Agile and GLAST gamma-ray experiments for exotic matter research

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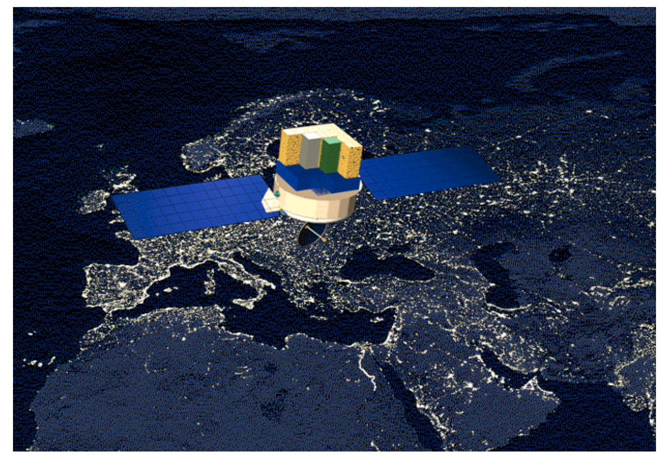
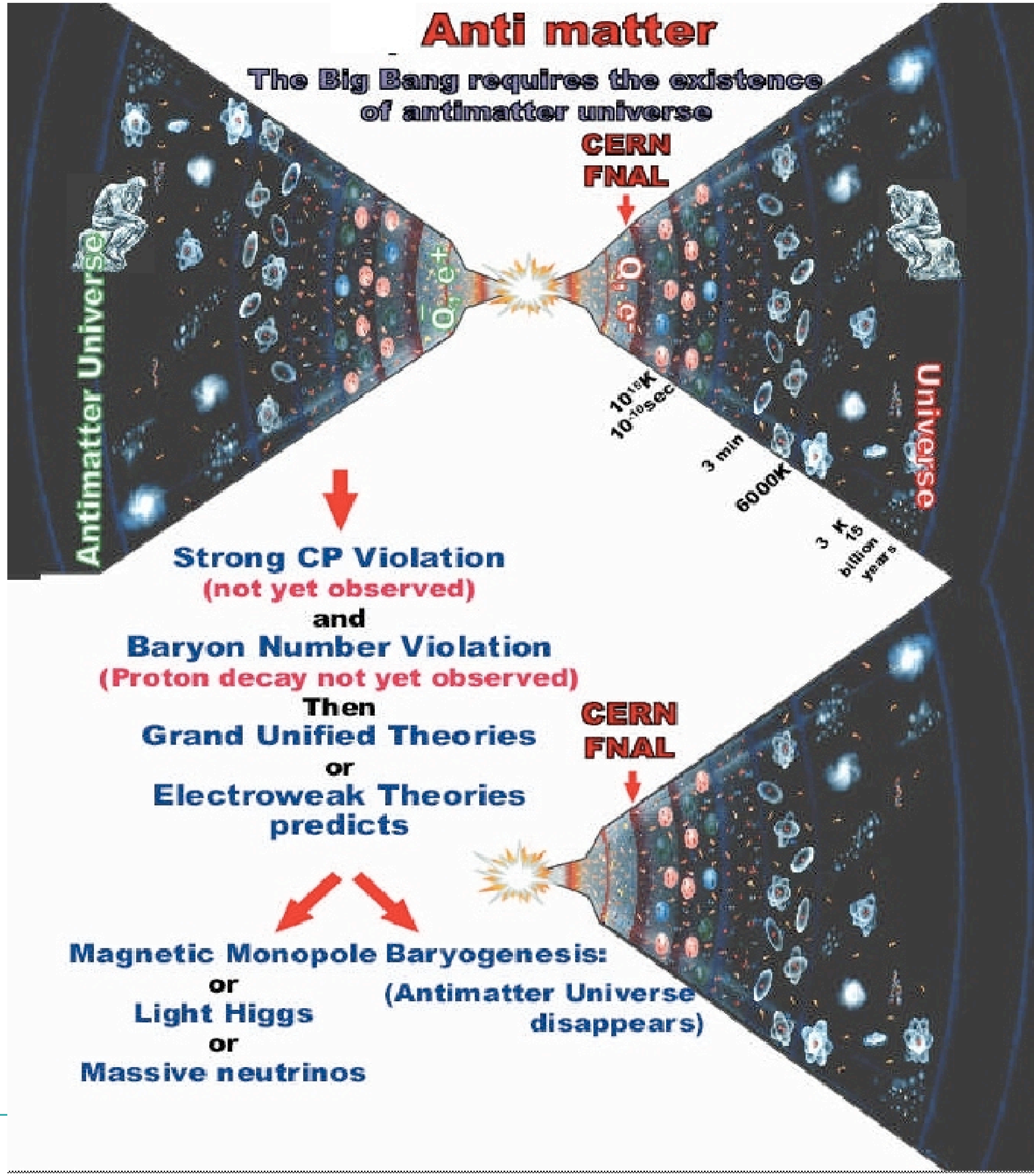


XIVth Rencontres de Blois, Wednesday, June 19


Anti matter
The Big Bang requires the existence of antimatter universe
Antimatter Universe
Universe
CERN FNAL
10^{15}K 10^{-10}sec
3 min
6000K
3 K 15 billion years
Strong CP Violation
(not yet observed)
and
Baryon Number Violation
(Proton decay not yet observed)
Then
Grand Unified Theories
or
Electroweak Theories
predicts
Magnetic Monopole
or
Light Higgs
or
Massive neutrinos
Baryogenesis:
(Antimatter Universe disappears)
CERN FNAL

Observations

Indirect

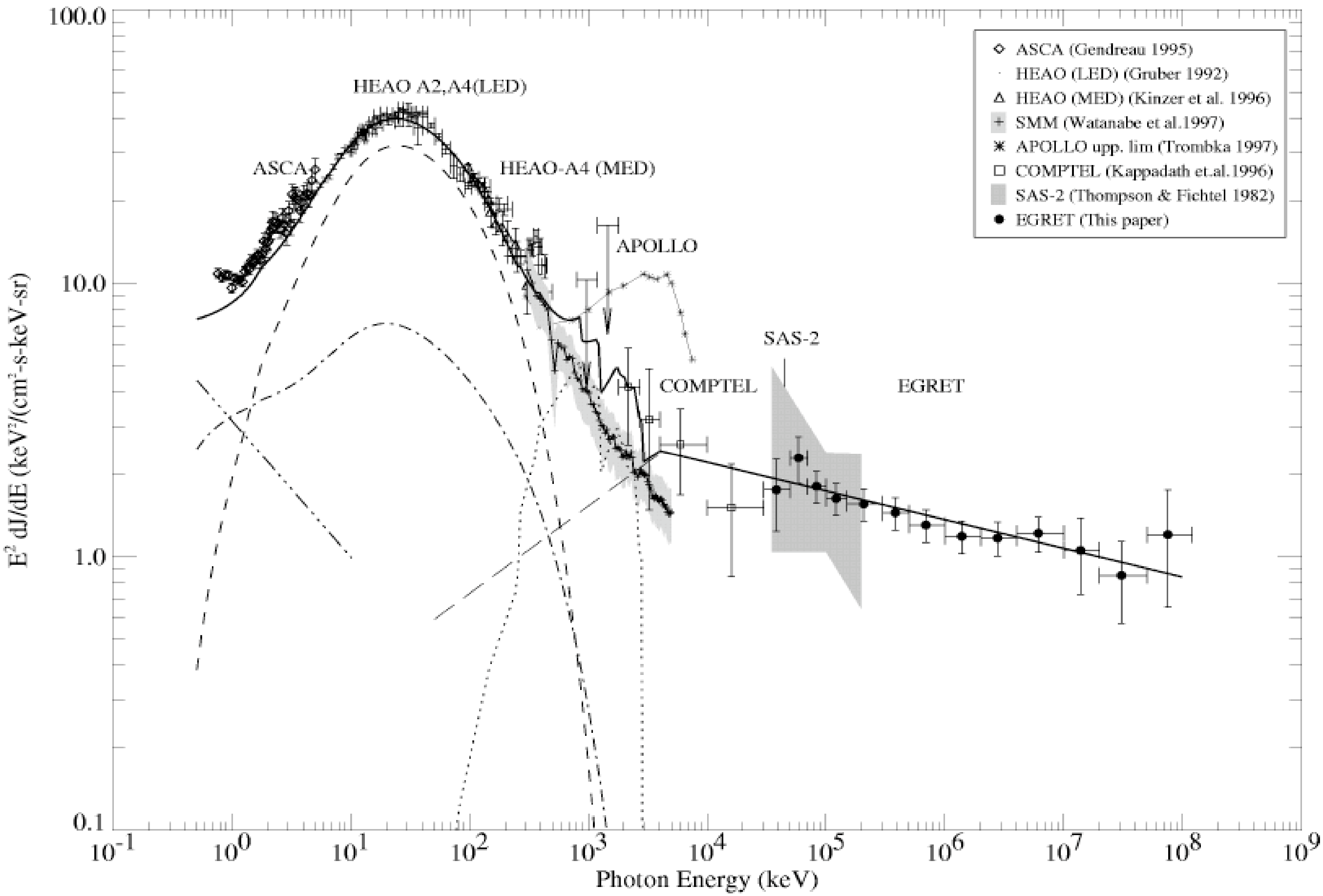
By measuring

- The distortion of the CBR spectrum
- The spectrum of the Cosmic Diffuse Gamma (CDG)

Direct

- By searching for Antinuclei
- By measuring $\bar{p}$ and e^+ energy spectra

Cosmic Diffuse Gamma



P. Sreekumar et al, astroph/9709257

Antimatter/Matter fraction limits

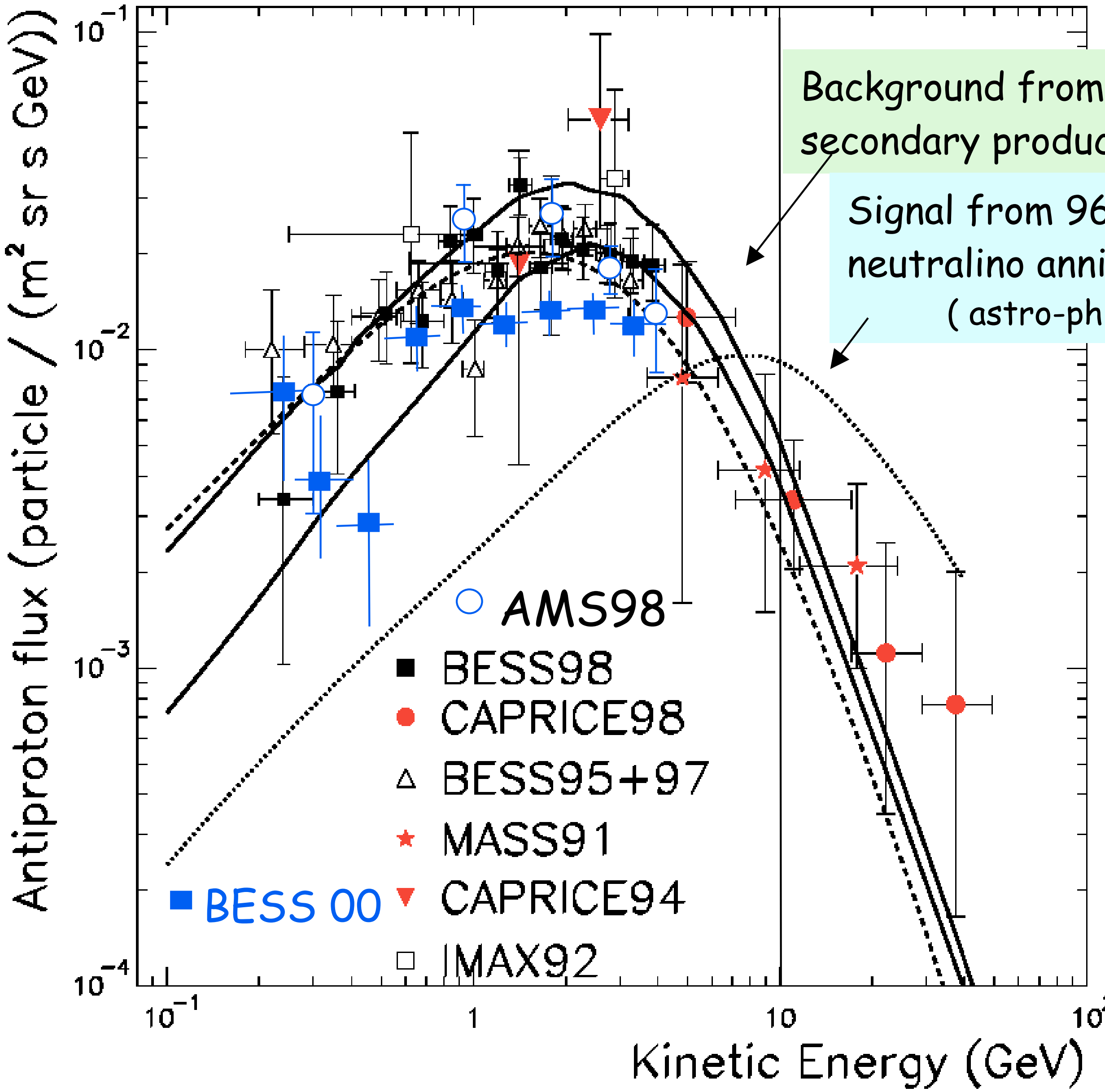
- In Galactic molecular clouds: $f<10^{-15}$
- In Galactic Halo: $f< 10^{-10}$
- In local clusters of galaxies: $f<10^{-5}$

Antimatter must be separated from matter at scales at least as 20 Megaparsec

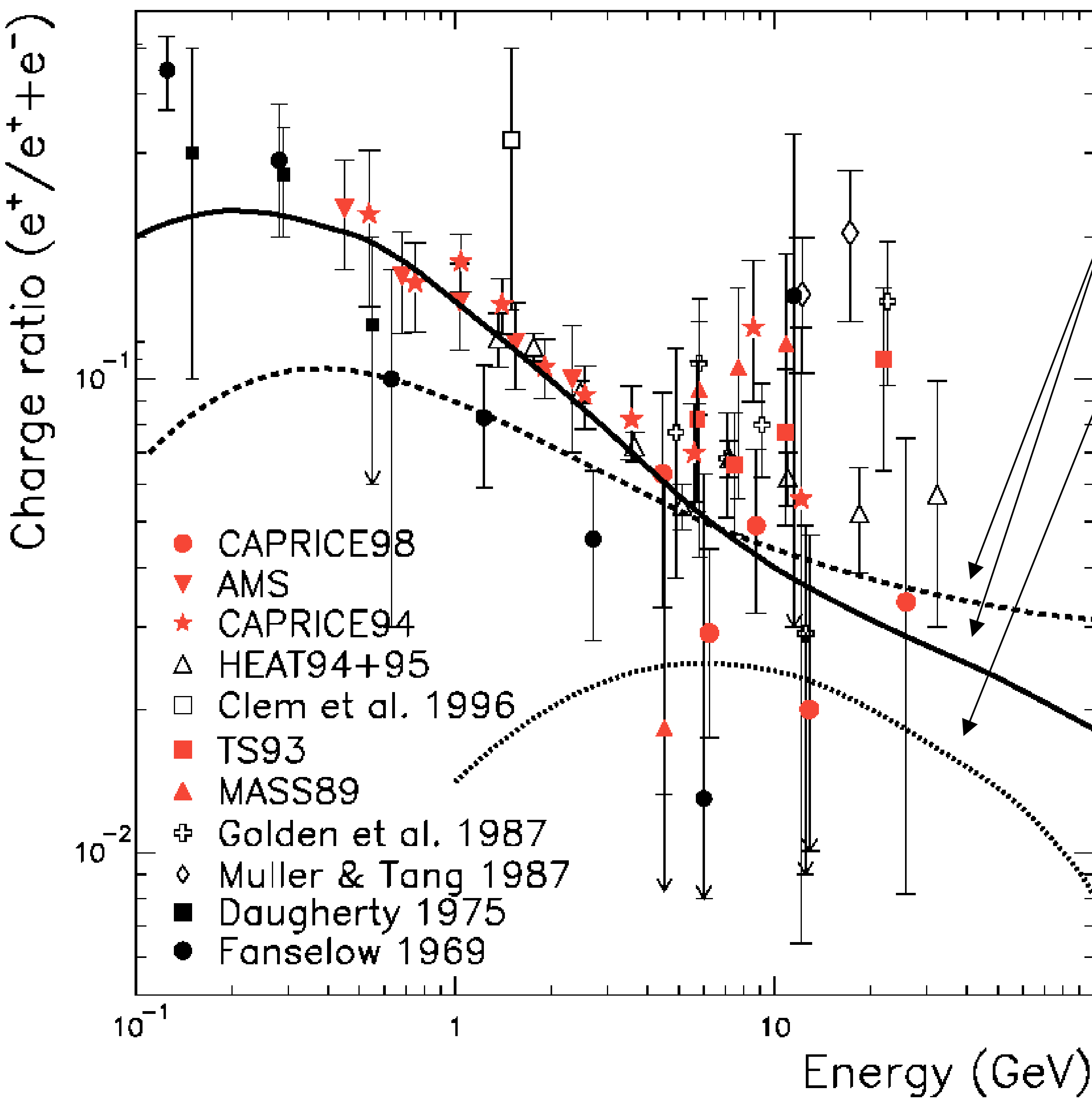
Distortion of the secondary antiproton flux induced by a signal from a heavy Higgsino-like neutralino.

Particles and photons are sensitive to different neutralinos. Gaugino-like particles are more likely to produce an observable flux of antiprotons whereas Higgsino-like annihilations are more likely to produce an observable gamma-ray signature

- ▼ Caprice94 data from ApJ, 487, 415, 1997
- ★ Mass91 data from XXVI ICRC, OG.1.1.21 , 1999
- ● Caprice98 data from ApJ, 561, (2001), 787. astro-ph/0103513
- BESS data from Phys.Rev.Lett, 2000, 84, 1078
- ○ AMS data : preliminary



Positron Ratio

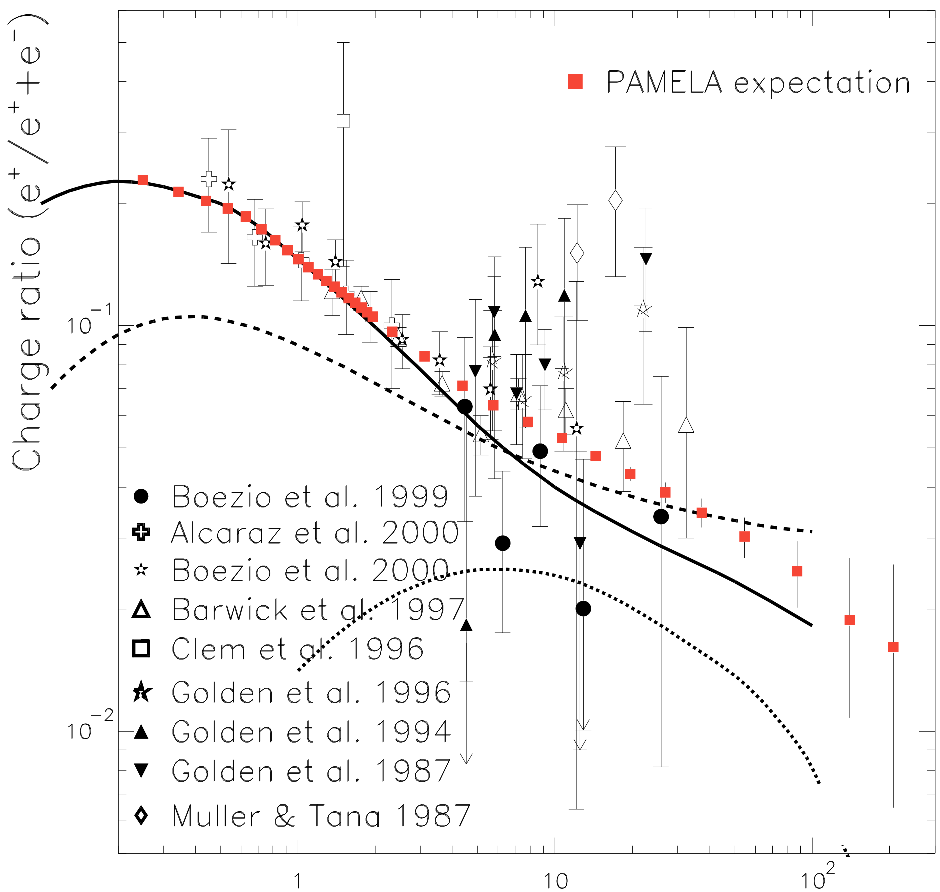


- Background from normal secondary production
  (ApJ 493, 694, 1998)
- Signal from ~ 300 GeV neutralino annihilations
  (Phys.Rev. D59 (1999) astro-ph 98008243)

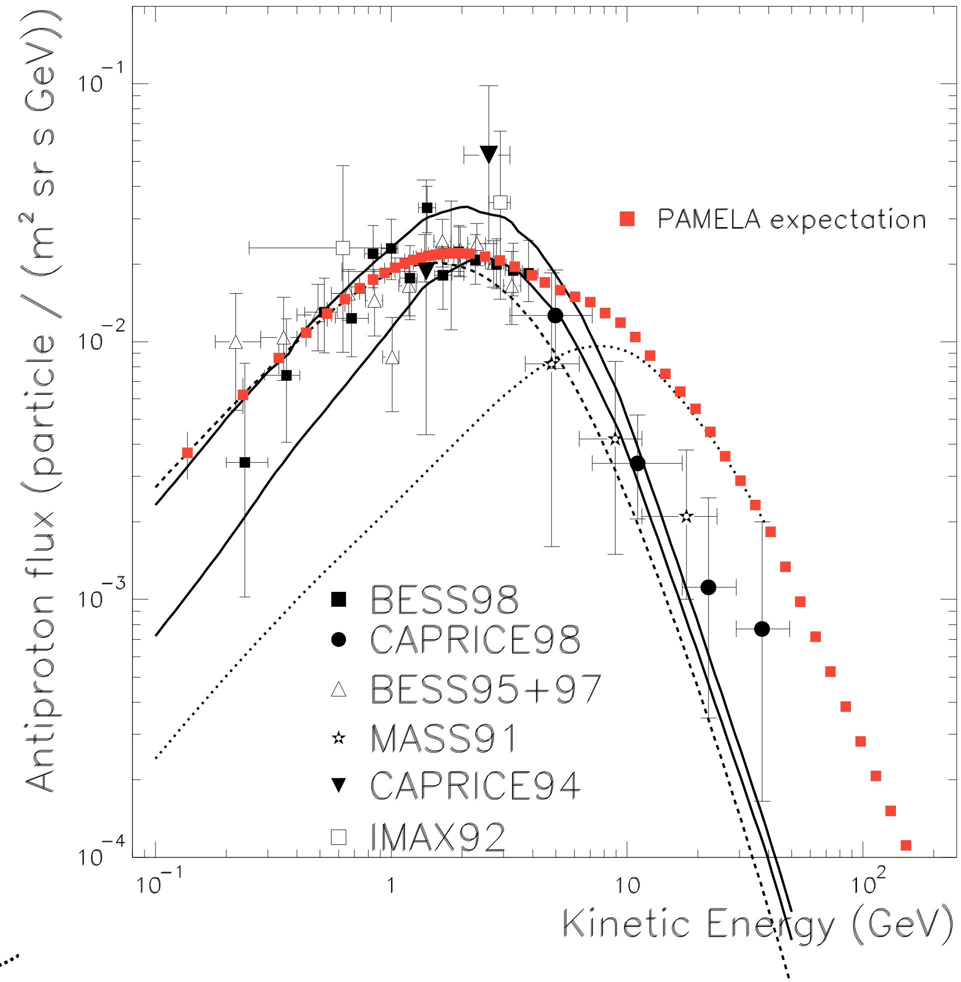
● Caprice98 data from XXVI ICRC, OG.1.1.21, 1999

★ Caprice94 data from ApJ , 532, 653, 2000

Distortion of the secondary positron fraction induced by a signal from a heavy neutralino.

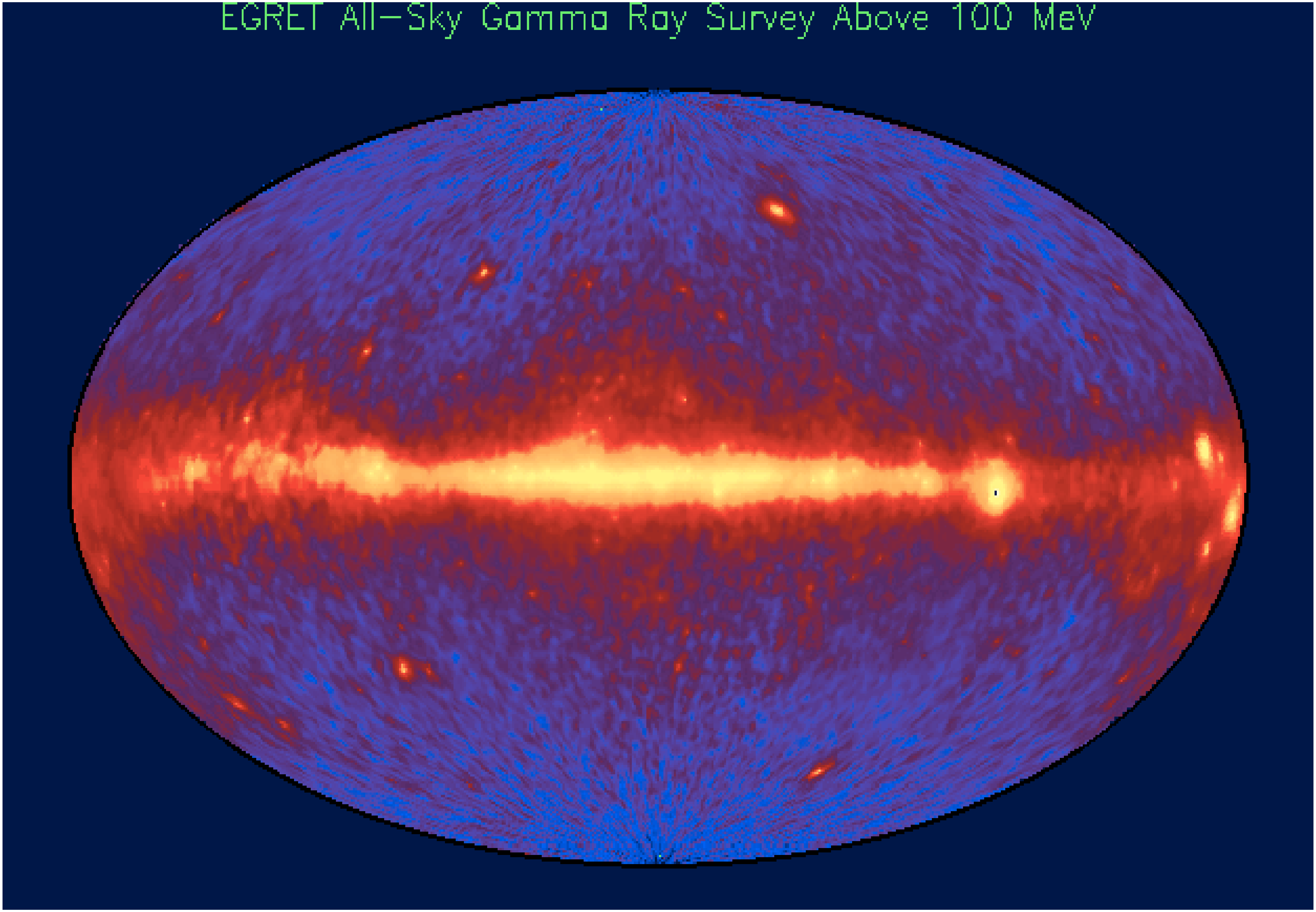


Distortion of the secondary antiproton flux induced by a signal from a heavy Higgsino-like neutralino.

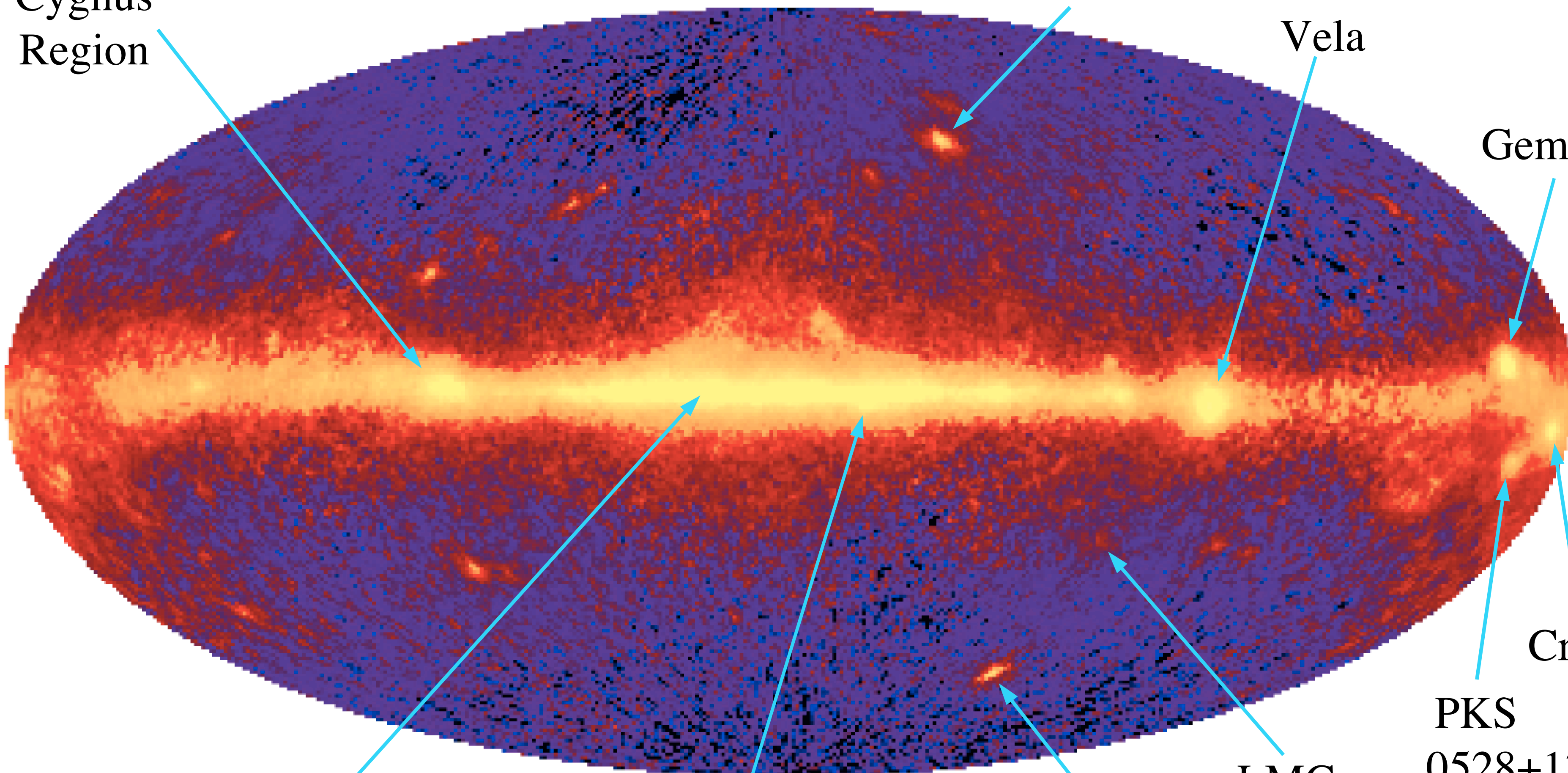


Expected data from **Pamela** for two years of operation are shown in red.

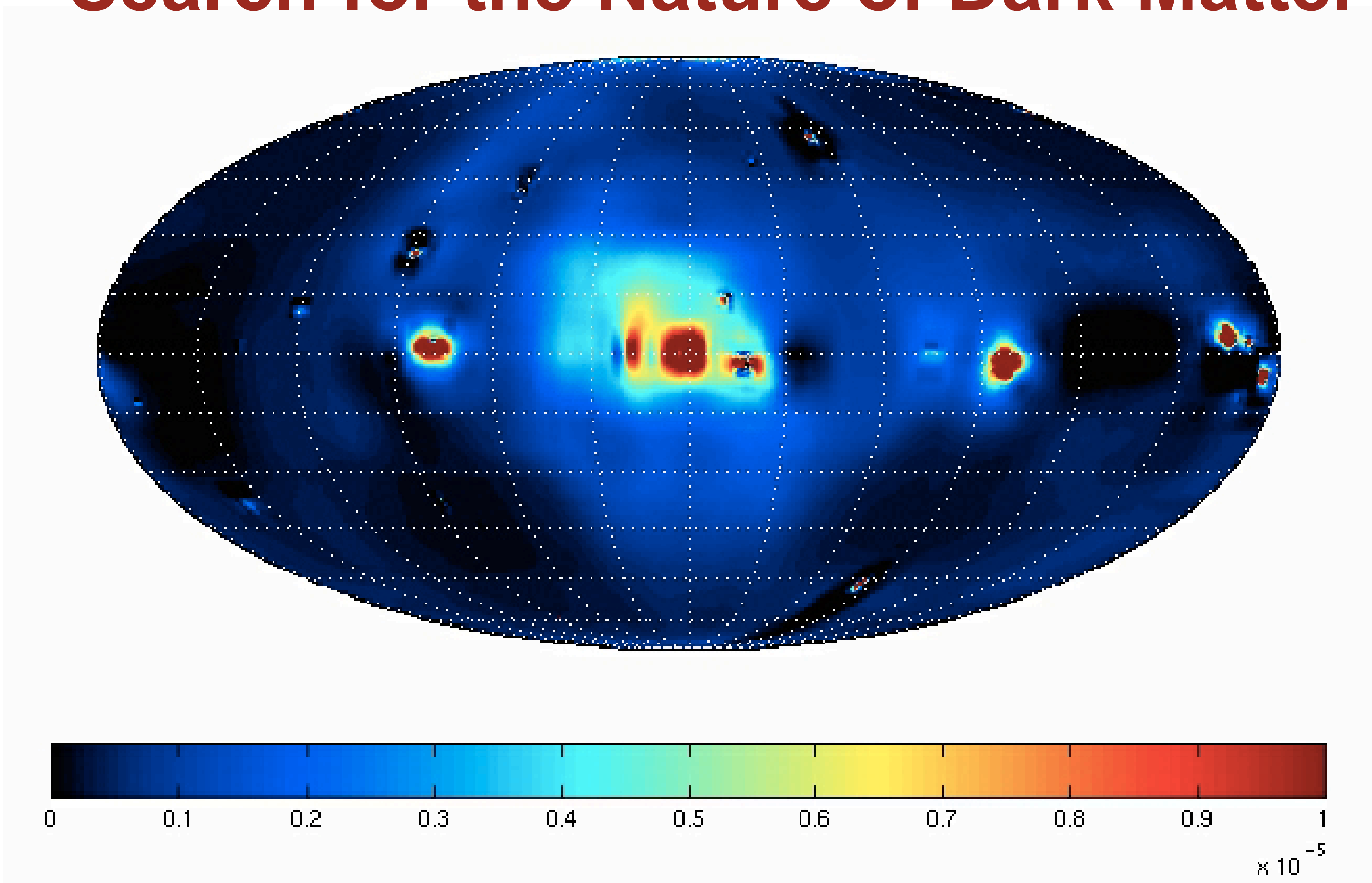
P.Picozza and A.Morselli,astro-ph/0103117


EGRET All-Sky Gamma Ray Survey Above 100 MeV

EGRET All Sky Map (>100 MeV)



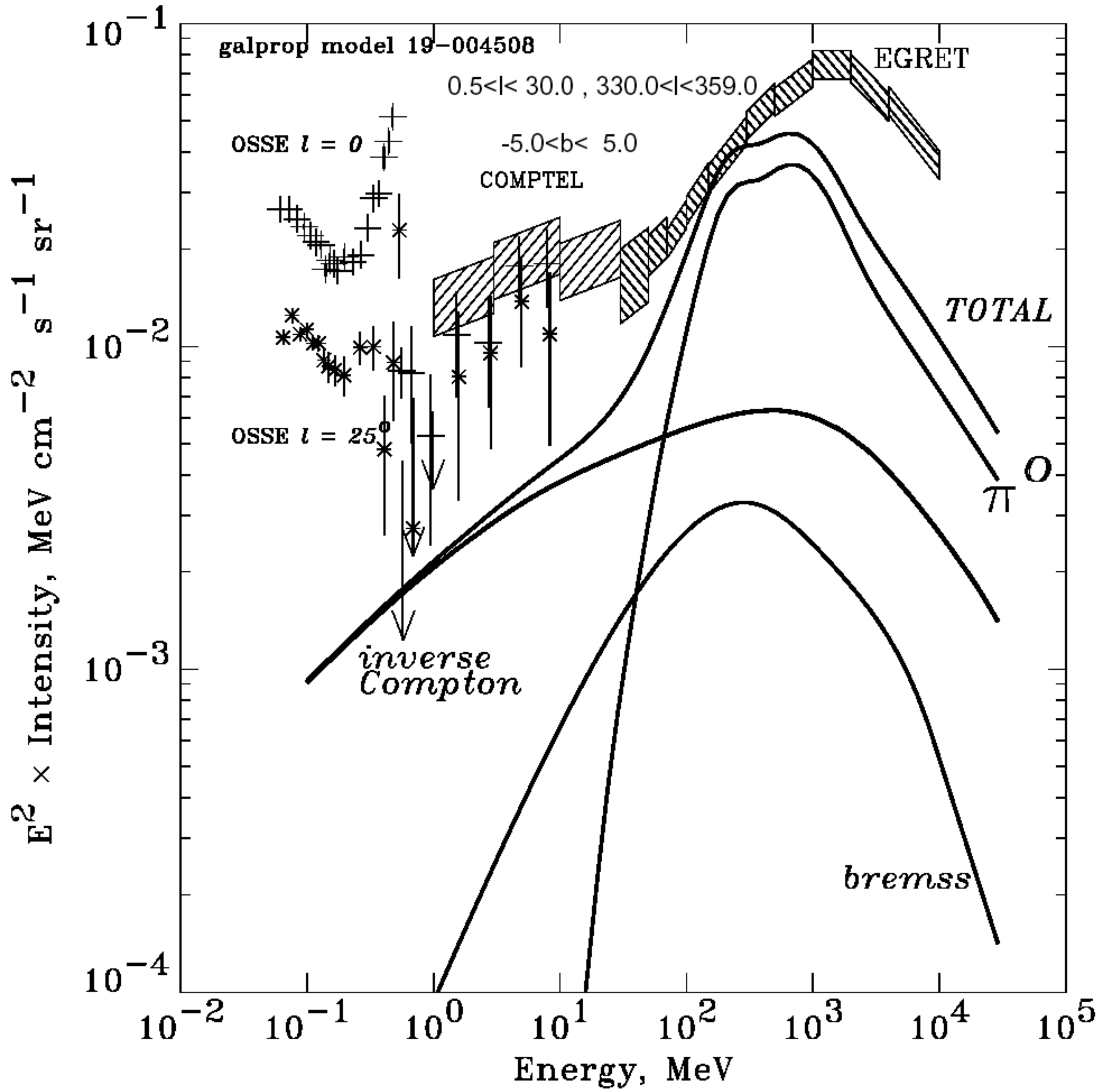
Search for the Nature of Dark Matter



Contours of photons intensity in units of 10^{-5} ph cm^{-2} sec^{-1} sr^{-1} for E > 1GeV, after subtraction of "best estimate of Galactic Diffuse model. Data indicates presence of a galactic halo (Dixon et al. 1998).

Cosmic Ray Interaction with Inter Stellar Matter (1)

Galactic Background Model

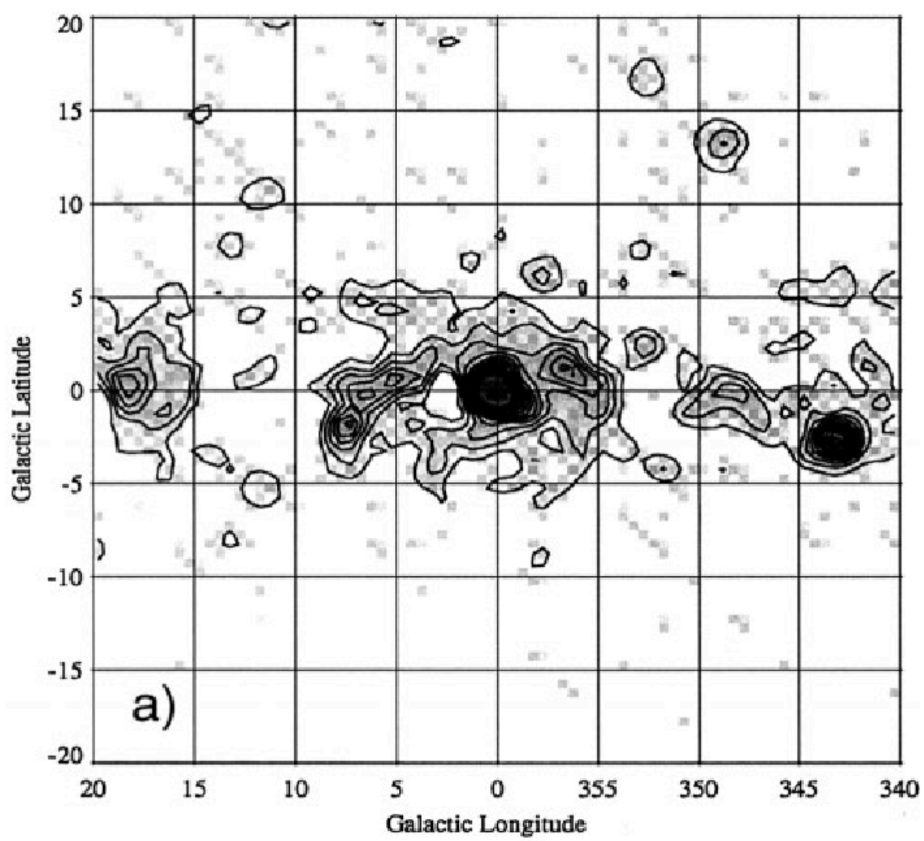


Inner Galaxy (|l|<60°,|b|<10°) by EGRET.
ID=Elect. Brems.,
IC=Inv. Compton,
Isotr. Diff., and
NN : π^0 production and decay

Strong et al. astro- ph/ 9811296
ApJ , 537: 763, 2000 July 10

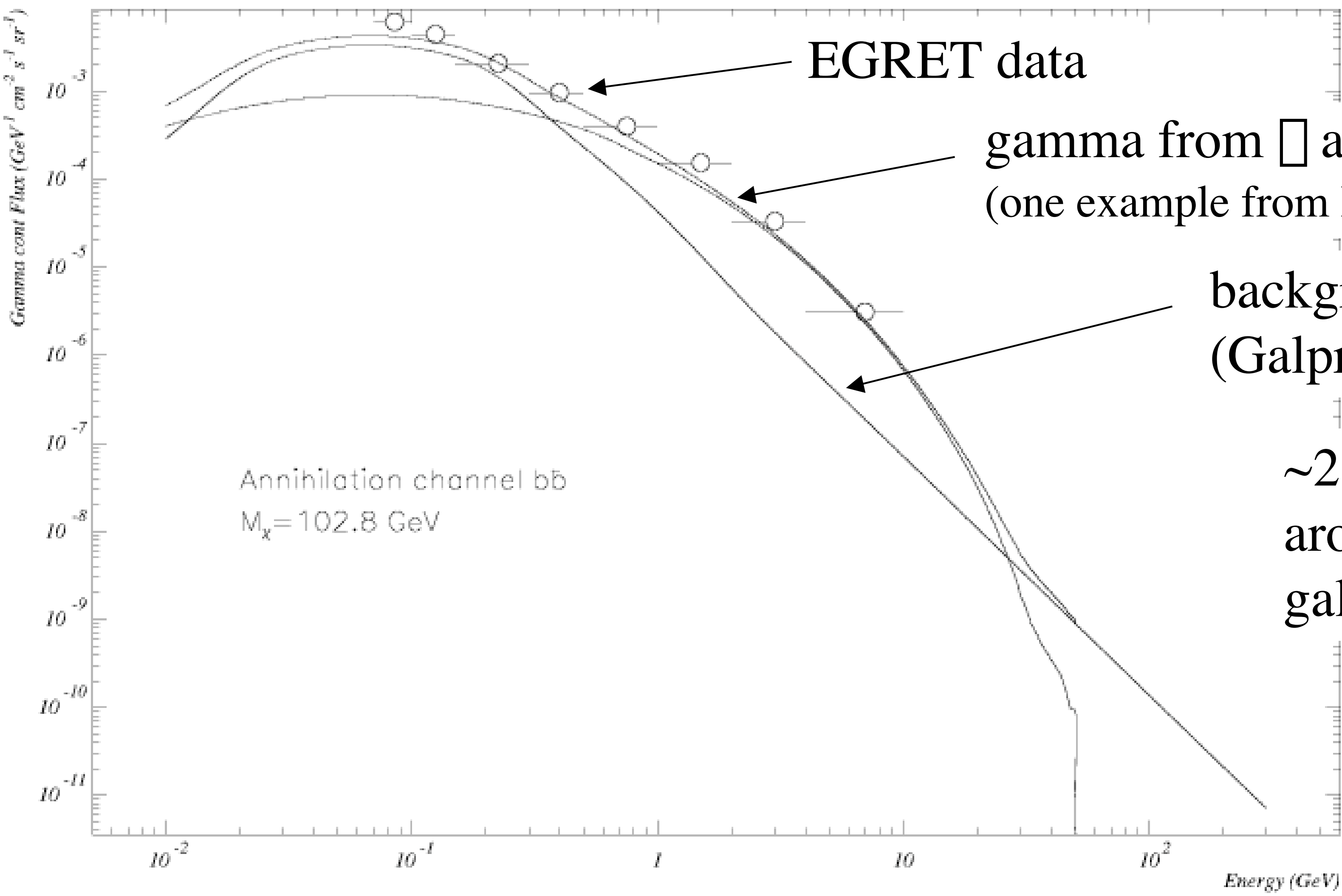
Search for the Nature of Dark Matter

• The EGRET team (Mayer-Hasselwander et al, 1998) have seen a convincing signal for a strong excess of emission from the galactic center, with I(E) x E^2 peaking at ~ 2 GeV, and in an error circle of 0.2 degree radius including the position $l = 0^o$ and $b = 0^o$. In their paper it was speculated that among other possible causes, this excess could be due to the continuum γ-ray spectrum from Wimp annihilation. With the dramatically improved angular resolution and effective area of GLAST, this effect should become both more localized and pronounced if it is a Galactic Center phenomenon.



EGRET Map of Galactic Center Region

EGRET data & Susy models



EGRET data

gamma from □ annihilation
(one example from DarkSusy)

background model
(Galprop)

~2 degrees
around the
galactic center

Supersymmetry introduces free parameters:

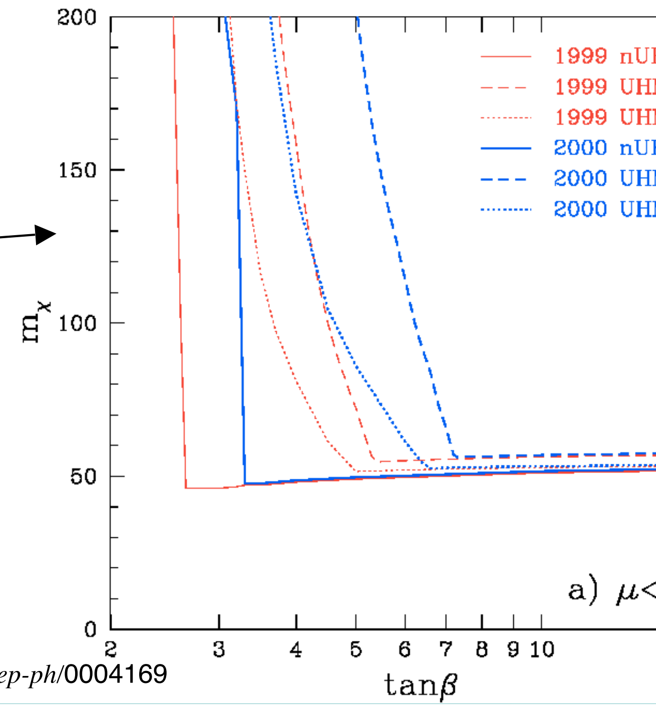
In the MSSM, with Grand Unification assumptions the masses and couplings of the SUSY particles as well as their production cross sections, are entirely described once five parameters are fixed:

- $M_{1/2}$ the mass parameter of supersymmetric partners of gauge fields (gauginos)
- the higgs mixing parameters μ that appears in the neutralino and chargino mass matrices
- m_0, the common mass for scalar fermions at the GUT scale
- A, the trilinear coupling in the Higgs sector
- the ratio between the two vacuum expectation values of the Higgs fields defined as:

$$\tan\beta = v_2 / v_1 = \langle H_2 \rangle / \langle H_1 \rangle$$

Experimental lower limit on the mass of the lightest neutralino assuming MSSM

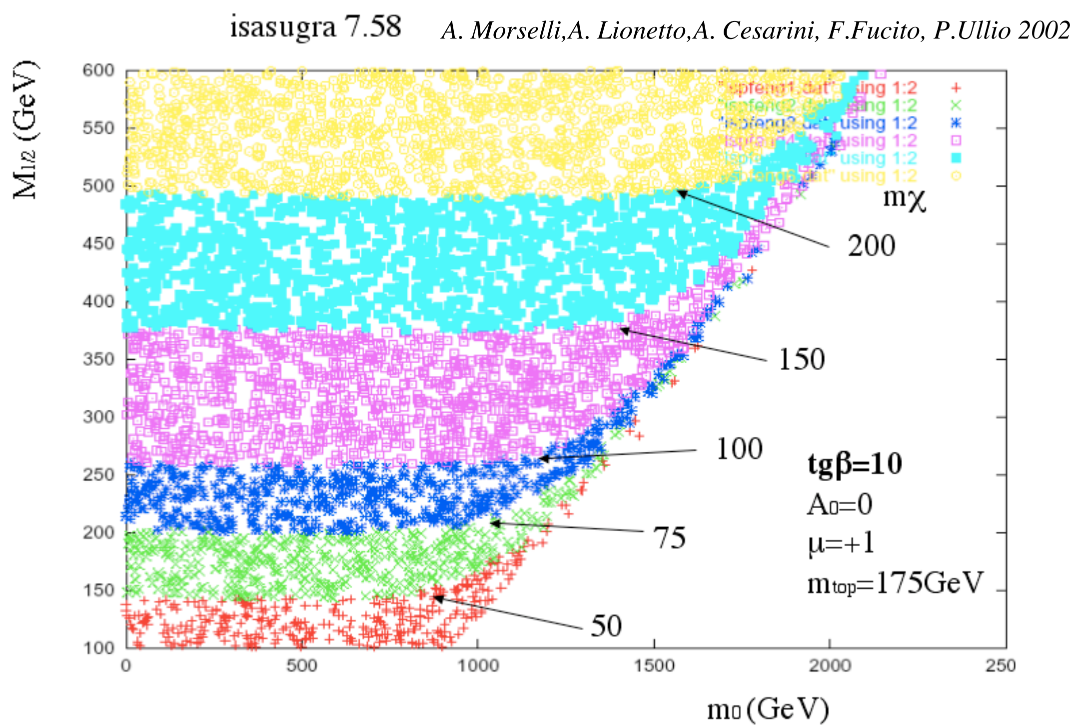
(Minimal Standard Supersymmetric Model)

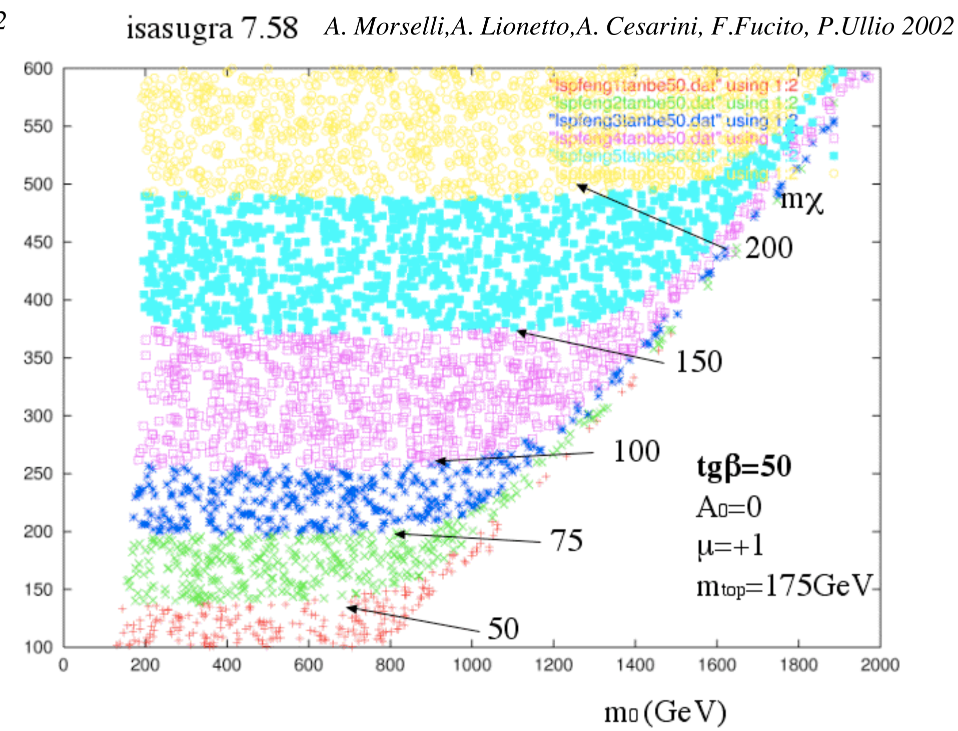


hep-ph/0004169

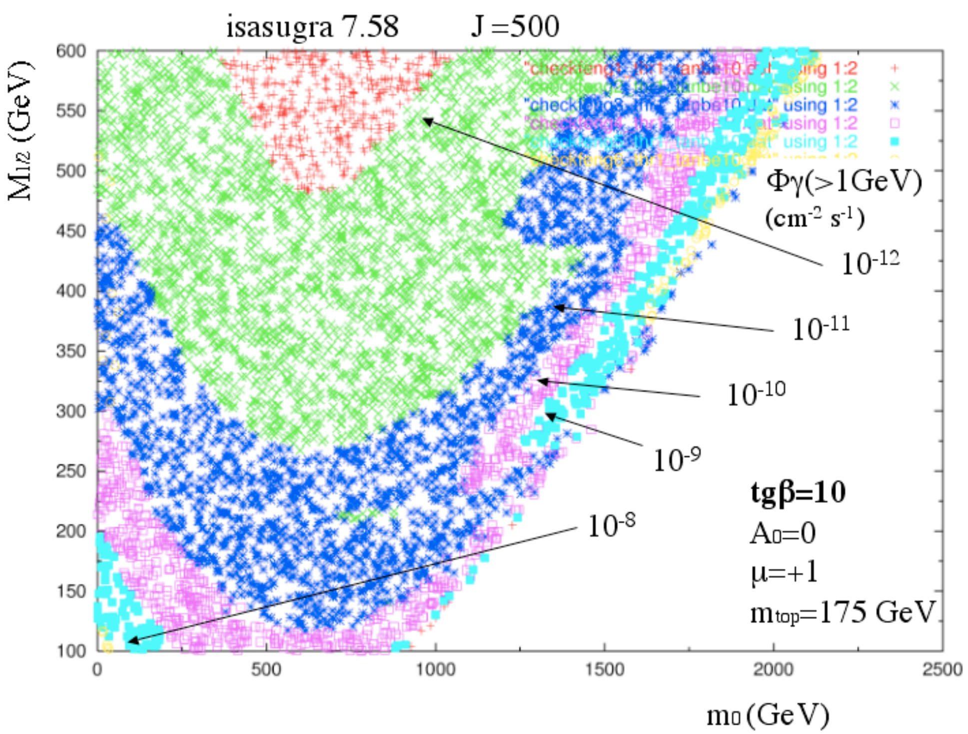
M_χ > 50 GeV (Lep $\sqrt{s}$ = 189 GeV)

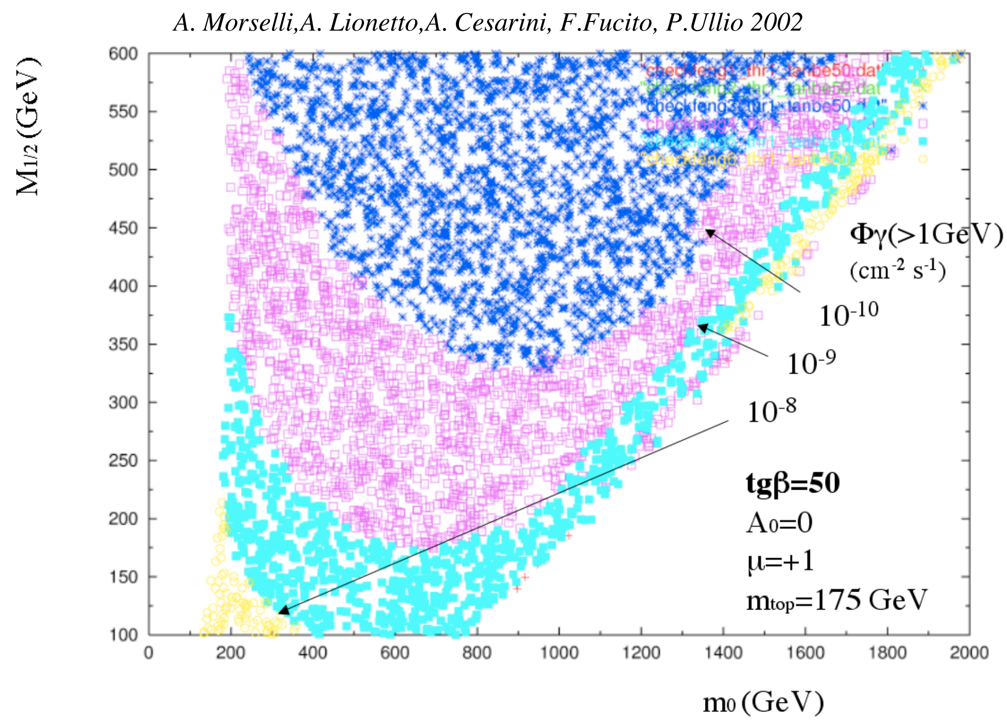
results: regions with different m_{χ} in the $M_{1/2}$ m_0 plane





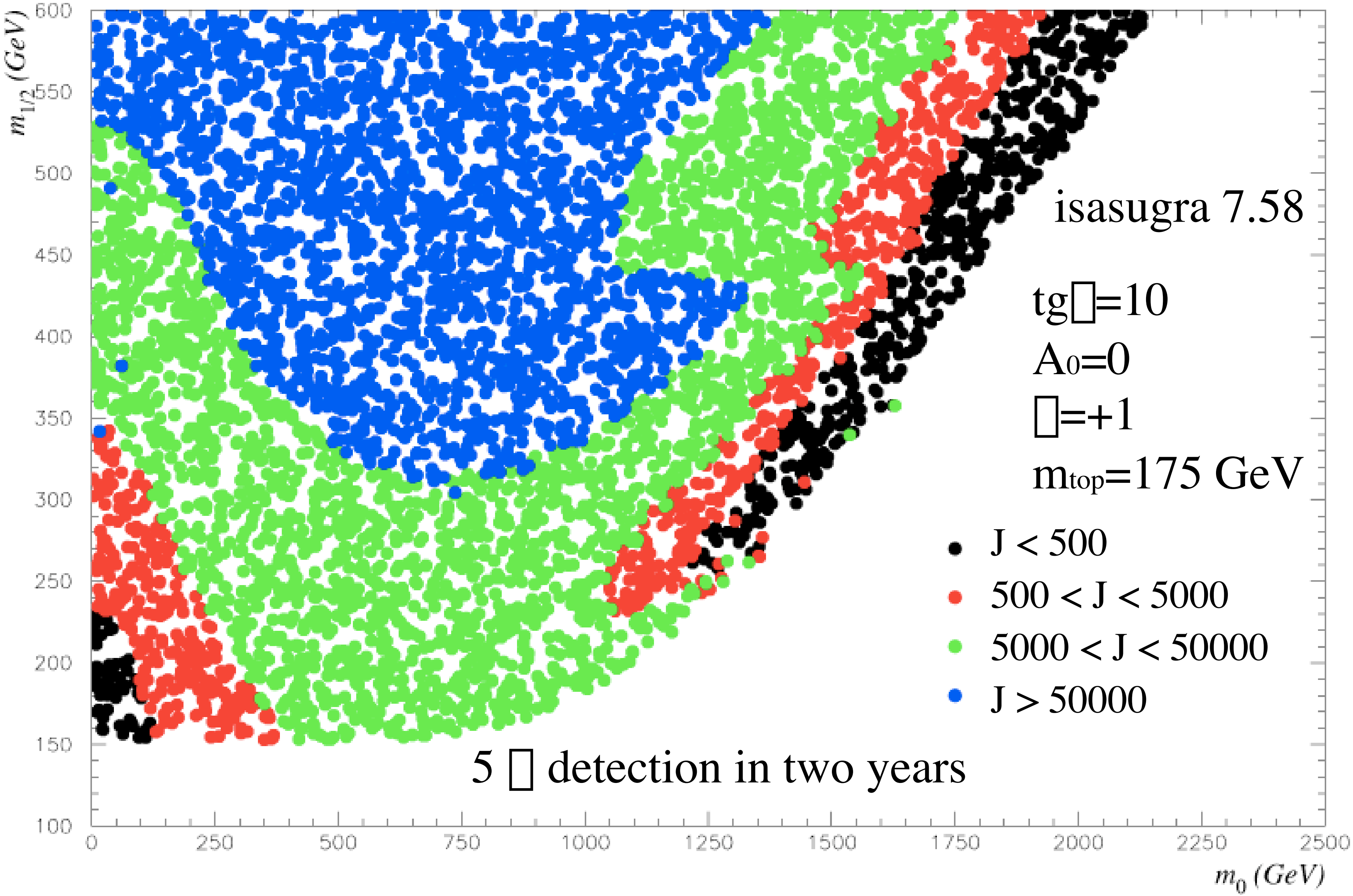
□-ray flux from a 10^{-3} cone around the galactic center





resolving the γ-ray continuum:

A. Morselli,A. Lionetto,A. Cesarini, F.Fucito, P.Ullio 2002



the method:

background

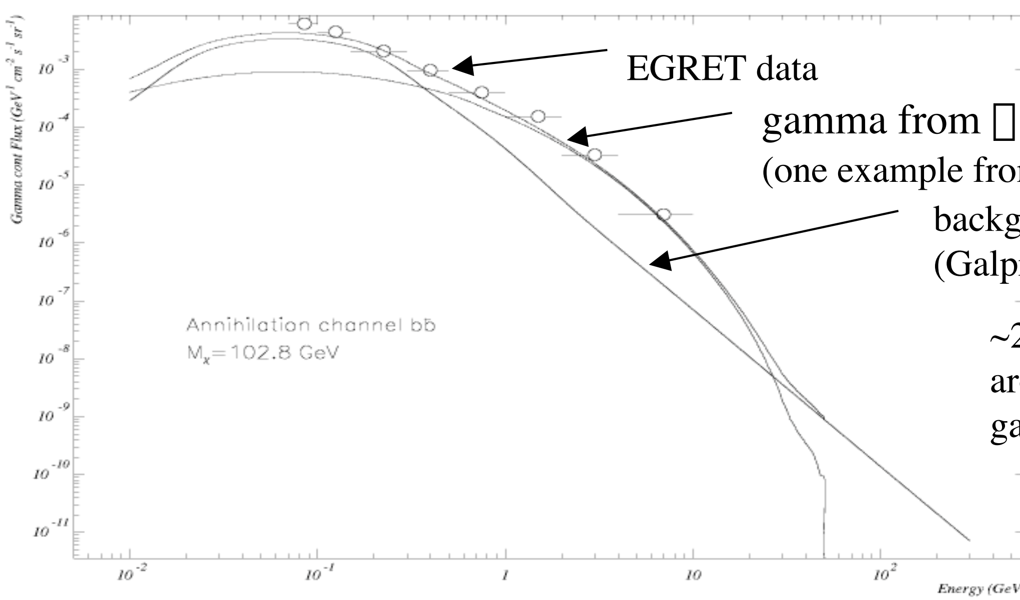
neutralino signal

$$\phi_{diffuse} = N_b\phi_b + N_\chi\phi_\chi$$

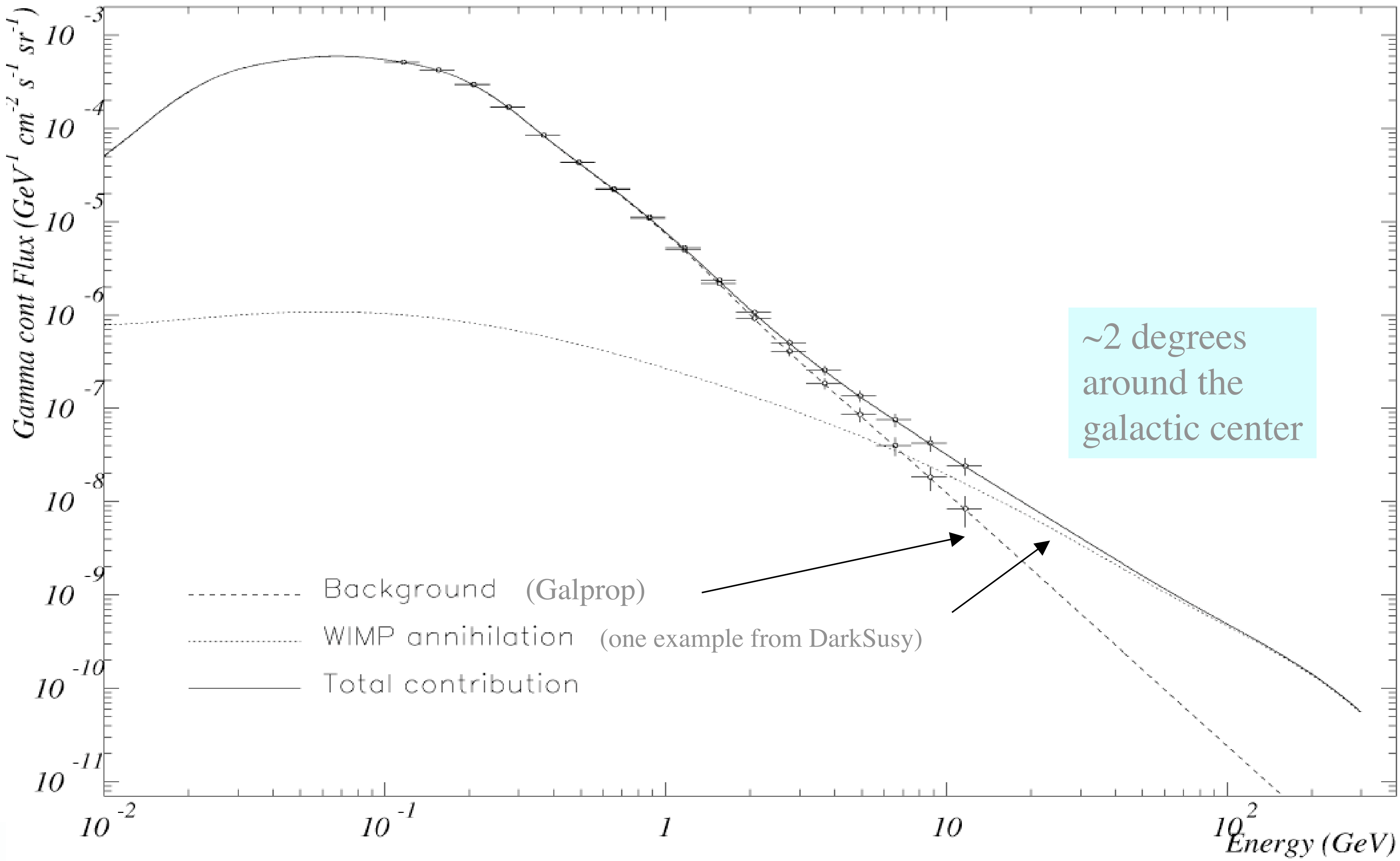
- We choose all the values of the parameters (N_b , N_χ) that satisfy the condition

$$(\phi_{diff})_{SM} \leq N_b\phi_b + N_\chi\phi_\chi \leq \phi_{EGRET}$$

we fixed N_b to the maximum value allowed by the above condition (when N_χ=0)
The points indicate the regions where we can discriminate the neutralino signal with GLAST at 5 sigma level in two years.



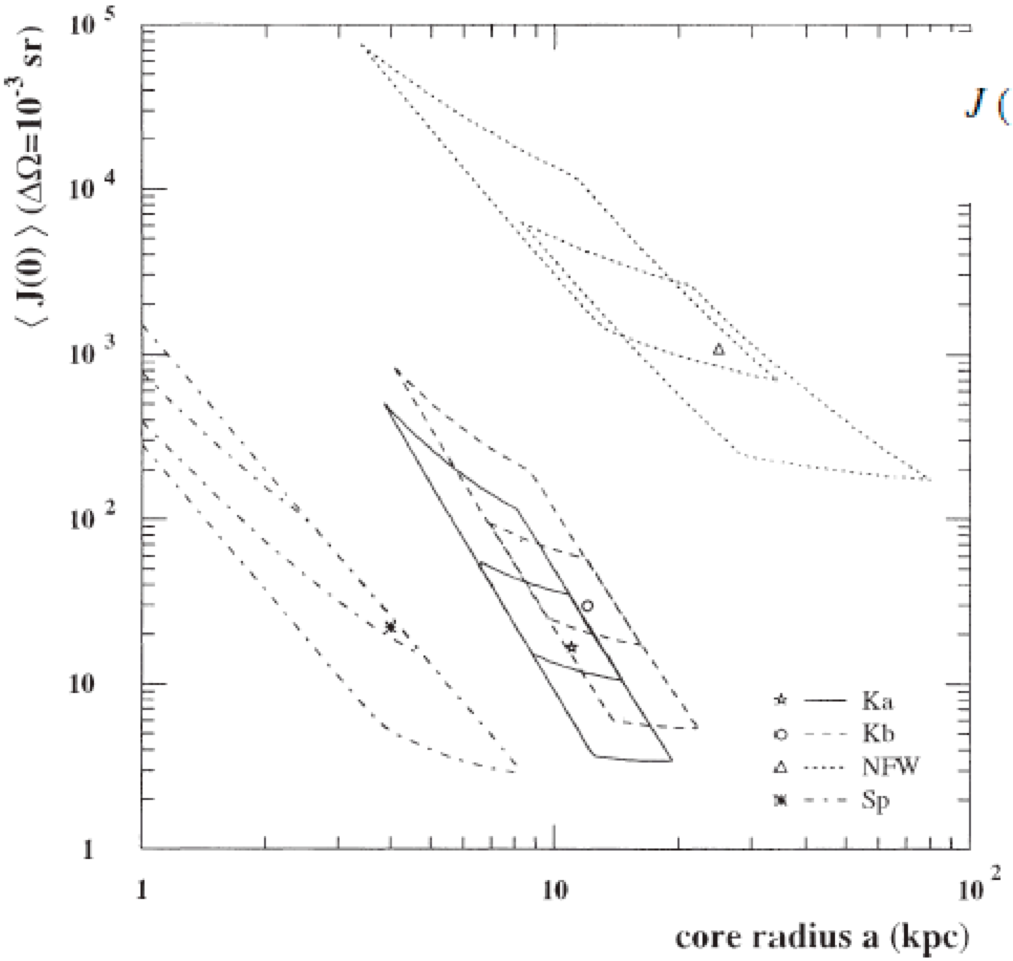
GLAST Expectation & Susy models



Permitted values of J(ψ):

$$\Phi_\gamma(\psi) = \frac{N_\gamma v\sigma}{4\pi M_\chi^2} \int_{\text{line of sight}} \rho^2(l)\, dl(\psi)$$

$$\Phi_\gamma(\psi) \simeq 1.87 \times 10^{-11} \left(\frac{N_\gamma\, v\sigma}{10^{-29}\ \mathrm{cm^3\,s^{-1}}}\right) \left(\frac{10\ \mathrm{GeV}}{M_\chi}\right)^2 J(\psi)\ \ \mathrm{cm^{-2}\,s^{-1}\,sr^{-1}}$$



$$J(\psi) = \frac{1}{8.5\ \mathrm{kpc}} \left(\frac{1}{0.3\ \mathrm{GeV/cm^3}}\right)^2 \int_{\text{line of sight}} \rho^2(l)\, dl(\psi)$$

$$\boxed{\langle J(0)\rangle(\Delta\Omega) = \frac{1}{\Delta\Omega}\int_{\Delta\Omega} J(\psi)\, d\Omega}$$

a =core radius of halo

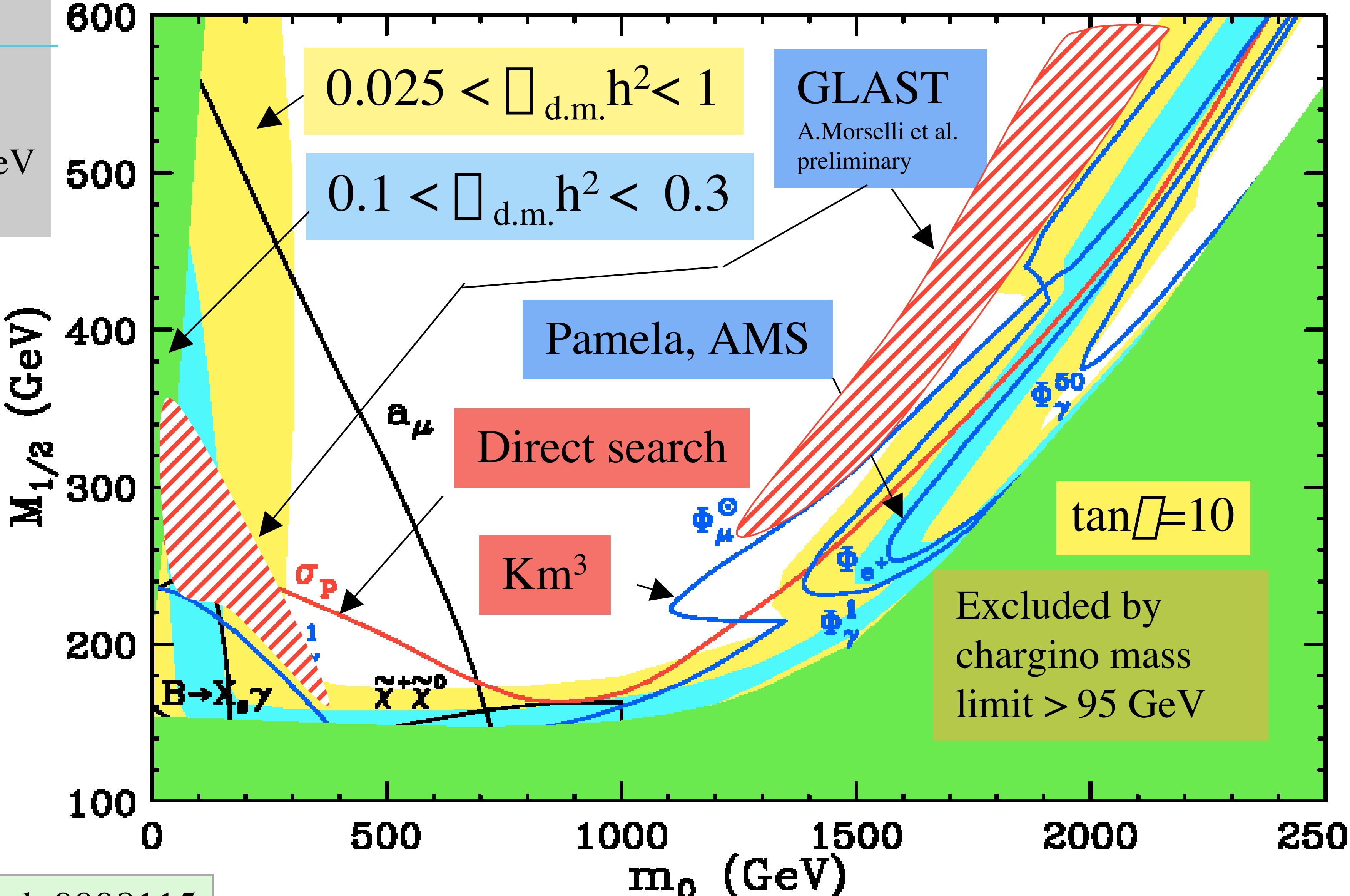
$$\rho(r) \propto \frac{1}{(r/a)^\gamma\,[1+(r/a)^\alpha]^{(\beta-\gamma)/\alpha}}$$

	α	β	γ
Isothermal profile γ =0 no cusp	2	2	0
Navarro-Frenk-White	1	3	1
Moore et al…	1.5	3	1.5
Kravtsov et al.(a)	2	3	0.2
Kravtsov et al.(b)	2	3	0.4

Estimated reaches before LHC

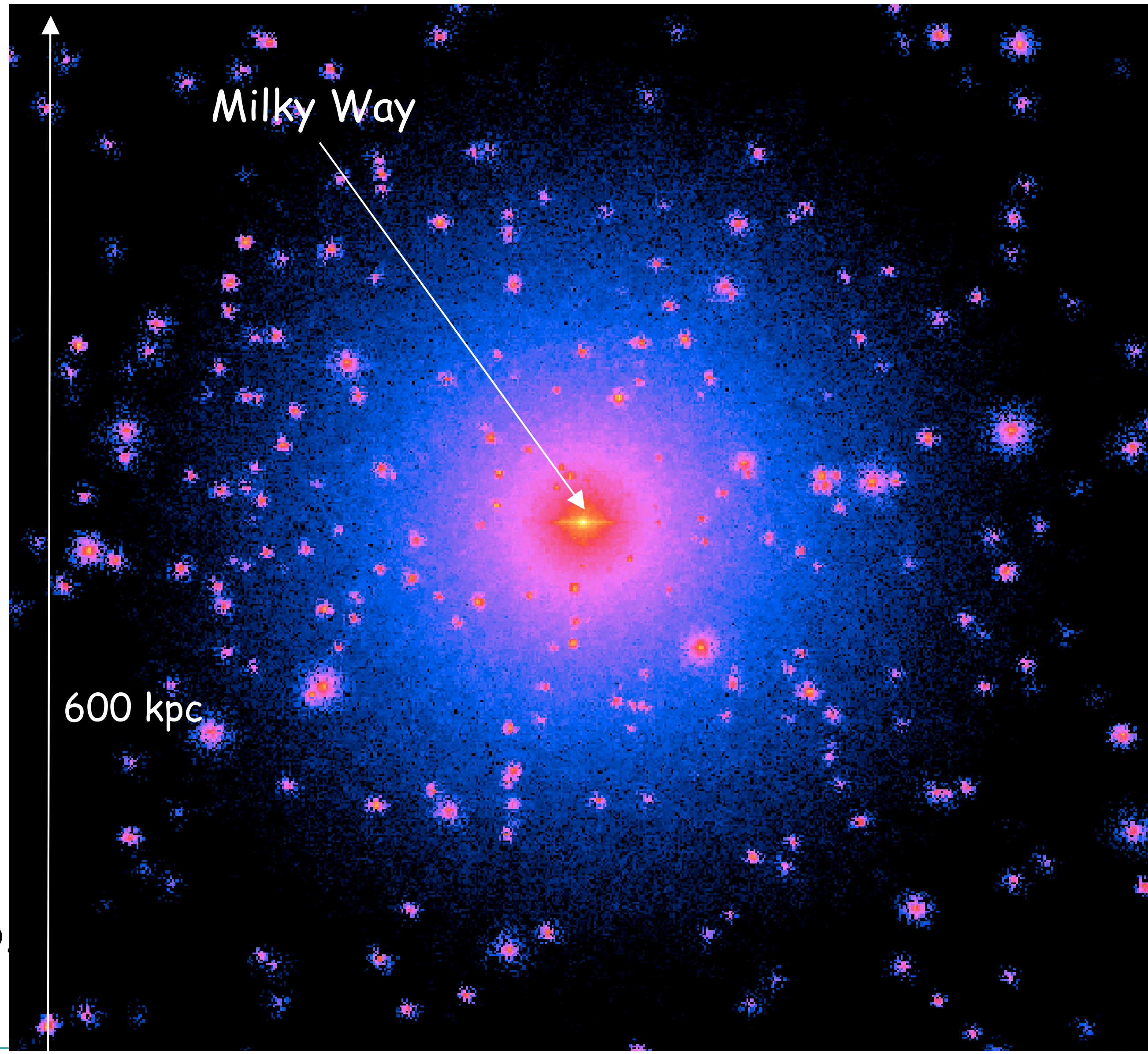
MSSM
$A_0 = 0$
□ > 0
m_t =174 GeV
tan □ = 10

Fixed Halo profile, indirect limits better if halo is clumpy

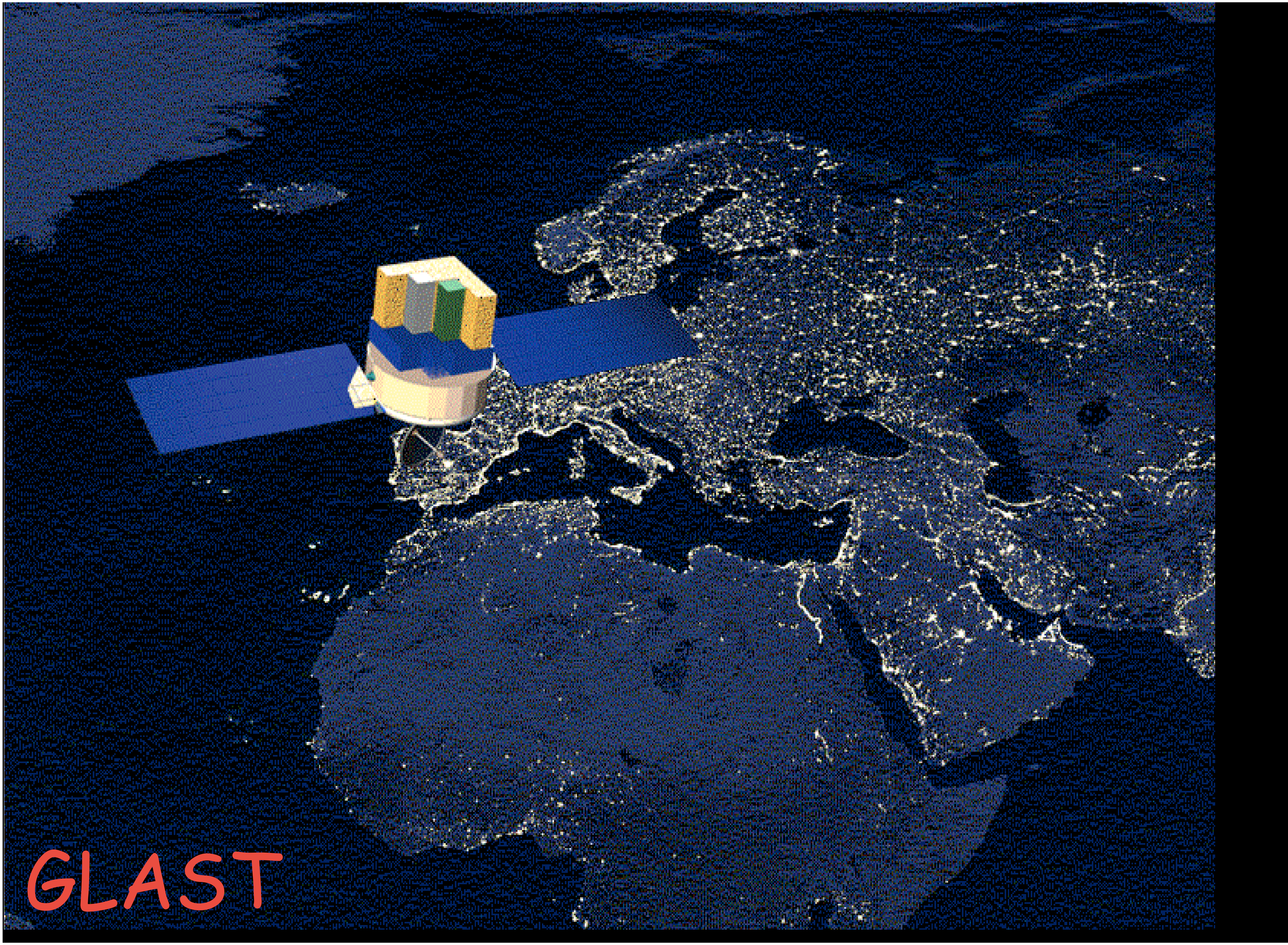


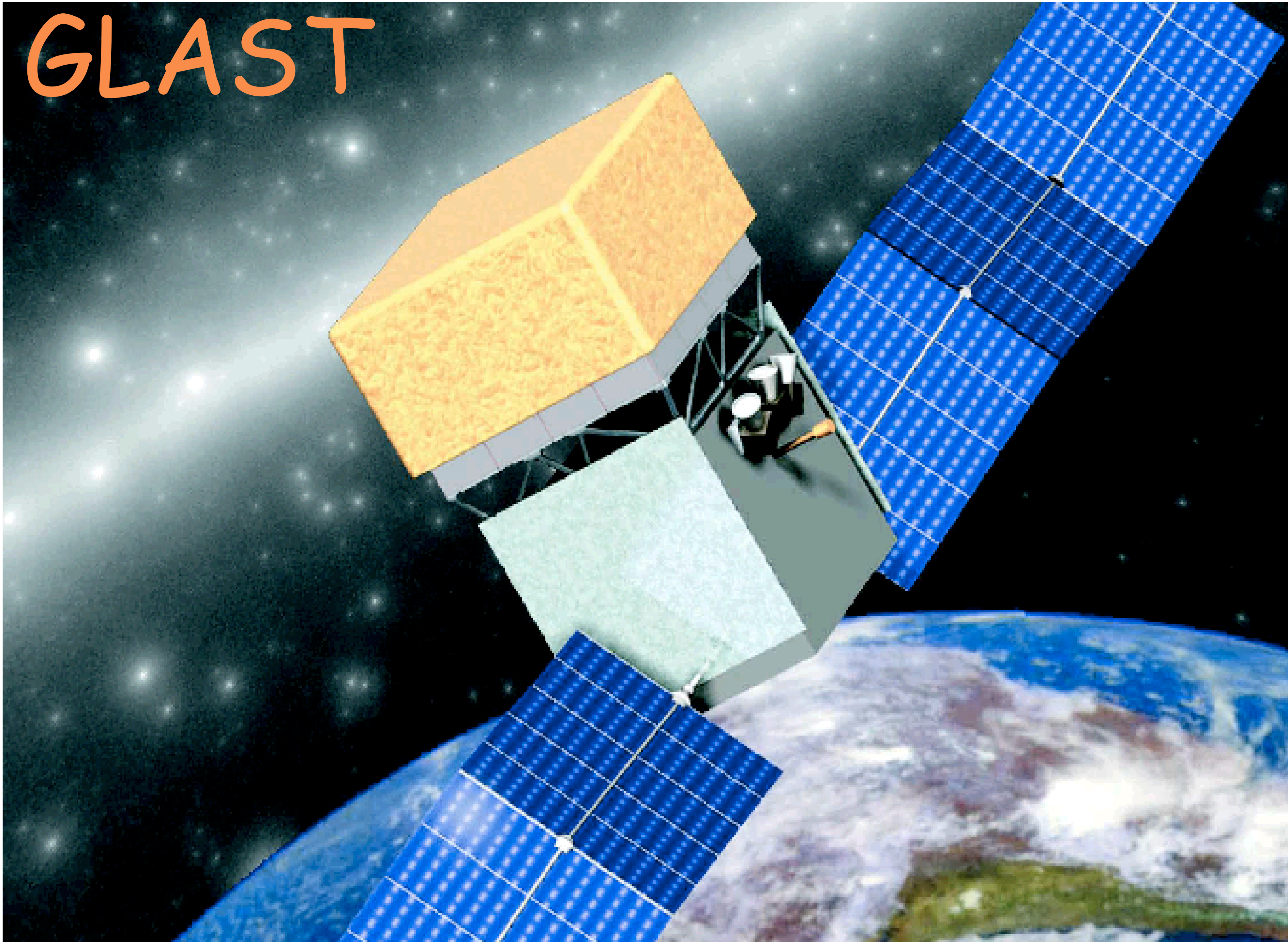
See astro-ph 0008115

HALO SUBSTRUCTURE

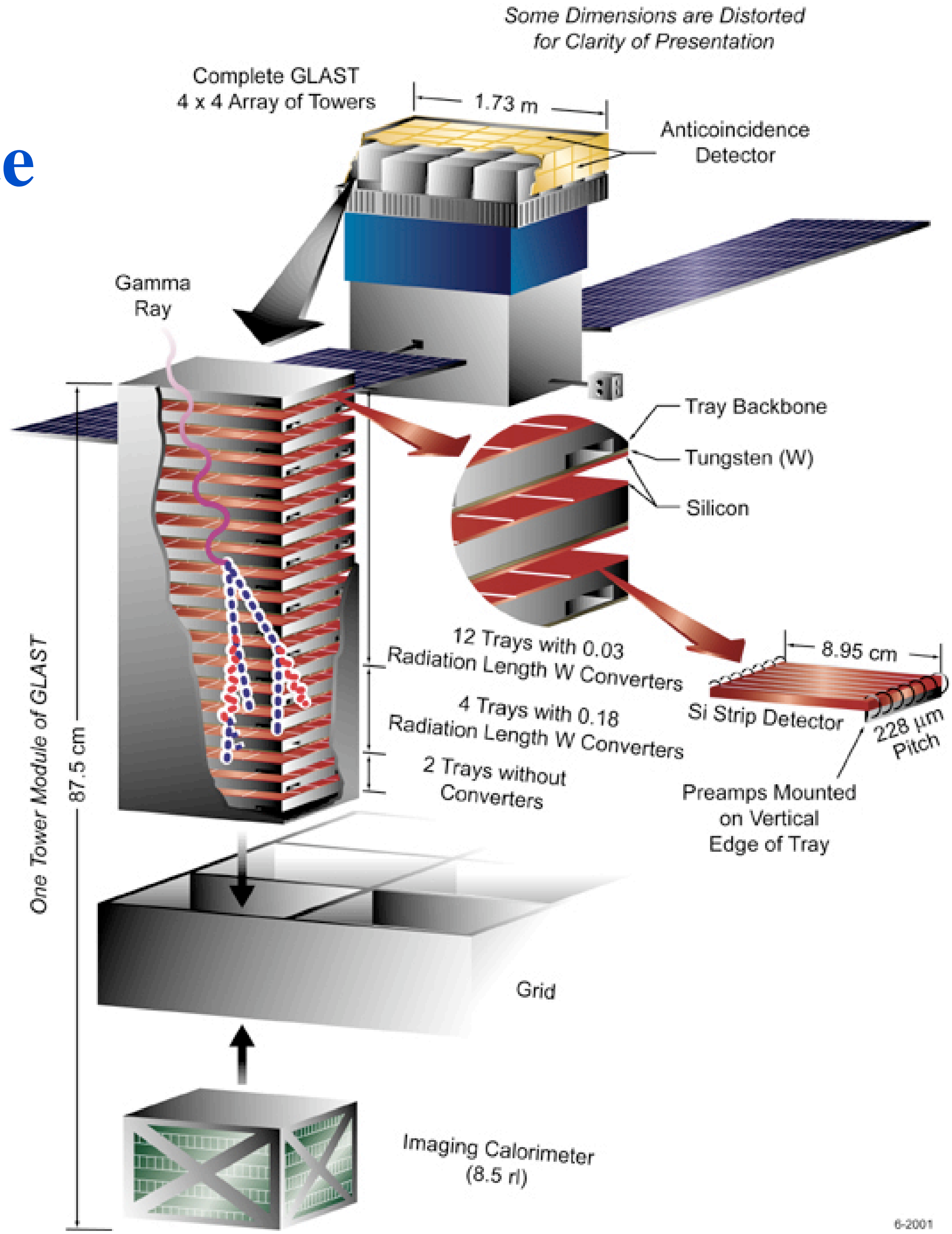


A.Font and J.Navarro,
astro- ph/ 0106268


GLAST


GLAST

Gamma-Ray Large Area Space Telescope



The GLAST Participating Institutions

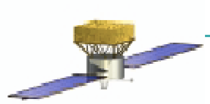
Italian Team Institutions
INFN - Instituto Nazionale di Fisica Nucleare: Units of Bari, Perugia, Pisa, Rome 2, Trieste
ASI - Italian Space Agency
IFC/CNR- Istituto di Fisica, Cosmica, CNR

American Team Institutions
SU - Stanford University, Physics Department and EGRET group, Hanson Experimental Physics Laboratory
SU-SLACStanford Linear Accelerator Center, SLAC, Particle Astrophysics group
GSFC-NASA Goddard Space Flight Center, Laboratory for High Energy Astrophysics
NRL - U. S. Naval Research Laboratory, E. O. Hulburt Center for Space Research, X-ray and gamma-ray branches
UCSC- University of California at Santa Cruz, Physics Department
SSU- Sonoma State University, Department of Physics & Astronomy
UW- University of Washington , TAMUK- Texas A&M University-Kingsville

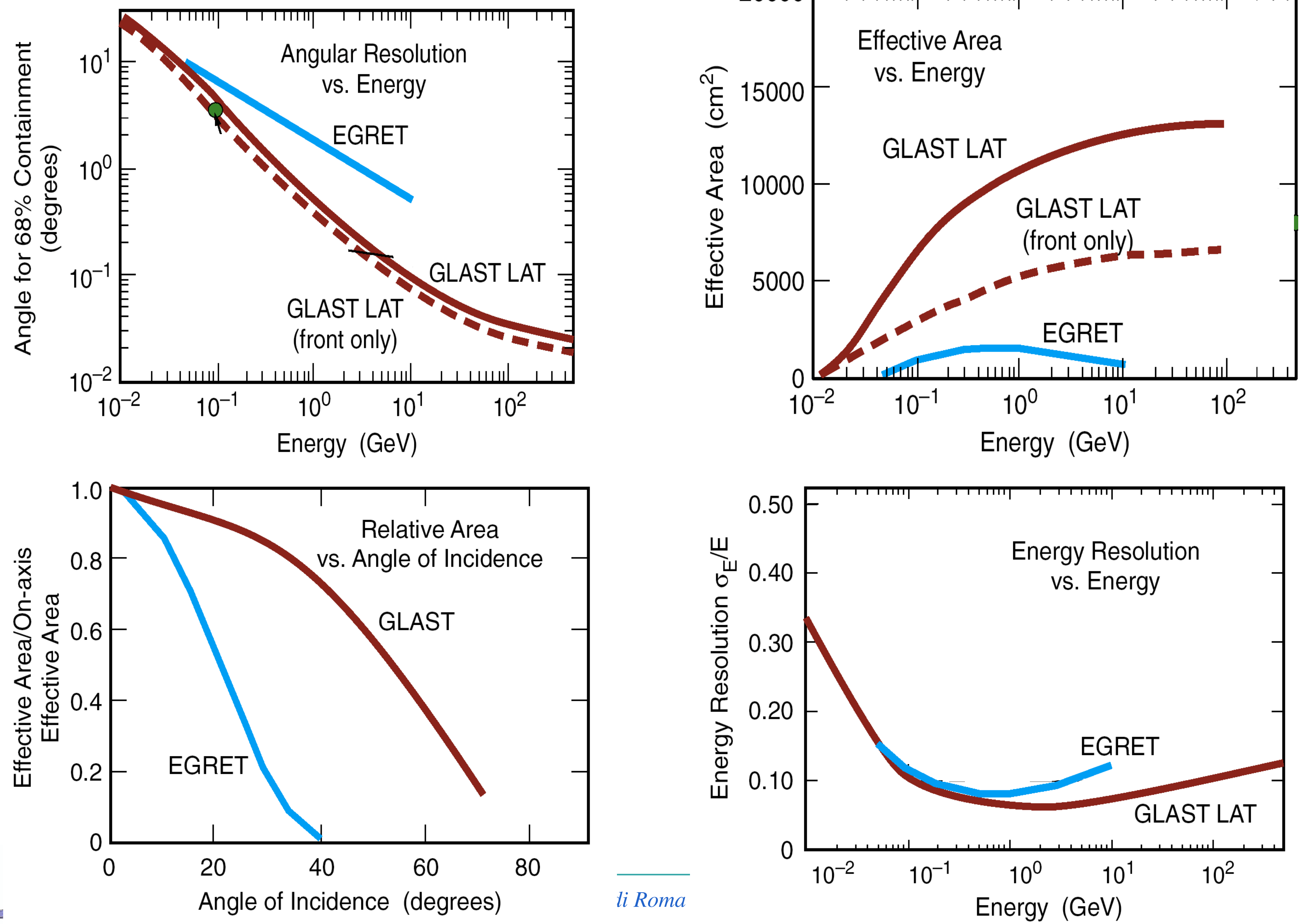
Japanese Team Institutions
University of Tokyo
ICRR - Institute for Cosmic-Ray Research
ISAS- Institute for Space and Astronautical Science
Hiroshima University

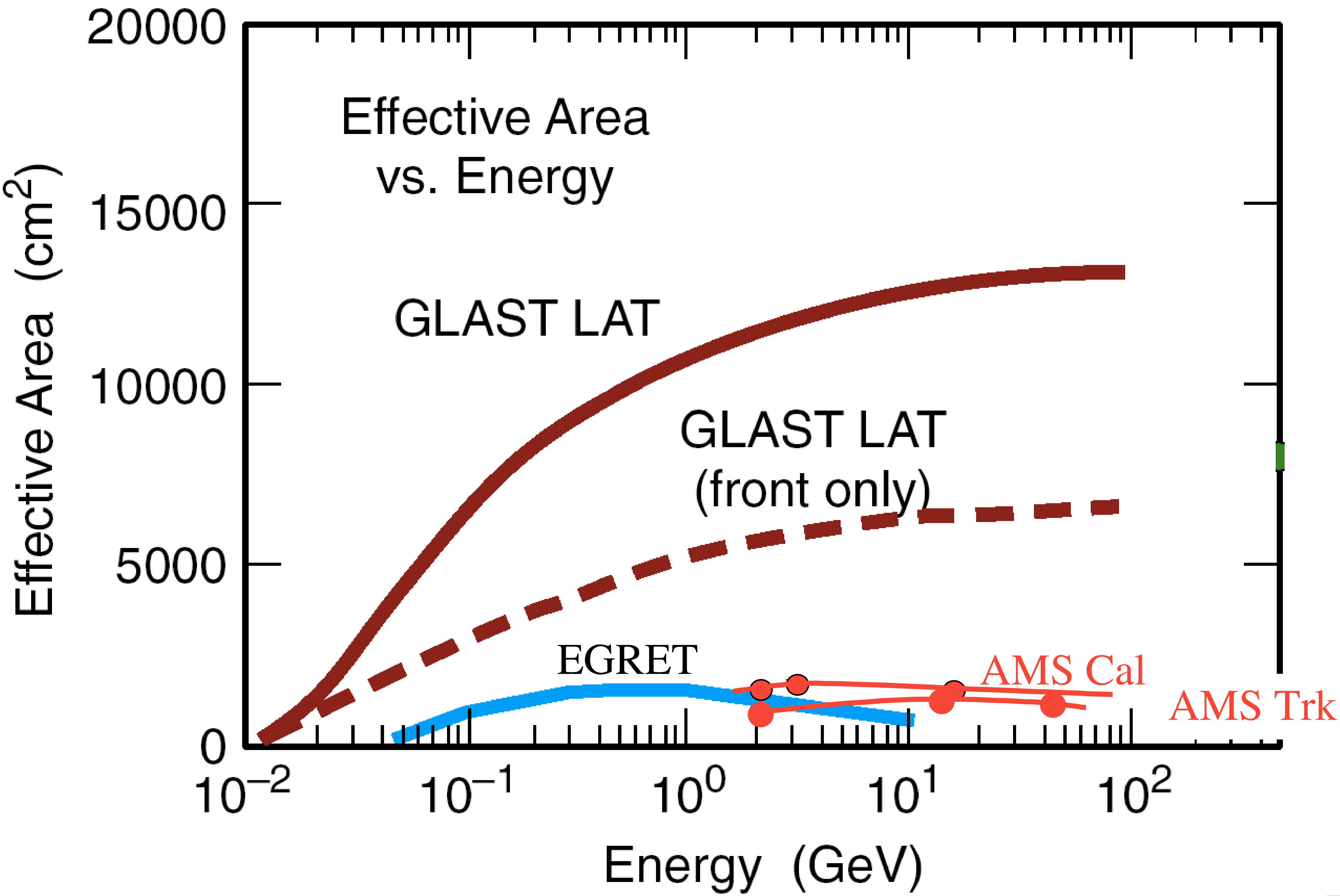
French Team Institutions
CEA/DAPNIA Commissariat à l'Energie Atomique, Département d'Astrophysique, de physique des Particules, de physique Nucliaire et de l'Instrumentation Associée, CEA, Saclay
IN2P3 Institut National de Physique Nucléaire et de Physique des Particules, IN2P3
IN2P3/LPNHE-X Laboratoire de Physique Nucléaire des Hautes Energies de l'École Polytechnique
IN2P3/PCC Laboratoire de Physique Corpusculaire et Cosmologie, Collège de France
IN2P3/CENBG Centre d'études nucléaires de Bordeaux Gradignan

Swedish Team Institutions
KTHRoyal Institute of Technology
Stockholms Universitet



GLAST Performance

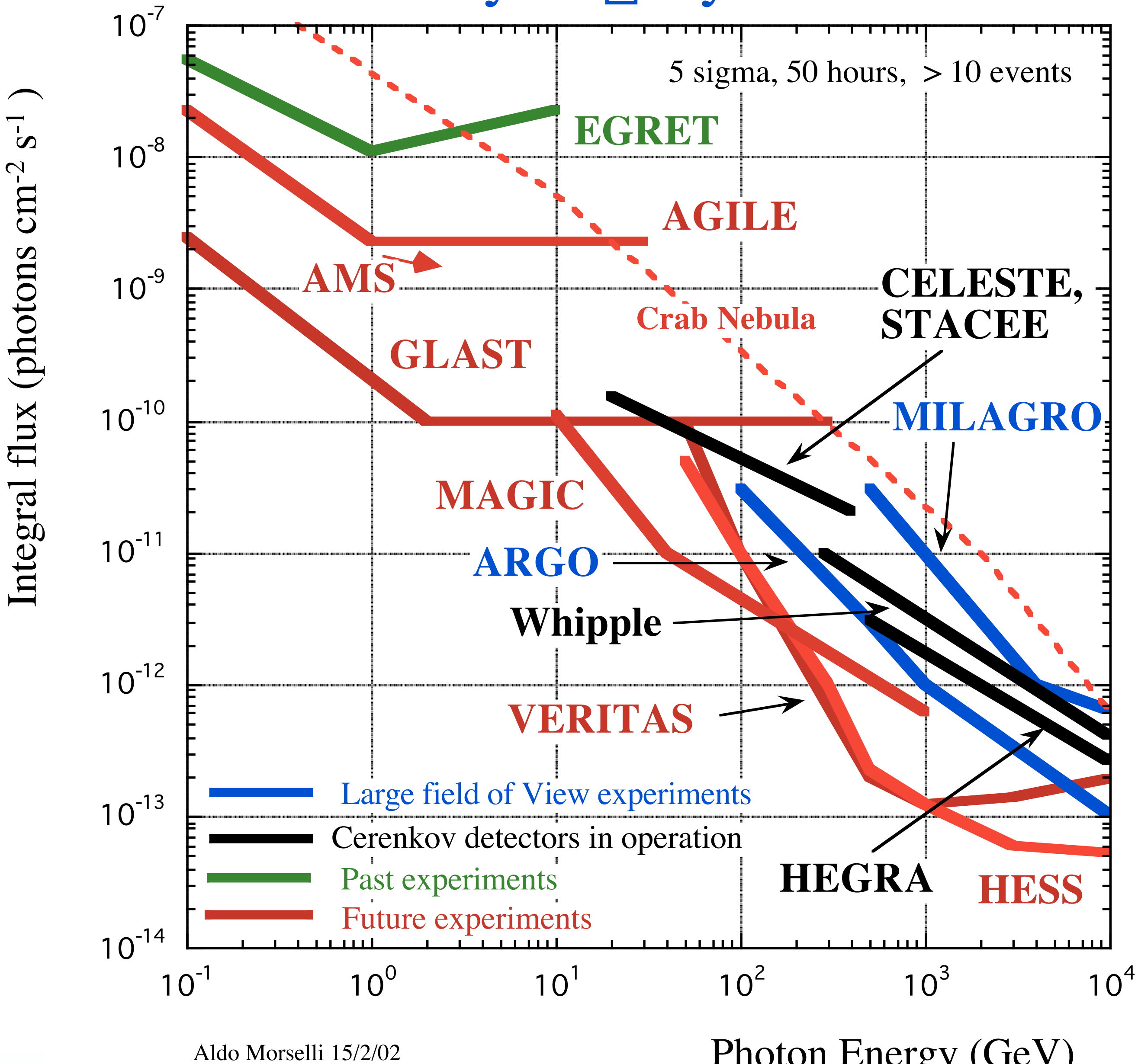



Effective Area vs. Energy
GLAST LAT
GLAST LAT (front only)
EGRET
AMS Cal
AMS Trk
Effective Area (cm^2)
20000
15000
10000
5000
0
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Energy (GeV)

GLAST Instrument Description

- **General Characteristics**: imaging, wide field-of-view, pair-conversion telescope, backed by EM calorimetry using modern HEP technology:
  - energy range: 10 MeV to 300 GeV
  - energy resolution: 10%
  - effective area: $> 8{,}000\ cm^2$ (above 1 GeV)
  - field-of-view: ~2□ sr
  - point source sensitivity: $2 \times 10^{-9}\ ph\ cm^{-2}\ s^{-1}$ (@ 100 MeV)
    $10^{-10}\ ph\ cm^{-2}\ s^{-1}$ (> 1 GeV)
  - source location determination: 30 arcsec - 5 arcmin
  - cosmic ray/□rejection $> 10^5$ to 1

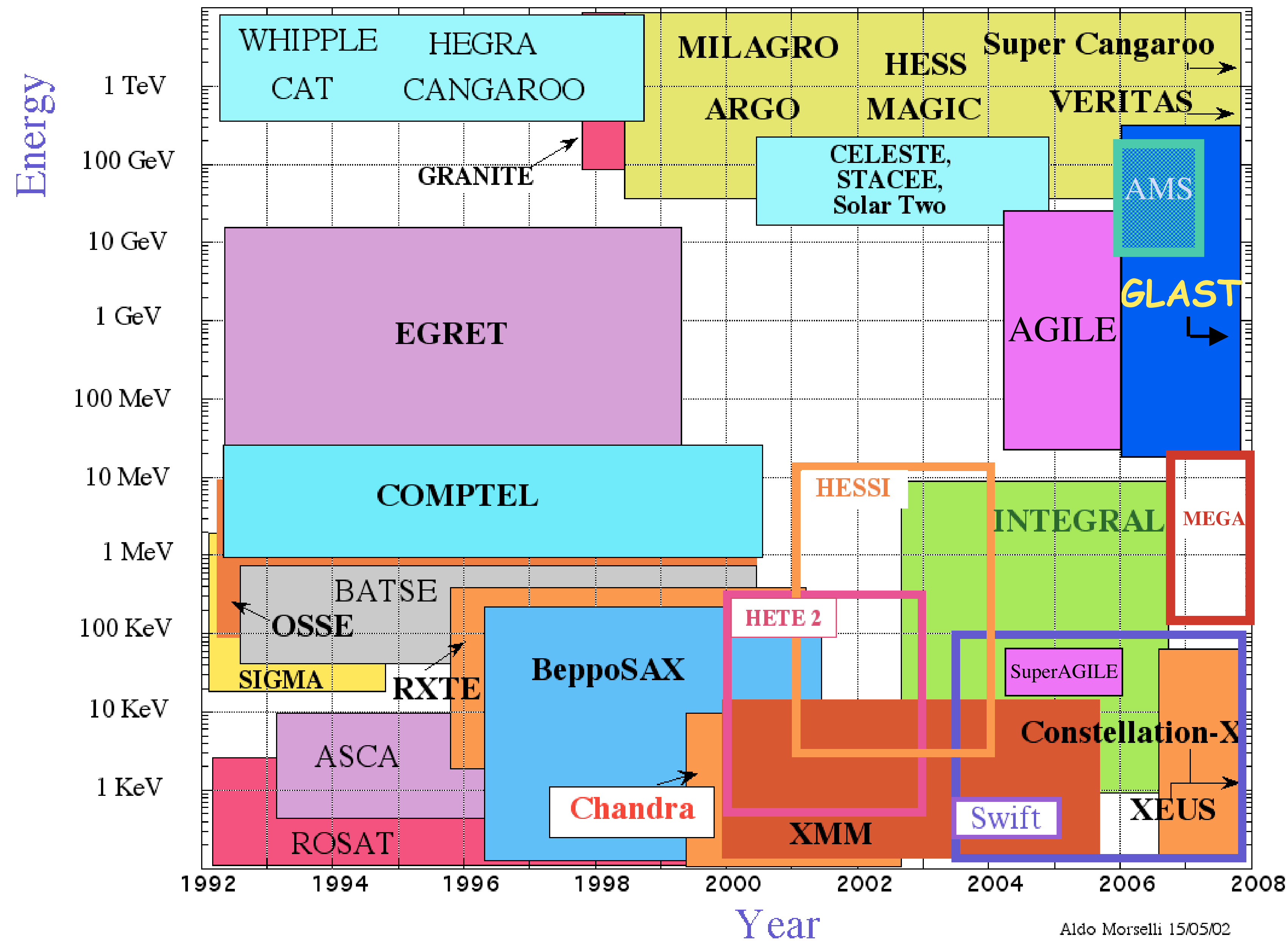
Sensitivity of γ-ray detectors



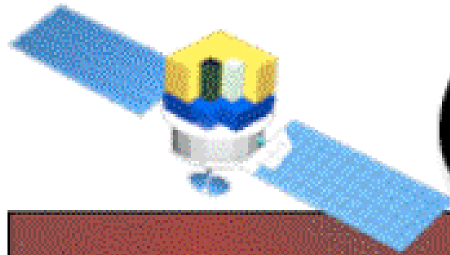
All sensitivities are at 5σ.
Cerenkov telescopes sensitivities (Veritas, MAGIC, Whipple, Hess, Celeste, STACEE, HEGRA) are for 50 hours of observations.
Large field of view detectors sensitivities (AGILE, GLAST, MILAGRO,ARGO are for 1 year of observation.

MAGIC sensitivity based on the availability of high efficiency PMT's

Energy versus time for X and Gamma ray detectors



Agile



GLAST

Astro-rivelatore Gamma a Immagini LEggero		
Energy Range :	20 MeV - 50 GeV	
Field of view:	3 sr	
Energy Resolution	~1 at 300 MeV	
Point source Sensitivity:	0.1 GeV	5×10^{-8}
(ph cm^{-2} s^{-1})	1 GeV	5×10^{-9}
	10 GeV	5×10^{-9}
Event deadtime	<100 μs	
Peak Effective Area	600 cm^2	
Orbital Parameters	Equatorial, 550 Km	
Possible Earth Station	Malindi (Kenia)	
Required Power	65 W	
Payload Weight	65 Kg	
BUS+ Payload	200 Kg	

Gamma-Ray Large Area Space Telescope		
Energy Range :	20 MeV - 300 GeV	
Field of view:	3 sr	
Energy Resolution	5% at 1 GeV	
Point source Sensitivity:	0.1 GeV	2×10^{-9}
(ph cm^{-2} s^{-1})	1 GeV	2×10^{-10}
	10 GeV	1×10^{-10}
Event deadtime	~20 μs	
Peak Effective Area	10000 cm^2	
Orbital Parameters	28^0, 600 Km	
Required Power	600 W	
Payload Weight	3000 Kg	

More information on AGILE, PAMELA and GLAST :

please visit us:

http://wizard.roma2.infn.it/

Conclusions

- GLAST will explore a good portion of the supersymmetric parameter space

….. and this is only an additional item for GLAST !

➪ GLAST will be an important step in gamma ray astronomy (~10 000 sources compared to ~ 200 of EGRET)

➪ A partnership between High Energy Physics and Astrophysics

➪ Beam test and software development well on the way

➪ Wide range of possible answers/discoveries

➪ Gold era for multiwavelenght studies