# Fermi highlights of the γ-ray sky

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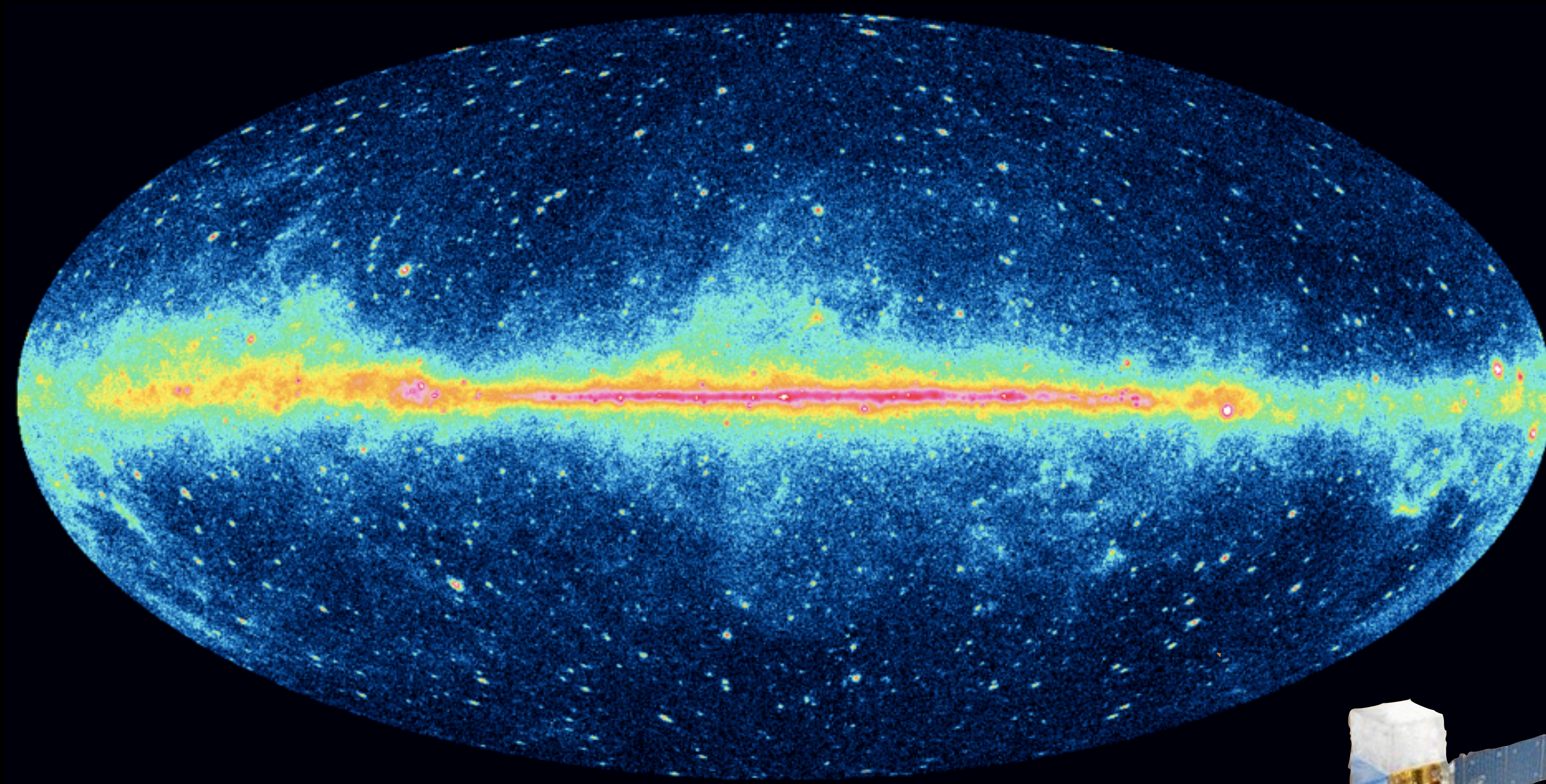
& the Fermi LAT collaboration

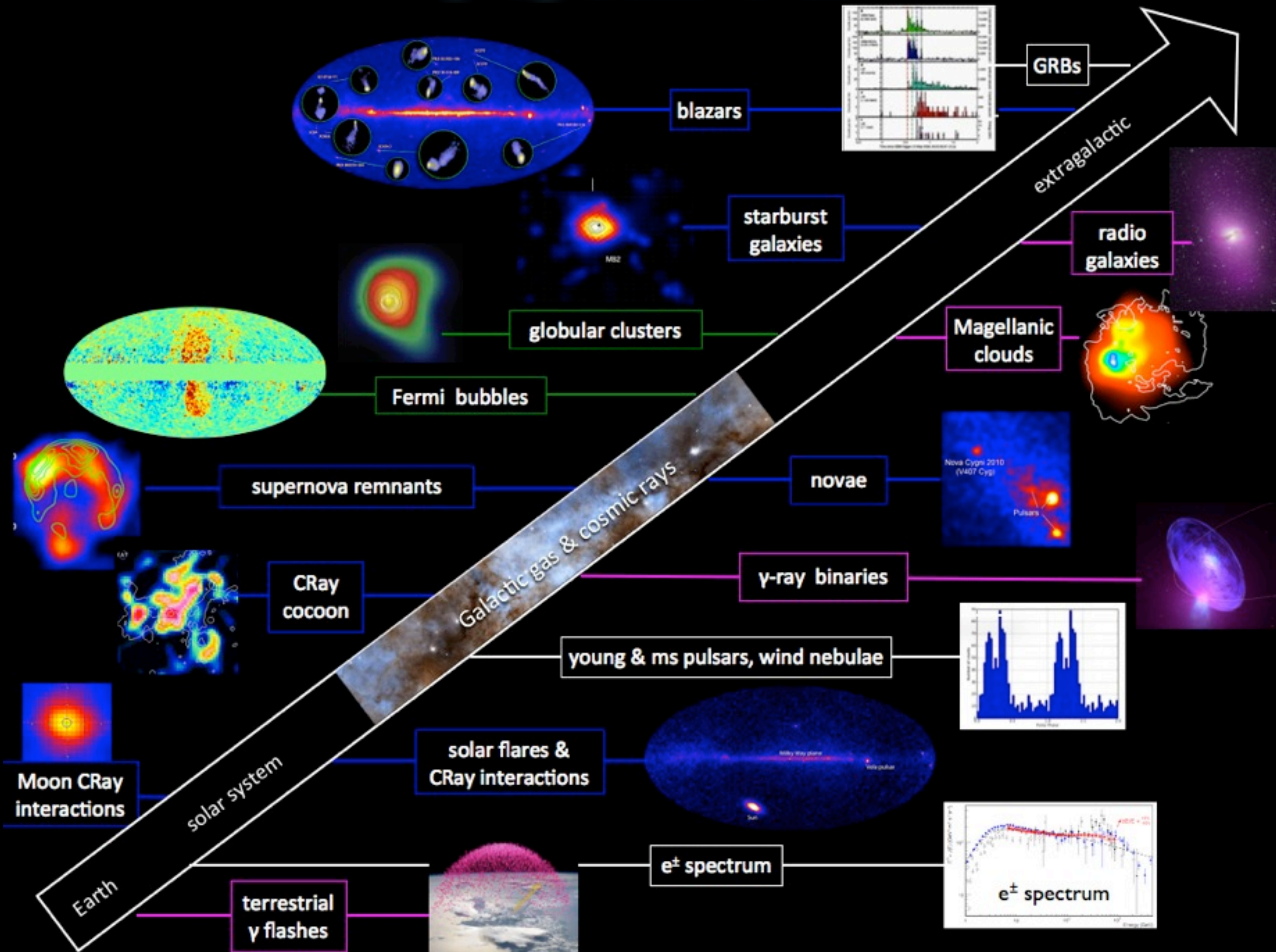
Saclay SPP 17/12/12

# the γ-ray sky above 1 GeV

- 4 years with Fermi Large Area Telescope
- whole sky every 3 h
- > 1870 sources + interstellar CRay emission + extragalactic background

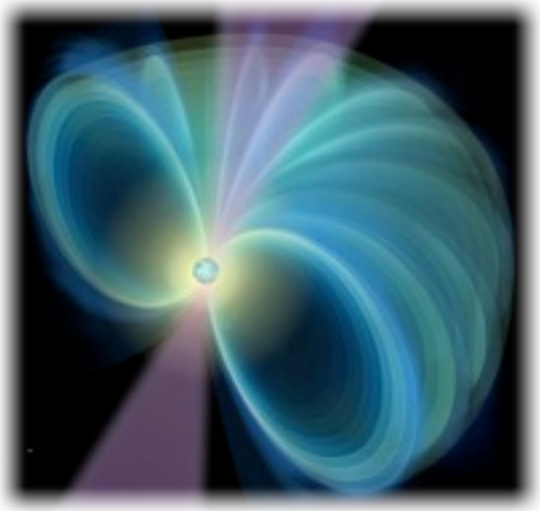


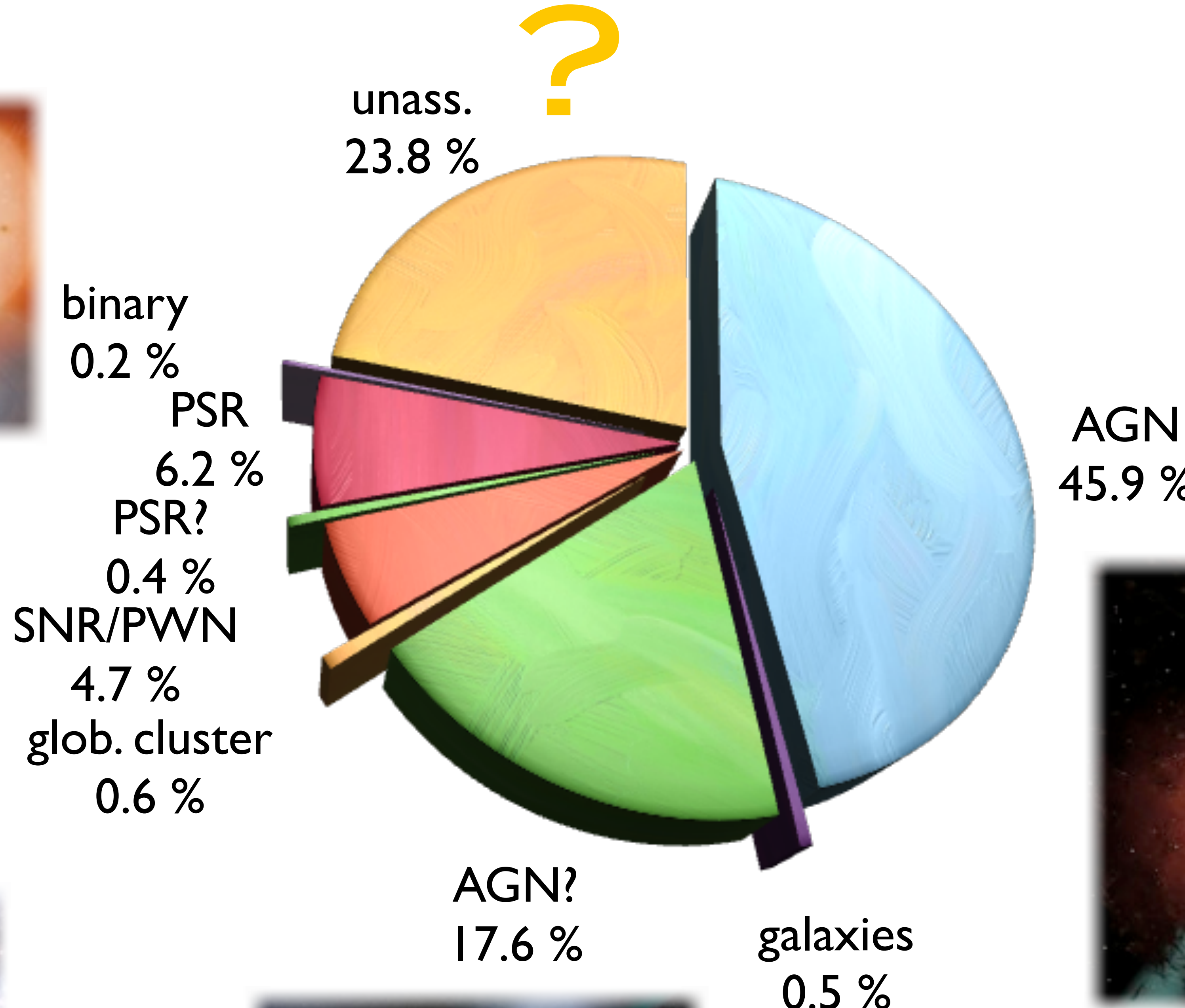
# γ-ray discoveries

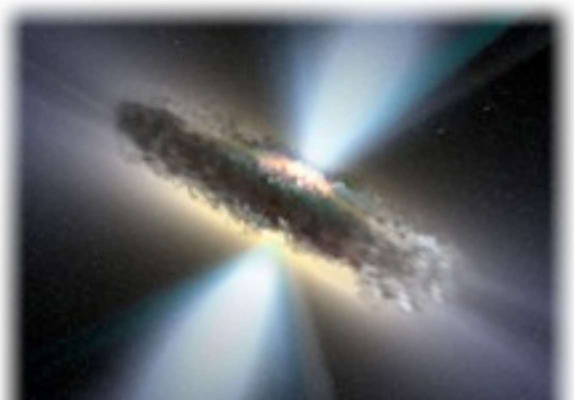


# 2FGL source catalogue

1873 sources

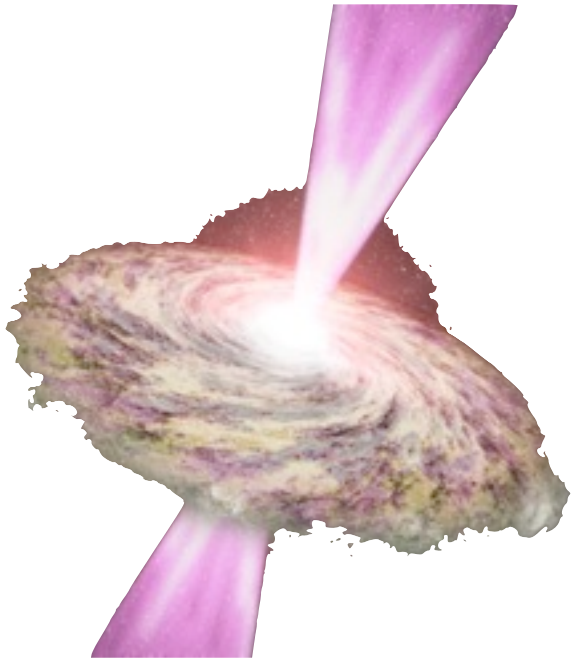


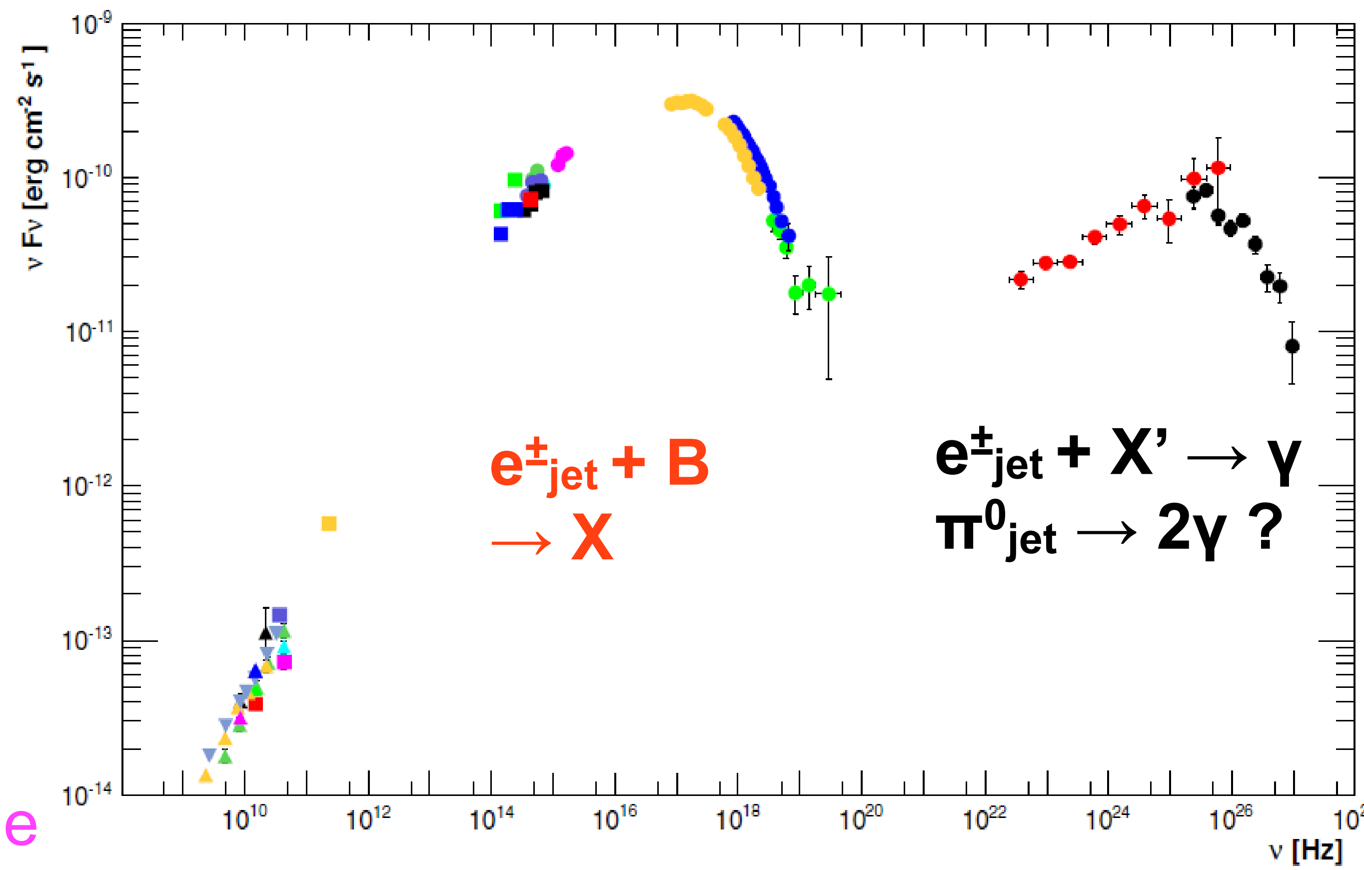


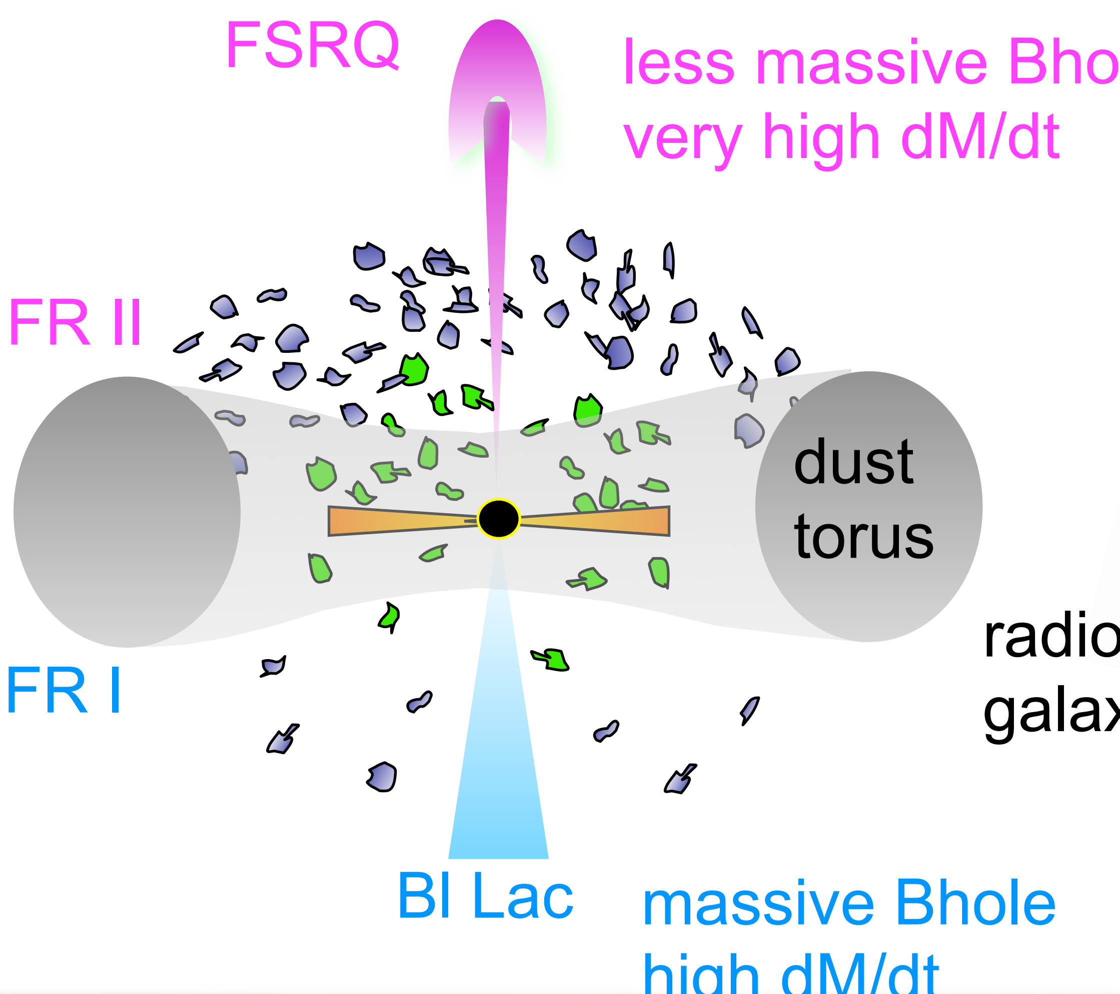




accelerator 1:
accretion +
jet propulsion

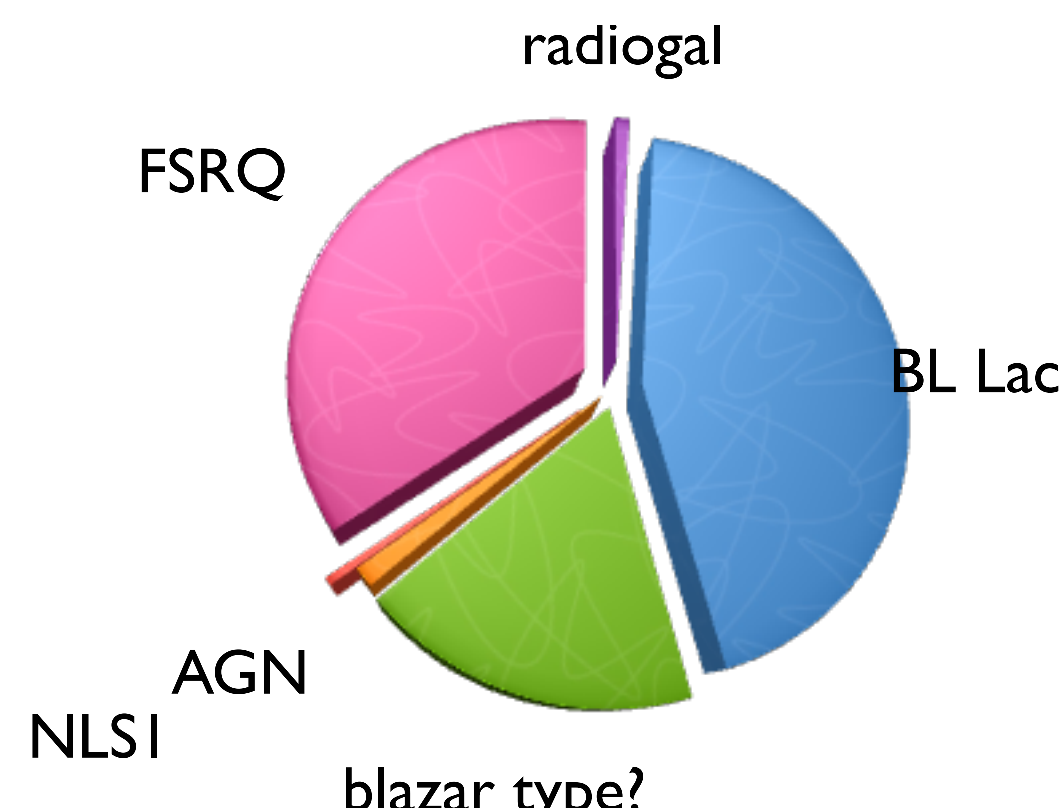
# a thousand γ-ray quasars



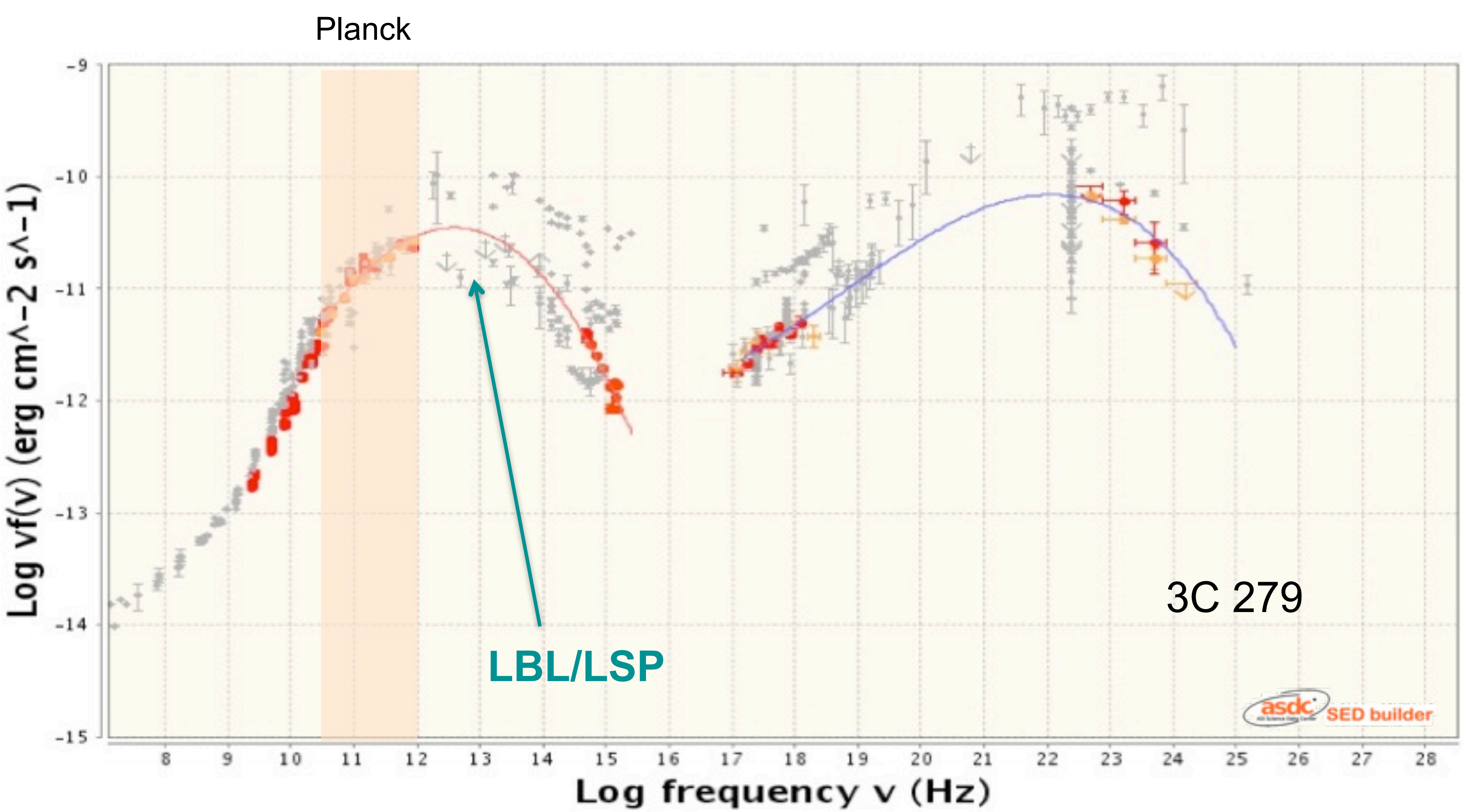




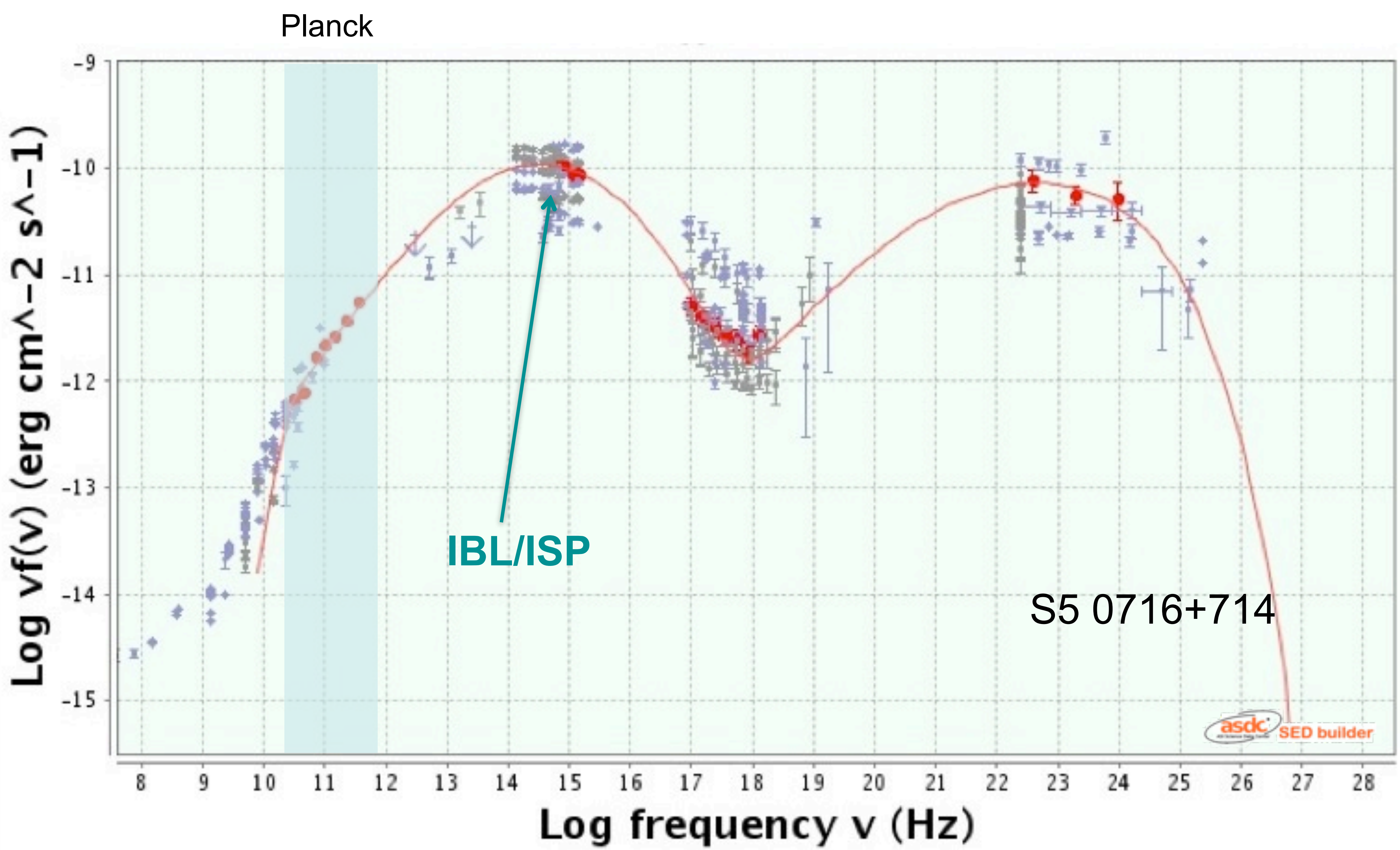


# constraining blazars SEDs



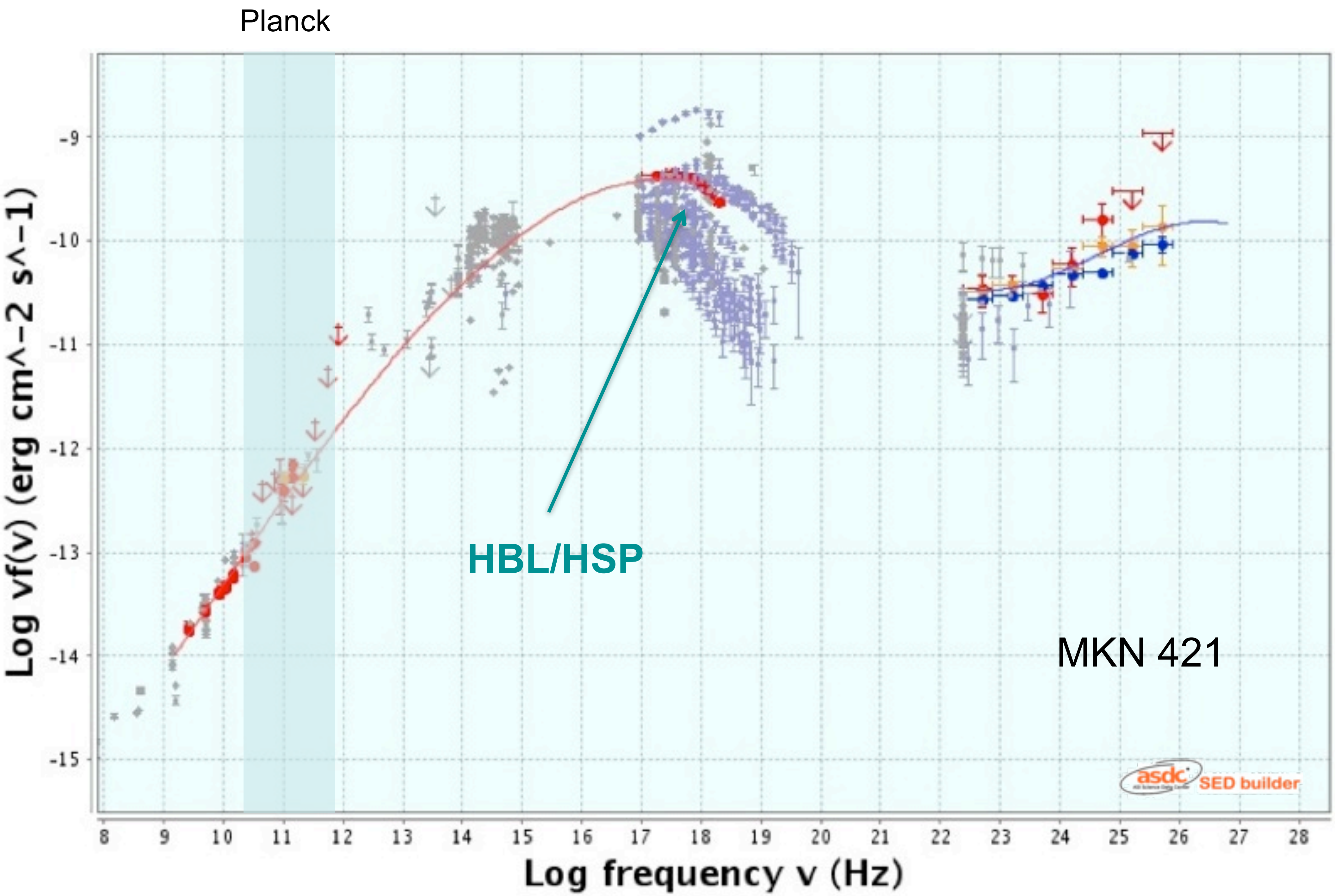

- low synchrotron peaked

# constraining blazars SEDs




- intermediate synchrotron peaked

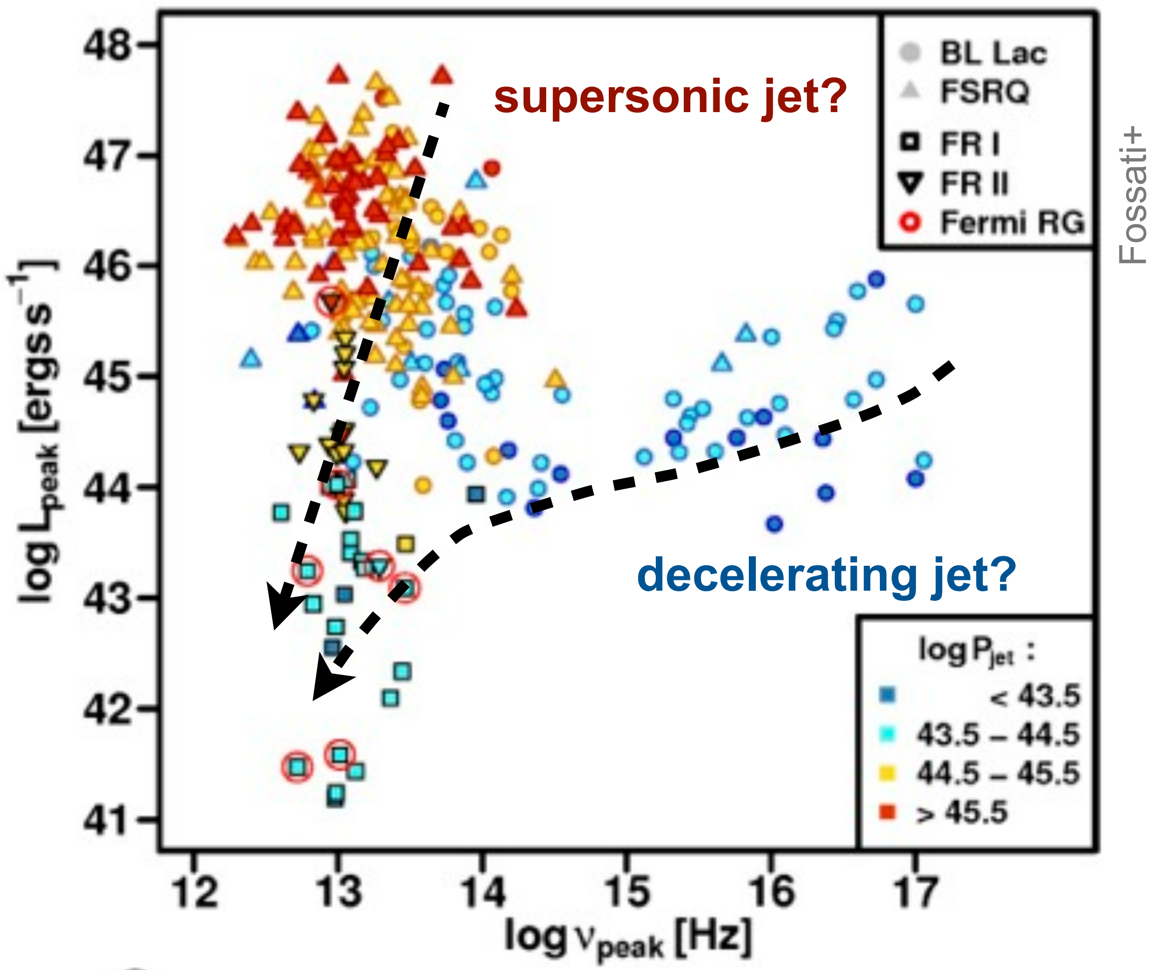
# constraining blazars SEDs

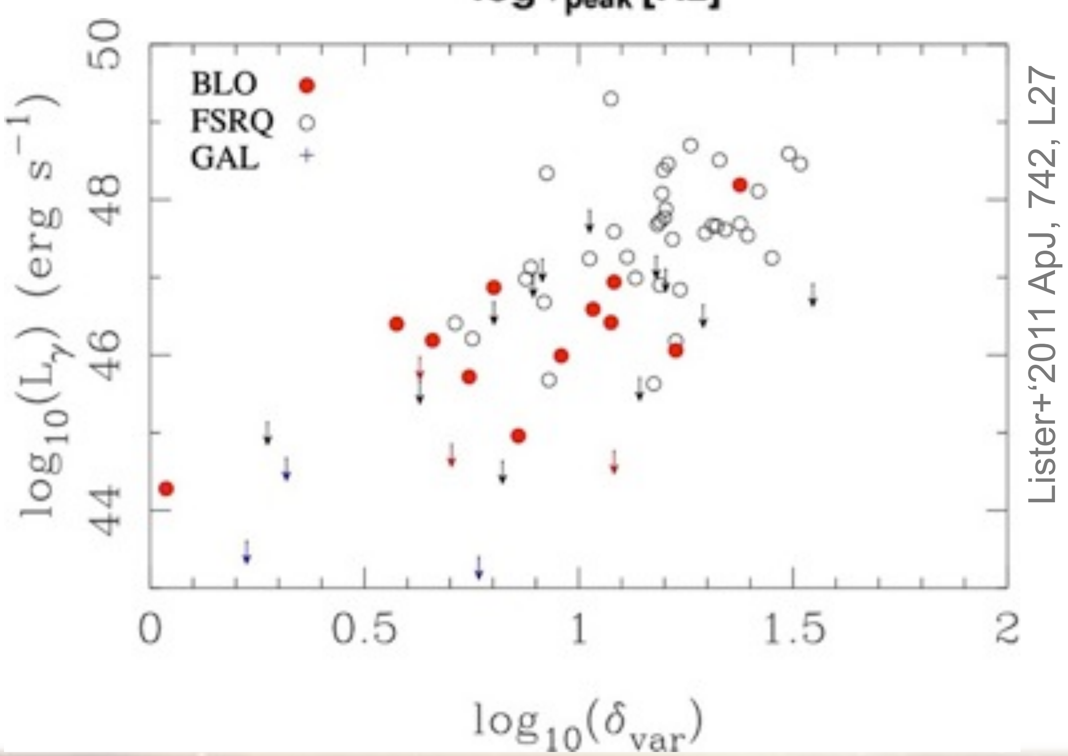



- high synchrotron peaked

# suggestions of blazar sequences

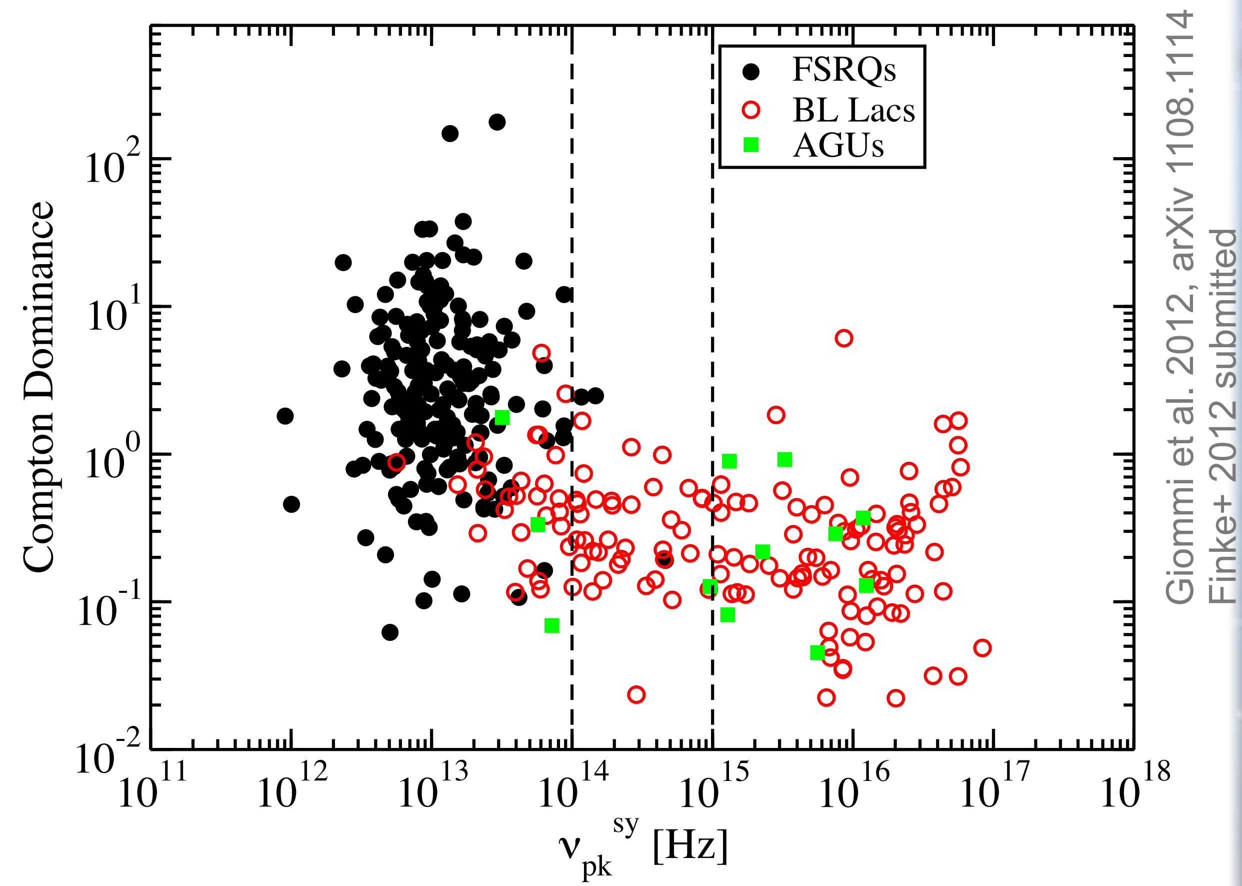
- the jet in synchrotron




- the jet in γ rays

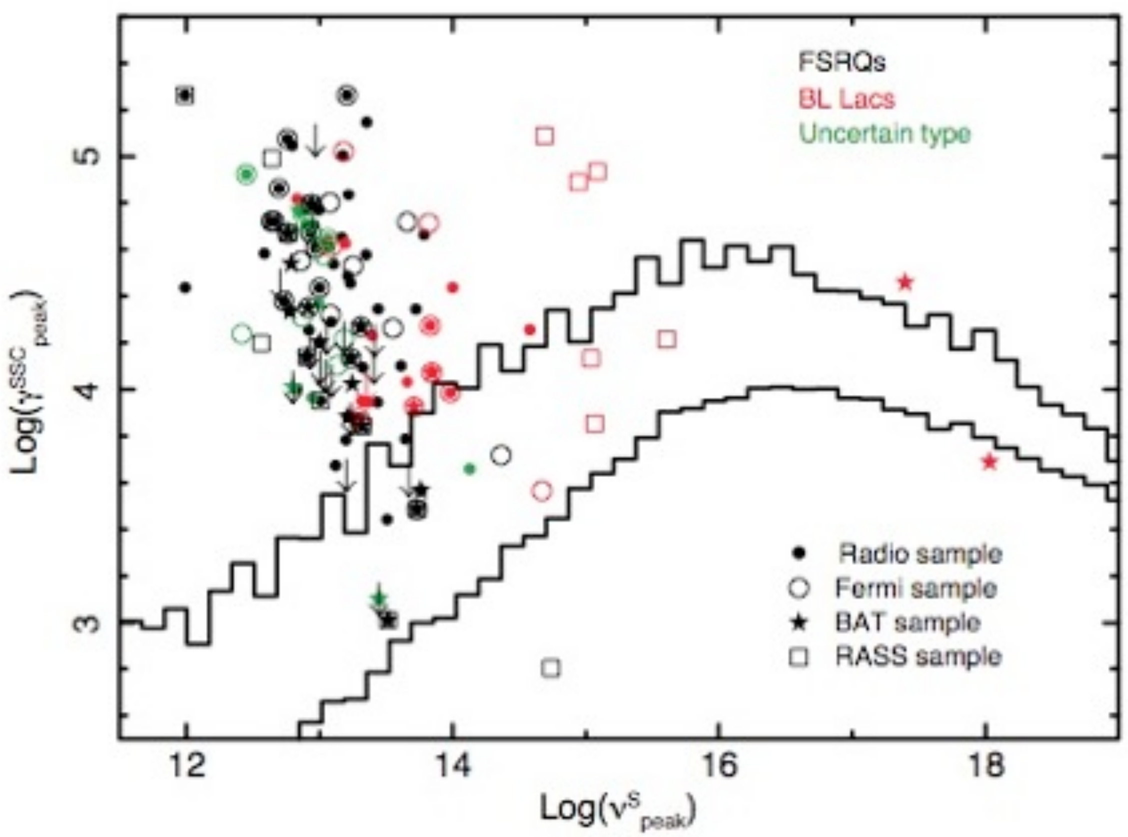
Compton dominance = $L_{peak\ \gamma}$ / $L_{peak\ syn}$




- the brighter in γ rays...
- the softer in γ rays ...
- the faster the jet ...
- the more Compton dominated
- the more variable in γ rays ...
- the lower the synchrotron peak energy ...
- the fainter in X rays ...
- the brighter in the radio ...

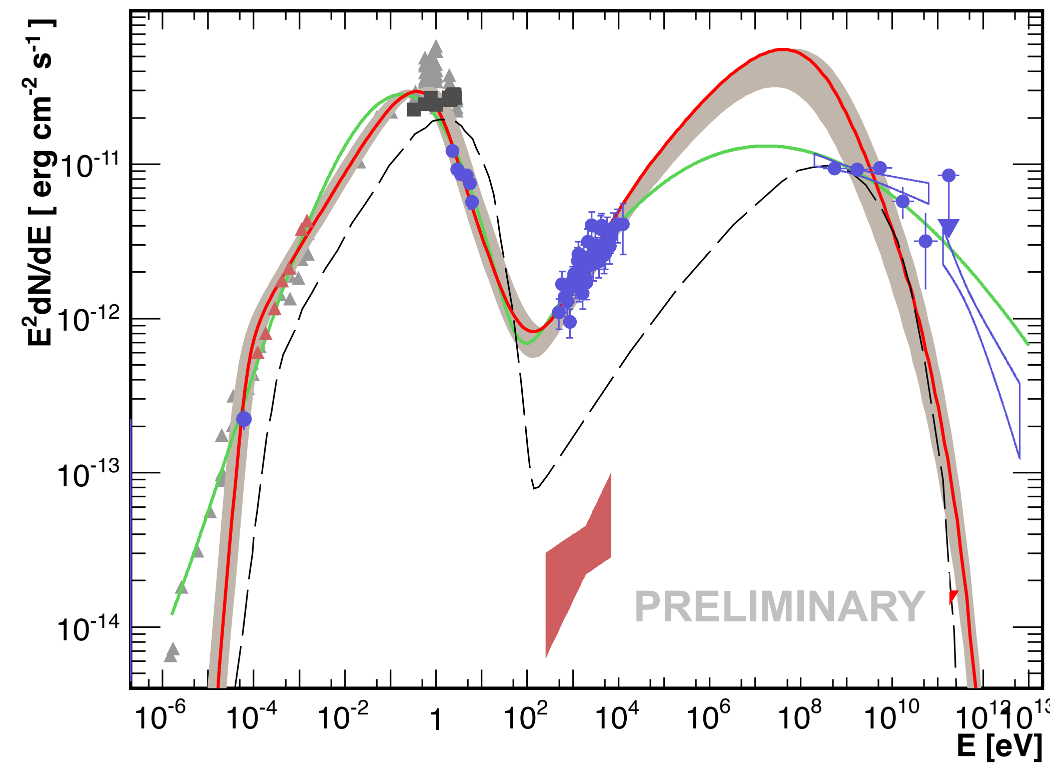
# SED modelling difficulties

- SSC models fail to explain most LAT blazars

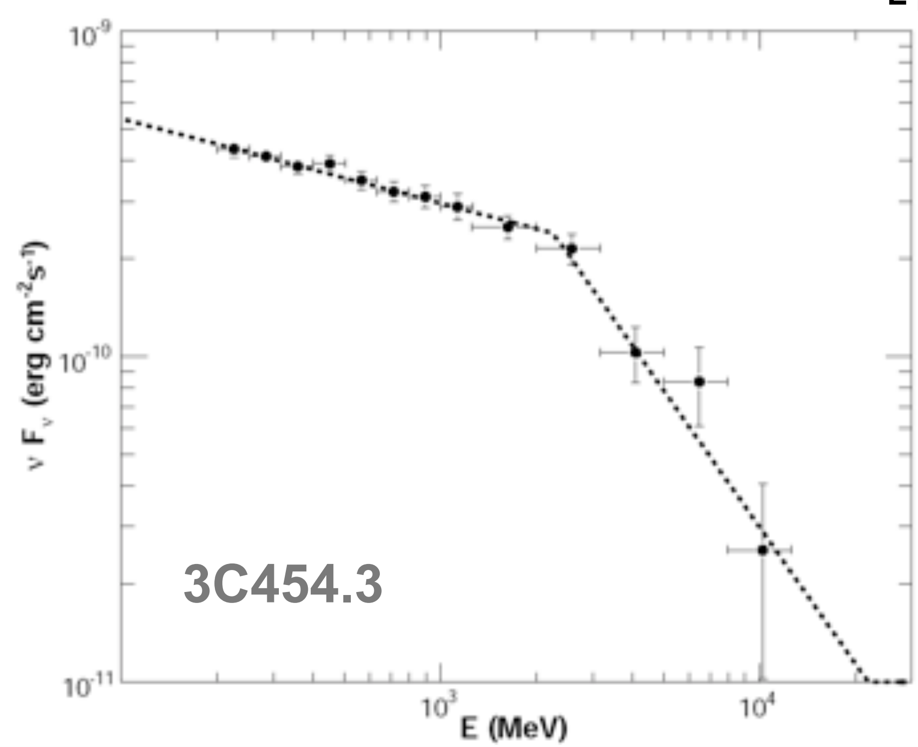



Giommi et al. 2012, arXiv 1108.1114

- one-zone models cannot explain 8 blazars
  - ex: AP Librae (LAT + HESS)




Abramowski+ '2012




Abdo+ '09, ApJ 699, 817

- origin of the few GeV breaks ???
  - $(X_{disc} + BLR_{lines}) + e_{jet} \rightarrow \gamma$ with KN cutoff?
  - $\gamma + \gamma_{BLR\ lines} \rightarrow e^{\pm}$

# γ-ray source location?

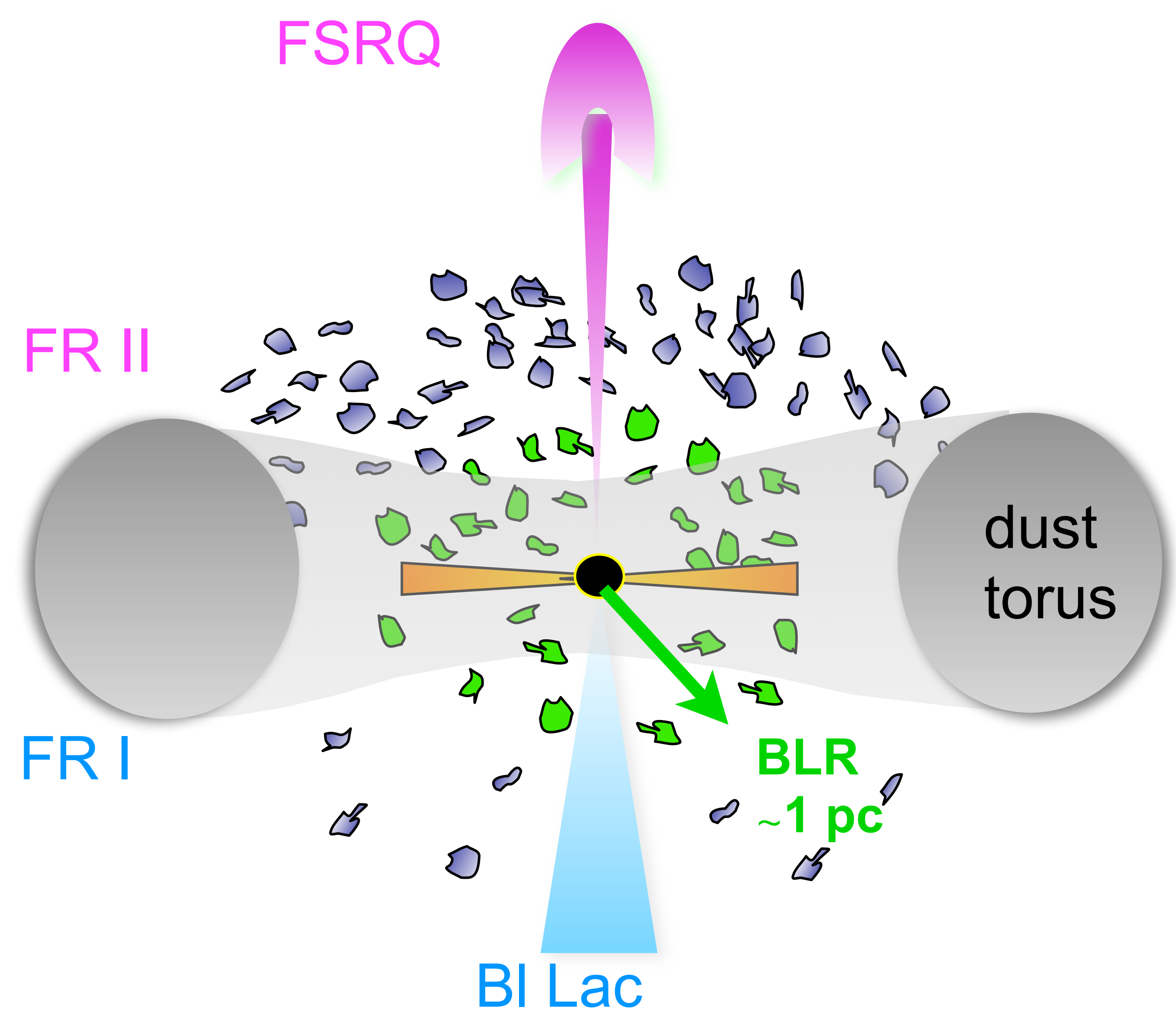
- outside the broad-line region?
  - PKS1510-089:
    intense radio + γ flare in Oct. 2011
    ⇒ D ≈ 7 - 17 pc outside BLR

    (Orienti+ ’12, arXiv:1210.4319)

  - 4C+21.35:
    10 mn flare up to 400 GeV (MAGIC+LAT)
    ⇒ $\gamma + \gamma \rightarrow e^{\pm}$ absorption if inside BLR

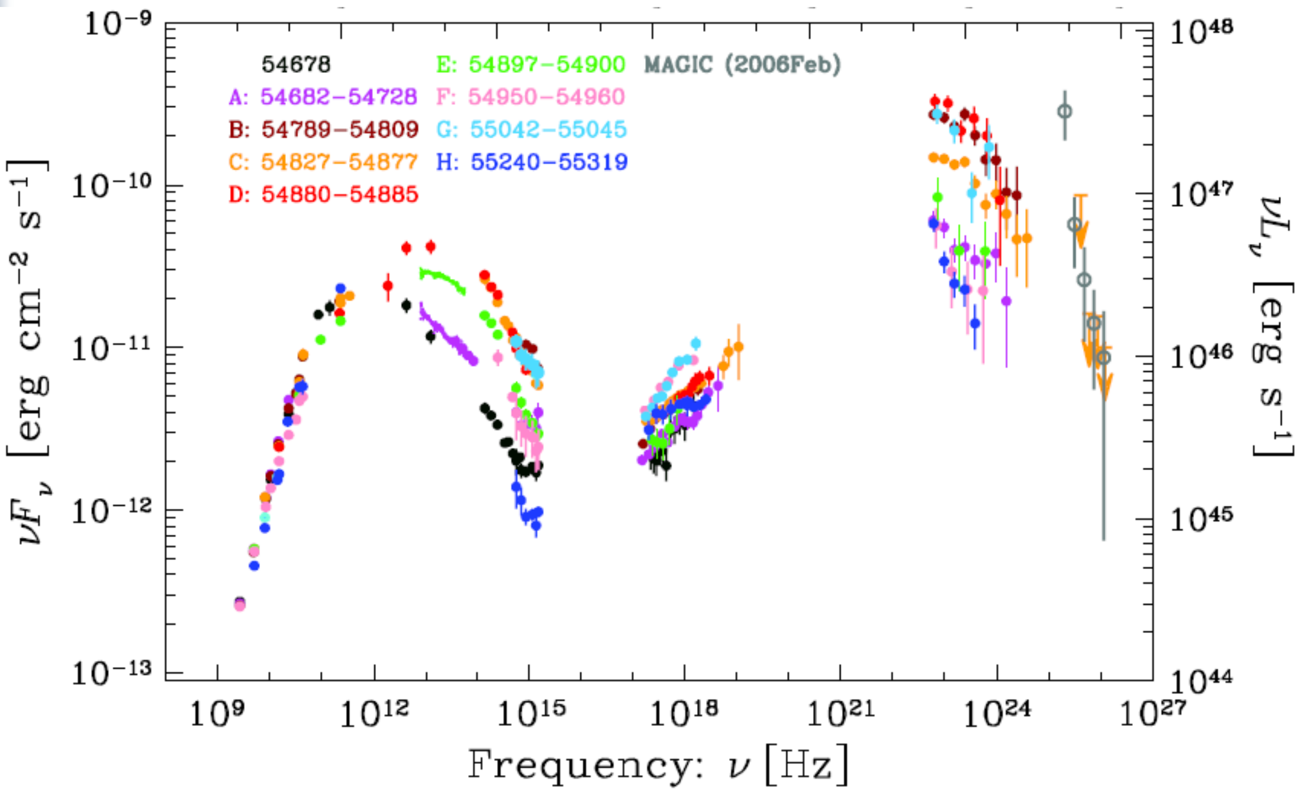
    (Aleksic+ 2011)

- rapid variability far from the black hole?
  - jet recollimation
  - jet B reconnection
  - neutron transport
  - ???



# blazar variability

- the brighter in γ rays, the softer, the more variable & larger amplitude of variations

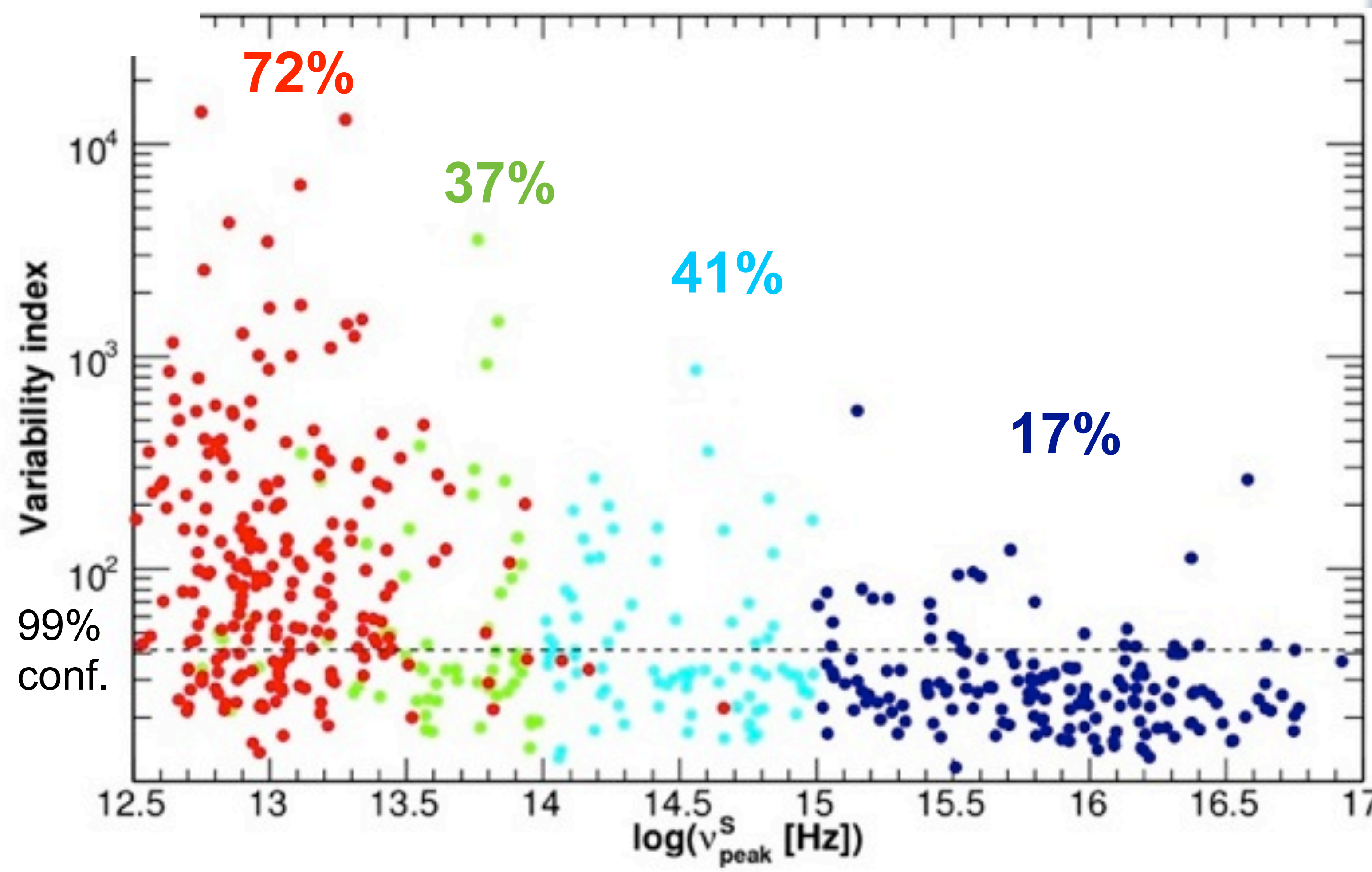



Ackermann+'2011 ApJ 743 171

more "brownian" changes

slightly longer timescales

more "flickering"




- duty cycles: 5-30% of time with

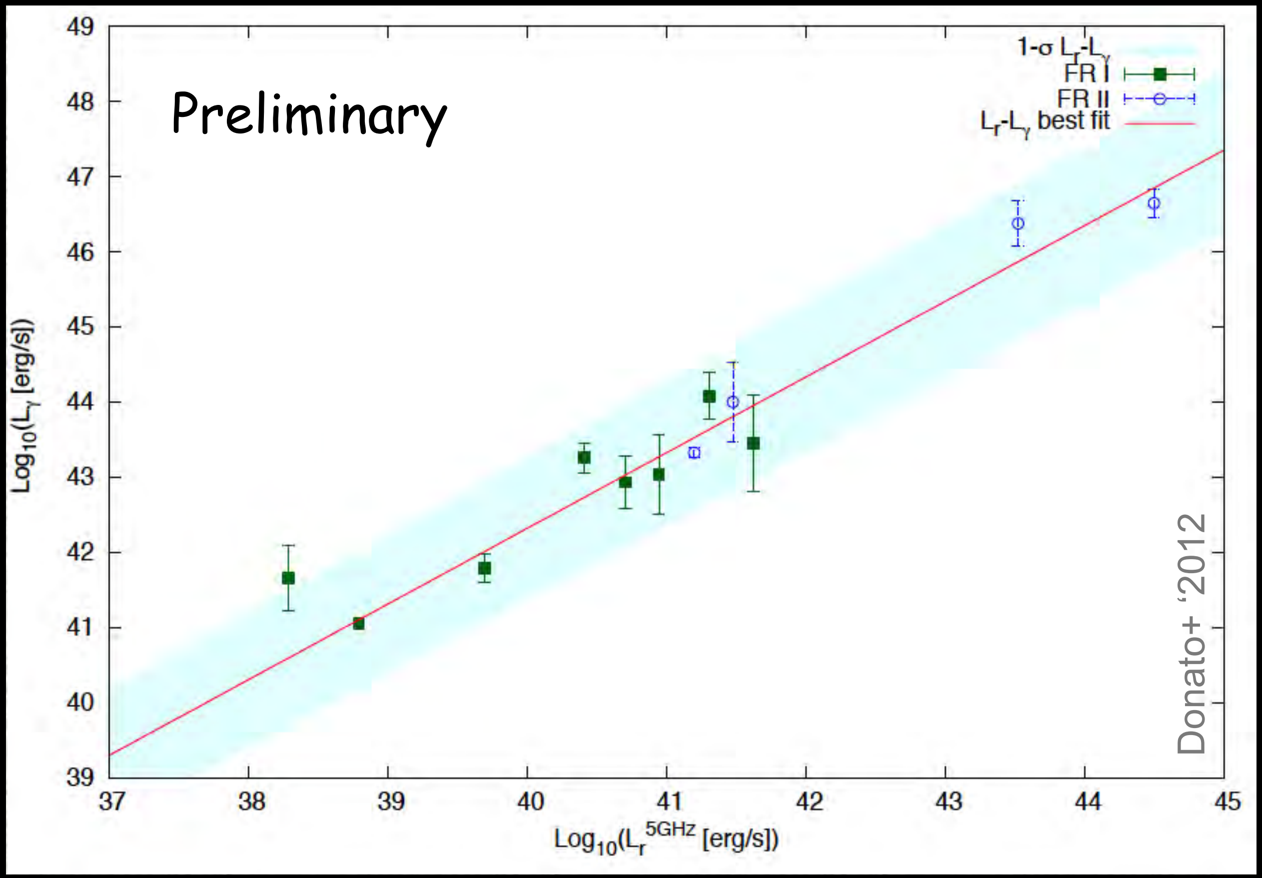
$$F > \bar{F} + 1.5\sigma_F + \sigma_i$$

- often correlated opt-X vs. γ flares

⇒ common syn + IC emitting pairs

# γ-ray radiogalaxies: misaligned agn

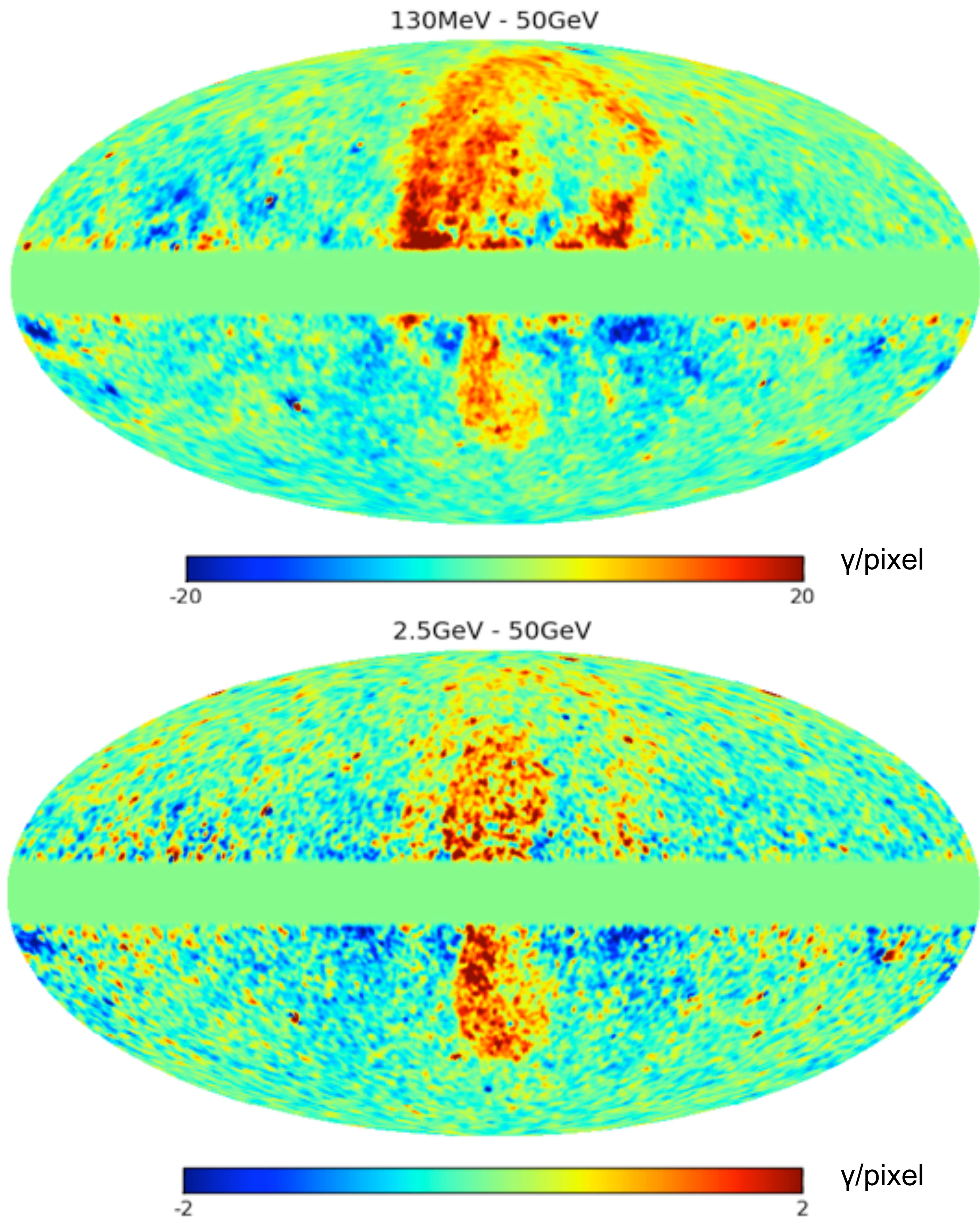
- 15 radiogal. detected by Fermi
- the γ-ray luminosity scales with that of the radio core




- Cen A lobes:
  electron IC losses ⇒ in-situ (re)acceleration

# Loop I & Fermi bubbles

- Fermi LAT 3 years residuals above gas, IC, isotropic, & point-sources

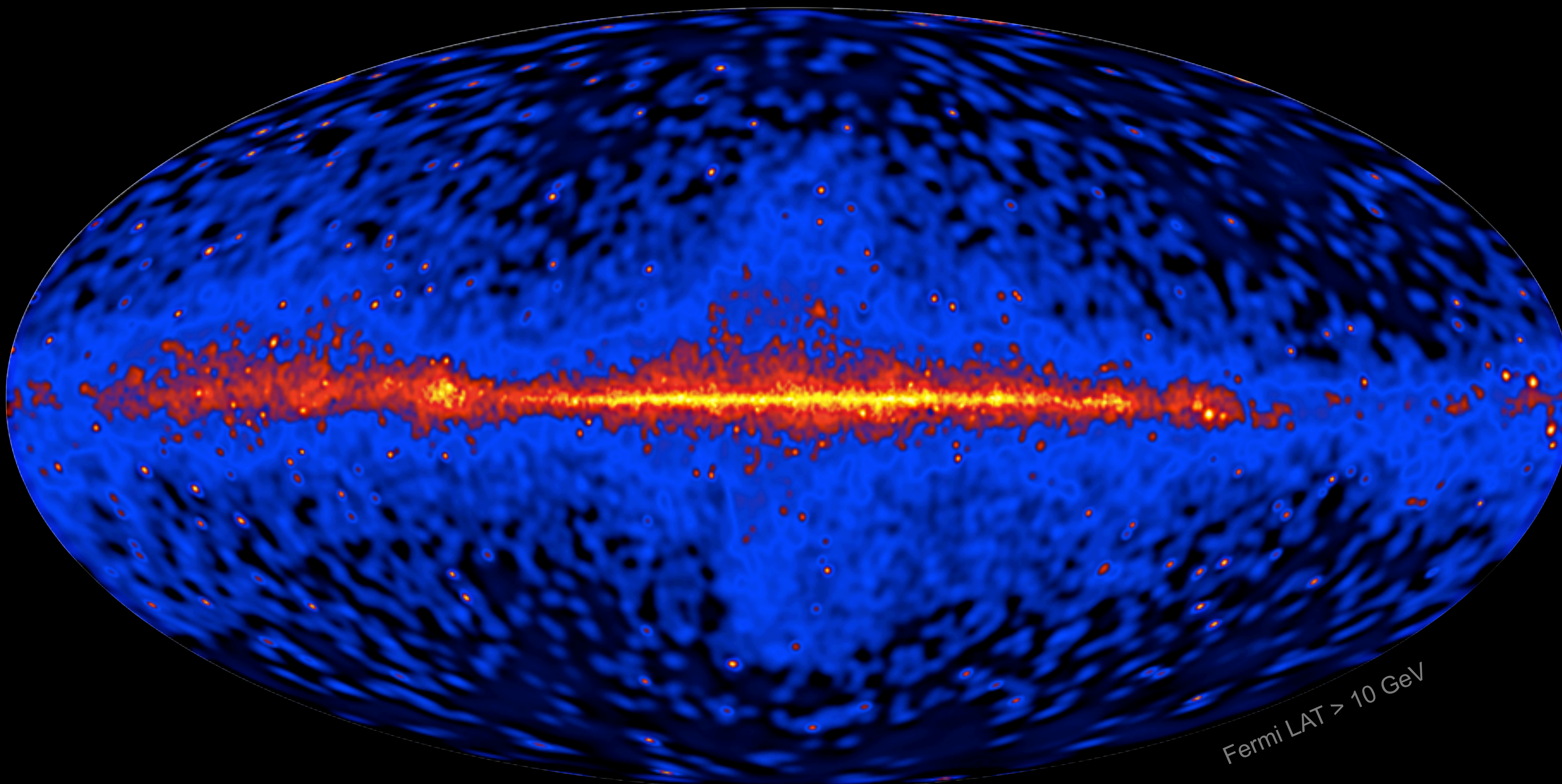



Casandjian et al. 2009
eConf Proceedings C091122

Su et al. 2010, ApJ 724, 1044

# whence ?

- 4 years Fermi > 10 GeV and Planck haze
- cosmic rays in Galactic winds? from a nearby bubble? jets from the central black hole?



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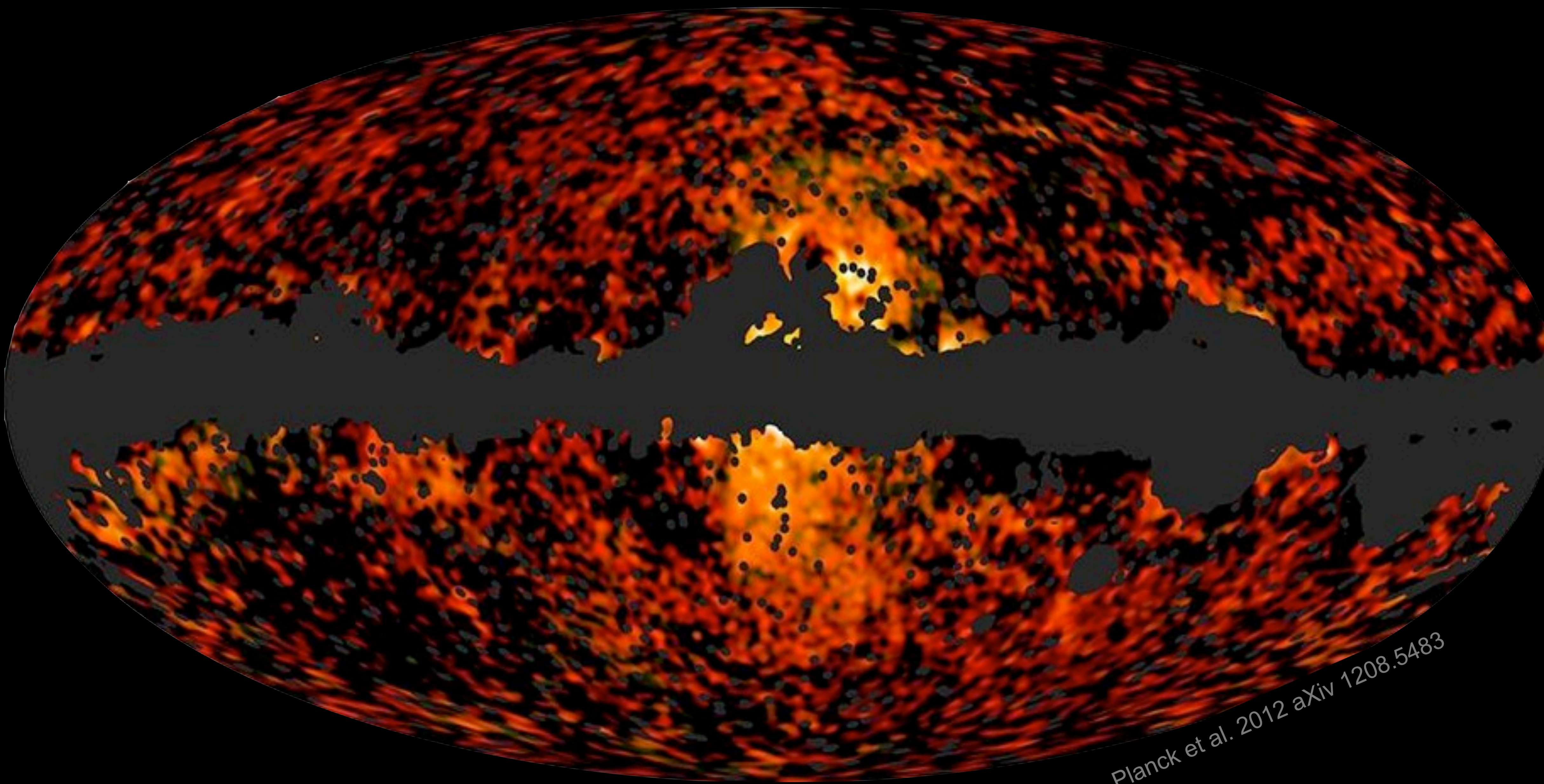

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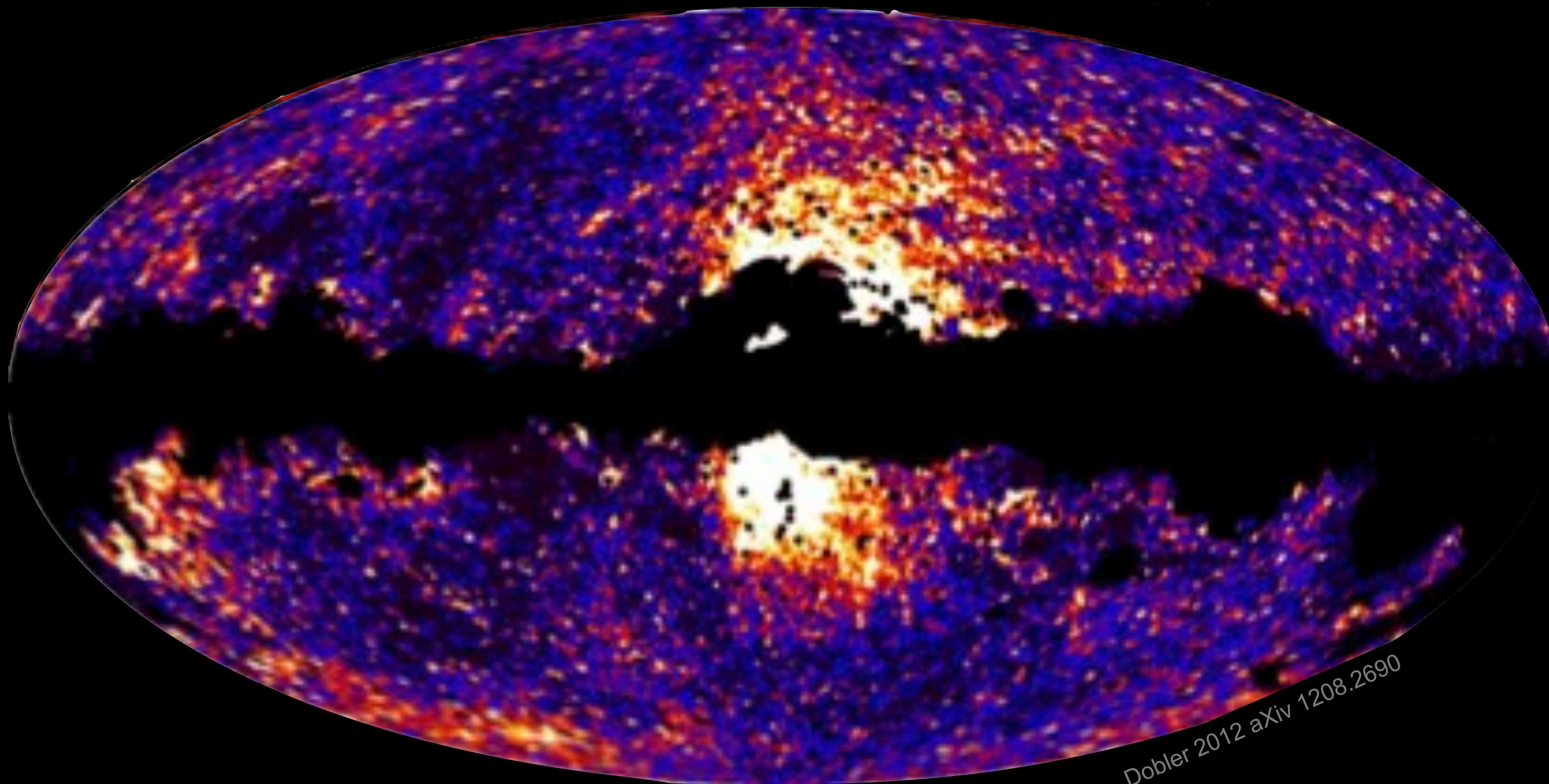
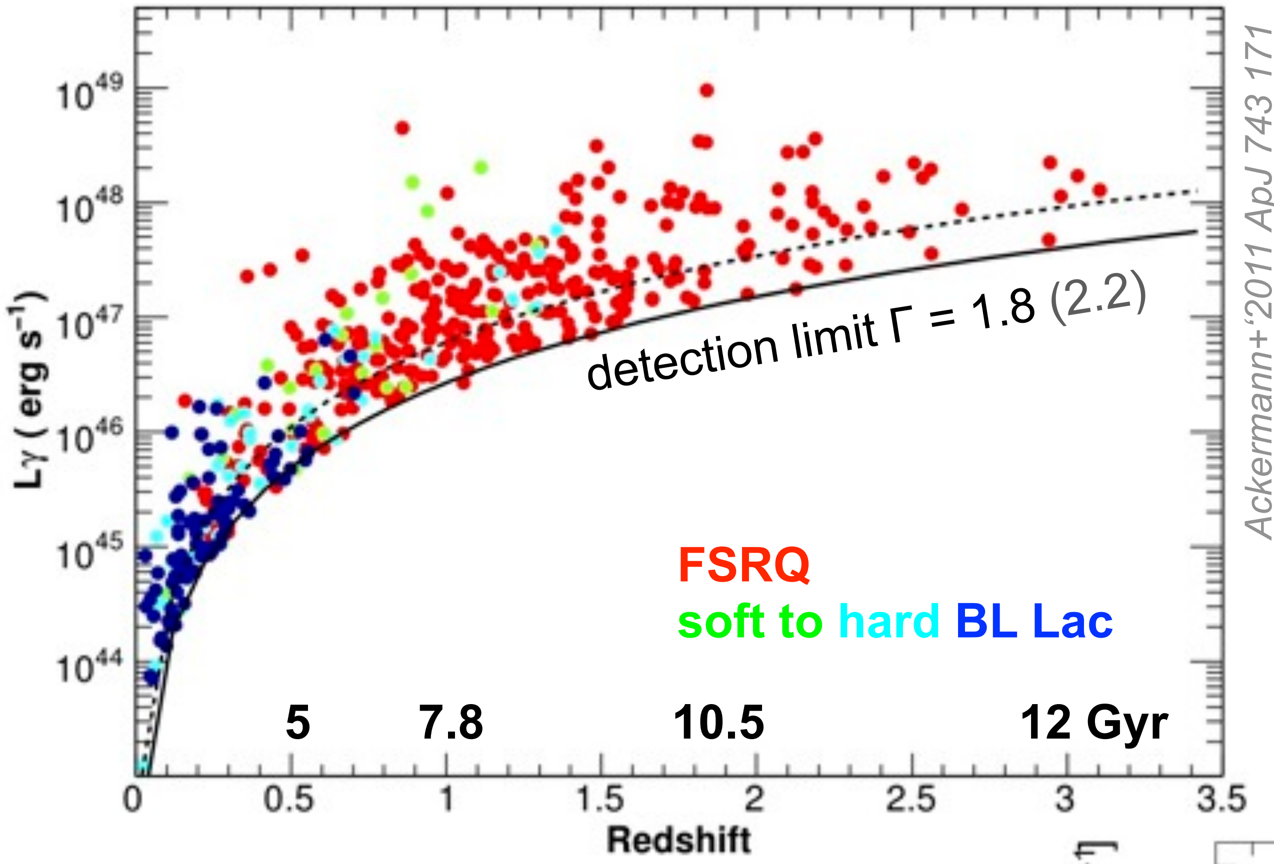
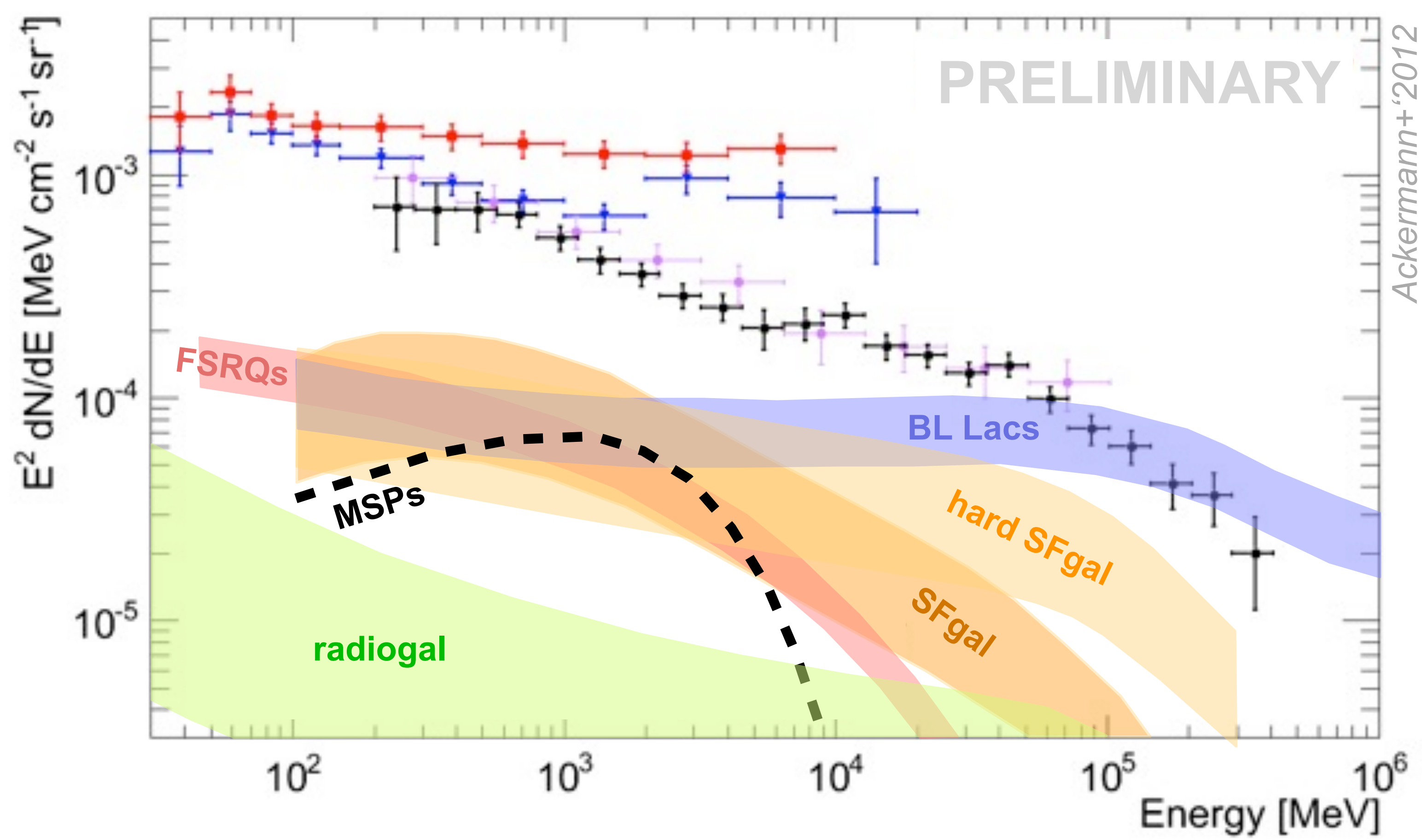


# cosmological impacts




- γ-ray background light
  - 25% foreground uncertainty
  - other sources?
  - CRay halo? DM χχ → γ halo?
  - UHE CRays + EBL → γ ?

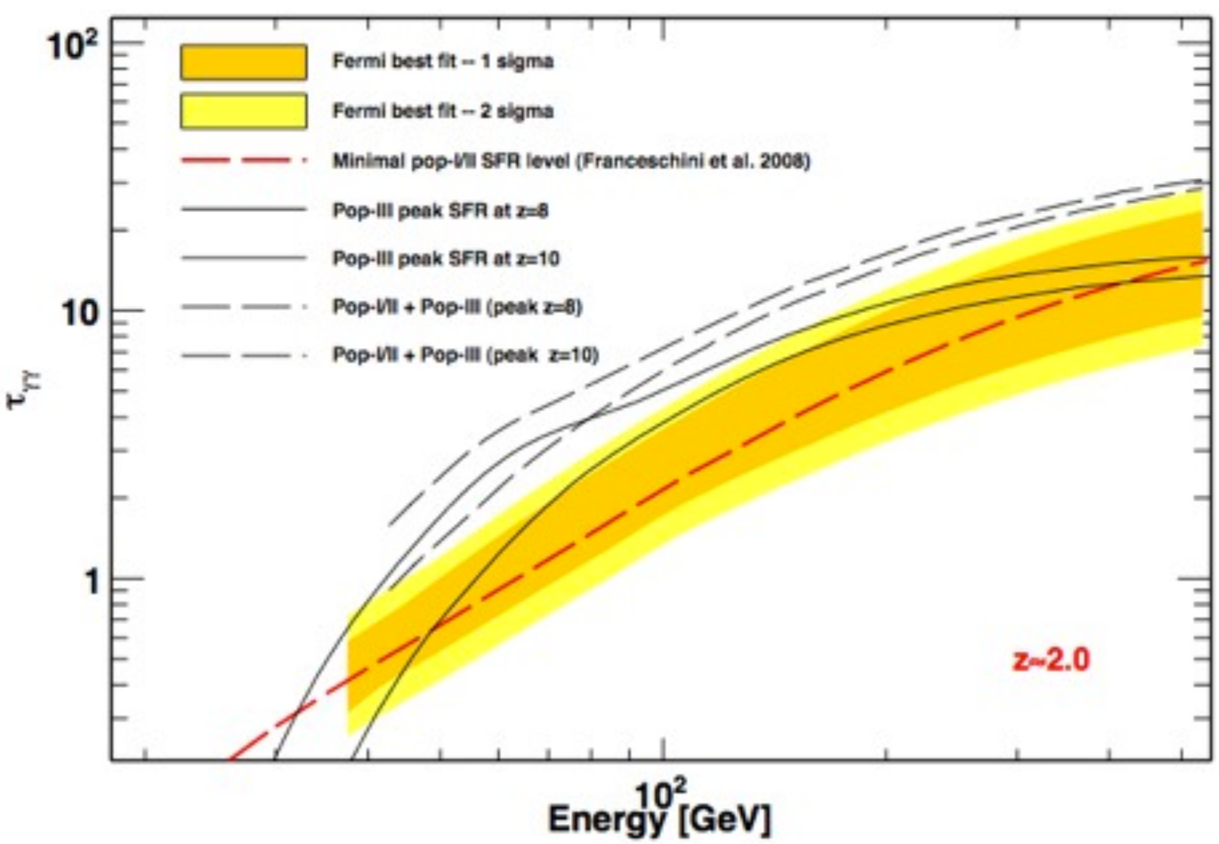
- jet activity and duty cycle
  - feedback on intergalactic scales and galaxy accretion
  - BHole growth linked with galaxy evolution

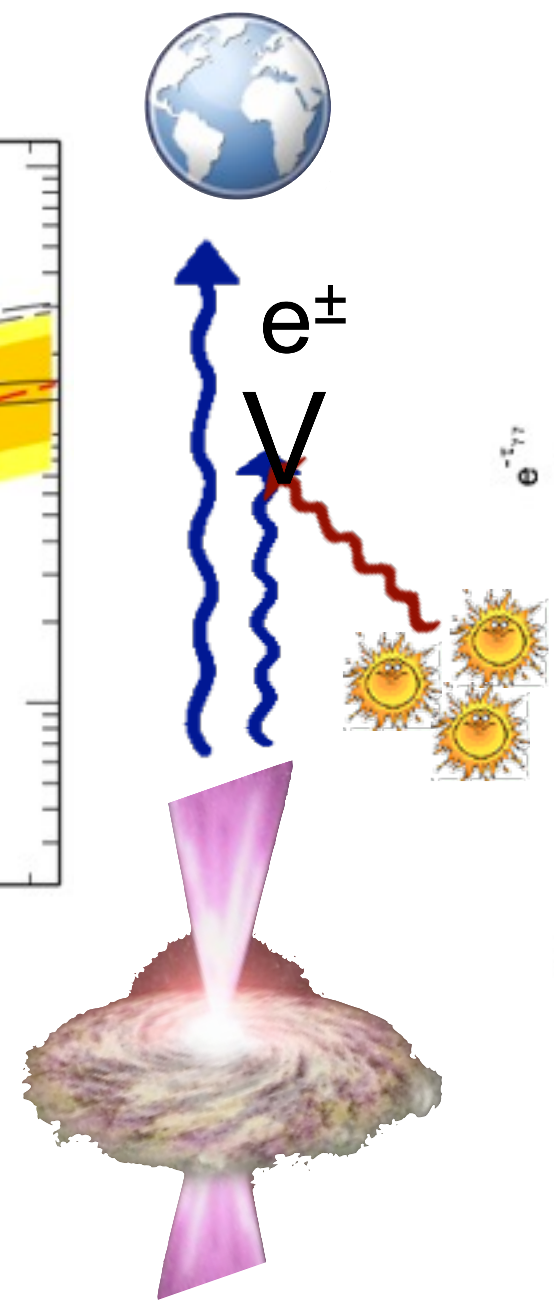


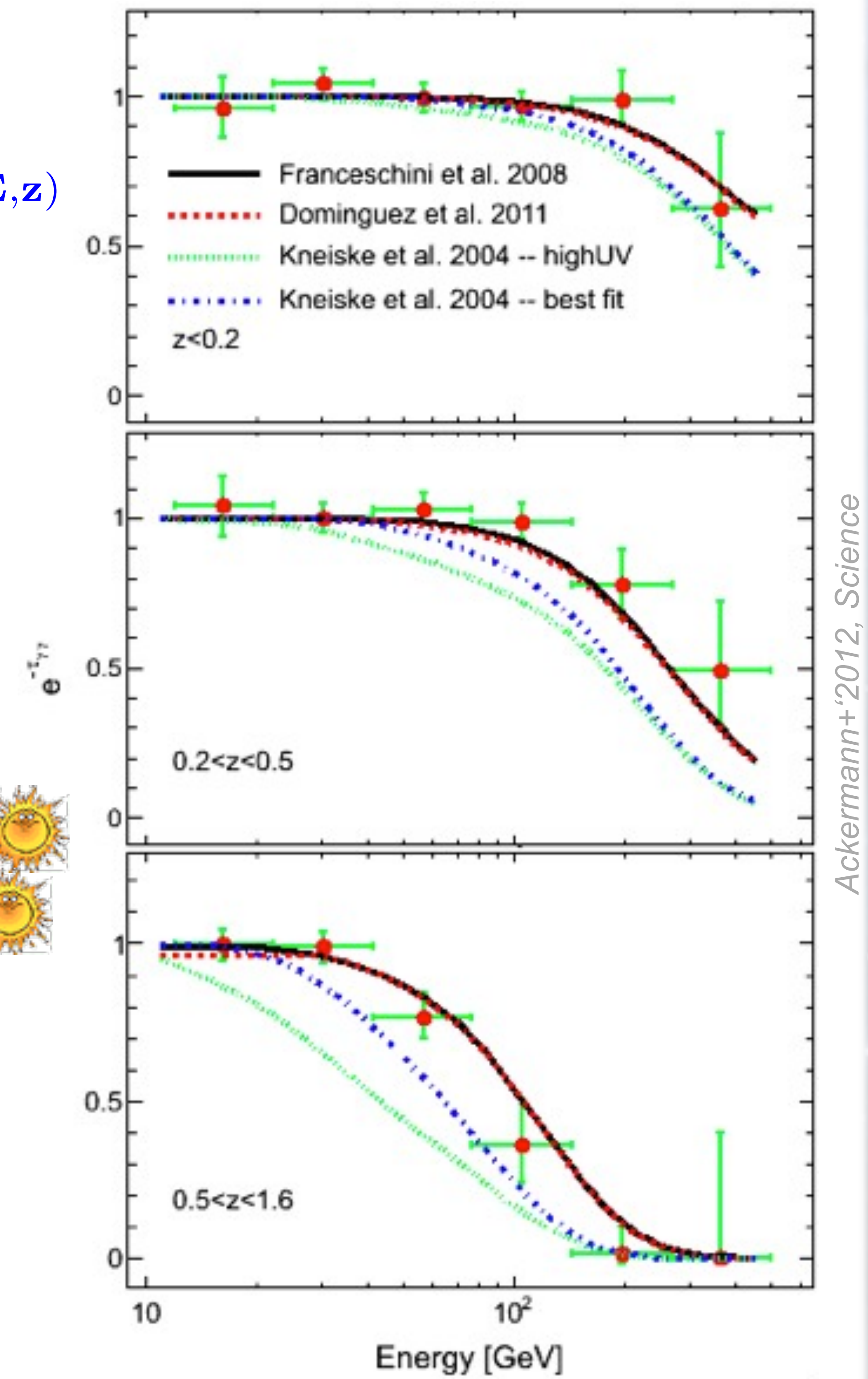
# γ-ray attenuation by ancient starlight

- difficult measurement because of intrinsic spectral breaks & variability in sources
  - absorption compatible with minimal starlight based on resolved galaxy counts
    peak SFR at z > 10 and < 0.5 M⊙ $yr^{-1}$ $Mpc^{-3}$
  - incompatible with high formation rate of pop III stars

$$\mathbf{F_{obs} = F_{int}\, e^{-\tau_{\gamma\gamma}(E,z)}}$$



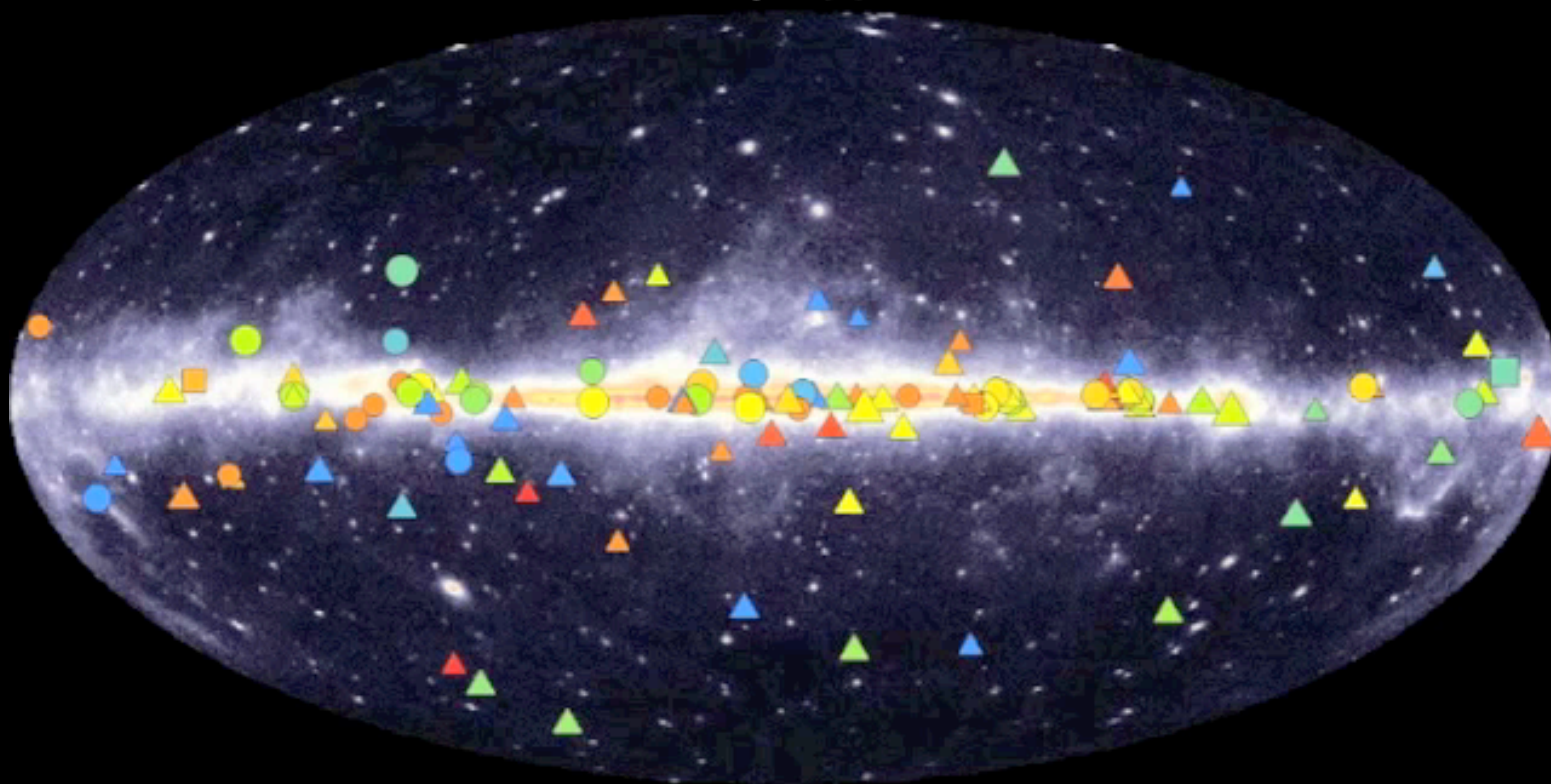




Accelerator 2:
pulsar dynamo

# the twinkling γ-ray sky

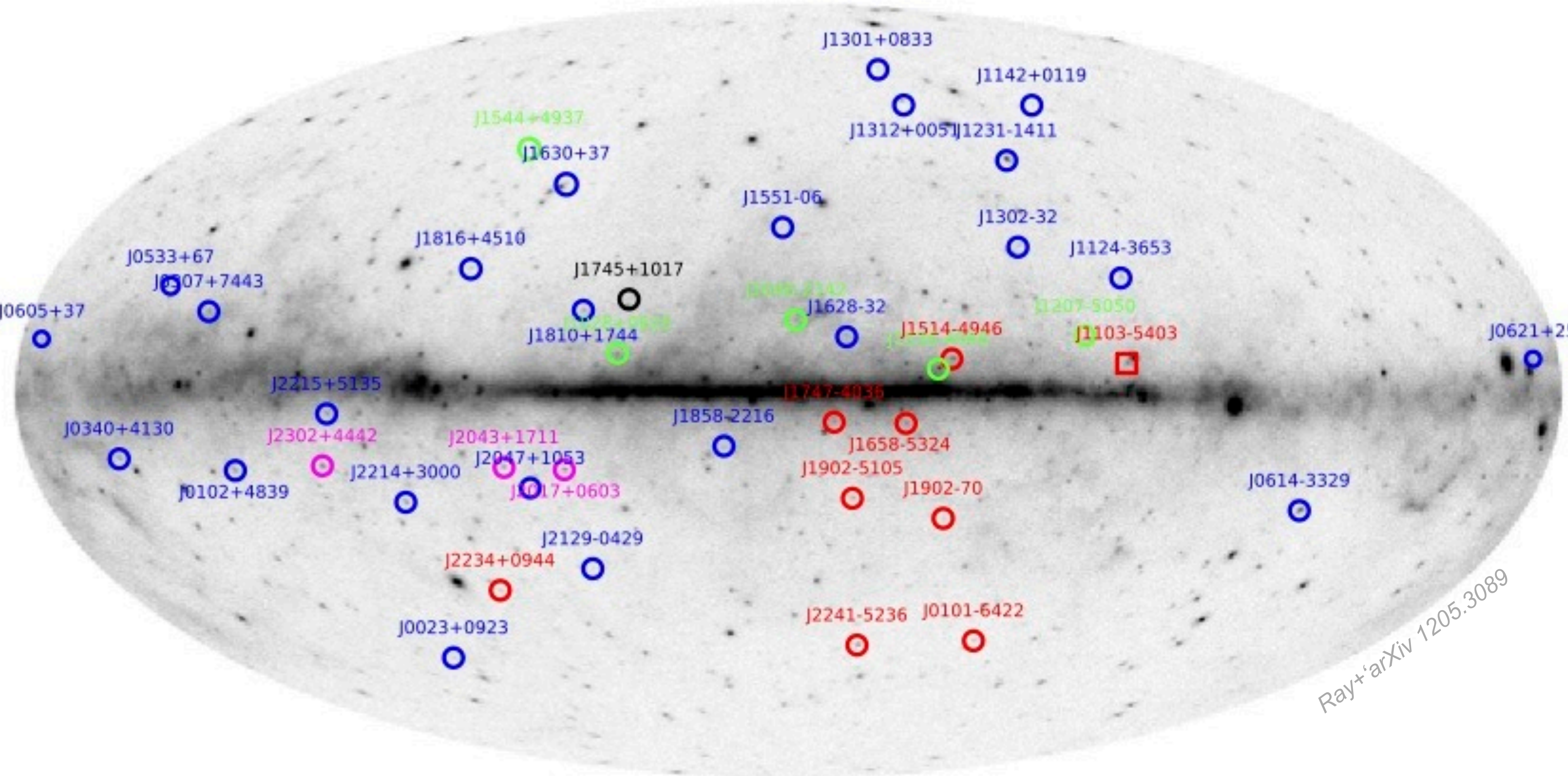
- 117 pulsars with 1.6 ms to 0.46 s periods
- **1/3 radio + γ** emitters, **< Myr-old** isolated pulsars
- **1/3 γ only** emitters, **< Myr-old** isolated pulsars
- **1/3 radio + γ Gyr-old** ms pulsars (many binaries)

Fermi LAT γ -ray pulsars



originally discovered in γ rays O, radio Δ, X rays Ξ

# 40 new millisecond pulsars




Nançay (France)

GMRT (India)

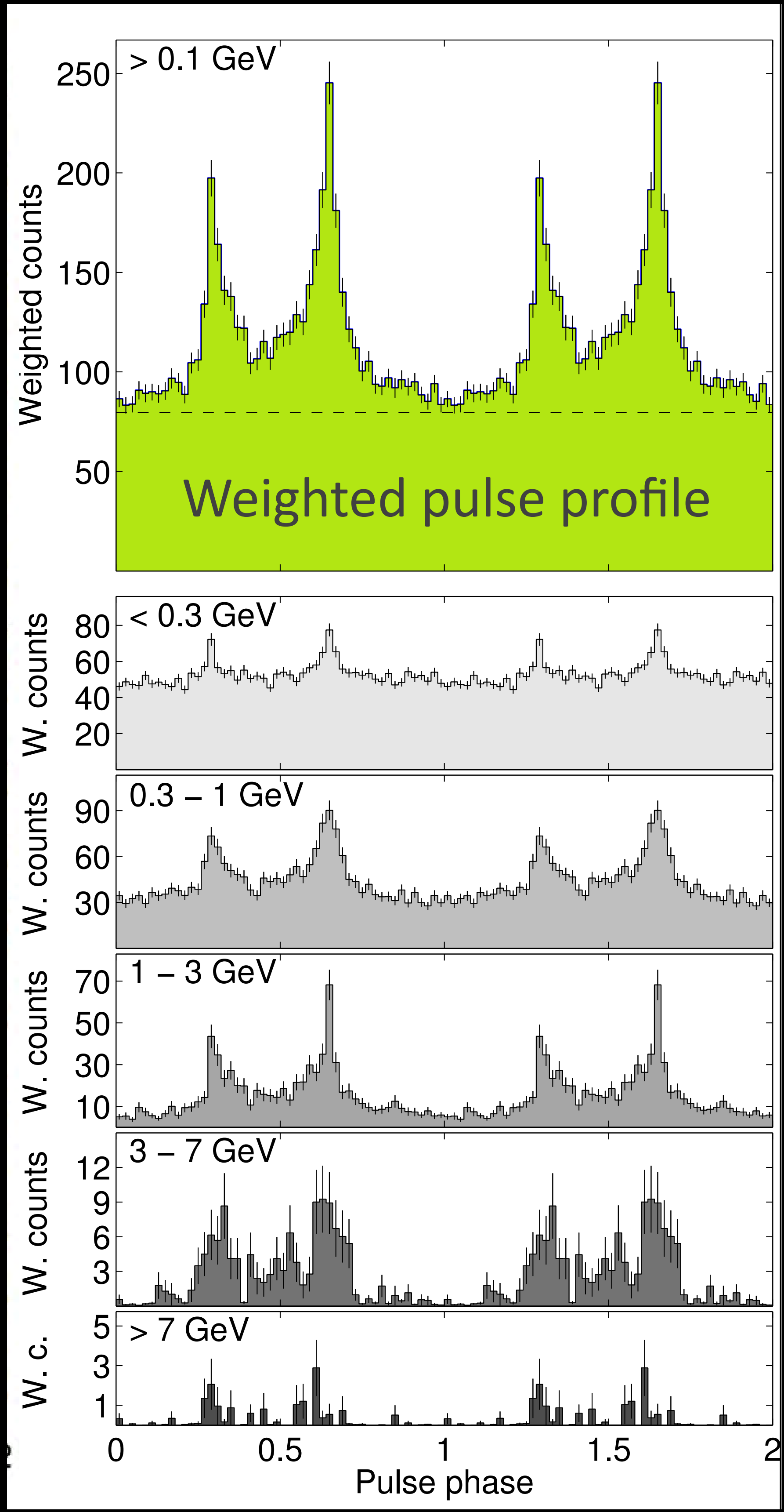
GreenBank (USA)

Parkes (Asutralia)

Effelsberg (Germany)

# PSR J1311-3430

- first blind-search γ-ray ms pulsar
- very compact system ($P_{orb}$ = 0.065 day, $M_{comp}$ > 8 $M_{Jupiter}$)



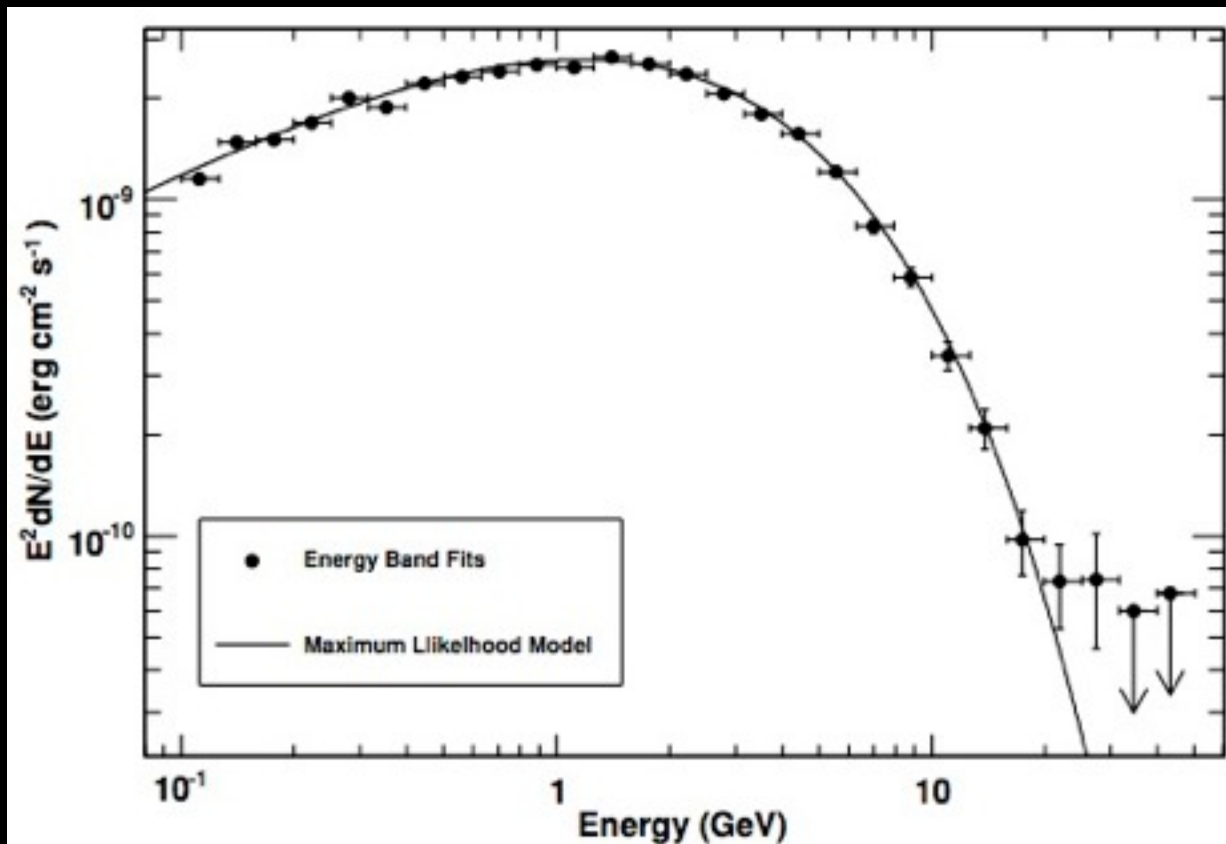

Einstein@Home

*Pletsch+'2012 Science 25/10/12*

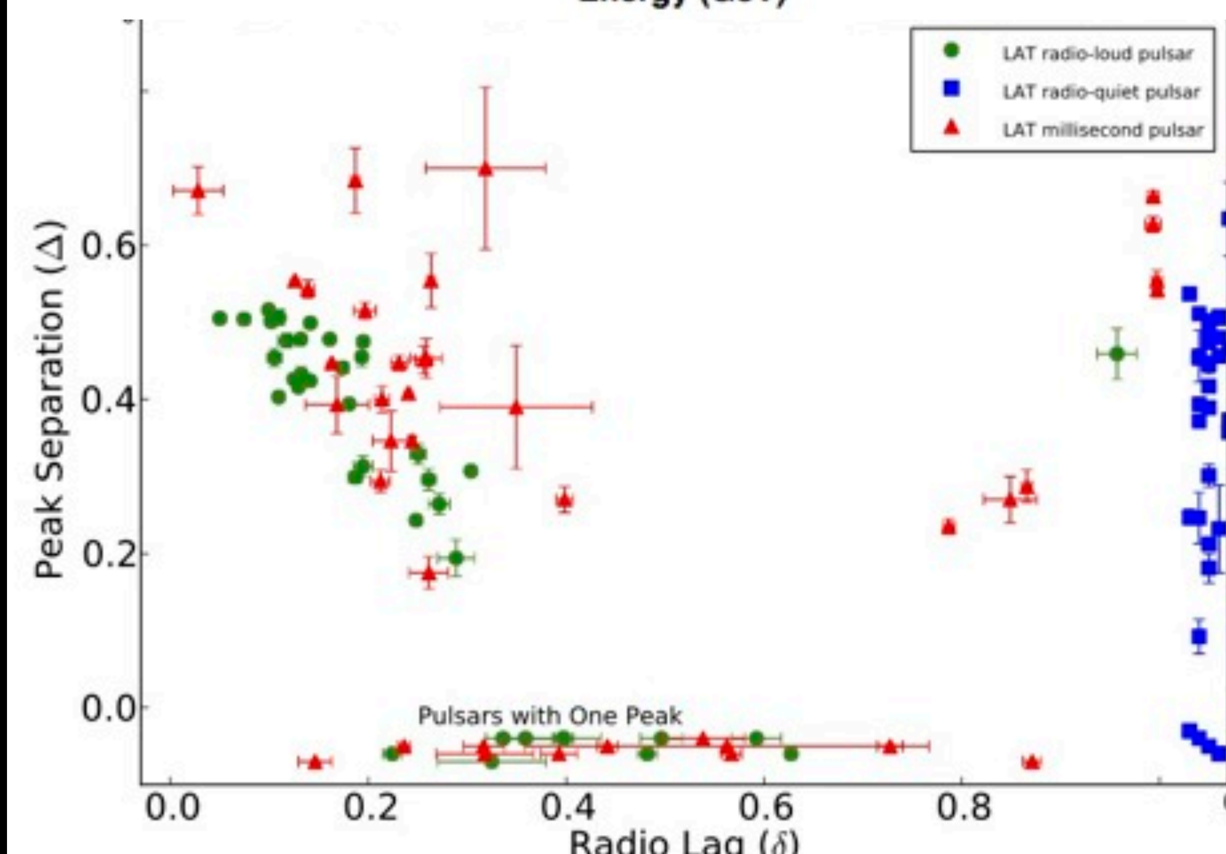
# accelerator in the outer magnetosphere

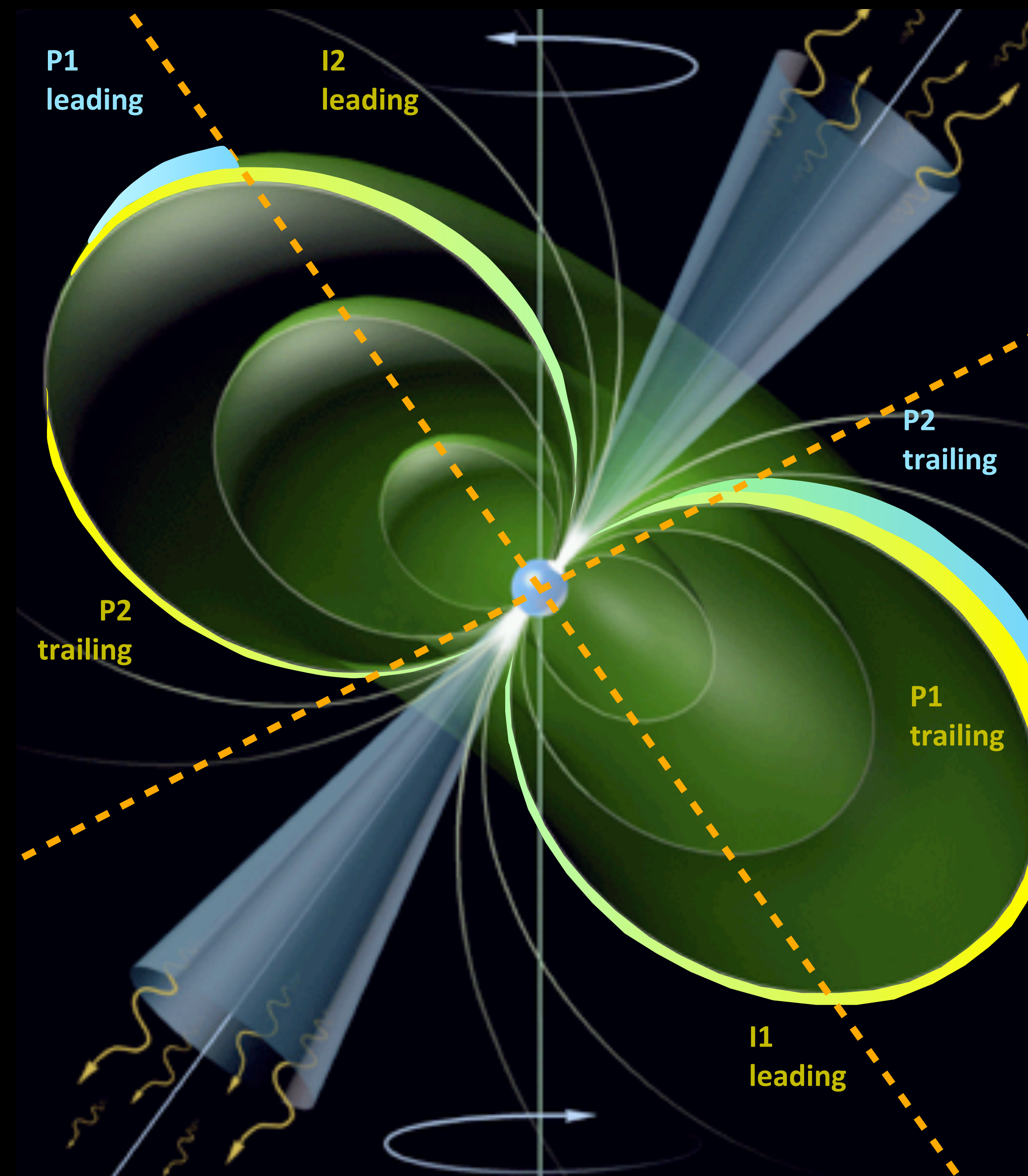
- 10 TeV accelerator in the outer magnetosphere, maybe over a single pole

*Abdo+2010, ApJ 713, 154*




*Ackermann+ 2013 PSRCAT2*

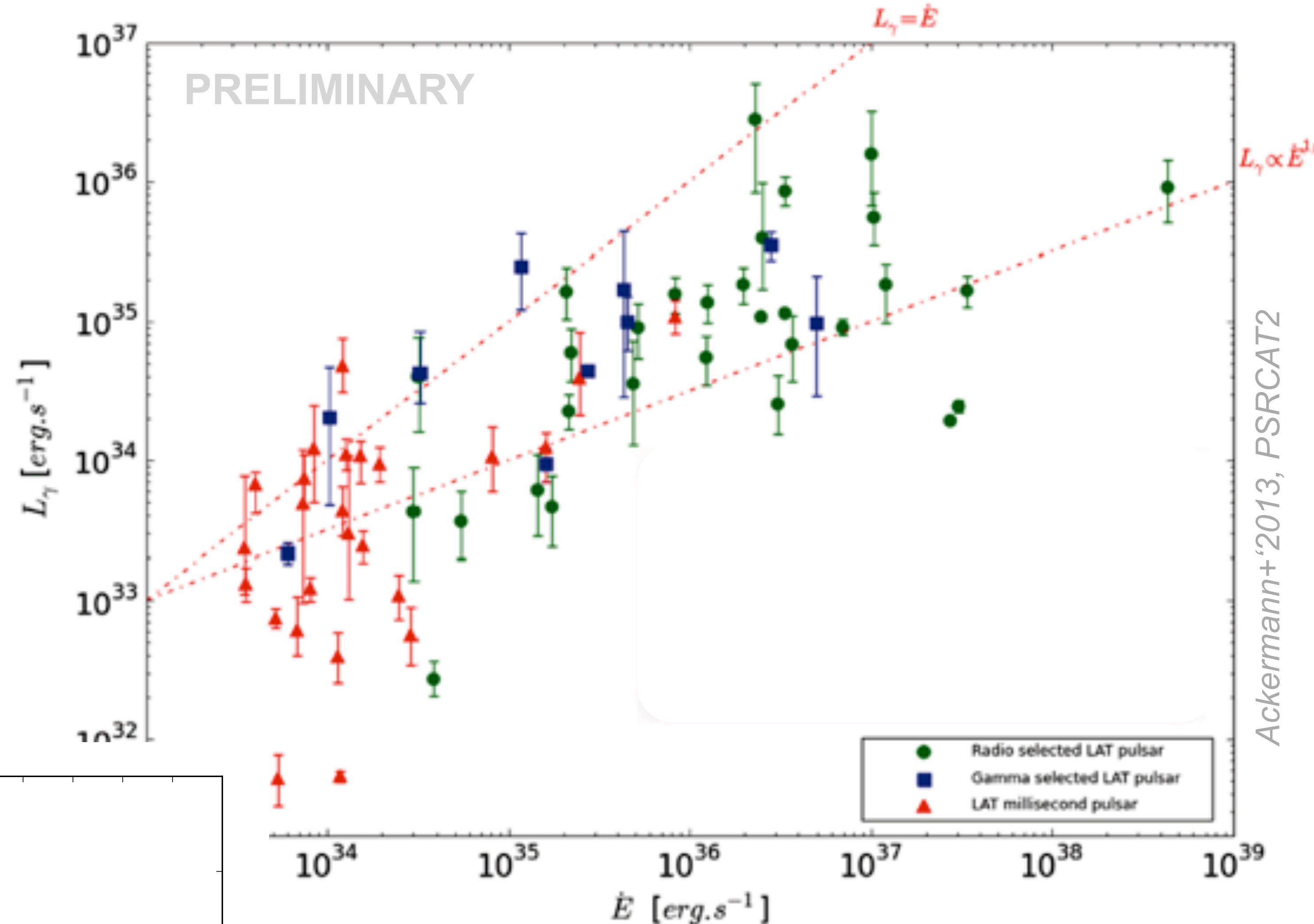


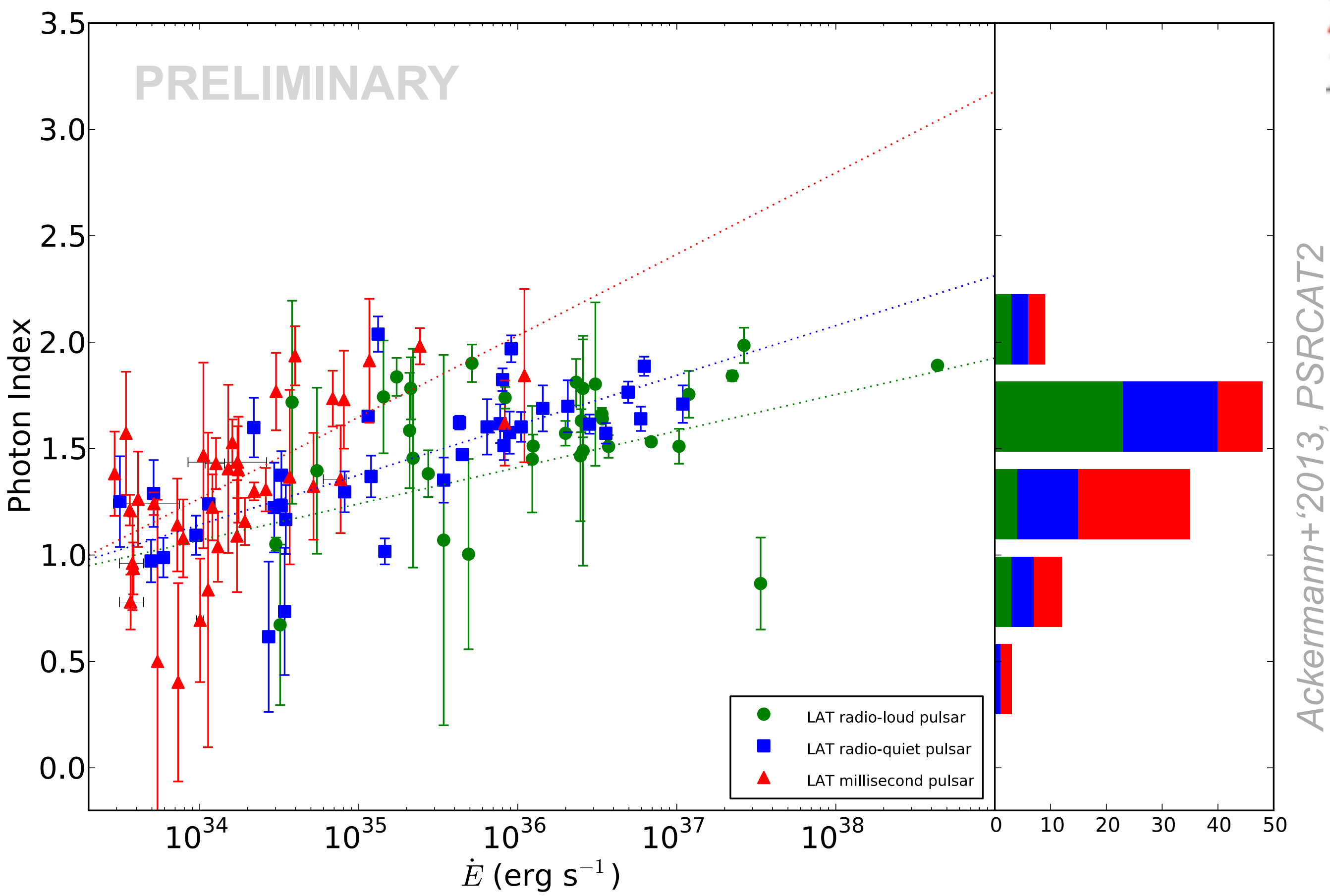



# evolutionary trends

- unexplained evolution in the extraction of the dynamo power as the pulsar slows down

- the older, the harder in γ rays

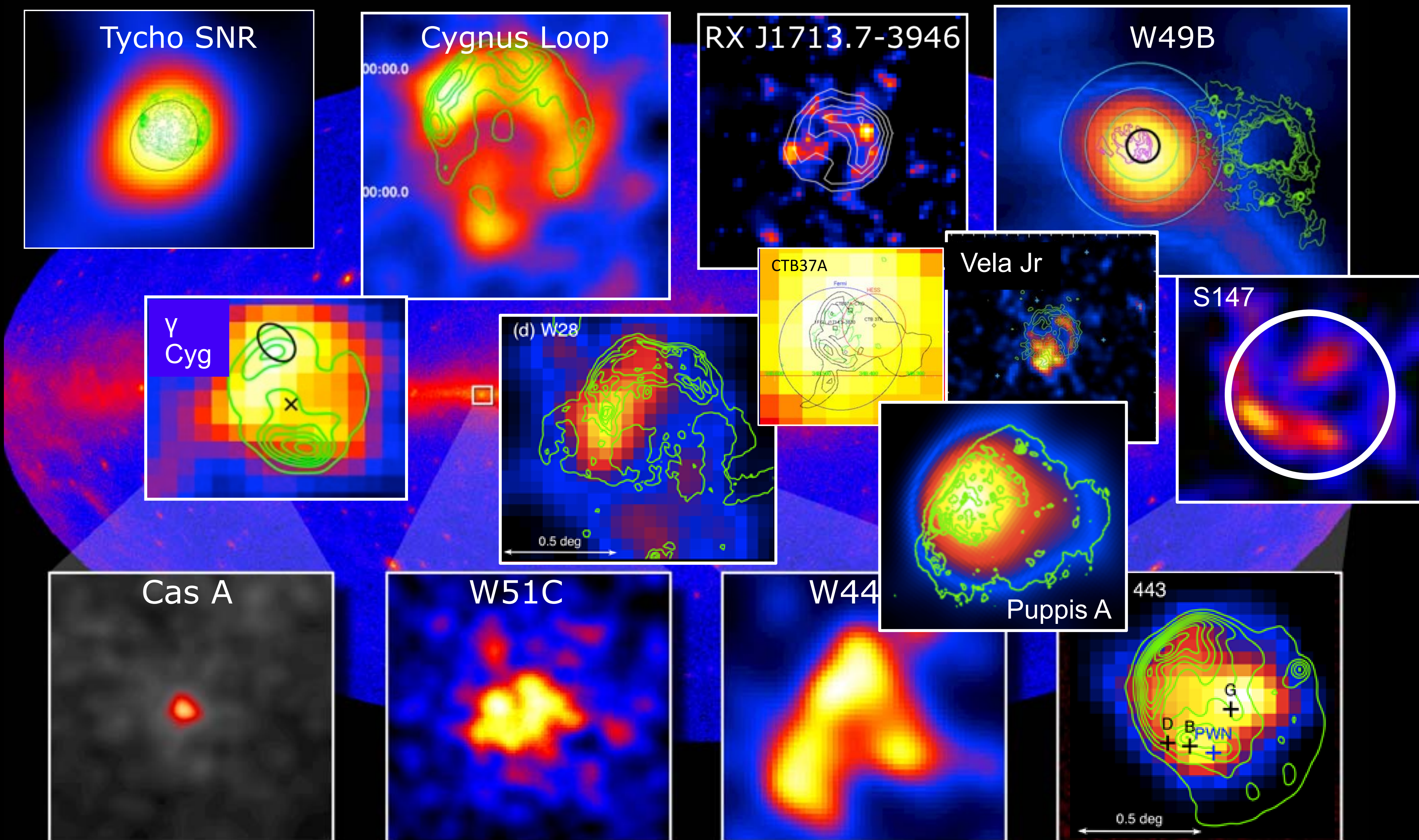


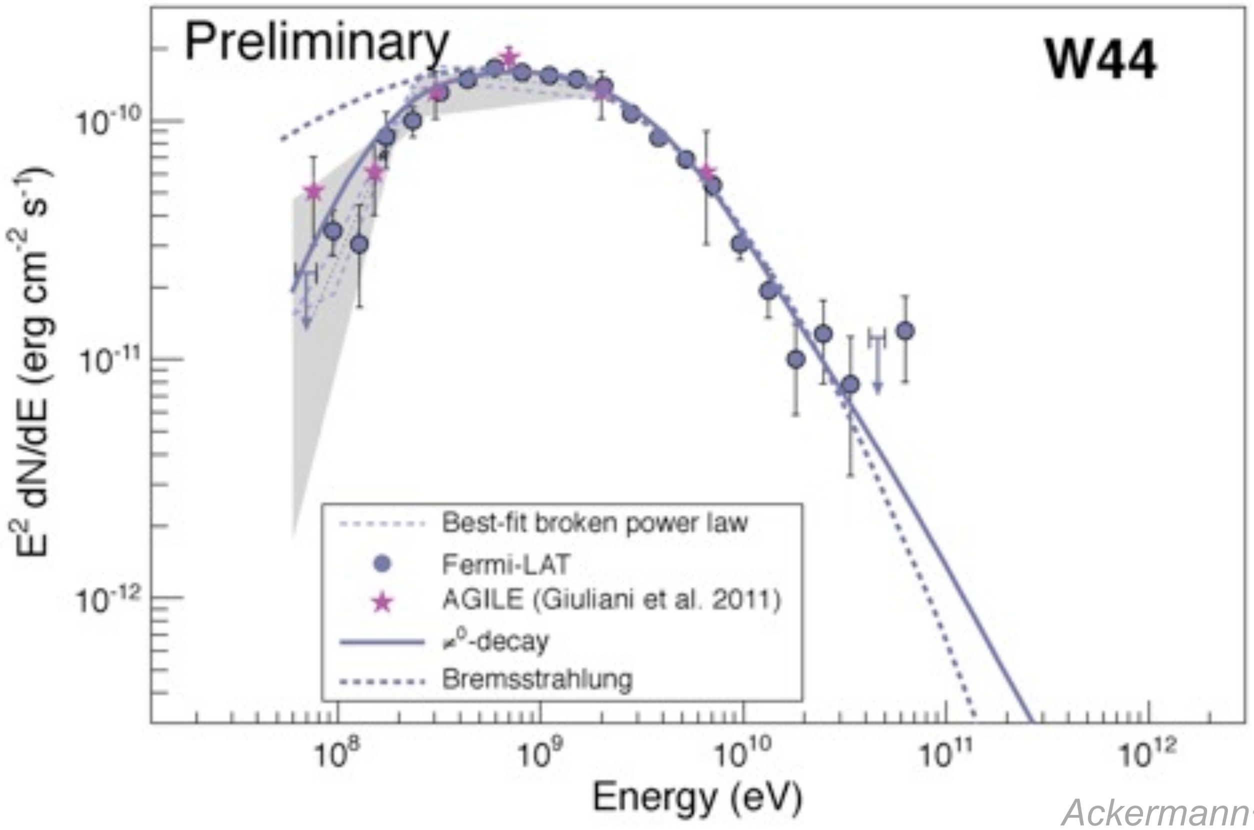

Accelerator 3:
diffusive shock
acceleration

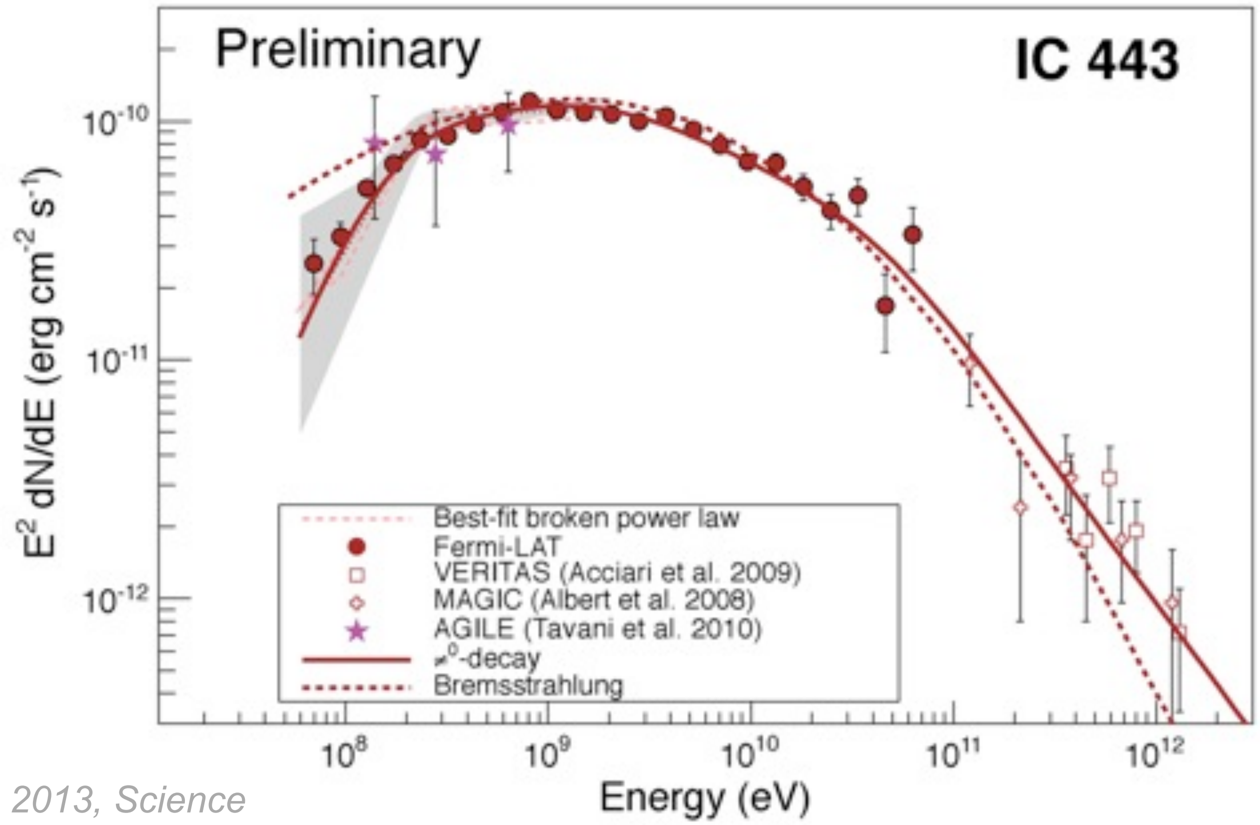
# gallery of GeV supernova remnants

- spatial correlations of multi-GeV electrons and γ rays inside remnants ?
- electron ageing inside remnants

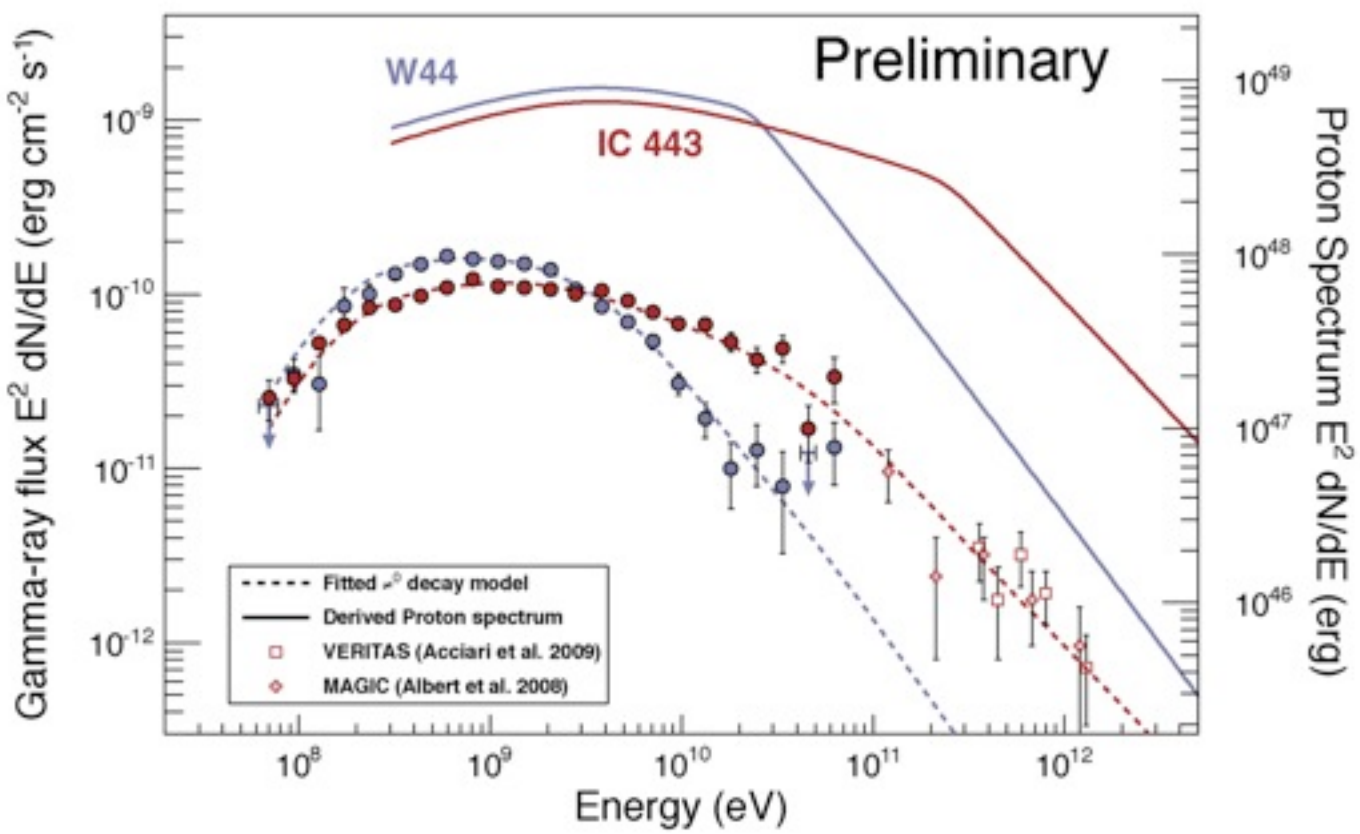


# signature of the $\pi^0$ bump?



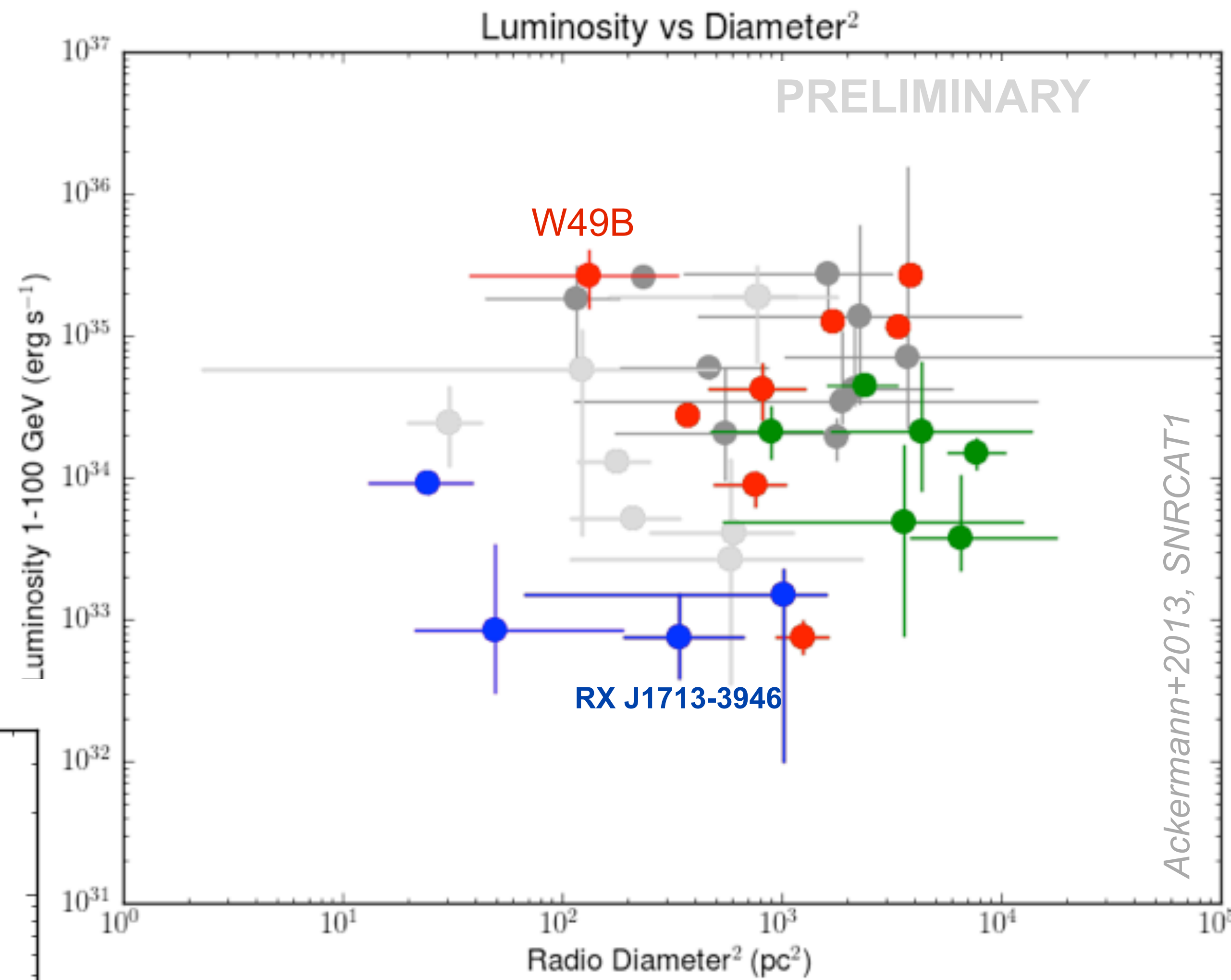

*Ackermann+ 2013, Science*

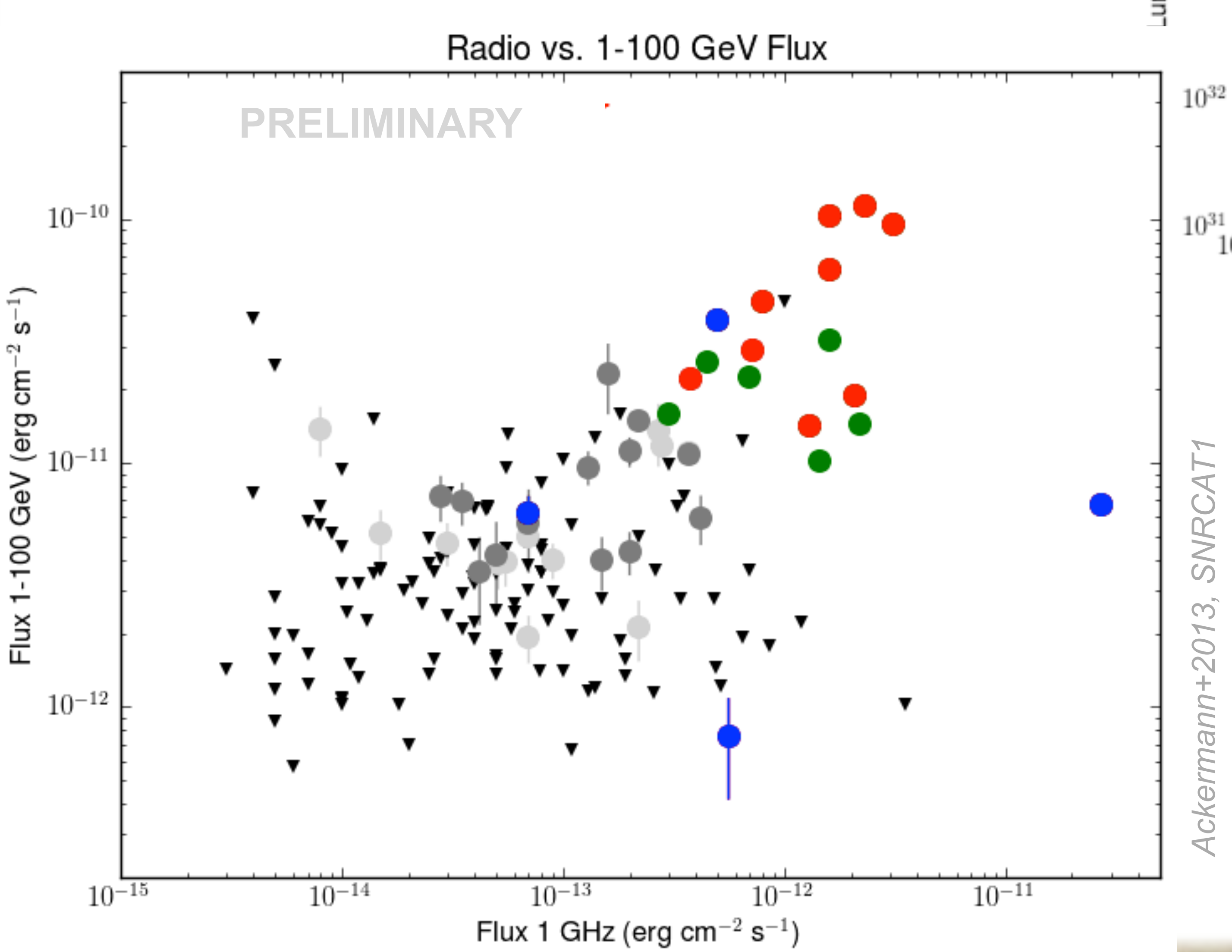


# collective properties

- luminosity increases with age ($n_{ISM}$ ↑ ?)
  - esp. for SNR near clouds

- SNRs are radio bright
  - esp. for SNRs near clouds
  - compressed shock?

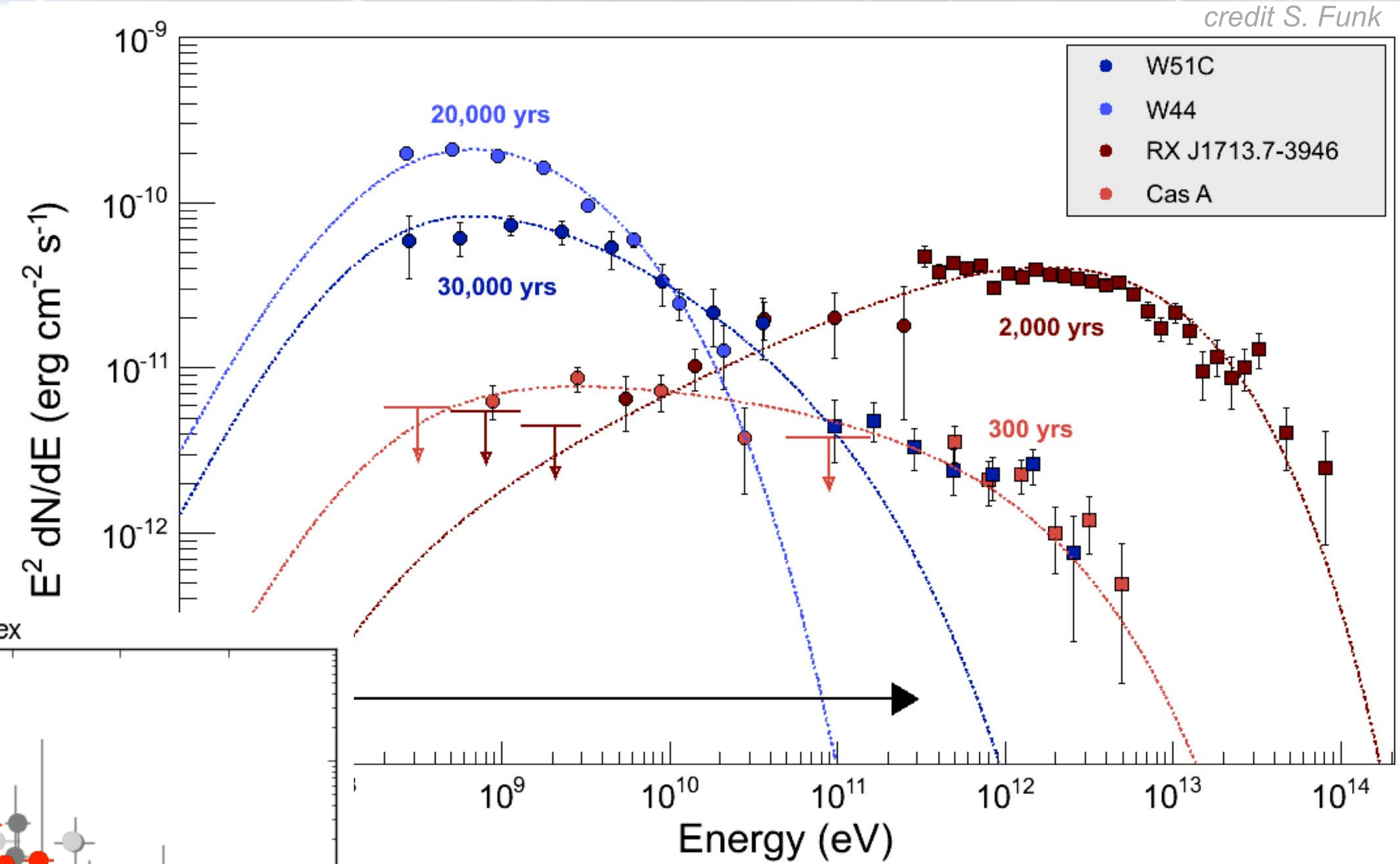


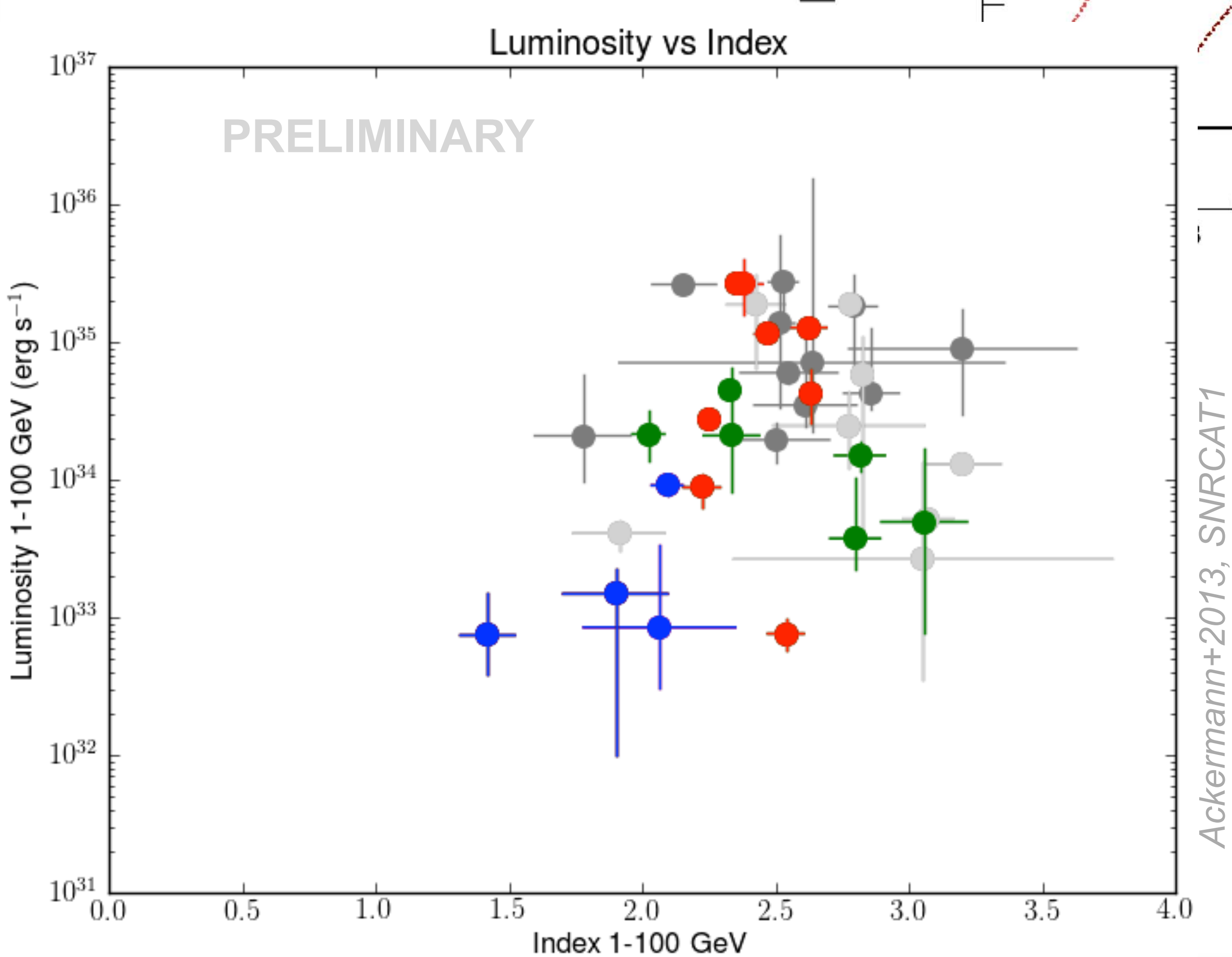




**< 2 kyr old SNR**
**SNR impacting cloud**
**new candidate**

GeV breaks

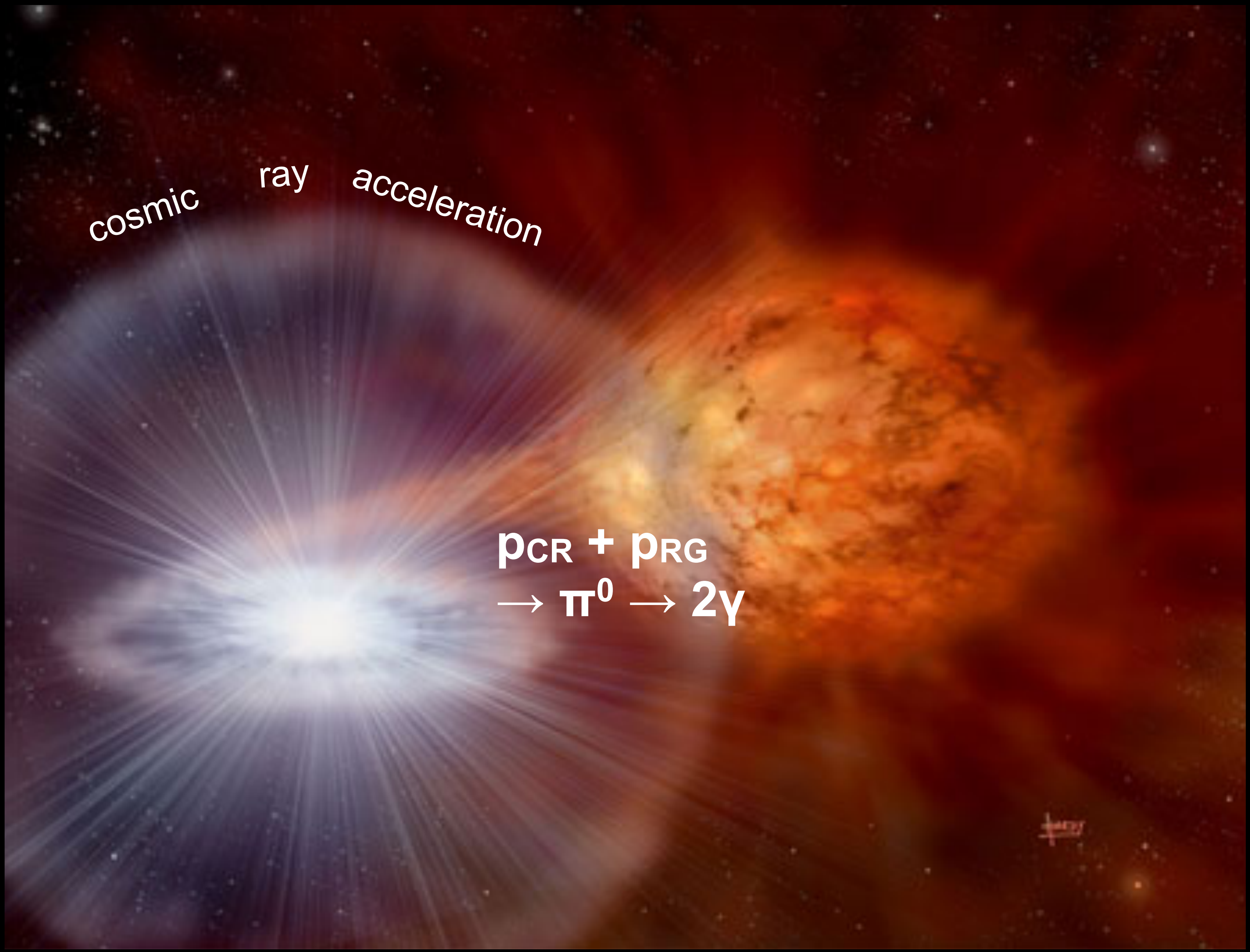
⇒ escaped CRays ?

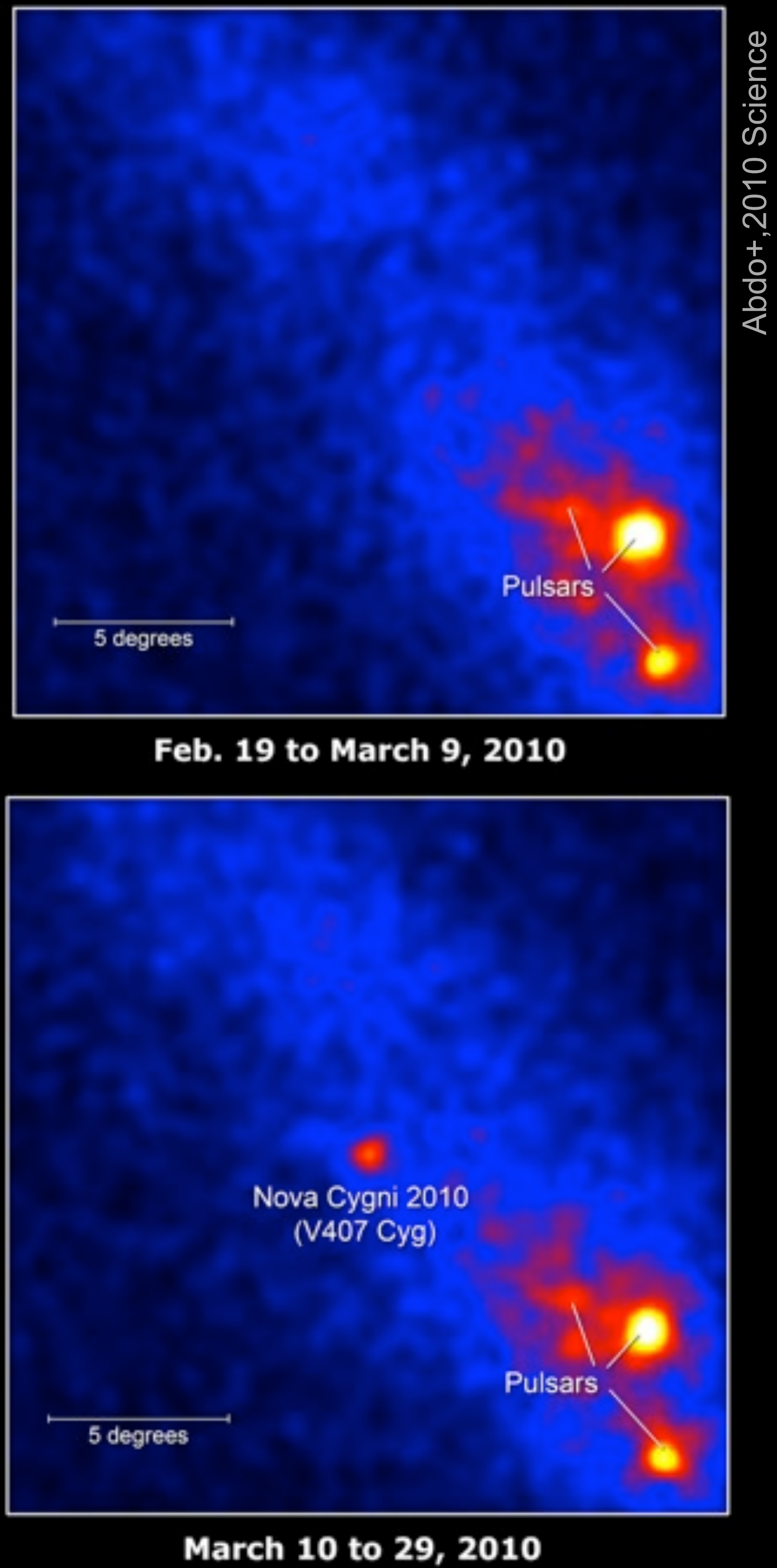


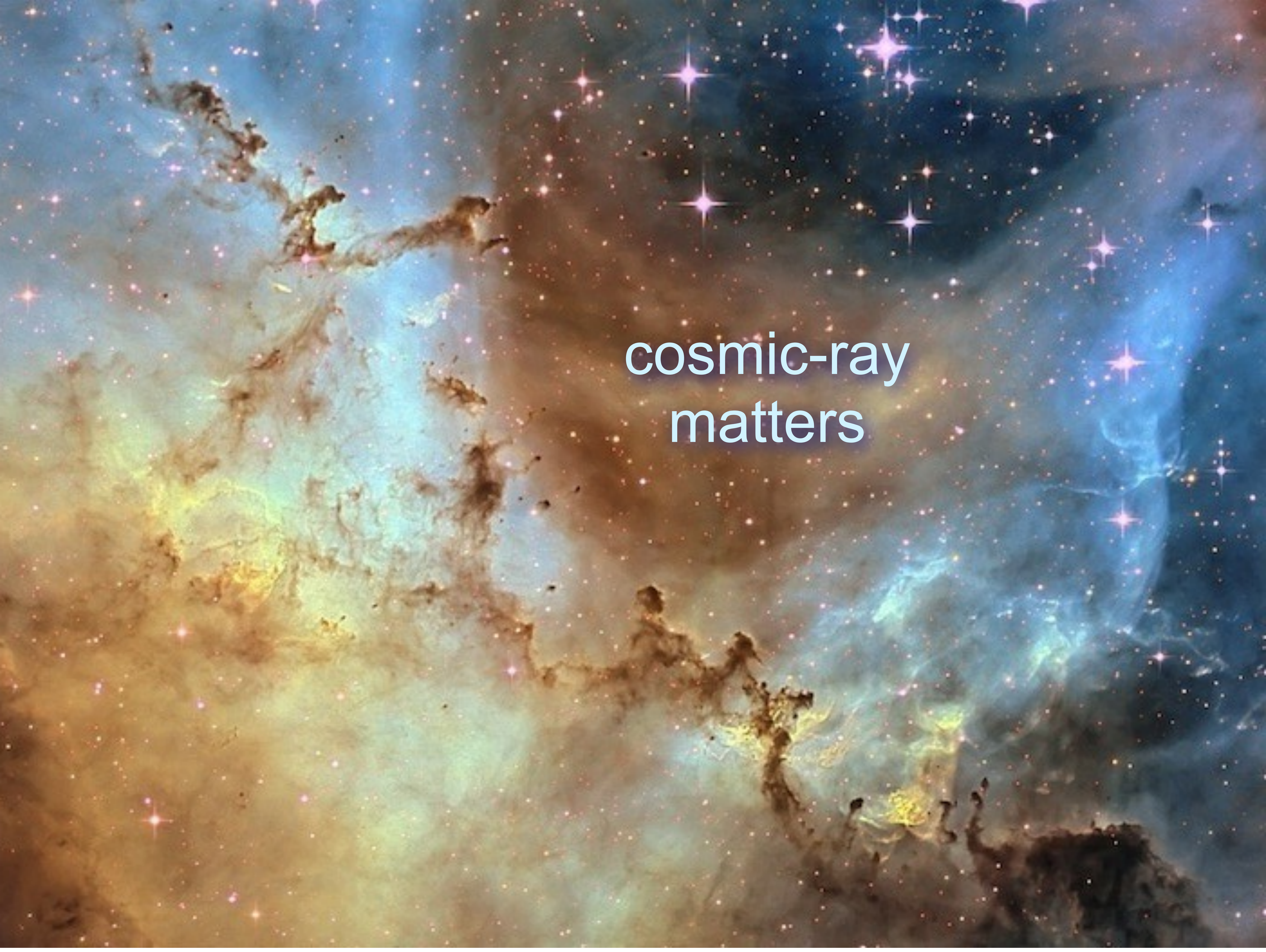



# mini-supernova shock waves

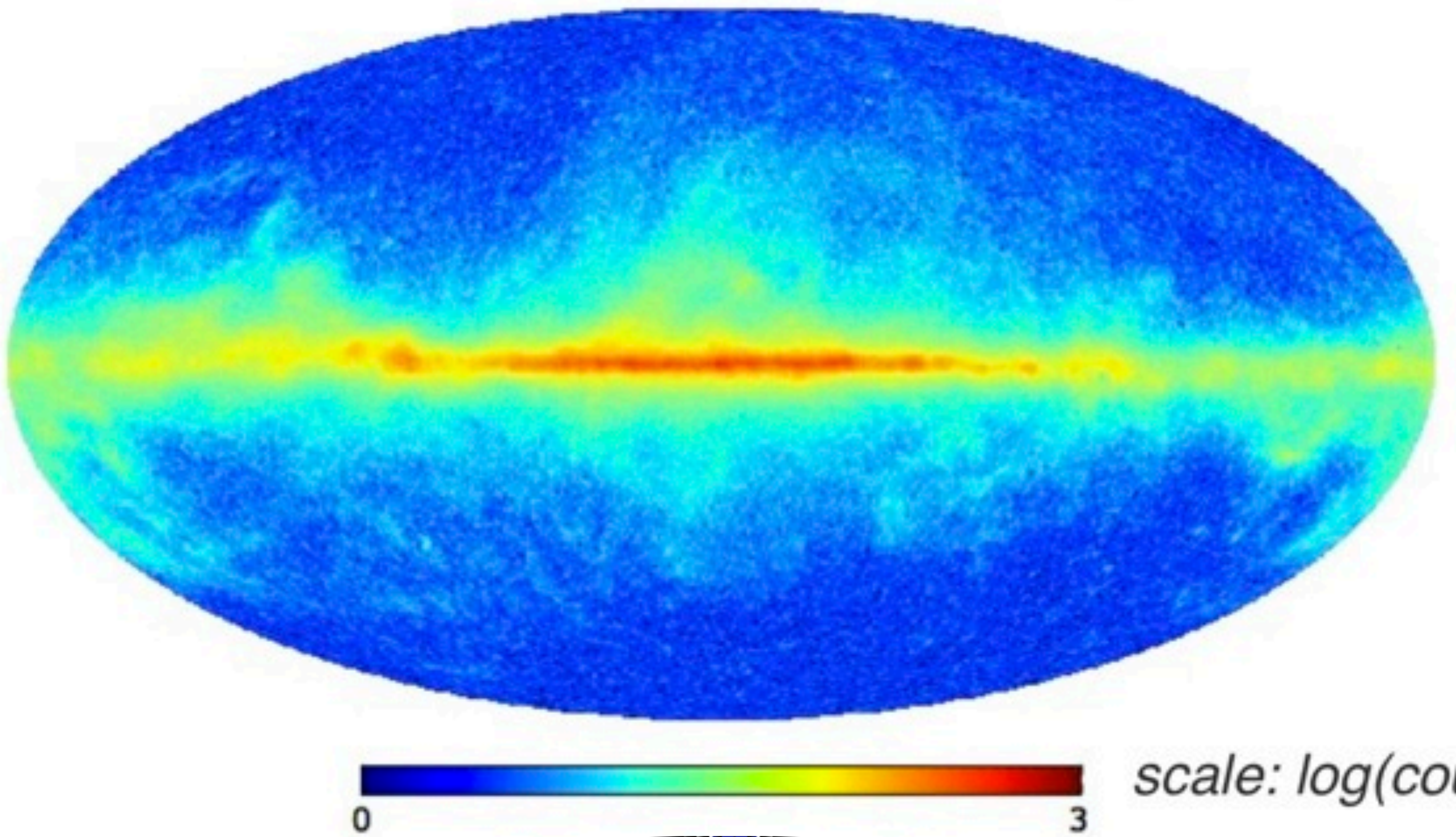
- nova V 407 Cyg
- $10^{37}$ J, 44 Mkm/h shock
- 1 to 2 novae per year

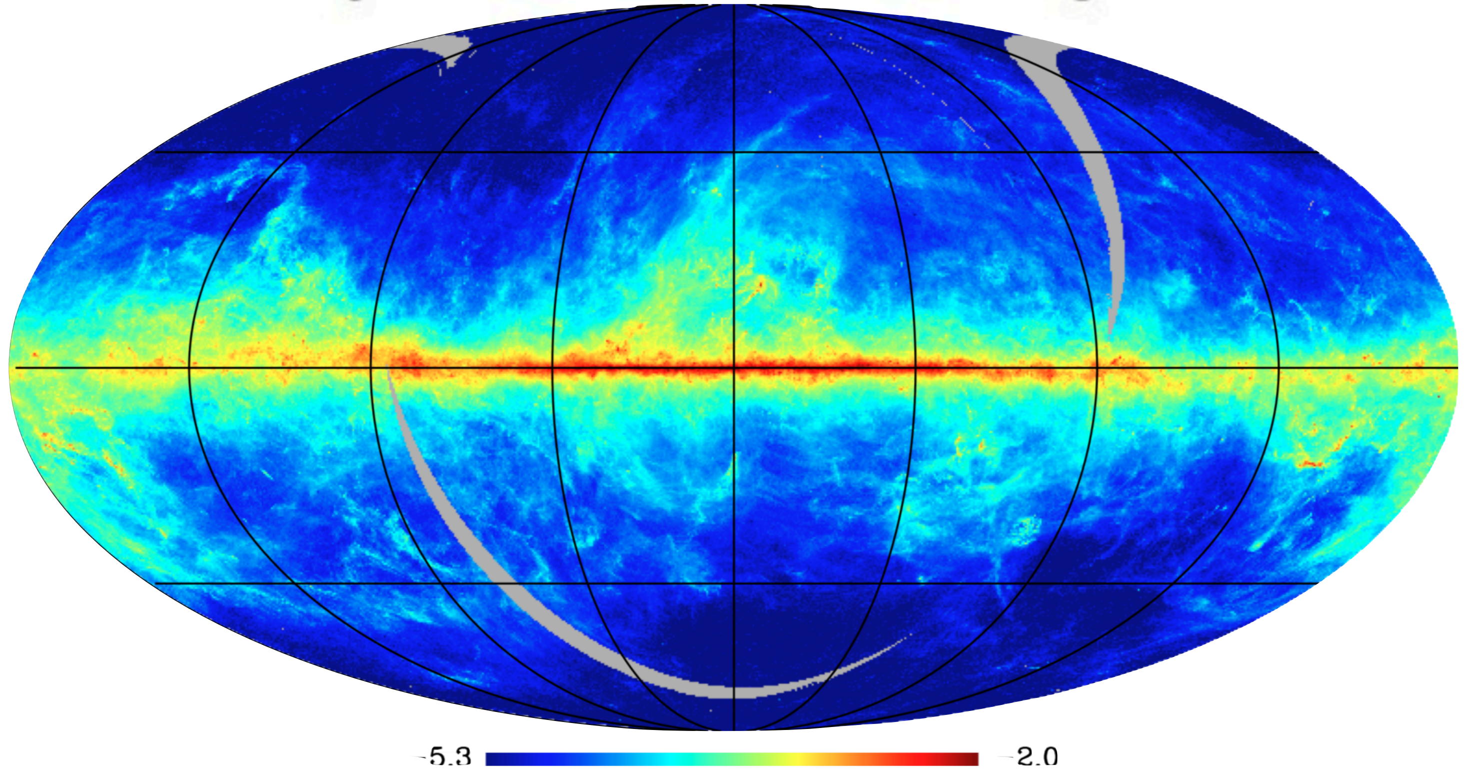



cosmic-ray
matters

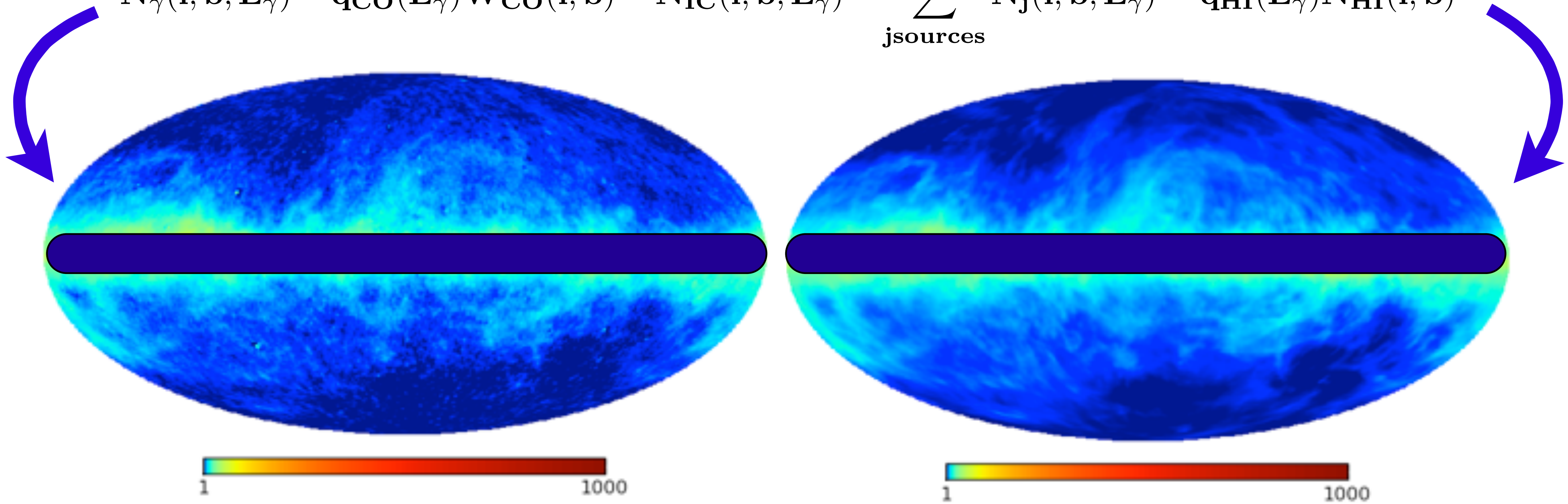
# the total ISM



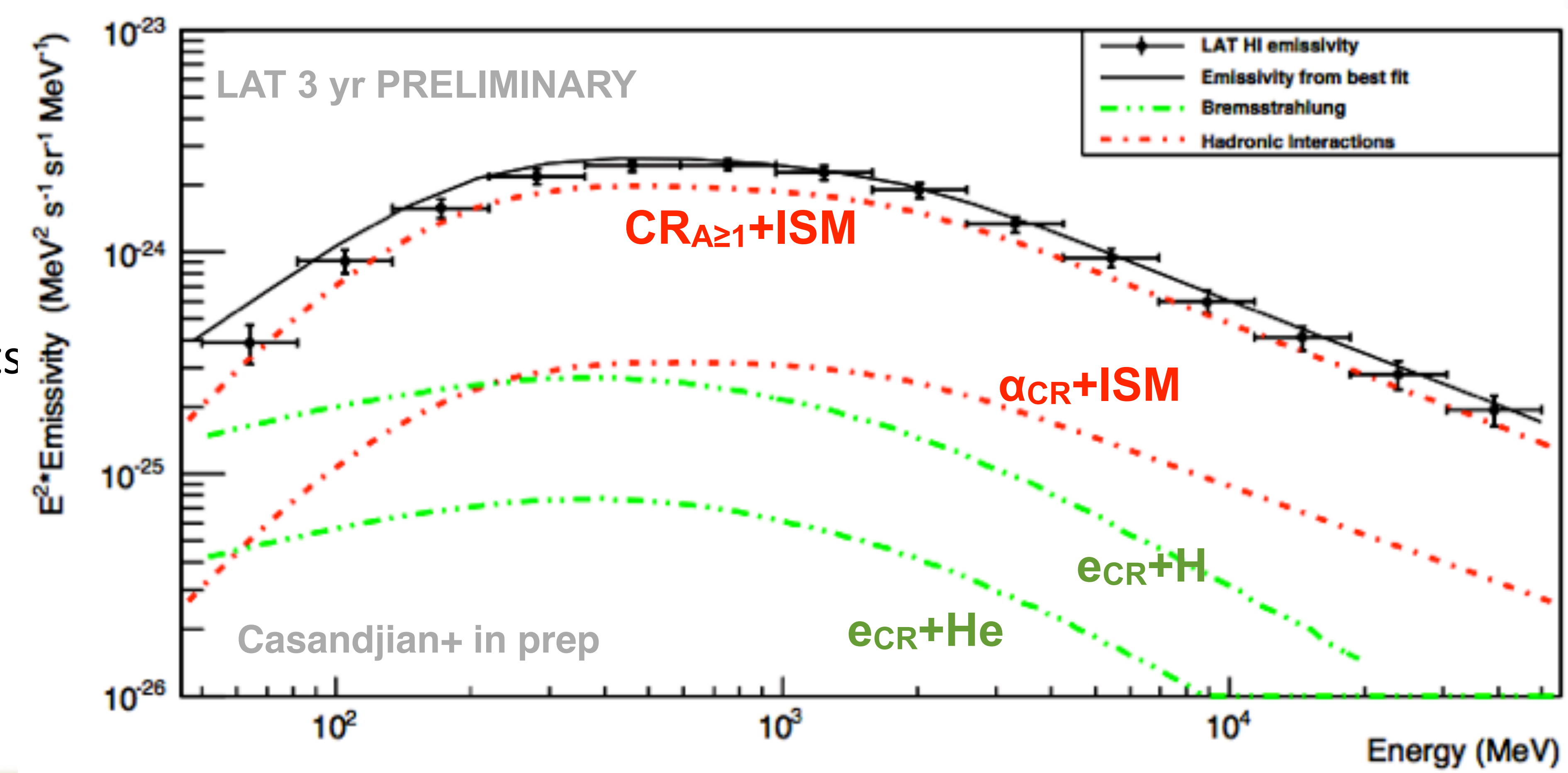
# HI emissivity spectrum < 1 kpc

$$N_\gamma(l,b,E_\gamma) - q_{CO}(E_\gamma)W_{CO}(l,b) - N_{IC}(l,b,E_\gamma) - \sum_{jsources} N_j(l,b,E_\gamma) = q_{HI}(E_\gamma)N_{HI}(l,b)$$




- CRay spectrum outside the solar system consistent with near-Earth measurements + solar demodulation

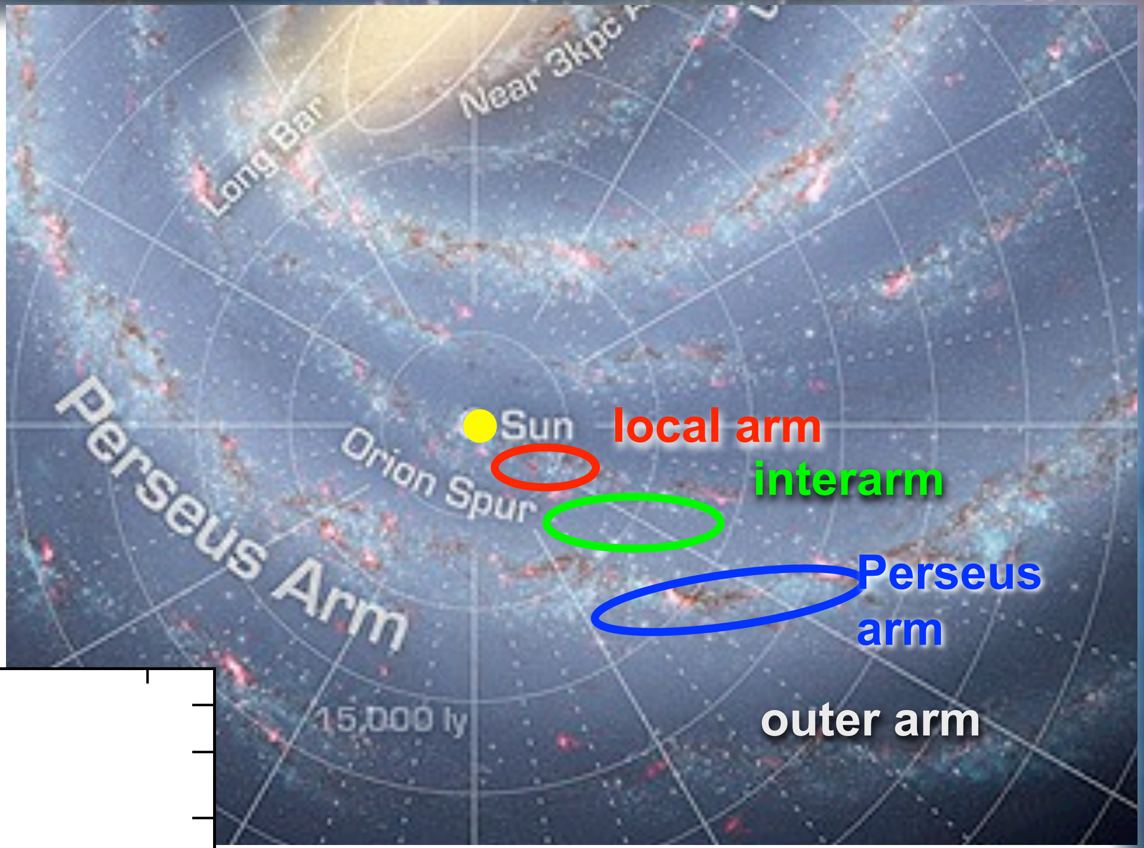
⇒ measures of the solar modulation

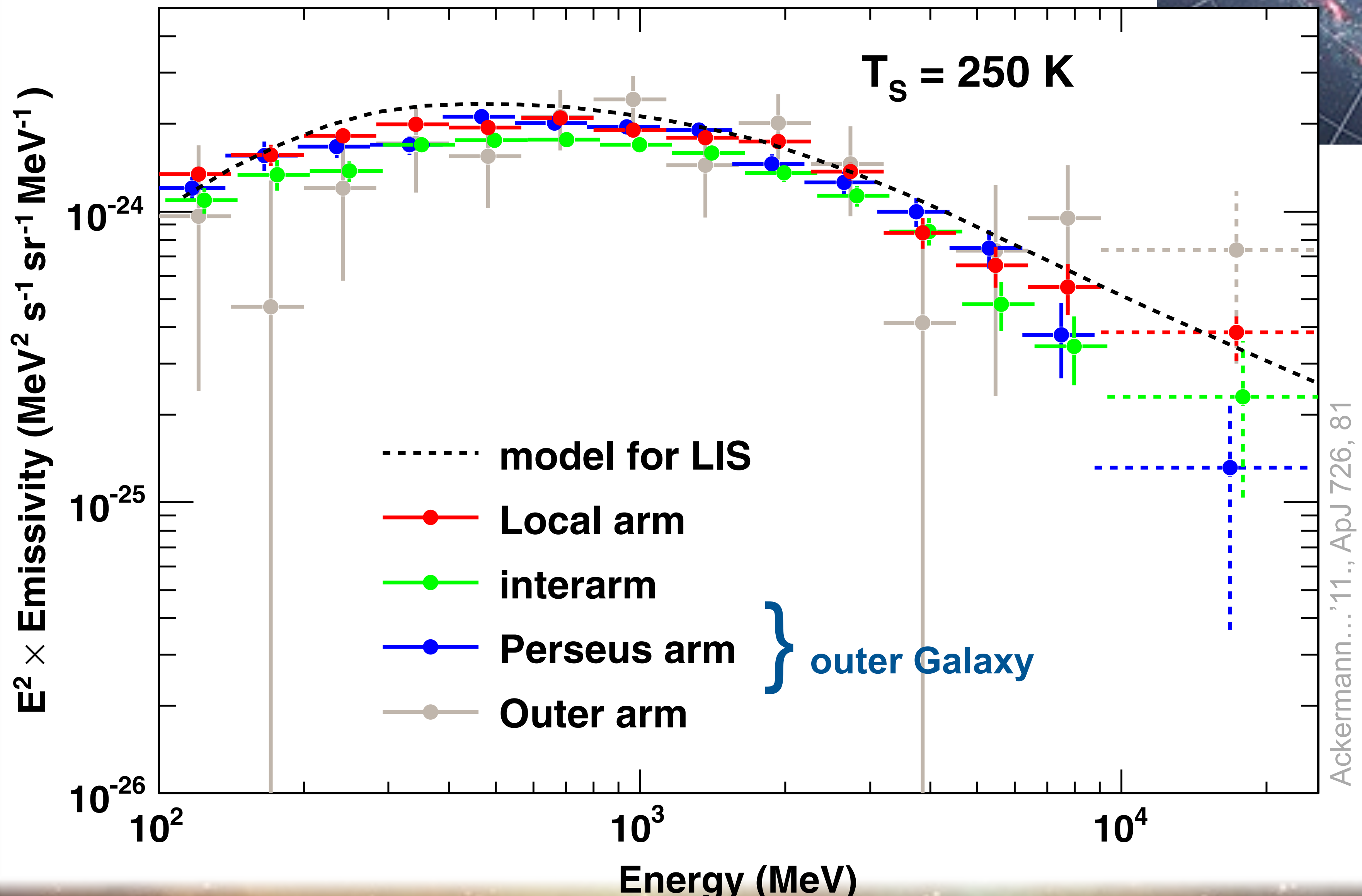


# uniform spectrum across arms

- consistent with LIS spectrum
- little arm/interarm contrast

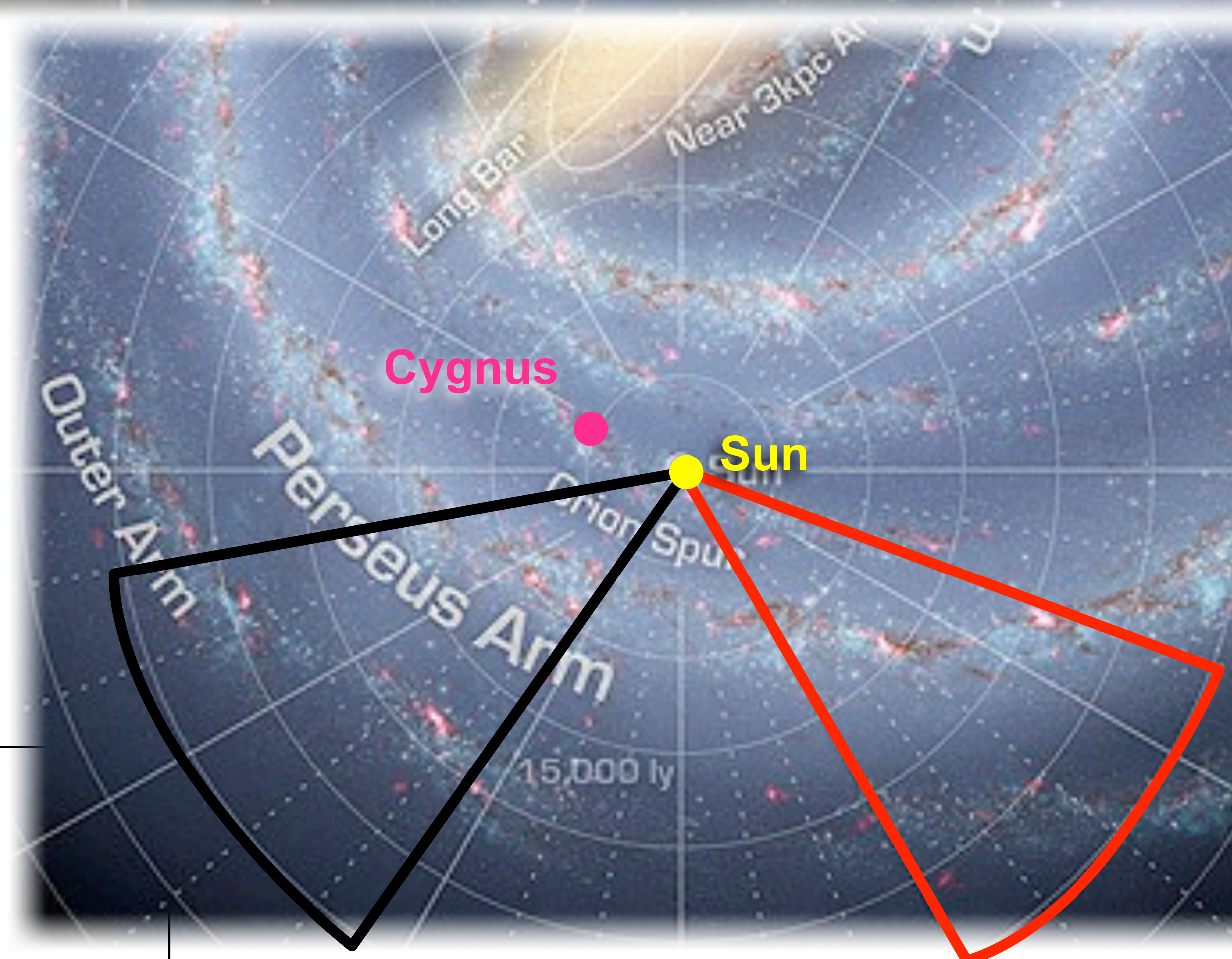
=> loose coupling with the kpc-scale surface density of gas or star formation

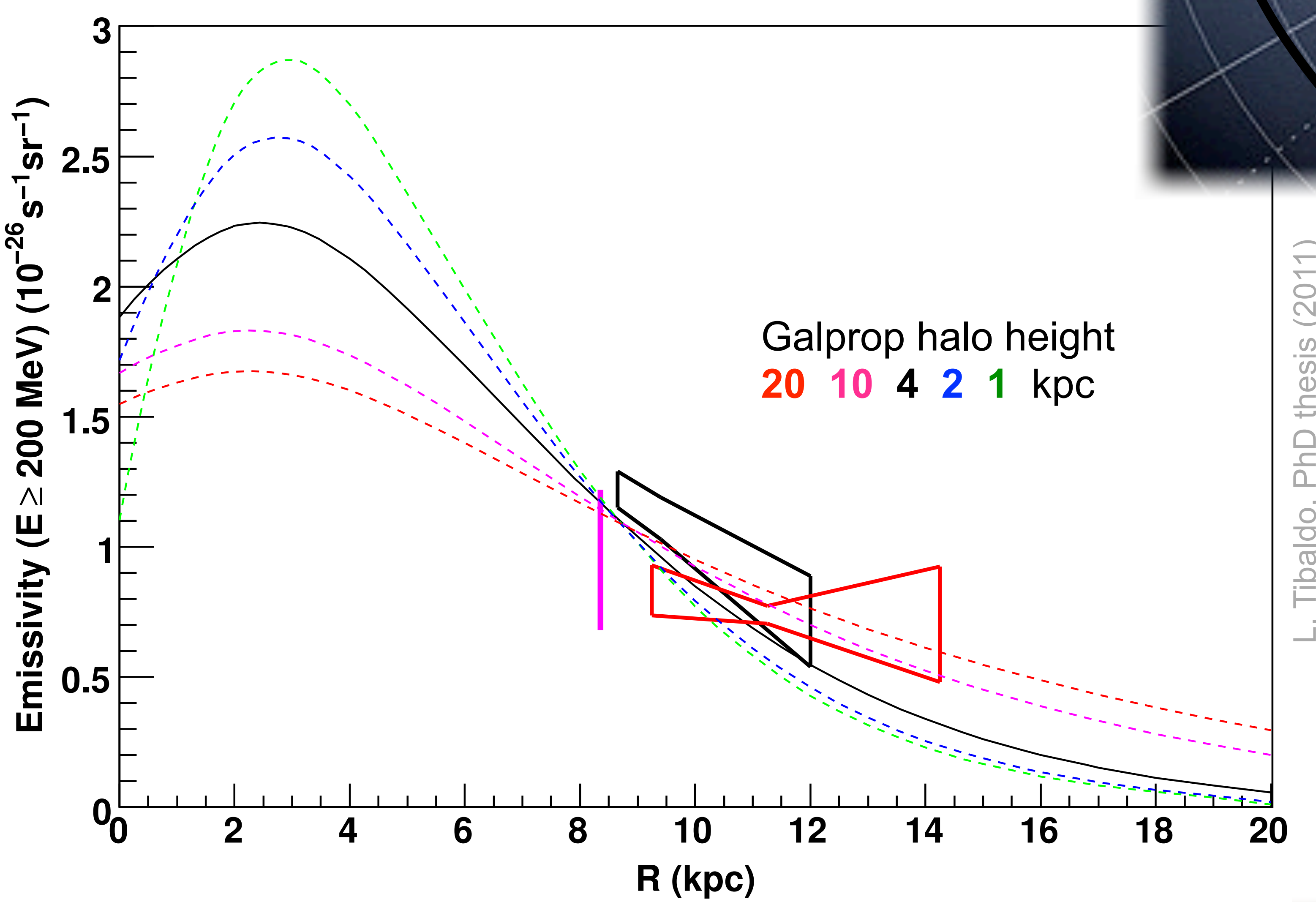


# shallow CR gradient in the outer Galaxy

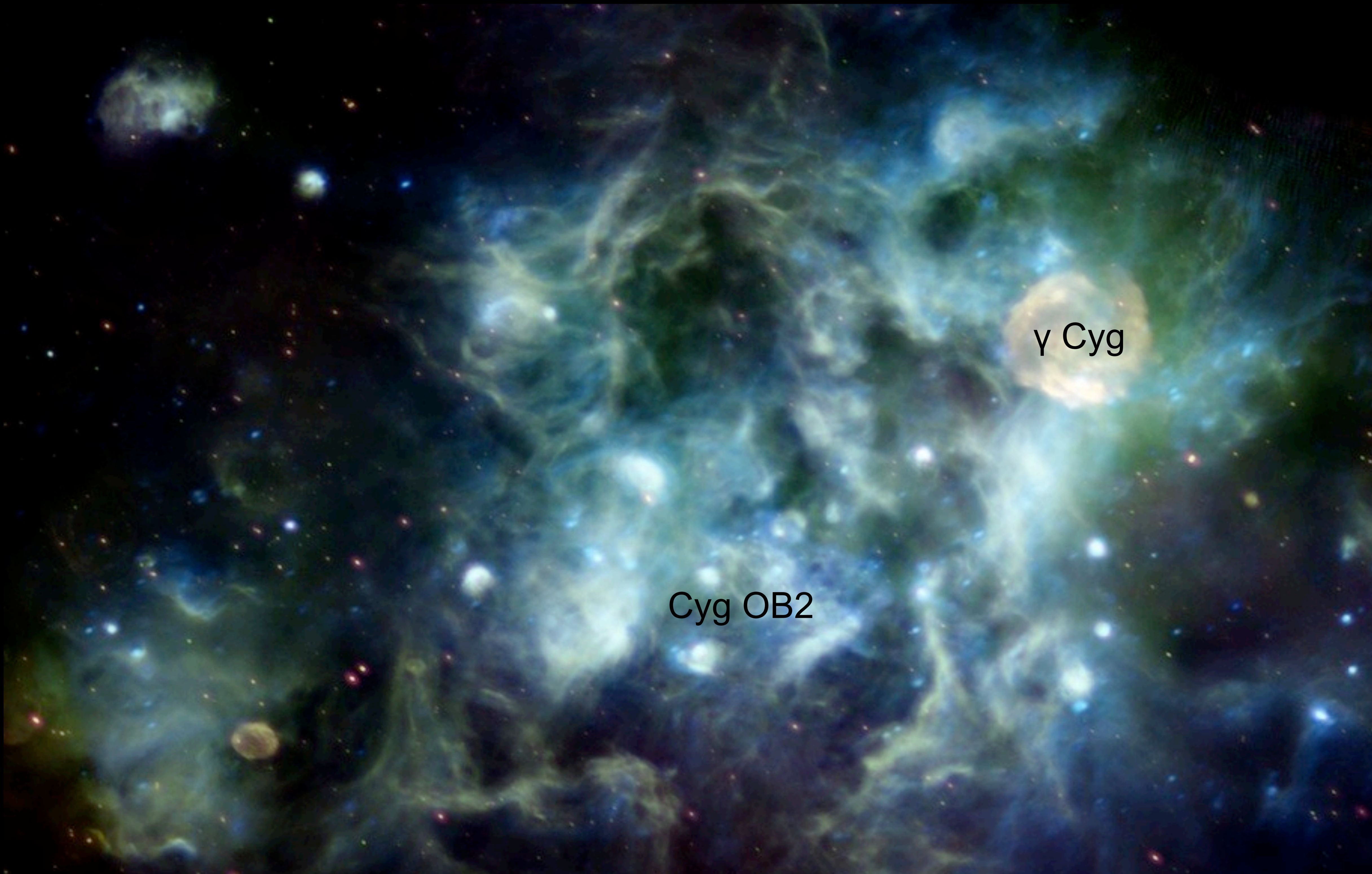
- flat emissivity gradient beyond the Solar circle
  - large uncertainty due to HI gas mass
    $100 \leq T_{spin}(HI) \leq 400$ K
- CR source distribution too steep with uniform diffusion if pulsar-like or SNR-like source distributions, even if large halo size
  - large amounts of missing gas ?
  - non-uniform diffusion?



# a little tour of Cygnus X

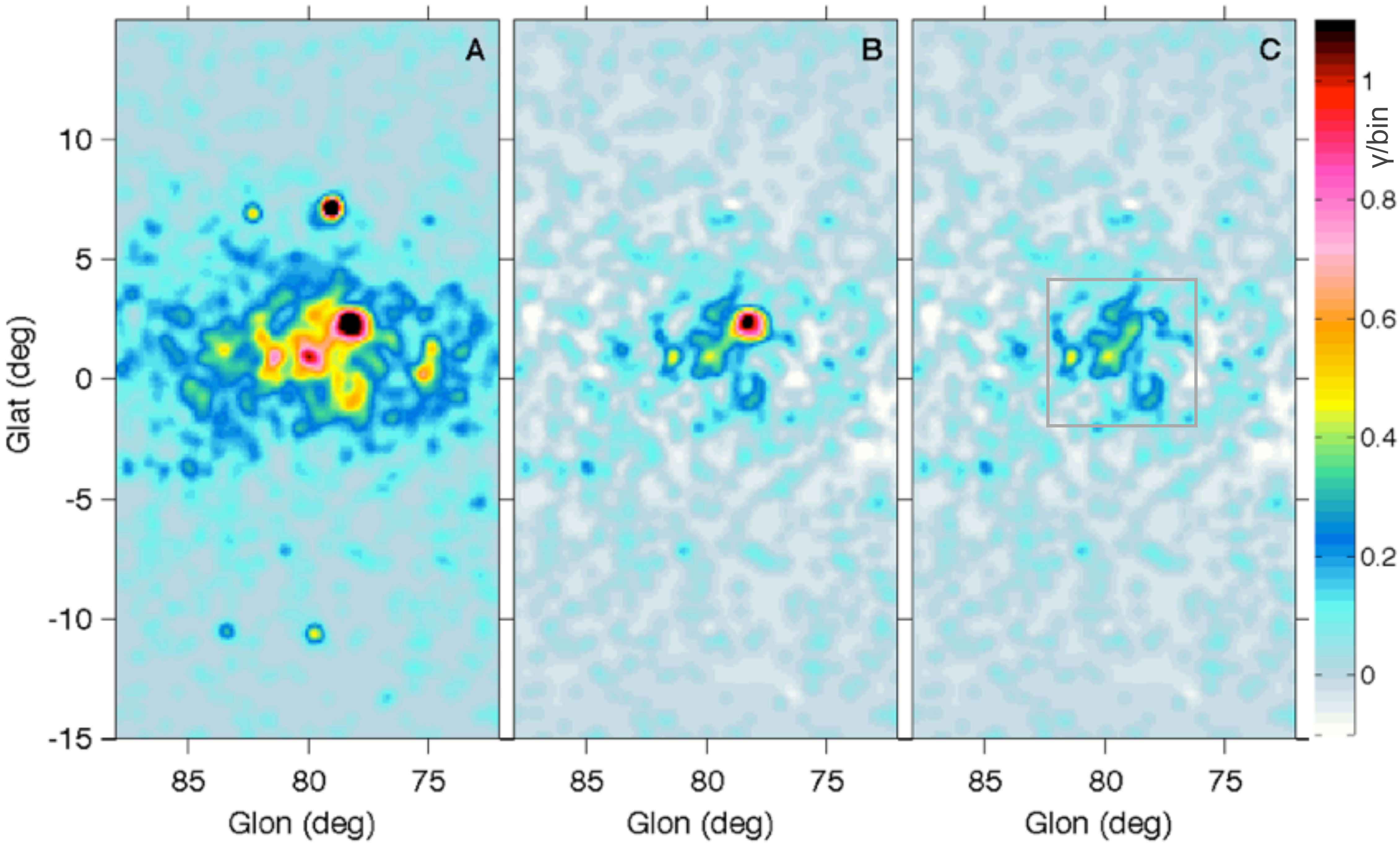
- most active star-forming region at 1.4 kpc
- CGPS/IRAS 74 cm 21 cm 60 μ 25 μ



# an extended γ-ray excess

- Fermi, 10-100 GeV band, smoothed (0.25°)

total emission | total - γ(ISM) - point sources | total - background - extended γ Cyg

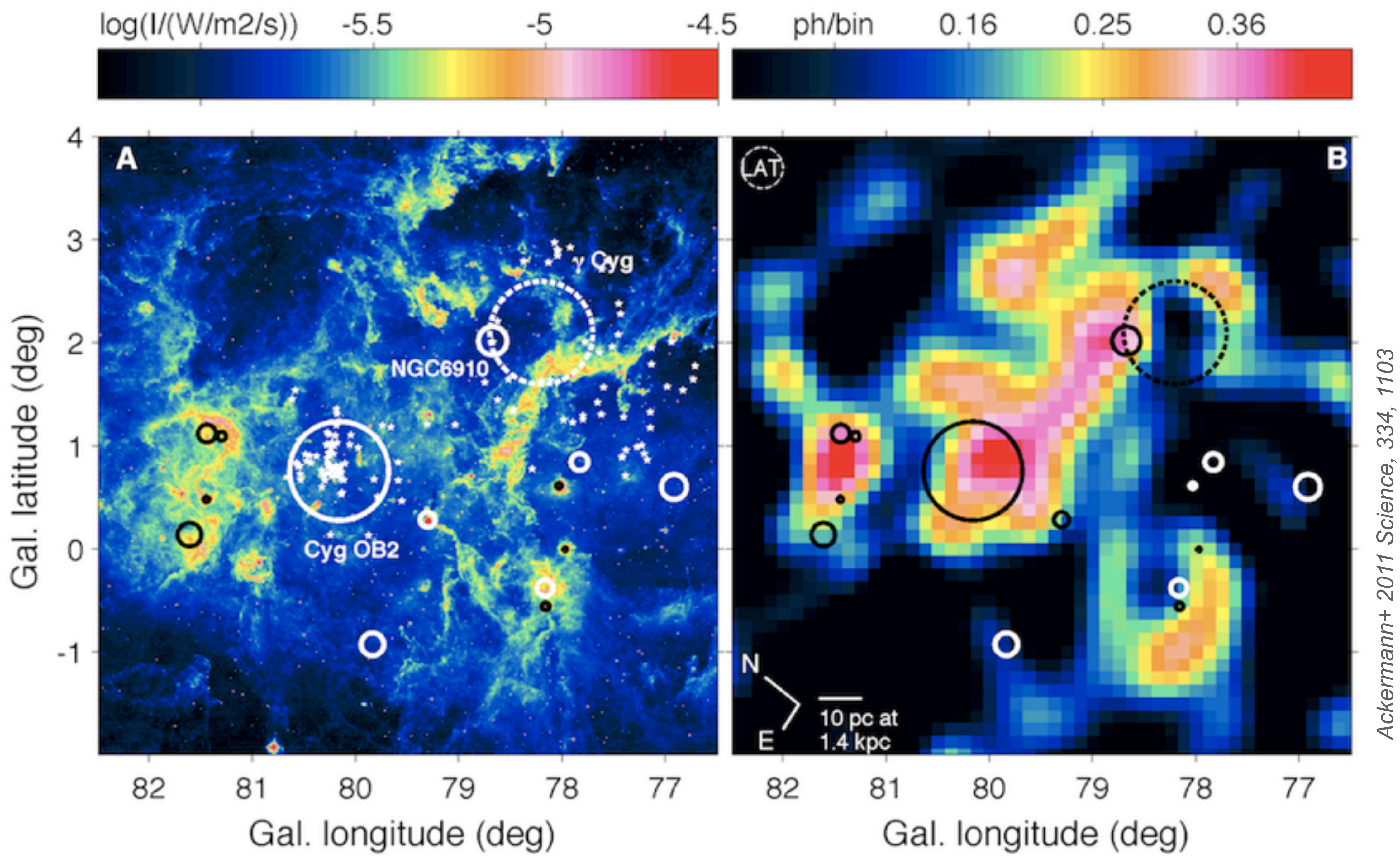



Ackermann+'2011 Science, 334, 1103

- broad Gaussian: 10.1 σ detection > 1 GeV, 1σ radius = 2.0° ± 0.2°

# a γ-ray superbubble

- bounded by PDRs
  - extension >> SNR or cluster sizes, smooth radial profile, spectral uniformity
  - worse fit with discrete point sources
- turbulent superbubble

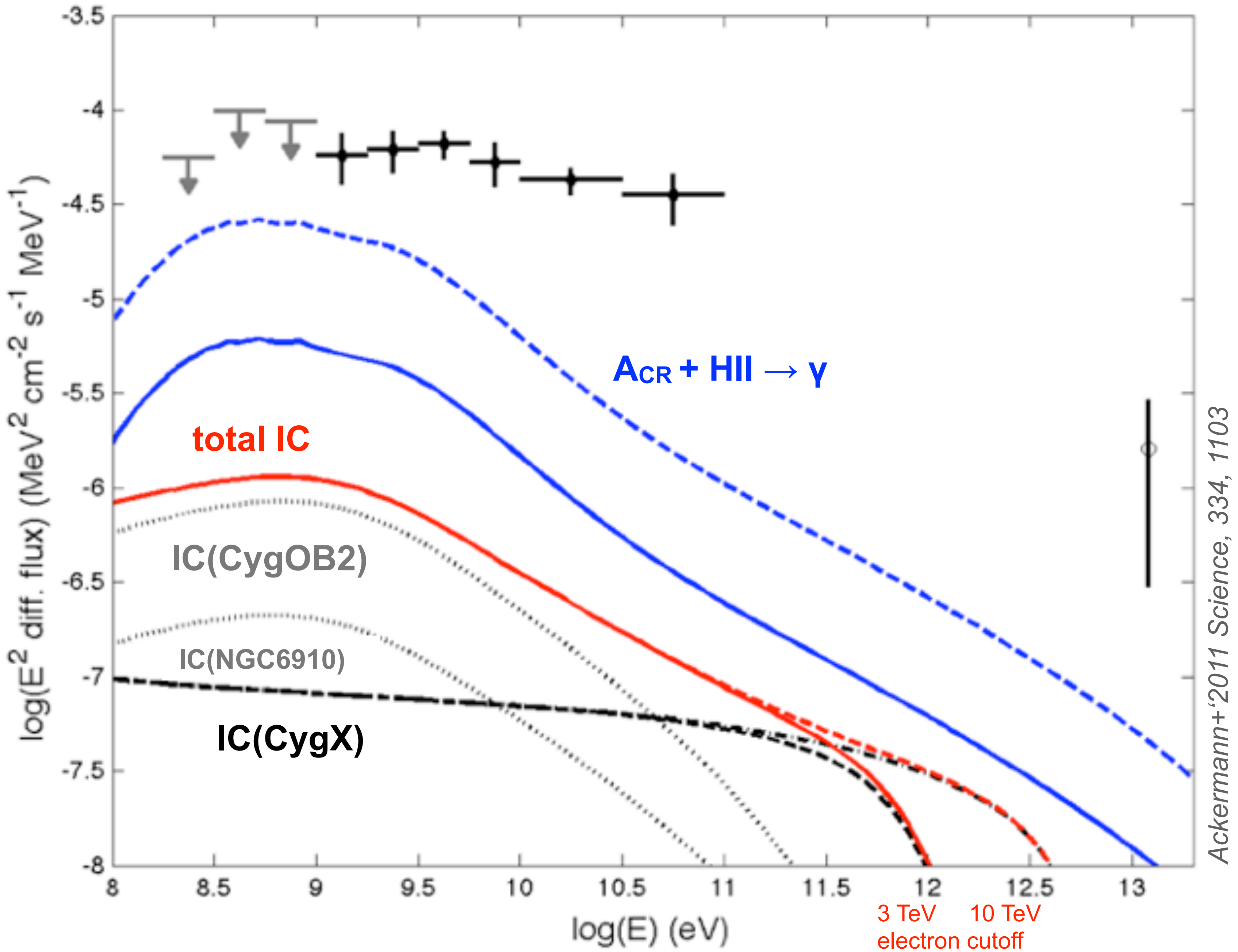


# cocoon of freshly accelerated cosmic rays

- hard excess E > 1 GeV
- if pure IC: $E_{tot} = 4\ 10^{41}$ J
- if pure pion: $E_{tot} = 1.3\ 10^{42}$ J ≈ 1% $E_{SN}$

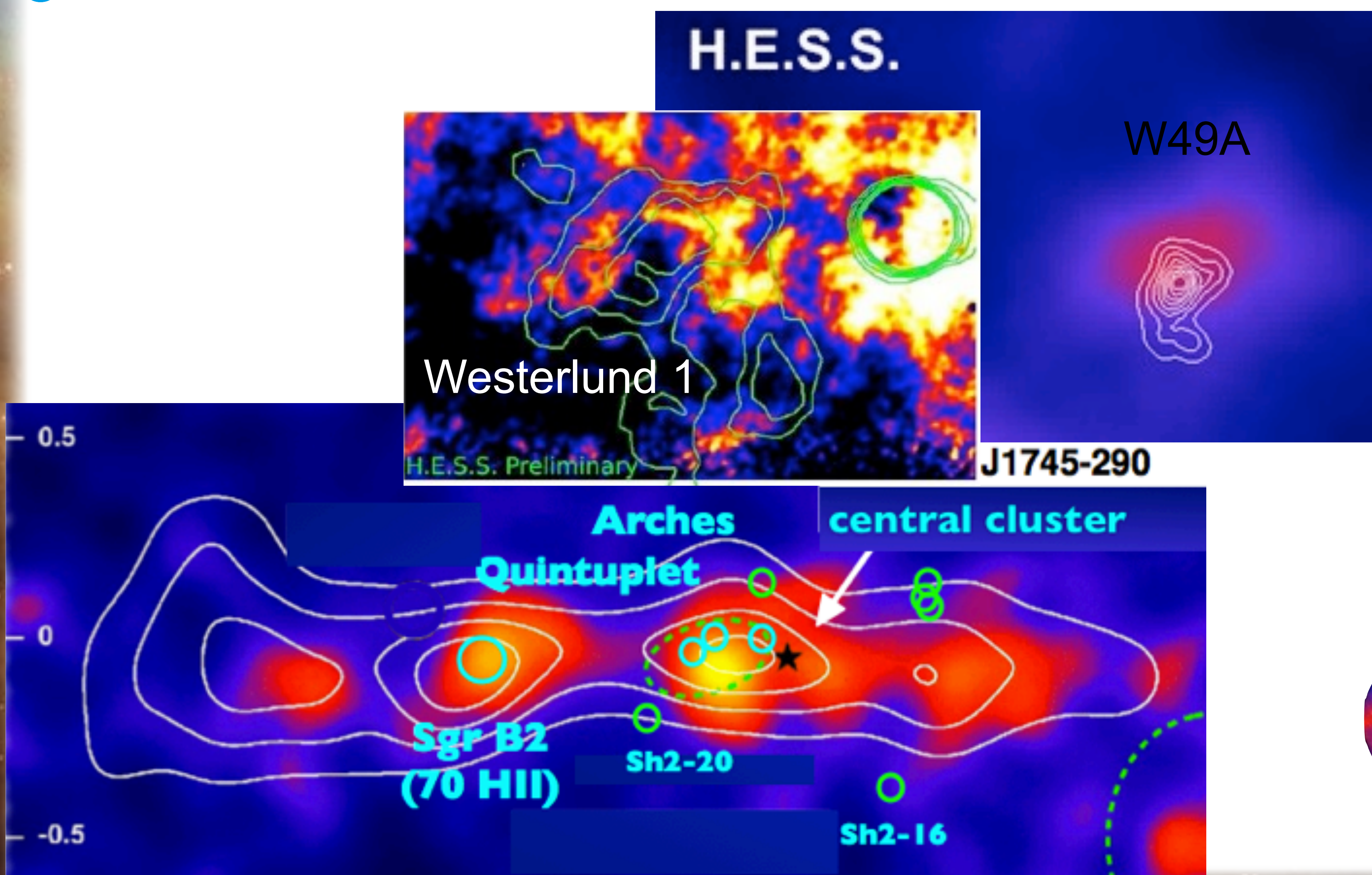
$$\left(\frac{dN_e}{dSdtd\Omega dE_e}\right)_{LIS} \times 60 \left(\frac{E_e}{10GeV}\right)^{0.5}$$

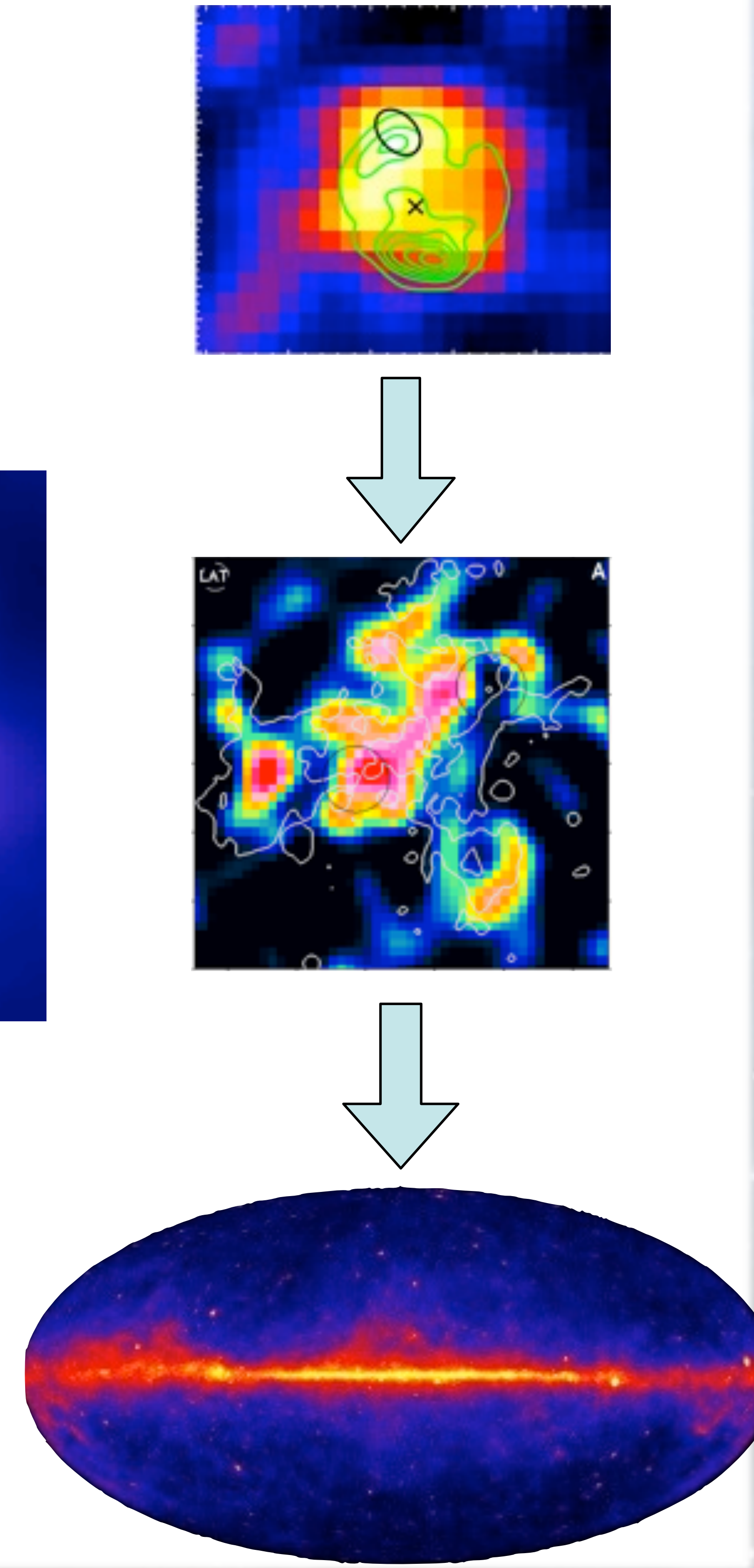
$$\left(\frac{dN_A}{dSdtd\Omega dE_A}\right)_{LIS} \times (1.5 - 2.0) \left(\frac{E_A}{10GeV}\right)^{0.3}$$



# an active "airlock" between sources & ISM

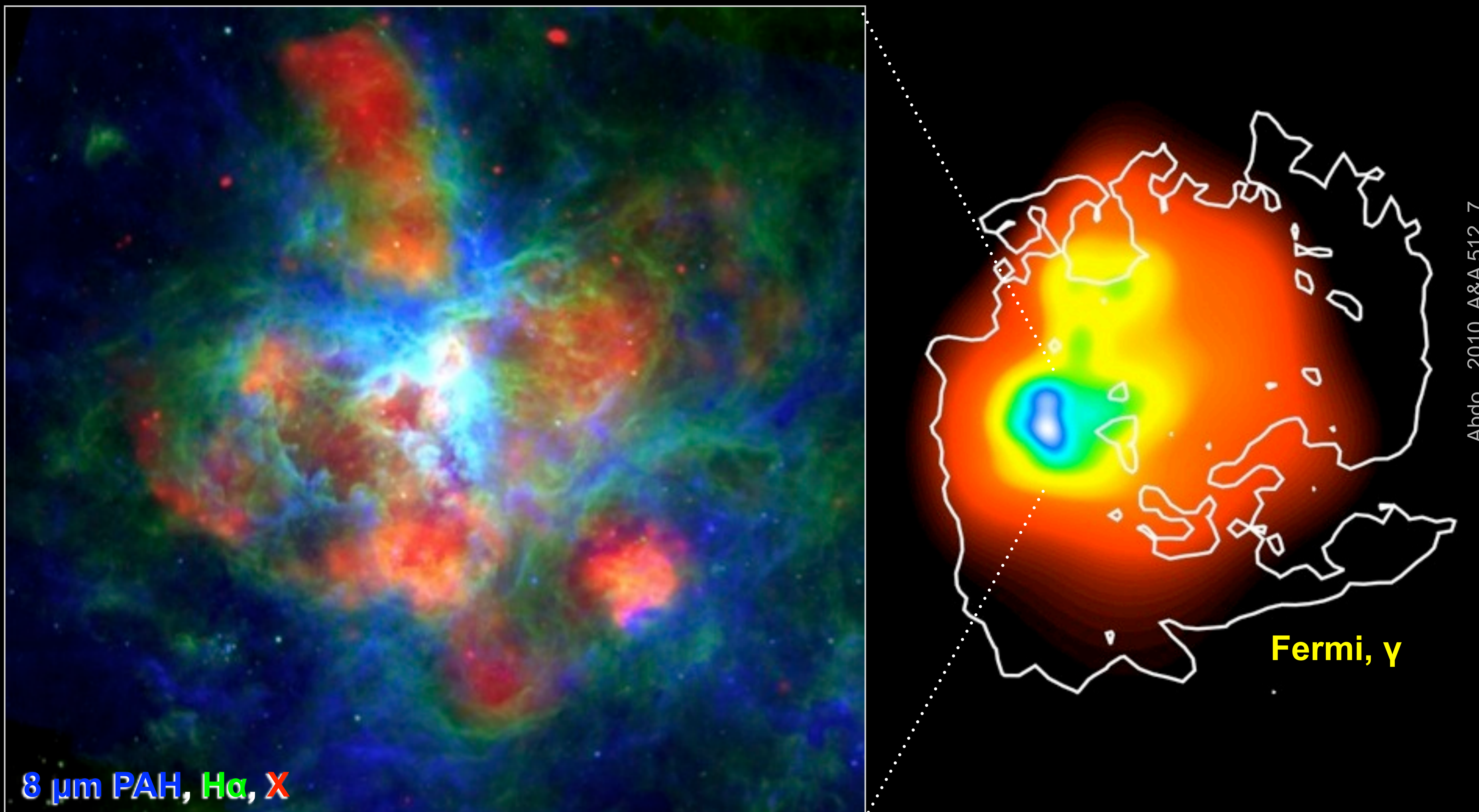
- diffusion D ≈ $D_{ISM}$ / 100 => trapping
- what leaks out?
  - hard reaccelerated particles
  - or soft exhausted ones?
- HII & dark gas flooded with young CRays
  - but "normal" CR flux averaged over the whole complex
- ionization rate in all the PDRs?



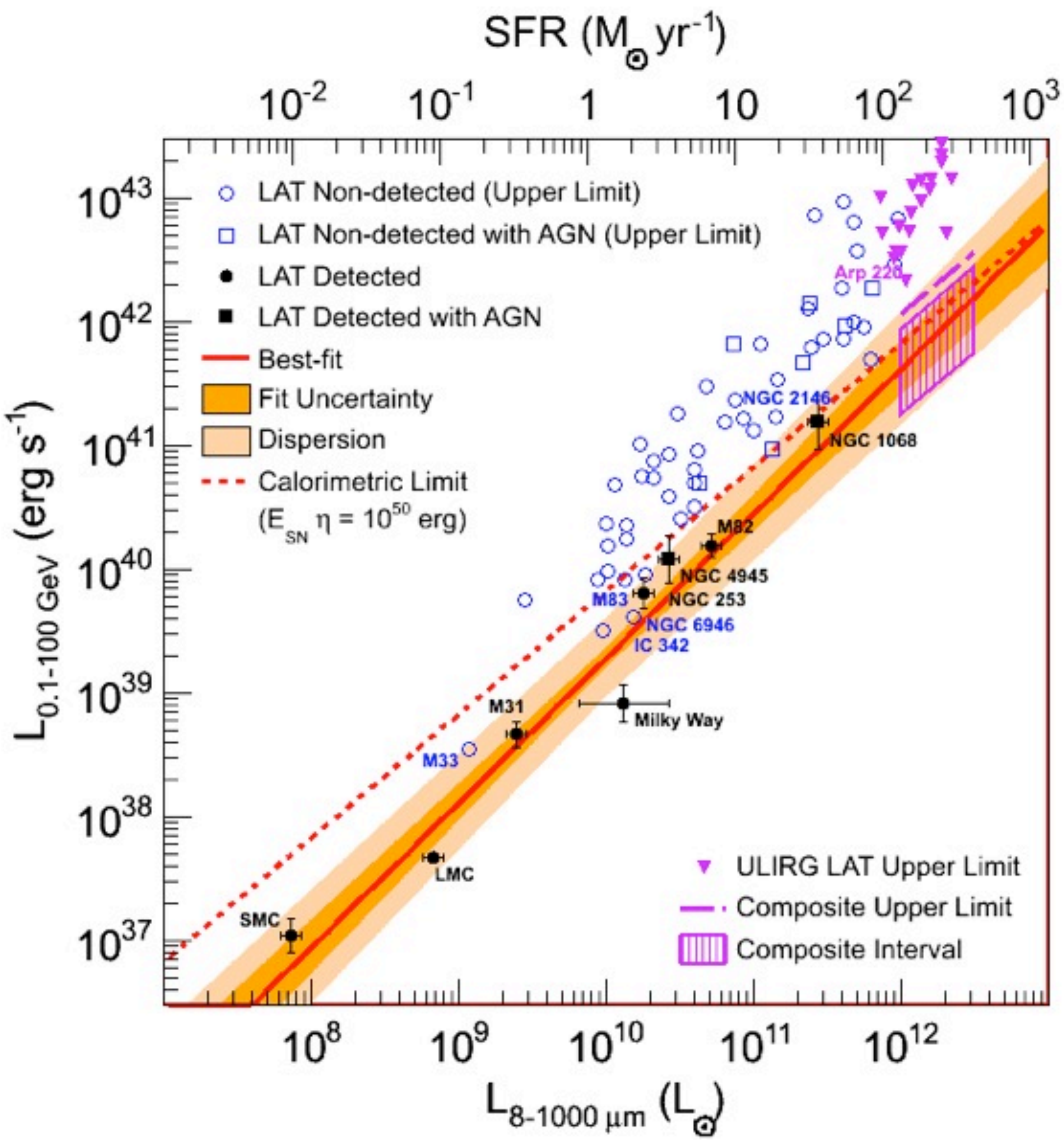



# 30 Dor in LMC

- radio/γ study: $L_{electrons} \approx$ 100-140 pc at ~3 GeV and $L_{nuclei} \approx$ 200-320 pc at ~20 GeV if accelerated in 30 Doradus (Murphy et al. 2012)



# stellar vs. cosmic-ray activity




Ackermann+ '12, ApJ 755, 164
Ackermann+ 2012, in preparation

lundi 17 décembre 12

Science Support Center:
http://fermi.gsfc.nasa.gov/ssc/

http://www.nasa.gov/mission_pages/GLAST/main/index.html

Fermi Sky on iphone