*GALAXIES IN ISOLATION: EXPLORING NATURE VERSUS NURTURE*
*ASP Conference Series, Vol. 421, 2010*
*L. Verdes-Montenegro, A. del Olmo, and J. W. Sulentic, eds.*

# Early-type Galaxies in Isolation: an H I Perspective with ATLAS$^{3D}$

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**Abstract.** We present preliminary results of our H I WSRT observations of early-type galaxies in the ATLAS$^{3D}$ sample. We discuss the dependence of H I properties on environment. We detect H I in about half of the galaxies outside the Virgo cluster. The H I morphology/kinematics changes as a function of environment, going from regular, rotating systems around "isolated" galaxies to progressively more disturbed structures for galaxies with neighbours or in groups. In denser environment, inside Virgo, nearly none of the galaxies contains H I.

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## 1. Early-Type Galaxies and the ATLAS$^{3D}$ Project

Nearby early-type galaxies (ETGs) are a fundamental class of objects. They provide a fossil record of galaxy assembly and allow us to study the physical processes that drive the continuing evolution of galaxies at $z\sim0$. Their proximity enables detailed studies at high spatial/spectral resolution and high signal-to-noise ratio. However, work done so far has been limited to relatively small and incomplete samples (e.g., de Zeeuw et al. 2002; Thomas et al. 2005). The ATLAS$^{3D}$ project, which we discuss in this contribution, is an attempt to overcome this limitation.

ATLAS$^{3D}$ (http://purl.org/atlas3d) is a complete, multi-wavelength, volume-limited survey of 262 nearby ETGs, supported by numerical simulations and semi-analytic models of galaxy assembly. The ATLAS$^{3D}$ sample is selected on the basis of optical morphology from a parent sample of 844 galaxies (of all types) meeting the criterions *distance* $\leq$42 Mpc and $M_K \leq -21.5$ (with additional constraints on declination and galactic latitude). The morphological classification is based on the (non-) detection of spiral arms in optical images taken from SDSS DR6 (available for 82% of the parent-sample) or DSS2-blue. A detailed description of the sample selection and its characterisation in terms of, for example, luminosity function, distribution on the colour-magnitude diagram and environment can be found in Cappellari et al. (in prep.). Nearly all ATLAS$^{3D}$ galaxies lie on the bright part of the red sequence defined in Baldry et al. (2004). The Virgo cluster of galaxies is included in the sample, so that we span a factor of $\sim 10^3$ in environment density. The luminosity function of the sample follows that of larger, $z\sim0$ samples (e.g., Bell et al. 2003).

Data taken within the ATLAS$^{3D}$ project include optical integral-field spectroscopy with SAURON; molecular-gas, millimetre, single-dish observations with IRAM and interferometric follow-up of detections with CARMA; and neutral-hydrogen 21-cm interferometry with the WSRT. Furthermore, INT SDSS-like imaging has been obtained for ATLAS$^{3D}$ galaxies outside the SDSS coverage.

The observation of H I gas in ETGs is a fundamental component of the ATLAS$^{3D}$ project. In particular, deep radio interferometry allows us to determine the detailed morphology and kinematics of the H I around ETGs. As proven by previous work, this is important to study the state of the cold gas as a signature of the recent gas-accretion history of the host galaxy (e.g., Morganti et al. 2006). In this contribution, we present preliminary results of our H I observations focusing on the dependence of ETG H I properties on environment.

## 2. HI and Environment of Early-Type Galaxies

The ATLAS$^{3D}$ H I observations consist of a 12-h WSRT integration per galaxy for objects at DEC$\geq$+10 deg and outside the Virgo cluster. Galaxies inside the Virgo cluster have been observed by the Alfalfa collaboration (Giovanelli et al. 2005) and were re-observed by us with the WSRT only in the few cases of Alfalfa detection. In Fig.1 we show the detected H I mass plotted against the $K$-band total luminosity for nearly all objects. Open and filled symbols represent galaxies inside and outside the Virgo cluster respectively. Circles and triangles represent detected and non-detected objects respectively. In case of undetected objects,

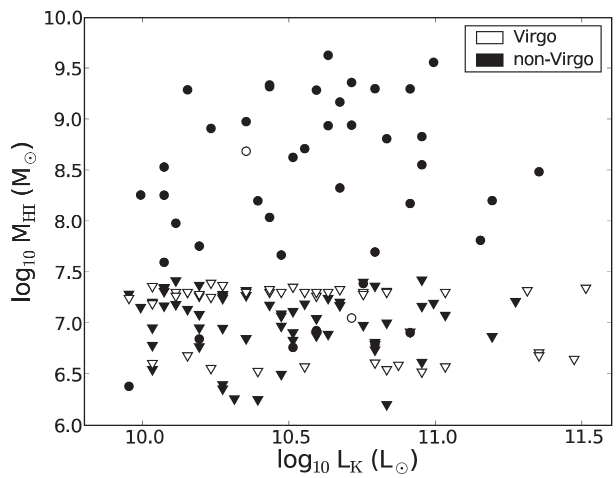


Figure 1. H I content of nearly all ETGs in the ATLAS$^{3D}$ sample at DEC$\geq$+10 deg. Open and filled symbols correspond to Virgo and non-Virgo galaxies respectively. Circles are H I-detected galaxies, triangles are upper limits on $M$(H I) (see text).

the upper limit on $M$(H I) is calculated assuming a $3\sigma$ signal spread over 200 km/s. Outside Virgo, about half of all ETGs contain H I at the $M$(H I)$\geq 10^7$-$M_{\odot}$ level. This confirms earlier (but less complete) results showing that H I is a fairly common characteristic of ETGs outside the densest environments (e.g., Morganti et al. 2006; Oosterloo et al. 2007; Grossi et al. 2009).

The distribution of points in Fig.1 shows a very strong environmental effect: ETGs become much less-likely to contain H I if they reside inside the Virgo cluster (see Grossi et al. 2009). The hot intra-cluster medium and the high galaxy-density in Virgo prevent galaxies from retaining and/or accreting H I, as is evident also from the observation of late-type objects (Chung et al. 2009).

Our WSRT H I images reveal another interesting environmental effect. Gas in/around galaxies residing in the lowest-density environment appears more relaxed than gas in/around galaxies residing in, e.g., groups. To perform this analysis we define the environment of a galaxy as a cylinder of radius 2 Mpc on the sky and depth 600 km/s in line-of-sight velocity, centred on the galaxy itself. The total luminosity (or the luminosity density) of galaxies inside this cylinder can be used as an estimate of the environment density and was calculated using the parent sample described in Sec.1., limited to $M_K \leq -21.5$.

In Fig.2 we show a few typical examples of H I-detected ATLAS$^{3D}$ ETGs outside the Virgo cluster. The top row contains galaxies in higher-density environment (e.g., small groups). The bottom row contains “isolated” galaxies, i.e., systems for which no other galaxy could be found within the cylinder defined above (and at the magnitude limit of the parent sample). The H I around “isolated” galaxies is typically found in extended, regularly-rotating distributions, significantly more relaxed than the H I detected around objects in denser environments. The rate at which galaxies interact with their satellites and neighbours is naturally determined by the environment density. The H I properties

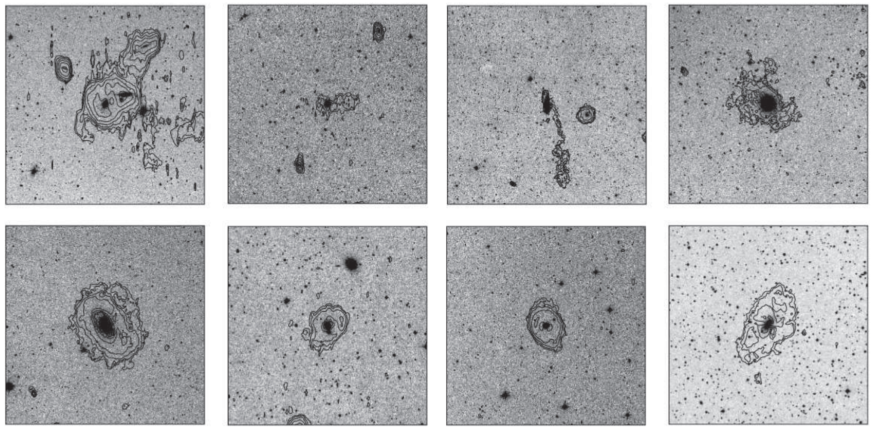

Figure 2. Preliminary H I images of some of the galaxies in the ATLAS$^{3D}$ sample outside the Virgo cluster. Black contours of constant H I column density are plotted on top of optical DSS images. All images have a side of 180 kpc. H I contours are drawn at $\sim 1.5{\cdot}2^n \times 10^{19}$ cm$^{-2}$ ($n$=0,1,2,...). The top row shows galaxies in higher-density environment (e.g., groups). The bottom row shows isolated galaxies (see text for our definition of isolation).

of ETGs show convincingly that such interaction is still occurring at $z{\sim}0$ and is a fundamental driver of ETG gas properties. In the most quiet environment, there is sufficient time for ETGs to accrete regular but dilute H I systems that can survive for many Gyrs (i.e., many gas orbits) without forming a stellar disc.

## 3. Conclusions

We have presented preliminary results of an H I WSRT survey of ETGs in the ATLAS$^{3D}$ sample. We confirm a strong dichotomy between Virgo and non-Virgo galaxies, with the former being systematically H I-poorer than the latter. We find that, outside Virgo, H I systems become progressively more settled as the environment density decreases. "Isolated" ETGs are characterised by very regular, rotating cold-gas systems while galaxies with neighbours or residing in galaxy groups typically have disturbed H I morphology/kinematics. This confirms that environment is a fundamental driver of ETG's evolution at $z{\sim}0$.

### References

Baldry I. K., et al. 2004, ApJ, 600, 681
Bell E. F., et al. 2003, ApJ, 149, 289
Chung A., et al. 2009, ArXiv e-prints
Giovanelli R., et al. 2005, AJ, 130, 2598
Grossi M., et al. 2009, A&A, 498, 407
Morganti R., et al. 2006, MNRAS, 371, 157
Oosterloo T. A., et al. 2007, A&A, 465, 787
Thomas D., et al. 2005, ApJ, 621, 673
de Zeeuw P. T., et al. 2002, MNRAS, 329, 513