VIPERS: galaxies and large scale structure at $z \sim 1$ in unprecedented detail

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We summarize the present state of the VIMOS Public Extragalactic Redshift Survey (VIPERS). We discuss the status, and review some of the (numerous) scientific results of the project.

1 Introduction

The VIMOS Public Extragalactic Redshift Survey (VIPERS) is a European Southern Observatory Large Program. Its main goal is to provide a detailed map of the spatial distribution of galaxies over a large volume of the Universe when it was around the half of its present age. VIPERS spectroscopic observations were carried out by the multispectrograph VIMOS, installed at Melipal - one of the Very Large Telescope (VLT) units on Mount Paranal in Chile. The aim of the VIPERS was to measure ~100,000 redshifts for galaxies in the redshift range $0.5 < z < 1.2$ and red magnitude range $17.5 < I_{AB} < 22.5$. The survey covered an area of 24 square degrees on the sky, in two separate fields located inside two fields of the Canada-France-Hawaii Telescope Legacy Survey Wide catalogue (CFHTLS-Wide) which allowed to use 5-band CFHTLS photometric data for the selection of spectroscopic targets for VIMOS.

In 2015, the observations were finished, and all the redshift measurements performed. As a result, the whole 24 square degrees of a survey are covered by observations, with more than 90,000 spectra in the VIPERS database, out of which 95% with successfully measured redshifts. The spectroscopic targets were preselected based on the combination of the measurement of the object's apparent size and the Spectral Energy Distribution (SED) fitting to eliminate stars, and then on a robust color-based pre-selection in order to eliminate low-z galaxies. And, indeed the stellar contamination of our sample is as low as 2.5%.

A resultant sample proved to be ~98% complete at $z > 0.6$, and its target sampling rate exceeds 40% (Guzzo et al., 2014, see also http://vipers.inaf.it). The combination of these numbers - a high sampling rate, a large covered area and a high completeness make VIPERS unique among galaxy surveys at redshift $z \sim 1$. Probing a volume of $\sim 5 \cdot 10^7 h^{-3}\mathrm{Mpc}^3$ (assuming Hubble constant $H_0 = 100h$ km/s/Mpc), VIPERS allows for comparisons with the large local ($z \leq 0.2$) galaxy surveys on nearly equal statistical footing.

The main scientific goal of VIPERS is the measurement of cosmological parameters using the data from an epoch when the Universe was about half of its today's age. The choice of this cosmic epoch is not just a coincidence - it is exactly the time when the Universe, according to now best estimated concordance model's parameters, started its accelerated expansion, i.e. when the "cosmic energy" stared the most drastic manifestation of its existence. Obviously this does not exploit the possibilities opened by the survey: measurements of physical properties of galaxies (for instance, see Siudek et al., 2016; Krywult et al., 2016, in this volume) of large scale structure with unprecedented statistical accuracy at these redshifts, and relate these two important aspects of cosmic evolution: the growth of the "cosmic web" and of galaxies nested in it.

In 2013 the spectroscopic measurements for 57,204 objects, including 54,756 galaxies and 2,448 stars, were publicly released (see Garilli et al., 2014; Guzzo et al., 2014). In 2014, the corresponding galaxy spectra were also released. The release contains also a wealth of ancillary information, including the survey masks and weights, and photometric ancillary data from the CFHTLS. They make it possible to reproduce the main results published by the VIPERS team, as well and many independent analyses[1].

2 Selected results

Automate data classification in modern huge astronomical databases poses a growing statistical challenge. An approach to "blindly" classify and repair VIPERS spectra through the has been principal component analysis (PCA) has been presented by Marchetti et al. (2013). Małek et al. (2013) used the support vector machine (SVM) based method to design a method to distinguish galaxies, quasars and stars from the CFHTLS data, with the VIPERS used as a training sample. The next step is to use a similar method to select narrow-line Active Galactic Nuclei, AGN, difficult to distinguish from star-forming galaxies during a routine redshift measurement. A large sample of narrow- and broad-line AGNs at $z \sim 1$ will allow to test, among other things, the AGN unification model.

The central topic of VIPERS is the analysis of the cosmic large scale structure at $z \sim 1$, followed by high precision measurement of cosmic parameters, in particular related to the dark energy. The first-epoch measurements include a measurement of redshift space distortions and structure growth factor from VIPERS (de la Torre et al., 2013), measurement of the luminosity- and stellar mass - dependence of galaxy clustering (Marulli et al., 2013), measurement of the cosmological parameters through a measurement of the galaxy clustering ratio (Bel et al., 2014) and extensive tests of the methods of estimation of the galaxy density field (Cucciati et al., 2014). Granett et al. (2015) presented a method to reconstruct of the redshift-space galaxy density field using the Bayesian formalism, while Micheletti et al. (2014) constructed the catalog of cosmic voids in VIPERS. Cappi et al. (2015) performed the first ever measurement of high-order correlation functions at $z \sim 1$ in a spectroscopic redshift survey this confirming the hierarchical scaling between the volume-averaged two- and three-point and two- and four-point correlation functions in all the tested range of scale and redshift.

It is already well known that the large scale structure looks different when we use

[1] The public release data can be found under the link: http://vipers.inaf.it/rel-pdr1.html

different types of galaxies as its tracers, and that this effect changes with cosmic time. The environmental dependence of galaxy evolution is not yet sufficiently understood. With the VIPERS data, Davidzon et al. (2013) confirmed that high mass red galaxies evolve more slowly with redshift, when compared to lower mass red galaxies, while Fritz et al. (2014) found that most massive red galaxies have had their star formation quenched already before $z \sim 1$, and merging played only a limited role in their evolution. In the case of less massive red galaxies truncation of star formation and minor mergers were both important evolutionary factors.

Now, when the main measurements of VIPERS are finalized, the next step will be the completion of all the ongoing analyses, relating the evolution of galaxies and of large scale structure, as well as cosmological parameters. In the same time, the data are being prepared for the public release which is expected as early as in the coming year. This means that all the worldwide scientific community will be able take part of the exciting adventure of exploration of the $z \sim 1$ Universe with the advantage of an unprecedented statistical quality of the VIPERS data.

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