Observations of the supernova remnant RCW 86 with the Fermi Large Area Telescope

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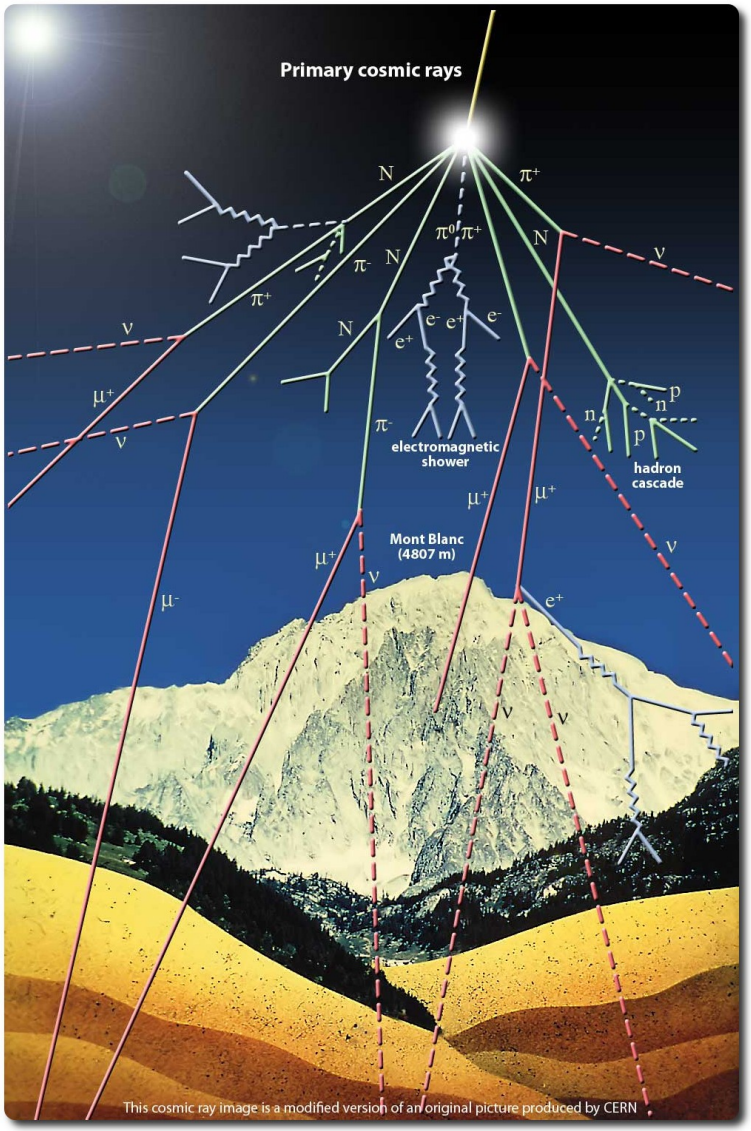
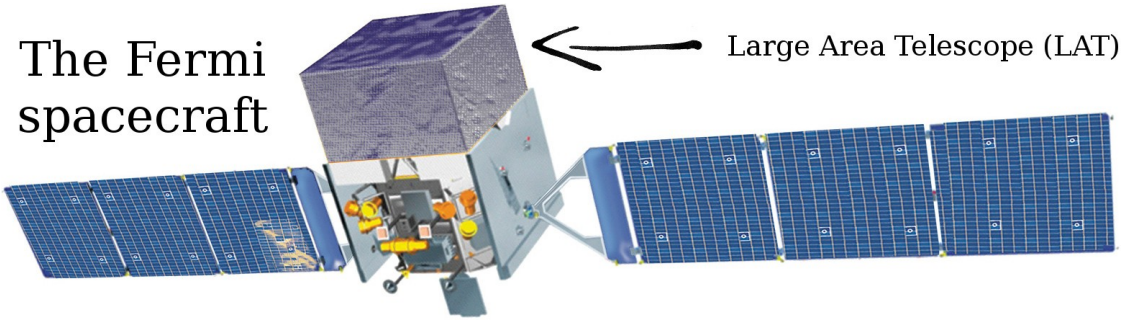
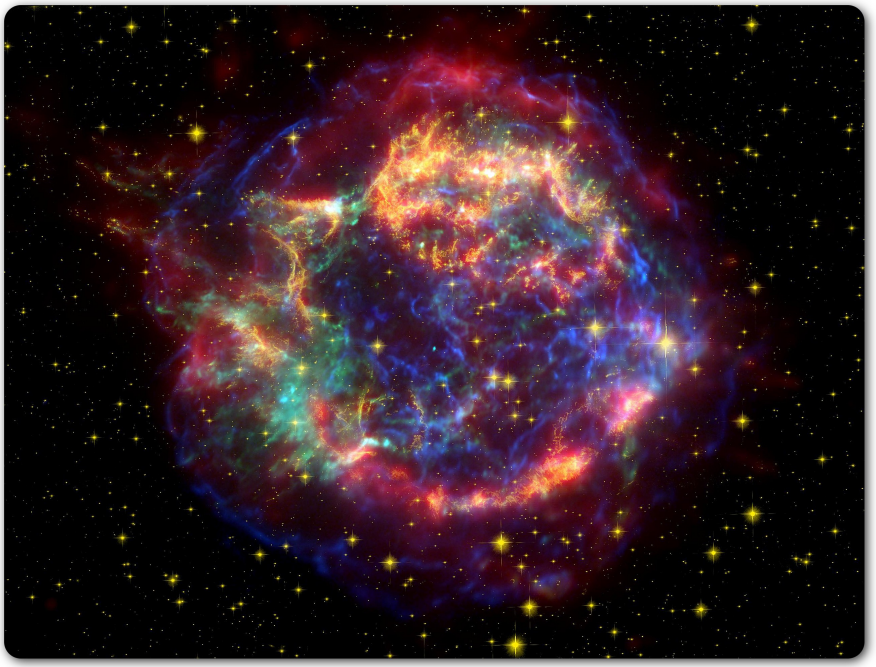
Overview



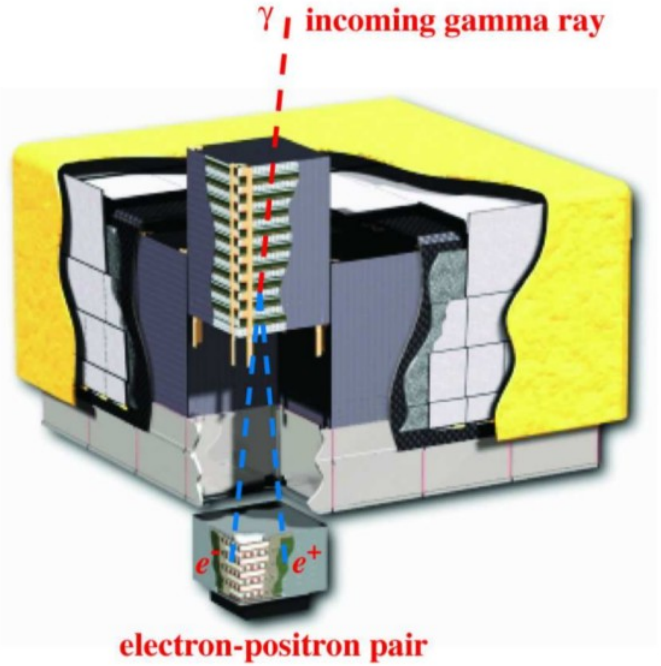




Cassiopeia A (X-ray, Infrared and Optics)

Fermi - Large Area Telescope

Launched in August 2008 for a 10 years mission
(*should be extended beyond 2018*)



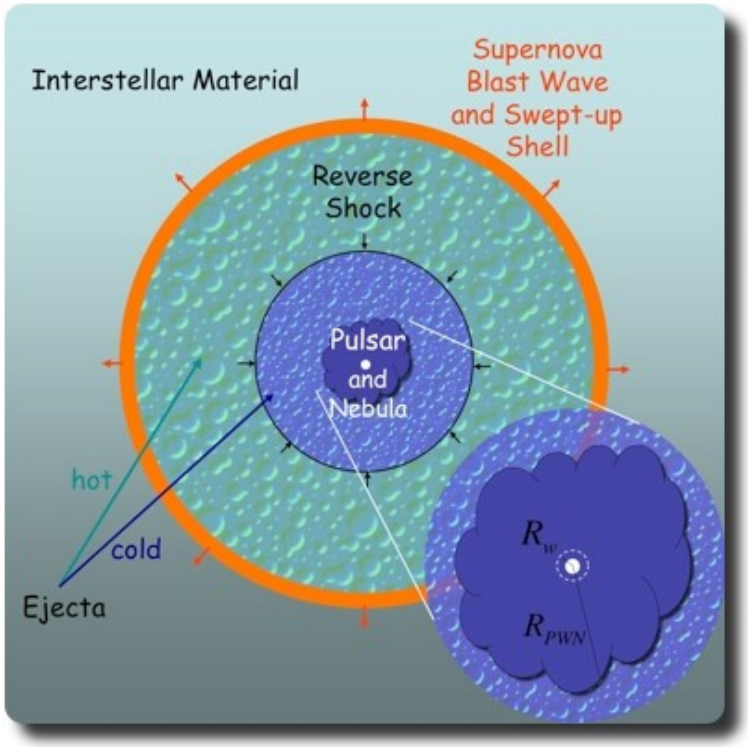
Description (LAT) :

- Converter / Tracker
- Calorimeter
- Anti-coincidence system

Performances :

- 20 MeV to 500 GeV
- Field of view ~ 2.4 sr
- PSF ~ 0.08° (68% contain.) at 10 GeV for the best event class

Supernova Remnants (SNR)



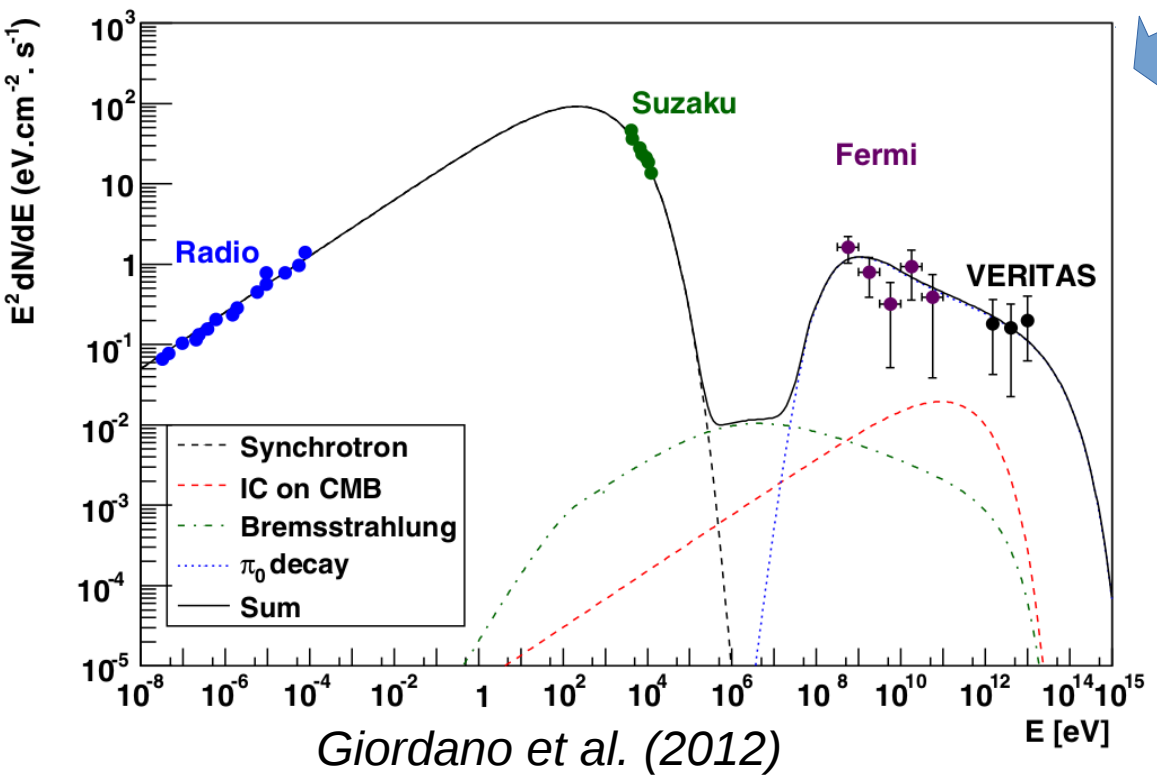
(diagram of a SNR in the case of a Core-Collapse SN)

- SNR = shock wave produced by a supernova and propagating through space

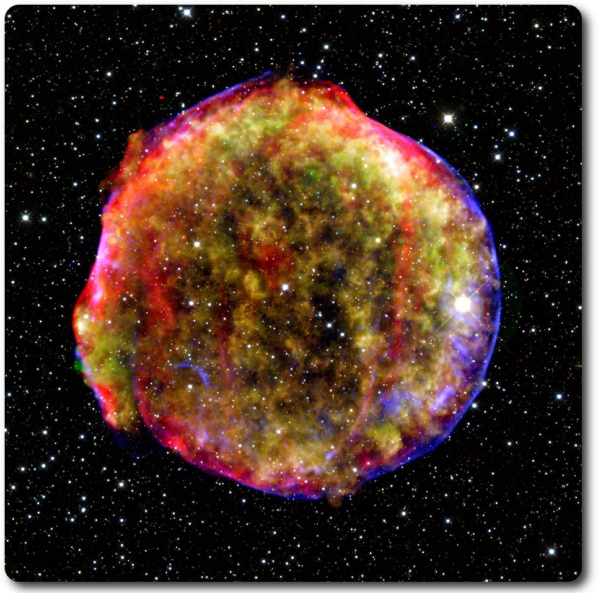
- Three phases :
  - Free expansion phase :
    - Mass of matter swept up < Mass ejecta
    - Highest shock velocity
  - Adiabatic phase (Sedov-Taylor) :
    - Mass of matter swept up ~ Mass ejecta
    - Slower shock velocity, interaction with interstellar medium
  - Radiative phase :
    - The SNR cools
    - Electrons recombine with ions (UV emission)
    - Deceleration of the shock
  - Then merging with the ISM ...

Supernova Remnants (SNR)

- Gamma-rays are produced by two mechanisms :
  - The decay of neutral pions (protons acceleration)
  - The Inverse Compton scattering of high energy electrons on ambiant photons (electron acceleration)
- What are we looking for ?
  - Pion-decay "bump"
  - emission up to 1 PeV



Giordano et al. (2012)



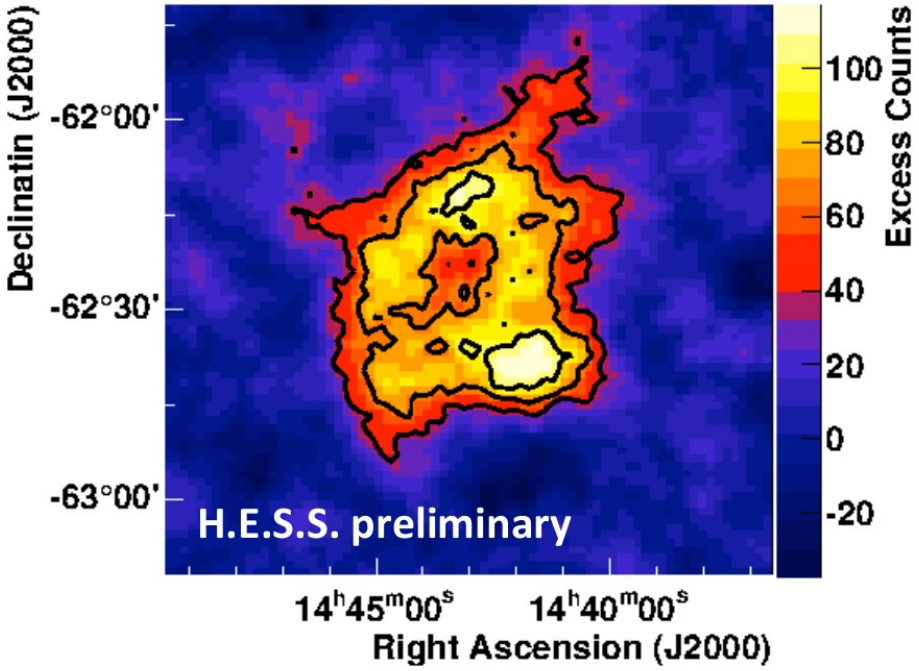
(View of Tycho in X-rays and infrared)

RCW 86 -- G315.4-2.3 -- MSH 14-53

- Remnant of a Type Ia supernova
- Associated to SN 185
- Age ~ 1850 years
- Distance ~ 2.5 kpc

View in X-ray (Chandra/XMM-Newton) and Infrared (Spitzer/WIZE)

(From I. Jung-Richardt - ICRC 2015)



Why this remnant ?

- Thin filaments emiting in X-rays

  ==> B-field amplification

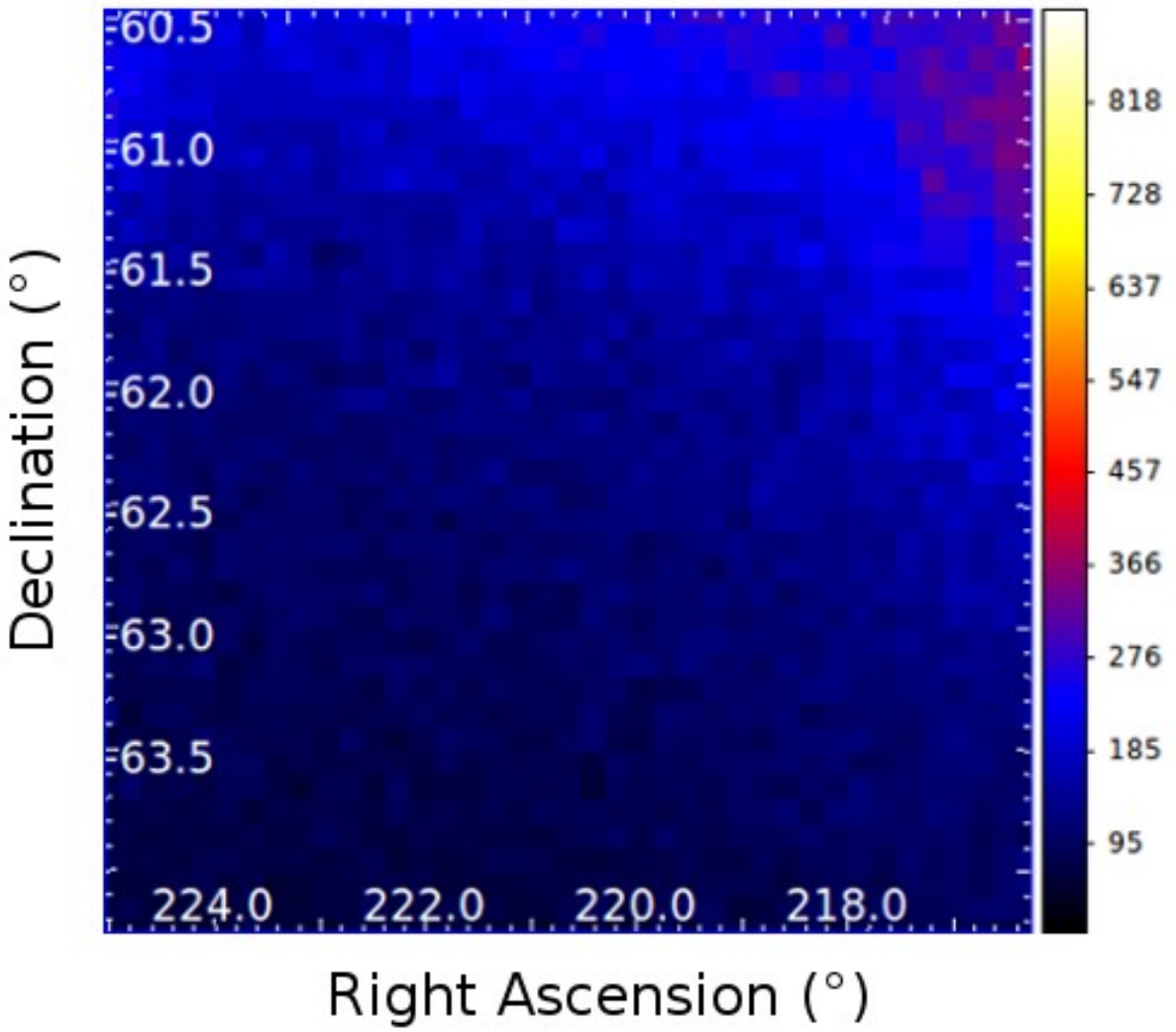
  ==> Efficient particle acceleration

- Lots of multiwavelength data

How does the Fermi-LAT see RCW 86 ?

How does Fermi-LAT see RCW 86 ?

Count map above 100 MeV



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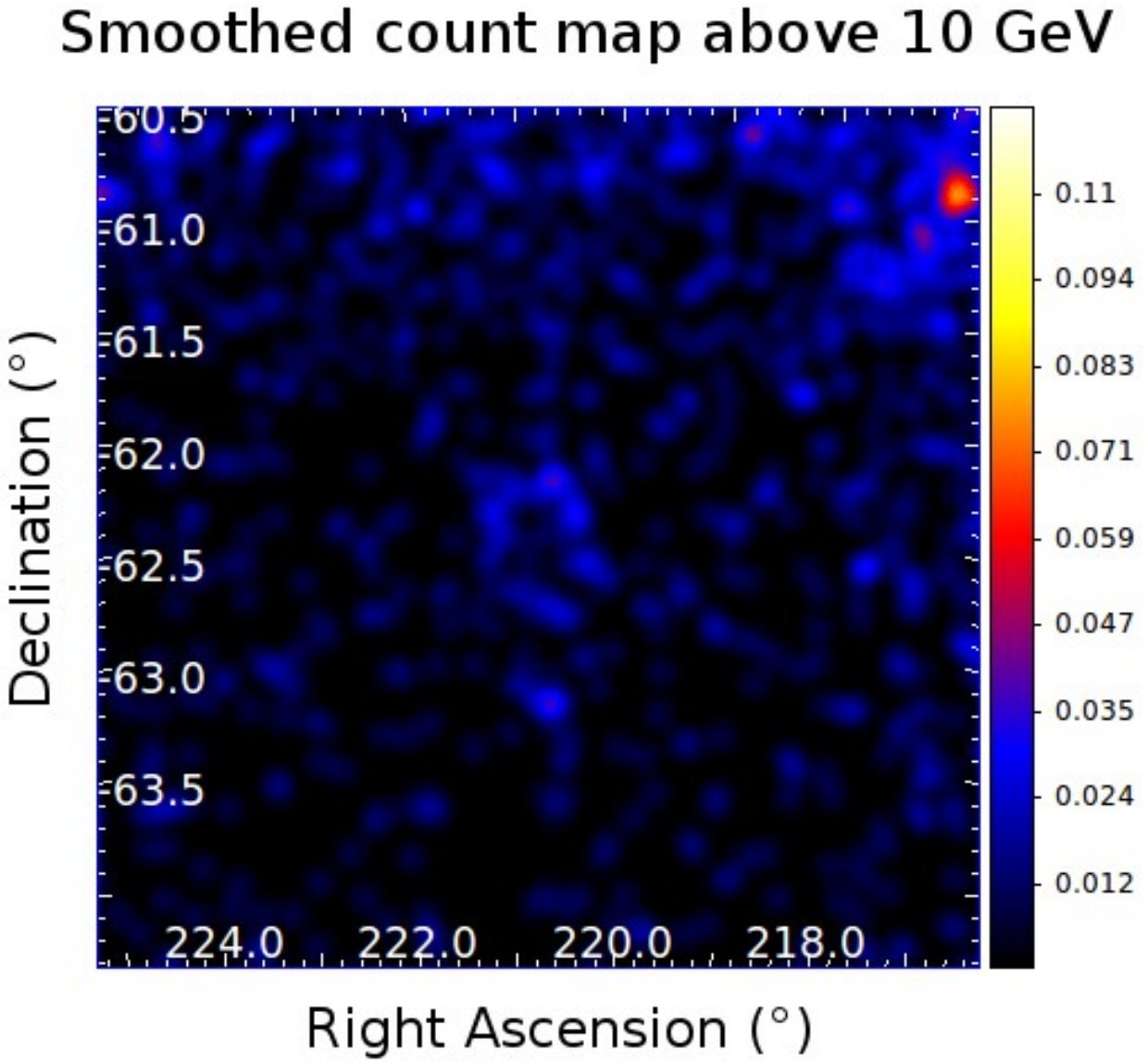


Analysis of the Fermi data

1. We create a model of the sky (XML file)

   - List of all the sources located in the studied region
     + Galactic + Isotropic + Earth Limb

   - For each sources : spectrum shape + spatial model

2. We fit the data with the model

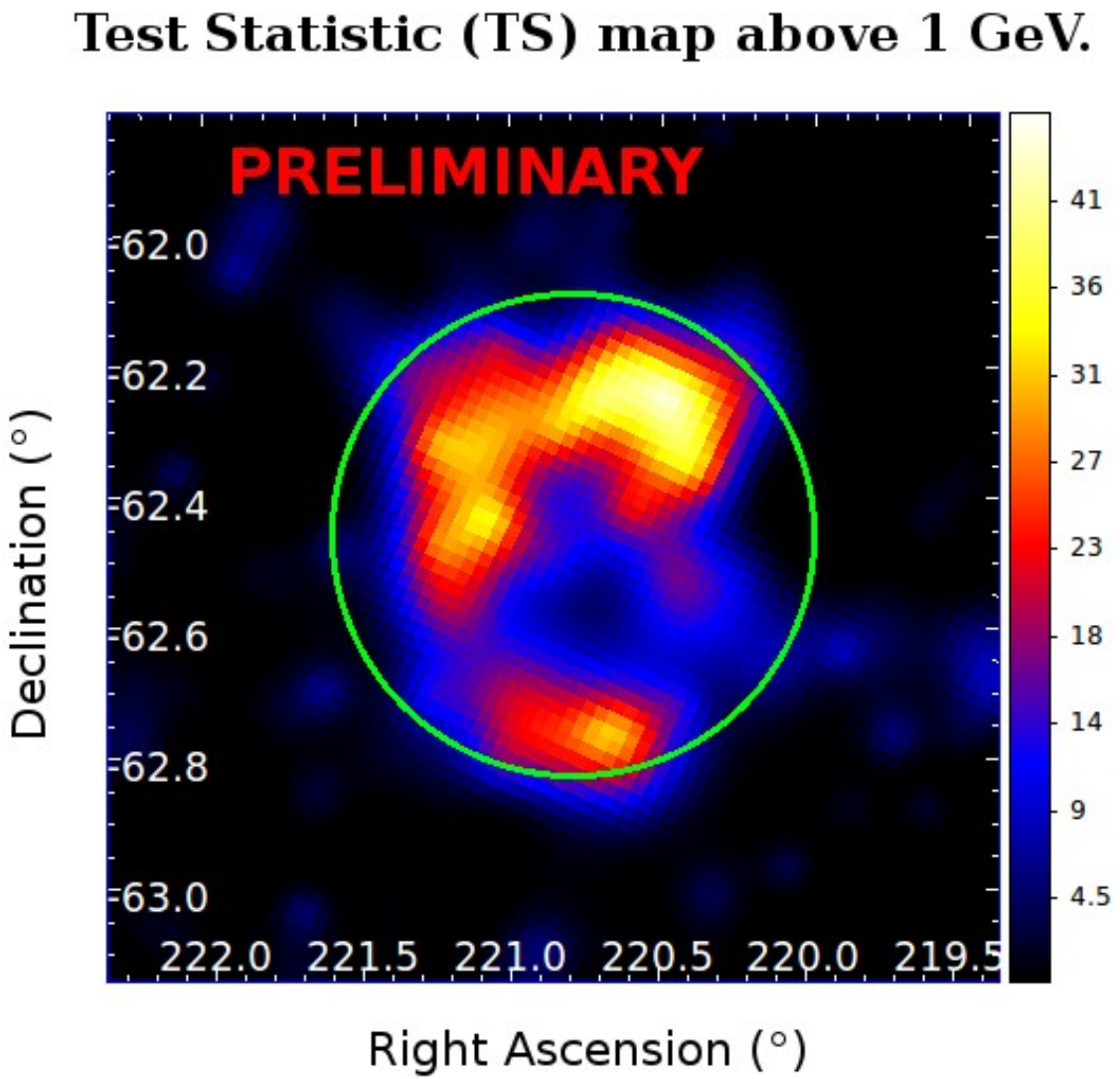
   ==> Maximum likelihood method

3. We compute the Test Statistic of the source :

$$TS = 2 \times [\ \ln(L_1) - \ln(L_0)\ ]$$

   L1 : with the source
   L2 : without the source

Morphological analysis

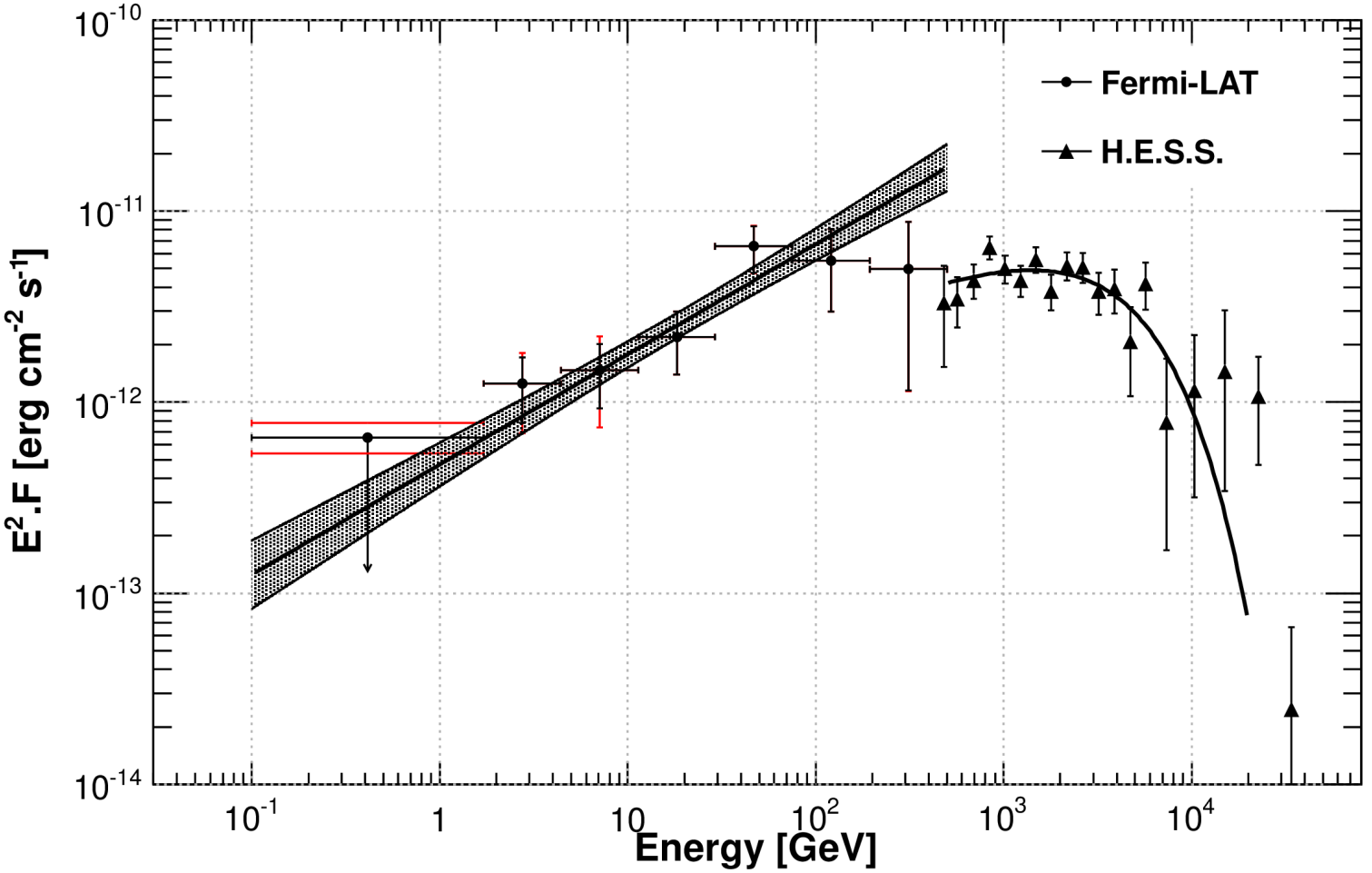


Template	TS	N_{dof}
Pointlike source	50	4
Disk	113	5
Ring	119	6

- First detection of RCW 86 as an extended source !! (significance > 5σ)
- Radius = 0.37° ± 0.02°

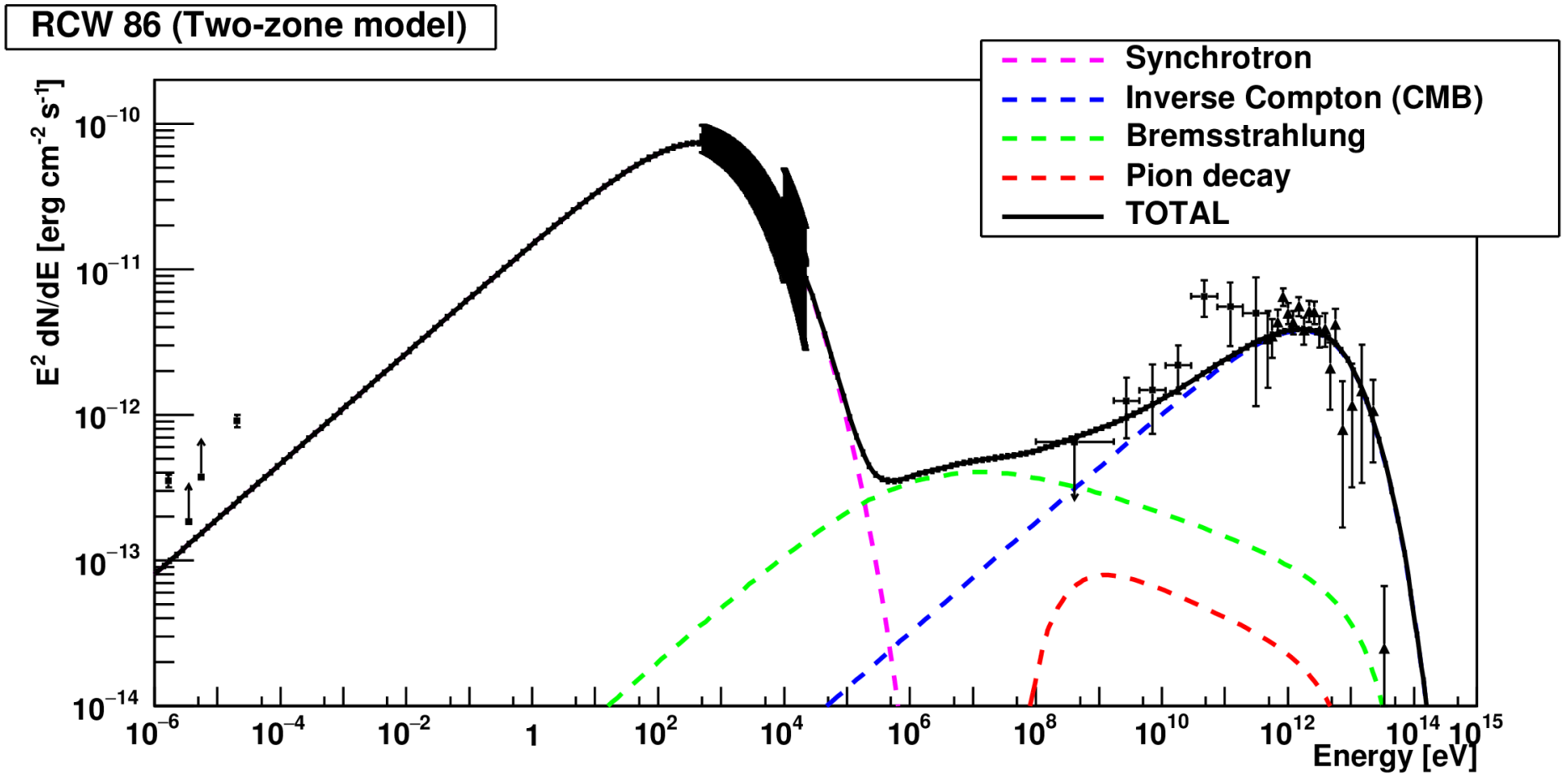
Spectral analysis (100 MeV - 500 GeV)

- Analysis between 100 MeV and 500 GeV
- Spectrum shape : Power Law (Index ~ 1.4)



(Improvement of 2.5 sigma only with a Smooth Broken Power Law)

Broadband modeling of the non-thermal emission



Leptonic scenario favoured over a hadronic scenario ! (index, density)

No evidence of efficient proton acceleration in the whole remnant.

Conclusion

- The first year :
  - Analysis of the SNR RCW 86
    - Detection of the extension
    - New constraints
    - Paper in preparation

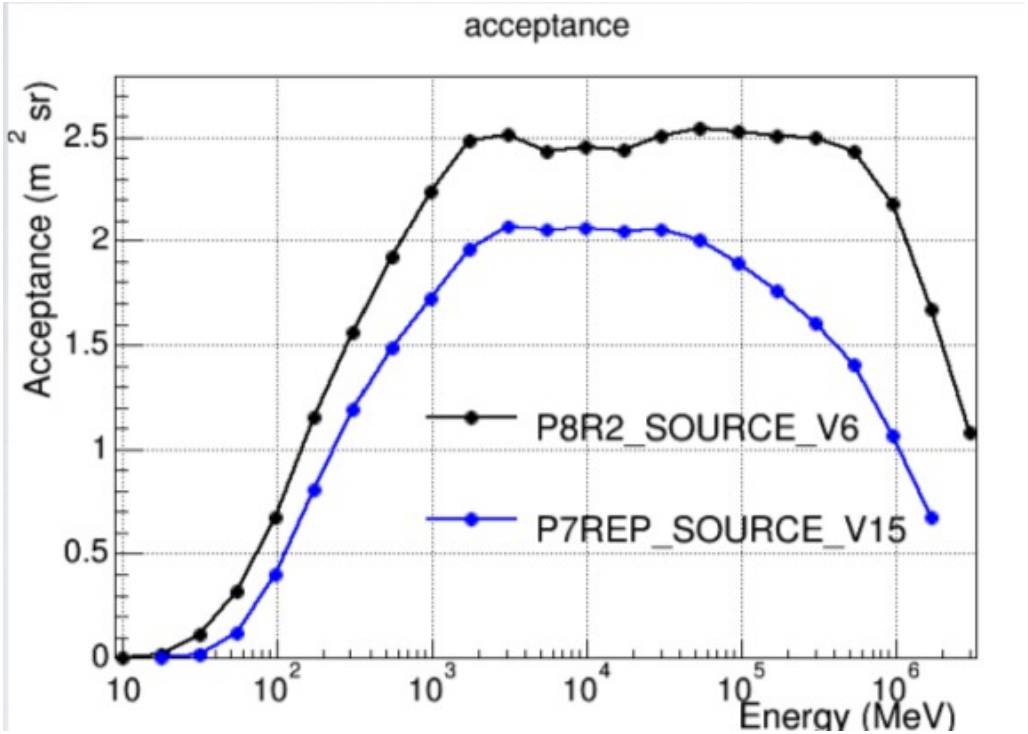
- In the near future :
  - Contribute to the improvement of the analysis with the 5th telescope (perspectives for CTA)
  - Analysis of another SNR with Fermi-LAT data

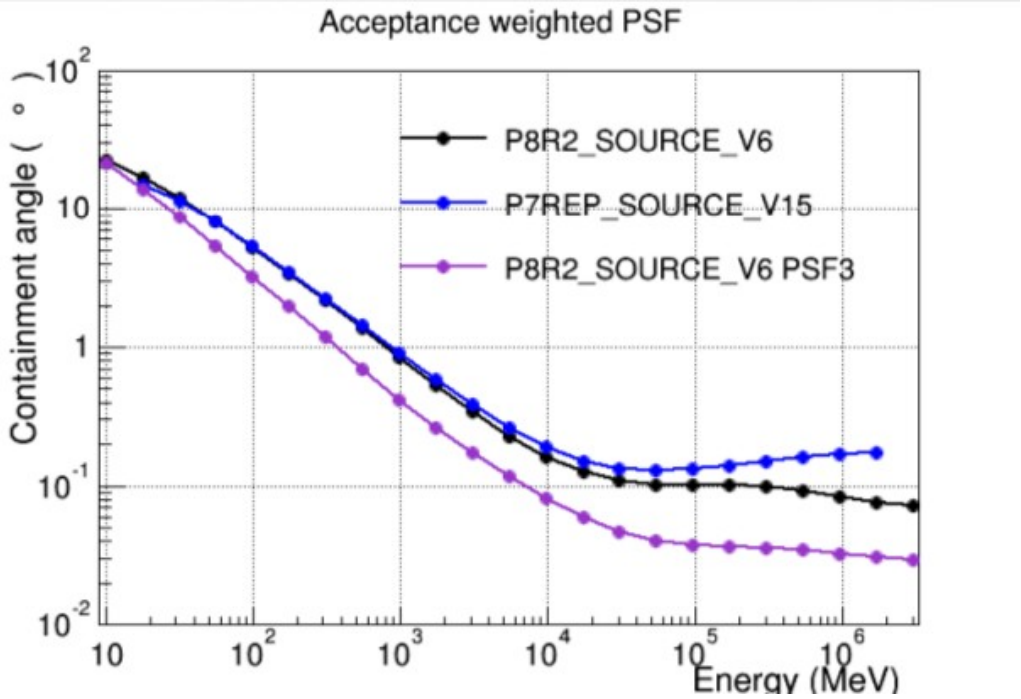
Fermi - Large Area Telescope

Pass 8 : latest version of the Fermi data (after several years of development).

- complete revision of the event reconstruction set
- better reduction of the background
- implementation of a multivariate analysis framework

Results : better acceptance, better PSF, better energy resolution !





Analysis of the Fermi data

Example of an XML file containing a list of sources.

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  <spectrum  type="PowerLaw" apply_edisp="false">
    <parameter name="Prefactor" value="0.972554800014" error="0.00042502616525" free="1" max="100.0" min="1e-05" scale="1.0" />
    <parameter name="Index" value="0.00594696769998" error="0.000475416187137" free="1" max="1.0" min="-1.0" scale="1.0" />
    <parameter name="Scale" value="500.0" free="0" max="500.0" min="500.0" scale="1" />
  </spectrum>
  <spatialModel file="/afs/slac/g/glast/groups/diffuse/rings/4year/preliminary/template_4years_P8_V2_scaled.fits" type="MapCubeFunction">
    <parameter name="Normalization" value="1.0" free="0" max="1e3" min="1e-3" scale="1.0" />
  </spatialModel>
</source>
<source name="RXJ1713" type="DiffuseSource" RA="258.421" DEC="-39.746">
  <spectrum type="SmoothBrokenPowerLaw">
    <parameter name="Prefactor" value="8.42682068137" error="0.00223087982026" free="1" max="100000.0" min="1e-05" scale="1e-13" />
    <parameter name="Index1" value="0.932281588678" error="0.042530291576" free="1" max="5.0" min="0.0" scale="-1.0" />
    <parameter name="Index2" value="1.95321018995" error="0.0872690782345" free="1" max="5.0" min="0.0" scale="-1.0" />
    <parameter name="BreakValue" value="1.18981954934" error="0.0125718874474" free="1" max="100.0" min="0.1" scale="1000.0" />
    <parameter name="Scale" value="1000.0" free="0" max="1000.0" min="1000.0" scale="1" />
    <parameter name="Beta" value="0.1" free="0" max="0.1" min="0.1" scale="1" />
  </spectrum>
  <spatialModel type="SpatialMap" file="/nfs/farm/g/glast/u/condon/sources/RXJ1713/TEMPLATE/template_RXJ1713_HESS.fits" >
    <parameter name="Prefactor" value="1.0" free="0" max="1e3" min="1e-3" scale="1.0" />
  </spatialModel>
</source>
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  <spectrum  type="LogParabola">
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    <parameter name="alpha" value="1.95605590504" error="0.0236937629315" free="1" max="5.0" min="-0.0" scale="1.0" />
    <parameter name="beta" value="0.134491279582" error="0.0100040074985" free="1" max="10.0" min="-10.0" scale="1.0" />
    <parameter name="Eb" value="0.5589400097" free="0" max="1000.0" min="1e-05" scale="1000.0" />
  </spectrum>
  <spatialModel type="SpatialMap" file="/nfs/farm/g/glast/u/condon/sources/RXJ1713/TEMPLATE/template_CTB37A_Disk.fits" >
    <parameter name="Prefactor" value="1.0" free="0" max="1e3" min="1e-3" scale="1.0" />
  </spatialModel>
</source>
</source_library>
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