Module: Elective Advanced Lectures: Modern Astrophysics

Module No.: astro850

Course: Dynamics of Astrophysical Fluids and Plasmas

universitätbonn

Course No.: astro8508

Category	Type	Language	Teaching hours	CP	Semester
Elective	Lecture with exercises	English	2+1	4	ST

Requirements for Participation:

Preparation:
Needed: "Introduction to astrophysics", "Electrodynamics"
Useful: "Hydrodynamics", "Plasma physics", "Statistical physics", "Stellar physics"

Form of Testing and Examination:
Requirements for the examination (written or oral): successful work with the exercises

Length of Course:
1 semester

Aims of the Course:
Astrophysical objects, like stars, the interstellar medium, galaxies, and galaxy clusters, are typically modeled as fluids. Since baryonic matter (= non-Dark Matter) in the Universe is partially or sometimes even fully ionized, astrophysical fluids are coupled to cosmic magnetic fields which are detected by radio telescopes everywhere where we have the means to do so. Therefore, astrophysical flows follow the laws of magnetohydrodynamics (MHD), making this an essential tool for a modern theoretical astrophysicist.
In this course, I will review the basics of MHD with selected applications to astrophysics. The students will learn which different MHD effects are important in which astrophysical problem. They will also learn how to solve the MHD equations analytically (~60% of the exercises will be pen and paper work) for special problems and the basics of how to perform numerical simulations (the remaining ~40% of the exercises). For this, the publicly available Pencil Code will be used (http://pencil-code.nordita.org/). The students will be running 2D sample simulations and analyze the output data with python. Python libraries for reading the simulation data will be provided.

Contents of the Course:
1) Introduction to astrophysical fluids; 2) From kinetic to continuum; 3) Ideal fluids; 4) Viscous fluids; 5) Compressible fluids; 6) Perturbations in hydrodynamics: waves and instabilities; 7) Turbulence; 8) Numerical methods in hydrodynamics; 9) The plasma Universe; 10) Collisionless plasma processes; 11) From kinetic theory to 1-fluid magnetohydrodynamics; 12) Basic MHD; 13) MHD turbulence and dynamos

Recommended Literature:
Choudhuri, "The physics of fluids and plasmas. An introduction for astrophysicists", Cambridge University Press, 1998
Biskamp, "Magnetohydrodynamic Turbulence", Cambridge University Press, 2003
Brandenburg & Subramanian, "Astrophysical magnetic fields and nonlinear dynamo theory", Physics Report, 2005