MAUCA

MASTER IN ASTROPHYSICS

D. Mary, M. Carbillet, P. Bendjoya with 50 researchers
of University of Nice & Observatory of Côte d'Azur
and 12+ partner Universities and companies

Objectifs

- Allier théorie recherche et expérience
- Master de ``haut niveau'', attractif et international
- Etudiants actifs
- Adaptivité (bckd et envies) et interactivité
- Autonomie, esprit critique
- Large spectre d'outils et compétences scientifiques

MAUCA
MASTER IN ASTROPHYSICS

Actions

- Projets et suivi individualisés
- Encadrants : experts publiants du domaine uniquement
- 1 meteor = 2-3 étudiants max
- Immersion sur 6-9 semaines
- Evaluation écrite, orale, projet
- Cours en anglais
- Appui sur laptops individuels
- Chaque meteor a été choisi
- Ressources en ligne : slides, cours rédigés, biblio, codes, data,…

UNIVERSITÉ CÔTE D'AZUR

MAUCA

MASTER IN ASTROPHYSICS

A new international master with innovative research-based training

% foreign students **50**

% **training in total immersion** in research Labs / Industry **75**

% training in English **100**

Two paths:

Astronomy/Astrophysics
Space/Industry

Structure

MAUCA
MASTER IN ASTROPHYSICS

Master 1

S1

UE Fundamental Courses (serie 1) 6*3 ECTS

UE C2PU 6 ECTS 3 weeks

UE METEOR 1 6 ECTS 6 weeks

S2

UE Fundamental Courses (serie 2) 6*3 ECTS

UE METEOR 2 6ECTS 6 weeks

UE METEOR 3 6 ECTS 6 weeks

Master 2

S3

UE METEOR 4 6 ECTS 8 weeks

UE METEOR 5 6 ECTS 8 weeks

UE Scientific Com 6 ECTS

UE METEOR 6 international 12 ECTS 9 weeks

S4

UE Research/Industry Internship (30 ECTS 14 weeks

Structure

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METEOR : Module d' Enseignement Théorique et Expérimental Orienté Recherche

Master 2

S3

UE METEOR 4 6 ECTS 8 weeks

UE METEOR 5 6 ECTS 8 weeks

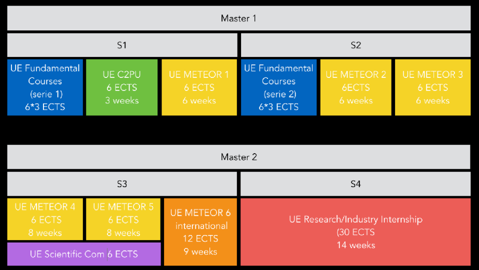
UE METEOR 6 international 12 ECTS 9 weeks

UE Scientific Com 6 ECTS

S4

UE Research/Industry Internship (30 ECTS 14 weeks

MAUCA (morning) Fundamental Courses



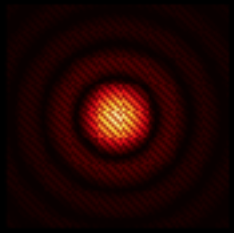
MASTER IN ASTROPHYSICS

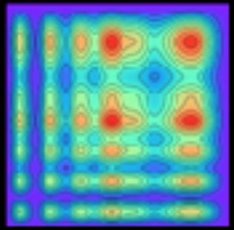
First series : S1

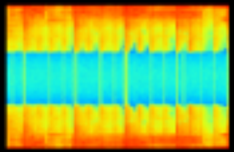

FC1.1 General Astrophysics Documents


FC1.2 Statistical physics Documents


FC2.3 Dynamics and Planetology Documents

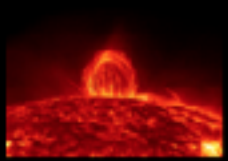

FC1.4 Fourier optics Documents


FC1.5 Numerical methods Documents

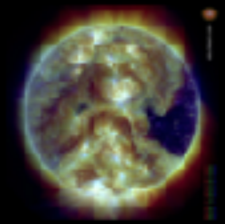

FC1.6 Signal/image processing

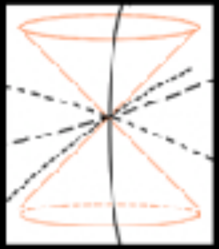
Second series : S2


FC2.1 Maths/Stat Documents


FC2.2 Fluid mechanics Documents


FC1.3 Quantum mechanics Documents


FC2.4 Stellar Physics Documents


FC2.5 General Relativity, Extragalactics and Cosmology Documents


FC2.6 Atmospheric turbulence, Image Formation, Adaptive Optics Documents

Master 1					
S1			S2		
UE Fundamental Courses (serie 1) 6*3 ECTS	UE C2PU 6 ECTS 3 weeks	UE METEOR 1 6 ECTS 6 weeks	UE Fundamental Courses (serie 2) 6*3 ECTS	UE METEOR 2 6ECTS 6 weeks	UE METEOR 3 6 ECTS 6 weeks

Master 2			
S3			S4
UE METEOR 4 6 ECTS 8 weeks	UE METEOR 5 6 ECTS 8 weeks	UE METEOR 6 international 12 ECTS 9 weeks	UE Research/Industry Internship (30 ECTS 14 weeks
UE Scientific Com 6 ECTS			

2 week immersion in a professional research Observatory @ Calern

CENTRE PEDAGOGIQUE PLANETE ET UNIVERS
C2PU

Structure - Programme

MAUCA
MASTER IN ASTROPHYSICS

Master 1

S1

UE Fundamental Courses (serie 1) 6*3 ECTS

UE C2PU 6 ECTS 3 weeks

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Master 1					
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UE Scientific Com 6 ECTS			

MAUCA

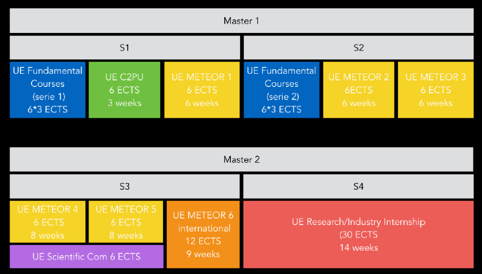
MASTER IN ASTROPHYSICS

Each student chooses 6 out of 40+ METEOR

METEOR are grouped in categories :

- Planetology
- Stellar and Galactic Physics
- Extragalactics/Cosmology/Relativity
- Signal-Image Processing/Numerical methods
- Astronomical Optics and Instrumentation
- Space-Industry

Possible to tune between astrophysics and space/industry



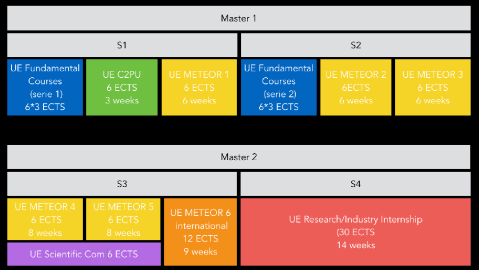
MAUCA
MASTER IN ASTROPHYSICS

METEOR are grouped in categories :

- Planetology
- Stellar and Galactic Physics
- Extragalactics/Cosmology/Relativity
- Signal-Image Processing/Numerical methods
- Astronomical Optics and Instrumentation
- Space-Industry
- 3 METEORs on space missions
- 5 training modules in space techniques @ TAS

Space/Industry track

Possible to tune between astrophysics and space/industry



MAUCA
MASTER IN ASTROPHYSICS

METEOR are grouped in categories :

- Planetology
- Stellar and Galactic Physics
- Extragalactics/Cosmology/Relativity
- Signal-Image Processing/Numerical methods
- Astronomical Optics and Instrumentation

Astrophysics track: METEOR cover 4 categories

- Space-Industry
- + 5 training modules in space techniques @ TAS

Possible to tune between astrophysics and space/industry

METEOR Example

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Build a Nanosatellite!

Have you ever thought of building an artificial satellite yourself? It is now more than 60 years that the first artificial satellite, Sputnik, was set into orbit around the Earth. This satellite served as an inspiration of generations of researchers and engineers to develop the technologies of aeronautics and space, which are nowadays very commonly found in everydaylife (telecommunications, localisation, computers, materials, etc.).
This METEOR aims at bringing space technologies to the hands of students in the form of short courses, and a direct contribution to the "Nice cube" project, the nanosatellite project of Université Côte d'Azur, which will demonstrate a LASER link between the ground and the satellite.

Nanosatellite — Theory

by F. Millour

Today, it is possible to test and validate scientific ideas and new technologies in space on small timescales (less than 5 years). This can be done aboard tiny satellites called "cubesat". These are standardized satellite platforms made of cubes of 10 cm side and 1 W of available electrical power (1U format). Several cubes can be combined (2U, 3U, etc.). Such a platform enables motivated students to learn on a hands on project the technologies, project management, and all the space-related competences.

In this METEOR, the student will first follow courses on space technologies. The following aspects will be addressed:

- How to set-up a space mission characteristics – orbit, satellite size, satellite characteristics – ?
- GNSS: what is it and why embarking it on a satellite?
- ADCS: what is it and why embarking it on a satellite?
- How to make science with a space-based instrument?

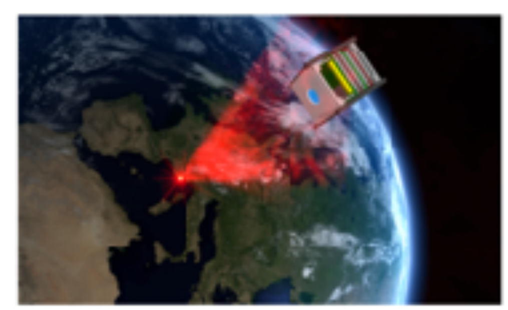
Nanosatellite — Applications

The Nice university is working on a space mission called "Nice cube". It will have two goals, one scientific goal of characterizing the air pollution above the French Riviera, and one technological of demonstrating the ability to transmit the scientific data with an optical link between the satellite and the ground.

The Nice cube mission goals will first be presented in details to the students, and the main characteristics of the subsystems will be detailed (ground and space segments).

The students participating in this METEOR will have the opportunity to participate to one aspect of the Nice Cube mission, and conduct a mini-project on the following aspects of the satellite:

- orbit choice,
- how to catch with a LASER a 3 cm corner cube at 600 km speeding at 7 km/s in less than 5 mn,
- what can be integrated in a 1U cubesat?



See also

Nice cubesat project
The PICSat satellite webpage

Contact

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✉ fmillour@oca.eu

Extragalactics, Cosmology and Relativity

METEOR Example

THE BEPI-COLOMBO MISSION

The Bepi-Colombo mission is an ESA large mission of exploration of Mercury. Its main goal is the characterization of the internal structure of the closest to the sun planets together with the tests of general relativity. In this METEOR, we will firstly see how the solar system can be a very efficient tool for testing general relativity. We will then focus on Mercury and see how the Bepi-Colombo mission can contribute in testing alternative theories of gravity.

Theory

by A. Fienga

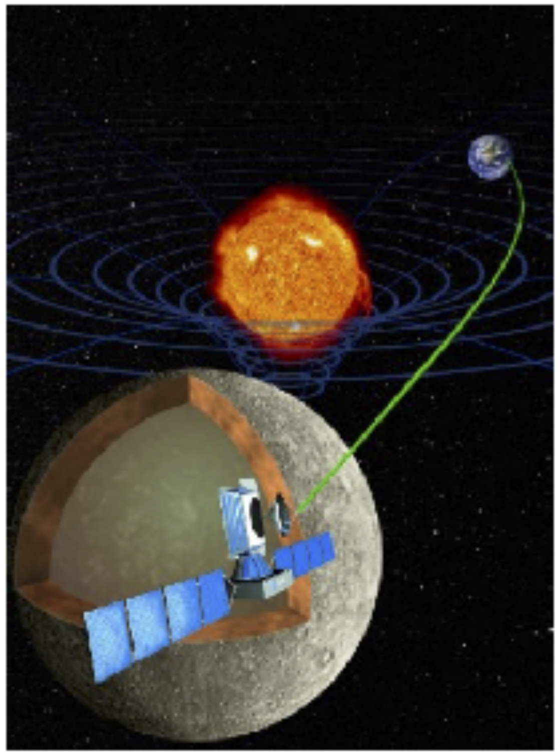
I) Introduction to special and general relativity
In this section, we will introduce different theories of gravity starting from the fondation of general relativity with the definition of the metrics, the geodesics and the different timescales to tensor-scalar theories and phenomenological approaches such as MOND theory. We will see how these diverse models impact the modelization of the light path and the equations of motion for spacecraft and solar system objects.

II) The solar system as a laboratory for testing gravity
In this section we will explore the tests of general relativity presently done in the solar system : from the estimation of supplementary advance of perihelia to the verification of the equivalence principle.

Applications

by A. Fienga

The students will perfom numerical simulations based on a simplified version of the INPOP code for coding different theories of gravity into the equations of motion of the planets and estimating their impact on the planetary motions.



After getting familiar with the code in C language, the students will implement different theories of gravity such as MOND or pressuron modellings. They will estimate the impact of such models on the orbits of the planets and more specifically on the earth-planet distances. In a second step, by comparisons with the mission specifications, they will see what models could be detected by the radioscience experiments and which one would not be.

See also

- Bepi-Colombo mission overview
- Testing GR with the Bepi-Colombo mission

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MASTER IN ASTROPHYSICS

Signal and Image Processing

METEOR Example

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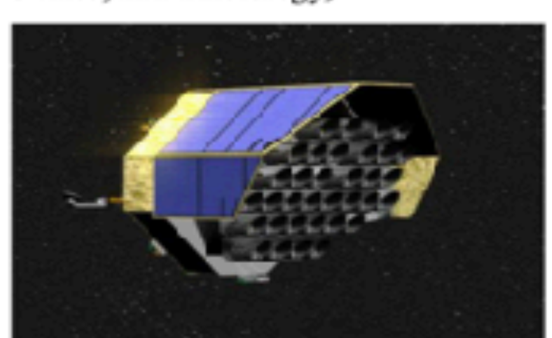
Exoplanet detection

The METEOR provides a training in detection methods for time series with application to the two most prolific techniques for exoplanet detection: radial velocities (RV) and transits. Currently used detection methods will be reviewed and studied in the general framework of statistical detection theory. The METEOR considers applications to ground-based instruments for RV and to the space mission PLATO for transits.

Theory

by D. Mary

With 3432 exoplanets known to date (June 9, 2016), exoplanet detection is an extremely active field of research. Two methods, Radial Velocities (RV) and transits, have brought together more than 90% of these discoveries. This METEOR focuses on these two methods. Students will learn in detail their principles, respective advantages and limitations. Like all exoplanet detection techniques, RV and transit detection algorithms rely on a model of the data. This model encapsulates information on the signature that one wishes to detect (*e.g.*, sinusoids for RV, U-shaped signatures for transits) and the perturbations that affect the data (*e.g.*, photon, detector or stellar noises,...). This perturbation always involves random phenomena ((*e.g.*, photon noise, read-out detector noises, spatial and temporal fluctuations of the stellar atmosphere). Hence, the data model on which the detection test is built is always a *statistical* model, which involves parameters related both to noise and to the planetary signature. In this framework, current detection algorithms can advantageously be understood and analyzed in the general framework of statistical detection theory. Most transit detection algorithms fall in the category of Matched-Filter detection, and most RV detection methods are based on periodogram analyses. Detection theory provides Astronomers with an arsenal of systematic methods, of tools to analyze and quantify their performances, or of new concepts in multiple testing like the False Discovery Rate or the Higher Criticism. For this reason, the theoretical part of this METEOR will heavily build on FC1.6 (Signal-image processing) and FC2.2 (Statistical methods). Students will investigate an arsenal of statistical tools than are routinely used in various other fields like climatology, genetics, econometrics or telecom (although no application to these field will be provided). So, even if RV and transit depend on physical parameters (like orbital and stellar parameters) that will indeed be studied, it should be clear that the heart of this theoretical part is truly statistical methods (this is why this METEOR is not, for instance, in Planetology).



Application

by D. Mary

The METEOR provides a brief overview of the main techniques currently used to detect exoplanets (namely, RV, photometric transits astrometry, timing, microlensing and imaging). The tests investigated in the theoretical part will be applied to real data such as HARPS for RV and to data simulated in the context of PLATO, an ESA satellite that will search for transits of rocky exoplanets (launch in 2024). The METEOR also provides an intensive formation to Matlab.

See also

M. Perryman, *The exoplanet handbook*, Cambridge Univ. Press, 2011.
T.H. Li , *Time series with mixed spectra*, CRC Press, 2013.
Exoplanets
Ground instruments (RV) : HARPS (La Sila, Chile, 2004), NESPRESSO (VLT, Chile, 2016), CODEX (ELT, 2025-2030).
PLATO.

Contact

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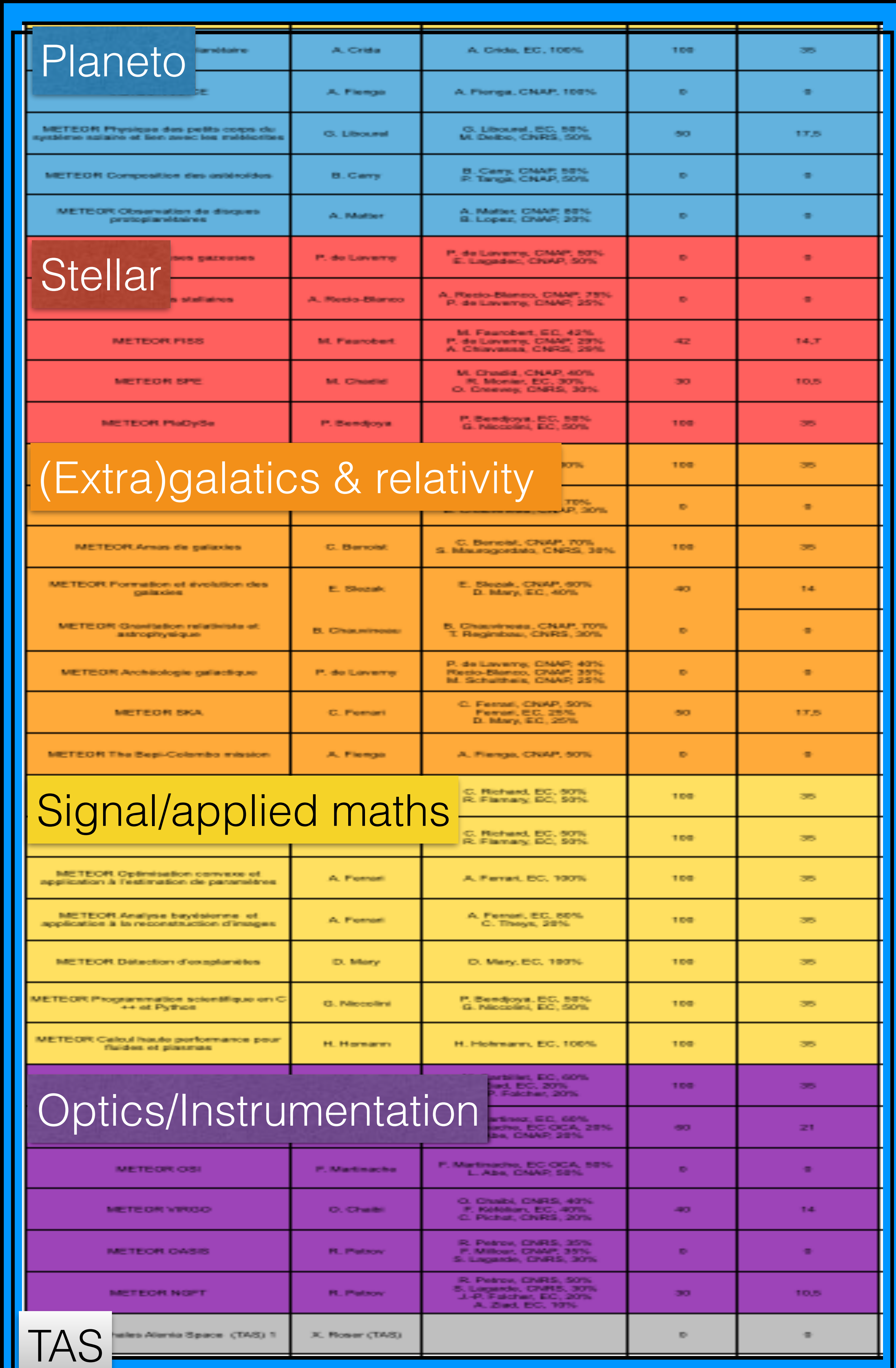

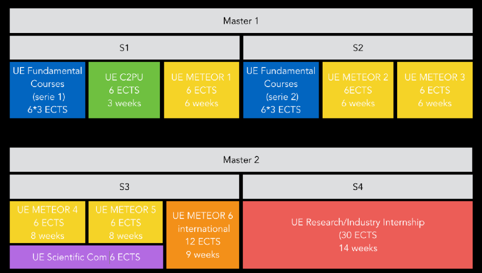

List of METEORS @ Nice

Each student chooses 5 METEORS in this list.

The 5 METEOR must cover 4 thematics

METEOR list 2019-20: http://mauca.unice.fr/index.php/articles/list-of-meteor/

2019 METEOR book

Master 1					
S1			S2		
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UE Scientific Com 6 ECTS			

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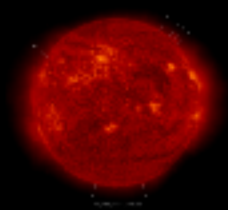
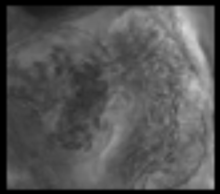
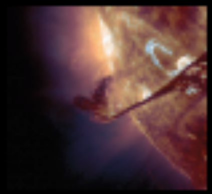
- Glasgow (Scotland)



Solar image processing

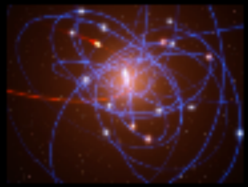


High precision analysis of heartbeat information



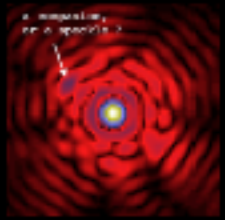
Observations or modelling of solar prominences

- Oldenburg/Bremen (Germany)



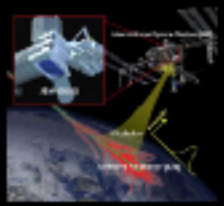
Geodesics, black holes, accretion disks

- Yverdon (Switzerland)

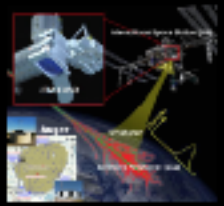


Hard Core Optical Engineering for Astrophysics

- Torino (Italy)

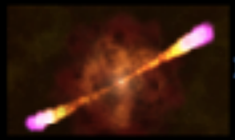


Modelling of space- and ground-based observations of meteors and exotic matter



Modelling of space- and ground-based observations of Ultra-High Energy Cosmic Rays

- Thessaloniki (Greece)



Particle acceleration in turbulent astrophysical jets

- Brussels (Belgium) & Leiden (Netherlands) : Radio perturbations correction for LARA/EXOMARS 2020
- UCL Leuven (Belgium)

University of Glasgow

INAF - IASF BOLOGNA
ISTITUTO DI ASTROFISICA SPAZIALE E FISICA COSMICA - BOLOGNA

Obbservatoire Royal de Belgique

INFN

Université de Liège

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ΤΜΗΜΑ ΦΥΣΙΚΗΣ, ΑΠΘ

Observatoire de la CÔTE d'AZUR

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ARTEMIS

FASTLITE

Some pictures sent by the students during their internship abroad

MNRAS 000, 000–000 (2018) Preprint 15 May 2018 Compiled using MNRAS LaTeX style file v3.0

Diffusive Shock Acceleration and Turbulent Reconnection

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[1]Master of Astrophysics, Université Côte d'Azur (MAUCA), Département de Physique de l' Université de Nice Sophia-Antipolis and Observatoire de la Côte d'Azur, Parc Valrose, 06100 Nice, France
[2]Department of Physics, Aristotle University, 54124 Thessaloniki, Greece

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT
Diffusive Shock Acceleration (DSA) cannot efficiently accelerate particles without the presence of self-consistently generated or pre-existing strong turbulence ($\delta B/B \sim 1$) in the vicinity of the shock. The problem we address in this article is: if large amplitude magnetic disturbances are present upstream and downstream of a shock then Turbulent Reconnection (TR) will set in and will participate not only in the elastic scattering of particles but also in their heating and acceleration. We demonstrate that large amplitude magnetic disturbances and Unstable Current Sheets (UCS), spontaneously formed in the strong turbulence in the vicinity of a shock, can accelerate particles as efficiently as DSA in **large scale systems and on long time scales.** We start our analysis with "elastic" scatterers upstream and downstream and estimate the energy distribution of particles escaping from the shock, recovering the well known results from the DSA theory. Next we analyze the additional interaction of the particles with active scatterers (magnetic disturbances and UCS) upstream and downstream of the shock. We show that the asymptotic energy distribution of the particles accelerated by DSA/TR has very similar characteristics with the one due to DSA alone, but the synergy of DSA with TR is much more efficient: The acceleration time is an order of magnitude shorter and the maximum energy reached two orders of magnitude higher. We claim that DSA is the dominant acceleration mechanism in a short period before TR is established, and then strong turbulence will dominate the heating and acceleration of the particles. In other words, the shock serves as the mechanism to set up a strongly turbulent environment, in which the acceleration mechanism will ultimately be the synergy of DSA and TR.

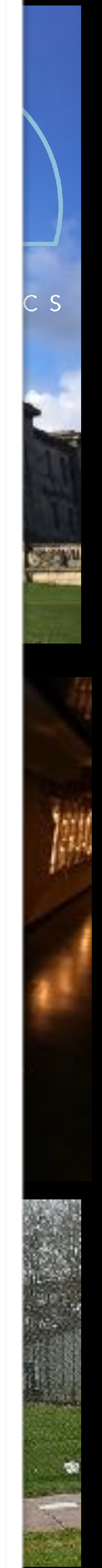
Key words: particle acceleration and heating – turbulence – diffusive shock acceleration – reconnection — turbulent reconnection

1 INTRODUCTION

The acceleration of charged particles in space and astrophysical plasmas remains an open problem. In space plasmas the major breakthrough in understanding particle acceleration was made in the beginning of the 50s by Fermi (Fermi 1949, 1954). Fermi proposed two acceleration mechanisms for astrophysical plasmas. One was based on the **stochastic** interaction of particles with large amplitude magnetic irregularities ("magnetic clouds") and the second one on the **systematic or regular** acceleration of particles by converging magnetic traps.

The studies following the initial ideas proposed by Fermi gradually departed from the concepts put forward by Fermi. The stochastic acceleration (second order Fermi acceleration) was modeled in the form of resonant or non resonant interaction of particle with a spectrum of low amplitude ($\delta B/B << 1$) linear MHD waves (Kulsrud & Ferrari 1971). For more details see the analyses presented in the reviews Melrose (1994, 2009); Miller et al. (1990, 1997); Petrosian (2012) and the references therein. The systematic acceleration (first order Fermi acceleration) was modeled as Diffusive Shock acceleration (DSA) (Krymskii 1977; Axford et al. 1978; Bell 1978; Blandford & Ostriker 1978). It is worth discussing briefly the weaknesses of the models used to implement the ideas proposed by Fermi.

The stochastic acceleration or stochastic "turbulent" acceleration (STA), as it is called, was modeled as the diffusion of particle energy within a spectrum of low amplitude waves, by using the Fokker Planck equation. The transport coefficients were estimated through the quasilinear approximation (Achterberg 1981). For the STA to be efficient two conditions should be satisfied: (1) The energy of the waves should be sufficiently large and (2) the particles should have a sufficiently large velocity to resonate with the waves (Melrose 1994). The stochastic interaction of particles with low amplitude waves made this mechanism inefficient for the acceleration of high energy particles. The strong dependence of the index of the accelerated particles on the spectrum of the waves suggested that there is no universal index for the accelerated particles, in contrast to what is usually observed. The STA is not necessarily the correct model for the stochastic acceleration of particles by **large amplitude** magnetic disturbances, as it has been shown



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Training exclusively by experts on cutting edge science

UNIVERSITÉ CÔTE D'AZUR

Volume étudiants et débouchés

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Total # MAUCA students

2016	2017	2018	2020 Steady state (Target)
5	11	16	24

% Admission acceptance rate 2018: 20

% Graduated MAUCA students enrolled in PhD/space industry: 90

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mauca@unice.fr **Web : mauca.unice.fr**

On-line applications for 2020-21 will open in Spring 2020.

> *Note : For year 2019-20, the Academic Council has voted to maintain the tuition fees for national Masters program to the standard price (less than 300€ per student and per year). Hence, non-European nationals enrolling for the first time in a university program in France were NOT required to pay tuitions fees of 3 770€ for Masters programs, as this may be the case in other places. The fees applicable for next year will voted by the Academic Council of Université Côte d'Azur later on this year.*

MAUCA – Master in Astrophysics Université Côte d'Azur – is a new international Master in Astrophysics. Each student chooses a list of METEOR (Modules Experiments ThEory Research) according to his personal interests, allowing to tune its training in two main fields : Astronomy-Astrophysics and Space Industry.

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Ressources en ligne

- METEOR
  - METEOR book 2019-2010
  - METEOR book 2018-2019
  - METEOR AGB stars observed with VLTI-MATISSE
  - METEOR Build a Nanosatellite !
  - METEOR AAO
  - METEOR C2PU
  - METEOR JUICE
  - METEOR Simulations of cosmic structure formation
  - METEOR Galaxies formation evolution and detection
  - METEOR OASIS
  - METEOR Exoplanet detection
  - METEOR Distribution of Composition of Asteroids in the Solar System
  - METEOR Planet Migration

Open online courses

[For links directing to Moodle an anonymous connexion can be obtained by clicking on
icon]

Fundamental Courses 1

- General Astrophysics
- Dynamics and Planetology
- Statistical Physics
- Fourier optics
- Numerical methods (need connection to jalon)

Fundamental Courses 2

- Math/Stat
- Quantum mechanics
- Stellar Physics
- General Relativity
- Atmospheric turbulence, Image Formation, Adaptive Optics
- Fluid Mechanics

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METEOR related to Space/Industry track

- Space – Industry

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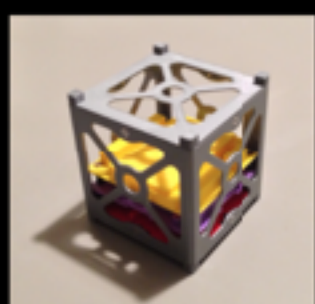

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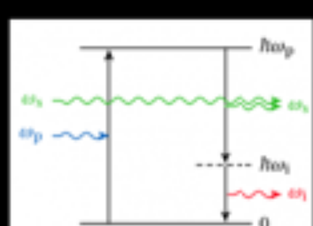

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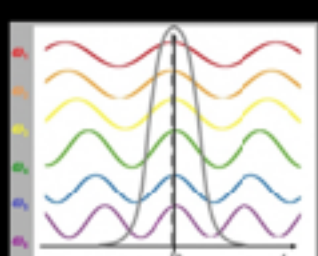

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- Signal–Image processing & Numerical simulations

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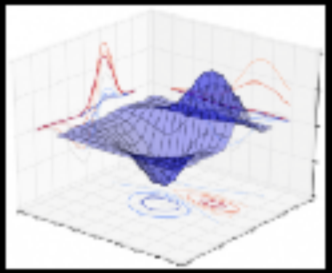

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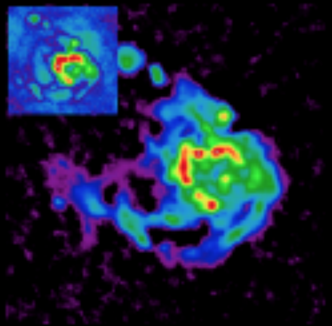

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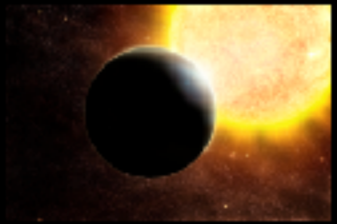

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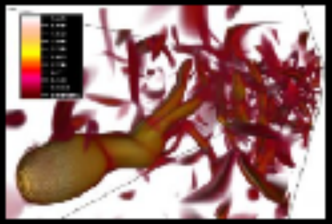

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- Astronomical optics and instrumentation

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