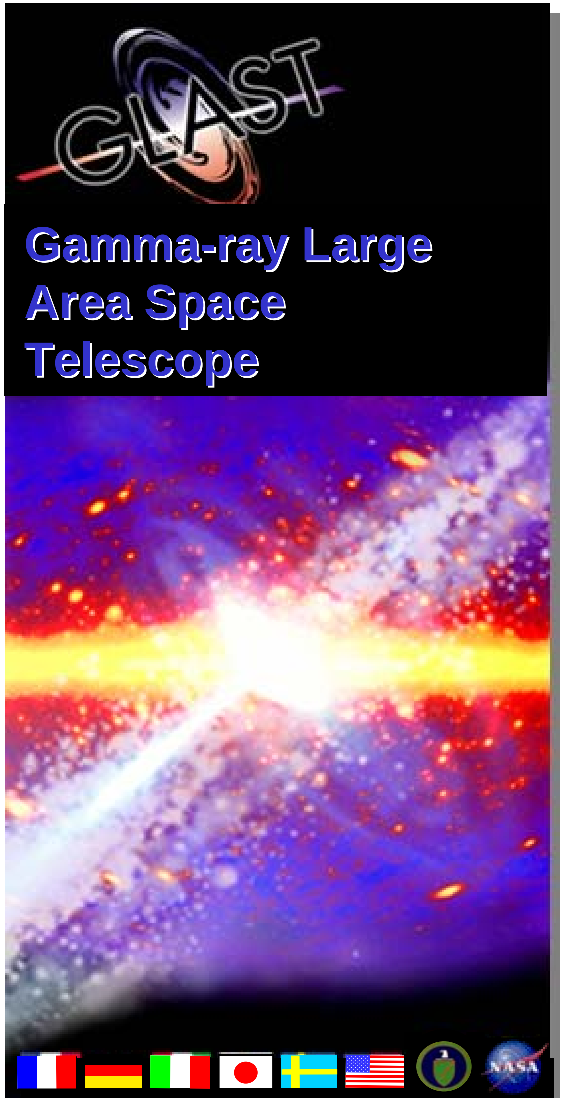


Dark Matter in Galactic Gamma Rays

Marcus Ziegler
Santa Cruz Institute for Particle Physics

Are there two kinds of dark matter seen in Galactic gamma rays?

Matt Roos, Dated January 10, 2005

- Popular SUSY model

- EGRET

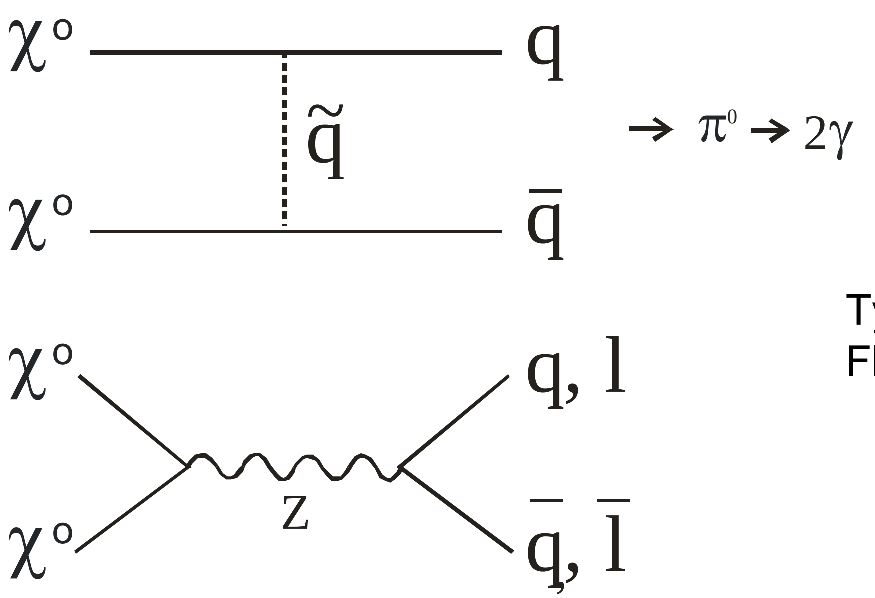
- WMAP

- HESS

=> Two kinds of Dark Matter

Popular SUSY model

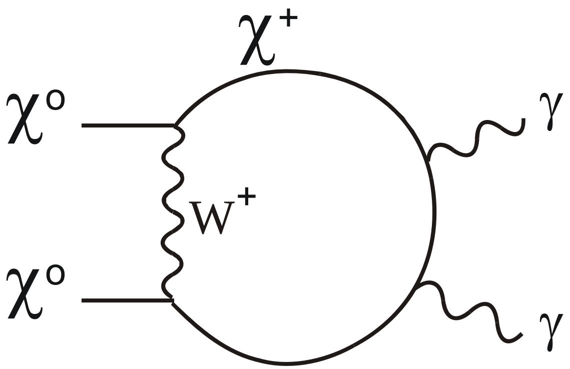
The popular SUSY models offer several DM candidate particles.
The most particular the lightest SUSY particle (LSP) χ^o.



Typically about 30-40 Photons
Flat spectrum with peak at 70 MeV

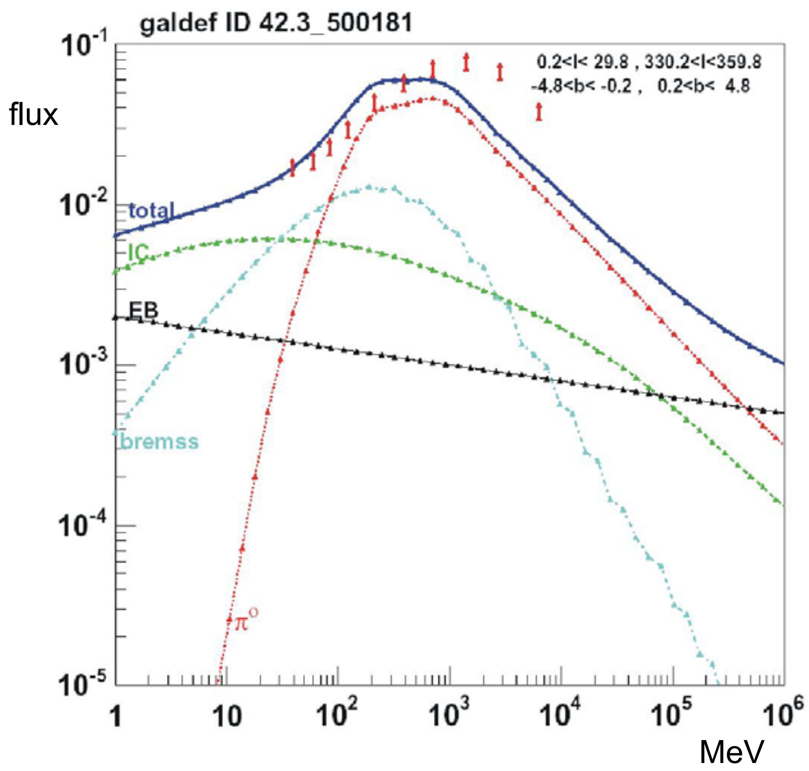
DM lines decay

The χ^o can also annihilate into two photons.
This process involves a loop and is suppressed.



EGRET on board of the CGRO

Energy spectrum as detected by EGRET

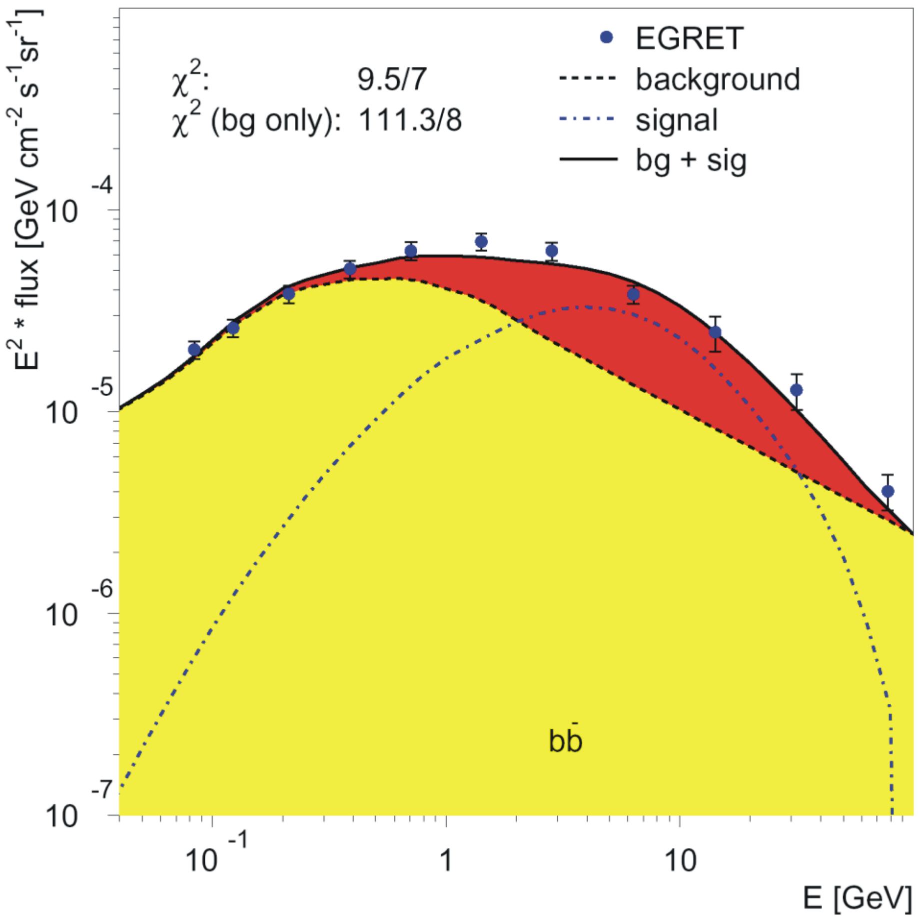


Main sources of background are:

- Decay of π^o mesons
  Inelastic pp or p-He collisions
- Inverse Compton scattering
- Bremsstrahlung from electrons
- Extra galactic background

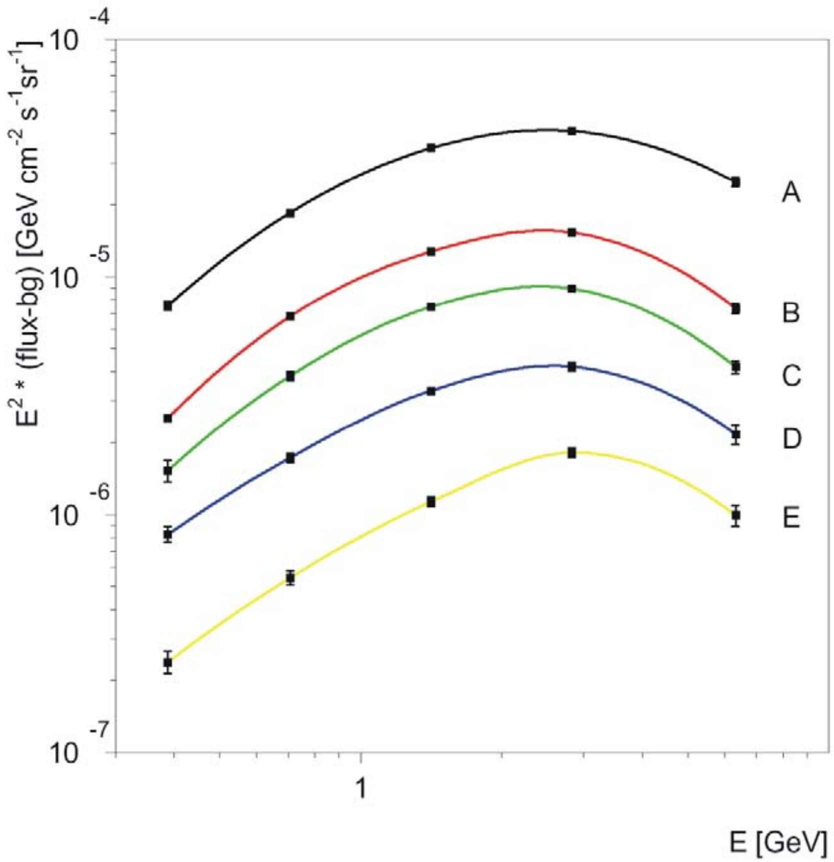
From: arXiv:astro-ph/0408272 v2 19 Aug 2004
Excess of EGRET Galactic Gamma Ray Data
interpreted as Dark Matter Annihilation

Energy spectrum as detected by EGRET



Diffuse gamma-ray spectrum as calculated with the GALPROP model.

Excess of EGRET data



The excess of the EGRET data for the various sky regions, determined by plotting the differences between the conventional GALPROP model and the EGRET data.

Region	Longitude l	Latitude $\|b\|$	Description
A	330-30	0-5	Inner Galaxy
B	30-330	0-5	Galactic disc without inner Galaxy
C	90-270	0-10	Outer Galaxy
D	0-360	10-20	low longitude
E	0-360	20-60	high longitude
F	0-360	60-90	Galactic Poles

One observes the same spectral shape for all regions, indicating a common source for the excess.

Largest excess from galactic center (A)

Fits to spectral shape

•The same spectrum from all sky directions is the hall mark of DMA and practically excludes the possibility that the excess originates from unknown point sources.

• The observed point sources have a much softer spectrum than the high energy gamma rays.

• The many point sources in the direction of the galactic center increase the gamma ray flux by only 20%, which only changes the normalization.

• The largest excess comes from the galactic centre (region A), but at large latitudes (regions D and E) there exists still a strong signal, as expected from DMA.

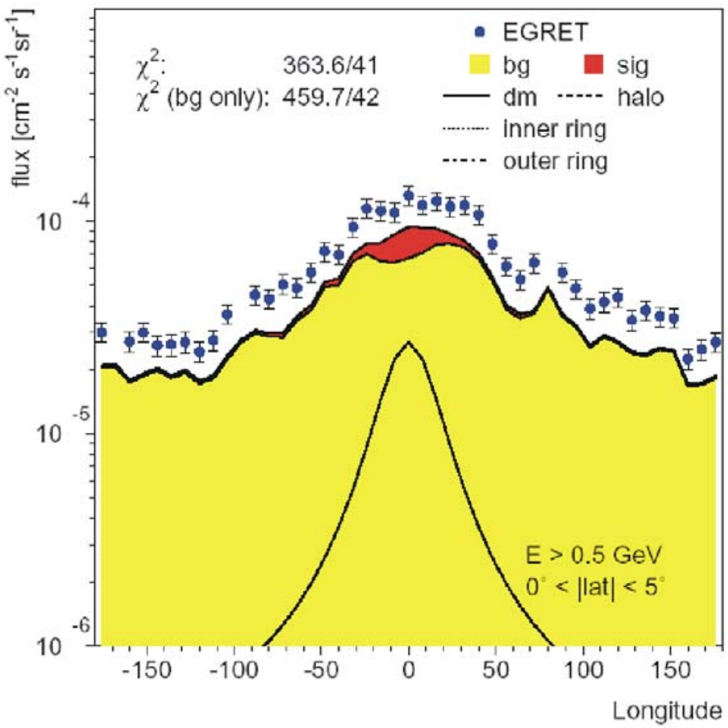
• The DMA signal contributes differently for the different sky directions, as expected from the fact that the halo profile has a maximum towards the centre and the annihilation rate is proportional to the DM density squared.

Various proposed shapes of halo profiles can be tested

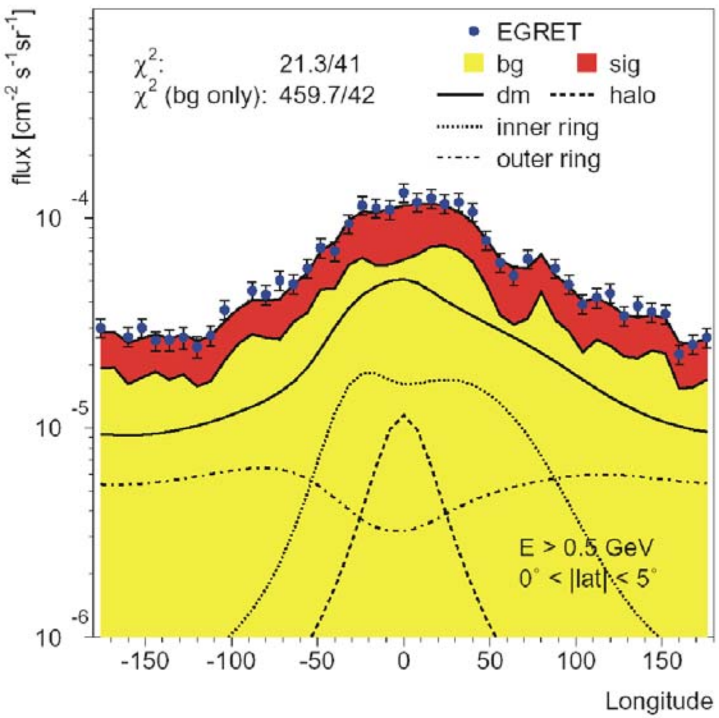
Determination of the Halo Profile Parameters

Calculate WIMP mass distribution along the line of sight
-> prediction of gamma ray flux

expected triaxial DM halo

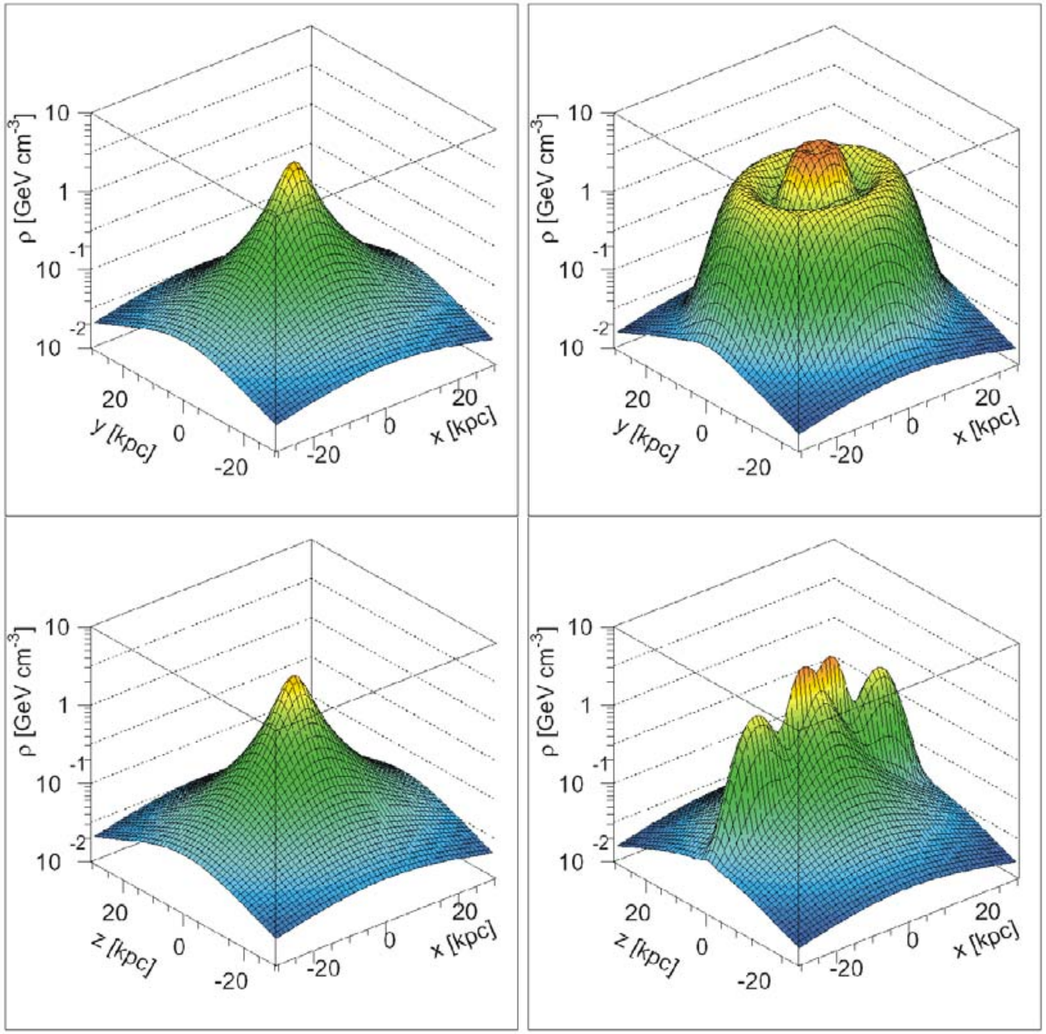


two DM rings model



Longitude distribution of diffuse gamma-rays for latitudes 0. < |b| < 5. for the isothermal profile without (left) and with rings (right).

3D-distributions of haloprofile



Profile without (left) and with (right) rings

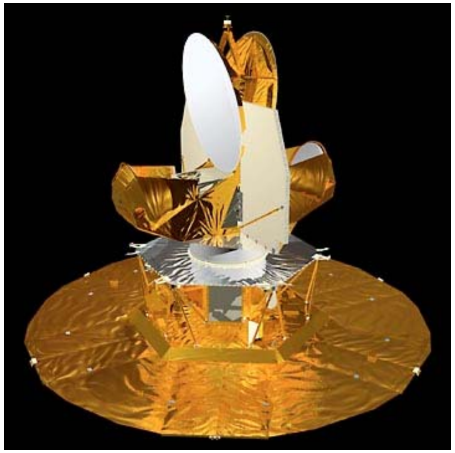
Two rings of DM
inner ring at 4.3 kpc
outer ring at 14 kpc

- Rotation curve change of slope at 9.4 kpc
- Ring of starts at 14 – 18 kpc

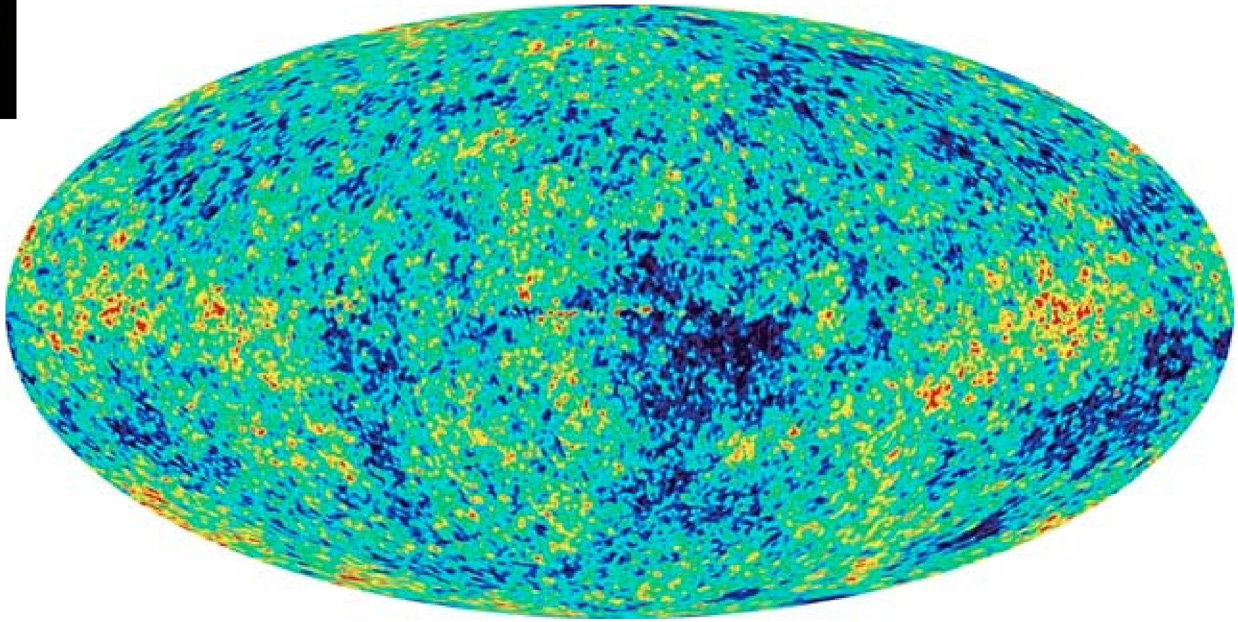
Thus the EGRET excess appears to be well explained by γ-rays from the self annihilation of LSPs with a relic density in consistency with the first year result of WMAP $\Omega\chi = 0.23 \pm 0.04$
and with a total annihilation cross-section $\langle\sigma_A \upsilon\rangle$ □ $2 \cdot 10^{-26}$ cm^3/s

WMAP Microwave Emission Interpreted as Dark Matter Annihilation in the Inner Galaxy

Douglas P. Finkbeiner



Wilkinson Microwave Anisotropy Probe



WMAP Data

The Wilkinson Microwave Anisotropy Probe (WMAP) has observed the sky with good sensitivity (□ 150 μK per pixel in the 1 yr data)

The galactic foreground signals have been removed to not interfere with the cosmological signal.

⇒ Thermal dust emission

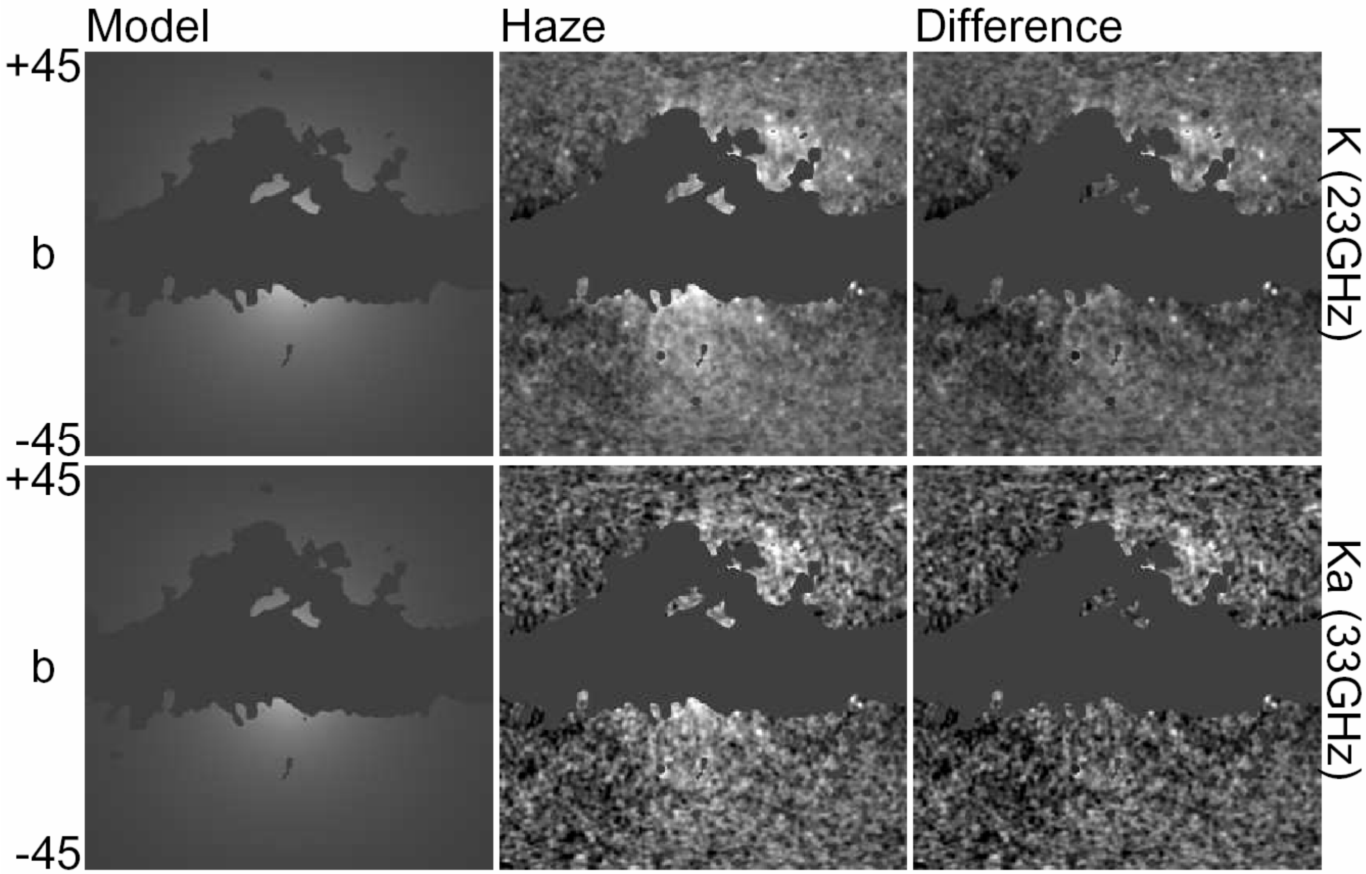
⇒ Free-free (thermal bremsstrahlung),

⇒ “ordinary” synchrotron (relativistic electrons accelerated by supernovae and spiraling in the Galactic magnetic field)

⇒ Spinning dust

=> Evidence for an additional emission component has emerged

WMAP Haze



⇒ Microwave emission observed in the inner galaxy is consistent with synchrotron emission from highly relativistic electron pairs produced by DM annihilation

⇒ EGRET and WMAP have two different density profiles, but still observe the annihilation of the same particle χ.

H.E.S.S. Array of Cherenkov Telescopes

Very high energy gamma rays from the direction of Sagittarius A (November 2004)

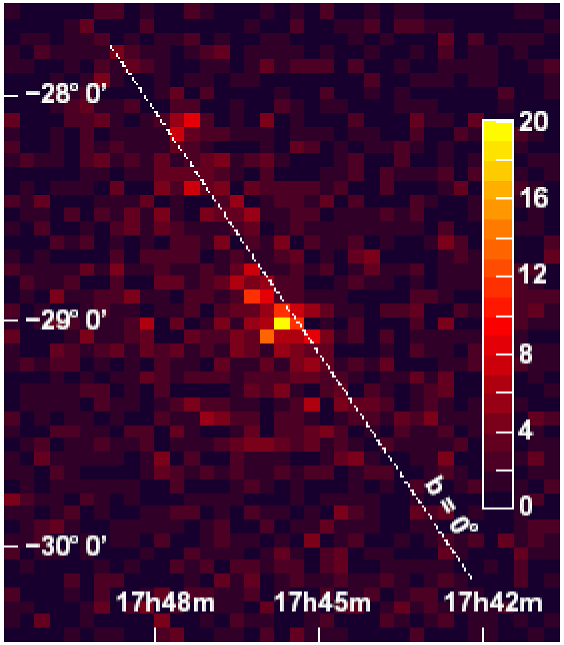


Fig. 1. Angular distribution of γ-ray candidates for a 3° field of view centred on Sgr A*. Both data sets ('June/July' and 'July/August') are combined, employing tight cuts to reduce the level of background. The significance of the feature extending along the Galactic Plane is under investigation.

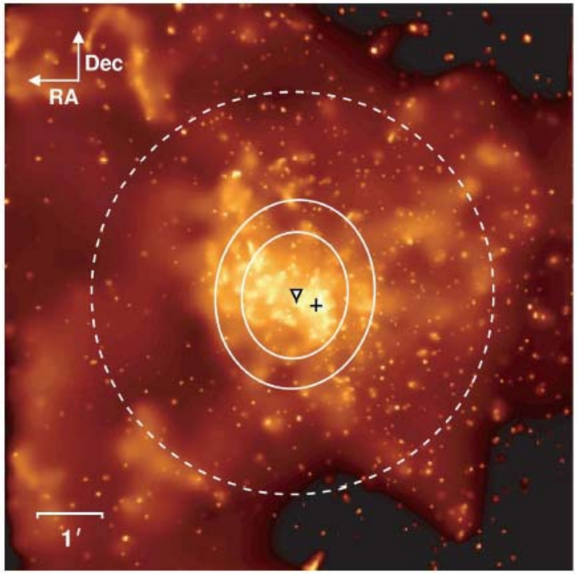


Fig. 2. Centre of gravity of the VHE signal (triangle), superimposed on a 8.5′ by 8.5′ Chandra X-ray map (Muno et al. 2003) of the GC. The location of Sgr A* is indicated by a cross. The contour lines indicate the 68% and 95% confidence regions for the source position, taking into account systematic pointing errors of 20″. The white dashed line gives the 95% confidence level upper limit on the rms source size. The resolution for individual VHE photons - as opposed to the precision for the centre of the VHE signal - is 5.8′ (50% containment radius).

Point like source within 1' of Sagittarius A

H.E.S.S. Energy spectrum

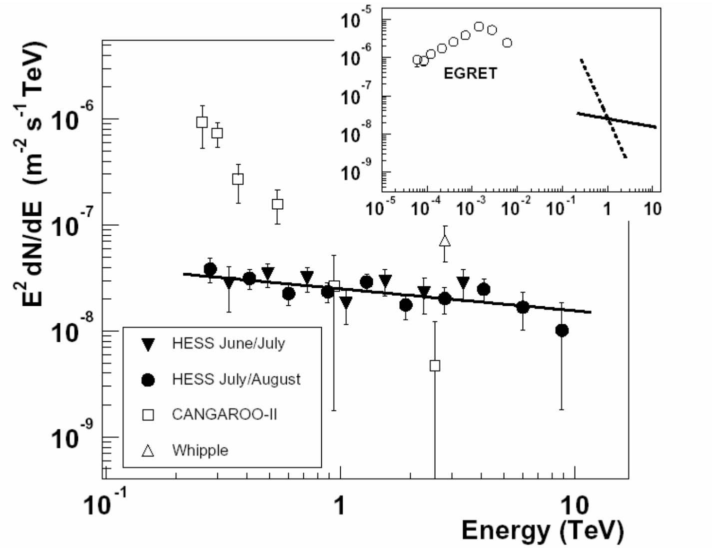


Fig. 4. Energy spectrum E^2dN/dE of γ-rays from the Galactic Centre. Full circles: H.E.S.S. 'July/August 2003' data set. Full triangles: H.E.S.S. 'June/July 2003' data set. The line indicates a power-law fit to the 'July/August' spectrum. Open squares: CANGAROO-II spectrum from Summer 2001 and 2002 (Tsuchiya et al. 2004). Open triangle: Whipple flux from 1995 through 2003 (Kosack et al. 2004), converted to a differential flux at the peak detection energy assuming a Crab-like spectrum. The inset shows the EGRET flux from 1991 to 1996 (Mayer-Hasselwander et al. 1998) (circles) compared to fits to the CANGAROO-II (dashed line) and H.E.S.S. (solid line) spectra. Due to the poor angular resolution of EGRET (1°) the flux shown may include other sources.

Energy spectrum ranges from 0.3 TeV to 10 TeV

=> Annihilation of a heavier WIMP, ξ

Can not be the source of the much softer χ annihilation gamma-rays seen by EGRET and WMAP.

Discussion from Matts Roos

This two-WIMP conjecture has several interesting consequences

- Knowing the approximate masses and annihilation cross-sections of two neutral SUSY particles is a considerable new input to SUSY spectroscopy

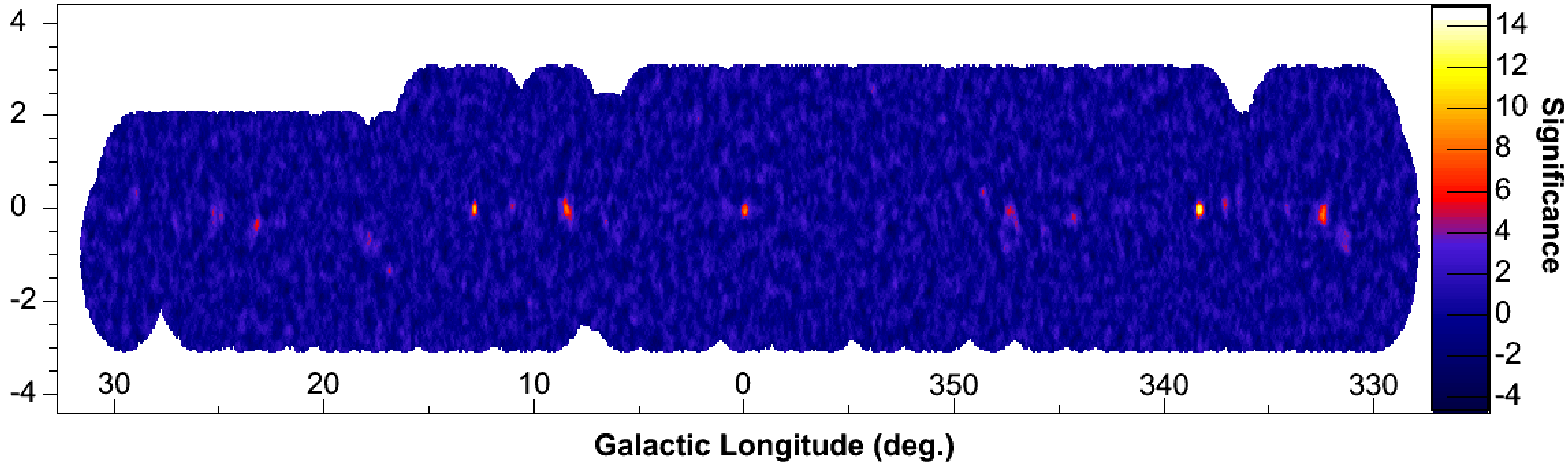
- Changes the picture of galaxy density profiles

- The χ need not have much of a central cusp, the ξ probably dominates the innermost region

- Some of the charged ξ annihilation products may perhaps diffuse out of the GC and spill lower energy photons into the upper ends of the EGRET and WMAP spectra.

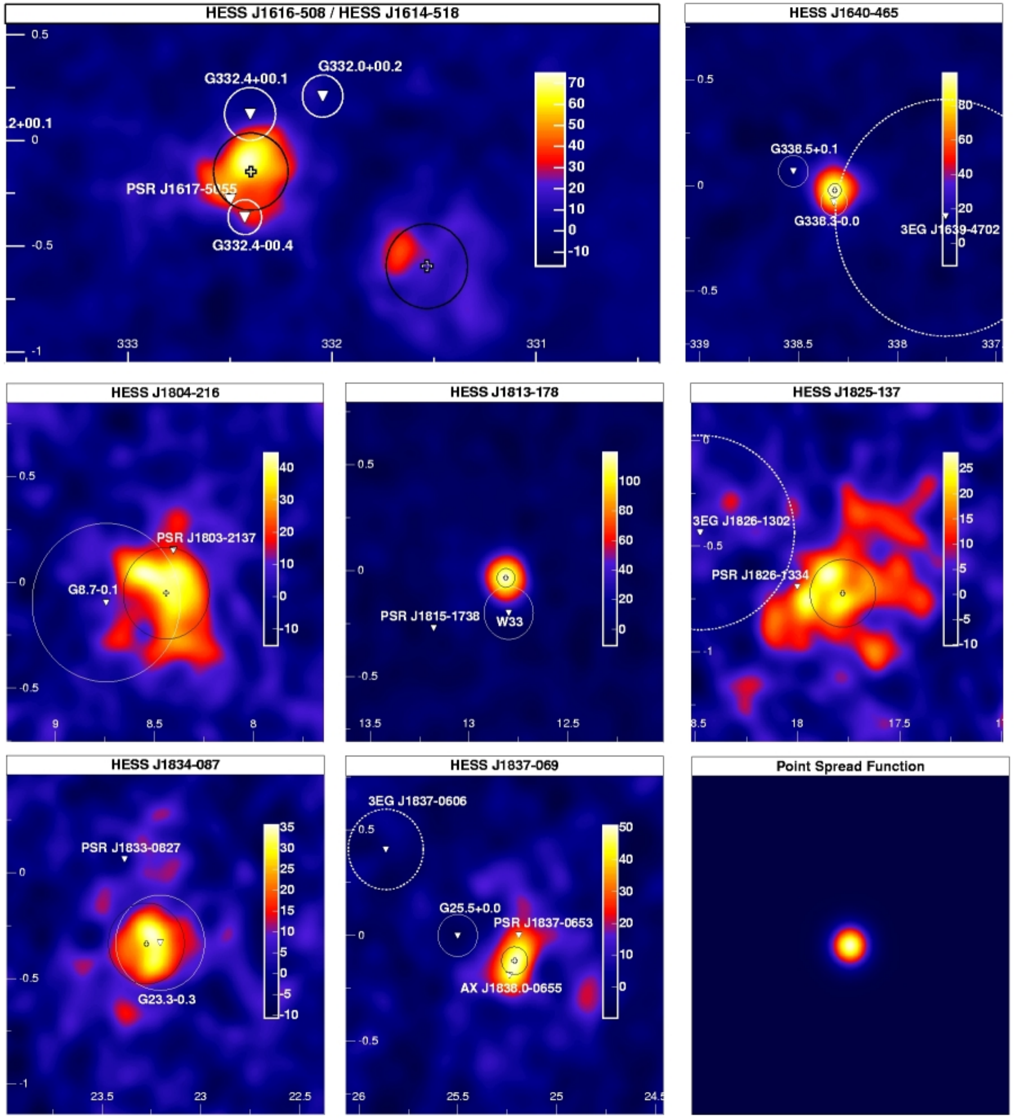
New H.E.S.S. data

Science March, 25th 2005.



New sources found in galactic plane

New H.E.S.S. data



=> Unlikely that they are from DM annihilation

A GALPROP model compatible with EGRET data

Diffuse Galactic Continnum Gamma Rays.

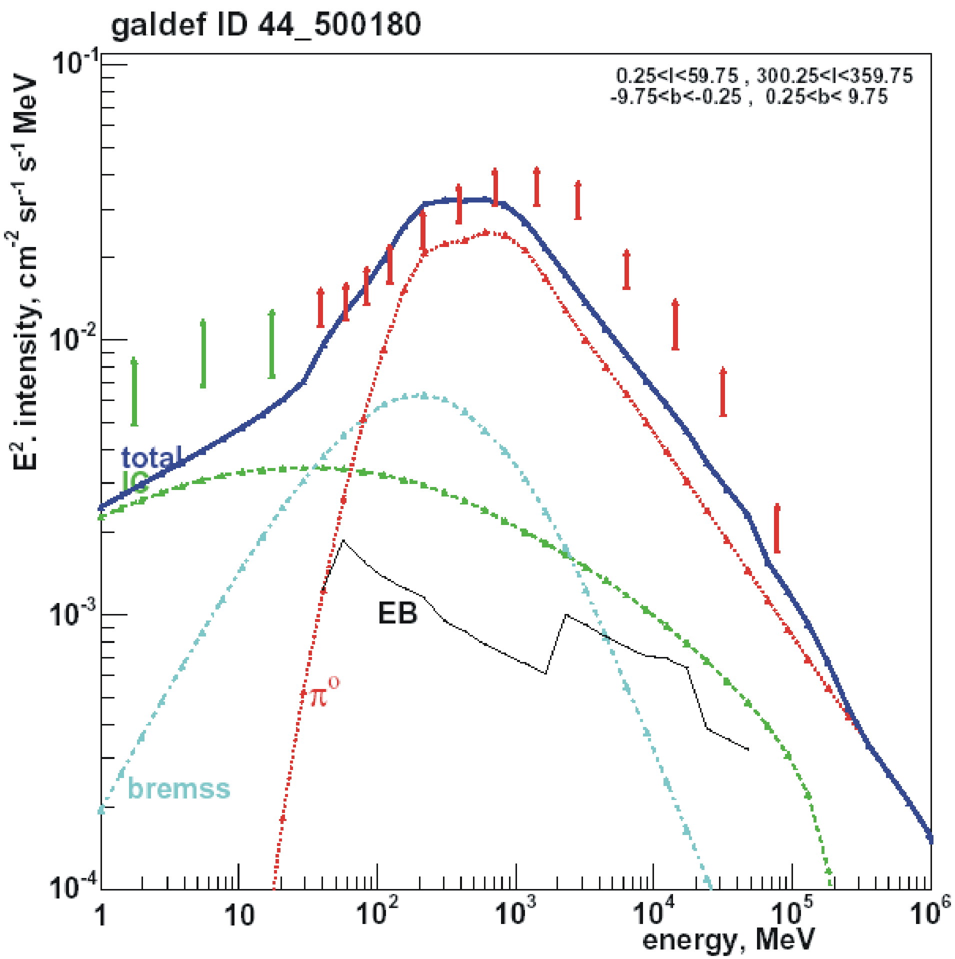
A Model Compatible with EGRET Data and Cosmic Ray Measurements

A.W. Strong, I.V. Moskalenko, O. Reimer

Models of the gamma ray sky are computed by using the GALPROP cosmic-ray propagation and gamma-ray production code.

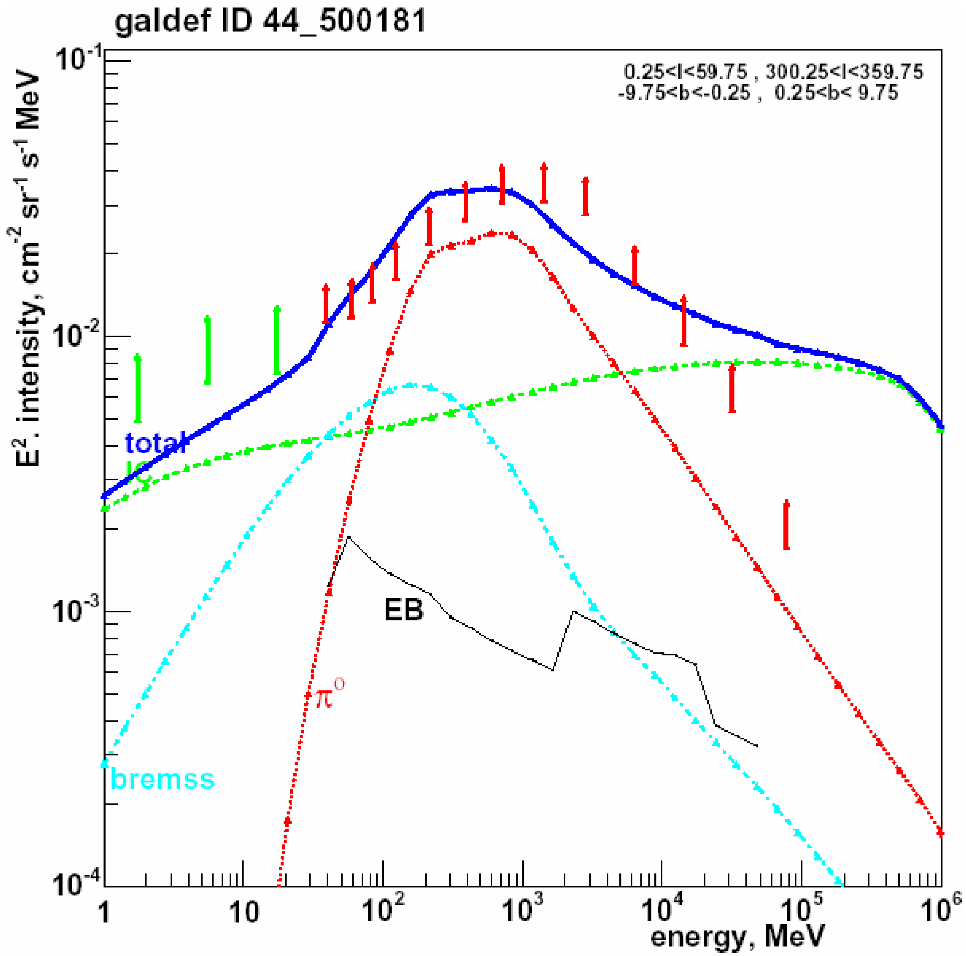
-> The conventional model is inadequate for all sky regions.

Conventional model



⇒The proton and electron spectrum are consistent with the locally observed spectra.

Hard Electron Injection Spectrum Model

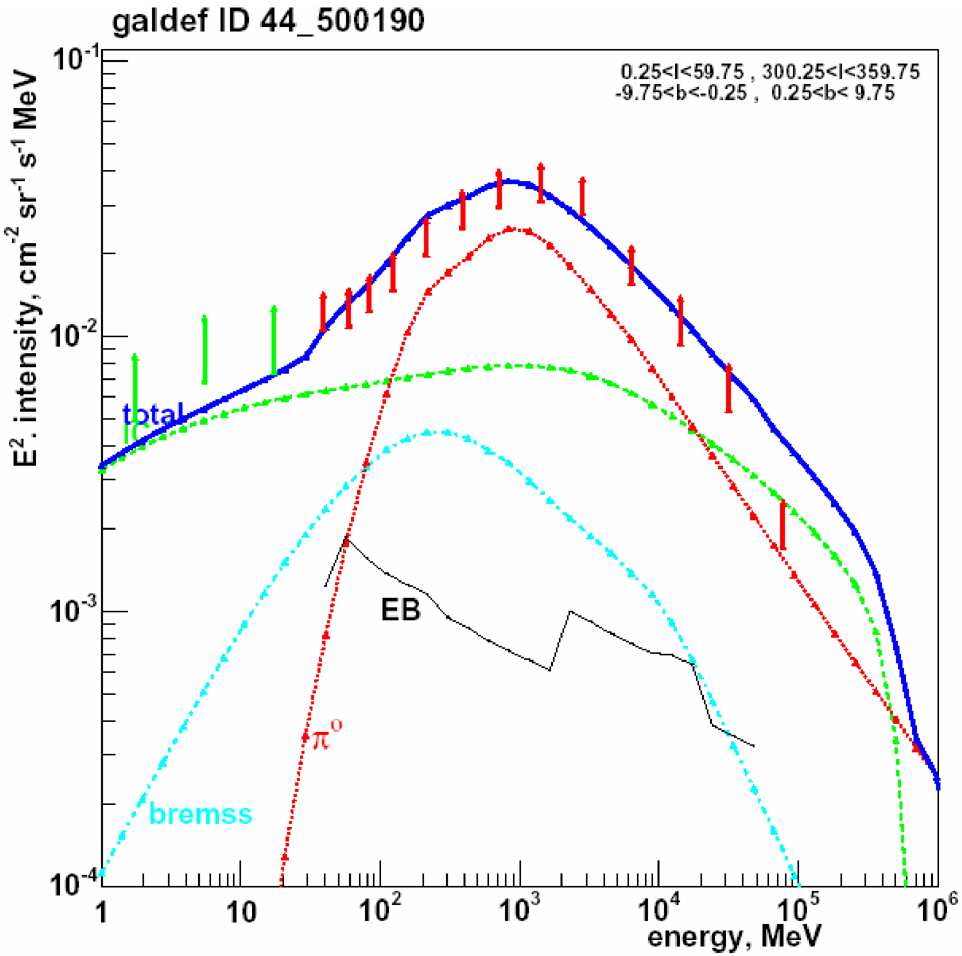


⇒Reproduces GeV excess

⇒Spectral shape not well reproduce

⇒Spectrum above 10GeV is much too hard

Optimized model



⇒Less drastic change in electron spectrum

⇒The proton injection spectrum is normalized upward by a factor of 1.8

⇒The fits to the observed gamma-ray spectra are better than for the conventional and the hard electron spectrum models.

Conclusion

The Unknown

As we know,
There are known knowns.
There are things we know we know.
We also know
There are known unknowns.
That is to say
We know there are some things
We do not know.
But there are also unknown unknowns,
The ones we don't know
We don't know.

Donald Rumsfeld, Department of Defense news briefing
Feb. 12, 2002