Numerical simulations of accretion disks - COURSE SYLLABUS

1.	**Course title:** *Numerical simulations of accretion discs*
2.	**Lecturer:** *Miljenko Čemeljić, Bhupendra Mishra*
v3.	**Field, type and level of studies, year of study:** *astrophysics, full-time doctoral studies, all years*
4.	**Course character:** *monographic lecture*
5.	**Teaching method:** *Hybrid, MC in CAMK, BM online*
6.	**Language:** *English*
7.	**Course type and number of hours:** *lecture 30h*
8.	**Estimated load of student's independent work:** *24h*
9.	**Total workload and number of ECTS points:** *54h, 3 ECTS*
10.	**Short description and main focus of the course:** *Accretion processes are among basic mechanisms in the universe.The similarity of underlying principles of accretion at different scales and energetic ranges offer a deep insight with the least assumptions. To obtain anything more than simplest solutions, numerical simulations must be employed. In this course we will outline from the simplest, ideal hydrodynamical, to most complicated and novel, magnetized accretion disc solutions with viscosity and electrical resistivity. We will detail the used numerical methods, and guide the participants through their own simulations. The course will encompass both Newtonian and general relativistic numerical simulations, with hands-on experience through running the codes and visualizing the results in the exercises which will run in parralel with the lectures. The acquired knowledge could easily be used in other fields which benefit from numerical simulations.* *We will cover the following:* *-basics of the non-relativistic thin accretion disc theory* *-analytical solutions for a purely hydrodynamical disc* *-numerical simulations of a thin disk in purely hydrodynamical setup with the code PLUTO* *-visualization of the results in 2 and 3 dimensions* *-simulations of the astrophysical jets and outflows* *-basics of the general relativistic thin accretion disc theory* *-hydrodynamical and magnetic instabilities, turbulence*

-processing of the obtained results for further modelling
-basics of General Relativity
-pseudopotentials for simulations of black holes, neutron stars and naked singularities
-general realtivistic numerical simulations of thin accreton disc

The lectures will be shaped in „hands-on" approach: In parallel with the lectures, we will introduce the participants from the very beginning to the numerical simulations. The exercise part od the lectures will be dedicated to this. Our tools will be state-of-the-art codes: a versatile open source code PLUTO for the Newtonian simulations and Athena++ for the general relativistic simulations.

11. References:

Books:
Frank, King & Raine, „Accretion power in astrophysics"
Kato, Fukue & Mineshige, „Black-Hole Accretion Disks: Towards a New Paradigm",
Journal papers:
Shakura & Sunyaev, 1973, non-relativistic disk
Novikov & Thorne, 1973, general relativistic disk
M. Čemeljić, 2019, "Atlas" of numerical solutions for star-disk magnetospheric interaction, A&A, 624, A31
Čemeljić, Klużniak, Parthasarathy, 2023, „Magnetically threaded accretion disks in resistive magnetohydrodynamic simulations and asymptotic expansion", A&A 678, A57
Zhu & Stone, 2018, „Global Evolution of an Accretion Disk with a Net Vertical Field: Coronal Accretion, Flux Transport, and Disk Winds", ApJ, 867, 34
B. Mishra, 2016, ."Strongly magnetized accretion discs: structure and accretion from global magnetohydrodynamic simulation", MNRAS 492, 1855
On-line resources:
Abramowicz & Straub, Accretion discs, Scholarpedia article: http://www.scholarpedia.org/article/Accretion_discs

12. Prerequisites:

General physics level of mechanics, heat and thermodynamics and electromagnetism, basic level of General Relativity theory, basic usage of linux

13. Educational outcomes:	**PQF level 8 codes:**
Knowledge: *Students learn the basics of accretion disk theory and use it for the understanding of numerical simulations. They also learn the coding part and he visualisation methods/*	*P8S_WG*
Practical Skills: *Students learn the essentials of numerical simulations and also of visualization of the results.*	*P8S_UK*
Social Skills: *Students understand the importance of accretion and obtain enough knowledge to explain the basics to public and discuss the topic with specialists. They also can critically read publications and participate in preparation of the scientific reports ot publications.*	*P8S_KK*

14. Evaluation of the educational outcomes:

Delivering a max 10 pages report about performed simulations with a chosen Newtonian or general relativistic setup and discussing it with the lecturers.

15. Criteria to complete the course:

	At least 70% attendance, final grade depends on the evaluation of the report.
16.	**Contact with the lecturer:** *Email: miki,mbhupe@camk.edu.pl, consultation in CAMK, office A14 with M.Cemeljic, online with B.Mishra*