Particle Acceleration in the Universe

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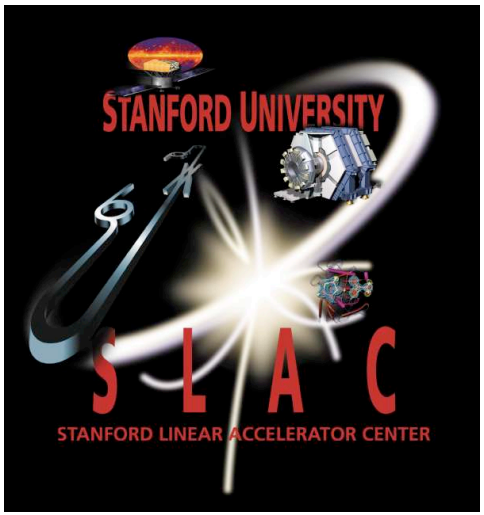
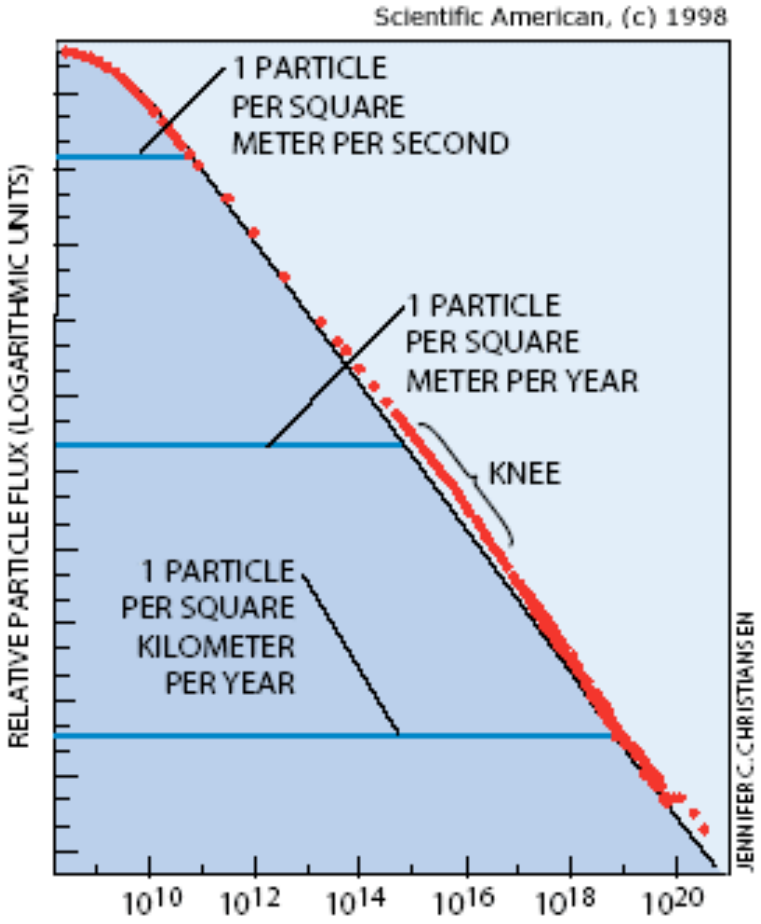
on behalf of SLAC GLAST team



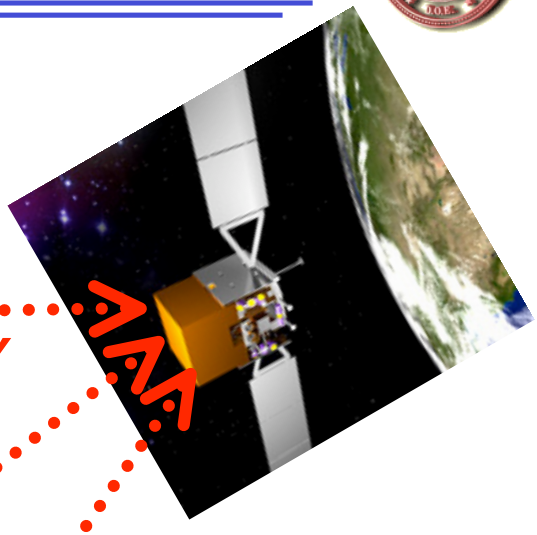
June 7, 2006
SLAC DOE HEP Program Review

Cosmic Particle Accelerators

- **Origin of cosmic ray protons?**
  - **Galactic SNRs (Supernova Remnants) are considered as the best candidates for cosmic-rays below "Knee".**
    - Only circumstantial evidence
      - Diffusive shock acceleration. (Blanford&Eichler 1977)
      - CR energy sum consistent with SNR kinetic energy. (Ginzburg&Syrovatskii 1964)
    - No observational evidence for hadronic acceleration.
  - **Cosmic-rays above "Knee" are considered extragalactic.**
    - Gamma-ray bursts (GRB).
    - Active Galactic Nuclei.
    - Galaxy clusters.



Hadronic Cosmic-ray Interactions



γ (CMB)

γ (Cosmic Microwave Background)

e^+e^-

Compton scattering

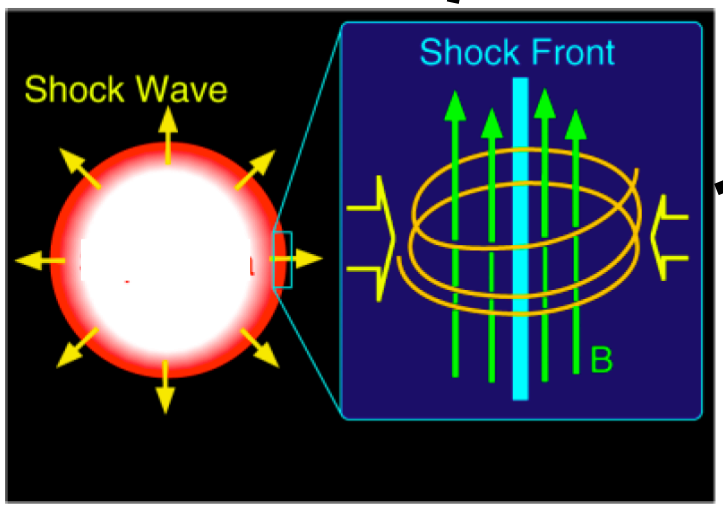
γ

p

π^0

γ (CMB)

$\pi^\pm \rightarrow \mu^\pm \rightarrow e^\pm$

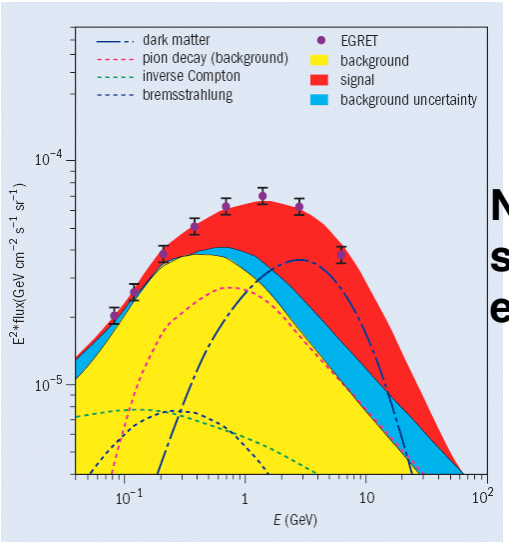


p

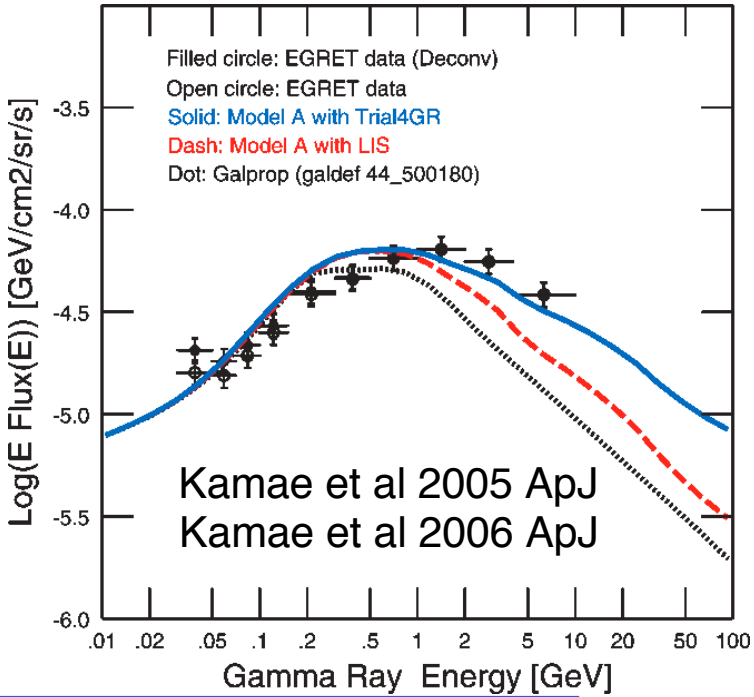
p (Inter stellar medium)

New Hadronic Interaction Model

- **Better modeling of hadronic interaction**
  - **Diffraction dissociation, scaling violation and rising inelastic cross-section.**
  - **Crucial to model gamma-ray emission from hadronic interaction.**
    - 20–50% of "GeV excess" in EGRET Galactic ridge spectrum was accounted for by new model.
      - BG spectrum for dark matter search.



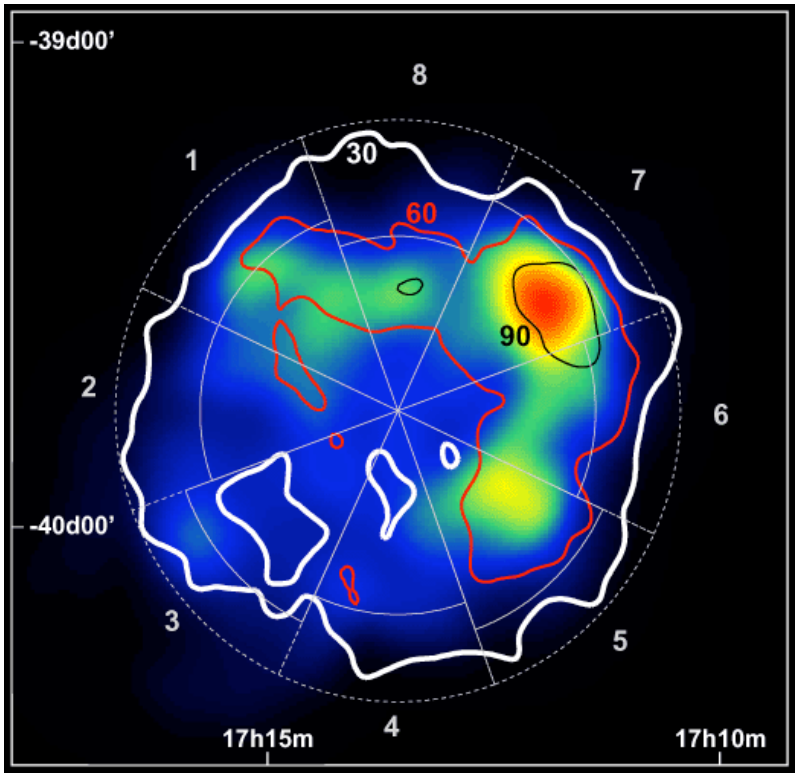
No need for 60 GeV WIMP suggested by W. de Boer et al, A&A 2005.



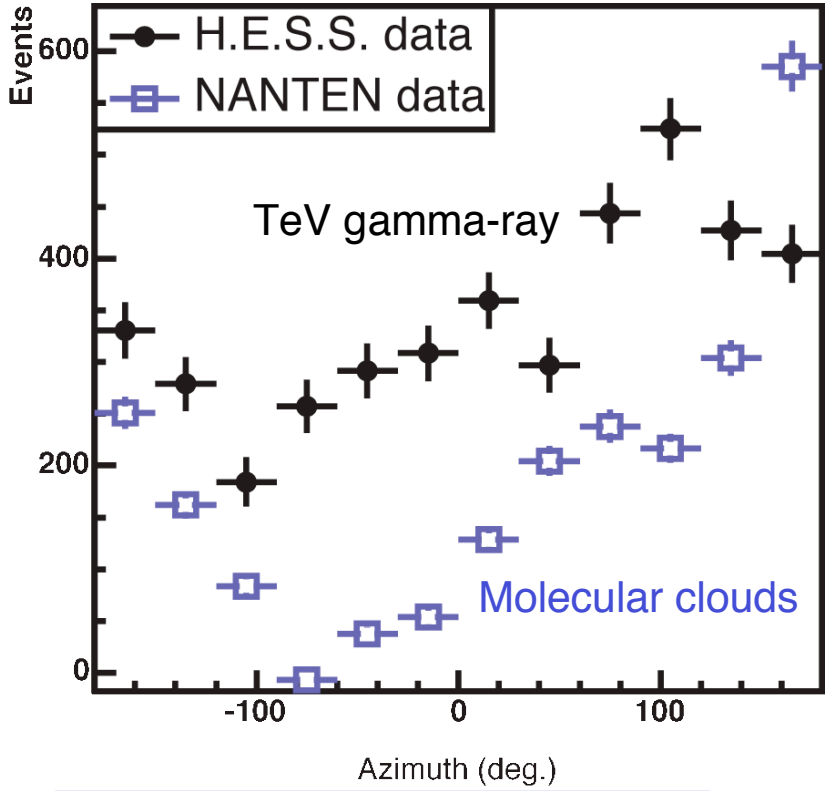
TeV Gamma-ray from SNR

- **HESS TeV gamma-ray observation of RX J1713-3946**
  - **Evidence for particle acceleration > 100 TeV.**
  - **Azimuth profile does not match very well with molecular clouds.**
    - Detailed 3D molecular cloud map
    - Angular distribution from new particle interaction model.

Aharonian et al. 2005



Aharonian et al. 2005



Gamma-ray Spectrum for RX J1713

- **HESS spectrum may prefer hadronic origin.**
  - **Not conclusive.**
- **GLAST can positively identify hadronic contribution.**
  - **Gamm-rays from π^0 decays due to hadronic interaction with molecular clouds.**

Berezhko 2006 & Aharonian et al. 2005

B_d = 126 μG
K_{ep} = 10^{-4}
E_{SN} = 1.8 x10^{51} erg
τ_{age} = 1600 year

Model independent (π^0 production and decay kinematics)

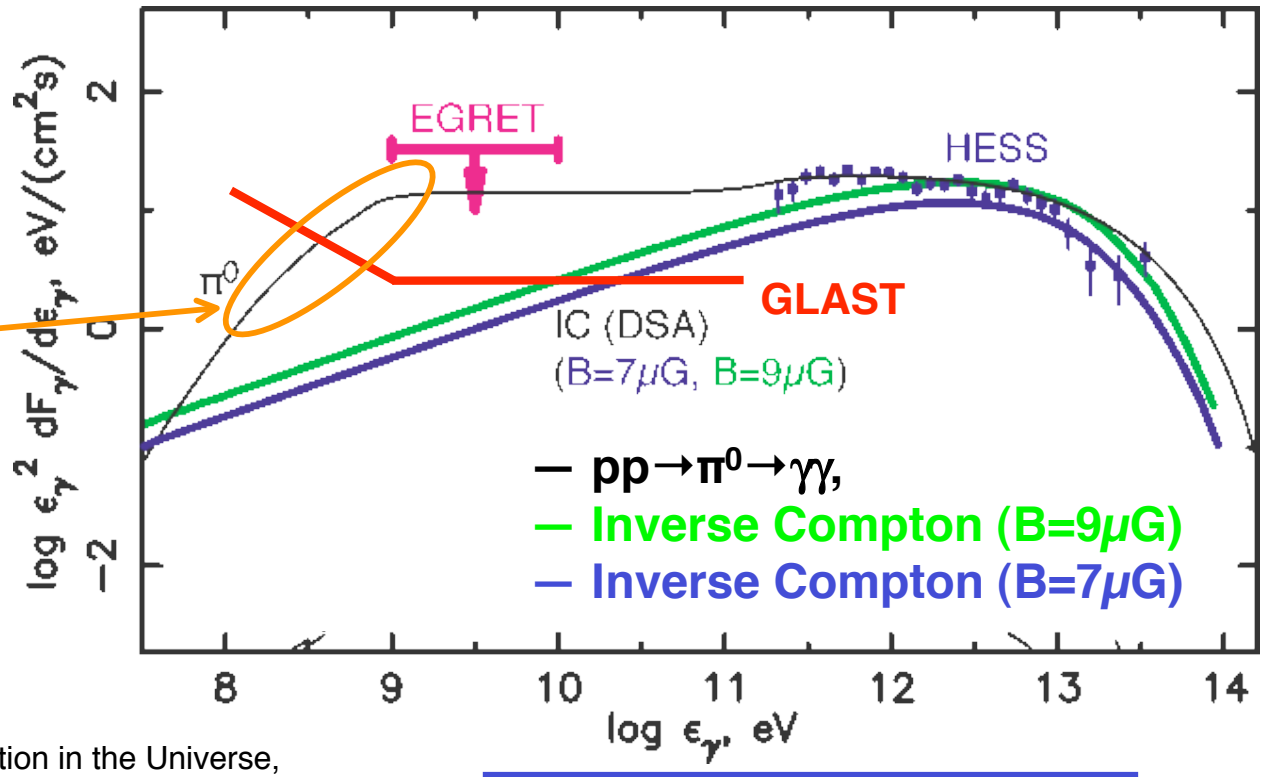
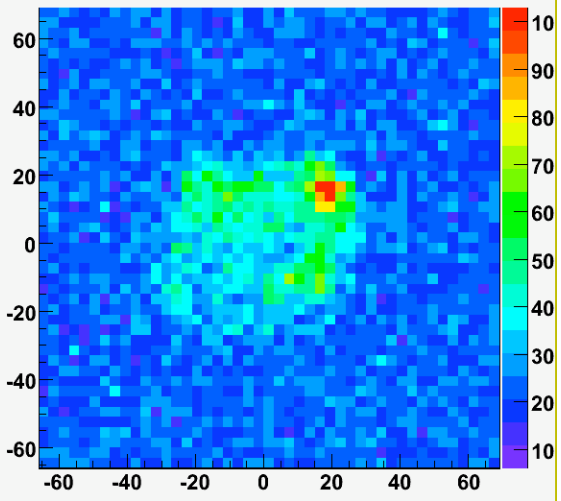


Image Deconvolution for Diffuse

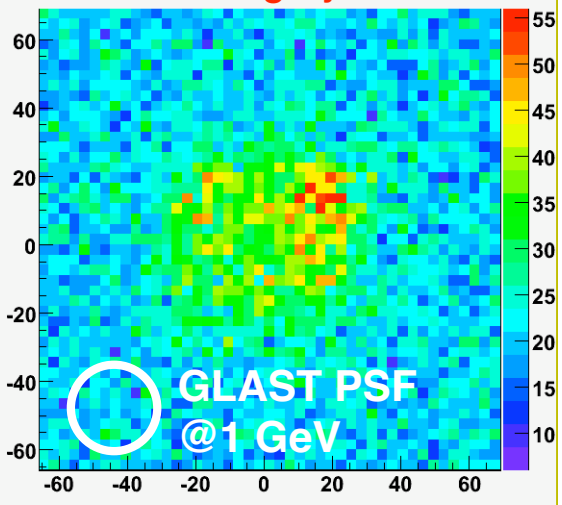
- **Poor GLAST PSF make it difficult to resolve RX J1713-3946.**
  - **Model independent image deconvolution required.**
- **Image deconvolution is essential for extended sources.**
  - **Galactic diffuse, dark matter search, galaxy clusters.**
- **Deconvolved image gives better representation of input image.**
  - **Overall shape recovered.**

Toy MC demonstration
GLAST 3.2×10^{11} s•cm^2 observation
@ 10^{-12} erg/cm^2/s, $\propto E^{-2}$, E > 1GeV, PSF = 2.5–27'

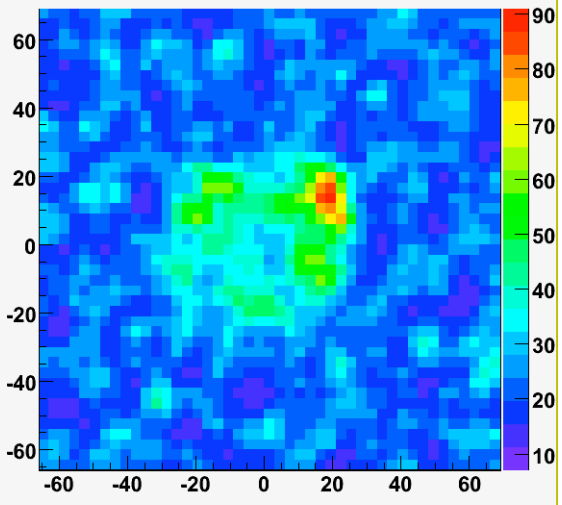
Generated image for RX J1713-3946



After smearing by PSF

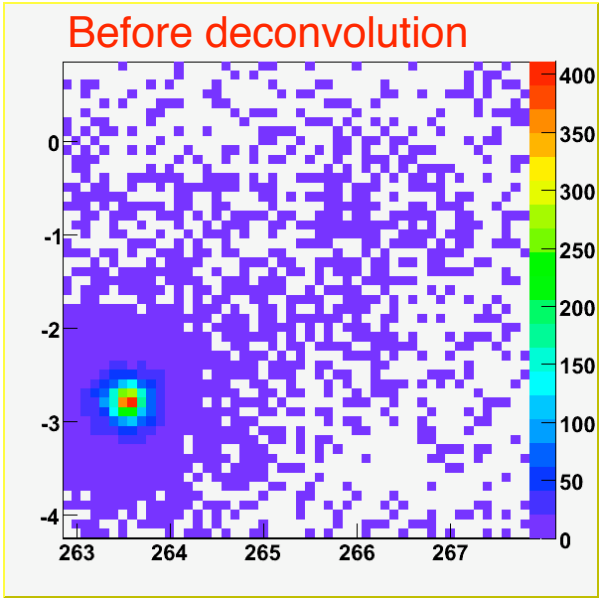


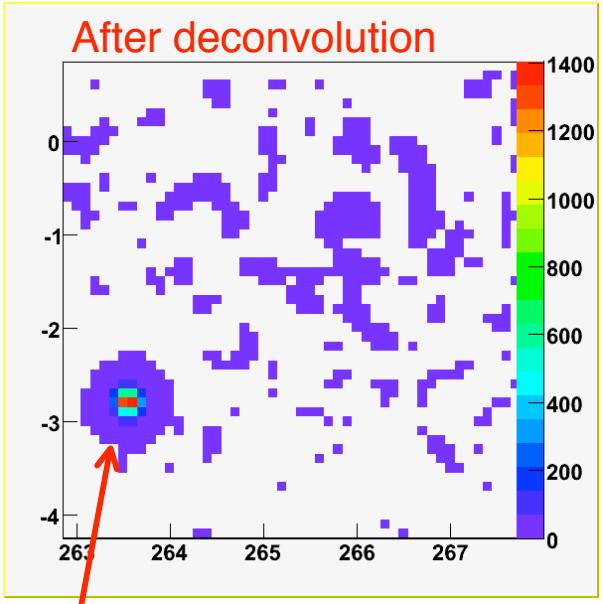
After deconvolution

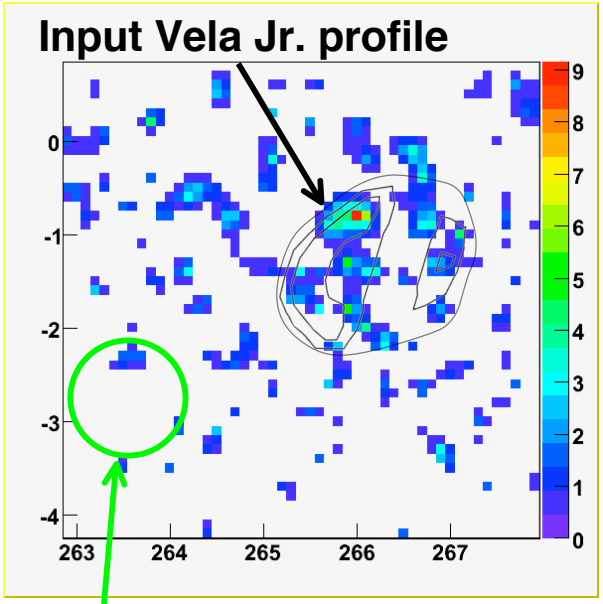


Demonstration with Realistic MC

- **GLAST Data Challenge II**
  - **More realistic Monte Carlo with full detector simulation and reconstruction for 2 months observation.**
  - **Event-by-event PSF with tail.**
    - Depends on energy and incident angle.







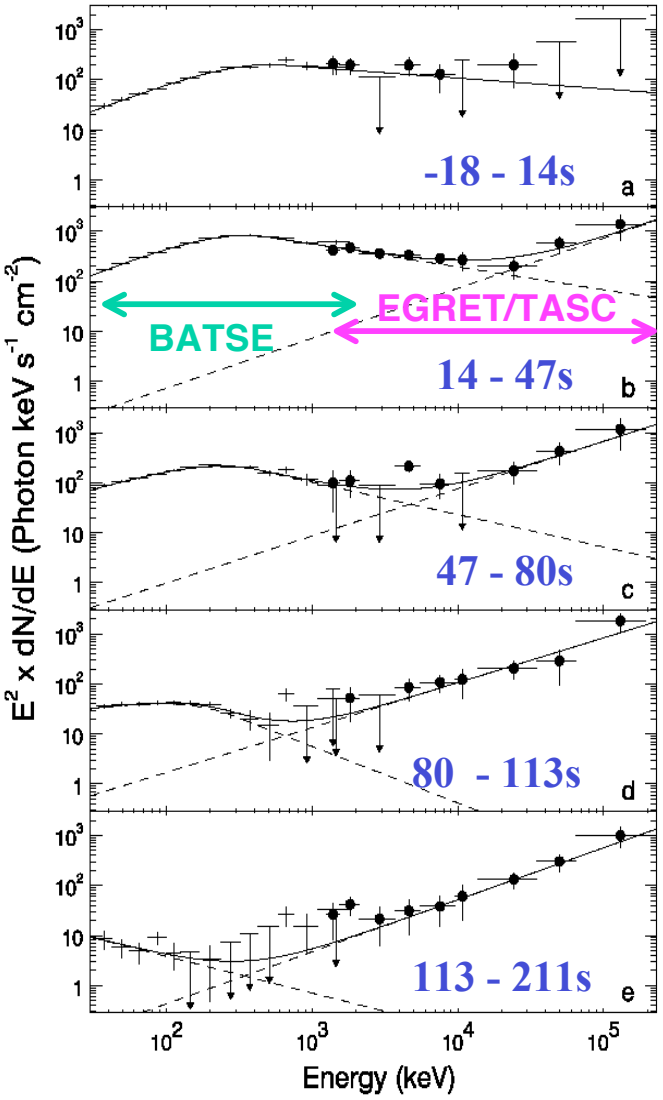
(263.55, -2.80)
(263.55, -2.79): Vela Pulsar

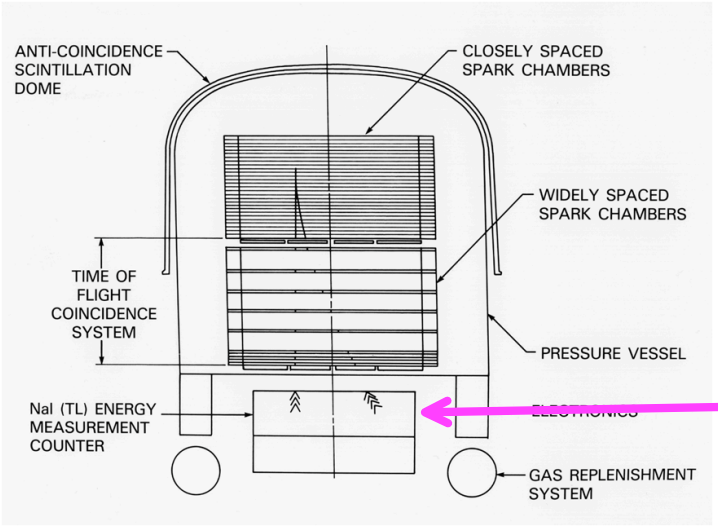
Strong point source can be removed cleanly to observe faint extended sources.

GRB Delayed Gamma-ray Emission

- **Delayed gamma-ray emission from GRB is observed by EGRET.**
  - **It is hard to explain by conventional electron synchrotron models.**
  - **Proton acceleration?**
  - **More samples required to understand further.**
    - Systematic analysis of EGRET data in progress.
    - GLAST will add much more samples.
  - **GLAST extend the energy reach to ~200 GeV.**
    - Broadband spectra constrain emission models.

Gonzalez, Nature 2003 424, 749



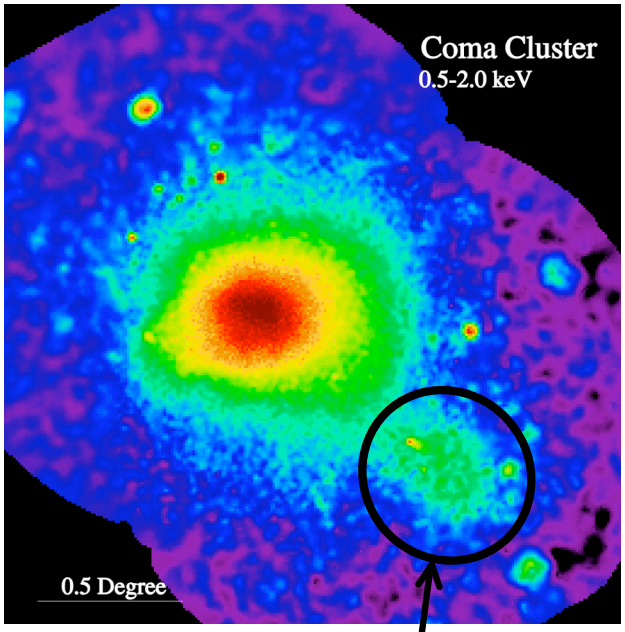


Total Absorption Shower Counter

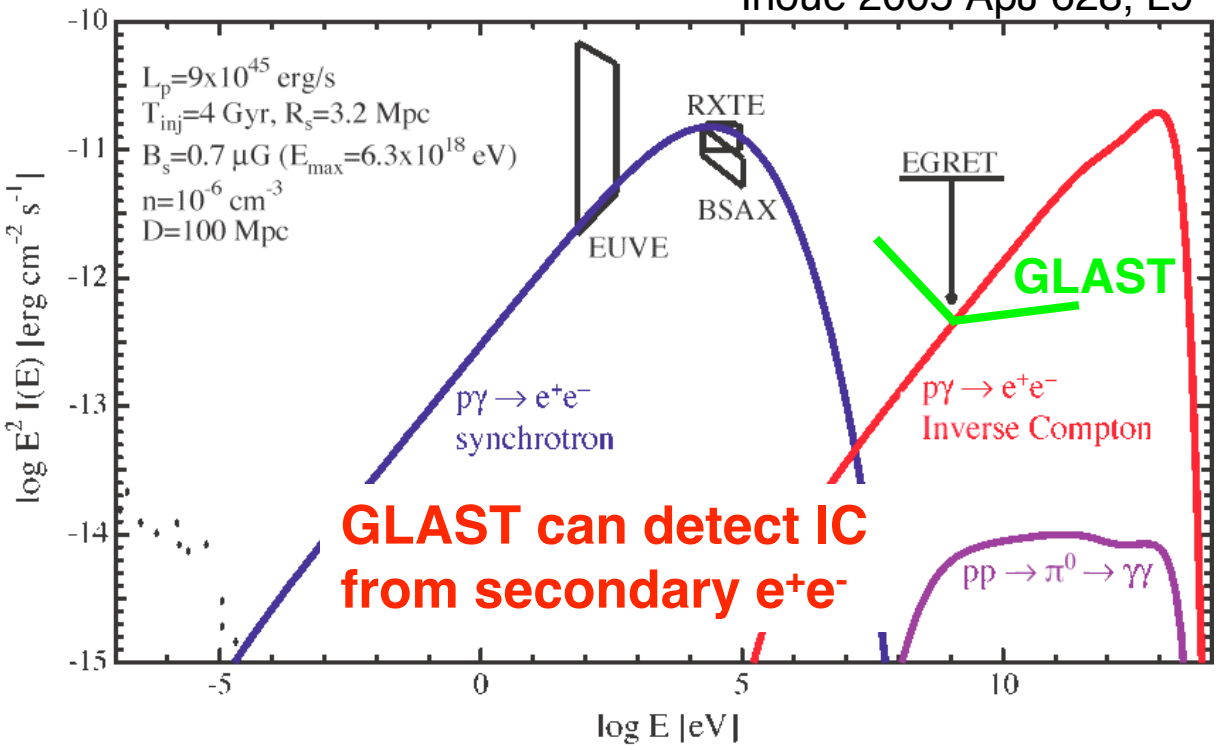
γ-rays from Merging Galaxy Cluster

- **Strong shock due minor merger of galaxy clusters.**
  - **Model parameters are tuned to be consistent with existing measurements.**
  - **Particle acceleration up to 10^{19} eV. (Origin of UHE-CR?)**
  - **Secondary e^+e^- following proton interaction with CMB photon are dominant origin of gamma-rays.**

Inoue 2005 ApJ 628, L9



merging galaxy group



Summary

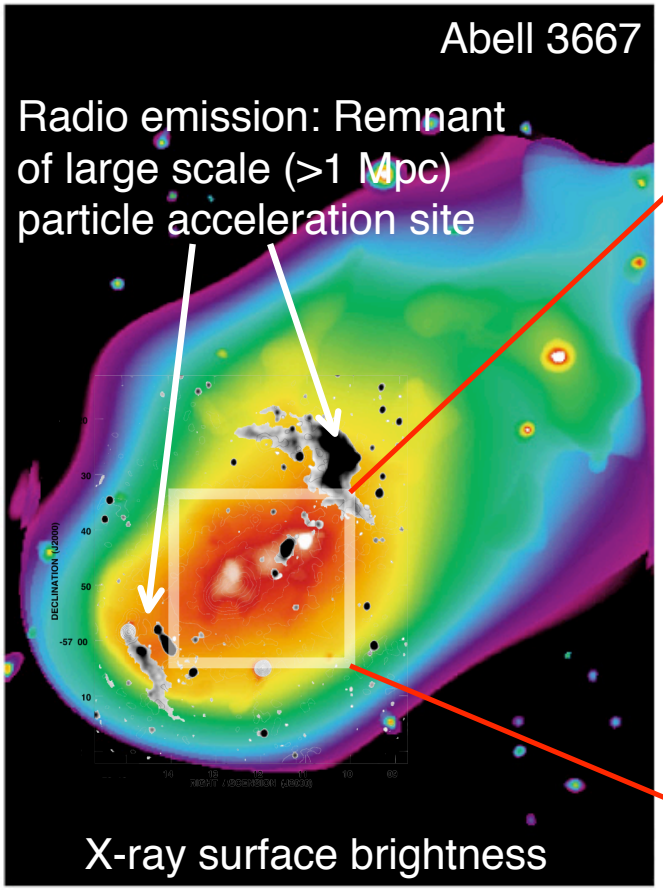
- **GLAST will give conclusive proof on the origin of gamma-rays from SNR, RX J1713-3946.**
  - **In conjunction with X-ray and TeV measurements.**
  - **Measure parent proton spectrum.**
  - **More SNRs will be observed in gamma-rays by GLAST.**
- **GLAST will provide constraints on models of particle acceleration in GRBs and merging galaxies and galaxy clusters.**

- **Major contributions by SLAC scientists on**
  - **Better modeling of gamma-ray emission from hadronic interactions.**
  - **Image deconvolution to study extended sources (SNR, Galactic diffuse, dark matter, galaxy cluster).**

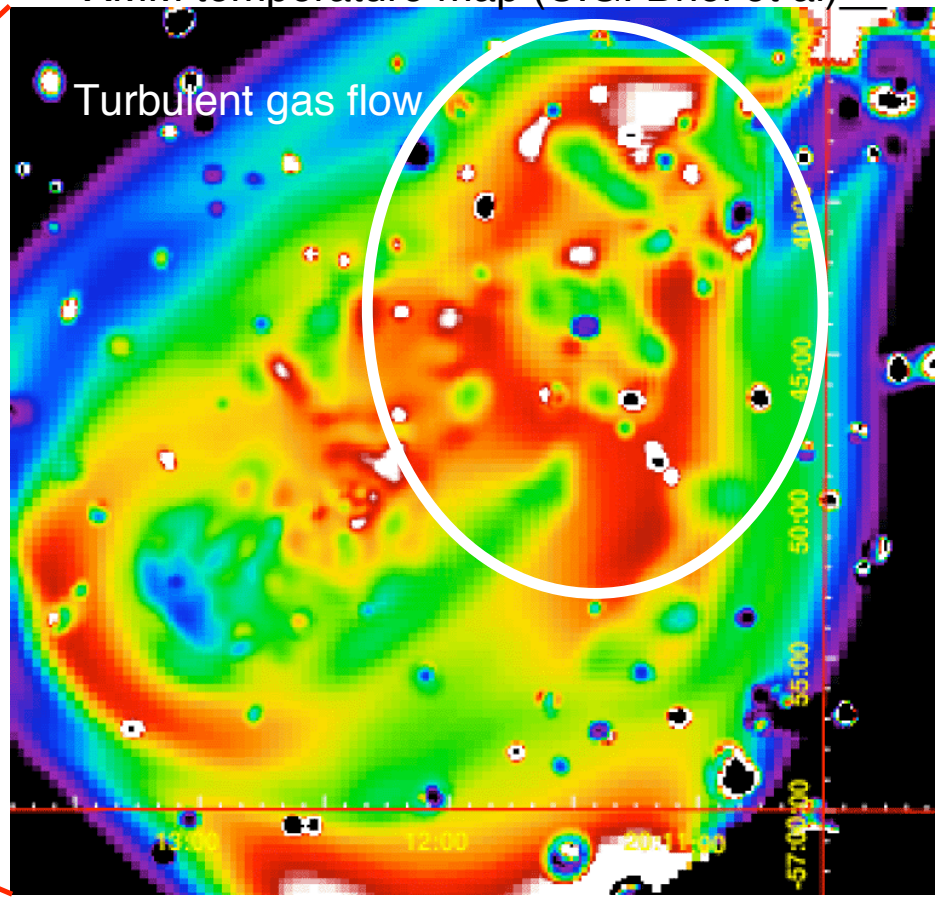
Merging Galaxy Clusters

- **Large scale shock by merging galaxy clusters.**
  - **Origin of Ultra High Energy Cosmic-ray (UHECR)?**

ROSAT März 2003

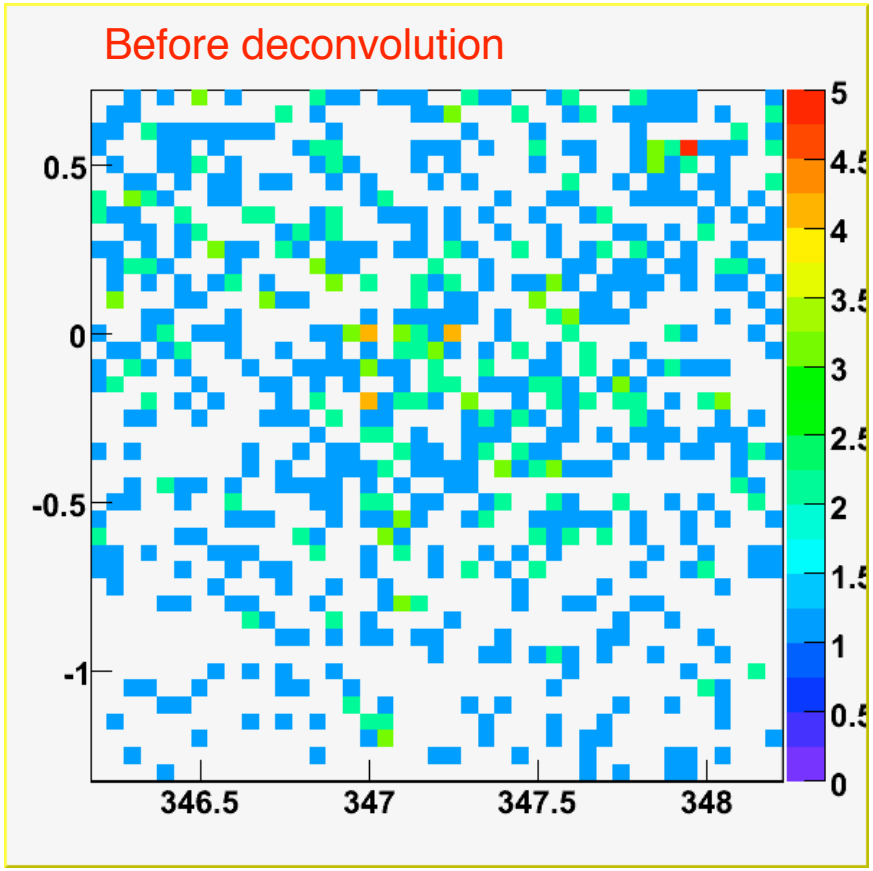


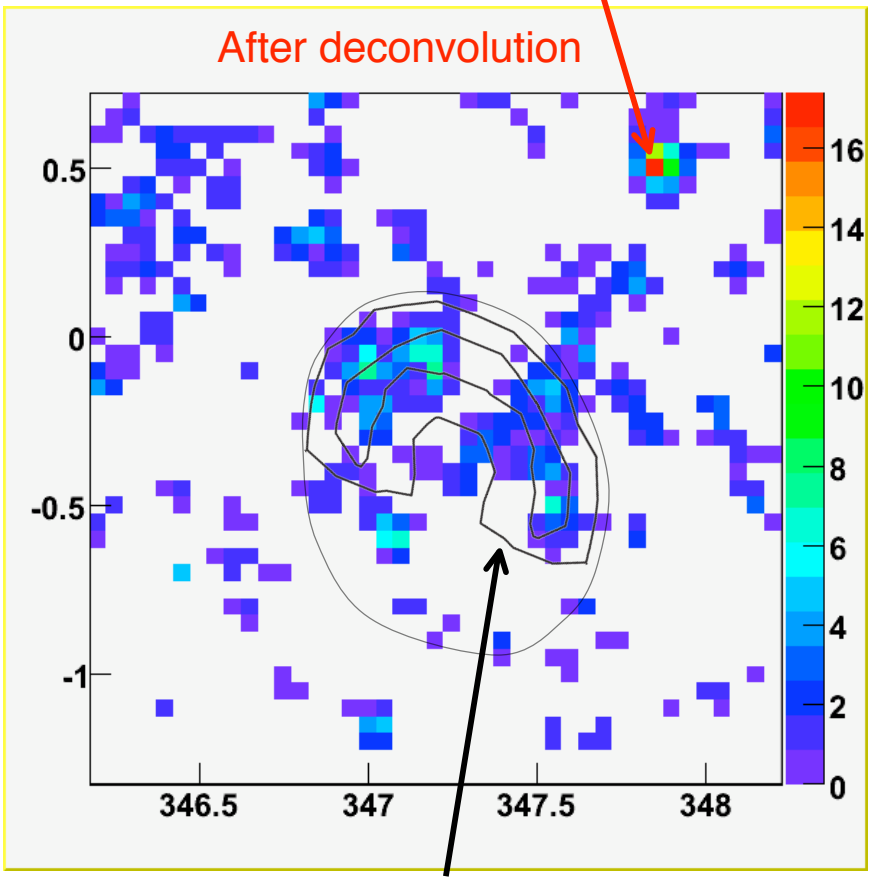
XMM temperature map (U.G. Briel et al)



RX J1713 in DC2 Sample

(347.86, 0.51)
(347.86, 0.51): Pulsar





Generated
RX-J1713 profile