SF2A 2015
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THE CANADA-FRANCE IMAGING SURVEY: EVOLUTION OF GALAXIES AND CLUSTERS OF GALAXIES

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Abstract. In this paper we discuss the interest of the wide-field CFIS (Canada-France Imaging Survey) regarding extragalactic/cosmology science, focusing on the evolution of galaxies and clusters of galaxies. A deep photometric survey such as CFIS in the Northern hemisphere is presently missing for the needs of different ongoing projects based on photometric redshifts, such as EUCLID or eROSITA.

Keywords: Galaxies, clusters of galaxies, extragalactic surveys

1 Introduction

The CFIS (Canada-France Imaging Survey) is a large program presently under definition in the framework of a call for proposals to be conducted at the CFHT, starting in 2017. This wide-field survey in the Northern hemisphere is expected to be conducted with MegaCam. Its main scientific goals are the study of our Galaxy, the low-surface brightness universe (see also R. Ibata, this conference), as well as extragalactic/cosmology science. As compared to other ongoing or planned surveys, the CFIS is expected to provide a unique combination of image quality, wavelength coverage and depth ($\sim$2 magnitudes deeper than the SDSS; see J.C. Cuillandre, this conference). In this paper we briefly discuss the particular interest of the CFIS regarding the evolution of galaxies and clusters of galaxies used as cosmological probes.

2 Motivation

The motivation behind CFIS is to provide a deep optical survey in the Northern hemisphere, which is presently missing, for the needs of key projects based on photometric redshifts, such as EUCLID (see Laureijs et al. 2011) or eROSITA (see e.g. Merloni et al. 2012). EUCLID (launch expected $\sim$ 2020) has been optimized for the measurement of cosmological weak-lensing and galaxy clustering, including also the use of clusters of galaxies as cosmological probes. eROSITA (launch 2017) is also intended to detect a large sample of clusters of galaxies up to z$\geq$ 1, in order to study the large scale structure in the universe, and to constrain the cosmological models.

We discuss below the impact of CFIS photometry on the expected accuracy for photometric redshifts, as well as the implication for SED-fitting analyses of galaxy populations, and the identification of clusters of galaxies for cosmological studies.

2.1 Photometric redshift accuracy

In order to estimate the accuracy expected on photometric redshifts, and more precisely the impact of CFIS-like observations on their final quality, we have carried-out a series of simulations. Synthetic catalogs were produced, covering a wide parameter space in terms of galaxy types, age of the stellar population and extinction, with a flat N(z) distribution of sources between z= 0 and 5 (to preserve a uniform statistics as a function of refshift). Photometry includes the 4 EUCLID bands (VIS, Y, J and H), and 4 MegaCam filters (g,r,i and z), with and without the u-band. Errors in magnitudes were introduced in a consistent way, assuming a Gaussian error distribution, with S/N scaled to magnitudes in order to reproduce as close as possible the conditions expected for a EUCLID+CFIS survey (see J.C. Cuillandre, this conference). Photometric redshifts were computed with

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the new version (v12.3) of the public code *Hyperz*(*New–Hyperz* *), originally developed by Bolzonella et al. (2000). Only a flat prior in luminosity was used, with a simple cut in the permitted range of luminosities. *New–Hyperz* performs a χ^2 minimization in the parameter space, yielding the best-fit photometric redshift for each input source, as well as a number of fitting subproducts (e.g. absolute magnitudes in the different bands, normalized redshift probability distribution, error bars, secondary solutions, stellar masses, etc...).

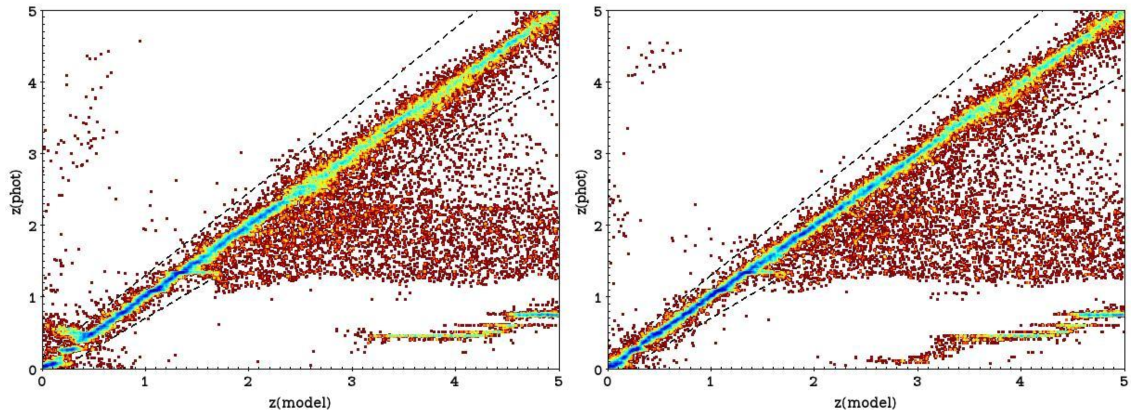

Fig. 1. Left: Comparison between photometric and true redshifts for a simulation of a survey based on EUCLID filters $+griz$ bands. **Right:** Same as in the left panel, for EUCLID filters $+ugriz$ bands. Colors encode the density of test galaxies in this plane using a logarithmic scale.

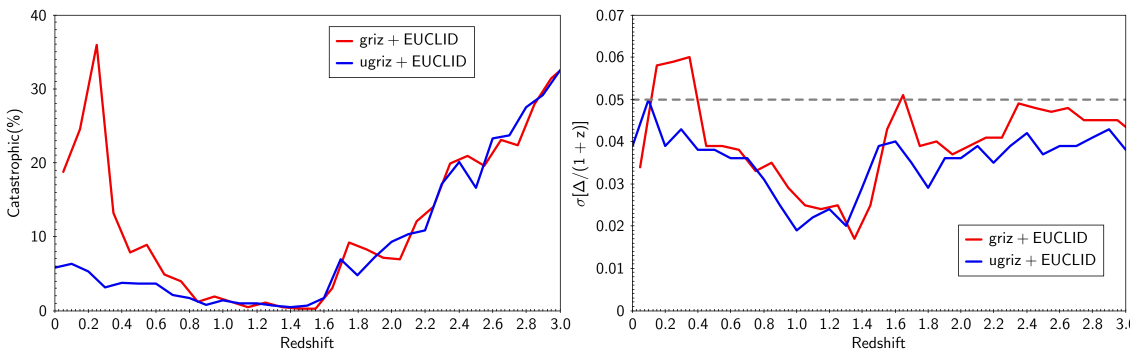

Fig. 2. Left: Fraction of catastrophic identifications expected in the z =0-3 interval based on EUCLID filters + different combinations of filters in the optical wavelengths. **Right:** Same as for the left panel, for the dispersion expected in the photometric redshift determination. Note that, in the two cases, including the u-band has a dramatic effect on the quality of photometric redshifts at $z \leq 0.5$

Fig. 1 displays the comparison between photometric and true redshifts for $\sim 2\times 10^4$ objects in these simulations, with redshifts in the z =0-5 interval and for two different choices of filters (with and without u-band photometry). Fig. 2 presents the fraction of catastrophic identifications (sources with $|z(true) - z(phot)| > 0.15(1 + z(true))$) and the dispersion expected in the photometric redshift determination within the z =0-3 interval, based on EUCLID filters + different combinations of filters in the optical wavelengths. A CFIS-like survey is clearly needed to reach the requirements of the key projects mentioned above. Including the u-band has a dramatic effect on the quality of photometric redshifts at $z \leq 0.5$.

2.2 Photometric redshits and SED-fitting

Photometric redshits and SED-fitting procedures play an increasingly important role in understanding the physical processes of galaxy assembly through cosmic ages. They allow us to sample the galaxy population

*`http://userpages.irap.omp.eu/~rpello/newhyperz/`

beyond the spectroscopic limits, increasing the size of available samples, therefore improving statistics through the relevant parameter space. Needless to say that this approach has a key role in the identification and study of the sources responsible for the reionization. This situation is not expected to change dramatically in the next coming decade.

Photometric redshits and SED-fitting procedures provide the following important elements when deriving the properties of galaxies:

- A classification of sources into spectro-morphological types, allowing the selection of samples (e.g. for spectroscopic follow up studies).
- A view of the stellar-population properties in galaxies, including dust content, stellar masses, star-formation rates, and possibly other parameters such as the average age of stellar populations when combining photometry with spectroscopic and/or multi-wavelength information. An illustration of the performances expected in this field when combining CFIS-like photometry with EUCLID data is presented in Fig. 3, showing the distribution of stellar masses as a function of redshift for galaxies in the WIRCam WUDS survey, based on a $H + K$ selection on the CFHTLS-D3 field (Groth Strip) (see Pello et al. 2015, in preparation).
- Properties of (extremely) high-redshift galaxies.
- The evolution in the global properties of the galaxy population as a function of redshift and environment: star-formation rate density, luminosity and stellar-mass functions, clustering, ... Different approaches have been used in the literature since the pioneer papers based on pure photometric redshifts and associated PDZ (see e.g. Subbarao et al. 1996; Arnouts et al. 1999; Bolzonella et al. 2002), to modern (massive) surveys making use of spectroscopic data to calibrate photometric redshifts for high-quality results (e.g. Scoville et al. 2007; Ilbert et al. 2013).

Recovering the above properties from broad-band SED-fitting is clearly a degenerate problem, as shown by different authors (see e.g. Maraston et al. 2013; Pforr et al. 2013, and references therein), in particular when relying on photometric redshifts. In this respect, a well suited wavelength coverage is crucial, and the u-band is essential for an optimal exploitation of the key projects mentioned above.

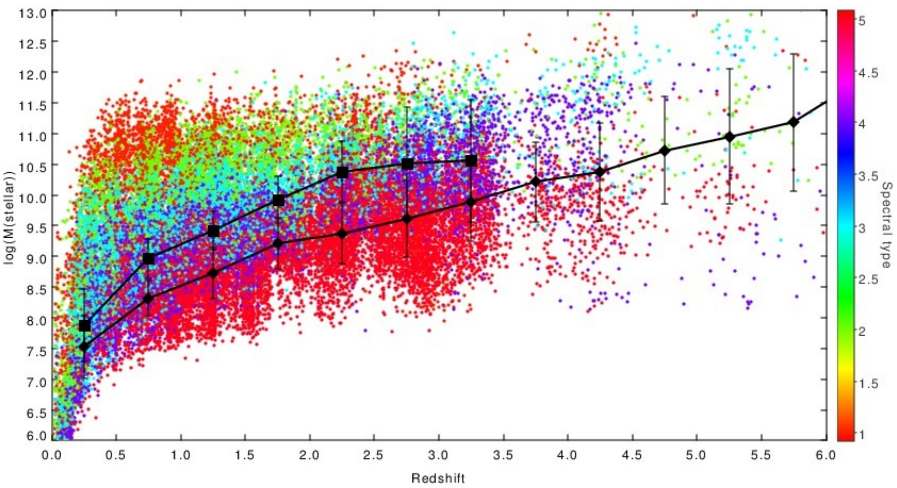

Fig. 3. Distribution of stellar masses as a function of redshift for galaxies in the WIRCam WUDS survey, based on a $H + K$ selection. Colors encode the different spectral types of galaxies, from early types (code 1) to late types (code 5). Black squares and diamonds represent the completeness limits in mass up to $K_s = 24.75$, for early and late-type galaxies respectively. Error bars represent the dispersion within the sample.

2.3 *Clusters of galaxies*

As described in a recent paper by Sartoris et al. (2015), clusters of galaxies selected from EUCLID data are expected to provide important constrains on the cosmological parameters. A large fraction of this sample will be detected using a pure photometric selection (i.e. $\sim 10^6$ clusters are expected with masses above $\sim 10^{14}$ M$\odot$ at a 3σ level, 20% of them at z≥1). Internal calibration in mass will be available for these clusters based on weak-lensing analysis and the dynamics traced by spectroscopy of cluster galaxies, with obvious limitations. Regarding eROSITA, it is expected to perform an all-sky X-ray Survey during its 4-year mission, with a Deep Field Survey on ∼100 deg^2. More than 10^5 clusters are expected to be detected up to z≤1.5, and close to 10^6 AGN (see e.g. Merloni et al. 2012), therefore increasing by a large factor the present sample of ∼20 clusters at z≥1 seen in X-rays. As illustrated in Fig. 2 and 3, the lack of u-band photometry could compromise this exercise at $z \leq 0.5$ in both cases. Clearly the CFIS is ideally suited for the identification of clusters in these surveys based on photometric redshifts.

Photometric redshifts in this context are particularly useful for

- Cluster/structure finding algorithms.
- Determination of cluster redshifts (in complementarity with spectroscopic data).
- Cluster-membership criteria.
- Selection of spectroscopic samples for follow up observations.

Based on current surveys, the accuracy in these determinations is more sensitive to the filter set used rather than the redshift of the cluster, provided that the sensitive rest-frame wavelengths, containing the main spectral features, are covered (e.g. the 4000 Å break). The accuracy on the determination of cluster redshifts is better than for individual galaxies (see e.g. Pelló et al. 2009).

3 Conclusion

In conclusion, a deep photometric survey such as CFIS in the Northern hemisphere is clearly required for the needs of different ongoing extragalactic/cosmology projects based on photometric redshifts, such as EUCLID or eROSITA. It is also needed for target-selection for projects based on (massive) spectroscopy, such as DESI or the Mauna Kea Spectroscopic Explorer (MSE), which is intended to select targets based on CFIS and EUCLID data (see poster by C. Schimd, this conference). It is worth mentioning that follow up observations of CFIS sources will be possible with the TMT.

This work was supported by the French CNRS and the Agence Nationale de la recherche bearing the reference ANR-09-BLAN-0234. WUDS results are based on observations obtained with WIRCam, a joint project of CFHT, Taiwan, Korea, Canada, France, and the Canada-France-Hawaii Telescope (CFHT) which is operated by the National Research Council (NRC) of Canada, the Institute National des Sciences de l'Univers of the Centre National de la Recherche Scientifique of France, and the U. of Hawaii.

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