Prospects for indirect dark matter detection with Fermi and IACTs

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Signals of Dark Matter (DM) at γ–ray telescopes

Observations suggest that most ($\gtrsim$80%) of the matter in the universe is not composed by any of the particles that have so far been observed, or artificially created in particle colliders.

The very own success of the Standard Model of Particle Physics requires new particles at the TeV scale, which will soon be probed at the LHC.

The lightest of these could compose the DM, and generate a (weak, but distinctive) γ–ray flux that could be detected by Fermi or at IACTs.

Outline

Pointing the detectors

Vanilla DM: thermal WIMPs

Decaying DM, can we tell the difference?

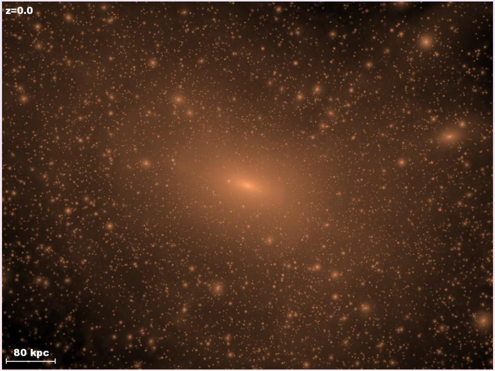
Preliminaries

FLUX = AMOUNT OF DM $\times$ NUMBER OF γS / PARTICLE(S)

- The first factor requires knowledge of the astrophysical environment, while the second depends on the particle physics model.
- Factorization does not hold in some scenarios.

The distribution of DM

N-body simulations predict *cuspy* halos and plenty of substructure.

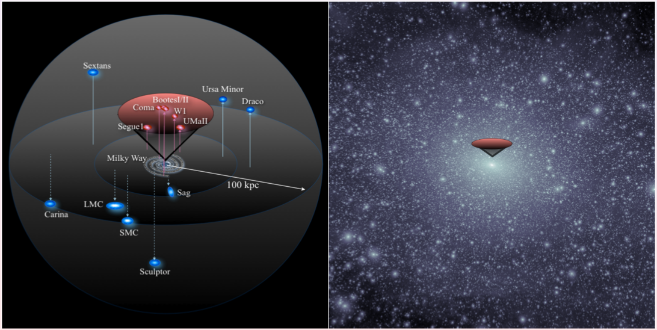


Diemand *et al.* 08

The distribution of DM: observations

The number of known satellites in the MW is much lower than what simulations indicate. Also, the central parts of the galaxy are not dominated by DM.

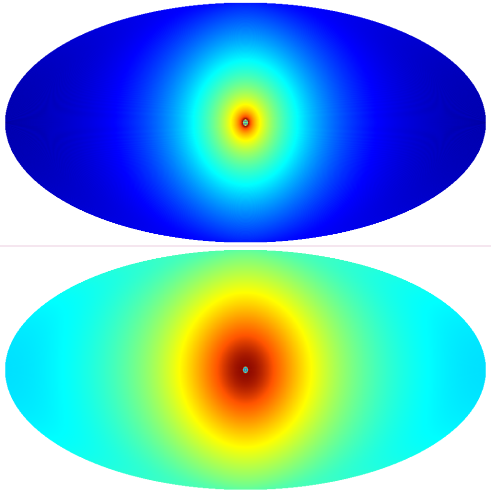
We hope to observe fluxes from our *particular* galaxy, which might differ from the average synthetic realization. Should take into account *observational* data when available. FF, Evans, Sarkar 04



Bullock *et al.* 09

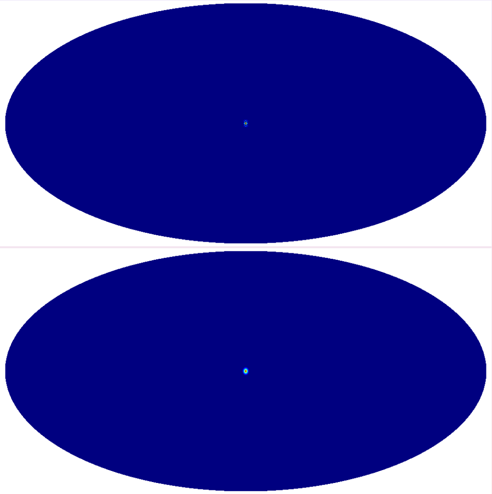
The distribution of DM: the galaxy

Cuspy profiles predict that most of the flux will come from the central region. The predicted fluxes, from the galactic center are uncertain by a few orders of magnitude.

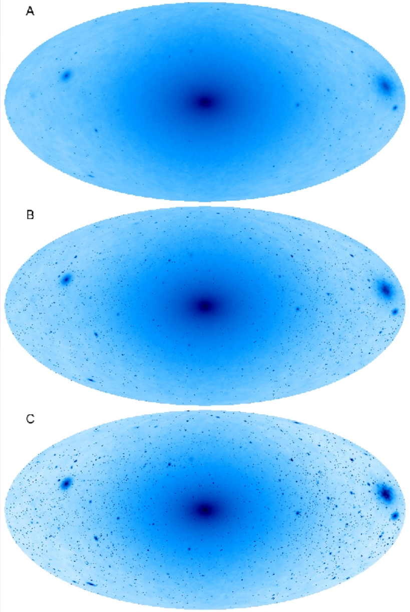


The distribution of DM: the known satellites

The fluxes are smaller, but more robust. Also, we have observations to infer the density profile.



Satellite enhancement



The role of Fermi and IACTs

- γ–ray telescopes have the unique ability to map the distribution of DM (with some PP input). ✓
- It is difficult to make robust predictions of the expected fluxes. ✗
- Our knowledge of nearby DM dominated regions has vastly improved in the last decade, although not enough. ✓
- A ring around the GC is also a good target for Fermi. ✓

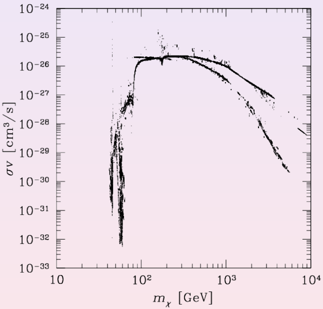
WIMPs

- To stabilize the SM, new (weakly interacting) particles should exist at the TeV scale.
- To stabilize the proton, the lightest one should be stable.

If neutral, these particles come up with the right DM relic density, and they could give rise to γ–ray lines with no astrophysical counterpart.

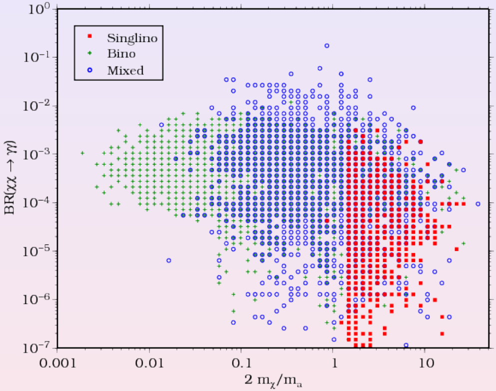
WIMPs

- $\langle \sigma v \rangle$ is generally *lower* due to coannihilations ...
- Monochromatic lines are very weak, and hard to detect.



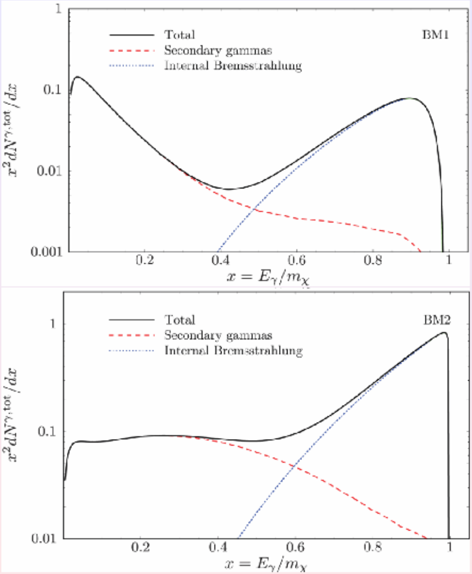
But DM could have larger σ if it were not thermal. G. Kane's talk

WIMPs



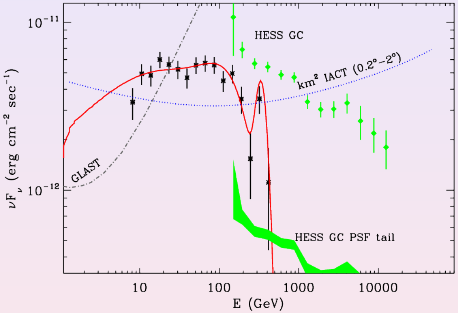
FF, Krauss & Profumo 06

WIMPs



Bringmann *et al.* 08, Vallinotto's talk

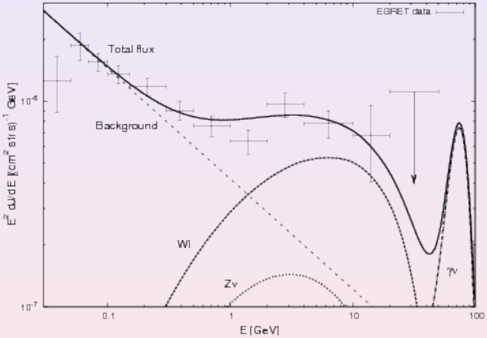
Km^2 ACTs



Buckley *et al.* 09

Unstable DM

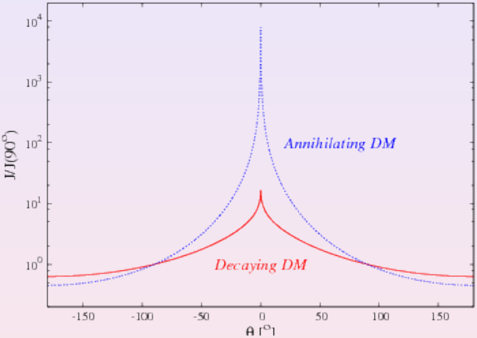
DM decays, like annihilations, can give rise to detectable monochromatic lines.



Ibarra & Tran 07

Can γ-ray telescopes distinguish them?

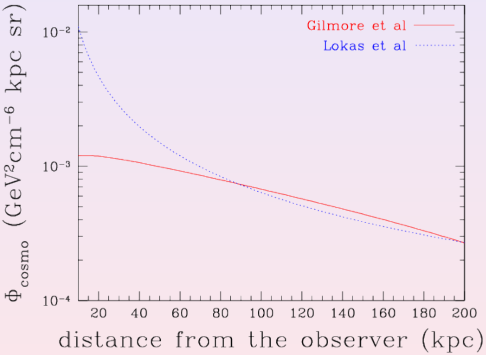
Mapping the region around the GC might help. Hooper & Serpico 09



But, we do not know the DM density distribution. Annihilations following a cored profile could be mistaken by decays. Ferrer (in progress)

Dwarf galaxies as standard rulers

Dwarf galaxies show surprisingly similar DM distributions regardless of their luminosity. Strigari *et al.* 08



Pieri *et al* 08

Dwarf galaxies as standard candles

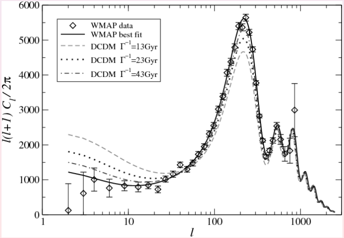
- Regardless of the exact shape of the DM profile, assume that it is the same (in the central regions).
- We would then observe the same signal at different distances. Studying its intensity and angular variations obtain information about the nature (decay vs. annihilation) of the DM.
- We can also learn about the DM density distribution in dwarf galaxies.
- If DM decays, however, the emission from dwarf satellites is diluted by the host galaxy contribution. (FF, in progress)

Cosmological limits on DM decay

Decaying DM injects particles at a rate:

$$Q(E, \boldsymbol{r}) = \frac{\rho(\boldsymbol{r})}{M_{DM}\tau_{DM}} \times \frac{dN}{dE}$$

A TeV scale WIMP with $\tau \gtrsim 10^9 \tau_{\Lambda CDM}$ gives a good fit to the anomalous positron fluxes observed by PAMELA. Ibarra *et al.* 09



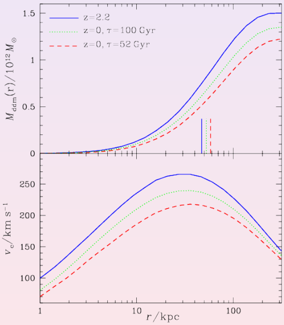
This *constraint does not apply* to DM decaying into invisible products, or to super-heavy] DM. But, CMB observations give $\tau_{DM} \gtrsim 4 \times \tau_{\Lambda CDM}$ irrespective of M_{DM}. Ichiki *et al.* 04

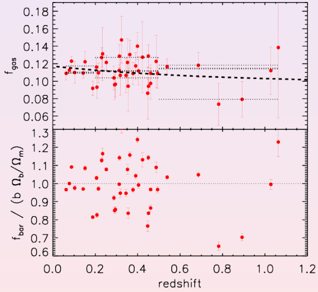
Galaxy evolution with DDM

Galaxies at higher redshifts appear more compact/massive.

Cresci *et al.* 09, Cimatti *et al.* 08

Halo evolution caused by DM decay ($\tau \sim 4 \times \tau_{\Lambda CDM}$) fits the observed structural evolution. FF, Nipoti & Ettori 0905.3161





M–τ in range for UHECR contribution Birkel & Sarkar 98, Ellis *et al.* 99, 06.

Conclusion

- γ-ray telescopes can provide an unambiguous signal of DM annihilation or decay and directly map the emission region. However, without further knowledge of the nature of DM it is hard to disentangle the density distribution.
- Dwarf satellite galaxies seem to have universal profiles, which can help in breaking degeneracies.
- If DM decays it will affect the evolution of galactic structures. With a lifetime $\tau \sim 4 \times \tau_{\Lambda CDM}$ it could explain the intriguing hints that, for the same luminosity, galaxies were more massive at $z \sim 2$.