FERMI-LAT OBSERVATIONS OF SUPERNOVA REMNANT KES 79

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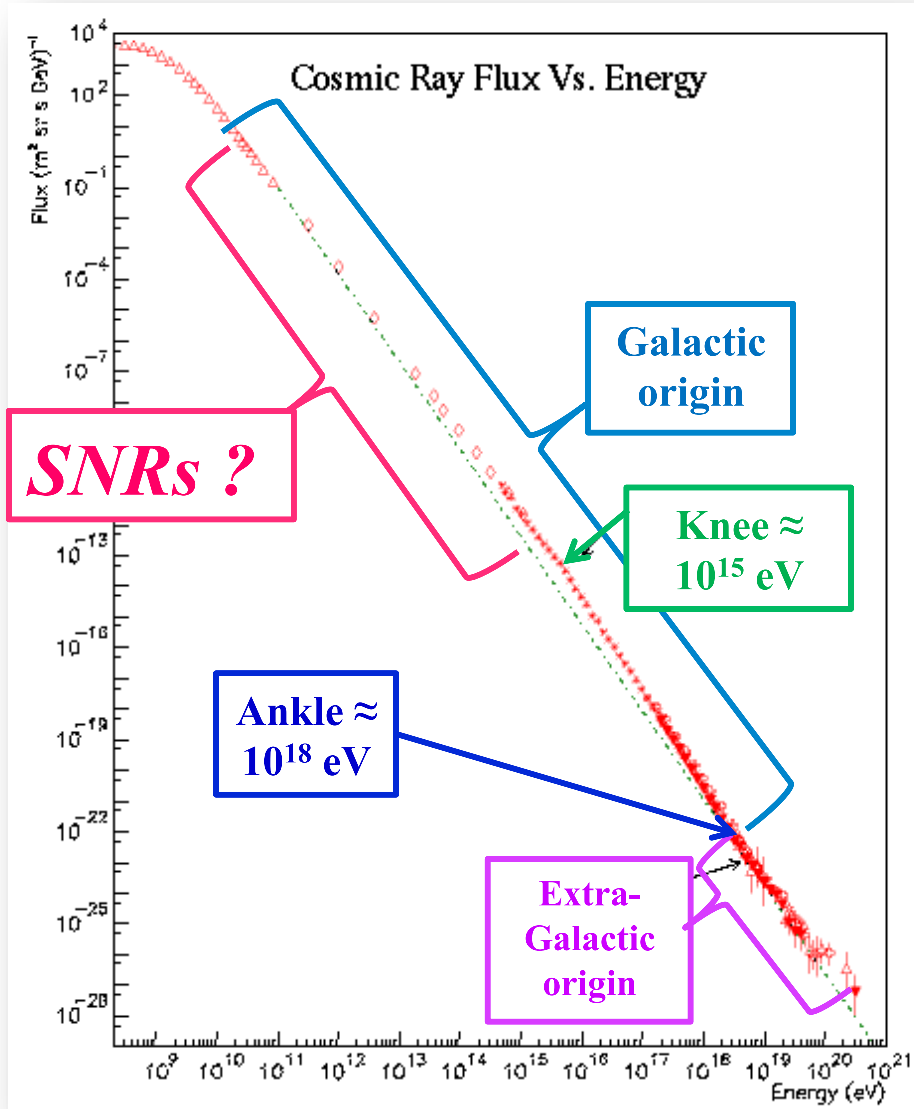
Connecting Cosmic Rays & SNRs

- *Below E_{knee}, CRs are thought to be Galactic in origin:*
  - *Supernova remnants (SNRs)*
  - *Colliding stellar winds.*
- *Evidence in favour of SNRs:*
  1. *CR energy density ≈ 1 eV cm^{-3}.*
     - *SNRs can naturally explain this.*
  2. *Spectral index of CR spectrum at Earth ≈ 2.*
     - *Consistent with spectral index of derived by DSA.*



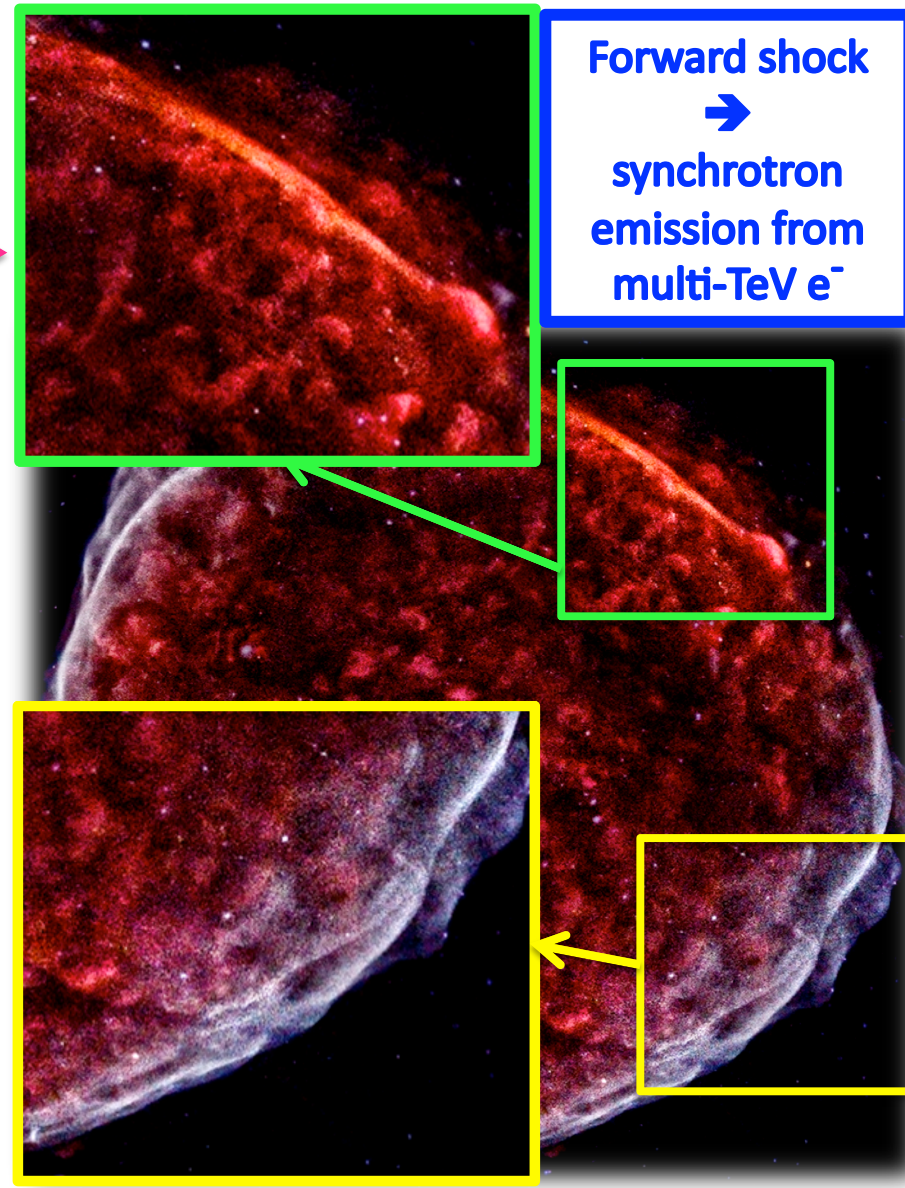
Diffusive Shock Acceleration

- *Forward shock (& reverse shock??) of a SNR can <u>accelerate</u> particles*
  - *eg. SN1006*
- *Shock-wave propagates & particles scatter off MHD waves giving:*

$$\frac{dN}{dE} \propto E^{-2}$$

- *Lagage & Cesarsky (1983) applied DSA to shell-type SNRs*
  - *Particles in SNRs can be accelerated up to 10 -100TeV.*

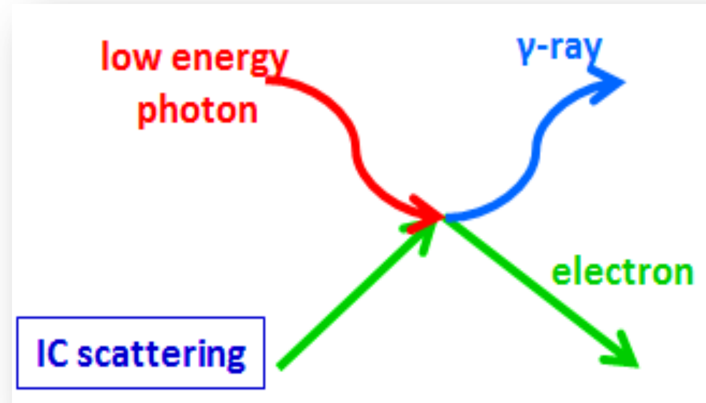
➔ *SNRs can be CR accelerators!*



Chandra X-ray image(NASA/CXC/Middlebury College/F.Winkler)

Particles lose energy via…

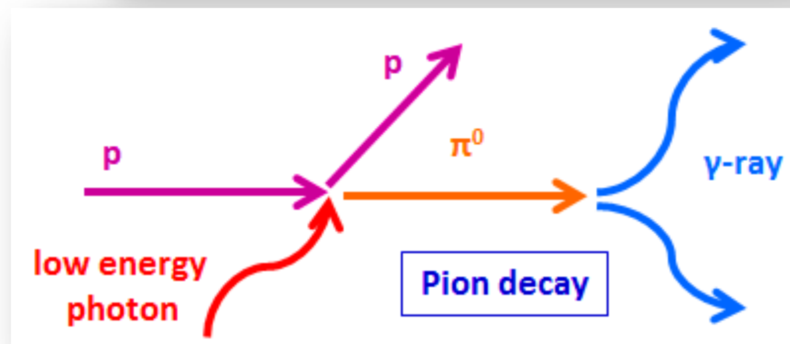
- *Leptonic emission:*
  - *Inverse Compton (IC):*
    - *electron transfers energy to a low energy photon*
  - *Non thermal Bremsstrahlung.*



- *Hadronic emission:*
  - *Pion decay:*

$$p + p \longrightarrow \pi_0 + X \longrightarrow \gamma + \gamma + X$$

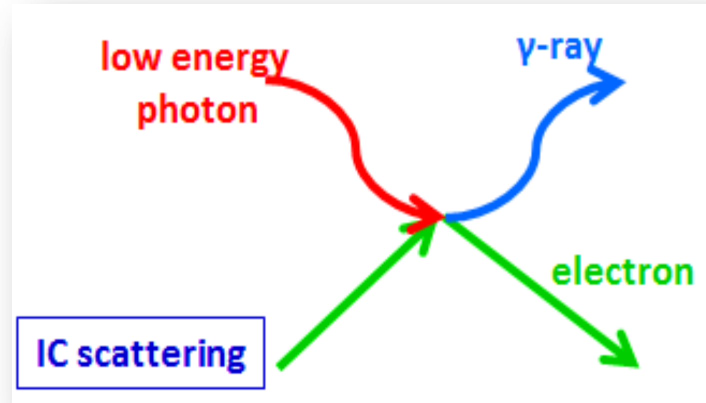
    - *consequence of SNRs interacting with dense material*



…producing GeV/TeV gamma-rays

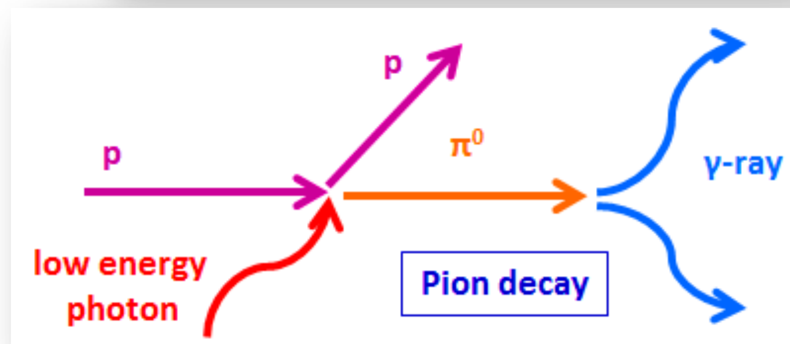
How can we distinguish?

- *Leptonic emission:*
  - *Inverse Compton (IC):*
    - *electron transfers energy to a low energy photon*



  - *Non thermal Bremsstrahlung.*
- *Hadronic emission:*
  - *Pion decay:*

$$p + p \longrightarrow \pi_0 + X \longrightarrow \gamma + \gamma + X$$

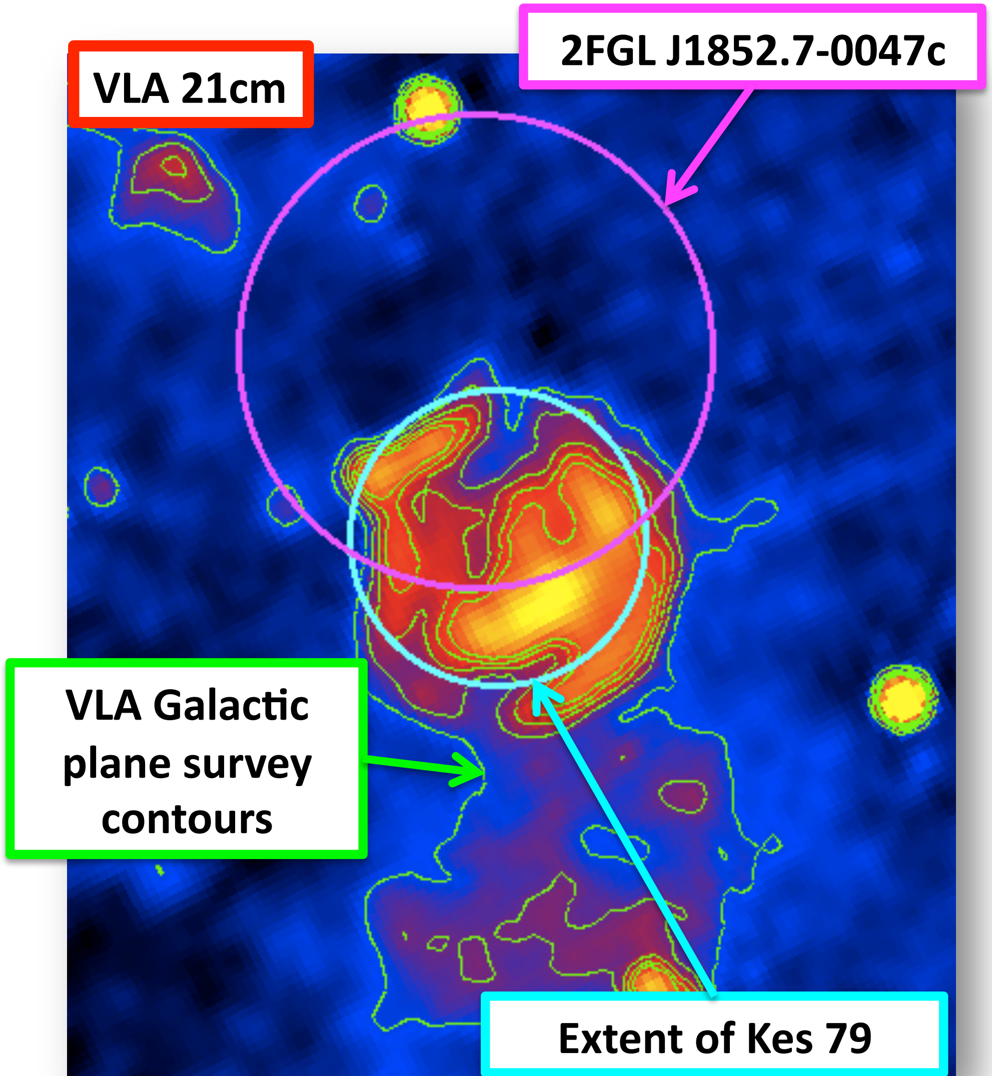


    - *consequence of SNRs interacting with dense material*

γ-ray, X-ray & radio data can help!

Kesteven 79

- *Poorly defined "shell" type remnant.*
- *Distance: ~7.1 kpc*
- *Radio emission seen towards the NE and SW.*
- *Broad 1667 MHz OH absorption feature found at ~105 km s^{-1}.*
- *CO survey reveals large elongated molecular cloud toward the east, at similar velocity.*
- *Has an X-ray pulsar* CXOU J185238.6+004020



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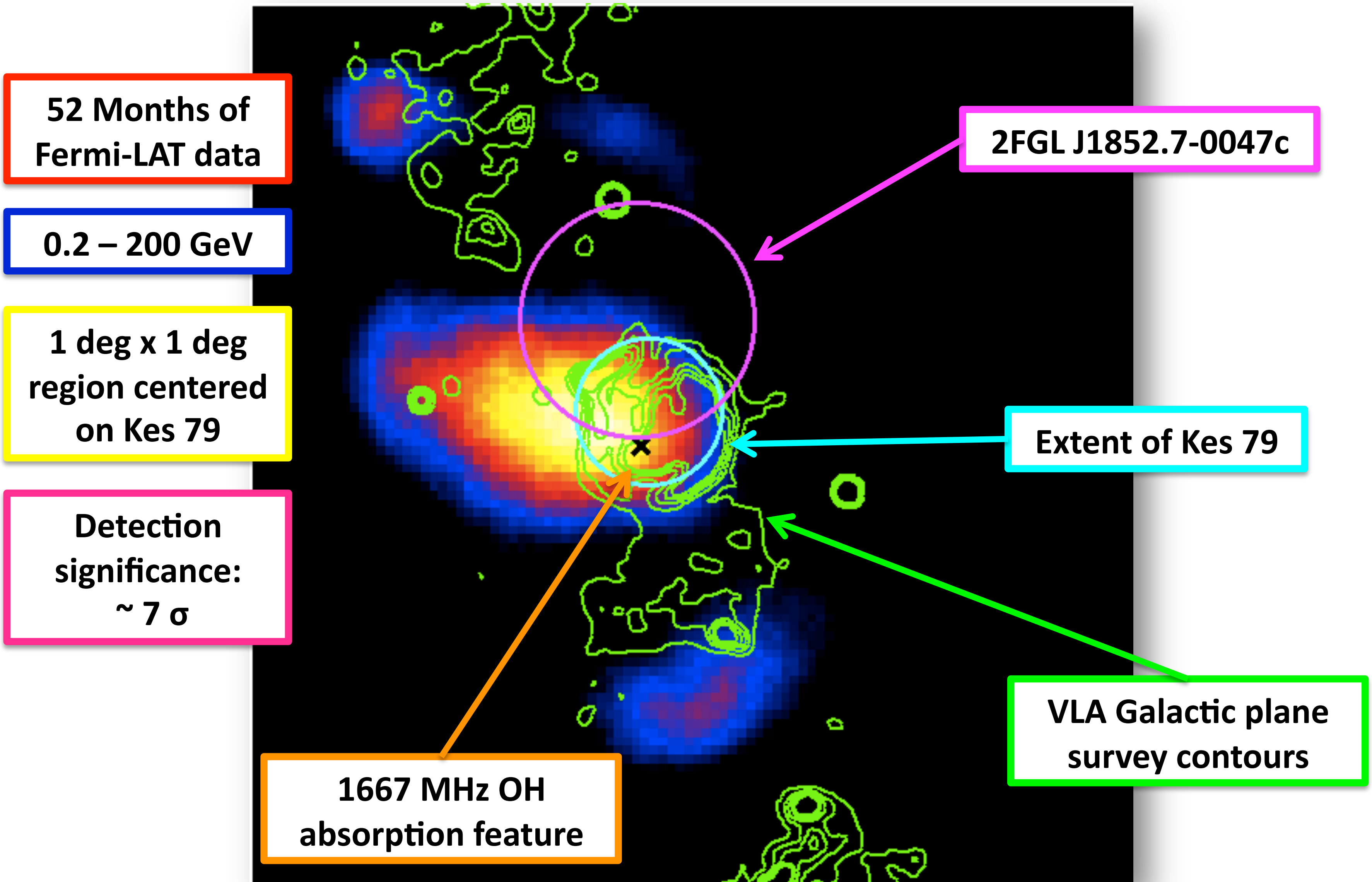
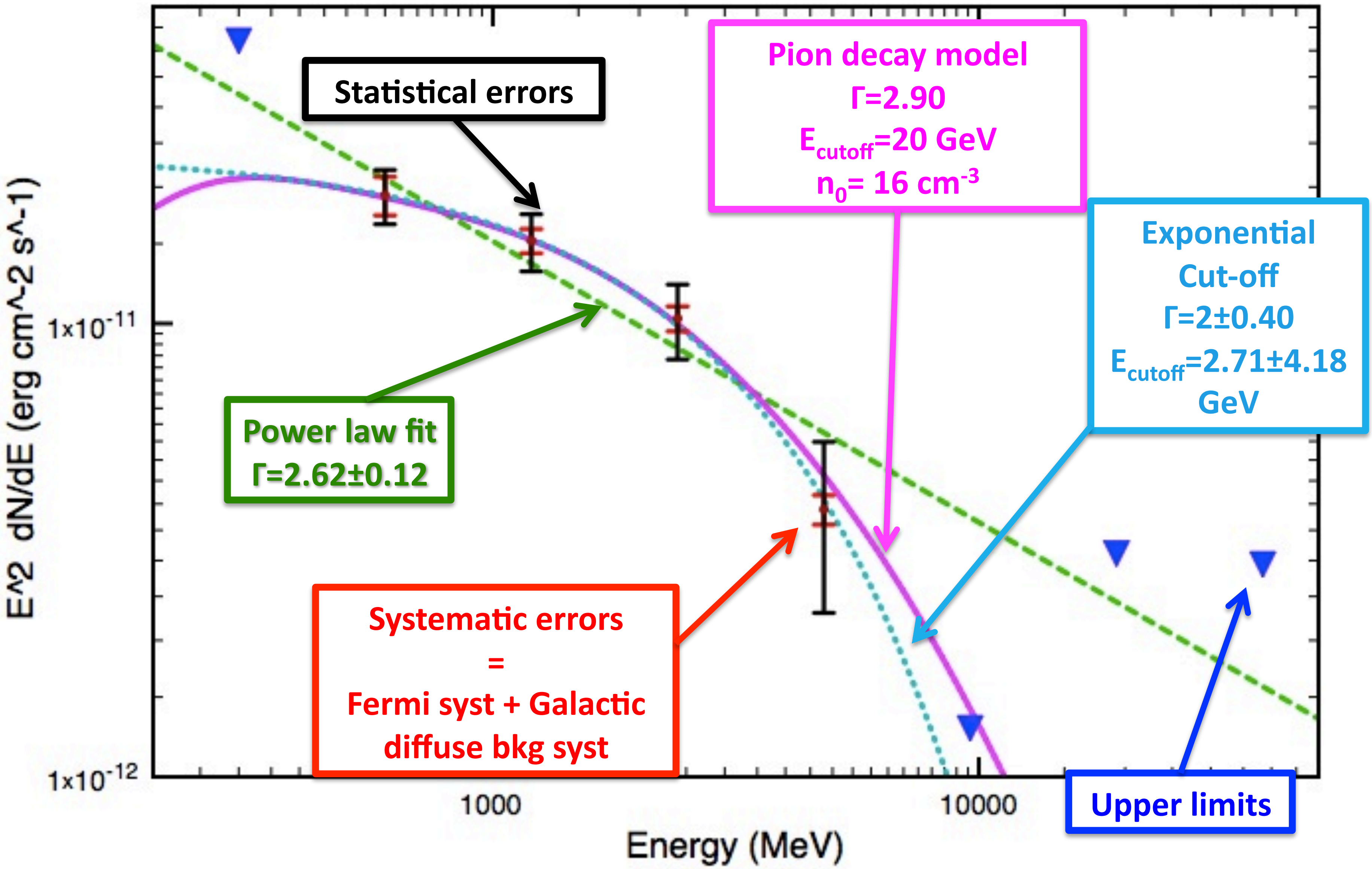
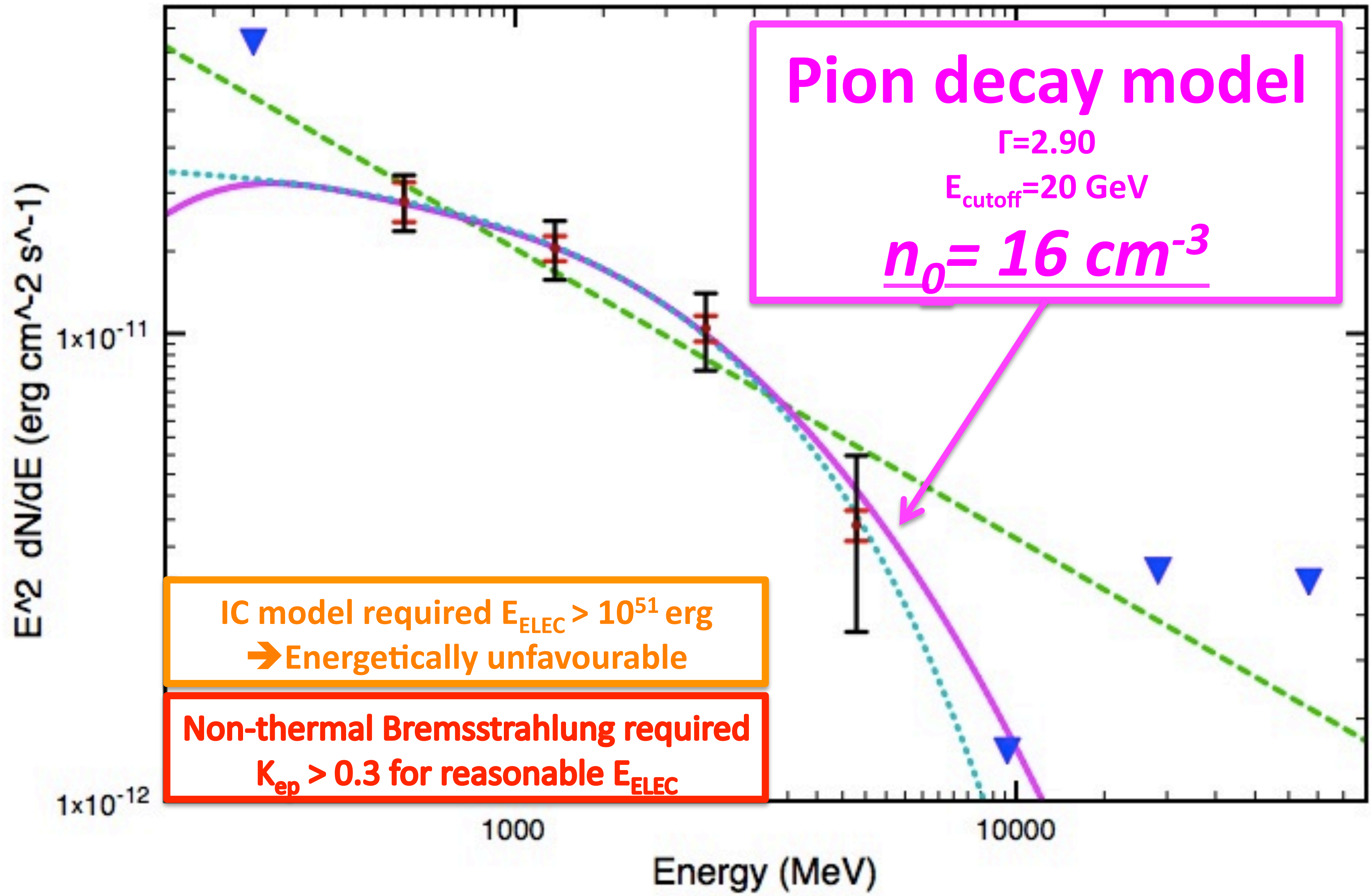
Counts map of Kes 79



Gamma-ray spectrum of Kes 79

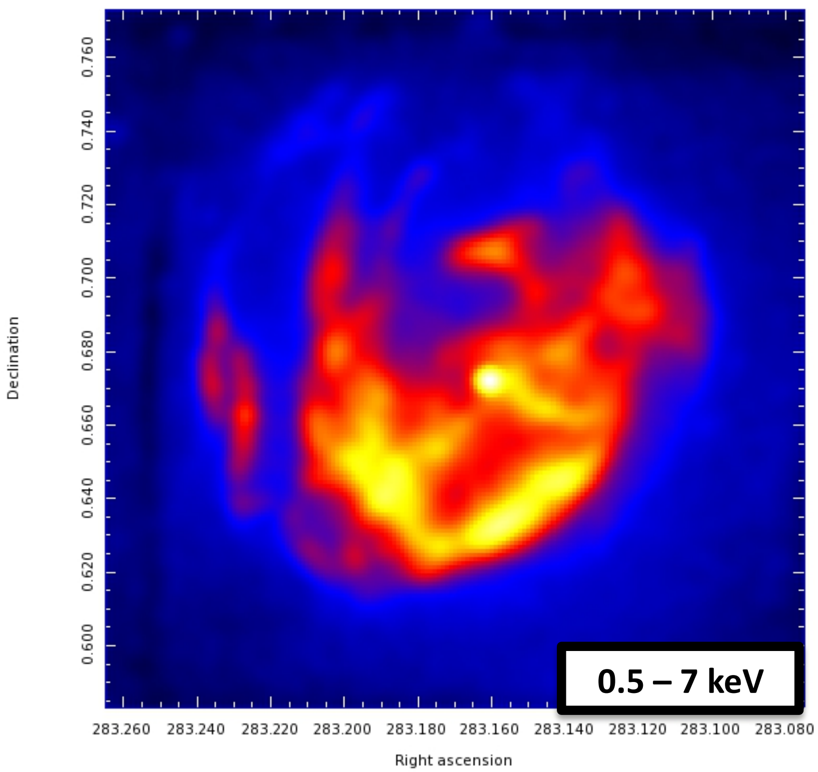


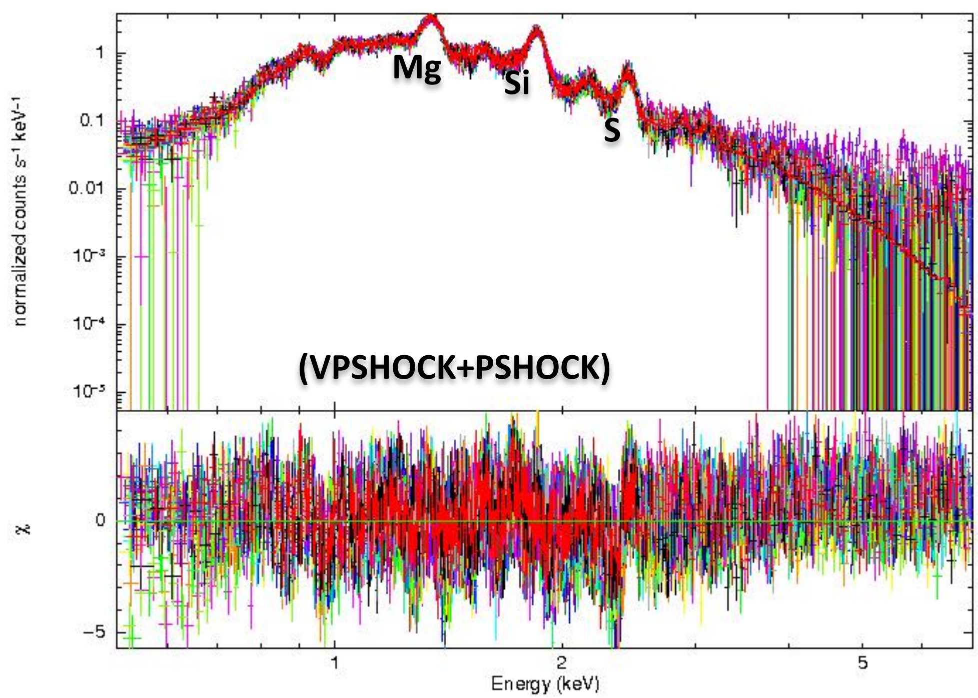
Gamma-ray spectrum of Kes 79



X-ray analysis of Kes 79

- *Spectral analysis of 14 regions.*
- *21 archival XMM obs.*
  - *Total time ~450 ks.*
- *Model using two component NEI model (vpshock+pshock)*
- *Derive ambient density*





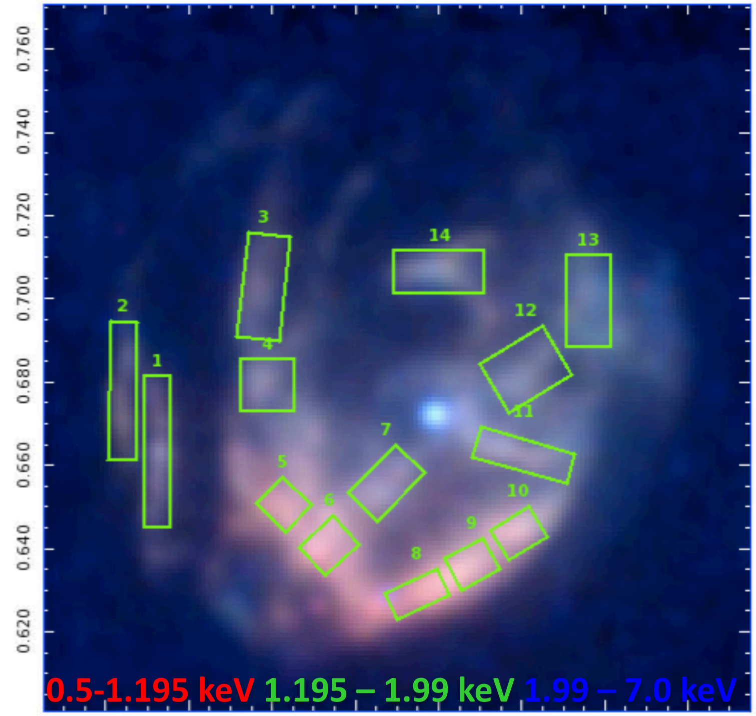
Inferred ambient density

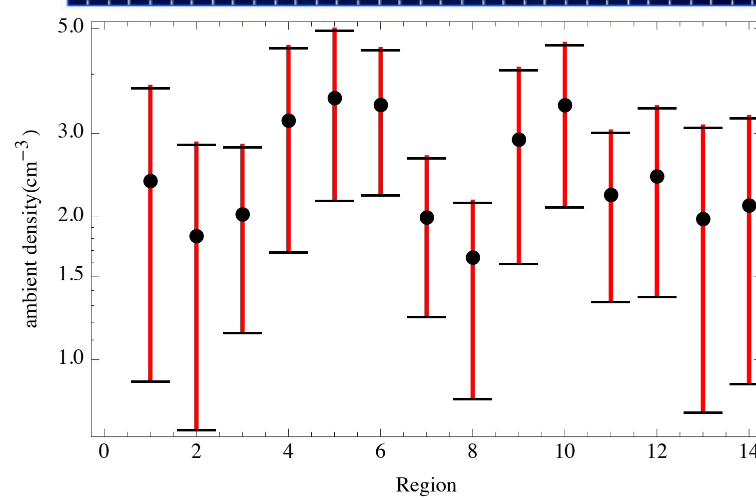
- *Inferred:*

$$\boxed{n_0 = 1.61^{+0.55}_{-0.78} - 3.49^{+1.41}_{-1.31}\ f^{1/2}\ d_{7.1}^{5/2}\ cm^{-3}}$$

- *Smaller than n_0 derived using γ-ray analysis!*
  - ➢ *Dense material does not radiate significantly in X-rays.*
  - ➢ *Escaped particles interact with upstream material, enhancing γ-rays.*
- *MC found towards E/SE of Kes 79*
  - – *MCs are clumpy & have n_0 similar to above (Chevalier 1999)*

➔ Kes 79 likely to be interacting with MC

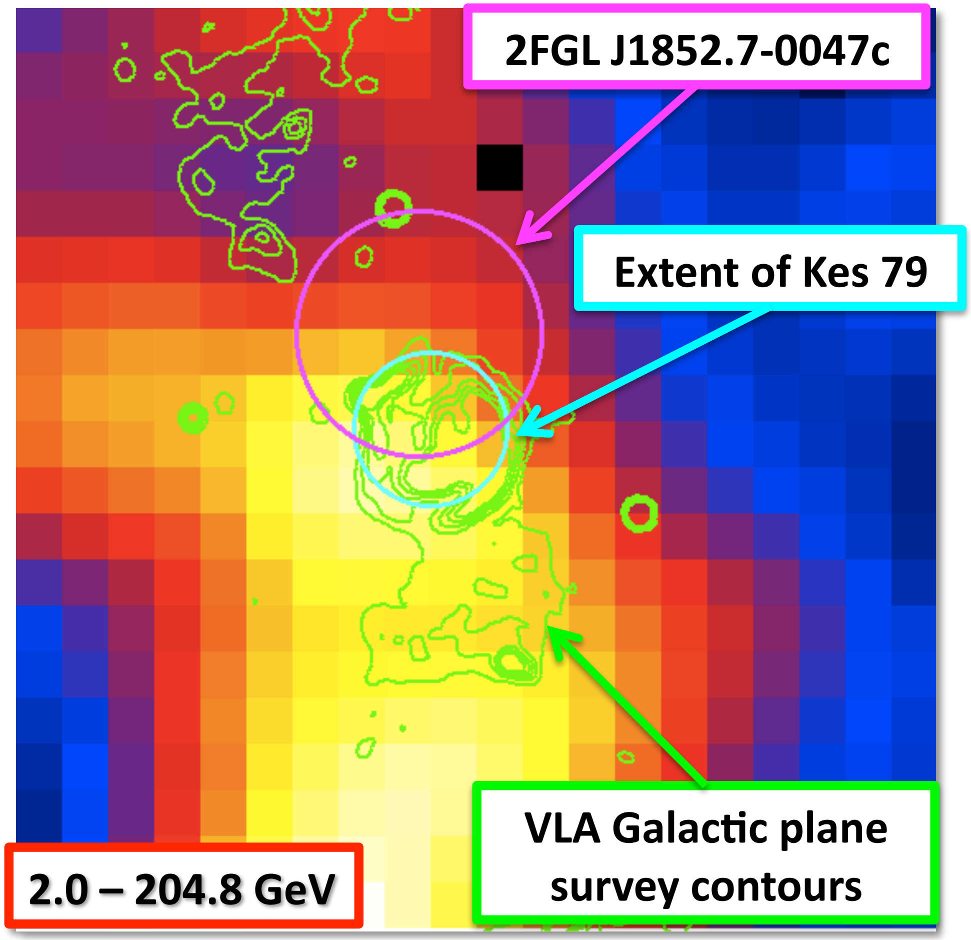




Conclusion

- *SNRs can accelerate CRs!*
- *Accelerated particles emit γ-rays via leptonic & hadronic emission*
  - *SNRs interacting with dense material (MCs) are strong candidates for γ-ray emission.*
- *Using ~52 months of Fermi-LAT data we detected γ-rays from Kes 79.*
- *Assuming pion-decay model, we inferred n_0 larger than n_0 derived from thermal X-rays.*
  - *Kes 79 is interacting with a dense clumpy material which do not radiate significantly in X-rays.*

Test Statistic (TS) Map



$$\mathrm{TS} = 2\log\left(\frac{L_{ps}}{L_{null}}\right)$$

- *L_{ps} = Likelihood of a point source being found at a given position.*
- *L_{null} = Likelihood of the model without the additional source*
- *Assuming a background set of sources, it models the residual γ-rays that are not accommodated in the background model*