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Supervisor's report on the PhD thesis of Ms. Ivana Ebrová
"Shell galaxies"

The PhD thesis of Ivana Ebrová deals with two largely independent – and in the past insufficiently explored – aspects of shell galaxy formation, modelling and observing, while focussing on the so-called type-I shell galaxies, presenting a regular shell structure and believed to have been formed by a nearly radial collision of two very unequal-mass and probably elliptical galaxies.

The first aspect, dynamical and technical, consisting in properly evaluating the role of dynamical friction (DF) and comparing/improving its various implementations, stood as the main original motivation for the thesis, with the goal to extend the previous work the author had carried out in the framework of her master thesis (Ebrová 2007, hereafter E07). This topic is covered by Part III of the thesis. DF sufferred by a dwarf galaxy involved in a destructive collision (a so-called merger) with a giant elliptical one, has since long been suspected (Dupraz & Combes 1987) to play a potentially imporatnt role in shaping the resulting shell distribution and contrast, as well as in setting the merger time-scale. However, most of the past simulations of shell galaxies were performed using test-particle or various simplified hybrid calculations without any DF at all, and only few of them dealt with this process, moreover very rarely by means of full N-body simulations, primarily due to CPU-time restrictions. The goal of the thesis was first to extend the new semi-analytical implementation of DF (E07) to more realistic models of giant elliptical galaxies (including dark matter halo as an additional component to the stellar one) and, second, to compare the simulations with other DF implementations, including full N-body simulations. The key component of the motivation was to test if a new fast semi-analytical DF treatment could be reliably used to dramatically reduce the prohibitively large CPU time that would be required to produce large sets of full N-body simulations, needed to explore a vast parameter space of shell-forming galaxy collisions.

In this respect, I. Ebrová went several steps further beyond her master thesis and previously published works: a) she generalized her semi-analytical DF implementation to a more complex numerical implementation enabling the use of two-component giant elliptical galaxies (sections 17.1 and 21.2); b) compared her DF treatment to the so-called Multiple Three-Body Algorithm (MTBA) of Séguin & Dupraz (1994) and full N-body simulations carried out by Kateřina Bartošková with GADGET-2 code (sections 18 and 19); and c) performed test-particle simulations coupled with her treatment of DF and gradual decay of the smaller galaxy to show how positions and contrast of shells vary compared to simulations neglecting those two processes (sections 20-21), again comparing the outcome to the above mentioned N-body simulations.

The Part III of the thesis can be summarized as follows. The author's implementation of the DF produces qualitatively similar results to MTBA and N-body treatments, however it gives a significantly faster orbital decay than MTBA which is itself overestimating DF compared to full N-body simulations. Together with the difficulties inherent to the coupling of DF and of the gradual decay of the smaller galaxy, the presented implementation seems not to be a reliable alternative to full N-body simulations if one needs to know precisely the positions, and contrast of the shells, as well as to date the merger. Nonetheless, such a conclusion should not be interpreted as the author's failure to fullfill the initial goal. It was by no means a priori guaranteed that a computationally fast and precise non-N-body treatment of DF could be worked out, and it had to be tried if this is so. The current answer – while not necessarily a definitive one – seems to be rather 'no'. The presented DF implementation however still seems quite useful in giving, at a low CPU cost, an upper limit for DF on a radial orbit as well as for giving valuable hints on how the shell structure qualitatively differs compared to pure test-particle simulations on which most of our knowledge on shell galaxies is still based.

While preliminary findings of Part III were published in conference proceedings – Ebrová et al. 2010a,b, and 2011b (Appendices E.1 – E.3 of the thesis) – the complete results are not yet fully ready for a refereed publication: they need a more systematic comparison of different methods for a larger set of initial conditions. However, they represent a good basis for a fast advance in this direction and I would like to encourage Ivana not to miss this opportunity.

The second studied aspect of shell galaxies – a kinematical signature of the shells and its potential use to constrain the dark matter distribution in giant elliptical galaxies – is presented in Part II of the thesis. Since it is largely based on a recently published paper in Astronomy & Astrophysics (Ebrová et al. 2012, Appendix E.7) it doesn't need as detailed comments from my side as Part III. In summary, a new theoretical prediction for the – still unobserved – shape of spectral line profiles across the shell locations is made, followed by an analysis of how this shape can be used to evaluate the gravitational potential of the host galaxy. The line profile is quadruple-peaked, which qualitatively changes the former prediction of a double-peaked shape by Merrifield & Kuijken (1998), who neglected the radial propagation of shells, and quantitatively substantially modifies the relation between the locations of the peaks and quantities characterizing the gravitational field. Principles of this new method to constrain the dark matter distribution around giant ellipticals are laid down and several versions of extracting the related physical information are compared.

Since the above mentioned A&A paper is a team work of 8 co-authors, it is needed – in the context of the thesis evaluation – to assess the specific contribution of Ivana Ebrová. As a first author of the paper, she was leading and coordinating – during most phases – the effort on putting up all the necessary ingredients for the study as well as editing the wording of the manuscript. But even most importantly, she is the author of the several-level approximations that enabled to make a connection between the predicted properties of the line-of-sight velocity distributions (LOSVD) of shell galaxies and quantities related to the gravitational potential. This is a fundamental aspect of the newly proposed method and of the paper. [1]

Parts II and III, together with a comprehensive review on observational, theoretical and modelling aspects of shell galaxies (Part I), accompanied by several nice and instructive videos of shell galaxy formation (Appendix C), represent from my point of view a substantial piece of original scientific, as well as pedagogical, contribution to the field, and deserve to be recognized as a valuable PhD thesis. I recommend it to be admitted for a PhD defense.

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1. On the other hand, it is fair to note that in the initial phase of this project, in 2010, Lucie Jílková, a PhD student, was leading this collaborative research, making very important contributions to our understanding of the phenomenon and also upgrading the test-particle code used to complement the analytical results. In this respect, I would find appropriate if the first paragraph of the thesis Part II, introducing the topic, made explicit reference to the proceedings paper of Jílková et al. (2010, attached to the thesis as Appendix E.5) as an important step in which the quadruple-peaked structure of the spectral line has first been discussed, instead of just saying that the idea of using the LOSVD peaks “has been proposed by Merrifield & Kuijken (1998a) ... and we further developed it in the paper Ebrová et al. 2012”.

I further appreciate enthousiasm and team spirit of the author which enabled active participation of several other young researchers (PhD students and a postdoc) from Prague and Brno on the fascinating topic of shell galaxy formation.

Nevertheless, I would also like to point out a couple of negative points that Ivana Ebrová should try to eliminate in her future research path that she seems to wish pursuing. First, despite quite frequent participations at international conferences and summer schools, she seems not to have established any collaboration with external experts and students working on related topics. Second, her work intensity and concentration appeared somewhat fluctuating during the five years of PhD studies. As a result, her thesis, while certainly valuable, is also, in my opinion, a parade of missed opportunities, which is, among others, apparent from the fact that it contains only one refereed paper, a strict minimum requirement for admission to a PhD thesis defence. Taking into account that she has been working on the topic since her master thesis, which had an excellent level, I expected her to go deeper and further during the PhD thesis than she actually did. I am convinced that within the unnecessarily prolongated five years period it was not only possible to bring the dynamical friction part to a refereed publication but also to explore and publish on other important and not yet treated sub-topics like: a) including into simulations two-component dwarf galaxies with up-to-date density profiles; b) comparing models with various stellar and dark matter profiles for the giant elliptical galaxies, instead of just keeping the computationally simple but in many aspects quite restrictive Plummer sphere profile; c) simulating non-radial collisions and thus more frequent types of shell galaxies with less regular shell structure.

The last year of the thesis however seems to have brought back the combination of enthousiasm and systematic work so in this respect the missed opportunities could be quickly recovered and I would like to encourage Ivaana to energically pursue her effort, believing her potential for an independent and cutting-edge research in the galaxy astrophysics is huge.

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