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THE KINEMATICS OF THE LOCAL GROUP IN A COSMOLOGICAL CONTEXT

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ABSTRACT

Recent observations constrained the tangential velocity of M31 with respect to the Milky Way (MW) to be $v_{\rm M31,tan} < 34.4$ km s^{-1}and the radial velocity to be in the range $v_{\rm M31,rad} = -109\pm4.4$ km s^{-1}(van der Marel et al. 2012). In this study we use a large volume high resolution N-body cosmological simulation (Bolshoi) together with three constrained simulations to statistically study this kinematics in the context of the ΛCDM. The comparison of the ensembles of simulated pairs with the observed LG has been done with respect to the observed radial and tangential velocities, the reduced orbital energy ($e_{\rm tot}$), angular momentum ($l_{\rm orb}$) and the dimensionless spin parameter, λ. Our main results are: (i) the preferred radial and tangential velocities for pairs in ΛCDM are $v_{\rm r} = -80 \pm 20$ km s^{-1}, $v_{\rm t} = 50 \pm 10$ km s^{-1}, (ii) pairs around that region are 3 to 13 times more common than pairs within the observational values, (iii) 15% to 24% of LG-like pairs in ΛCDM have energy and angular momentum consistent with observations while (iv) 9% to 13% of pairs in the same sample show similar values in the inferred dimensionless spin parameter. It follows that within current observational uncertainties the quasi-conserved quantities that characterize the orbit of the LG, i.e. $e_{\rm tot}$, $l_{\rm orb}$ and λ, do not challenge the standard ΛCDM model, but the model is in tension with regard to the actual values of the radial and tangential velocities. This might hint to a problem of the ΛCDM model to reproduce the observed LG.

Subject headings: galaxies: kinematics and dynamics, Local Group, methods:numerical

1. INTRODUCTION

The Milky Way (MW) and Andromeda galaxy (M31) are the dominant galaxies in the Local Group (LG). Astronomical observations of their mass distribution impose constraints on the standard cosmological model. The satellite overabundance problem (Klypin et al. 1999b; Moore et al. 1999), tidal disruption features (McConnachie et al. 2009) and the disk dominated morphology (Kazantzidis et al. 2008) are examples on how LG studies are linked to the cosmological context. Detailed studies on the Magellanic Clouds dynamics and their possible link to M31 add to the interest of understanding the details of the LG kinematics and dynamics (Besla et al. 2007; Tollerud et al. 2011; Knebe et al. 2011; Fouquet et al. 2012; Teyssier et al. 2012). However, a general concern in the use of the LG as a tool for near-field cosmology (Freeman & Bland-Hawthorn 2002; Peebles & Nusser 2010) is how typical is the LG regarding the properties of interest (Busha et al. 2011; Liu et al. 2011; Forero-Romero et al. 2011; Purcell & Zentner 2012).

A new valuable piece of information in this issue is the recent observational determination of the proper-motion measurements of M31, which until recently had been out of reach (van der Marel et al. 2012). The reported measurements set an upper bound for the tangential velocity of M31 with respect to the MW of $v_{\rm tan,M31} \leq 34.4$ km s^{-1}. Together with the values of the relative radial velocity of $v_{\rm rad,M31} = -109 \pm 4.4$ km s^{-1}observations show that the relative motion of the MW and Andromeda is consistent with a head-on collision. With this information it is possible to quantify how common is this kinematic configuration in a ΛCDM Universe.

This Letter presents such study. We use a large volume, high resolution dark matter only N-body simulation in the concordance ΛCDM cosmology to find a set of halo pairs with similar characteristics as inferred in the LG. We quantify these results in terms of the number of pairs with given radial and tangential velocities in the galactocentric rest frame. We also find the pairs that are consistent with a head on collision in terms of the ratio of the radial to tangential velocity $f_{\rm t} \equiv v_{\rm tan}/v_{\rm rad} < 0.32$ and present these results in terms of the reduced angular momentum, mechanical energy and dimensionless spin parameter.

In addition we make use of three constrained N-body simulations which are constructed to reproduce the observed large scale structure of the Local Universe on scales of a few tens of Mpc. The special feature of these simulations is that each volume features a pair of halos with the right characteristics to be considered LG-like objects.

This Letter is structured as follows. In the next section we present the N-body simulations, the criteria we use to select LG-like halo pairs. In Section 3 we present the results for the dynamics in these pairs in terms of the tangential/radial velocities and the orbital angular momentum/mechanical energy. In the same section we summarize these dynamical results in terms of the dimensionless spin parameter of the pairs. Finally, in the last section we comment and conclude about the implications

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