Study programme: Astronomy and Astrophysics – PhD Studies
Course: Simulations of Astrophysical Plasmas
Teacher or teachers: Vladimir Zeković
Status: optional
ECTS credits: 9
Requirements: none
Course objective: Gaining an advanced knowledge in the use of simulations in studying the high-energy astrophysical plasma processes.
Course outcome: Upon successful completion of the course, student is trained to write its own and use the existing programming codes in the modeling of astrophysical plasma processes. The mastered experimental and theoretical methods enable the student to study the plasma processes on its own, from kinetic to macroscopic scales, and in the range of relativistic and non-relativistic energies, such as: shocks, particle acceleration to cosmic-ray energies, particle diffusion, Pulsar magnetospheres, relativistic jets and accretion disks of Active Galasctic Nuclei and compact objects, turbulence on all scales.
Course description: **Theory.** Astrophysical plasmas: motion of charged particles, kinetic and magnetohydrodynamic approaches. Plasma instabilities, waves, and turbulence. An example of the programming code used in simulating the test particle motion in an electromagnetic (EM) field. Boris pusher and other integrators. Code parallelization and optimization. Kinetic particle-in-cell (PIC) plasma simulations. Magnetohydrodynamic (MHD) simulations. Configuring the HPC clusters and running the simulations. **Research Project.** Defining the research topics, i.e. the specific astrophysical case study which is related to the student interests or her/his doctoral dissertation. Making the initial conditions, modifying the exisiting code (if required) and running PIC or MHD simulations in the given case; or, writing/parallelizing the own code which is used to simulate the particle motion in an analytic EM field that has previously been defined to resemble the selected case. Visualizing the simulation results by using the Python or IDL programming languages.
Recommended literature: 1. Gurnett D. A., Bhattacharjee A., 2017, *Introduction to Plasma Physics: With Space, Laboratory and Astrophysical Applications*, Cambridge University Press, UK 2. Spitkovsky A., 2005, *Simulations of relativistic collisionless shocks: shock structure and particle acceleration*, AIP Conference Proceedings, **801**, pp. 345-350. 3. Mignone A., Bodo G., Massaglia S., Matsakos T., Tesileanu O., Zanni C., Ferrari A., 2007, *PLUTO: A Numerical Code for Computational Astrophysics*, ApJS, **170**, pp. 228-242. **Note:** Lecturer may add other appropriate literature.

Total number of classes: 10	**Theoretical classes**: 4	**Practical classes**: 6

Teaching methods: Ex cathedra, group work, student research
Grading system (maximum number of points: 100)

Pre-exam requirements	points	**Final exam**	points
Activity in class		Written exam	
Practical work		Oral exam	15
Project	75		
Seminars	10		
Colloquia			