The ATLAS^{3D} project : A paradigm shift for early-type galaxies

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Abstract. In this short paper, we present a few preliminary results from the ambitious ATLAS^{3D} project, which intends to probe the first volume-limited sample of early-type galaxies observed via multi-band photometry, integral-field spectroscopy, radio and millimeter observations, and supported by a large library of numerical simulations and models. We more specifically address the existence of two main families of early-type galaxies, the slow and fast rotators.

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INTRODUCTION

Early-type galaxies represent nearly half of the stellar mass density in the nearby universe [1]. As such they are thought to correspond to the end product of violent processes such as mergers and harassment in dense environments. The standard classification allows for a transition from spiral galaxies to ellipticals via the S0 class [5], i.e. bulge-dominated disk galaxies. This scheme has been used for decades to probe galaxy populations at various redshifts and reconstruct the formation and evolution scenarios. In this short paper, we present some new results obtained in the course of the ATLAS^{3D} project (`http://purl.org/atlas3d`), and sketch what could be a significant shift in the current paradigm for early-type galaxies.

TOWARDS SLOW AND FAST ROTATORS

We have now conducted an ambitious multi-wavelength survey of a volume limited sample of 261 early-type galaxies, complemented by state-of-the-art numerical simulations (see [2] in this volume) and models. This observational and modeling campaign includes data on the ionised, molecular and neutral gas and two-dimensional mapping of the stellar kinematics and stellar populations, simulations of galaxy mergers and clusters, semi-analytic predictions and detailed dynamical modeling.

Using SAURON two-dimensional spectroscopy, [3] and [4] have shown that there seem to be two families of early-type galaxies: the fast rotators which have regular stellar kinematics, contain disks, and slow rotators which exhibit no or low apparent angular momentum per unit mass (λ_R), have stellar kinematics misaligned with the photometry and often contain kinematically decoupled components (KDCs). We now extend this view with ATLAS^{3D} with a complete sample of galaxies properly accounting for the galaxy luminosity function down to about -21.5 in K: nearly 90% of all early-type galaxies within the probed volume are fast rotators, slow rotators representing then only a minor fraction of such a population. Nearly all slow rotators do contain kinematically decoupled cores (KDCs, hereafter), which thus seem to be a common feature in galaxies with low specific baryonic angular momentum.

THE NEED FOR A SCALE

In Figure 1, we are showing the λ_R values with respect to the ellipticity values within 1 R_e (bottom panel) and $R_e/2$ (top panel). We also use different symbols when the galaxy includes a KDC or showing no apparent rotation (triangles) and others (circles).

There is a clear trend for galaxies with KDCs to have low apparent angular momentum. This is easily seen in the bottom panel of Figure 1 where the values are derived for 1 R_e, but as ellipticity increases, there is a general trend for galaxies to have λ_R also increasing. This is expected as a constant anisotropy curve would have exactly such a behaviour, and galaxies with similar λ_R values but significantly different ellipticities must have very different orbital structures.

This picture gets even clearer when we use λ_R measured within $R_e/2$ (top panel of Figure 1). The separation line between the two broad classes of galaxies is in fact consistent with the threshold of $\lambda_R = 0.1$ mentioned in [3]. Two effects probably concur to blur this result when we move to larger apertures (see also [7] in this volume). First, obviously a number of galaxies in the ATLAS^{3D} sample are not fully covered up to 1 R_e which may affect their exact position on such a diagram. But more importantly, we do expect that a large majority of galaxies have *increasing* λ_R profile, angular momentum being expelled outwards. This is clearly observed in our complete sample of galaxies, with objects having ellipticities above 0.3 tending to have a more rapidly increasing λ_R profile. $R_e/2$ therefore appears as a better discriminant for the two observed populations.

We definitely need to consider a fixed relative scale as to design a robust classification scheme, and to conduct relevant comparisons between various subsamples of galaxies. While larger field coverage may obviously bring additional constraints on the overall, large-scale, structures for these galaxies, the signatures for slow and fast rotators seem

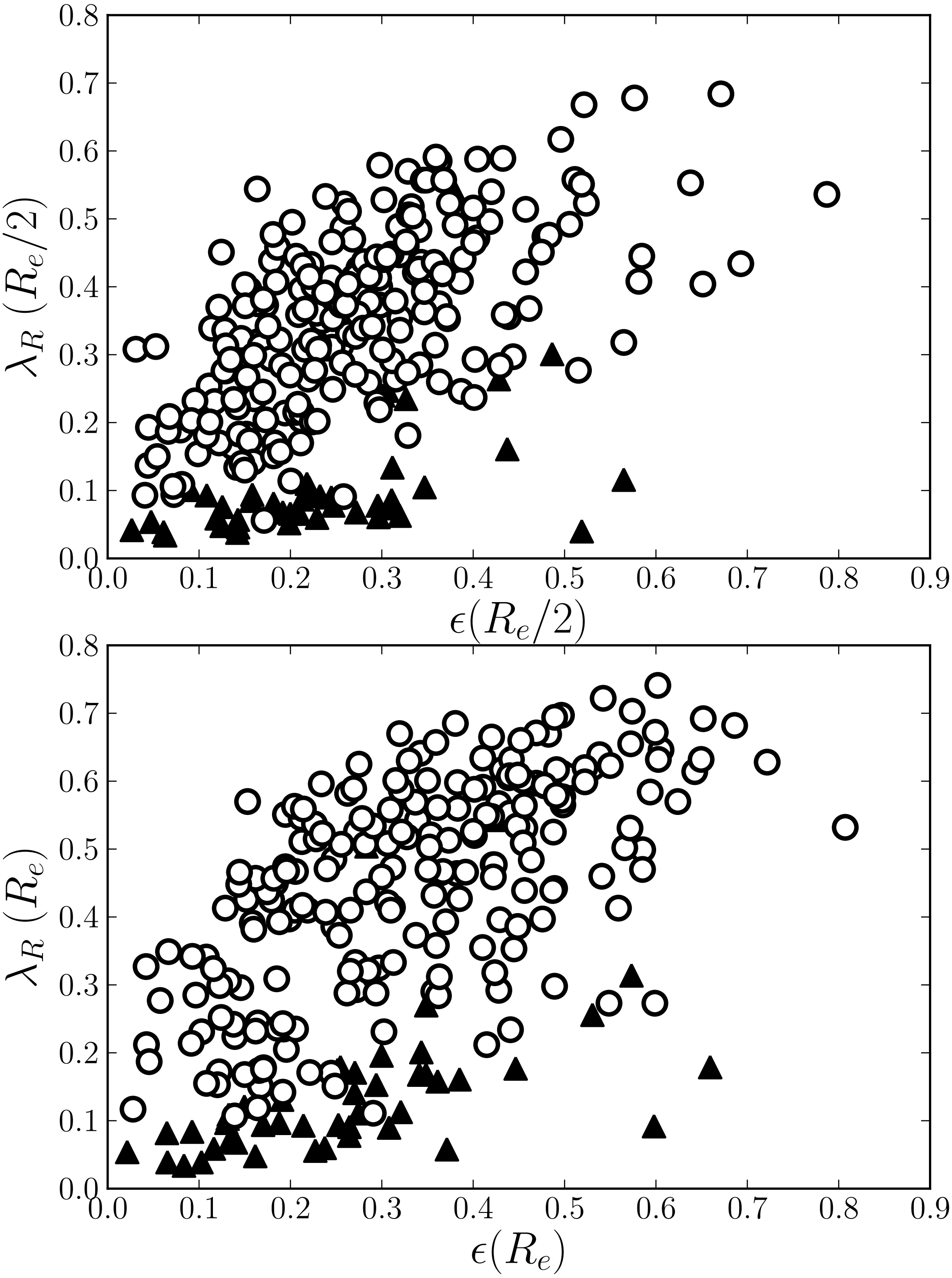

FIGURE 1. λ_R versus ellipticity ε as measured within 1 R_e (bottom panel) and $R_e/2$ (top panel). Galaxies hosting a kinematically decoupled component or having no apparent rotation are shown as filled triangles, the others, generally showing regular rotation and small kinematical misalignments, as circles.

to be optimally defined at a relatively small radius, such as $R_e/2$. This is confirmed by high resolution simulations of mergers ([2] in this volume).

CONCLUSION

The apparent angular momentum per unit stellar mass of early-type galaxies already provides new insights regarding the importance of major and minor mergers in their formation and assembly [6, 2]. Stars accreted during minor merging events may for instance be observed at large radii, wrapped around the most massive progenitor, thus causing a significant change in the baryonic angular momentum vector. However, the inner regions of early-type galaxies appear as keys to understand their overall history, with λ_R at one half of the effective radius holding an important signature of the assembly processes.

In a coming series of papers, we will refine this view via the large dataset of ATLAS^{3D} multi-wavelength observations, state-of-the-art simulations and modeling. This will provide us with strong constraints on the formation and evolution scenarios for early-type galaxies, and more specifically on the assembly of slow and fast rotators.

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