X-ray cluster surveys and the optical spectroscopic follow-up challenge

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Introduction

The cluster cosmological applications are degenerate with the mass calibrations of galaxy clusters (e.g. Merloni et al. 2012). Large X-ray surveys select galaxy clusters by their X-ray luminosity (i.e. rather than by their masses M), so that the L−M relation is required to recover the scale of clusters in terms of cluster mass, hence the cluster mass function. Mass estimates from e.g. optical spectroscopy and gravitational lensing, independent of the X-ray luminosity measurement, provide an X-ray blind reference of the cluster mass to calibrate the L−M relation (e.g. Kaiffe et al. 1990; Wu et al. 1998; Zhang et al. 2008; Leauthaud et al. 2010; Hoekstra et al. 2014; Mantz et al. 2015).

Combining X-ray and optical surveys for mass calibration is promising because a vast number of telescopes are dedicated to carry out the optical spectroscopic surveys of galaxy clusters, e.g. eBOSS/SPIDERS (www.sdss.org/futureboss.php) and eROSITA. The combination of such optical spectroscopic surveys and X-ray surveys is suitable for cluster cosmology (e.g. Bocquet et al. 2015; Mantz et al. 2015), in which the cosmological parameters and mass calibration are constrained simultaneously based on independent X-ray and optical mass measurements.

Dynamical mass estimates are sensitive to the redshift range the tested optical spectroscopic setups are reliable for measuring the cluster dynamical masses.

HIFLUGCS Sample: calibrating X-ray luminosity as mass proxy with dynamical mass

Sample and analysis: We performed the mass calibration for the HIFLUGCS sample based on high-quality XMM-Newton and ROSAT pointed observations as well as optical spectroscopic redshifts of more than ten thousand cluster galaxies (Zhang et al. in prep.). We carried out the X-ray and optical analyses independently (Zhang et al. 2011), apart from taking the dynamical mass determined Mdyn using the X-ray luminosity. Since the luminosity values measured within r200 and 2.5r200 differ only by 10% on average, using the Mdyn derived from the dynamical mass, in computing the X-ray bolometric luminosity will not cause any significant bias in our result.

Down-sampling of the HIFLUGCS sample using the eBOSS/SPIDERS and 4MOST configurations

Optical spec- survey configurations: Both large optical spectroscopic surveys and individual pointed observations will be used to follow galaxy clusters detected in upcoming large X-ray surveys, e.g. eROSITA and Athena. We calibrated the dynamical mass estimates according to different spectroscopic survey setups, and demonstrate the results for the following two follow-up programs of the eROSITA detected clusters. The Extended Baryon Oscillation Spectroscopic Survey (EBESS; e.g. Schindler et al. 2011) is a redshift survey covering a wavelength range from 340 nm to 6000 nm, with a resolution R ~ 3500–4800. This survey targets clusters redshift to z ~ 2. With the eBOSS setup, the Spectroscopic Identification of ROSita Sources (SPIDERS; e.g. Merloni et al. 2012) survey will take observations of X-ray emitting quasars and galaxies in the northern and southern clusters detected by eROSITA. The 4-metre Multi-Object Spectroscopic Telescope (4MOST, e.g. de Jong et al. 2012) is designed to obtain more than 20 million spectra at resolution R ~ 5000 (500–9000 km s−1) within five years. It is suitable to follow-up the clusters in the southern sky in the eROSITA survey.

Analysis: In practice, only a number of cluster galaxies per cluster can be targeted by the optical spectroscopic setup around the high-redshift end. The bias of the cluster dynamical mass estimates is often large close to the high-redshift end. The underestimation of the dynamical mass from the eBOSS/SPIDERS setup is better than 15%, 28%, 34%, and 27% at z ~ 0.2, 0.4, 0.6, and 0.8. The dynamical mass is recovered with less than 20% underestimation up to redshift z ~ 0.8. The redshift bin of 0.8, the underestimation of the dynamical mass on average according to the 4MOST setup is better than 0.6%. Assum- ing the eBOSS/SPIDERS (4MOST) setup, the dynamical mass can be used as an independent reference blind to the X-ray observables to calibrate the cluster mass to better than 20% from z ~ 0.2 to 0.6, with 2% (3%) catastrophic outliers in upcoming X-ray surveys.

Optical spectroscopically follow-up the clusters in the southern sky in the eROSITA survey.

Fig. 1. Down-sampling of the HIFLUGCS sample using the eBOSS/SPIDERS and 4MOST configurations.

Fig. 2. Down-sampling of the HIFLUGCS sample using the eBOSS/SPIDERS and 4MOST configurations.