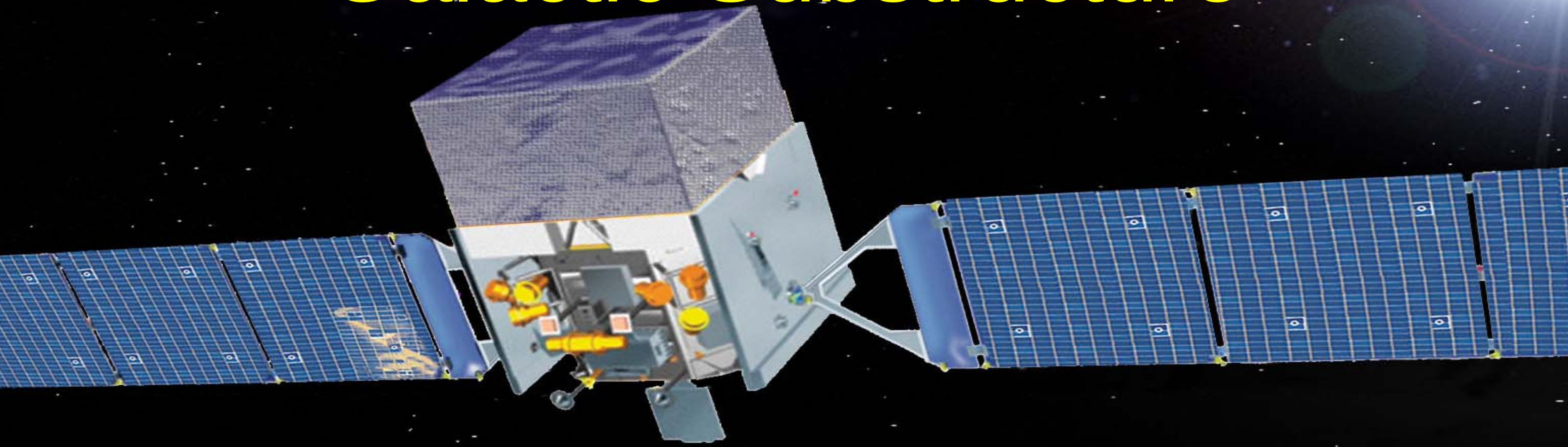
Constraining Dark Matter in Galactic Substructure



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GLCW 2010

Image Credit: fermi.gsfc.nasa.gov/

Outline

- Background: detecting dark matter with gamma rays
- Our Model: mapping the gamma ray photons from dark matter substructure
- Analysis: can the Fermi Telescope detect WIMPs?

Indirect Detection

- How can we detect dark matter?
  - Direct detection (e.g. CDMS, COUPP, etc.)
  - Collider (e.g. Tevatron, LHC)
  - **Indirect detection of annihilation products (e.g. gamma rays)**

- Advantages of indirect detection:
  - Gamma rays are “easy” to detect (e.g. Fermi)
  - Annihilation cross section is what sets relic abundance

- Many places to look:
  - Diffuse dark matter in our galaxy
  - Extragalactic dark matter
  - **Galactic substructure**

Indirect Detection

- Rate of photon production:

$$\Gamma = \frac{N_\gamma < \sigma v >}{m_\chi^2} \int_V \rho^2 dV$$ **[photons/sec]**

- Canonical wimp: $< \sigma v > \approx 3 \times 10^{-26}\ \mathrm{cm}^3\mathrm{s}^{-1}$

$$m_\chi \approx 50\,\mathrm{GeV}$$

$$N_\gamma \approx 10$$

$$f_{WIMP} \approx 10^{-28}\ \mathrm{cm}^3\mathrm{s}^{-1}\mathrm{GeV}^{-2}$$

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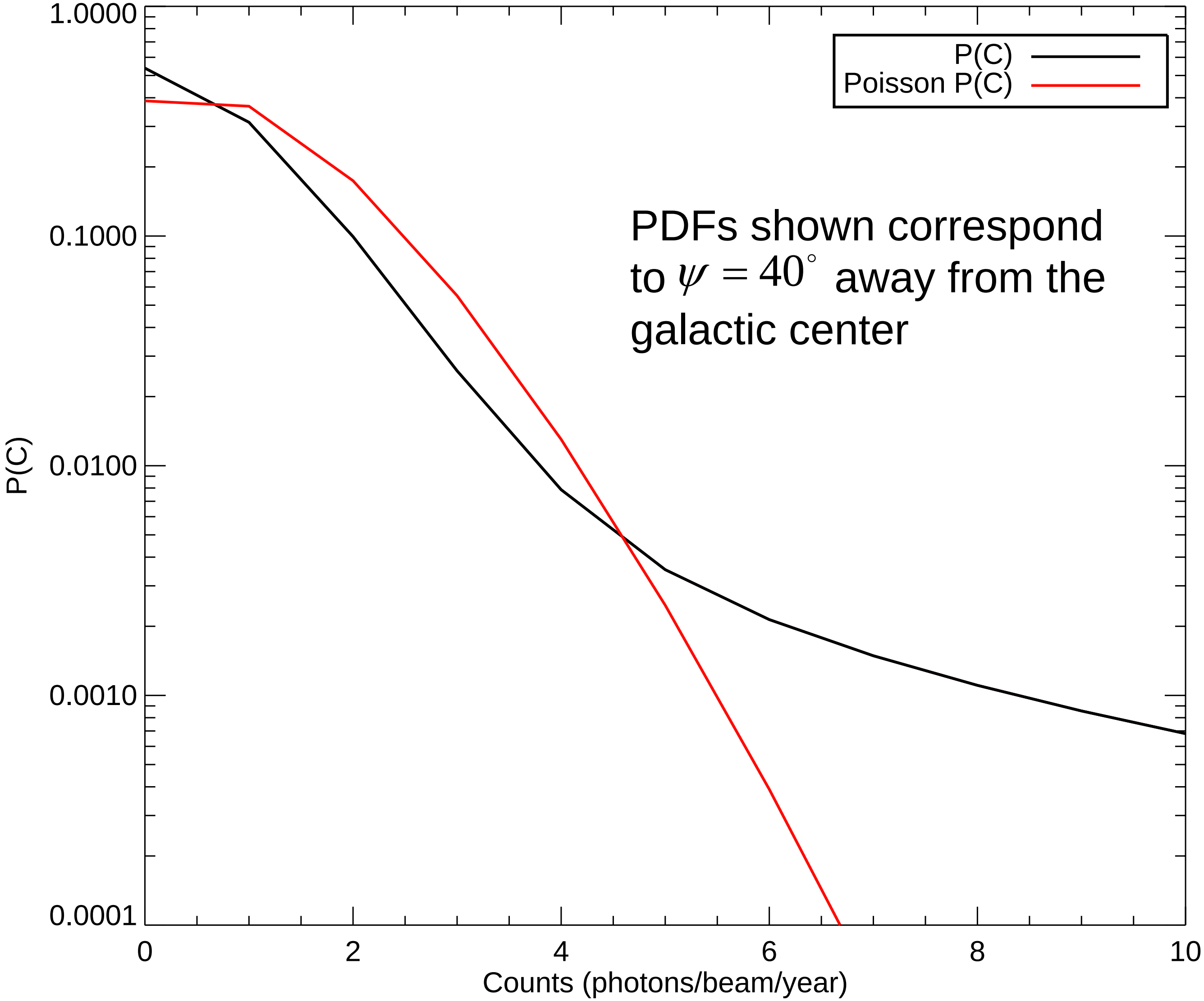
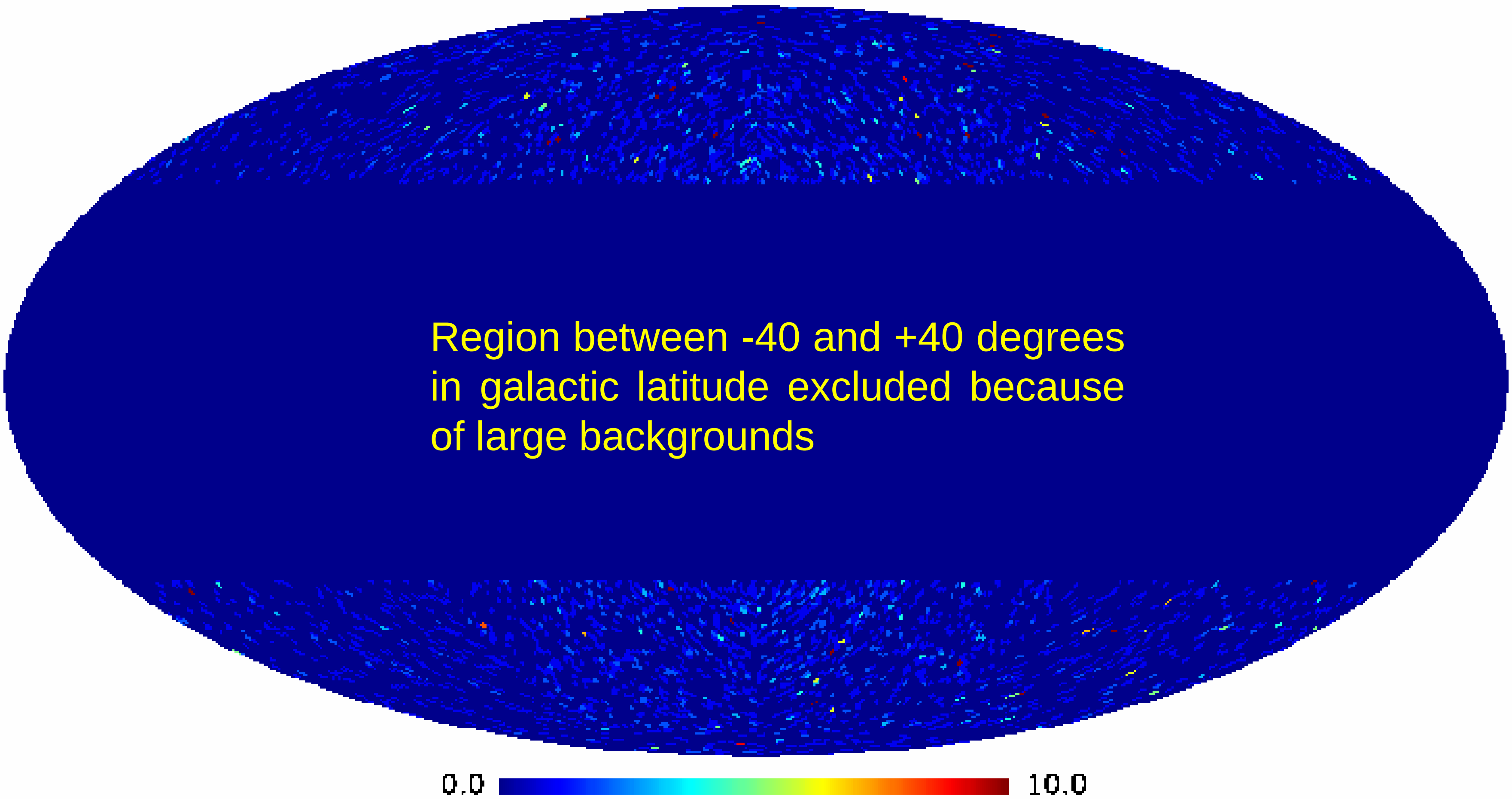
Our Model

- **We have developed a model for the photon counts probability distribution function (PDF) from galactic substructure**
  - Based on work done by Lee et al. ‘09
  - We have calculated the probability, $P_i(C)$, of observing C photons in the i^{th} pixel
  - 3 component model: dark matter signal, galactic background, and extragalactic background
- **Incorporates:**
  - Mass function for subhalos from simulations
  - Mass-luminosity relation for subhalos from simulations
  - We integrate these relations over lines of sight to calculate PDFs
  - Background model from Fermi collaboration
- **We have made projections for the Fermi Telescope**
  - Angular resolution ~1 $degree^2$
  - Exposure time of 1 yr
  - Collecting area ~2000 cm^2

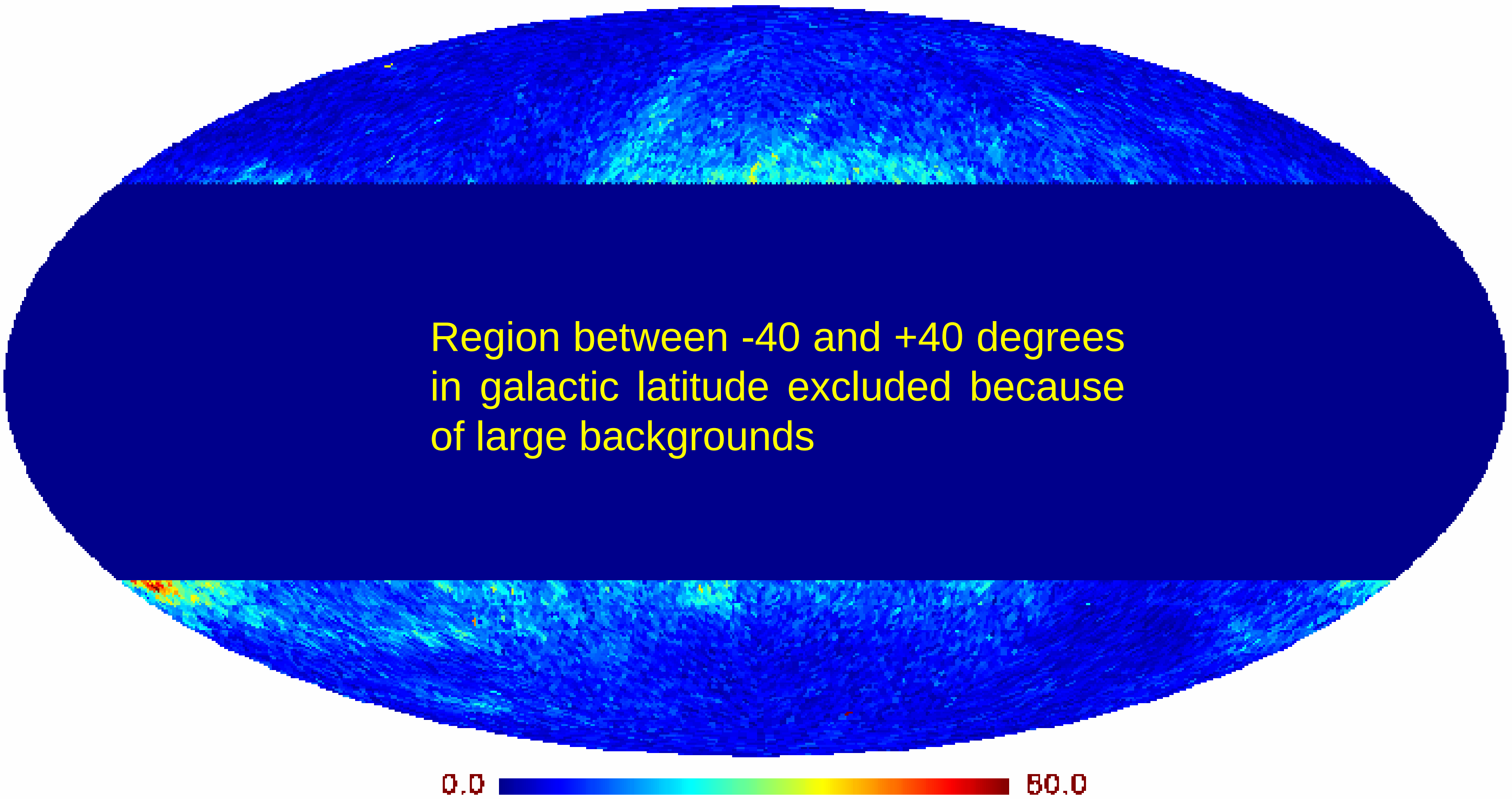
The Dark Matter Gamma Ray PDF



The Dark Matter Signal



Now with backgrounds…



Region between -40 and +40 degrees in galactic latitude excluded because of large backgrounds

Analysis

- Having P(C) enables us to compute the likelihood of observations given model parameters

- We consider 3 parameters: f_{WIMP}, galactic background normalization, extragalactic background normalization

- Perform analysis in two ways:

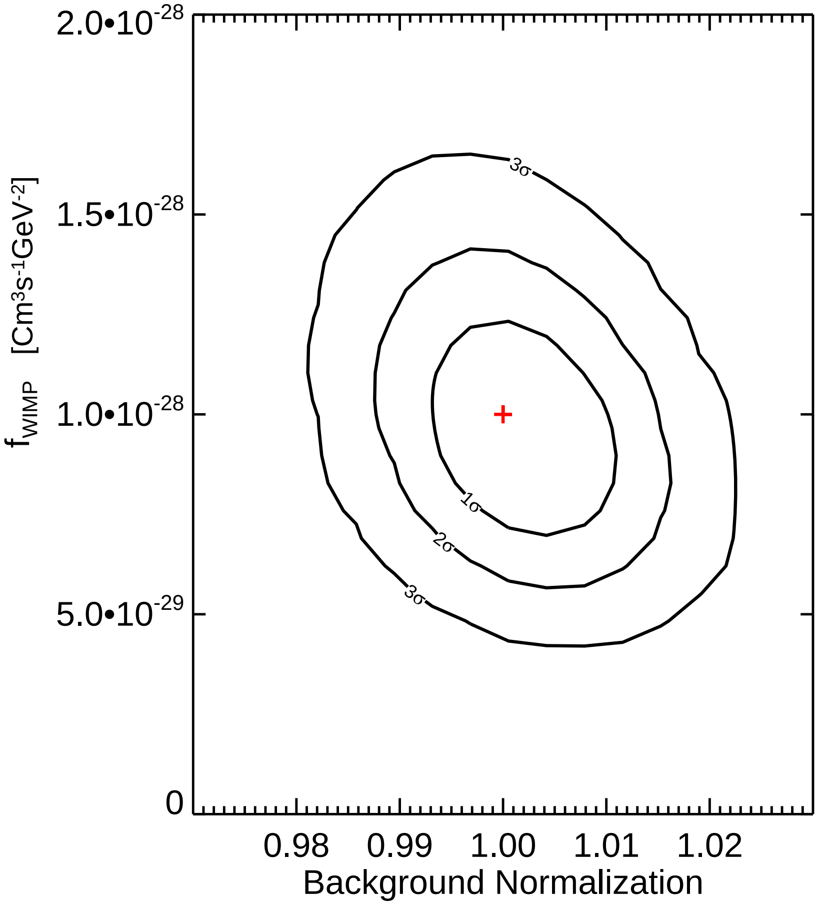
  1) Using true P(C)

  2) Using Poisson P(C) with same mean

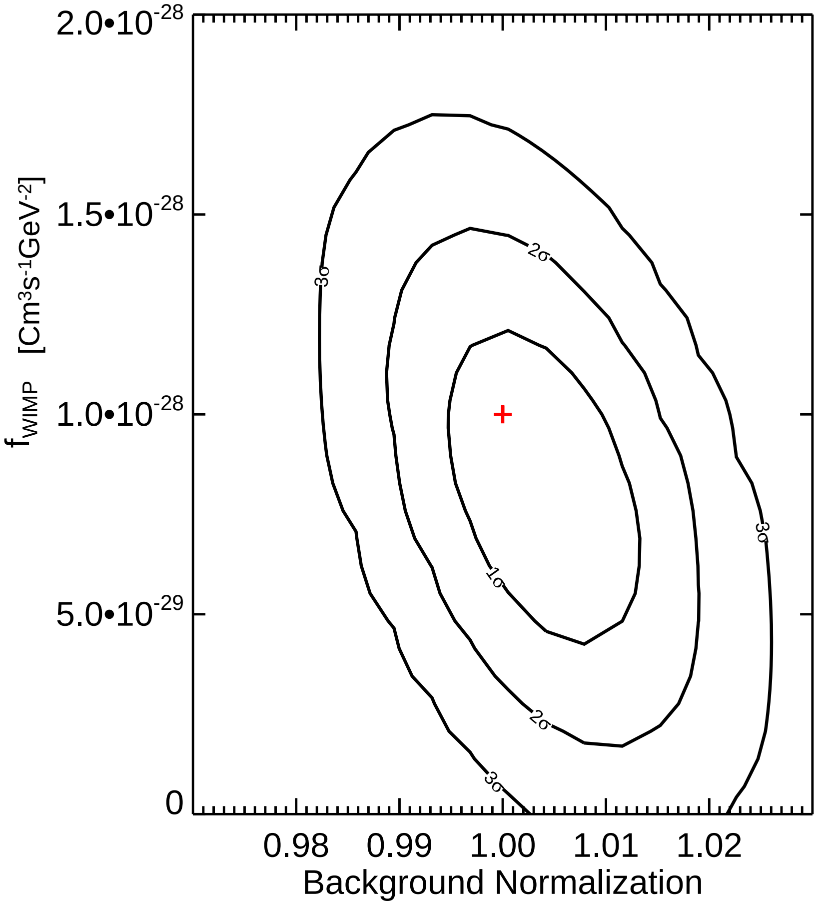
  This will allow us to determine if knowing the true P(C) is important

Contours of the likelihood function

Using the true P(C):

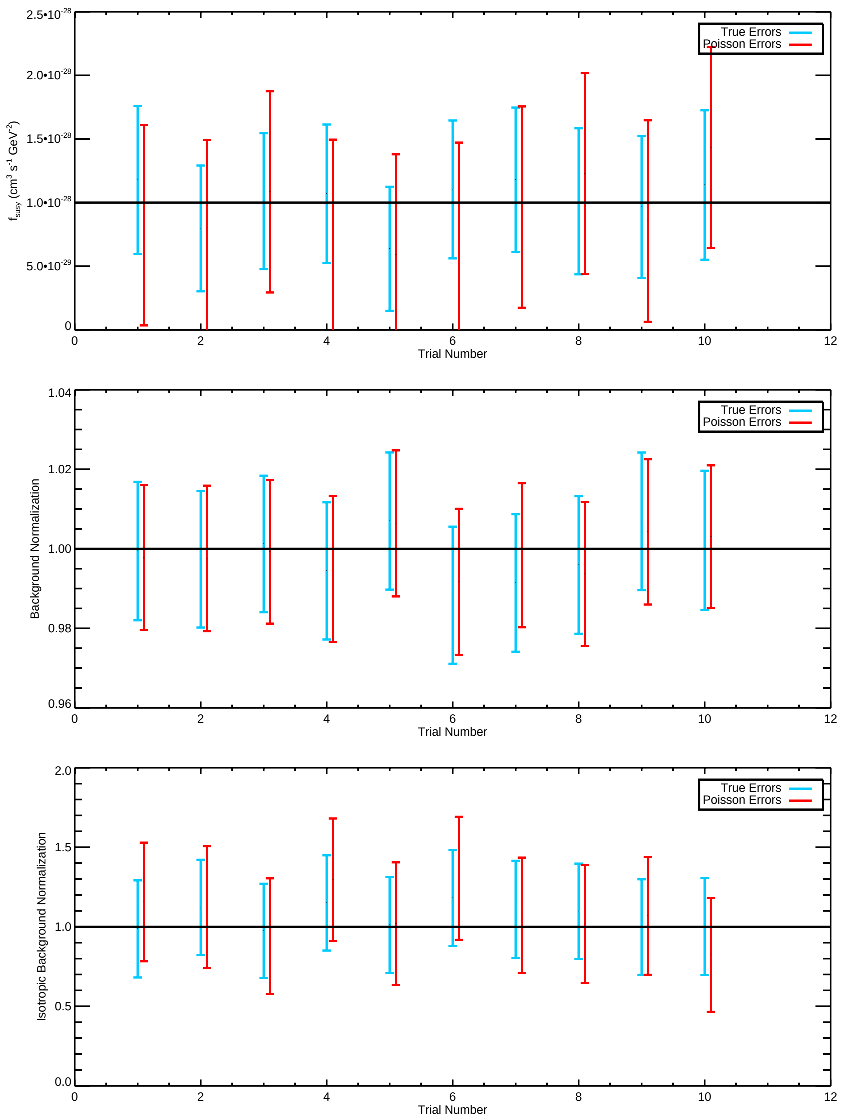


Using a Poisson P(C):



Conclusions

- There is enough information in one year of Fermi data to detect a canonical WIMP
  - Of course, actual detection is complicated by large uncertainties in the model and background
  - This data has already been collected!
- Using the incorrect P(C) yields an unbiased estimate of f_{WIMP}, but with error bars that are ~40% larger
- Future work:
  - Incorporate energy information
  - Analyze actual data!



True Errors
Poisson Errors
f_susy (cm^3 s^-1 GeV^-2)
2.5•10^-28
2.0•10^-28
1.5•10^-28
1.0•10^-28
5.0•10^-29
0
Trial Number
Background Normalization
1.04
1.02
1.00
0.98
0.96
Isotropic Background Normalization
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12

Relative Magnitude of Model Components