University of Orléans, France

International Master in Space Sciences and Applications

A one-year intensive training in Space Sciences, in English

April 21, 2020

Contents

The international Master in *Space Sciences and Applications* (SSA) is a **one-year intensive training in space sciences** that is taught in English at the at the University of Orléans (France). The programme targets French and international students who have a solid background in Physics (and completed a 1st year Master's degree or equivalent) and wish to carry out high level research in space agencies, research bodies, and government agencies.

The programme covers a wide range of space-related fields including radioastronomy, heliospheric physics, solar-terrestrial science and space weather, satellite propulsion, nanosatelites and space-based systems engineering. The courses are exclusively taught in English and the total number of credits (ECTS) is 60.

SSA Students will be in contact with scientists from several laboratories and facilities that carry out cutting-edge research in space sciences (LPC2E), in spacecraft propulsion (ICARE), in radioastronomy (Nançay radio-observatory) to name a few. Students will learn about and understand our space environment. They will also be involved in the exploitation of data from major space missions and from radioastronomy facilities.

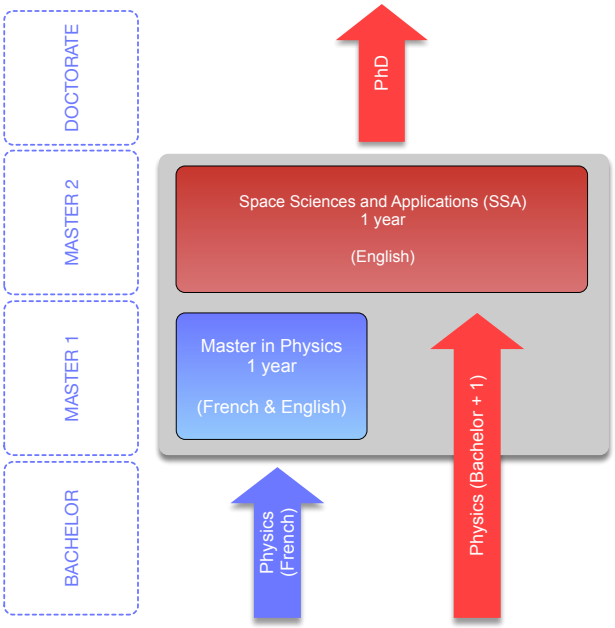
1 Organisation

The SSA Master's degree has been designed as a one-year training, running from mid September till early September. Enrollment is possible with a degree corresponding to a 1st year Master's diploma in Physics, or equivalent. Typical examples are students who have a Bachelor's in Physics + 1 or 2 years in Master's degree in Physics, or an engineering degree in Physics.

Students who want to join with a Bachelor's degree in Physics first need to successfully complete a one-year Master training in Physics. At the University of Orléans this is possible by completing the first year of the Master in Fundamental and Applied Physics (in blue, see below), whose courses are taught in French.

International students are expected to enrol in SSA directly with a level equivalent to a 1st year Masters diploma, as indicated in red below. French students are more likely to apply after obtaining their Bachelor degree (Licence de Physique), followed by one year of the Master in Fundamental and Applied Physics (in blue).

Students who successfully complete SSA will get 60 credits (ECTS) and receive a Master's diploma.



SSA actually is part of a two-year Master programme in *Applied and Fundamental Physics* whose first year is taught in French, while the second year offers two independent orientations : SSA and *Matter and Radiation*. However, the curricula have been designed in such a way that the one-year SSA programme is independent of the others and can be joined directly.

2 Programme

The courses with the number of hours taught are listed below. All courses are compulsory, with no options. In France, courses are traditionally divided into lectures (cours: C), exercises (travaux dirigés: TD) and labs (travaux pratiques: TP).

September to February

Course name	lectures (C) hrs	exercises (TD) hrs	labs (TP) hrs	ECTS
Astrophysics	25	25	34	6
Space exploration and space systems	18	6		4
Space plasma physics	17	8		4
Plasma propulsion for spacecraft	17	8		4
Space environment	25	25	12	6
Computational Space Science	18	12		4
Project approach and quality	6	6		1
Seminars	6			1
Total	132	90	46	30

February to end of August

Course name	lectures (C) hrs	exercises (TD) hrs	labs (TP) hrs	ECTS
Project and colloquium		12		8
Internship (4 to 5 months)	4			22
Total	4	12	0	30

Most lectures are available online at ent.univ-orleans.fr (registration required). The French grading system ranges from 0/20 to 20/20. Marks under 10/20 are considered as "fail" and do not yield ECTS on the final transcript of records. All courses are evaluated by continuous assessment (*contrôle continu* in French), with regular oral and written exams, and project reports.

Students wishing to learn French are encouraged to attend courses given at the French Institute (IDF). Preliminary enrolment can be done online, see www.univ-orleans.fr/idf.

SSA also has a partnership with the Graduate School Orléans Numérique (GSON, www.univ-orleans.fr/fr/gson), which offers interdisciplinary courses in data science and in machine learning.

The detailed contents of the SSA courses are:

Astrophysics

Objectives: Study of the solar system and beyond, putting to application the tools previously acquired in the general physics modules.

Programme:

- Solar System
- Planetary motion
- Sources of radiation in astrophysics
- Astrophysics without photons
- Stellar structure
- Stellar formation and evolution
- Galaxies, distances in the Universe, cosmology

The module includes a one-week stay at Nançay radio-observatory dedicated to radioastronomical observation and data processing.

Tutors: J.-M. Grießmeier, L. Guillemot

Space Exploration and Space Systems

Objective: Basics of space systems engineering and space scientific applications

Programme:

- Celestial mechanics for artificial bodies: Newtonian, Lagrangian and Hamiltonian mechanics. 2-body and restricted 3-body problems. Natural and artificial perturbations. Constants of motion. Orbits: Elliptic, parabolic, hyperbolic, geostationary, Sun-synchronous. Interplanetary trajectories: patched conic approximations. Orbital manoeuvres: Earth asphericity, in- and out-of- plane orbit changes, Hohmann transfer, gravity assist. Orbit determination. Relativistic orbital effects.

- The gravitational field of the Earth
- Launchers
- Busses
- Radio science and nanosatellites in a swarm configuration
- Gravitational waves and the LISA mission
- Plasma and the Cluster mission
- Time metrology and navigation systems (GPS, Galileo)

Tutor: A. Spallicci

Space Plasma Physics

Objectives: Understanding and using the main components of space plasma physics

Programme:

- Basics of the Physics of Ionized Environments: Characteristic parameters, Motion of charged particles, Waves in a cold plasma
- Theoretical models of plasmas, Statistics and kinetic treatment of charged particles, Moments and fluid equations, Transport phenomena, Magnetohydrodynamics, Alfvén theorems
- Physics of the plasma-body interaction, Sheath effect, Transition regions, Bow shocks
- Waves and Instabilities, Wave generation and propagation (quasi-static, EM, MHD, ...), Wave-particle interactions, Characterization of instabilities

Tutors: O. Randriamboarison, M. Kretzschmar

Plasma Propulsion for Spacecraft

Objectives: Understanding the basics of space propulsion, microsatellite design and the handling of space debris

Programme:

- Space propulsion: Foundations, Chemical propulsion, electric propulsion, Assets, concepts, Sources of energy, fuels, types of propellants, Micropropulsion for nano- and micro-satellites
- Space debris: Generalities, detection and follow-up, legislation, Deorbitation methods, Controlled reentry
- Scientific Cubesats: Specificity and assets of Cubesats, Basic elements of a mission, Principles and instrumentation for plasma measurements, Examples of scientific CubeSats
- Associated projects (TP): Hall thrusters and Cubesats: characterization of thrusters and Cubesat instruments in the NExET bench (vacuum chamber for electric propulsion), Atmospheric reentry of debris: measurements of plasma parameters in the PHEDRA wind tunnel (high enthalpy flow, arc jet generator)

Tutors: S. Mazouffre, R. Joussot, M. Kretzschmar

Space Environment

Objectives: Develop advanced understanding of the basic physical processes acting in the Heliosphere, its different regions and their interactions; understand how to study them with satellites and with ground-based facilities.

Programme:

- Overview of the Heliosphere and its different regions
- Solar interior and solar variability
- Solar atmosphere: structure, heating and generation of the solar wind; solar activity and solar transients (flares, CMEs, ...); important physical processes (reconnection, acceleration, ...)
- Solar wind and solar-terrestrial disturbances: generation and propagation; turbulence

- Near Earth's environment and its couplings; phenomenological description (magnetosphere, ionosphere, ...); physical processes (adiabatic invariants, reconnection, ...); interaction with the solar wind; magnetosphere/ionosphere/atmosphere coupling; global electric circuit
- Other bodies of the solar system and their interaction with the solar wind
- Societal effects: space weather and space climate
- Basics of space plasma instrumentation and techniques
- Archives and virtual observatories

Tutors: T. Dudok de Wit, S. Célestin, P. Henri, M. Kretzschmar, V. Krasnoselskikh

Computational Space Science

Objectives: Gain advanced knowledge in Computational Space Physics; get acquainted with specific numerical techniques used in Space Plasmas; perform critical analysis of numerical simulations with emphasis on stability and errors. Highlight links/applications of concepts met in other lectures.

Programme:

- Introduction to particle methods (N-body problem; SPH; particle mover)
- Particle-in-Cell (PIC) method (particle and field weighting)
- Monte Carlo methods (collisional transport; null-collision scheme)
- Hydrodynamics (finite difference methods; finite volume methods)
- Shocks
- Radiative Transfer

Tutor: S. Célestin

Project Approach and Quality

Objectives: Provide a global and synthetic view of the project management approach, with the basics of project methodology and fundamental tools of project management. Project management is a key transversal skill that is required in many companies to implement and achieve the set of objectives in project.

Programme:

- Definition (project management / product insurance)
- Methodology and tools (planning management, documentation, risks)
- Good practices in a "project" team

Tutor: C. Agrapart

Seminars

Objectives: Discover latest developments in space sciences

Programme: 10 seminars given by scientists from the academic and private sectors. Each of them addresses topical issues in Physics or in space sciences.

Coordinator: T. Dudok de Wit

Project/Colloquium

Objectives: Learn how to organise a mini-symposium and how to present scientific results.

Programme: This seminar involves Master students from the first and the second year, working in space sciences and in material science. Each student carries out a 3-week project in a local research lab, and presents his/her results in an oral presentation. Students are also sollicited to organise the colluquium and thereby learn how to disseminate results. The two-day colloquium takes place at the end of February.

Coordinator: T. Dudok de Wit

Internship

Objectives: Learn how to address and solve a real-world and complex problems in collaboration with a research team

Programme: The internship is what best reveals the capacity of the Master student to apply his/her skills in solving complex scientific problems. This internship can be carried out in France or abroad; it lasts from February till the end of August, and the minimum duration is 4 months. At the end, the students produce a report and have an oral defence.

In France only, over 200 internships are proposed in all areas of astrophysics, see stages-masters.sf2a.eu

Coordinator: O. Randriamboarison

3 Partners of SSA

In France, each Master is backed by public or private partners whose members teach and also propose internships. For SSA, the *local* partners are:

- Institut de Combustion Aérothermique Réactivité et Environnement (ICARE, Orléans): one the premier French research institutes in electric propulsion;
- Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E, Orléans): a space-grade laboratory that exploits instruments onboard several space missions such as BepiColombo, Solar Orbiter, Parker Solar Probe and Taranis;
- Observatoire de Paris (OBS, Paris): the largest French cluster of research laboratories in astrophysics and astronomy;
- Station de Radioastronomie de Nançay (USN, Nançay): the facility running radiotelescopes among the largest in the world;
- Centre de Biophysique Moléculaire (CBM, Orléans) with a team working on exobiology;
- Groupe de Recherches sur l'Energétique des Milieux Ionisés (GREMI, Orléans), which focuses more on plasma energetics and plasma processes.

Together, these institutes represent over 1000 scientists and carry out cutting-edge research in space sciences, electric propulsion, Radioastronomy, etc. Several of these teams are actively involved in space missions or exploit ground-based facilities for Radioastronomy.

Several private partners are also associated with SSA through the strong interactions the research institutes have with them. These are space agencies (NASA, ESA, CNES) but also industrial partners in spacecraft operation and exploitation (Airbus, Thales, SAFRAN, Exotrail, etc.)

The number of partnerships is not exclusively limited to these partners institutions and SSA students are strongly encouraged to make use of the networks our teams have in France, in Europe and beyond. The list of internships that are proposed in France can be consulted at stages-masters.sf2a.eu

4 Admission requirements

Enrollment in SSA is possible for students who have obtained their Bachelor's degree in Physics and have successfully completed at least one year in a Master in Physics (or equivalent, e.g. engineering school) with excellent academic results. The dedicated teaching programme aims to bridge the gap between different students' backgrounds. It does not matter whether your initial training had a stronger focus on one particular field of Physics as long as you have a solid training that covers all the major fields of modern Physics, including Computational Physics, Quantum Mechanics, Statistical Physics, etc. Plasma physics and Astrophysics are an asset but are not mandatory. In addition, a proficiency in English (B2 level) is required.

The selection committee will assess applicants based on their academic qualifications and their motivation for pursuing a research career in Physics.

5 Registration

There are two different registration procedures, depending on your country of citizenship or residence:

1. If you are a citizen or permanent resident of one of the 28 EU countries, including Norway, Iceland, Liechtenstein, Switzerland, Andorra or Monaco:

   Apply directly at the University of Orléans between April 1st and the end of June. There is no need to apply for a visa.

   To register:

   - Go to www.univ-orleans.fr/fr/univ/formation/candidature-et-inscription/candidater-sur-ecandidat (the website is still in French only)
   - Create an account
   - Fill in the field Informations personnelles and Adresse. Do not provide the INE number of you don't have one.
   - Go to Offre de Formation » UFR Sciences et Techniques » Master LMD » M2 physique fondamentale et applications Parcours SSA

2. If you have the nationality of: Algeria, Argentina, Benin, Brazil, Burkina Faso, Burundi, Cameroon, Chad, Chile, China, Colombia, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Gabon, Guinea, Haiti, India, Indonesia, Iran, Japan, Kuwait, Lebanon, Madagascar, Mali, Mauritania, Mauritius, Mexico, Morocco, Nigeria, Peru, Russia, Senegal, Singapore, South Korea, Taiwan, Togo, Tunisia, Turkey, United States, Vietnam:

   There is one single platform called *Campus France*. The application process starts early February and ends early March.

   To register:

   - Go to www.campusfrance.org/en
   - Create an account
   - Fill in the field your application form (in English).

3. If you belong to neither of the two categories, contact us directly, see Section 10.

Officially, French tuition fees are 3770 €/year for Master programmes. For the time being, however, the University of Orléans still applies lower fees. In 2019-2020 the annual tuition fee is 243 €/year regardless of the country of residence. This however, may change in a near future.

6 Your career after SSA

After obtaining your Masters degree in *Space Sciences and Applications* your skills will include analytical and critical thinking, and also strong research skills with extensive Mathematics and Physics knowledge.

Most students with a Master's degree in space sciences pursue their career with a PhD in Space Physics, in France or abroad. Indeed, a PhD is mandatory for most scientific careers such as scientist in academic research, R&D engineer in research centres and in space agencies, data scientist in the industry, etc. Typical positions are researcher, project scientist and consultant. In all these positions your main asset is your ability to run projects and to solve complex problems requiring physical, mathematical (and often computational) skills, rather than being the expert in one narrow field.

Statistics: SSA opens in 2020 and so we cannot yet provide statistics. However, lessons learnt from similar Masters in France show that over 90 % of the students pursue with a PhD and those who have good marks (> 12/20) have no problem in getting funded for that. After completing their PhD, less than 25% pursue with an academic career as the number of positions is limited. Most continue in space sciences, however, typically working in companies that provide digital solutions for satellite design or satellite data analysis. In recent years, a majority of PhD students have been hired for doing data science while staying in contact with advanced physical concepts.

7 Important dates

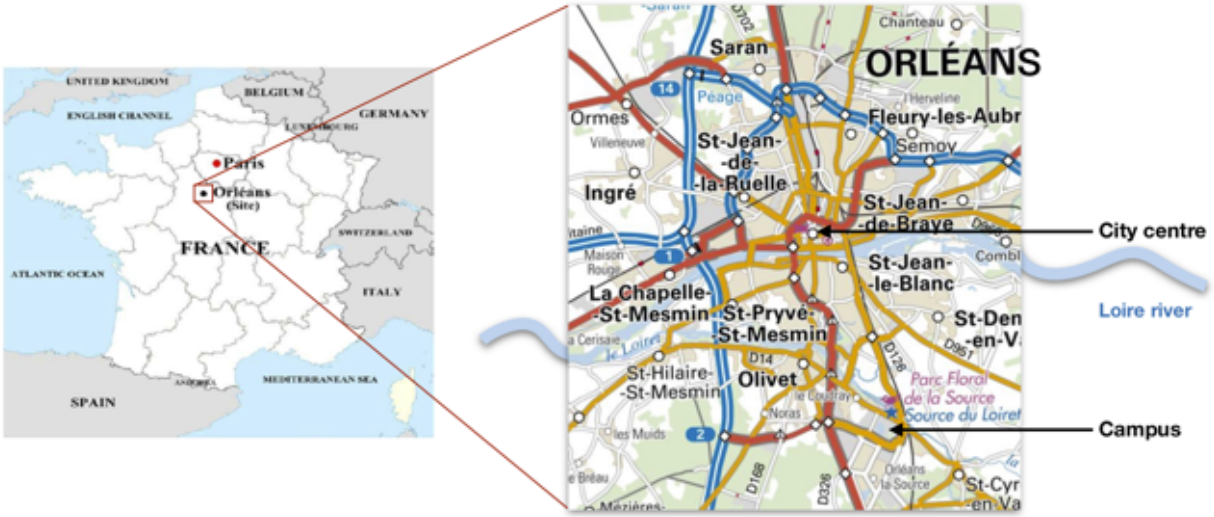
Dates may slightly vary

- Early February till early March: registration for non-EU citizens
- Early April till mid June: registration for EU citizens
- Mid September till the end of February: regular courses
- End of February: Physics colloquium together with 1st year Master students
- Early March till end of August: internship (4 months minimum)
- First week of September: project defence

Calendar of the University of Orléans
www.univ-orleans.fr/service-central-de-scolarite/calendriers

8 Living in Orléans

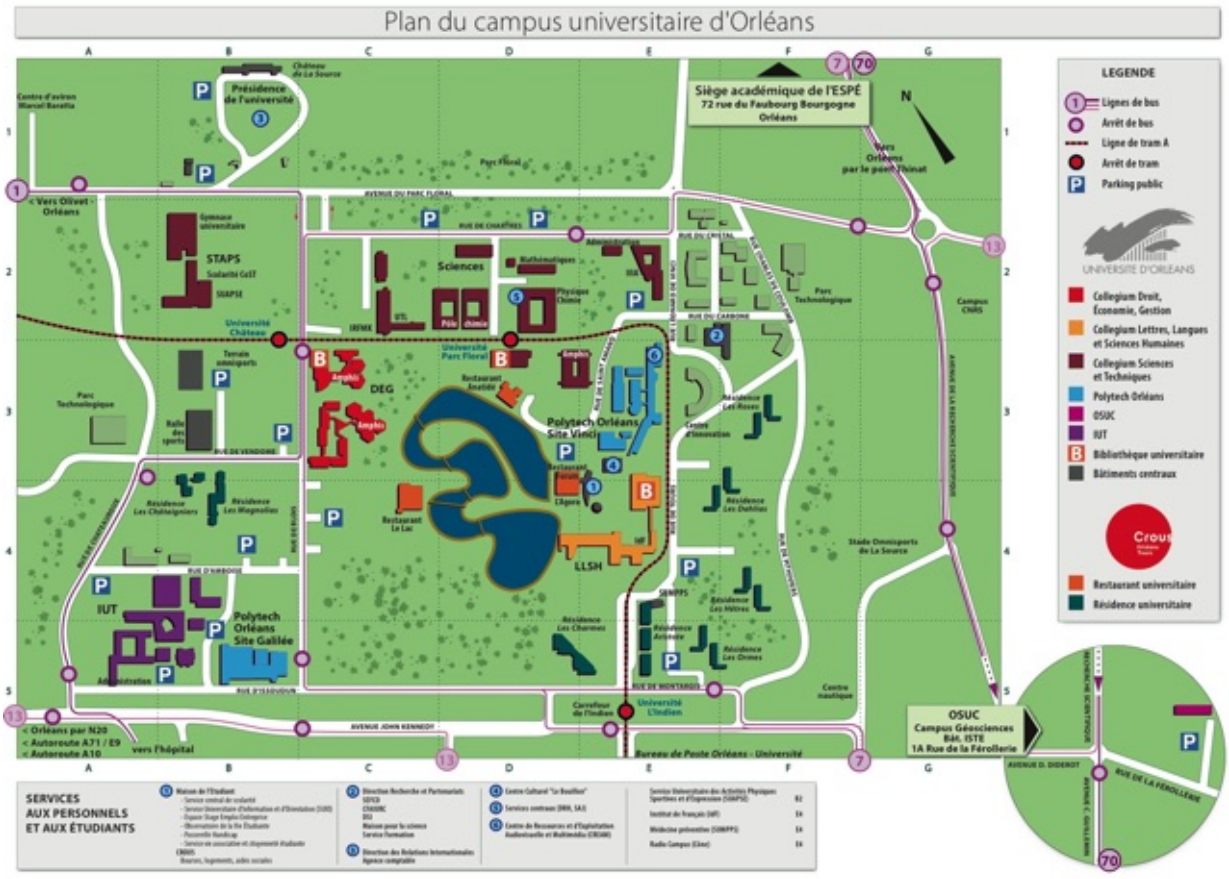
Orléans is a medium-size city (by French standards) that is located in the heart of the Loire valley, see en.tourisme-orleansmetropole.com. The city is located approximately 140 kms south of Paris and can be easily reached by train from Paris Austerlitz station, with hourly connections and a 65-minute journey, see en.oui.sncf/en/



The University campus is located approximately 8 kms south of Orléans and can easily be reached from downtown Orléans by tram A or by using bus lines nr 1, 7 and 70. For schedules and maps, see www.reseau-tao.fr. There is also a bicycle track from downtown Orléans to the University and CNRS campuses. The trip takes about 25 minutes.

There are several students residence halls on campus but most students live in downtown Orléans. The monthly rent for a small apartment ranges from 250 to 500 €, which is less than half of what you would pay in Paris. Generally speaking, the cost of living is considerably lower in Orléans than in large French and European cities.

All lectures are given in the Physics department, see Physique-Chimie in D2 on the map below. Most local research laboratories are located on the CNRS campus (G2-G5).



9 Useful links

General information on studying and living in France
www.campusfrance.org/en
www.diplomatie.gouv.fr/en/coming-to-france/studying-in-france/

Accomodation at the University of Orléans
www.univ-orleans.fr/en/univ/international/coming-university/accommodation

Financial aids
www.campusfrance.org/en/bursaries-foreign-students
www.diplomatie.gouv.fr/en/coming-to-france/studying-in-france/

Social security in France
www.campusfrance.org/en/healthcare-student-social-security

Social security for non-EU citizens
etudiant-etranger.ameli.fr

University of Orléans
www.univ-orleans.fr/en

Campus life in Orléans
www.univ-orleans.fr/en/univ/campus-life

10 Contact

For any information regarding SSA, write to master-PhyFA@univ-orleans.fr

Website of SSA with latest information:
www.univ-orleans.fr/en/sciences-techniques/formation/physique/master/le-master-phyfa-mr-et-ssa/

For any information regarding the admission, contact

Laurent JEAN-ALPHONSE
Secrétariat du Pôle de Physique
1, rue de Chartres, BP 6759
45067 ORLEANS cedex 2
Tel : +33 02 38 41 70 19
Email : laurent.jean-alphonse@univ-orleans.fr

Coordinator for the SSA orientation

Prof. Thierry DUDOK DE WIT
Email : ddwit@cnrs-orleans.fr

Coordinator for the Matter and Radiation orientation

Prof. Pascal ANDREAZZA
Email : pascal.andreazza@univ-orleans.fr