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Report on Mr Zhiqiang Yan's dissertation

"Chemical evolution of galaxies with an environment-dependent stellar initial mass function"

To whom it may concern

It is my pleasure to provide this report on Mr Zhiqiang Yan's dissertation.

The thesis addresses one of the most debated topics in the current literature in astrophysics: the stellar initial mass function (IMF) and its role in the formation and evolution of galaxies. The IMF has been studied for decades and attracted a fair amount of controversy. The field has been shaken substantially over the past ten years by the discovery of new evidence that the IMF may not be universal as initially thought, but varying between galaxies of different mass and/or type. These recent results are challenging, as they were missing an adequate theoretical framework. The present dissertation provides the latter and develops an interesting contribution to this debate which may well lay the path to resolve this riddle.

I can confirm that the work by Mr Yan presents new results that are of high relevance for the specific research area and beyond. The concept of the Integrated Galactic IMF (IGIMF) is new, and this thesis opens up new avenues by incorporating this theory into simulations of galactic chemical enrichment. The range of applications for neighbouring research areas is wide, as star formation theory and the shape of the IMF are fundamental players in galaxy formation and evolution. Most importantly, the concept presented in this dissertation in the framework of a relatively simple galactic chemical enrichment code can be applied to hydrodynamical, cosmological simulations of galaxy formation and thus address one of the key questions of astrophysics.

In the following I add a few detailed comments to the individual chapters.

Chapter 1: The dissertation lays out in detail the recent evidence for a non-universal IMF in massive early-type galaxies. However, it misses to confront the findings based on stellar population modelling directly with the evidence from gravitational lensing by Smith et al

(2013) that instead favours a Milky Way-like IMF even in these systems. I further struggle somewhat with the notion that the IMF can be bottom-heavy and top-heavy at the same time. I would challenge the suggestion that time dependence makes this possible by considering the formation of top-heavy stellar populations at early times and bottom-heavy populations at late times. Certainly for passively evolving systems like massive early-type galaxies, the stellar populations *observed at late times* were *formed at early times* hence must have the same IMF. Also, the IMF does not change shape with time by definition of being the *initial* mass function, contrary to what is claimed in the thesis. I would ask Mr Yan to elaborate more on these points. However, as mentioned before, the concept of the gwIMF and optimal sampling introduced in this chapter is novel and highly interesting, and the comparison with astronomical observations is compelling.

Chapter 2: This chapter introduces the code and is the most novel part of this dissertation. The author certainly provides strong evidence for his ability of creative scientific work. I appreciate that the Python3 code GalIMF developed in this PhD project is open source and available through Github. The chapter could have provided more detail on some aspects of the model. For instance, how are the results affected by a variation of the time resolution? While the present model is novel through its implementation of the gwIMF, I note that similar models relaxing the instantaneous recycling approximation have been produced well before in the literature. It would also have been good to see a calibration of the code with the chemical enrichment history of the Milky Way, as we have very detailed information available through observations of individual stars.

Chapter 3: The applications are extremely interesting and it is good to see progress toward resolving the tension between galactic chemical evolution and the finding of a variable IMF from the side of GCE. It remains to be seen, though, what effects the implementation of the gwIMF in stellar population model fitting would have on the measurement of IMF slopes from integrated light observations. It would have been interesting to provide a discussion in this regard in the thesis. However, the results presented here are certainly promising, and I look forward to further developments in this field by the author and other groups in the subject area.

To conclude, I am happy to confirm that the work presented is novel and interesting, and certainly complies with the standard of a PhD thesis.

Sincerely yours,

Prof Daniel Thomas
Head of School