One of the most fundamental symmetries present in nature is chirality. We say that an object is chiral when it is distinct from its mirror image.

The most recognizable example of something chiral are human hands. The left hand varies from the right (try wearing the left glove on the right hand), but one is the mirror image of the other. Many other objects in common life have similar chiral properties, for example shoes, spring screws, etc.

In science, the most important example of chirality exists in biology. The crucial building blocks of all living organisms at the molecular level are built from chiral compounds. DNA, RNA, and their building blocks are all right-handed, whereas amino-acids that form proteins are only left-handed. Although the origin of this specific asymmetry is still a mystery, it is a topic of multiple developing hypotheses and theories.

Chirality is also of significant importance in optics. Light is an electromagnetic wave propagating in space. This wave has a particular property known as polarization, which tells the direction of oscillations in space. Specifically, such polarization can be circular when the electric field rotates like a helix. This polarization has a chiral nature of two distinct left-hand circular and right-hand circular polarization.

Within this project, we plan to investigate how light of such chiral properties can interact with matter, and specifically with chiral matter.

In the beginning, we plan to concentrate on obtaining chiral crystals of perovskites. Perovskites are a novel family of materials. Especially recently, perovskites gained significant attention because of their promising applications in large-scale photovoltaic cells. Another advantage of perovskites is the ability to change their properties by adjusting their composition. Specifically in this project, we propose to exchange the cation in the perovskite structure to a small organic with chiral structure.

Earlier research has already shown that such chiral perovskites react differently to light of different circular polarization. Depending on the chirality of the cation, light of different circular polarization is absorbed stronger or weaker. This effect is also known as circular dichroism.

A significant part of the project will be devoted to studying how such a circularly dichroic material will behave when incorporated inside an optical microcavity, a planar photonic structure used to confine light. We plan to investigate novel phenomena originating from the circular dichroism belonging to so-called non-Hermitian physics. We want to observe an exceptional ring as well as localization of the wavefunction at the boundary, known as non-Hermitian skin effect.

In another approach, we also plan to create a chiral cavity, confining light of only one circular polarization. To achieve that, we plan to use polymerized layers of cholesteric liquid crystals. In cholesteric liquid crystals, anisotropic molecules of the liquid crystal are arranged into helices. Interestingly, such structures due to their helical structure strongly reflect light of one circular polarization but highly transmit the opposite circular polarization. By stacking two layers of such a cholesteric liquid crystal we can form a cavity, where circularly polarized light will be effectively trapped between two highly reflective surfaces.