

**The Current
Astrophysical and
Experimental Picture of
Dark Matter**

Paolo Gondolo

The Case



The “best” matter density

WMAP (Bennett et al., 2003)

$$\Omega_m h^2 = 0.135^{+0.008}_{-0.009}$$

of which

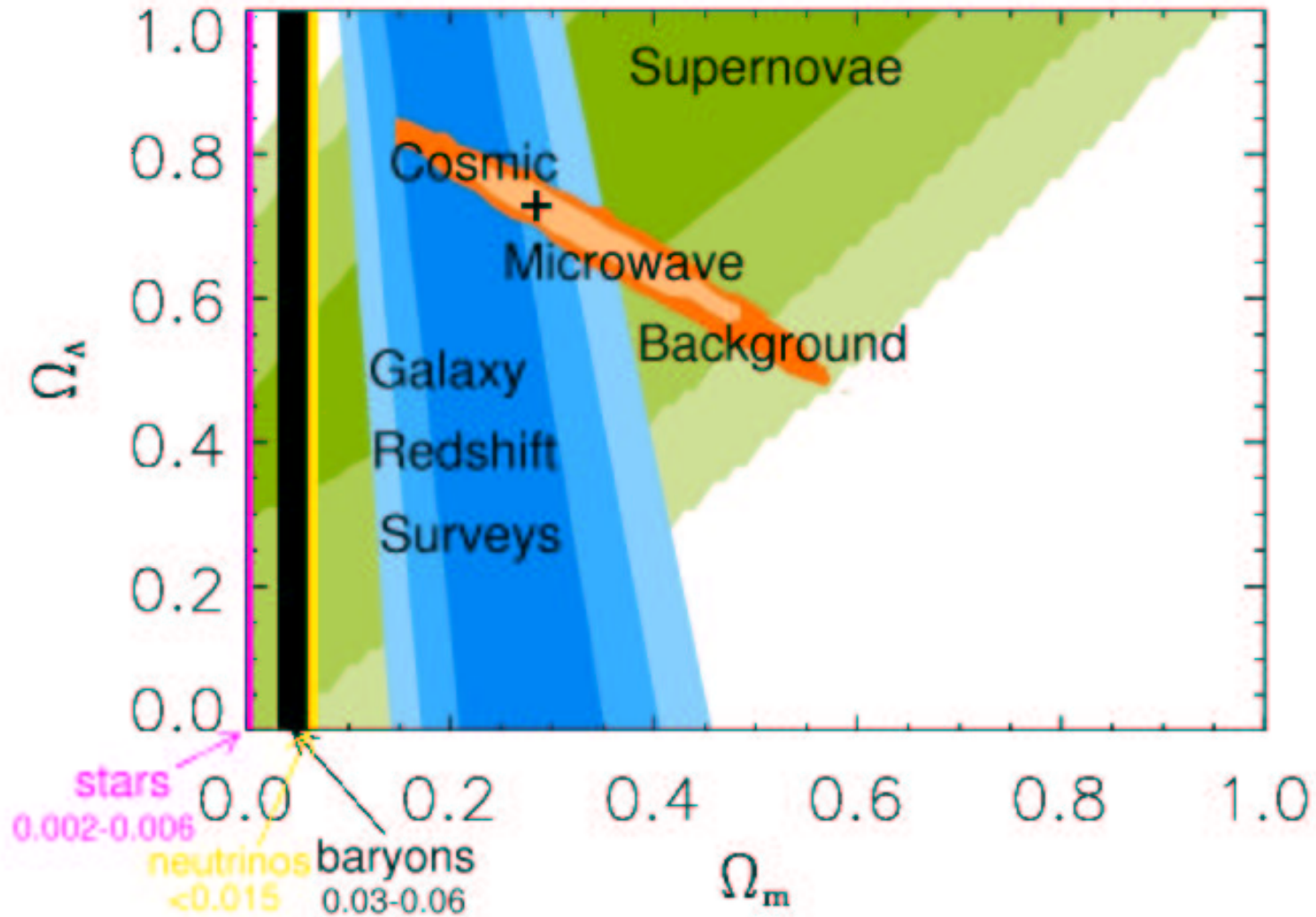
$$\Omega_\nu h^2 < 0.0076 \text{ (95\%CL)}$$

$$\Omega_b h^2 = 0.0224 \pm 0.0009$$

$$\Omega_{\text{CDM}} h^2 = 0.113^{+0.008}_{-0.009}$$

(Units are $1.879 \times 10^{-29} \text{ g/cm}^3$)

The concordance cosmology



Adapted from L. Verde

The dark matter problems

- **Missing baryons at low redshift**
- **Non-baryonic dark matter**

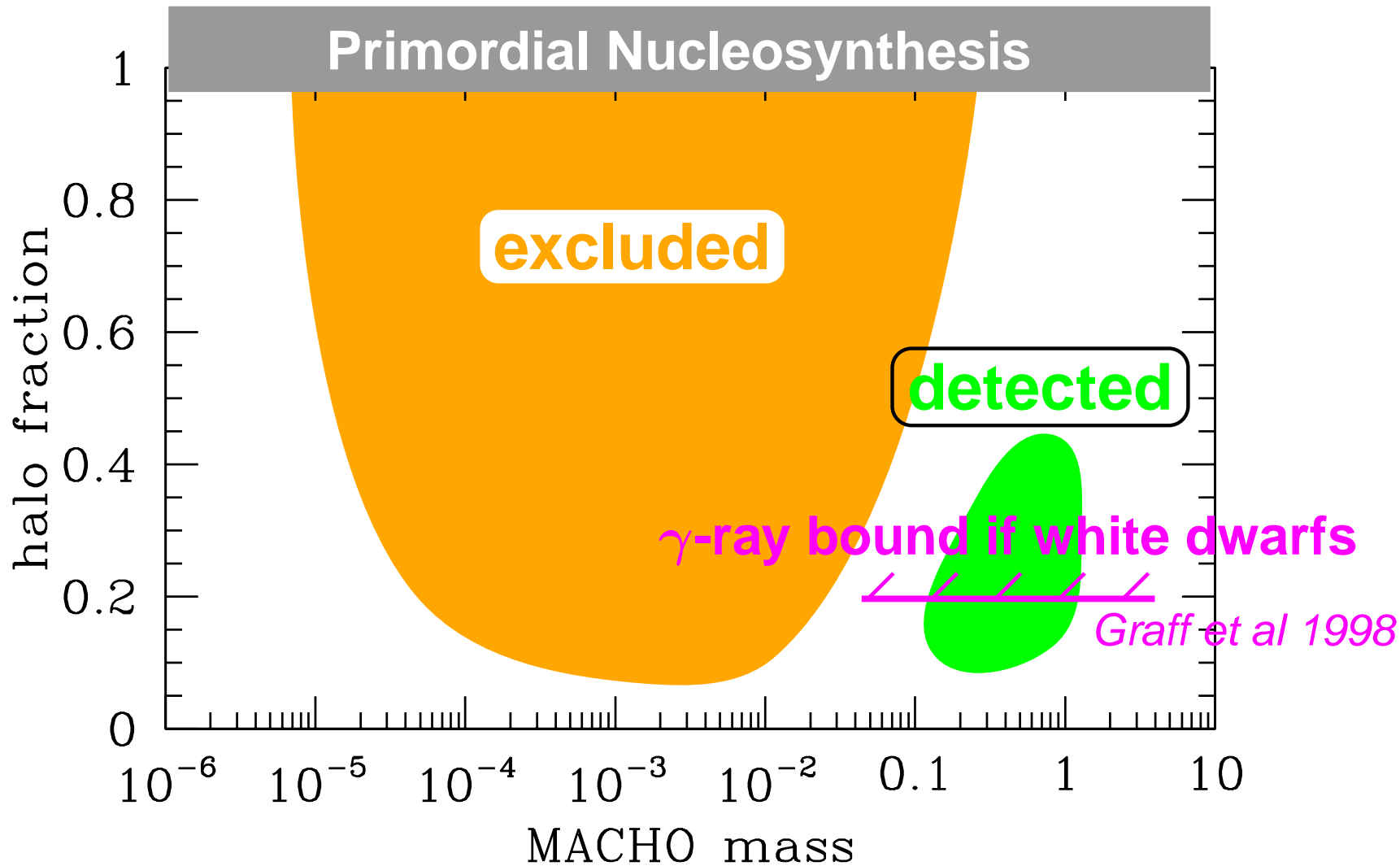
Suspects



Suspect #1: MACHOs

Massive Compact Halo Objects

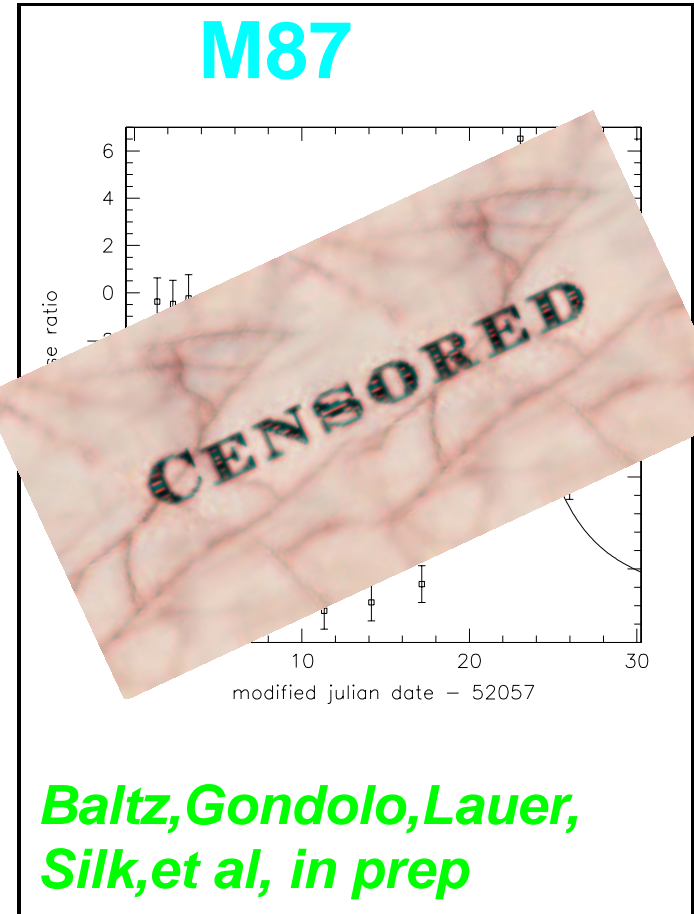
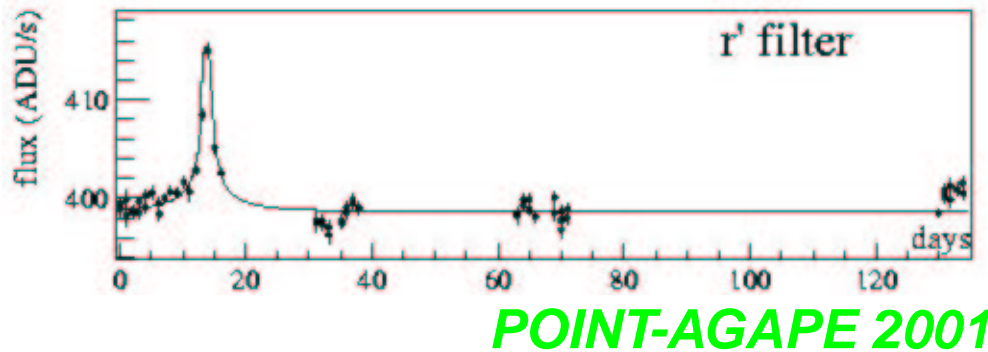
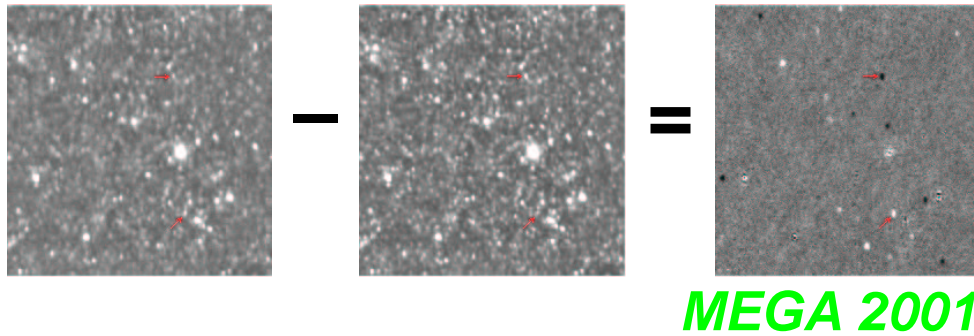
MACHOs!



MACHO & EROS 1996-2000

“Pixel” microlensing

monitor unresolved stars in M31, M87, ...



Suspect #2: neutrinos

Neutrinos as dark matter

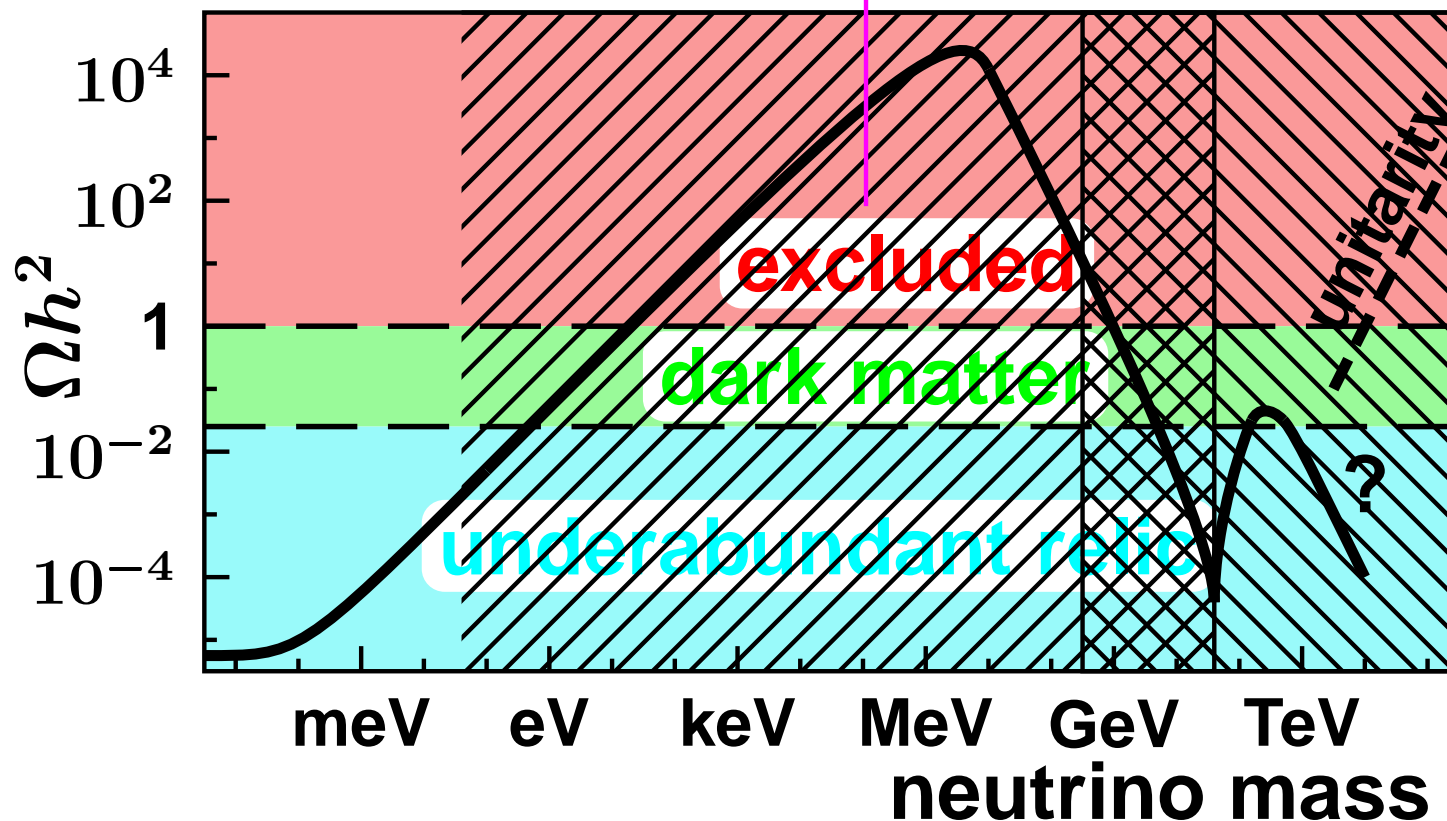
Hot Dark Matter

~~Cold Dark Matter~~

SuperK

LEP

DM searches



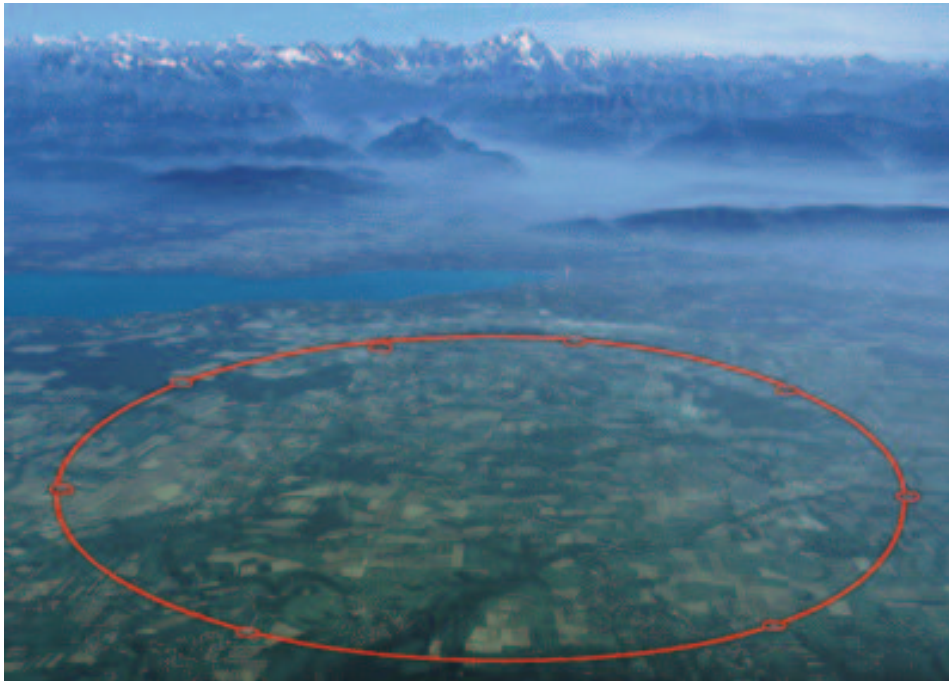
Suspect #3: WIMPs

**Weakly Interacting Massive
Particles**

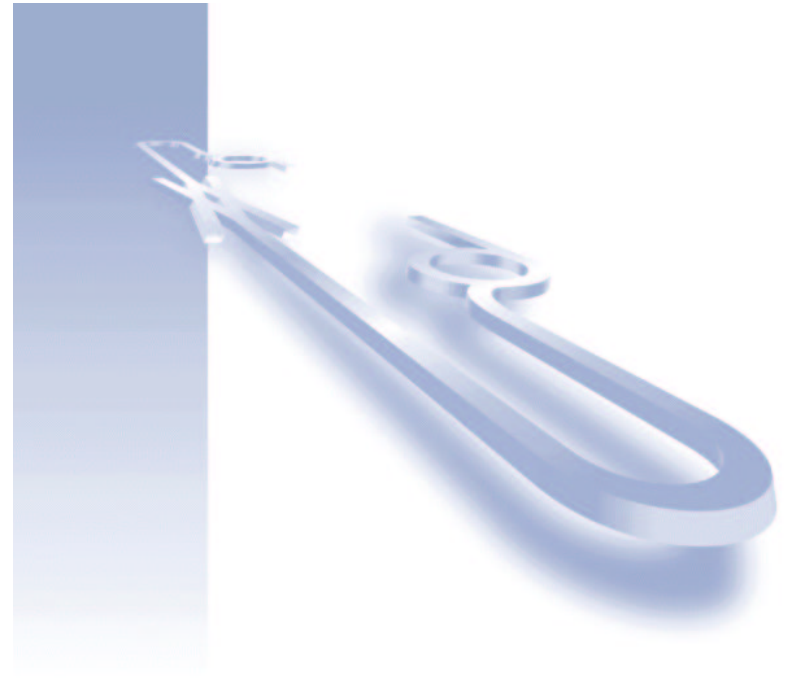
Supersymmetry

- Unification of fundamental forces
- Stabilization of scalar masses

slepton	\leftrightarrow	lepton
squark	\leftrightarrow	quark
gaugino	\leftrightarrow	gauge boson
higgsino	\leftrightarrow	Higgs boson



Large Hadron Collider

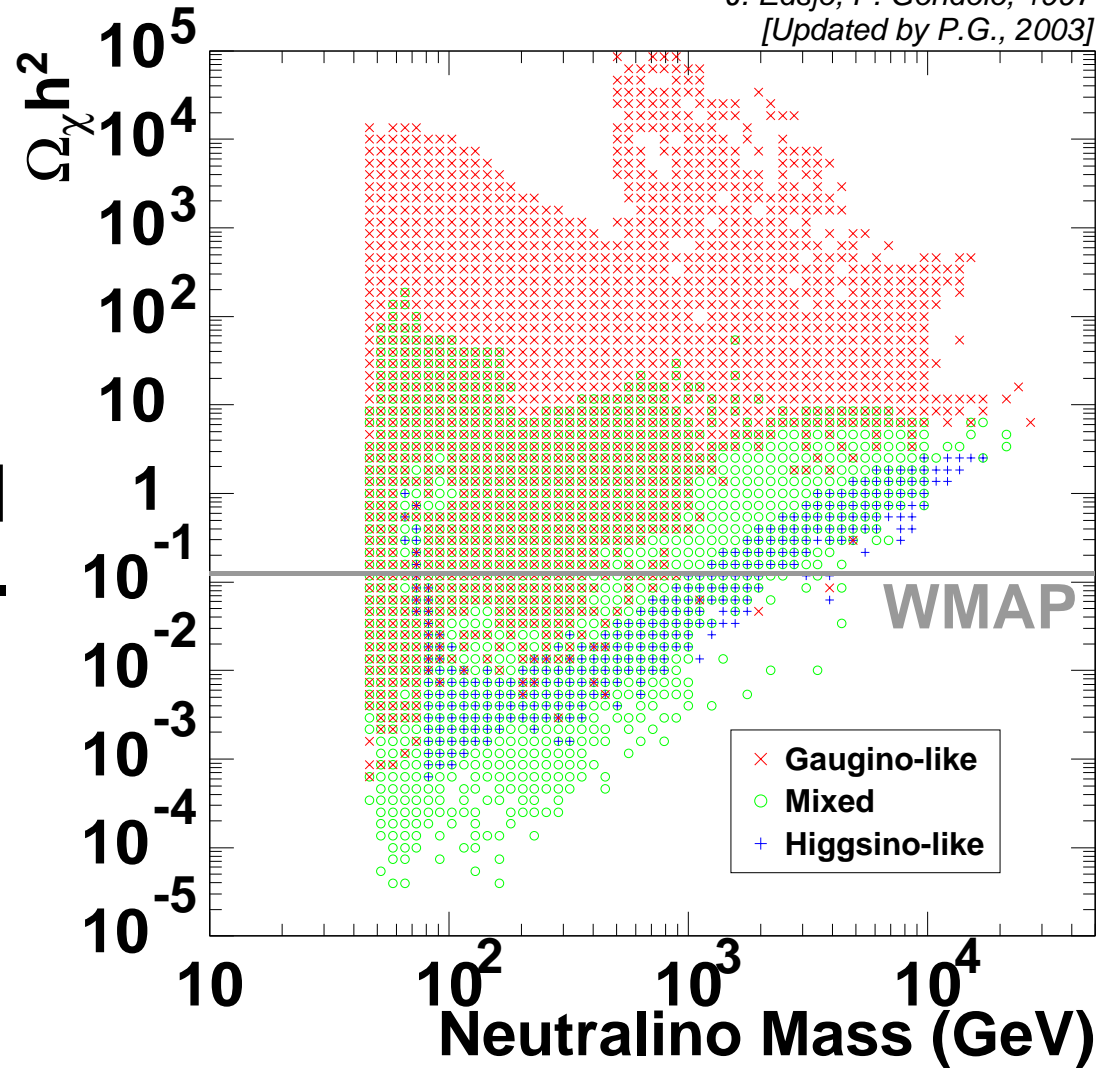


Next Linear Collider

Supersymmetric dark matter

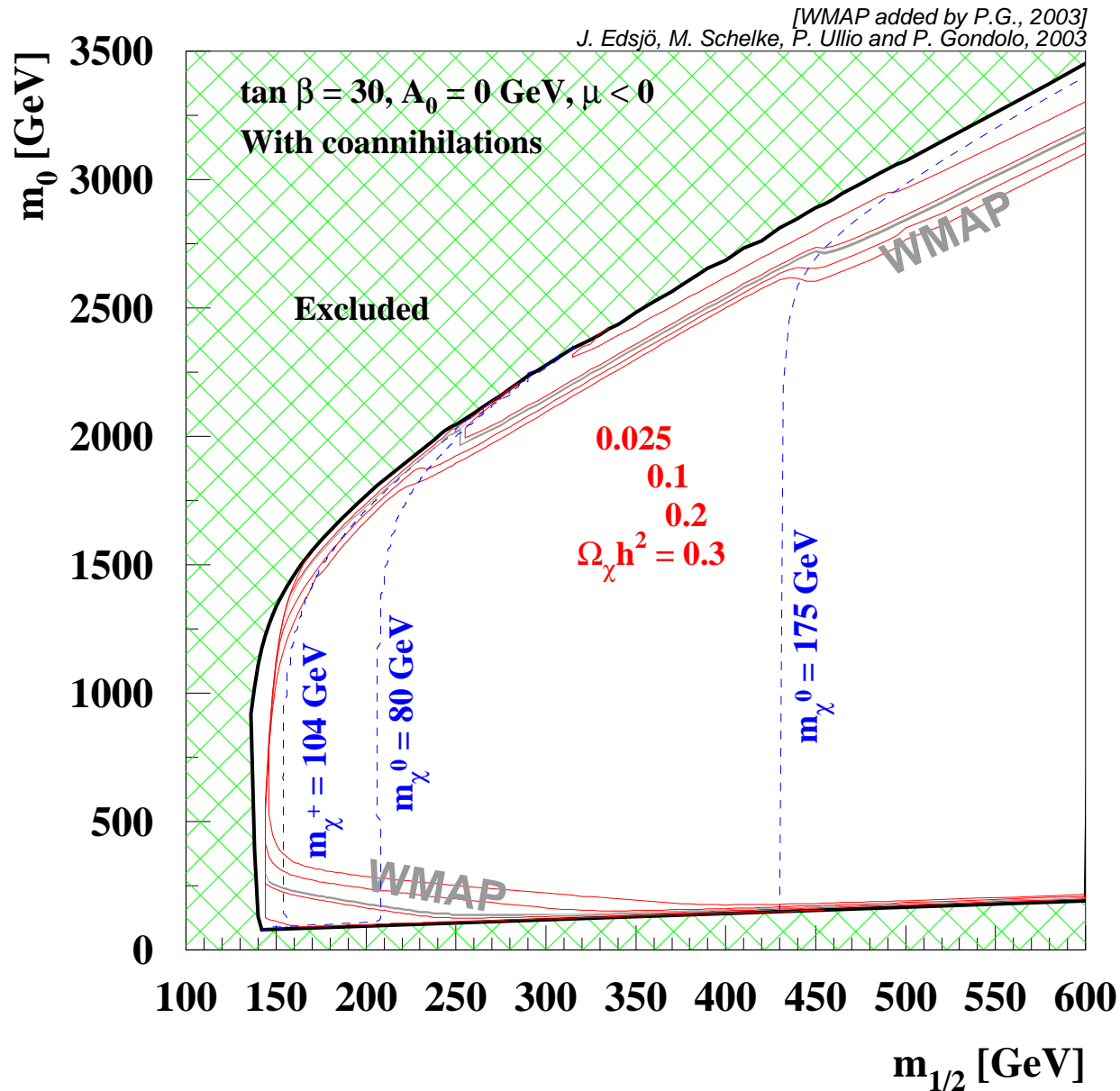
J. Edsjö, P. Gondolo, 1997
[Updated by P.G., 2003]

The lightest supersymmetric particle is a good dark matter candidate



Updated from Edsjö, Gondolo 1997

Some results in mSUGRA



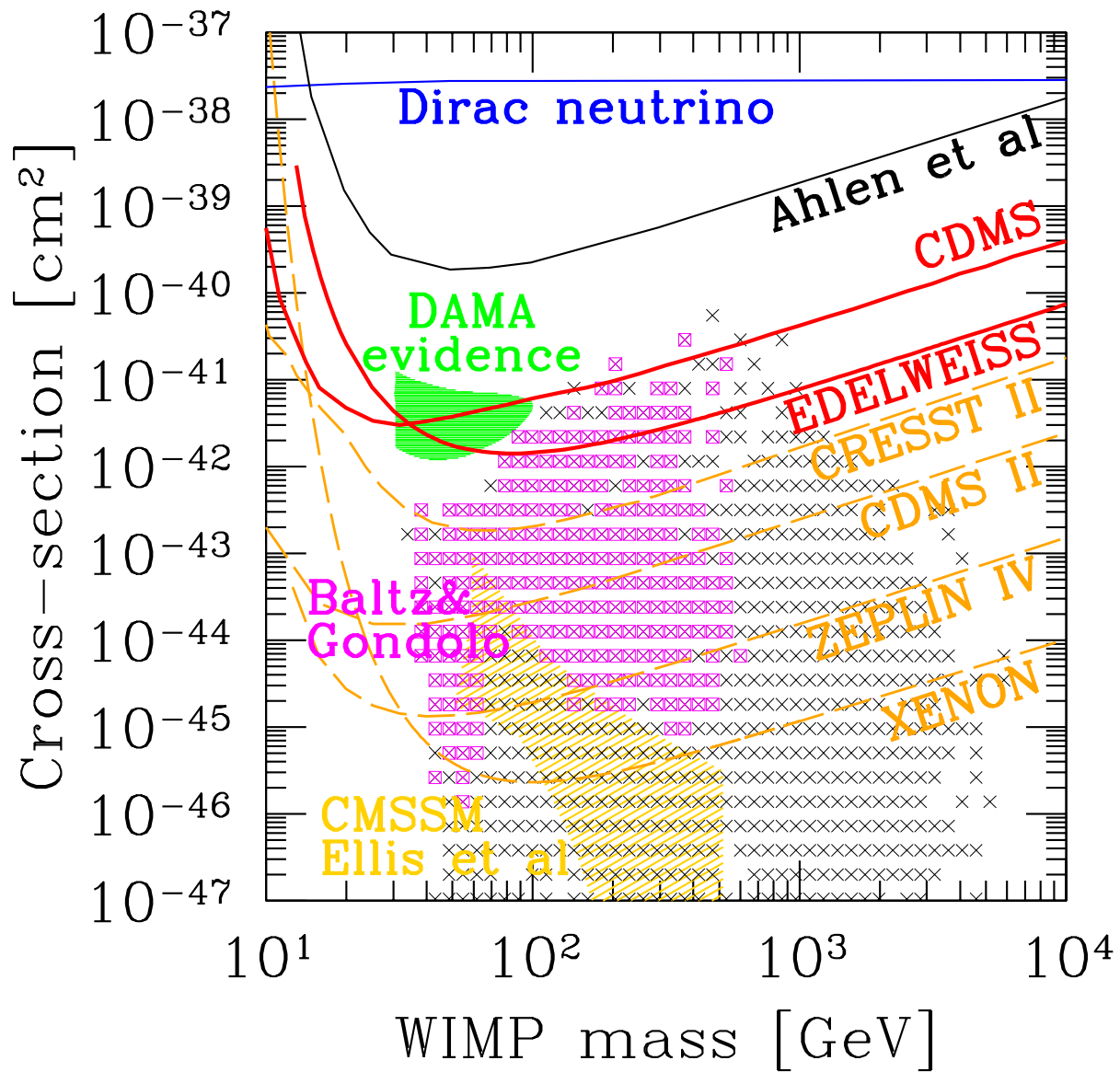
Cosmology and mSUGRA

- **Cosmological data on $\Omega_\chi h^2$:** **7%**
WMAP first year data: $\Omega_{\text{CDM}} h^2 = 0.113_{-0.009}^{+0.008}$
- **Neutralino annihilation chain:** **1%**
Edsjö, Schelke, Ullio, Gondolo, 2003
- **Masses from GUT parameters:** **50%**
See Allanach, Kraml, Porod, 2003

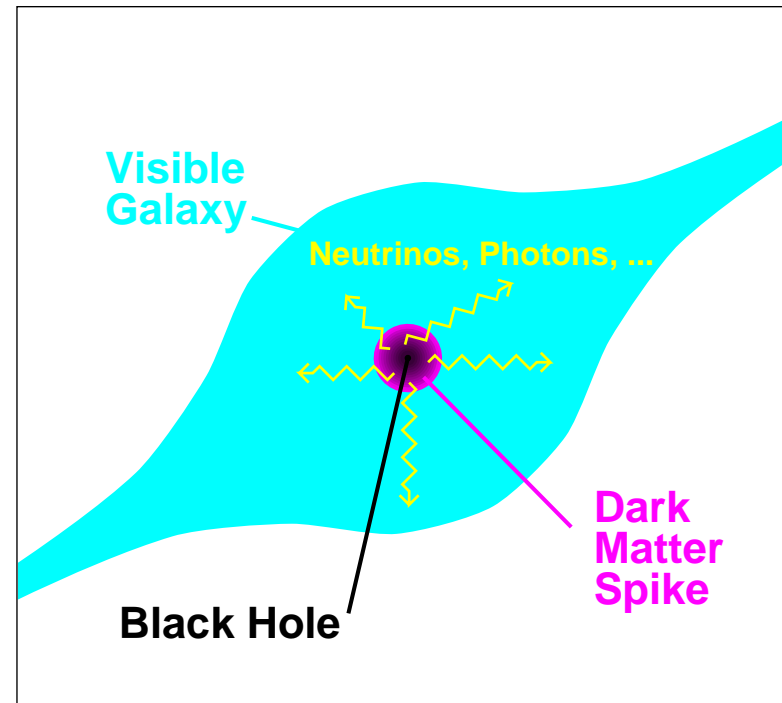
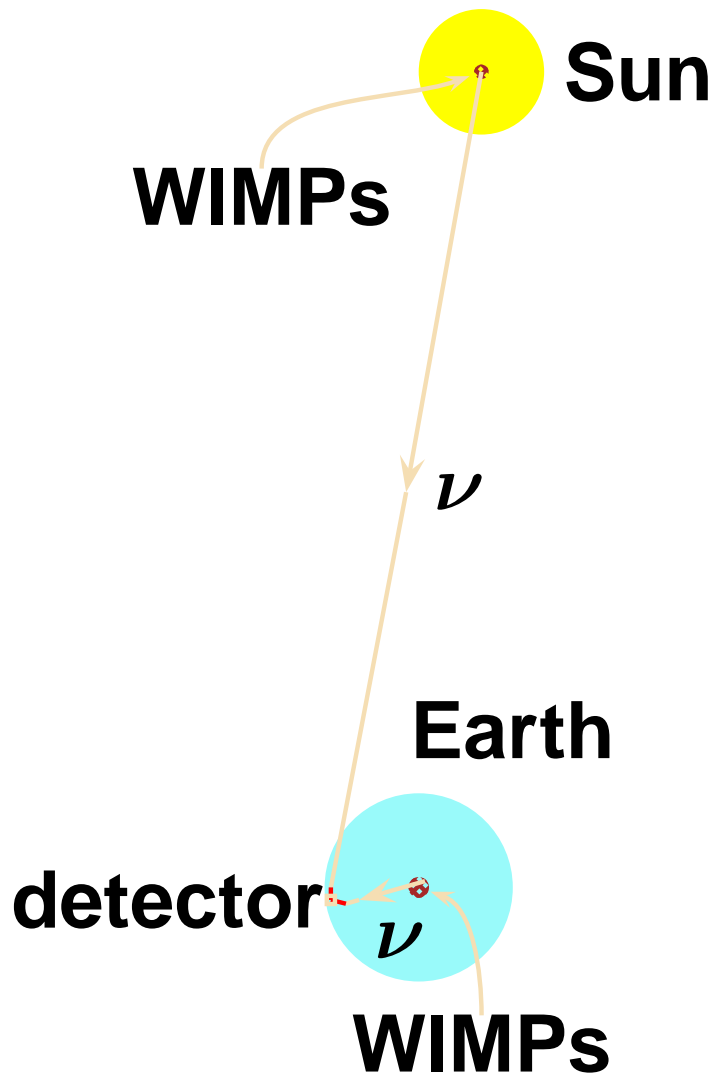
Searching for dark WIMPs

- **direct detection**
- **neutrinos from Sun/Earth**
- **anomalous cosmic rays from galactic halo**
- **neutrinos, gamma-rays, radio waves from galactic center**

WIMP direct searches



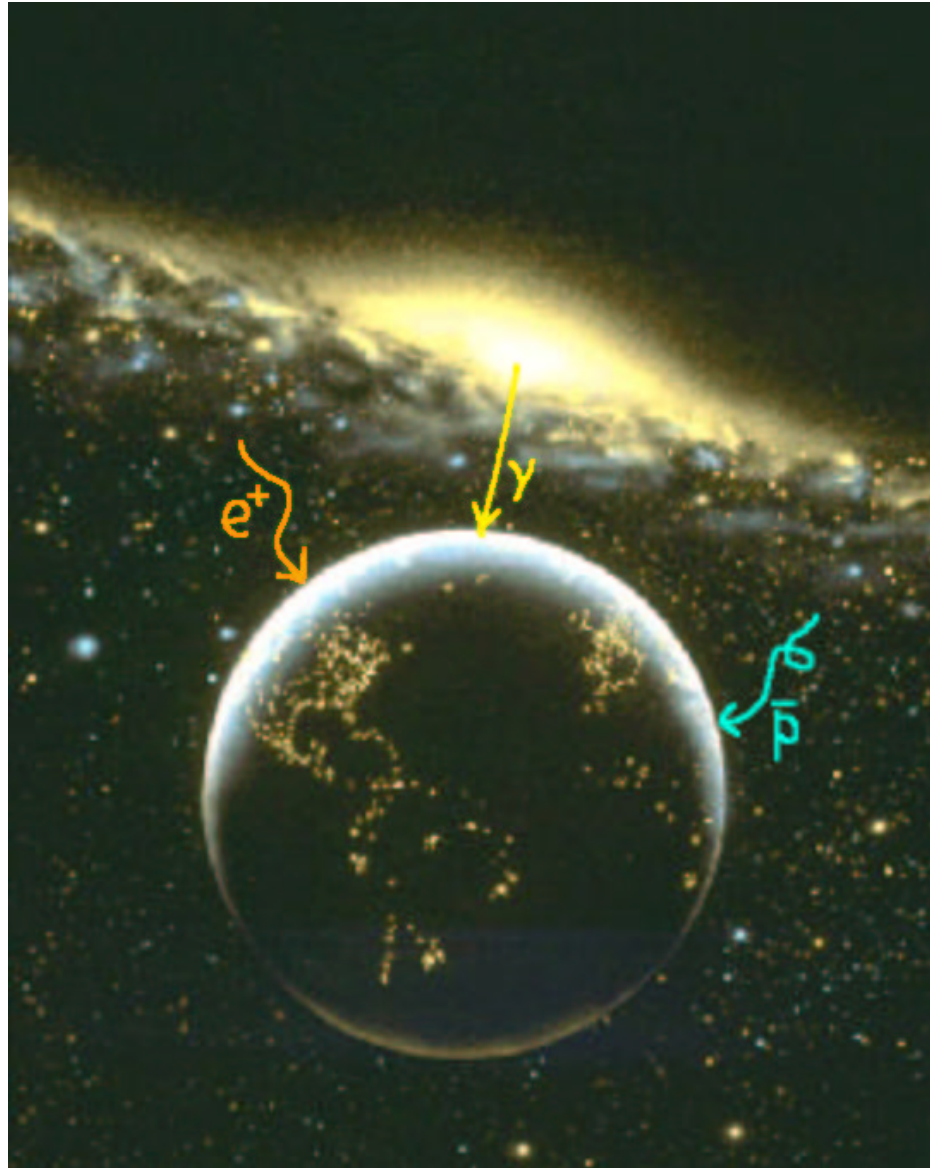
Neutrinos from dark matter



Gondolo, Silk 1999, Gondolo 2000

**SuperK, AMANDA,
Antares, IceCube, ...**

Cosmic rays from dark matter

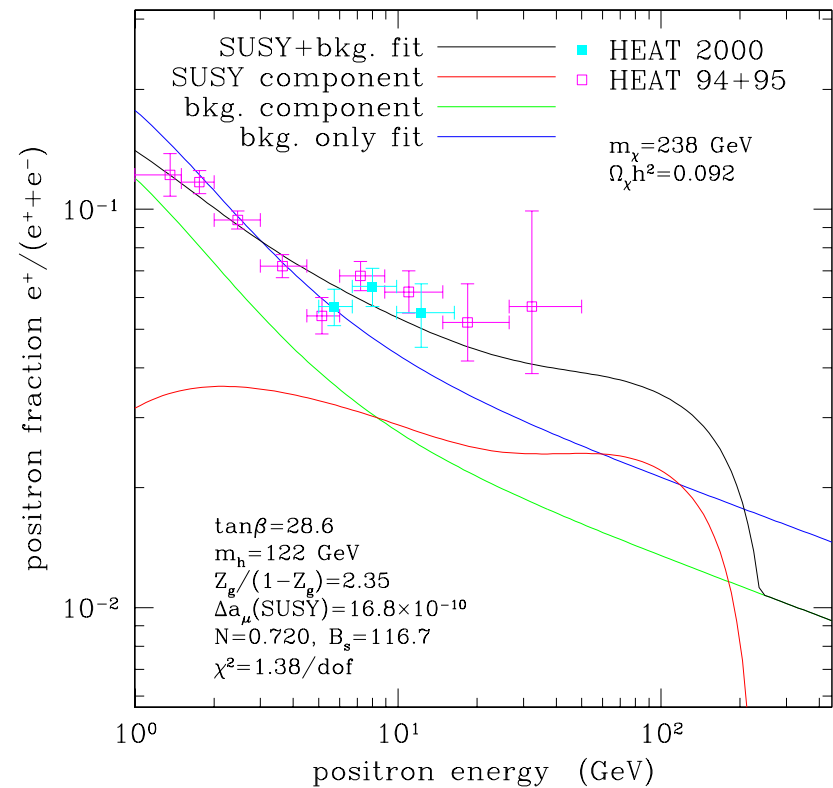
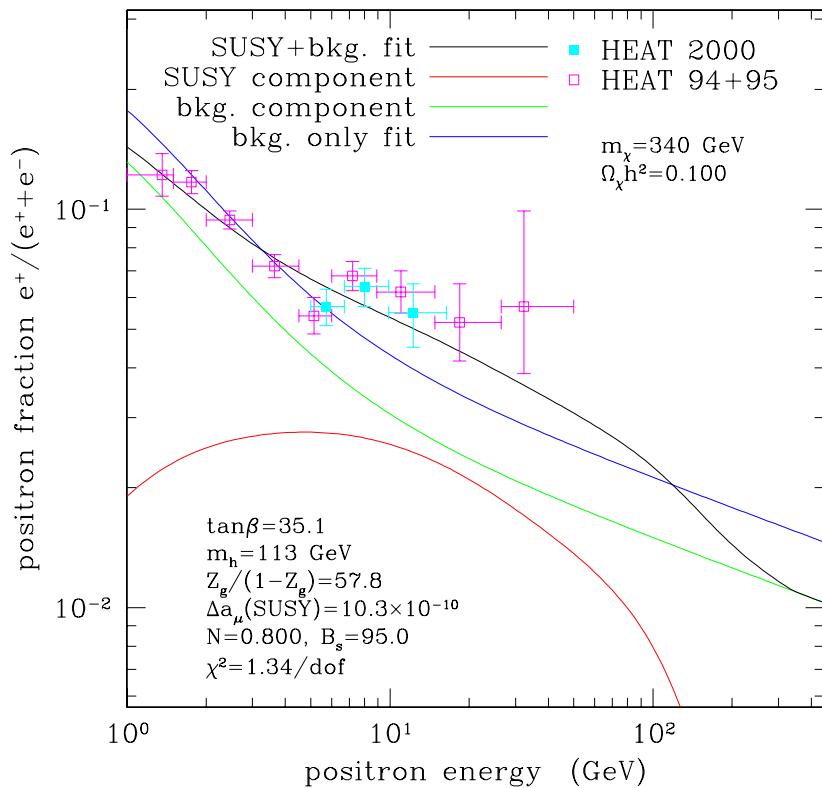


Background by J. Lomberg 1989

Positron excess

HEAT balloon finds anomaly in cosmic ray flux

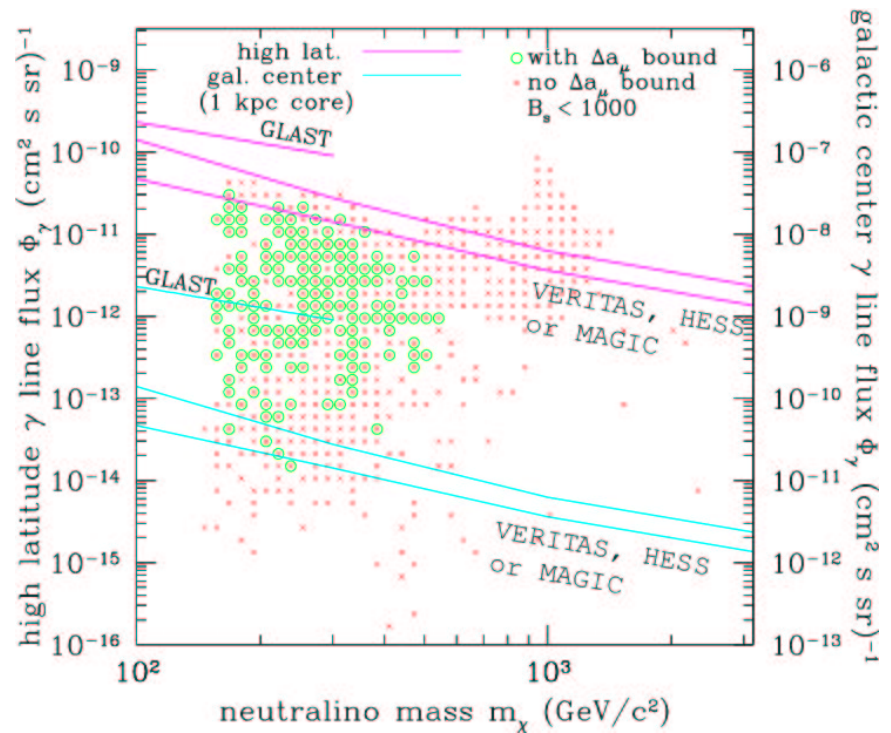
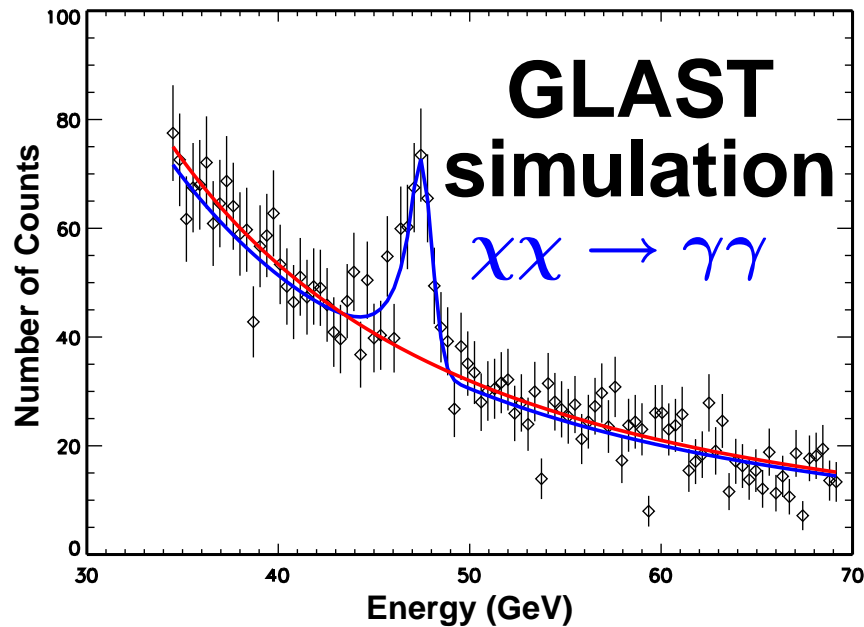
Possible explanation: supersymmetry in the galaxy



Baltz, Edsjö, Freese, Gondolo 2001

Positron excess

Future test of WIMP explanation:
Gamma-rays from galactic halo



Baltz, Edsjö, Freese, Gondolo 2001

Other suspects:

Missing baryons:

**black holes,
cold-warm gas,**

...

Non-baryonic:

**axions,
WIMPZILLAs,
Kaluza-Klein particles,**

...

Summary

Baryonic and non-baryonic dark matter

In search of the missing baryons

In search of non-baryonic dark matter

Dark Matter Mystery Solved

