Semester report - Doctoral School of Physics

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1 Introduction

In this semester I started to work on a different project compared to what I have been working on the previous two semesters. The main reason of the switch was the hopefully shorter time needed for a future publication. The new project is the resuscitation and large-scale application of the so-called AvERA simulation framework, which is essentially a cosmologic N-body simulation package with a few novel tweaks compared to the mainstream cosmologic simulations.

Since the change I mainly focused on having the solid foundation in terms of the relevant literature and the first mock-simulations at a small scale with smaller computational resources. The aim of my upcoming work is to establish a large-scale simulation with AvERA (Average Expansion Rate Estimation) and to have a meaningful comparison between mainstream comsologies. After that it would be also a side-goal to implement the package into the *Astropy* module.

2 Description of research work carried out in current semester

AvERA was introduced in [1] as a new approach to N-body simulations, where local expansion rates are calculated for a large number of regions in the simulation and the global expansion rate is calculated from them. This approach leads to an interesting result, namely that the simulation closely tracks the growth history of the widespread ΛCDM model without the need for dark energy, offering a viable alternative. Beside that it succesfully resolves the Hubble tension [2]. These results validate the further work we set out to do with this model.

The mock-simulations are run locally with small computational resources using the original code written in C/C++ which works with Delauney tessellation utilising the DTFE [3] algorithm. Sadly the original code for that is not officially available any more, so we might have to look for other such tools, like the powerful CGAL [4].

Of course, not all previous work was in vain, as the AvERA can also be used to calculate the ISW (Integrated Sachs-Wolfe effect) [5], which was already studied from the point-of-view of the 3D reconstruction of the structure of the universe.

The new run with AvERA is planned with using a GitHub fork from the powerful simulation library of either the Gizmo [6] or the Gadget-4 [7]. The distinguishing between those

two is still left for the upcoming work. Using one of those libraries makes it also achievable to later include the framework into the *Astropy* module.

Another possible method worth exploring will be using the StePS (Stereographically Projected Cosmological Simulations) [8], which is an in-house N-body simulation tool for multi-GPU simulation capabilites.

3 Publications

I had no publications in this semester.

4 Studies in current semester

In this semester I attended two courses. The course *Fronts and Patterns* was about how one handles a system of nonlinear differential equations in terms of its fix points and the instabilities around them. I also attended the course: *Quantum Optimization* to follow up my interest in the field..

5 Conferences in current semester

I attended no conferences this semester.

6 Teaching activity in current semester

In this semester I had a teaching activity in the course *Computer Simulations* where I guided 10 students through 2 projects and then took part in their examination.

References

[1] *Concordance cosmology without dark energy | Monthly Notices of the Royal Astronomical Society: Letters | Oxford Academic*. https://academic.oup.com/mnrasl/article/469/1/L1/2982870?login=false. (Accessed on 01/29/2024).

[2] *2004.02937.pdf*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://arxiv.org/pdf/2004.02937.pdf. (Accessed on 01/29/2024).

[3] *[1105.0370] The DTFE public software: The Delaunay Tessellation Field Estimator code*. https://arxiv.org/abs/1105.0370. (Accessed on 01/29/2024).

[4] *content.pdf*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://pure.mpg.de/rest/items/item_1819514/component/file_2599071/content. (Accessed on 01/29/2024).

[5] *1801.08566.pdf#page=8&zoom=100,400,160.pdf*. chrome-extension://efaidnbmnnnibpcaj https://arxiv.org/pdf/1801.08566.pdf. (Accessed on 01/29/2024).

[6] *1409.7395.pdf*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://arxiv.org/pdf/1409.7395.pdf. (Accessed on 01/29/2024).

[7] *gadget4-code-paper.pdf*. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://wwwmpa.mpa-garching.mpg.de/gadget4/gadget4-code-paper.pdf. (Accessed on 01/29/2024).

[8] *StePS: A Multi-GPU Cosmological N-body Code for Compactified Simulations*. https://synthical.com/article/968131b8-3fad-4c8b-a49c-d5c082441a3e. (Accessed on 01/29/2024).