Title: Illuminating the 130 GeV Gamma Line with Continuum Photons

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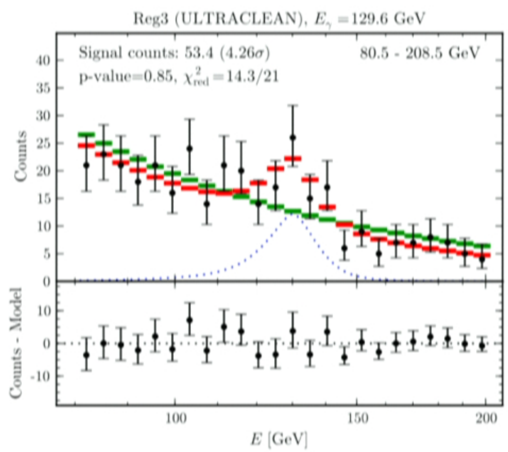
Abstract: There is evidence for a 130 GeV gamma-ray line at the Galactic Center in the Fermi Large Area Telescope data. Dark matter candidates that explain this feature should also annihilate to Standard Model particles, resulting in a continuous spectrum of photons. To study this continuum, we analyze the Fermi data down to 5 GeV, restricted to the inner 3 degrees of the Galaxy. We place a strong bound on the ratio of continuum photons to monochromatic line photons that is independent of uncertainties in the dark matter density profile. Neutralino dark matter is excluded by the derived constraints.

Tentative Line in Fermi Data

Weniger [1204.2797]

Roughly 50 photons in optimized regions extending
~15° above/below Galactic plane



3.3σ significance

$\langle \sigma_{\gamma\gamma} v \rangle \simeq 1.3 \times 10^{-27} \mathrm{cm}^3/\mathrm{s}$

for Einasto profile

Alternate analysis finds 5σ evidence
within 3° of Galactic Center

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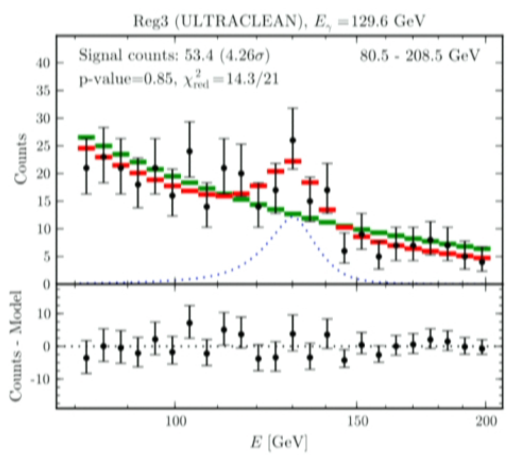

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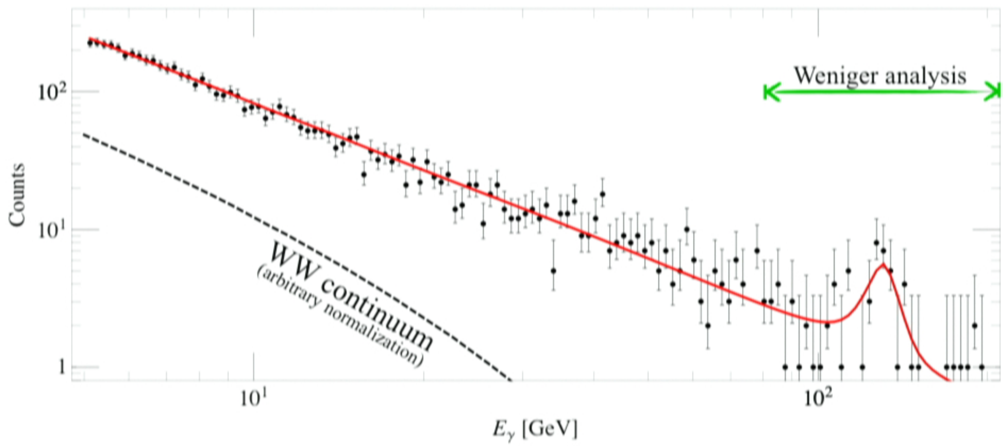
Signal Analysis

Fermi LAT 3.7 year data, Pass 7_Version6 (Ultraclean)

5-200 GeV photons from 3° about Galactic Center,
with inner degree masked

Well-modeled by falling power law background + 130 GeV peak



Model Interpretation

What is the origin of this signal?

Many models typically give $\gamma\gamma$ and γZ^0 signals

130 GeV $(\gamma\,\gamma)$ & 115 GeV $(\gamma\, Z^0)$ lines

130 GeV $(\gamma\, Z^0)$ & 145 GeV $(\gamma\,\gamma)$ lines

Usually $\sigma(\gamma\, Z^0) > \sigma\,(\gamma\,\gamma\,)$

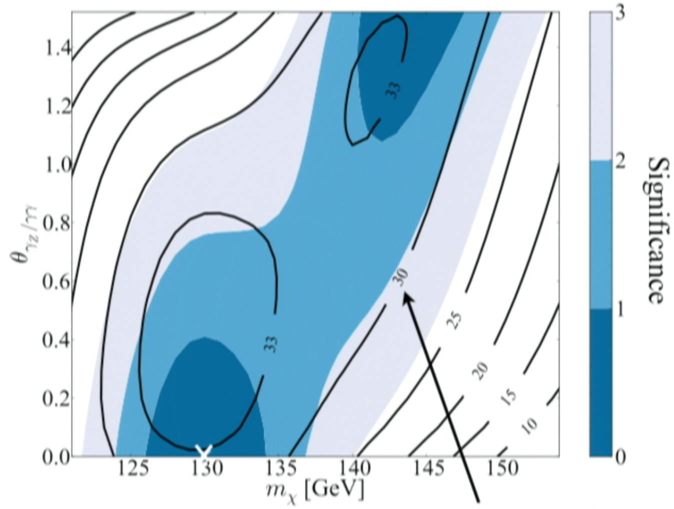
Two Lines?

Log-likelihood fitting procedure assumes single power-law background and $\gamma\gamma$ and γZ^0 peaks modeled with Fermi IRFs

$$\theta_{\gamma Z/\gamma\gamma} \equiv \arctan \frac{N_{\gamma Z}}{N_{\gamma\gamma}}$$

Best-fit point:
130 GeV $\gamma\gamma$, no γZ^0
~30 photons in peak

However, all ratios consistent within 2σ



See also Rajaraman, Tait, Whiteson [1205.4723]

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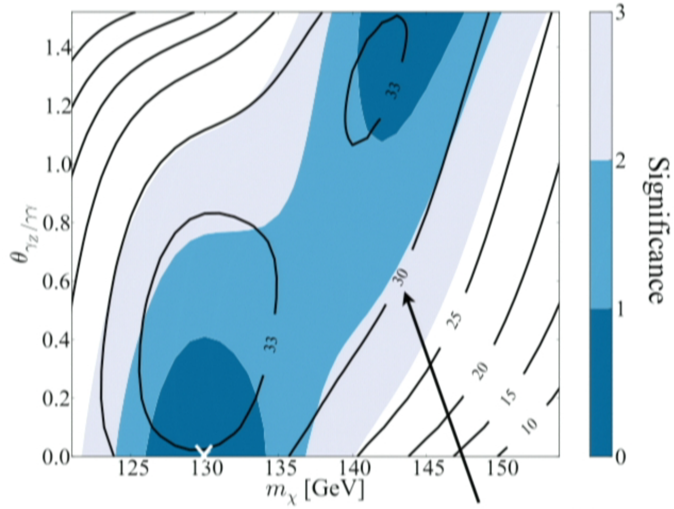

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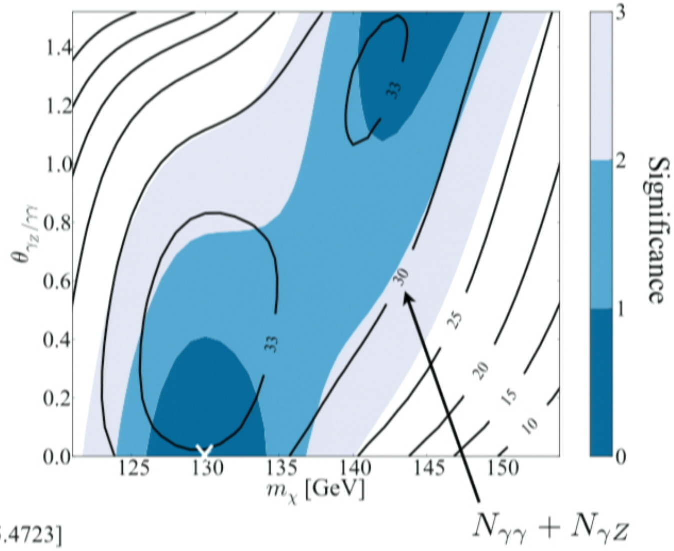

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Continuum Photons

In many models, dark matter can have tree-level annihilations to

$$WW, b\bar{b}, \mu\mu, \tau\tau, \ldots$$

The decay products of these final states shower and hadronize, producing many photons

Constrain the ratio of the number of continuum photons to the number of photons in the 130 GeV line

$$R^{\rm th} = \frac{\sigma_{\rm ann}}{2\sigma_{\gamma\gamma} + \sigma_{\gamma Z}}$$

All astrophysical uncertainties cancel out!

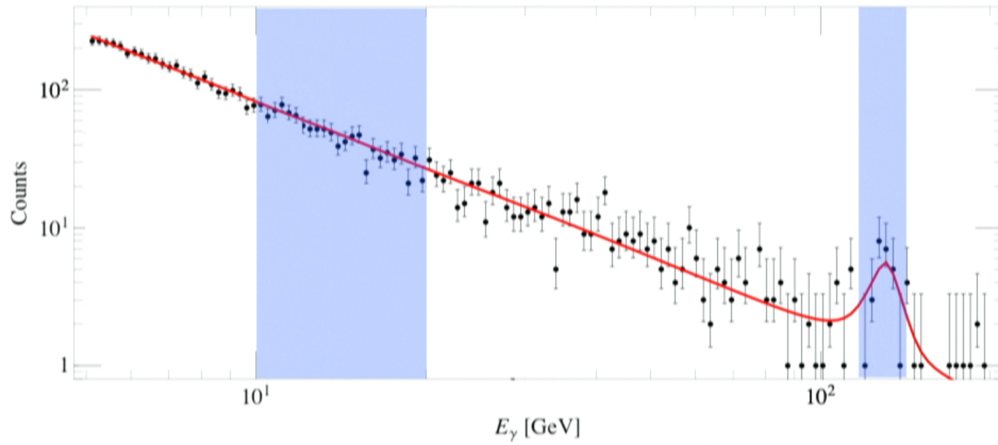
Supersaturation Constraint

Conservative assumption:

All photon counts in given energy bin are due to dark matter annihilation [10-20 GeV for WW, ZZ continuum]

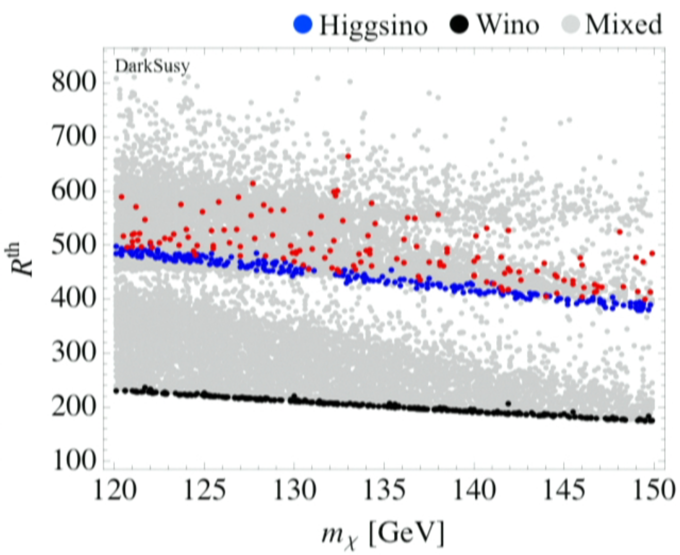
Compare to:

Photon counts in the 130 GeV peak



Neutralino Implications

A more thorough scan through MSSM parameter space shows that mixed-state neutralinos also ruled out



$$R^{\rm th} \gtrsim 200$$

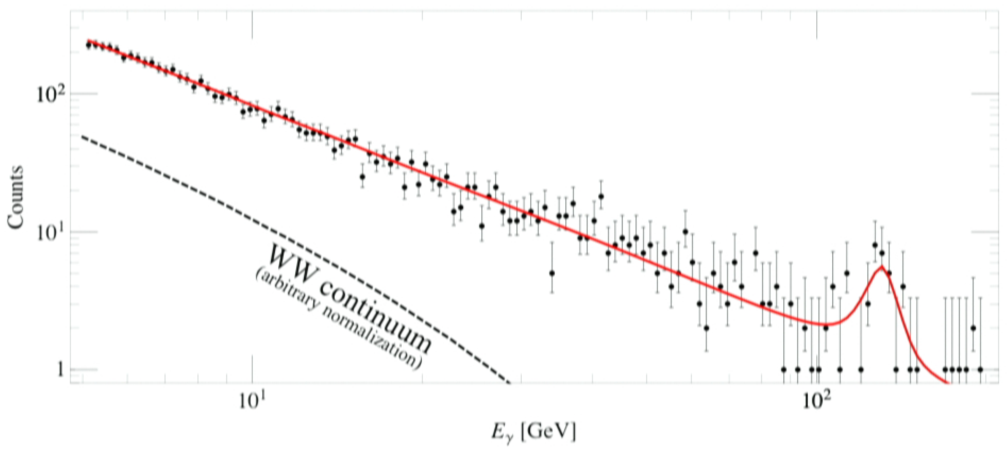
for MSSM neutralinos with viable annihilation cross sections to explain the signal

Ruled out!

(as explanation for line)

Shape Constraint

Even tighter constraints can be placed by fitting the **shape** of the data to the continuum + line + background model

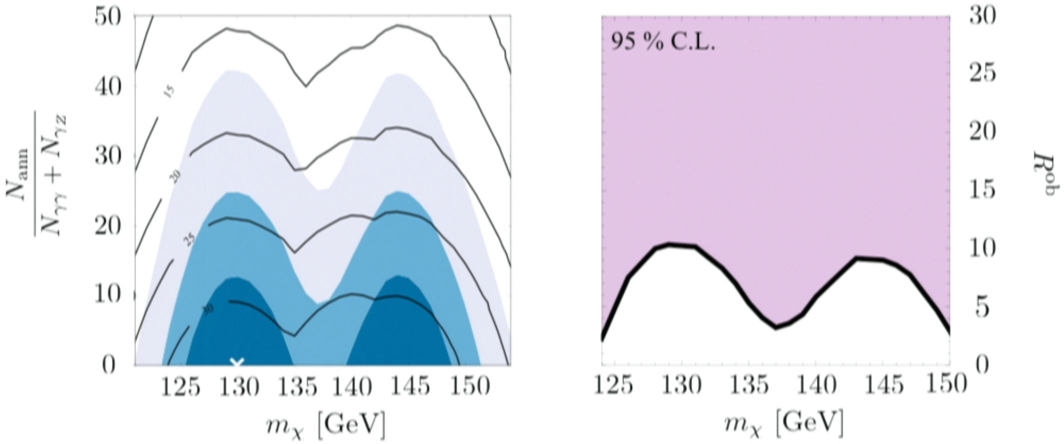


Shape Constraint

Annihilation contribution is highly suppressed, with

$$R < 10!$$

Nearly a factor of 8 tighter than supersaturation constraint.



General Implications

Dark matter that annihilates to W^+W^-, Z^0Z^0 at tree level and $\gamma\gamma$, γZ^0 at loop level is ruled out

Kills many classes of models

Also...

Constraint on ratio of Z^0Z^0 to γZ^0 is $\mathcal{O}(10)$

If this approaches $\mathcal{O}(1)$ with more data, it will pose an even greater challenge to model-building

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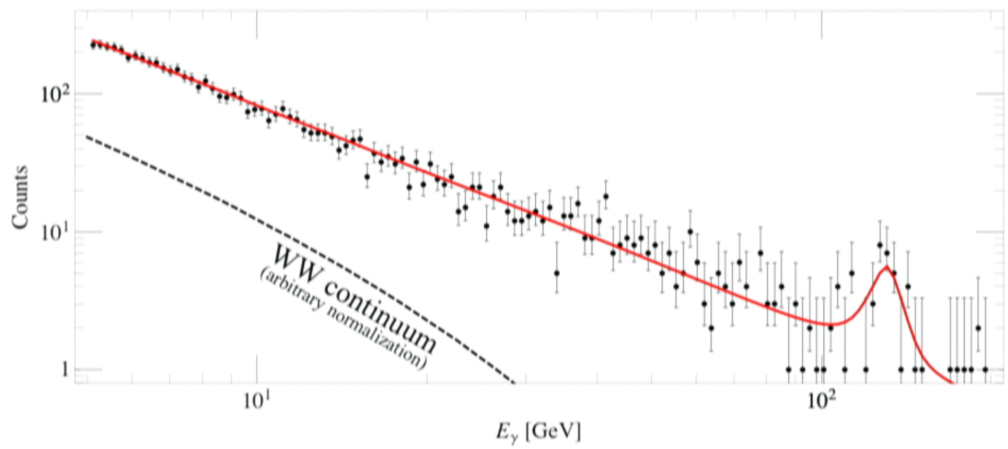


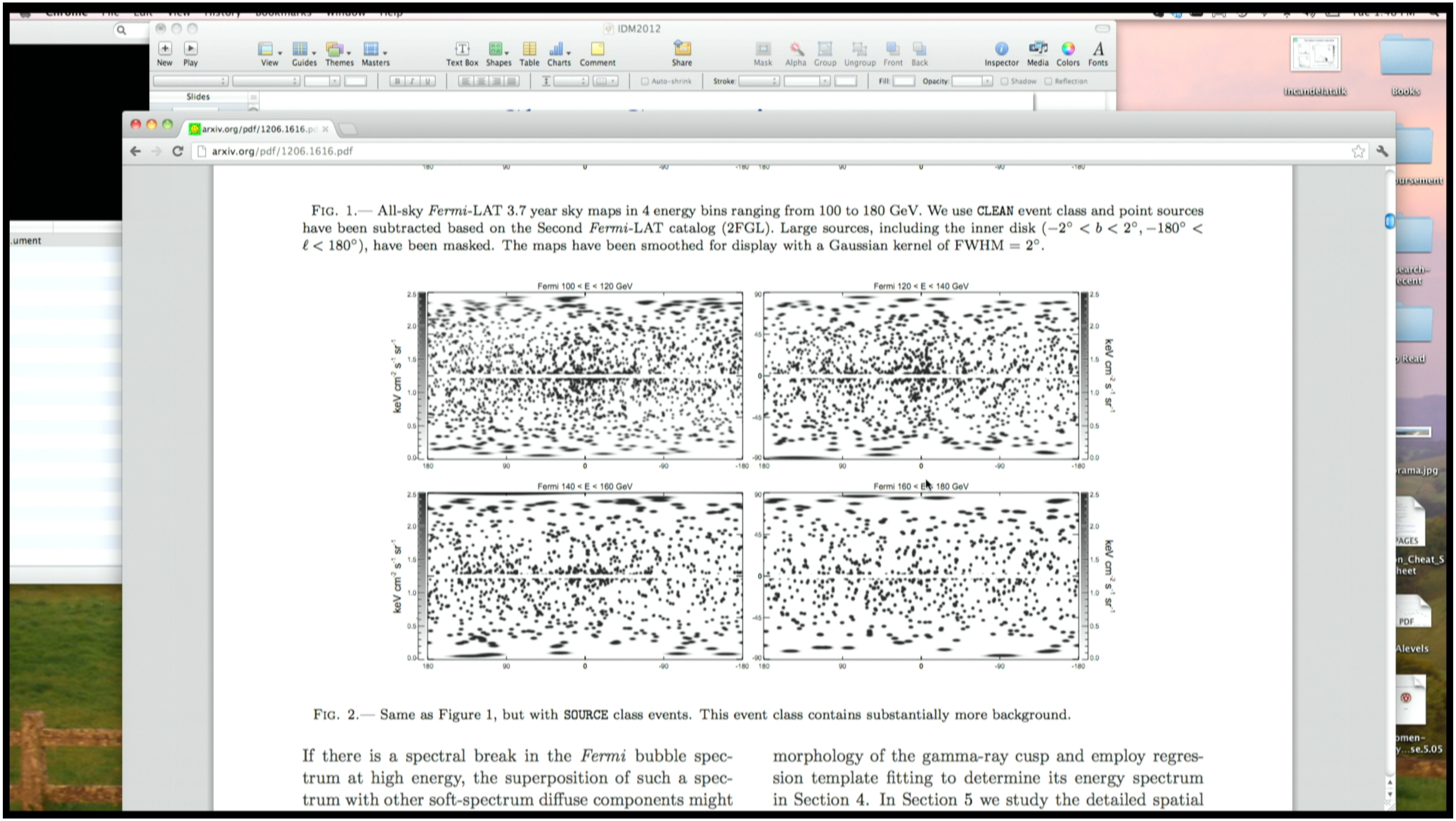
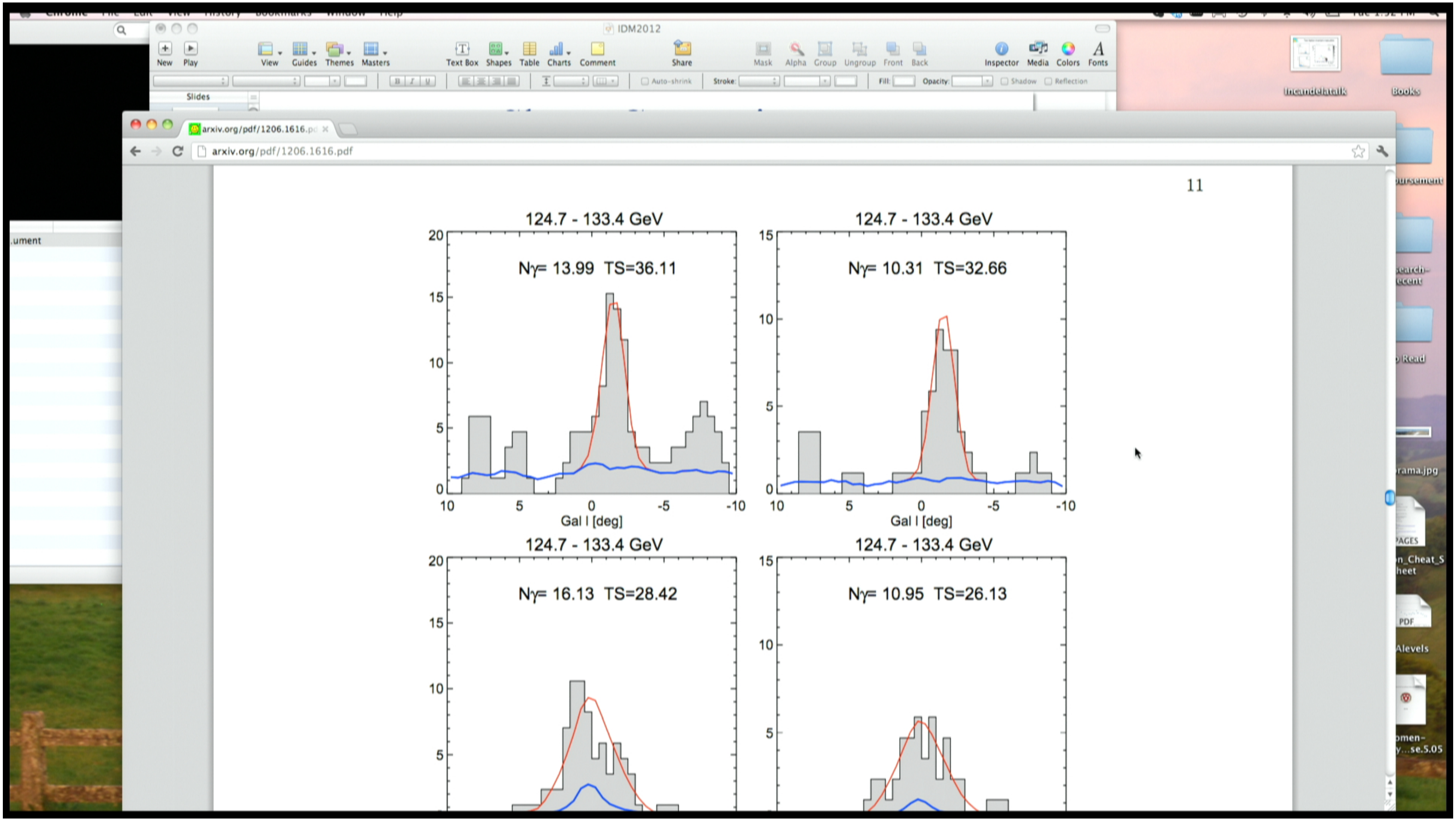


FIG. 1.— All-sky *Fermi*-LAT 3.7 year sky maps in 4 energy bins ranging from 100 to 180 GeV. We use CLEAN event class and point sources have been subtracted based on the Second *Fermi*-LAT catalog (2FGL). Large sources, including the inner disk ($-2° < b < 2°$, $-180° < \ell < 180°$), have been masked. The maps have been smoothed for display with a Gaussian kernel of FWHM = 2°.

FIG. 2.— Same as Figure 1, but with SOURCE class events. This event class contains substantially more background.

If there is a spectral break in the *Fermi* bubble spectrum at high energy, the superposition of such a spectrum with other soft-spectrum diffuse components might

morphology of the gamma-ray cusp and employ regression template fitting to determine its energy spectrum in Section 4. In Section 5 we study the detailed spatial


arxiv.org/pdf/1206.1616.pdf
11
124.7 - 133.4 GeV
Nγ= 13.99 TS=36.11
Nγ= 10.31 TS=32.66
Gal l [deg]
Nγ= 16.13 TS=28.42
Nγ= 10.95 TS=26.13