# Semester report - Doctoral School of Physics

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## 1 Introduction

In this semester I continued working on the 3D Large Scale density reconstruction of the universe based on photometric measurements. After previously using the self-organizing map (SOM) as the dimensionality reduction method, other powerful methods were taken into account as well.

Beside the 3D density reconstruction one of our further goals is to estimate the Integrated Sachs-Wolfe effect (ISW) from quasar redshift data I also had to study cosmology models and begin to look at quasar catalogues, as these were not contained in my explicit previous education. Most importantly I examined the ΛCDM model as perhaps the most state-of-the-art cosmology model to this day.

A few practical advancements have also been implemented also in terms of the data used and the machine learning methods applied.

## 2 Description of research work carried out in current semester

This semester it can be stated that my work was predominantly involved reading literature on the ΛCDM model and a few other cosmologies, quasar studies and catalogues, dark energy and further high-scale photo-z density reconstruction. Below, I mention a couple.

In [1] the growth of the large scale structure of the universe is examined by implementing it with an approach using dark energy with a time varying state and the appropriately modified Friedman equations. They also present a large scale numerical simulation of structure formation. In [2] they apply "angular diameter-redshift" cosmological test to galaxies with giant redshifts, $z > 15$. These old galaxies have been observed by the James Webb Space Telescope (JWST) and have contradictory observed properties as they should not have had enough time to evolve into similar galaxies to the ones in the late-Universe. In [3] they address the problem of photo-z large scale density reconstruction in case of large redshift uncertainties and manage to get accurate inferences on scales smaller than those with the help of a forward model using Markov Chain Monte Carlo realizations and field-level inference. In [4] they challenge the Cosmological Principle of the Universe being homogeneous and isotropic on sufficiently large scales by showing the difference in their found dipole from quasars and that of the Cosmic Microwave radiation. In [5] they present a new quasar catalogue of photometrically selected candidates.

Aside from the strengthening of my theoretical background and learning I also implemented a few improvements to my existing model and tried other practical approaches. As I mentioned I also learned the UMAP and t-SNE dimensionality reduction methods to have some other, possibly more powerful alternatives to SOM, in case it falls short in some regard in the future. Furthermore I have run my model on the latest available Sloan Digital Sky Survey (SDSS) data, namely the data release No, 18 (DR18). It contains newer and more observations, simply more and better data. I also reevaluated one of the neural networks I worked with in the past, namely the Inception-module neural network which I used for the estimation of cosmological redshifts of galaxies for my BSc. It proved particularly useful as a task to further familiarize myself with the *pytorch* package.

The further steps will include the practical realizations of the knowledge I acquired during the semester in my work and implement them accordingly into my machine learning model.

# 3 Publications

I had no publications in this semester.

# 4 Studies in current semester

In this semester I attended two courses. The course *Fractal growth* was about the fractal property of different models and real networks and different generative methods realizing fractal properties. I also attended the course: *Quantum Information Theory* to quench my long-lasting 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 no teaching activity.

# References


[1] E. V. Linder and A. Jenkins. "Cosmic structure growth and dark energy". In: *Monthly Notices of the Royal Astronomical Society* 346.2 (Dec. 2003), pp. 573–583. ISSN: 0035-8711. DOI: 10.1046/j.1365-2966.2003.07112.x. eprint: https://academic.oup.com/mnras/article-pdf/346/2/573/4294515/346-2-573.pdf. URL: https://doi.org/10.1046/j.1365-2966.2003.07112.x.

[2] Nikita Lovyagin et al. "Cosmological model tests with JWST". In: *Galaxies* 10.6 (2022), p. 108. DOI: 10.3390/galaxies10060108.

[3] Eleni Tsaprazi et al. "Higher-order statistics of the large-scale structure from photometric redshifts". In: (Jan. 2023). arXiv: 2301.03581 [astro-ph.CO].

[4] Lawrence Dam, Geraint F. Lewis, and Brendon J. Brewer. *Testing the Cosmological Principle with CatWISE Quasars: A Bayesian Analysis of the Number-Count Dipole*. 2022. arXiv: 2212.07733 [astro-ph.CO].

[5] Alice M Eltvedt et al. "The VST ATLAS quasar survey I: Catalogue of photometrically selected quasar candidates". In: *Monthly Notices of the Royal Astronomical Society* 521.3 (Feb. 2023), pp. 3384–3404. ISSN: 0035-8711. DOI: 10.1093/mnras/stad516. eprint: https://academic.oup.com/mnras/article-pdf/521/3/3384/49630470/stad516.pdf. URL: https://doi.org/10.1093/mnras/stad516.