The Hierarchical Origins of Galaxy Morphology

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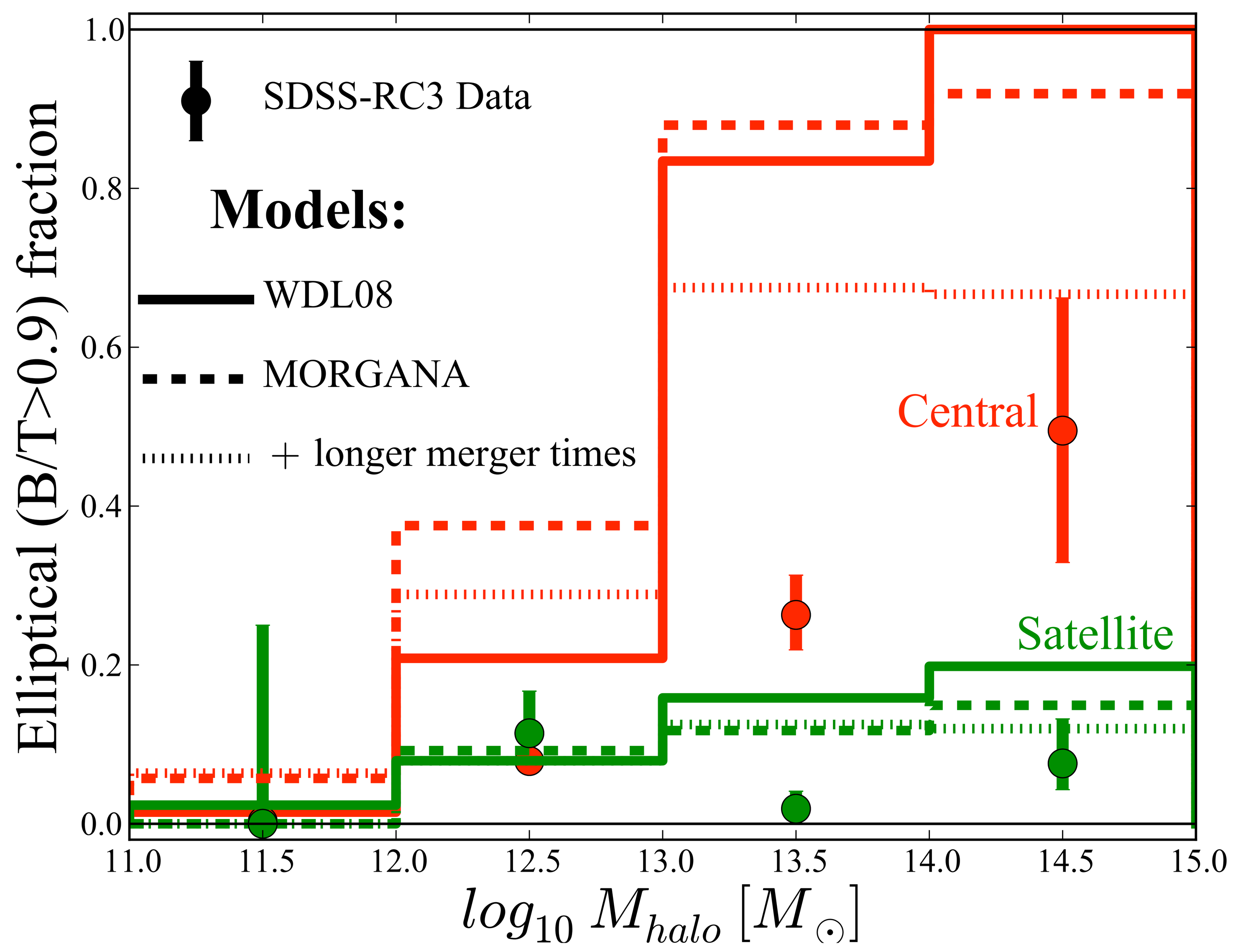
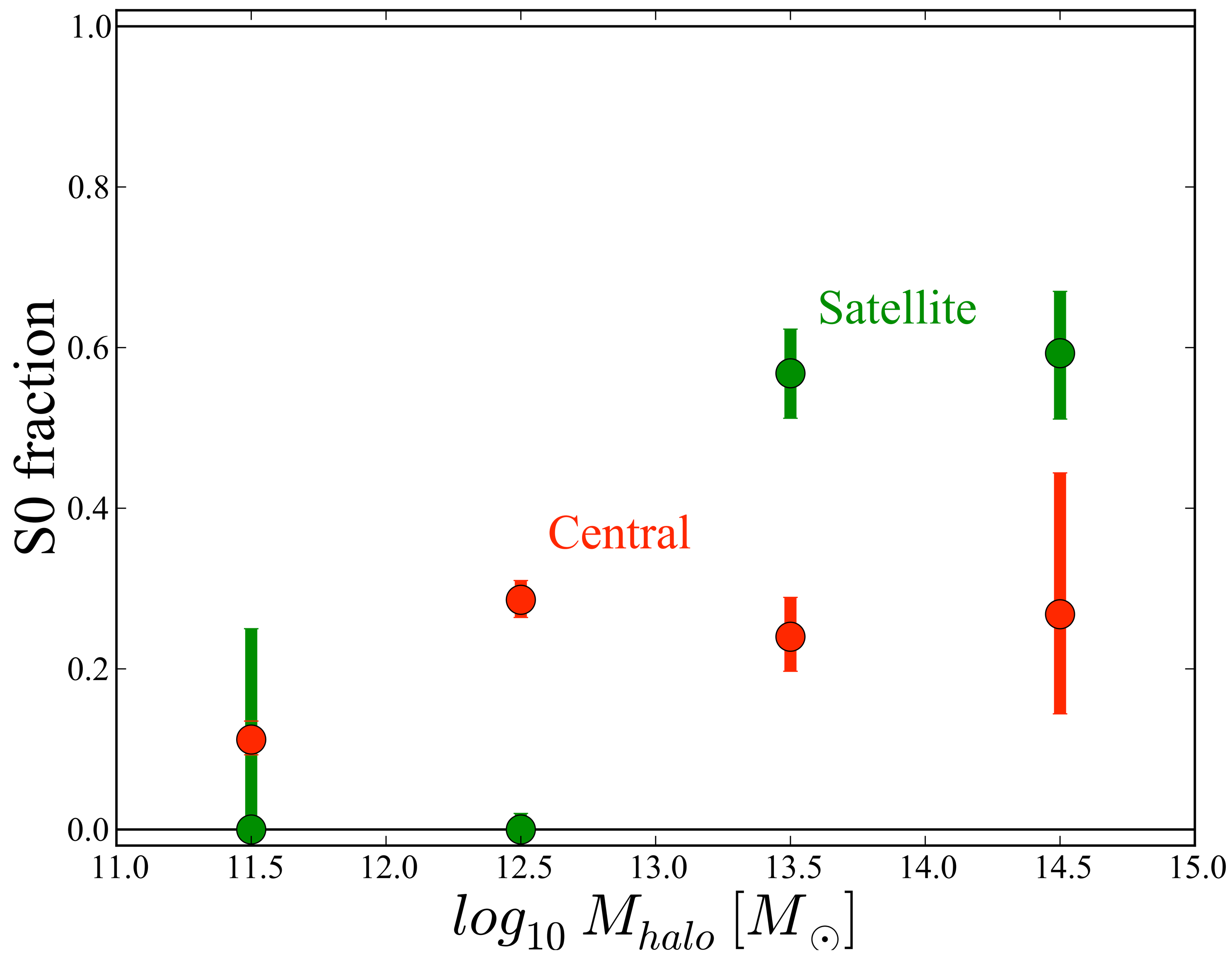
We find that ellipticals are especially abundant in the cores of massive halos, consistent with a merger origin. In contrast, there are two distinct components to the S0 population: ~25% of central galaxies are S0 at all halo masses, while ~60% of satellite galaxies are S0 - but only in haloes of mass $>10^{13}M_\odot$. This can be explained if there are two distinct processes for suppressing star formation and spiral arms in disk galaxies.

The evolution of galaxies and their local environment is heavily intertwined within a CDM cosmology. In dense clusters and groups, elliptical and lenticular galaxies predominate, the fraction correlating with the local density of galaxies within the cluster [1,2]. We match the RC3 catalogue with well understood morphological classifications [3] to the SDSS DR4, with accurate photometry and highly complete halo catalogues [4]. We present incompleteness-corrected fractions of morphological types as a function of halo mass for M_B<-19 galaxies at z~0, separated according to whether they are the central galaxy or a satellite galaxy within their halo.





Above: Fractions of Elliptical (Left) amd S0 (Right) galaxies as a function of halo mass, computed at z~0 for galaxies of luminosity M_B<-19, and subdivided into central (red) and satellite (green) populations. Overplotted in the left panel is the fraction of B/T>0.9 galaxies from Wang et al, 2008 (WDL08 [5]) and MORGANA (Monaco et al, 2007 [6]) models in which bulges form only in mergers (pure merger models, see De Lucia et al, 2011 [7]), and a second implementation of MORGANA with longer merger times (time from halo merger until their central galaxies merge).

The morphological dichotomy seen when dividing central from satellite galaxies is striking.

Elliptical galaxies are more common amongst central galaxies, increasing steeply with halo mass, whilst satellite ellipticals are rare at any halo mass. This is consistent with their formation in the centre of haloes where dynamical friction means that mergers will typically take place - semi-analytic models from Wang et al, 2008 (WDL08 [5]) and MORGANA (Monaco et al, 2007 [6]), adapted so that all bulges form in mergers, qualitatively reproduce these trends, but overproduce ellipticals in massive haloes. As described by De Lucia et al, 2011 [7], a longer merger time - the delay between the halo merger and the merger of their central galaxies - sensibly reduces the fraction of ellipticals formed by MORGANA.

The observed fraction of central galaxies with lenticular morphology is ~25%, almost independent of halo mass, suggesting that halo mass independent processes can transform spirals into lenticular galaxies. Satellite galaxies are remarkably different - in our sample no lenticular lives as a satellite in haloes of mass $< 10^{13}M_\odot$, whereas above this threshold they make up ~55-60% of the satellite population! This suggests a second, environmental mechanism which suppresses star formation and spiral arms in disk galaxies, but only after accretion as a satellite onto a halo of mass $> 10^{13}M_\odot$.

References:

[1] Dressler, 1980, ApJ, 236, 351
[2] Wilman et al, 2009, ApJ, 692, 298
[3] de Vaucouleurs et al, 1991, Third Reference Catalogue of Bright Galaxies
[4] Yang et al., 2007, ApJ, 671, 153
[5] Wang, De Lucia et al., 2008, MNRAS, 384, 1301
[6] Monaco, Fontanot & Taffoni, 2007, MNRAS, 375, 1189
[7] De Lucia, Fontanot, Wilman & Monaco, 2011, MNRAS, 414, 1439