Dark Matter in Draco

new considerations of the expected gamma flux in IACTs

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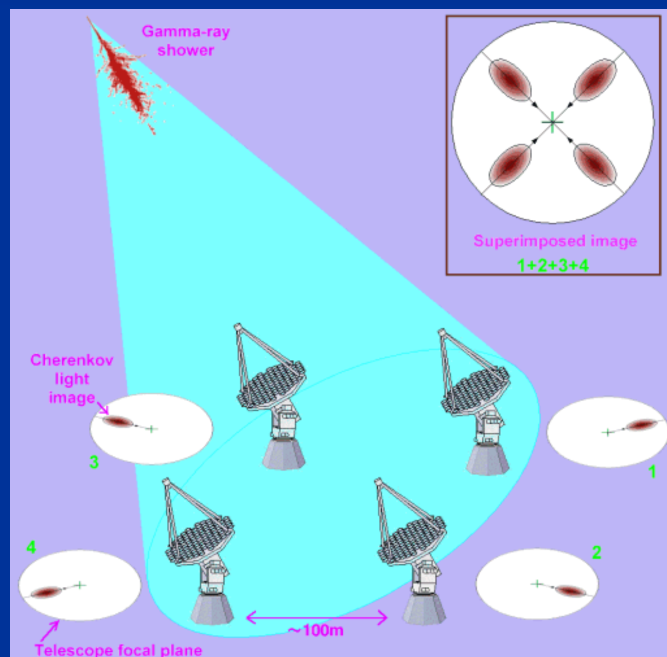
Indirect Dark Matter Searches

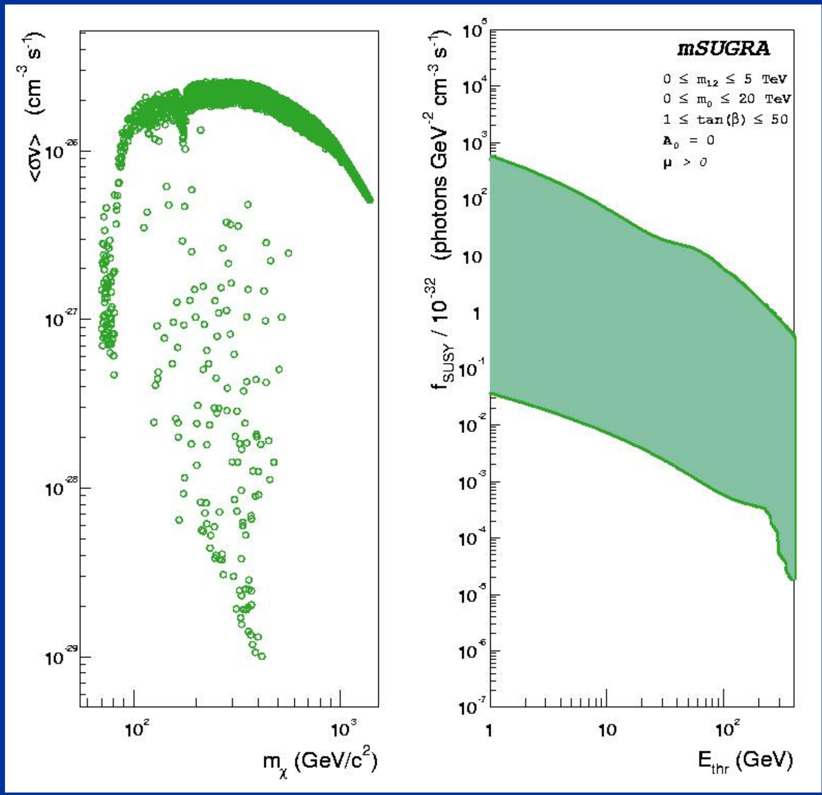
- Detectability of gamma rays coming from the annihilation of SUSY DM.
- IACTs and satellites: HESS, VERITAS, MAGIC, GLAST…



The DM gamma signal

$$F_\gamma(E > E_{th}) = \frac{1}{4\pi} f_{susy} \cdot U(\Psi_o)$$ photons cm^{-2} s^{-1}

Particle physics (f_{susy}) — astrophysics ($U(\Psi_o)$)



Prada et al. (2004)

SUSY Model:

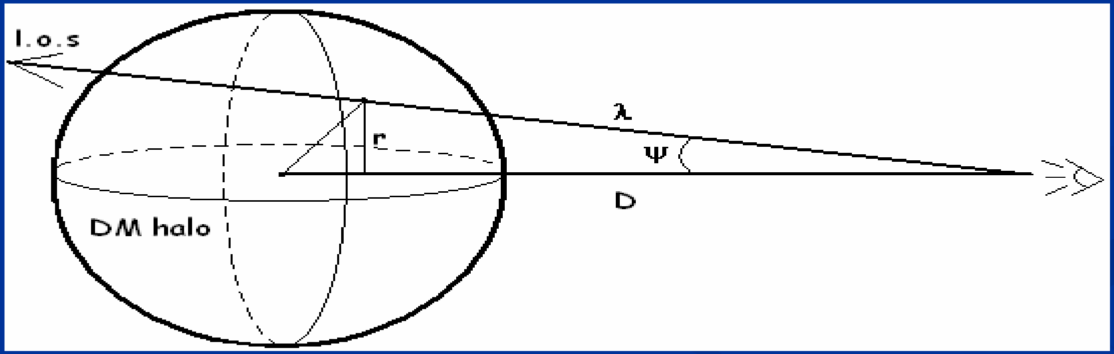
$$f_{susy} = \frac{N_\gamma \langle \sigma \cdot v \rangle}{2 m_\chi^{\ 2}}$$

- N_γ: Number of photons
- $\langle \sigma \cdot v \rangle$: cross section
- M_χ: mass of the neutralino

Astrophysical parameters

$$U(\Psi_o) = \int J(\Psi) B(\Omega) d\Omega$$

Integral along the l.o.s.: $$J(\Psi) = \int_{l.o.s} \rho_{dm}{}^2(r) dl = \int_{r\,min}^{r\,max} \frac{\pm \rho_{dm}{}^2(r) \cdot r}{\sqrt{r^2 - d_{sun} \sin \psi(\theta, \phi)}}$$



Point Spread Function (PSF) of the telescope: $$B(\Omega) d\Omega = \exp\left(\frac{-\theta^2}{2\sigma_t{}^2}\right) \sin\theta d\theta d\phi$$

PSF plays a very important role on the way we “see” the signal.

Previous works did not take into account its effect (except Prada et al. 2004)

Targets

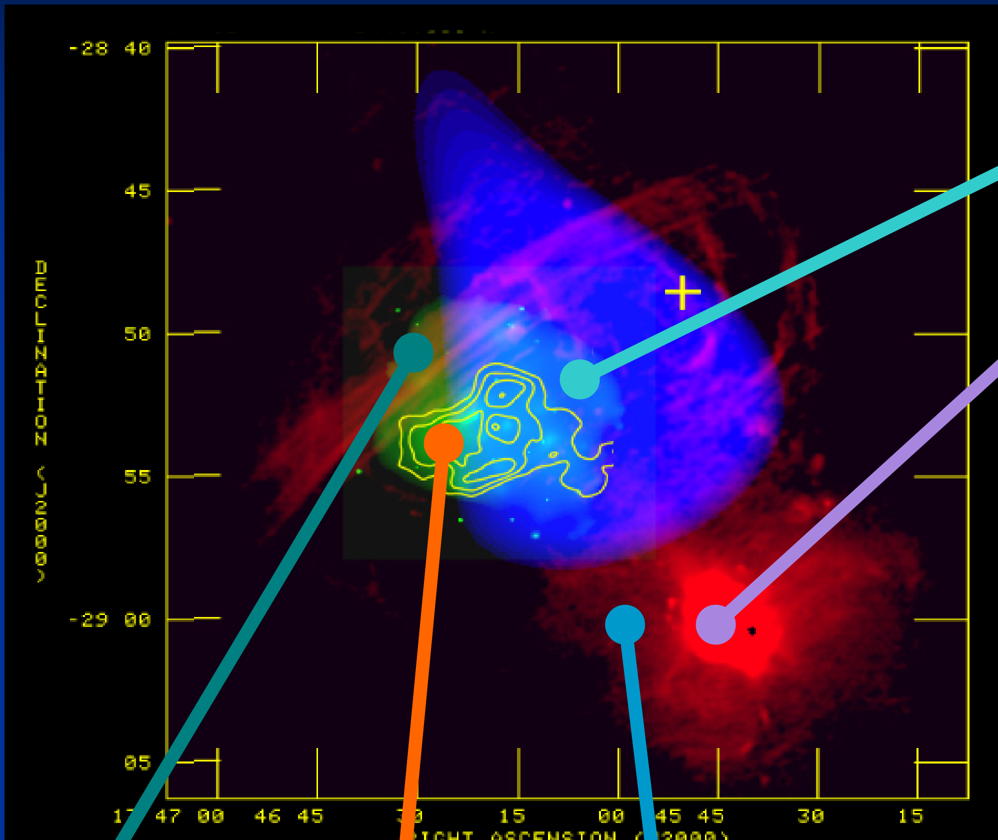
Where to search?

- Our galaxy (Galactic Center, minihalos, substructure...)
- Dwarf spheroidal galaxies (e.g. Draco, Fornax, LMC, SMC...)
- Andromeda
- Galaxy clusters (e.g. Virgo)

The Galactic Center, in principle the best option...

- Very near, so flux should be high.
- HESS and MAGIC reported a point-like source: a very massive neutralino, no compatible with WMAP cosmology.
  (Aharonian et al. 2004; Albert et al. 2005)
- Recently, an extended emission was discovered, but associated to the galactic plane and molecular clouds.
  (Aharonian et al. 2006)

GC is a very crowded region !



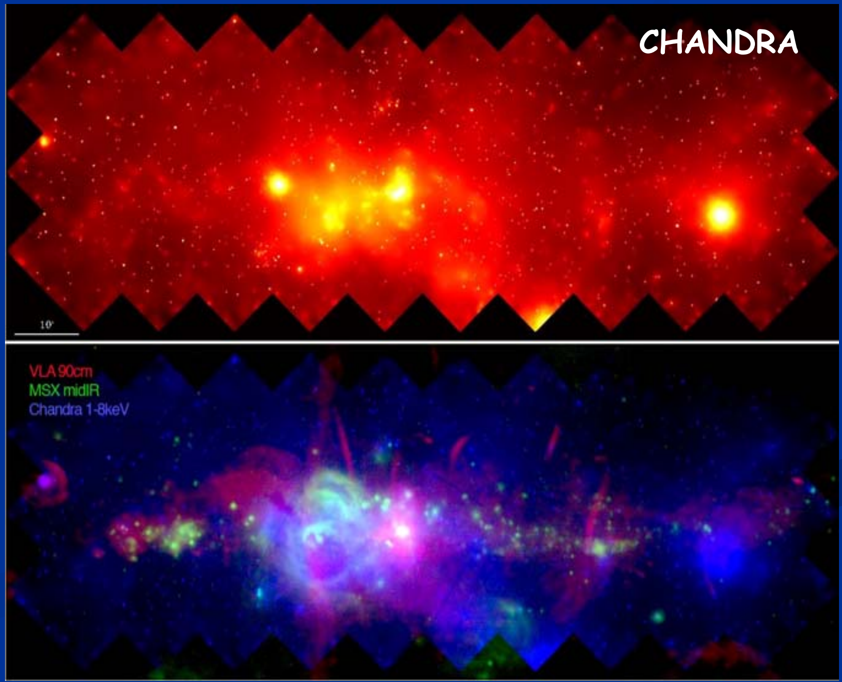
EGRET source

Black Hole (Sgr A*)

X-ray source

SNR

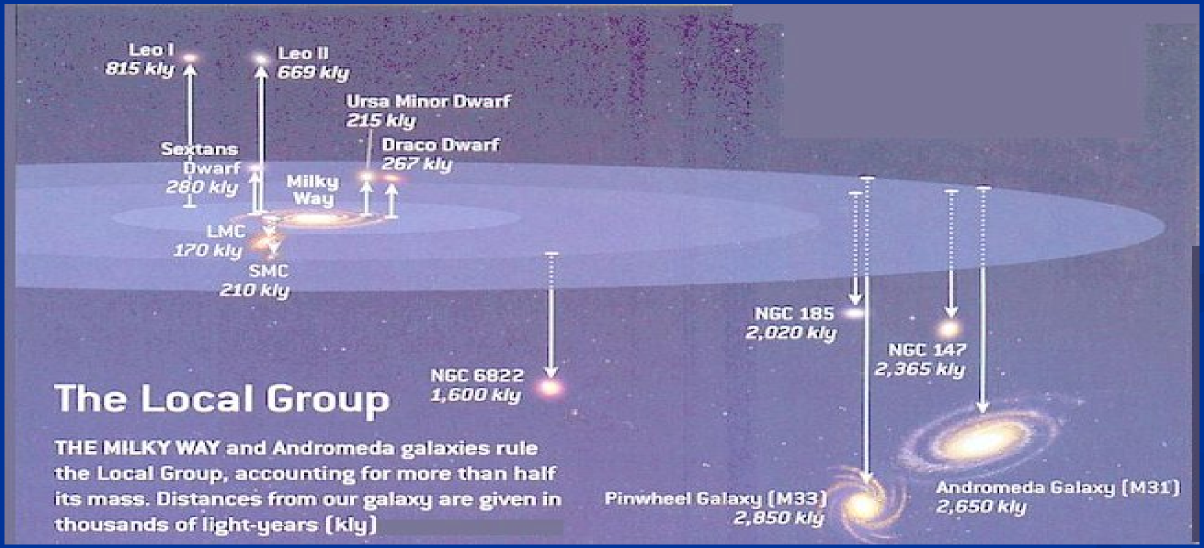
SgrA East



Targets (II)

What about dSph galaxies?

- High M/L ratios
- At least 6 dSph nearer than 100 kpc from the GC (Draco, LMC, SMC, CMa, UMi and Sagittarius)



Draco

- Draco is the dSph with more observational constraints.
- Near (80 kpc).
- M/L ~ 300
- Recently, CACTUS reported a gamma-ray excess from Draco.

A DM model for Draco

$$\rho(r) = \frac{M_D}{4\pi r_b^{\,2}} \frac{1}{r^\alpha} \exp\left(\frac{-r}{r_b}\right)$$

(Kazantzidis et al. 2004)

For α=1, essentially NFW + cut-off:

- r_b = 0.33 kpc
- M_D = $6.5 \cdot 10^7$ Msun

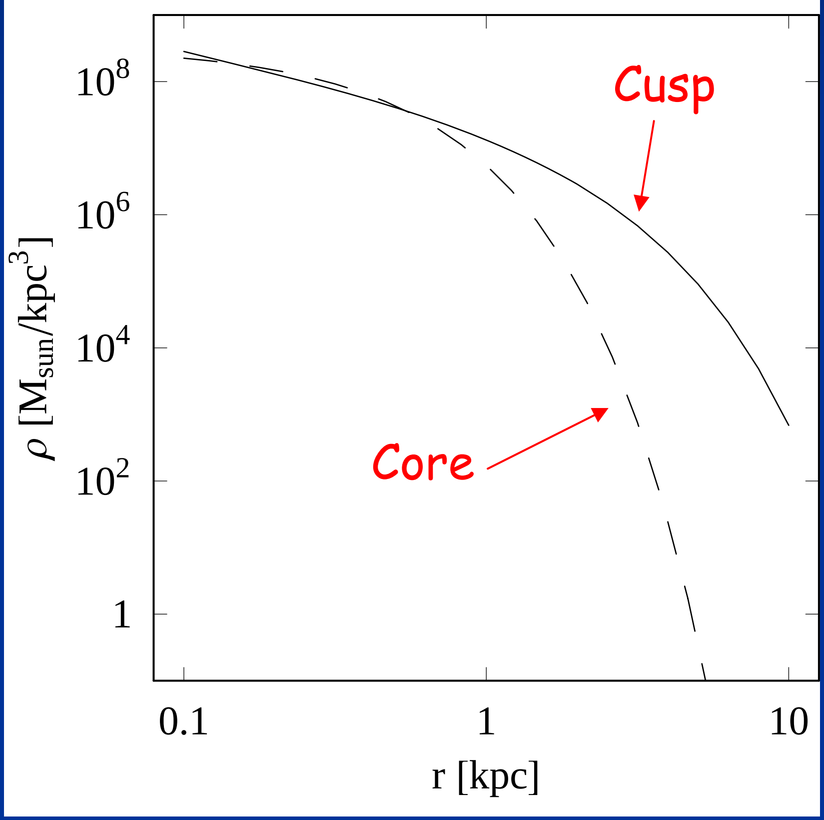
(Lokas, Mamon & Prada 2005)

New estimations for r_b and M_d according to the latest data analysis:

Cusp (α=1):
- r_b = 1.308 kpc
- M_D = $5.48 \cdot 10^8$ Msun

Core (α=0):
- r_b = 0.24 kpc
- M_D = $1.22 \cdot 10^8$ Msun

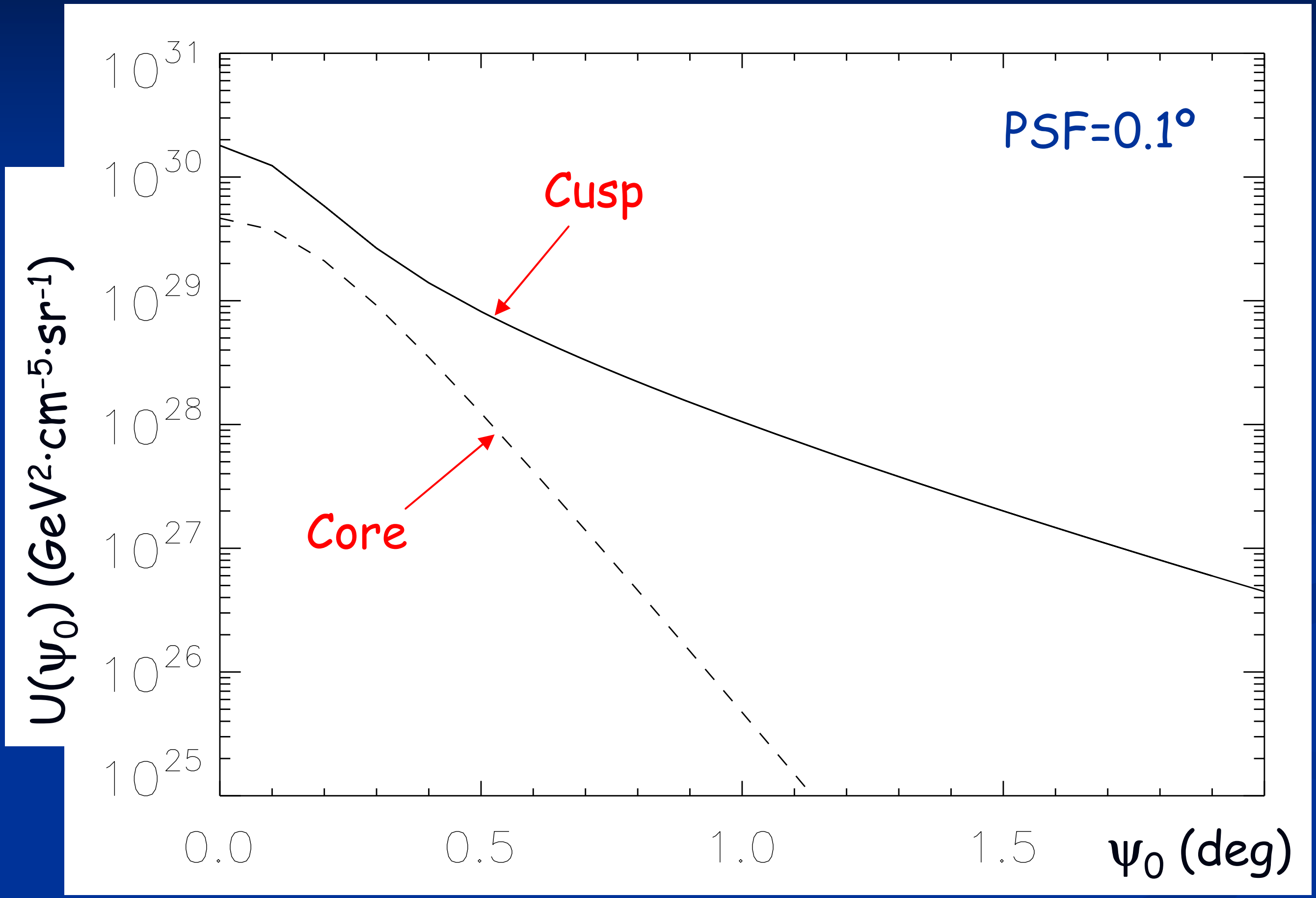
A DM model for Draco (II)



(Sánchez-Conde, Prada, Lokas et al., in prep.)

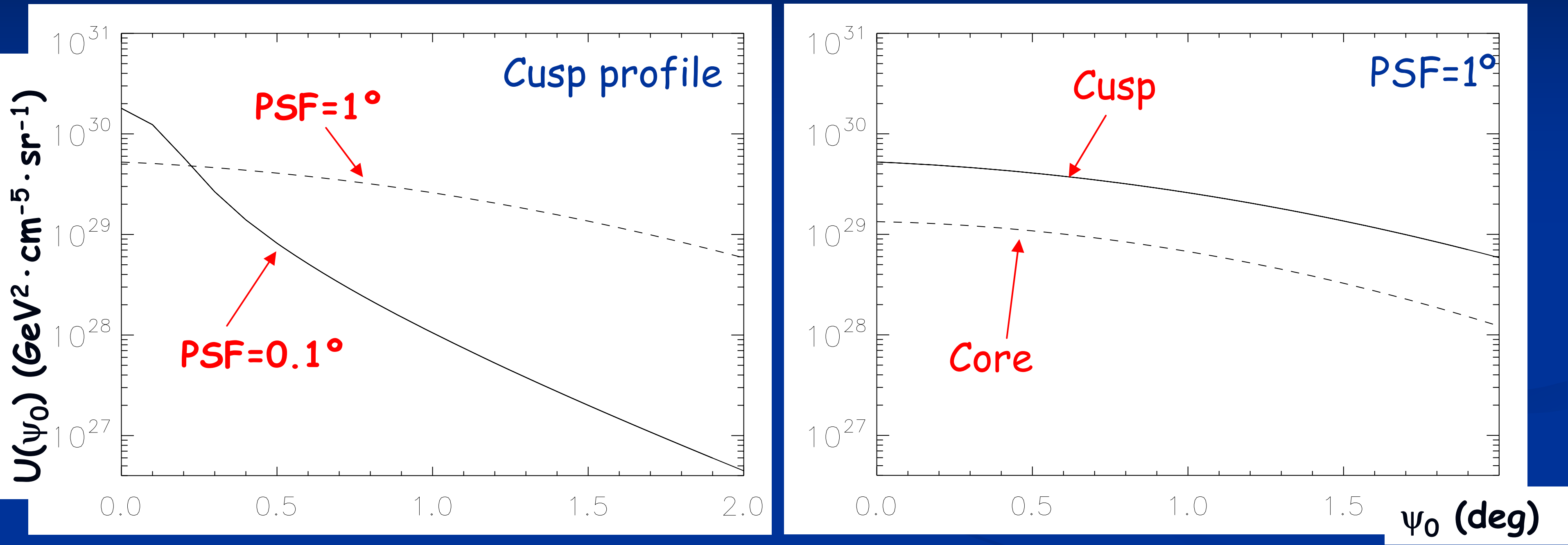
- Both profiles similar up to 1 kpc (constrained by the data).
- Different break radius to reproduce the known velocity dispersion profile.

$U(\psi_0)$ predictions for Draco



- $U(\psi_0)$ predictions for the "core" and "cusp" density profiles; PSF=0.1° (the typical PSF for an IACT like MAGIC or HESS).
- We could distinguish between them thanks to a characteristic shape in each case.

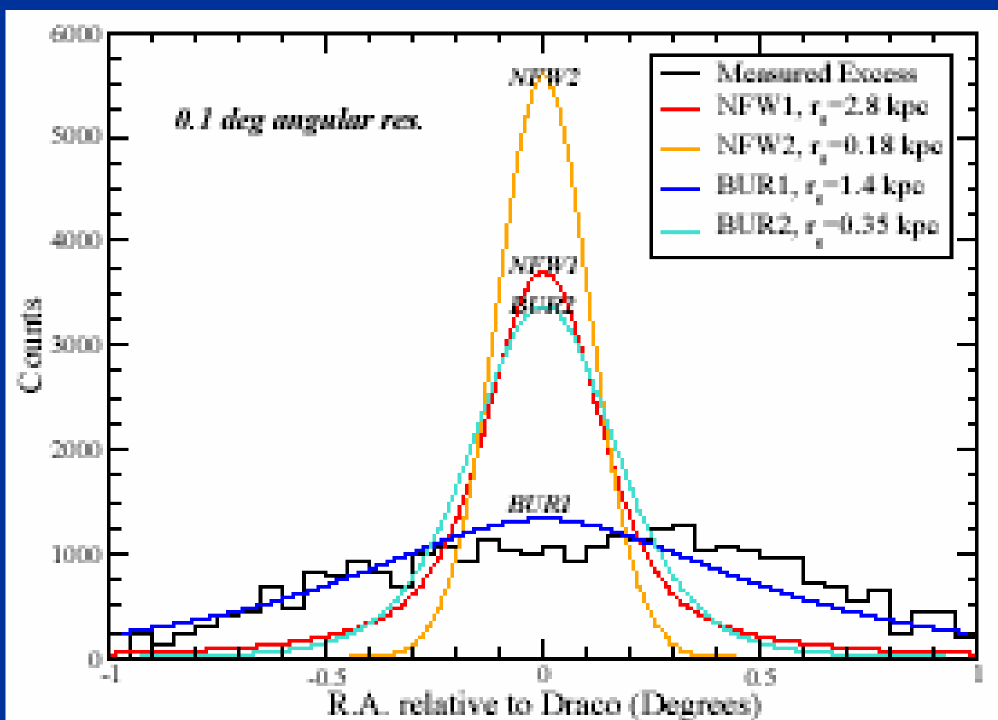
The role of the PSF



- For the same model, a worse PSF flatten the profile.
- For different models, a worse PSF makes indistinguishable the profiles because all of them have the same shape.

A revision of CACTUS results

- CACTUS:
  - A ground based gamma-ray telescope in California.
  - Sensitive to gamma-rays above 50 GeV, and Aeff ~50000m^2
  - It was designed for solar observations and no for gamma-ray astronomy. PSF around 1°.
- Recently, they reported a gamma-ray excess from Draco (Marleau 2005)



- Flux estimations computed without taking into account the PSF.

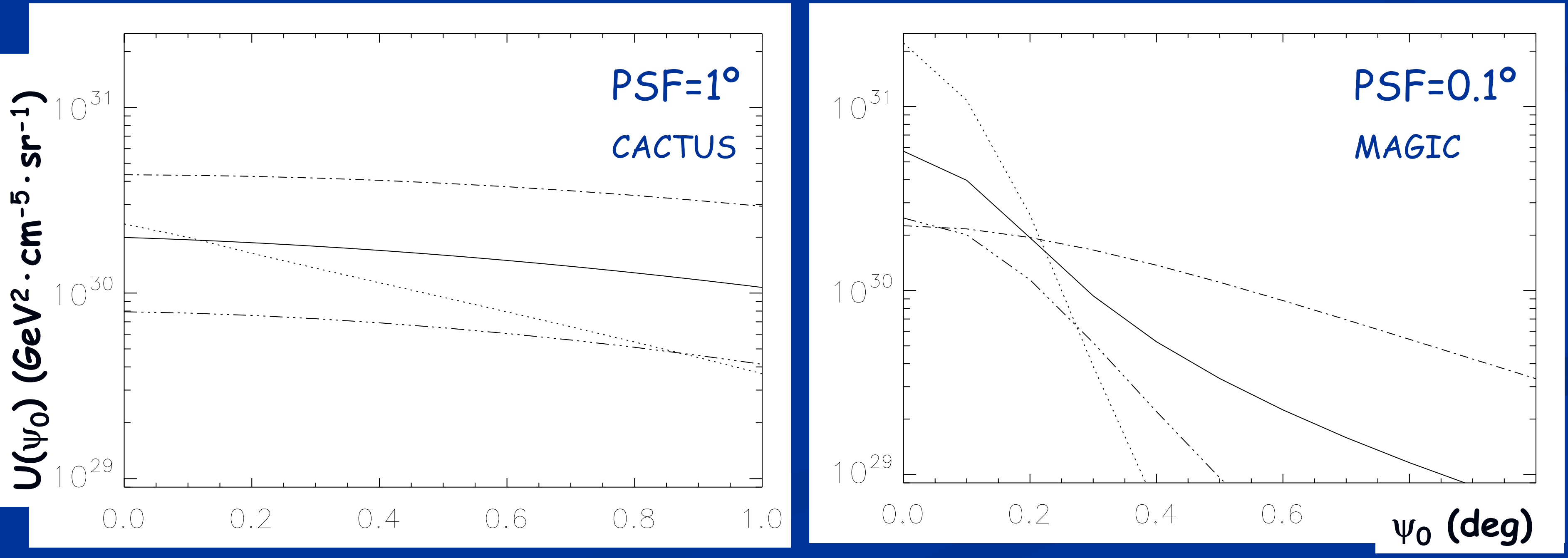
- CACTUS data was superimposed, but they have a PSF of 1°!

Profumo & Kamionkowski (2006)

A revision of CACTUS results (II)

It is crucial here to take into account the effect of the PSF:

- Wiht a PSF = 1° (the CACTUS PSF), it is impossible to discriminate between the flux profiles.
- Only the absolute flux could give us a clue, but too many uncertainties!!
- With a PSF = 0.1°, we could distinguish between the different flux profiles (and different models for the DM density profile).



Conclusions

- The PSF of the instrument is crucial:
  - To estimate correctly the expected flux due to DM annihilation.
  - Its effect could make impossible to discriminate between different models of the DM density profile.

- CACTUS:
  - Their results for Draco (if real) should be interpreted carefully. No possibility to say cusp or core... May be they only detected an excess signal.
  - If the excess is real, MAGIC should see the signal without problems and could distinguish among the different DM density profiles.

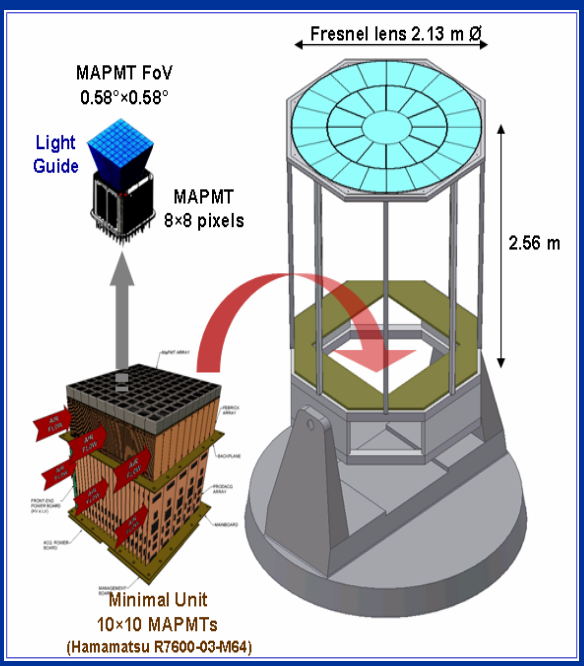
- New results from GLAST (PSF$<0.1°$) will be very important in the indirect search of DM.

- IACTs with LFOV and high sensitivity are the next step.

GAW – Gamma Air Watch: a new IACT

GAW is a R&D path-finder experiment for γ-ray astronomy:

- Above 0.7 TeV. PSF around 0.2°
- 3 identical telescopes working in steoroscopic mode (80m side).
- To test the feasibility of a new generation of IACT Cherenkov telescopes, which join high sensitivity with large Field of View.



When

GAW is an R&D experiment under development; a first part of the array should be completed and operative within winter 2008.

Where

GAW is planned to be located at Calar Alto Observatory, Spain, ~2150 m a.s.l..

Who

GAW is a collaboration effort of Research Institutes in Italy, Portugal, and Spain.

Draco and GAW

$$F_{\gamma,\text{Draco,GAW}}\left(E > 0.7\,\text{TeV}\right) = \frac{1}{4\pi} f_{susy} \cdot U(\Psi_o)$$

- Draco around 1.5° in the sky. GAW PSF = 0.2°
- If only detectability, no image, and S/N > 5σ (integrated flux)
- Large uncertainties: f_{susy} for 700 GeV, MW signal and substructure, Draco inner profile…

If we take:

1) $f_{susy} = 10^{-34}\,\text{ph}\cdot\text{GeV}^{-2}\cdot\text{cm}^{-3}\cdot\text{s}^{-1}$ for 0.7 TeV
2) a NFW with an exponential cut-off density profile:

$F_{\text{Draco,NFWc}} \approx 2.4876\ ^{-11}\ \text{ph cm}^{-2}\ \text{s}^{-1}$

[$F_{\text{min,GAW}}$ (50 h; 5σ) ≈ $3.5\cdot10^{-12}$ ph cm^{-2} s^{-1}]