Cosmology by its definition is the study of the origin, evolution and eventual fate of the universe. However, there is a lot of unknowns about the beginning of the universe, only uncertain theories about its future, and some huge questions about what happens in the middle. One of the most important of these questions is how the complex structure of galaxies observed in the local universe formed and evolved through time.

According to the modern cosmological models, which describes the state of our current understanding of the shape and evolution of the universe, the vast majority of its structure is build of something we can't directly observe. Because of that we named this component the ’dark’ matter, in opposite to the ’luminous’ matter we can observe. Studies showed that these two components are related and galaxies (or in general luminous matter) reside inside the dark matter haloes. Thus, in theory by tracing the evolution of the galaxy structures it should be possible to trace the evolution of the underlying dark matter structure. There is however one problem. This dark-luminous matter relation is never straightforward and depends, among others, on the different physical properties of galaxies. In result understanding the relationship between galaxies and the underlying dark matter become one of the key elements and the biggest questions of modern cosmology. The aim and purpose of our project is concentrated around this issue.

At first we address the problem measuring the level of galaxy concentration (clustering). Although this kind of studies have been conducted (extensively) on local Universe data, they have not been performed at early cosmic epoch, when the universe was very young. So seem natural and necessary to extend the analyses.

In this research project we propose an unprecedented study of the large scale structure performed at very early epochs of the evolution of the universe (when it was only 1.5 billions years old). Studies which were previously impossible due to the lack of good enough methods and technology allowing observations of the very weak objects. Now is possible thanks to the first of its type large spectroscopic galaxy survey aimed at observations of the young universe - the VIMOS Ultra Deep Survey (VUDS).

These analyses will allow us to answer the following questions: How, the highly concentrated large scale structure of the universe observed nowadays, has formed and evolved through time? What is the difference between the underlying dark matter density distribution and the observed luminous structures at different cosmic times? What is the physical relation between these two components: dark and luminous, and how this relation changed through time? What processes drive, regulate and truncate the formation of stars inside galaxies? When and what kind of mechanisms dominated the evolution of different galaxy types with given properties at different cosmic epochs. By answering these questions, we want (i) to test if our observations and measurements fit into the modern commonly accepted cosmological model framework and (ii) contribute to the developement of models of galaxy formation and star formation in the early cosmic epochs, which at present are still highly uncertain and lack sufficient observational evidence. This project aims at providing such an evidence.

The level of galaxy concentration can be quantify by measurements of two point correlation function, which will be the very base of all our the studies. This function is based on the very simple idea of measuring the probability of finding two galaxies separated by a given distance. Although the idea is relatively simple, this definition cannot be straightforwardly applied to compute the correlation function from real data samples, because of the limitations of galaxy surveys themselves. In principle, to retrieve ideal correlation functions one would need an access to an unlimited survey which covers the whole sky, and includes all galaxies. Naturally, in practice such surveys are unreachable. So the very first task in our kind of studies is always finding the appropriate method of correlation function estimation. All necessary tools and computer codes have been already prepared and tested by the PI of this project and they are ready for planned new measurements.

Naturally measurement of the correlation function alone would not help us at all. We need to use its approximation in for of accurate and physically justified model. Obtaining the best-fit model parameters allows to interpret the measurements and drive conclusions. There are many prescriptions for such of models. In the first place we are going to use recently the most extensively used ones - so called the halo occupation distribution (HOD) models. However we are also going to challenge the standard construction of the existing HOD models, by modifying their components and possibly adding new parameters. This become a crucial task as the 'standard' prescriptions are slowly ageing. The existing models served (still serve) great in the past decade or so, but they need to be update as there is increasing number of upcoming large galaxy surveys, which statistic will allow to measure very detailed correlation functions. Hence also detailed approximation, without simplified components, is now required.

In conclusion most of planned in this project measurements are going to be among the first ones ever performed with a high accuracy for data form early epochs of galaxy formation. As such, they will provide a valuable benchmark for the interpretation of the co-evolution of galaxies and Large Scale Structure at early epochs of galaxy formation (from the times when the Universe was only 1.5 billion years old) and put constrains on the efficiency of the processes which drive the star formation and mass assembly in galaxies at that time. All of this information can be used, among others, as an input to improve galaxy formation models and simulations, which are still uncertain and need to be informed by improved observational constraints. The measurements and results provided by this project can also be considered as a precursor of next generation studies coming with the advent of the new powerful facilities like e.g. the James Webb Space Telescope (JWST) or Extremely Large Telescopes (ELTs)
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Our project will put some new perspective and will improve understanding of the Universe as it was at the early stages of its evolution. For sure our studies will serve as the basis for new follow-up studies, taking us even closer to definitive answers for the unanswered, major cosmological questions.