It is a common situation in physics that the mathematical equation describing some natural law is solvable only for the simplified (with respect to reality) picture. Once we have such a simplified solution, we can think of how would it change if we slightly change some parameter or in other words if we add some perturbation. Perturbation theory finds applications in many disciplines of physics. It is a tool to generate an approximate solution to a mathematical formulation of a physical law. Solution that is 'close' in a suitable sense to usually simpler but exact, known solution. It relies on two important ingredients: we have to know that the exact solution obeys some physical law and importantly our actual physical situation we want to describe is very similar to the idealized one. This however is not always an easy task, especially in the context of cosmology and theory of gravity.

Physical cosmology is a branch of physics aiming at describing the Universe and its large scale structure constituted of galaxies, galaxy clusters, filaments and voids. The major role in formation of these structures is played by gravity and thus the theory used to perform calculations is Einstein's theory of general relativity.

Current cosmological model is based on simple solution to Einstein equations which is supposed to represent its large-scale behaviour and perturbations playing the role of 'seeds' for cosmic structures. Its name – the Λ CDM model- comes from two major ingredients predicted within this approximation. Cosmological constant (Λ) and cold dark matter (CDM) pose tremendous theoretical problems for fundamental physics and up to date have never been directly detected. In addition, recent observations reveal serious tensions with respect to our expectations based on the ΛCDM model. This strongly suggests that our current approach to cosmology is inadequate. Main ideas to solve this issues revolve around modifying general relativity or playing with matter composition of the Universe. There exist however third, scientifically more conservative way that we wish to take.

The main aim of this project is to tackle these major theoretical problems and persistent tensions with the full power of general relativity, not relying on the approximate perturbative approaches nor any alternations to existing well tested theory of gravity. When combined with the detailed studies of light propagation results of our research will put a scientific community in a strong position to attack the persistent mysteries of the true physical nature of dark energy and dark matter and in principle will relieve at least some of the observational tensions. After all, in our pursuit of unveiling the nature of the Universe, we should first fully exhaust the well tested, fundamental principles we put our scientifically justified confidence in, before calling for any sort of 'new physics'.