MICROSCOPE - Metrology and Dynamics in the Earth's environment to test gravitation

SUMMARY.
In this training we will question the theory of gravitation by studying the following points:
(i) limits of General Relativity and needs to extend it,
(ii) gravity theories versus experiments,
(iii) space as a relevant laboratory to test gravitation,
(iv) focus on a flying space mission to test the Equivalence Principle.

OBJECTIVES

- To understand the limit of General Relativity and investigate some alternative gravity theories.
- To imagine experimental ways to test the Universality of Free Fall and to find their practical limitations.
- To understand the principle of a space accelerometer and its applications for experimental physics in space.
- To model a space experiment to test the Equivalence Principle using accelerometers.
- To analyse real data from the MICROSCOPE space mission.
- To learn how to compute the motion of a spacecraft.
- To know the existence of specific orbits and to understand their avantages.

PREREQUISITES

Fundamental courses linked/coming in support to this METEOR: General Relativity, Dynamics and Planetology (in particular the 2-body problem, and applications), Numerical methods (in particular Discrete Fourier Transform), Maths/Stat (in particular Legendre Polynomials and Least Squares regression).

THEORY

by Bertrand Chauvineau and Gilles Métris

Geometric gravity and the free fall motion problem.

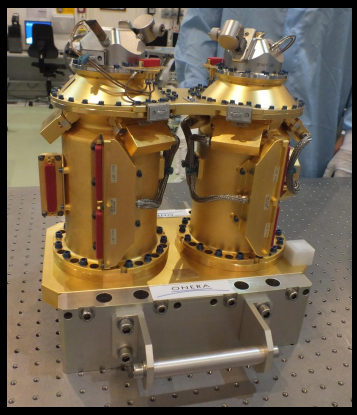
The aim of this part of the Meteor is to get some knowledge in gravity theories necessary to understand space missions aiming to test them, like the MICROSCOPE mission. The basics learned in the fundamental courses will be extensively used.
After an overview on alternative gravity theories, we will examine the problem of the motion of freely falling perfect fluid made bodies. The induced relevant notions of "masses" will be introduced, and the possibility for a neo-Newtonian interpretation of the equations of motion is discussed. The scalar-tensor gravity case is more closely emphasized.

Dynamics of artificial satellites

The space offers a very interesting environnement to test gravitation theories, either by observing the long term dynamics of natural or artificial bodies in gravity fields, or by embarking dedicated experiments in spacecrafts. In any case, the knowledge of the main elements of satellite dynamics is required. In these lessons, we will learn the main elements of orbit dynamics: motion parametrization and equations, simplest solutions, main perturbations.

APPLICATIONS

by Gilles Métris



The MICROSCOPE space mission aims at testing the Equivalence Principle, through the Universality of Free Fall which is one of its most important consequences. In this part we will understand the principle of the experiment, set up a simplified model of the measure, study the main perturbation

(namely the gravity gradient) and try to imagine methods to minimize the impact of this perturbation and we will apply these methods to real data.

MAIN PROGRESSION STEPS

- First half of the period: theoretical courses, starting of the project, bibliography.
- Second half of the period: last theoretical courses, progress of the project.
- Two last weeks: written exam, preparation of the final oral presentation.

EVALUATION

- Written exam based based on the lectures: 30%
- Participation note (answers to the exercises, activity in the project): 30%
- Oral presentation of the project (context, objectives, methods, results): 40%

BIBLIOGRAPHY & RESSOURCES

MICROSCOPE web site
The experiment end its first results
C.M. Will, *Theory and Experiment in Gravitational Physics*, Cambridge Univ. Press, 2018

CONTACT

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