DESCRIPTION FOR GENERAL PUBLIC

Spiral galaxies such as our Milky Way are surely among the most beautiful objects in the universe with their bright and graceful spiral arms, but they are also among the most complex. These spirals are embedded in a disk, which is the dominant visible structure of spiral galaxies, and is rotating, producing angular momentum. This angular momentum (AM) plays a central role in the development of the galaxy, as it influences the overall shapes, extent and rotation of their components, such as the spiral arms. Therefore, understanding how the AM is distributed and exchanged is crucial to predict and comprehend spiral galaxies properties and evolution, and progress is still to be made in this area. Many features can influence and perturb the angular momentum in the disk, such as galactic winds. These winds are produced and accelerated in supernovae explosions, and transport hot gas throughout the whole galaxy. In particular, these explosions also create and accelerate cosmic rays, a relativistic high-energy gas mostly made of protons and alpha particles. Cosmic rays then interact with the galactic magnetic field, to produce powerful cosmic rays driven winds in the galaxy. These winds have several effects on the galaxy and on its AM. They can expel low AM gas out of the disk, which decreases the amount of gas available in the disk to form stars. The gas can also be transported from one region of the galaxy to another, so that the winds redistribute gas and AM throughout the whole disk. Cosmic Rays and the magnetic field are therefore essential to apprehend the formation and evolution of disk galaxies and their substructures, however they are rarely included in galaxy simulations. This project aims to explore for the first time the role of CR driven winds in the AM distribution of spiral galaxies, in a realistic cosmological context, i.e. in presence of other surrounding galaxies and of environmental effects. Furthermore, an important fraction of spiral galaxies (such as the Milky Way) hosts a bar, an elongated bright structure in the center of the galaxy. This bar exchanges AM with the galactic gas, as it produces torques driving gas toward the center, and decreases the gaseous AM. While this phenomena has mostly been investigated as an isolated process, I am interested in probing how CR driven winds affect this mechanism, if they can shut it down or enhance it.

During this project, I will be running and analyzing high resolution numerical simulations of spiral galaxies including magnetic field, cosmic rays and numerical particles to represent the stars, to address the question of AM exchanges and distribution in presence of CR driven winds. The simulations will be run using PIERNIK, an open-source, multipurpose magneto-hydrodynamical code developed at Nicolaus Copernicus University in Toruń, and will include stars, gas and dark matter, with a few million numerical particles. The preliminary part of the project will be devoted to testing the new module in PIERNIK allowing to implement numerical particles, and to adopting it to the planned galaxy evolution simulations. The team I will be joining in Toruń is actively developing the code and providing support for new team members, and I will have access to powerful supercomputers to run the simulations.

I will then simulate galaxies in presence of their neighborhood, i.e. with other galaxies around, using the publicly available Illustris simulation. Illustris is a huge cosmological simulation simulating a portion of the universe, producing hundred thousands of realistic galaxies. I will take some of the most interesting spiral galaxies in Illustris, and will re-simulate them at higher resolution with PIERNIK. This will allow to create high resolution galaxy simulations that are very realistic, because evolved in a cosmological context. This sample of simulations will allow me to investigate how CR driven winds impact the AM of disk galaxies in different situations, and their influence in presence of other features affecting the AM, such as bar driven gas flows towards the center, or interactions with other galaxies. This analysis will be done in collaboration with Prof. M. Hanasz in Toruń, who has expertise in simulations including magnetic field and Cosmic Rays, and with Dr. T. Naab from the MPA Institute in Garching, as the team in MPA is a world leading expert on galaxy formation and evolution.

Despite knowing the importance of AM in the formation, evolution and structure of disk galaxies, we still lack a global picture of all the phenomena determining and influencing the AM distribution and exchanges. With this project, I aim at building a more complete and accurate view of the AM evolution in spiral galaxies. In particular, Cosmic Rays and magnetic field are a rather recent and still marginal addition to galaxy simulations, so that we only start to apprehend their importance for galactic formation and evolution, in the form of CR driven winds. This project will thus unveil for the first time their role for galactic AM distribution in the global picture of spiral galaxies formed in a realistic cosmological context, in presence of a bar or galaxy interactions. This will put new constraints on future simulations of disk galaxies, and show the importance to include magnetic field and CR in galaxy simulations.