Universidad Zaragoza

Academic Year/course: 2021/22

68351 - Mathematical and computational methods in cosmology, astrophysics and particle physics

Syllabus Information

Academic Year: 2021/22
Subject: 68351 - Mathematical and computational methods in cosmology, astrophysics and particle physics
Faculty / School: 100 - Facultad de Ciencias
Degree: 628 -
ECTS: 6.0
Year: 01
Semester: Annual
Subject Type: Compulsory
Module:

1. General information

1.1. Aims of the course

The aim of the course is to provide the student with the knowledge and competencies on methodology and on the mathematical and computational tools needed to tackle research activities on the subjects of the master. The course is chiefly of a practical character, and focusses on providing current and useful skills to future researchers and/or technologists. To align the objectives of the course with the interests of each student, a third of the course consists of subjects to choose among three options. This will allow students to receive training oriented towards a profile in astrophysics, experimental (astro)particles or theoretical physics.

1.2. Context and importance of this course in the degree

This course, together with the course on *Frontier Topics*, comprises the compulsory part of the syllabus of the master. It is conceived, therefore, as a transversal course that will bring to students important methodological skills, useful for the rest of the subjects and the master thesis, as well as for their future professional development, especially if they intend to continue studies towards a PhD thesis. This transversal character is enhanced through practical work, that could be related to other subjects in the master, depending on the student's interests. It is therefore intended that, notwithstanding its compulsory character, the course be flexible enough to offer students skills adapted to their particular interests, and also aligned with the required competencies to carry on with a PhD thesis in one of the subjects of the master.

1.3. Recommendations to take this course

To be able to follow the course the students need to have some knowledge of software programming in general, and specifically some experience in the C programming language. They also need knowledge on mathematics and statistics at a level corresponding to a degree in Physics. It is also recommended that the third module of the course is elected in line with the chosen optional subjects of the master.

2. Learning goals

2.1. Competences

On passing the course, the student will be more competent to:

- use the computing techniques and tools of modelling, simulation and data analysis most commonly used in the subjects of the master.
- analyse, process and interpret experimental data obtained in experiments related to the subjects of the master.
- be able to deal with problems and theoretical developments related to the subjects of the master.
- collaborate on the development of software projects related to the subjects of the master.

2.2. Learning goals

To pass this course, students need to demonstrate the following results:

- To deepen their knowledge of numerical and data analysis methods useful in cosmology, astrophysics, particle physics and astroparticle physics.
- To know the basic concepts of differential geometry, tensor analysis and Lie groups and algebras of special importance in cosmology, general relativity and particle physics.
- To know and use databases with information and tools for astronomy and particle physics.
- To understand the basic concepts of probability and statistics and their application to particle physics, astrophysics and cosmology.

2.3. Importance of learning goals

The use of statistical and computational methods is nowadays essential for research on cosmology, astrophysics, particle physics and astroparticle physics. It is also basic to know how to use the existing databases in astronomy and particle physics. On the other hand differential geometry lies at the very foundations of general relativity, whereas Lie groups and algebras play a pivotal role in the formulation of the standard model of particle physics.

3. Assessment (1st and 2nd call)

3.1. Assessment tasks (description of tasks, marking system and assessment criteria)

The student has to demonstrate that he/she has achieved the expected learning outcomes through the following assessment activities:

- Evaluation of reports and written work: 40%.
- Evaluation of case study analysis, problem solving, questions and other activities: 30%.
- Evaluation of computational work: 30%.

The final mark will be obtained according to the percentage assigned to each assessment task. To pass the course that final mark has to be 5.0 or more, and the mark on each individual assessment task should be 4.0 or more.

A single global test

The course has been designed for students who attend face-to-face classes in the classroom, and carry out the evaluation activities described above. However, there will also be an assessment test for those students who have not carried out the assessment activities or have not passed them. This global test will be carried out on the dates established by the Faculty of Sciences and will consist of an assessment of the same learning results as in the continuous assessment tests.

Honors degree qualification

The honors degree will be awarded to students who achieve the maximum grades, as long as it is above 9.0.

4. Methodology, learning tasks, syllabus and resources

4.1. Methodological overview

The learning process that has been designed for this course is based on the following activities:

- Master classes.
- Problem solving.
- Computer activities.
- Written works.
- Tutorial classes.
- Work and personal study.
- Assessment tests.
- Guided projects.

4.2. Learning tasks

The program offered to the students to help them achieve the expected outcomes includes the following activities:

1. Assistance and involvement in lectures, in person or telematically: 30 in person hours.
2. Resolution of problems related to the subjects of the course: 15 hours, 10.5 in person.
3. Computer sessions practice: 15 hours, 10.5 in person.
4. Development of guided projects: 40 hours, 4 in person.

5. Development and presentation of written work: 10 hours, 0 in person.
6. Development of practice reports: 15 hours, 0 in person.
7. Tutorials, in person or telematically: 5 hours, 4 in person.
8. Individual study: 20 hours, 0 in person.

Teaching and assessment activities will take place in person, unless, due to the pandemic, the provisions of the authorities and the University of Zaragoza dictate otherwise.

4.3. Syllabus

The syllabus is structured in two compulsory modules and three optional ones, all of them of 2 ECT. Student will choose one of the optional modules in accordance with their interests.

Compulsory modules:

- Introduction to Python and its scientific libraries. Fundamental numerical methods.
- Statistics for data analysis in particle physics and astronomy and astrophysics.

Optional modules:

- Geometrical methods in physics: foundations of differential geometry, tensor analysis, Lie groups and algebras and some of their applications in physics.
- Tools for data analysis and simulation in nuclear and particle physics: ROOT, GEANT4, databases of nuclear and particle physics.
- Tools for simulation and data analysis in astrophysics, astrophysical databases.

4.4. Course planning and calendar

Calendar of in person sessions and presentation of work:

The dates will be chosen and announced by the lecturers at the beginning of the course.
Classes will begin and end on the dates established by the Faculty of Science.

- Theory and problem classes: 2.5 hours per week. Dates to be decided.
- Problems and computing practice classes: 1,5 hours per week. Dates to be decided.
- Assessment dates: to be decided.

4.5. Bibliography and recommended resources

http://psfunizar10.unizar.es/br13/egAsignaturas.php?codigo=68351