Dark matter annihilation in the Galaxy

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Abstract

The annihilation of dark matter in the Galactic halo is enhanced due to the presence of small-scale dark matter clumps. The small-scale clumps are efficiently disrupted at early stages of structure formation starting from the time of clump detachment from the universe expansion. The survived clumps can be further destructed in the galaxies by tidal interactions with stars in the Galactic bulge, disk and halo. The resulting enhancement (boost factor) η of annihilation signal due to the halo clumpiness strongly depends on the primordial perturbation spectrum and varies in the range $\eta \sim 10 - 100$.

One of the promising indirect manifestation of Dark Matter (DM) particles is their possible annihilation in the Galactic halo [1]. The most intriguing signature of DM annihilation was found in the EGRET gamma ray data, which shows a clear excess for energies above 1 GeV in comparison with the expectations from conventional galactic models in all sky directions [2].

A local annihilation rate is proportional to the square of number density of DM particles. Therefore, annihilation proceeds more efficiently in the dense DM substructures of the Galactic halo. The inflation models predict the power-law primordial fluctuation spectrum with an power index $n_p \simeq 1.0$. The small-scale clumps are formed earlier than the larger ones and captured by the larger clumps in the process of a hierarchical clustering in the expanding Universe. Both analytical calculations [3, 4, 5, 6] and numerical simulations [7, 8, 9] with the inflationary-produced adiabatic density fluctuations predict the existence of DM clumps in the Galactic halo. The enhancement of the annihilation signal due to the presence of substructures in the Galactic halo depends on the fraction of the most dense small-scale clumps [5, 10]. The relative *enhancement* (or boost factor) of the annihilation signal due to the presence of DM clumps in the Galactic halo can than be written as $\eta(r) = I_{\rm dif} + I_{\rm cl}/I_{\rm dif}$, where $I_{\rm dif}$ and $I_{\rm cl}$ are an annihilation signal from diffuse DM in the halo and clumps respectively.

The most essential characteristics of clumps for calculations of DM annihilation in the Galactic halo are the minimum mass and distribution function of clumps. At the same time the tidal destruction of clumps [5] strongly influences the number density of clumps in the Galaxy. Clumps at the central part of the halo are tidally destructed by stars [12, 13, 14] and by the Galactic disk shocking when clumps intersect the Galactic plane [11]. The tidal destruction of clumps by the Galactic disk is the most important process. The fraction of survived clumps $P(r)$ was calculated in [11]. For disk shocking this fraction depends on galactocentric radius r and the clumps mean density $\rho_{\rm cl}$. For destruction by halo stars there is an additional weak dependence on the clump mass M. At the same time the destruction of clumps by halo stars is much weaker in comparison with the disk destruction. With good accuracy we may neglect the M dependence. All small-scale DM clumps are totally destroyed by stars inside the Galactic bulge at distances $r \leq 3$ kpc. Therefore there is a void in clumps distribution with a size 3 kpc. See in the Fig. 1 the fraction of survived clumps $P(r)$ in the galactic halo and the integrated along the line of sight (observed) enhancement factor $\eta(\theta)$ for some galactic halo model [15] in dependance on angle θ between the directions to the Galactic center and the line of observation.

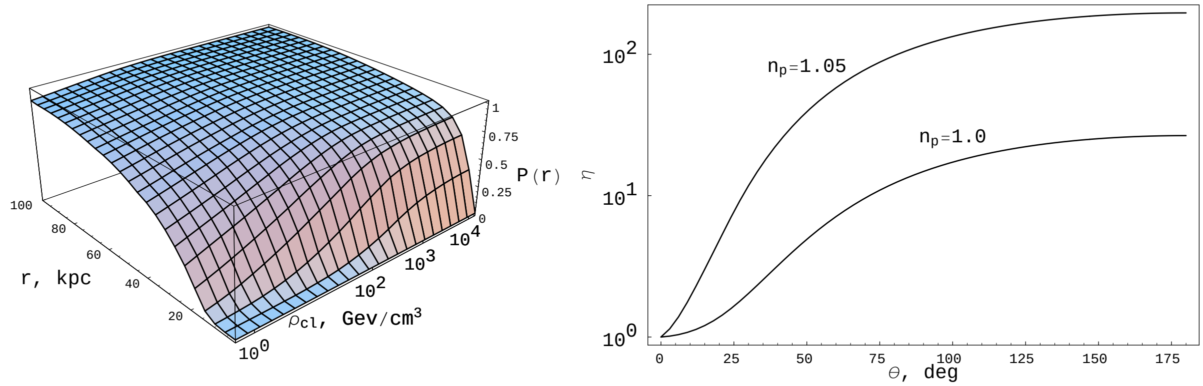

Figure 1: In the left panel is shown a survived fraction of small-scale clumps $P(r)$ in the Galaxy halo inside the radial distance 100 kpc. The mean internal density of clump $\rho_{\rm cl}$ is in GeV cm^{-3}. In the right panel is shown an integrated along the line of sight (observed) enhancement factor $\eta(\theta)$ for clump internal density profile $\rho_{\rm cl}(r) \propto r^{\beta}$, $\beta = 1.8$, minimal clump mass $M_{\rm min} = 2 \cdot 10^{-8}$, $n_p = 1.0$ and $n_p = 1.05$ in the case of Navarro-Frenk-White spherical symmetric halo model.

Acknowledgments: This work was supported in part by the Russian Foundation for Basic Research grants 04-02-16757 and 06-02-16342, and the Russian Ministry of Science grant 1782.2003.2.

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