The purpose of the project. The goal of this project is to describe the evolution of star-forming galaxies in the Universe over time, using populations of distant galaxies observed by the James Webb Telescope. The main question I will answer is: 'How has the efficiency of star formation evolved over time in our universe?' During the project, the first thing will be to describe the average rate of star formation in the Universe from the point of view of the so-called Star Formation Rate Density (SFRD) – how many stars, on average, are forming per unit of time and volume in the universe at any given time in its history. To go further, I will also describe how the star-forming properties evolved in individual galaxies at any given time in the history of our Universe, depending on their optical parameters such as their mass, distance, etc.

Project description. In order to describe the various properties of galaxies in the early Universe, large sky maps are needed to collect samples that can be considered representative of the entire Universe. In addition, the maps must be deep enough for galaxies large and small to be observed in large enough numbers. The latest maps of the James Webb Telescope, which will be used in this project, will identify more than 100,000 galaxies that formed when the Universe was only about 300 million years old (~3% of its current age). My group will use James Webb's catalogs, along with high-resolution FIR data from the Atacama Large Millimeter Array (ALMA) to construct the Lumiosity Functions that describe the densities of galaxies in the Universe at a given time in its evolution. Using the appropriate relationships, the evolution of the star formation rate in the Universe can be accurately described. Since most galaxies cannot be directly observed at FIR wavelengths, the contribution to the SFRD in the universe from dimmer objects will be described by my group using a method called 'stacking' (averaging the brightness of multiple sources by overlaying images) in FIR maps, which will allow us to get average values of the star formation rate for objects for which it cannot be observed directly. During the stacking procedure, average luminosities will be determined for groups of galaxies with similar physical properties, such as stellar masses. During this process, many relationships between the physical properties of galaxies and their FIR luminosity will be carefully calibrated.

Motivation. One of the main goals of observational cosmology is to describe the evolution of star formation in the universe over time. As it is one of the most fundamental observational properties, it is one of the basic inputs of today's simulations of the evolution of the entire Universe. In addition, the Luminosity Functions needed to describe the SFRD are used to test cosmological models. An accurate description of this evolution is therefore essential not only for observational astronomy, but also for theoretical models describing the evolution of life in our Universe. The problem is that in order to do this, you need to have maps of the sky large enough in ultraviolet (UV; sensitive to starlight) and FIR (dust emission) wavelengths. Due to the limited access to FIR maps, the evolution of the SFRD over time, as well as the Luminosity Function, is very difficult to describe, which means that many previous works give strongly inconsistent results.

The James Webb Telescope, as the successor to the Hubble Telescope, is a powerful instrument that allows us to observe distant galaxies, previously unattainable to us. With the catalog of the farthest galaxies in the universe, and with the help of maps constructed using the SCUBA-2 instrument mounted on the James Clerk Maxwell Telescope in Hawaii, and high-resolution data from the ALMA interferometer, as well as additional optical catalogs, we can significantly expand the current knowledge about the evolution of star-forming galaxies, and the star-formation rate density in the early Universe.

Expected results. The aim of the project is to describe the properties of star-forming galaxies out to z~12. The project consists of 9 main research tasks that will be divided among the members of the group. First, James Webb's galaxies will need to be stacked in the far infrared to find the infrared luminosity, and thus the dust-shrouded star-formation rate. This will be carried out for both star-forming and quiescent populations and will allow us to quantify the properties of galaxies as a function of various optical properties, including redshift, stellar mass, UV slope and more. Most importantly, it will also allow us to derive the redshift evolution of the star-formation rate density out to z~12.