Can one distinguish between decaying and annihilating dark matter using gamma ray observation?

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Gamma ray emission from dark matter

Production

- **Directly from DM annihilation or decay**
- **From FSR** (CB,Ensslin,Silk 2002; Beacom et al 2004)
- **From electrons/positrons ``scattering'' off Inter Stellar Radiation Field**

Observation:

- **FERMI [with possible ways of correlating with PAMELA, HEAT,..]**

Line (E=mDM). Flux is suppressed

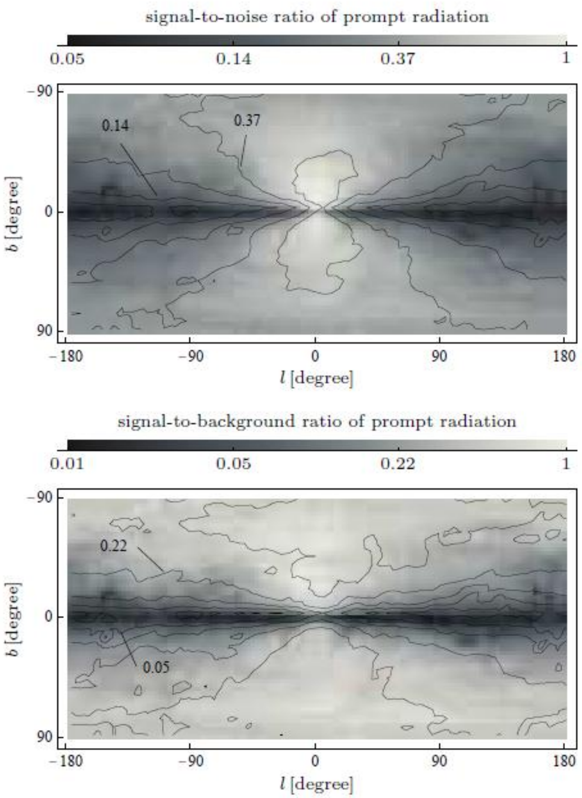
Continuum. Flux is alpha suppressed

Continuum. Traces the electron distribution after spatial and energy propagation

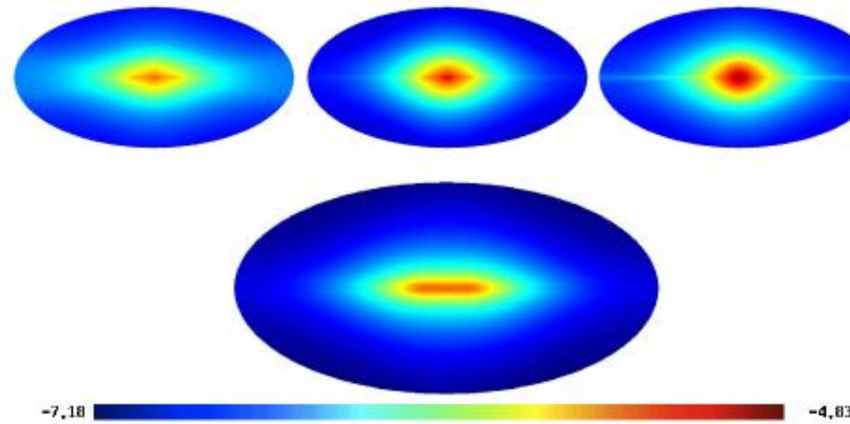
The gamma ray must have an energy that is within FERMI's reach

Previous studies

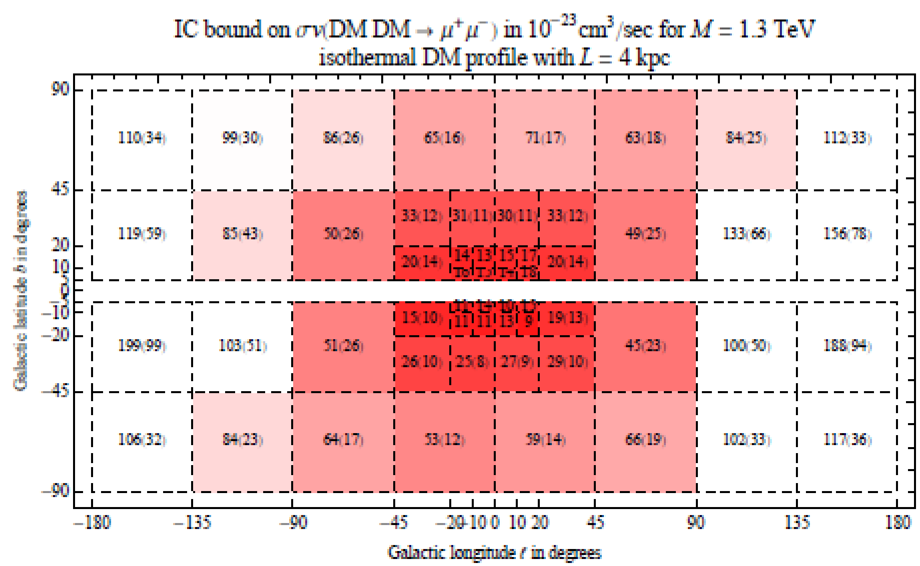
Ibara, Tran, Weniger 2009



Zhang et al 2009

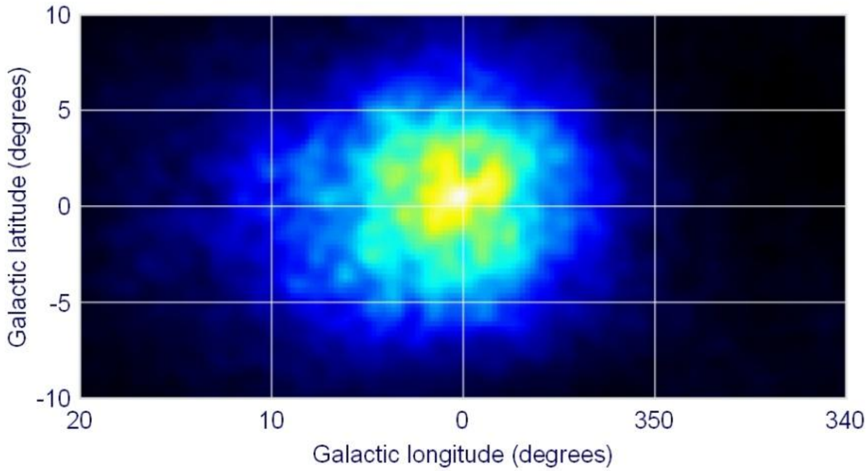


Papucci, Strumia 2009



How to distinguish the different scenarios?

Let us look at the morphology of the emission!



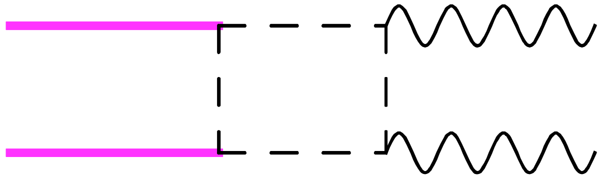
After all, morphology was very important for the 511 keV line.

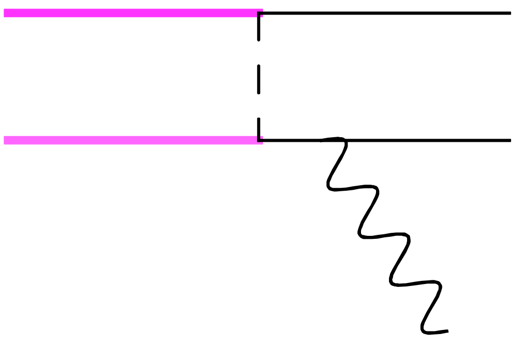
Indeed this has enabled to rule out decaying DM and even (within a specific model) annihilating fermionic DM).
See Ascasibar et al 2006

From now on, I will only speak about:

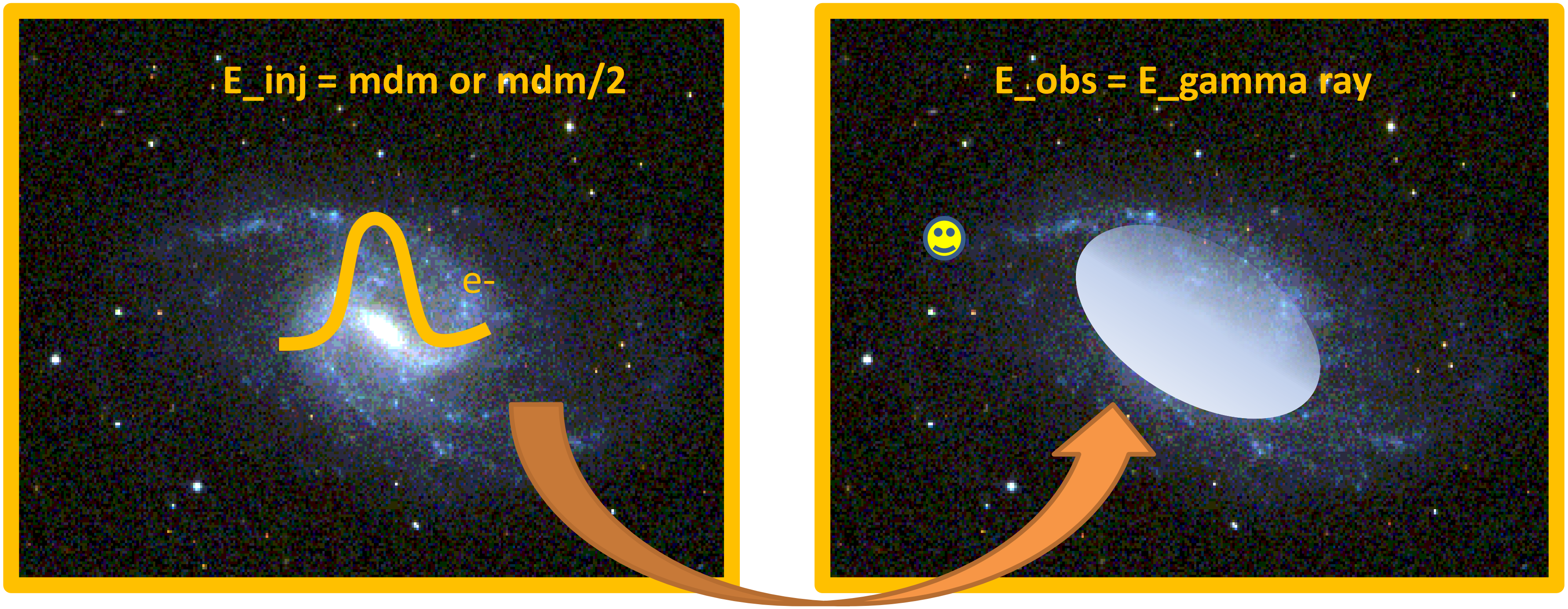
The gamma ray emission from electron/positron propagation

No:





Electron spatial and energy propagation



Produce gamma rays while propagating and interacting with Inter Stellar Radiation Field

Diffusion equation with:

Source term: Annihilation or decay

All losses (synchrotron, IC on CMB, star light, UV, Bremsstrahlung)

No convection; no wind

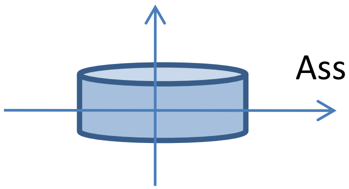
Electron energy corresponding to a given gamma ray energy.

BB	$E_\gamma = 1$ GeV	$E_\gamma = 10$ GeV	$E_\gamma = 50$ GeV
CMB	527 GeV	1.7 TeV	3.7 TeV
IR	151 GeV	479 GeV	1.1 TeV
Stellar	49 GeV	155 GeV	348 GeV
UV1	15 GeV	48 GeV	107 GeV
UV2	11 GeV	35 GeV	78 GeV
UV3	6 GeV	18 GeV	40 GeV

So different propagation length (starting from a given electron energy)!!!

Propagation length and characteristics

Delahaye et al 2007



Assume that diffusion zone is well approximated by a cylinder

Radius of the cylinder

$$\tilde{I}(\lambda_{\mathrm{D}}) = \sum_{i=1}^{\infty} \sum_{n=1}^{\infty} J_0(\alpha_i r / R_{\mathrm{gal}}) \, \varphi_n(z) \, \exp\left\{ -\tilde{C}_{i,n} \left(\tilde{t} - \tilde{t}_S \right) \right\} \, R_{i,n}$$

Bessel in r_cyl

Fourier in z_cyl

Source term

Propagation length

$$\lambda_{\mathrm{D}}{}^2 = 4 K_0 \tau_E \left\{ \frac{\epsilon^{\delta-1} - \epsilon_S^{\delta-1}}{1 - \delta} \right\}$$

$$K(\mathrm{x}, E) = K_0 \, \epsilon^{\delta} \text{ where } \epsilon = E/E_0$$

Finally flux is proportional to the integral over l.o.s (and dE) of $\tilde{I}(\lambda_{\mathrm{D}})$

Assumptions

- Dark matter annihilates or decays directly into electrons
- No Final State Radiation
- ISRF : almost all Black-Body
- Doesn’t account for extragalactic background

Electrons have a Dirac distribution

Normalizing the maps to the central pixel then ensures that the approach is model independent

Always suppressed anyway

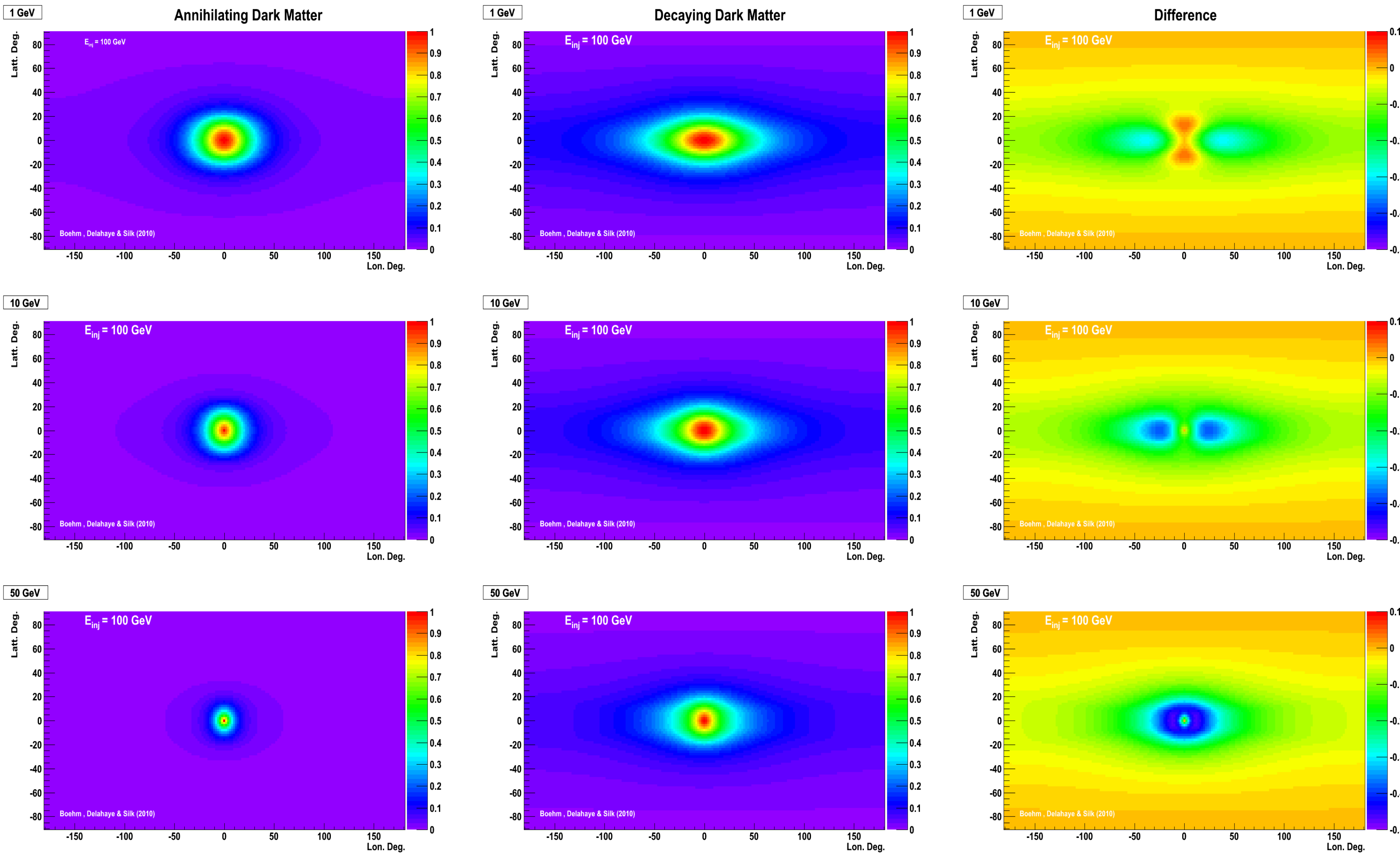
even though, this traces the halo energy density distribution

Good approximation

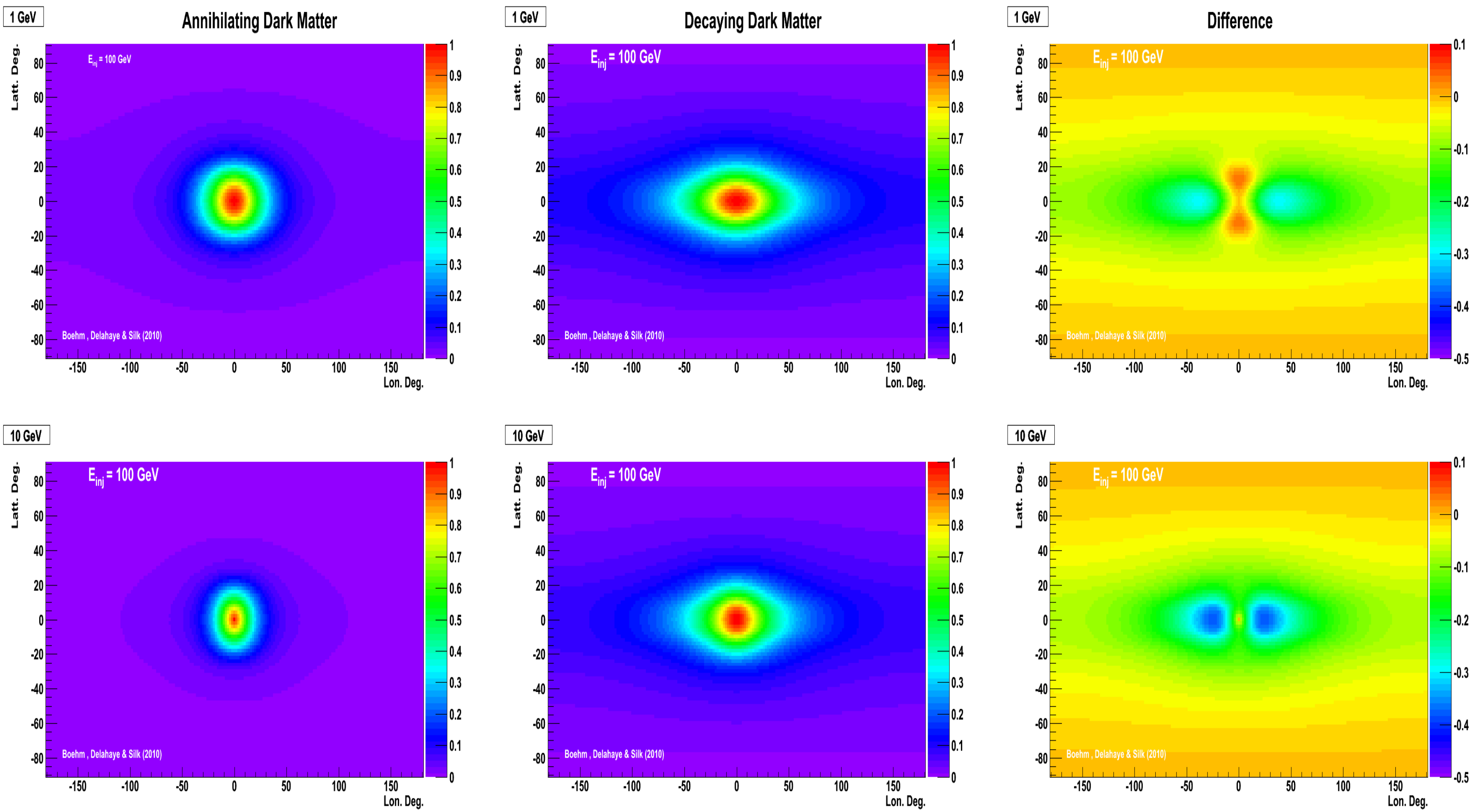
Too faint

Maps where the electrons are produced with an energy equal to E = 100 GeV

observed at E_gamma =

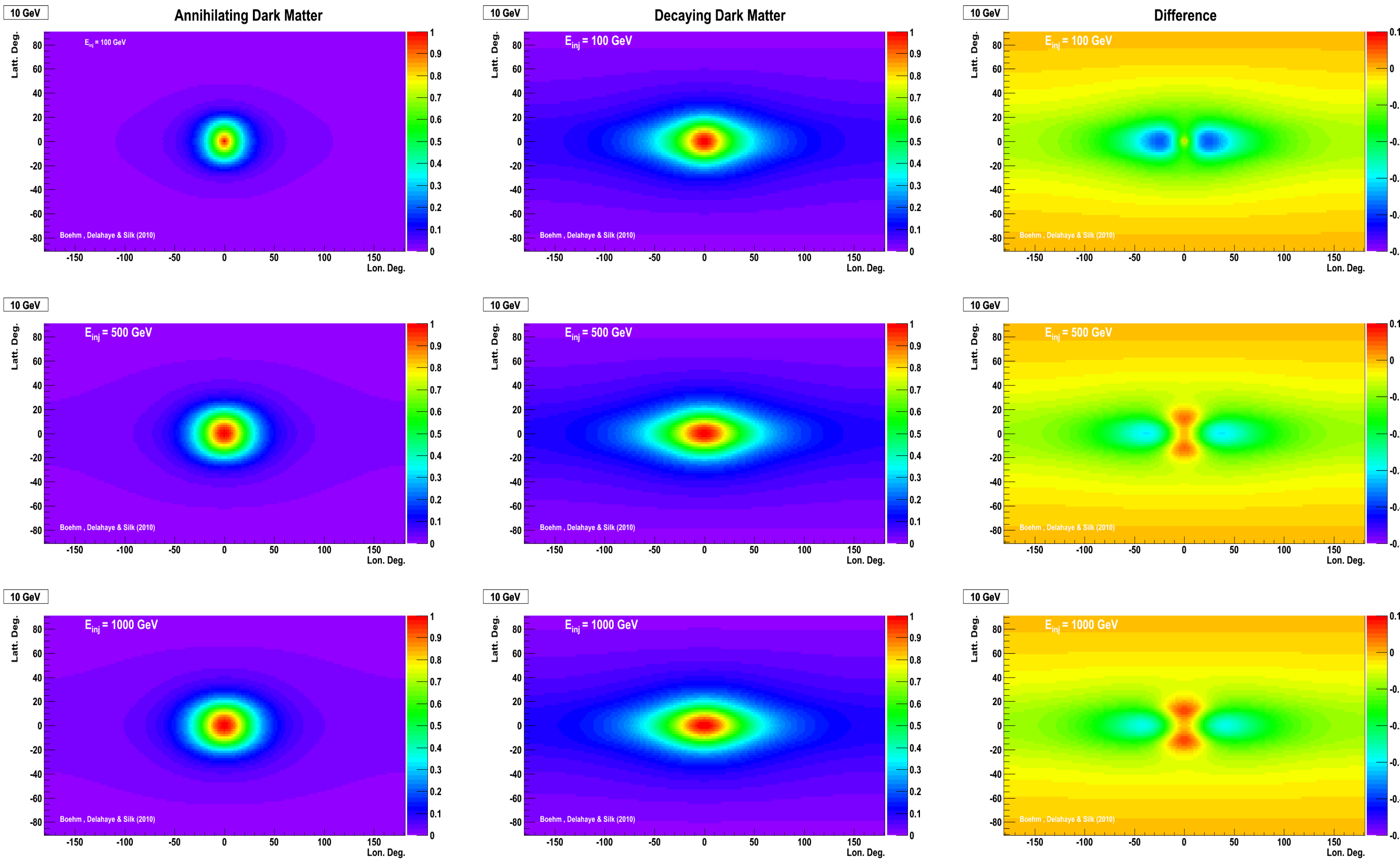


The electrons responsible for the prod of the less energetic gamma rays propagate further
The morphology of decaying DM does differ from annihilating DM



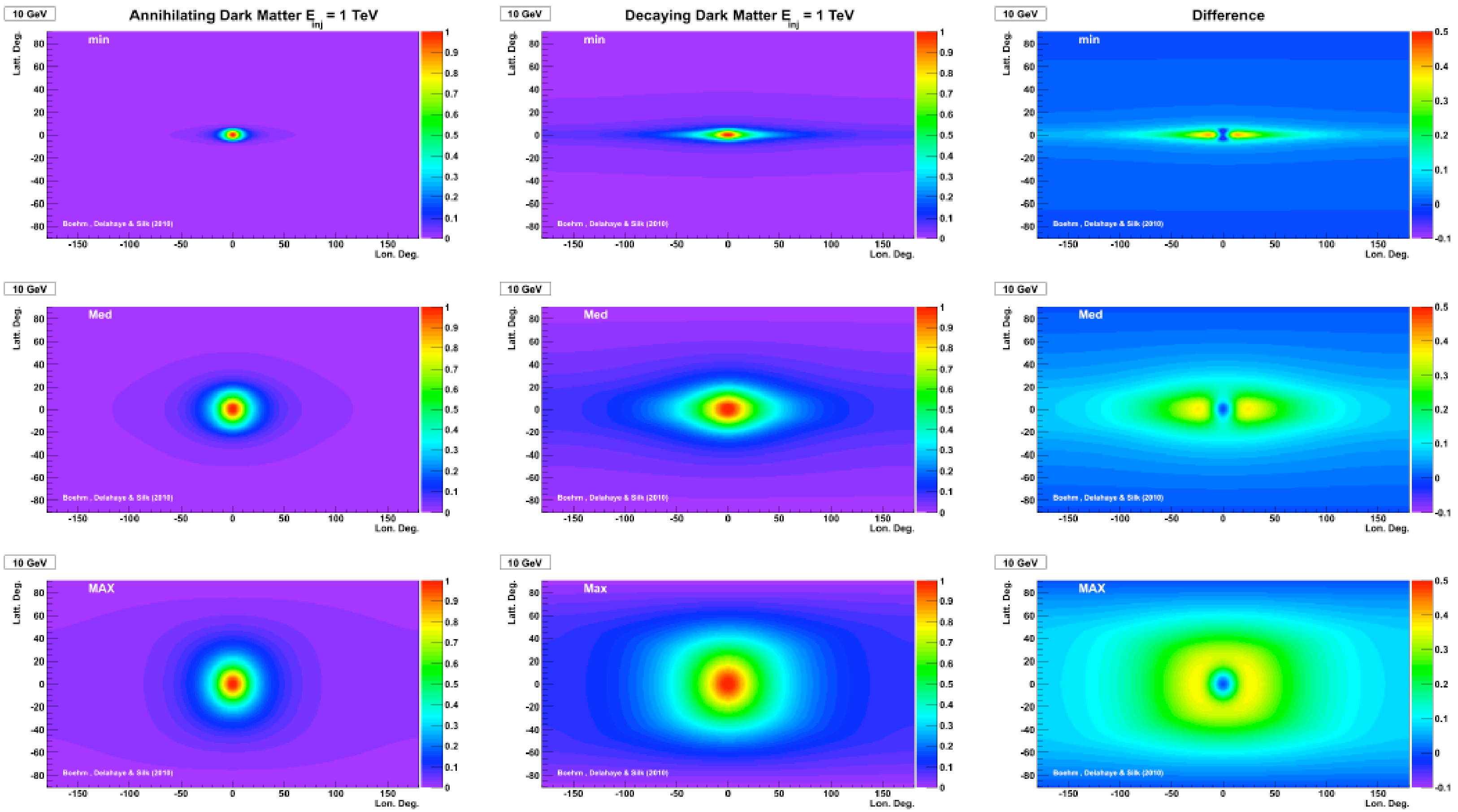
Higher injection energies induce longer propagation length at a fixed gamma ray energy

Fixed E_gamma; varying electron E_injection



Effect of the propagation parameters

Model	δ	K_0 [kpc^2/Myr]	L [kpc]
MIN	0.85	0.0016	1
MED	0.70	0.0112	4
MAX	0.46	0.0765	15



Conclusion
Can one distinguish between decaying and annihilating Dark Matter?

Proposition: let us use the morphology of the emission!

- Yes if propagation are MED or MAX (but not that easy if MED)
- Will be very difficult if MIN because the features are localized in the disk and will be hard to separate from background.
- Remains to add the effect of astrophysical sources
- A lot of improvement can be made but :

Quite exciting for the future!