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Mr Salvatore Ferrone

Stellar Streams for Galactic and Cosmic Archaeology: when gravity meets complexity

The content of Mr Ferrone's doctoral thesis offers a valuable contribution to theoretical and observational astrophysics, with emphasis on the area of stellar dynamics. Specifically, Chapters 3, 4, and 5 offer tangible evidence of original scientific developments, i.e. solutions to scientific problems of astrophysical interest, as I will discuss below. Chapters 1 and 2 also offer appropriate evidence of Mr Ferrone's general knowledge in the subject area. Finally, by providing an outlook of future research prospects, Chapter 6 further demonstrates his ability to independently conduct scientific work.

At the heart of the thesis lies the development of an open-source code (`tstrippy` - Tidal Stripping in Python) that models tidal perturbations, removal and orbital evolution of cluster stars via the numerical solution of an approximate form of the circular, planar, restricted three-body problem defined by the star-cluster-galaxy system of interest. This methodology and numerical implementation is described in detail in Chapter 3, which also provides a useful reader's guide, in preparation for its application to the subsequent science case. The main results obtained by the application of `tstrippy` to the study of Galactic tidal streams have been organised in the "e-TidalGCs project", which is presented in Chapters 4 and 5.

Refreshingly, appropriate care is given to a detailed discussion of the general formulation of the above problem, and, even more importantly, of the conceptual and numerical limitations of the adopted modeling approach. Since the computation of direct N-body models of fully realistic globular star clusters (i.e. with $N \geq 10^6$ stars) as tidal streams' progenitors is still prohibitively expensive to be used to conduct comprehensive parameter explorations, nowadays approximate methods are still a necessity. The advantages resulting from these methods must, therefore, always be accompanied by a critical assessment of their drawbacks - as it is done in the present thesis manuscript (see especially Sections 3.3 and 3.4).

The e-TidalGCs project takes advantage of a pre-existing set of routines and codes, collectively called "Globular Clusters' Tidal Tails" (GCsTT), developed by the research group of which Mr Ferrone is a member. While these codes were already in existence before the start of this thesis, there is clear evidence that the e-TidalGCs project has been developed in its fully-fledged form in the context of Mr Ferrone's doctoral research activities.

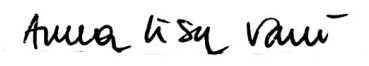
Chapter 4 presents the computation and characterisation of the extra-tidal features surrounding all Galactic globular clusters for which phase space information, masses and sizes are currently available (i.e., more than 159 globular clusters). Mr Ferrone and collaborators focus on the analysis and presentation of the results on the distribution of extra-tidal features, with careful attention to projection effects. They note that a wide variety of morphologies can be found: beyond the usual configuration of "standard" tidal tails, their models show that the extra-tidal features generated by globular clusters take a wide variety of shapes, thickness and curvatures. They also compare some well-studied Galactic stellar streams to their model predictions (e.g., among many others, the streams associated with NGC 3201, NGC 4590, NGC 5466 and Palomar 5). Additionally, they investigate how the projected distribution and extension of the simulated streams vary with the choice of Galactic potential, by making use of three different models (i.e., with or without a central spheroid, or a stellar bar). They formulate a prediction for the mass lost by the current globular cluster population into the field and they state that most of this lost mass is deposited in the inner Galaxy. I note that all simulations computed in this work are now publicly available to the community, providing impact and adding value to this project.

Finally, in Chapter 5, Mr Ferrone and collaborators offers further attention to the case of the Palomar 5 stellar stream, specifically how it responds to the Milky Way's gravitational field in the presence of other globular clusters. They provide evidence that the internal dynamics of globular clusters can strongly influence the morphology of the resulting tidal streams. In particular, they note that gap formation from the fly-by of a massive perturber requires very specific stream conditions: regions close to the progenitor, where the morphology is still dominated by epicyclic overdensities, are less prone to gap formation. This is a genuinely new insight, which has not been accounted for by previous studies within the community. This evidence is significant, particularly via the quantification of the frequency and range of globular clusters' encounters perturbing Palomar 5, as it demonstrates that such interactions must be taken in high consideration, particularly in the context of dark matter subhalo searches – a very popular science case which is indeed anchored on dynamical inference of Galactic tidal streams data.

The contents of Chapters 4-5 have already been presented as articles accepted for publication in the international journal "Astronomy & Astrophysics" – this accomplishment further testify the quality of Mr Ferrone's results and his ability to bring projects to a formal completion. I also note that Mr Ferrone has authored or co-authored additional publications in the area of Galactic astronomy and asteroid science. Very appropriately, these publications have not been forced into the structure of the manuscript which, otherwise, would have suffered from some logical inconsistency. I commend Mr Ferrone for this choice, that further attests his scientific maturity. The manuscript is appropriately structured, complete, and contains only minor presentational flaws. Overall, the presentation of the thesis is of excellent level.

Summing up, I consider the scientific level of the doctoral thesis of Mr Salvatore Ferrone to be excellent. Therefore, my assessment is that the thesis meets the criteria prescribed by the Paris Sciences et Lettres University (Université PSL) for a doctoral dissertation to be defended without modifications.

Yours sincerely,



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