Studies of EGRET unidentified sources with a novel image restoration technique

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February 7, 2007
GLAST Symposium
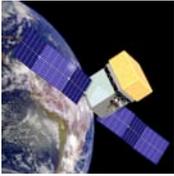
GLAST Analysis of Extended Source

- **GLAST Point Spread Function**
  - » **Varies from 0.1° to 10° (2 order of magnitude)**
    - • Depends on energy and incident angle.
  - » **Worse than most extended sources**

- **Image restoration is essential for extended source analysis.**

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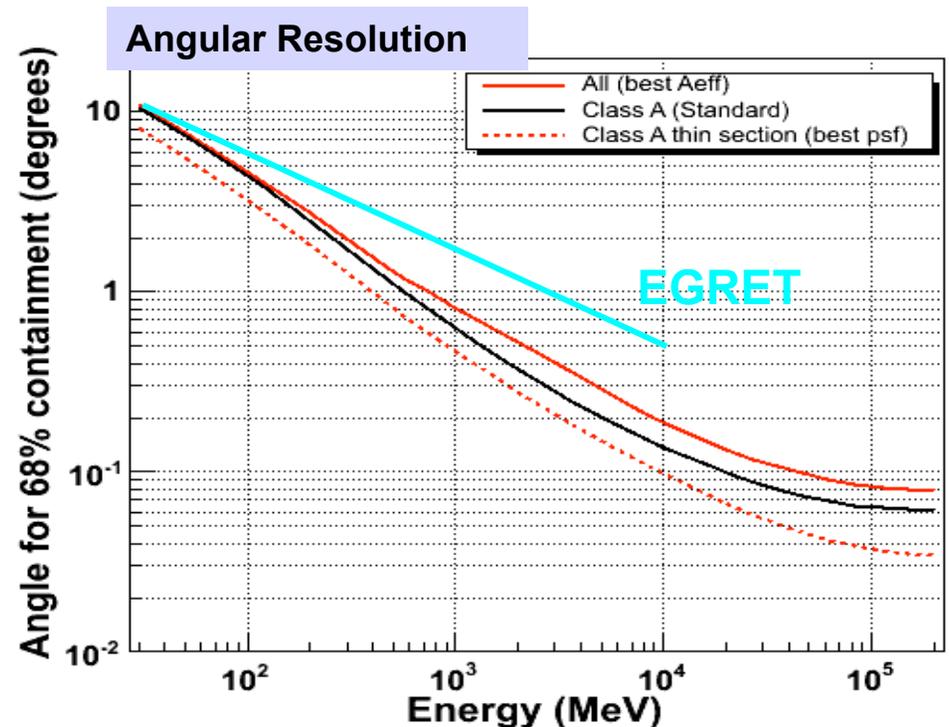
Image Restoration Technique

- **Richardson-Lucy Deconvolution Algorithm.**
  - » **When we observe an event at position x.**
    - P(x:ξ): probability that it came from a "true" position ξ due to instrument response.

Lucy 1974
Richardson 1974

$$\psi^{r+1}(\xi) = \int \tilde{\phi}(x) \frac{\psi^r(\xi)P(x:\xi)}{\int P(x:\zeta)\psi^r(\zeta)d\zeta} dx$$

  - » **Generalization to Event-by-event $P_k(x:\xi)$.**

$$\psi^{r+1}(\xi) = \frac{1}{N}\psi^r(\xi)\sum_{k=1}^{N} \frac{P_k(x_k:\xi)}{\int P_k(x_k:\zeta)\psi^r(\zeta)d\zeta}$$

    - Can be used for event-by-event data with varying PSF.
    - No energy spectrum assumption necessary.
  - » **Point sources can be incorporated using dual-channel method.**

$$\psi = \psi_{\text{point}} + \psi_{\text{extended}}$$

Hook&Lucy 1994
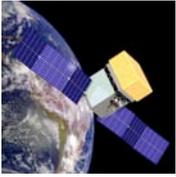
- **Minimize the effect of Poisson noise.**
  - » **Wavelet filtering technique.**

Starck&Murtagh 1994

ϕ: observed image
$R^n = \phi - \phi^n$, $\phi' = R'^n + \phi^n$

$$\phi$$

$$\psi^n \rightarrow \phi^n = P \bullet \psi^n \rightarrow R^n \xrightarrow{\text{FILTER}} R'^n \rightarrow \phi' \rightarrow RL \rightarrow \psi^{n+1}$$
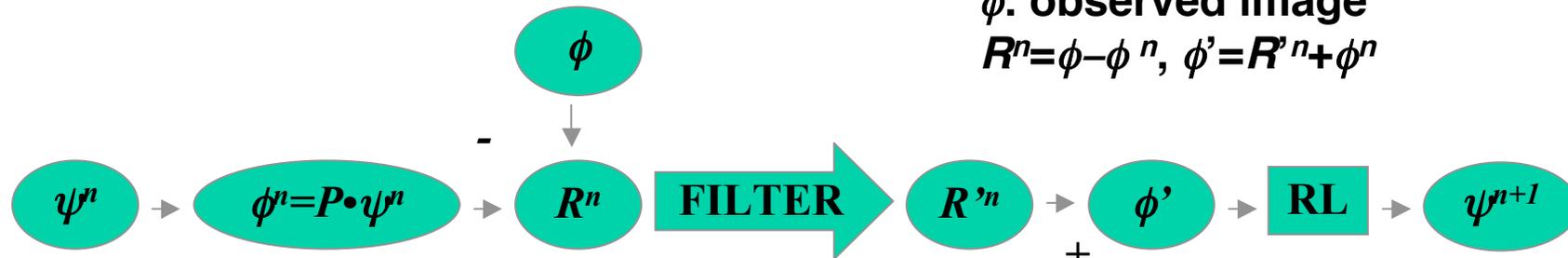
Wavelet decomposition

$$\psi = \sum_{j=0}^{n} w_j + c_n$$
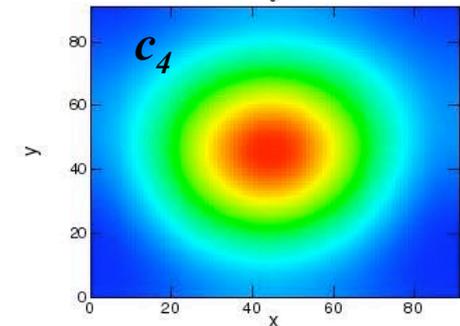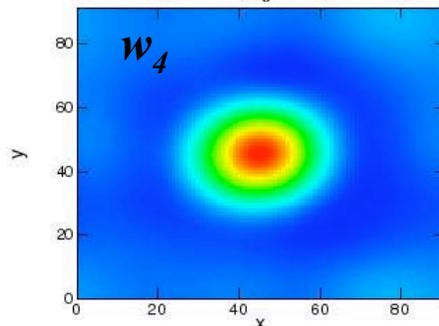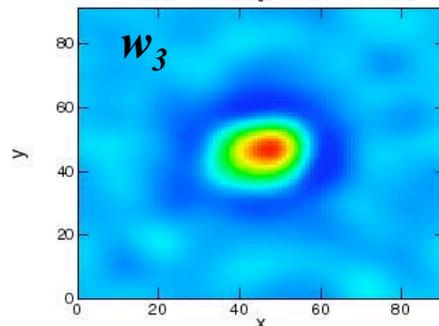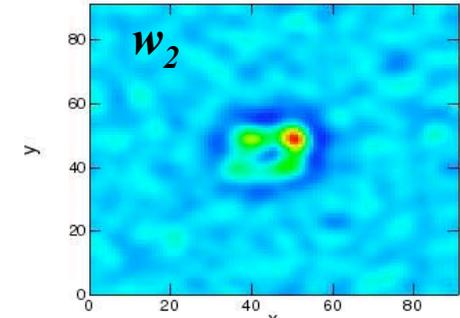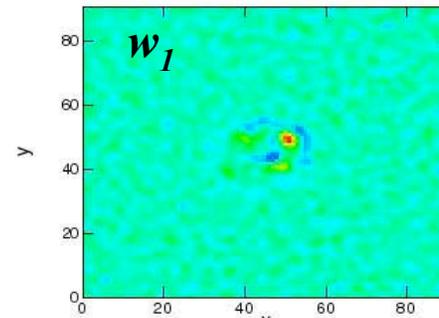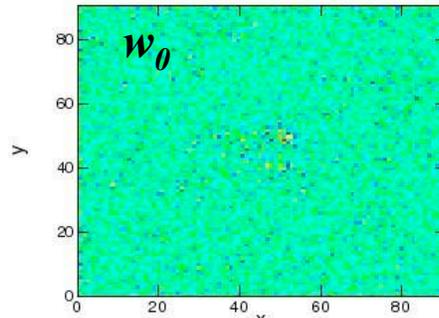
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Image Restoration of Toy MC

- **Restored image gives better representation of input image.**
  - » **NW rim clearly stands out.**
  - » **Overall shape recovered.**
  - » **Poor image at low statistics.**
    - Image restoration can not fix statistical fluctuation

PSF effect included

Original image

Before restoration

After restoration

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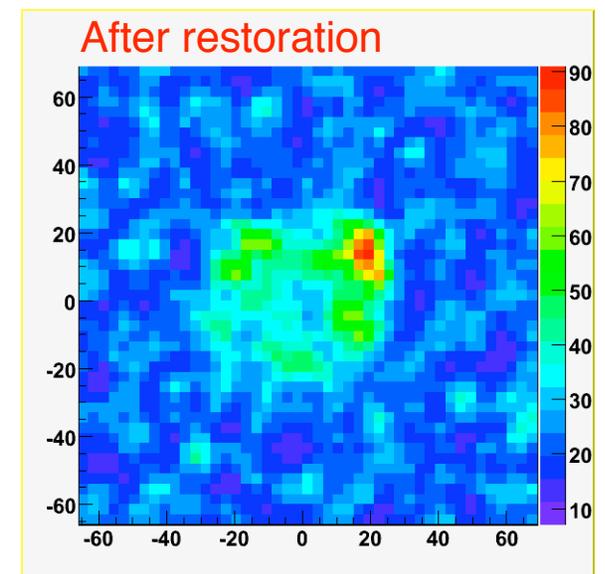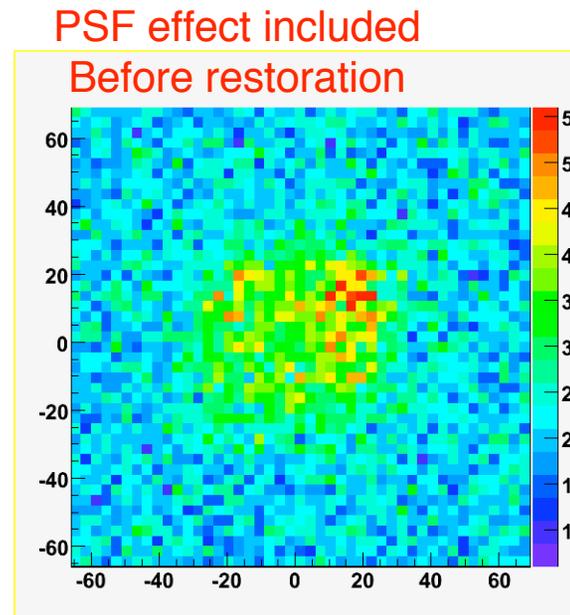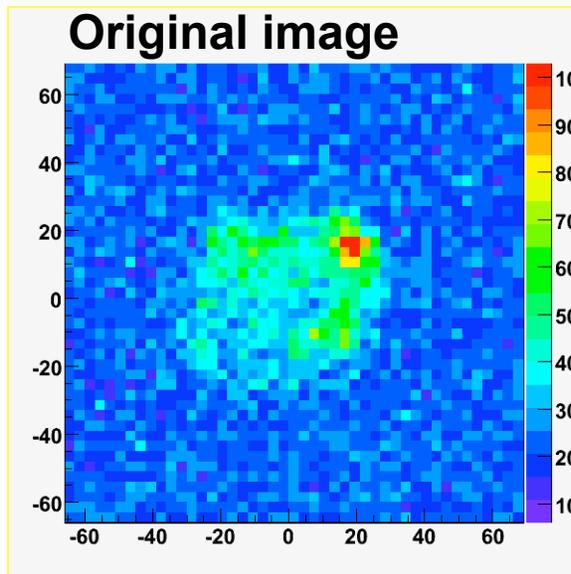
- ## Large Magellanic Cloud
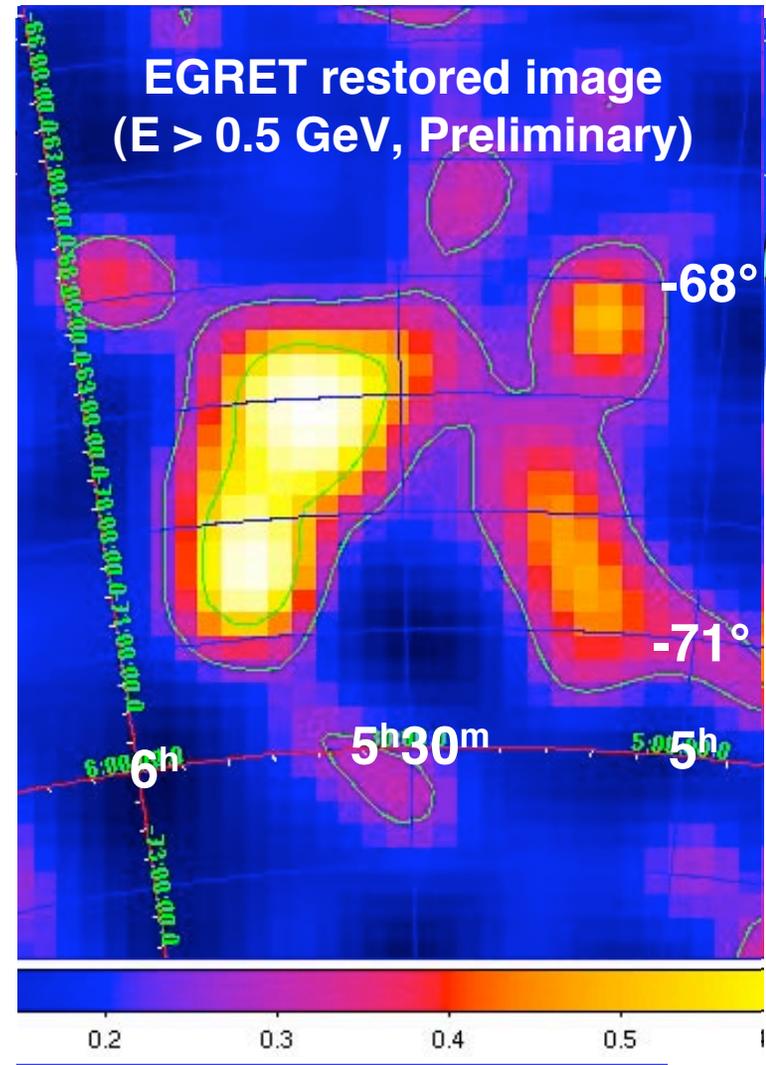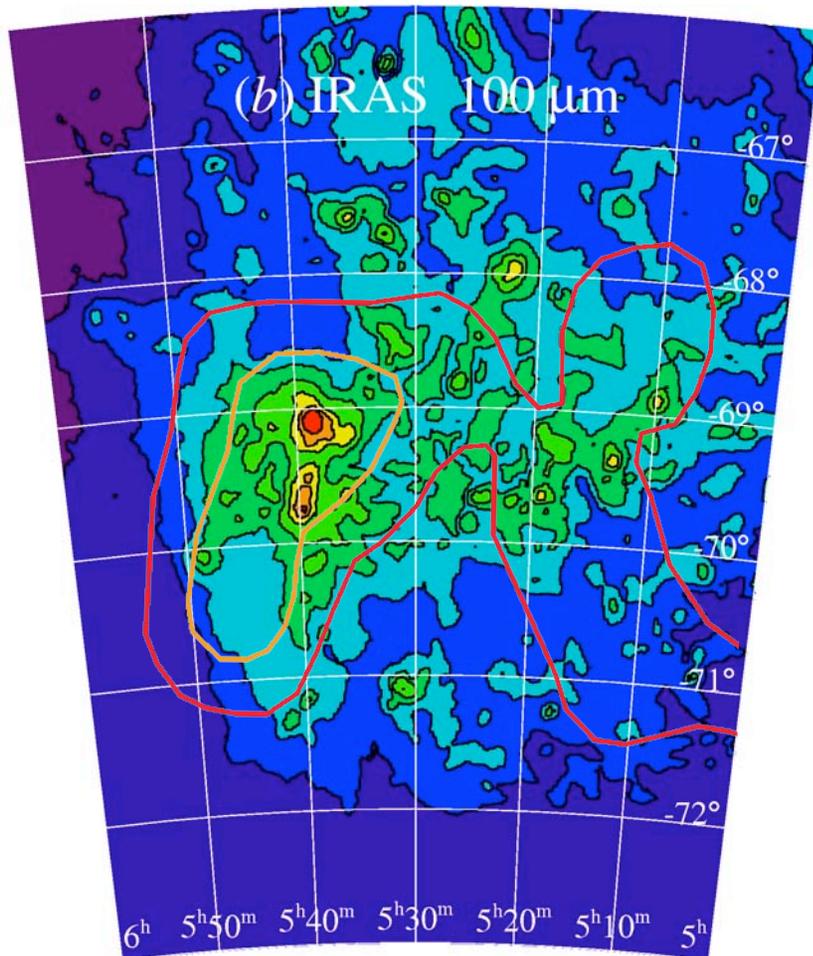
Seth Digel

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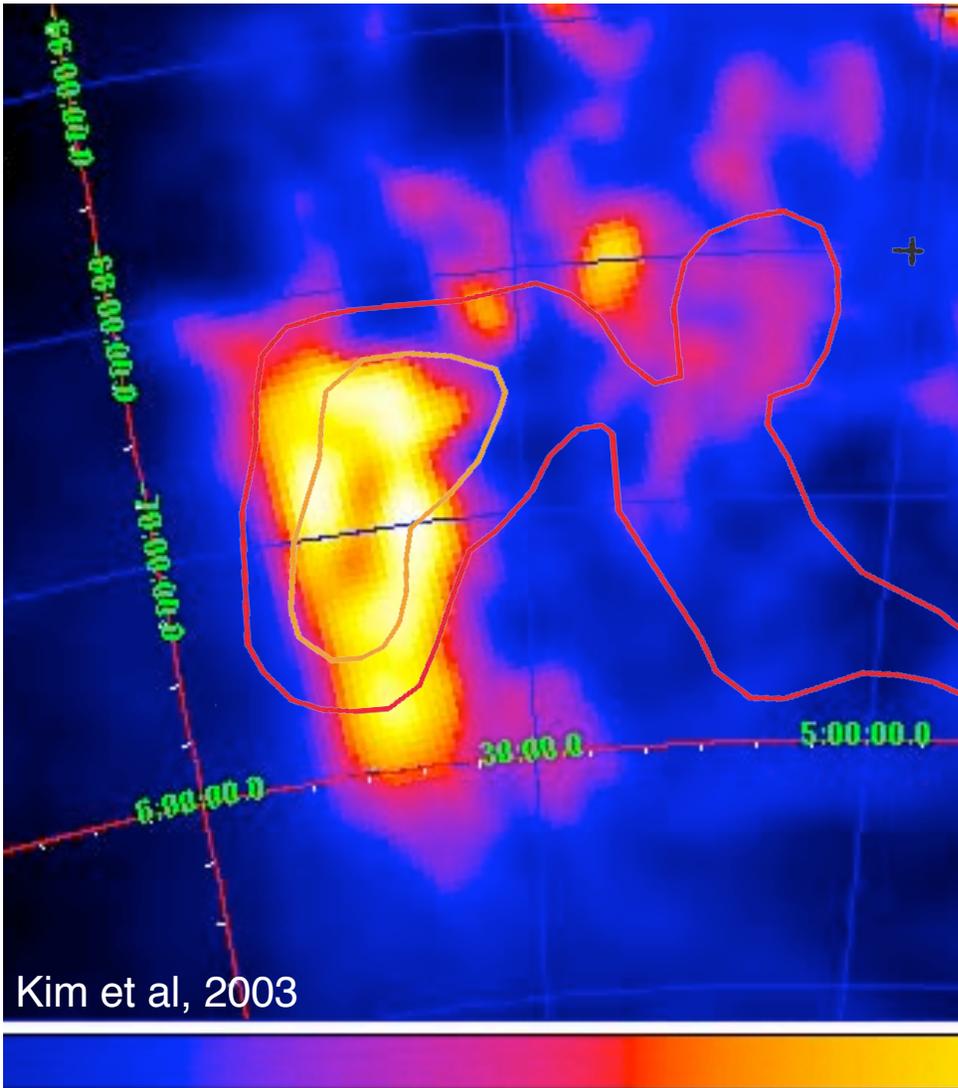
Kim et al, 2003

1E+21   2E+21   3E+21
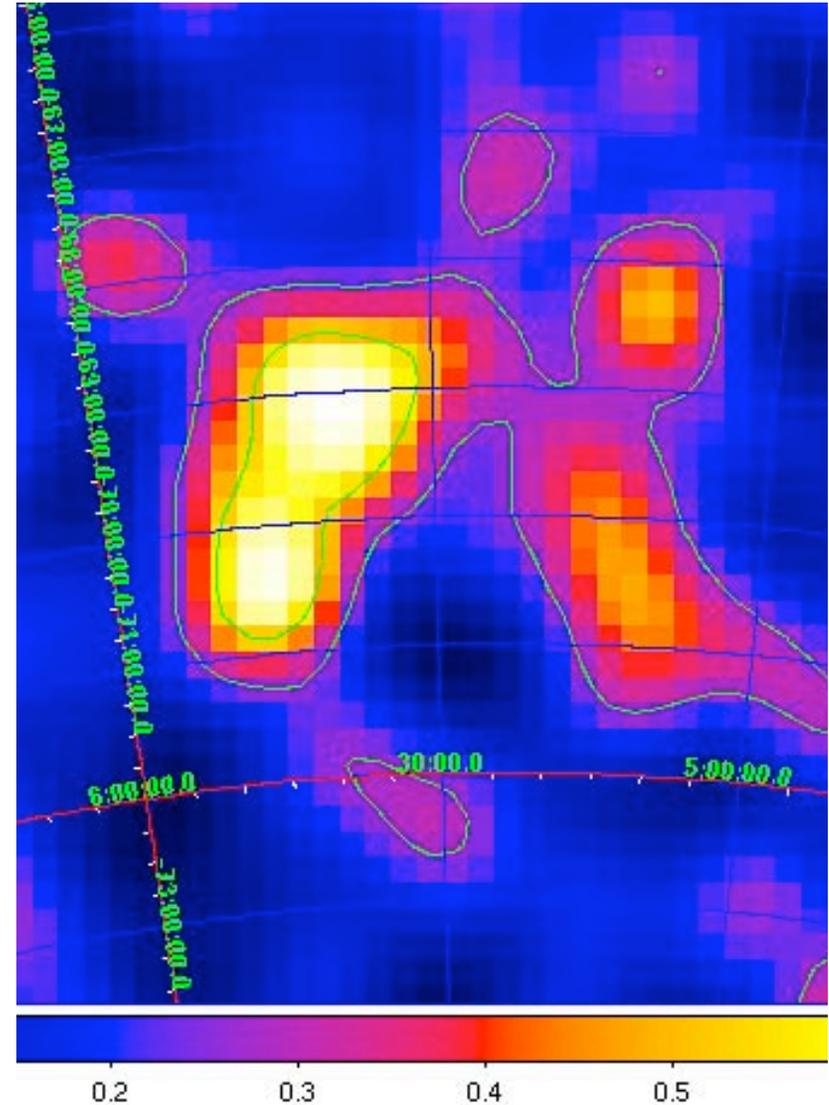
0.2   0.3   0.4   0.5

- **Two HESS sources are too close to resolve.**

E > 0.5 GeV
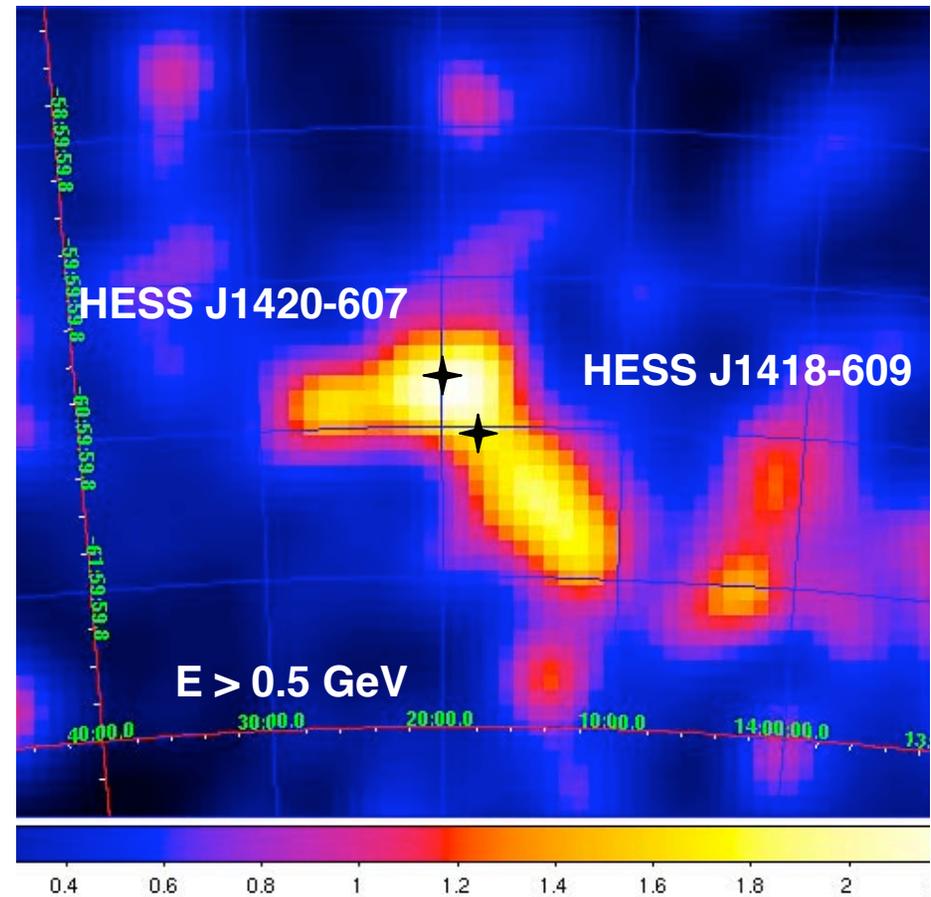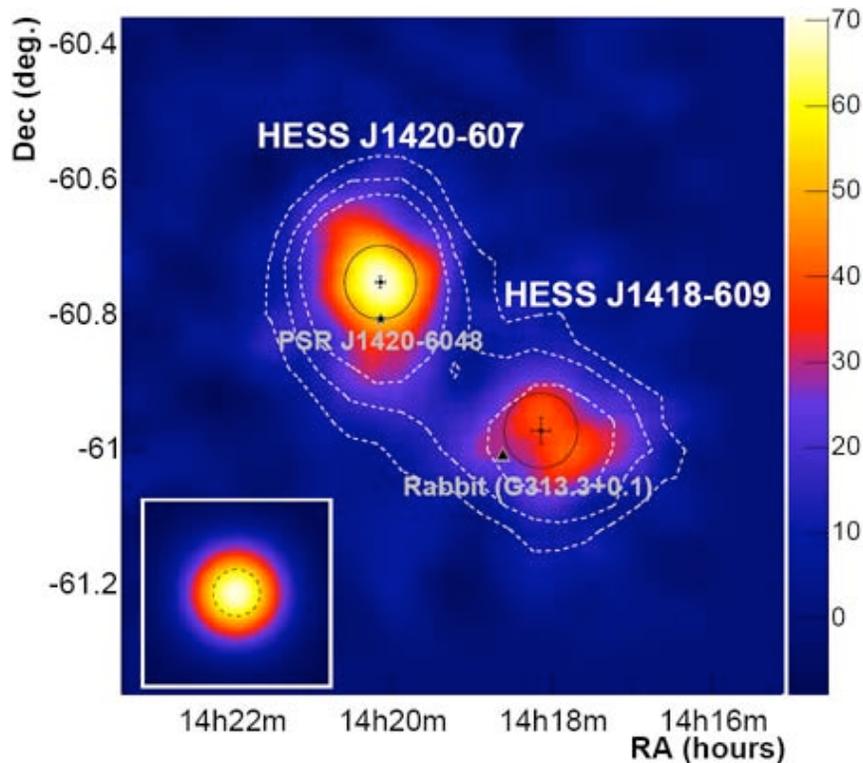
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High Galactic Latitude EGRET UID

- **3EG J1234-1318**
  - » **An extended source? Two point sources?**
  - » **Source position is offset from brightest spot.**
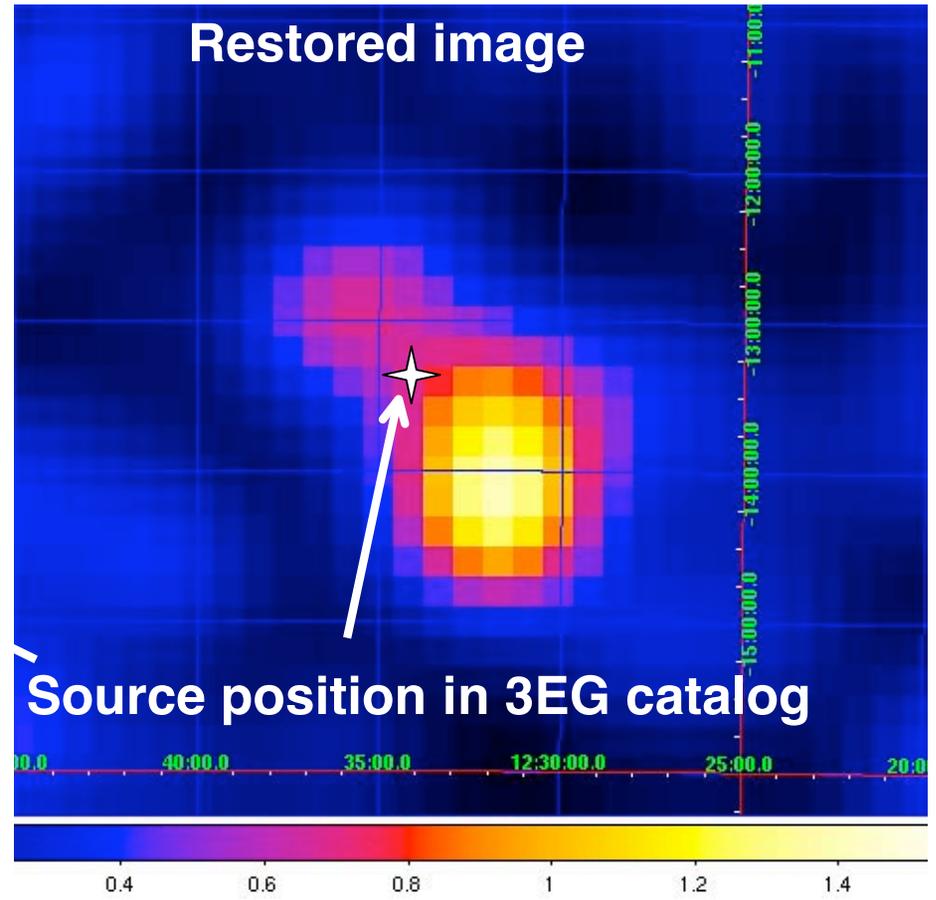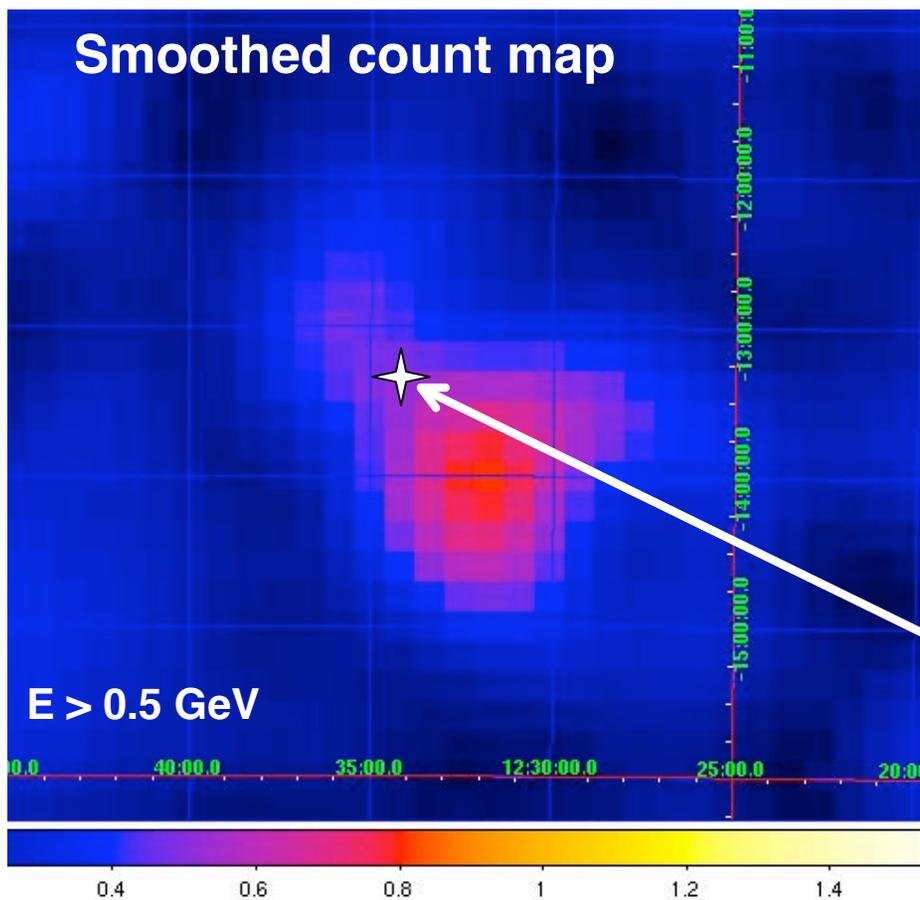
Smoothed count map

E > 0.5 GeV

Restored image

Source position in 3EG catalog

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- **Point source (from 3EG catalog) removal works very well.**
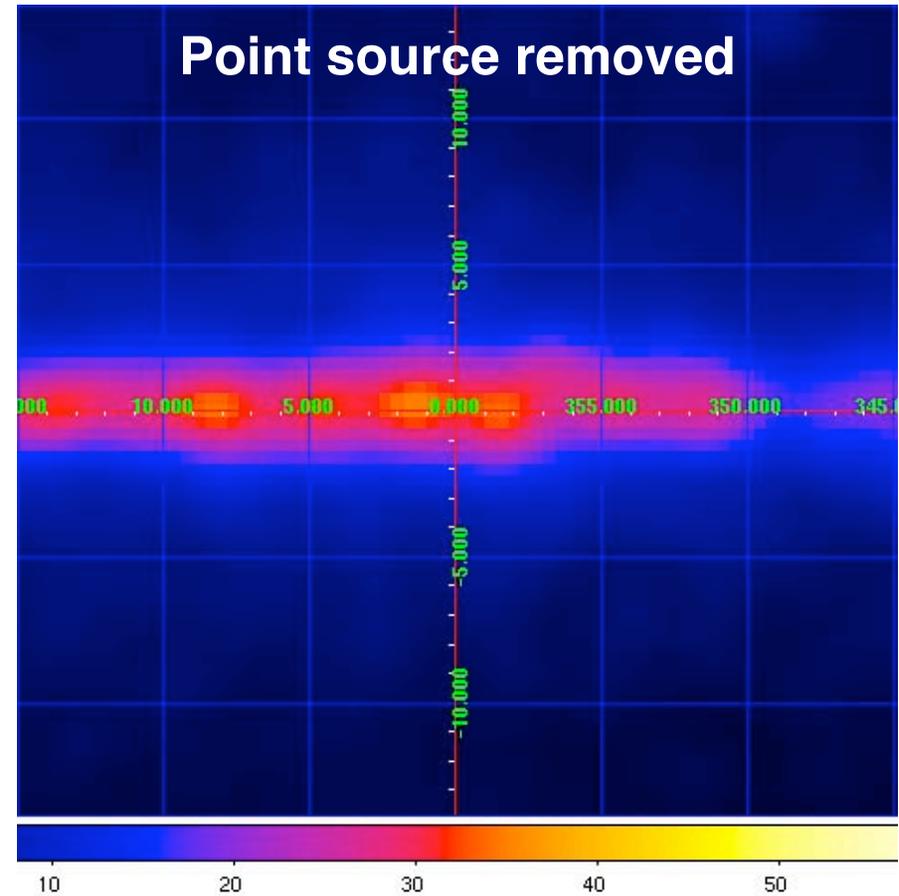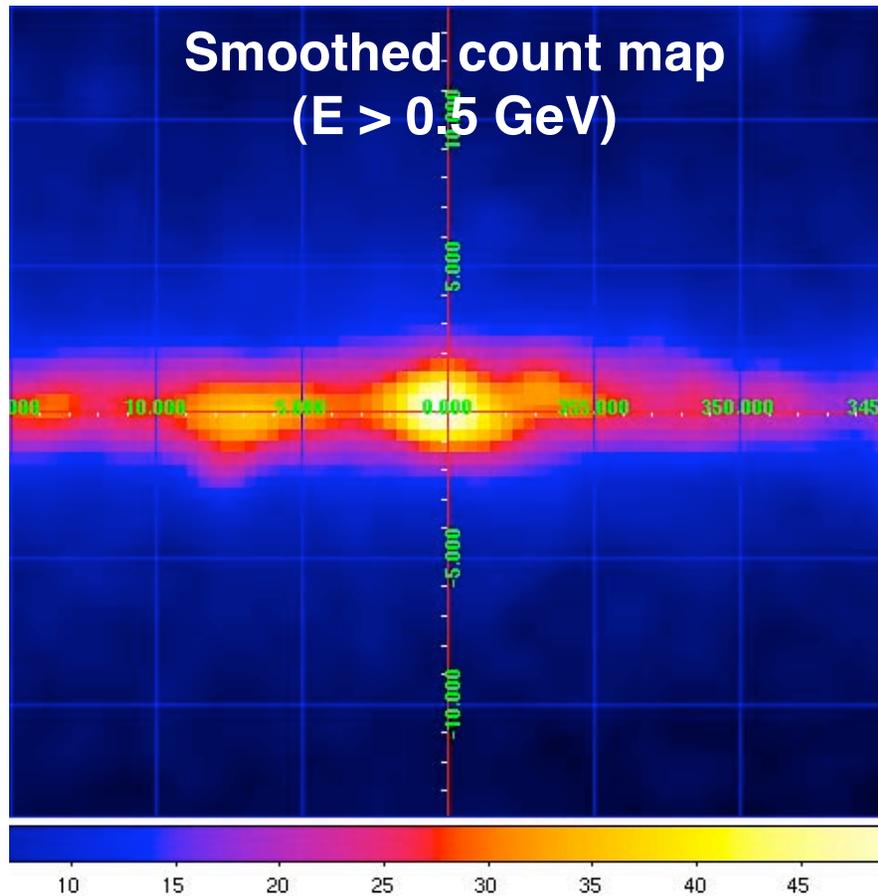
Smoothed count map (E > 0.5 GeV)

Point source removed

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- ## 3EG point sources are removed.
  - » **E > 0.5 GeV**
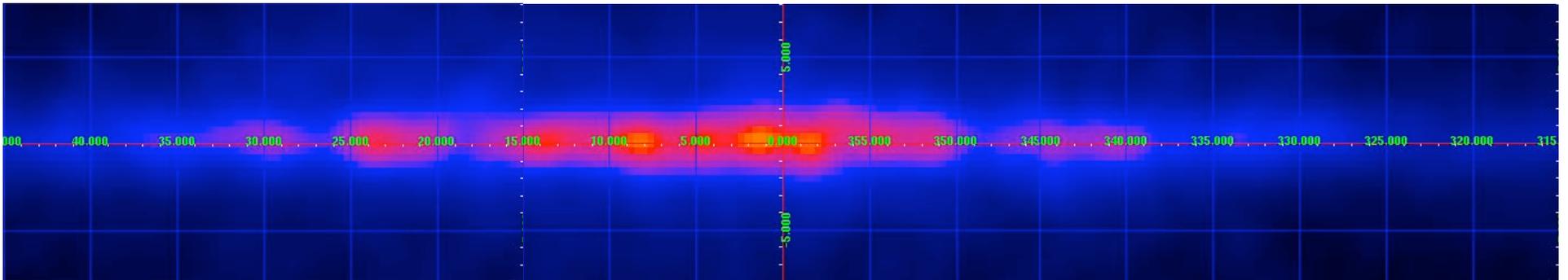
  - » **0.5 > E > 0.2 GeV**
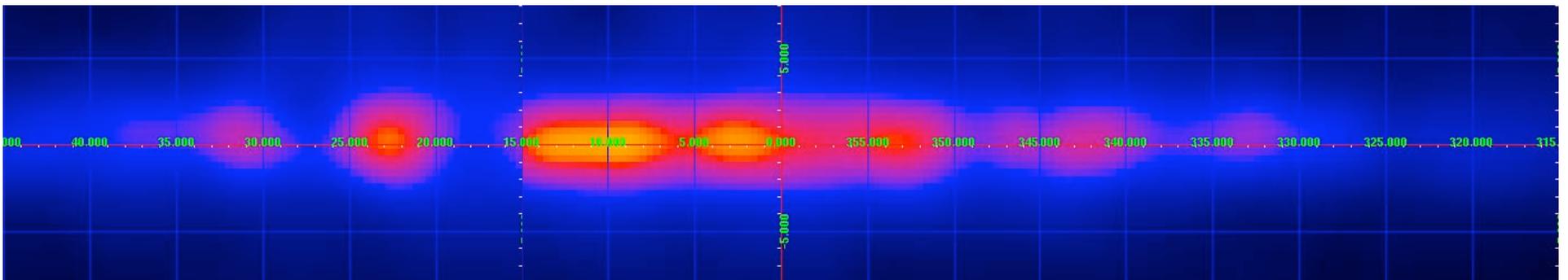
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Summary

- **Image deconvolution with event-by-event PSF is a promising tool study extended sources in EGRET and GLAST.**

- **Demonstration with EGRET sources.**
  - » **Improved image of LMC.**
  - » **Indication of an extended source or two point sources for 3EG J1234-1318.**

- **Further improvement and studies.**
  - » **Derive energy spectrum for each source.**
  - » **Understand systematic effects.**
    - • Statistical treatment of signal candidates.