

Waves emitted by distant astronomical objects, electromagnetic and gravitational, are the main source of information about the Universe available for astronomers. However, in order to understand what astronomers really register with their instruments we need to understand how waves travel through the spacetime. In this project we will advance the theory of their propagation through curved spacetimes. In particular, we want to include the effects beyond the standard geometrical optics approximation and the effects of possibly complicated motions of the sources and the Earth.

We will study two concrete examples of astrophysical wave sources. The first example is a pair of black holes on a tight orbit around each other, or binary black hole, orbiting at the same time an even more massive object, i.e. a supermassive black hole. Such sources would emit gravitational waves that could potentially be detected by gravitational wave detectors on Earth. Their signal, or waveform, will differ from the waveforms of free-floating binary black holes, detected routinely these days, and the purpose of our project is to understand that difference and determine what kind of information about the objects in question we could learn from such detection.

The second example is a strongly lensed galaxy or other distant luminous object. It is known that a heavy mass between the light source and the Earth, for example a galaxy cluster, may act as a gravitational lens: its gravity bends the light rays, which may lead to the emergence of multiple deformed images of a single distant background object. In this project we will address the question if it is possible to detect transverse motions of sources and the lens by monitoring the images of strongly lensed objects, their precise positions and their redshifts (wavelengths) over a 10-year period.