Anisotropy of dark matter annihilation in the Galaxy

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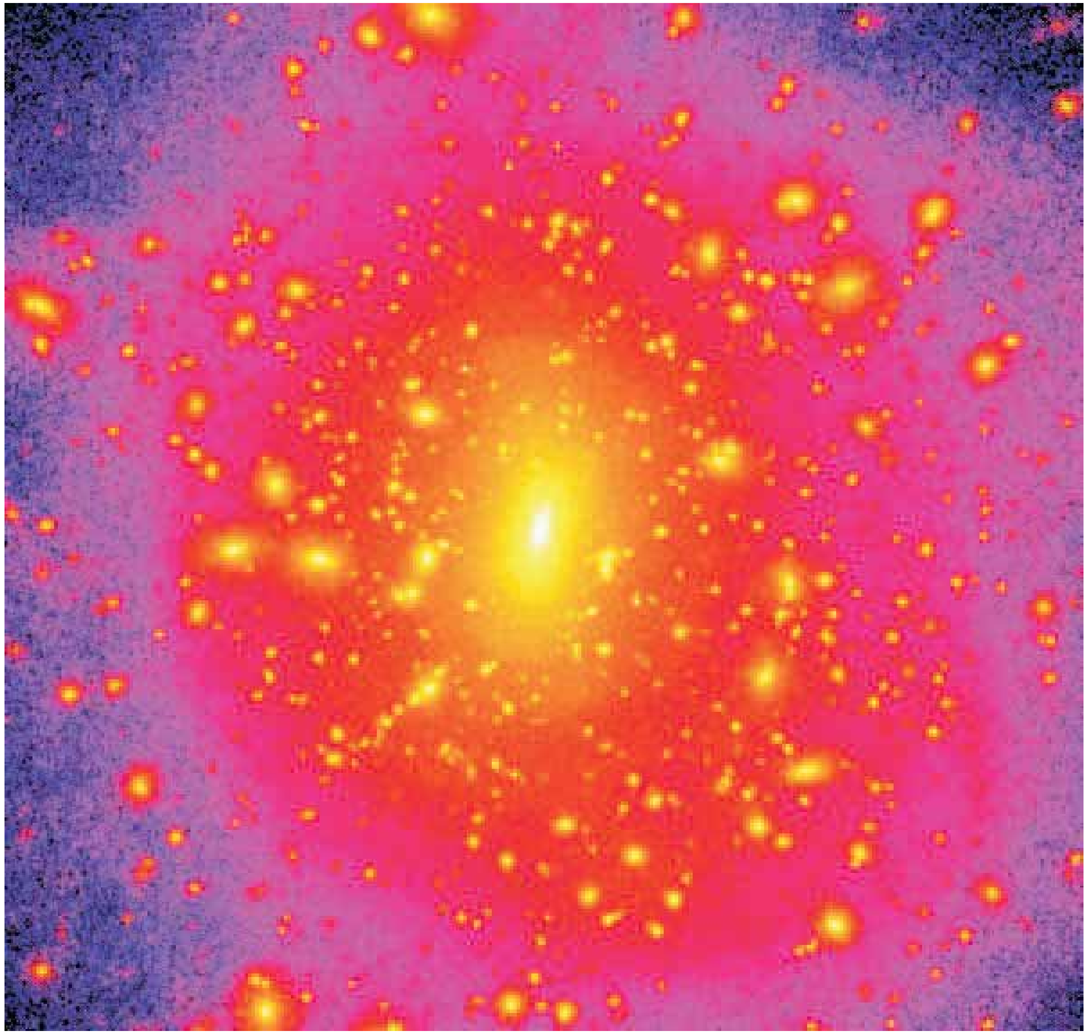
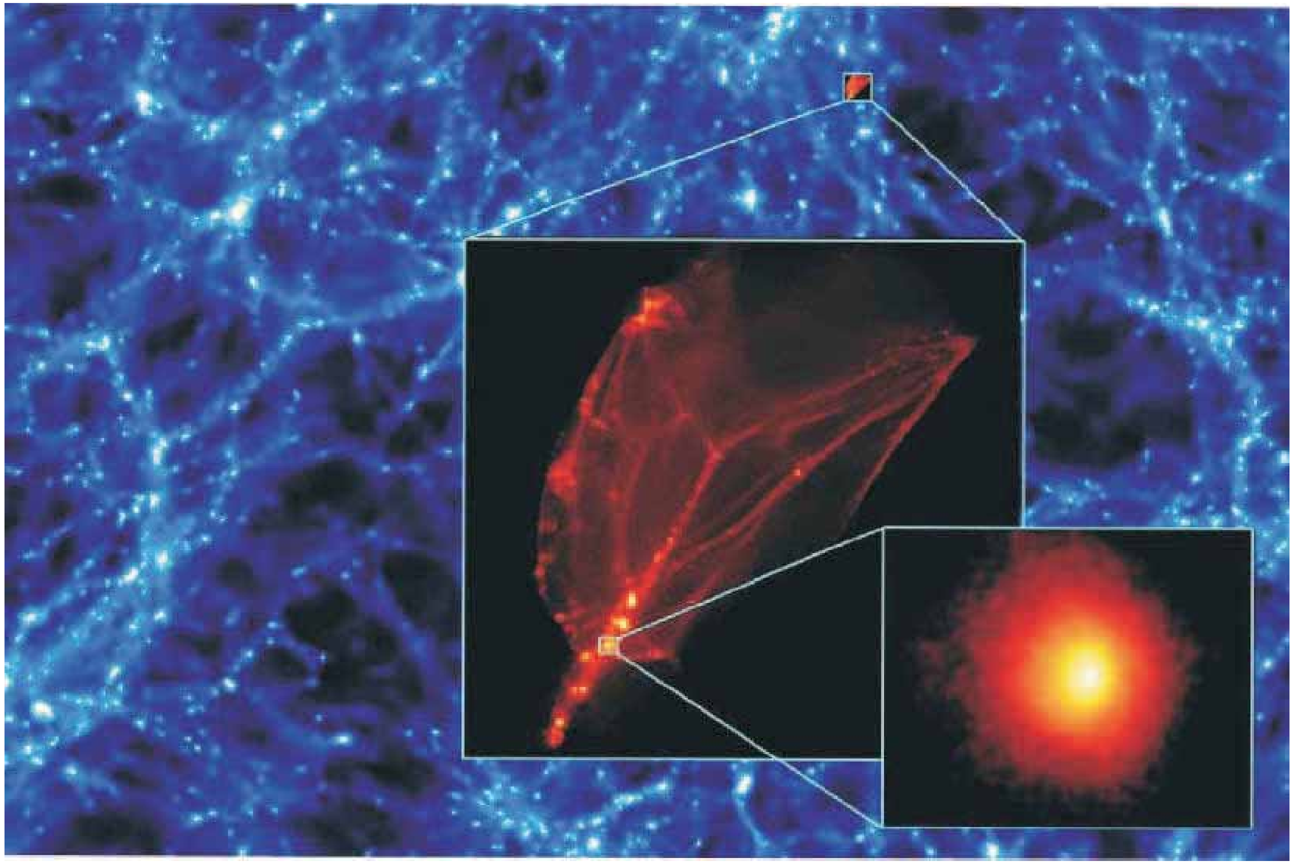
◇ **Large-scale DM clumps from simulations**



DM halo clumpiness

◇ Small-scale DM clumps from simulations

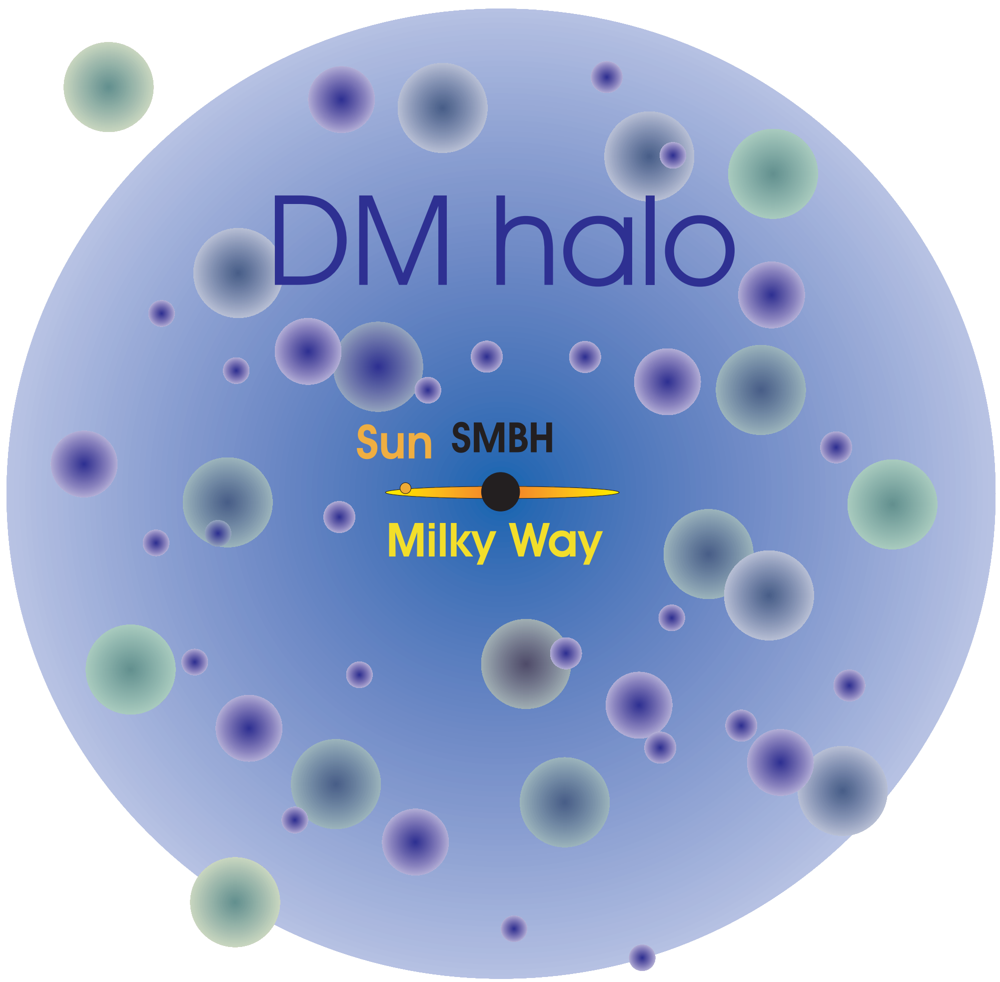


3 kpc　　60 pc　　0.024 pc

$N = 62 \cdot 10^6$, $m = 1.2 \cdot 10^{-10} M_\odot$, $z = 350 \rightarrow 26$

Diemand, Moore & Stadel '05

Small-scale DM clumps in the Galactic halo



from primordial fluctuations. . .

◇ Internal density profile of DM clump

$$\rho_{\rm int}(r) \;=\; \begin{cases} \rho_c, & r < R_c; \\ \rho_c \left(\dfrac{r}{R_c}\right)^{-\beta}, & R_c < r < R; \\ 0, & r > R, \end{cases} \qquad \beta \simeq 1.8$$

Analytical theory: Gurevich & Zybin ’90 ’97

DM clump core radius?

$$\frac{R_c}{R} \leq 0.01$$

Model: Berezinsky, Dokuchaev & Eroshenko ’03, ’06

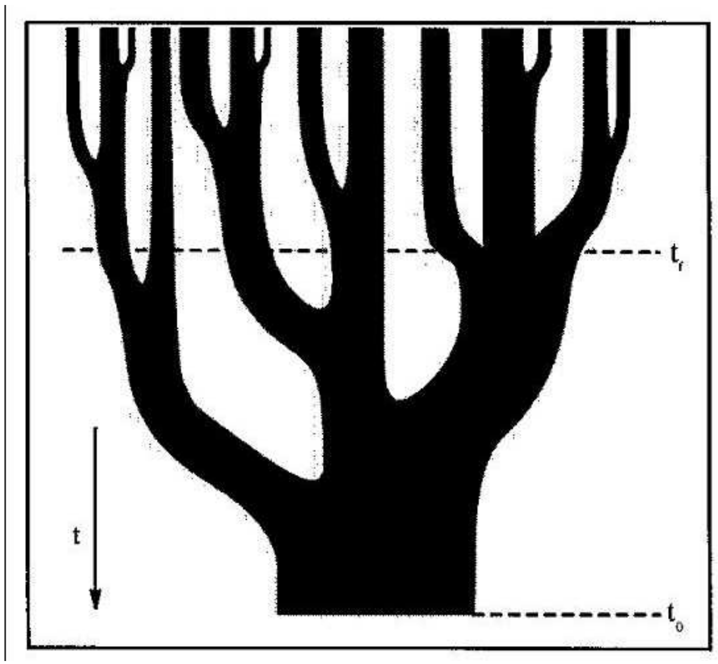
Simulations: Diemand, Moore & Stadel ’05

◇ Tidal destruction of clumps in hierarchical clustering

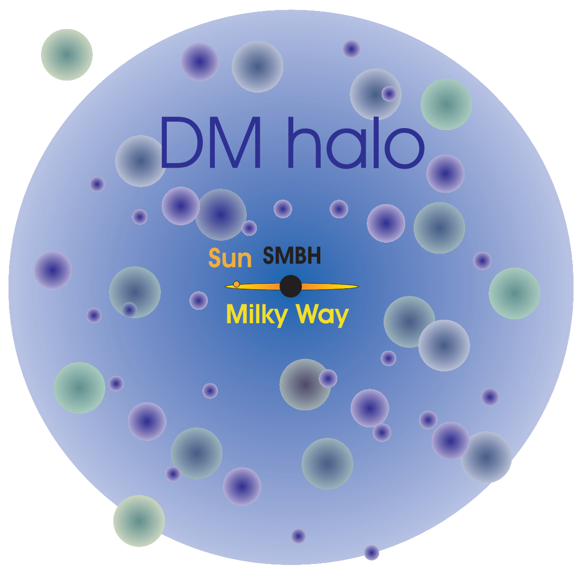
Number density of unconfined (free) clumps

$$\phi_{PS} dM = \left(\frac{2}{\pi}\right)^{1/2} \frac{\rho}{M} \frac{\delta_c}{D(t)\sigma_{\rm eq}^2} \frac{d\sigma_{\rm eq}}{\rm dM} \exp\left[\frac{-\delta_c^2}{2D(t)^2\sigma_{\rm eq}^2}\right] dM$$

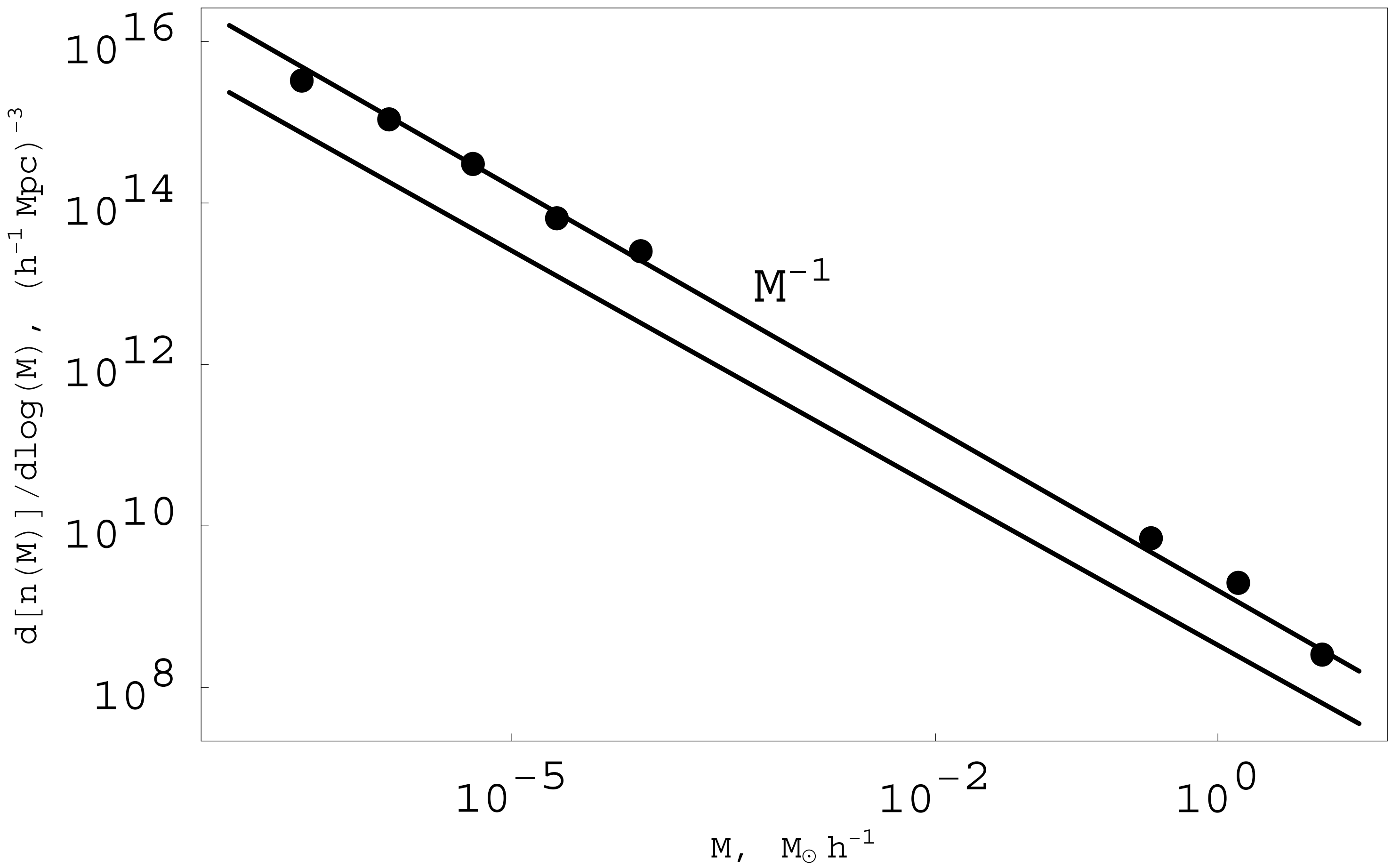
Press & Shechter ’74



Small-scale DM clumps in the Galactic halo



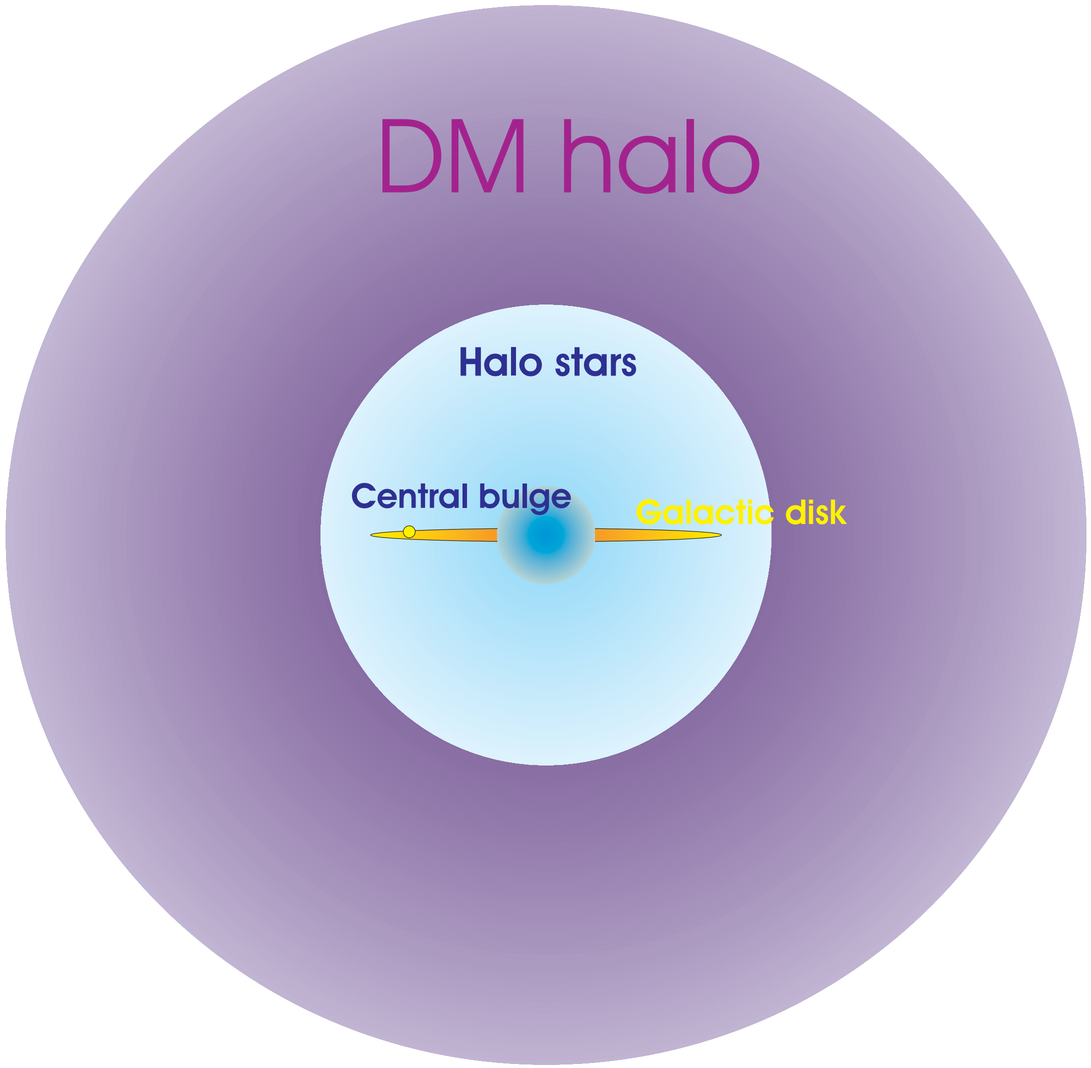
◇ Mass function of small-scale DM clumps



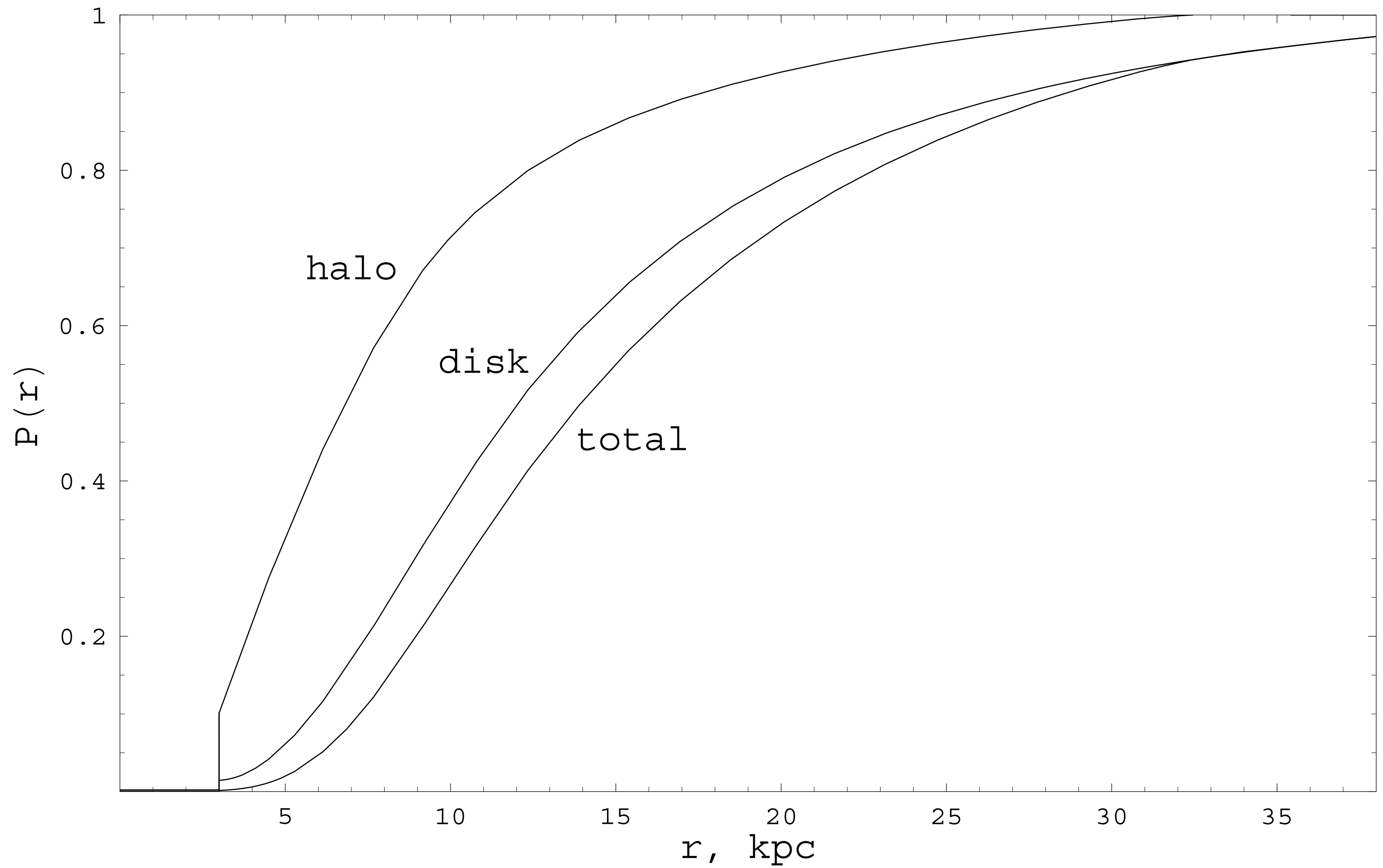
Lower line – model calculation
Dots – numerical simulations

Berezinsky, Dokuchaev & Eroshenko '03
Diemand, Moore & Stadel '05

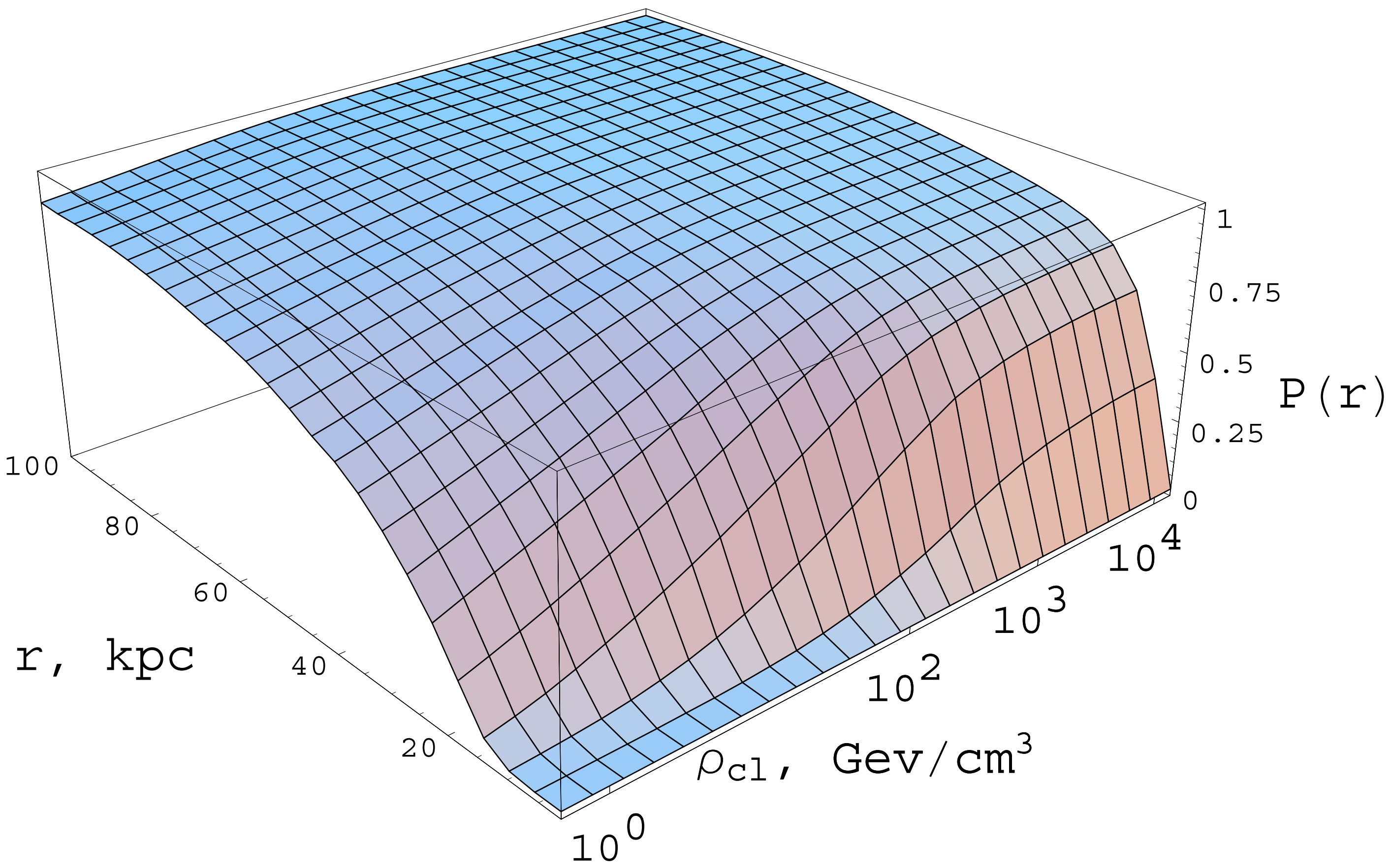
Stellar components of the Milky Way



Tidal destruction of small-scale DM clumps by stars

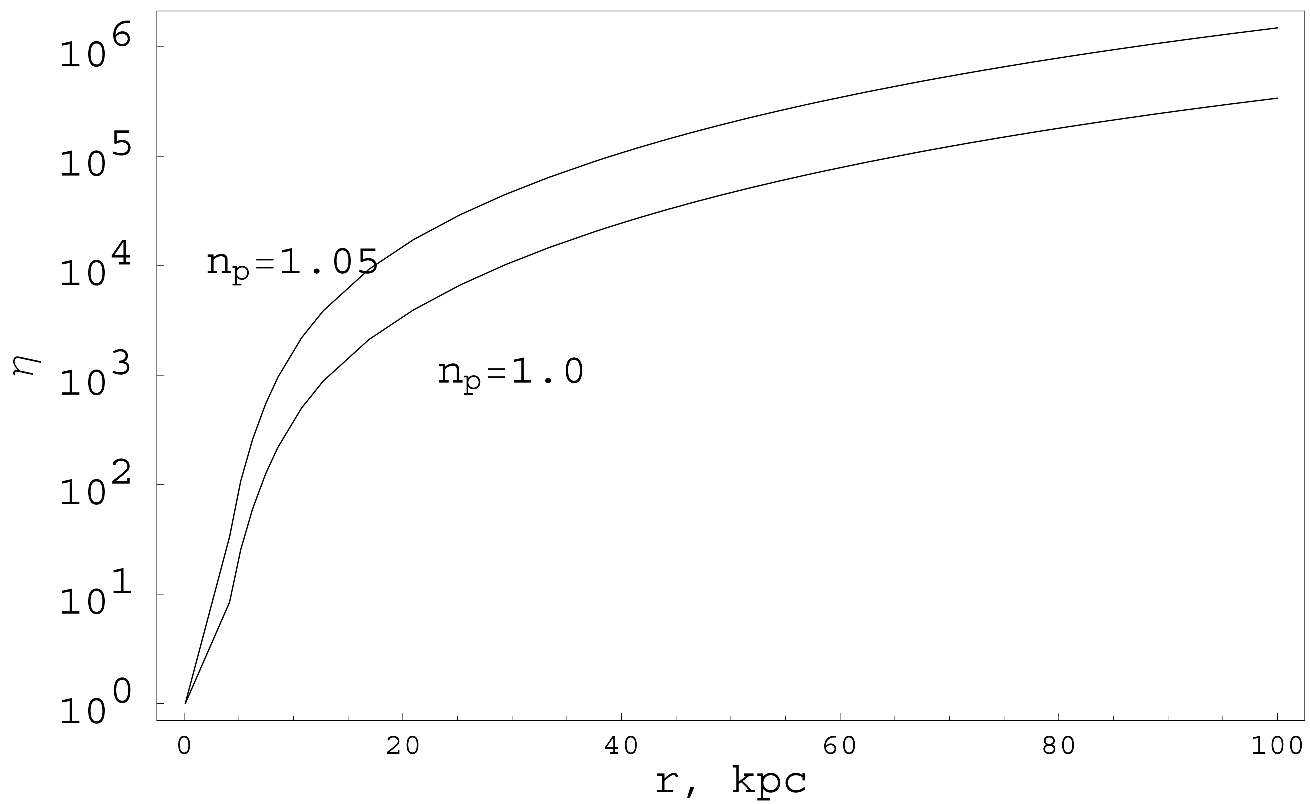


The fraction of clumps with mass $M = 2 \cdot 10^{-6} M_{\odot}$ survived through tidal destruction in the Galactic disc $P_{\rm d}$, Galactic halo $P_{\rm H}$, $P_{\rm tot} = P_{\rm H} P_d$ Absence of clumps inside the bulge at $r < 3$ kpc.



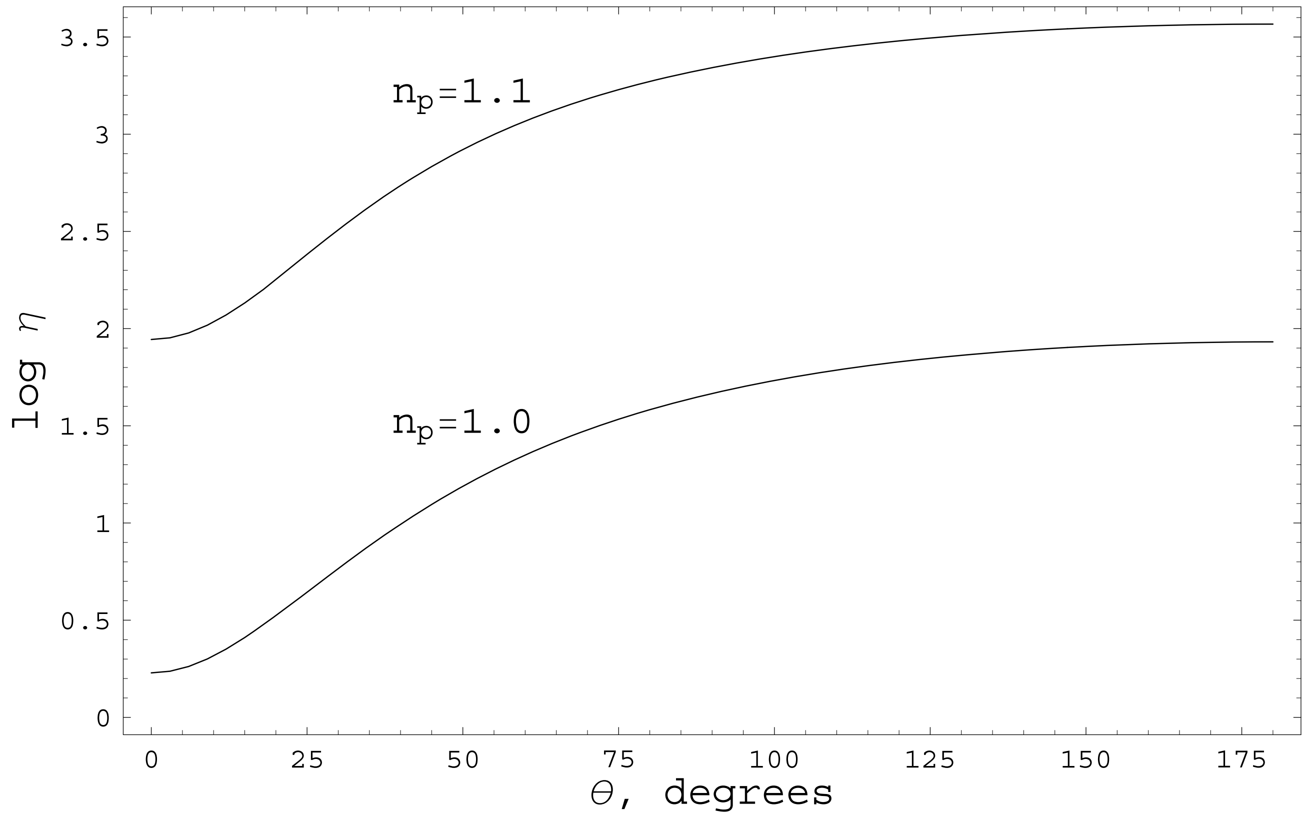
The survived fraction of clumps $P(r)$ in the Galactic halo
Internal density of clumps ρ_{cl} in GeV cm^{-3}

◇ **Boosting = clumpiness factor = annhilation enhancement = $\eta(r)$**



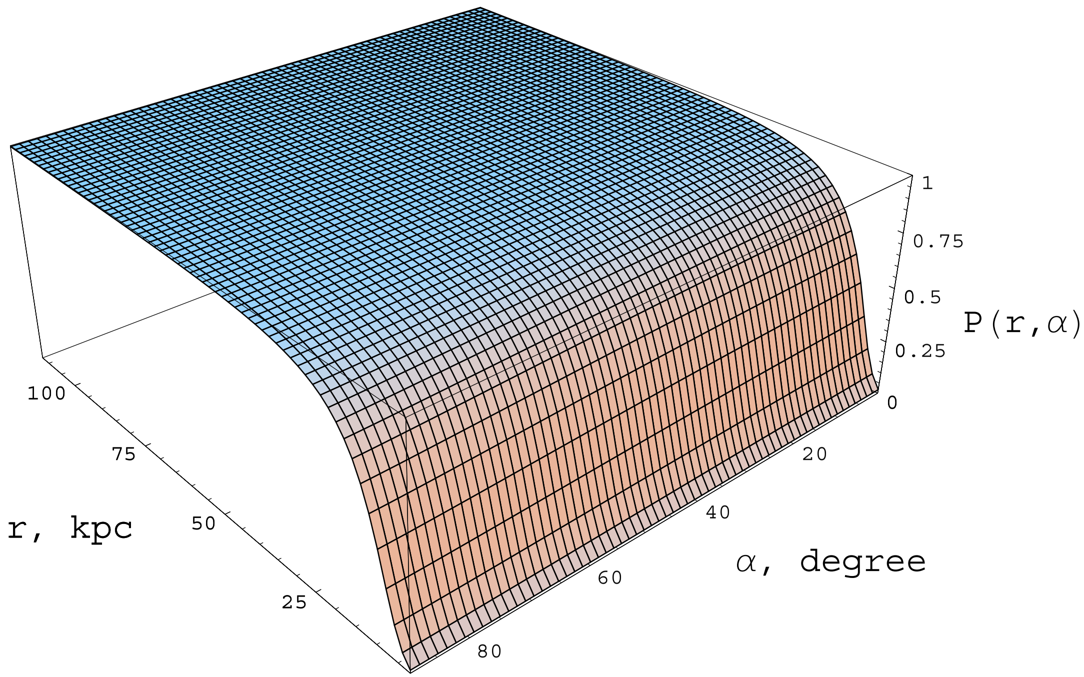
Local annhilation enhancement factor η
Inside central 3 kpc small-scale clumps are completely destructed by stars in the bulge

◇ Boost factor $\eta(\theta)$ integrated along the line of sight



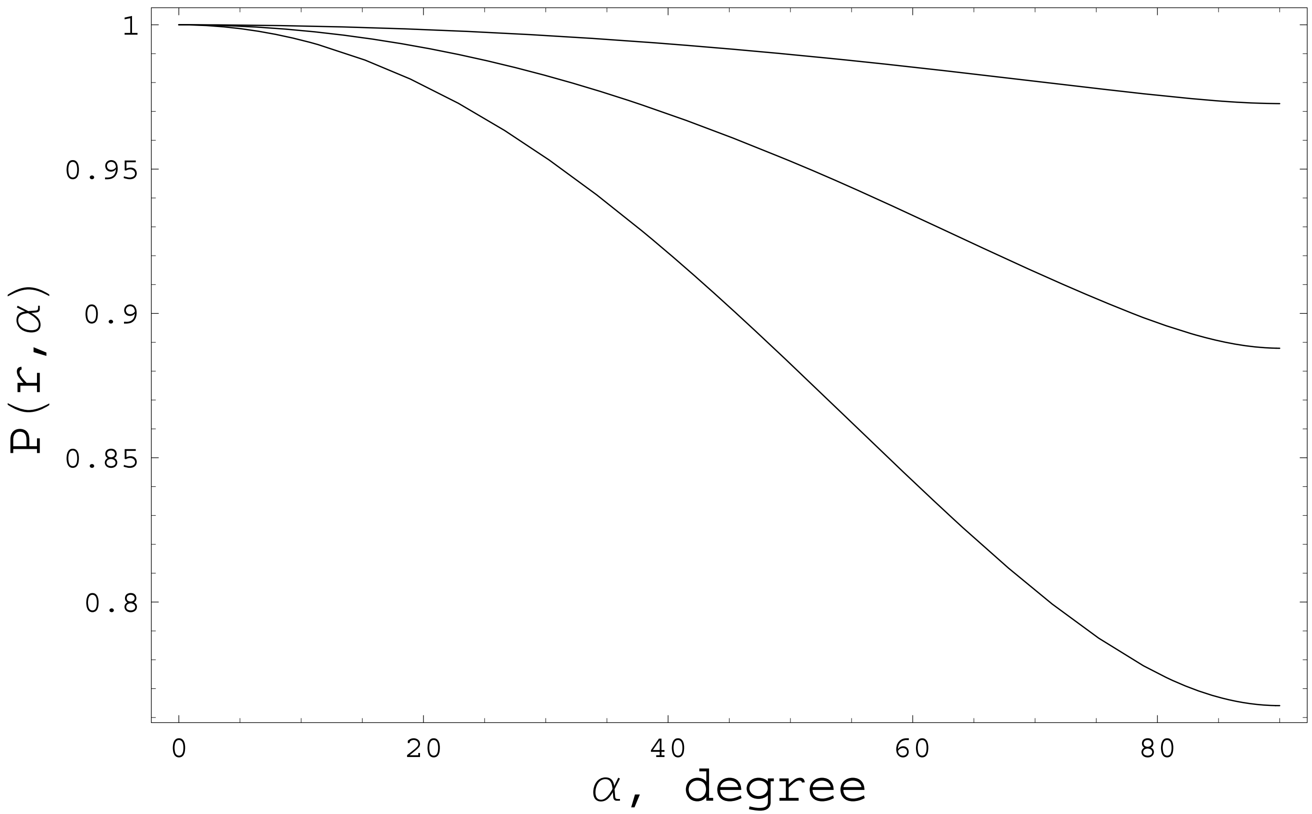
in the direction of the polar angle θ, $\beta = 1.8$, $M_{\rm min} = 2 \cdot 10^{-8} M_\odot$, $n_p = 1.0$ and $n_p = 1.1$, isothermal spherically symmetric halo model

◇ Anisotropy of DM clump distribution in the Galaxy



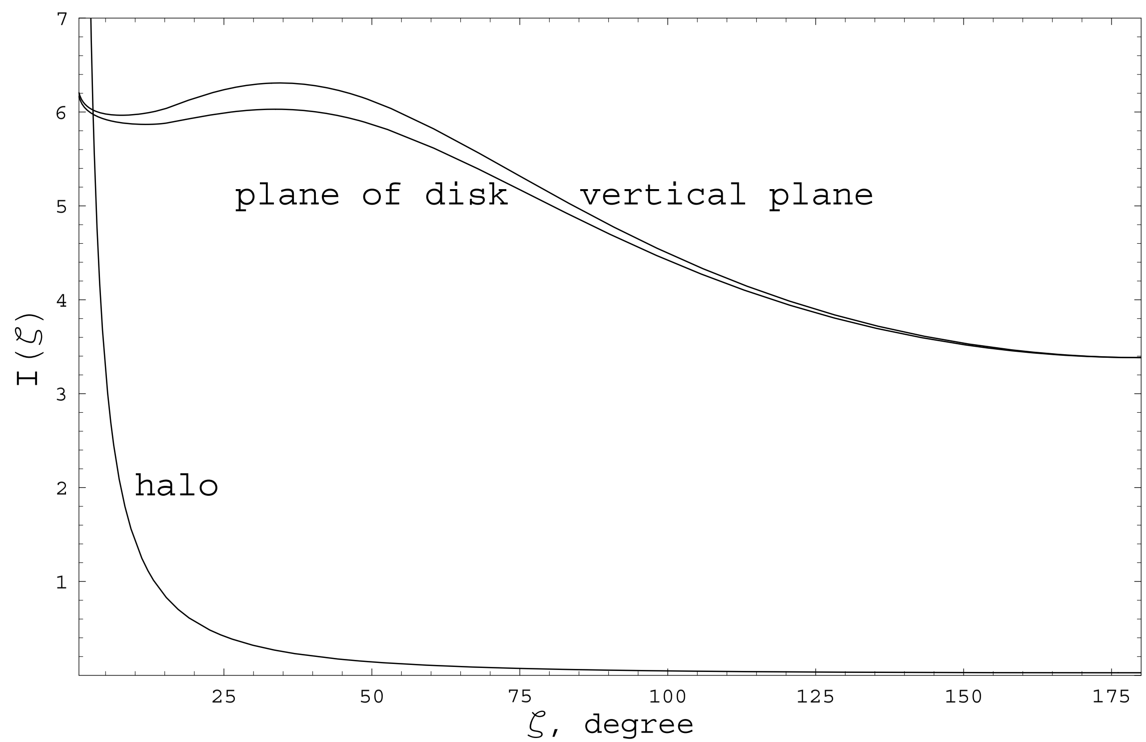
A survival probability $P(r,\alpha)$ of DM clumps in the halo as a function of the orbit inclination angle α

◇ Normalized anisotropy of DM clump distribution



The normalized fractions of DM clumps in the halo $P(r,\alpha)$ as a function of inclination angle α radial distance for $r = 3, 8.5$ and 20 kpc (from the bottom to the top)

◇ An annihilation signal from DM clumps



An annihilation signal in the Galactic disk plane and in the vertical plane as a function of angle ξ between the line of observation and the direction to the Galactic center. For comparison it is shown also the signal from the Galactic halo without the DM clumps

◇ Conclusions

- DM annihilation rate in the Galactic halo is dominated by clumps if mass fraction in clumps is above a few percent

- Amplification (boosting) of annihilation signal due to DM clumps is $\sim 10 - 10^3$ and crucially depends on the initial perturbation spectrum

- Tidal destruction of clumps with orbits near the disk plane occurs more efficiently as compared with the near-polar orbits

- Annihilation of DM particles in the small-scale clumps produces anisotropic ($\sim 5\%$) gamma-ray signal with respect to the Galactic disk