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A POSSIBLE SCENARIO FOR A BARYONIC DARK HALO*

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ABSTRACT

The recent observations of microlensing events in the LMC by the MACHO and EROS collaborations suggest that an important fraction of the galactic halo is in form of Massive Halo Objects (MHO) of about $0.1 M_\odot$. Here, we argue that the galactic halo is mainly baryonic and constituted by dark clusters of MHO and/or H_2 molecular clouds.

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We present a scenario for a baryonic dark halo, in which the formation of MHO and/or H_2 molecular clouds in the outermost part of the halo naturally arises,[1] because in a quiet ambient the Jeans mass can reach values as low as 10^{-2} $M_{\odot}$. What is crucial in discriminating the evolution of proto globular cluster (PGC) clouds towards stellar globular clusters or dark clusters is the decreasing collision rates and UV-fluxes with increasing galactocentric distances.

The proposed scenario relies on the theory for the origin of proto globular clusters[2,3] and on the suggestion of Palla et al.[4] that the lower bound on the fragment masses in a collapsing, metal poor, cloud can be as low as $10^{-2} M_{\odot}$.

The main coolants below 10^4 K are molecular hydrogen and any heavy element produced by a first generation of stars. Molecular hydrogen, however, would be dissociated by various sources of UV radiation such as an AGN and/or a population of massive young stars in the center of the proto galaxy.

In the outermost part of the proto Galaxy, where the incoming UV radiation flux is suppressed due to the distance, the PGC clouds cool more gradually. Then, cooling and collapse occur simultaneously and the evolution of the PGC clouds proceed according to the scenario proposed by Palla et al.[4] , leading to a subsequent fragmentation into smaller clouds that remain optically thin until the minimum value of the Jeans mass ($\leq 0.1 M_{\odot}$) is attained.

The result of the above picture would be the formation in the galactic halo of dark clusters of MHO with mass ~ 0.1 $M_{\odot}$ or less. Using numerical values in Table 2 of Kang et al.,[5] we estimate the critical distance above which dark clusters can form to be $R_{crit} \sim 10 - 20$ kpc. A further question which arises is whether dark clusters are stable within the lifetime of the Galaxy. Dark clusters could be destroyed due to collisions,[6] if they are located within a certain galactocentric distance R_{dis}. Assuming the dark clusters to have half mass radius $r_c \simeq 10$ pc, this distance is estimated to be[1] $R_{dis} \simeq 6$ kpc. Then, dark clusters of MHO can still be present today at distances larger than R_{dis}. The most promising way to detect such clusters is through correlation effects in microlensing observations.

However, we don't expect the fragmentation process to be able to convert the whole gas mass contained in a PGC cloud into MHO. Thus, the remaining gas would form self-gravitating H_2 molecular clouds, since in the absence of strong stellar winds the gas remains gravitationally bound in dark clusters. The possibility that the gas is diffuse in the dark cluster or in the galactic halo is excluded due to its high virial temperature that would make the gas observable. The further possibility that the gas entirely collapsed into the disk is also excluded because then its mass would be of the order of the inferred dark halo mass.

A difficult task is the detection of H_2 molecular clouds. A possible signature of their existence would be the γ-ray flux induced by cosmic ray protons in the halo. Unfortunately, this quantity is unknown and the only information comes through theoretical estimates for the mass-loss rate of a typical galaxy. We furthermore assume the same energy dependence as measured on Earth and scale the overall cosmic ray density with the distance as R^{-2}.

Actually the cosmic ray protons in the halo which originate from the galactic disk are mainly directed outwards. This fact implies that also the induced photons will leave the galaxy. However, the presence of magnetic fields might give rise to a temporary confinement of the cosmic ray protons similarly to what happens in the disk. In addition, there could also be extragalactic sources of cosmic ray protons and also (probably more important) sources located in the halo itself, as for instance isolated or binary pulsars in globular clusters. Unfortunately, we are unable to give an estimate of the above effects, so that we take them into account by introducing an efficiency factor ϵ, which could be rather small.

The best chance, if any, to detect the γ-rays in question is provided by observations at high galactic latitude, leading to[1] $\Phi_\gamma \simeq \epsilon\, 1.7 \times 10^{-6}\ photons\ cm^{-2}\ s^{-1}\ sr^{-1}$.

The inferred upper bound for γ-rays in the 0.8 - 6 GeV range for high galactic latitude is $3 \times 10^{-7}\ photons\ cm^{-2}\ s^{-1}\ sr^{-1}$. Hence, we see that the presence of molecular clouds does not led at present to any contraddiction with the upper bound provided $\epsilon < 10^{-1}$.

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