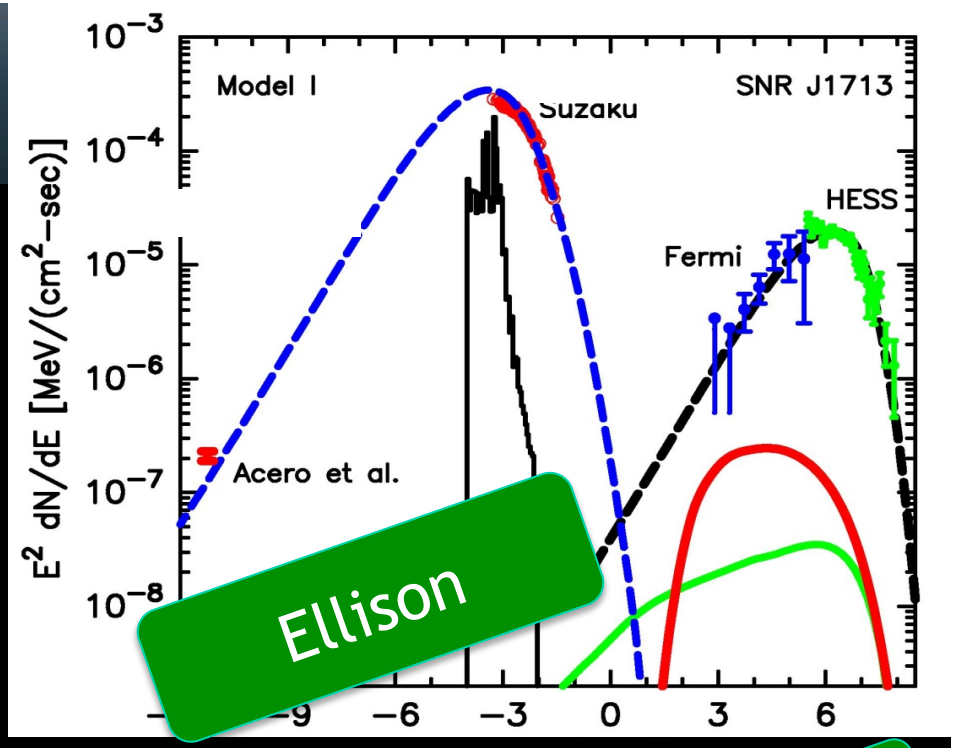
- Interpretation??
  - Strong evolution of spectral shape of protons (in regions of high density)
    - escape and propagation effects, time evolution of E_{max}

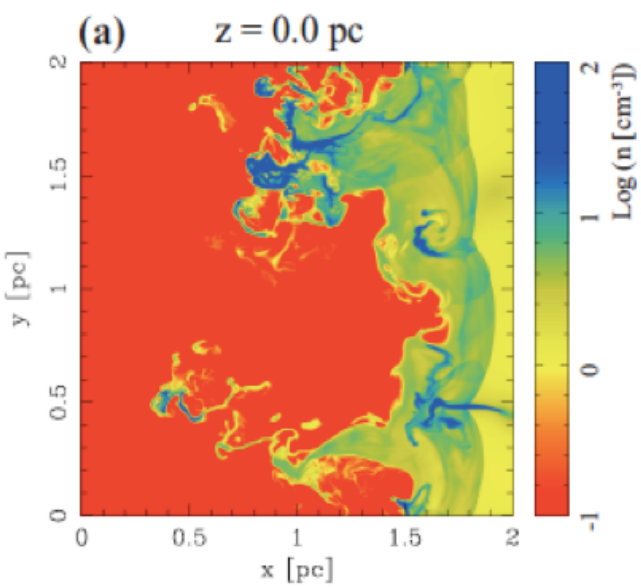
and/or

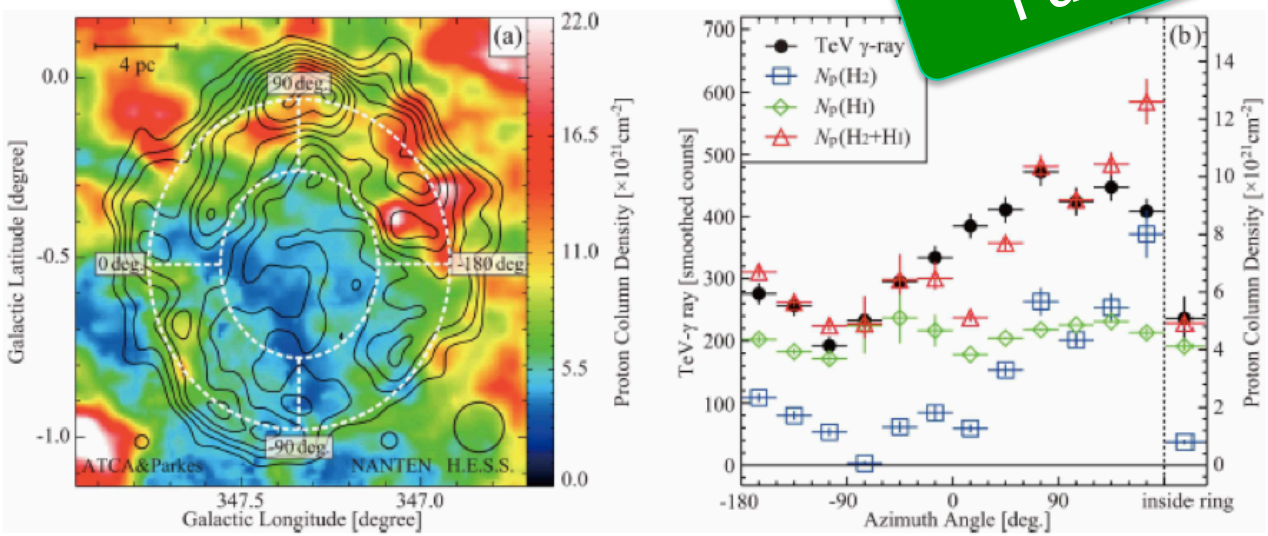
  - Dominance of IC at certain evolutionary stages / in some environments

RX J1713.7-3946

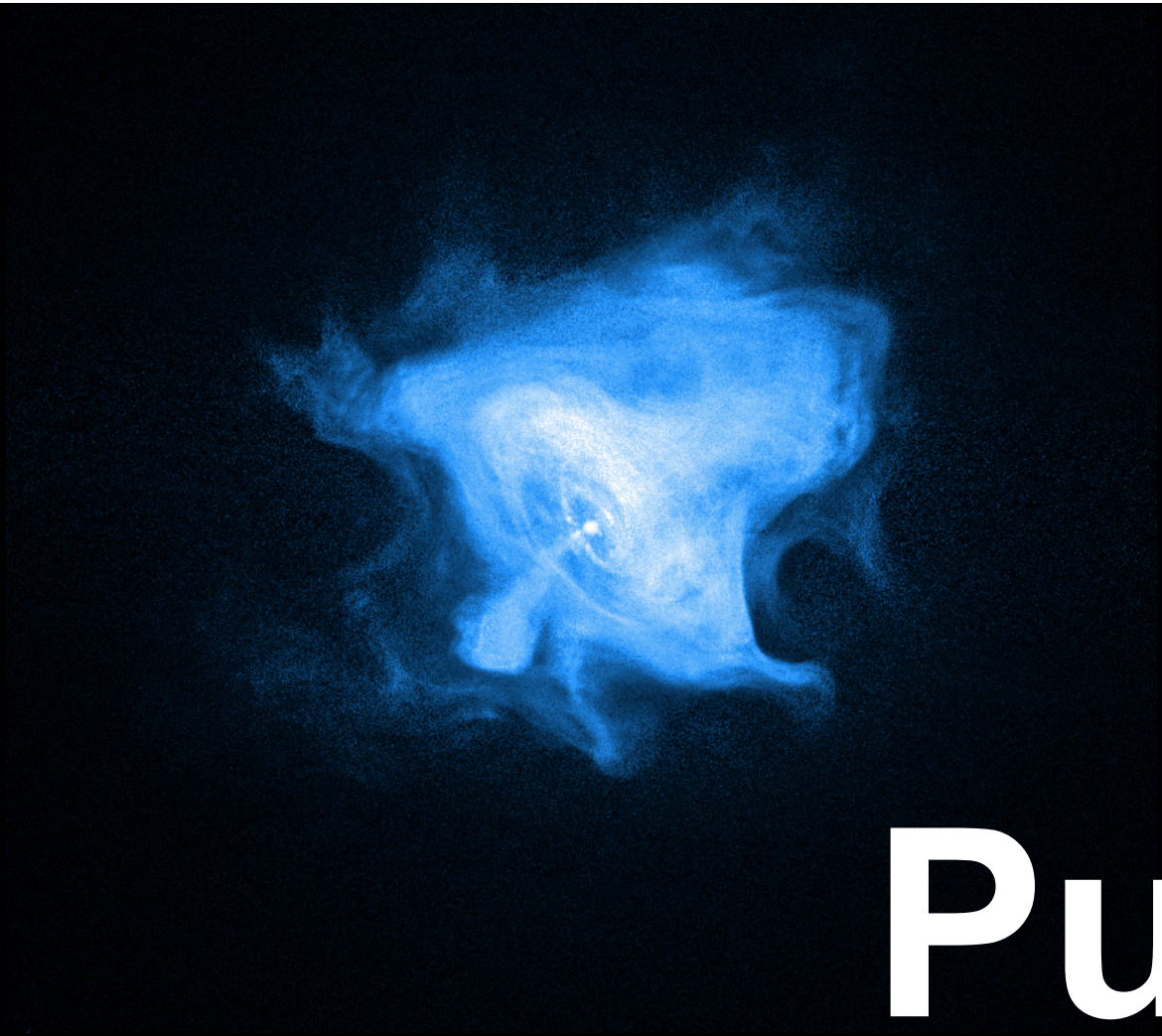
- Leptons versus Hadrons
  - Lack of thermal emission ➔ IC can dominate even if $n_p >> n_e$, BUT
  - much target material may be in cold clumps, hard for CRs to get inside…





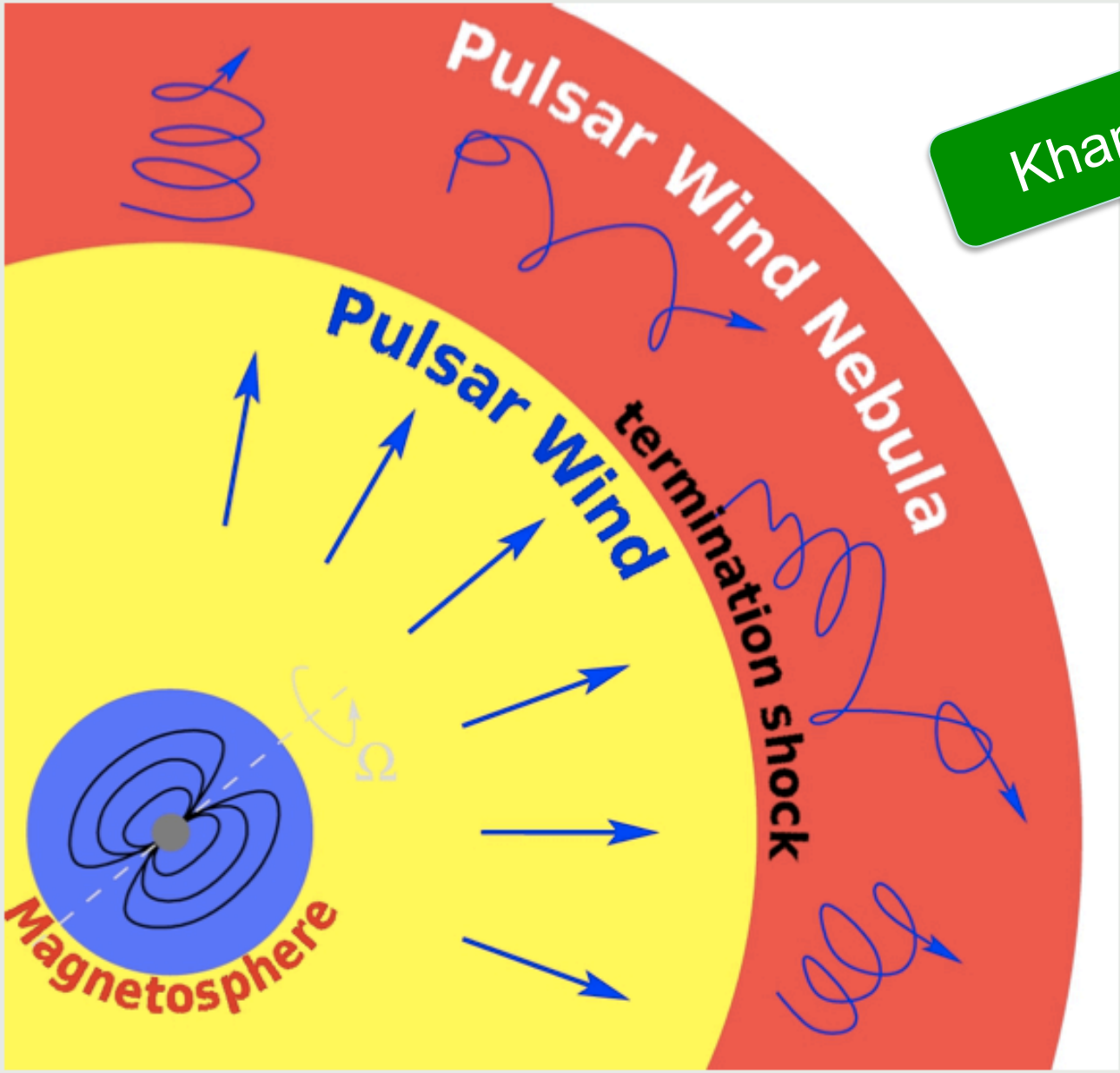


HI + 2H2



Pulsars & PWN

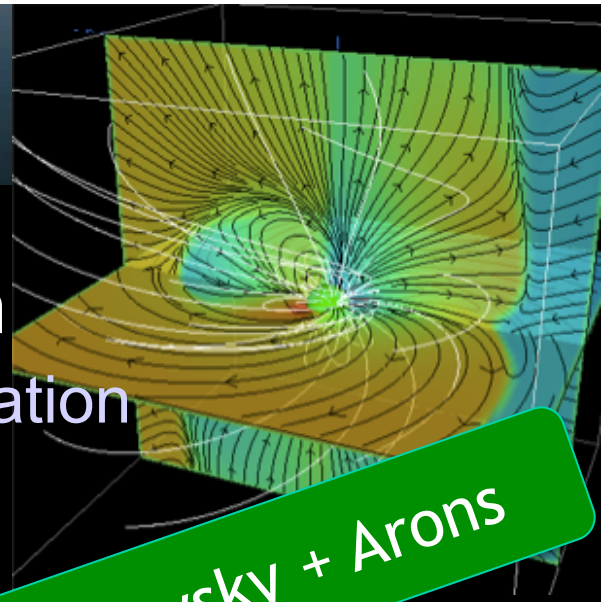
Pulsar Related Emitting Zones



Khangulyan

Pulsed Emission

- (dominantly) Magnetospheric origin
  - Expect(ed) sharp cut-off from pair-creation
  - Hints for hard tails in Fermi data
  - MAGIC detection >25 GeV (2008)
  - New VERITAS + MAGIC obs. …



Spitkovsky + Arons

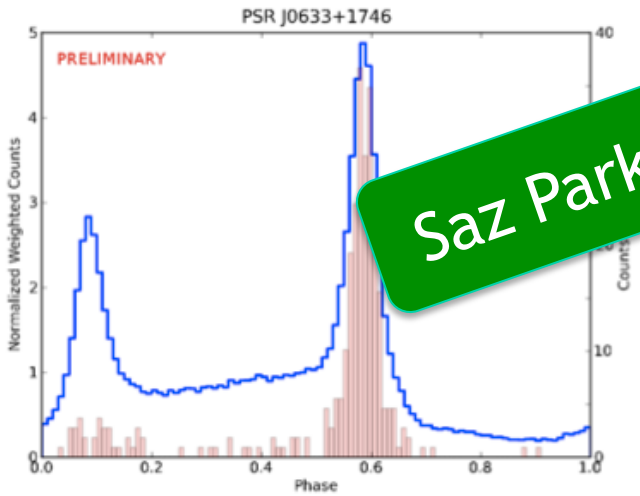
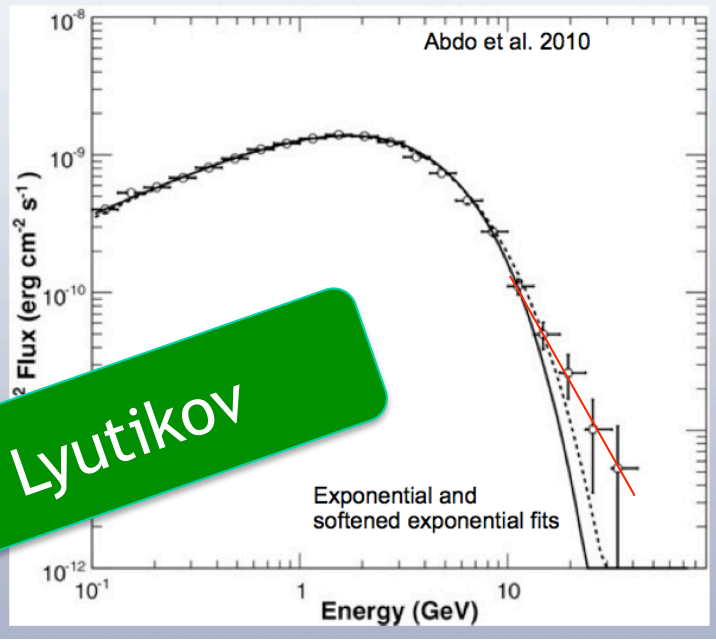


Figure: Geminga normalized weighted light curve (100 bins) in the 0.3-10 GeV range (blue) and unweighted light curve above 10 GeV (pink).

Saz Parkinson

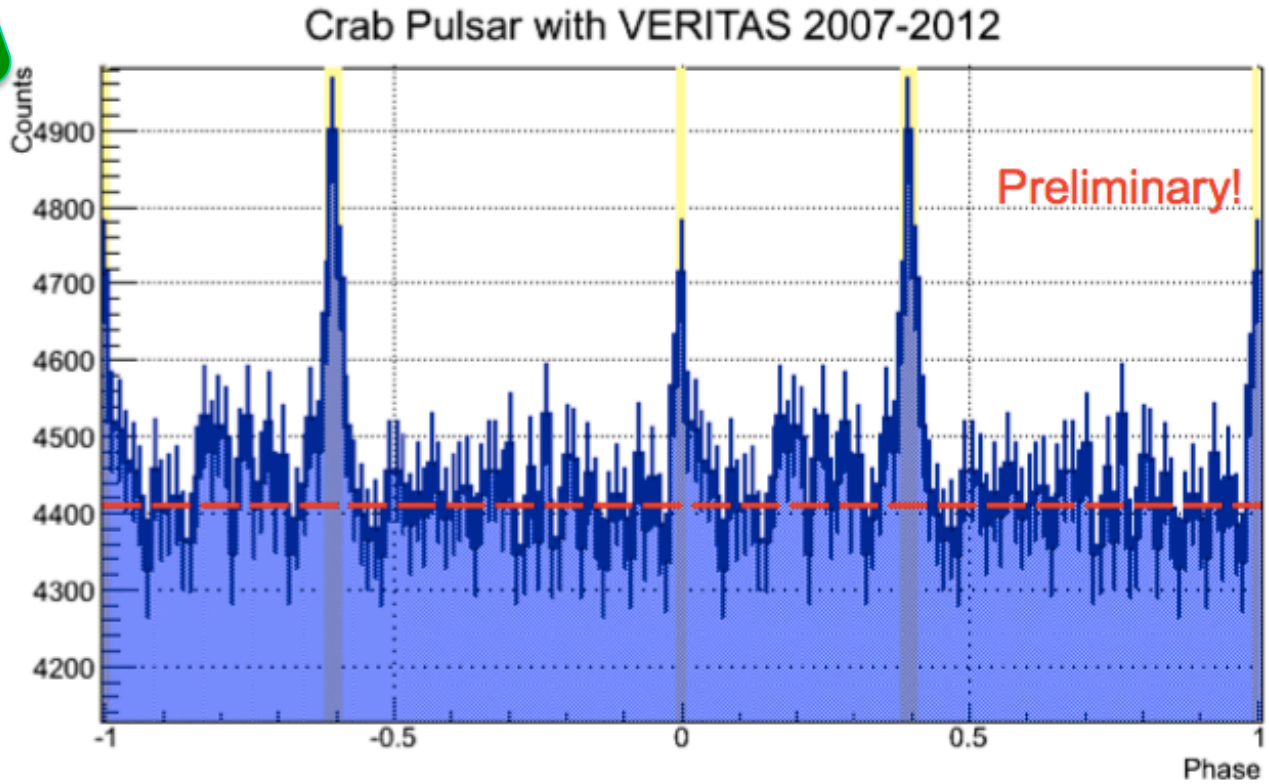
Fermi spectrum of Geminga

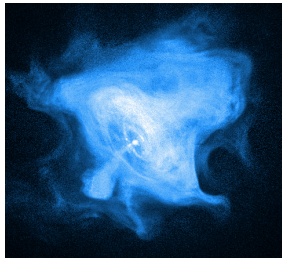


Lyutikov

Pulse Profile: 2007-2012

Zitzer





Preliminary results

~130hrs total observation time

10.7σ using Li & Ma significance

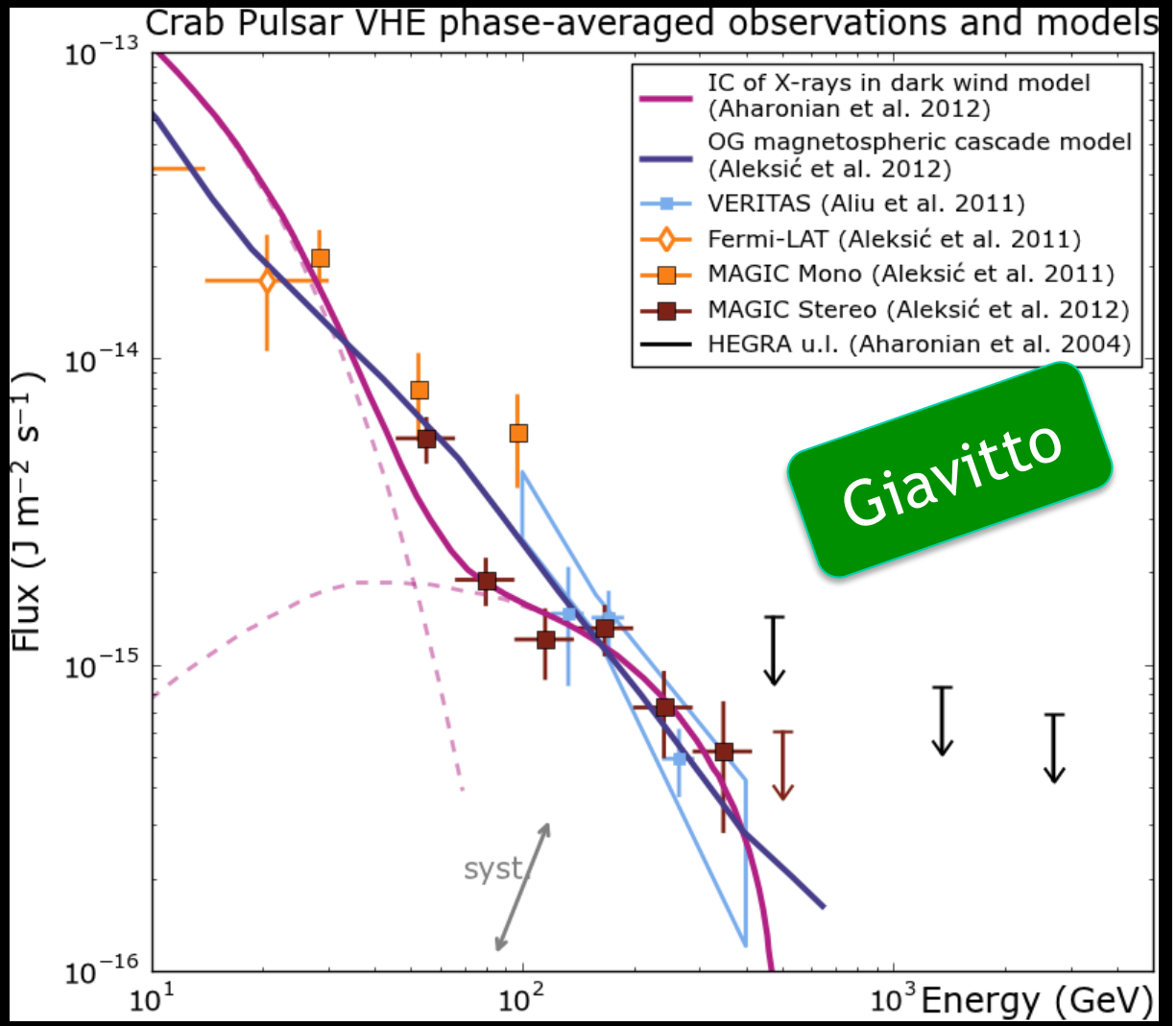
1514 ±145 total pulsed excess events in P1 and P2

>~150 GeV (?)

Crab Pulsed Spectrum

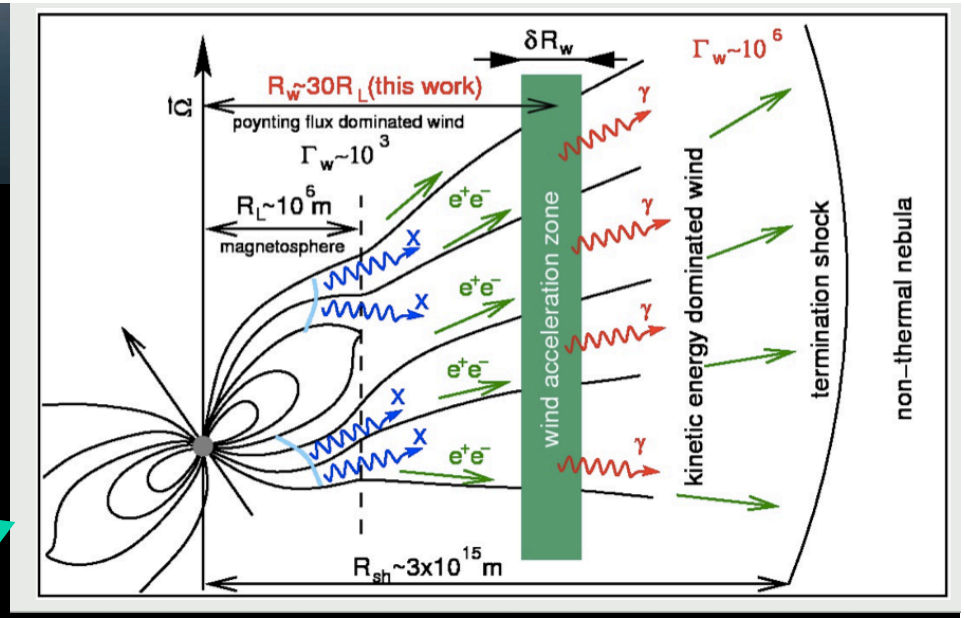
University of Leicester

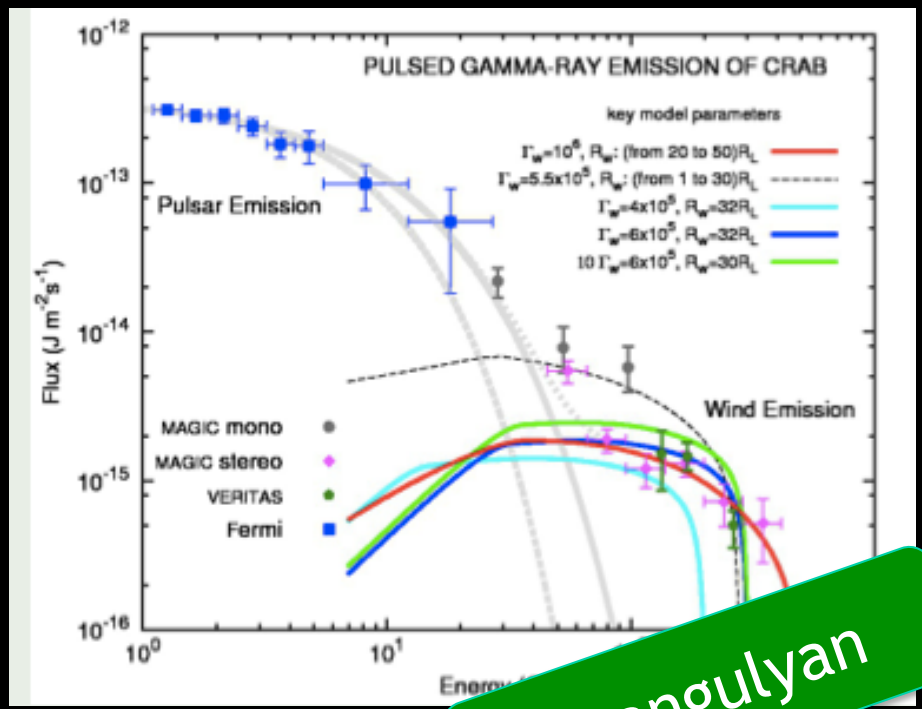
- Spectrum extends to at least ~300 GeV
- Good agreement MAGIC +VERITAS
  - feature at 100 GeV
  - cut-off?



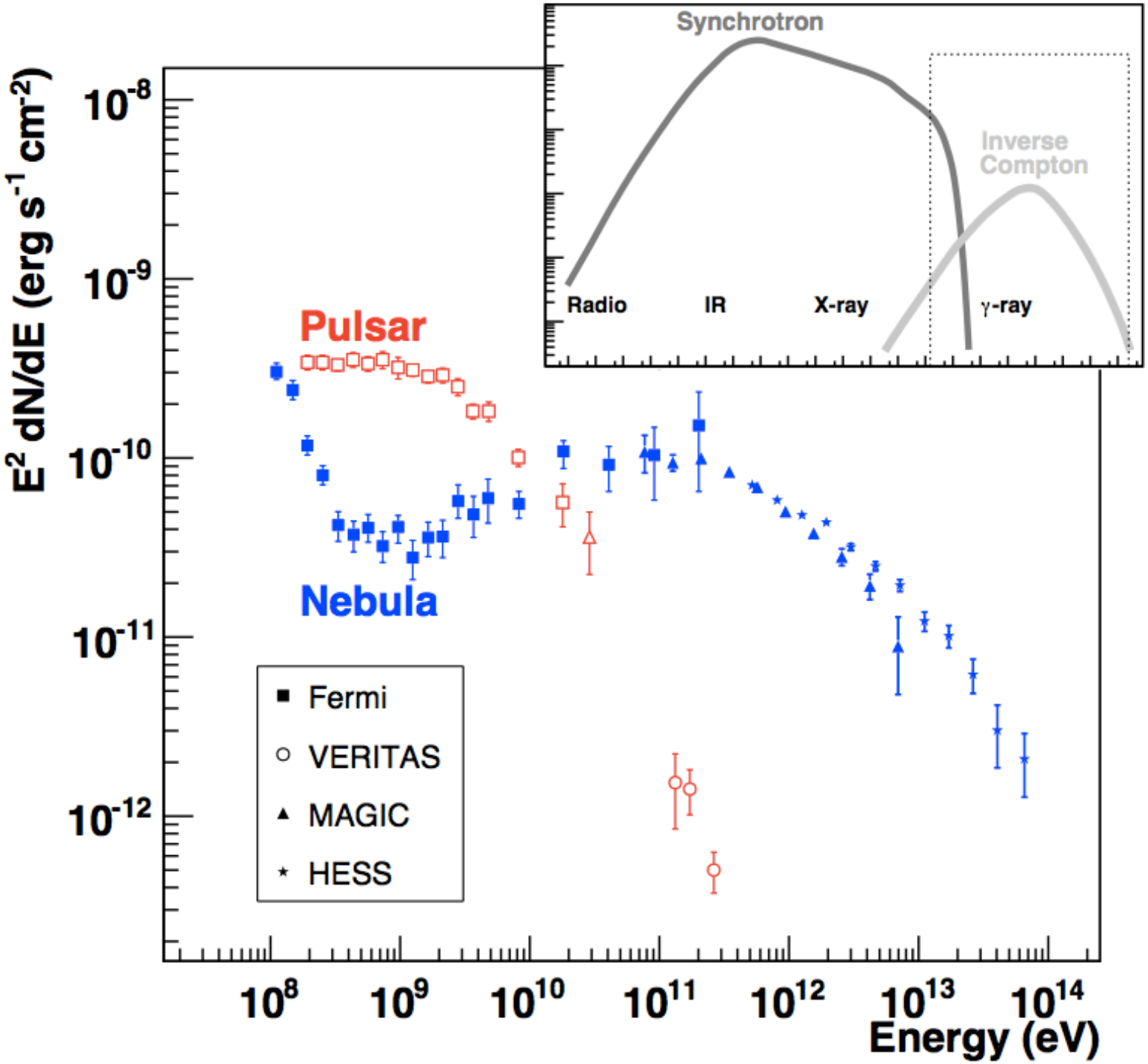
Interpretation

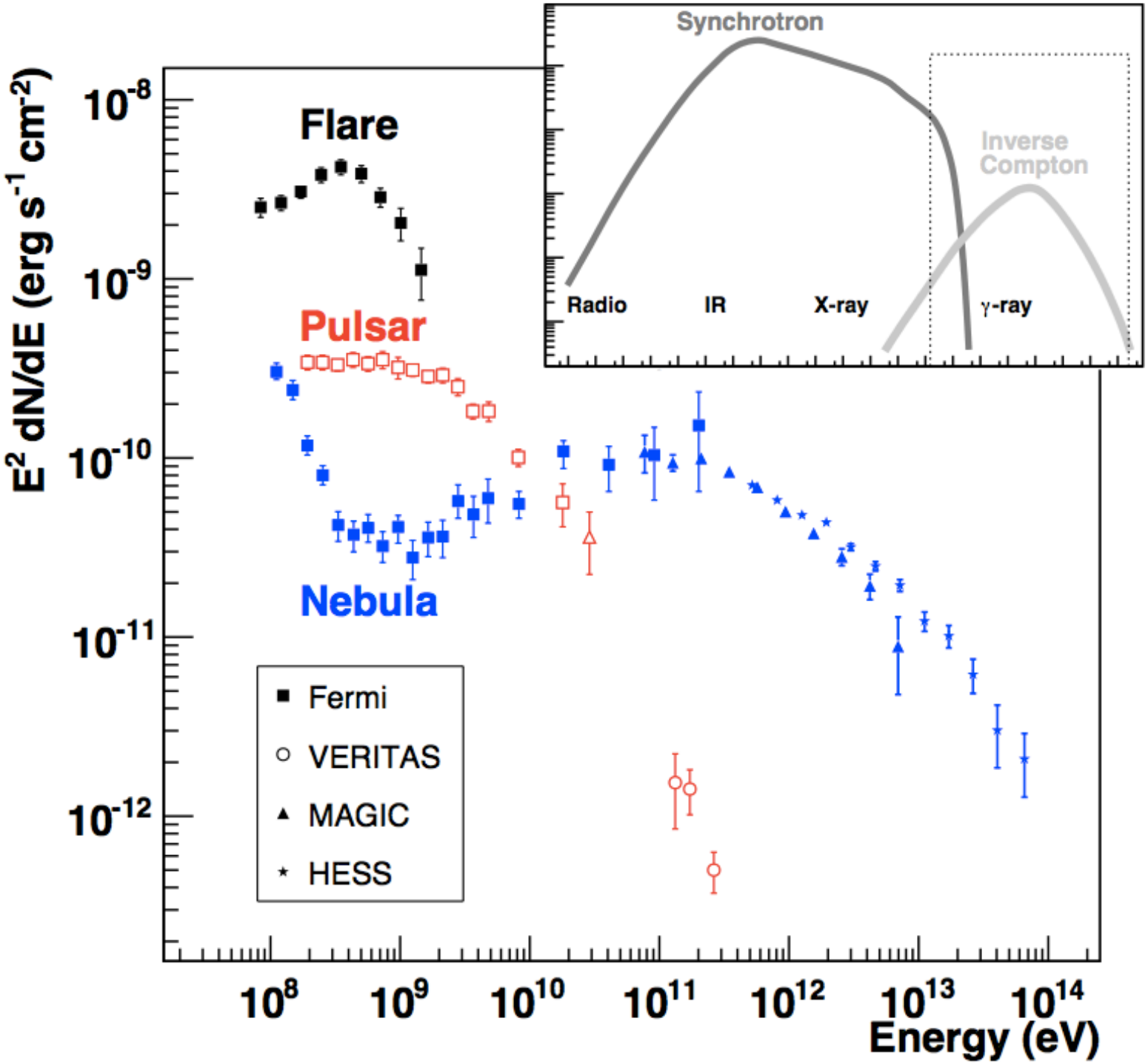
- Curvature radiation is tricky, IC from pairs? synchrotron? IC from cold wind?
- Improved spectra should be able to discriminate
  - deeper observations with IACTs needed





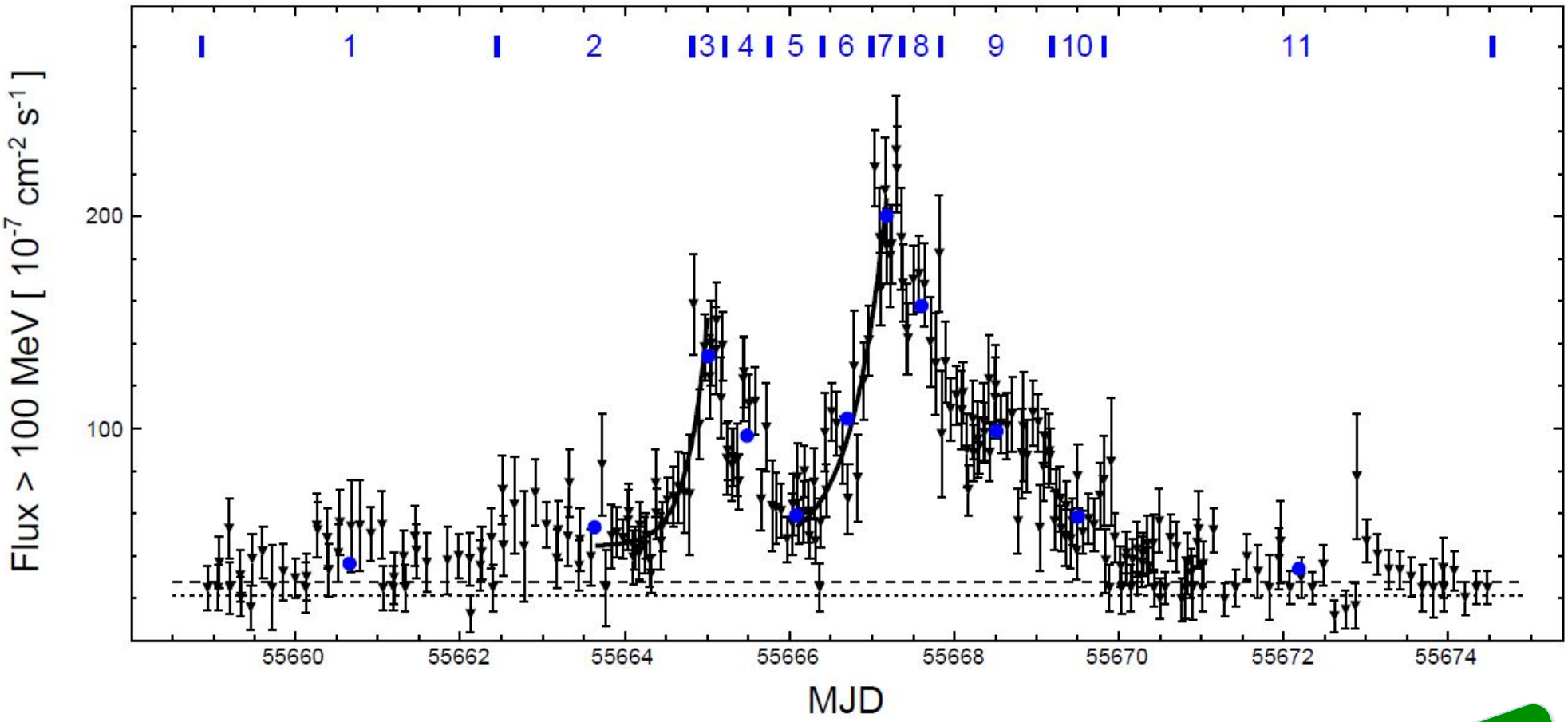
Khangulyan


Synchrotron
Inverse Compton
Radio
IR
X-ray
γ-ray
Pulsar
Nebula
Fermi
VERITAS
MAGIC
HESS
E² dN/dE (erg s⁻¹ cm⁻²)
Energy (eV)


Synchrotron
Inverse Compton
Radio
IR
X-ray
γ-ray
Flare
Pulsar
Nebula
Fermi
VERITAS
MAGIC
HESS
E² dN/dE (erg s⁻¹ cm⁻²)
Energy (eV)

The Crab major gamma-ray flare in April 2011

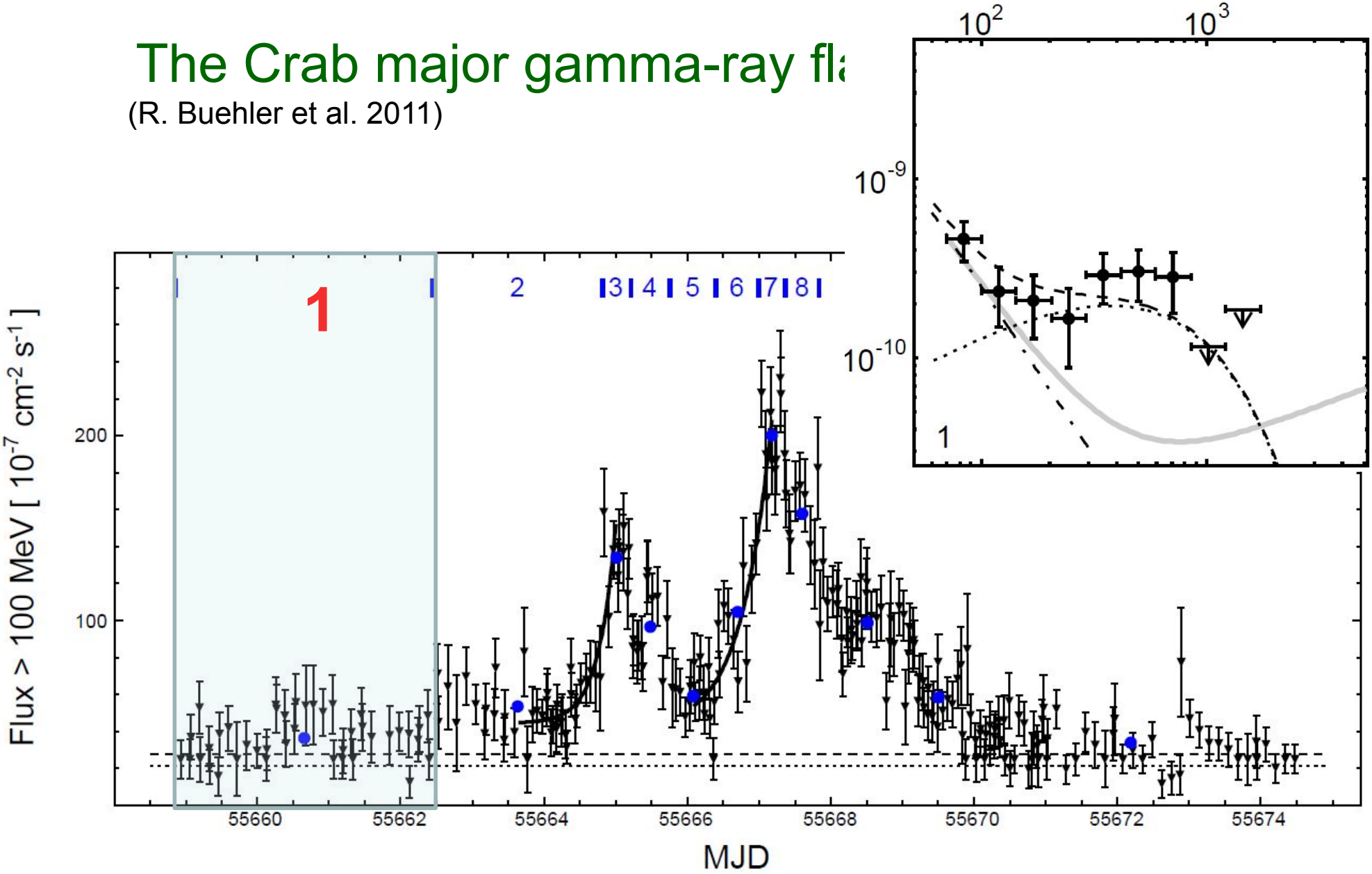
(R. Buehler et al. 2011)



Tavani

The Crab major gamma-ray fl

(R. Buehler et al. 2011)



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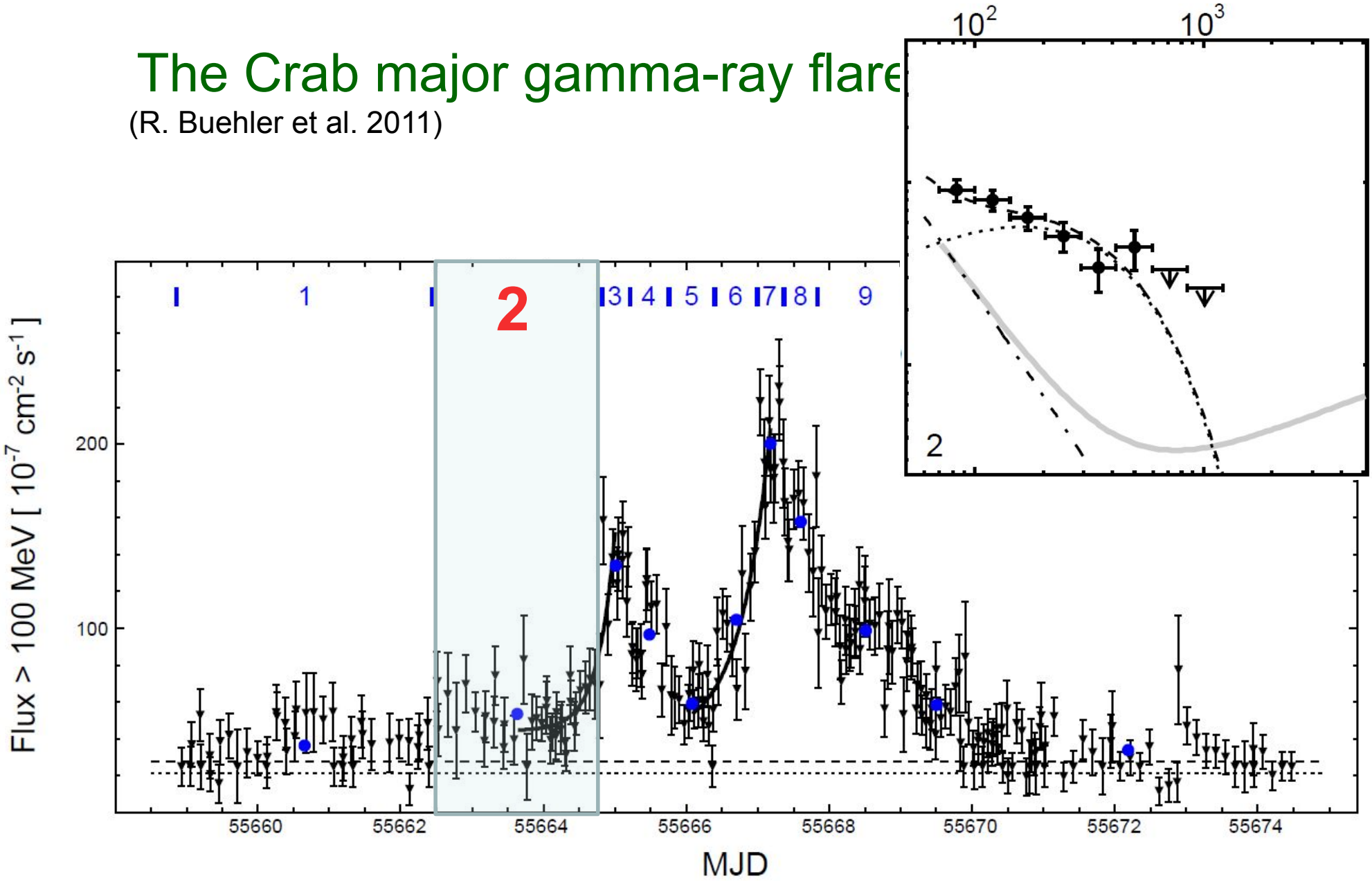

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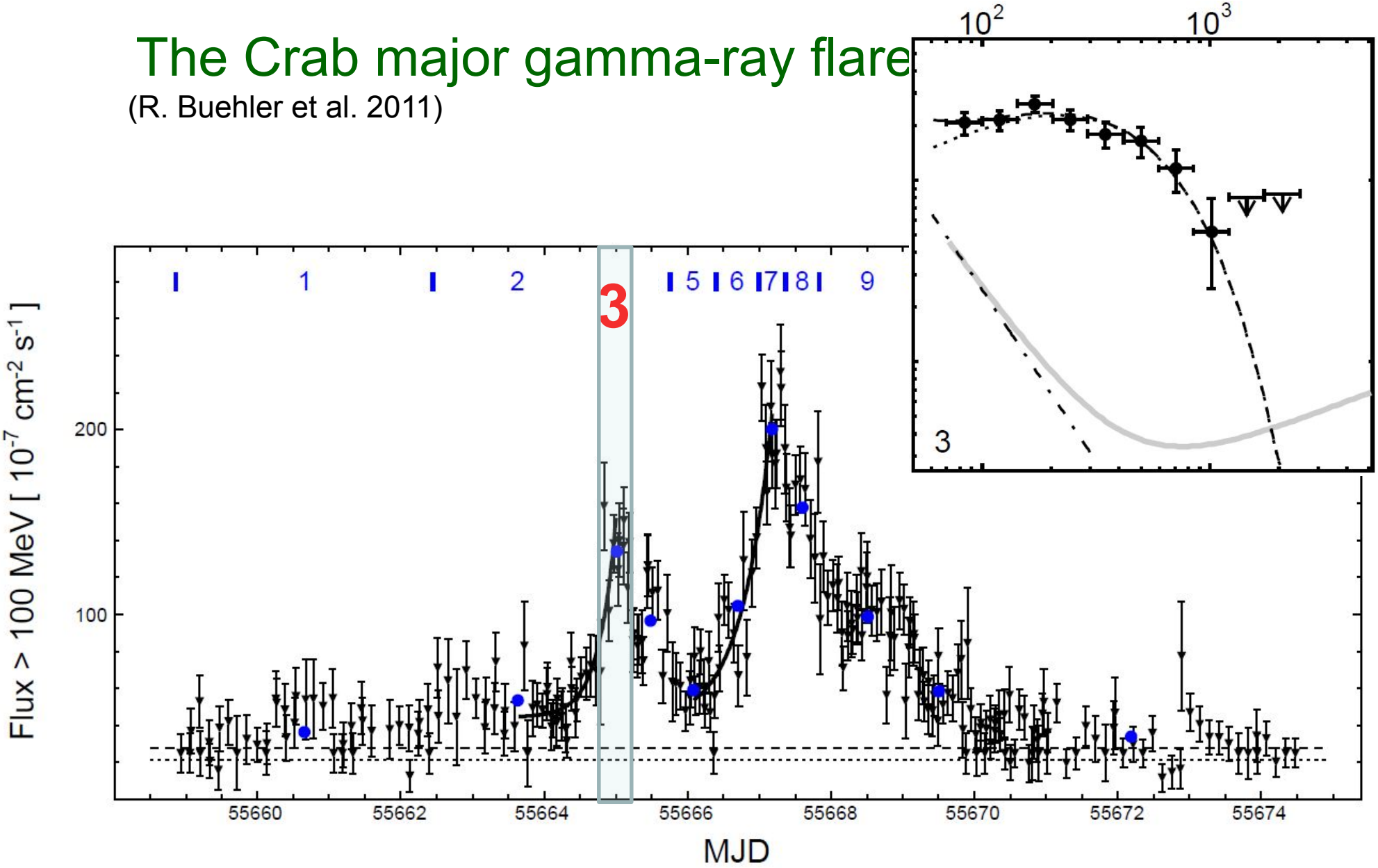

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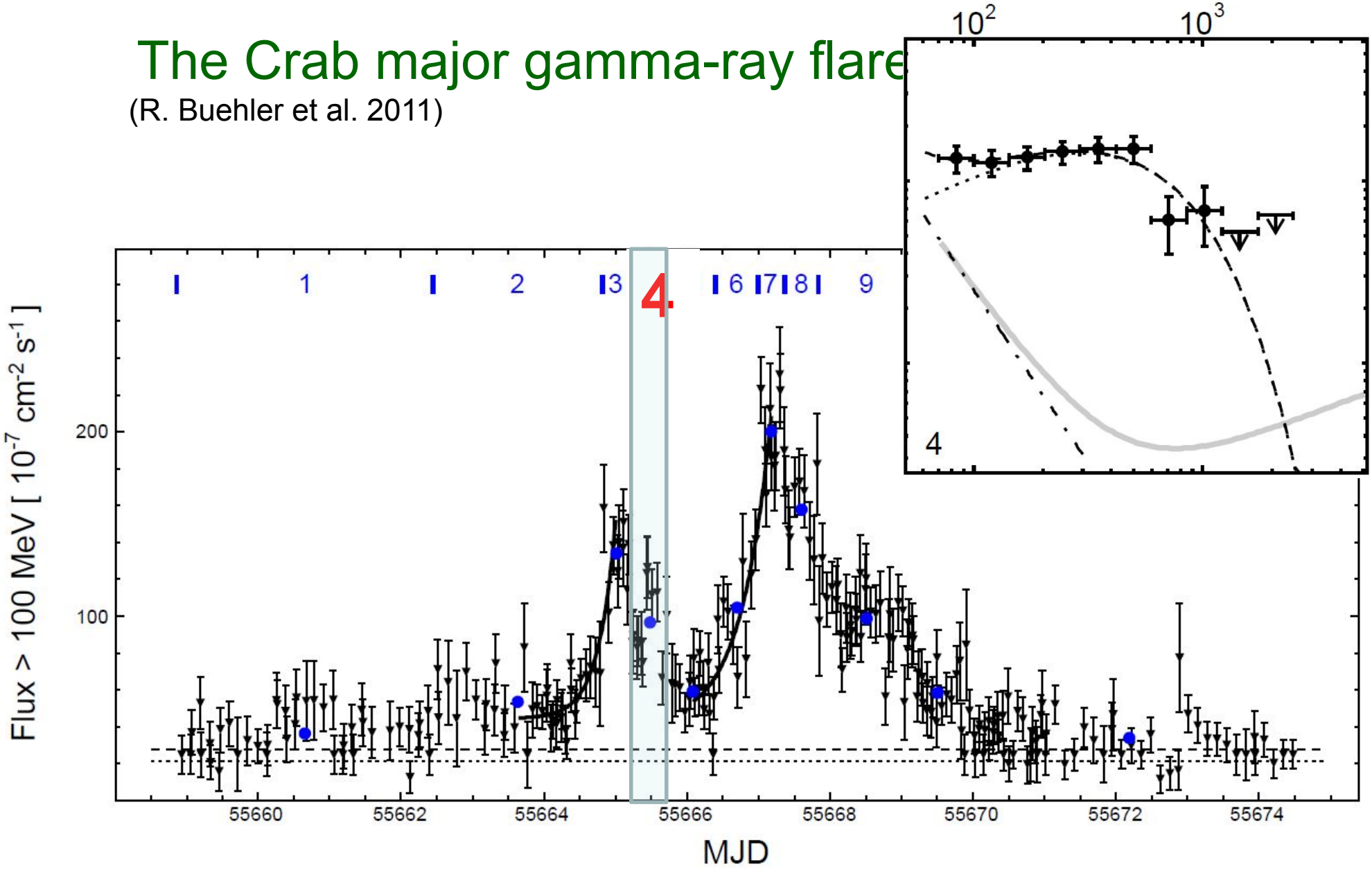

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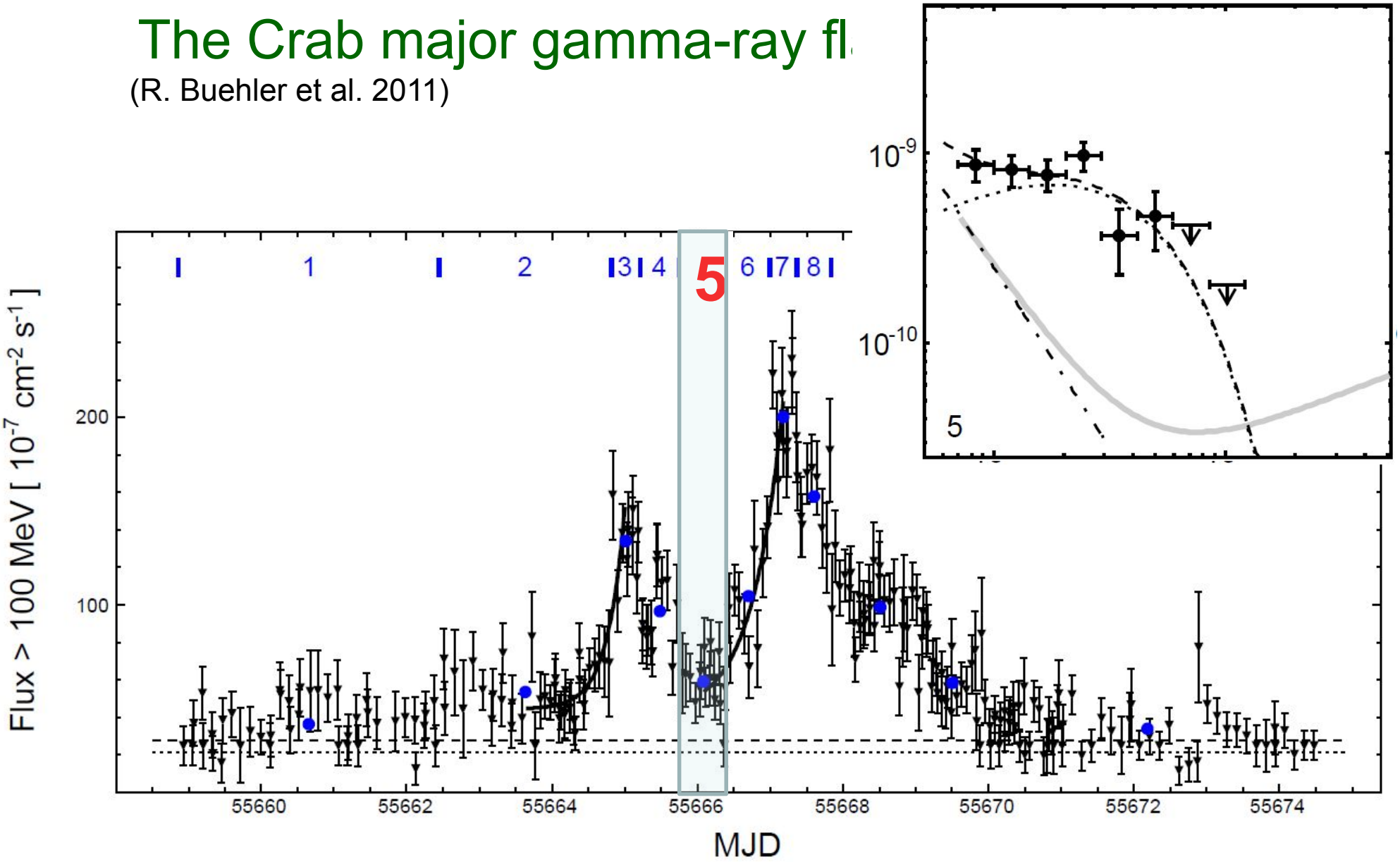

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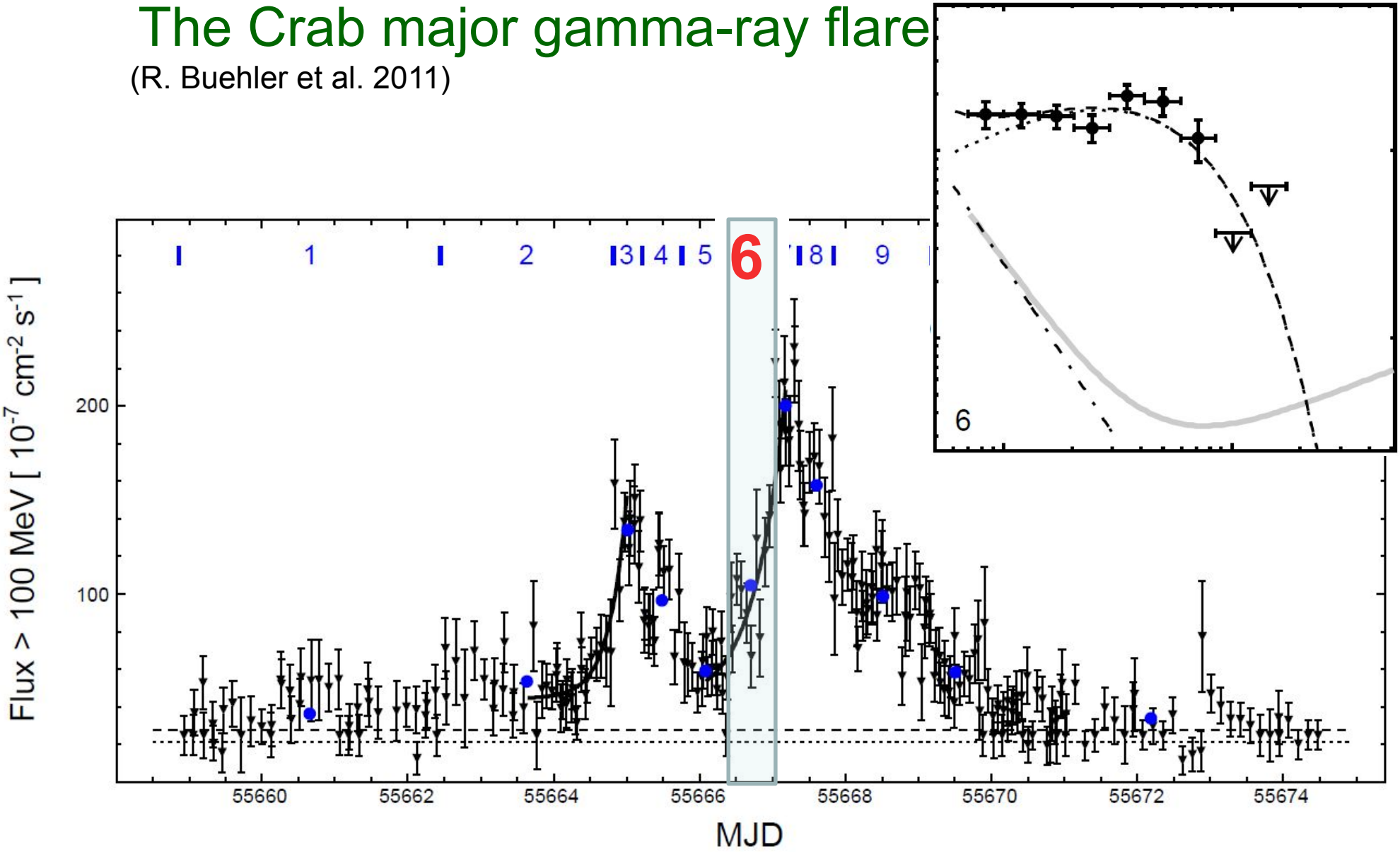

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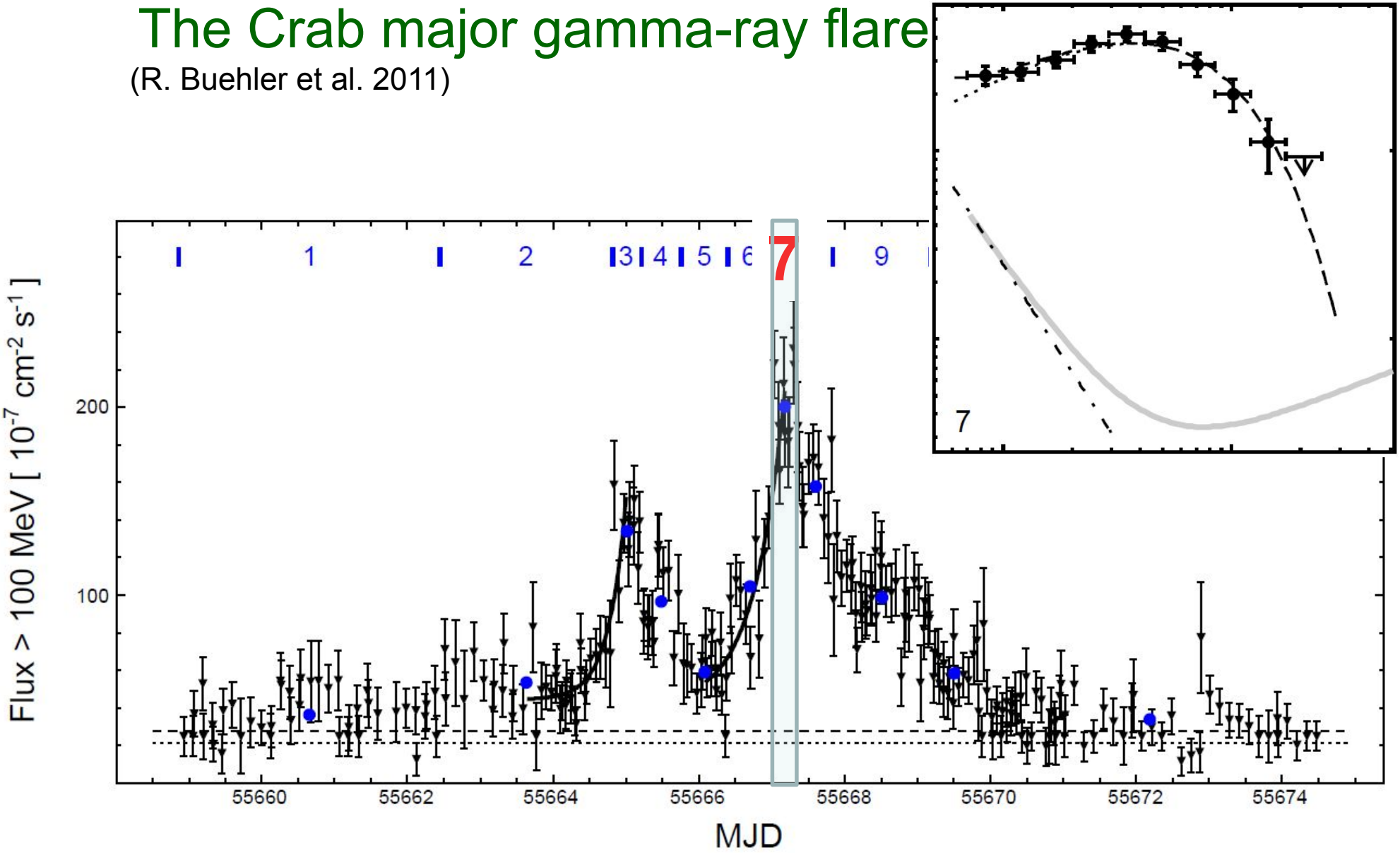

The Crab major gamma-ray flare

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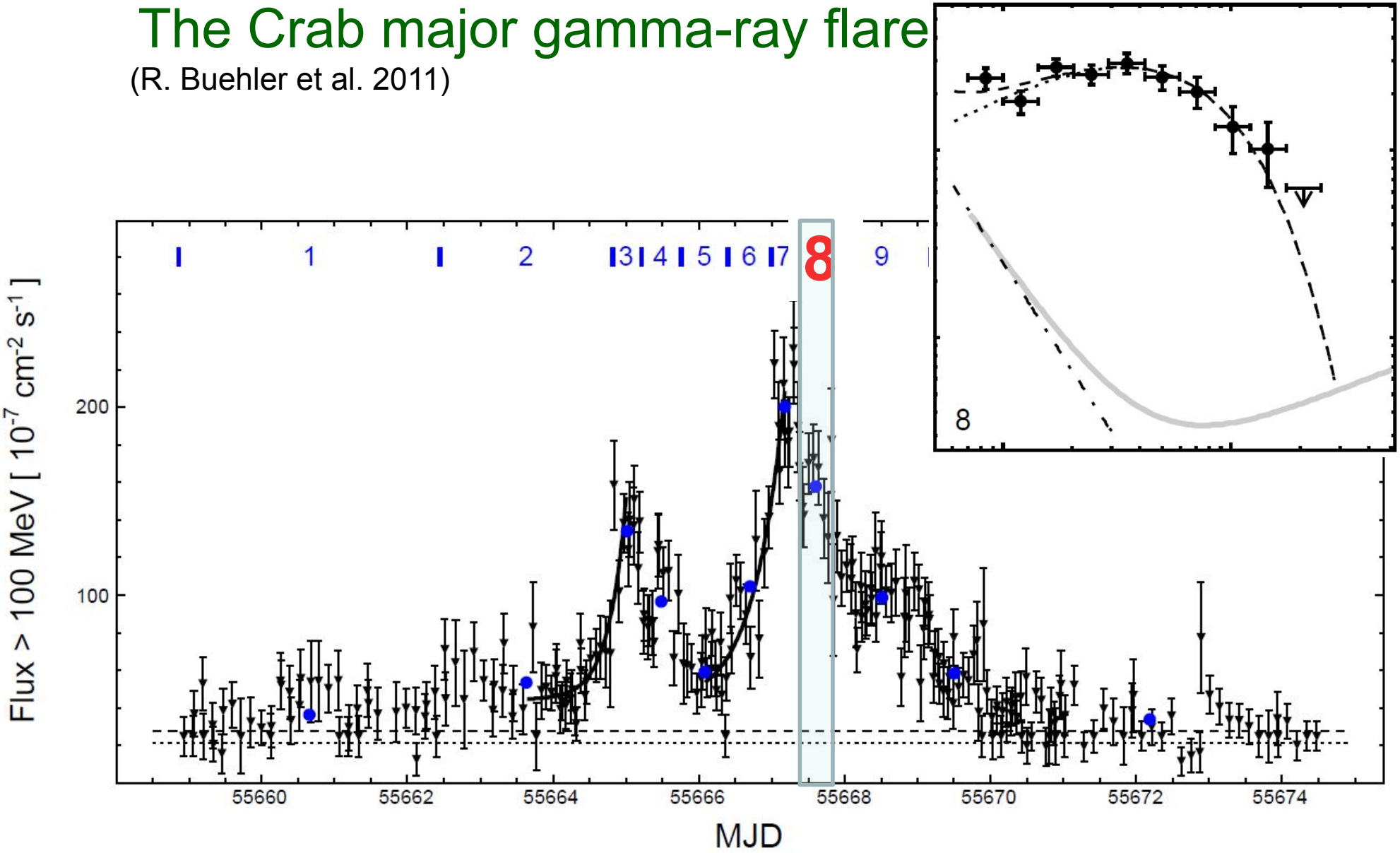
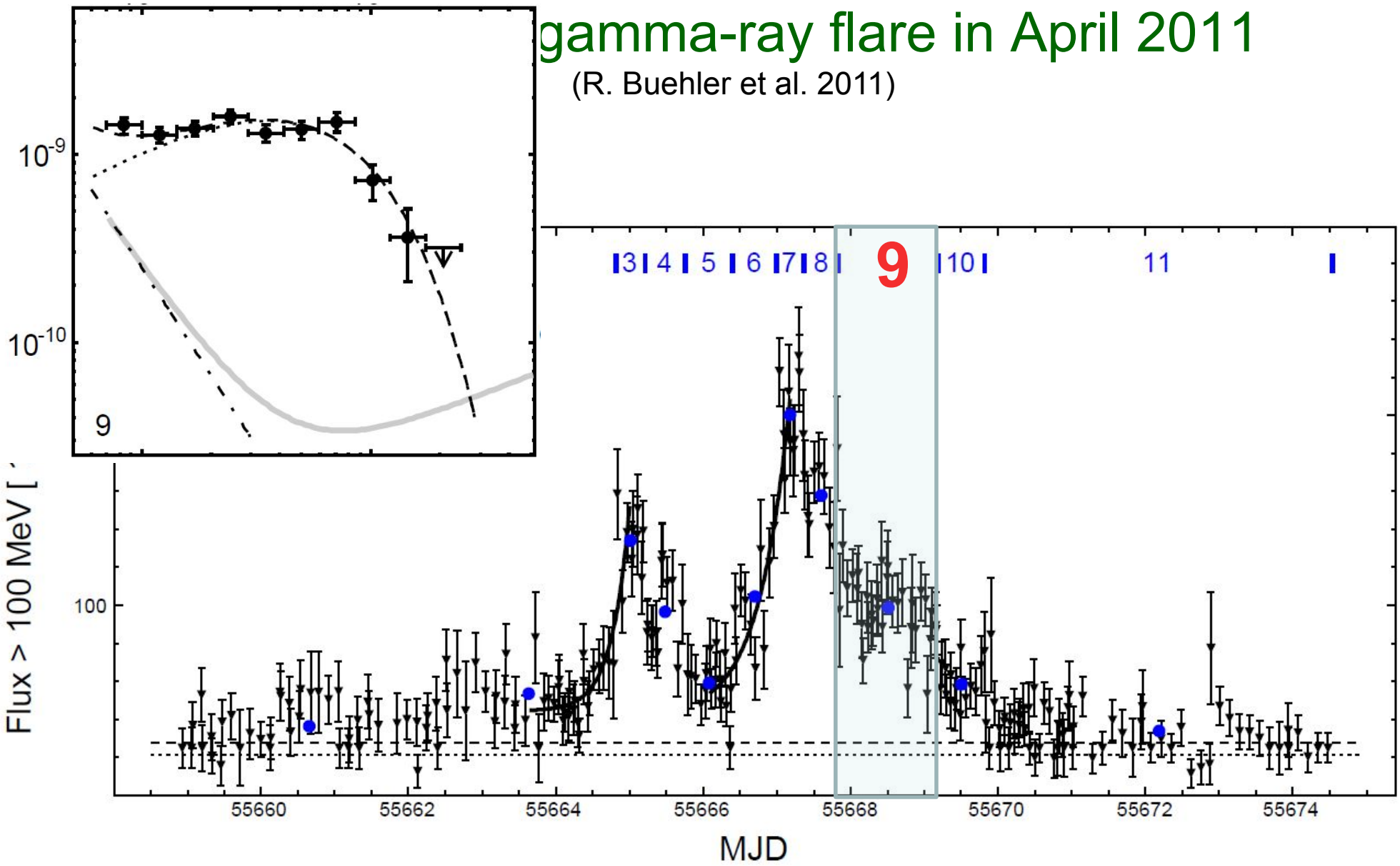


gamma-ray flare in April 2011

(R. Buehler et al. 2011)



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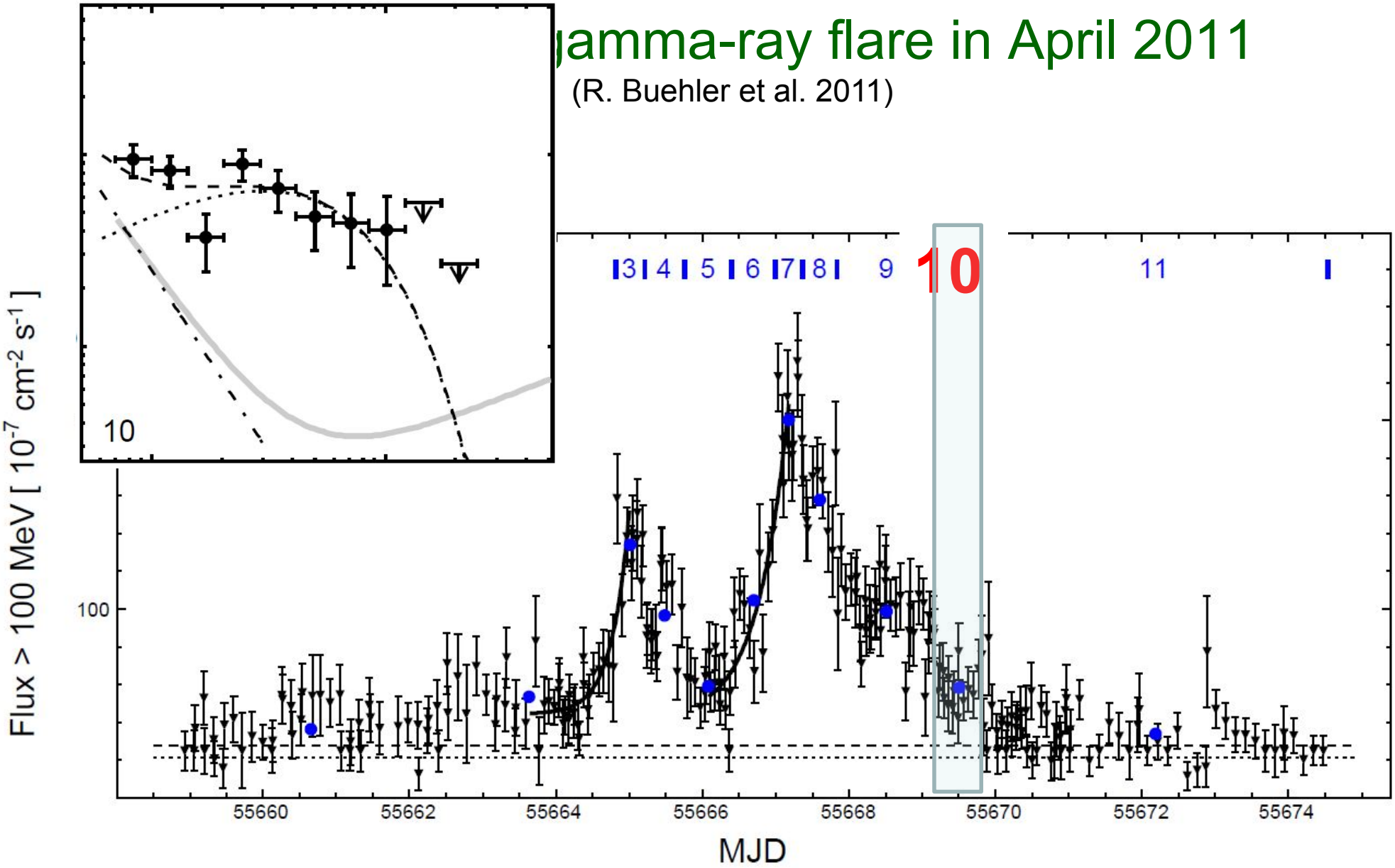

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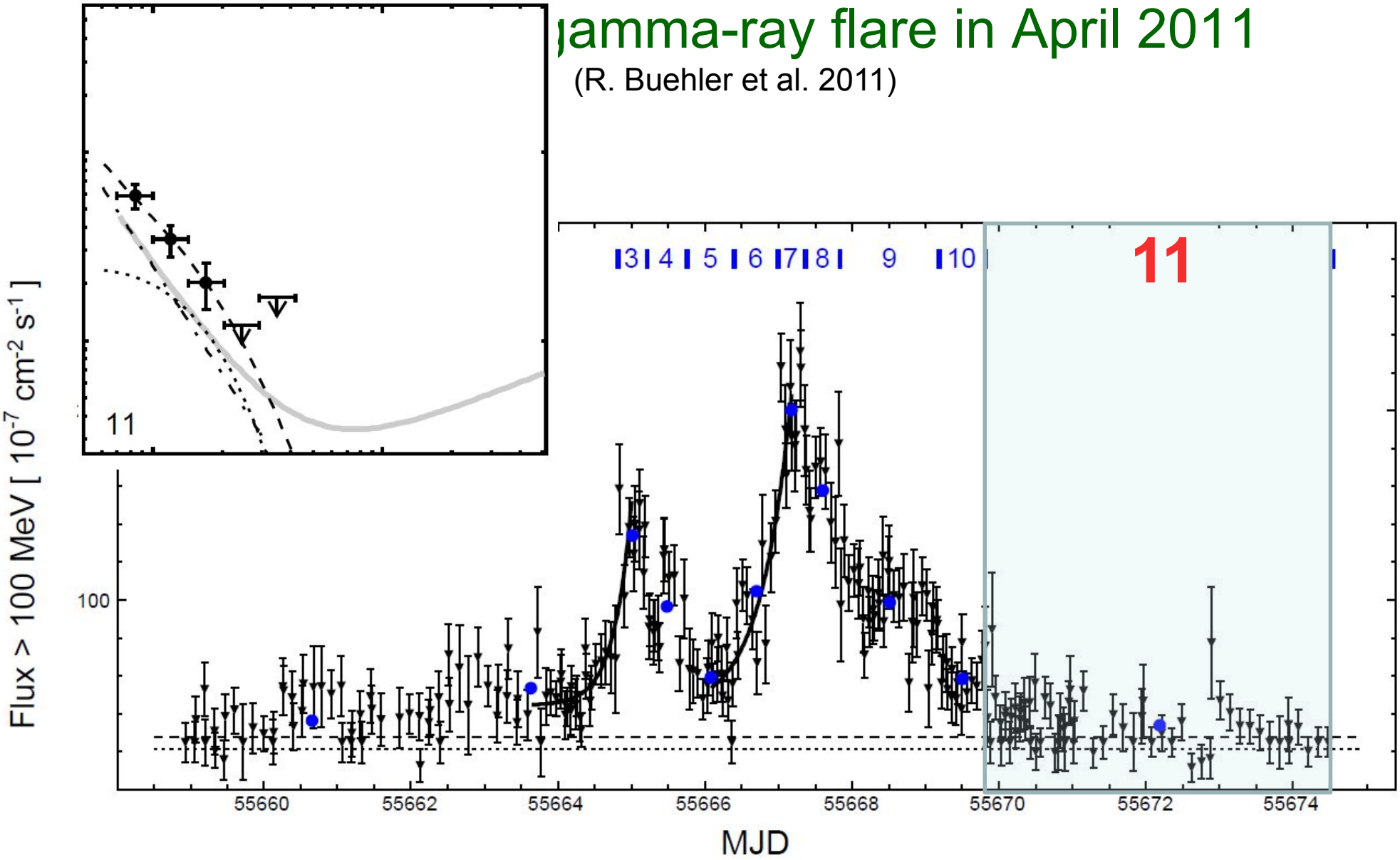
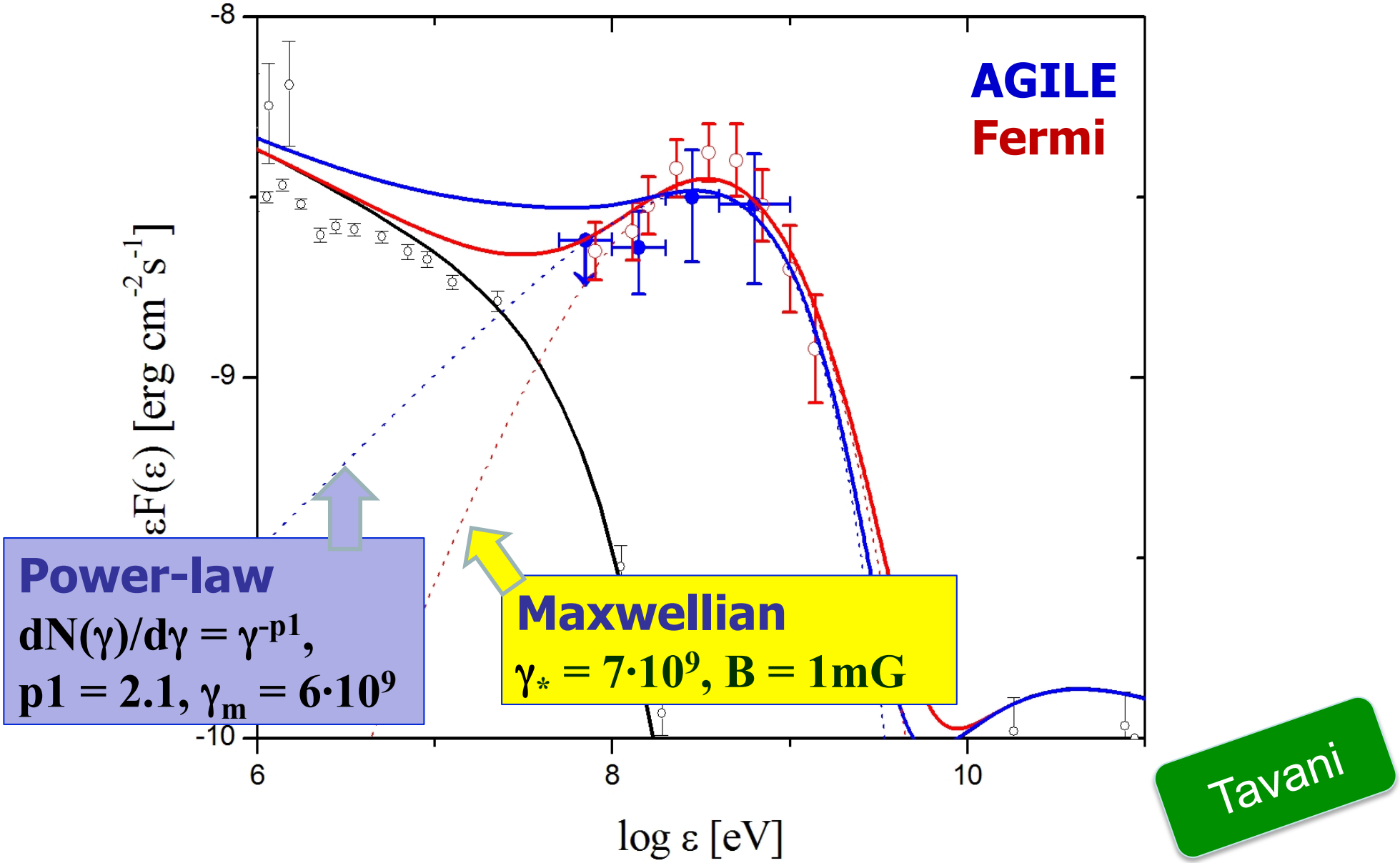
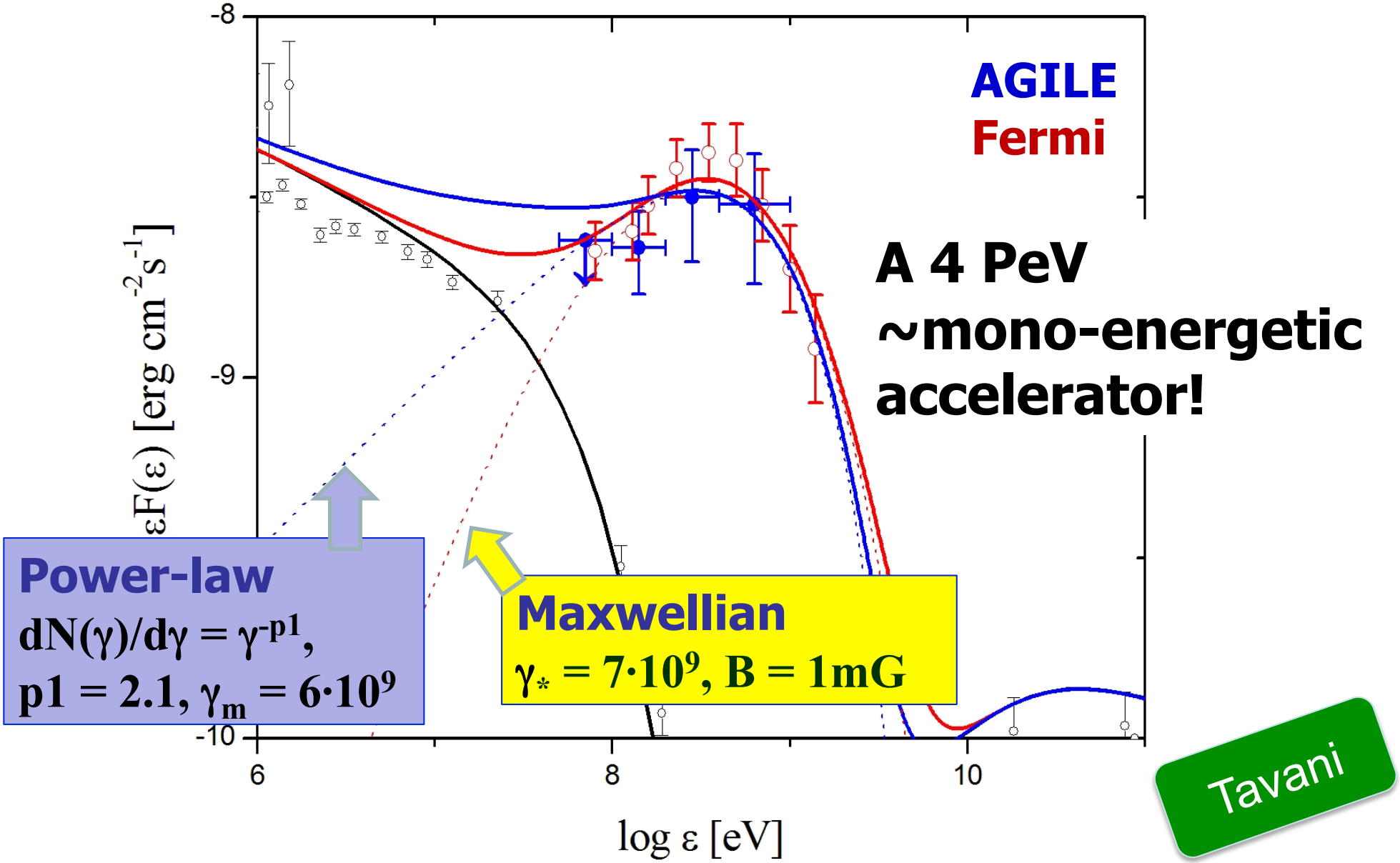


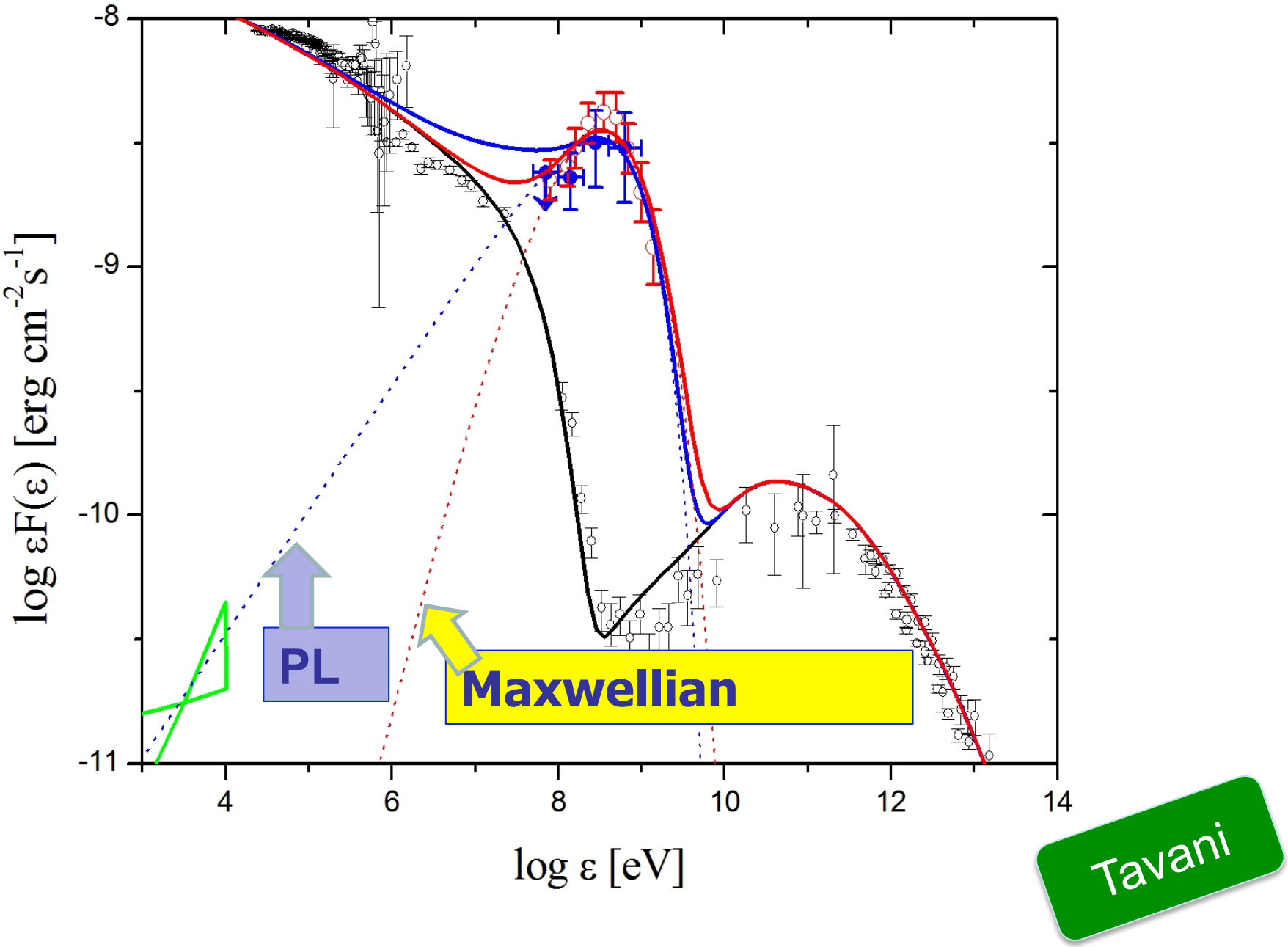
<8 hour flux doubling timescales

modelling of the April 2012 super-flare



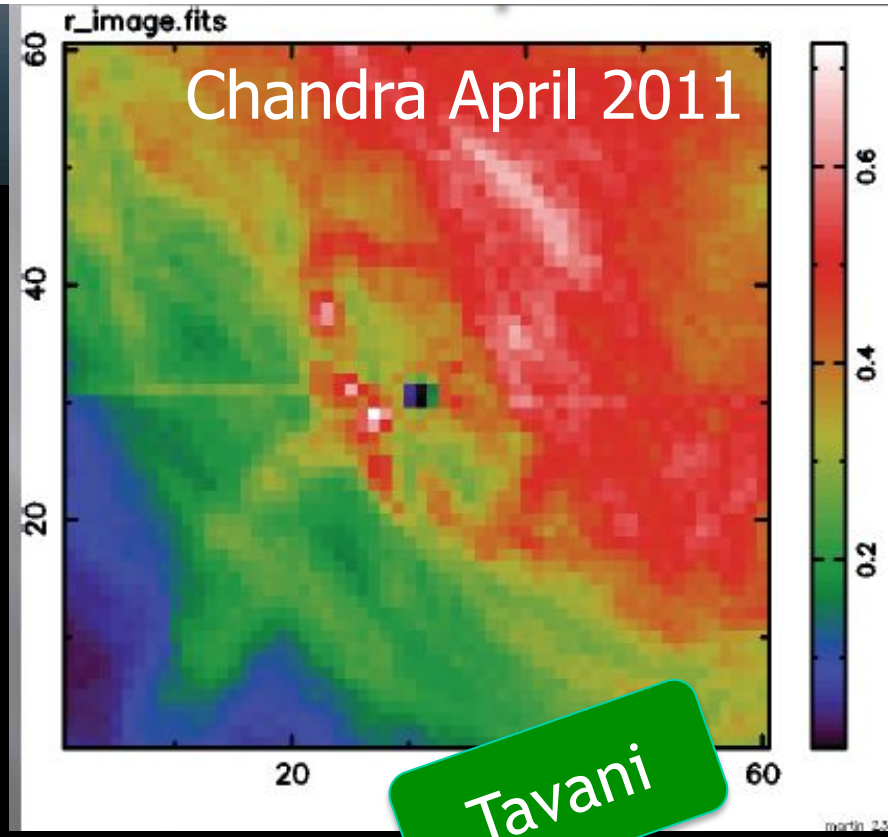
modelling of the April 2012 super-flare



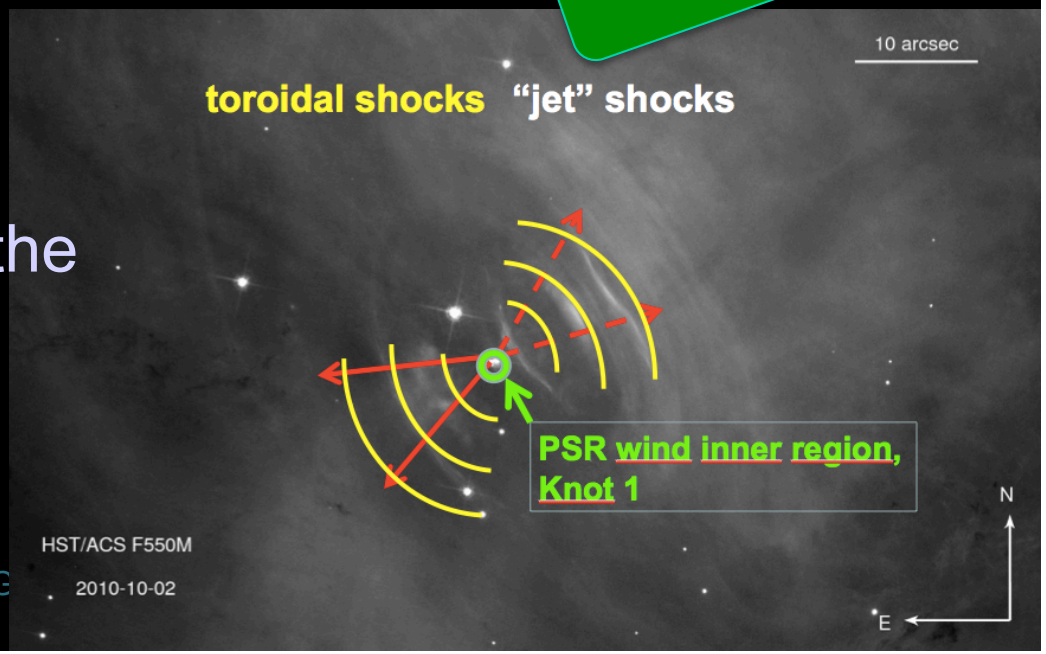

-8
-9
-10
-11
4
6
8
10
12
14
log εF(ε) [erg cm^{-2}s^{-1}]
log ε [eV]
PL
Maxwellian
Tavani

Origin?

- Properties
  - Flares reach significant fraction of spin down-power of pulsar in < 10 hours, and the decay away in ~days
    - fast acceleration and fast cooling
- Acceleration site/ mechanism?
  - several possibilities in the inner nebula
  - reconnection attractive



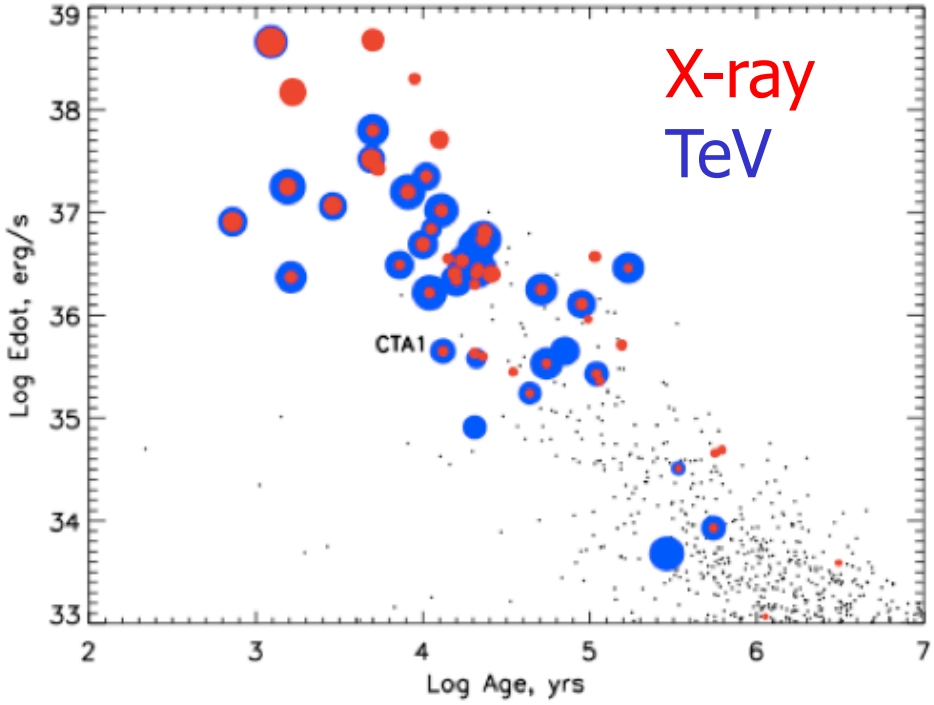
Tavani

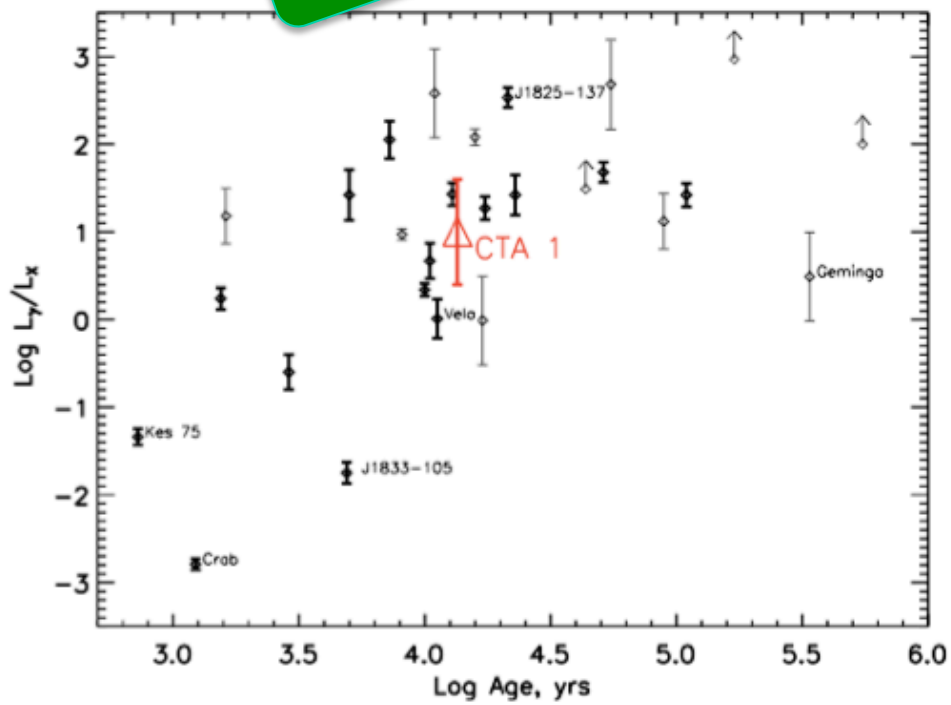


Pulsar Wind Nebula

University of Leicester

Park



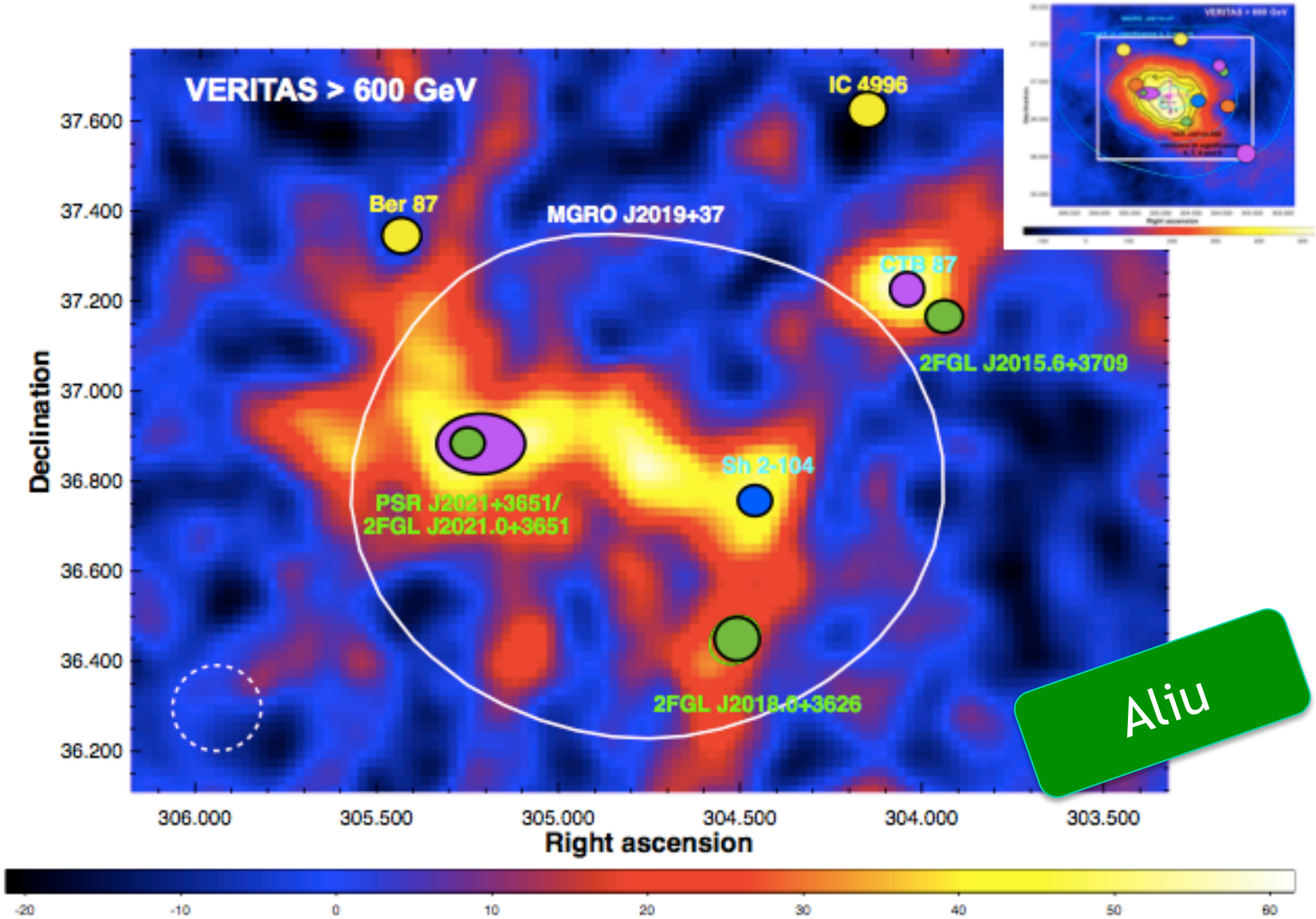


- Steadily growing population of TeV PWN
- Brightest objects now being identified in GeV
- "Standard" TeV PWN
  - ~10 ky old, smaller/dimmer X-ray nebula, offset/large

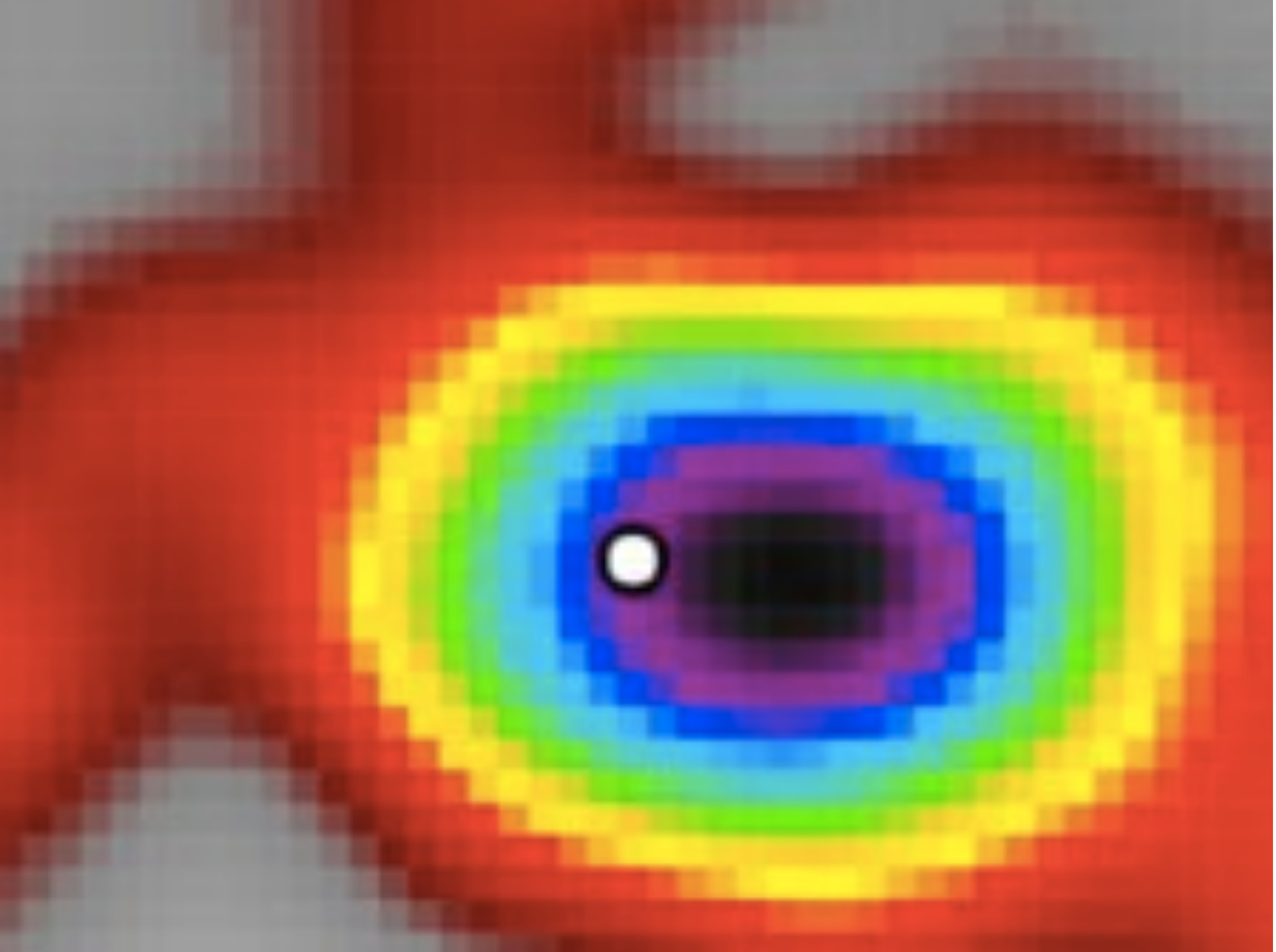
Search Radius ~ 0.09 deg (≳ VERITAS PSF)

VERITAS Coll. in preparation

- Clearly separated source coincident with SNR (6.2σ post-trials)
- Elongated complex emission in the center (> 5σ post-trials)



Aliu



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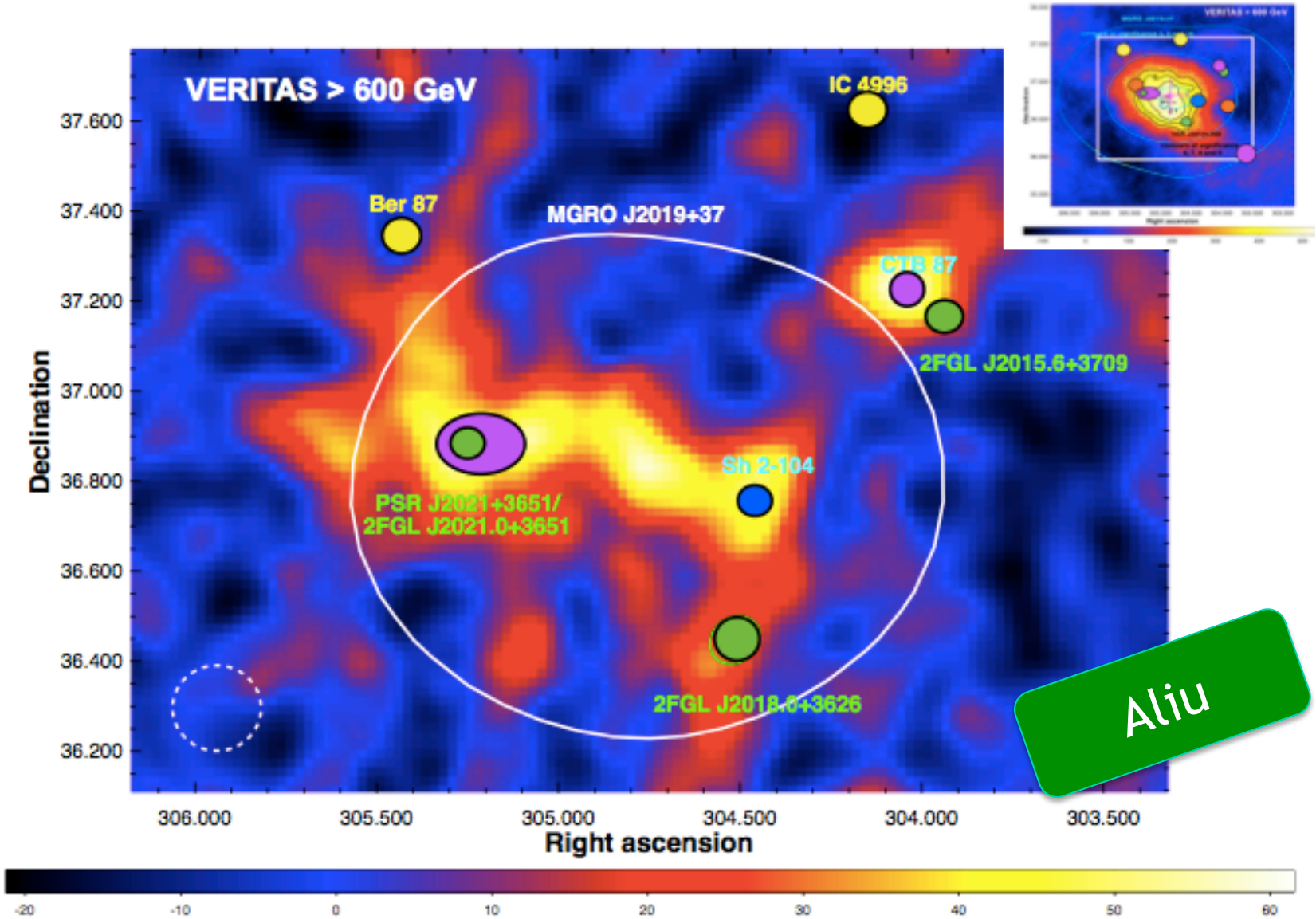
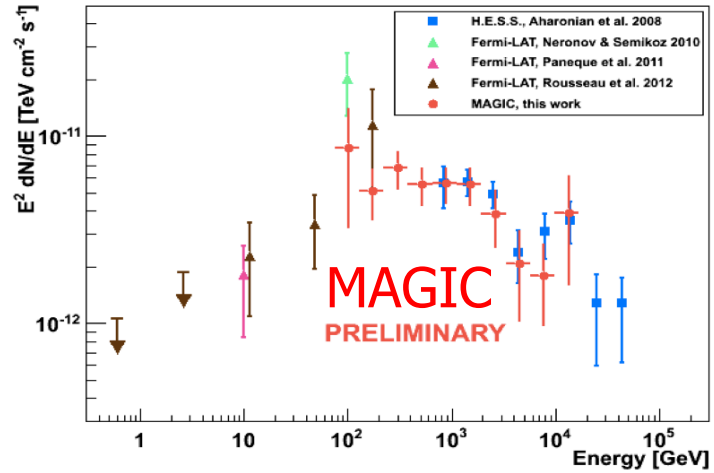


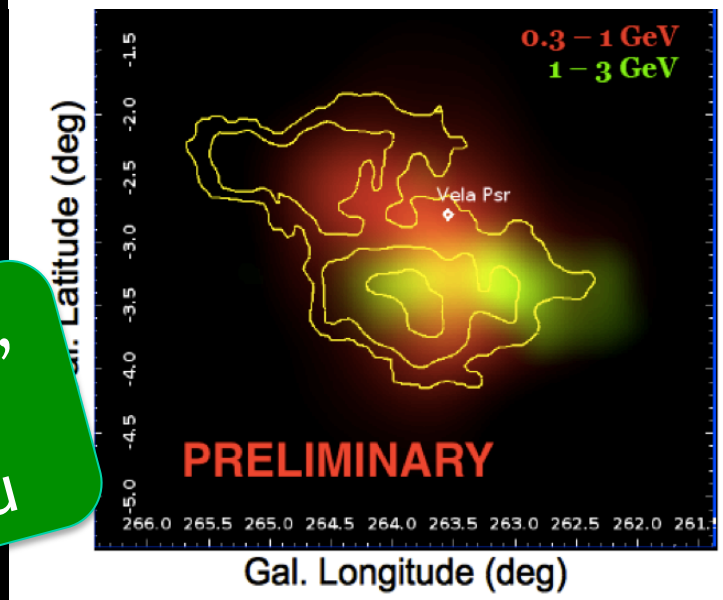
Aliu

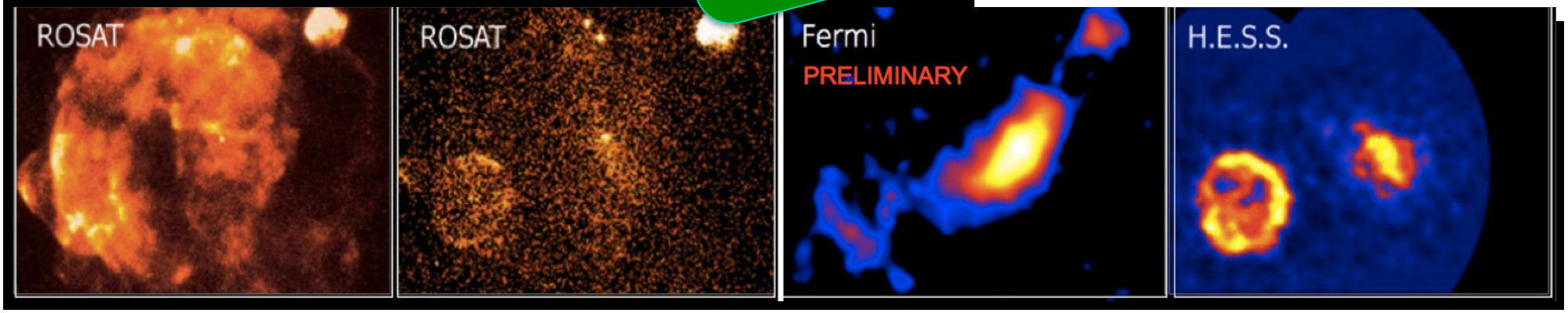
Fermi + TeV PWN

- e.g. Vela-X, J1857, J1825
  - large, hard-spectrum Fermi sources associated with brightest TeV PWN
  - standard picture: slower-cooling and hence older electron populations
    - injection spectrum?
    - transport?
    - escape?

Stamatescu, Grondin, Rousseau



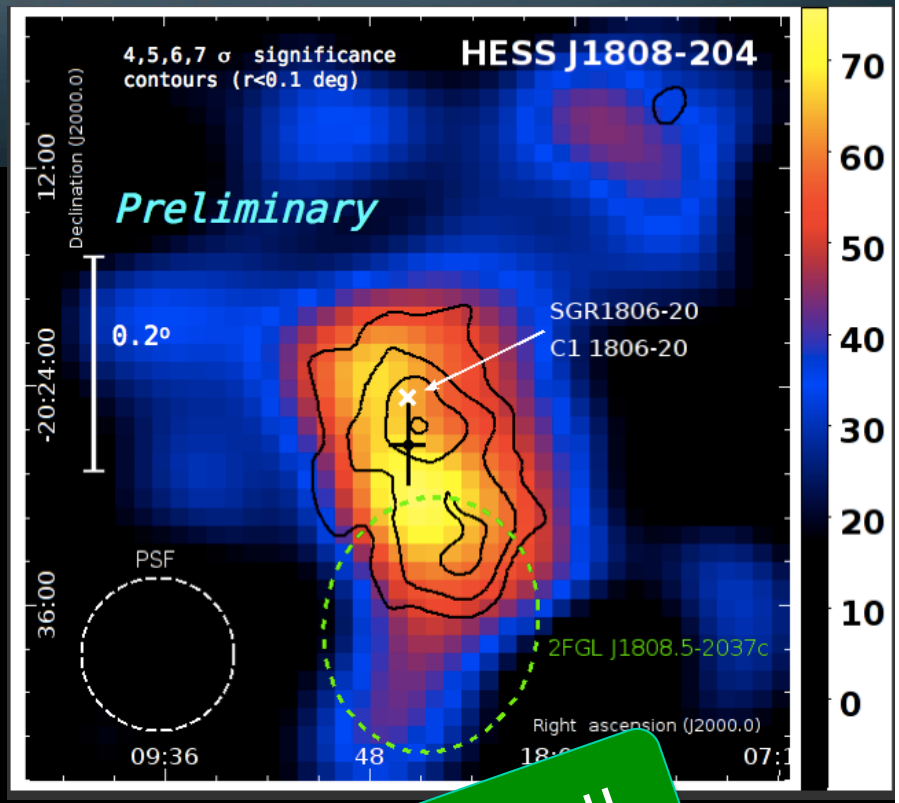




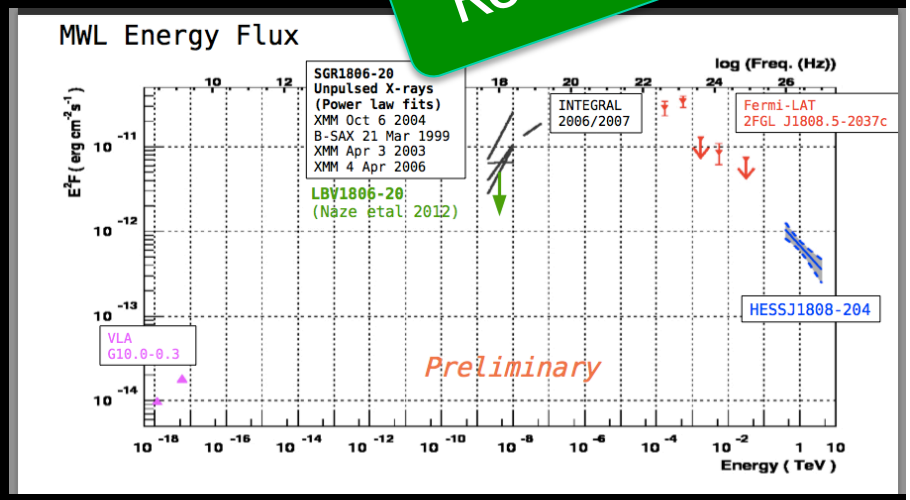
Everything Else

SGR 1806-20

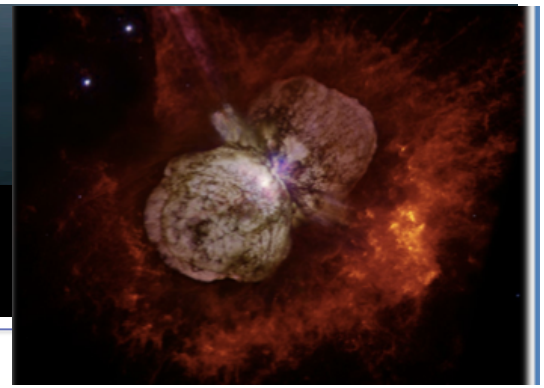
- Extended TeV nebula around soft gamma-ray repeater
  - but no evidence for X-ray nebula, not much spin-down power…
- LBV association?
  - Non-thermal radio nebula associated with an LBV star close by…
- Another famous LBV is a gamma-ray source…



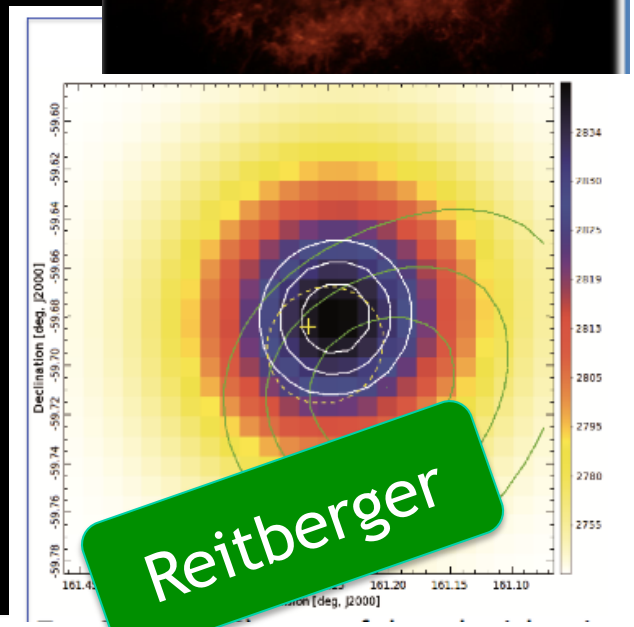
Rowell

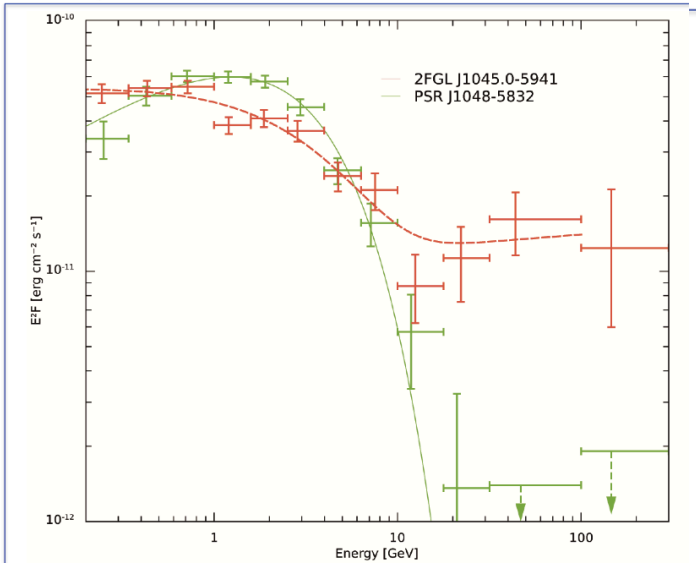


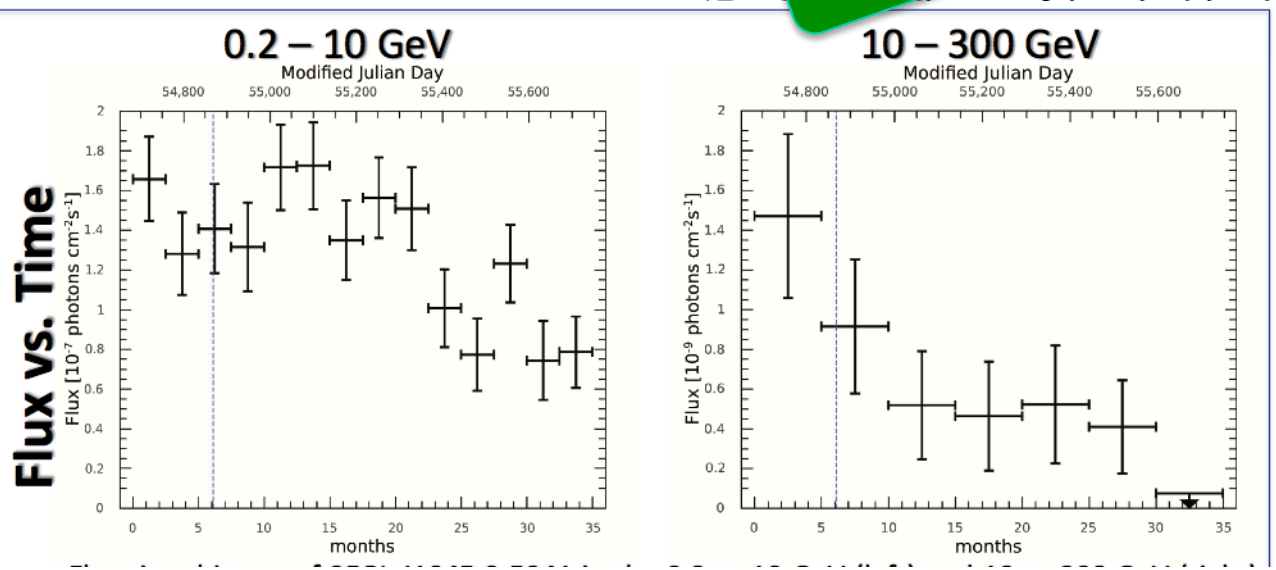
Eta Carinae



- Eccentric 5.5 year period LBV+
  - colliding wind binary system
- 2-compontent Fermi source coincident with Eta Car at low and high energies
- Variability now seen in both bands
  - limit from HESS (Ohm+)







Summary

University of Leicester

- A vibrant field both observationally and theoretically
  - a steady stream of important new obs. results
  - increasing MWL work, increasingly detailed theory
  - Upgrades / new instruments on the horizon to continue to drive progress
- Most important galactic accelerators?
  - (Old) SNRs becoming established as (very) significant sources of ~GeV cosmic ray hadrons
  - Pevatrons?: **The Crab**, look at young SNRs for hadrons
- Trends?
  - “Escape” and “Reconnection”