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Abstract for the general public

When we point a telescope at the sky in order to make an observation, our detector receives a bundle of light rays from a distant object in the Universe. The observational information we obtain from the sky regarding the brightnesses, the distances and the image distortions of the astrophysical objects resides in the properties of this light bundle.

It is true that we can treat light as a collection of particles, called photons, for many of the observations on the sky. This means that the ray picture of light is a good–enough approximation to detect certain phenomena in the Universe which belong to the subject field of Einstein's theory of general relativity. On the other hand, it is also true that light demonstrates certain wave properties at the same time. In general, those wave properties can be classical or quantum in nature. However, there exists no generic formalism in the literature which studies the classical and quantum behaviour of light in general relativistic scenarios. In this project, we aim to fill this gap.

Previously, we obtained the light bundle propagation in the Universe via a method that is analogous to the one of the light propagation through an optical device. This formalism has certain features that allow one to switch from the ray–picture to a wave–picture. In the current project, we would like to use this method in order to establish a theoretical framework to study (i) classical wave effects and (ii) quantum effects on the propagation of a thin light bundle which are most relevant for the observations on the sky. Even though the main objective is the light propagation, gravitational waves will be our other point of interest.

Within this project, we will try to find answers to some very important fundamentals problems. For example, how is the distance calculations of astrophysical objects change when we use wave–properties of light? Can one discover new wave phenomena in the Universe which are analogous to the ones we measure in a typical transistor of an electric kettle? More importantly how do the two distinct domains of quantum and gravitational physics can be merged considering the observations on the sky? Finding the successful answers to those questions not only will help us to identify the ingredients of the Universe in a practical sense but also will help us to understand our physical existence in the Universe on a foundational level.

We are expecting a big impact of this project as there has been an increased interest in the wave effects of the propagation of both the electromagnetic and gravitational waves lately. We believe we will provide a considerable amount of contribution to this subject and start a new page in our understanding of light propagation in the Universe.