A dynamical study of the vast thin plane of galaxies orbiting the Andromeda galaxy

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Observational Motivation

The origin of the recently discovered ´´vast thin plane of corotating dwarf galaxies´´ orbiting the Andromeda galaxy remains a puzzle (Ibata et al 2013). Such a structure, which is around 400 kpc in diameter and has a perpendicular scatter of less than 14.1kpc, cannot be explained by current galaxy formation models. Some alternative attempts have been made to explain this planar structure, but a validation or rejection of any possible formation scenario requires a rigorous dynamical understanding of the system. In this work, we carry out a numerical study of this plane of dwarf galaxies to better understand the dynamics and the long term stability of such a structure.

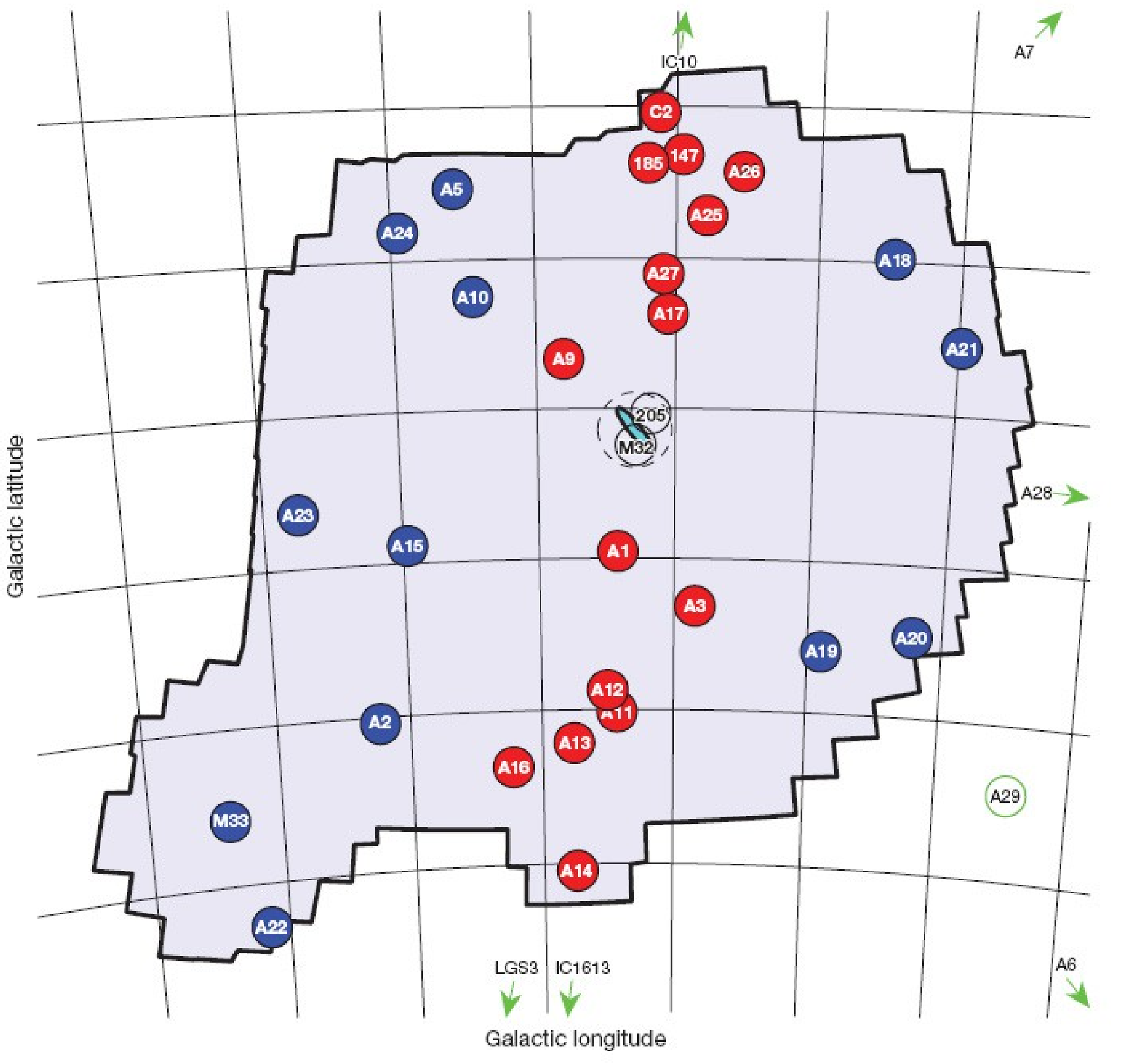
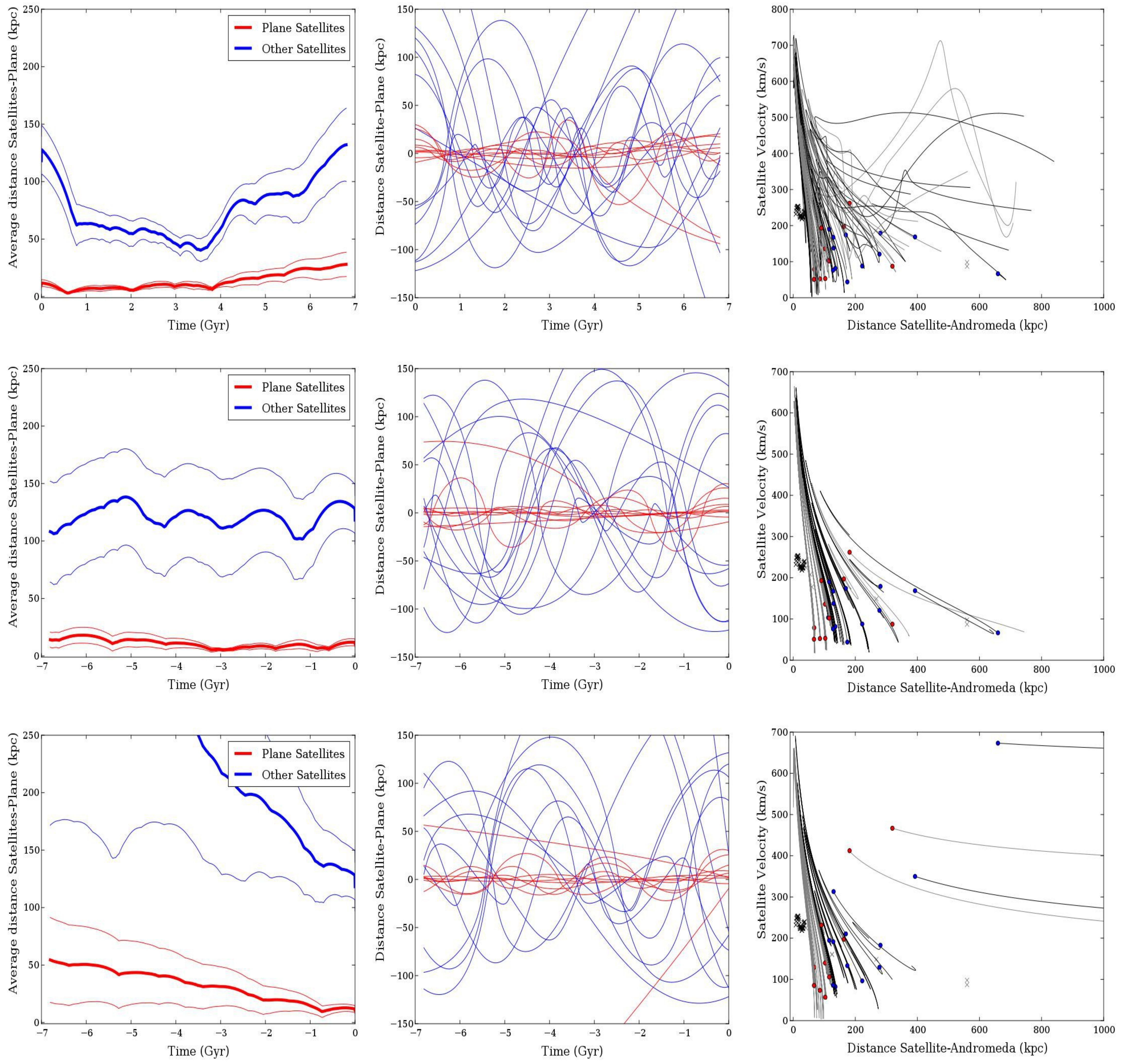


Figure 1 (from Ibata et al 2013) shows the satellite galaxies of Andromeda observed by the PAndAS survey (grey area). Red dots represent the satellites that are part of the planar structure and blue dots those that aren't.

Dynamical Analysis

We integrate the orbits of the different satellites, both backwards and forward in time, assuming they are point masses embedded in the potential of both Andromeda and the Milky Way galaxies.

As initial conditions we use the 3D positions (Conn et al. 2012) and line of sight velocities (Collins et al. 2013, Kalirai et al. 2010) of the different satellites.



Discussion

Figure 2 allows us to study the dynamics of the plane of satellites from different perspectives:

From the average distance of the two groups (plane and not) of satellites we can conclude that the plane of satellites is a long lived structure in particular for the backwards in time integration with the line of sight velocities as initial conditions.

The analysis of the individual distances (middle column) shows that increases in the average distance are due to individual satellites that become unbound (upper and lower rows).

Finally, the velocity- distance plots show that we must improve the inferred initial velocity of the satellites: On one hand, the minimum distance in several of the resulting orbits is too small for a satellite to survive such a close encounter with Andromeda. On the other hand, assuming a “circular” initial velocity results in unbound satellites. It is also important to note that in the forward in time integration, several satellites become unbound due to the increased proximity o the Milky Way and Andromeda.

Figure 2 shows three different sets of plots (columns) for three different cases (rows). In the left column, the evolution of the average distance to the best-fit-plane (Conn et al. 2013) is plotted both for the plane-satellites group (red line) and the non-plane-satellites group (in blue). In the middle column the distances are plotted for each individual satellite (using the same color coding). In the third column the magnitude of the orbital velocity of each satellite is plotted as a function of its distance to the center of Andromeda. The upper row corresponds to a forward in time integration, and the middle and bottom row to a backwards in time integration of the orbits. Additionally, the bottom row assumes that the initial velocities are ´´circular´´.

References

Conn, A. R.; Ibata, R. A.; Lewis, G. F.; Parker, Q. A.; Zucker, D. B.; Martin, N. F.; McConnachie, A. W.; Irwin, M. J.; Tanvir, N.; Fardal, M. A.; Ferguson, A. M. N.; Chapman, S. C. & Valls-Gabaud, D. A Bayesian Approach to Locating the Red Giant Branch Tip Magnitude. II. Distances to the Satellites of M31, The Astrophysical Journal, 2012, 758, 11

Conn, A. R.; Lewis, G. F.; Ibata, R. A.; Parker, Q. A.; Zucker, D. B.; McConnachie, A. W.; Martin, N. F.; Valls-Gabaud, D.; Tanvir, N.; Irwin, M. J.; Ferguson, A. M. N. & Chapman, S. C. The Three-dimensional Structure of the M31 Satellite System; Strong Evidence for an Inhomogeneous Distribution of Satellites, The Astrophysical Journal, 2013, 766, 120

Ibata, R. A.; Lewis, G. F.; Conn, A. R.; Irwin, M. J.; McConnachie, A. W.; Chapman, S. C.; Collins, M. L.; Fardal, M.; Ferguson, A. M. N.; Ibata, N. G.; Mackey, A. D.; Martin, N. F.; Navarro, J.; Rich, R. M.; Valls-Gabaud, D. & Widrow, L. M. A vast, thin plane of corotating dwarf galaxies orbiting the Andromeda galaxy, Nature, 2013, 493, 62-65

Collins, M. L. M.; Chapman, S. C.; Rich, R. M.; Ibata, R. A.; Martin, N. F.; Irwin, M. J.; Bate, N. F.; Lewis, G. F.; Peñarrubia, J.; Arimoto, N.; Casey, C. M.; Ferguson, A. M. N.; Koch, A.; McConnachie, A. W. & Tanvir, N. A Kinematic Study of the Andromeda Dwarf Spheroidal System, The Astrophysical Journal, 2013, 768, 172

Kalirai, J. S.; Beaton, R. L.; Geha, M. C.; Gilbert, K. M.; Guhathakurta, P.; Kirby, E. N.; Majewski, S. R.; Ostheimer, J. C.; Patterson, R. J. & Wolf, J. The SPLASH Survey: Internal Kinematics, Chemical Abundances, and Masses of the Andromeda I, II, III, VII, X, and XIV Dwarf Spheroidal Galaxies, The Astrophysical Journal, 2010, 711, 671