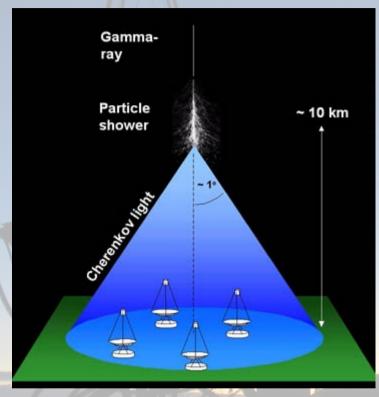


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GDR PCHE 12-13 Mars 2009

H.E.S.S. experiment



Characteristics:

- stereoscopic system: 4 telescopes Ø 13m
- energy threshold ~ 100 GeV
- field of view 5°
- energy resolution ~ 15%
- angular resolution ~ 0.1°
- sensibility 1% of the Crab nebula in 25h
- several events reconstruction codes used: Hillas, Model2D, Model3D
 - and multi-variables combination



Dark matter search with yastronomy

Predict γ flux for WIMPs annihilation:

$$\frac{d\Phi}{dE}(\Delta\Omega, E) = \Phi_0 \frac{dN}{dE} \frac{\langle \sigma v \rangle}{\langle \sigma v \rangle_{ref}} \left(\frac{1 \, TeV}{m_{DM}}\right)^2 \frac{1}{d\Omega} \int_{\Delta\Omega} \int_{l.o.s} \rho^2(r[s]) \, ds$$

Detector:

Angular acceptance Angular resolution for H.E.S.S. : $\Delta\Omega$ = 2 10⁻⁵ sr

Particle physics: WIMPs annihilations

annihilation of neutralino in 2 framework

- pMSSM
- mSUGRA

Search for the continuum component with H.E.S.S.

(lines processes are 2^{nd} order \rightarrow suppressed)

Astrophysic:

halo density profile

$$J = \int_{l.o.s} \rho^2(r[s]) ds$$

$$\bar{J}(\Delta\Omega) = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} PSF * J d\Omega$$

Potential targets for H.E.S.S.

Galactic Center

- asset: proximity
- difficulty: great number of standard γ-rays sources

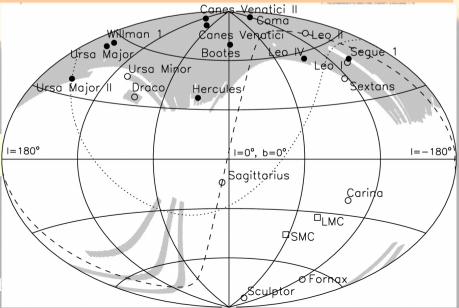
Upper limits on the DM contribution of the observed signal [H.E.S.S. PRL, 2006]

Galaxies cluster ex: Virgo (M87)

- H.E.S.S. observed flux variability
- observed flux widely greater than DM prediction

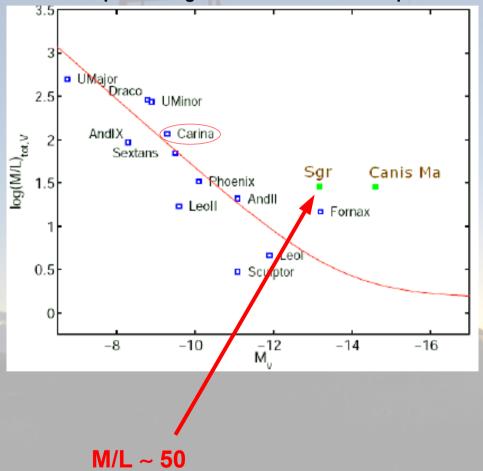
Hypothesis of the main part of the observed signal due to DM origin excluded [H.E.S.S. Science, 2006]

Dwarf spheroidal galaxies



Dwarf spheroidal galaxies

Mass to luminosity ratio versus absolute magnitude for the dwarf spheroidal galaxies of the Local Group



M/L ratio 10-100

DM dominated objects

Low astrophysical background (stellar gaz and dust)

No known γ -ray emitters expected (contrary to the Galactic Center)

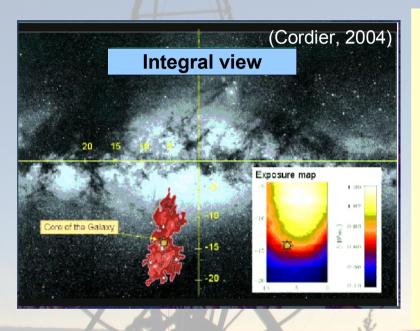
 $\Phi_{\gamma} \propto M_{DM}/d^2$ order of magnitude $M_{DM} \sim 10^7 \, M_{solar}$ for dwarf spheroidal galaxies

⇒ distance d is the important parameter for dwarf galaxies

H.E.S.S. observed dSph

Name	Observation time (h)	Distance (kpc)	M/L ratio	Mean zenith observation angle (°)	Coordinates (1,b)	
Sagittarius dwarf (Sgr dSph)	18,1	24	52	16	5,6	-14
Canis Major	9,6	8	50	12	240	-8
Carina	2,7	100	31	30	260	22

Sagittarius Dwarf Galaxy (Sgr dSph) (I)



Characteristics:

 Discovered in 1994, behind the galactic plane

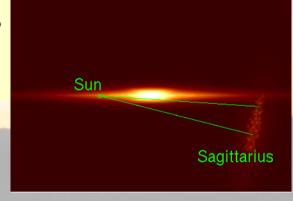
• Distance: 24kpc

• Mass: 4.9 10⁸ solar masses

• Position: I = 5.6°, b = -14.0°

• Size: 3° × 8°



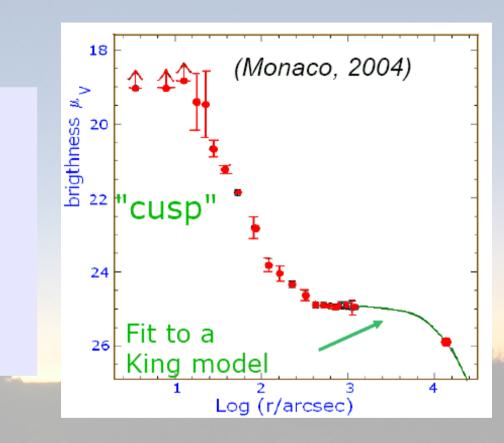


- Dwarf spheroidal galaxy nucleated (spatialy coincident with the globular cluster M54)
- Disrupted by important tidal effects (10 passages through the Galatic plane)
- Ratio M_{total}/M_{Luminous} ~ 52

Sagittarius Dwarf Galaxy (Sgr dSph) (II)

Two components in the luminous density profile:

- Compact component (cusp)core radius ~ 3 pc
- → Diffuse component well fitted by a King model with a characteristic size of ~ 1.6 kpc



Signal expected in the compact region, of a size inferior of H.E.S.S. Point Spread Function

⇒ search for a ponctual signal

Dark Matter halo modelisation of Sgr dSph

2 different plausible models used:

NFW cusped profile:

$$\rho_{NFW}(r) = \frac{A}{r(r+r_s)^2}$$

- $A \equiv normalisation factor$
- $r_s \equiv scale radius$

Parameters values taken from [Evans et al., PRD 2004]

Cored profile:

$$\rho_{core}(r) = \frac{v_a^2}{4\pi G} \frac{3 r_c^2 + r^2}{(r_c^2 + r^2)^2}$$

- $v_a = \text{velocity scale}$
- $r_c \equiv core radius$

$$J(\Delta \Omega = 2 \times 10^{-5}) = 75 \times 10^{24} \, GeV^2 \, cm^{-5}$$

 $\rightarrow \bar{J}(\Delta \Omega = 2 \times 10^{-5}) = 2.2 \times 10^{24} \, GeV^2 \, cm^{-5}$

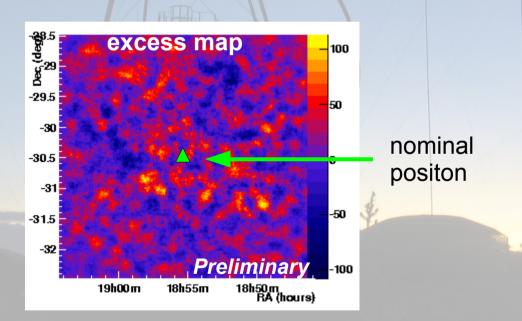
Parameters values obtained (H.E.S.S.) by analytic resolution of Jeans equation and latest measurements of central velocity dispersion [Zaggia et al., 2004]

Observation results

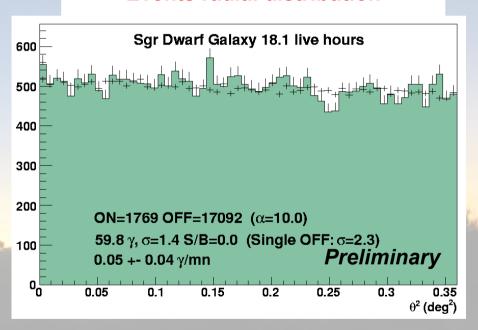
Sgr dSph has been observed in june 2006 and may 2007

18 h of data after selection criteria

observational mean zenith angle: 16°



Events radial distribution



No significant signal observed in any reconstruction methods used

 \Rightarrow limit on number of γ coming from Sgr dSph region

For energies > 250 GeV, we observed

$$N_{ON} = 1769$$
 $N_{OFF} = 17092$
 $N_{OFF} / Tobs_{ON} = 10.0$
 $N_{\gamma}^{95\% C.L.} = 82$

$$N_{\gamma}^{95\% C.L.} = 82$$

Upper limit on number of γ @ 95% C.L. obtained by Feldman & Cousins method

Upper limit on DM cross section times DM velocity can then be derived knowing H.E.S.S. effective area:

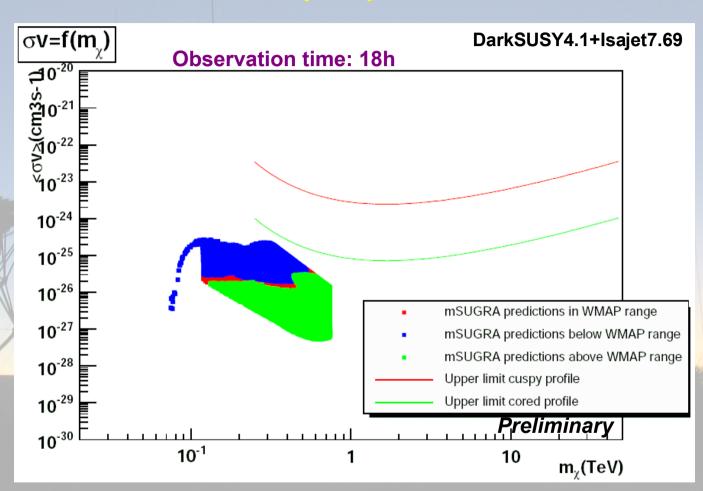
$$\langle \sigma v \rangle_{min}^{95\%C.L.} = \frac{4\pi}{T_{obs}} \frac{m_{DM}^2}{\bar{J}(\Delta\Omega)\Delta\Omega} \frac{N_{\gamma}^{95\%C.L.}}{\frac{m_{DM}}{\int_{0}^{m_{DM}} A_{eff}(E_{\gamma}) \frac{dN_{\gamma}}{dE_{\gamma}} dE_{\gamma}}}$$

 $\frac{dN_{\gamma}}{dE_{\gamma}}$ is model dependent: pMSSM and mSUGRA: parametrization according to Bergstrom et al.

Gross section limits (II): mSUGRA

Scanned parameters:

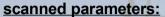
- m₀ [500: 3500] (GeV)
- m_{1/2} [300: 1700] (GeV)
- $\bullet \quad A_0 = 0$
- $\tan \beta = 55$
- sign $\mu = +$



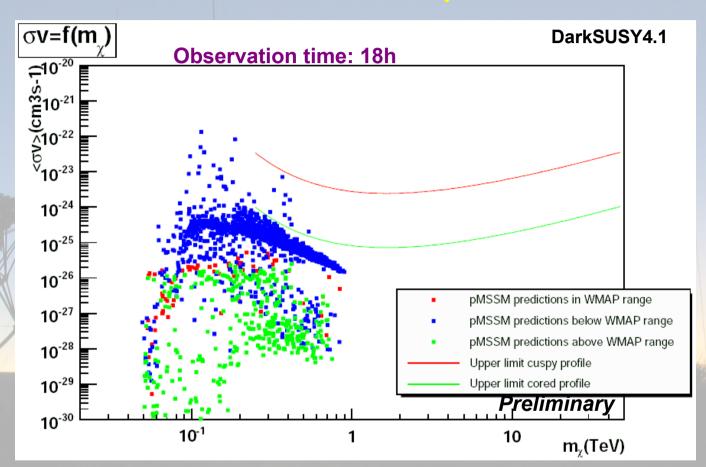
mSUGRA:

- The scanned region corresponds to the funnel region, hardly accessible with collider experiments
- Constraints far from the scanned region

Cross section limits (III): pMSSM



- μ [100:30 10³] (GeV)
- M₂ [500: 3500] (GeV)
- M_A [300: 1700] (GeV)
- m₀ [100:1000] (GeV)
- A, [-3:3]
- A_b [-3:3]
- tan β [1.2:60]



pMSSM:

The cuspy profile does not constrain any of these models In case of a cored profile, some models with low relic density can be excluded

Conclusions and propects

Dwarf galaxies are excellent targets for search of dark matter annihilations, as background contamination is expected to be very low

At present no significant excess has been found by H.E.S.S. observations of Sgr dSph

If we consider a cored halo profile for the Sagittarius dwarf spheroidal galaxy, the present observation time allows to reach the request sensitivity to put constraints on dark matter particle annihilation cross section for pMSSM models with low relic density

A combination of the different observations on the same type of objects may allow to produce stronger constraints on models beyond the SM

In autumn 2009, the future H.E.S.S. II phase, with the additionnal fifth telescope of $28m \varnothing$ will decrease the energy threshold to ~ 50 GeV and then will allow to consider constrains of WMAP compatible models

