Limits on Supersymmetric Dark Matter from EGRET Observations of the Galactic Center Region

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COSMO 03 Workshop, Ambleside

- Supersymmetric Dark Matter
  - -Description of the MSSM
  - -Neutralino Characteristics
- The Galactic Center
  - -Dependence on Halo Models
  - -Cusps, Cores and Spikes
- EGRET Analysis
  - -Refinement of Angular Resolution
  - -New Limit For Galactic Center
  - -Prospects for GLAST

(Based On astro-ph/0210617 with Brenda Dingus)

Dark Matter and Supersymmetry

- Evidence for Dark Matter

  -CMB, Supernovae Redshifts, Galactic Rotation Curves, etc.

  -Requires Large Cold (non-relativistic), Weakly-Interacting Component

  -This Component Remains Unknown

- The Lightest Neutralino

  -In Most SUSY Models, the Lightest Superpartner is a Neutralino, χ^0

  (χ^0 =Mixture of Superpartnerts of Photon, Z and Higgs Bosons)

  -The LSP Is Stable By Virtue of R-Parity

  -Neutralinos are Weakly Interacting

  $\rightarrow$ Excellent Dark Matter Candidate!

SUPERSYMMETRY

- The Minimal Supersymmetric Standard Model (MSSM)
  -New Superpartner for Each Standard Model Particle: Sleptons, Squarks, Neutralinos and Charginos
  -Requires 5 Higgs Bosons (2 Higgs Doublets)
  -Numerous Ways To Break Supersymmetry, Described By Over 100 Free Parameters
  -We Limit our Parameter Space to the Following:
  $M_2, \mu, \tan\beta, \mathrm{m_{SUSY}}, \mathrm{m_A}, \mathrm{A_t}, \mathrm{A_b}$
- Neutralino Properties
  -Properties Derive From 4x4 Neutralino Mass Matrix
  -Depends Only $M_2, \mu, \tan\beta, (\mathrm{M_1})$
  -Diagonalization Determines Masses, Composition and Couplings
- Relic Density
  -From Mass and Annihilation Cross Section, Present Abundances Can be Calculated for a Thermal Relic
  -The Lightest Neutralino Naturally Provides a Cosmologically Interesting Relic Density

The Galactic Center

- Annihilation Region
  -Dark Matter Can Exist in High Densities in the Galactic Center
  -Large Annihilation Rates Provide Large Gamma-Ray or Neutrino Fluxes
- Halo Models
  -The Structure of the Dark Matter Halo is Unknown, Especially Near the Center
  -Observations Seem to Favor Low-Density Cores, Simulations Predict High-Density Cusps or Even Spikes
  -Cuspy Halo Models Appear As Point Sources
  -The Dark Matter Annihilation Rate is VERY Dependent on the Choice of Halo Model

Halo Models

- Cuspy Halo Models

  -Many Body Simulations Favor Cuspy Halo Models, $\gamma \sim 1 - 1.5$

  -Includes Navarro, Frenk, White (NFW), and Moore *et.al.* Profiles

- Core Halo Models

  -Observations Favor Models With Flat Cores, $\gamma \sim 0$

  -Probably Not Dense Enough to Observe Dark Matter Annihilation

- Spikes

  -Adiabatic Accretion of Dark Matter Leads To a Spike, $\gamma \sim 2$

- Clumpy Halo Models

  -Clumpy Halos May Lead To Less Dense Cores

The EGRET Analysis

- EGRET: The Energetic Gamma Ray Experiment Telescope

  -Launched on the Compton Gamma Ray Observatory in 1991

  -Sensitive To Gamma Rays Between 30 MeV and 30 GeV

  -Accumulated an Exposure of $\simeq .2 \times 10^{10}\,\mathrm{cm}^2\,\mathrm{sec}$ of the Galactic Center Region

- Angular Resolution

  -Previous EGRET Analysis Considered Single Point Spread Function and Binned in .5 Degree Bins

  -We Used An Energy Dependent Point Spread Function and Unbinned Likelihood Technique

  -Tests of This Method Were Conducted on Data From the Crab Pulsar, Vela Pulsar and Others

  -Improvement on Results in 3rd EGRET Catalog

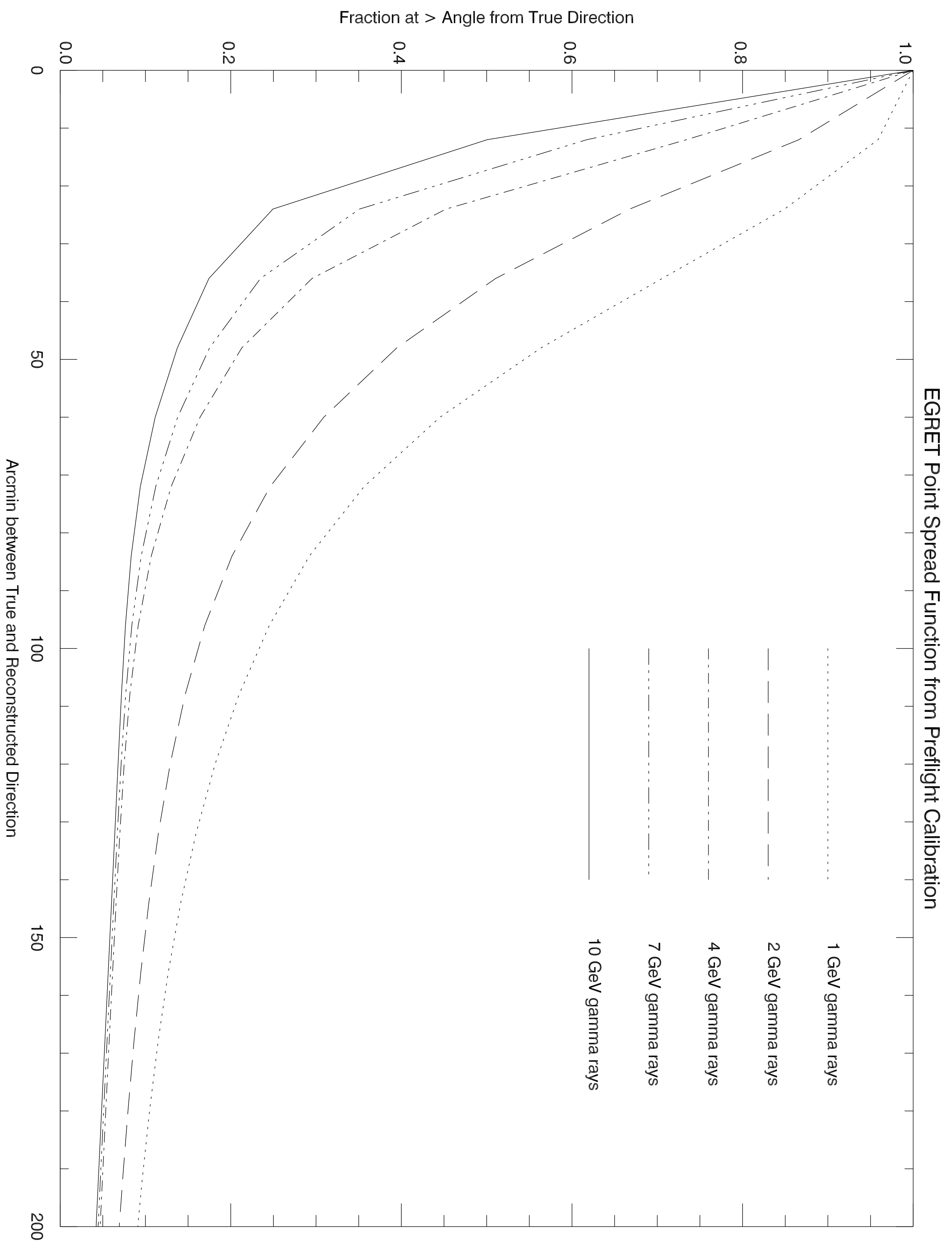
EGRET Point Spread Function from Preflight Calibration
Fraction at > Angle from True Direction
Arcmin between True and Reconstructed Direction
0.0
0.2
0.4
0.6
0.8
1.0
0
50
100
150
200
1 GeV gamma rays
2 GeV gamma rays
4 GeV gamma rays
7 GeV gamma rays
10 GeV gamma rays

Figure 1:

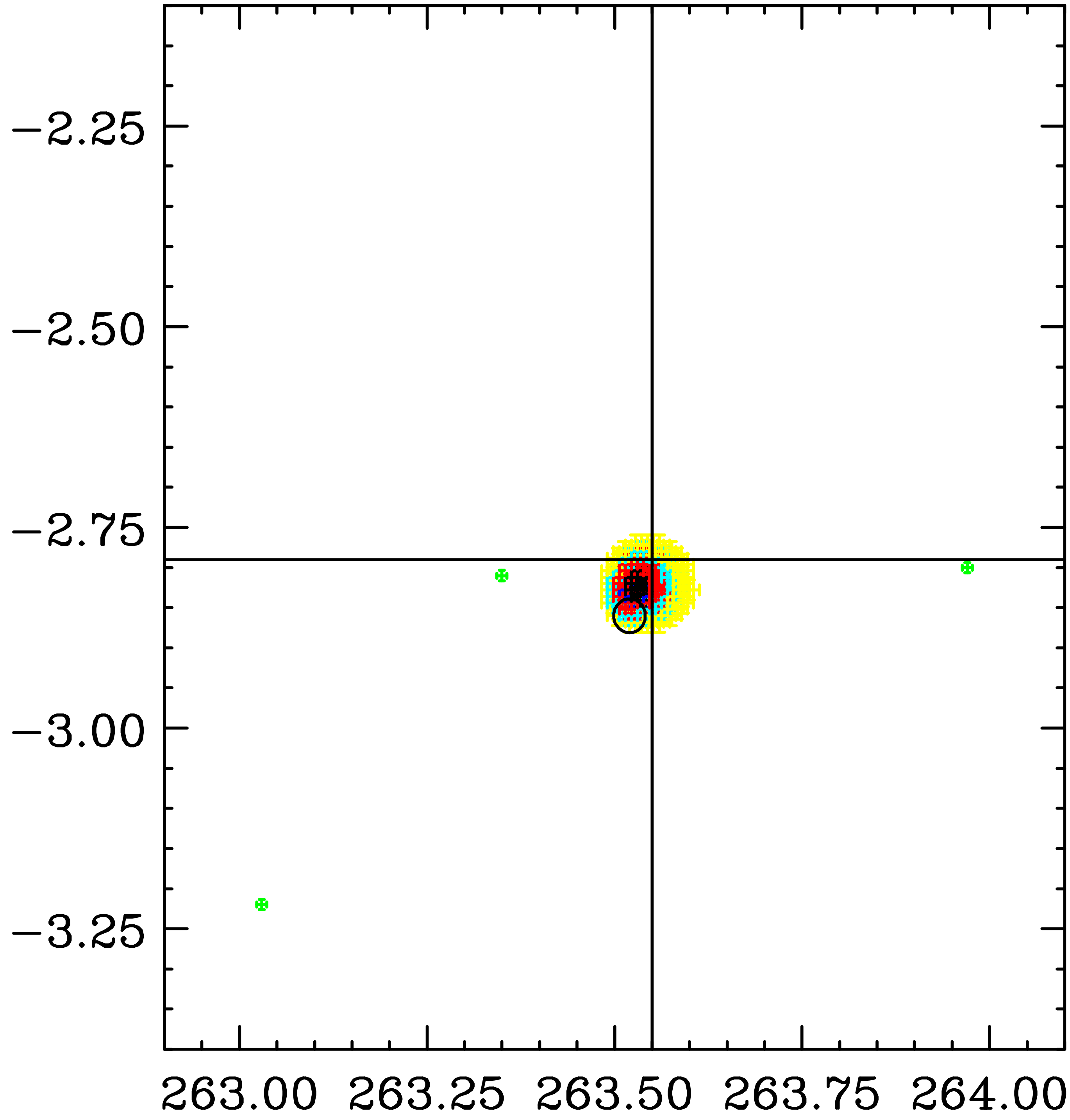

Figure 2: The Vela Pulsar. 50, 68, 95, 99 and 99.9% Confidence Levels are Shown Using Our Method. The 95% Confidence Contour of the EGRET Catalog Position Is Shown For Comparison. Also Shown Are all Gamma-Rays Above 10 GeV.

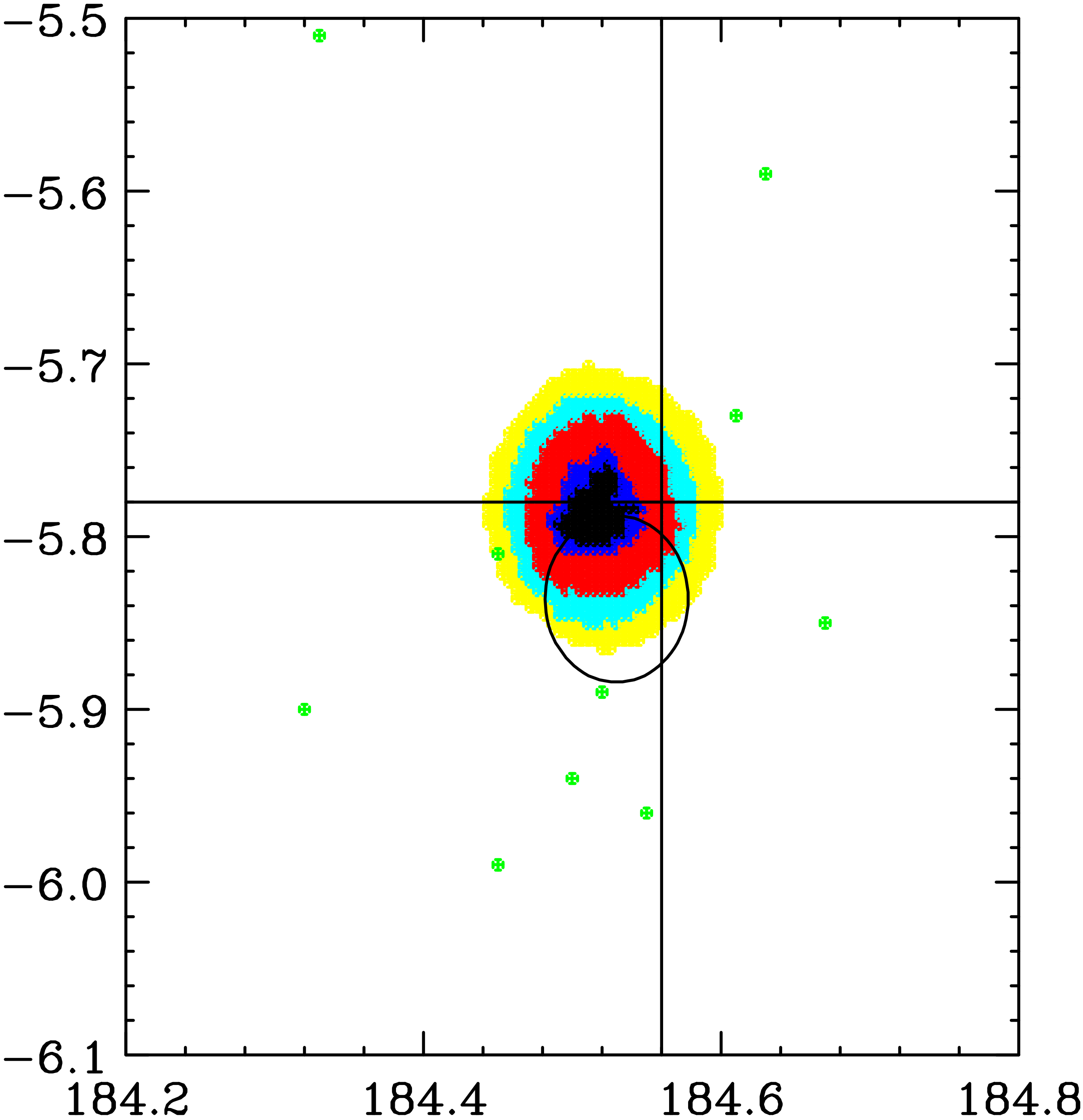

Figure 3: The Crab Pulsar. 50, 68, 95, 99 and 99.9% Confidence Levels are Shown Using Our Method. The 95% Confidence Contour of the EGRET Catalog Position Is Shown For Comparison. Also Shown Are all Gamma-Rays Above 10 GeV.

THE EGRET ANALYSIS (CONTINUED)

- Search For Galactic Center Point Sources

  -Iteratively Search For Power-Law Point Sources

  -Brightest Source Present at $\sim .2$ Degrees Off Galactic Center

  -Source Excluded As Galactic Center Beyond 99.9% Confidence Level

  -Include As Part of Background

- Galactic Center

  -With This Background, Galactic Center is Consistent With No Flux

  -Parametrize Continuum Gamma-Ray Spectrum As Function of Neutralino Mass

  -Calculate Exclusion Confidence Levels as a Function of Neutrialino Mass and Halo Profile

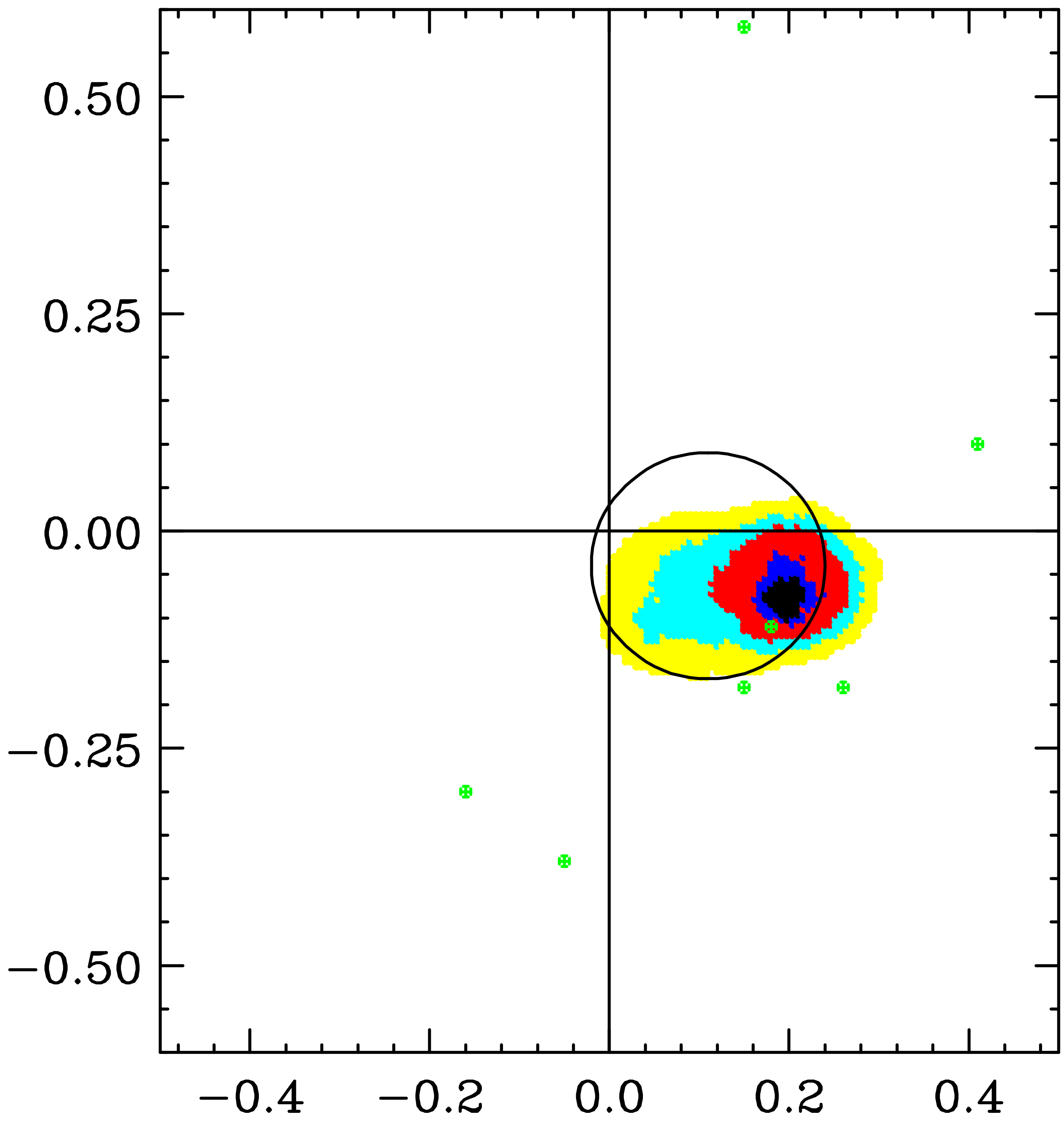

Figure 4: The Galactic Center Off-Center Point Source. 50, 68, 95, 99 and 99.9% Confidence Levels are Shown Using Our Method. Note that the Galactic Center is Excluded Beyond the 99.9% Confidence Level as the Location of the Source. The 95% Confidence Contour of the EGRET Catalog Position Is Shown For Comparison.Also Shown Are all Gamma-Rays Above 10 GeV.

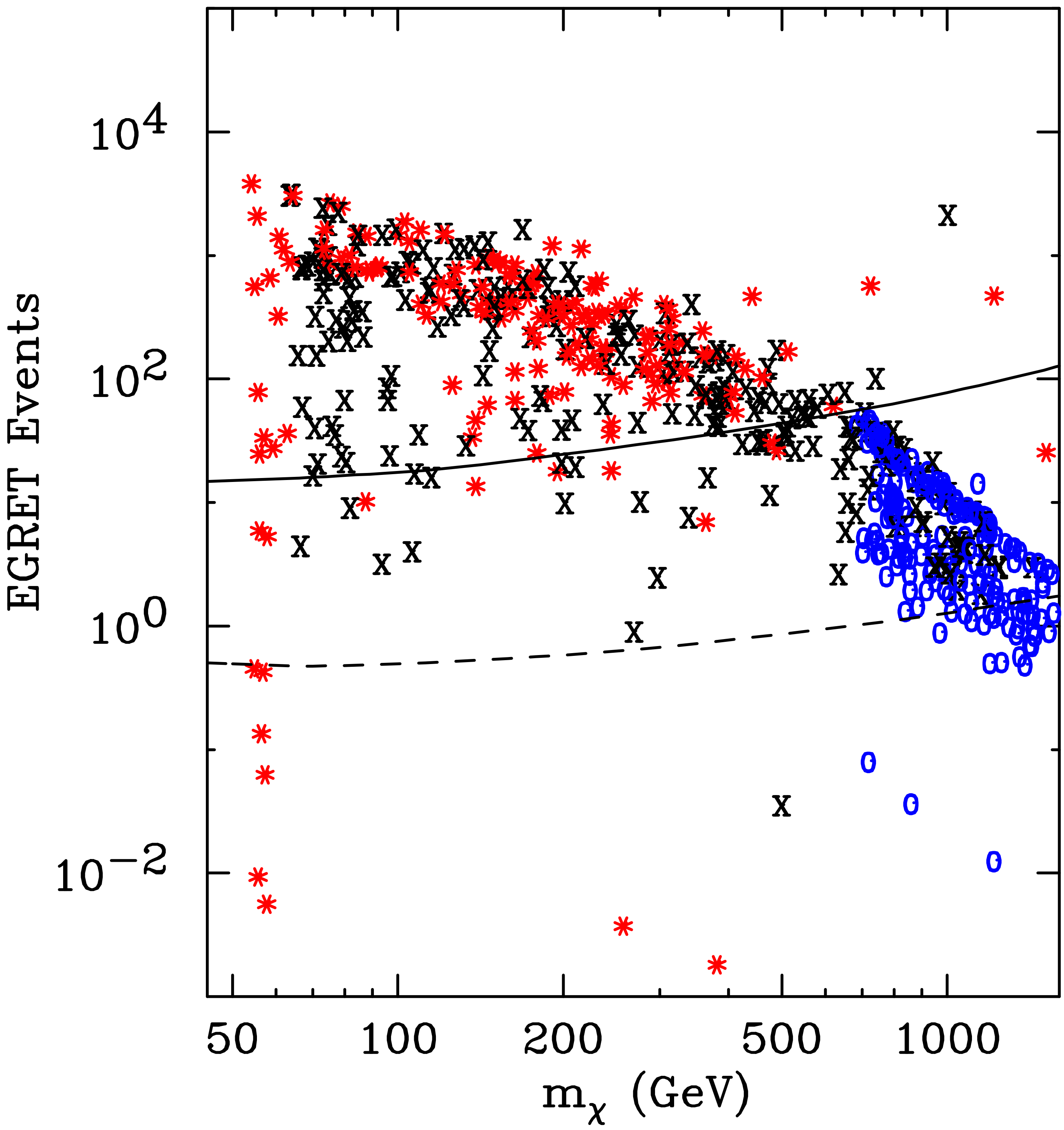

Figure 5: SUSY Model 95% Exclusion Contour For a Moore et. al. Halo Profile. Also Shown Are Approximate 95% Exclusion Contours For GLAST

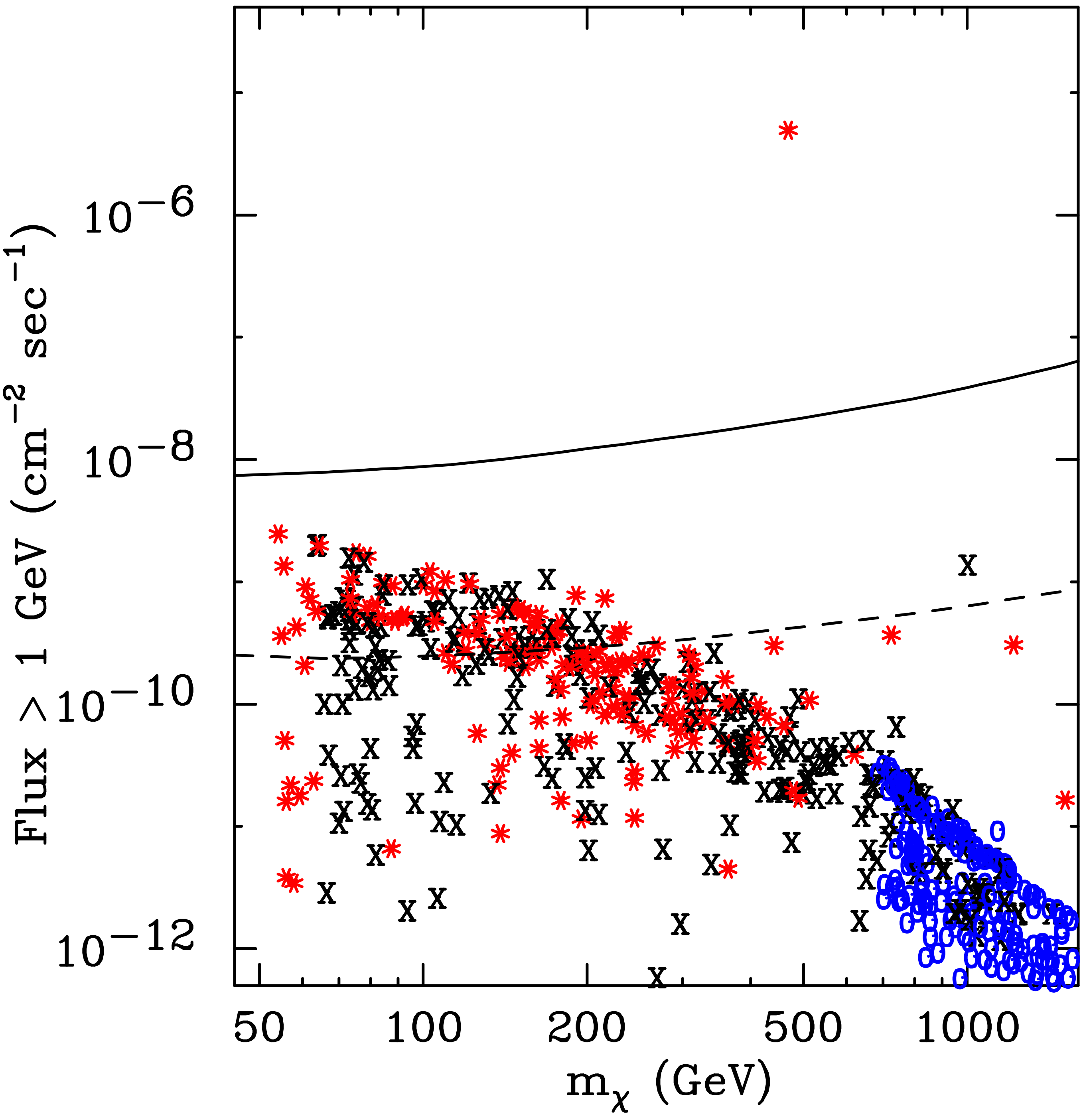

Figure 6: SUSY Model 95% Exclusion Contour For a NFW Halo Profile. Also Shown Are Approximate 95% Exclusion Contours For GLAST

CONCLUSIONS

- New Analysis of EGRET Data

  -Energy Dependent Point Spread Function Reduced Background Significantly

  -Identified An Off-Center Source As Background

- New Limits, Halo Models and Supersymmetry

  -New Limits A Factor of 10-15 Below Previous EGRET Limits

  -Capable of Testing Most SUSY Models For Very Cuspy Halo Models Moore *et.al.*

  -Approaching Sensitivity for NFW Halo Models

  -GLAST Capable of Testing Many SUSY Models for NFW Profiles