Warszawa, 27 sierpnia 2022 r.

Recenzja rozprawy doktorskiej mgr Unnikrishnana Potty Sureshkumara

Referee's report on the PhD Thesis of Mr. Unnikrishan Potty Sureshkumar

entitled

"Environmental dependence of galaxy properties using marked statistics"

1 Short description

The doctoral dissertation of Mr. Unnikrishan Potty Sureshkumar presents his original work concerning the relation between the clustering of galaxies of different properties and their environment. Not surprisingly, the thesis is written in perfect English. In total it consists of eight chapters, including Introduction (chapter one) and Summary and Conclusions (chapter eight). The dissertation, together with appendices and comprehensive bibliography contains 131 pages. The text is well written; subsequent parts of the work are elucidated step by step. It is written in a modular form, what additionally facilitates the process of reading. Figures presented in the thesis are also very helpful. They are well-thought and not overloaded with content, which is unfortunately very common in the scientific literature. As an observational data, galaxy catalogues from two galaxy spectroscopic surveys are used: Galaxy and Mass Assembly (GAMA) and the Sloan Digital Sky Survey (SLOAN). The large synthetic galaxy catalogue CosmoDC2 is also analysed.

The standard correlation function (CF) has several shortcomings. For example, the value that is used to split the parent sample is arbitrary. Furthermore, once the splitting is done, we are left with a lesser number of galaxies in each sub-sample. These problems

can be overcome by using the marked correlation function (MCF). First, luminosities (or strengths of any other physical property) of galaxies in the sample are assigned to them as so-called "marks". Then, every galaxy is assigned a weight, equal to the value of its mark divided by the mean mark of the sample. The MCF is the weighted CF which uses all galaxies along with their weights. I am impressed by the high programming skills of the Author as well as by the high quality of the error analysis. To compare clustering of galaxies of different properties (e.g. luminosities in different wavebands or other properties like stellar mass or star formation rate), the Author applies the rank-ordered MCF. By using the data from the GAMA survey, he convincingly shows that correlations of galaxies of different properties are very different. In particular, the strength of the correlation forms a remarkable hierarchy that is preserved from the smallest to the largest separations of galaxies in the sample. This is a very interesting phenomenon which has to be explained by models of galaxy formation and evolution.

2 Referee's comments

2.1 Questions

1. In the halo model, the spatial two-point CF has two contributions: one from galaxies residing in the same halo and another one from galaxies residing in two separate haloes. At scales smaller than about 1 h^{-1}Mpc, the first component dominates and at this scale the CF changes shape. By using the GAMA galaxies, Mr. Sureshkumar is able to measure the projected CF (pCF) down to $0.1h^{-1}$Mpc. However, the change of the shape of the CF cannot be clearly seen. Is it an effect of projection?

2. Sheth et al. (2005) argue that the marked statistics can be constructed without the necessity of constructing a random catalogue. Despite this claim, the random catalogues are constructed here. Why?

3. In the case of the marked statistics, a random catalogue should be constructed not only by randomizing galaxy positions but also their marks. Why was it not done? All galaxies in random catalogues described in the dissertation have marks equal to unity.

2.2 Critical remarks

1. The thesis lacks a clear definition of 'environment'. This is all the more surprising as the thesis is on 'Environmental dependence of galaxy properties using marked statistics'. A non-expert reader may gain a wrong impression that the dissertation – though by using sophisticated statistical tools – shows not much more than the fact that galaxies of some property exhibit different clustering than galaxies of a different property. For example, galaxies weighted by their absolute luminosity measured in K-band cluster more strongly than galaxies weighted by their r-band luminosity. Or, that stellar mass galaxies cluster more strongly than galaxies weighted by their absolute luminosity in all wavebands.

   It is true that the existing literature on the subject is very laconic with definitions of the environment. For example, Sheth *et al.* (2005) mentions this word 26 times, but without any clarification. However, Sheth & Tormen (2004) define the environment as a region of roughly the Lagrangian radius of a typical-mass halo. They also mention a different definition of environment in the paper of Lemson & Kauffmann (1999). Full understanding of the dissertation and full appreciation of its content is thus not possible without additional reading of the literature. This is a serious drawback of the thesis and definitely does not help to give the thesis a high score. I suppose that the notion of environment was well defined in two refereed papers of Mr. Sureshkumar (one published and another one submitted). Still, I am awaiting a comprehensive response of the Author to my criticism during the defence.

2. The Author finds that the strength of the clustering of massive galaxies (with high stellar mass) is the highest compared to the strengths of clustering of galaxies marked by other properties. The second highest is the absolute luminosity of galaxies in the K-band as a chosen property. The Author then concludes that 'K-luminosity is a proxy of stellar mass'. However, a linear correlation between the stellar mass and K-luminosity is a well known observational fact. The finding of Mr. Sureshkumar is thus rather an independent confirmation of this fact than a discovery. Moreover, the observed similarity of the correlation strengths of galaxies with the aforementioned properties is rather a well-based indication than a proof of the fact. A convincing proof would be the calculation of cross-correlations between stellar-mass galaxies and all-waveband galaxies and demonstration that the cross-correlation is the highest for K-band luminosity.

3. Figure 3.13 shows the dependence of the pCF on galaxy properties when the parent sample is split based on the mean of the properties; Figure 3.14 shows the corresponding dependence when the sample is split based on median of the properties. The Author states that this dependence is the same in both figures, 'regardless of whether the mean or median is used to divide the parent sample'. Correct. However, a closer inspection of Table 4.2 shows that for all selected properties of galaxies, the values of the mean and median are almost identical. The figures are therefore very similar simply because the criteria of division of the sample are very similar. That's all.

3 Conclusions

My main criticism concerns one aspect of the presentation of the work but not its content. Other comments, presented above, do not diminish the value of the work, which in my judgement provides a valuable contribution to the field of extragalactic astronomy and cosmology.

In my opinion, the doctoral dissertation of Mr. Unnikrishnan Potty Sureshkumar meets all the formal and customary requirements for doctoral theses. I therefore make a formal request for admission of Mr. Unnikrishnan Potty Sureshkumar to further stages of his doctoral procedure.

dr hab. Michał Chodorowski