

The Andromeda Plane

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Accepted xxx. Received xxxx; in original form xxxx

ABSTRACT

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

1 INTRODUCTION

The anisotropic 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 corotation in SDSS (Ibata).

First attempts to find such planar structures in only DM simulations (Baumgardt 2013) found a probability 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 Λ CDM DM only simulations.

In recent papers Sawalla 2014 finds that when including baryonic matter in cosmological simulations the discrepancies in the number and distribution of satellites between simulations and observations disappear. 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 incidentally 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 observationally tested by Tempel 2015 and XXXXXXXX using the SDSS catalog to reconstruct the filamentary structure XXXXX. Other possible explanations for the alignment 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 (XXXXXX) 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 galax-

ies. Another scenario, proposed by Goerdt 2013, proposes that the plane satellites were delivered by cold gas streams.

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 show in Section XXXX, the resulting orbits that we obtain. Finally, we discuss the possible 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?)(?)

$$x = \quad (1)$$

$$y = \quad (2)$$

$$z = \quad (3)$$

We use a similar principle for the velocities

$$V_x = \quad (4)$$

$$V_y = \quad (5)$$

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$$V_z = \quad (6)$$

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

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

The disk component of the potential is given by

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

and the bulge component follows a Hernquist profile (?)

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

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

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

2.3 Tangential Velocities

We make the following assumption: if the plane of satellites is a dynamically 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 assumption 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 ($-\sqrt{3}v_r + \sqrt{3}v_r$)

3 RESULTS

4 DISCUSSION

5 ACKNOWLEDGEMENTS

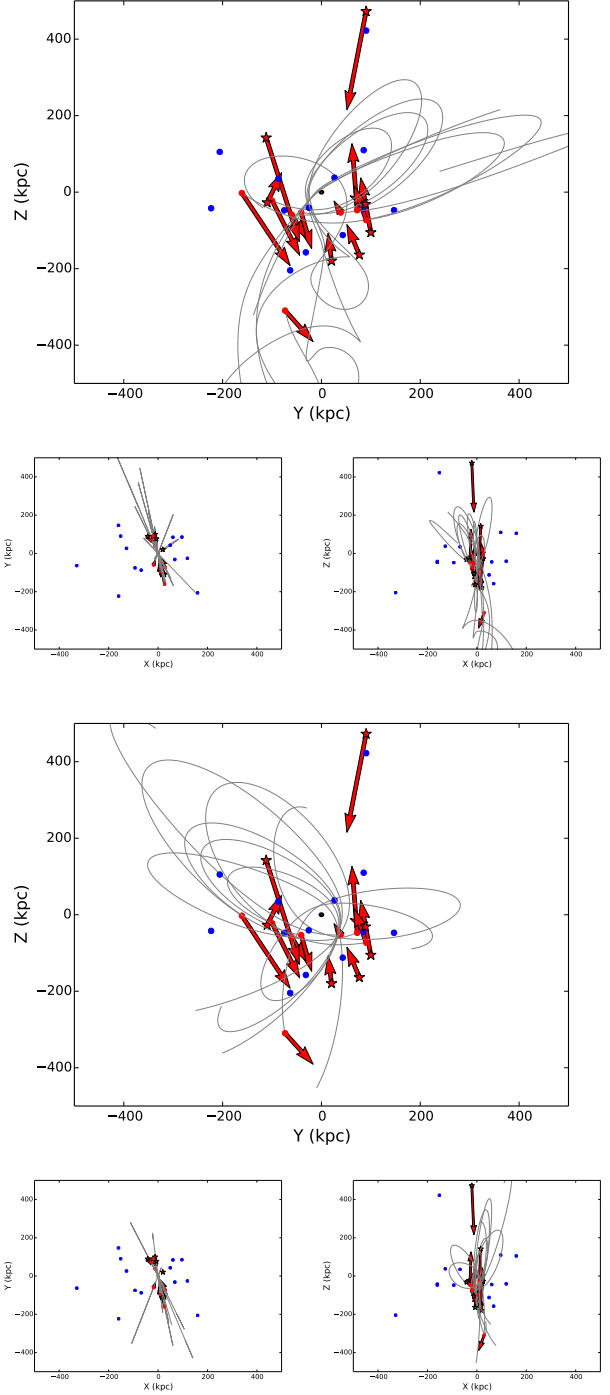


Figure 1. .

