VESTIGE: A VIRGO ENVIRONMENTAL SURVEY TRACING IONISED GAS EMISSION

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Abstract. VESTIGE is a deep, blind narrow-band Hα+[NII] imaging survey of the Virgo cluster carried out with MegaCam at the CFHT. This survey covers the cluster up to one virial radius (104 deg^2) at a sensitivity of $f(H\alpha) = 4 \times 10^{-17}$ erg s^{-1} cm^{-2} (5σ detection limit) for point sources and $\Sigma(H\alpha) = 2 \times 10^{-18}$ erg s^{-1} cm^{-2} arcsec^{-2} (1σ detection limit at 3 arcsec resolution) for extended sources. This survey has been designed to detect extended low surface brightness features produced after the interaction of galaxies with the surrounding environment, and thus shade light on the role of the environment on galaxy evolution. We briefly describe the technical aspects of the survey and we summarise the first scientific results obtained after one semester of observations.

Keywords: galaxies: clusters: general, galaxies: clusters: individual: Virgo, galaxies: evolution, galaxies: interactions, galaxies: ISM

1 Introduction

Deep narrow-band imaging surveys are becoming one of the most powerful observing technique to identify galaxies undergoing a perturbation in dense environments. Indeed, the interaction of galaxies with other objects or with the surrounding hot intracluster medium typical of high density regions such as clusters and groups produces tails of ionised gas that can be detected with deep observations through interferential filters centered on the Hα line at λ 6563 Å. Spectacular tails of ionised gas have been detected in the clusters A1367 (Gavazzi et al. 2001; Cortese et al. 2006), Coma (Yagi et al. 2010; Fossati et al. 2012), Norma (Zhang et al. 2013) and Virgo (Yoshida et al. 2002; Kenney et al. 2008; Boselli et al. 2016a, 2018a; Fossati et al. 2018) and are now predicted by hydrodynamic simulations (Tonnesen & Bryan 2010). For this reason we have proposed to carry on a deep, blind narrow-band Hα+[NII] imaging survey of the whole Virgo cluster region up to its virial radius (104 deg^2) using MegaCam at the CFHT. This large program named VESTIGE (A Virgo Environmental Survey Tracing Ionised Gas Emission; `https://mission.lam.fr/vestige/team.html`.) has been awarded of 50 nights and started in spring 2017. The ultimate aim of this ambitious program is that of understanding the role played by the environment in shaping galaxy evolution (Boselli & Gavazzi 2006, 2014). In this short communication we briefly introduce the survey with its technical aspects and we summarise the first results obtained after one year of observations. For a more detailed description of the large program VESTIGE and of its scientific goals we refer the reader to a dedicated publication (Boselli et al. 2018b). The first spectacular results obtained by the team have been published in Boselli et al. (2016a) using pilot observations and in Boselli et al. (2018a) and Fossati et al. (2018) using the data acquired after one year of observations.

2 The Virgo cluster

The Virgo cluster is the ideal laboratory to study the nature of the different kind of perturbations acting on galaxies in rich environments. Located at a distance of 16.5 Mpc (Gavazzi et al. 1999; Mei et al. 2007), Virgo is the closest concentration of galaxies to the Milky Way. Thanks to its proximity, all galaxies down to the dwarf population can be easily resolved at different frequencies, providing thus a unique database for statistical

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studies or for dedicated analyses of representative objects. It is a cluster in formation, with a large fraction of late-type systems with properties suggesting an ongoing transformation (Vollmer et al. 2001; Boselli et al. 2014b,a, 2016b; Gavazzi et al. 2013). Furthermore, multifrequency data of excellent quality are already available for this regions, including GALEX UV (the GUViCS survey, Boselli et al. (2011)) and optical *ugiz* imaging data (the NGVS survey, Ferrarese et al. (2012)), as well as far-IR *Herschel* (the HeViCS survey, Davies et al. (2010), the HRS, Boselli et al. (2010)) and HI data (the ALFALFA survey, Giovanelli et al. (2005)). A huge amount of multifrequency data for the Virgo cluster are collected on the GOLDMine database (Gavazzi et al. 2003).

3 The survey

The VESTIGE survey has been designed to cover the whole Virgo cluster region up to its virial radius (104 deg^2). As defined, this region perfectly matches that covered by the NGVS survey of Ferrarese et al. (2012) in the optical bands, which has been able to detect $\sim$ 5000 objects identified as Virgo cluster members (Ferrarese et al. 2016). The survey is carried out in two different filters, a narrow-band Hα+[NII] filter ($\lambda = 6591$ Å, $\Delta\lambda = 106$ Å), with a typical transmissivity of 93%, and the broad r-band filter for the subtraction of the stellar continuum. The data are taken following a specific observing strategy especially tuned to minimise the reflections of stars within the frame and to optimise the detection of extended low surface brightness features as those expected in interacting systems. Two hours of integration in the narrow-band filter and 12 minutes in the broad-band filters are required for this purpose. The data are reduced using Elixir-LSB, a specific pipeline designed to detect extended low surface brightness features. The typical sensitivity of the survey is of $f(H\alpha) = 4 \times 10^{-17}$ erg s^{-1} cm^{-2} (5σ detection limit) for point sources and $\Sigma(H\alpha) = 2 \times 10^{-18}$ erg s^{-1} cm^{-2} arcsec^{-2} (1σ detection limit at 3 arcsec resolution) for extended sources. The data acquired so far are of excellent imaging quality, with a typical seeing of 0.65 arcsec in both bands (see Boselli et al. (2018b) for details).

The survey started in spring 2017 (semester 2017B) and continued for a couple of nights in 2018A (January), when the Virgo cluster is observable (12h<R.A.<13h). Unfortunately the whole 2018B semester has been lost for bad weather conditions (only 3 hours of observing time out of the 76 hours programmed were useful !). The status of the survey in fall 2018 is depicted in Fig. 1. Figure 1 shows that we are well below the expected completion (41 %) after one year of observations, and that the scientific success of this project will be seriously compromised if the same success rate will be attended in the next years. Luckly, the TAC of the CFHT has decided to support all the ongoing large programs to guarantee the sufficient completeness necessary for the full exploitation of the data.

4 The first results

The data obtained during the 2017 observing campaign or during a few pilot observations carried out in 2015 and 2016 to test the feasibility of the project have provided excellent results. We were able to detect spectacular tails of ionised gas associated to galaxies undergoing a ram pressure stripping event such as NGC 4569 (Boselli et al. 2016a) and NGC 4330 (Fossati et al. 2018), the presence of extraplanar HII regions in the tidal tail of NGC 4254 (Boselli et al. 2018a), and filaments of ionised gas in the Markarian chain NGC 4438-M86 (Boselli et al. 2018b). The images of NGC 4569 and NGC 4438-M86, included in the central 4×1 deg^2 strip, are shown in Fig. 2 and extensively described in Boselli et al. (2016a) and Boselli et al. (2018b).

5 Scientific objectives

As extensively described in Boselli et al. (2018a), the unique set of narrow-band imaging data that VESTIGE will provide will be used to study different aspects of galaxy evolution. We will be able to identify on a strong statistical basis the fraction of galaxies undergoing a perturbation through the detection of extended tails of ionised gas. The Hα luminosity of galaxies will be measured to estimate their star formation activity (Kennicutt 1998; Boselli et al. 2009), derive the main star forming scaling relations and measure the star formation luminosity function in cluster galaxies (e.g. Boselli et al. (2015)). They will also be used to study the fate of the stripped gas within the cluster (e.g. Fossati et al. (2016)), the ionised gas emission in early-types (e.g. Gavazzi et al. (2018)) and the formation of dwarf ellipticals in dense regions (e.g. Boselli et al. (2008a,b)). Point sources will be detected and identified as planetary nebulae (e.g. Longobardi et al. (2013)) in the cluster or background [OIII], [OII], and Lyα line emitters (e.g. Ouchi et al. (2008)), for which we plan to estimate

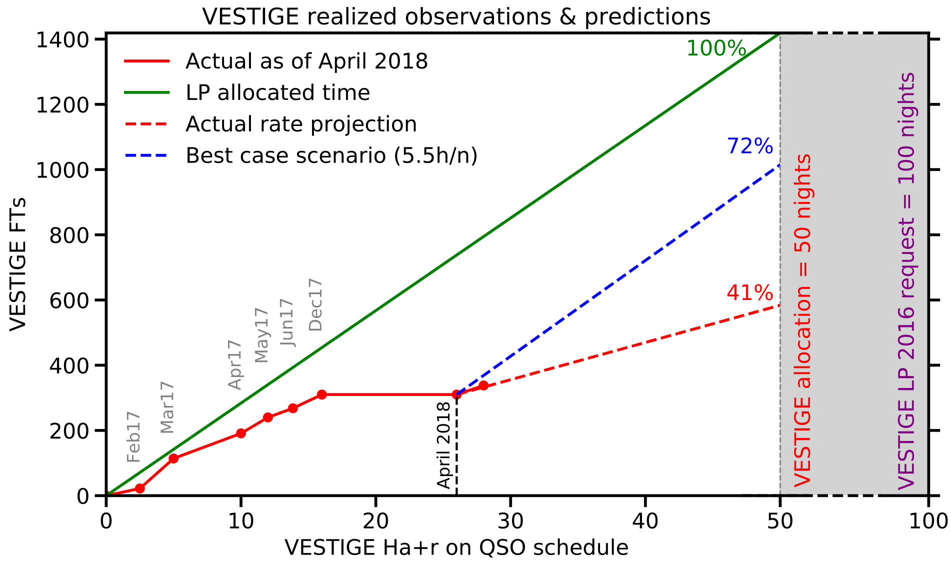

Fig. 1. Status of the VESTIGE survey at the end of semester 2018B (April, given the position of Virgo in the sky). Out of the 100 nights requested to complete this project, 50 were allocated. To be completed, 1417 frames per band must be taken (green line). At present only 41% of the programmed exposures have been taken mostly because of the poor weather conditions encountered at Mauna Kea in spring 2018 (red line)

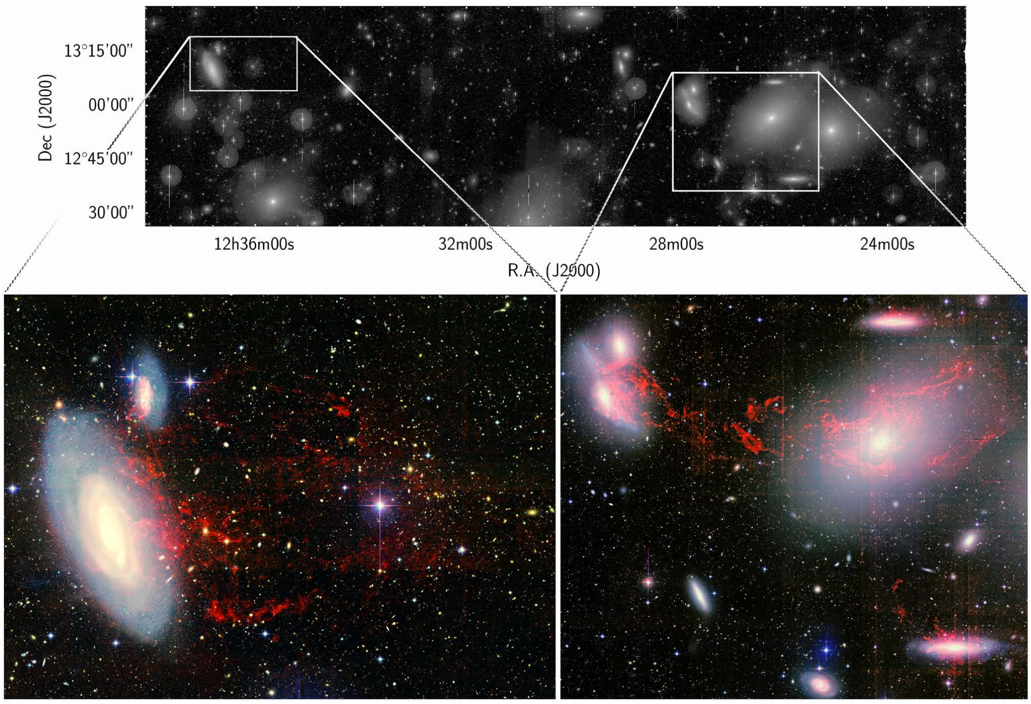

Fig. 2. Upper panel: g-band image of the 4×1 deg^2 strip of the core of the cluster north of M87. The lower panels are a magnified view of the boxed regions marked on the upper panel. They show the pseudo-colour images of NGC 4569 and IC 3583 (lower-left panel) and of the NGC 4438-N4388-M86 complex (Markarian chain, lower right panel) obtained combining the NGVS optical u and g in the blue channel, the r and NB in the green, and the i and the continuum-subtracted Hα in the red (from Boselli et al. (2018b)).

their statistical properties such as the luminosity function and correlation function. We also expect to detect the diffuse ionised gas emission of the Milky Way (e.g. Reynolds et al. (1998)).

This work is done on behalf of the VESTIGE team, which includes 50 astronomers

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