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The Andromeda Plane

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ABSTRACT

Key words: Local Group — galaxies: dwarf – galaxies: individual (M31)

1 INTRODUCTION

The anysothropic distribution of the satellite galaxies in the Milky way has been long known (Linden-Bell, Pawlowsky).

Plane of satellites in M31 (Conn, Ibata). 14kpc, extended 400 kpc. Corrotating.

Other evidence of planes in XXX(Tully) and evidence of corrotation in SDSS (Ibata).

First attempts to find such planar structures in only DM simulations (Baumgardt 2013) found a probablility of XXX but these numbers decreased even further to XXXX in two revised studies by Ibata 2013 and Pawlowsky 2013, who concluded that the observed structures cannot be explained by ΛCDM DM only simulations.

In recent papers Sawala 2014 finds that when including baryonic matter in cosmological simulations the discrepancies in the number and distribution of satellites between simulations and observations disapear.

Additionally, Gillet 2015, finds corrotating planes in simulations that include hydrodynamics and concludes that the M31 plane could be the result of a group of satellites that entered their host together and have coherent orbits and some satellites that are on the plane incidentaly and probably have significant velocities perpendicular to the plane.

This work seems to reconcile the results from simulations with the observations, with the caveat that the plane observed in the Andromeda galaxy is always colder than the planes found in simulations, and hints at possible formation scenarios for the M31 plane.

Formation scenarios have also been explored by Libeskind XXX, who showed that, in the simulations, there were preferential directions for satellite accretion dictated by the filamentary structure of the cosmic web and in particular the velocity shear vector.

This result was observationaly tested by Tempel 2015 and XXXXXXXX using the SDSS catalog to reconstruct the filamentary structure XXXXX.

Buck et al.

Other possible explanations for the alignement of the satellites have been proposed by Kroupa et al 20XX and Pawlowski 20XX who claim that the satellites of the MW and of M31 are tidal dwarfs.

This scenario has also been explored by Fouquet (XXXXX) who finds, using N-Body simulations, that the satellites of the Milky Way and M31 could be the result of a past interaction between these two galaxies.

This paper is organised as follows. In Section 2 we describe introduce the numerical model used to describe both the Milky Way and the M31 potentials and the restriction we impose on the unknown tangential velocities of the satellites. We the show in Section XXXX, the resulting orbits that we obtain. Finally, we discuss the posible implications of XXXXXXXX

2 METHOD

2.1 M31 coordinate system

We have the observed line of sight velocities and distances and positions of the satellites. We transform those to a coordinate system centered in M31 and whose xxxx-axis point in the M31-MW direction as shown in figure XXXX. The new x, y and z positions are given by (Conn et al 2013) (Arias et al 2015)(**??**)

$$x = \tag{1}$$

$$y = \tag{2}$$

$$z = \tag{3}$$

We use a similar principle for the velocities

$$V_x = \tag{4}$$

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$$V_y = \tag{5}$$

$$V_z = \tag{6}$$

Finally, we rotate this coordinate system so that the xy plane coincides with M31's disk.

2.2 Potentials of M31 and the Milky Way

The Andromeda potential is described as a three component model, first proposed by **?**. The dark matter halo is described as a Navarro-Frenk and White (NFW) potential (**?**) given by

$$\Phi_{\rm halo}(r) = -\frac{\rm GM_{halo}}{r}\log\left(\frac{r}{r_{\rm halo}}+1\right), \tag{7}$$

The disk component of the potential is given by

$$\Phi_{\rm disk}(r) = -2\pi G\Sigma_0 {r_{\rm disk}}^2\left[\frac{1-\exp^{-r/r_{\rm disk}}}{r}\right] \tag{8}$$

and the bulge component follows a Hernquist profile (**?**)

$$\Phi_{\rm bulge}(r) = -\frac{\rm GM_{bulge}}{r_{\rm bulge}+r}. \tag{9}$$

The Milky Way potential is described by a Hernquist bulge, a NFW halo potential (see equations (9) and (7)), and a Galactic disk described by a Miyamoto-Nagai potential (**?**) given by

$$\Phi_{\rm disk}(R,z) = -\frac{\rm GM_{disk}}{\left(R^2+\left(r_{\rm disk}+\sqrt{(z^2+b^2)}\right)^2\right)^{1/2}} \tag{10}$$

2.3 Velocities in the tangential plane

Collins et al. and Tollerud et al. measured the line of sight (or radial velocities) of XXX of M31's satellite galaxies but we lack information on their proper motions. In this work we investigate the possible orbits of the satellites in M31's potential and therefore we need to account for the unknown proper motions. We make the following assumption: if the plane of satellites is a dynamicaly coherent structure, then the total velocities of the satellites must be contained in such plane. We have measured radial velocities v_r (Collins 2013, SPLASH survey 20XX) so we can construct a tangential velocity vector such that the total velocity is on the plane. This asumption determines the direction of the unknown tangential velocity vector and we are left with only its magnitude as a free parameter. If we vary this parameter between reasonable values (-$\sqrt{3}v_r$ + $\sqrt{3}v_r$)

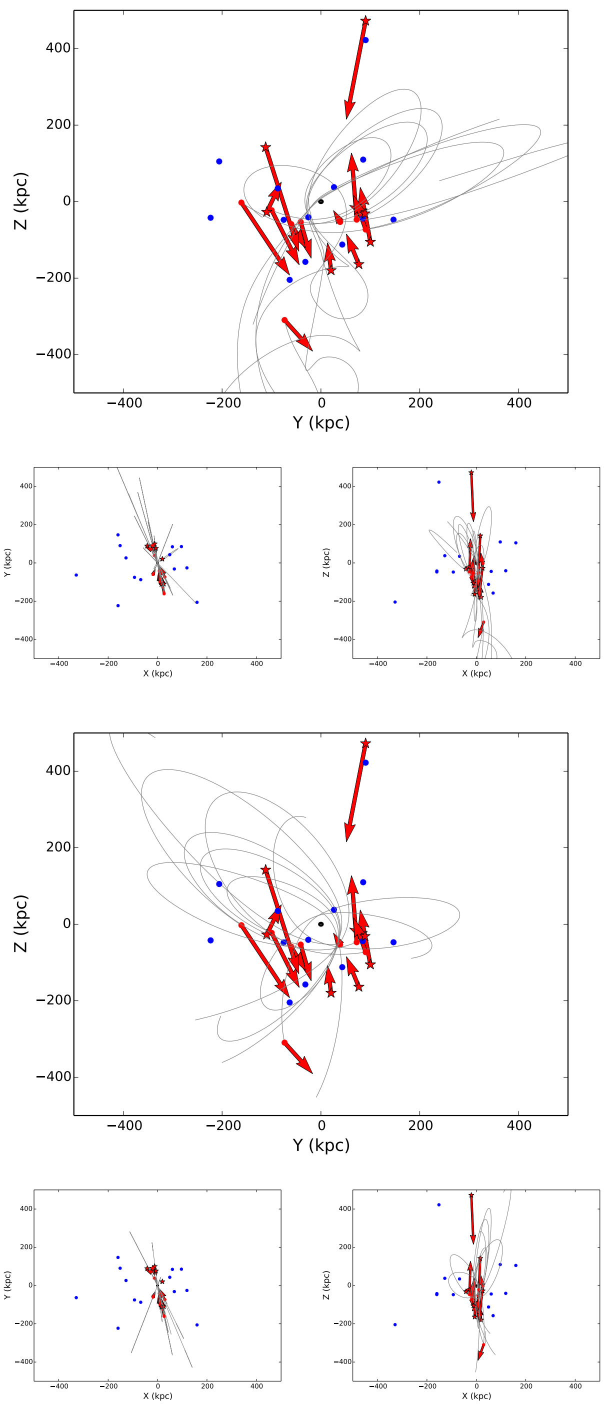
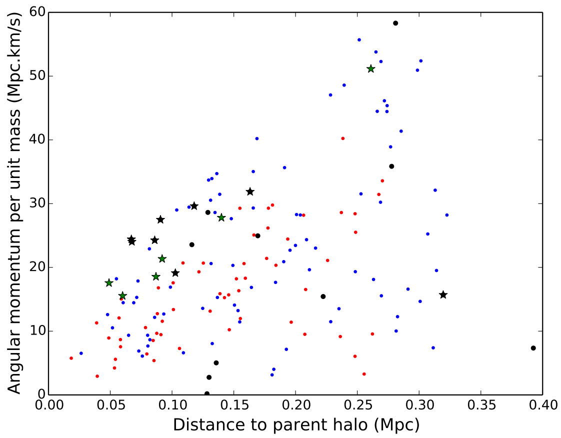


Figure 1. .

3 RESULTS

4 DISCUSSION

5 ACKNOWLEDGEMENTS


Angular momentum per unit mass (Mpc.km/s)
Distance to parent halo (Mpc)
0
10
20
30
40
50
60
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40