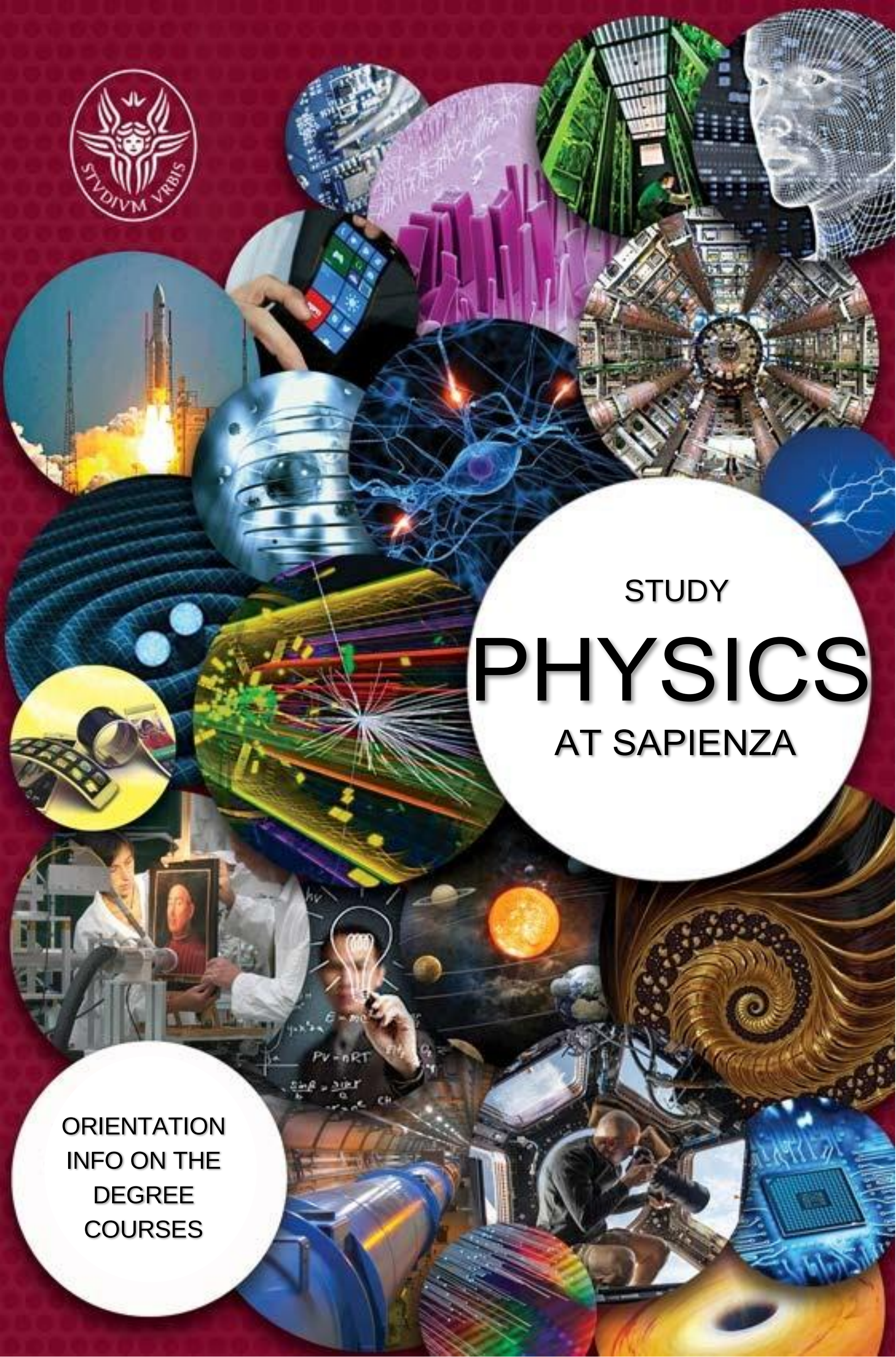

STUDY

PHYSICS

AT SAPIENZA

ORIENTATION
INFO ON THE
DEGREE
COURSES

We are pleased to publish an updated version of the volume containing information about the scientific activity and teachings of the Physics Department.

This booklet aims to introduce the students to the degrees in Physics at Sapienza (Laurea, Laurea Magistrale e Dottorati), and to provide practical information about the teaching activity. The booklet also briefly describes the broad spectrum of the research activities in our Department to help the students to choose the scientific sector of their interest.

We believe this information is useful to the freshmen and all the students who study and work in our Department as an instrument of mutual knowledge.

Additional info and updates on the activities the Physics Department can be found on the website https://www.phys.uniroma1.it/fisica/didattica/orientamento, where it is also possible to download this booklet in PDF format.

Paolo Mataloni
Director of the Physics Department

Edited by the Physics Department

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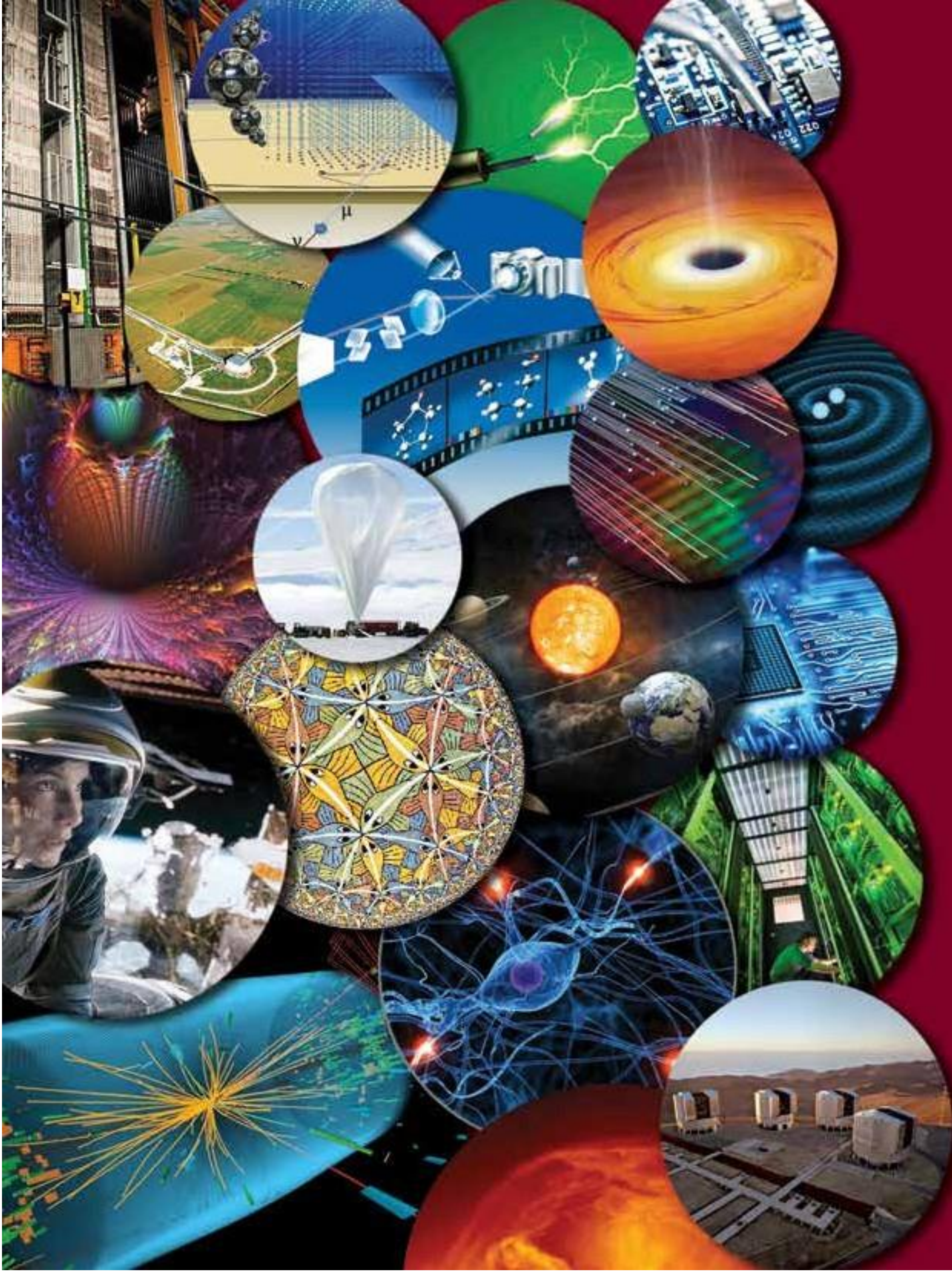


Research in Physics at Sapienza

The physicists of our Department are active in all the research areas shown in the previous picture. The various topics differ, sometimes even significantly, in terms of survey methods, dimensions of the experimental equipment, computational instruments or the breadth of applicative effects. Despite these differences, often the dividing line between traditionally named sectors is blurred.

It is the case, for instance, of two fields quite far from each other until relatively recent times such as astrophysics and elementary particle physics. Nowadays, in many ways, they deal with the same problems. The intersection between astrophysics and elementary particle physics is also called “astroparticle physics”: answering questions about the “ever-smaller” is today equivalent to address issues of “getting closer to the birth of the Universe”.

Similarly, investigations in statistical mechanics spurred by relatively abstract speculations, which were far from any practical application, are now fundamental to tackle problems in biological complex systems. It is the case, for instance, of the research in neuronal networks, a very productive sector which lie at the intersection between statistical physics, biophysics, cybernetics and matter physics.

In the next pages, it can be found, without any pretence of completeness, brief indications regarding some of the great questions and stimulating open problems on which the Department is working, and the prospects of advanced research in these sectors.

- Particle Physics
- Condensed Matter Physics
- Astrophysics and Cosmology
- Theoretical Physics
- Biophysics

Particle physics

Particle physics studies the fundamental constituents of matter and their interactions. However, this field is not limited to studying the smallest things. The research carrying out in this branch of Physics has an ever-increasing impact on cosmology and the study of the large-scale structure of the Universe, despite the introduction of gravity at the quantum level is still an open problem. In some cases, the techniques and methodologies developed in apparently very distant fields merge, leading to new branches such as astroparticle physics. This new field employs particle physics tools and techniques to study the cosmos. In the last years, significant progress has been made, also thanks to the physicists of our Department. They have had and continue to have critical roles in particle physics experiments taking place in the most advanced laboratories around the world. Particle physics employs extremely complex instruments at the edges of current technologies, making it a field with a strong international character.

Among the most relevant results achieved by our research groups, we mention the **Higgs boson** discovery in 2012 and the first direct observation of **gravitational waves** made in 2015.

The attention of the physicist of our Department is mainly focused on the search of "new physics": new phenomena sometimes unexpected, sometimes predicted by theoretical physicists. The presence of new physics can be highlighted thanks to precision measurements or the study of rare or prohibited processes in the Standard Model. This type of research is conducted in many cases by studying rare processes of low energy with fixed target experiments, searching for phenomena prohibited by the Standard Model, but allowed according to other theories like the ones predicting the existence of Majorana neutrinos.

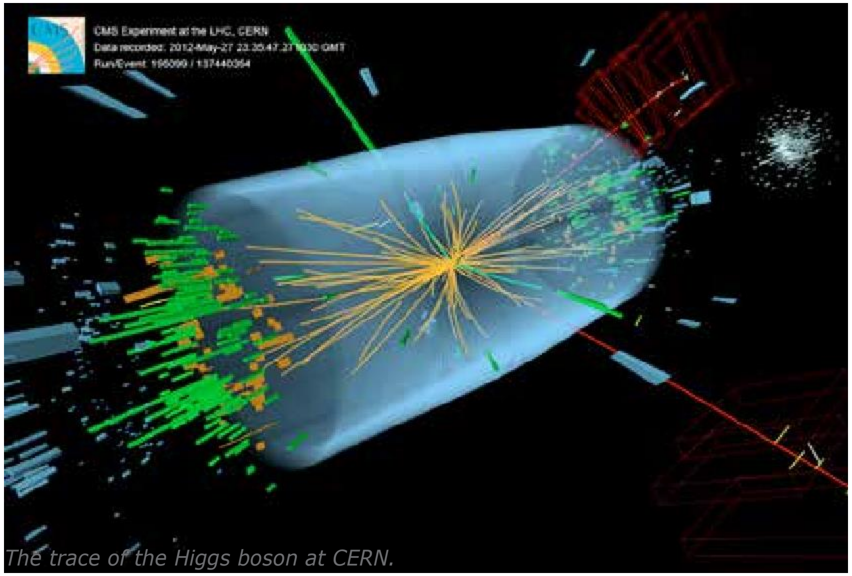
The weak force underlies hydrogen combustion in the stars

The latter can be manifested through the so-called "double-beta" decay, in which tellurium nuclei transmute into xenon producing two electrons without neutrino emission. An experiment of this type takes place at the INFN Laboratories of GranSasso.

Hints on the presence of new physics can also be obtained with collider experiments like **DAPHNE**, at the Frascati National Laboratories of the INFN.

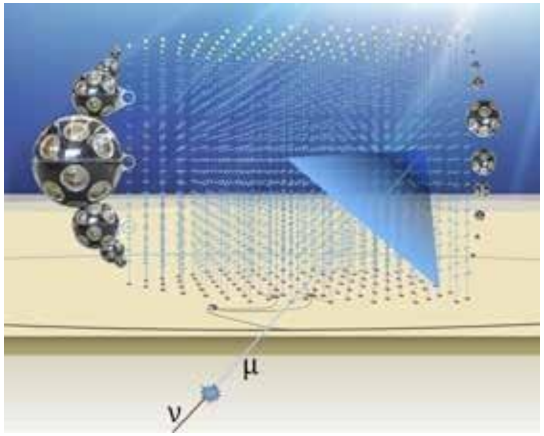
New particles are also being searched at large colliders such as **LHC**, where a possible signal of new physics has been recently revealed. Such signal consists of the observation of an anomalous production of high energy proton pairs. In the next years, **ATLAS** and **CMS** experiments, on which many physicists of our Department are working, will continue researching in this field.

As an example of contamination between apparently different disciplines, we mention the problem of "dark matter", whose nature is still unknown despite multiple astrophysical measurements suggest its existence.



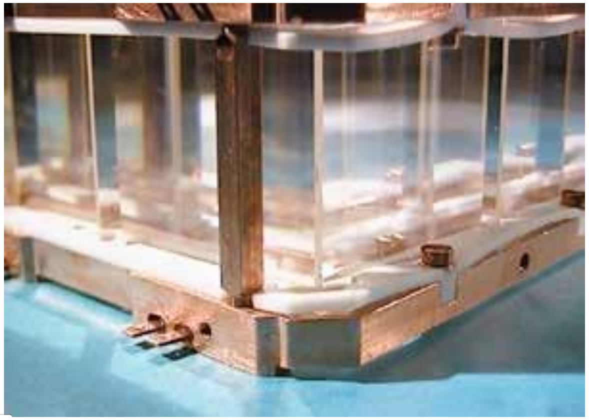
The trace of the Higgs boson at CERN.

In our Department, new experiments are prepared and carried out for direct and indirect detection of these type of particles.
The study of high-energy cosmic rays is part of the research interests of the Physics Department. Of relevant note are the new experiments that use underwater detectors to reveal events produced by cosmic neutrinos, which can bear valuable information from the most remote regions of the Universe. This experiment is another example of contamination between different fields.



The underwater detectors of the K3 experiments reveal cosmic neutrinos through the Cerenkov radiation emitted by muons during the interactions.

Moreover, the experimental study of particle physics allows us to develop technologies that can be used in the most varied fields: from medical physics to safety, from agriculture to the semiconductors industry.
Finally, it is essential to mention the scientific computation: in Rome, there is one of the most efficient Computational Center in the world for LCH experiments, which is also an excellent example of **green computing**.



Detail of the dioxide tellurium crystals of the experiment CUORE for the search of double beta decay without neutrinos.

Astrophysics

Astrophysics, more than a Physics sector by itself, is to be considered a field that applies the knowledge of all the Physics sectors to understand the phenomenology linked to the celestial bodies, and the matter and energy distribution in the Universe.On the one hand, it is based on the observation of cosmic phenomena, on which it is not possible to exert a direct control, differently to what happens in the lab experiments. On the other hand, the stars and the cosmos are proper "laboratories", where extreme situations untestable on Earth naturally occur. Sometimes physical theories can be directly tested only in astronomical phenomena such as supernova explosions, black holes, gravitational lenses, neutron stars.The observations involve the entire electromagnetic spectrum and, therefore, the most diverse technologies: from radio telescopes and planet size interferometers to space observatories for infrared, ultraviolet, visible radiation and X and gamma rays, to the very-large optical telescope on the ground.

"Non-electromagnetic windows" are also open on the cosmos: neutrinos, cosmic rays of very high energy (much higher than that obtainable in the large particle accelerators), and the gravitational radiation predicted by the theory of General Relativity.

8.2 m four telescopes of the Very Large Telescope of ESO (European Southern Observatory), usable as an interferometer (VLTI).
Cerro Paranal (Chile)

Theoretical and observational research activities of our Department concern some of the fundamental questions of astrophysics:

- What is the geometry and what is the global dynamic of the Universe?
- What is the geometry and what is the global dynamic of the Universe?
- What are the galaxies and dark matter distributions in the Universe and their link with the overall cosmic dynamics?
- How were galaxies and active galaxy nuclei born and evolve?
- How is the "central motor" of an active galactic nucleus fed, and what is its relation to the dynamics of galaxies that host it?
- What are the mechanisms that explain the spectral distribution, from radio frequencies to gamma rays, of the high energy cosmic sources?
- What is the behaviour of the extremely dense matter that is present in the neutron stars nucleus?
- What is the behaviour of the gravitational interaction in the strong field regime, like that induced by black holes and neutron stars?

Several researchers of our Department are also currently involved in data analysis of space mission Planck of the **European Space Agency**, which has recently produced the most accurate maps of the cosmic radiation background.
The results of this experiment, which are considered the most important for cosmology in the last ten years, have established in a practically definitive manner the correctness of our view of the Universe and redefined its energetic content.

Planck satellite on Kourou launch base (French Guyana)

Cosmic radiation background of the Universe

Coming from the primordial stages of the Universes, the cosmic microwave radiation background (CMB) allows to probe the origin and the physical phenomena that took place in such extreme conditions. Cosmic inflation, Baryogenesis and matter-antimatter asymmetry, Nucleosynthesis and origin of the elements, Recombination and atoms formation are all processes that can be investigated through detailed studies of the cosmic microwave background. After the measurements of Planck, the researchers in our Department are involved in the development of stratospheric balloons experiments which provide quick and relatively cheap access to the near-space (as shown by the Boomerang experiment, which has started the precision measurements of CMB). The **LSPE-SWIPE** experiment probes, through the study of the polarization of the CMB, the process of cosmic inflation, hypothetical occurred a moment after the Big Bang and the associated primordial gravitational waves.The **OLIMPO** experiment studies the plasma presents in the Universe, especially in the galactic clusters, and the process of reionization occurred at the formation of the first stars. The **COSMO-LDB** experiment studies the deviation of the CMB from the black body spectrum, tied to primordial phenomena. Innovative apparatuses are invented and developed to carry out these experiments. For instance, the kinetic inductance detectors made in collaboration with IFN/CNR were tested in space for the first time with the OLIMPO experiment. CMB ground measurements also take place, in Antarctica (Concordia base, **COSMO** experiment) and the Andes (**QUBIC**).

OLIMPO experiment, launched in July 2018 from the Svalbard Islands (Artic).

Research in Physics at Sapienza

A new Astronomy with gravitational waves

Gravitational waves are the new messenger that carries information on the dynamics of the objects in the Universe. The observation of these signals goes side by side those of traditional Astronomy based on the observation of electromagnetic signals and the emerging Neutrinos Astronomy.

Bird's eye view of the Virgo

Virgo is one of the interferometers of the advanced network detectors of gravitational waves, which includes the two analogous American interferometers LIGO and the fourth Japanese interferometer KAGRA.

LIGO and Virgo have observed the sky and detected coalescence signals of binary systems formed by two black holes, or by two neutron stars, or by neutron star-black hole mixed systems.

The exploration of the Universe through gravitational waves continues. In the next months, KAGRA will join the LIGO-Virgo network, enriching the catalogue of events collected, also with signals associated with different astrophysical processes, such as the rotation of neutron stars and supernova explosions. All of this will lead to an entirely new way of doing Astronomy.

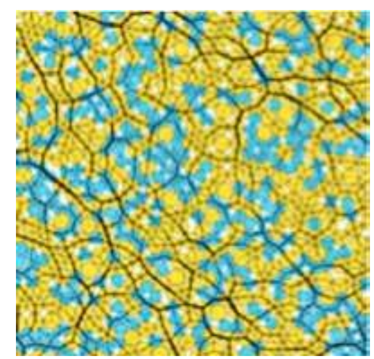
Physics, Complexity and Cisorder

Statistical physics of disordered systems

Statistical mechanics is a branch of physics that developed from the end of the XIX century to describe natural phenomena involving an enormous number of constituents, such as molecules, atoms, electrons. It allowed us to understand thermodynamics from a microscopic point of view. For instance, entropy in thermodynamics is defined in terms of the heat exchanged in a transformation; now it acquires an entirely new meaning. The entropy measures the number of microscopic states (configurations) that the system can take, a concept that it was then exported to many other areas. Statistical mechanics has also allowed understanding how the same substance can have different phases and transitions between these phases: typical examples are the solid-liquid and liquid-vapour transitions that water undergoes at 0 and 100 degrees Celsius respectively.

Many of the substances encountered in everyday life can occur in three different states (or phases), depending on the temperature: a state-ordered solid, in which the atoms or molecules occupy the sites of a crystalline lattice, a liquid state and a gaseous state. However, these are not the only possibilities: Nature is much more varied, and one can observe substances with different behaviours. Glassy systems represent an exciting class of systems. At sufficiently high densities, they show an amorphous phase, with entirely new characteristics and, so far, not completely understood. A straightforward model of such materials is given by a mixture of spheres with different radii that can deform elastically. Despite increasing the density, the system is unable to form an ordered solid. The distribution of spheres remains disordered, and the forces acting between them can have very different intensities because not all the spheres are pressed by neighbours in the same way (in the figure the thickness of the black lines gives the strength of the forces).

Glassy systems show bizarre properties, which are exploited in many areas. The study of glasses is, in fact, today a vast field, which interests physicists, chemists and engineers, each of whom with his/her expertise. They study the different characteristics of the glasses, with essential applications in the development of new materials. In our Department there is an intense research activity on disordered systems, mainly focused

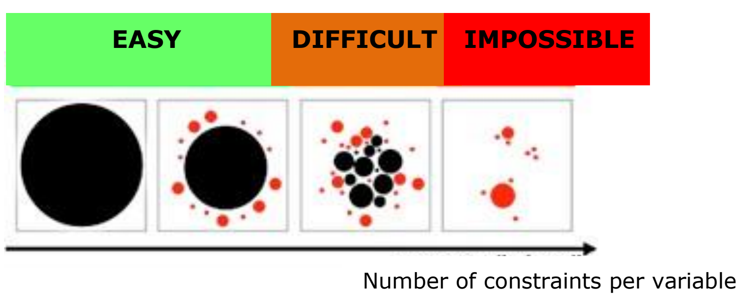


on the understanding of the fundamental principles that explained the variety of the observed behaviours, using both analytical methods and large-scale numerical simulations.

Statistical physics of disorderd systems applications

Statistical mechanics has developed to describe condensed matter systems composed by an enormous number of elements (solids, liquids, gas). However, it is possible to use the same techniques to study other problems of different nature but still composed of a vast number of interacting variables: for instance, neuronal networks or networks of interactions between biomolecules in biology, up to optimization and inference problems in statistics and computer science.

Often, they are complex problems, in which the whole system behaviour is not just the "sum of the parts". The interaction, even simple but strong, among the many variables, can produce unexpected collective behaviour. As an analogy, by observing a glass of water at room temperature is difficult to say that the same system at 0 and 100 degree Celsius drastically changes its state.In optimization, the aim is to find a configuration of the variables of the problem that satisfies all the constraints (for instance, there is the well-known problem of colouring a map so that two confining states are not of the same colour). The theoretical study of these problems has been focused on understanding the origin of the so-called computational complexity, which makes some of these problems virtually impossible to solve if the number of variables becomes too large. Statistical physics allows obtaining a very detailed description of the solutions space.



The figure shows an example: as the number of constraints per variable increases, the number of solutions, represented by the coloured areas, not only decreases, but their structure changes drastically. Disconnected clusters of solutions form and the red clusters contain solutions that they are, in principle, impossible to find.

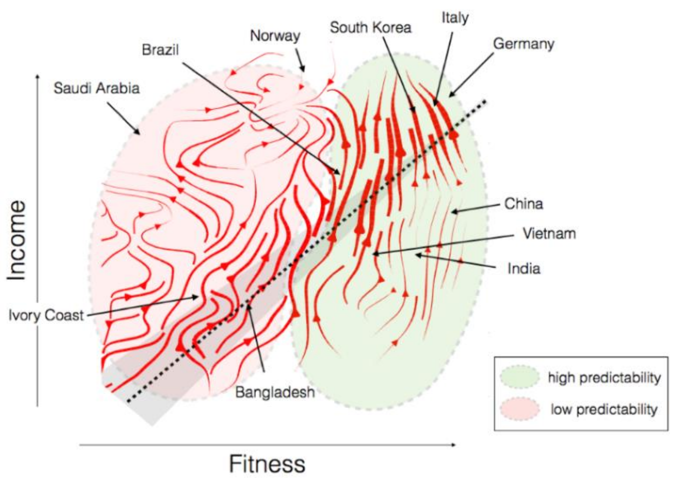
These drastic changes are real phase transitions, and they have direct consequences on algorithms that need to solve problems of optimization and statistical inference, which are of interest for many scientific fields. The activity of our Department plays a leading role internationally in these applications.

Complexity in socio-economics systems

"Techno-social" systems is the term currently used to identify social systems in which technology merges originally and unpredictably with cognitive, behavioural and social aspects typical of human beings. The new communication and information technologies (ICT) play an increasingly pervasive role in our culture and everyday life. This revolution does not come without contraindications, and in our complex societies, new global challenges always emerge that require new paradigms and original thinking for being addressed: global financial crises, the pandemics, city growth, urbanization and migration patterns, to mention a few examples.

In recent years, Statistical Physics has shown that it can play an essential role in understanding and controlling social dynamics, in a real trans-disciplinary effort involving physicists, mathematicians, computer scientists, social scientists and humanists. Therefore, new prospects open up, which were unimaginable up to a few years ago, that wisely mix different factors. On the one hand, theoretical and modelling tools of the physics of complex systems, together with the ability to analyse, interpret and visualise the complex amount of data (big data). On the other hand, the true essence of the techno-social systems provides a unique opportunity to exploit the new ICTs to monitor and quantify the digital traces of human behaviour and collective social phenomena with an unprecedented resolution.

Our Department is among the pioneers of these activities and boasts a distinguished tradition in these areas. Concrete examples range from the study of the information dynamics of opinions and norms to the processes of cultural diffusion and assimilation, from the dynamics of language to innovation processes, from individual awareness to decision-making processes, up to the dynamics of learning. To the theoretical and computational tools, it is now possible to combine the possibility of realising real social experiments on the web, which can be presented to the public in the form of a game in order to increase participation. Recently, a new research line has been developed in our Department which studies social, economic and financial phenomena using models and methodologies borrowed from Statistical Physics and Complex Systems Physics. Analysing the Big Data of international trade provided by the UN is possible to define the economic complexity of a country, i.e. its competitiveness and potential from an industrial and technological point of view, by describing it with a single quantity called Fitness. This description was possible thanks to an algorithm, similar in spirit but different from a mathematical point of view to the one used by Google to sort web pages by most to the less relevant. This algorithm was applied to the network of the countries and their exported products. The figure shows the temporal evolution of the richness (vertical axis) and the Fitness (abscissa) for different nations. For low values of Fitness (left side of the graph), the motion is chaotic and irregular. In contrast, for nations with high Fitness (right side of the graph), we observe a regular flow upwards, pointing out that several countries grow regularly. This type of approach, which is different in the spirit and the methodology compared to standard economic analysis, allows us to do long term forecasts and to give suggestions to improve the industrial competitiveness of countries.



Photonics: the art of light

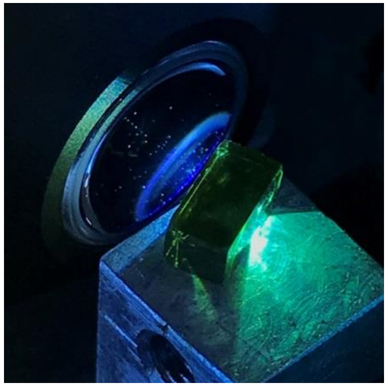
Photonics is the science that studies the propagation and generation of light; it is the science of lasers and their applications in microscopy, in telecommunications, in scientific experiments, up to new techniques to accelerate particle. Photonics was borne with the invention of the laser, which is the acronym for "light amplification by stimulated emission of radiation", a device whose theoretical foundations can be traced back to Albert Einstein, but that was first built in 1960 by Theodore H. Maiman.

Since then, the field of photonics has been continuously accelerating. It is enough to observe that many Nobel prizes in recent years are attributable to laser applications. Thanks to these light sources, today we can produce energy peaks so intense as to induce nuclear fusion. The most modern lasers are so precise that they can be used as clocks to explore the limits of validity of the physical laws. A frontier is a study in the laboratory of the fundamental physical laws, and the direction is to develop experiments capable of testing theories of quantum gravity. Laser interferometers, which allow length measurements, are today used to observe astrophysical phenomena like gravitational waves.

These modern laser applications are studied in our Department in order to determine the extreme limits of light propagation, as to be able to pass a laser beam through the human skin to implement new techniques for microscopy. New materials are also developed for applications previously unthinkable, such as invisibility, or like the construction of bodies capable of absorbing energy with very high efficiency, like solar cells, for example.

The figure at the top of the next page shows the laser propagation through a perovskite able to rectify the optical path of a light beam, regardless of the angle of incidence and colour.

In our Department, we also develop applications inspired by the way Nature itself exploits photonics. There are flowers, such as edelweiss, able to survive even in the presence of high concentrations of ultraviolet radiation because the morphology of the petals provides the ability to reflect shorter wavelengths coming from the Sun. This behaviour is an example of structural colours science, i.e. those optical properties that are not based on chemistry, but the physical properties, such as the shape and density of a material. Thanks to this science, we can know what colour animals that lived hundreds of millions of years ago had. The study of structural colours and its applications is of fundamental importance and is being developed through experiments, theoretical models, and simulations on the most advanced computational resources. It is difficult to think of physics today without photonics; this science is so vital that it can now be considered an independent field, whose applications today have the most significant social, economic and scientific outcomes.



In our Department, many groups use lasers and photonics technologies, and the major applications of this research field are developed.

Observe physical processes in real-time with light

How would it be watching a football match on television without having the slow-motion that it slows down the imagines and tells us if it is a goal or no goal? It is possible nowadays to make a slow-motion for atoms and molecules, which allow us to visualize fundamental physical and chemical processes that occur very quickly, such as the motion of electrons inside semiconductors devices or molecular dynamics in biochemical processes of vision and photosynthesis. Thanks to sophisticated laser systems, it is now possible to generate extremely short light pulses, which last a few femtoseconds. One femtosecond is 10-15 seconds, that is 0.000000000000001, which stands at one second as a second is to 32 million years.

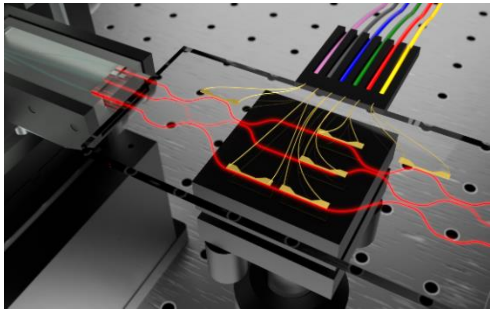
It is possible to understand, for instance, how fast a molecule is changing under the action of a chemical process by taking advantage of the possibility of varying the relative delay between two ultrashort pulses. The sequence obtained by putting together the different shots corresponding to time delay gradually increasing constitutes a real molecular movie, i.e. the complete visualization of the reaction dynamics. Today many scientists worldwide, as in our Department, study the ultrafast processes with femtoseconds spectroscopy in gases, in liquids and solids, on surfaces and in polymers. The applications range from the operation of molecular catalysts to the study of the most delicate life processes and the designs of future medicines. Thus, dominating the femtosecond time scale means to unify the approach to problems of chemical, physical and biological interest.

Integrated quantum photonics

The modern world is based even more on our capacity to elaborate and transmit the information. While the technologies of the classical information are getting closer to their fundamental limits, in several research laboratories they are working on the technologies of the future. Among the most promising technologies, there is quantum information, which exploits the properties of the quantum world to carry out operations that would be impossible according to the law of classical physics. Some examples are making codified information unbreakable (quantum cryptography), processing information much faster compared to a classical computer (quantum computation) or building a new generation of sensors better than the classical ones (quantum metrology). The realization of a quantum computer able to solve the classically intractable problem is still far. Thus, it is necessary to find the proper intermediate steps to show the potential of a quantum computer.

The Physics Department has made several significant contributions in this direction using the integrated photonics. Thanks to a writing technique, developed by CNR, using ultra-short laser pulses, it is possible to draw an actual optical circuit inside a glass chip. This technology allows realising photonic microprocessors, capable of integrating different types of optical elements with highly innovative three-dimensional architectures and allowing to create reprogrammable circuits. The photons that propagate inside these circuits can, therefore, simulate complex systems dynamics and be the fundamental constituents of advanced sensors.

The creation of these new technologies also requires efficient quantum transmitters of optical signals encoded in single photons. Nanotechnologies offer a development opportunity in this direction, another sector in which the Physics Department is involved in several activities (see p. 22).



Schematic depiction of a quantum simulator made with integrated photonics. The single photons are sent inside the device and run through the several allowed paths made using waveguides. The operation carried out by the circuit can be programmed from the outside through electrical connections.

Matter Physics

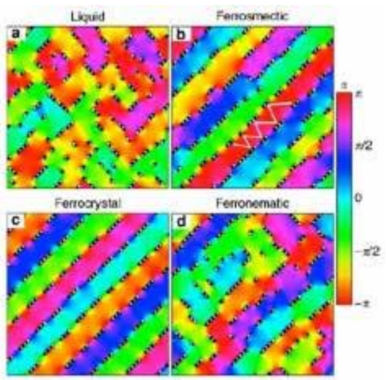
It is generally referred to Matter Physics that part of Physics studying the behaviours and the typical properties of aggregates made of numerous constituents. The individual properties of the constituents and the interactions between them are well known (the forces at play are electromagnetic), but the collective behaviour of the system under exam may be new and unexpected due to a large number of components. The questions that arise in this sector are the most disparate, and they range from questions of immediate application interest to questions of a fundamental character.

Hard matter and soft matter

The so-called "hard condensed matter" studies solid-state matter and its electronic properties. Electrons in solid materials can be found in different states, the so-called phases, in which the material takes on very different properties. The phases can be such as electronic insulating, conductive as in metals or superconductive, in which the electrical resistance is zero, magnetic.

Currently, hard condensed matter devotes much attention to systems where different electronic phases coexist or compete, creating a vast field that has substantial overlaps with the Physics of complex systems. Understanding these systems is of great importance both for applications and from a conceptual point of view. It is possible to create electronic states with new properties, emphasise some properties by creating, for example, superconductivity at high temperature, and allow easy, quick and controllable changes of the electronic properties.

In this context, a phenomenon recently highlighted is the emergence of electronic "softness": when phases with different electronic densities compete, fluctuations are created that generate inhomogeneities because electrons gather in some region and thin out in others. The so-called soft-electronics is based on this behaviour, in which electrons can aggregate and sort according to modes very similar to the systems of the traditional soft matter such as, for instance, the liquid crystals used in screens. The figure reports an example of these "electronics molecules", which are thought to form in some materials.



Superconductivity

In the broad context of emerging electronic properties, one of the most debated problems of Matter Physics in the last three decades is the origin of high-temperature superconductivity in certain ceramic materials. Superconductors have been known since the time of the First World War, and their functioning was understood in the 1950s. They are metal that below a specific temperature very close to the absolute zero (-273 °C) offer zero resistance to the passage of electric current. Because of this, in a simple superconductive wire closed in a loop, and without any generators plugged in, the electric current can flow indefinitely. Superconductors today are mainly used to obtain high magnetic fields, such as those that hold up the magnetic levitation trains (see photo) and that curve the trajectory of particles travelling almost at the speed of light in large accelerators.

If it was possible to operate a superconductor at room temperature, electricity could be transmitted from the power plants to our houses without losses, computer much faster than the current ones could be built, or powerful magnets at much lower cost could be manufactured.

A magnetic levitation train like this one, thanks to its superconductive magnets, carries passengers at 550 km/h between the city of Shanghai and its airport.

A step forward in this direction was made in 1986 when new superconducting ceramic materials working at about 100 degrees above the absolute zero were discovered. However, both to improve these materials and to find new ones with even higher working temperatures, one must understand how superconductivity is triggered in these ceramics. Even though there are some hints related to the "electronics softness", physicist still do not know the exact mechanism, despite the significant research effort that is still ongoing today also in our Department.

Research in Physics at Sapienza

Nanotechnologies

Nanotechnology is another fascinating field in which our Department is active. In recent years, matter scientists have learnt how to build new atomic and molecular architectures and to control dimensions, shapes and functions of a great variety of materials on the atomic scale. This expertise has allowed discovering electric, mechanical, optical and magnetic properties often unexpected. If atoms and molecules aggregate in structures on the nanometric scale (1 nanometre = 1 billionth of a metre), they can have properties different respect to solid materials on a macroscopic scale.

The scientific interest in studying the properties of these new structures has raised the now popular neologisms of nanoscience and nanotechnology to label the science and the technology dealing with the architectures/engineering of new atomic and molecular structures with specific properties. For instance:

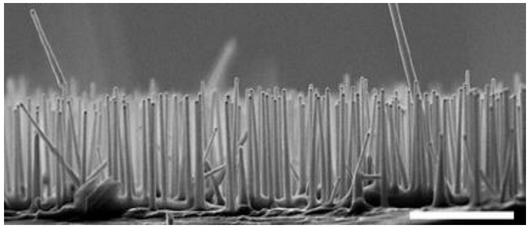
Is a two-dimensional crystal stable?

Can metals exist in one dimension?

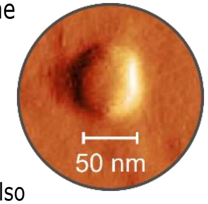
By varying the number of atoms of semiconductor nanocrystals, how the optical properties change?

We can, therefore, consider nanostructures as a state of matter whose properties do not depend only on the chemical composition but also on the size and shape. It is the case of the nanowires shown in the figure below whose main properties derive from the large surface exposed compared to the volume, giving them great potential for photovoltaic applications and sensors. Another prominent example is represented by the structures formed by the three-dimensional aggregation on nanometric scales of semiconductor materials. Several research groups in the world are pushing semiconductor technologies borrowed from micro- and optoelectronics to the limits of miniaturization by manufacturing nanostructures typically composed of a few tens of thousands of atoms. These nanostructures are also called artificial atoms thanks to their ability to confine individual electrons in space and to emit photons in a controlled manner.

semiconductor nanowires of indium phosphide, a material of interest for solar cells and telecommunications. Nanowires have a diameter of about 100 billionths of a metre and are long a millionth of a metre (the white bar corresponds to one-millionth of a metre).

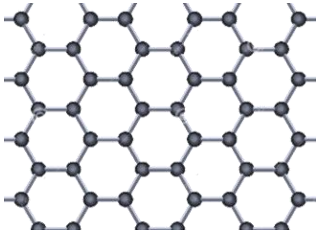


Researchers in our Department have shown that they can employ quantum of lights generated in this way in quantum teleporting experiments, and they actively work on optimization strategies for the employment in quantum information technologies.



atomic force microscopy image with a resolution on the scale of one billionth of a metre. The nanostructure, highlighted from the raised area, is composed of an arsenide crystal of gallium, a material also used to produce LEDs and laser diodes.

Moreover, from the union of superconductivity with nanotechnologies, new applications are born, which can be employed to considerably increase the sensibility and finesse of instruments used in other research areas. Some examples are the bolometers and micro-refrigerators to measure cosmic radiation, and the SQUID to measure magnetic fields (which are also used by researchers in the Department to study the fundamental laws of physics). These improved devices can also find then a large number of practical uses.



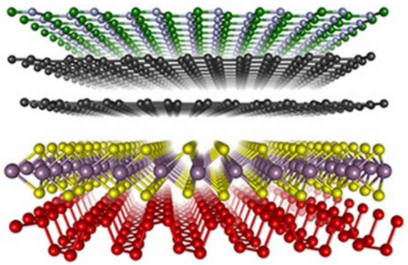
The family of crystals in two dimensions: graphene and others

The graphene, discovered in 2004, is made up of carbon atoms arranged on a single hexagonal planar lattice. Graphene was initially isolated from exfoliation of graphite in single atomic layers. Soon the scientists realized the vast potential of this new form of carbon, and, in 2010, physicists Geim and Novoselov won the Nobel Prize in Physics for first isolating a single layer of graphene and highlight its unique mechanical, electrical and thermal properties.

Starting from the discovery of graphene, researchers have explored the possibility of obtaining other forms of two-dimensional crystals starting from so-called exfoliable materials.

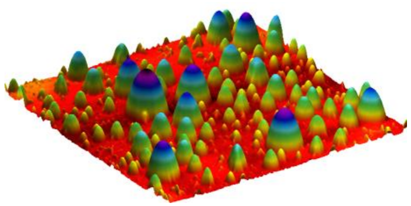
So, from graphite (contained, for example, in pencils) is possible to isolate a single layer of carbon atoms (graphene); likewise, nature offers thousands of other materials with this feature. In their two-dimensional form, these crystals exhibit physical and chemical properties surprisingly different from the material from which they were isolated. Like graphene, they are incredibly resistant crystals from a mechanical point of view, but also flexible and elastic.

Furthermore, two-dimensional crystals, depending on their chemical composition, can be insulators, metals, semiconductors or superconductors with electronic, optical, and thermal characteristics often unique.



Scheme of a superstructure built from different two-dimensional crystals: going from bottom to top a layer of black phosphorus, of molybdenum disulphide, two layers of graphene and finally a layer of nitride of hexagonal boron are stacked.

Even more relevant is that these crystals can be combined to exploit the peculiar properties of each chemical species. Nowadays, as shown in the figure on the side, two-dimensional superstructures formed by different materials are assembled like Lego bricks to make transistors, light-emitting diode (LED), solar cells, batteries, biological or gas sensors. All of that expands the opportunities to create new low-cost and low-energy consumption devices.
In our Department, several research groups synthesize these structures and investigate their electronic, optical and mechanical properties with the support of advanced calculation techniques. Elastic deformation is also researched by deforming them on scales of millionth or billionth of a meter. As shown in the left figure, this possibility allows for varying the properties of these materials as desired.



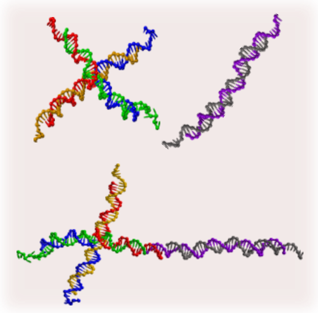
Atomic force microscopy image of a set of micro- and nano- hydrogen bubbles encapsulated by deformed layers of a MoTe2 two-dimensional crystal. The side of the image measures 8 microns, and the maxim height is 100 nanometres.

Soft Matter

Atoms and molecules, based on microscopic interactions, organise themselves to form condensed, gaseous, liquid and solid states. The laws of quantum mechanics set such interactions. The variety of condensed states and their different chemical/physical properties (for example, their ability to conduct electricity and heat) reflect the diversity of atoms and molecules that generate them.

Physicists, chemists and materials engineers have sought in the last decades to extend the range of materials going beyond those typically present in nature. They built (starting from atoms and molecules) specific aggregates (particles) that remain unchanged, but that interact as if they were atoms (superatoms) on a larger length scale. Such "superatoms" can then organise in gas, liquids and crystals and new mesophases. In these new materials, the particles interact with each other with forces that often are not a mere extension, on a larger scale, of the forces between atoms. This relevant peculiarity expands the range of possible properties of the materials. The goal that scientists intend to achieve is to build materials with the desired macroscopic properties, starting from aggregates of particles and how particles interact with each other. Achieving this objective requires a strong effort in modelling, to learn how to predict the collective behaviour of the system, starting from the knowledge of the interactions between the individual constituents and vice versa.

In recent years, scientists have tried to extend this line of research with increasingly complex and varied particles. For instance, they are trying to create "super-molecules". The molecules, having directional interactions, produce condensed phases with properties very different from those of solids consisting solely of atoms. A "supermolecule" has controllable interactions which allow producing increasingly sophisticated materials, capable of modifying their macroscopic properties following changes in external parameters (electric fields, temperatures, chemical/physical properties of the environment). These researches also involve the Physics Department of Sapienza, and in particular, the researchers of the soft matter group are at the forefront of this type of research. Among the recent studies, there is the invention and the theoretical and experimental study of new particles entirely made up of DNA. The basic idea is to use DNA, essential for biology because it allows the transmission of genetic traits, as a molecule to build materials. As illustrated in the figure, these particles entirely consisting of DNA oligomers create spontaneously star-shaped structures with a programmable number of arms, capable of binding together and form an extended lattice. The resulting material is fluid at high temperature but forms a gel at low temperature.



Physics and cultural heritage

Cultural Heritage includes a vast number of artefacts – books, sculptures, frescoes, mosaics, vases, buildings – made with the most diverse materials (pictorial pigments, paper or wood). Physics, especially matter physics and elementary particles physics, in recent years, has learned to use on these materials the experimental methodologies that for decades have been used in the study of atoms, molecules and crystals. Techniques used in our Department are based on the use of THz radiation, infrared and visible for multispectral imaging of works and the identification of the materials used. Besides, systems of digital imaging both in the Terahertz region and in the mid-infrared have been developed. The information obtained is often crucial for the study of the genesis of the artwork and its conservation. In recent years, research into Cultural Heritage has been mainly dedicated to the study of medieval scrolls and manuscripts of recent times on paper, combining Terahertz imaging, infrared spectroscopy, Raman spectroscopy and X-Ray fluorescence (XRF). The analysis of illuminated codes is one of the most widespread applications of spectroscopy techniques and imaging. In these scrolls, reflectometry and imaging in THz and the infrared allow to identify within the work the metallic materials (gold and silver foils) and to highlight drawing lines and text lines hidden. Also, the spectroscopy in the visible and the medium infrared, combined with XRF analysis, provides information on the molecular composition of the pigment and inks. The set of spectroscopic data offers a reading of the work complementary to the philological-artistic one, providing at the same time a more precise identification of art schools, diagnostics of the state of conservation and recovery strategies. In this Department, it has been carried out a study of codes dated between the fourteenth and fifteenth century tracked down in private libraries, containing miniatures never studied so far. This research is in collaboration with the Department of Fundamental Sciences Applied for Engineering and the Department of Documentary Sciences, Linguistic-Philological and Geographical.

Biosystems Physics

The inherent complexity of biological systems makes studying the physics of these systems fascinating and challenging. It is also true that the quantitative approach to biological problems, typical of physics and its conceptual and concrete tools, is making enormous contributions to the solution of the problems posed by modern biology. The "physical" approach to the study of the living systems, the physics of biosystems, is a field of research with many overlaps with biochemistry, molecular biology, nanoscience, bioengineering, systems biology, and others, making it a field connoted by a strong interdisciplinary "vocation". One of the crucial challenges in biosystems physics is the characterization with theoretical/conceptual methods, experimental and computational, of the behaviour of biomolecules, their interactions and their regulatory mechanisms, all framed and studied with the techniques of statistical mechanics, spectroscopy and microscopy.

Every living organism has instructions, in the genes that are "written" in its genome, which allows it to "build" the molecules it needs to live, move, multiply, defend itself from external attacks. It is necessary to identify them all, but it is not enough because these molecules almost always act in concert and are present or absent in different times and different cells.

We must, therefore, also understand how they cooperate to give rise to life with the ultimate goal of understanding how a living system works. We now know that the complexity of a biological system is not linked to the number of its components (humans and sea urchins have almost the same number of genes but very different complexity), but to sophisticated mechanisms of interaction and mutual influence. These mechanisms give rise to complex biochemical networks underlying the functionality of organic systems.

A fundamental contribution of physics in the biological field is represented from the development of new and more sophisticated investigation and diagnostic techniques, like the new super-resolution microscopies. Some of these new microscopies are the PALM and STORM microscopies, of which the importance of their introduction was recently recognized with the Nobel prize, the structured light microscopy or the new-born Brillouin (which has re-launched the studies of biomechanics). In this context, methodologies of data and image analysis that have a long history in other sectors of physics find more and more space (for example, machine learning and neural networks are at the basis of modern algorithms for processing the images collected).

Another very topical issue is the study of the collective processes of spontaneous aggregation (self-assembly) of molecules, which lead to the formation of complex biological structures (such as those reported in the figure on the previous page).

For example, the spontaneous aggregation of numerous molecules much smaller than proteins, the lipids, forms the main structure of cellular membranes, the "lipid matrix". It is in this matrix that proteins and other macromolecules take place to form the membranes, flexible structures with multiple functional properties.

Even the "molecular motors" are formed by proteins that aggregate forming nanoscopic "machines", capable of converting chemical energy into mechanical energy. For example, the kinesin protein can move on protein strands (microtubules) that make up the "skeleton" of the cell, transporting "loads" from one point to another in the cell in a much more efficient way than what would happen by diffusion. The observation of the extraordinary structures generated by the spontaneous organization of relatively simple molecules drives research towards the study of "self-assembly" mechanisms. This research also aims to obtain artificial materials and "nanomachines" for innovative applications. The extraordinary characteristics of specific natural materials derive in fact from their structure on a molecular scale: for example, the surprising mechanical strength of the shells, made of hard but fragile limestone, and of flexible protein fibres.

Supercalculators

Numerical simulations are a fundamental tool for basic research of theoretical and experimental groups. In the INFN (Instituto Nazionale Fisica Nucleare) are traditionally active scientific communities using supercomputers for the numerical study of strong interactions (LQCD, Lattice Quantum Chromo Dynamics), of Statistical Mechanics problems, of fluid dynamics in turbulent conditions, computational biology as well as neuronal networks simulations. Over the past thirty years, in the wake of the tradition that originates from a suggestion made by Enrico Fermi, the INFN through the APE project (https://apegate.roma1.infn.it/) has developed in our Department several generations of parallel computing machines, optimized and specialized in simulations of scientific and engineering problems.

The architectural characteristics of the APE systems have constituted a real paradigm, which proved successful in the field of high-performance parallel computing, and which are now implemented in commercial supercomputers of the latest generation. As an example, we cite apeNEXT, the latest generation of "custom" APE systems, consisting of a set of supercomputers installed at the University of Rome "La Sapienza". Another example is the project apeNET, which realizes computing systems based on commercial PC clusters with dedicated APE derivation networks, implemented on programmable components (FPGA) and accelerated through the adoption of GPU (Graphics Processing Unit).

As a direct technological follow-up, NaNet projects should be mentioned, where the architecture based on apeNET is applied to the read-out of the detectors and trigger computing of high energy experiments at CERN, and the network of the interconnection of ExaNeSt and EuroEXA systems, the prototype of future European ExaScale supercomputers. The research team also contributes to the technological and scientific activities of the project EU flagship H2020 HBP (Human Brain Project) where, among other things, explore the optimized interconnection design for "spiking" neural network simulations on large-scale.

Finally, we must not forget how this initiative allowed the training of dozens of researchers, active in academy and industry, specialized in the design of hardware, system software and optimization of applicative software. This initiative represents a unique and strategic experience in the Italian panorama and of great scientific and technological value at the European level.

Collaborazioni

Principali Istituzioni
Laboratori Nazionali
e Internazionali

SLAC Stanford Linear Accelerator Center

INFN Istituto Nazionale di Fisica Nucleare

CERN European Organization for Nuclear Research

Fermi National Accelerator Laboratory

DESY Deutsches Elektronen-Synchrotron

LAL Laboratoire de l'accèlerateur Linèaire

Consiglio Nazionale delle Ricerche

ESRF European Synchrotron Radiation Facility

Elettra Synchrotron Light Source

esa European Space Agency

asi Agenzia Spaziale Italiana

INAF Istituto Nazionale di Astrofisica

ESO European Southern Observatory

The protagonists

The two buildings into which the Department is divided (Marconi and Fermi), some classrooms (Amaldi, Cabibbo, Conversi, Corbino, Majorana, Careri), small rooms (Persico, Touschek) and laboratories (Pontecorvo, Segrè) are named after principal protagonists of the Italian physics history who were active as teachers and researchers at the Roman Physics Institute. In the following, there are some short biographical notes on these characters, and on Pietro Blaserna, first director of the new Physics Institute in via Panisperna, which he founded after Rome became the capital of the Italian state in 1870.

Who they were

Edoardo Amaldi

(Carpaneto Piacentino 1908 - Roma 1989)

Graduated in 1929 in Rome from the Fermi group, he collaborated on fundamentals research on neutron physics (induced radioactivity, slow neutrons).

He spent several stays abroad: in 1931, in Leipzig by Peter Deybe to study the X-rays diffraction in liquids; in 1934 at the Cavendish Laboratory in Cambridge, and in 1936, at the Columbia University in New York and in the Department of Earth Magnetism of Carnegie Institution in Washington D.C. From 1937 he held the chair of Experimental Physics in Rome.

After the war, he has played a determining role in the establishment in Italy of National Institute of Nuclear Physics (INFN, of which he was president from 1960 to 1965) and in Europe, in Geneva, of the Conseil Europèen pour la Recherche Nuclèaire (CERN, 1952). A key figure in the research policy in Italy, was one of the main protagonists in the birth of the national laboratories of Frascati, in the ESRO space projects (organization born in 1962 from which ESA originated), in the energy policy.
He also made considerable contributions to the study of elementary particles (in cosmic rays and with the use of accelerating machines) and finally promoted, since 1971, the research for gravitational waves.
His commitment to disarmament was constant and active: he joined the Pugwash pacifist movement since its establishment in 1957.
From 1966 he was president of the International School on Disarmament and Research on Conflicts (ISODARCO).

Pietro Blaserna

(Fiumicello in Aquileja 1836 - Roma 1918)
Assistant of Andreas von Ettingshausen, director of the Institute of Physics of Vienna, he perfected his training of experimental physics at the Sorbonne in Paris, in Regnault laboratory.
Back in Italy, in 1862 he obtained a position at the Instituto Superiore of Florence and a year later he was called to hold the chair of Physics in the University of Palermo. In 1872 he was transferred in Rome, at the La Sapienza University, to the chair of Experimental Physics and the following year he was appointed director of the Physics Institute, a position he has held until 1918. The significant contribution made by Blaserna to the creation of the Physics school in Rome was the design of the Physics Institute in via Panisperna, where the Institute moved in 1881. President of the Board of Directors of Meteorology and Geodynamic Service, he was appointed senator of the Kingdom in 1890 and vice president of the Senate in 1904; he was in the same year President of the Royal Academy of the Lincei.

Nicola Cabibbo

(Roma 1935 - Roma 2010)
The University of Rome "La Sapienza" had the privilege to count Nicola Cabibbo among his teachers, distinguished Theoretical Physicist who gave his name to one of the fundamental constants that describe the weak interactions, known as the Cabibbo angle.
This discovery, which occurred in 1963, extended the theory, initially proposed by Fermi in 1933 to describe nuclear beta decay, to the decays of strange particles, thus opening the way for the formulation of the Standard Model. Since 1966 Nicola Cabibbo has been a professor in Rome, where he has formed a school of theoretical physicists that have had a substantial impact on the development of the physics of fundamental interactions. Among the most relevant results we can remember the theory of hadronic annihilation of e+e-, the calculation of the electroweak radiative corrections at the magnetic moment of the muon, the study of the beta decay of heavy quarks, the prediction of a deconfined phase transition in the hadronic matter, the proposal to use non-perturbative numerical calculations on a lattice to the study of weak interactions, the calculation of limits for the Higgs boson mass in a theory of grand unification. Together with Giorgio Parisi, Cabibbo has also designed and created a parallel supercomputer dedicated to non-perturbative studies

of QCD regularized on a lattice. Nicola Cabibbo has also had a significant influence on scientific policy and was president of INFN (1983-1992) and ENEA (1993-1998). In recognition of his scientific merits has received various important awards, among which the Prize of the European Physical Society (1991), the Sakurai Prize of the American Physical Society (1989) and the Dirac Medal of the ICTP (2010).

Marcello Conversi

(Tivoli 1919 – Roma1988)
He graduated in physics in Rome in 1940, and he has taught Higher Physics at the Universities of Pisa and Rome. Between 1950 and 1958 he directed the Physics Institute of the University of Pisa, between 1960 and 1966 that of the University of Rome. During the war years, together with E. Pancinie and O. Piccioni, led to the Institute of Physics G. Marconi of Rome a series fundamentals experiments, which showed that the mesotron it was not the particle expected by Yukawa, but a heavy lepton later called muon. In 1955, in Pisa, together with A. Gozzini, he created the first "spark chamber" detector. Still, in Pisa, he directed the project for the construction of an advanced electronic computing centre.

Orso Mario Corbino

(Augusta, 1876 – Roma1937) Born in Augusta, in the province of Syracuse, from a modest family of pasta artisans, he graduated in Physics at the age of solely 20 years at the University of Palermo, where he later became assistant to Damiano Macaluso. In 1904 he won the chair of Experimental Physics at the University of Messina. In 1908 he moved to Rome, called by Blaserna to succeed Alfonso Sella to the chair of Complementary Physics. Died Blaserna, in 1918 he succeeded in the direction of the Physics Institute and the chair of Experimental Physics. He covered principal administrative and political offices: in 1917 he was appointed president of the Superior Council of Water and Public Works, senator of the Kingdom on the proposal of Giovanni Giolitti in 1920, Minister of Education in 1921 in the Bonomi government, Minister of National Economy in 1923-1924. He was also president of the General Electricity Company, of the Southern Electricity Company and the Commission for artistic directives and technical supervision of radio broadcasts. In the academic field, he was a national partner of the Lincei, president of the Italian Society of Sciences, called the XL (1914-1919),

president of the Italian Society of Physics. He established in Rome the first chair of Theoretical Physics, on which he called Fermi in 1926, and the chair of Spectroscopy on which he called Franco Rasetti in 1930. He discovered the "Corbino effect" (1918-22), a variant of the Hall effect. He studied the theory of the electric pile in-depth and definitely (1927). He made numerous contributions in electrical engineering and the nascent electronics.
In photoelasticity, he verified Volterra's theory of elastic distortions and was a pioneer in the practical applications of stress analysis in materials. In 1936 he founded the CNR Electroacoustic Institute in via Panisperna.

Enrico Fermi

(Roma 1901 - Chicago 1954)

Practically self-taught, in 1918 he entered the Scuola Normale Superiore of Pisa to attend the physics course. Even during the university period, he studied independently relativistic and quantum physics, becoming soon an authority in these sectors not only in the Pisan university but also in the rest of Italy, where the resistances to the "new physics" were strong. Graduated in July 1922, he spent some periods of study in 1923, at Gottingen, Germany, with M. Born, and in 1924 at Leiden, Holland, with P.Ehrenfest. At the end of 1925, he formulated a new statistic (now called Fermi-Dirac) for particles with semi-integer spin (electrons, protons, neutrons, today called fermions). He held in 1926 the first chair of theoretical physics in Italy, established specifically for Fermi by Corbino at La Sapienza University. He moved in the autumn of 1926 to Rome in the via Panisperna. He started a group of collaborators: the first was Rasetti, to which joined E. Segrè, E. Amaldi, B. Pontecorvo. Occasionally, and only for the theoretical problems, E. Majorana participated in the work of the group. Fermi made numerous first-rate contributions to theoretical physics, among which the most important is the beta decay theory formulated at the end of 1933, which it can be considered the birth of modern theoretical physics of elementary particles. In January 1934, I. Curie and F. Joliot announced in Paris that they had observed artificial radioactivity caused by alpha particles in light elements (boron, aluminium and magnesium). After the announcement, Fermi thought that the best way to produce artificial radioactivity would be to employ neutrons as bullets (discovered only two years earlier by J. Chadwick). Neutrons do not undergo the coulombian repulsion of the core since they are electrically neutral. In a short tim Fermi, in collaboration with Rasetti, Segrè, Amaldi, the chemist O. D' Agostino, to which the recent graduate Pontecorvo had joined, it began a systematic study with positive results. Fermi and collaborators also discovered that for subsequent collisions with the hydrogen nuclei of a hydrogenate material, the neutrons are significantly slowed down, and the so obtained slow neutrons are up to a hundred times more effective than fast neutrons in producing nuclear reactions with gamma emission. Fermi, in this period, formulated the theory of the slowdown of neutrons, which contained many of the ideas that will underlie the nuclear reactors theory. For research on nuclear physics of the group directed by Fermi in the Thirties in via Panisperna, he was awarded in 1938 the Nobel prize for physics. At the end of the same year, shortly after the promulgation of racial laws in Italy (his wife, Laura Capon, was Jewish), emigrated to the USA. In Chicago, he built the first fission nuclear reactor, which began operating on December 2, 1942. Fermi was one of the main protagonists of the scientific work that led to the realization in Los Alamos of the fission bomb.
After the war he was a professor at the University of Chicago, dealing with variousfundamental physical problems, and carrying out scientific consultancy activities for the United States government.

Ettore Majorana

(Catania 1906 – scomparso nel 1938) After enrolling in Engineering in Rome in 1923, he moved to Physics in 1928, where he graduated in July of the following year under the guide of Fermi, with a thesis on "The quantum theory of radioactive nuclei". In the following years, he published some atomic and molecular physics contributions and ensued free teaching in theoretical physics in November 1932. He then dedicated to a series of original works that mark the birth of the theoretical physics of nuclei and elementary particles. In 1937, more than ten years after the first competition for a chair in theoretical physics of 1926, another competition was requested by the University of Palermo. Majorana competed among other candidates, but in front of its evident superiority the commission, chaired by Fermi, could not apply the usual procedure in his case. Then the commission asked the minister of the National Education Giuseppe Bottai to resort to a law, already invoked for Guglielmo Marconi, which appointed to the young theoretical physicist one chair out of the

competition. Majorana won "by clear fame" in November 1937, the chair of theoretical physics at the University of Naples.
After taking up service in the new location and starting lessons, he mysteriously disappeared on March 26, 1938, after a ferry trip from Naples to Palermo. Despite a lot of research and much guesswork about its end, nothing has been known for sure. A comment on the scientific personality of Ettore, done by Fermi to Giuseppe Cocconi immediately after the news of his disappearance, and told by them in a letter to E. Amaldi from 1965 summarizes the figure of this "genius without common sense: " for Fermi, there are various categories of scientists, first, second and third rank. But then there are geniuses, like Galileo and Newton. Well, Ettore was one of those. Majorana had what no one else in the world has; unfortunately, he missed what is common to find in other men, the good sense".

Guglielmo Marconi

(Bologna 1874 – Roma1937)

After the famous "hill experiment" (Pontecchio, 1895), in which Marconi managed to create a transmission and reception system of electromagnetic waves at a great distance, he moved to England because he was convinced that his invention could find in that country a more favourable ground. In 1897 he obtained his first patent on "Improvements in the transmission of impulses and related devices", and in the same year, Wireless Telegraph and Signal Co. Ltd was established (since 1900, Marconi's Wireless Telegraph Co. Ltd.) with the right to employ patents worldwide. In December 1901 Marconi managed to make the first interoceanic connection between Poldhu, Cornwall, and St. John in Newfoundland. In 1909 he shared the Nobel prize in Physics with K.F. Braun, the first Italian to receive this high recognition.
In 1914 he was nominated Senator of the Kingdom of Italy. In 1928 he became president of the CNR; in 1930, president of the Royal Academy of Italy, and the same year, he began the design of the shortwave Vatican Radio, inaugurated by Pope Pius XI in 1931. For the occasion, Marconi was appointed Pontifical Academician and was awarded the Grand Cross of the Order of Pius IX. In 1932 he received in London, from Lord Rutherford, the Kelvin Medal and was elected member of the National Academy of Sciences of Washington. A national partner of the Lincei in 1931 and president of the Italian Encyclopaedia Institute in 1933. Appointed professor of electromagnetic waves in the Royal University of Rome in 1935, Marconi never taught in the Roman Physics Institute which after his death has been called the "Guglielmo Marconi" Institute of Physics.

Enrico Persico

(Roma 1900 -1969)

Friend and fellow student of Fermi, he graduated in physics in Rome in 1921 and then became Corbino's assistant from 1922 to 1927. In 1926 he won the chair of theoretical physics at the Physics Institute of Arcetri in Florence, where he contributed to the formation of a group of young physicists, including Bruno Rossi, Gilberto Bernardini, Giuseppe Occhialini, Giulio Racah. In 1930 he moved in Turin to teach.
In 1947 he moved to Laval University in Quebec, Canada to cover the place left vacant by Rasetti, to return then in Rome in 1950 to take the chair of Higher Physics. Since 1953 he had directed the INFN theoretical section working on the design of accelerator components, and in particular to charged particle injection systems. In 1958, still in Rome, he went on to teach theoretical physics. In addition to the relevant contributions given to theoretical physics, he played, together with Fermi, a fundamental role in the diffusion of this research sector in Italy.

Bruno Pontecorvo

(Pisa 1913 – Dubna 1993) Graduated in 1934 with E. Fermi, he collaborated at fundamental research on the properties of slow neutrons. Shortly afterwards he moved to Paris to F. Joliot at the Institut du radium, obtaining remarkable results in the field of nuclear physics, and then (1940) in the United States where he developed a method of neutron coring. In 1943 he participated in the construction of the first Canadian nuclear reactor; in 1948 he took on one of the technical directions of Harwell's British Atomic Laboratories; in 1950 he moved to the USSR at the Dubna Nuclear Institute (Moscow). Fundamental were his contributions to neutrino physics: he hypothesized the existence of two types of neutrinos (neutrino-e and neutrino-m) suggesting how to highlight them experimentally. Moreover, he devised the chlorine-argon method for detecting neutrinos, and he did essential studies on the mass of neutrinos and their "oscillations".

Giorgio Salvini

(Milano 1920 – Roma 2015)

Graduating in Milan in 1942, he started his research activity by studying extended cosmic rays first in Italy and then in the Princeton University. He returned to Italy in 1951, and he taught in the universities of Cagliari, Pisa and finally from 1955 to the "Sapienza" in Rome, where it had been a professor of General Physics until 1990. In 1953 he was entrusted with the direction of the national project for the construction in Frascati of an electron synchrotron of 1,100 MeV, one of the leading accelerators in those years. An enterprise that Salvini led to success by leading a group of brilliant young graduates chosen from various Italian universities. The enterprise has created the National Laboratories of Frascati of the INFN and marked the "Italian way to high energies". It was the beginning of a school of accelerator physics, which had as a milestone the birth in Frascati of the electron-positron colliders and the construction of the collider e+e- ADONE. In 1977 he started working on the design and implementation of an experiment at the proton-antiproton collider of CERN which observed the intermediate W and Z bosons in 1983. For this discovery in 1984 Carlo Rubbia was awarded the Nobel Prize. Giorgio Salvini with Edoardo Amaldi was one of the protagonists of the rebirth of Italian physics after the war.

Academician of the Lincei from 1959, he was president of the Academy from Kelvin Medal and was elected member of the National Academy of Sciences 1990 to 1994 and later Honorary President, president of the INFN from 1966 to 1970, Minister of the University and Scientific and Technological Research between 1995 and 1996.

Emilio Segrè

Emilio Segrè

(Tivoli 1905–Lafayette, California ,1989)

Graduated in Rome from the Fermi group, he collaborated to fundamental research on physics of neutron (induced radioactivity, slow neutrons). From 1936 to 1938 he was a professor at the University of Palermo where he isolated the technetium, the first artificial element. Refugee due to racial laws in the United States (where he took the citizenship in 1944), he participated in the project Manhattan for the construction of the first nuclear weapons. After the war, his research concerned nuclear physics and elementary particle physics problems. In 1955, with O. Chamberlain, he discovered the antiproton among the ultra-high-energy proton-nucleon interaction products; for this discovery, he was awarded the Nobel prize for physics.

Bruno Touschek

(Vienna 1921 – Innsbruck1978)

Forced to leave Austria because he was a Jew, he moved to Germany in 1940 where he was captured in 1943 by the Gestapo. Escaped in 1945, he managed to graduate in physics in Gottingen in 1946, and later (1949) he got the PhD in Glasgow. In 1954 he moved to Rome, where he taught, at the Institute of Physics, mathematical methods for physics. He was responsible for the design and implementation, at the national laboratories of Frascati, of the first accumulating ring of colliding beams for electrons and positrons, ADA. The first collisions at high energy in the centre of mass frame of electron-positron were observed at ADA, where it was also shown the possibility of making more powerful rings. Foreign partner of the Lincei since 1972.

The protagonists today

Who we are

The tradition of scientific excellence, linked to prestigious names such as those that we have presented, has been kept alive by their successors and continues today. Our researchers have made significant contributions in various fields of physics, contributing to the high international reputation of our Department. Some of our teachers also held or now hold prestigious institutional positions in the world of research.

The Department hosts 36 laboratories with many skills, among which we remember those in Particle Physics, Astrophysics, Computational Physics, Matter Physics, Classical and Quantum Photonics. In recent years, the Department has been a protagonist in some of the most important scientific results achieved in recent years in various fields of physics, among which we remember the discovery of Higgs and the observation of the gravitational waves.

The Department qualifies in high positions of different International rankings. For example, according to the international Academic Ranking of World Universities 2018, published by the University of Shanghai, our Department ranks 29th in the world and first in Italy. At the beginning of 2018, the Physics Department was selected by the MIUR as one of the 180 Italian "Departments of Excellence".

The high quality of the research conducted by our Department is evidenced by the numerous funding obtained through over 40 projects, funded by the European Union, MIUR, other institutions and foundations (in the period 2015-2017). Besides, Sapienza University is the first public Italian university by the number of funding from the European Research Council (ERC) and the Physics Department currently hosts 5 of these projects. In the ten years of the ERC, 15 grants were granted to a member of our Department.

The scientific articles published in prestigious international journals are approximately 2000 in the three years 2015-2017, and in particular, those in journals with impact factors greater than ten are more than 50 in the same period.

The Department organized a large number of international events, workshops and conferences (about 20 workshops and international conferences only in the three years 2015-2017). The presence in scientific committees of our teachers and researchers is substantial.

In the context of the third mission, we gained recognition by MIUR as good practice the Alternanza Scuola Lavoro project of the Department,

LAB2GO: http://www.istruzione.it/alternanza/_RMPM12000L.html

The Museum of the Physics Department

On the first and third floors of the Fermi Building, there is the Museum of Physics documenting the history of this institution, teaching and research that had been carried out in it since the times of the ancient palace of the Sapienza, then later in the building in via Panisperna (today home of the Centro Fermi) and, finally, to the university campus. The Physics Museum is part of the Sapienza Museum Center. Many information on the museum's collections can be found on the website at https://web.uniroma1.it/polomuseale/museo-fisica.

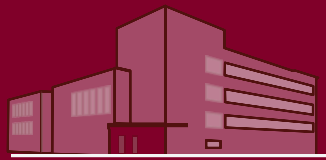
The museum welcomes visits by students of all ages, curious, enthusiast and professionals. Access is free, and during opening hours, a guide is always available to illustrate the most interesting instruments to the visitors. In particular, the guides do not just describe the objects of the past exhibited, but they also explain how the instruments work. Moreover, the guides compare the old instruments with the most modern technologies and highlight the evolution of measurement technologies.

Often, in the oldest apparatuses with an unusual appearance for the present day, the physical principles appear more evident. However, with the instrumentation today available, it is much easier to get results that in the past require much effort. In some cases, during guided tours, experiments are performed using the equipment of the time and modern instruments like smartphones. These experiments allow appreciating the ingenious solutions adopted by past physicists to obtain the information they need not having the current technologies.

The collections range from the eighteenth century to the research years of the "Ragazzi di via Panisperna" group, and it includes unique pieces such as the Armonium of Pietro Blaserna or very rare as the De La Rive apparatus for the study of the northern lights. They are an integral part of the museum's collection original equipment used by Enrico Fermi for the discovery of neutron-induced artificial radioactivity and the beam separator of the Virgo experiment, exhibited in the Marconi building.

STUDY PHYSICS AT SAPIENZA

INFORMATION TO STUDENTS



Orientation and Information Activities

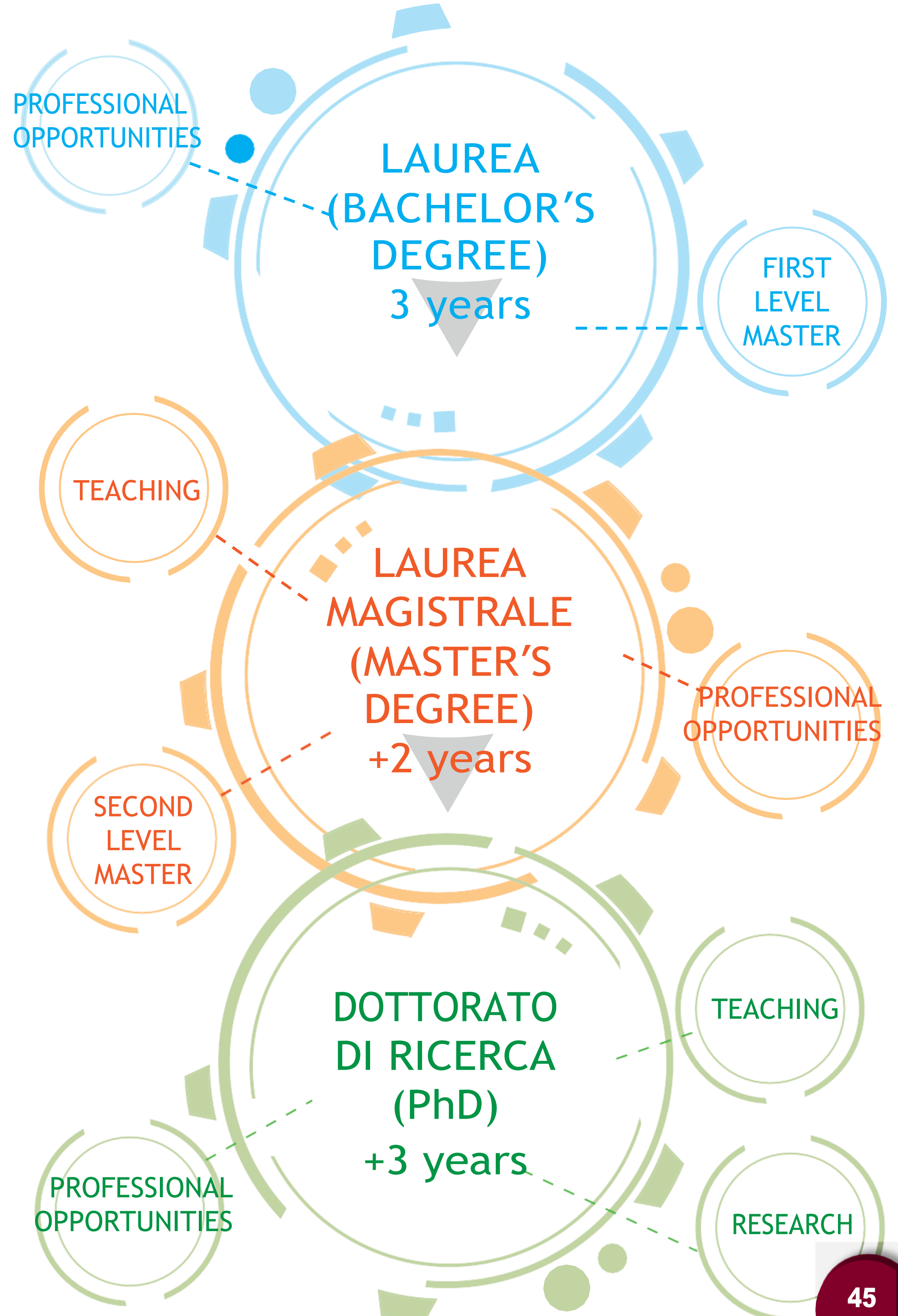
The orientation activities are aimed at the following categories of users:

- High school students and future first-year students, for whom meetings are organized at the schools during their last year of higher studies. Contact antonio.polimeni@roma1.infn.it, tel. 06.4991.4770
and in the context of Piano Lauree Scientifiche, contacts and details in
https://www.phys.uniroma1.it/fisica/PLS

- Students of the previous categories and university students, who want information on study courses in Physics
https://www.phys.uniroma1.it/fisica/didattica/corsi_lauree_
(Department website)
and https://corsidilaurea.uniroma1.it/ (University website)
Didactic secretariat, at the ground floor of the Marconi Building :
segreteriadidatticafisica@uniroma1.it
dott.ssa Sonia Riosa - room 007 - tel. 06.49914232
sonia.riosa@uniroma1.it
dott. Marco Dante - room 005 - tel. 06.49914517
marco.dante@uniroma1.it
Student information point - room 001a Marconi building
sort.fisica@uniroma1.it – tel. 06.49914233
(timetable on the website:
https://www.phys.uniroma1.it/fisica/segreterieesportelli).

- Students, for administrative information (enrolment formalities, fees, scholarships): website of the Administrative Secretariat for students of Faculty of Mathematical, Physical e Natural Sciences (Facoltà di Scienze Matematiche, Fisiche e Naturali):
segrstudenti.scienzemmffnn@uniroma1.it
https://www.uniroma1.it/it/pagina/segreteria-studenti-di-scienze-matematiche-fisiche-e-naturali
for access tests and enrolment in the Laurea Triennale, see also the section ENROLMENT, TRANSFERS, EXAM RECOGNITIONS on the following pages.

- Students, for information on general services (e.g. catering) and services obtainable through competition (such as scholarships, accommodation, projects): see the University website in the dedicated pages.



The structure of teaching in physics is divided into several cycles:

LAUREA (BACHELOR'S DEGREE)

The Physics Department of the La Sapienza University of Rome offers a Bachelor's degree course, called **Physics**. The course is divided into three curricula, Astrophysics, Physics, Applied Physics.

The degree provides a basic preparation which allows:

- The continuation of the studies in Master's Degrees and Masters; among the Master's degrees the most chosen by students are the master's degree in Physics and that in Astronomy and Astrophysics.
- Starting a professional carrier (e.g. in the field of Physics and Environment, Electronics, Computers, Technological Innovation, Astronomy, Astrophysics and Space Research).

LAUREA MAGISTRALE (MASTER'S DEGREE)

The Physics Department of the La Sapienza University of Rome offers two courses in both two-years Master's degree:
Physics, Astronomy and Astrophysics.
The courses allow the continuation of studies, access to PhD, insertion in fundamental or applied research, promotion and technological development, in professional activities and projects related to Physics (Industry, Environment, Healthcare, Cultural Heritage and Public Administration, Astronomy, Astrophysics and space research). Moreover, the Master's Degrees provide access to courses activate for teaching in primary and secondary second-degree schools.

DOTTORATO (PhD)

The PhDs represent the completion of the researcher's training, and they constitute an indispensable title for access to researcher competitions in University and Research Institutes. For more information, see the following pages and the online information dedicated to PhD programs:
https://www.phys.uniroma1.it/fisica/node/5566

DIDACTIC MODES

The teaching activities are distributed on a half-yearly basis. The teachings are provided through lectures and exercises in the classroom or the laboratory. The schedule of activities is organized in such a way as to allow students an adequate time to devote to personal study. Assessment of learning is based on written tests, which can be taken during and at the end of the course, and oral exams. The laboratory courses provide an introductory part ex-cathedra, and a part carried out in the laboratory by the students, divided into small groups, under the guidance of the teachers; in these cases, the assessment is based on laboratory reports, by group or individual, and oral exams.
The duration of the bachelor's degree courses is six semesters, equal to three years. The duration of the master's degree courses is four semesters, equal to two years.

UNIVERSITY TRAINING CREDITS (CREDITI FORMATIVI UNIVERSITARI - CFU)

The University Training Credit (CFU) measures the amount of work done by a student to achieve an educational goal. The student acquires the CFU by passing the exams. The credit system adopted in the Italian and the European universities corresponds to a CFU 25 hours of commitment by the student, divided into:

- Lessons, exercises, laboratory activities, which correspond to about 8 hours of lessons, or 12 hours of laboratory or guided exercises
- Individual study, for the remainder of the 25 hours.

The Department's teaching website contains the breakdown of credits and teaching hours, requisites, learning outcomes of the courses and a general program. The total workload for the bachelor's degree is 180 CFU, corresponding to 4500 hours of total commitment by the student, while for the master's degrees is 120 credits, equal to 3000 hours of commitment.

STUDY PLAN

The study plan is the list of exams that the student intends to take (or has already taken), divided by course years and semesters. It can comply with one of the schemes prepared by the Didactics Area Council or CAD (curricular study plan or Percorso Formativo Curriculare PFC) or freely designed by the student who proposes it (individual study plan, Percorso Formativo Individuale, PFI). The PFI schemes contain options and exams to choose which the student is required to specify.

However, PFI must comply with the requirements set out in the Manifesto of the Education. Both PFC and PFI contain 12 CFU chosen by the student, which can be chosen from all the Sapienza courses.
The study plan can be presented at the beginning of each academic year by filling in an online form.
In any case, exams already recorded can no longer be replaced. The CAD handles the approval, which is identical for PFC and PFI: in the case of negative opinion, the student is invited to modify the plan. In the absence of an approved study plan, the student can only take the compulsory exams, common to all curricula of the degree course. The student enrolled in the bachelor's degree courses cannot choose exams of the teachings of the master's degree. Conversely, the master's degree students can put exams of the bachelor's degree in his/her study plan only after receiving specific authorization from the CAD.

EXAMINATION TESTS

Assessment of knowledge takes place through examination tests. The majority of exams end with an oral test, which is accessed passing a written test or an individual laboratory test, or successfully taking the tests during the course. The assessment is expressed with a mark in thirtieths or an eligibility judgment. In case of a numerical vote, the minimum mark to pass the exam is 18 out of 30.

FREQUENCY, REQUISITES, PASSAGGE TO SUBSEQUENT YEARS

The main courses are delivered in multiple channels. The attribution methods of the students to the channels are shown in the pages of the Degree courses. Regular attendance at all courses is an essential condition for profitable use of the teachings and is therefore highly recommended. For courses which include laboratory exercises, attendance is mandatory.
In the courses related to the Physics Department, there are no formal entry requirements for the courses. However, the placement of the teachings in the study plan is one clear indication of the optimal order in which to follow the courses and take exams.
If the student does not pass an exam, there will be no administrative barriers to pass subsequent exams; the student will have to schedule the recovery of the failed exam as not to produce a mismatch between courses taken and exams to be prepared.

PART-TIME REGIME

The modalities for applying for the part-time regime are set in the University Manifesto and are available on the Sapienza website.

ACADEMIC CALENDAR

The start and end dates of the lectures in each semester and the start and end dates of each exam session are published on the Degree Courses website.
Typically, the courses are structured as follows:

- first semester: from end of September to January
- forst exams session: February
- second semester: from March to June
- second exams session: June/July
- third exams session: September

As an example, the weekly timetable of the first year of the Bachelor's Degree in Physics typically includes:

- 3 or 4 hours of lectures per day from Monday to Friday
- 4 laboratory hours per week.

The periods dedicated to lectures and exams cannot overlap.
Notwithstanding this rule, to allow students close to graduation and those who have not graduated on time (and assimilated) to complete the missing exams, there are two extraordinary exams sessions reserved to them, usually in May and November.

PATH OF EXCELLENCE

The CAD annually announces a Path of excellence for each of the Degree courses, with announcements available on the Department website. The purpose of the excellence Paths is to enhance the training of deserving students interested in deepening and cultural integration activities.

TUTORING

The Degree courses provide all students with teachers and tutor of reference, who are available to students for information and advice. Their names and contacts are available on the teaching website of the Department and the pages of the University degree courses.

Bachelor's Degree in Physics

The degree course in Physics (class L-30, Physical Sciences and Technologies) is divided into three curricula: **Physics, Astrophysics, Applied Physics.**

The specific learning objectives are aimed at providing an essential preparation both for starting a professional carrier and for continuing studies (Master's Degrees, PhDs, Master's ourses).

https://www.phys.uniroma1.it/fisica/didattica/corsilauree/laurea-triennale-fisica

https://corsidilaurea.uniroma1.it/

Employment and professional opportunities

The methodological training, the spectrum of knowledge and the operational flexibility acquired allows the graduate in Physics, if he/she does not intend to continue the studies in the second level, to find places in a wide range of professional areas. These professional areas include all of the ones requiring knowledge about natural and artificial systems, and generally in all activities with a high level of technological innovation in both the public and private sectors.

The reference areas include industry, with particular regard to electronics, space, semiconductors and energy, the activities of product quality assessment, research and development laboratories, the environmental monitoring and evaluation, the tertiary sector relating to the use of calculators (e.g. data acquisition and processing systems), the scientific sector sales (e.g. sales technician/service technician) and the financial sector.

As regards the Astrophysics curriculum, in the Astronomical Observatories is nowadays consolidated the need for an interface between the astronomer, which defines the scientific activities, and instrumentation. It, therefore, becomes essential the presence of a professional figure who knows how to manage the instrumentation and optimize the observational program based on the scientific objectives.

The curriculum in Applied Physics is specifically aimed at students who want to start a professional career without attending the Master's Degree. It, therefore, includes application and laboratory courses. The Physics degree prepares specialists in Physical, Mathematical and Natural Sciences (ISTAT category 2.1.1, and more specifically Physicists and Astronomers, cat. 2.1.1.1) whose training can be completed through a Master's degree course.

The course degree

I The three curricula within the Physics degree include the acquisition of a mathematical background suitable for understanding topics related to the three-years courses; knowledge and understanding of Classical Physics (Mechanics, Electrodynamics and Thermodynamics), the elements of Optics and Chemistry, the foundations of Modern Physics, with particular regard to Quantum Mechanics, Statistics and Relativity; basic knowledge in advanced fields such as Electronics, Matter Physics and, in the case of the Physics curriculum, Nuclear and Subnuclear Physics; knowledge of the essential elements of computer science (structure of computers, networks, programming languages). As far as it concerns the curriculum in Astrophysics, it is expected to acquire necessary skills in IT and the design of the astrophysical application software. Also, for this curriculum, some laboratory activities are planned to acquire application skills in the field of Astrophysics and space sciences.

Enrolment, transfers, exams recognition

The didactic regulation provides detailed rules on the following aspects (further indications are available from the Didactic Secretariat):

- enrolment requirements
- assessment of the starting knowledge, through a test, **mandatory but not selective**
- passages and transfers of students from degree courses of Sapienza, from other universities, or military institutions of higher education
- shorter course duration for enrolled students, holders of other three-years degrees, specialistic or master's degree of a previous system
- recognition of credits already acquired as a result of one of the previous cases or extracurricular exams (ex art. 6)

All the information can be found in the General Manifesto of the studies on the University website and on the pages of the University Degree courses: https://corsidilaurea.uniroma1.it/

Assessment of linguistic knowledge

The training course of the Physics degree requires the acquisition of 3 CFU for English. At the end of the course, the student must have a knowledge of English at least at level B1.

Master's Degree in Physics

The Master's Degree in Physics (class LM-17, Physics) is divided into four curricula: **Biosystems, Theoretical Physics, Condensed Matter Physics, Particle and Astroparticle Physics** .

The third and fourth curricula are delivered in English: all basic courses and optional ones are in English. As for the curricula in Biosystems and Theoretical Physics, all fundamental courses are in English; some optional ones are still in Italian. Given the high level of internationalization of the master's degree program, a good knowledge of English is required at enrolment. At the end of the study course, the student must have English knowledge at the B2 level.

The educational objective is to train a physicist with solid essential preparation and adequate specialistic knowledge in one of the sectors of modern physics corresponding to the chosen curriculum.

To this end, the training course requires the completion of the necessary education through courses in theoretical physics, mathematical physics and experimental laboratory common to all curricula and the related specialistic study to the chosen curriculum. All the curricula are strongly linked to the scientific research activities of the Department, covering the fields of matter physics, elementary particles physics, theoretical physics, biophysics, medical physics and electronics and computer science applications to physics research. See the part of this publication dedicated to the research carried out in the Department

Thesis work, which occupies a large part of the second year, provides the student with the opportunity to be included in the activity of a research group and complete the preparation. It is also aimed at the postgraduate insertion to a professional career, particularly in the areas of public and private research.

https://www.phys.uniroma1.it/fisica/didattica/corsilauree/laurea-magistrale-fisica

https://corsidilaurea.uniroma1.it/

Admission requirements

To access the Master's Degree in Physics, a three-year university degree or university diploma is required, or another equivalent qualification obtained abroad. Good knowledge of classical and modern physics and the necessary mathematical and computer science tools are required. For these subjects, the didactic regulation indicates the number of credits that must have been acquired in a three-year degree in order to access the Master's degree. Knowledge of English at B1 level is also required.

Students who do not meet these curricular requirements can enrol in single courses, as indicated by the Study Manifesto of the University, and take the related exams before enrolling in the Master's Degree.

Students of Sapienza or from other universities who have not graduated yet can also apply for enrolment in the Master's Degree course, provided that they graduate by the dates indicated in the Study Manifesto. The required knowledge is verified by a commission, which approves students who meet the requirements and interview the others for verification..

Internationalization

As part of the movement towards internationalization, common to all the University, an increasing year by year number of courses of the Master's Degree in Physics is delivered in English. Starting from the academic year 2019/20, two curricula are entirely delivered in English.

Final Test

The final test consists of the discussion of a thesis, consisting of a document preferably in English, which presents the results of original research, theoretical or experimental. Thesis preparation takes place under the direction of a supervisor and in the second year of the course, lasting about three-quarters of it.

The final grade is based on the evaluation of the study curriculum, the thesis and the ability to meet the deadlines established by the educational system. The Degree Commission gives the mark in one hundred and ten. It may also grant the candidate the highest marks with praise.

Employment and professional opportunities

The methodological training, the spectrum of knowledge and operational flexibility acquired allows the Master's Degree graduate in Physics to continue studies through the PhD, second-level masters and various graduate schools. It is also possible to access internship or training courses to prepare teachers for secondary school. Second-cycle graduates can also find a position in one of a wide range of professional areas, which require specialistic knowledge relating to natural and artificial systems, and generally in all activities with a high level of technological innovation, both in private and public sectors.

The reference areas include industry, in particular regarding electronics, space, semiconductors and energy, product quality assessment activities, research and development laboratories, environmental monitoring and evaluation, the tertiary sector related to computers (e.g. data acquisition and processing systems), the financial sector. The Master's Degree in Physics prepares specialists in Mathematical, Physical and Natural Sciences, in particular physicists and astronomers (ISTAT 2.1.1.1) and more specifically physicists (ISTAT 2.1.1.1.1), researchers and technicians with a degree in physical sciences (ISTAT 2.6.2.1) and professors of mathematical and physical sciences (ISTAT 2.6.3.2.1). Based on Almalaurea data regarding graduates with a Master's Degrees in Physics, the adequacy of professional training and the effectiveness of the degree in terms of useful knowledge for the post-graduate jobs are very high, see Almalaurea data..

Master's Degree in Astronomy and Astrophysics

The learning objectives of the Master's Degree in Astronomy and Astrophysics are dictated by the belonging class (LM-58, Sciences of the Universe). The graduates of this course are characterized by the achievement of the following educational objectives:

- a mastery of the scientific method of investigation, based on the robust essential culture in classical and modern physics and in-depth knowledge and experience of using mathematical methodologies and IT support tools.
- excellent knowledge of modern astronomy and astrophysics, with extensive scientific and operational skills in observations and theory, in the subjects characterizing the Class
- advanced competence in modern instruments and observation techniques, in the related data collection and analysis procedures, and model building

These skills can also allow continuing the studies in PhDs or masters and specialization schools' courses for teaching. The ultimate goal is to empower graduates to work with high autonomy, even assuming full responsibility for projects and scientific and technological structures at national and international level. The training course includes the completion of essential training in physics, mathematics and laboratory in the first year. In the second year, the study plan includes courses and the preparation of the thesis work. To the end of the study course, the student must know English at B2 level.

https://www.phys.uniroma1.it/fisica/node/10142

https://corsidilaurea.uniroma1.it/

Employment and professional opportunities

The Master's Degree in Astronomy and Astrophysics directs to research work and management of structures and technical-scientific projects in universities, in the Institutes of the CNR, in the Astronomical Observatories, in space institutes, in public and private companies operating in advanced technological sectors. The Master's Degree in Astronomy and Astrophysics prepares specialists in Mathematical, Physical and Natural Sciences, in particular:

Physicists and astronomers (ISTAT 2.1.1.1)
Researchers (ISTAT 2.6.2.1)
Upper secondary school teachers (ISTAT 2.6.3.2.1)

Based on Almalaurea data regarding graduates with a Master's Degrees in Astronomy and Astrophysics, the adequacy of professional training and the effectiveness of the degree in terms of useful knowledge for the post-graduate jobs are very high, see Almalaurea data.

Internationalization

As part of the movement towards internationalization, common to all the University, an increasing year by year number of courses of the Master's Degree in Astronomy and Astrophysics is delivered in English

Admission requirements

To access the Master's Degree in Astronomy and Astrophysics, a three-year university degree or university diploma is required, or another equivalent qualification obtained abroad. Good knowledge of classical and modern physics and the necessary mathematical and computer science tools are required. For these subjects, the didactic regulation indicates the number of credits that must have been acquired in a three-year degree in order to access the Master's degree. Knowledge of English at B1 level is also required.

Students of Sapienza or from other universities who have not graduated yet can also apply for enrolment in the Master's Degree course, provided that they graduate by the dates indicated in the Study Manifesto. The required knowledge is verified by a commission, which approves students who meet the requirements and interview the others for verification..

Final test

The final test consists of the discussion of a thesis, consisting of a document preferably in English, which presents the results of original research, theoretical or experimental. Thesis preparation takes place under the direction of a supervisor and in the second year of the course, lasting about three-quarters of it.

The final grade is based on the evaluation of the study curriculum, the thesis and the ability to meet the deadlines established by the educational system. The Degree Commission gives the mark in one hundred and ten. It may also grant the candidate the highest marks with praise.

PhDs

After obtaining a second-level degree, it is possible to continue university studies to obtain a PhD. In the following paragraphs are described the PhD courses in the Department https://www.phys.uniroma1.it/fisica/node/5566

Structure of the PhDs

The PhD lasts three years. Admission at the PhD requires passing a selection test, whose announcement is published annually and can be consulted on the website. PhD students are required to follow the specific courses dedicated to them and to take related exams, according to a specific study plan. They also required to follow the general seminars that are held in the Department. The division of the activity over the three years is similar for the various doctorates. PhD students can request permission from the Faculty Board to carry out training periods at Italian and international research institutes or universities

PhD in Physics

Secretary: sig.ra Anna De Grossi -tel. 06 49914343, room 010, ground floor Marconi building e-mail: anna.degrossi@uniroma1.it

The PhD in Physics aims at training scientific researchers endowed with a broad general culture and, therefore, with full flexibility concerning any future choice, and high professional qualification in all disciplinary sectors in which research in physics is active today. The goal is to bring PhD students to levels of preparation and autonomy appropriate to their inclusion in national and international scientific and technological research institutes. Thus, the study plan of the PhD course consists of an initial period mainly devoted to advanced courses and a subsequent phase concerning a research activity in a specific sector.

PhD in Astronomy, Astrophysics and Space Science

Secretary: sig.ra Fernanda Lupinacci -tel. 06 49914305, room 013, ground floor Marconi building e-mail: fernanda.lupinacci@uniroma1.it

The PhD in Astronomy, Astrophysics and Space Science is established in English. The admission exam notice is issued every other year by the Sapienza and Tor Vergata universities. At the end of the PhD course, the Doctoral degree is jointly issued by the two universities.

The PhD course aims to start research in astrophysics and space sciences. PhD students must acquire an in-depth technical knowledge of these subjects, good knowledge of mathematics, physics and computer sciences. The critical ability of the PhD students will be developed, together with the technical knowledge of Italian and English and the ability to collect and present their results.

Phd in Accelerators Physics

Secretary: sig.ra Laura Santonastaso -tel. 06 49914356, room 226, second floor Marconi building e-mail: laura.santonastaso@roma1.infn.it

Particle accelerators were developed by physicists in the research of fundamental interactions. Today they have also become excellent tools at the service of industry, medicine, cultural heritage, environment, electronics, geology and new materials.

In the industry, accelerators are widely used in all sectors of semiconductors electronics, for precision mechanical machining and as tools for the pasteurization of some products. Some applications include

- medical diagnostics, new drugs, hadrontherapy and mass spectrometry
- laboratories of nuclear techniques for cultural heritage
- the analysis of atmospheric particulates, of fine particles dispersed in the air, the tracking of pollutants in water flows, paleoclimatology studies
- the study of magmas, the composition of microcrystals and the dynamics of volcanoes
- synchrotron light emission, free-electron laser, Compton sources, THz sources and X-rays imaging

The goal of this PhD course, unique in Italy, is the training of young researchers through a study plan created with the skills of excellence at La Sapienza and the National Institute of Nuclear Physics (INFN), which historically has contributed to the development of particle accelerators in Italy and the world since the 1950s. The courses are held partly at La Sapienza and partly at the offices of the INFN. They aim to consolidate basic scientific knowledge in the physical sciences, acquired during the Master's degree, to acquire a solid knowledge of construction and operation principles, and to offer an overview of the main fields of applications of these machines

PhD in Mathematical Models for Engineer, Electromagnetism and Nanoscience - Curriculum in Material Science

One of the curricula of this PhD, which is in the Department of "Fundamental and Applied Sciences for Engineering", is of particular interest to graduates in physics. The aim of this curriculum is the training of experienced researchers in the field of innovative nanoscale materials.

In recent years, materials science has developed all over the world, due to the enormous demand for unique materials with peculiar and suitable characteristics to the most varied applications. Some of these applications range from electronics and sensors, from the chemical and physical sciences to biological applications, from construction to the automotive or aviation industry, to name just a few significant examples.

It is therefore essential to train researchers who present the right balance between basic knowledge and perception of application guidelines, such as required today by industries and businesses that operate with increasingly advanced technologies in a perspective of continuous innovation, and from the environments of international scientific research.

Materials science, with particular attention to the development of new innovative materials on the nanoscale, it develops in different fields, from chemistry to physics, from physics-chemistry of organic-inorganics hybrid systems to electronics, from applied mathematics to crystallography.

The research groups mainly present in the Physics and Chemistry Departments of the "La Sapienza" University of Rome have high international scientific skills in the fields mentioned above and the inclusion of PhD students in active experimental groups constitutes one of the main aspects of training.

Classrooms and Laboratories

The Physics Department has 14 classrooms for a total of approximately 1500 seats, which allow all enrolled students to follow the lessons in an appropriate way.
The didactic laboratories, with a capacity of about 400 workstations, allow the students to carry out practical exercises weekly.
Students also have access to computer labs with around 100 personal computers, both for taking computational courses and individual study. Finally, the Physics Department has a library and a room for individual study at the Fermi building.
Information on the location of the facilities can be found online on the website of the Department.

Physics Library

Information
The Library of the Physics Department has undergone a transformation process both structurally and logistically for modernizing services.
In 2005 the new venue was inaugurated, with spaces rationally distributed. The new arrangement made it possible to use the new automated services, which give access to the Internet to read digital documents online. The new library was possible thanks to the library staff collaboration and the planning and innovation strongly desired by prof. Guido Martinelli, at the time Director of the Department and prof. Giovanni Ciccotti, delegate of the library director.
Consult our website at
https://www.phys.uniroma1.it/fisica/biblioteca

The website gives access to all the information and documents available, but it is also important to come and visit us!

The library of the Physics Department is located on the ground floor of the Marconi building, at the Città Universitaria, headquarters of Sapienza, p.le Aldo Moro 5. It is open:
from Monday to Friday, non-stop from 8:30 to 19:30
and is accessible to those with disabilities.

There is also a 32-seat study room on the third floor of the Fermi building.

The ancient background

The book room

The exhibition space

The reading room

Services provided

Library services can be accessed both traditionally and in online mode. At the reception area, it is possible to register for consulting books and magazines in the two reading rooms with a total of 90 seats (all equipped with electrical sockets for laptops), request books on loan, get journals not owned by our library.

Furthermore, thanks to the use of radiofrequency technology (RFID), it is possible to use the self-loan service. In fact, all students can request the new Card on Infostud, prepared by Sapienza, see http://www.uniroma1.it/card-studenti. This new Card allows access to the rooms 24 hours a day and can also be used in our library for the self-loan.

All the volumes owned by the library (monographs and periodicals) are present in the electronic catalogue available at the following web address: https://opac.uniroma1.it/SebinaOpacRMS/.do?sysb=univ

"FisicainMente"

An update guide to resources and services

Online at the web address
http://www.phys.uniroma1.it/fisica/sites/default/files/5801_Biblio_Fisica_Libretto_WEB.pdf

Together with the basic services, it is possible to book and use two computers available for Internet navigation and access to the Sapienza wireless network.

For access to the service, Sapienza students must use the same login credentials of Infostud.

Historical archive

It is almost superfluous to underline the high importance, for historical-scientific research, of the archival documentation made up of scientist's papers, to reconstruct their stories and their thoughts.

The collection, storage, the rearrangement ad inventory of these documents also has an intrinsic cultural significance, given the increasingly important role played by science in modern society.

Our Department keeps the personal archives of Mario Ageno, Edoardo Amaldi, Carlo Ballario, Giorgio Careri, Marcello Conversi, Giovanni Gentile jr, Enrico Persico, Carlo Salvetti, Giorgio Salvini, Vittorio Somenzi, Bruno Touschek and Claudio Villi. The preserved documents constitute the most relevant existing source in Italy for the study of the Italian physics history in the post-WWII period. The website https://sapienzadipfisica.archiui.it/ allows online consultation.

In particular, due to the relevance of Edoardo Amaldi in the scientific and institutional events of Italian and European physics, the historical importance of the Amaldi's papers is enormous. This documentation merged into the Amaldi Collection after its passing on December 1989.

These papers, by Edoardo Amaldi methodical style of work and sensitivity for the memory preservation, constitute an almost complete testimony of all aspects of its multiple activities. It is not excessive to say that the

Physics Library

Amaldi Archive is the memory of the events of the Italian physics and a large part of European scientific collaboration in the second half of the twentieth century.
The archive also contains sporadic testimonies of the years between 1928 and 1938 which saw Amaldi's collaboration with Fermi, within the group of the "Ragazzi di via Panisperna", and rich documentation relating to the war years and those immediately following.

General Information

The Sapienza Department of Physics hosts teachings and research activities. It is located within the University City "La Sapienza", Piazzale Aldo Moro 5, Rome.

The Physics Department consists of two buildings, the Marconi building and Fermi building, of the Segrè Laboratories, located within the University City of Rome – Sapienza, and of the Bruno Pontecorvo Laboratories, located in via Tiburtina 205.

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