The main goals of the LUSTRE project are related to the biggest open questions in the contemporary science. These unprecedentedly difficult problems call for implementation and developing of the most advance and novel techniques of computer simulation and data analysis.

In the past two decades cosmology has become one of the most important and most successful branch of physical sciences. The clear testimony for this are three Nobel prizes awarded in this field in recent years. All these amazing discoveries and theoretical breakthroughs lead to the constitution of the Standard Cosmological Model (SCM).

The standard model consists of a set of theories and established parameters which gives us the most adequate description of the Universe and its evolution on the largest scales. The SCM successfully predicts and explain a wealth of astronomical observations. In particular it describes how tiny primordial density fluctuations present in young and hot Cosmos had evolved in over 13 billions years of cosmic evolution to from the observed magnificent large-scale structure of the cosmic web in which galaxies and their clusters are arranged.

Despite these all unquestioned great successes, the advancement of the modern cosmology and extragalactic astronomy had brought also the biggest unsolved puzzles of the modern science. One of those is to find and explain the physical mechanism responsible for accelerated expansion of the Universe. The standard model employs General Relativity (GR) for describing the gravitational interactions on all scales. Within the framework of the Einstein's theory the accelerated expansion is driven by the so-called Cosmological Constant (CC), which would have to be very small. On the other hand the quantum physics predicts that if the speeding up of the expansions is caused by the CC it vale would be 50 orders of magnitude greater than the observed one. It is the biggest discrepancy between the theory prediction and a measurement in the history of the natural sciences.

The search for accelerated expansion explanation and the CC problem have become topics of the whole new area of research in modern theoretical cosmology. There have been many interesting ideas put forward to modify GR in a way that would allow for accelerated expansion of space-time without the CC. On the other hand we also know that the Einstein's theory has been rigorously tested only on the interplanetary distance scales. Yet we apply GR to describe the whole Universe. This is an extrapolation of the theory over 15 orders of magnitude in scale!

It is not surprising then that the construction and conduction of novel gravity tests on cosmological scales had become one of the most important and pressing challenges of the contemporary cosmology. The LUSTRE project will contribute significantly towards solutions of these problems.

In this project we aim to test dark energy and gravity by studying in great detail the formation of the local universe and to use the local universe as a cosmological laboratory to study the nature of gravity and dark energy. Specifically we aim to run constrained simulations of the local universe assuming standard dark energy (GR) and proposed alternative such as modifications to gravity, in an effort to provide new independent ways of ruling one in or out. Constrained simulations are cosmological simulations of structure formation where the initial conditions have been constrained by observational data, such that the final result is destined to reproduce the observed cosmographic landscape. Such simulations allow cosmologists to directly model the environment of the Milky Way and Local Group, instead of simulating random statistically similar structures. The German side is a world leader in running and analysing such simulations, while the Polish side is a world leader in testing theories of modified gravity. By combining our expertise we will, for the first time, be able to produce models of the Local Universe under the assumption that the laws of general relativity, one of the foundations of modern physics that has stood prime for over a century, are only an approximation to nature, revealed on small scales. Our project will have a major impact in both the fields of galaxy and structure formation (addressing question of how the local group and local universe formed), as well as in the field of modified gravity ruling in or out specific models that have been put forth in the literature.