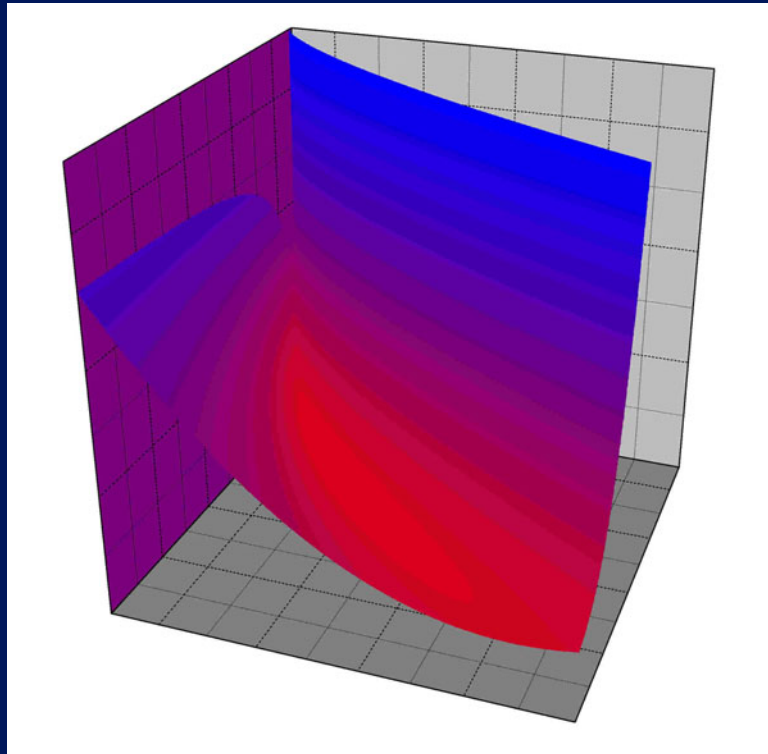


# *Indirect Dark Matter Searches in Gamma Ray, Cosmic Ray and Neutrino Channels*

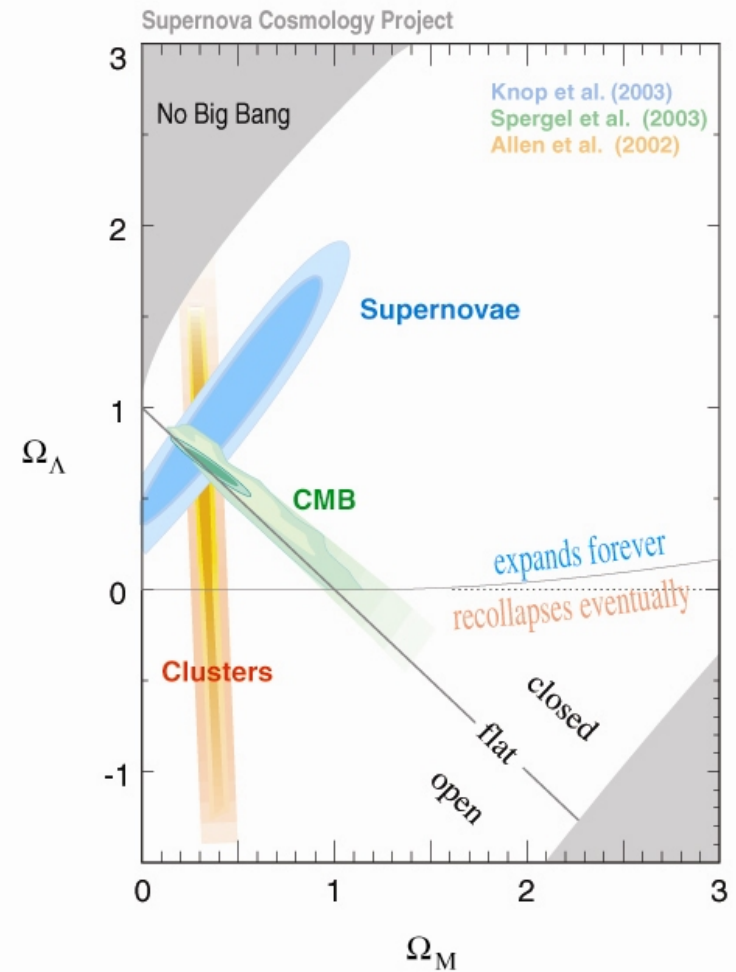
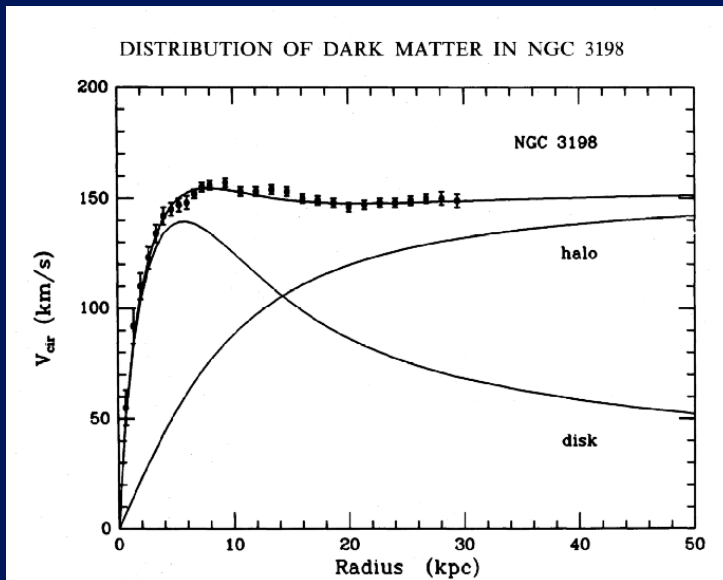


# Concordance Cosmology

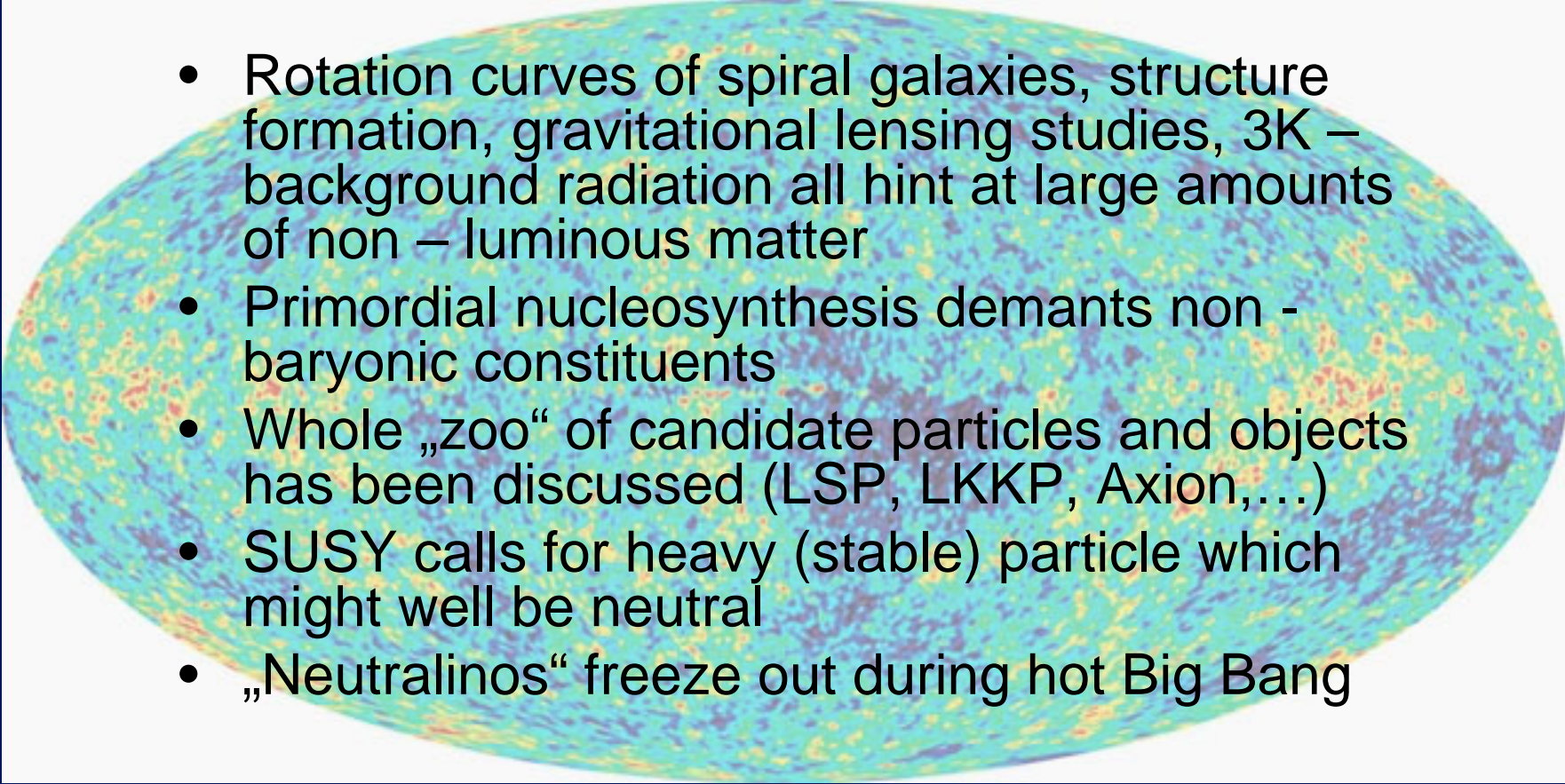
Baryonic Matter: 4%

Dark Matter: 23%

Dark Energy: 73%



# Dark Matter in the Universe

- 
- Rotation curves of spiral galaxies, structure formation, gravitational lensing studies, 3K – background radiation all hint at large amounts of non – luminous matter
  - Primordial nucleosynthesis demands non - baryonic constituents
  - Whole „zoo“ of candidate particles and objects has been discussed (LSP, LKKP, Axion,...)
  - SUSY calls for heavy (stable) particle which might well be neutral
  - „Neutralinos“ freeze out during hot Big Bang

# Annihilation of Neutralino CDM

- In many SUSY-scenarios, the neutralino ( $\chi$ ) is the LSP; it can be considered a natural WIMP candidate
- Annihilation – channels into photons:

$\chi \chi \rightarrow q\bar{q}, \tau\bar{\tau}, \dots \rightarrow \text{pions} \rightarrow \gamma\gamma$



**Continuum**

$\chi \chi \rightarrow Z_0 \gamma$



**Gamma ray lines**

Loop suppressed

$\chi \chi \rightarrow \gamma\gamma$

- SUSY-induced gamma ray flux:

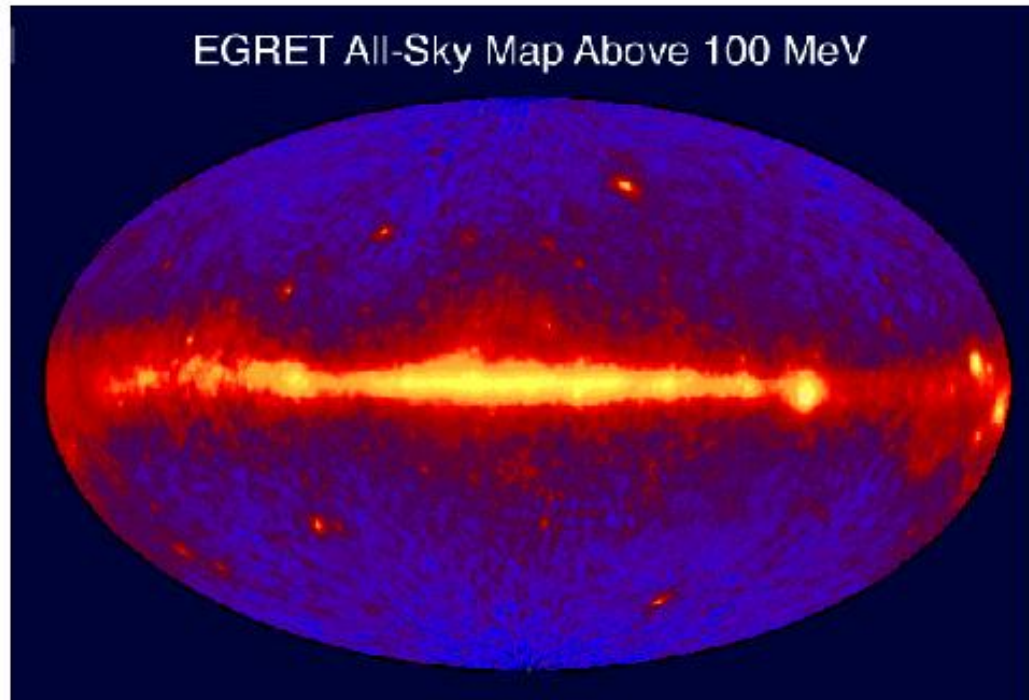
$$\Phi_\gamma(\varepsilon) = \frac{1}{4\pi} \times \frac{\frac{1}{2} \langle \sigma v \rangle}{m_\chi^2} \times \int \rho_\chi^2 \times df[\varepsilon(1+z)] ds$$

- SUSY-setup and halo parameters determine the flux; presently, both are subject to huge uncertainties (e.g. influence of substructure, cuspsiness, adiabatic compression!)
- Knowledge of astrophysical/instrumental backgrounds is essential



## EGRET All-Sky Map

EGRET All-Sky Map Above 100 MeV

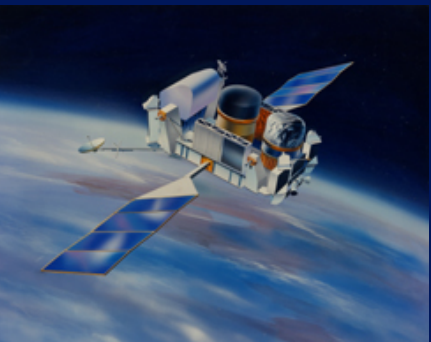


GLAST

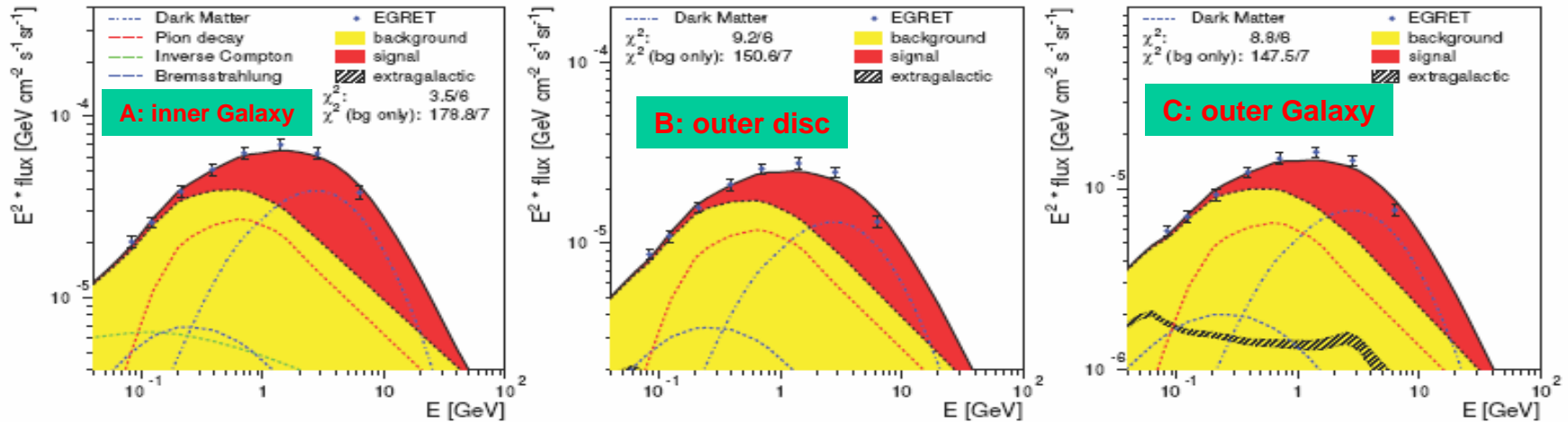


## Some words about the EGRET diffuse backgrounds

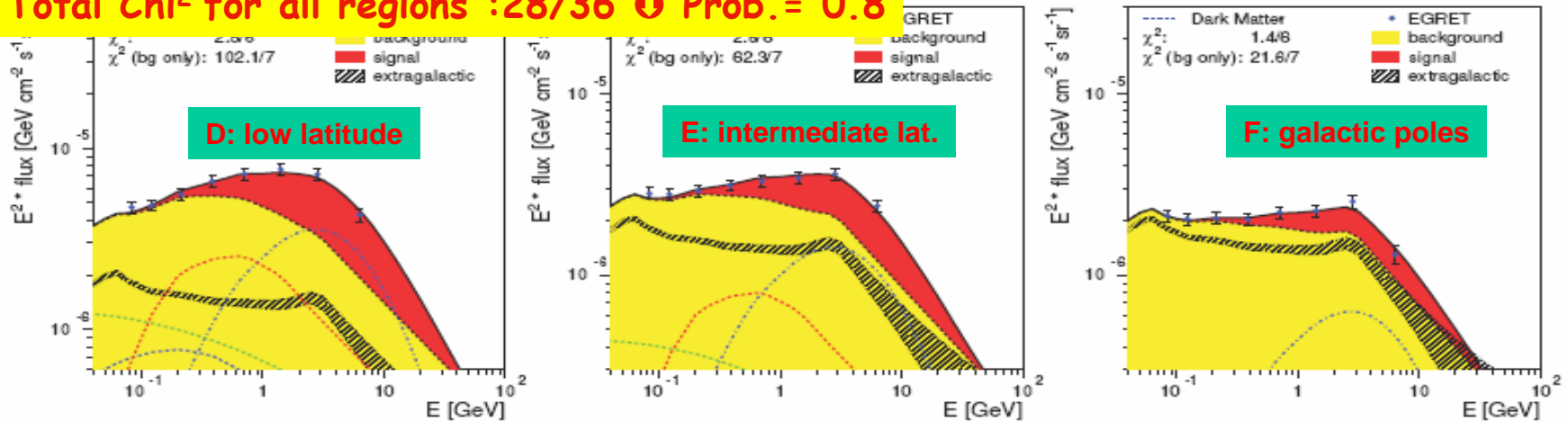
- Data taking from 1991 to 2000
- Subtract point sources
- Need to disentangle galactic and extragalactic contributions
- Sreekumar et al., 1998: (fairly) featureless power law (-2.1) for the EGRB
- Left – over galactic „Dixon – Halo“
- Strong et al. determination (2004) shows steeper power law (-2.3) plus multi – GeV excess in EGRB
- GeV – Excess over conventional model predictions still present in galactic data



# Galactic gamma rays: Hints of DM annihilation?

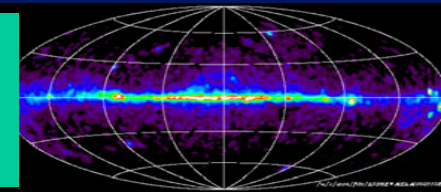


**Total  $\chi^2$  for all regions : 28/36  $\cup$  Prob. = 0.8**



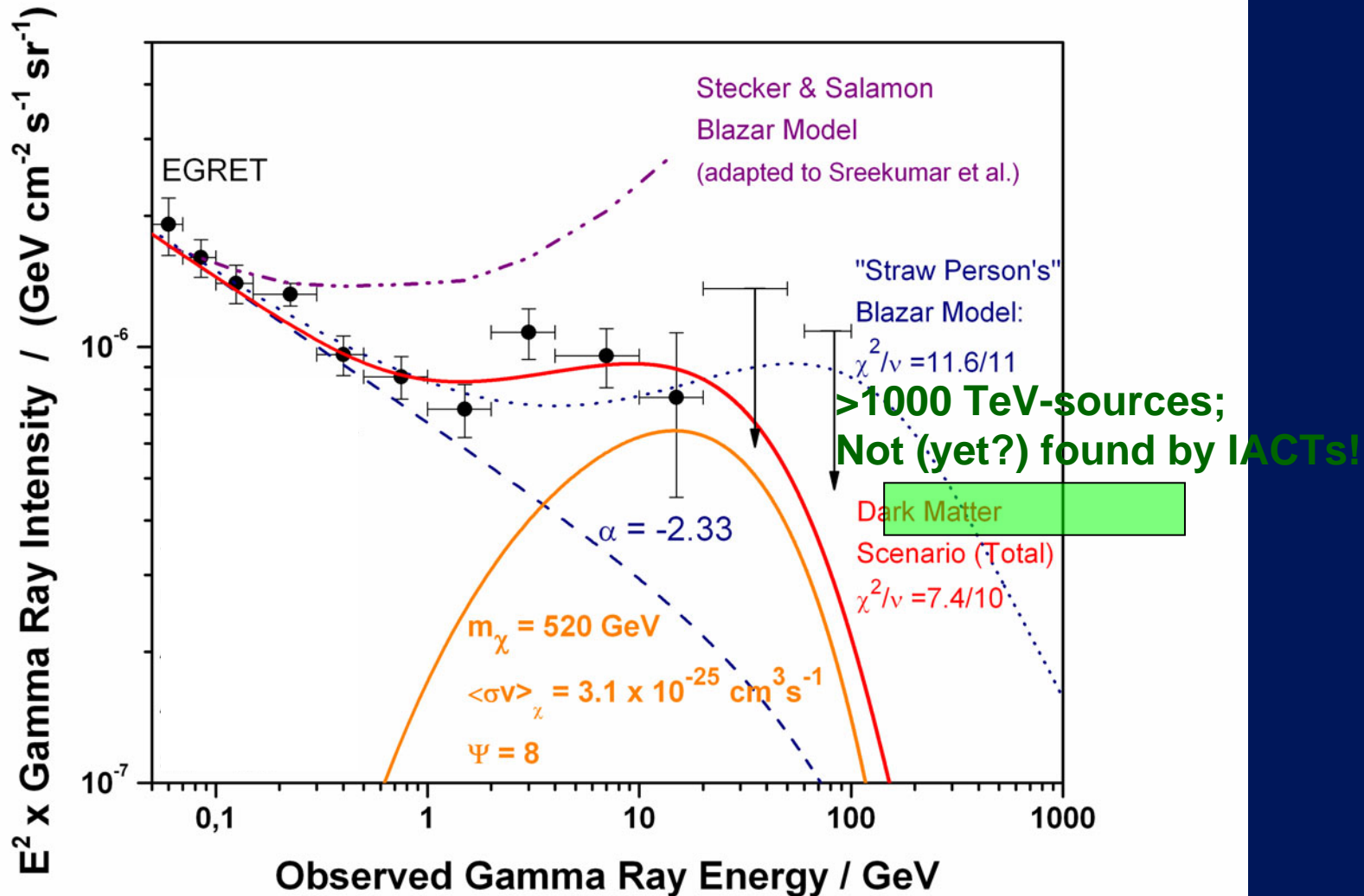
**A: inner Galaxy ( $l = \pm 30^\circ$ ,  $|b| < 5^\circ$ )**  
**B: Galactic plane avoiding A**  
**C: Outer Galaxy**

**D: low latitude ( $10-20^\circ$ )**  
**E: intermediate lat. ( $20-60^\circ$ )**  
**F: Galactic poles ( $60-90^\circ$ )**



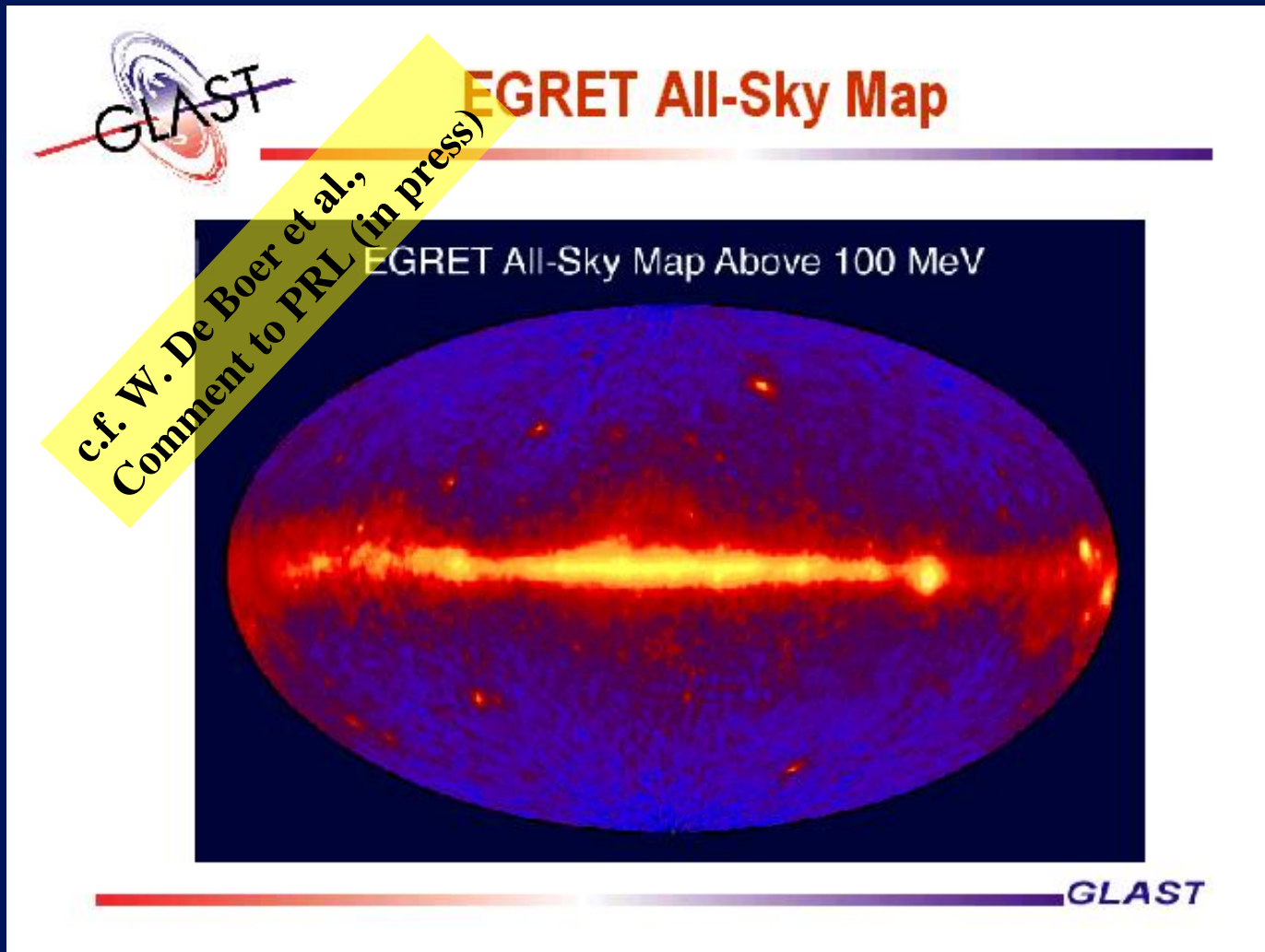
# Extragalactic Gamma Ray Background: Hints of DM – annihilation?

D. Elsässer & K. Mannheim, Phys.Rev.Lett. 94:171302, 2005



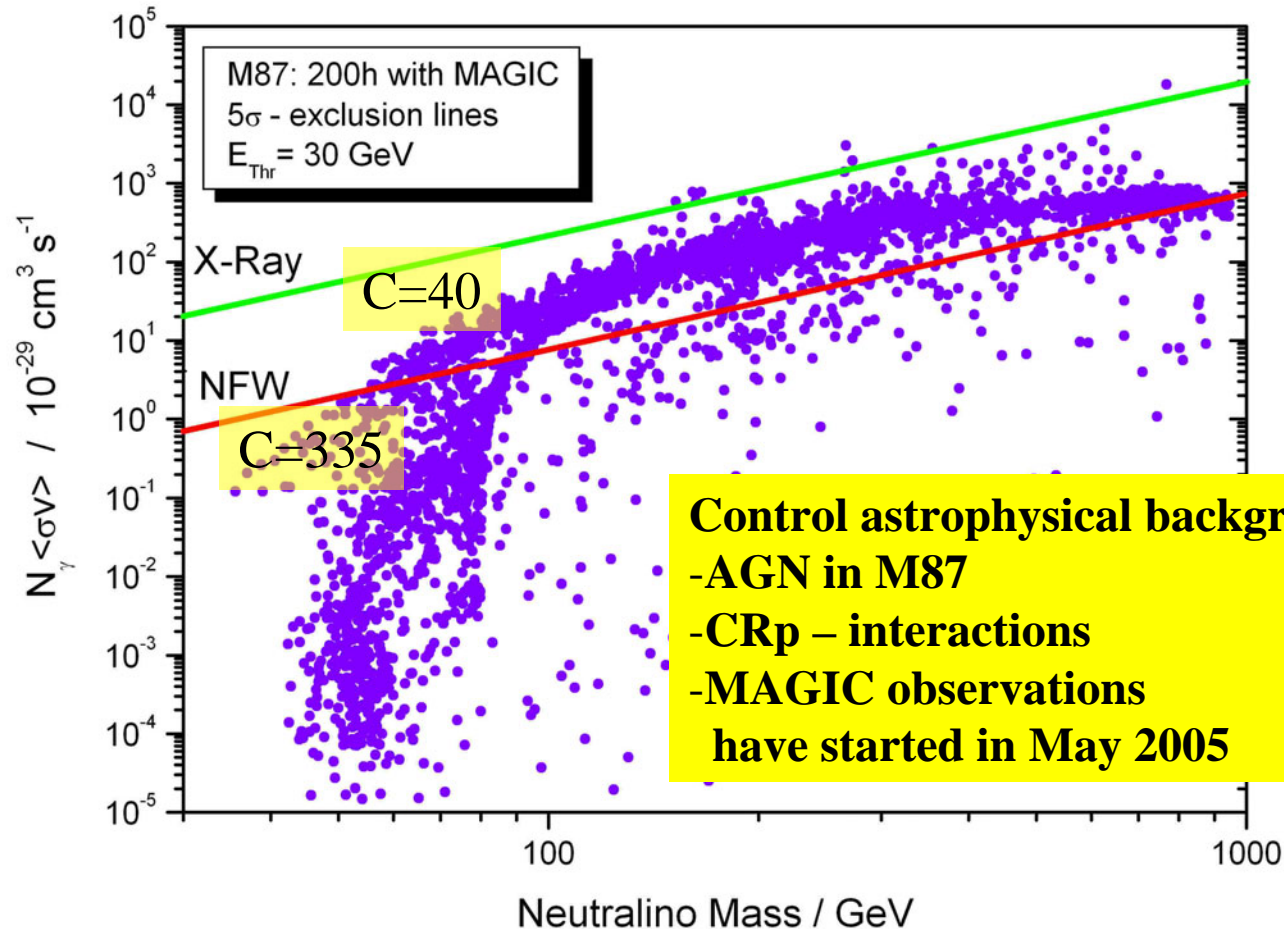


... one dataset, but different inferred WIMP mass from analysis of galactic vs. extragalactic data → need for improved modelling of galactic foreground radiation



# M 87 / Virgo Cluster

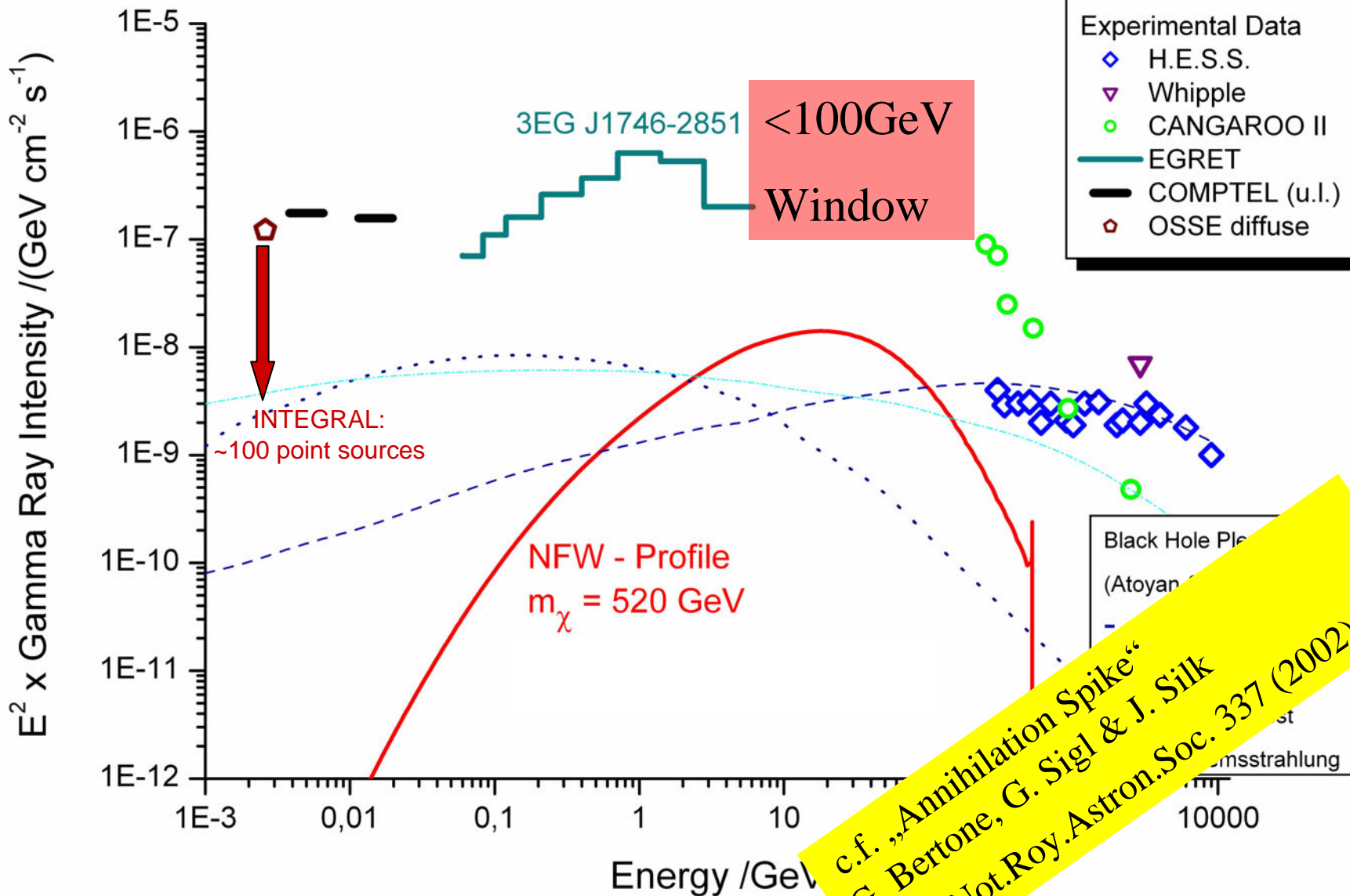
DarkSusy scan



Targeted observations seem promising with new – generation experiments

Dominik Elsässer  
Universität Würzburg

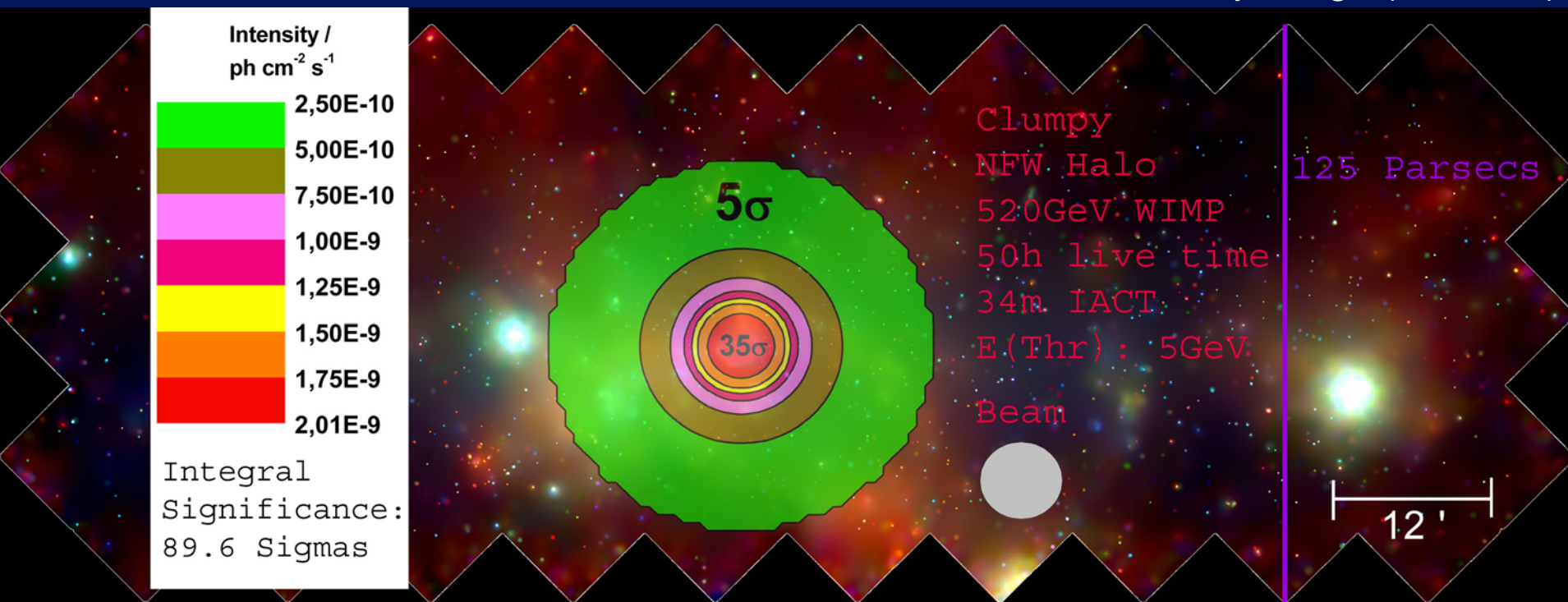
# Galactic Center MeV - TeV



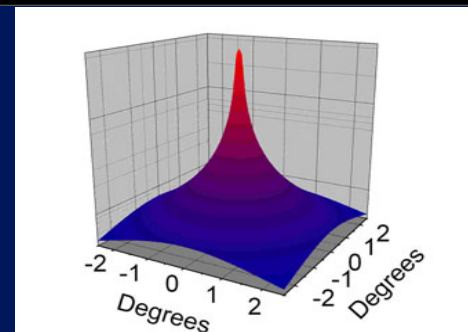
# Galactic Center Neutralino Annihilation

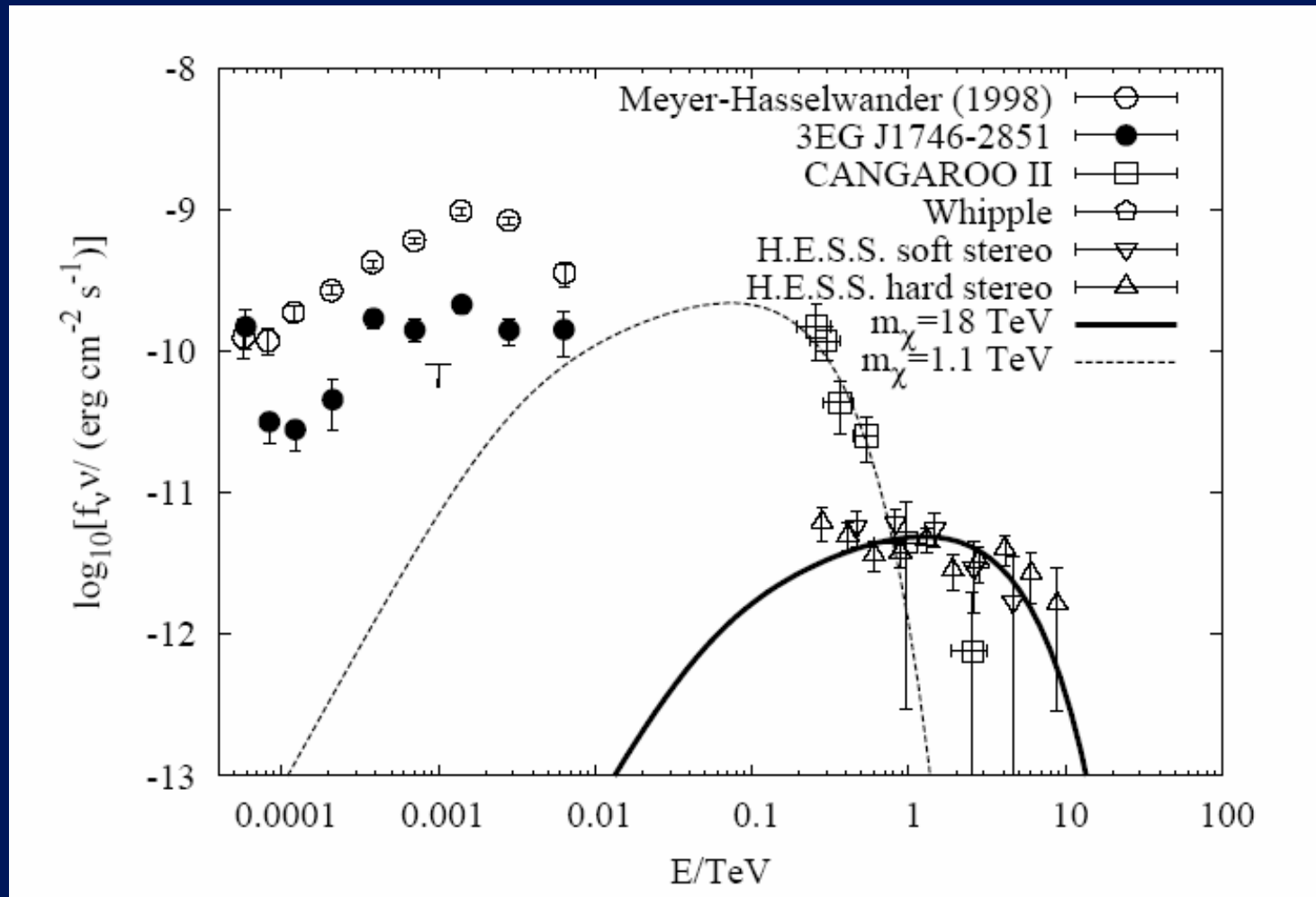
## How would the source look?

X – Ray image (Chandra)



Radial profile  
of signal strength



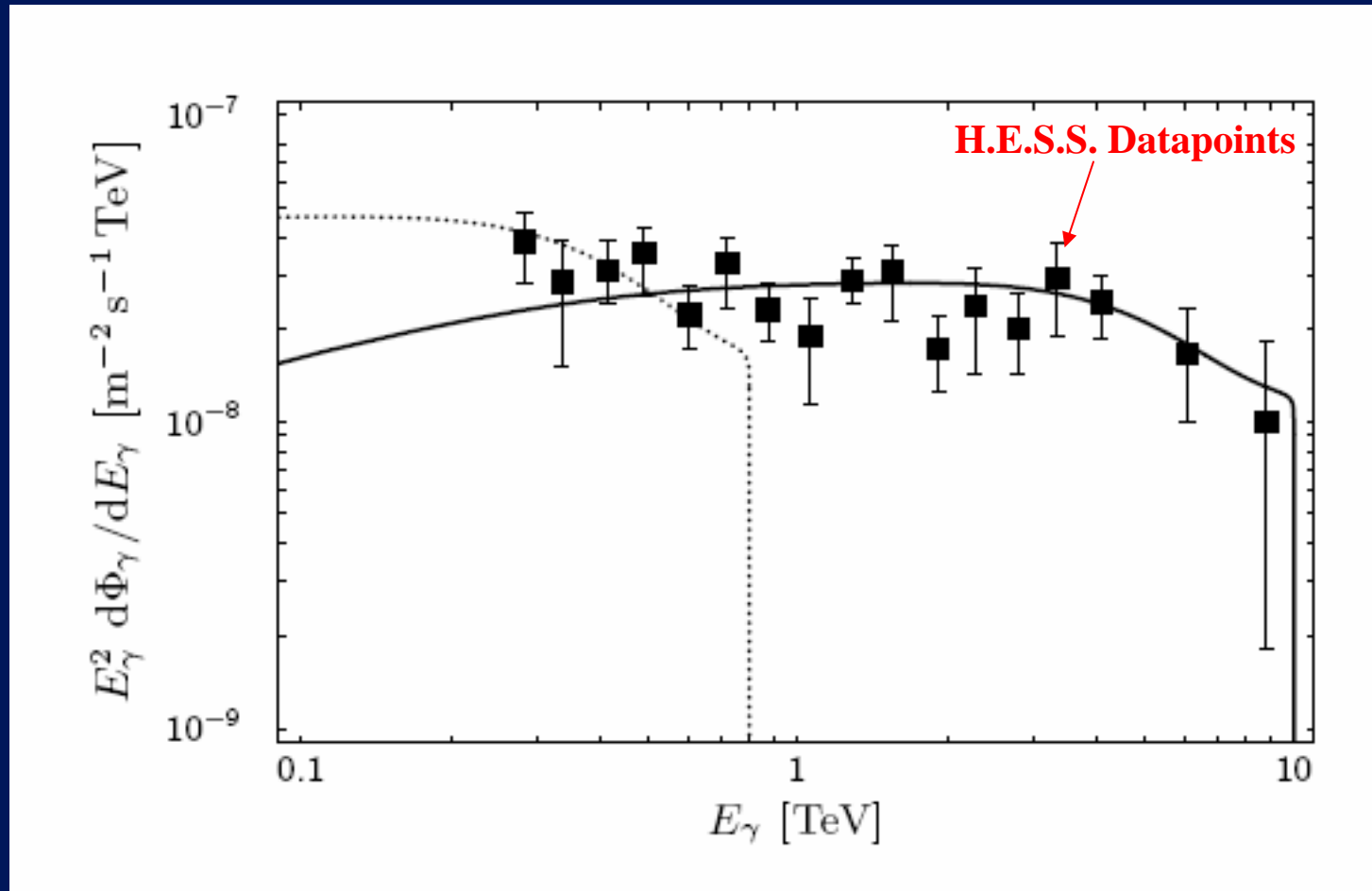


...extended source?



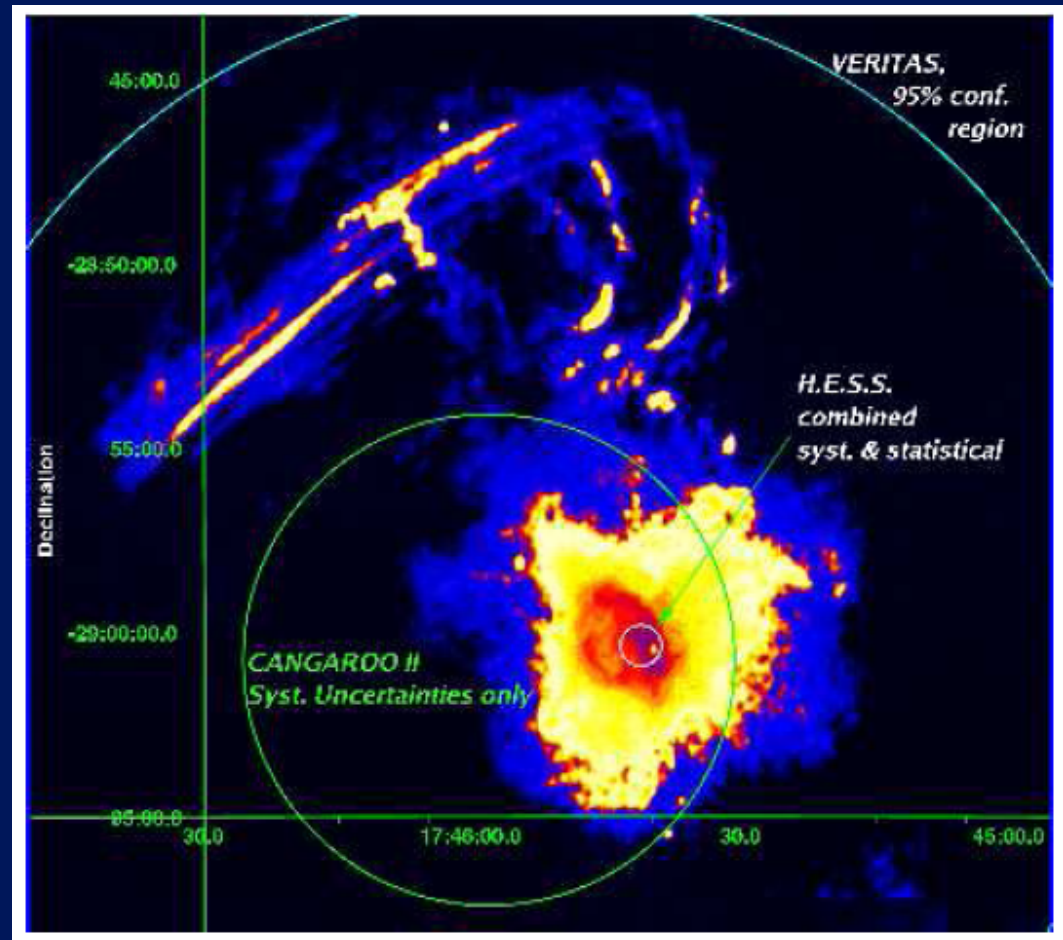
# Kaluza – Klein – DM?

L. Bergström et al., Phys.Rev.Lett. 94 (2005) 131301



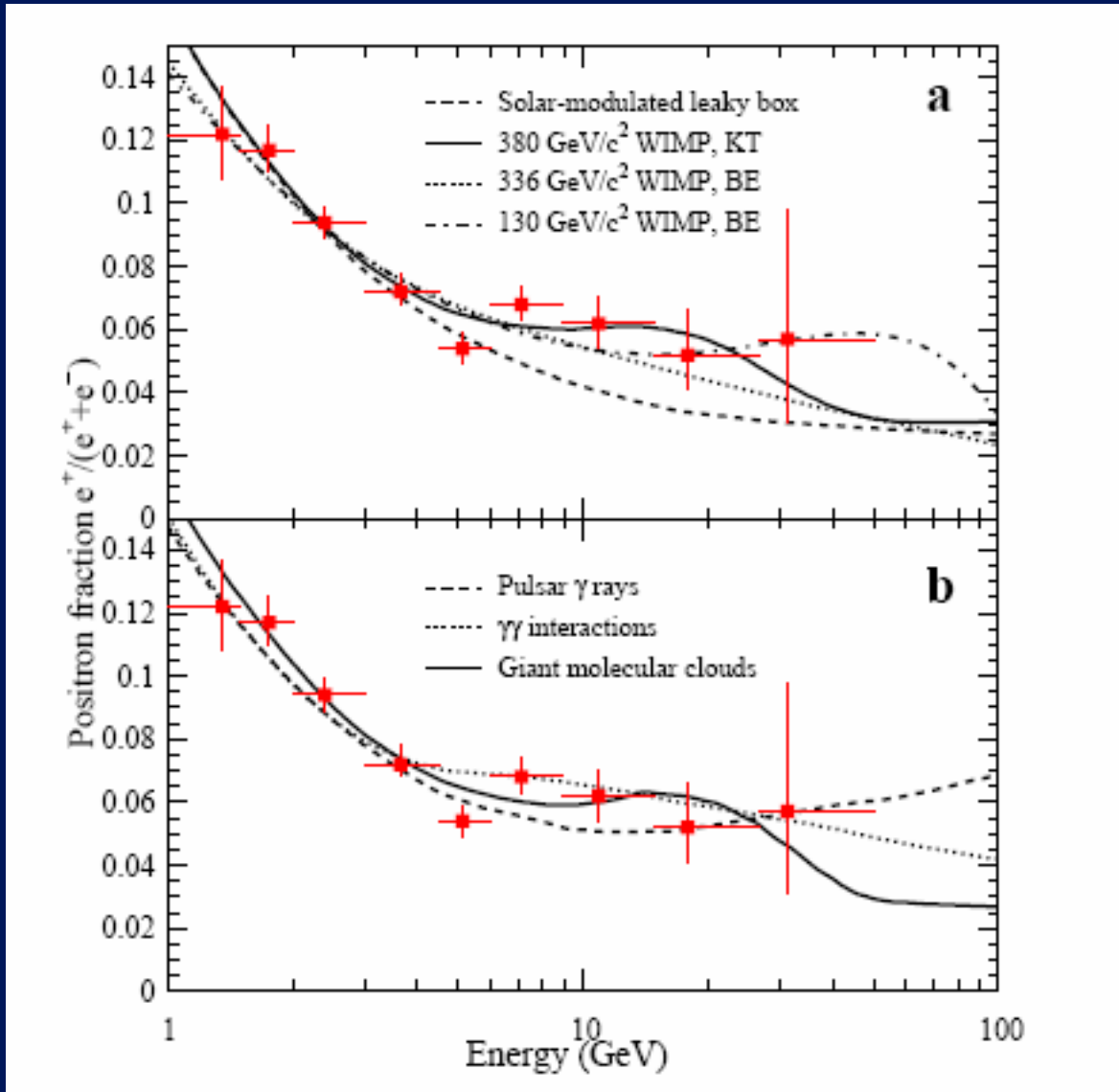
# H.E.S.S. and CANGAROO II

- Different measured spectra
- Variabel source?  
(would exclude DM interpretation)
- However: vastly different spatial resolution of the two experiments
- Follow up observations needed (e.g. MAGIC observations in 2004/2005: c.f. Poster Presentation)



# Positron Fraction („HEAT – Excess“)

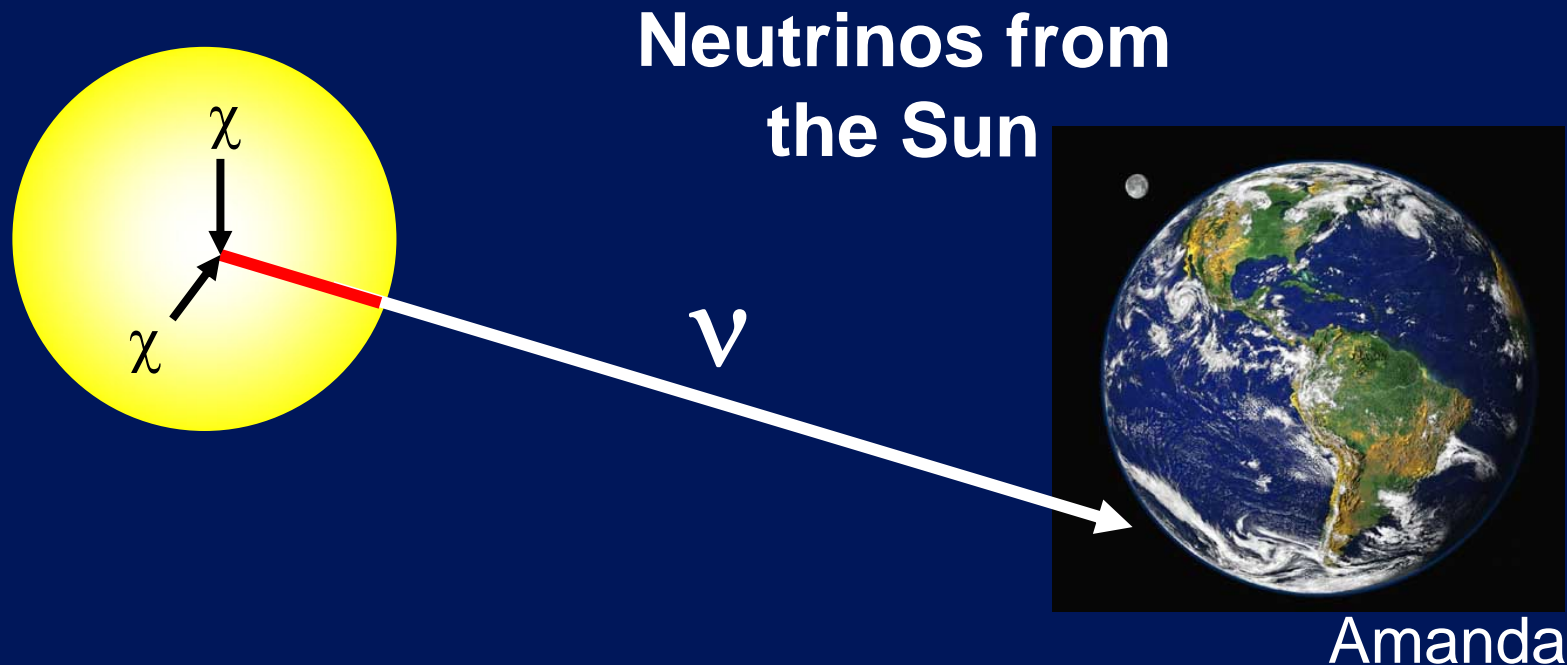
S. Coutu et al., *Astropart.Phys.* 11 (1999) 429-435



Demand for  
improved  
measurements,  
AMS

# Neutrino Channels

(C. Spiering)



At South Pole the Sun sinks maximally  $23^\circ$  below horizon. Therefore only Amanda-II with its dramatically improved reconstruction capabilities for horizontal tracks (compared to Amanda-B10) can be used for solar WIMP search.

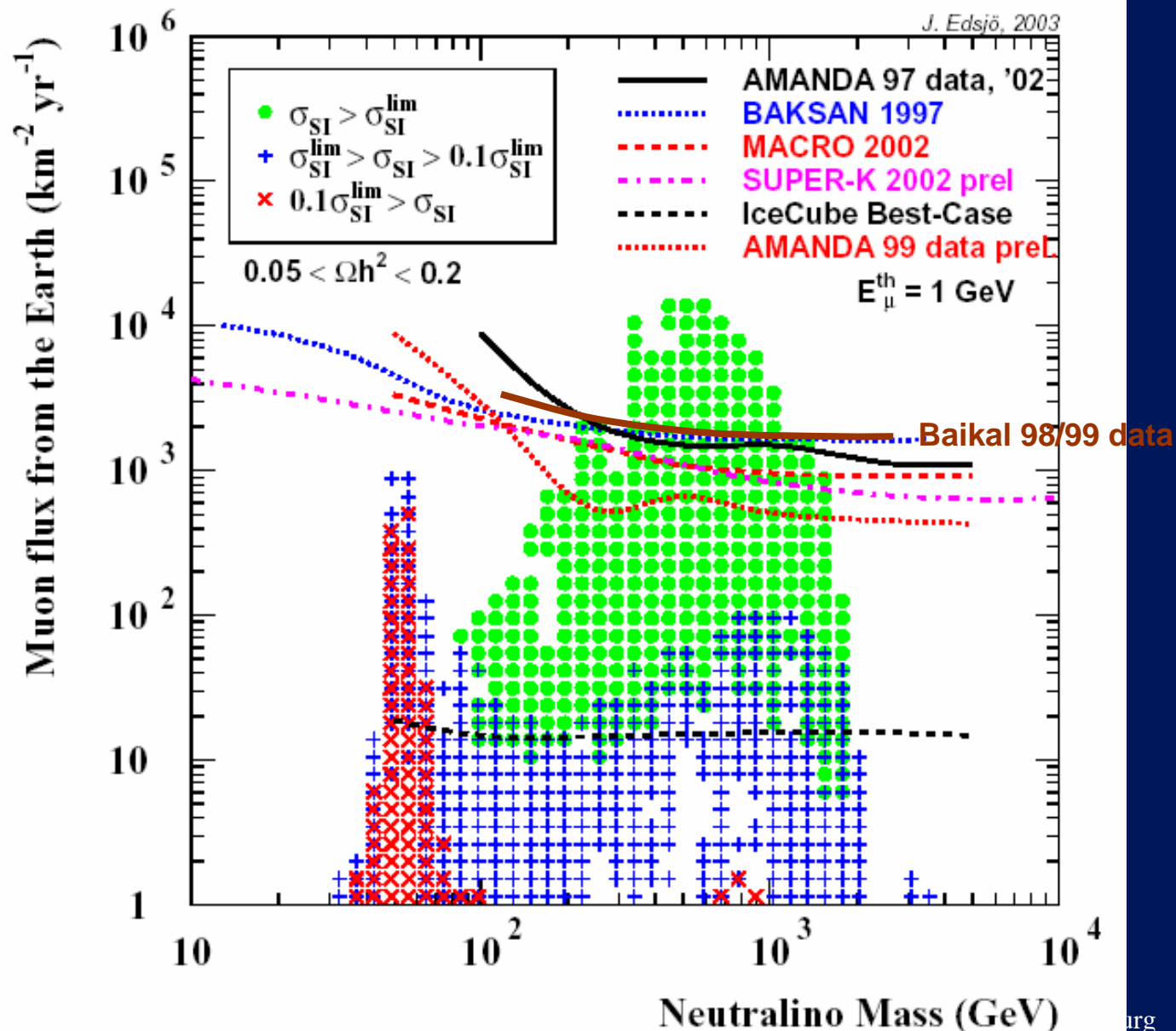
# Upper limits on muon flux from neutralino annihilations in center of Earth

Neutralinos from the galactic halo are captured in the center of the sun via multiple elastic scattering

Search for GeV – TeV neutrinos due to neutralino annihilation

**Green dots:**  
Excluded by present direct searches

**Blue crosses:**  
can be excluded by 10 times more sensitive direct searches





# Conclusions

- Existing high – energy gamma ray observations might already hold interesting hints to the nature of the dark matter in the Universe
- Interesting signatures also possible from neutrino, antiproton and positron channels
- MAGIC-II: AGN counts,  $M 87 < 100\text{GeV}$   
H.E.S.S.-II: Galactic Center  $< 100\text{GeV}$   
GLAST: Galactic halo & EGRB  
IceCube & KM3NET: Neutrino Channels  
AMS: Nature of the HEAT - Excess

**Complementary  
theoretical studies**