# Rebuttal

## prof. dr. H. Talbot

*The manuscript is short and to the point. It is well written and the work is very interesting, While it has been clear for some time that simulations provide instructive and predictive models for astrophysics, the work presented in the manuscript is particularly instructive and also benefits from recent work in AI, specifically low-dimensional multi-manifold learning.*

*Given its dual public due to the Sundial collaboration, it would have been useful to include a longer introduction to both the astrophysics and the machine learning elements. The presented results seem intuitively correct and are supported by state-of-the-art simulation methodology.*

*On the latter part, particularly chapter 5, the candidate refers to Canducci et al 2021 which at the time of the review has not been published yet, and as far as I can tell, does not benefit from a preprint. This makes this chapter difficult to assess because most of the mathematical details are missing. I really don't see why a mathematical introduction to the work could not have been included in chapter 5.*

*There are very few typos in the manuscript and one incorrect cross references resulting into "??" on page 71.*

I fixed the reference at page 71.
Canducci 2021 has been accepted the 9th of August 2021. It can be found here:
https://doi.org/10.1016/j.artint.2021.103579

## prof. dr. F. Pearce

*Report on thesis of Michele Mastropietro*
*Numerical Simulations of dwarf galaxies in the Fornax Cluster.*

*This thesis introduces a novel numerical simulation approach to track infalling dwarf galaxies within the Fornax cluster. It contains three main sections, each of which forms the basis of a published or submitted paper. As such it clearly surpasses the threshold for both quality and volume of original work required for the award of a PhD. The work is also presented in a readable and sound scientific style throughout. Clear development of the scientific ideas contained within it is also evidenced, indicating the high quality of the supervisory team involved. I have no reservations in recommending the award for which this work was submitted.*

*There are, of course, some areas where I would personally have liked to see some further work. PhD programmes are by construction time constrained and also a balancing act between including everything and keeping the text concise and to the point. Overall this work achieves this balance well and these pointers are not presented as a required set of improvements but rather as a set of issues that could have been addressed given infinite time and space.*

*Overall: I would have liked to see a clear setting out as to precisely which elements of this work were performed by the student. Clearly the code package introduced in chapter 3 was not developed directly for this project, but what adaptions and tests did the student perform themselves? Did they perform the simulation set under direct*

*guidance? Similar issues surround the work in chapter 5 which reports work upon which the student is listed as the third author and for which the written text retains a stylistic change.*
*In chapter 3, which introduces the novel method used, this chapter underpins the entire thesis. As such I would have liked to see some evidence of code testing and verification undertaken as part of the thesis programme. For instance, a test of a dwarf model traversing a uniform tube directly compared to the same set-up but with a tracking box would have been computationally inexpensive and also both reassuring and illustrative.*
*I also found some of the description of the method detailed here to be incomplete. For instance, how is the SPH density estimate completed for incoming particles where the kernel volume can extend beyond the box? Presumably they are handled in some way but the text does not explain. Essentially the discussion of how to handle the key interface region is hard to follow. Compaction of a unit cube to match the required input density is also not obvious: is this achieved by compression along a single axis? Otherwise there will be cut-edge effects. A diagram of how this is done would have helped.*
*Essentially I'd have liked to see this chapter extended with a significant section on basis testing. Referring the reader to tests done by others is poor computational technique when adopting an external code. Given the quality of the team here I suspect these tests were actually performed by the student and just not reported but in a thesis in would be good to say so.*

I'm very grateful to prof. Pearce for the attentive reading of the manuscript and his comments. His remarks have helped to improve the quality of the thesis and to fix some issues.
Regarding the code presented in Chapter 3, I adapted the method to the Gent code base, implementing the necessary changes.
The mechanics of the simulation has been tested step by step: the quaternion machinery, the accelerations with the various additional components, the injection of particles in a controlled environment. Unfortunately, consistent reports of these checks have not been put in the manuscripts.
An end to end test has been performed with the moving box setup compared to a full fledged simulation of a dwarf galaxy in orbit around an NFW gravitational profile equivalent to the one shown in Figure 2.4. This tested the correctness of the accelerations as computed in the moving reference frames. No discrepancies have been noted and it has not been reported in the thesis. We also tried to compare the moving box with a full fledged simulation as shown in Figure 2.1 but that was not possible for computational reasons.
The suggested test of the traversing gas is simple and practically feasible but it tests only the correctness of the impinging gas velocity and correctness of the injection process.
The code has been run in periodic mode for the density estimations for particles where the kernel volume can extend beyond the box. I've clarified the description of the injection of particles and added a diagram Figure 2.4 to help the exposition.

*Chapter 4 is a specific study of a particular dwarf jellyfish galaxy within the Fornax cluster. A similar object is identified within the simulation sequence introduced in Chapter 3. This chapter is reliant on the veracity of the models generated earlier.*

*Chapter 5 applies a novel computational technique to the dataset constructed earlier in an attempt to define the dimensionality of the output, splitting it into computated manifolds automatically. Astrophysical quantities can then be computed along or across these manifolds. The variation in these quantities can then be used to illuminate the underlying physics. The main issue with this section is defining the extent of the contribution.*

My main contributions have been the idea of analysis of the jellyfish tails, the development of independent code to test the manifold analysis, the scientific questions driving the application of the method, the supervision on the implementation, the proposal of physical quantities to be analyzed from the simulation and their physical interpretation. I added a paragraph explaining more in detail my contributions in Section 5.1.

*The other minor point would be a better description of the required smoothing. Gaussian kernels are mentioned for instance, but these are not used by the SPH implementation presumably. Are they required by the method? Also, some SPH quantities are particle based (temperature for instance) whereas others are smoothed (for example, the SPH density). This in a major issue for SPH and should really have been discussed. Does it matter when making the manifold estimates? Also, the smoothing mentioned is both estimated by eye and apparently constant. This runs against the SPH philosophy of a fixed number of neighbours for the smoothing. Why not use an SPH-like smoothing for the method? This would presumably be both faster and already computed.*

Yes, in the AGTM, trivariate gaussian kernels are used. The SPH implementation uses the classic b-spline kernel. They are two different approaches to density estimation (both inspired by the Parzen window method aka Kernel density estimation), each one with its own assumptions. I have added a paragraph in section 5.4 with the goal to help in clarifying this. Given the probabilistic nature of the AGTM method, a mixture of gaussians have been used since the beginning. In Figure 5.5, I updated the diagrams showing SPH interpolated values in the graph nodes. In all the figures relative to the jellyfish galaxy, the smoothing lengths are taken from the SPH simulation. What is estimated by eye (r = 1 kpc) is the main parameter of diffusion and filtering, local dimensionality estimation and manifold crawling. It is therefore not used for smoothing. It is shown in figure 5.2 just for reference.

*In summary, this is a well concise and well-constructed thesis that in my opinion satisfies all the requirements for the award of a PhD.*

prof. dr. A. Van der Wel

*My main recommendation is as follows: add (at least) half a page in the Introduction where the scientific questions that motivate the thesis are described. Return to these questions in the concluding chapter -- outline what progress has been made. A minor issue is that some of the Figures (I noticed figures 3.2-3.5, but there may be more) lack axis information. This appears to be a technical issue.*

I added the requested text and I linked the scientific questions in section 1.2 to the conclusions. The technical issue has been solved using another pdf reader.