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Review of the doctoral thesis of
Francesco Pistis
National Centre for Nuclear Research
entitled:
The fundamental metallicity relation through cosmic time: from z~0 to z~1
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The thesis of Francesco Pistis tackles the topic of studies of the Fundamental Metallicity Relation (FMR) in different environments and at different stages of the evolution of the Universe. The Author uses new large catalogues of observational data in order to verify or deny previous claims from the literature which were based on much smaller samples of galaxies. The thesis is a well-composed end-to-end study of the properties of galaxies, in particular, stellar mass (M_*), Star Formation Rate (SFR) and metallicity for star-forming galaxies, and their relations at different redshifts. The work contributes significantly to the current knowledge of the galaxy evolution processes through detailed studies using a novel dataset, studies of possible biases in the selection criteria, application of different methods and detection of the first observational evidence for the evolution of the FMR.

The work comprises 153 pages and contains seven chapters, including the introduction, description of methods and data selection, followed by chapters based on articles led by the PhD candidate, published or soon-to-be-submitted to high-profile astrophysical journals and the final chapter with a summary. The presentation and layout of the thesis are very good, with numerous figures and tables and the wise use of colour. Each chapter is conveniently preceded by a very brief abstract. The English in the text is of excellent quality and easy to read. I found only a very small number of typos, errors and not explained acronyms, and I noticed that some figure labels and axes are either too small or too big. This, however, does not diminish the overall positive reception of the thesis.

The introduction Chapter 1 briefly outlines the scientific context of the thesis, introducing the field of galaxy formation and evolution and the parameters governing these processes. Basic relations are introduced, in particular the subject of the work, the Fundamental Metallicity Relation. Lines in Fig. 1.7 are not described in the caption. Table 1.1 shown at the very end with the numbers of galaxies used in various surveys, is not described extensively enough in the chapter and, in my opinion, does not match this chapter at all and should be moved to the second chapter where the measurement methods are presented, or to the data chapter.

Chapter 2 describes briefly the technicalities behind studying the properties of galaxies and methods on how to measure their parameters. Photometric and spectroscopic surveys are described as well as a variety of openly available codes for data processing.

Chapter 3 presents the observational data used in the thesis, namely the SDSS and VIPERS catalogues. The Author lists the selection criteria for both sets leading to the final number of galaxies used, as well as the creation of control samples. From Tab. 3.1. I understand that the availability of the redshift measurement is one of the major selection factors, however, it seems that for the VIPERS sample, the largest cut was made on “Line flags”. It is a pity this cut has not been explained at all in this chapter. Also, I think it is not made clear which parts of the analysis of the data were done by the student himself and which were taken from the catalogues or other works. It is hidden behind the use of an impersonal grammatical style which is mixed with the personal style (“we”).

Fig. 3.1 has four black solid lines that are described neither in the caption nor in the text, while their description appears only in Fig.3.4. I am wondering if newer Data Releases from SDSS would make a significant impact on the results, as the Author used DR7 from 2009 — the SDSS webpage states that the newest Data Release is number 17 from 2021.

Chapter 4 is based on the published paper of the PhD candidate, published in 2022 in Astronomy and Astrophysics. It is a comprehensive study of possible biases in the data selection and observations. This is a very crucial step in studying the properties of various samples of objects in order to recognise if the observed differences are due to selection criteria or are genuine astrophysical differences. The Author studies each of the most important cuts he previously applied to the SDSS and VIPERS samples of galaxies, for example, the BPT cut, S/N cut or choice of flags on the spectral data. It was found that the biggest impact on metallicity relations is due to the choice of quality flags of the spectra as well as the cut on S/N. This is an important discovery allowing for understanding the observed relationships between crucial galaxy parameters.

Chapter 5 is the core of the thesis as it is here where the Author utilises the data and methodologies described in previous chapters in order to detect any evolution of FMR. It is also a detailed study of the impact of different methodologies applied to the studies of FMR. The new large sample of galaxies constructed in previous chapters from SDSS and VIPERS survey data comprise objects at different ranges of redshifts. These datasets are studied for the evolution of FMR using two methods, parametric and non-parametric. In the parametric method, various projections of FMR parameters are investigated, however, the problem with this method is that it suffers from the biases identified in Chapter 4, while the non-parametric method is thought to be less affected by biases. The conclusions of the analysis are positive as the Author detects a significant evolution of metallicity relations up to a redshift of about 0.8. This is the very first time such a result has been shown, however, I think the chapter would benefit from expanding the discussion with the astrophysical consequences of the discovery, for example, in the light of contradicting claims presented in the literature (e.g. Lilly et al. 2013 vs Dave et al. 2011).

Fig.5.2 has extremely large labels of axes. For Fig. 5.10, I did not find any explanation for the large distance between the SDSS data and literature fits at the low-mass end of the plot. This is the most striking feature of the plot, however, it remains not discussed in contrast to other less pronounced discrepancies seen in that figure.

In Chapter 6, the Author applies the Machine Learning algorithm of Principal Component Analysis (PCA) to the two samples of galaxies gathered in this thesis from SDSS and VIPERS surveys in order to verify the claims of the previous chapter on the evolution of the FMR. The PCA and K-means clustering are common tools for multi-dimensional data studies and were applied to identify five clusters in SDSS and VIPERS data as well as to find outliers. I am curious about the setup and the parameters used in the ML analysis, for example, why the number of n=20 neighbours was used to find outliers. Is this based on previous experience or is commonly used in the literature (then a citation is missing)? The clusters were studied for their dependence on various parameters and only one relation was found, with the D4000n value, however, I miss a more detailed discussion on the consequences of this dependence. Furthermore, the D4000n break value parameter has not been explained before being used. There is also a common typo of D400n (e.g. Fig.6.12, Fig.6.14). The identification of outliers is potentially very useful in further studies of the FMR and its evolution.

Fig. 6.19 is incomplete as it misses the left panel with SDSS data (as in Fig.6.18). However, I think the readability of this figure is much higher when shown separately for each survey (not like in Fig. 6.18 when both surveys are shown together in one figure).

SUMMARY

Summarising, I think the PhD candidate has done an enormous research work and has done it very carefully and laboriously. The thesis contains a wealth of studies on the topic and yields important novel discoveries. The Author demonstrated his proficiency in research through the completion of numerous complex tasks in data handling, astrophysical analysis, modelling, and interpretation throughout the thesis.

In my view, Mr. Francesco Pistis's work meets all the necessary requirements imposed on PhD theses in Poland, and I, therefore, recommend it for further consideration.

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