MPI Kernphysik, Heidelberg
Humboldt Univ. Berlin
Ruhr-Univ. Bochum
Univ. Hamburg
LSW Heidelberg
Univ. Tübingen
Ecole Polytechnique, Palaiseau
APC Paris
Univ. Paris VI-VII
Paris Observatory, Meudon
LAPP Annecy
LAOG Grenoble
LPTA Montpellier
CEA Saclay
CESR Toulouse
Durham Univ.
Dublin Inst. for Adv. Studies
Charles Univ., Prague
Yerewan Physics Inst.
North-West Univ., Potchefstroom
Univ. of Namibia, Windhoek

Present and future Dark Matter searches by HESS experiment

Hunt for Dark Matter Symposium
Fermilab, May 10-12, 2007

Agnieszka Jacholkowska on behalf of HESS
LPTA Montpellier

OUTLINE

- HESS experiment and source observations
- Results from the Galactic Centre
- Analysis of Sagittarius Dwarf data and preliminary results
- Prospects for HESS2

HESS experiment

Four telescopes,
107 m^2 mirror area each

960 PMT cameras, field of view 5^o

Observation in moonless nights, ~1000 h / year

Each night several objects are tracked and ~300 images recorded per second

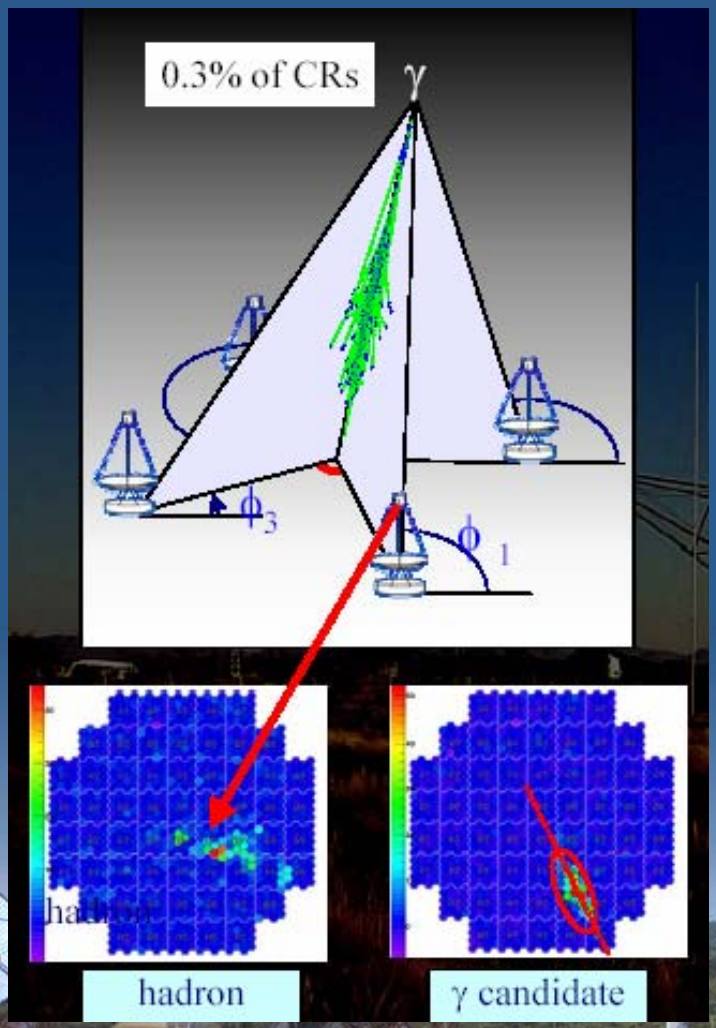
First analysis (almost) online in the same night on PC cluster in Namibia

Final analysis and calibration in Europe

Energy threshold:
~ 100 GeV

Sensitivity:
1% Crab in 25 h

HESS: principle of detection



Stereoscopy (2-4) telescopes: reconstruction of direction and energy of the particle

Angular resolution: ~ 0.1°
Energy resolution: ~ 15%

Analysis of the images: allows discimination between γ / hadron/ muon

HESS II (2008):
add 596m² mirror in the centre
→ E_{thr} ~ 20 GeV

γ flux from DM annihilation

$$\frac{d\Phi(\Delta\Omega, E_\gamma)}{dE_\gamma} = \frac{1}{4\pi} \underbrace{\frac{\langle\sigma v\rangle}{m_{DM}^2} \frac{dN_\gamma}{dE_\gamma}}_{Particle\ Physics} \times \underbrace{\bar{J}(\Delta\Omega)\Delta\Omega}_{Astrophysics}$$

$$J = \int_{l.o.s} \rho^2(r[s])ds \qquad \bar{J}(\Delta\Omega) = \frac{1}{\Delta\Omega} \int_{\Delta\Omega} PSF * J \, d\Omega$$

<σv> velocity-weighted annihilation cross section

dN/dEγ : annihilation spectrum of the DM particle

- neutralinos
- LKP (Kaluza-Klein)

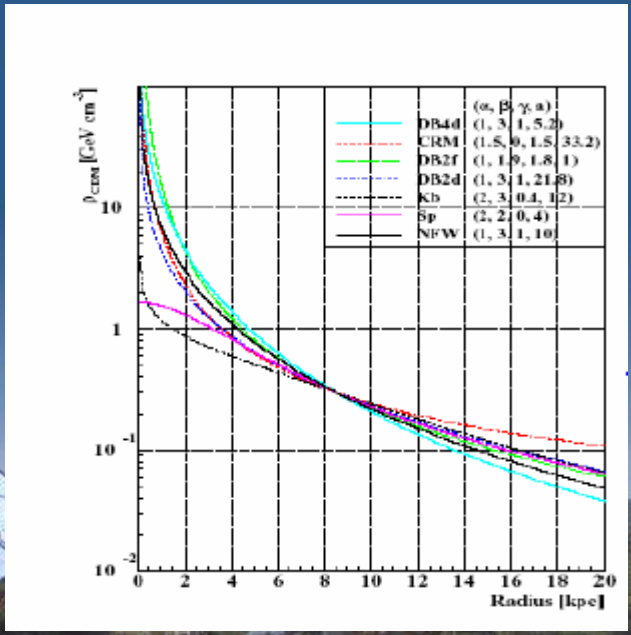
ρ: mass density DM profile

- cored profile
- NFW profile

Sources & astrophysical uncertainties

DM sources observed by HESS:

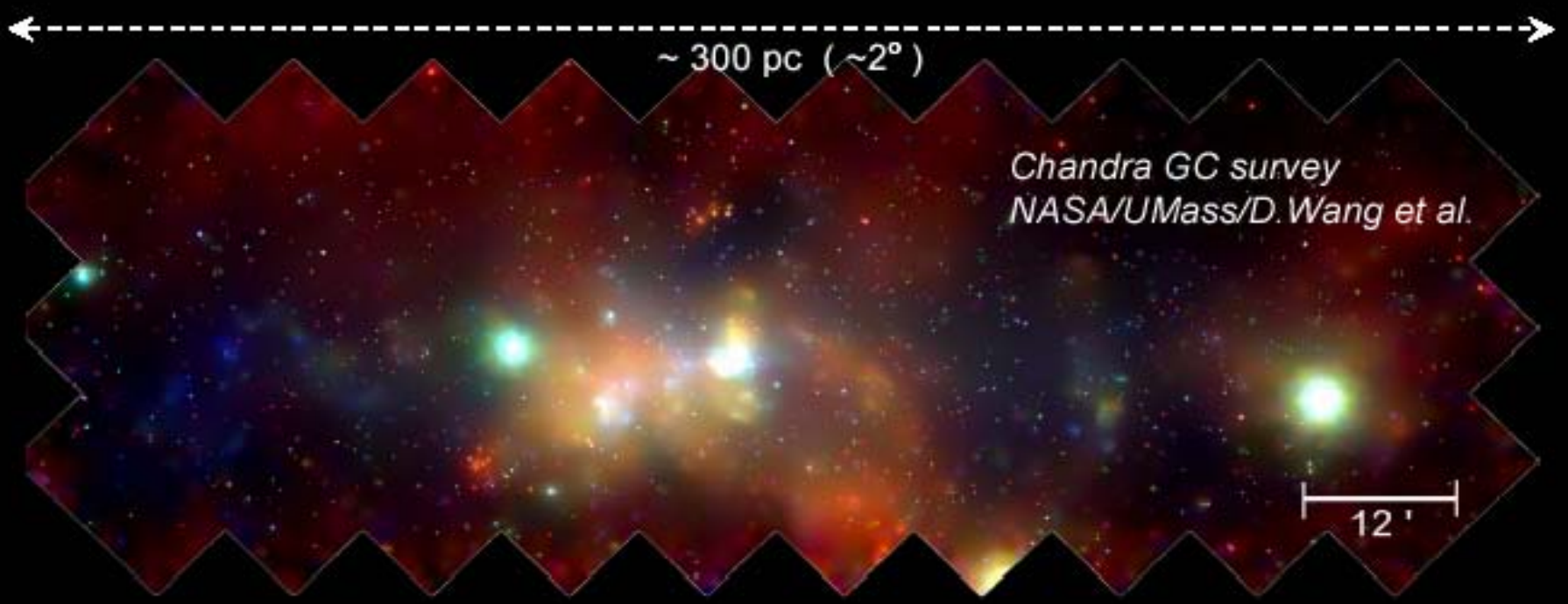
Galactic Centre
Globular Clusters – M15, Ω-centauris,...
Milky Way satellites – dwarf spheroidals, LMC, SMC
other galaxies - M31, M87



Halo density profiles parameterizations
Isothermal, Navarro-Frenk-White, Moore, ...

Uncertainties on flux predictions above 10^2 !

Galactic Centre region



Astrophysics:
- full "zoo" of objects
- Pulsars and PWN
- Supernova remnants
- X-Ray binaries
- Molecular clouds

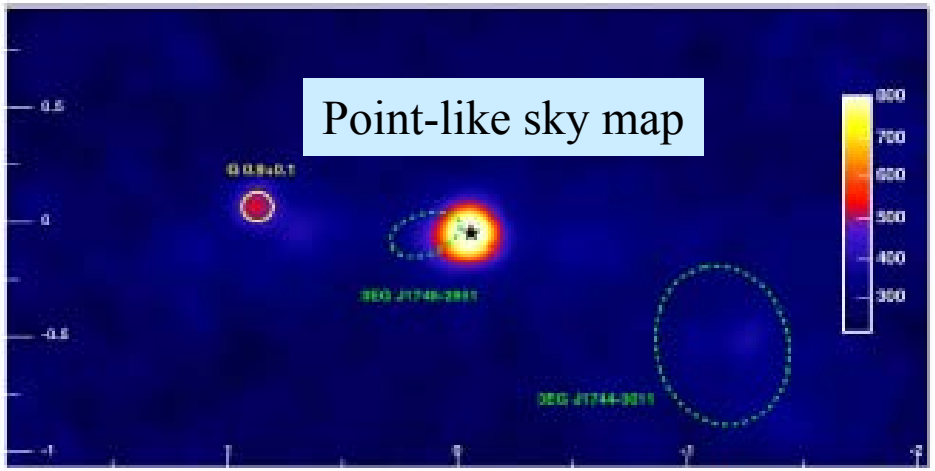
Bit more exotic:
- Supermassive BH Sgr A*

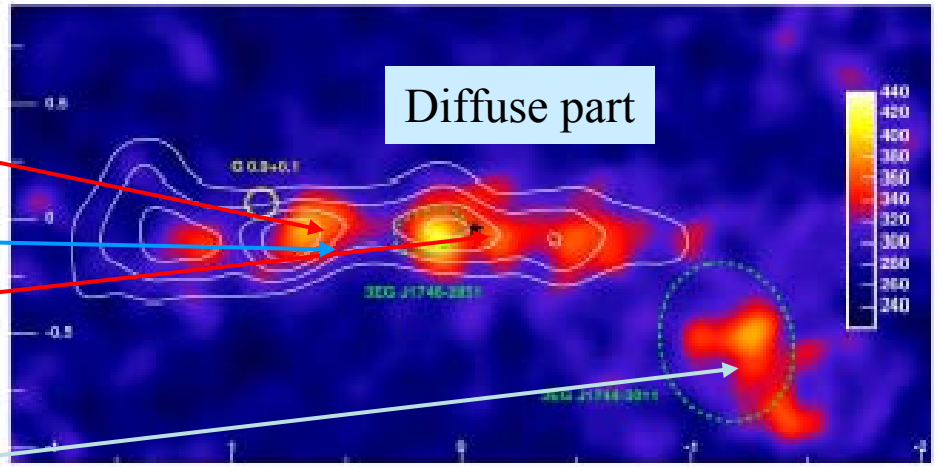
Even more exotic:
- Dark Matter accumulation
- → Neutralino annihilation

HESS: Galactic Centre

Galactic Centre is a very crowded region in all wave-lengths

<u>White contours:</u>
molecular cloud emission (CS rays)





SNR G 0.9+0.1

Sgr B

~3500 diffuse γ

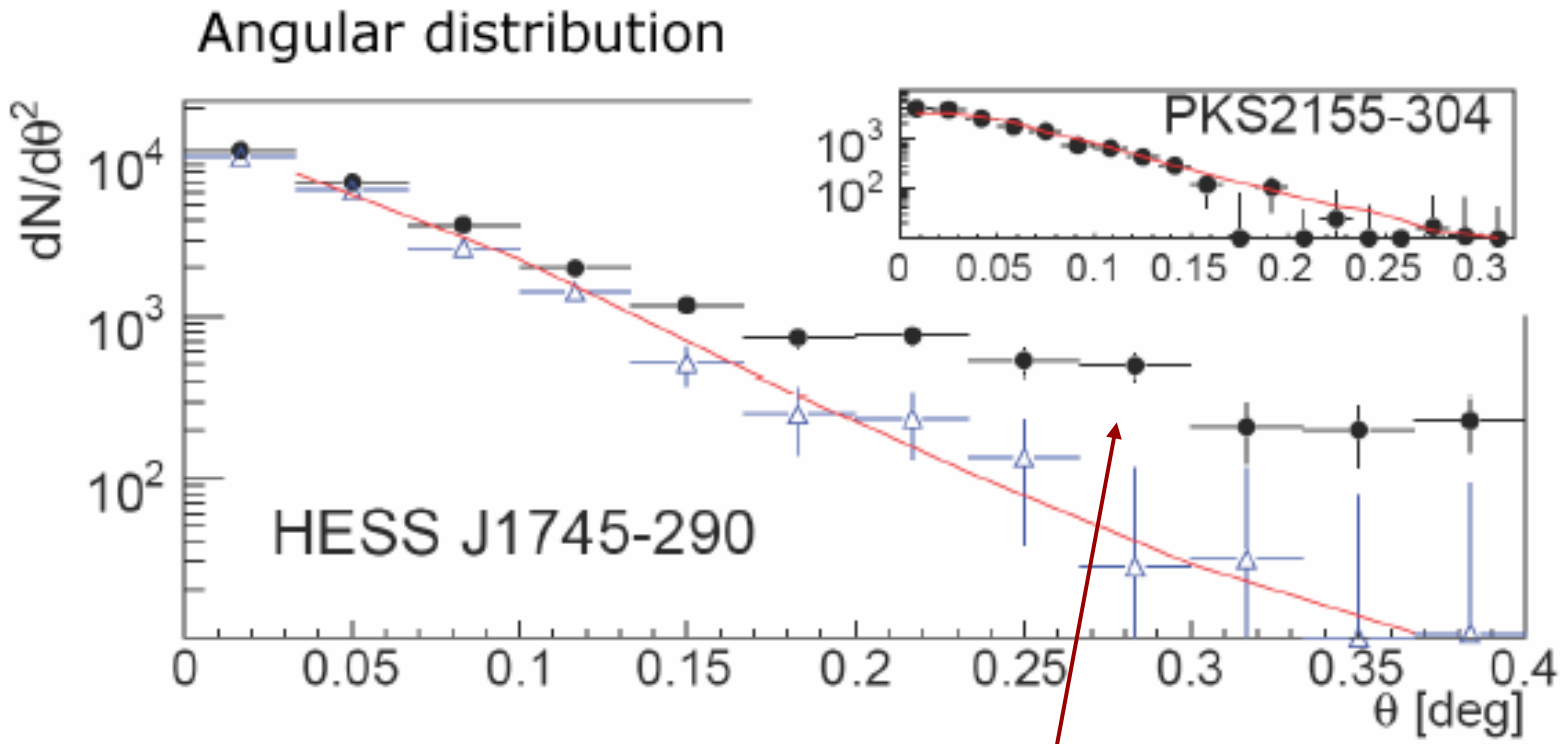
Sgr A*

Sig= 14.6σ

EGRET non-identified sources

HESS, NATURE, vol.439, p.695, 2006

HESSJ1745-290: morphology



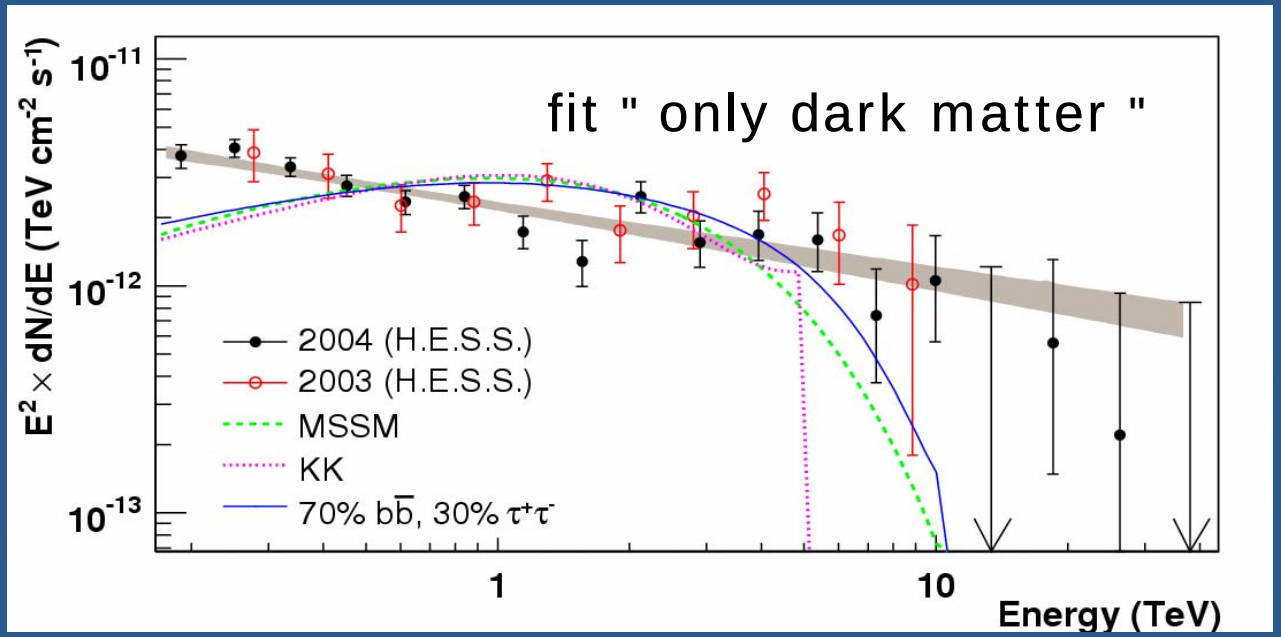
Well described by H.E.S.S. PSF for point like source

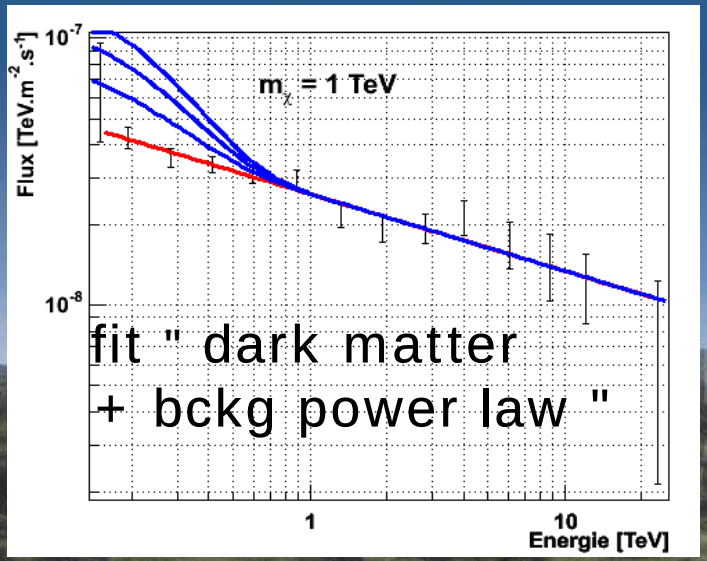
Source size: 0.12°

Diffuse component: 16%

H.E.S.S., PRL 97 (2006)

HESSJ1745-290: spectrum





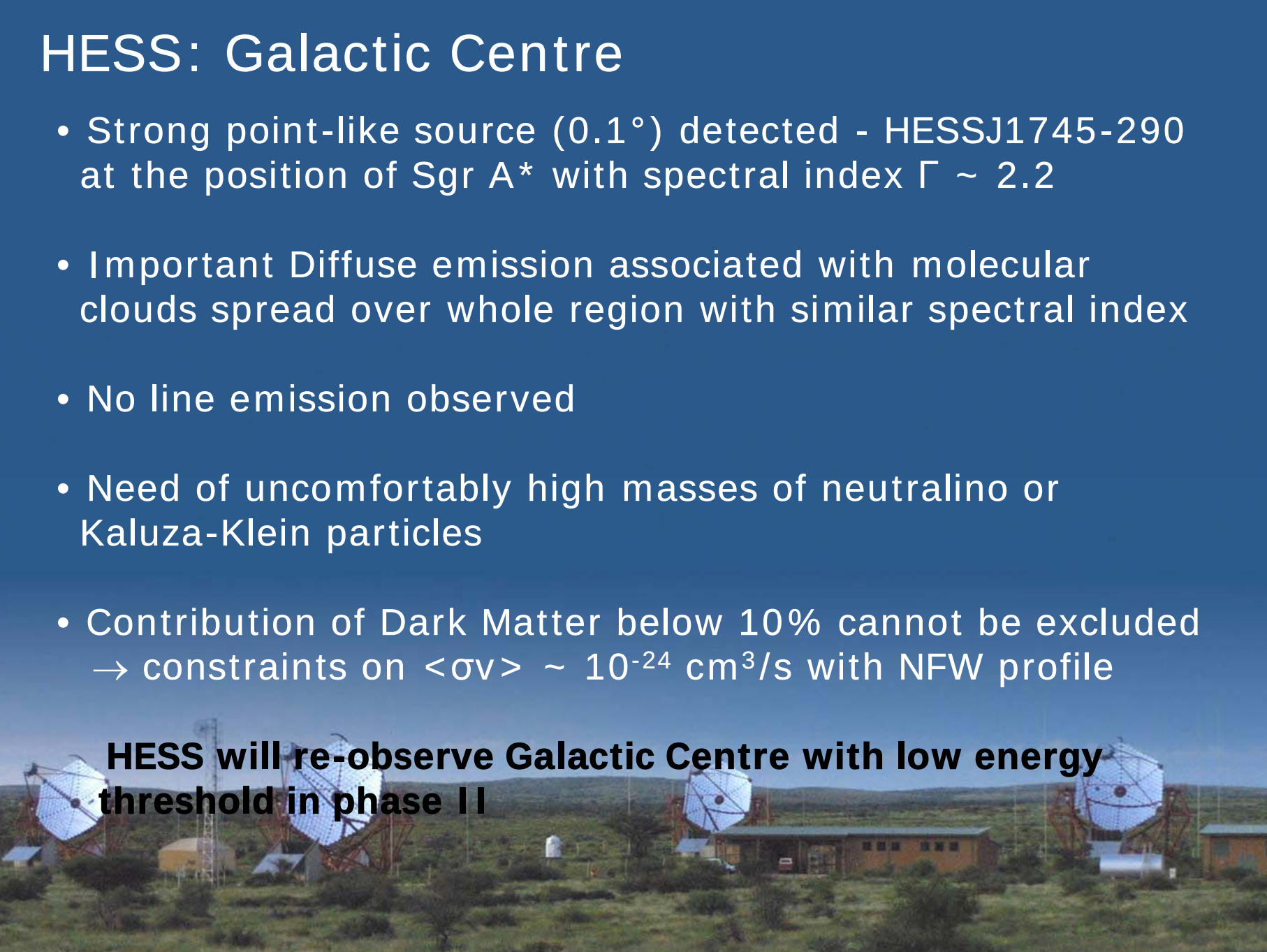
Data 2003/2004:

- Power Law Spectrum (E_{th} > 160 GeV)
  $\Gamma = 2.25 \pm 0.04 \pm 0.10$
- Exponential cut-off limit
  E_{cut} > 9 TeV (95% CL)
- Diffuse emission included

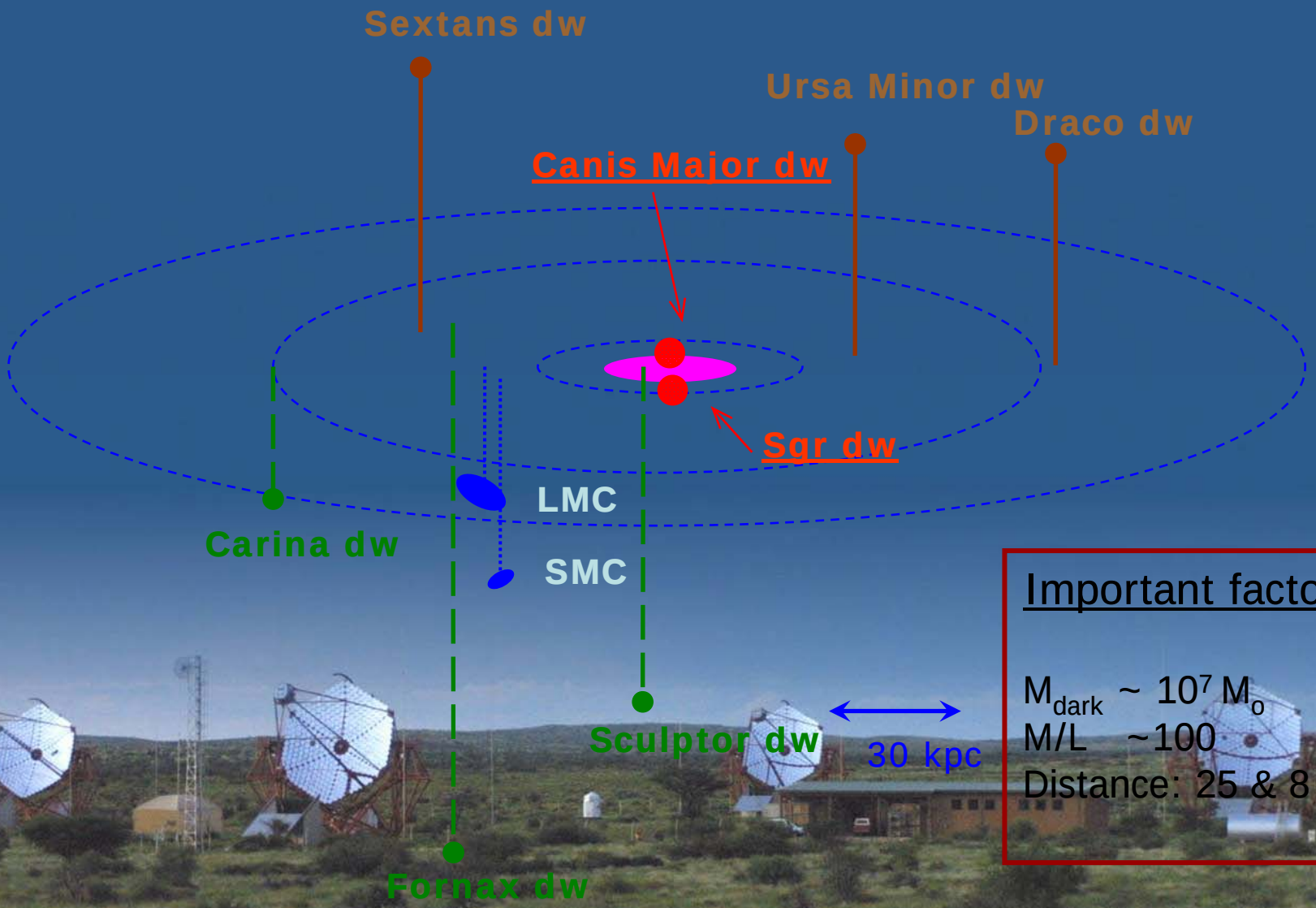
HESS: Galactic Centre

- Strong point-like source (0.1°) detected - HESSJ1745-290 at the position of Sgr A* with spectral index $\Gamma \sim 2.2$
- Important Diffuse emission associated with molecular clouds spread over whole region with similar spectral index
- No line emission observed
- Need of uncomfortably high masses of neutralino or Kaluza-Klein particles
- Contribution of Dark Matter below 10% cannot be excluded $\rightarrow$ constraints on $\langle \sigma v \rangle \sim 10^{-24}$ cm^3/s with NFW profile

HESS will re-observe Galactic Centre with low energy threshold in phase II



Sagittarius Dwarf and Canis Major



Important factors:

M_{dark} ~ 10^7 M_o

M/L ~100

Distance: 25 & 8 kpc

Dwarf Spheroidals: γ flux predictions

For a given particle model, dϕ/dE depends only on <J>

NFW halo:

$$\frac{\phi_{Sgr}}{\phi_{GC}} \sim 0.1-0.2 \qquad \frac{\phi_{CMaj}}{\phi_{GC}} \sim 0.5-0.75 \qquad \frac{\phi_{Draco}}{\phi_{GC}} \sim 0.03$$

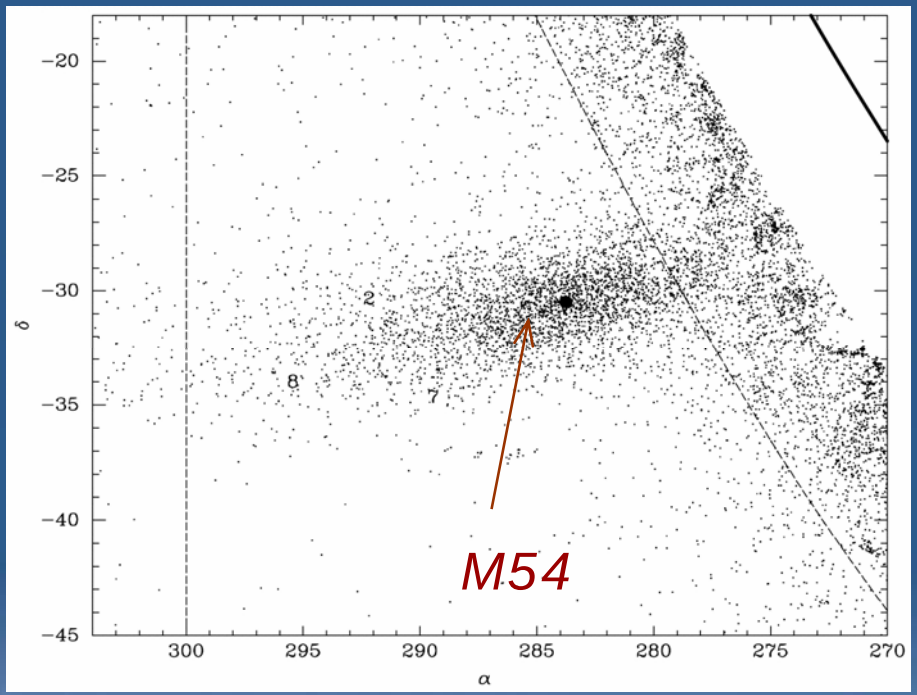
Halo with core:

$$\frac{\phi_{Sgr}}{\phi_{GC}} \sim 11 \qquad \frac{\phi_{CMaj}}{\phi_{GC}} \sim 12 \qquad \frac{\phi_{Draco}}{\phi_{GC}} \sim 7.3$$

Evans,Ferrer,Sarkar PRD 69 123501 (2004)

Sagittarius Dwarf and M54

Majewski et al. (2003)

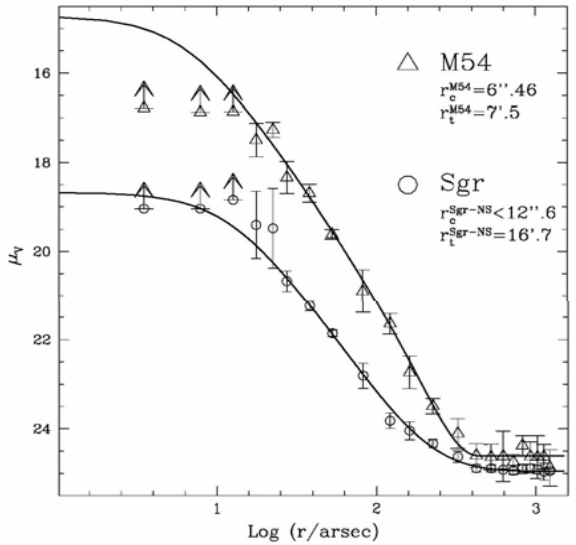


2 components in the luminous profile

- compact component : «cusp»
  core size : r_c = 1.5 pc
- large scale component :
  King model r_K = 1.6 kpc

Monaco et al., astro-ph/0411107

"nucleated dwarf galaxy"



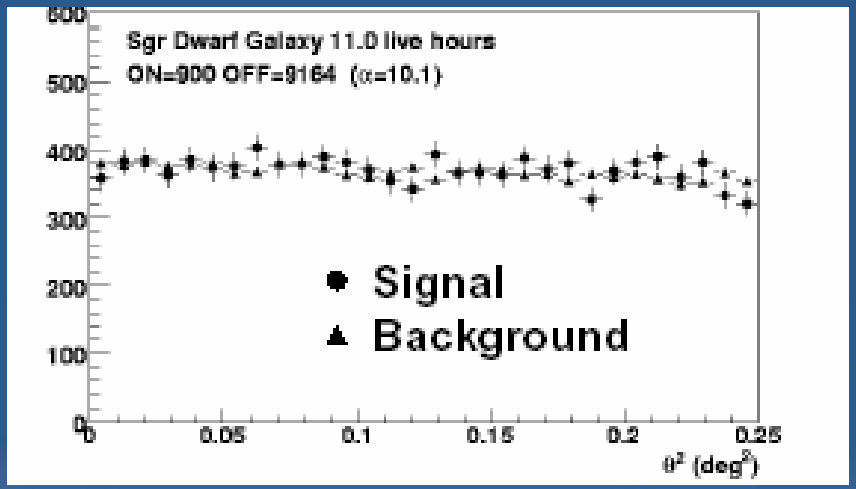
Sagittarius radial profile

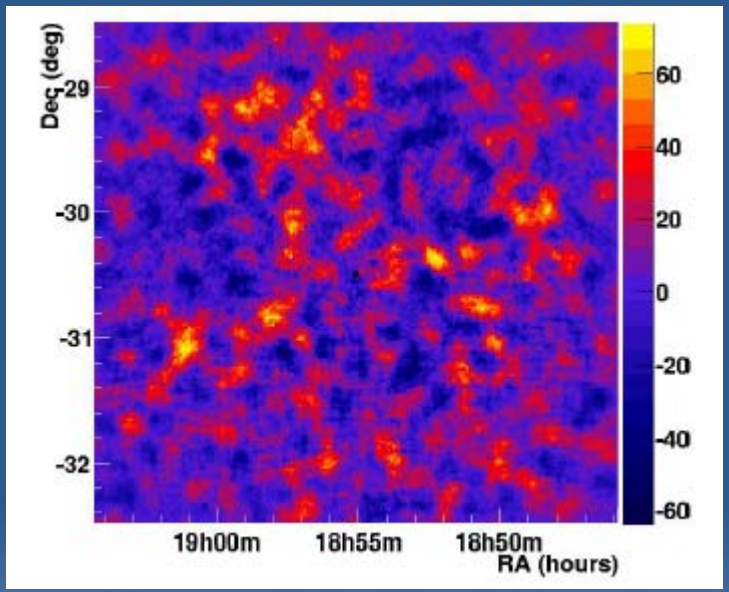
Almost all mass < 1.5 pc
→ search for a point-like source

Sagittarius Dwarf: observation results

Target position : RA = 18h54m40s Dec = -30d27m05s (J2000)

galactic coordinates : l = 5.6° b = -14°





No significant γ-ray excess → limit on flux:

$$\Phi_\gamma(E_\gamma > 250\,\mathrm{GeV}) < 3.6 \times 10^{-12}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}\,(95\%\,\mathrm{C.L.})$$

Modeling Sgr Dwarf halo profile

2 popular halo profiles:

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

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

Halo type	Parameters	$\bar{J}$ (10^{21}GeV^{2}cm^{-5})	Fraction of signal in $\Delta\Omega = 2\times10^{-5}$sr
Cusped NFW halo	$r_s = 0.2$ kpc $A = 3.3\times10^7 M_\odot$	2.2	93.6%
Cored halo	$r_c = 1.5$ pc $v_a = 13.4$ km s^{-1}	75.0	99.9%

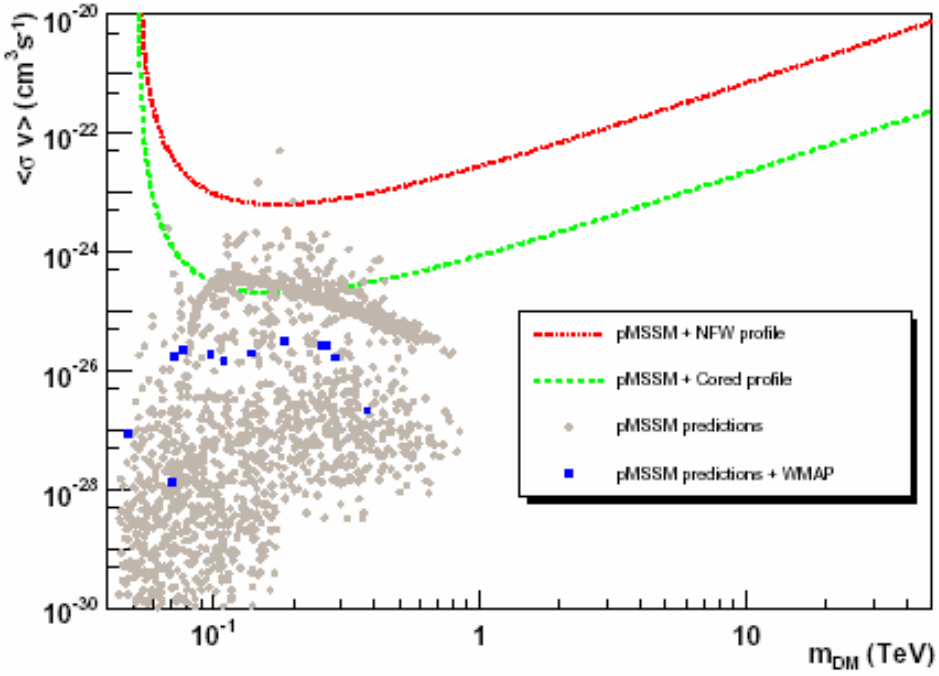
Table 1
Structural parameters for a cusped NFW (r_s, A) and a cored (r_c, v_a) DM halo model, respectively. The values of the solid-angle-averaged l.o.s integrated squared DM distribution are reported in both cases for the solid angle integration region $\Delta\Omega = 2\times10^{-5}$sr.

Sgr Dwarf: constraints on Neutralino DM

pMSSM models obtained with DarkSUSY4.1

- large scan of the parameter space

- 11 live hours
- 2 DM halo models :
  - NFW profile
  - cored profile

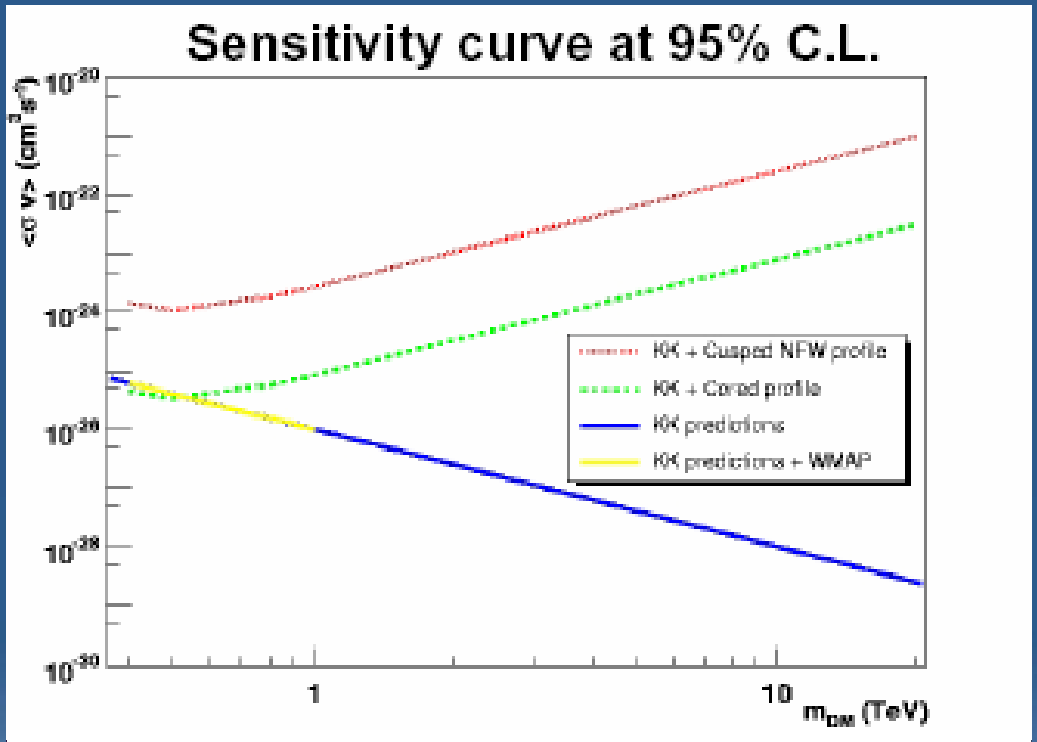


pMSSM models with low Ω_{relic} excluded in case of the cored profile

Sgr Dwarf: constraints on Kaluza–Klein DM

- Kaluza-Klein model predictions : analytic

- 11 live hours
- 2 DM halo models :
  - NFW profile
  - core profile



Some KK models with Ω_{relic} compatible with WMAP are excluded in case of the cored profile

Complementarity: LHC / Indirect searches

Assumption: dark matter is composed predominantly by SUSY or ExtraDim stable particles (and H_2)

- LHC (>2007) will provide:
  - indications for masses and BRs of new particles
  - will favor some classes of models

- Exotic interpretation of the annihilation signal:
  is degenerate with respect to various models of SUSY or Kaluza-Klein type

- Potential of LHC experiments is limited in some domains of the parameter space (large tanβ, Focus Point, ..) where annihilation flux prediction are most optimistic!

→ **common interest for model dependent/independent studies**

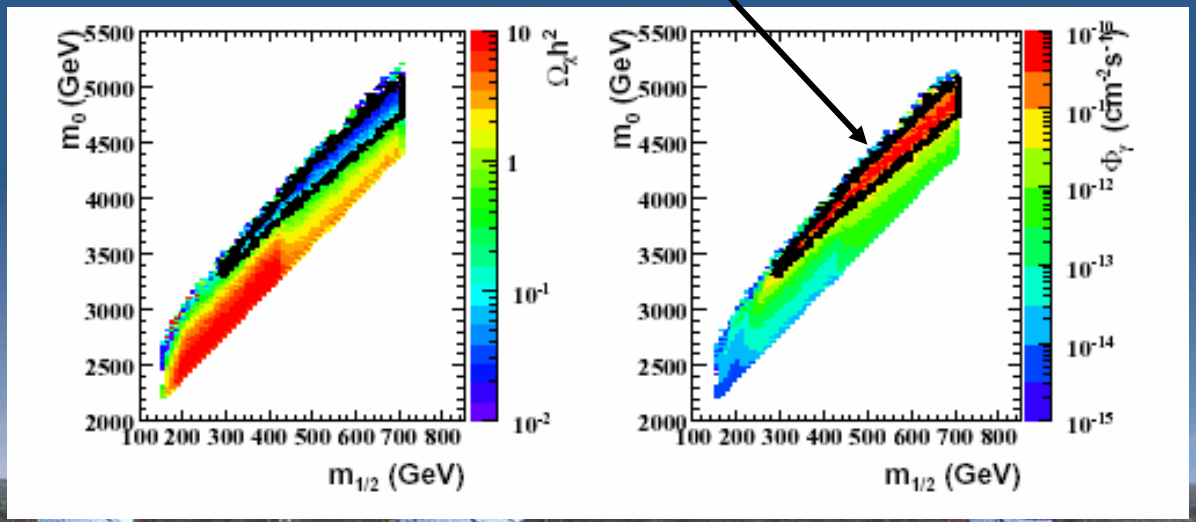
HESS phase II and LHC

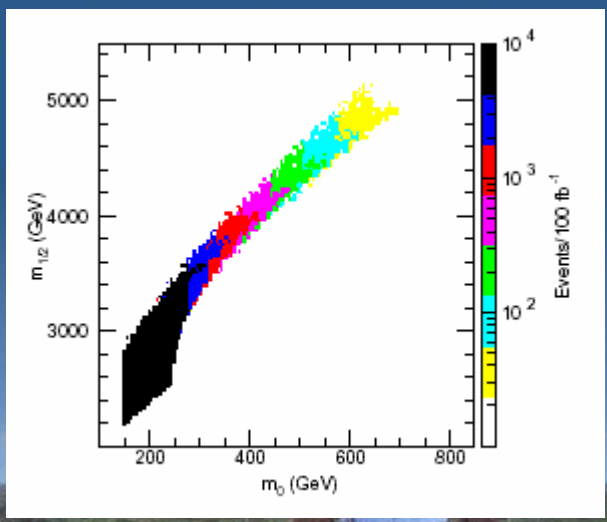
Studies in the Focus Point regions (ATLAS-HESS collaborators)
scan with IsaSugra (DarkSusy) simulation
—> $\Phi\gamma$, Ω_{relic}, Nevt (ATLAS)

$$A_0=0,\ \tan\beta=10,\ \mathrm{sign}(\mu)=+1 \text{ and } m_t=175 \text{ GeV}$$

HESS II (Eth > 20 GeV): 5σ sensitivity for 50 hrs

100 fb^{-1}: 3-body leptonic decays





LPTA: A. Jacholkowska, JL. Kneur E. Moulin G. Moultaka, E. Nuss
ATLAS: S. Asai, T. Lari, G. Polesello, D. Tovey, M. White, Z. Yang

Summary

- No exotic signal from HESS observations of the Galactic Centre which is not a « smoking gun » for dark matter detection as populated by various types of the standard astrophysical sources

- Sagittarius et Canis Major galaxies are potential targets of interest due to the high M/L ratio and quiet astrophysical environment

- First results from 11 hrs of observations Sagittarius Dwarf galaxy show no signal and allow to reject few SUSY & KK models with low Ω_{relic} and for a cored DM density profile

- From 2008 HESS II will start taking data with ~20 GeV threshold allowing to probe low mass neutralino range with improved sensitivity and first indications from LHC!