Indirect search for dark matter with H.E.S.S.

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- Introduction
  - γ-radiation from WIMP dark matter
  - The H.E.S.S. experiment
- Observations with H.E.S.S.
  - Galactic objects
  - Extragalactic objects
- Outlook and summary

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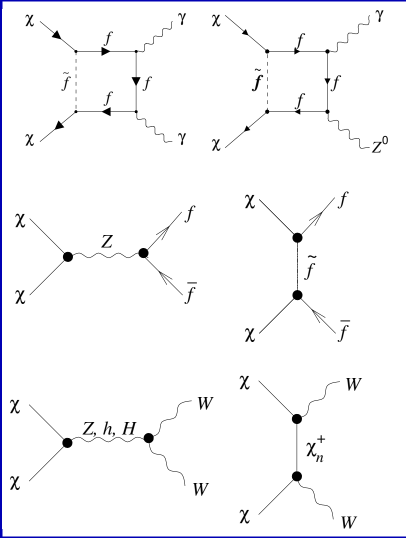
γ-radiation from annihilating WIMP dark matter

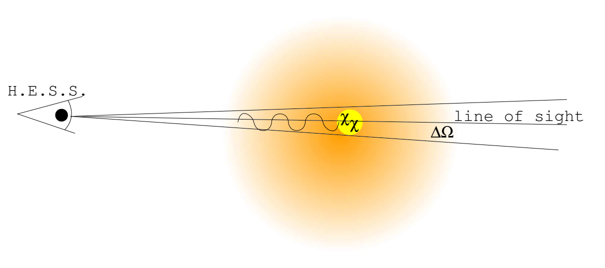


Bertone et al., Phys. Rept., 405:279, 2005

- Self annihilation of WIMP dark matter produces γ-radiation
- Direct production of photons leads to two emission lines (smoking gun), but is loop suppressed
- Photon production in secondary processes leads to continuous spectrum
- Radiative corrections contribute (not considered yet; Bringmann et al. 2007)

$\Longrightarrow$ Production of very high energy gamma radiation in WIMPs self annihilation

γ-radiation from WIMP dark matter



$$\Phi(E) = 2.8 \cdot 10^{-10}\text{cm}^{-2}\text{s}^{-1} \cdot \left(\frac{100\ \text{GeV}}{m_{\text{WIMP}}}\right)^2 \cdot \frac{dN_\gamma}{dE} \cdot \frac{\langle\sigma v\rangle}{\text{pb}\cdot c} \cdot \bar{J}(\Delta\Omega)\Delta\Omega$$

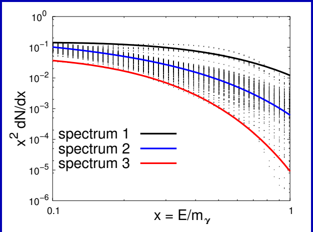
$$\bar{J}(\Delta\Omega)\Delta\Omega = \frac{1}{8.5\ \text{kpc}\cdot(0.3\ \text{GeV/cm}^3)^2} \cdot \int_{\Delta\Omega} d\Omega \int_{\text{los}} ds\ \varrho^2$$

$\Longrightarrow$ Search for γ-radiation from high density regions

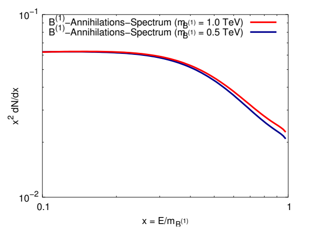
γ-radiation from WIMP dark matter

Energy spectrum

Neutralino annihilation:



$B^{(1)}$ annihilation:

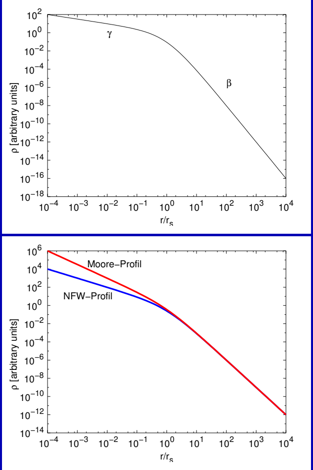


- Two investigated WIMP candidates:
  - Neutralino (Supersymmetry)
  - $B^{(1)}$ (Kaluza-Klein-theory)
- Many possible γ-radiation spectra for Neutralino

$\Longrightarrow$ Continuum photon spectra from WIMP self annihilation

γ-radiation from WIMP dark matter

Matter distribution



- Uncertainty in density profile leads to high uncertainty in flux normalisation
- Often used parametrisation:

$$\varrho(r) = \varrho_0 \cdot \frac{r_c^\gamma}{r^\gamma} \cdot \frac{(r_c^\alpha + r_s^\alpha)^{(\beta-\gamma)/\alpha}}{(r^\alpha + r_s^\alpha)^{(\beta-\gamma)/\alpha}}$$

- Special cases: NFW- and Moore-profile (N-body-simulations)

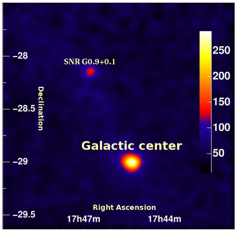
$\Longrightarrow$ Two different density profiles investigated

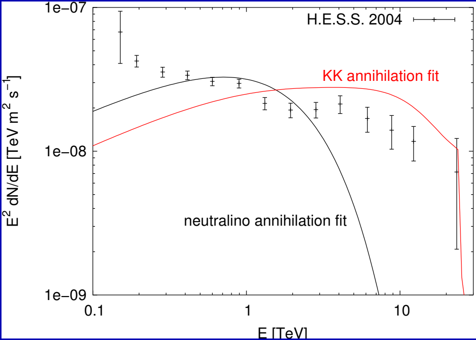
The H.E.S.S. experiment in Namibia

- Stereoscopic observation of air showers (Cherenkov light)
- Distinguish photon induced air showers from hadronic
- Search for photon sources on sky
- In full operation since 2004

- Angular resolution $\approx 0.08°$ per event
- Energy range ≈ 100 GeV – 100 TeV
- $\Delta E/E \approx 15\%$

The Galactic center as seen by H.E.S.S.

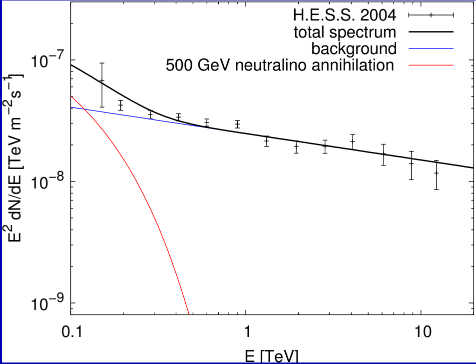




- Other potential astrophysical sources of high energy γ-radiation in this region:
  - Supermassive black hole
  - Supernova remnants
  - Molecular clouds
  - Pulsar wind nebula
  - ...

- Would need high WIMP mass and high annihilation cross section
- Energy spectrum not compatible with annihilation radiation neither from neutralinos nor from $B^{(1)}$

Dark Matter in the Galactic center

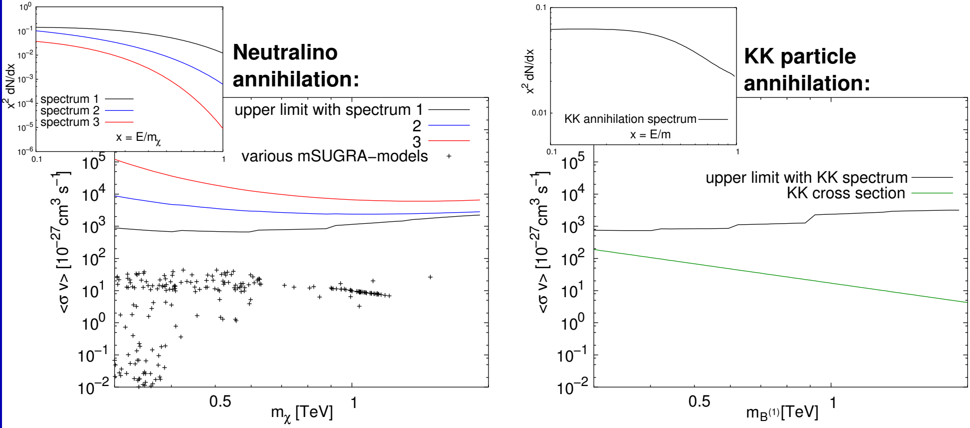


- Fit energy spectrum with annihilation radiation + background
- Increase part of annihilation radiation until fit becomes unacceptable

$\Longrightarrow$ Robust method for calculation of upper limits

Dark Matter in the Galactic center
Limits on annihilation cross section

Assuming density profile from Navarro, Frenck and White (NFW) ($\gamma = 1$, $\beta = 3$)

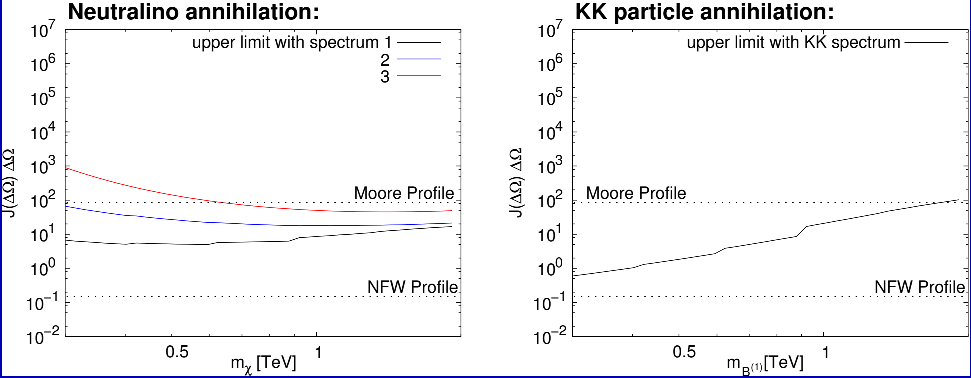


Ripken et al. ICRC 2005

$\Longrightarrow$ Upper limits not constraining for NFW profile

Dark Matter in the Galactic center
Limits on density profile

Assuming a specific cross section. (Neutralinos: $\langle \sigma v \rangle = 2 \cdot 10^{-26}\mathrm{cm}^3\mathrm{s}^{-1}$)

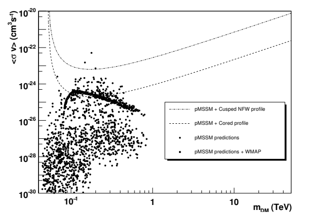


Ripken et al. ICRC 2005

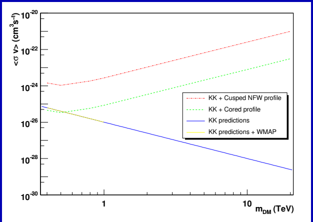
$\Longrightarrow$ Steep profiles can be ruled out

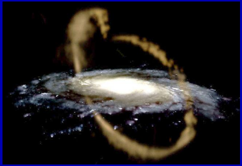
The sagittarius dwarf galaxy

Neutralinos:



$B^{(1)}$:

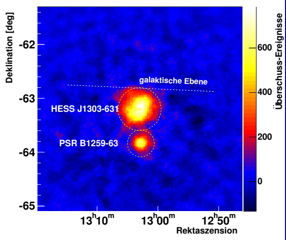


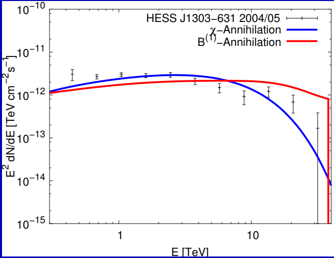


- Dwarf galaxy
- Distance 24 kpc
- Realistic models of density profile exist
- Observation with H.E.S.S. $(11\ \mathrm{h})$
  $\Longrightarrow$ No signal found

$\Longrightarrow$ Upper limits on annihilation cross section (Aharonian et al. 2008)

The unidentified source HESS J1303-631
A Dark Matter clump?

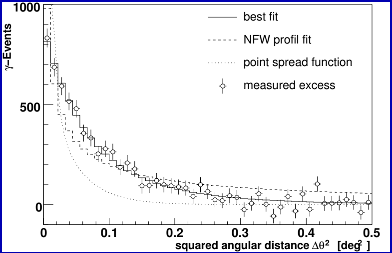


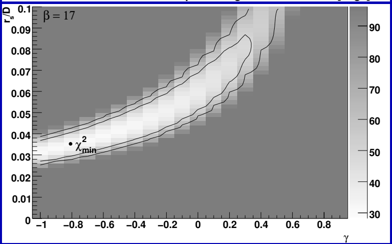


- Serendipitiously detected TeV-γ-rays during observations of PSR B1259-63
- Extended source with no flux variability
- No known counterpart in other wavelenths
- ≈ 10 unidentified sources known. If DM clumps $\Rightarrow$ common spectra. This is not the case.

$\Longrightarrow$ Annihilation spectrum doesn't fit measured spectrum well

The unidentified source HESS J1303-631
A Dark Matter clump?





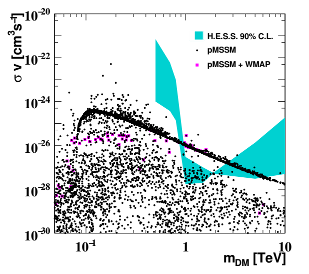
- Compare luminosity profile with expectations from density profile
- Parametrisation:

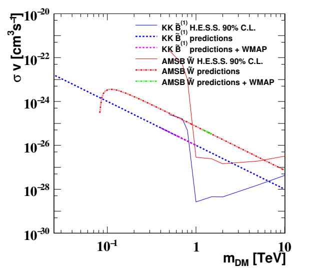
$$\varrho(r) = \varrho_0 \cdot \frac{r_c^\gamma}{r^\gamma} \cdot \frac{(r_c^\alpha + r_s^\alpha)^{(\beta-\gamma)/\alpha}}{(r^\alpha + r_s^\alpha)^{(\beta-\gamma)/\alpha}}$$

- Best fit: $\gamma = -0.8$ in contradiction to NFW-profile ($\beta = 3$ and $\gamma = 1$) and Moore-profile ($\beta = 3$ and $\gamma = 1.5$)

$\Longrightarrow$ Luminosity profile not as concentrated than expected from dark matter clumps

Intermediate mass black holes

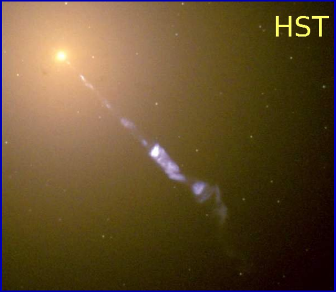


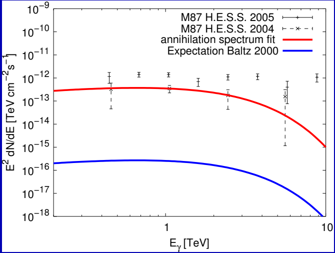


- Intermediate mass black holes ($10 - 10^6\ M_\odot$) can accumulate dark matter into mini-spikes (Bertone et al. Mod. Phys. Lett., 95:011301, 2005)
- Search for IMBH candidates in galactic plane scan
- No candidate found (see arXiv:0806.2981)

$\Longrightarrow$ Limits on annihilation cross section possible

The radio galaxy M87





- Center of Virgo cluster
- 16 Mpc distance
- Detection in TeV-γ-rays 1998/99 by HEGRA
- Confirmed 2004 and 2005 by H.E.S.S. with fast variable flux (Aharonian et al. Science 2006)
- Low flux state high above flux expectations
- Upper limits on dark matter high above model expectations, too

$\Longrightarrow$ No dark matter detectable so far

Outlook

- Lower energy window with GLAST
- Higher sensitivity with HESS II and CTA
- Accelerator search with LHC
- Direct search experiments with
  - larger detector
  - better background reduction

$\Longrightarrow$ Work in progress. We will find it

Summary

- Search for photons from WIMP self annihilation
- Limits on dark matter content in Galactic Center
- Upper Limits from observations of sagittarius dwarf galaxy
- Upper limits from intermediate black holes
- Unidentified source HESS J1303-631 unlikely dark matter clump
- Limits on dark matter content in M87