Possible detection of the Andromeda galaxy rotation in CMB data

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Galactic disks are well studied objects in all bands of the electromagnetic spectrum and give us important information on the mass distribution within and around galaxies. On the other hand, galactic halos are relatively less studied objects and there are still many ambiguities not only in the main halo constituents, but also in their basic properties such as, in particular, their rotation speed.

The degree to which galactic halos rotate with respect to the disks is a relevant and difficult issue to be investigated. Indeed, it is related to the formation scenario of galaxies: in the standard collapse model both the disk and the halo derive from the same population and so their angular momentum are expected to be aligned; in the hierarchical formation model, instead, the halo rotation should have a minor connection with the disk angular momentum since structures in the outer halo arrive later. In spite of the relevance of this issue, it has been recognized that testing for the rotation even of the closest galaxy (the Andromeda galaxy) halo is extremely difficult and still beyond our reach [1].

On the other hand, baryons constitute about 4% of our universe and we know that about 10% of them are in stars (i.e. in the visible part of galaxies); the hot gas in galaxies and galaxy clusters accounts for another $20-30\%$ of baryons; but about $60-70\%$ of all baryons are missing and is not known where and in which form they are hidden. A possibility is that these baryons are contained in the so-called cosmic filaments in the form of a warm-hot intergalactic medium. However, it is unlikely that all the missing baryons are confined in the cosmic filaments and, actually, there are many reasons to believe that a non-negligible amount of these hidden baryons are in galactic halos (for more details on this issue see [2]).

In a series of papers starting since 1995 we have developed a model for the formation of the galactic halos that naturally leads to the formation of MACHOs (Massive Astrophysical Compact Halo Objects) [3,4], necessary to explain microlensing observations towards the Magellanic Clouds. This model emerges from the present-day understanding of the globular cluster formation. Indeed, the Fall-Rees theory for the formation of globular clusters predicts, without any further assumption, that dark clusters made of brown dwarfs and cold gas clouds should lurk in the galactic halo at galactocentric distances larger that $10-20$ kpc. A further prediction of our model was the presence of cold gas clouds associated with the MACHOs in the galactic halo, a prediction that could in principle be tested by astronomical observations. Various attempts have been undertaken to discover these clouds such as searching for the presence of a gamma-ray halo [5,6], stellar scintillations [7,8], obscuration events towards the LMC stars [9], search for the ortho-H_2D^+ line at 372 GHz [10], and extreme scattering events in quasar radio-flux variations [11].

More recently (i.e. towards the end of 2010), motivated by a proposal made already in 1995 [12] in which it was suggested that the gas clouds, if present in the halo of the Andromeda galaxy (M31), would have induced a temperature asymmetry in the CMB (Cosmic Microlensing Background) data due to the Doppler shift effect induced by the halo rotation, we have attempted to use the 7-year WMAP data to look in detail towards both the disk and the halo of the Andromeda galaxy. Surprisingly enough, a disk temperature asymmetry along the direction of the M31 disk rotation has been observed for the first time in microwaves (see Figure 1) with a maximum of $\simeq 130$ μk/pixel at about 20 kpc from the M31 center. This temperature asymmetry is very likely induced by the Doppler shift effect due to the M31 disk rotation speed. [1] We also note that the anisotropy structure detected in the disk of the Andromeda galaxy resembles very closely the HI velocity maps recently obtained at 21 cm (see [13]).

Even more surprising has been what we have found towards the M31 halo where we found a temperature asymmetry as predicted in 1995. Indeed, we find a temperature asymmetry up to about 120 kpc with a peak temperature contrast of about 40 μK/pixel, the hotter part being that located in the south-east region. Although the confidence level of the signal, if estimated purely statistically (i.e. with 500 control fields and 500 simulated sky maps), is not high [2], the geometrical structure of the temperature asymmetry in the three bands point towards a real effect modulated by the rotation of the M31 halo. A size of about 120 kpc corresponds to the typical size inferred for the dark matter halos around massive galaxies and our approach might open the possibility of a new way of studying these systems, both galactic disks and halos, at microwave wavelengths. We emphasize that, in any case, a careful analysis of the Planck data that should be released shortly would allow either to prove or disprove our main results. For more details see [14].

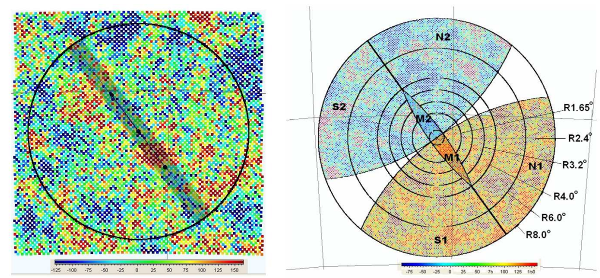

Figure 1. In the left panel, the WMAP W-band towards the M31 galaxy. The $8.5^0 \times 8.5^0$ sky field centered at $(121.17^0, -21.57^0)$ with the marked 4^0 circular region. The oblique strip indicates the M31 disk, and the analysis in the halo region of M31 galaxy is extended far beyond the region indicated in the figure. The detailed geometry (up to 8^0) used in the analysis is shown in the right panel.

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[1] The robustness of this result has been tested by considering 500 randomly distributed control fields in the three WMAP bands and also by simulating 500 sky maps from the best fit cosmological parameters. Both procedures give comparable results and imply that there is less than $\simeq 2\%$ probability that the signal is due to a random fluctuation of the CMB signal.

[2] We find, indeed, that there is a probability of less than about 15% that the detected temperature asymmetry in the M31 halo is due to a random fluctuation of the CMB signal (see [2]).