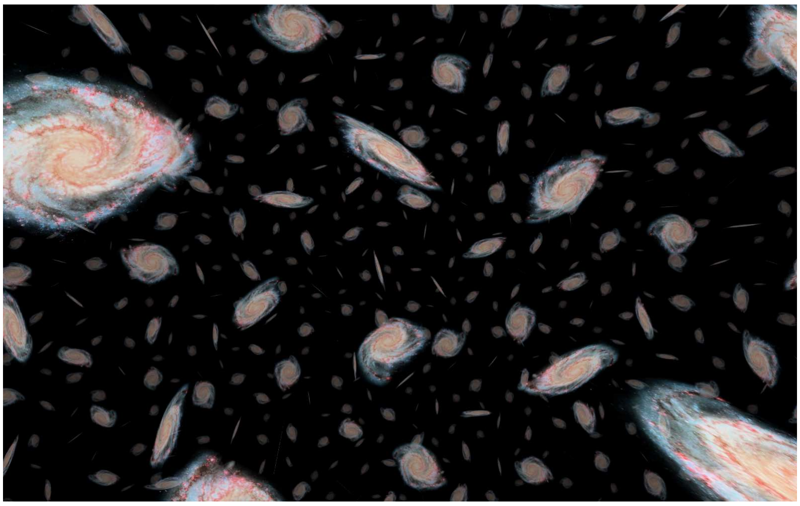
Cosmic topology and gravitation:
New theories and predictions

One question that philosophers tried to tackle through the millennia is whether the Universe is infinite or finite, and for the latter case what are its borders. While for a long time this question has been considered to be metaphysical, the development of mathematics and physics during the past centuries allowed scientists to give it a physical sense. However, in the possibility of a finite Universe, for instance with the shape of a cube, there would be no borders: travelling through one face of the cube would "teleport" us to its opposite face, similarly to some video games where a moving character, when arriving at the end of the screen, is found itself on the other side of that screen. In such a Universe, we would observe multiple copies of our galaxy, the milky way (see image). The positions of these images in the sky would depend on the shape of the Universe. The technical term physicists have for this shape is *Cosmic topology*.



Curved spaces software, Jeffrey Weeks

Using the ΛCDM model, which is the current paradigm of cosmology, along with telescope observations, it seems that the cosmic topology looks to be of a certain type, that we call Euclidean topology. But while we managed to find a lower bound for the size of the Universe, which is necessarily 100 000 times larger than our milky way, we are still not able to determine its precise shape. One reason for this is that the methods that are available to us to study cosmic topology do not describe all the possible aspects of this field of physics. Especially, two questions are still opened: **does the cosmic topology have an effect on the structures of galaxies, i.e. on how the galaxies are arranged together? Has the cosmic topology an effect on the expansion of the Universe?** The goal of this project is to develop new theoretical tools to study these problems.

One phenomenon which is common to both of these questions is gravity. We currently have two theories to describe that phenomenon: Newton's theory of gravity and Einstein's theory, the general relativity. While the latter is the more precise, it is also more difficult to use. That is why most of the calculations in cosmology use the former. The main problem we had until recently with that approach is that Newton's theory could not be used for all the possible shapes of the Universe. For this reason, during my PhD thesis I adapted that theory to allow for its use in any shape. Most of this project will focus on using that adapted theory, which I call *non-Euclidean Newtonian theory*, to answer the above questions.

Another point I will study during this project is linked to another result I obtained during my PhD thesis: general relativity seems not to be valid for any shapes, similarly to Newton's theory. Here I will focus on adapting general relativity for all the possible shapes of the Universe.

This project will pave the way for future detections of the cosmic topology with forthcoming galaxy surveys like the Euclid space telescope which will be soon launched by the European Space Agency.