1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan)

Project title: Numerical simulations of Cosmic Ray Propagation in galaxies.

1.1 Project goals

- To understand propagation of galactic cosmic rays (CRs) from the perspective of dynamically evolving interstellar medium (ISM).
- To construct numerical models of production and propagation of primary and secondary CRs coupled to magnetohydynamical (MHD) models of galactic ISM.
- To perform global galactic disk simulations with primary and secondary CRs.
- To investigate CR propagation properties via confrontation of numerical models against observational data of galactic CRs.

1.2 Outline

Cosmic rays are an important ingredient of galactic interstellar medium. Recent investigations clearly revealed their dynamical impact on galactic evolution through generation of galactic magnetic field and galactic winds (Hanasz et al., 2009, 2013; Girichidis et al., 2016, 2018).

The aim of the project is to construct a self-consistent MHD model combining CR-driven dynamics (Hanasz et al., 2009) of the ISM with the elaborated description of CR interactions developed within the GALPROP model (Strong et al., 2007) of CR production and propagation in the Milky Way. The main part of the research plan is to incorporate production and propagation of secondary CR components (Li, Be, B) into the MHD model of the Milky Way in order to estimate CR propagation parameters in a novel self-consistent way. The research plan includes development of numerical algorithms and numerical simulations with the aid PIERNIK MHD code and confrontation of simulation results against direct measurements of Galactic CRs and their emission properties revealed through the gamma-ray and radio-emission.

1.3 Work plan

1. Mastering usage of PIERNIK MHD code.
2. Mastering magnetohydrodynamical simulations of galactic ISM.
3. Implementing production of secondary CRs in PIERNIK MHD code.
4. Numerical simulations of the dynamics of galactic interstellar medium with primary and secondary CRs.
5. Analysis of simulation results and tuning CR propagation parameters to match observational properties of Galactic CRs.

1.4 Literature

- Girichidis, P. Pfrommer, C., Hanasz, M., Naab, T., (2020), MNRAS, 491, 993 - 1007.
- Girichidis, P., Naab, T., Walch, S., Hanasz, M., 2016, ApJL 816, L19
- Girichidis, P., Naab, T., Hanasz, M., and Walch, S.: 2018, MNRAS 479, 3042
- Hanasz, M., Lesch, H., Naab, T., Gawryszczak, A., Kowalik, K., and Wóltański, D.: 2013, ApJ 777, L38
- Hanasz, M., Wóltański, D., and Kowalik, K.: 2009, ApJ 706, L155
- Longair, M. S.: 2011, *High Energy Astrophysics*, Cambridge, UK: Cambridge University Press
- Strong, A. W., Moskalenko, I. V., and Ptuskin, V. S.: 2007, Ann.Rev. Nucl. and Part. Sci. 57, 285

1.5 Required initial knowledge and skills of the PhD candidate

➔ Analytical thinking

➔ Eager to learn

➔ Eager to work hard

➔ Basic knowledge about high energy astrophysics, fluid dynamics, numerical methods for fluid dynamics.

➔ Theoretical inclinations

➔ Some experience in numerical simulations

➔ Programming skills

1.6 Expected development of the PhD candidate's knowledge and skills

Cosmic rays and their impact on the formation and evolution of galaxies are currently a hot topic of theoretical astrophysics investigated in leading astronomical institutes in the world. The PhD candidate will learn very interesting aspects of rapidly developing understanding of galaxies, including the physics of interstellar medium, galactic magnetism, galactic evolution, cosmic ray astrophysics, magnetohydrodynamical simulations with modern numerical codes, advanced programming techniques and high performance computing. The candidate will develop his/her scientific personality in the international collaboration with excellent German scientists from Munich and Potsdam astronomical institutes.