Europhysics Conference on High Energy Physics, 21/07/2011

Indirect Dark Matter searches with the MAGIC Telescopes

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(on behalf of the MAGIC Collaboration)

The MAGIC Telescopes

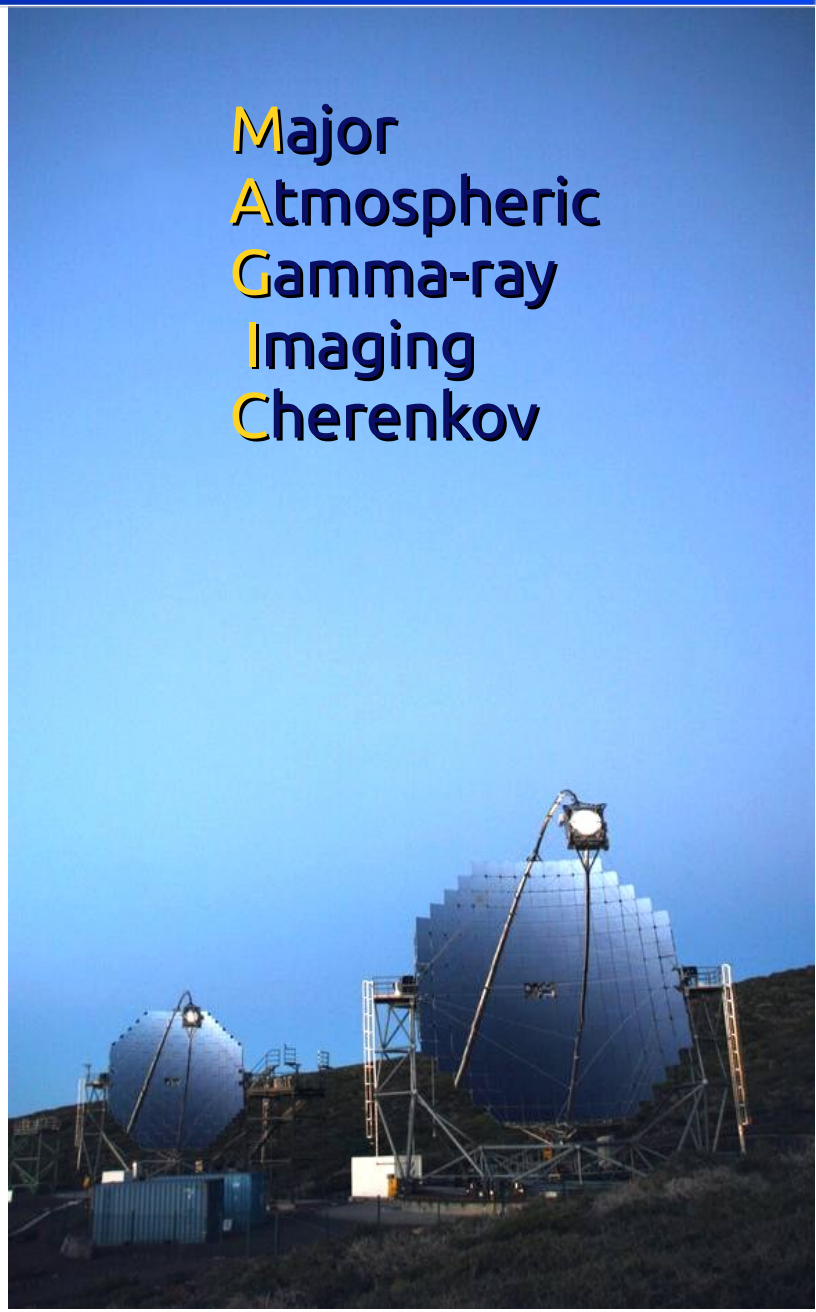
- Observatorio Roque de los Muchachos, La Palma, 2200 m altitude

- System of two, 17 m diameter IACTs

- Regular observations since 2004 (MAGIC 1) and 2009 (Stereo)

- Main characteristics:

  Field of view: 3.5 deg
  Energy threshold: ~50 GeV
  Energy resolution: 15 - 25%
  Angular resolution: 0.04° - 0.15°
  Sensitivity: 0.8% Crab Nebula flux in 50h
  Fast slewing: <40 s to any position

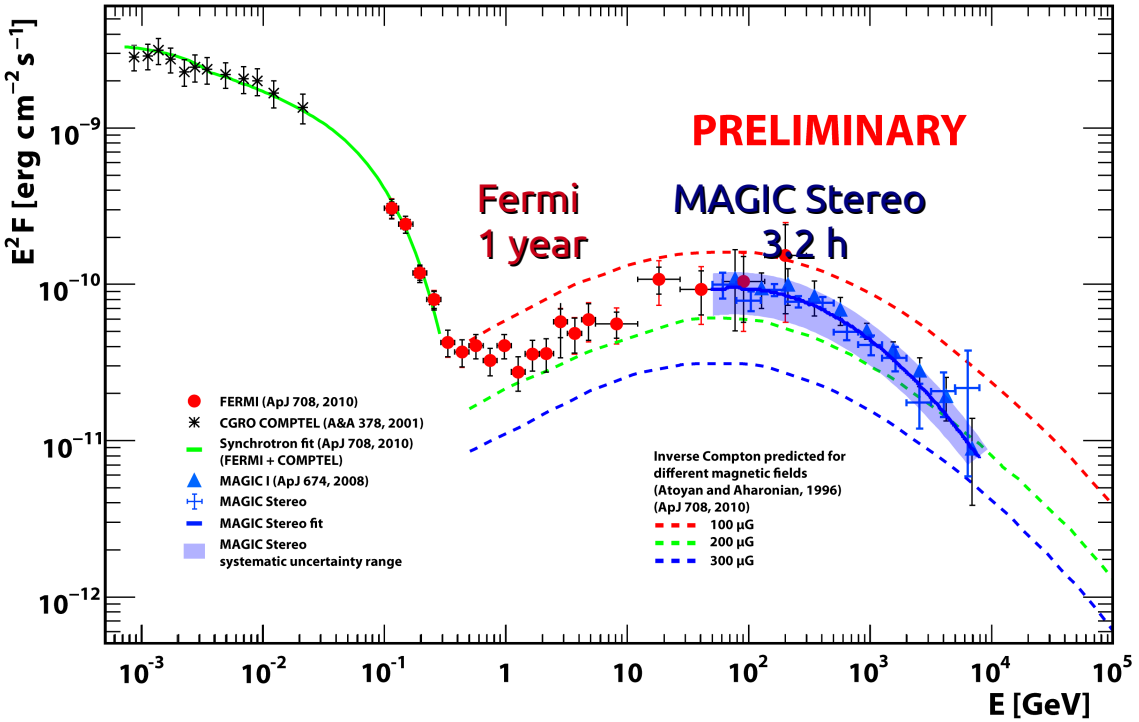


The MAGIC Telescopes

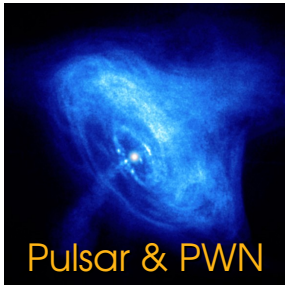
- Complementary with Fermi – the only IACT whose energy range overlaps with the satellite's for E<150 GeV

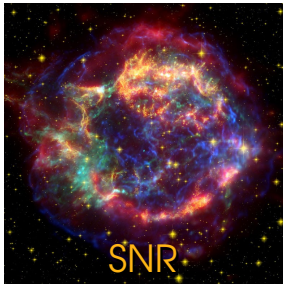
Crab Nebula Spectrum

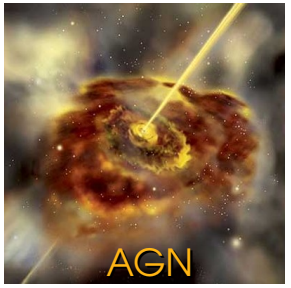
MAGIC Stereo in combination with neighbouring wavelengths

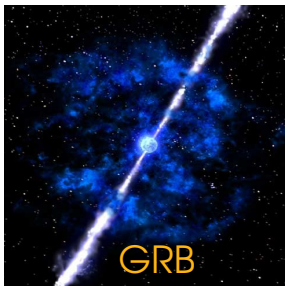


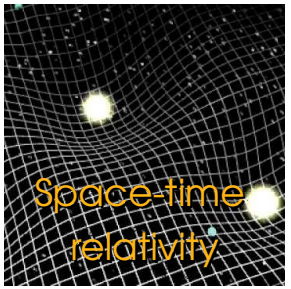
Physics with MAGIC →







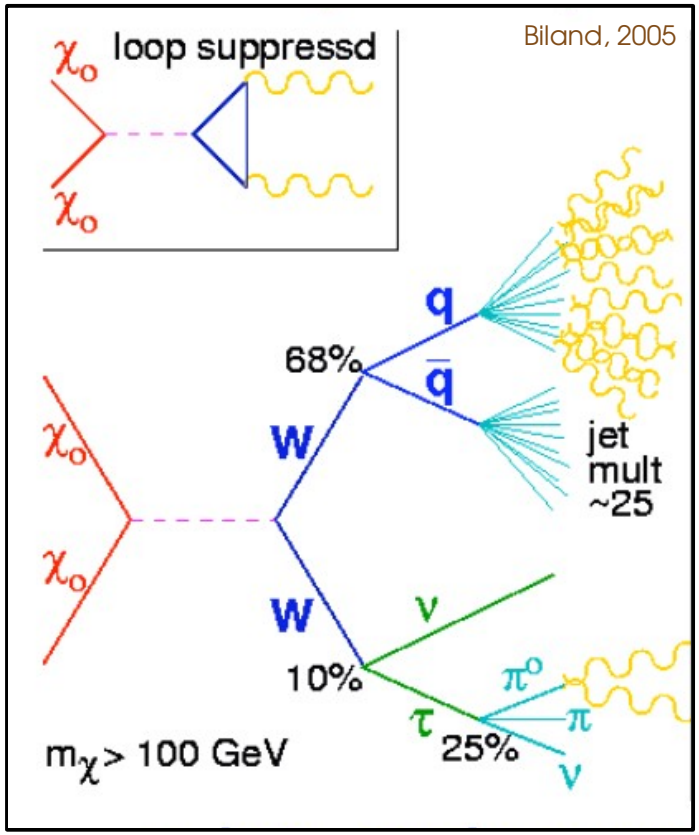




Dark Matter and IACTs

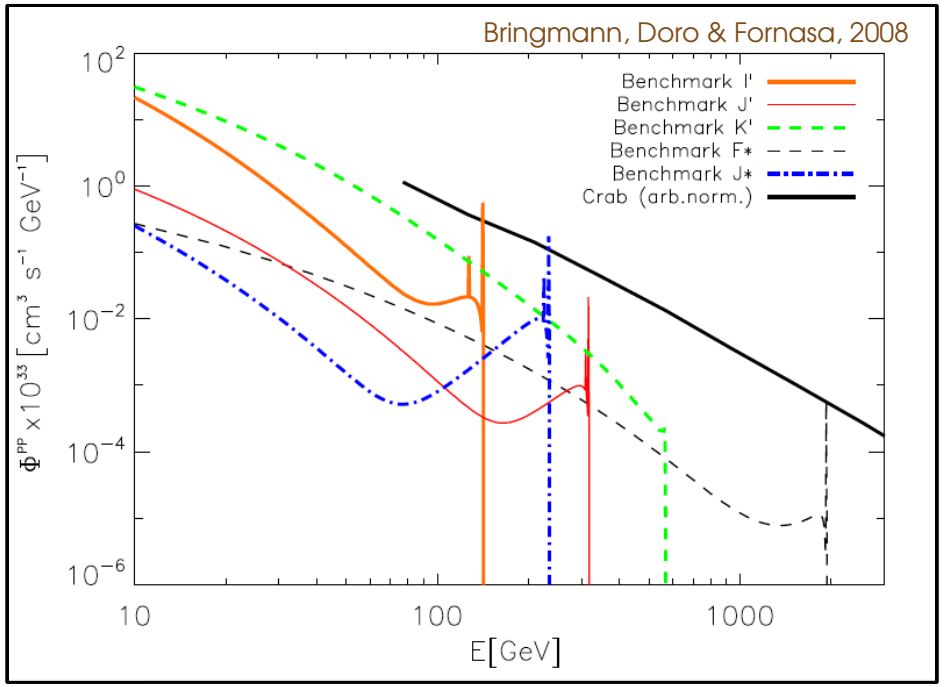
- For the IACTs, the best scenario (energy wise) is the supersymmetric Dark Matter annihilation

What should happen



(and other processes)

What should we expect



Monochromatic lines, IB, cut-off

Universal spectrum

Expected DM Flux

$$\Phi(E>E_0)=\Phi^{PP}\times J(\Delta\Omega)$$

Particle Physics factor

$$\Phi^{PP}(E>E_0)=\frac{1}{4\pi}\frac{\langle\sigma_{ann}\upsilon\rangle}{2m_\chi^2}\int_{E_0}^{m_\chi}\sum_{i=1}^{n}B^i\frac{dN_\gamma^i}{dE}dE$$

Astrophysics factor

$$J(\Delta\Omega)=\int_{\Delta\Omega}\int_{los}\rho^2(r(s,\Omega))\,ds\,d\Omega$$

Source dependent

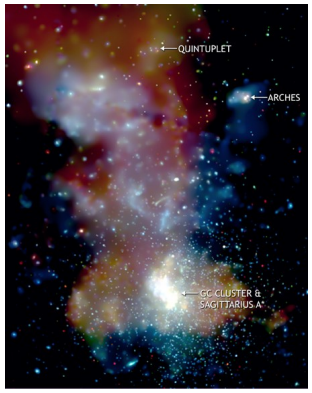
How do we choose what to observe?

Where to look?

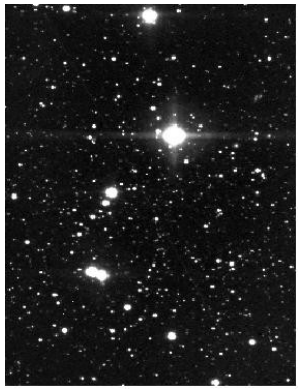
- IACTs have limited FOV → all-sky search impossible

What do we look for in a candidate?

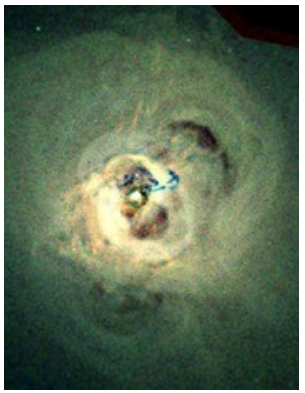
- high Dark Matter density
- small distance from us
- small apparent (angular) size
- as little as possible bkg from 'conventional' sources



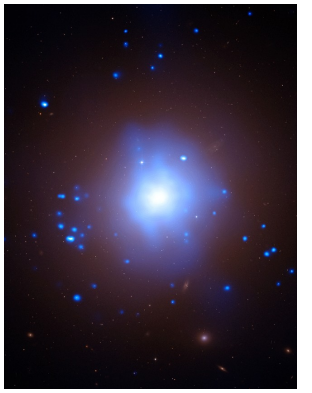
Galactic Center



dSph Galaxies



Galaxy Clusters



Mini-halos & IMBHs

MAGIC Results

Until September 2009 – only MAGIC 1!

Single telescope mode → Sensitivity 2x worse than in Stereo

MAGIC Results: Galactic Center

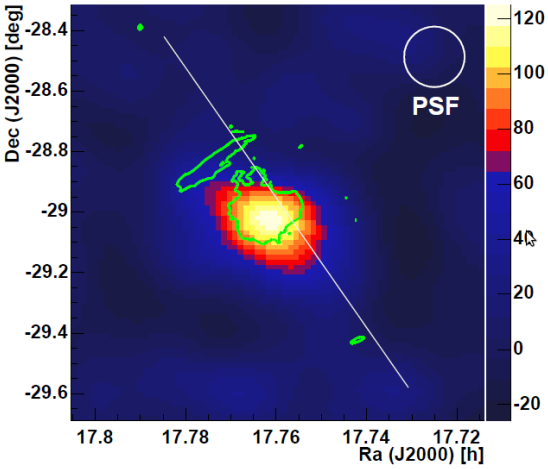
ApJ Letters 638, L101 (2006)

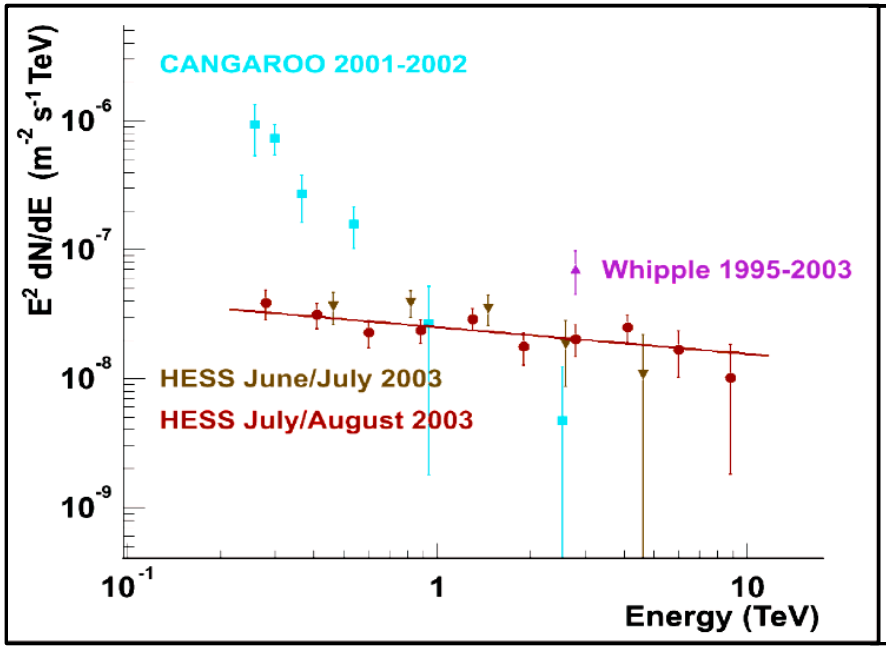
- 17 h of observations (2005)

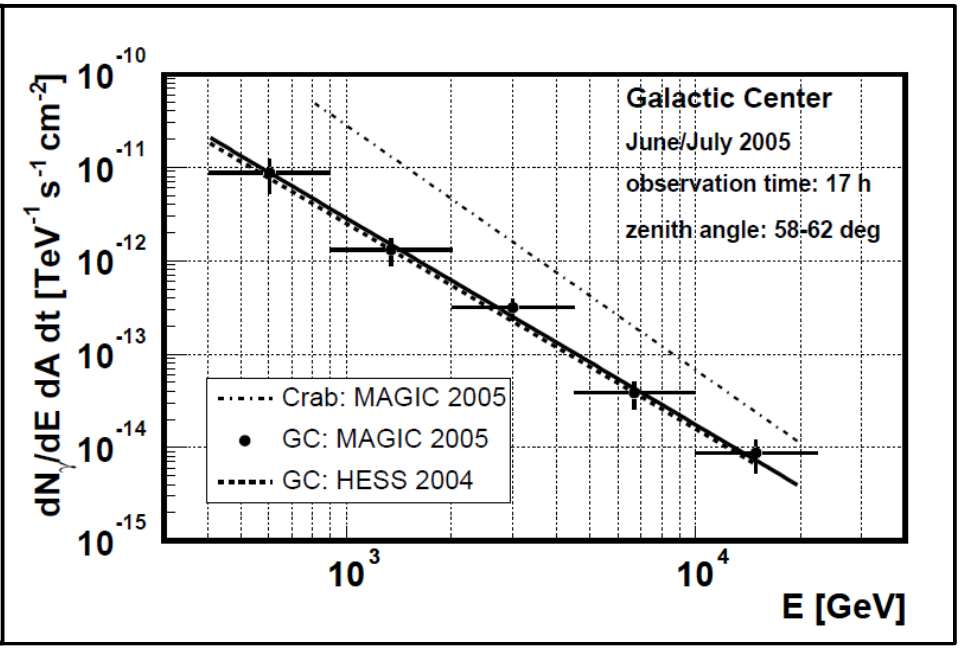
- high zenith angles → only high energies for MAGIC

- too much background (Sgr A* + diff.gamma)

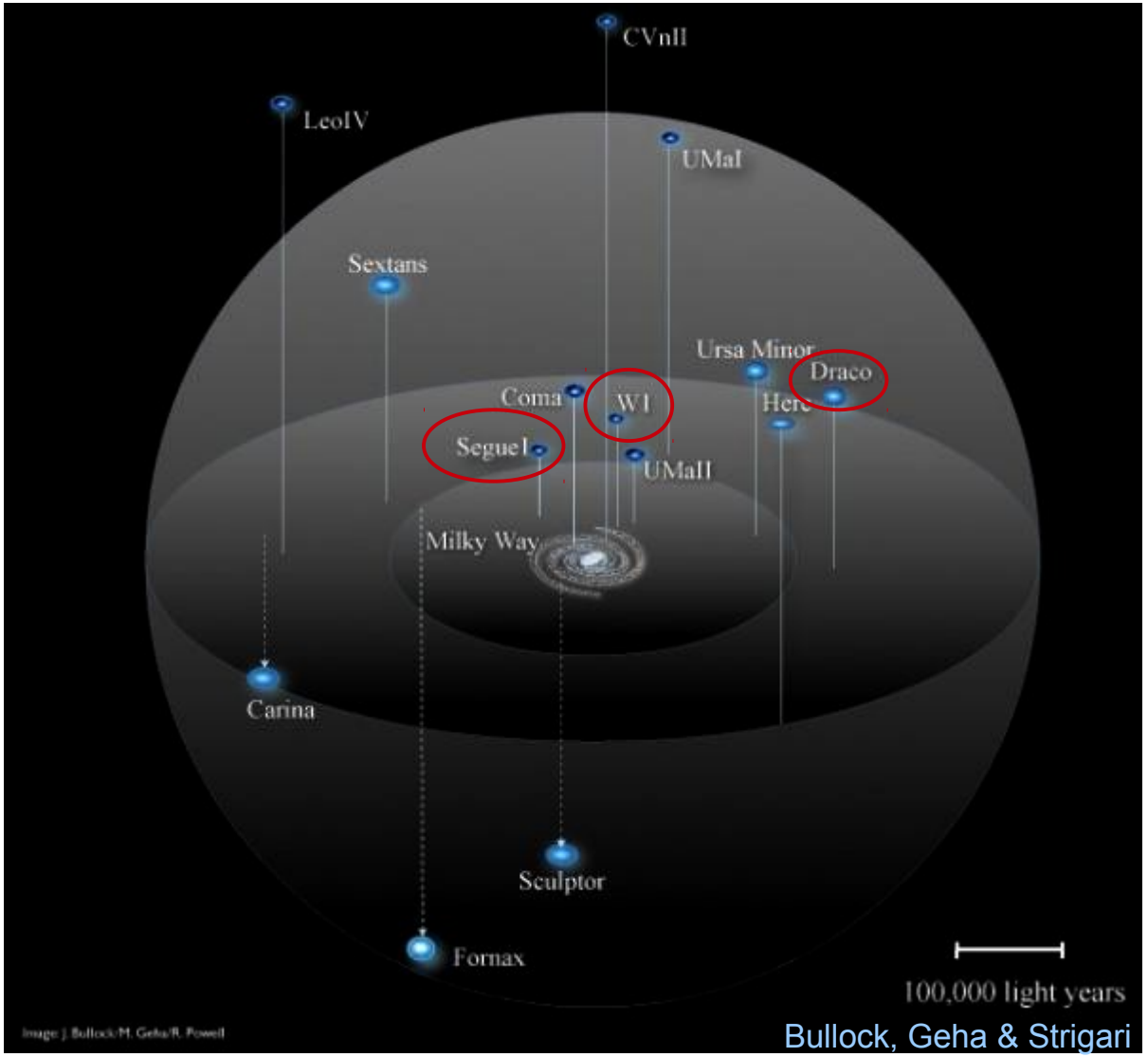
- results compatible with HESS







MAGIC Results: dSphs



Milky Way companions, highest known M/L, little astrophysical bkg

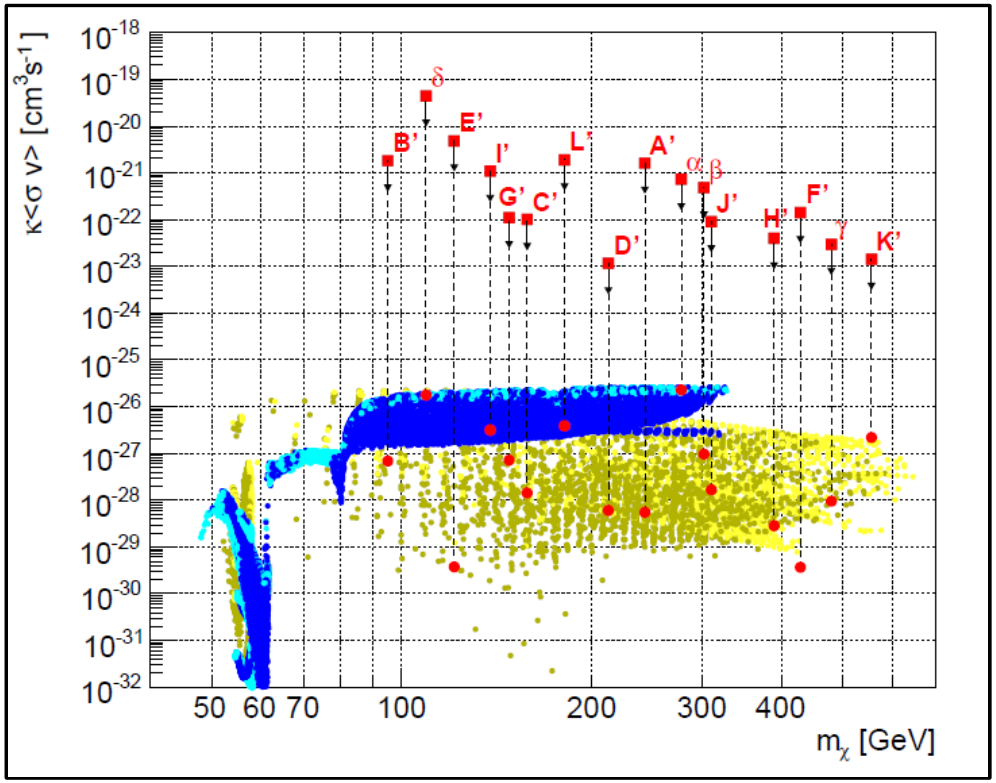
MAGIC Results: dSph Draco

ApJ 679, 428 (2008)

- 7.8 h of observations (2007)
- Medium zenith angles (>29°)
- E_{peak} = 140 GeV
- Upper limits for a set of mSUGRA benchmark points
- Halo model:
  power law+ exp. cut-off
  No IB (DarkSUSY 4.1)

$m_0 > 2$ TeV

$m_0 \leq 2$ TeV



U.L: O(10^3) - O(10^9) above models!

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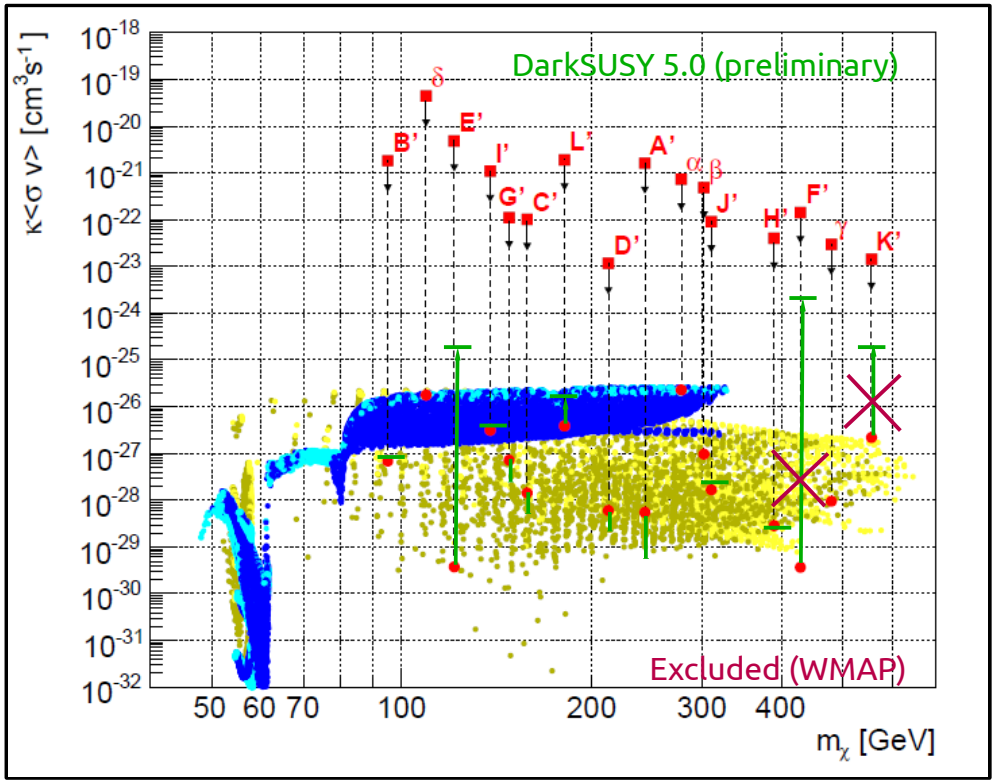


U.L: O(10^3) - O(10^9) above models!

MAGIC Results: dSph Willman 1

ApJ 697 (2009) 1299

- 15.5 h of observations (2008)

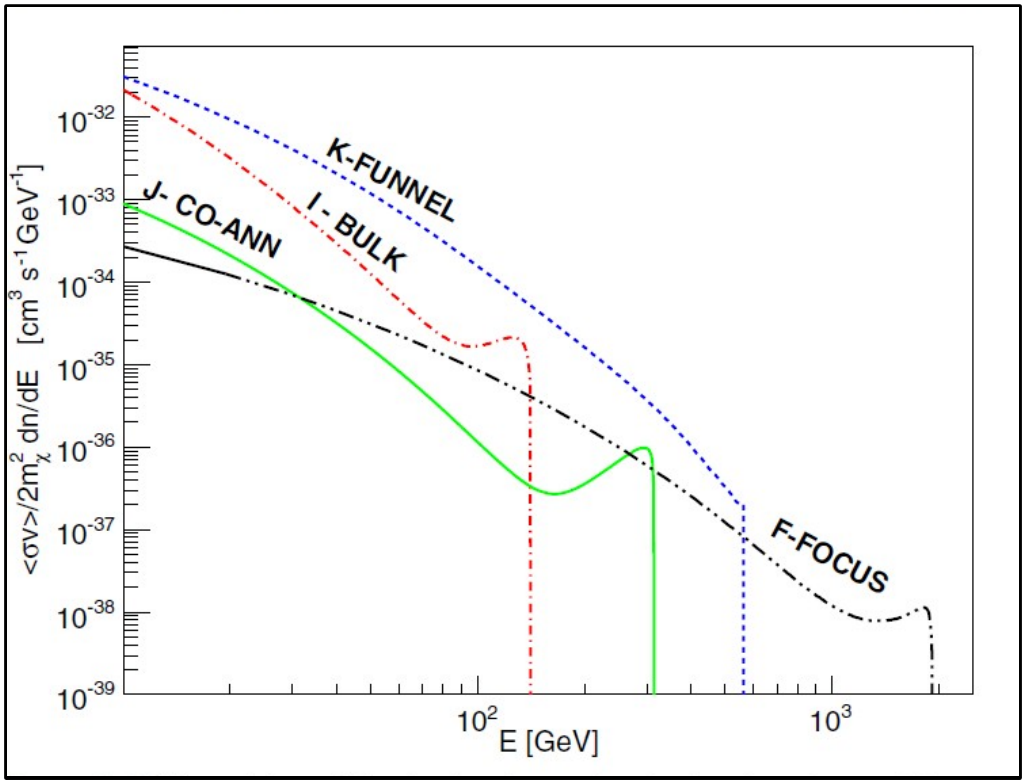
- Low zenith angles (22-30°)

- Upper limits for 4 mSUGRA benchmark points

- Halo model: NFW

IB included (DarkSUSY 5.0)

U.L: O(10^3) - O(10^5)



BM	$\Phi^{model}(>100\ GeV)$	$\Phi^{ul}(>100\ GeV)$	B^{ul}
I'	2.64×10^{-16}	9.87×10^{-12}	3.7×10^4
J'	4.29×10^{-17}	5.69×10^{-12}	1.3×10^5
K'	2.32×10^{-15}	6.83×10^{-12}	2.9×10^3
F^*	2.09×10^{-16}	7.13×10^{-12}	3.4×10^4

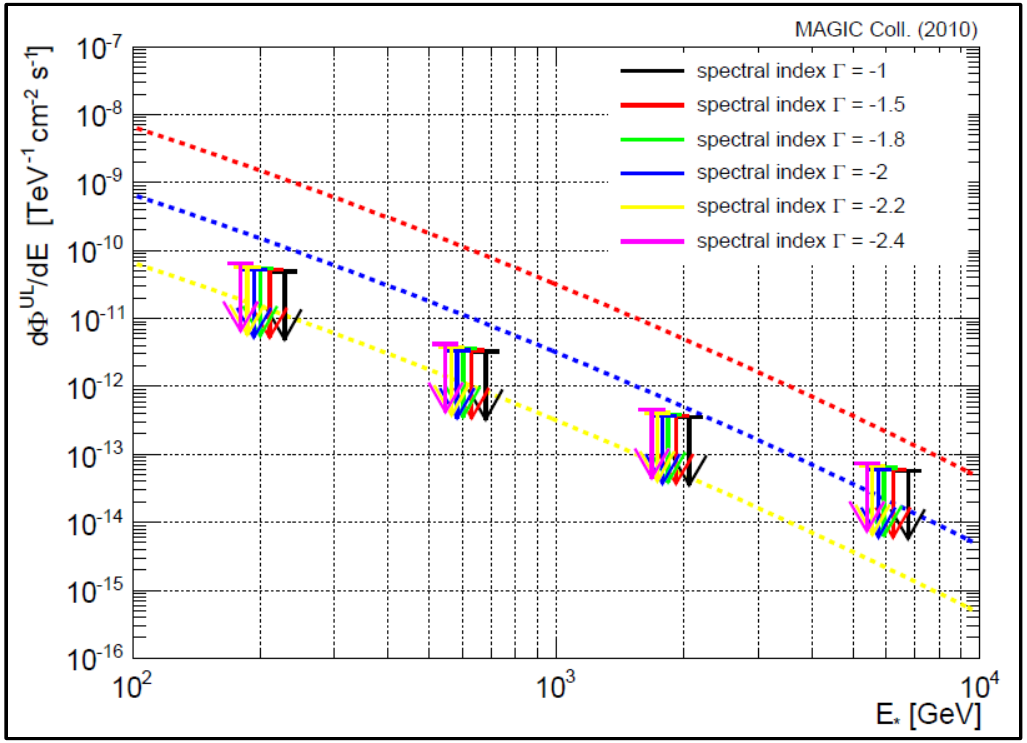
MAGIC Results: dSph Segue 1

arXiv:1103.0477 (2011)

- 30 h of observations (2008/09)

- Low zenith angles (12.7-33.9°)

- Integral Upper limits:
  - > 100 GeV: $<10^{-11}$ cm^{-2} s^{-1}
  - > 200 GeV: $<2\times10^{-12}$ cm^{-2} s^{-1}



MAGIC Results: dSph Segue 1

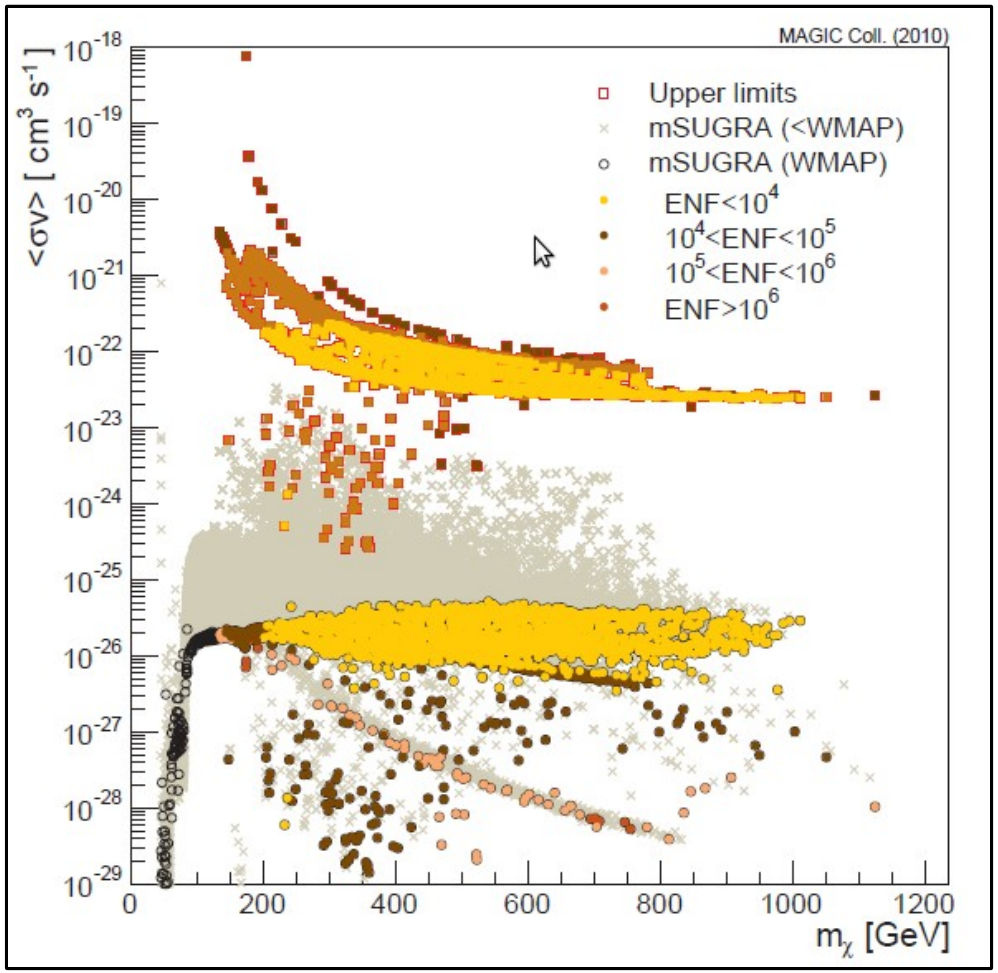
arXiv:1103.0477 (2011)

- Halo profile: Einasto

- more than 5x10^6 models scanned over mSUGRA

Parameter	Range	Steps
m_0	50 ; 5000 GeV	40
$m_{1/2}$	0 ; 5000 GeV	40
$\tan\beta$	2 ; 62	40
A_0	−7000 ; 7000	40
sign(μ)	+; −	2
Total number of models scanned		5.12×10^6
& passing SM bounds		2.42×10^6
& with $\Omega_{\rm DM}h^2 - \Omega_{\rm DM}^{\rm WMAP}h^2 < 3\sigma_{\rm WMAP}$		42427
& with $\lvert\Omega_{\rm DM}h^2 - \Omega_{\rm DM}^{\rm WMAP}h^2\rvert < 3\sigma_{\rm WMAP}$		4180

- Each square (limit) corresponds to the model (circle)



- For Ω_{DM} = WMAP ± 3σ, the boost factor is > 600 → still far from constraining mSUGRA

MAGIC Results: Perseus

- Galaxy Clusters: huge amount of DM (80%), distant (O(100 Mpc)), background

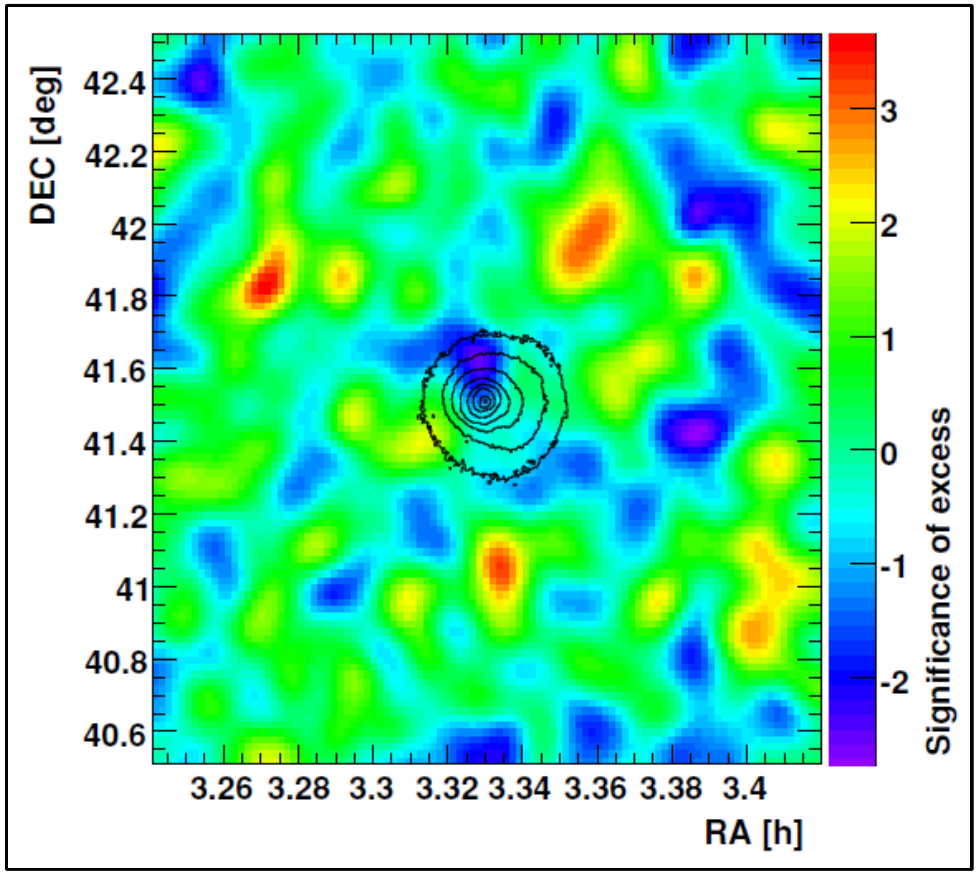
ApJ 710 (2010) 634

- 24.8 h of observations (2008)

- Possible emissions from:
  - individual galaxies
  - cosmic rays
  - Dark Matter (?)

- Integral U.L:
> 100 GeV: (4.6-7.5)x10^{-12} cm^{-2} s^{-1}

- O(10^4) above expected DM emission



- Upper limits for the central radio galaxy NGC 1275

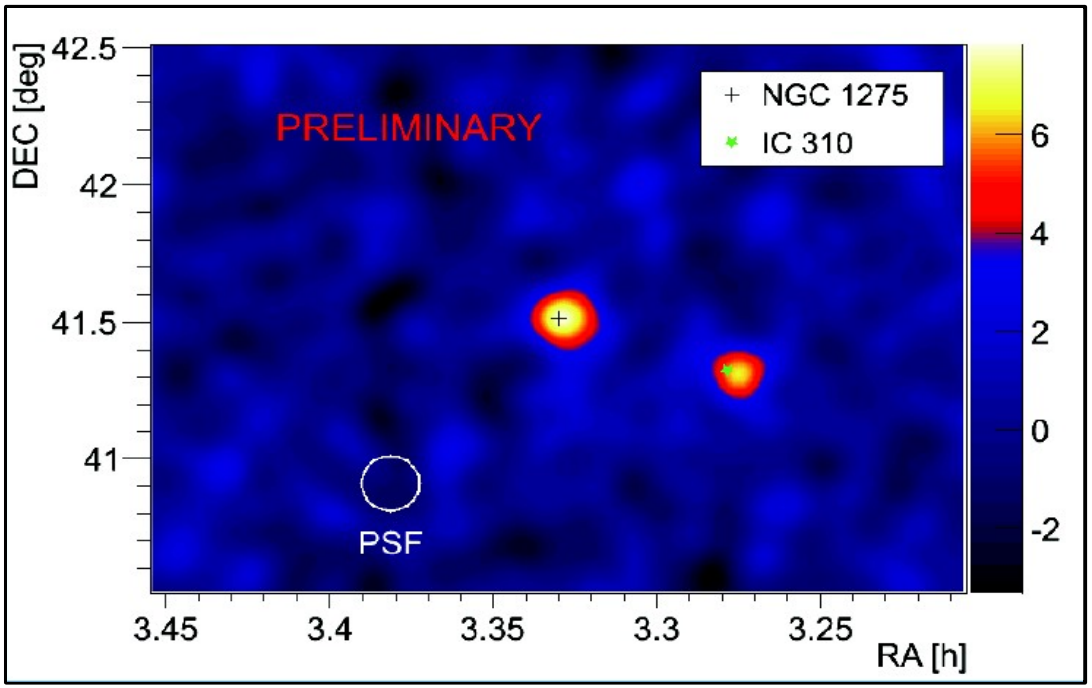
MAGIC Results: Perseus (STEREO)

ApJ Lett. 723 (2010) L207

STEREO: 2x improved sensitivity, lower E_{th} and better angular and energy resolution

- 20.6 h of stereo observations (2009/2010):
  Discovery of VHE emission from head-tail radio galaxy IC 310

- Stereo observations (2010/11):
  Detection of NGC 1275



MAGIC DM Search: UFOs

- Predicted existence of DM clumps within our Galaxy
- IMBHs (?) could have accreted large amounts of DM
- Might be very close, and very bright, but only through DM emission (Fermi, Agile could see them?)

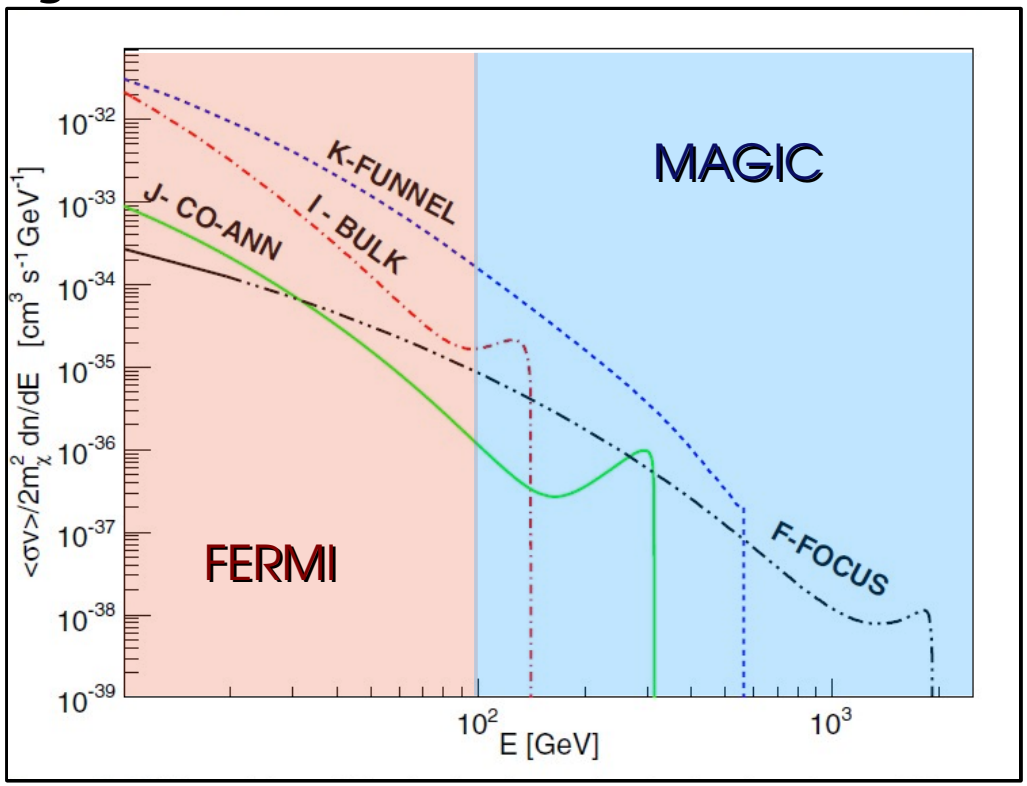
- Unidentified Fermi Objects (UFOs) – recently detected by Fermi, without known counterpart in other wavelengths

- Possible DM candidates:
  - + hard spectrum
  - + stable
  - + outside Galactic plane

Smoking gun: several UFOs with same spectrum!

- MAGIC might be more suitable to detect cut-off for $m\chi$<100 GeV

- Observations ongoing



Conclusions and Prospects

- MAGIC is observing promising DM targets since 2005.

- No detection yet, but chances increased with Stereo system:
  + sensitivity less than 1% Crab Nebula → go lower in flux
  + lower energy threshold → go lower in m_{χ}
  + angular resolution 20% better → study extended sources
  + energy resolution < 20% → look for spectral features

- Active group for Dark Matter searches

- Ongoing efforts on dSphs, Galaxy Clusters and UFOs

- For objects with 'known' DM distribution, MAGIC still can not constrain mSUGRA models

- Testing other DM theories? :)

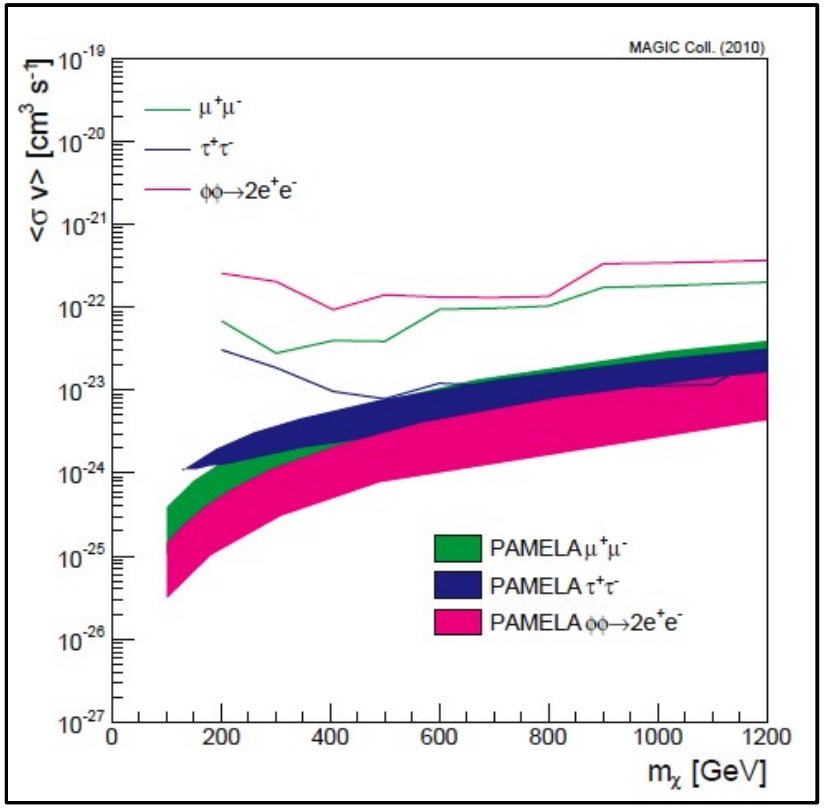
MAGIC Results: dSph Segue 1

arXiv:1103.0477 (2011)

- Compared models fitting PAMELA e^+/e^+e^- ratio (adapted from:
  Essig et al., PRD 82,
  Meade et al., Nucl. Phys. B 831)

- MAGIC limits start to probe the relevant region for

$$\chi\chi \longrightarrow \tau^+\tau^-$$



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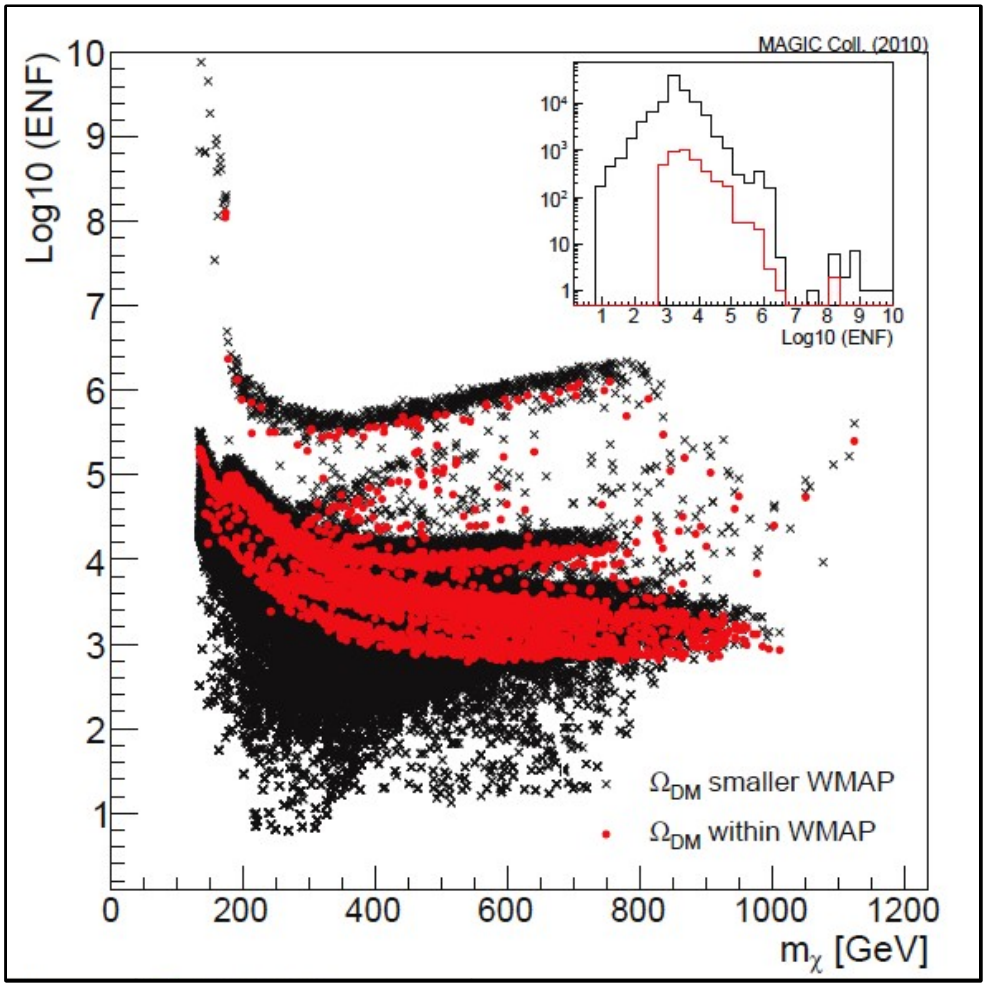

Enhancement factors as a function of the DM mass for models in the scan providing a relic density compatible with WMAP value (red crosses) or below (black crosses). The panel in the upper right part indicates the distribution of the ENFs for these two sets of models with the same color coding.