Summary of the thesis

Environmental dependence of galaxy properties using marked statistics

by

Unnikrishnan Potty Sureshkumar

The major aim of the thesis is to investigate how different galaxy properties are correlated with the environment in which the galaxies live, thereby contributing to our understanding of the environmental dependence of galaxy evolution. We explore the environmental dependence of luminosities in optical, near and mid-infrared bands, as well as stellar mass and star formation rate (SFR) in various redshift ranges.

We utilize robust statistical tools such as two-point correlation function (2pCF) and marked correlation function (MCF). The MCF is very sensitive to the environment and it allows us to investigate different scales at once. This makes it a better tool than local galaxy density with which we restrict our study to one particular scale. However, MCF has not been widely used in the galaxy studies so far. This thesis tries to exploit the possibilities and limitations of MCF to study the correlations between galaxy properties and the environment. We implement these tools to a set of galaxy samples selected from the Galaxy and Mass Assembly (GAMA) survey, Sloan Digital Sky Survey (SDSS), and cosmoDC2 mock catalogue. Additionally, we also study the influence of the survey flux limit on the clustering measurements.

During the initial stage of this work, I developed a well-performing C code for computing 2pCF and MCF. The code uses OpenMP for parallel programming so that it computes the 2pCF for different jackknife regions in parallel and the MCF for different properties in parallel. I have also written a separate code for power-law modelling of 2pCF using the covariance matrix and generalised χ^2-minimisation. These tools along with a step-by-step demonstration of how to compute them are explained in Chapter 2.

Using these codes, we first study the environmental dependence of optical and near-infrared luminosities, stellar mass, and SFR of galaxies in the GAMA survey. We check which of these properties is a better tracer of the environment. We measure the 2pCF and MCFs in a stellar-mass-complete sample in the redshift range $0.1 < z < 0.16$ with a flux limit $r < 19.8$ and stellar mass cut $\log (M_\star/M_\odot) > 9.3$. The MCFs are measured using different properties such as luminosities in *u*, *g*, *r*, *J*, and *K* bands, stellar mass, SFR, and specific SFR as marks. The results are described in Chapter 3.

Later, we extend the analysis to mid-infrared galaxy properties using the Wide-field Infrared Survey Explorer (*WISE*) counterparts of GAMA galaxies. We use a set of 3.4 μm-selected galaxy samples from the GAMA-*WISE* catalogue in the redshift range $0.07 \leq z < 0.43$. We study how the *WISE*

bands trace the environment using MCF. We also compare how the stellar masses and SFRs estimated using three different methods (GAMA, *WISE*, and ProSpect) trace the environment. Additionally, we study the luminosity dependence and redshift evolution of galaxy clustering using 2pCF. The results are described in Chapter 4.

We also investigate the impact of the survey flux limit on clustering measurements. For that, we compare the 2pCF and MCF measurements in galaxy samples from GAMA that have the same selection in redshift and stellar mass, but vary in flux limit. We repeat the measurements using SDSS and compare them to those from GAMA.

We also use cosmoDC2 mock catalogue, which is the state-of-the-art simulation catalogue developed for the upcoming Rubin Observatory. We implement the 2pCF and MCF measurements using the cosmoDC2 mock catalogues. The effect of flux limit and measurements in SDSS and cosmoDC2 are described in Chapter 5.

This work scored several interesting results and the general conclusions of the thesis are:

1. Different galaxy properties correlate differently with the environment in which the galaxies live, and MCF is an effective tool to trace these differences, particularly on small scales.
2. Out of optical to mid-infrared luminosities, stellar mass, and SFR, stellar mass shows the strongest correlation and SFR shows the strongest anti-correlation with the environment. The relative amplitudes of MCF reflect these correlations.
3. Luminosities in the *K* band (2.2 μm), W1 band (3.4 μm), and W2 band (4.6 μm) trace the environment similarly, although not as strong as the stellar mass. Similarly, *u* band (0.3 μm), W3 band (12 μm), and W4 band (22 μm) follow SFR in tracing the environment, but not exactly in the same way. These observations are crucial, as they demand the need for caution when using redder and bluer photometric bands as proxies of stellar mass and SFR, respectively, in clustering studies.
4. The flux limit of the survey has a significant impact on galaxy clustering measurements. This gives an alert to be aware of the possible incompleteness effects caused by the survey flux limit on samples selected based on a galaxy property, in particular the stellar mass.
5. CosmoDC2 mock catalogue does not reproduce the environmental dependence of galaxy properties that are observed in GAMA and SDSS. The findings of this thesis may be used in future to further improve the models used in simulations.

Our measurements are the first of this kind with galaxies as faint as $r < 19.8$. Our results can be a useful reference for clustering studies with flux-limited surveys. This work can be considered as a forerunner of galaxy clustering studies using next-generation surveys such as Vera C. Rubin Observatory and Euclid. I hope that the study described in this thesis brings new perspectives into the field of observational cosmology and leads to new methodologies to better understand the formation and evolution of the large-scale structure of the Universe.