Determination of the Dark Matter profile from the EGRET excess of diffuse galactic gamma rays

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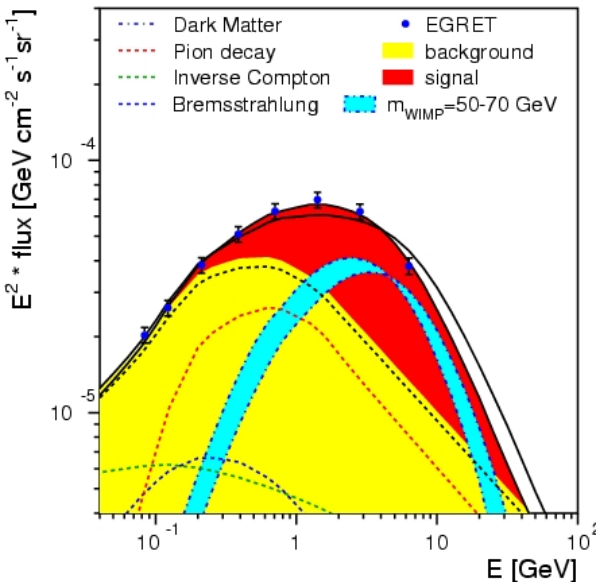
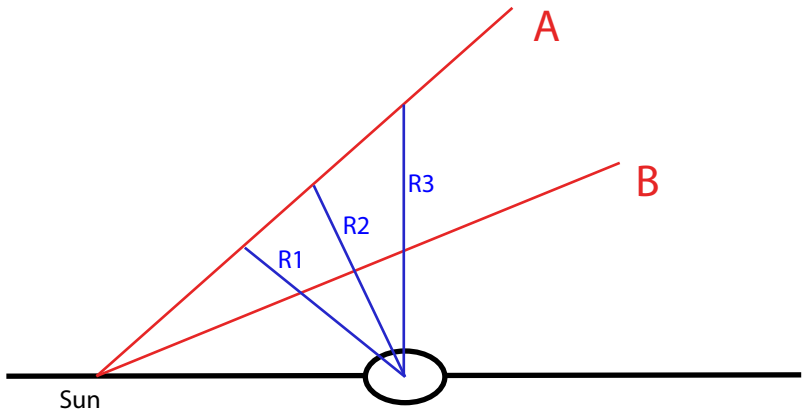
Halo profiles

Parametrisation of halo profiles

1. shape of the photon energy spectrum → WIMP mass
2. intensity distribution → halo profile





Determination of halo parameters

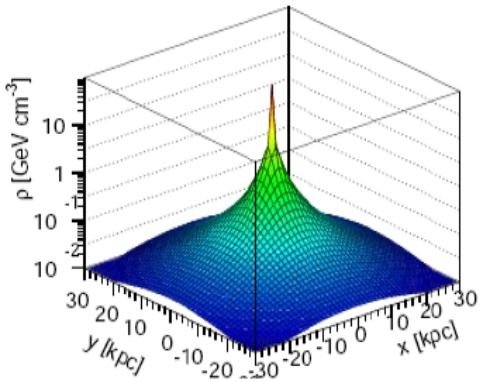
Parametrization of the halo profile

- halo can be parametrized as follows:

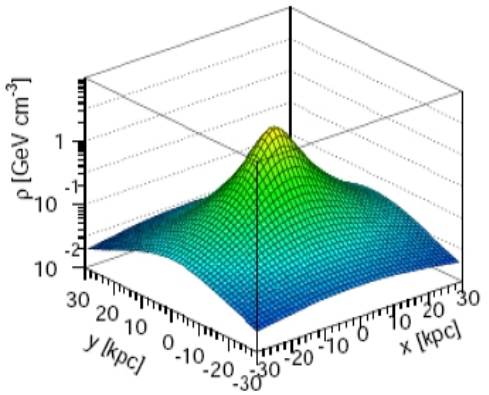
$$\rho(r) = \rho_0 \cdot \left(\frac{r}{r_0}\right)^{-\gamma} \left(\frac{1+\left(\frac{r}{a}\right)^{\alpha}}{1+\left(\frac{r_0}{a}\right)^{\alpha}}\right)^{\frac{\gamma-\beta}{\alpha}}$$

- Behaviour:
  - ρ_0 = local density at r_0
  - r_0 = radius (sun) = 8.3 kpc
  - a = scale radius
  - α describes behaviour for $r \approx a$
  - β describes behaviour for $r >> a$
  - γ describes behaviour for $r << a$
  - 1,3,1 $\rightarrow$ cuspy (universal) NFW profile
  - 2,2,0 $\rightarrow$ cored pseudo isothermal profile (PISO)

$\alpha = 1, \beta = 3, \gamma = 1$



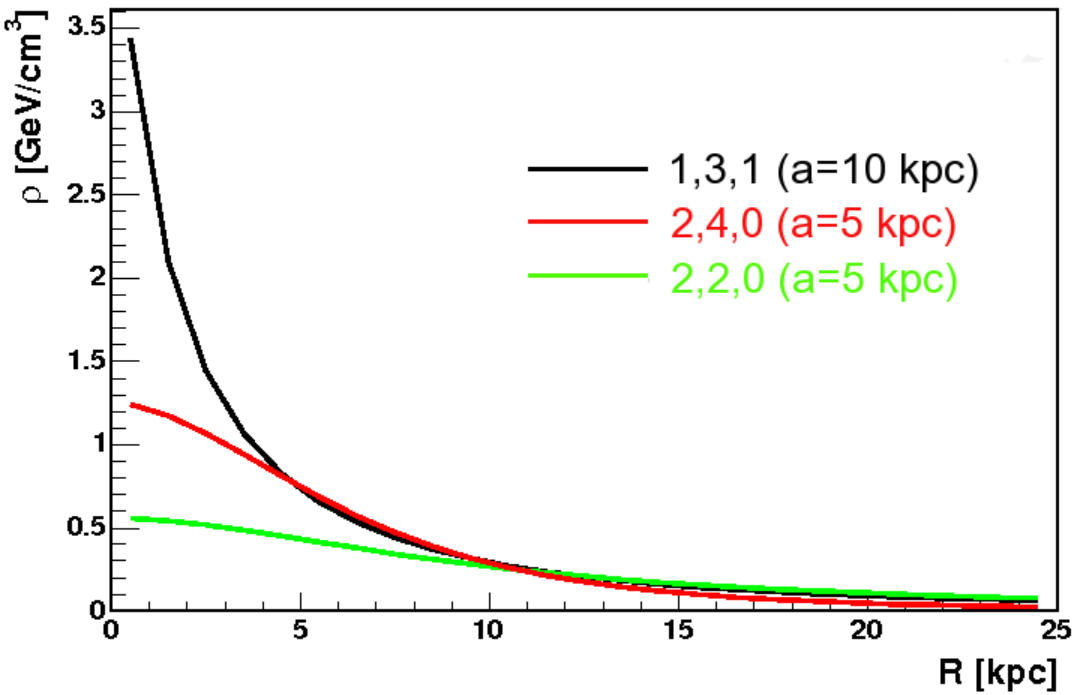
$\alpha = 2, \beta = 2, \gamma = 0$



Halo profiles

Parametrisation of halo profiles

1. also intermediate profiles between NFW and PISO profile possible



Determination of halo parameters

Directionality of the excess

- two different components of Dark Matter:
  1. diffuse Dark Matter
  2. clumpy Dark Matter
- signals in region Ψ:
  1. diffuse Dark Matter

$$\Phi_{DM} \propto \frac{1}{\Delta\Omega} \int d\Omega \int dl_\psi \left(\frac{\rho(l_\psi)}{m_\chi} \right)^2$$

  2. clumpy Dark Matter

$$\Phi_{DM} \propto \frac{1}{\Delta\Omega} \int d\Omega \int dl_\psi \left(\frac{\rho(l_\psi)}{m_\chi} \right) \int dV_{cl} \left(\frac{\rho_{cl}}{m_\chi} \right)$$

- DM clumps are local overdensities of DM $\rightarrow$ increase annihilation rate $\rightarrow$ boostfactor

Determination of halo parameters

Expected halo profiles from N-body simulations of galaxy formation

- density profile of DM clumps can be shallower than profile of diffuse DM (*J.Diemand, B.Moore, J.Stadel, astro-ph/0402160*)
  1. diffuse Dark Matter
     "cuspy" NFW profile
  2. clumpy Dark Matter
     "cored" PISO profile
- exp.: both profiles seem to exist (from rotation curves)

Determination of halo parameters

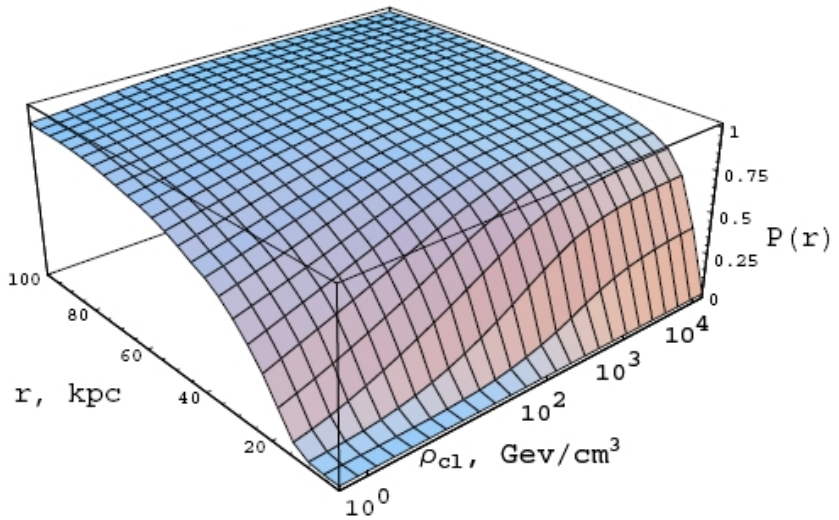
Disruption of DM clumps

- DM clump can be destroyed in the vicinity of stars by tidal forces
- $dF \propto \frac{1}{r^3}\, dr$
- $\Phi_{\mathrm{DM}}^{clump} \propto \int dl_\psi\, P(r) \left(\frac{\rho(l_\psi)}{m_\chi}\right)$
- clumps not completely destroyed after encounter
  $\Rightarrow$ core of the clump survives
  $\Rightarrow$ offset in surival probability of DM clumps
  (fit $\rightarrow$ offset ≈ 0.7)

Survival Probability P(r,ρ_{cl})

r = galactic radius

ρ_{cl} = clump density



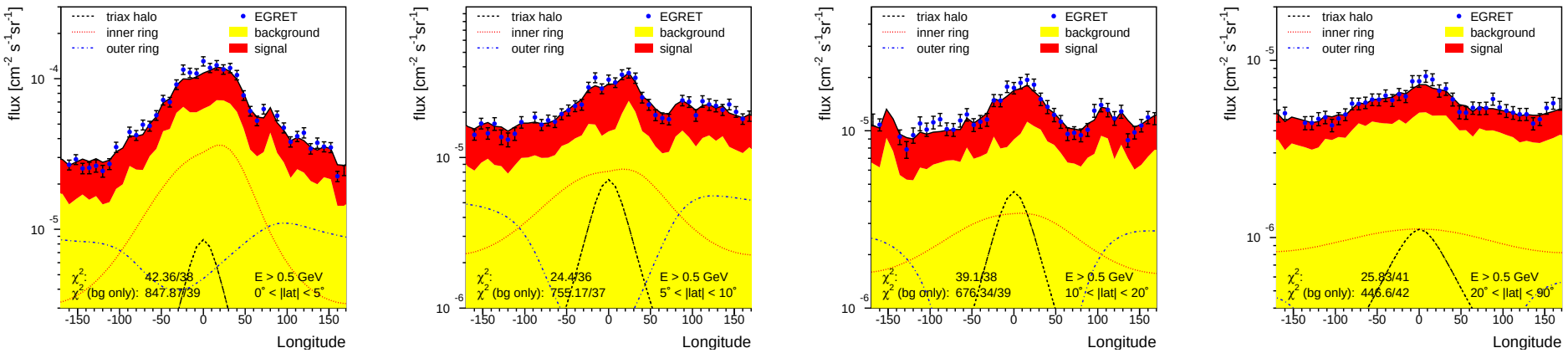
V. Berezinsky, V. Dokuchaev, Y. Eroshenko, astro-ph/0511494

Determination of halo parameter

Best fit

- clumpy profile $\longrightarrow$ 2,4,0, diffus profile $\longrightarrow$ 1,3,1, P $\approx$ 0.7, in 180 sky regions
- two ringlike substructures are needed
- Inner Ring at $\sim$ 4 kpc; $\sim$ thickness of the gal. disc
- Outer Ring at $\sim$ 13 kpc; thicker than gal. disc

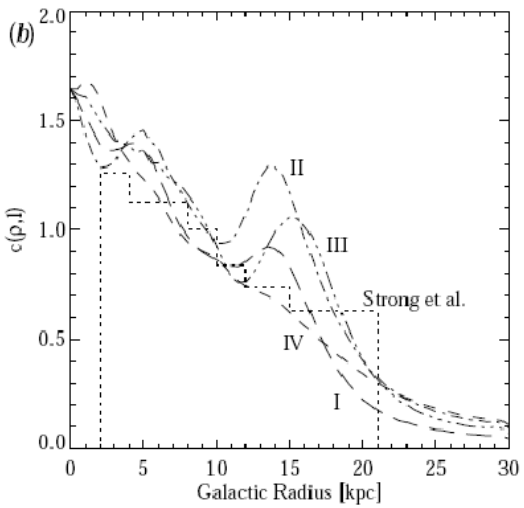
|lat| <5° | 5° < |lat| <10° | 10° < |lat| <20° | 20° < |lat|

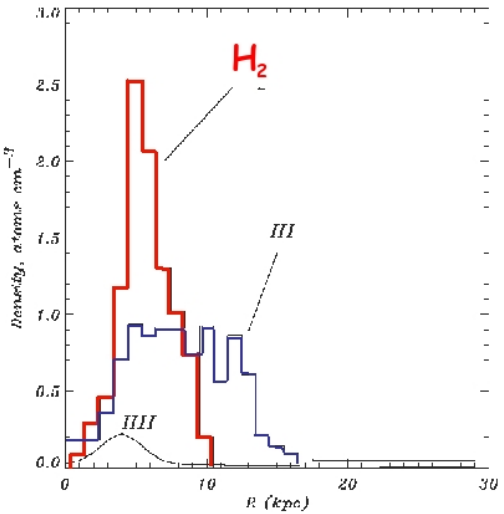


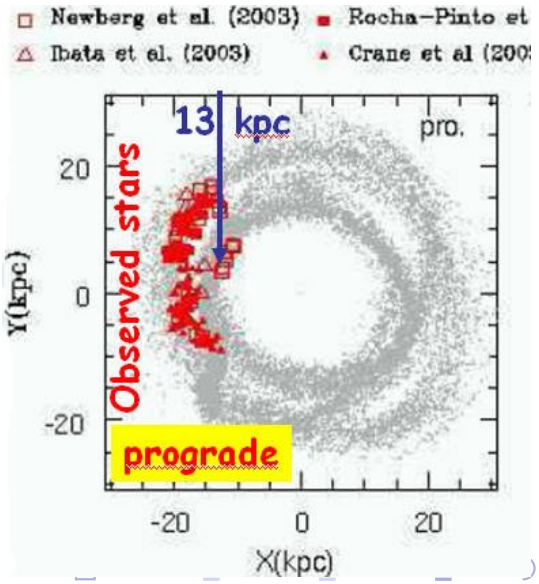
Determination of halo parameters

Substructure in halo

- first indication of substructure by Hunter et.al. (1997)
- inner ring related with ring of H_2 at r $\approx$ 4 kpc
- infall of another galaxy (e.g. Canis Major dwarf)
- tidal streams form ringlike structures



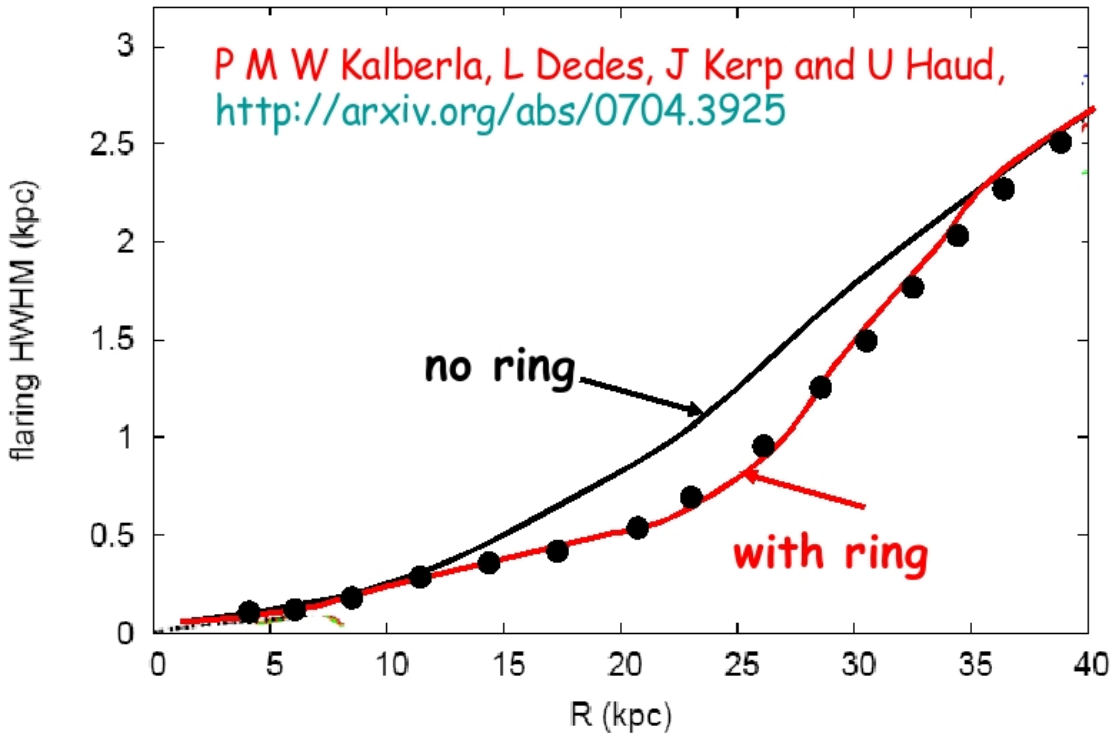




Determination of halo parameters

Substructure in halo

- another hint for a substructure: results from gas flaring observations of H_2 in the galactic disc

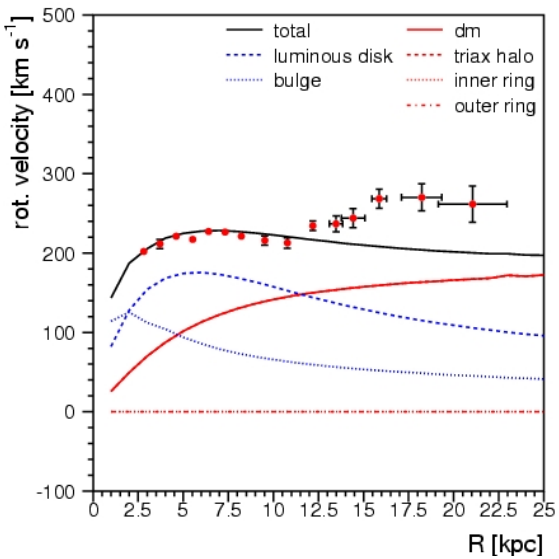


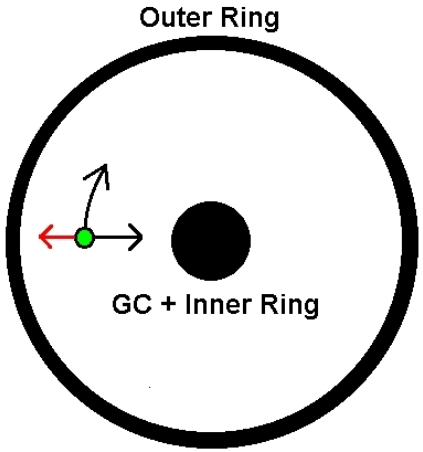
Rotation curve of the Milky Way

Comparison with measured rotation curve

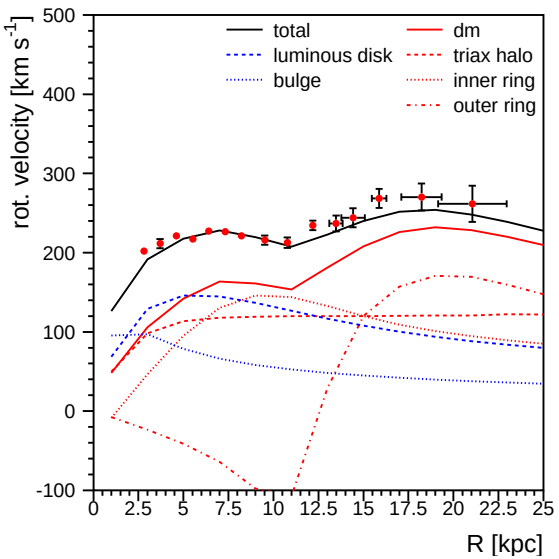
- data averaged from three measurements with different tracers (H^+, H und CO)
- DM rings can describe the change of the slope at $\sim$ 10 kpc

without rings:





with rings:



Conclusion

1. shape of the photon energy spectrum gives information about the WIMP mass
2. intensity and directionality of the photon flux can be used to determine a possible halo profile
3. halo needs ringlike substructure
   $\longrightarrow$ Outer ring as expected from N-body simulations (Canis Major tidal disruption)
4. Dark Matter outer ring also seen in gas flaring
5. halo profile compatible with rotation curve of the Milky Way, especially change of slope from outer ring