The General Assembly of Galaxy Halos: Structure, Origin and Evolution
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What can isolated elliptical galaxies tell us about Cold Dark Matter?

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Abstract. Due to their environment isolated elliptical galaxies (IEs) should not be undergoing extant evolutionary processes yet many IEs have interacting dwarf companions, and where no merger remnants are visible IEs are often dynamically young. Furthermore, some IEs do not require dark matter to explain their dynamics. However, according to Cold Dark Matter (CDM) simulations all elliptical galaxies should be dark matter dominated, even if isolated, and IEs are much rarer in nature than predicted by CDM. Moreover, merging at the $\sim 10^7$ $M_\odot$ level was recently discovered in the M31 system, showing that hierarchical merging may indeed be scale-free, as predicted by CDM. It seems a natural question to ask: what can IEs tell us about CDM? Here we analyse several IEs as probes of CDM. Our results spawn many new questions.

Keywords. galaxies: elliptical and lenticular, cD; galaxies: kinematics and dynamics; galaxies: structure; galaxies: evolution; galaxies: dwarf; galaxies: star clusters; dark matter

1. Introduction

Cold Dark Matter (CDM) theory has performed exceedingly well, and the existence of dark matter in spiral galaxies, or the possibility of a gravitational interaction which differs from that of Newtonian gravity, is not generally disputed. While it seems that central cluster galaxies and some of the most massive galaxies in the Fornax and Virgo clusters are embedded in massive dark haloes (Kelson *et al.* 2002, Schuberth *et al.* 2012), isolated elliptical galaxies (IEs) and galaxies in less dense environments are only beginning to be studied in detail.

IEs are important probes of CDM because, while galaxies in dense environments have been shown to behave dynamically as CDM predicts, some IEs have been shown not to require any DM to explain their dynamics (Richtler *et al.* 2015, Lane *et al.* 2015), in opposition to CDM, and CDM simulations predict many more IEs than we find in nature (Niemi *et al.* 2010). Furthermore, due to their environment the evolution of IEs should have stopped. However, many IEs have interacting dwarf companions (Lane *et al.* 2013, Richtler *et al.* 2015) or have dynamically young stellar populations (Lane *et al.* 2015), and merging at the $\sim 10^7$ $M_\odot$ level was recently discovered in the M31 system (Amorisco *et al.* 2014). These latter results are directly predicted by CDM simulations.

It is, therefore, vitally important that the dynamics of IEs are reconciled with CDM theories if we are to further our understanding of dark matter.

2. Results

One of the major results of this work is the extension of the study by Salinas *et al.* (2012) who found no requirement for DM in the inner $\sim 1R_e$ in NGC 7507. In Lane

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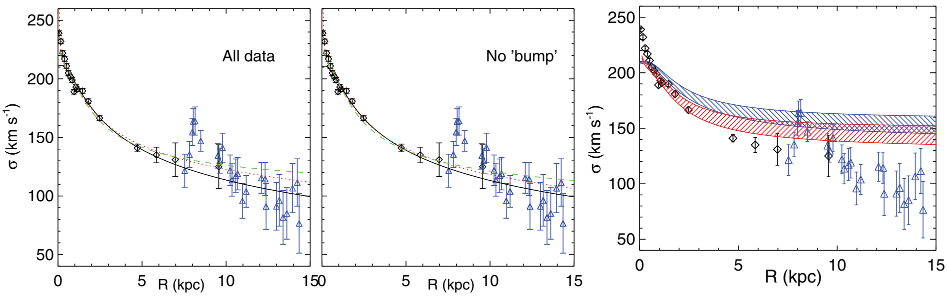

Figure 1. Velocity dispersion versus galactocentric radius for NGC 7507. Filled squares are from GMOS longslit spectra (Salinas *et al.* 2012), open squares are from GMOS slitmask spectra (Lane *et al.* 2015). *Left and middle panels:* models which consider all the velocity dispersion points. The solid black curve is the stars-only model. The red dotted curve is the best-fitting model with $\beta = 0.3$ and NFW halo with $c = 10$. The green dashed curve is the model under the anisotropy by Mamon & Łokas (2005) allowing the maximum amount of dark mater. *Middle panel:* same as left panel, but excluding the velocity dispersion "bump" between $70'' < R < 80''$ for the fits. *Right panel:* MOND models. Symbols as in the other panels. The blue hatched area covers isotropic models with the range of accepted a_0 values from Famaey *et al.* (2007), while the red area represents the same range for a_0 but under Mamon & Łokas (2005) anisotropy.

et al. (2015), using Jeans model fitting to velocities resulting from multi-object spectroscopic data, we extended the measured velocity dispersion to $\sim 3R_e$, and still find no requirement for dark matter to explain the dynamics of this system and, furthermore, our MOND models do not fit the data at any radii (see Figure 1).

Another interesting IE is NGC 7796 which has a dwarf companion with three separate young ($\sim 10^9$ Gyr) blue cores (Richtler *et al.* 2015). This appears to be evidence for hierarchical clustering at the $\sim 10^6\,\mathrm{M}_\odot$ level, the lowest mass merging yet uncovered. Furthermore, the companion is tidally disrupting, the first evidence of hierarchical merging at two different mass scales in the same system – something that is clearly predicted by CDM. A massive dark halo is, however, excluded by currently available data, although *some* dark matter, as required for the baryonic Tully-Fisher relation, might be present.

3. Conclusions

The more we search the more IEs we find that do not necessarily require any DM to describe their dynamics. This is puzzling because CDM tells us that all massive galaxies should be DM dominated. What is special about IEs that make them good candidates for this behaviour? That is a question that does not, as yet, have an answer.

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