

Predictions for indirect detection

of dark matter in the frame of

(HORIZON) N-body simulations:

Pros, cons and hopes

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Dark Matter targets — LPNHE-Paris

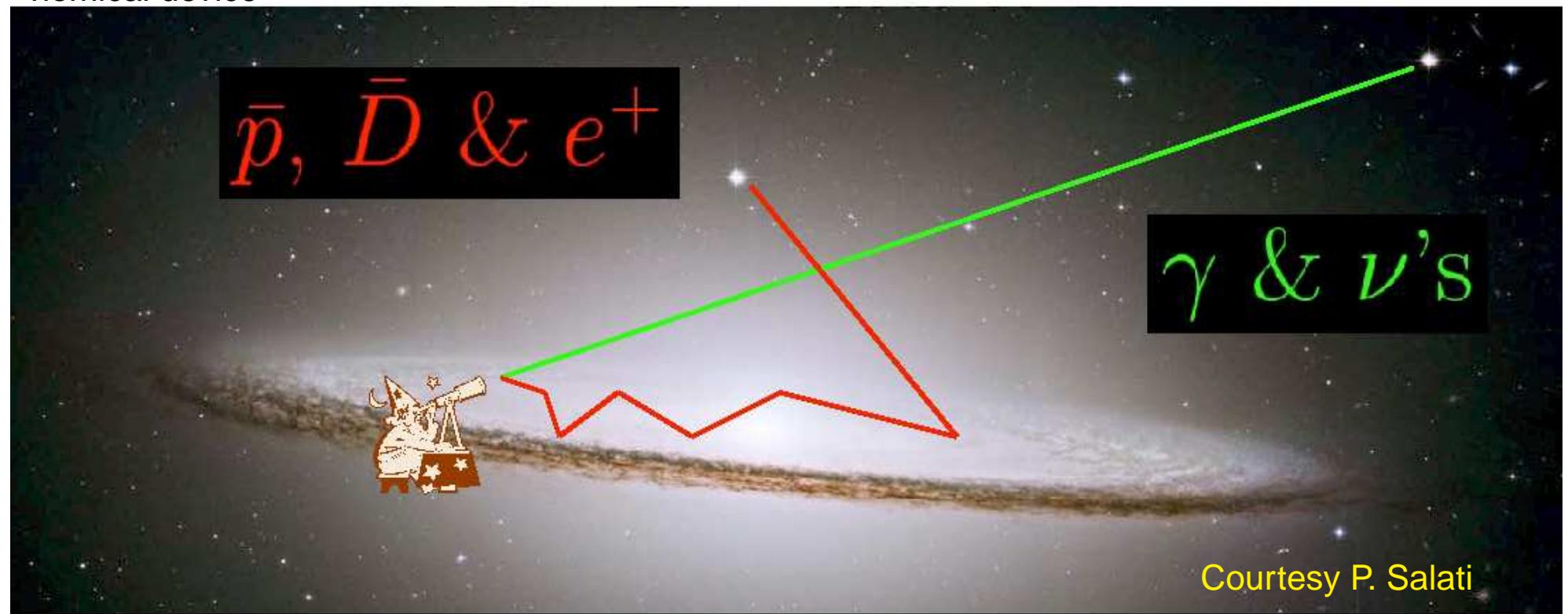
Thursday, March 12th 2009

Outline

- ⌚ **Reminder of ingredients**
- ⌚ **Analytical results (N-body inspired)**
- ⌚ **Possible improvements from directly using the N-body framework**
- ⌚ **Limits and caveats**
- ⌚ **Conclusion (more questions than answers)**

Indirect detection of Dark Matter

Non-baryonic DM may explain a large fraction of the masses of galaxies and clusters: If made of **exotic annihilating particles**, we might detect indirect signatures by means of astronomical device



⑥ γ and ν : travel directly from the source to the observer

⇒ Needs of large DM density regions
(Centers of galaxies)

⑥ Antimatter cosmic rays: diffuse on the magnetic turbulences

of Dark Matter

Non-baryonic Dark Matter

made of exotic
subatomic
particles

and clusters: If
they exist,
means of astro-

$$\frac{d\phi_{\text{prim}}}{dE} = \delta \frac{B_{\text{prim}} \times \langle \sigma v \rangle}{8\pi m_\chi^2}$$

$$\times \int dE_S \int d^3 \vec{x}_S \mathcal{G}(\vec{x}_\odot, E \leftarrow \vec{x}_S, E_S) \times \rho_{mn}^2(\vec{x}_S) \times \frac{dN_{\text{prim}}}{dE_S}$$

J'S

Credit: P. Salati



γ and ν : the
targets closest
to the observer

in high density regions



Antimatter cosmic
rays and magnetic
turbulences

(es)

of Dark Matter

Flux measurements:

PAMELA satellite data is coming

GLAST (gamma) soon

AMS-02 still not sure to operate

background predictions

$$\frac{d\phi_{\text{prim}}}{dE} = \delta \frac{B_{\text{prim}} \times \langle \sigma v \rangle}{8\pi m_\chi^2}$$
$$\times \int dE_S \int d^3 \vec{x}_S \mathcal{G}(\vec{x}_\odot, E \leftarrow \vec{x}_S, E_S) \times \rho_{mn}^2(\vec{x}_S) \times \frac{dN_{\text{prim}}}{dE_S}$$

BSM particle physics:

SUSY, KK, etc.

Dark matter distribution:

Prescriptions from N-body cosmological simulation

Found to not be smooth: clumpiness effects ?

and clusters: If
means of astro-

tesy P. Salati

Propagation Green function

or merely $\frac{1}{4\pi r^2}$ for γ 's



γ and ν : the flux
to the observer

in density regions



Antimatter cosmic
magnetic turbulences

The dark matter distribution in Galaxies

Usual assumptions for analytical predictions (almost N-body supported)

- ⑥ **Spherical symmetry (axisymmetry can easily be implemented)**
- ⑥ **N-body-inspired density profiles (cusps, Burkert or Einasto)**
 - △ + possibly kinematical constraints from rotation curves
(self-consistency ?)
- ⑥ **Subhalos (at least for cosmological consistency)**
 - △ universal mass distribution $\sim M^{-2}$
 - △ mass-concentration relation from empirical formulae (minimal mass?)
 - △ spherical spatial distribution (from antibiased to host-like)

γ -rays (see Lidia's talk)

Impact of dark matter distribution studied for many years:

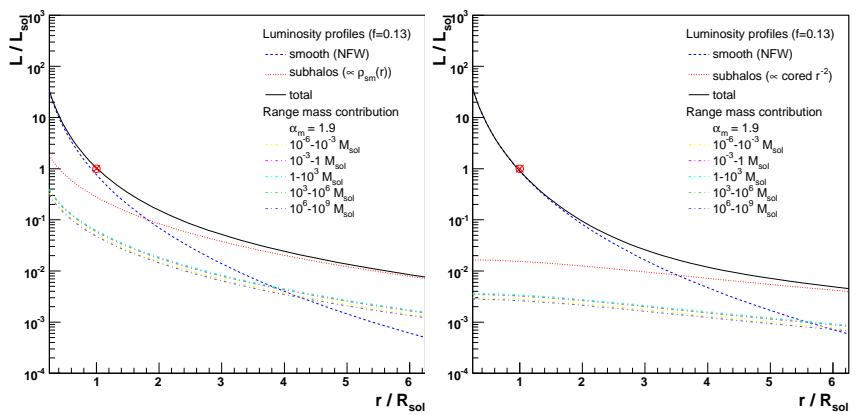
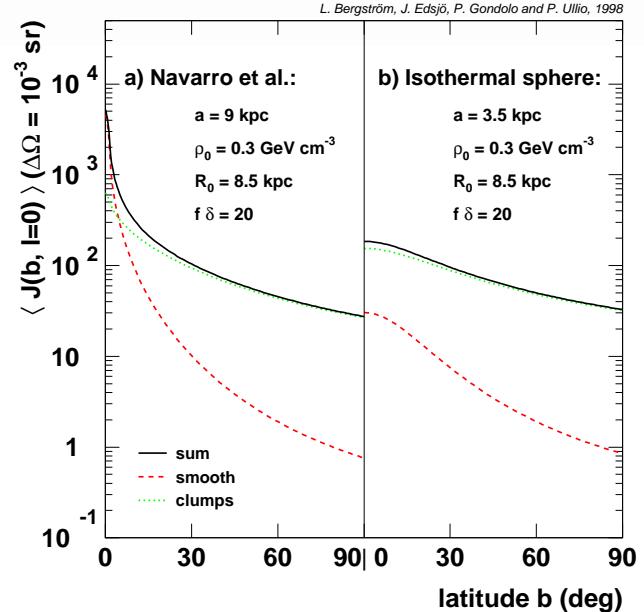
Smooth host halo

- △ Issue of the central cusp (more on this later) and possible effect from adiabatic compression driven by the central BH or the baryon infall

Subhalos

- △ Annihilation rate enhancement that depends on the angle between GC direction and line of sight.
Negligible boost when pointing towards the GC (cf. Bergström et al (1998), Berezhinsky et al (2003-2007)), but could be very large (~ 100) at high latitudes (cf. Berezhinsky et al, 2008).

- △ Statistical M-C analysis by Bi (2006), Pieri et al (2007)



Lavalle, Maurin et al (2008)

Charged antimatter cosmic rays

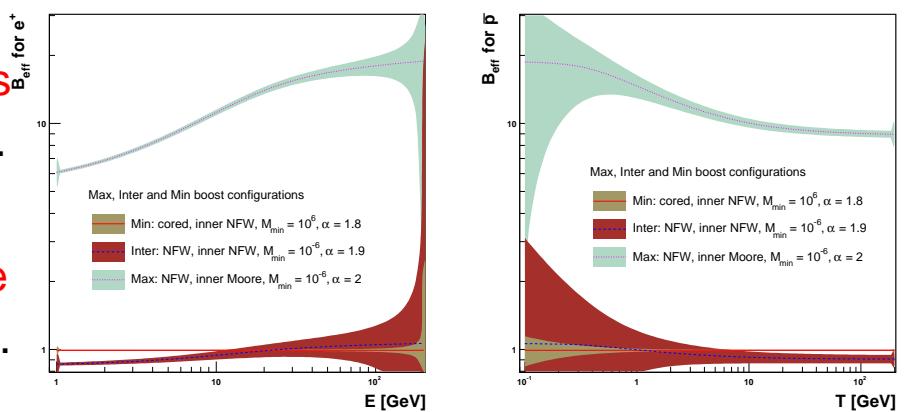
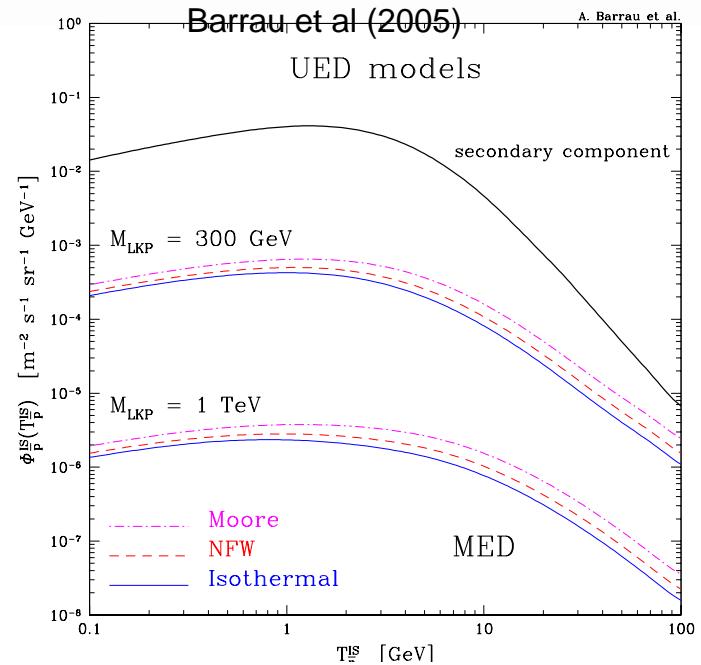
Impact of dark matter distribution mixes with propagation:

Smooth host halo

- Uncertainties on the central cusp is not a problem anymore (e.g. Barrau et al (2005), Lavalle et al (2008), Delahaye et al (2008)), except for propagation models with very thick diffusion zone.

Subhalos

- Boost factor** non trivial function of the cosmic ray energy, which depends on the clumps' properties and on cosmic ray species (cf. Lavalle et al (2007), Lavalle et al (2008)).
- Apart when particle physics effects are included (Sommerfeld-like), the most extreme parameters give $\mathcal{B} \lesssim 20$ (Lavalle et al (2008)).



Lavalle, Maurin et al (2008)

The yield of N-body simulations

Pros:

- ⑥ N-body galaxies are **constrained from accurate cosmological evolution!** More “realistic”.
- ⑥ Relaxing spherical symmetry: **more realistic shapes and peculiarities of dark matter halos**
- ⑥ Inhomogeneities from subhalos, tidal streams, etc.

Cons:

- ⑥ **Limited spatial resolution!** (particle mass $\sim 10^4 - 10^6 M_\odot$): central regions, subhalos, stream
- ⑥ Not constrained from kinematical data
- ⑥ **No baryons!** Likely important gravitational influence of baryons on dark matter structuration.

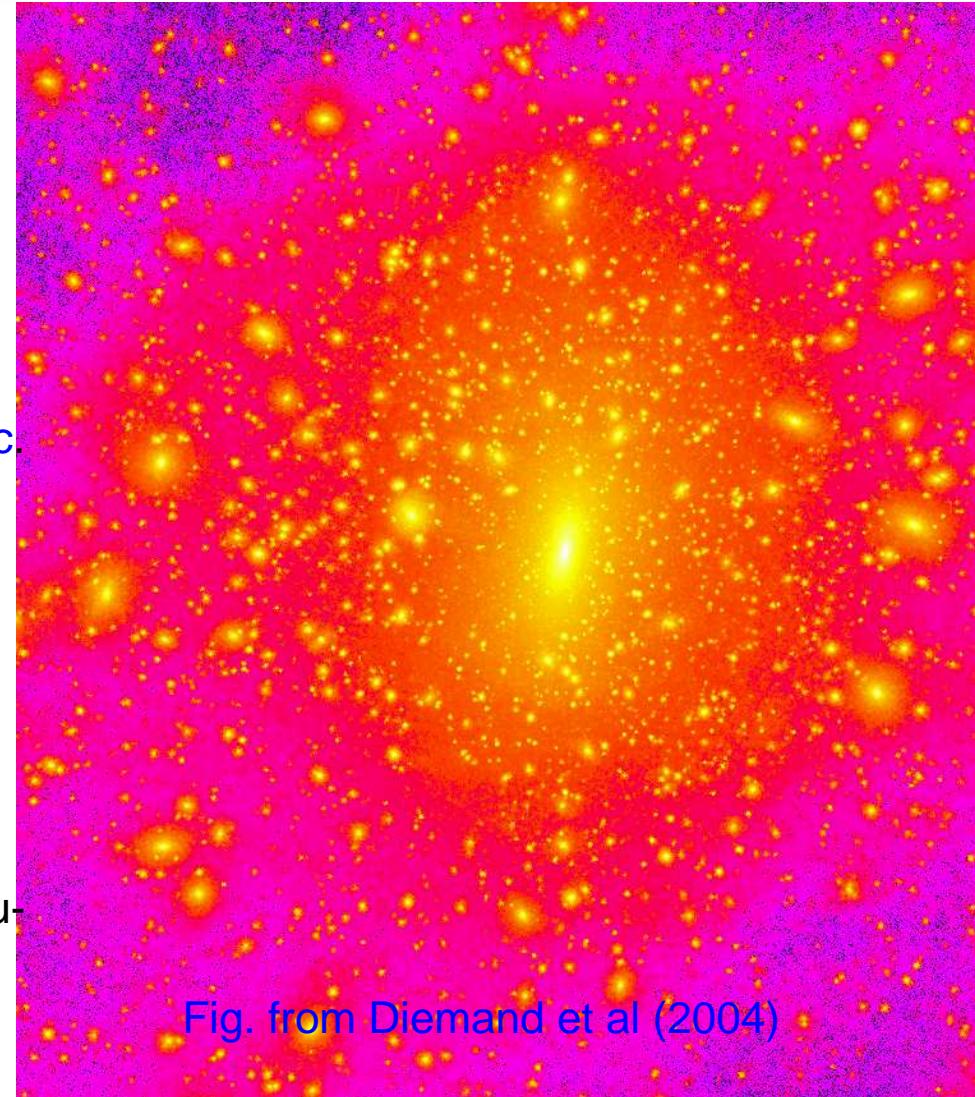
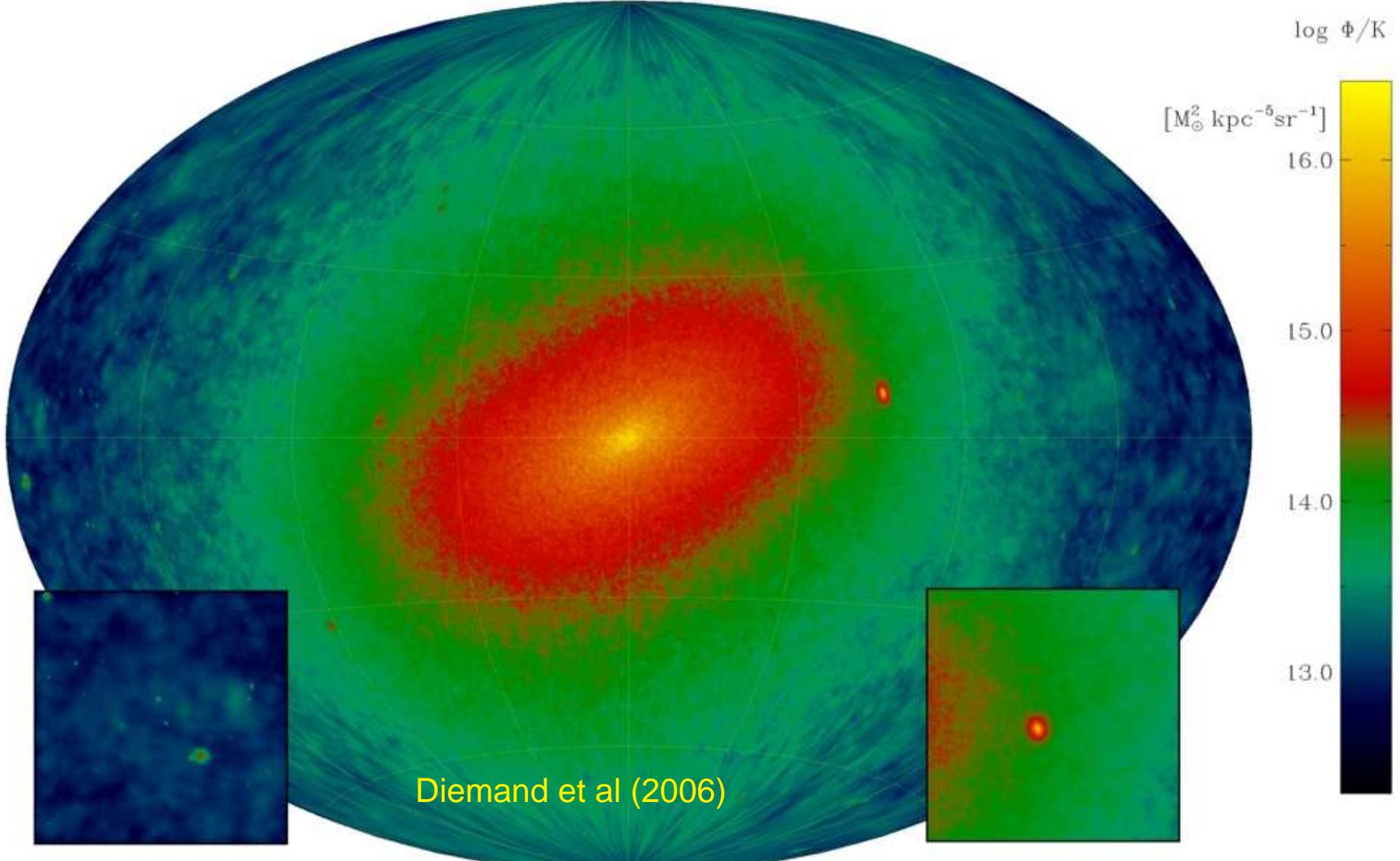


Fig. from Diemand et al (2004)

The Via Lactea (Diemand et al) and Aquarius (Springel et al) breakthrough



implementing tools for γ -rays and cosmic rays

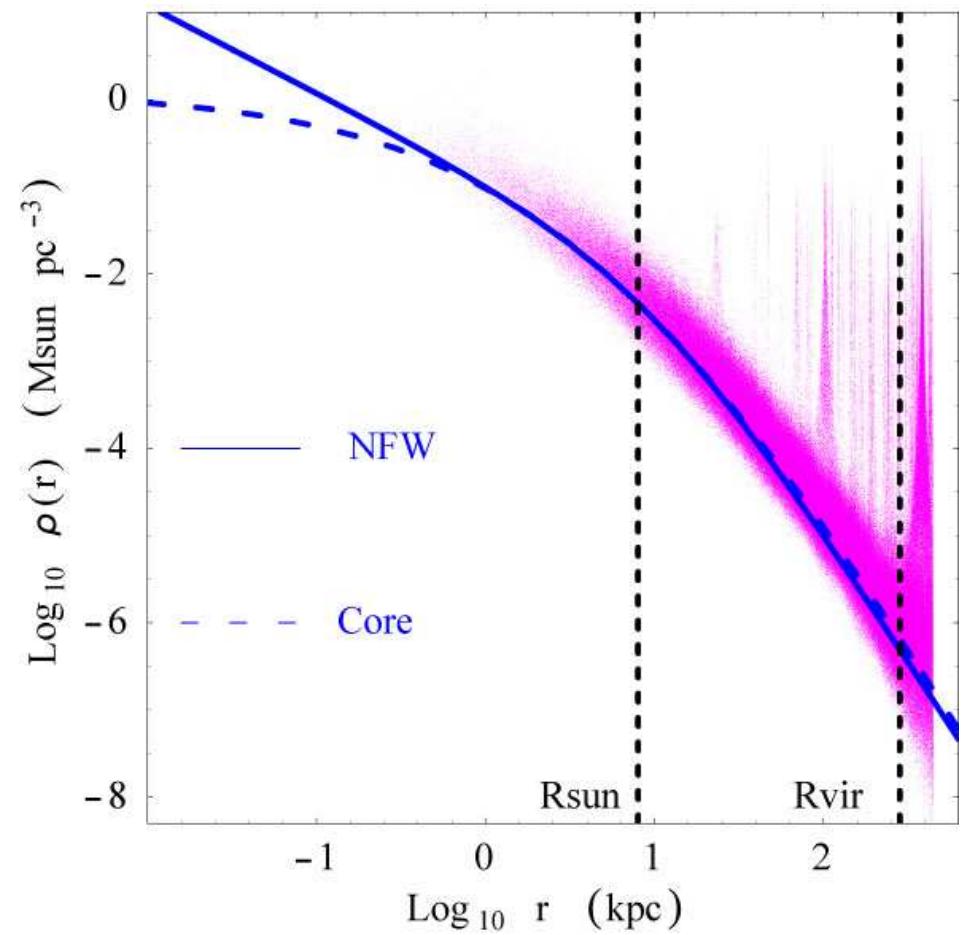
(PRD 78 (2008)

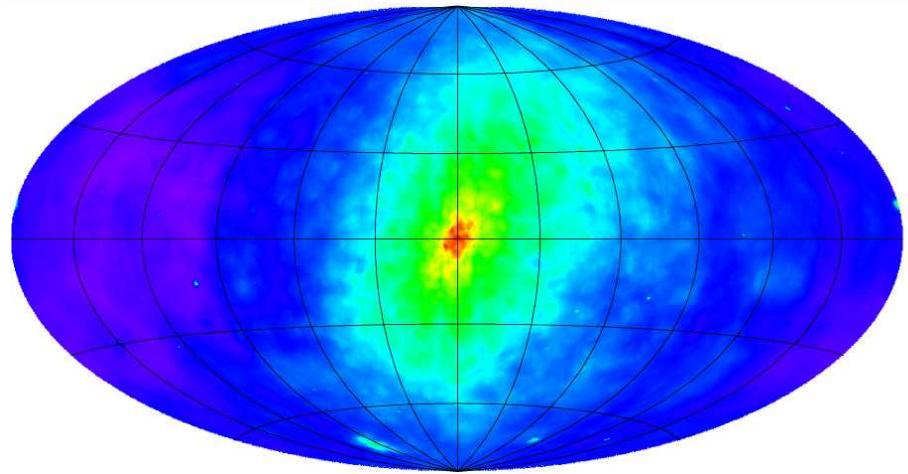
Lavalle, Nezri, Ling, Athanassoula &
Teyssier)

Athanassoula, Ling, Nezri & Teyssier
(arXiv:0801.4673)

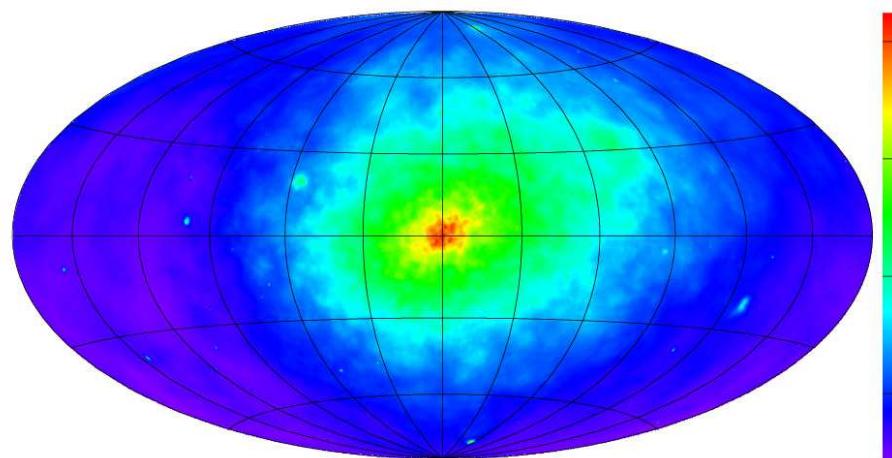
- ⑥ N-body data from the HORIZON Project (Teyssier, 2002) –
 $M_{\text{res}} = 10^6 M_\odot$; $L_{\text{res}} = 200$ pc
- ⑥ Analysis already made for γ -rays
(arXiv:0801.4673) – but not as good
as Diemand et al(2008) or Springel et
al (2008)
- ⑥ 1st trial for GCRs: study of the effects
due to actual density fluctuations and
departure from spherical symmetry

Results: \sim 1-2 order of magnitude un-
certainty on antimatter flux (local density
fluctuations or asphericity), but still be-
low the data: no excess expected below
100 GeV.

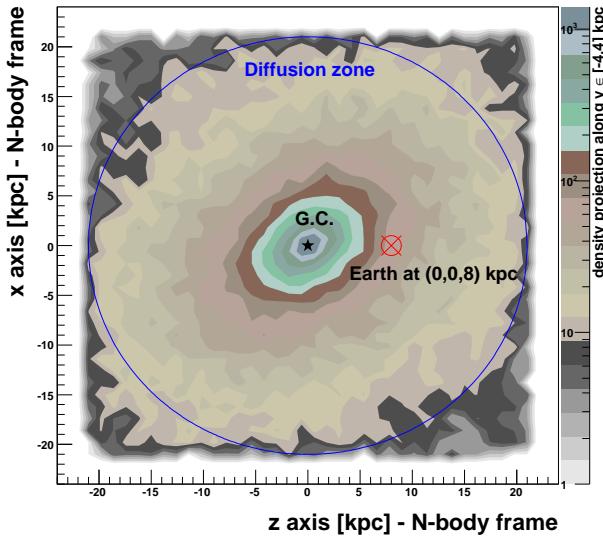
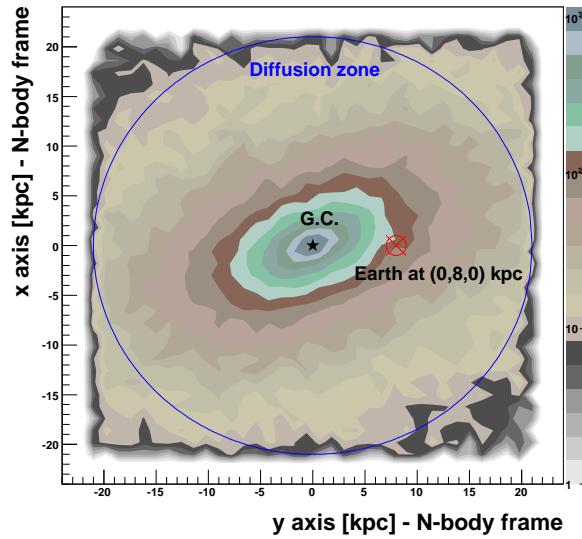
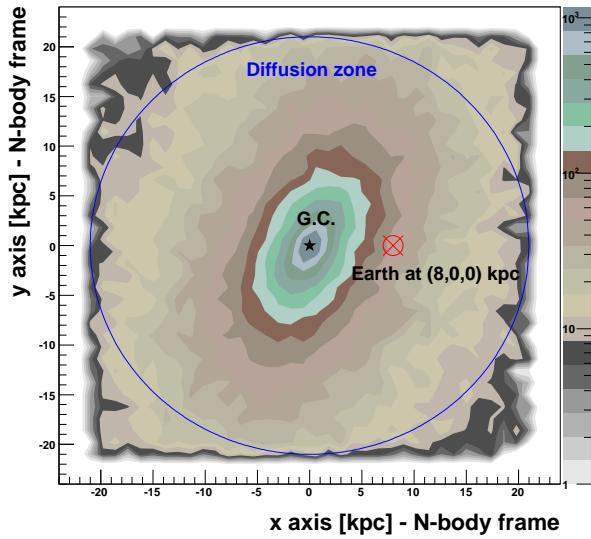


implementing tools for γ -rays and cosmic rays

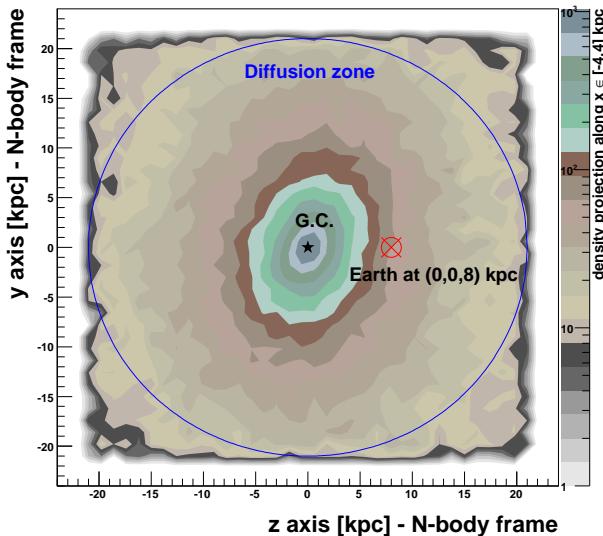
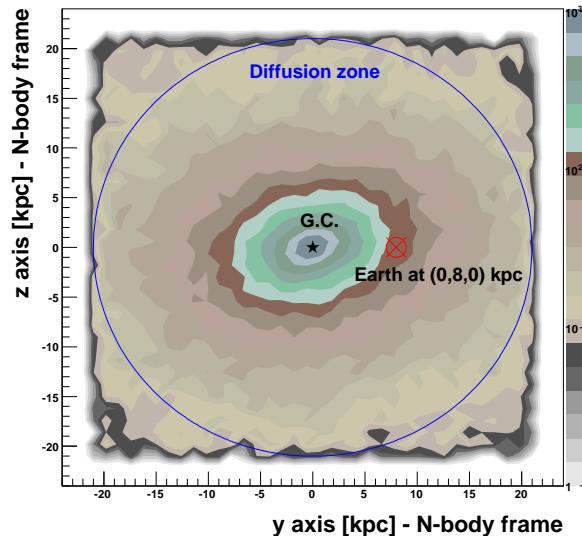
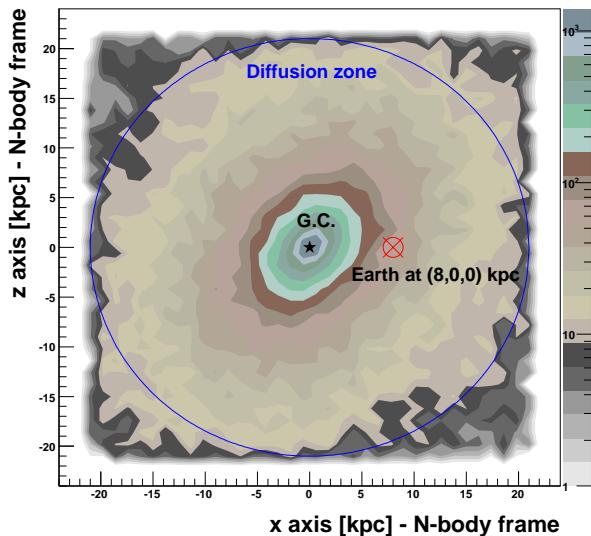
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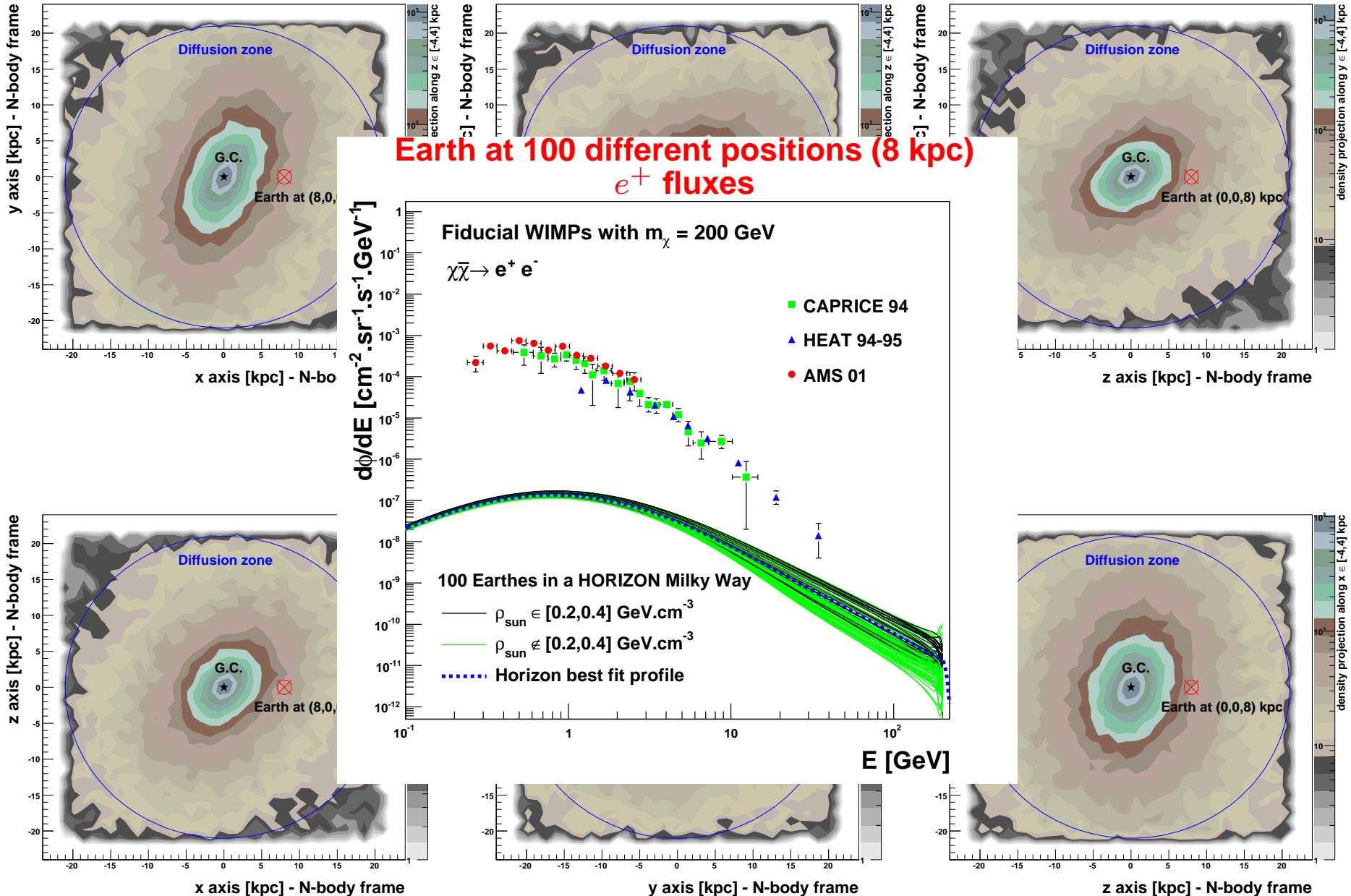
implementing tools for γ -rays and cosmic rays



Earth at different positions (8 kpc)

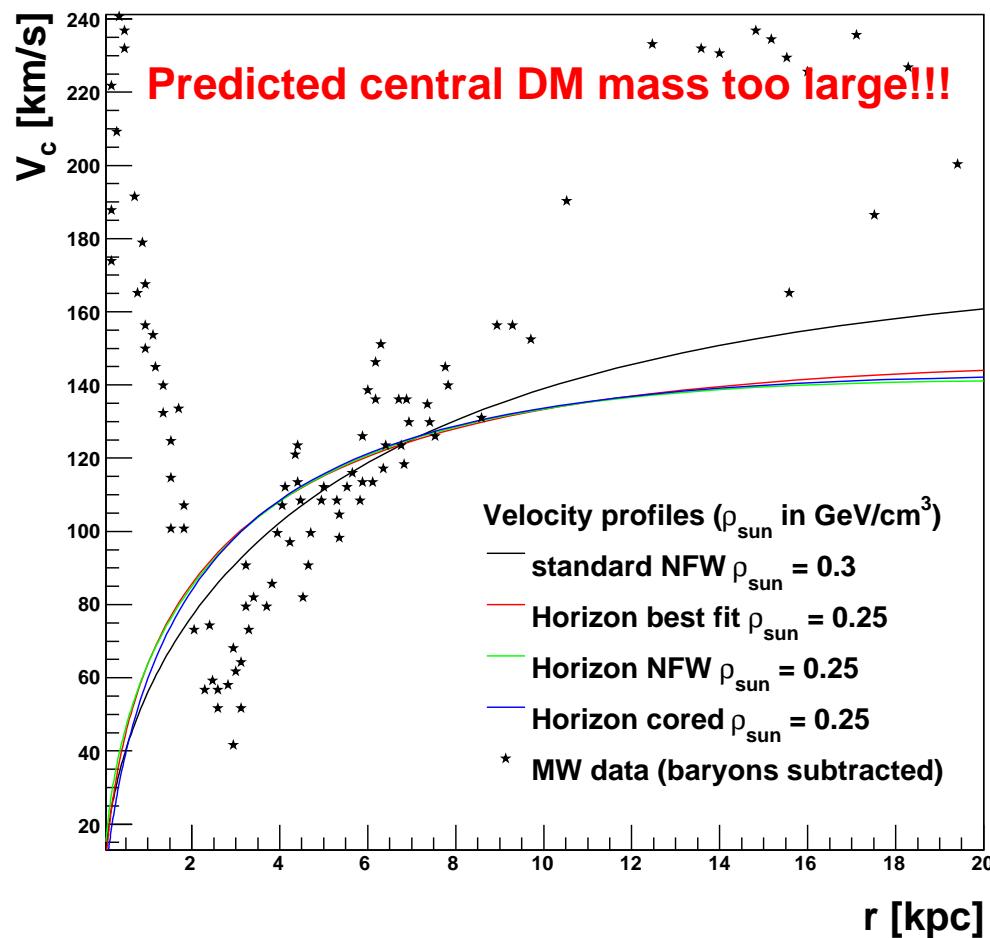


implementing tools for γ -rays and cosmic rays



CAVEATS: too simplistic galaxy model?

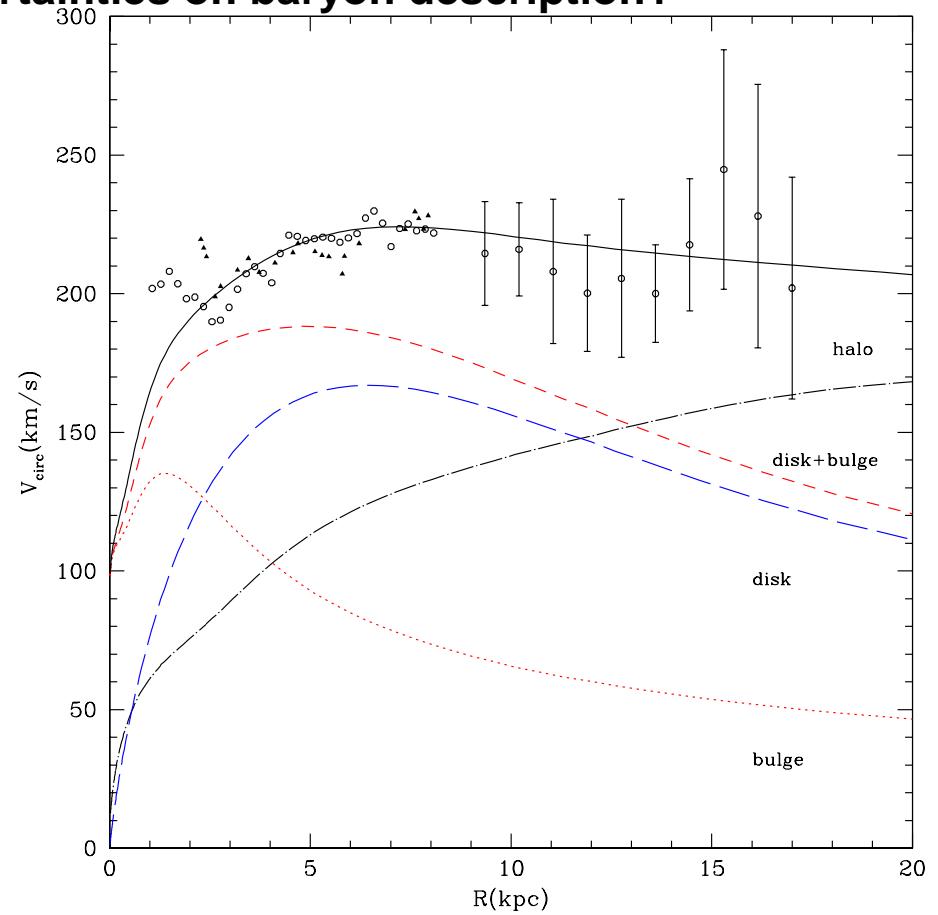
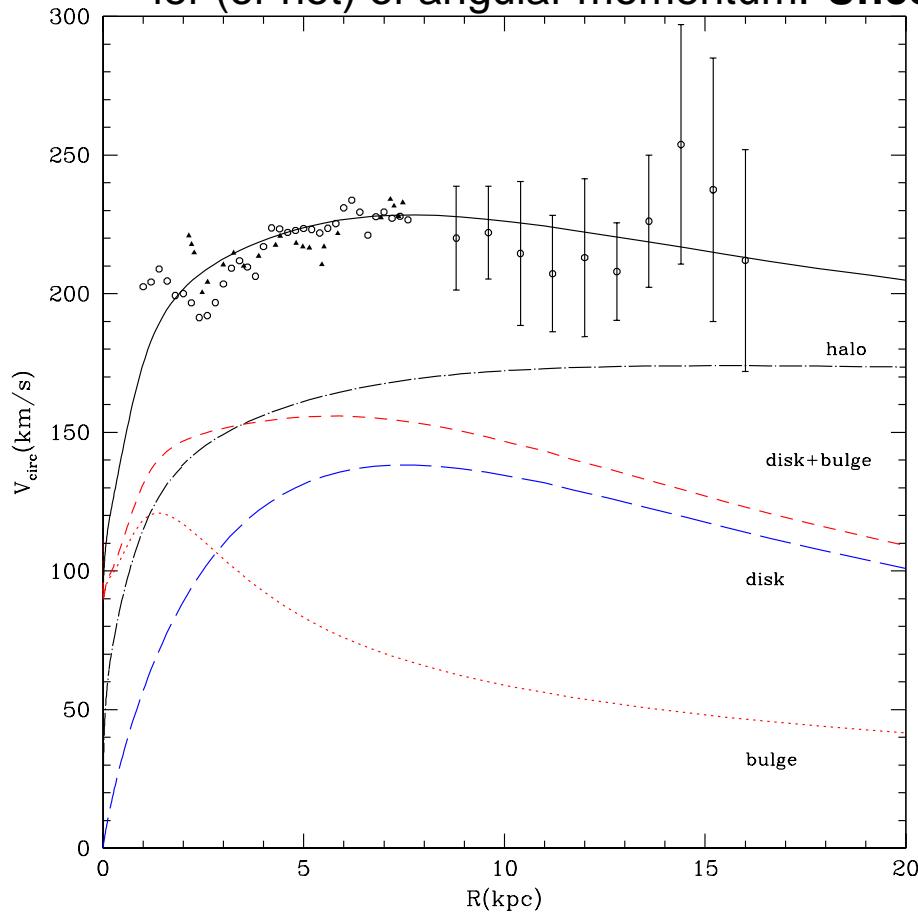
Rotation curves with baryon contribution (COBE/DIRBE inferred) subtracted
(Englmaier & Gerhard 2006)



Lavalle, Nezri et al – PRD 78 (2008)

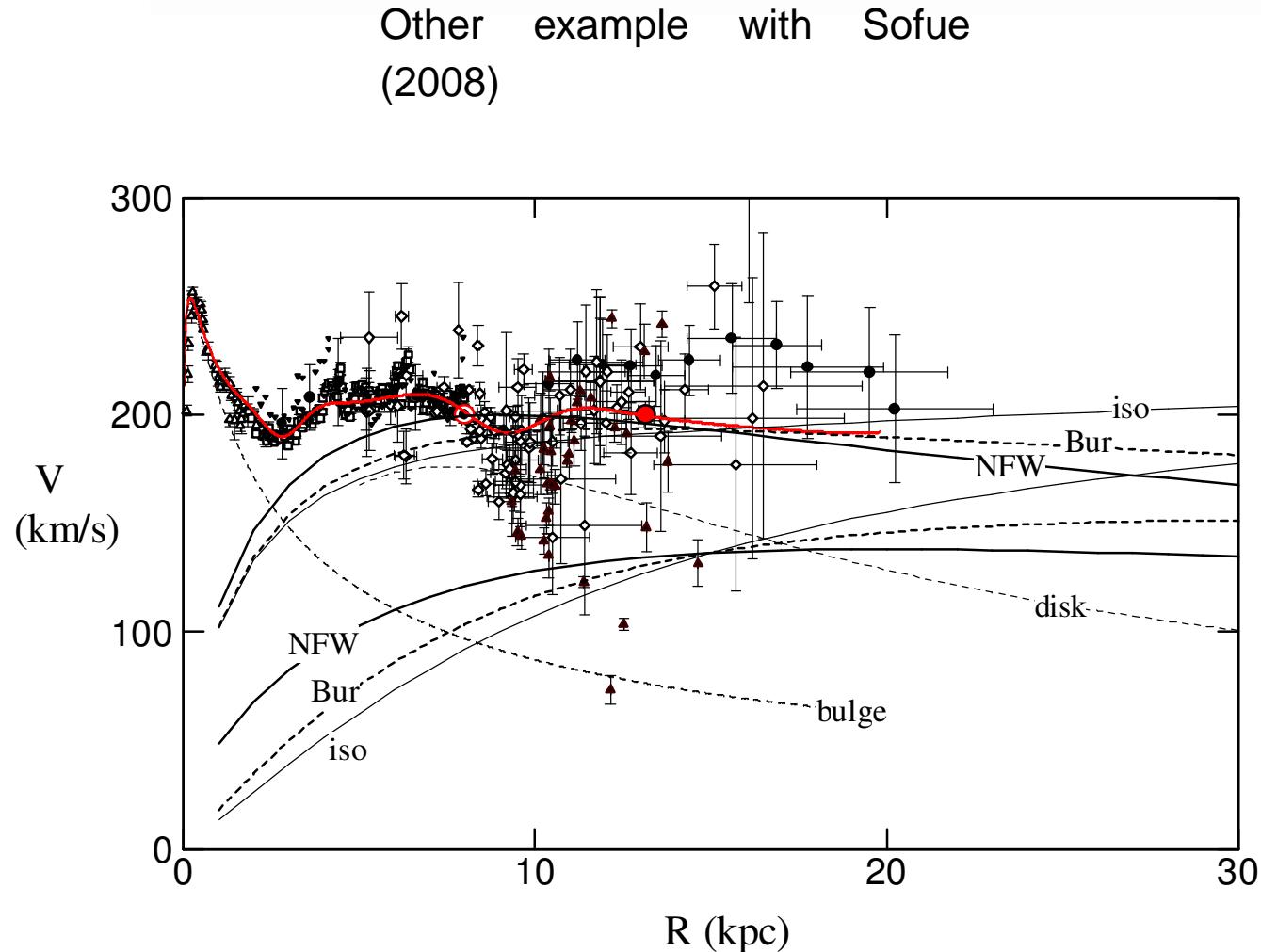
But in some cases, consistency with observations

Klypin et al (2002): adiabatic interaction between dark matter and baryons, transfer (or not) of angular momentum. **Uncertainties on baryon description?**



Starting from NFW, but ending with modified NFW!

But in some cases, consistency with observations



But no baryon-DM gravitational interaction considered here ...

HORIZON: *with baryons !!!*



Agertz, Teyssier & Moore (2009)

Exotic + standard cosmic ray study

Lavalle, Ling, Nezri & Teyssier (in prep)

Summary

- ⑥ Importance of self-consistent simulations of **dark matter plus baryons** in the cosmological context!
 - △ Open the possibility to treat both astrophysical and exotic processes in the same self-consistent framework
- ⑥ Improve the use of kinematical data, when available (especially for predictions of exotic signals)
- ⑥ **What are the observational/theoretical uncertainties in the baryon content description?** Quantify this in terms of possible window for dark matter.