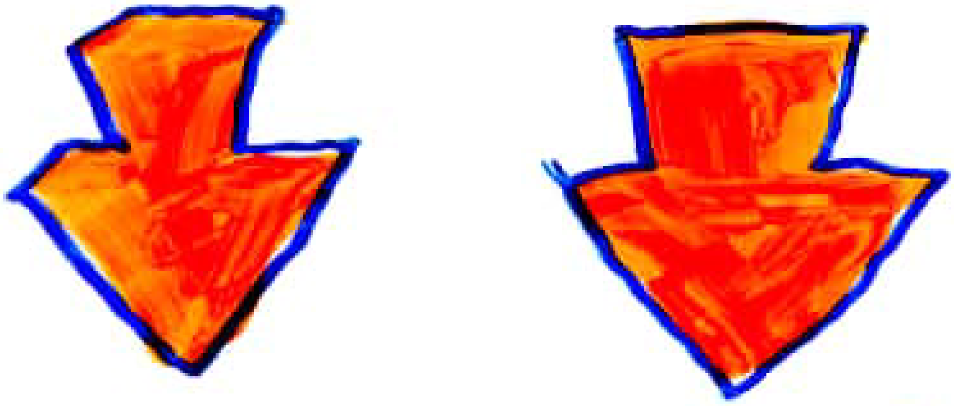
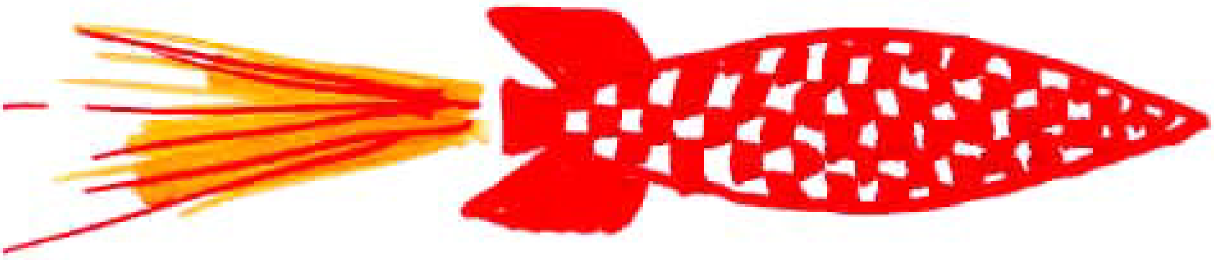
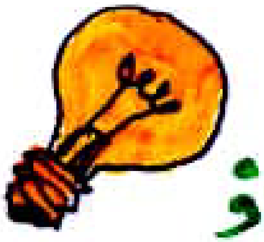
C.R.C HALO



C.R. COMM.



EXP {ARGH}

INSPIRED BY  ; OBS

CR E GALACTIC HALO

[BUT **NOT** BY ITS DETAILS]

DAR, DeR, ANTONIOU ASTRO-Ph 9901004 0005080

PROPOSE TESTS :

" A COMMON ORIGIN FOR ALL SPECIES OF HIGH ENERGY CRs "

DARWINIAN PROPOSAL :

$e, p, Z>1, \gamma$ DIFFUSE GBR

SHARE A COMMON LINEAGE
ABOVE CERTAIN ENERGIES

STRONG and MOSKALENKO CR TRASPORT MODELS

$^{10}Be/^{9}Be$ RATIO

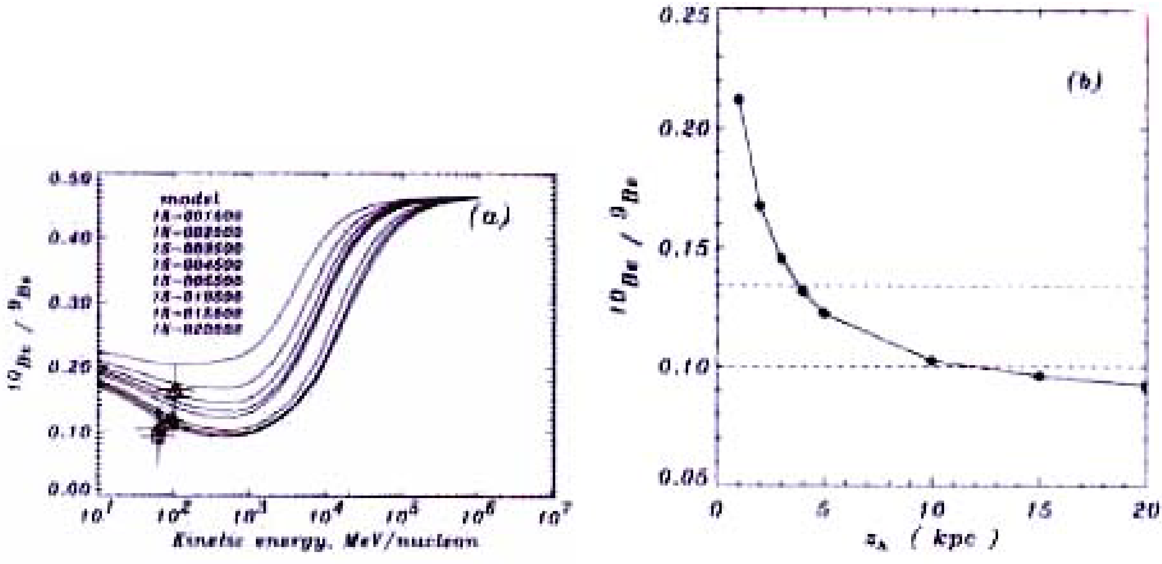


Figure 4: ^{10}Be/^{9}Be ratio for the diffusive reacceleration models of Strong and Moskalenko, 1998. (a) As a function of energy for $z_h = 1, 2, 3, 4, 5, 10, 15$ and 20 kpc. (b) As a function of z_h at 525 MeV/nucleon, the mean interestellar value for the Ulysses data, whose 1σ limits are the dashed lines. The data points are from Lukasiak el al. 1994 (square, Voyagers 1,2; open circle, IMP 7/8; triangle, ISEE 3) and Conell 1998 (filled circle, Ulysses).

"DIFFUSIVE REACCELARATION"

(S., M., et al)

D:  CR_s DIFFUSE in $\vec{B}$, D fit

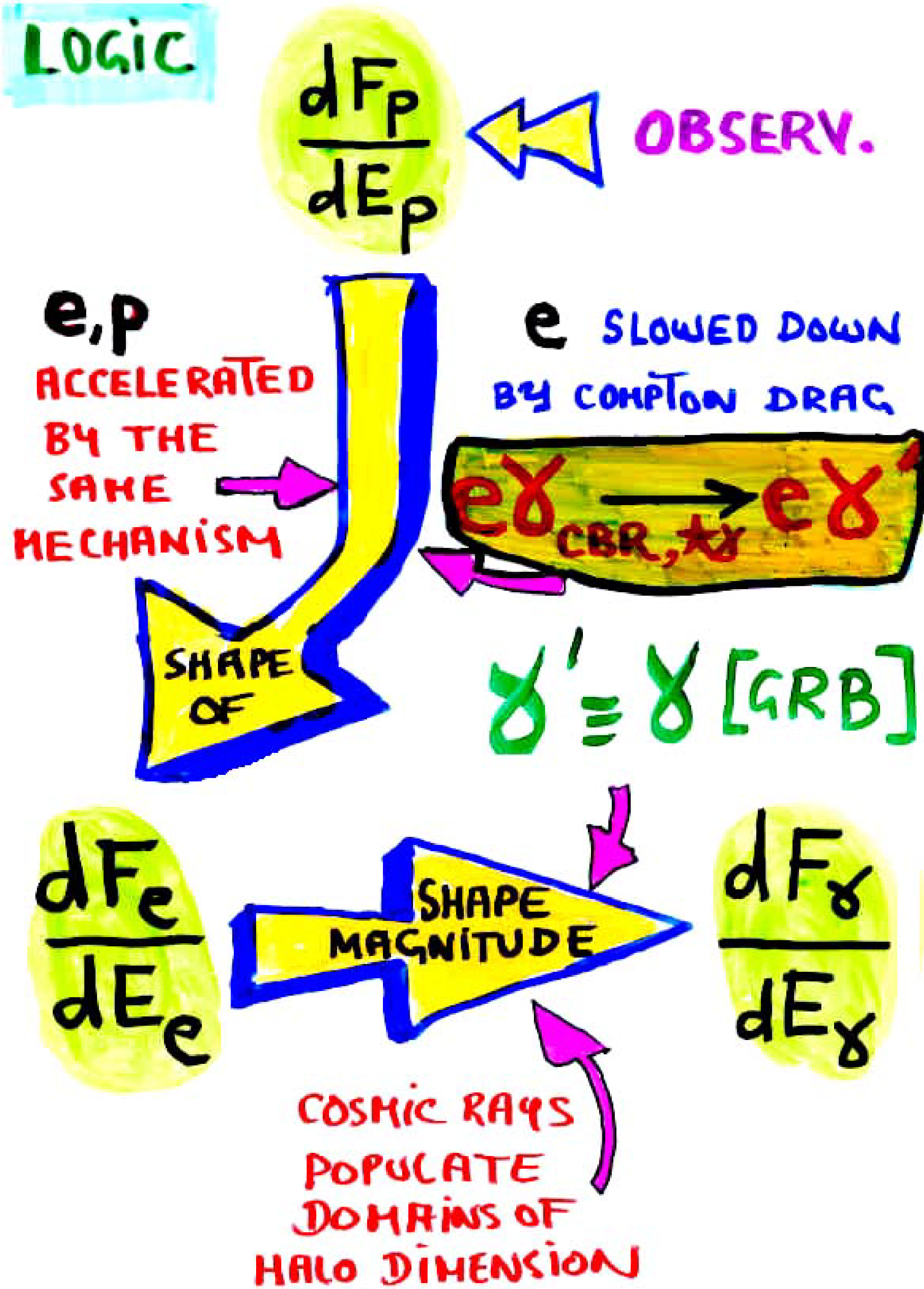
RA: e's lose E_e CLOSE TO SOURCE

: ARBITRARY $+ v_A$ (PART. MYSTERIOUS)

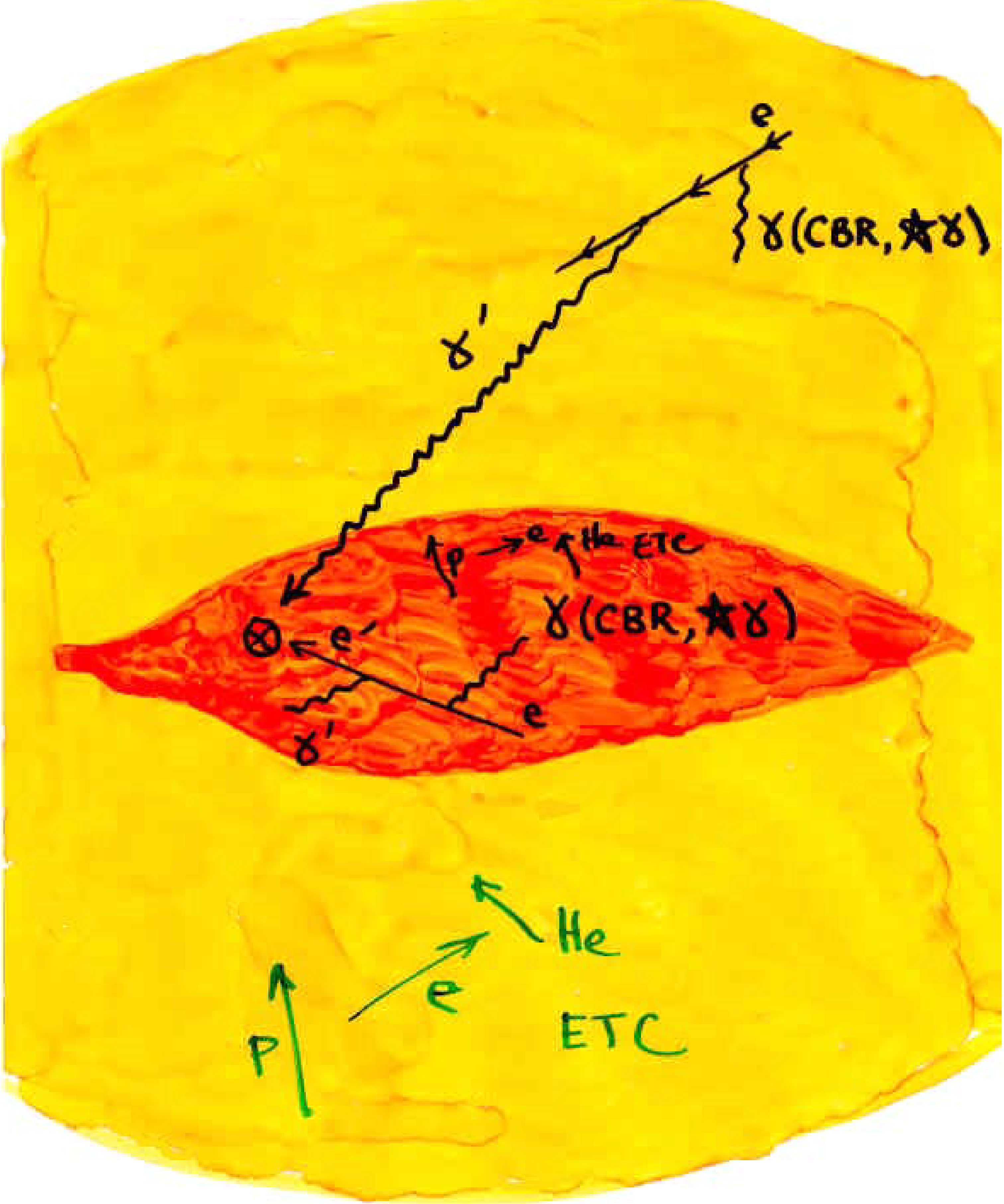
dF/dE_e (AVERAGE) $\neq \frac{dF}{dE_e}$ (LOCALLY)

CR SOURCES : AD HOC DISTRIBUTION

$\neq$ SN DISTRIB. (MUCH MORE EXTENSIVE)



LOGIC
$\frac{dF_p}{dE_p}$
OBSERV.
e,p
ACCELERATED BY THE SAME MECHANISM
e SLOWED DOWN BY COMPTON DRAG
$e\gamma_{CBR,*\gamma} \rightarrow e\gamma'$
SHAPE OF
$\gamma' \equiv \gamma$ [GRB]
$\frac{dF_e}{dE_e}$
SHAPE MAGNITUDE
$\frac{dF_\gamma}{dE_\gamma}$
COSMIC RAYS POPULATE DOMAINS OF HALO DIMENSION



CR - e SPECTRUM
"DIFFUSE" γ RAY BCKND.

INVERSE COMPTON SCATTERING

SHAPE OF $d\phi_e / dE_e$

CBR [MWBR now]

$T_0 \sim 2.7$ K $n_0 \sim 411$ cm^{-3}

$$\epsilon_0 \equiv \langle E_\gamma \rangle \sim 2.7\, T_0$$

(

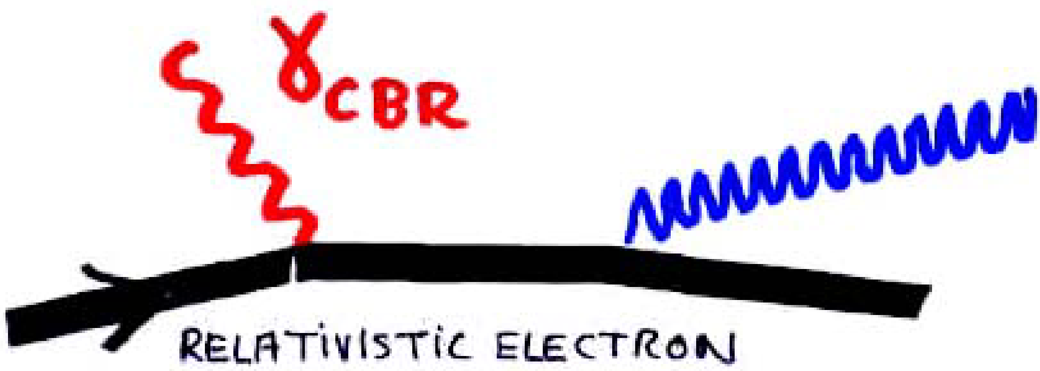

LOWER ENERGY γ

'COMPTON SCATTER.'

$s < m_e^2$

$$\sigma_T = \frac{8\pi}{3} \frac{\alpha^2}{m_e^2}$$

"THOMPSON"
)



HIGHER ENERGY γ

"INVERSE" C.S.

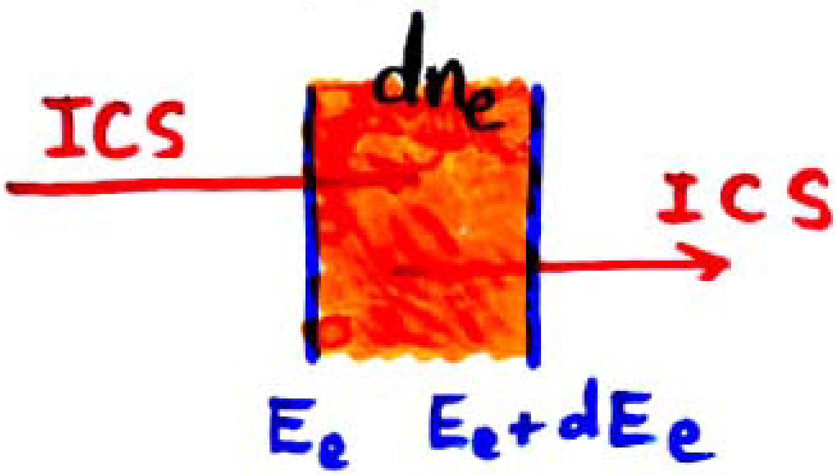
$$\overline{E_\gamma} \simeq |\overline{\Delta E_e}| \simeq \frac{4}{3} \epsilon_0 \gamma^2 \qquad \gamma = \frac{E_e}{m_e}$$

$e\gamma_{CBR}$ COLLISION RATE : $\sigma_T n_0 c$ $[1/t]$

R : PRODUCTION RATE OF CR e's $[1/t]$

dn_e^s/dE_e ELECTRON SPECTRUM AT SOURCE

$$\frac{\partial n_e}{\partial E_e \partial t} \xrightarrow[{[R,\sigma_T n_0 c]^{-1}}]{t \gg} \frac{dn_e}{dE_e}$$ EQUILIBRIUM



$$\sigma_T n_0 c \, \overline{\Delta E_e} \, \frac{d^2 n_e}{dE_e^2} = R \frac{dn_e^s}{dE_e} \qquad (1)$$

$\overline{\Delta E_e} \propto E_e^2$

$$F_e = \frac{c}{4\pi} n_e$$ WOULD ALSO $\ni$ (1) IF SUFF. HOMOGENEOUS

$$\Rightarrow E_e^2 \frac{d^2 n_e}{dE_e} \propto E_e^{-\beta_e^s} \Rightarrow \boxed{\frac{dn_e^{OBS}}{dE_e} \propto E_e^{-(\beta_s^e+1)}}$$

β_s^e ?

ACCELERATOR = MAGNETIC RACKET

$$\left.\frac{dn^s}{d\gamma}\right|_p = \left.\frac{dn^s}{d\gamma}\right|_e \propto \gamma^{-\beta^s}$$

$\gamma = E/m$

$$\Rightarrow \boxed{\beta_e^s = \beta_p^s}$$

β_s^p ?

$$\beta_p^{OBS} \sim 2.7 \quad E_p < E_{KNEE}^p$$

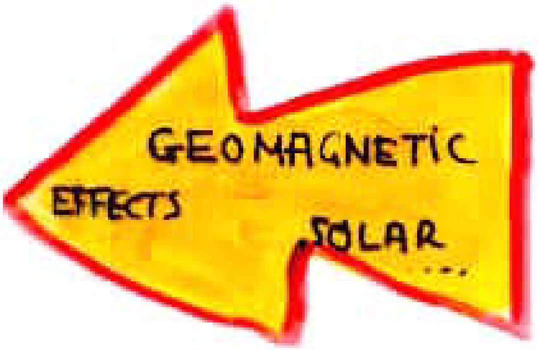
$$\frac{dn_p^{OBS}}{dE_p} \propto \frac{dn_p^s}{dE_p}\, \tau_{ACCUMUL}^{GALAXY}(E)$$

$E^{-2.7} \rightarrow E^{-2.2} \leftarrow E^{-0.6}$ ≈ → { C.R. COMPOS, ⊙ SHOCKS, SIMULATNS.

$$\boxed{\beta_e^{OBS} = \beta_p^s + 1 = 3.2}$$

$\tau_{ICS}^{SLOWDOWN} < \tau_{ACCUMUL.}^{GALAXY}$ above $E_e \sim$ few GeV

SHAPE OF dF_e/dE_e



$\beta = 3.2$

$\gamma_e = \gamma_p^{\kappa}$

e's

KNEE

$\Delta\beta \sim \frac{1}{4}$

10GeV

1TeV

"DIFFUSE" GRB

GAMMA RAY BACKGROUND

γ RAYS 30 MeV → 100 GeV

"DIFFUSE" GR "BACKGROUND":

OBSERVATION MINUS { POINT SOURCES, GALACTIC DISK EMISSION }

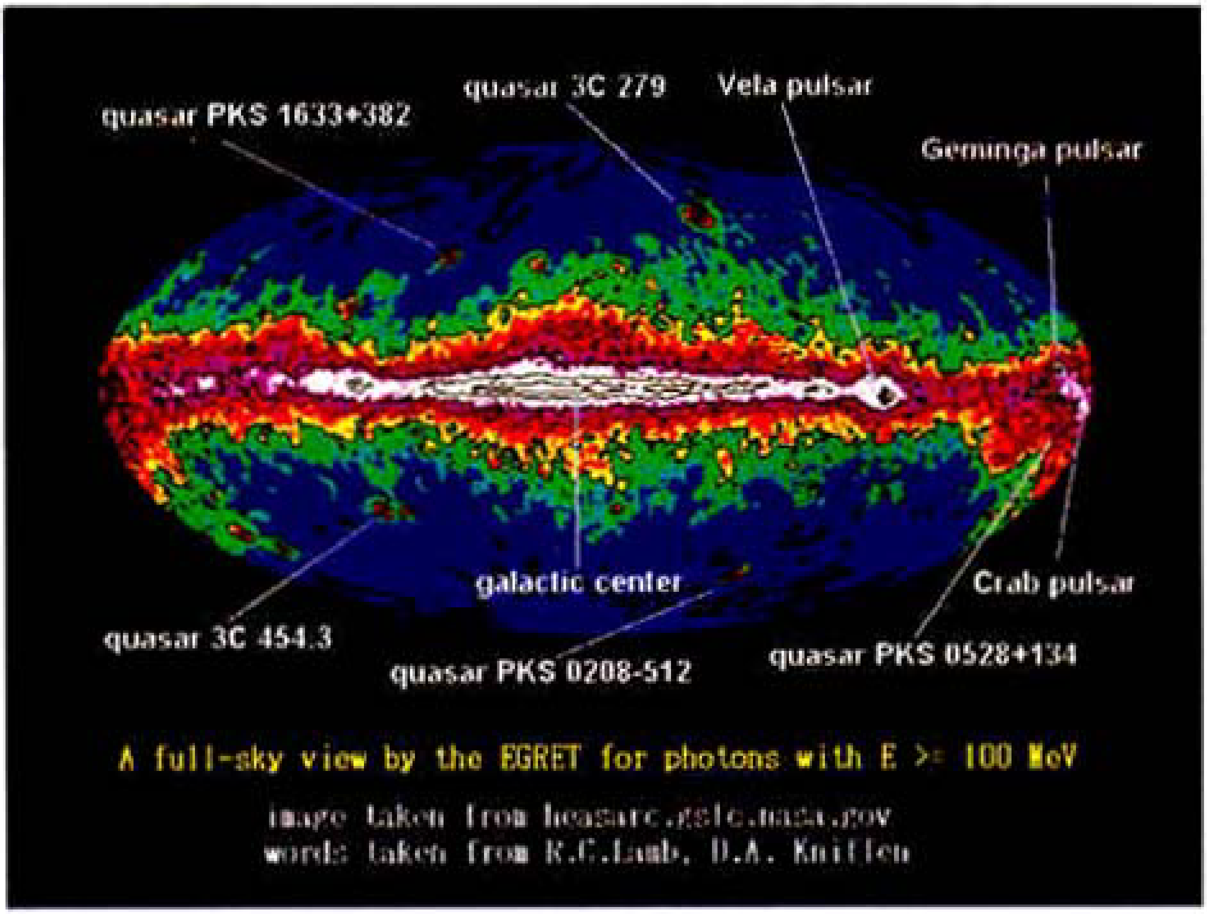
GRB is ISOTROPIC

± 20% OBSERV. ERROR

{ DISCOVERED BY SAS-2, MEASURED BY EGRET }

[E CGRO SATELLITE]

C: COMPTON, G: GAMMA, R: RAY, O: OBSERV.


quasar PKS 1633+382
quasar 3C 279
Vela pulsar
Geminga pulsar
galactic center
Crab pulsar
quasar 3C 454.3
quasar PKS 0208-512
quasar PKS 0528+134
A full-sky view by the EGRET for photons with E >= 100 MeV
image taken from heasarc.gsfc.nasa.gov
words taken from R.C.Lamb, D.A. Kniffen

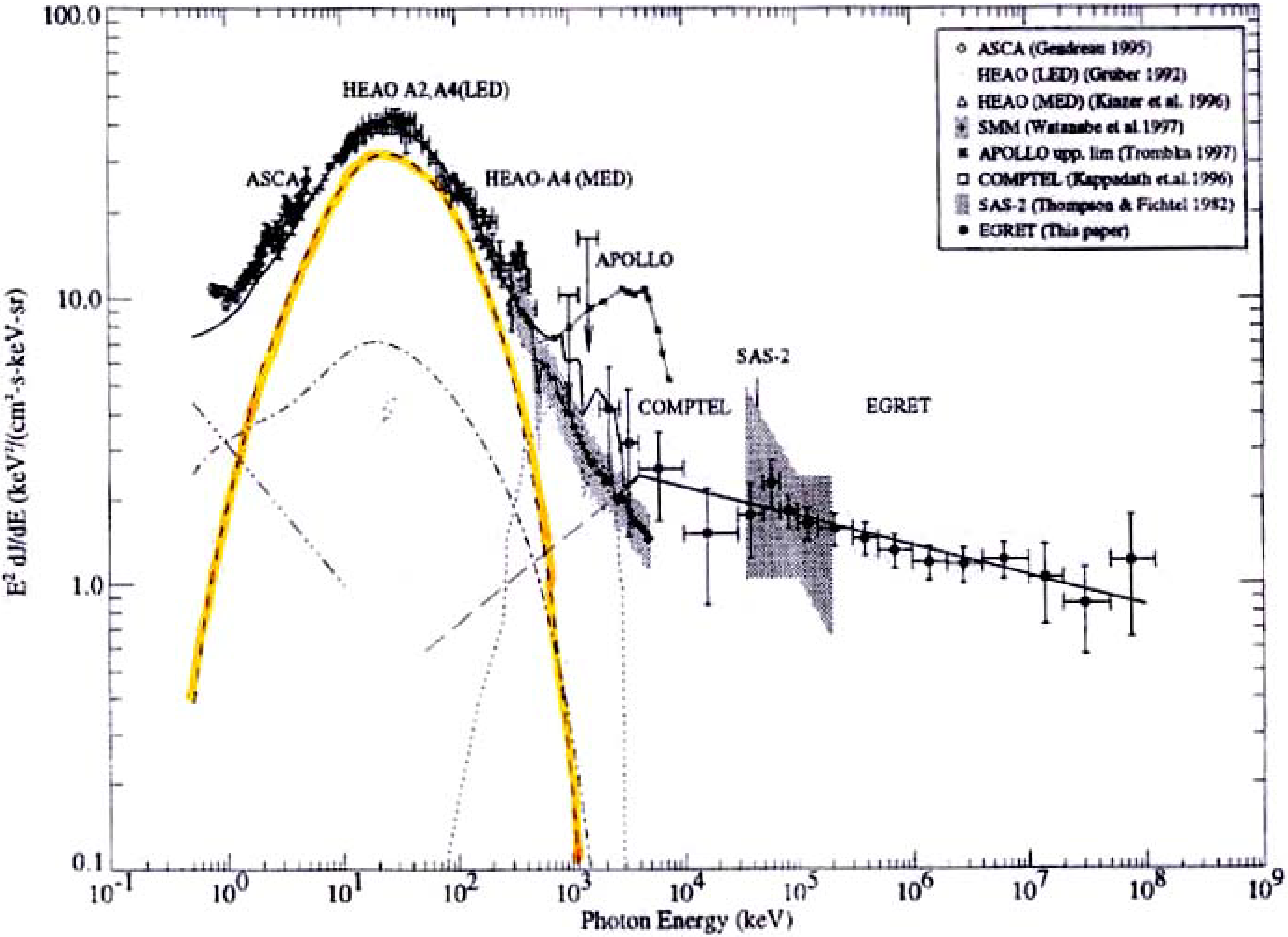
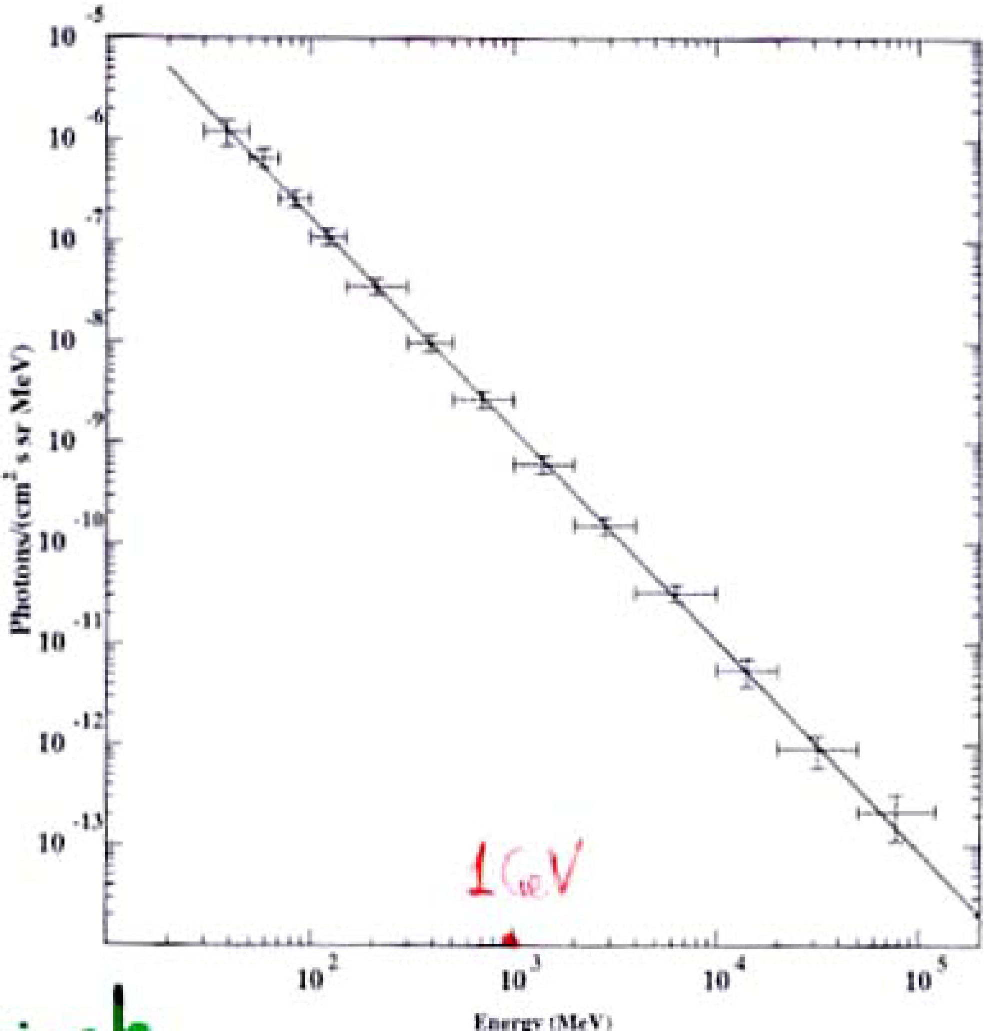


FIG. 10.—Multiwavelength spectrum of the extragalactic gamma-ray spectrum from X-rays to high-energy gamma rays. The estimated contribution from Seyfert I (*dot-dashed line*), and Seyfert II (*dashed*) are from the model of Zdziarski (1996); steep-spectrum quasar contribution (*triple-dot-dashed line*) is taken from Chen, Fabian, & Gendreau (1997); Type Ia supernovae (*dotted line*) is from The et al. (1993). The blazar contribution below 4 MeV (*long-dashed line*) is derived assuming the average blazar spectrum breaks around 4 MeV (McNaron-Brown et al. 1995) to a power law with an index of ~ −1.7. The thick solid line indicates the sum of all the components.

TOTALLY MYSTERIOUS

PRESUMED EXTRAGALACTIC

SREEKUMAR et al.



Fit h_e:

$$(2.74 \pm 0.11) \left[\frac{E_\gamma}{MeV}\right]^{-2.10 \pm 0.03}$$

$$10^{-3}\ cm^{-2} s^{-1} sr^{-1} MeV^{-1}$$

FORMULAE AND DRAWINGS AS IF

HALO WAS A SPHERE WITH

CONSTANT n_e INSIDE, 0 OUTSIDE

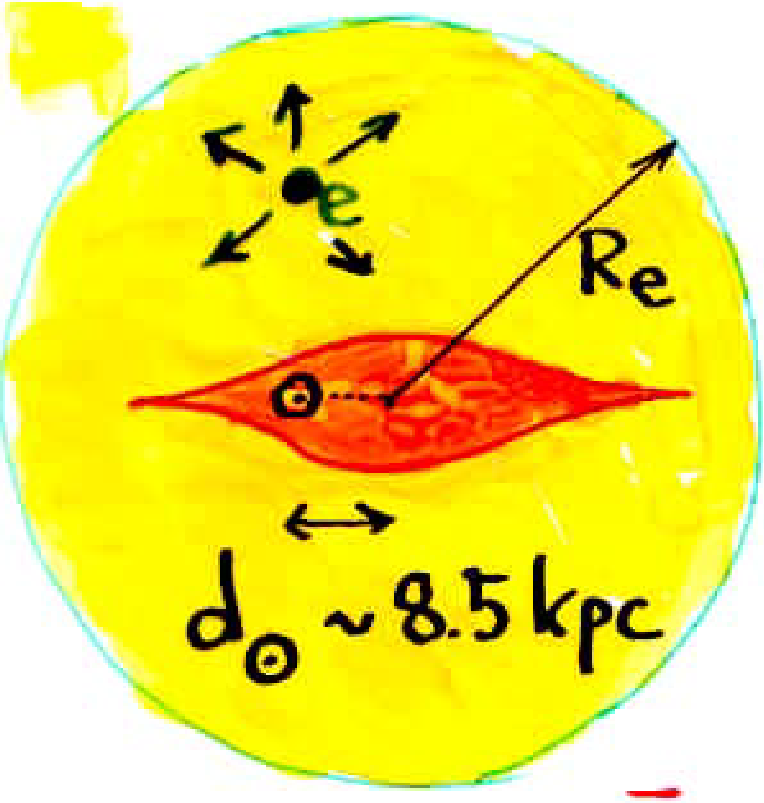
ACTUAL CALCULATIONS FOR A

GAUSSIAN n_e DISTRIB, CYLINDR. SYMM.

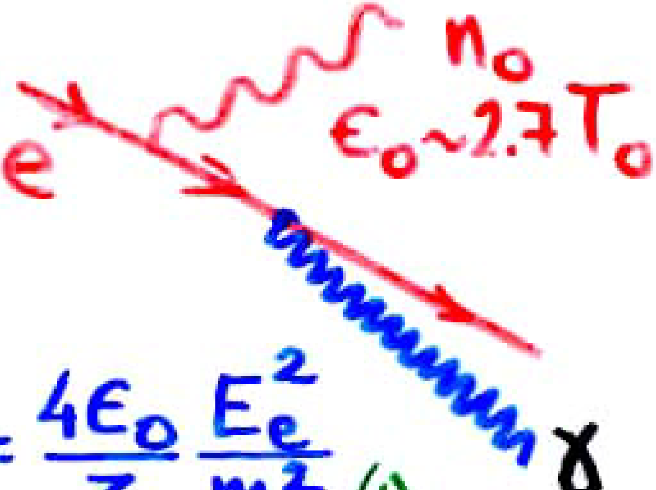
$\rho_e = 35$ kpc (RESULTS VERY INSENSITIVE)

$h_e = 20$ kpc (FIT TO GBR INTENSITY)

$\lesssim$ TWICE U.L. of STRONG MOSKALENKO



$$R_e \equiv \int \frac{dr}{n_e(0)} \frac{dn_e(r)}{dr}$$



AVERAGE $\bar{E}_\gamma = \frac{4\epsilon_0}{3} \frac{E_e^2}{m_e^2}$ (1)

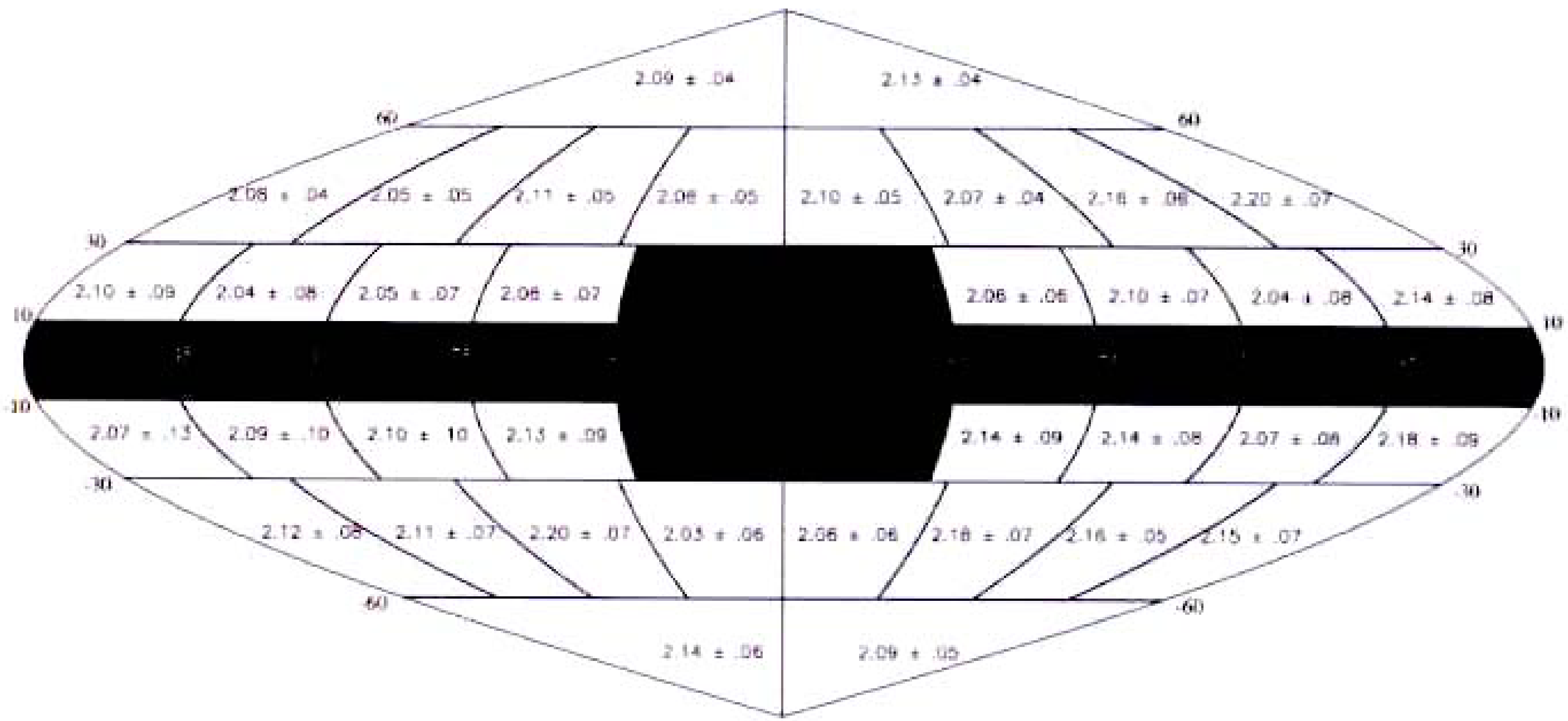
$$\frac{dF_e}{dE_e} \Rightarrow \frac{dF_\gamma}{dE_\gamma}[\vec{r}\,] \quad ; \text{at } |\vec{r}\,| = d_\odot \ll R_\odot$$

$$\frac{dF_\gamma}{dE_\gamma} \sim \frac{n_0 \sigma_T R_e}{2E_\gamma}\left[E_e \frac{dF_e}{dE_e}\right]$$

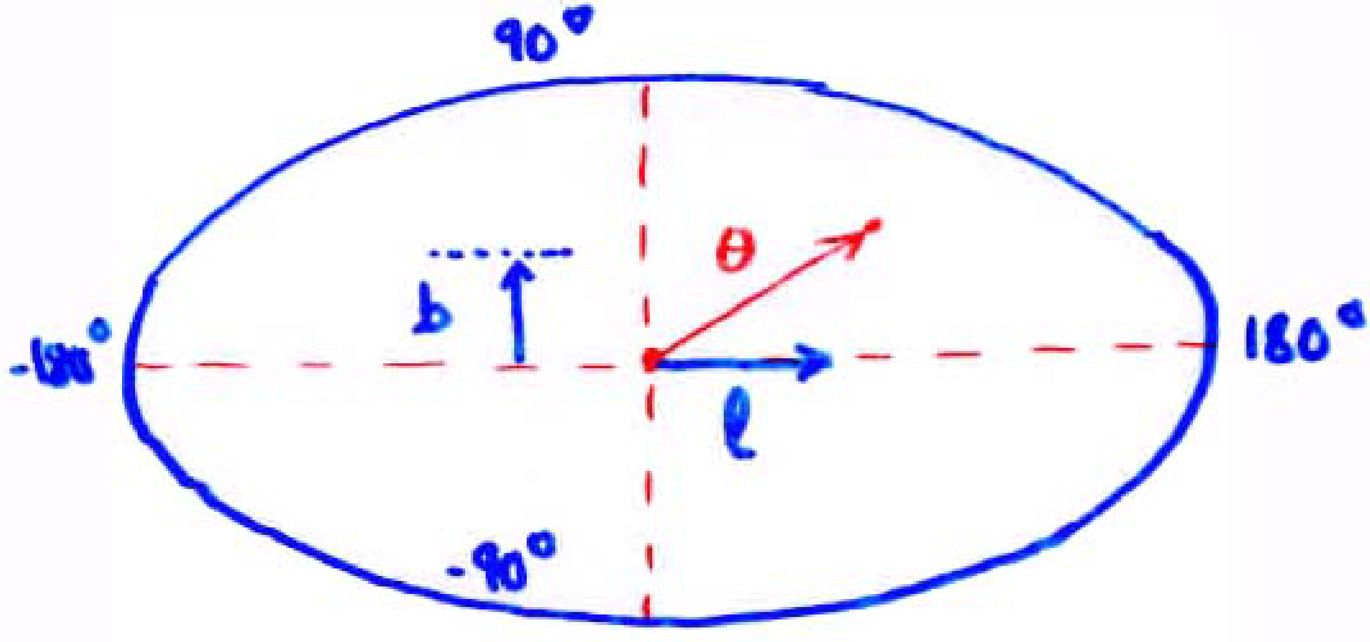
INVERT (1)
↓
$E_e = E_e(\bar{E}_\gamma)$

ELECTRON SPECTRUM OBSERVED ON EARTH

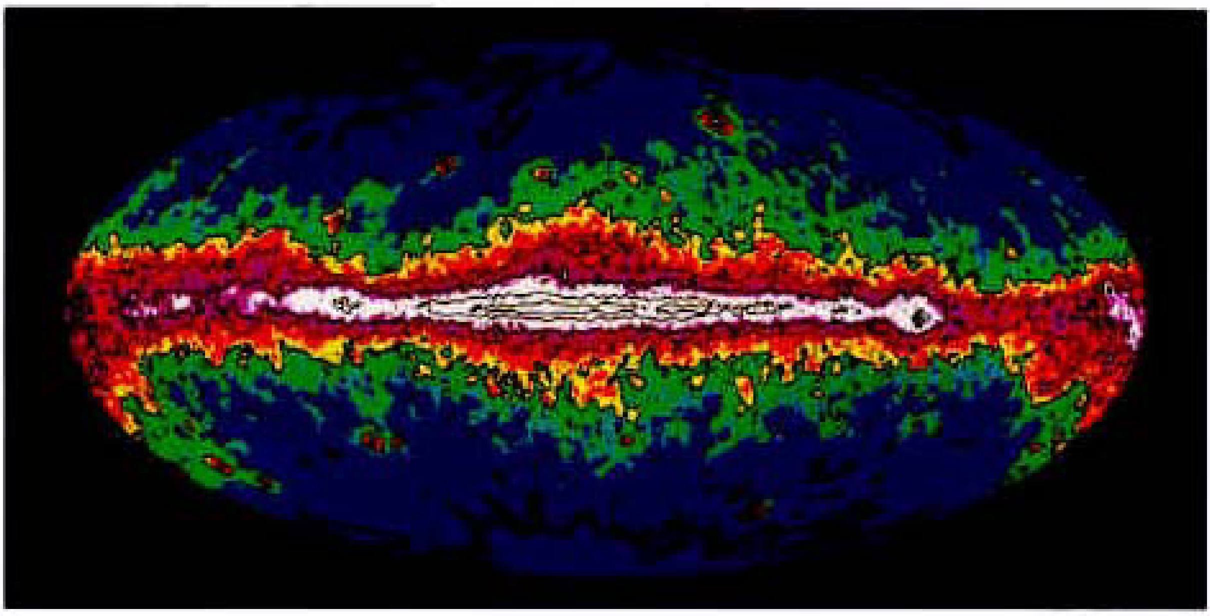
$$\sim (2.4 \pm 0.5)\, 10^{-3} \left[\frac{R_e}{50\,\mathrm{kpc}}\right] * \left[\frac{E_\gamma}{\mathrm{MeV}}\right]^{-2.10 \pm 0.05} \mathrm{cm^{-2}\,s^{-1}\,sr^{-1}\,MeV^{-1}}$$



2.09 ± .04
2.13 ± .04
60
60
2.08 ± .04
2.05 ± .05
2.11 ± .05
2.08 ± .05
2.10 ± .05
2.07 ± .04
2.16 ± .08
2.20 ± .07
30
30
2.10 ± .09
2.04 ± .08
2.05 ± .07
2.06 ± .07
2.06 ± .06
2.10 ± .07
2.04 ± .08
2.14 ± .08
10
10
-10
-10
2.07 ± .13
2.09 ± .10
2.10 ± .10
2.13 ± .09
2.14 ± .09
2.14 ± .08
2.07 ± .08
2.18 ± .09
-30
-30
2.12 ± .08
2.11 ± .07
2.20 ± .07
2.03 ± .06
2.06 ± .06
2.18 ± .07
2.16 ± .05
2.15 ± .07
-60
-60
2.14 ± .06
2.09 ± .05



90°
-180°
180°
-90°
b
θ
ℓ



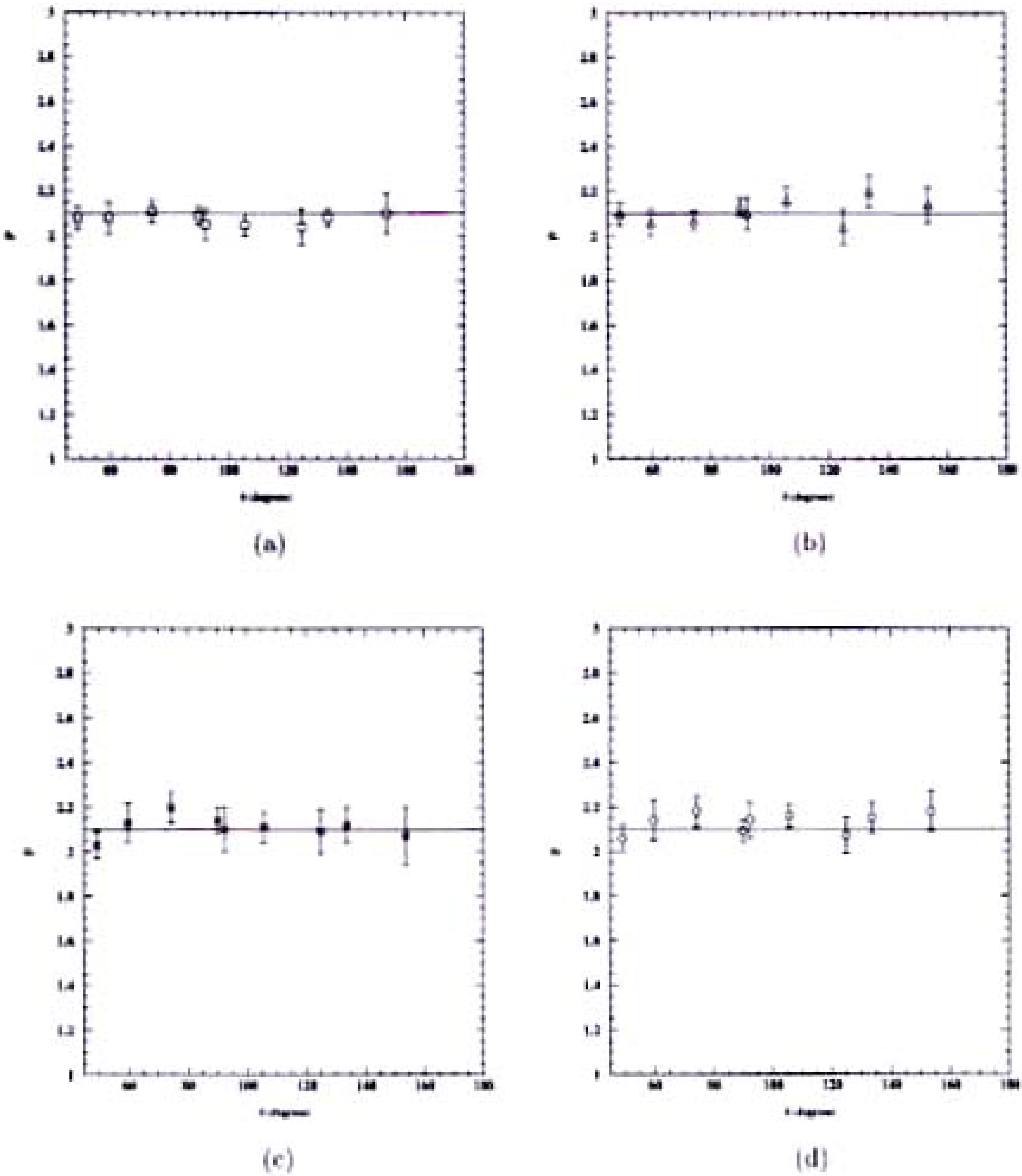


Figure 3: EGRET data on the GBR spectral index as a function of θ: the angle away from the direction of the galactic center. The line is the predicted spectral index. The various plots correspond to the individual half-hemispheres. (a) $b > 0$, $l > 0$. (b) $b > 0, l < 0$. (c) $b < 0, l > 0$. (d) $b < 0, l < 0$.

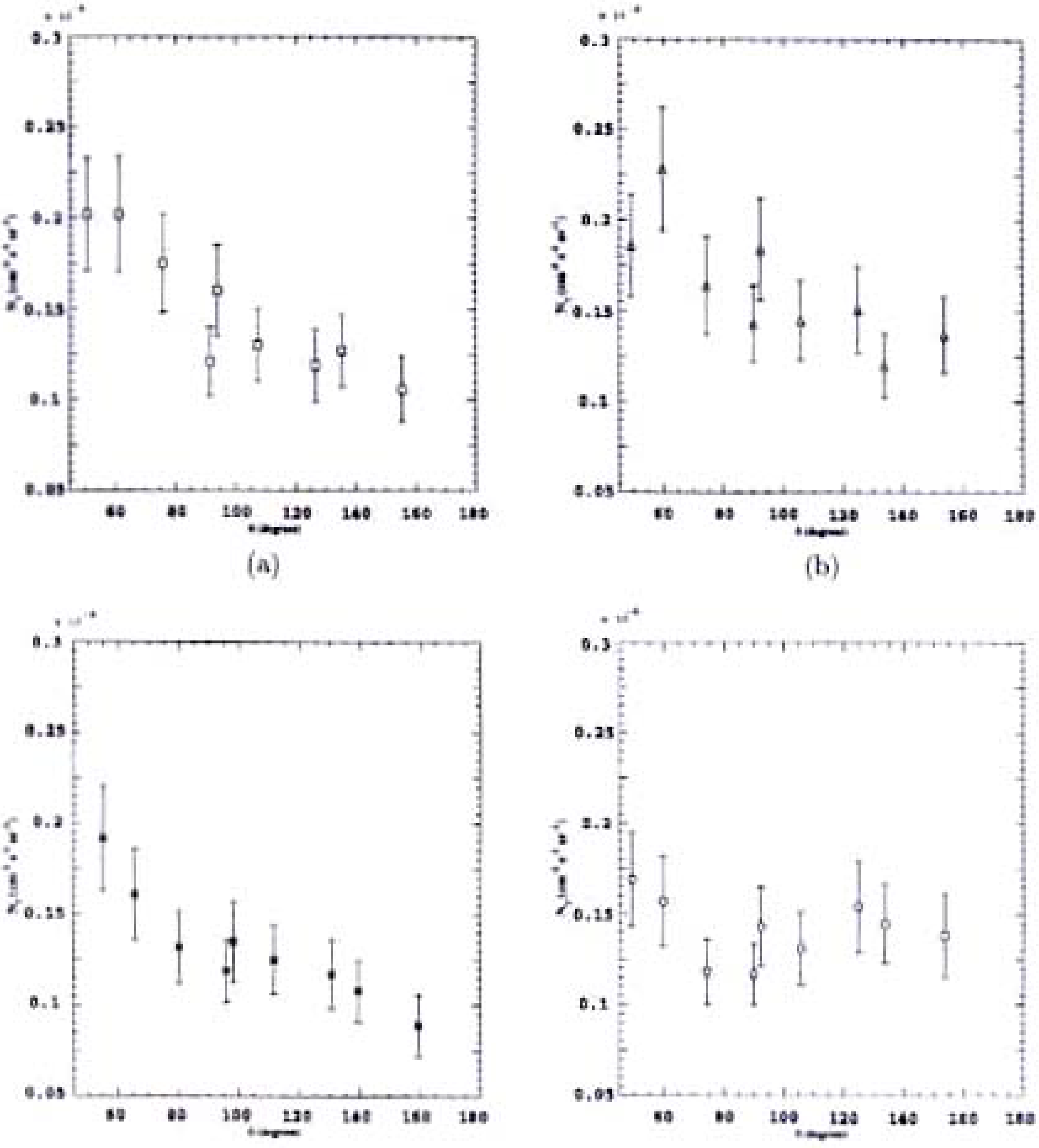
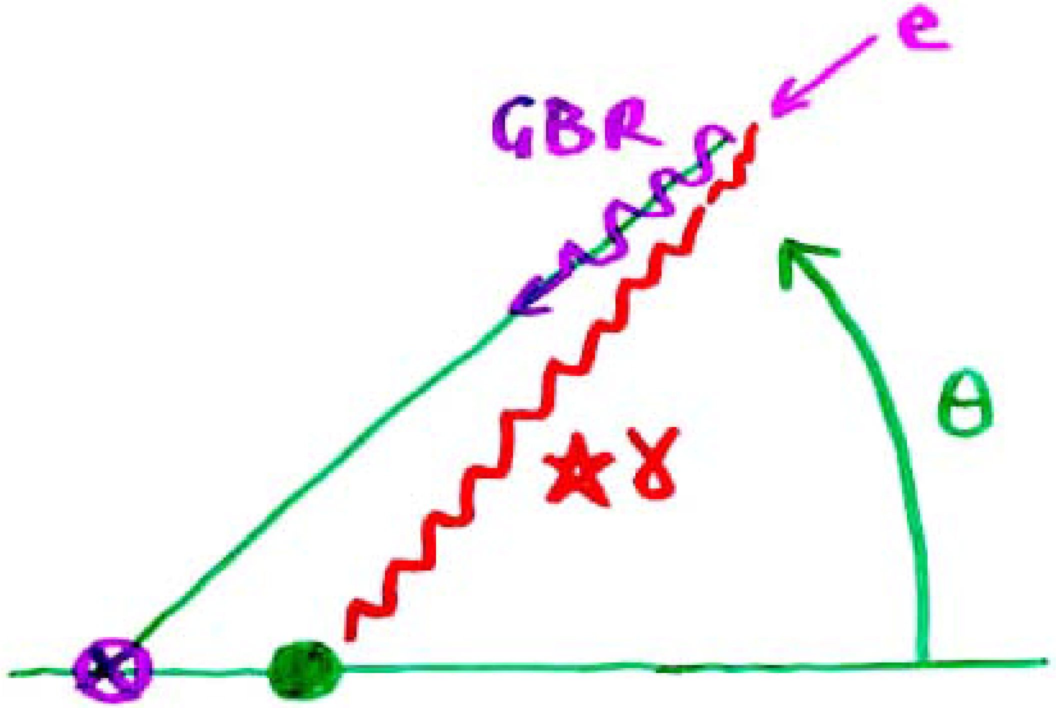


Figure 4: EGRET data, organized as in Fig. 3, for the dependence on θ of the GBR intensity above 100 MeV (10^4 times the number of photons/[cm^2 s sr]).



LOW θ MASKED

$\Sigma L_\star$ AT CENTRE

$$\frac{dF^{\gamma}_{MW}}{dE_{\gamma}} \left[42\%\,\text{CBR} + 40\%\,\star\gamma + 13\%\,{}_{\odot} + 5\%\right]$$

ALL OTHER GALAXIES

$\beta = 2.1$

γ KNEE

$\propto E^{-\beta}$

$\Delta\beta \sim \frac{1}{8}$

10 GeV

$$h_e \simeq 20\,\text{kpc} \pm 50\%$$

EXTRAGALACTIC GRB FLUX

Σ all other galaxies

y = Cosmotime

$y = \frac{T}{T_0} = \frac{R_0}{R}$

- $y = 1+z \qquad \frac{dy}{dt} = -H_0\, y\, f(y)$
- $H_0 = 100 \frac{km}{s\,Mpc}\, h \qquad f(y) = \left[(1-\Omega)y^2 + \Omega_m y^3 + \Omega_\Lambda\right]^{1/2}$
- $L_\star^{MW} \simeq 2.3\; 10^{10}\, L_\odot$
- $\rho_L^\star \simeq 1.8\; 10^8\, h\, L_\odot / Mpc^3$ LOCAL ★ LIGHT DENSITY
- $\rho_L^\star / L_\star^{MW} \sim \langle n[\text{MW-EQUIV}]\ \text{GALAXIES} \rangle$
- $R_{SFR}(y)$ STAR-FORMATION RATE
- ICS REDSHIFT E-FACTORS CANCEL

$$\frac{dF_\gamma}{dE_\gamma} = \frac{dF_\gamma^{MW}}{dE_\gamma}\left[1 + \frac{4\pi R_e^2}{3}\,\frac{\rho_L^\star}{L_\star^{MW}}\,\frac{c}{H_0}\int_1 \frac{R_{SFR}(y)}{R_{SFR}(1)}\,\frac{y}{f(y)}\,\frac{dy}{y^3}\right]$$

~12%

SAME ONLY FOR CBR

(★-LIGHT CONTR. REDSHIFT ...

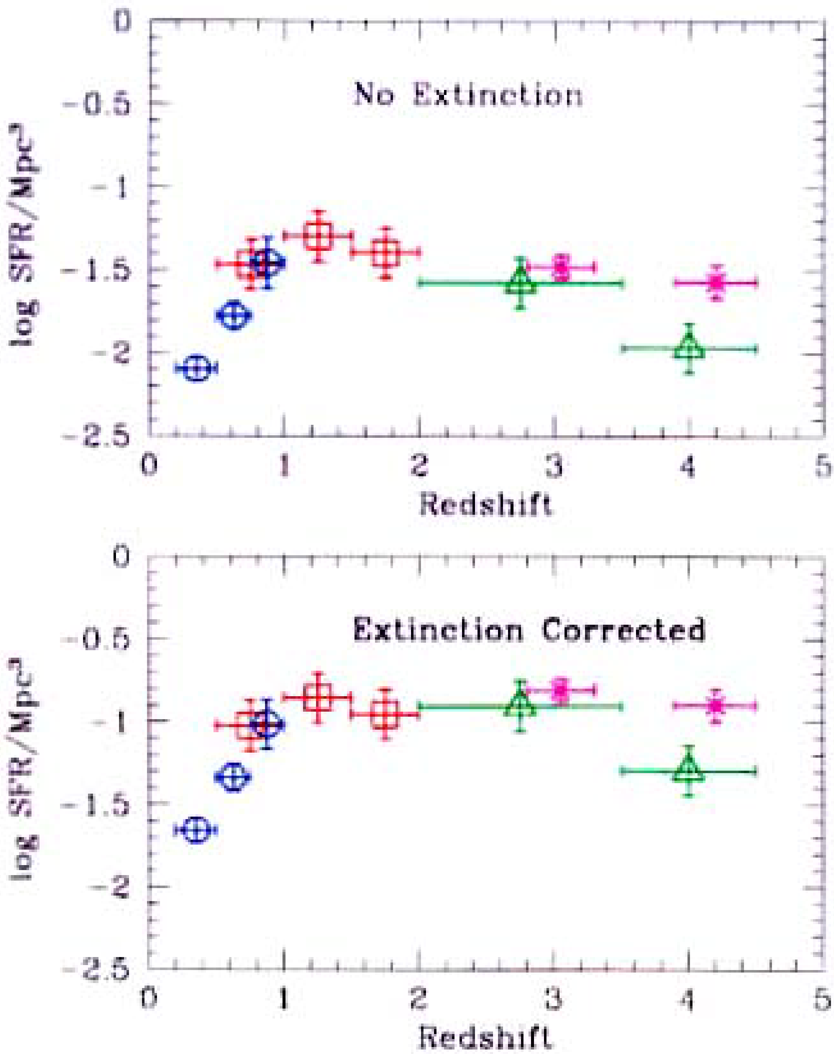
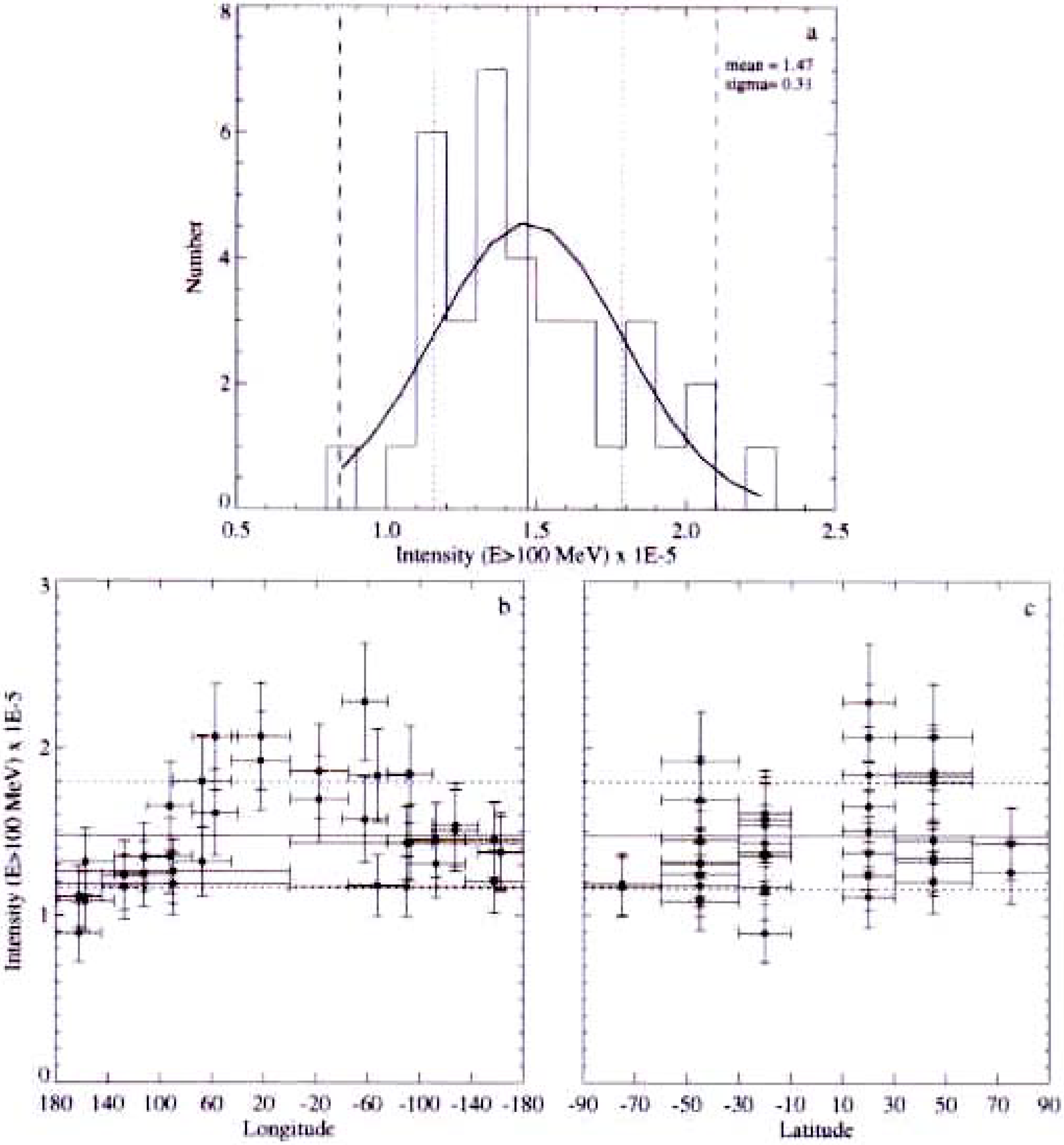
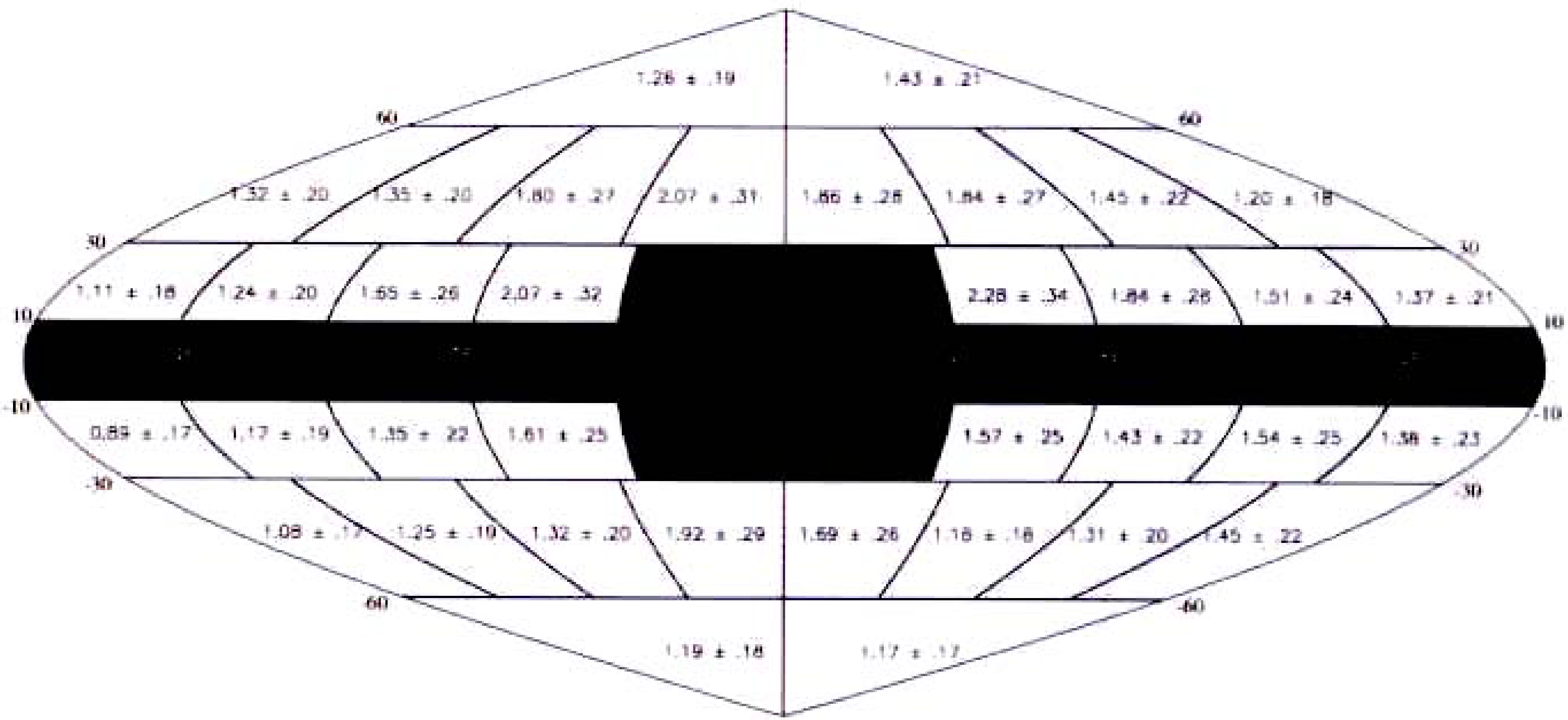
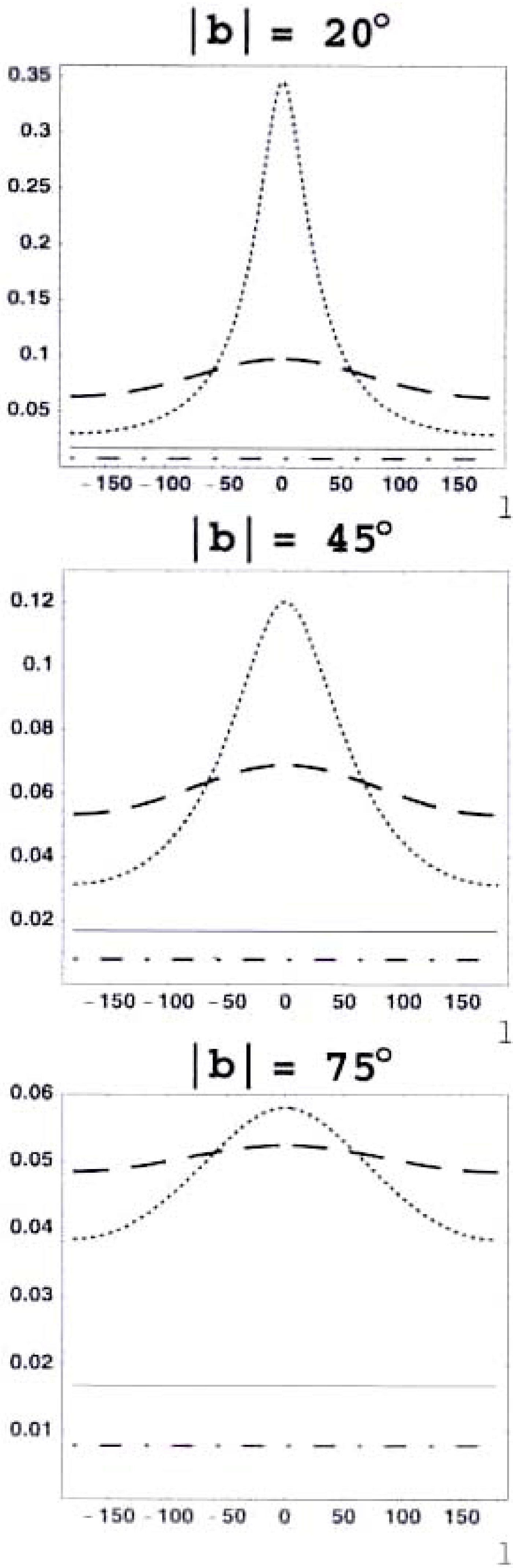


Figure 3: The star formation rate per comoving volume as a function of redshift, for h = 0.5, $\Omega_m = 1$ and $\Omega_\Lambda = 0$, uncorrected or corrected for extinction by Steidel *et al.* [28]. Circles are from Lilly *et al.*, squares from Conolly *et al.*, triangles from Madau *et al.* and crosses from Steidel *et al.*.



a
mean = 1.47
sigma= 0.31
Number
Intensity (E>100 MeV) x 1E-5
b
c
Intensity (E>100 MeV) x 1E-5
Longitude
Latitude


60
60
30
30
10
10
-10
-10
-30
-30
-60
-60
1.26 ± .19
1.43 ± .21
1.32 ± .20
1.35 ± .20
1.80 ± .27
2.07 ± .31
1.86 ± .28
1.84 ± .27
1.45 ± .22
1.20 ± .18
1.11 ± .18
1.24 ± .20
1.65 ± .26
2.07 ± .32
2.28 ± .34
1.84 ± .28
1.51 ± .24
1.37 ± .21
0.89 ± .17
1.17 ± .19
1.35 ± .22
1.61 ± .25
1.57 ± .25
1.43 ± .22
1.54 ± .25
1.38 ± .23
1.08 ± .17
1.25 ± .19
1.32 ± .20
1.92 ± .29
1.69 ± .26
1.18 ± .18
1.31 ± .20
1.45 ± .22
1.19 ± .18
1.17 ± .17


|b| = 20°
0.35
0.3
0.25
0.2
0.15
0.1
0.05
-150 -100 -50 0 50 100 150
l
|b| = 45°
0.12
0.1
0.08
0.06
0.04
0.02
-150 -100 -50 0 50 100 150
l
|b| = 75°
0.06
0.05
0.04
0.03
0.02
0.01
-150 -100 -50 0 50 100 150
l

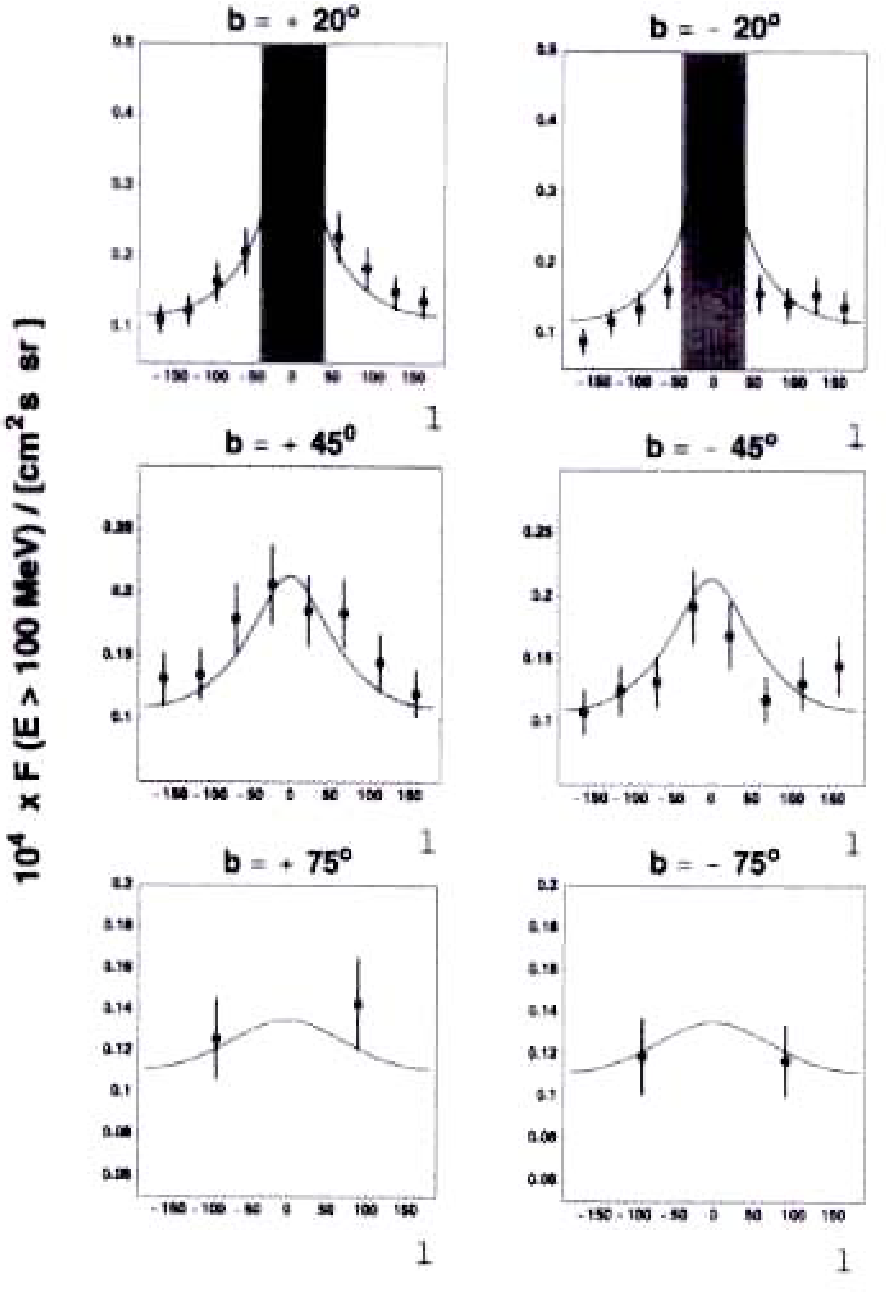


Figure 7: The flux of GBR photons above 100 MeV: comparison between EGRET data and our model for $h_* = 20$ kpc, $\rho_* = 35$ kpc, as functions of latitude at various fixed longitudes. The grey domain is EGRET's mask.

RESULTS

Too Good

FOR SOMETHING

WHICH IS NO DOUBT

AN

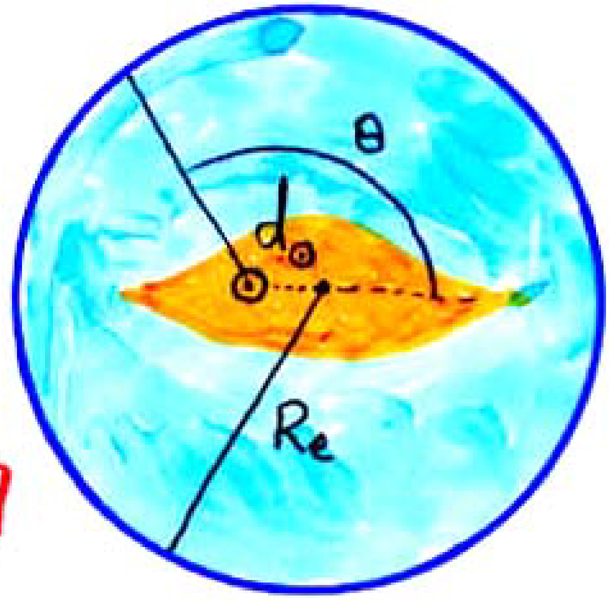
OVER-

SIMPLIFICATION

PREDICTIONS:

- KNEES IN e, γ SPECTRUM (VHE ANKLES) — AMS, GLAST
- ASYMMETRY

$$F_\gamma \propto \frac{d_\odot \cos\theta + \sqrt{R_e^2 - d_\odot \sin^2\theta}}{R_e}$$



OF GRB FLUX
[AFTER ★γ SUBTRACTION]

$$L_{>E} = \frac{16\pi^2 R_e^2}{3} \int E_\gamma \, dF_\gamma$$

$$\simeq (4.7 \pm 1.5)\, 10^{40} \left[\frac{E}{\mathrm{MeV}}\right]^{-0.10 \pm 0.05} \mathrm{ergs/s}$$

$$\otimes\, (R_e / 50\,\mathrm{kpc})^3$$

- IT MAY BE POSSIBLE TO OBSERVE THE γ-RAY GLOW OF ANDROMEDA'S HALO [GLAST ?] AND OTHER CLOSE-BY GALAXIES

THERE MAY BE
A TESTABLE
"STANDARD-
PARTICLE"
EXPLANATIONS
of the
GZK
CONUNDRUM

ALMOST 100 y
AFTER THEY WERE
DISCOVERED
COSMIC RAYS
ARE STILL
PUZZLING