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INTERVIEW

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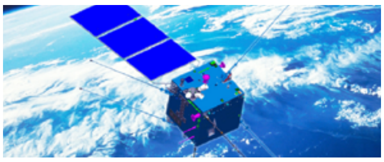

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GALILEO GALILEI INSTITUTE: IN ARCETRI PARTICLE PHYSICS IS THEORETICAL AND INTERNATIONAL

Interview with Stefania De Curtis, director of the Galileo Galilei Institute (GGI), INFN National Centre for Advanced Studies, and research director of the INFN division of Florence.

Since December 2019, Stefania De Curtis has been managing the Galileo Galilei Institute (GGI) in Florence, an institute of excellence for training and research in theoretical physics, founded in 2006. Starting from 2018, the GGI is an INFN National Centre for Advanced Studies, in partnership with the University of Florence.
GGI is located on the hill of Arcetri, a site of historical value for physics and astronomy and where Galilei spent the latter years of his life. Here, each year, over five hundred scientists from all over the world participate in conferences, advanced workshops for the theoretical physics of fundamental interactions and PhD schools dedicated to string and field theory, theoretical elementary particle physics, theoretical nuclear physics, statistical mechanics, astroparticle physics, and cosmology. This is a context of the highest scientific level, characterized by a rare concentration of multiculturalism and excellent ideas.
In 2018, GGI and INFN established the Galileo Galilei Medal, that this year was awarded to Alessandra Buonanno, Thibault Damour and Frans Pretorius. This year award connects Germany, France and the United States, without forgetting the merits of Italy.
We asked Stefania De Curtis to tell us about her career as a scientist and to outline the results and her vision for the future, after her first year as director of the first European institute dedicated to theoretical physics.

The GGI was founded in 2006 with the idea of continuing and encouraging the tradition that has characterised the history of the Hill of Arcetri. When did your personal story intertwine with that of GGI?
From its foundation. In 2004, Giuseppe Marchesini, President of the INFN Theoretical Physics Scientific Committee, promoted the foundation of an international research institute in Arcetri dedicated to the organisation of 2-3 months programmes on “hot” topics in theoretical physics, involving the world’s leading experts in the field. At that time, I was coordinator of the theoretical group of the INFN Florence

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division and fully involved in the foundation of the GGI.
Going back through the previous history, however, my involvement somewhat precedes this date. The foundation of the Galileo Galilei Institute owes much to the intention of a group of Florentine theoretical physicists to keep the "spirit of Arcetri" alive, which is linked above all to the historical value of the place: here, Galileo Galilei spent the latter years of his life in exile and Enrico Fermi wrote one of his fundamental works. Subsequently, in the '60s, Raffaele Raoul Gatto attracted many young theoretical physicists from Rome to Arcetri, who played a major role in the development of modern physics and organised a school of theoretical physics in Florence that has remained a benchmark. Gatto was one of my teachers and collaborators and I have no difficulty in imagining the atmosphere at Arcetri in that very fertile period, which led to the proposal to recreate the same conditions.
Since the first workshop in May 2006, more than 40 other workshops have been organised, with an ever-increasing number of participants. There's another activity, added to workshops, that is the foundation of GGI's prestige today. With its 5 PhD schools – which I have helped to organise and coordinate since their inception – GGI has become an international benchmark in the training of PhD students in theoretical physics. The GGI schools have the distinction of fostering discussion and interaction between professors and students. It is not uncommon at GGI for a world-renowned scientist to discuss unsolved physics problems and, why not, the best trattoria for a "fiorentina (steak)" with PhD students. Not to be underestimated is also the interaction between the students who, in close contact for 2-3 weeks, have a unique opportunity to share ideas and experiences. More than 250 young people attend GGI schools every year, demonstrating the high level of education provided.

For nearly fifteen years, every year GGI has hosted hundreds of scientists, whether researchers or PhD students, from all over the world. How do you manage a centre of this multicultural level and excellence? What goals did you set for yourself when you took office a year ago?
When I took over as director in 2019, GGI was already a Centre of absolute excellence. The task of maintaining such a high standard is certainly one of great responsibility. I felt it was essential to mantain continuity with the previous director and with those who had laid the foundation for the success we had achieved. Among the aspects I would like to develop, I plan to promote and develop outreach activities in order to make our activities and method and the role of our research known outside the theoretical physics community. The goals include not only disseminating knowledge, but above all arousing curiosity towards the biggest mysteries of our Universe, from quantum mechanics to cosmology, and promoting the idea that the technology of tomorrow is developed from the advances in theoretical physics and basic research of today.

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Unfortunately, after only three months as director, we were faced with the lockdown due to the COVID-19 pandemic and the subsequent mobility restrictions. We have had to reschedule some of our activities and run others, such as schools, in a new way. We nevertheless tried to remain a reference point for our community, especially for the community of young researchers. With this objective in mind, we organised “Cortona Young” and “Avogadro Meeting” in which young researchers were able to present their results to an international audience, taking advantage of the prominence of GGI. We also created a series of pedagogical discussion groups on cutting-edge topics in theoretical physics, the “GGI Tea Breaks,” and established new postdoctoral fellowships for new PhDs in theoretical physics (the “Boost” Program) in order to complement their training and receive new research ideas in such a challenging environment as that of GGI.

Since 2018, GGI has been promoted to INFN National Centre for Advanced Studies. What does this change in identity entail and how do you envision the institute developing in the years ahead?
On the occasion of the tenth anniversary of GGI, Fernando Ferroni, at the time President of INFN, announced the “promotion” of the GGI to an INFN National Center for Advanced Studies. This represented an important recognition and gave greater prestige to GGI, giving it a clear position within the INFN structures. I wouldn’t say it was a change in identity but rather an official recognition of GGI’s role in higher education. This status strengthens the already important link between GGI and the INFN Theoretical Physics Scientific Committee, whose president is Chair of the Scientific Committee that selects the research programs to be funded every year.
In addition, GGI’s status as an INFN Center helps in coordination with other similar international institutes. This is essential in order to propose impactful activities while maintaining our specificity. Certainly, the COVID emergency has changed the way we develop research programmes: we have been forced to discuss online and have learned how to do so! While interaction in front of a whiteboard is irreplaceable, I foresee a greater need for collaboration across research centres in order to better coordinate the proposal of research programmes.
Finally, together with the foundation of the GGI Center, the Galileo Galilei Medal was established. A prestigious award that this year went to three great scientists, Alessandra Buonanno, Thibault Damour and Frans Pretorius for their studies which, in a complementary way, have led to theoretical predictions confirmed by gravitational wave observations. This represents an outstanding contribution to research and a fundamental one for the birth of a new era, that of gravitational astronomy. I am sure it will give further prestige to the Galileo Galilei Medal.

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Your professional training also inevitably embraces the experimental aspects of particle physics. You have spent much time at CERN since the beginning of your career, at the historic stage when the LHC accelerator was being built. Why did you choose to work on theoretical physics?

There are still so many open problems, for which the existing "theory" has not yet answers.

After many years of research, the Higgs boson was detected at CERN's Large Hadron Collider, confirming the success of the Standard Model, but there is a common consensus that this is not the end of the story. In fact, there are many questions that are not answered within this formulation. The mass hierarchy of particles, to name one. In the Standard Model this is accomplished through numerical adjustments of parameters and is not predicted by the dynamics of the theory. The same is true for the mass of the Higgs boson. The search for an extension of the Standard Model that answers some of the open problems is one of the interests of my research activity. Obviously, this involves comparison with experimental data. For example, if the particle discovered in 2012 at the LHC had different properties compared to the Standard Model Higgs boson, an accurate measurement of them could confirm or rule out some of the proposed models.

Collaboration with experimental groups is therefore very important, so I periodically visit CERN and participate in working groups on physics beyond the Standard Model.

I started visiting CERN when I was a guest of Raoul Gatto at the University of Geneva. We were among the first to study possible signs of new physics at the LHC, which was still in the design phase. Those years were truly inspiring.

Now, with the discovery of gravitational waves, a new phase has opened up. It is possible that the Higgs field was formed as a result of a phase transition in the first moments of the evolution of the Universe. Depending on the nature of this transition, there could be a generation of gravitational waves that carry a complementary "message" to the collider experiments. This synergy paves the way for new developments in the knowledge of the structure of fundamental interactions.

11 February was the International Day of Women and Girls in Science. Reviewing the career that has led you to a management position, what would you recommend to a female student interested in a scientific career or a young female researcher at the beginning of her career?

Throughout my career, I have met great teachers and many collaborators with whom I have shared the joys and sorrows of this profession. The happiness for an accomplishment and the pains, the frustrations, for a calculation that doesn't add up or, even worse, for not even knowing how to set it up. Collaboration, discussion, and exchange of opinions is vital for research. But collaboration, discussion, and exchange of opinions are not always easy to establish by a female researcher when almost all of the collaborators

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are men. To navigate in a male environment, it is necessary to know the laws that regulate it, and to try to take advantage of the few spaces left free. It is undeniably very difficult, but not impossible.
What would I recommend to a female researcher at the beginning of her career? Certainly, to dedicate herself to what interests her most, and to believe in her abilities. Not to attribute the difficulties encountered along the way to an inadequacy in the subject. Her male colleagues never do that! The laws of the male environment can only be less dominant if there are more women in the same environment.

Stefania De Curtis is the director of the Galileo Galilei Institute (GGI) in Florence, since December 2019. She is research director in theoretical physics at the INFN division of Florence. After her degree in Physics from the University of Florence and a PhD from SISSA in Trieste, she was a guest of Raoul Gatto and his group at the Physics Department of the University of Geneva. Since 1988, she has been a researcher at the INFN division in Florence, though she spends several work periods at the University of Geneva and CERN, where she carries out research in the physics of fundamental interactions field. Since 2005, she has been coordinating the corresponding theoretical group of the Florence division. She contributed to the foundation of GGI, of which she has been coordinating the PhD schools since 2013. She is a member of the organising committee of the GGI Lectures on the Theory of Fundamental Interactions and of the Plenary European Committee for Future Accelerators (ECFA). She is the author of more than 100 papers published in international journals and of approximately 60 contributions to conferences and workshops. ■

AWARDS

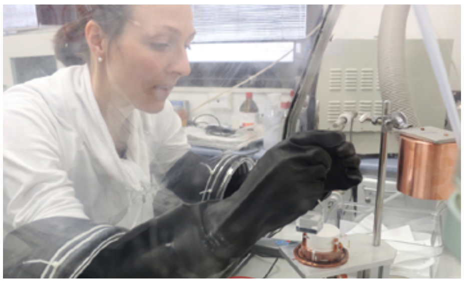
GIORGIO PARISI AWARDED THE PRESTIGIOUS 2021 WOLF PRIZE FOR PHYSICS

The theoretical physicist Giorgio Parisi has been awarded the prestigious 2021 Wolf Prize for Physics “for ground-breaking discoveries in disordered systems, particle physics and statistical physics”. The Wolf Prize was established by the Wolf Foundation of Israel in 1978 in recognition of scientists and artists who have produced “achievements in the interest of humanity and friendly relations between people”. Previous winners include Giuseppe Occhialini, Bruno Rossi, Riccardo Giacconi, Leon Lederman, Roger Penrose, Stephen Hawking and Peter Higgs. Parisi is full professor of Theoretical Physics at the Sapienza University of Rome, research associate at INFN, and since 2018 President of the Accademia dei Lincei. He conducted his studies at Sapienza University, where he graduated in physics in 1970 under the guidance of Nicola Cabibbo. During his scientific career, which started at the INFN Frascati National Laboratories, Parisi has made many decisive and widely acknowledged contributions in different areas of physics: particle physics, statistical mechanics, fluid dynamics, condensed matter and supercomputers. He has also worked on neural networks, the immune system and group movement of animals. He has been the winner of two ERC (European Research Council) advanced grants, in 2010 and 2016, and is the author of over six hundred articles and contributions to scientific conferences and four books. He has received the Boltzmann Medal, the Max Planck Medal and the Dirac Medal, and numerous awards and prizes. He is a member of the Accademia dei Quaranta, the Académie des Sciences, of the National Academy of Sciences of the United States, the European Academy, and the American Philosophical Society. ■

EUROPEAN PROJECTS

ITALY LEADS THE FIRST EUROPEAN COMPETENCE CENTER FOR CULTURAL HERITAGE

On 9 February, the 4CH - Competence Centre for the Conservation of Cultural Heritage - project, funded with nearly 3 million euros within the scope of Horizon 2020, was launched. 4CH will be a large distributed virtual network, coordinated by Italy with INFN and managed together with a partnership of public and private entities, which includes 19 partners from 13 different countries. It will be the first European competence centre for cultural heritage, and will become operational in three years, at the end of the first phase that will be used to establish the logistical and managerial infrastructure. Its activity will be divided into three main areas: 3D digital modelling of monuments and sites, semantic tools to archive documentation, classifying it and making data available ex post, and scientific analysis as a support for conservation and restoration. 4CH's entire infrastructure will be based on the cultural heritage cloud, part of EOSC's federated European cloud model, it will employ high-performance computing (HPC) and artificial intelligence tools. 4CH will be at the service of the European cultural heritage, exploiting the most innovative digital technologies, and the data and information will be made available to experts in various disciplines, who will work in an integrated way in order to monitor the health of our cultural heritage, assess the risks to which it is subject, and define restoration or reconstruction works in case of damage owing to natural degradation or environmental disasters. ■



EXPERIMENTS

GRAN SASSO LABORATORIES: COSINUS, STUDYING THE DARK SIDE OF THE UNIVERSE

Find experimental confirmation of the nature of dark matter: this is the challenge launched by COSINUS, a new experiment for its direct identification, which has recently received the green light for construction at the INFN Gran Sasso National Laboratories (LNGS). The concept behind the experiment was established in 2016, thanks to an idea of Karoline Schaeffner of the Max Planck Institute in Munich, and Florian Reindl of HEPHY and the Technical University of Vienna: COSINUS aims to identify the interaction of a dark matter particle in a scintillating crystal of sodium iodide held at cryogenic temperatures, close to absolute zero. The energy released by a particle inside the crystal causes a very slight increase in temperature of the system that can be measured using a special thermometer. At the same time, the scintillating properties of the crystal allow the different particles to be identified by exploiting the different light response for the same absorbed energy. The R&D phase of the detector was successfully conducted from 2016 to 2019, thanks to a €289,000 grant awarded to Schaeffner by INFN's 5th National Scientific Committee. Implementation of the experiment will take place thanks to the commitment of the Max Planck Society (Germany), which is contributing to the project with a total of 3 million euros, INFN, in particular LNGS which is contributing in terms of both resources and infrastructure in Italy, and the HEPHY Institute in Austria. The Collaboration was recently expanded with the adhesion of the Helsinki Institute of Physics (Finland). ■

AWARDS

VIRGO AND LIGO IEEE MILESTONES OF SCIENCE AND TECHNOLOGY

On 3 February 2021, the Virgo and LIGO gravitational wave interferometers were given the IEEE (Institute of Electrical and Electronics Engineers) Milestone award "for the first gravitational waves detection and the launching of the era of Multi Messenger Astronomy with the coordinated detection of gravitational waves from a binary neutron star merger". The ceremony was held as a global event, at the EGO European Gravitational Observatory, which in Italy hosts the Virgo interferometer, and in the US, at the twin LIGO interferomenters in Livingston, Louisiana, and Hanford, Washington. The events hosted at the three different locations were connected in a joint live event. The IEEE Milestone programme was launched in 1983 by the IEEE to celebrate significant milestones in the history of science and technology in IEEE's areas of interest. For example, in Italy to date, the IEEE has given awards to: Alessandro Volta's invention of the electric battery, Guglielmo Marconi's experiments with the wireless telegraph, and Enrico Fermi's decisive contributions to the quantum statistics of semiconductor materials. ■

AWARDS

BUONANNO, DAMOUR AND PRETORIUS AWARDED THE 2021 GALILEO GALILEI MEDAL

Physicists Alessandra Buonanno, Thibault Damour and Frans Pretorius have been awarded the Galileo Galilei Medal, an award given every two years by INFN with the GGI Galileo Galilei Institute, its National Center for Theoretical Physics in partnership with the University of Florence, to researchers who have made an outstanding contribution to the progress of research in theoretical physics. The Award, announced on 15 February, on the anniversary of the birthday of the great scientist Galileo Galilei, was awarded to Buonanno, Damour and Pretorius “for the fundamental understanding of sources of gravitational radiation by complementary analytic and numerical techniques, enabling predictions that have been confirmed by gravitational wave observations and are now key tools in this new branch of astronom”. Alessandra Buonanno is director of the Department of Astrophysical and Cosmological Relativity at the Max Planck Institute for Gravitational Physics in Potsdam, Germany. Following her studies in Pisa, she has had a brilliant career in the field of gravitational theoretical physics, working in Paris, the United States and subsequently Germany. She has received numerous awards including the Leibniz Prize, the leading research award in Germany. Thibault Damour is a full professor at the Institut des Hautes Études Scientifiques in Paris. A leading figure in the field of theoretical physics at the international level, he has worked in multiple research fields related to gravity, from black holes to cosmology and string theory, and has received numerous awards throughout his career. Frans Pretorius is a professor of physics at Princeton University and director of the Princeton Gravity Initiative. His main research field is General Relativity and he has worked on a variety of topics, including gravitational collapse, black hole mergers, cosmic singularities and black hole evaporation models. ■

OPEN DATA

AUGER OBSERVATORY MAKES 10% OF DATA PUBLIC

The scientific collaboration of the Pierre Auger Observatory has decided to make public 10% of the data recorded using the world's largest cosmic ray detector, which covers an area of approximately 3000 square kilometres in the province of Mendoza, Argentina. The goal is that the data can be used for both scientific research purposes and educational projects by a large and diverse community of users.

The data is a part of all the events selected to obtain the physics results recorded in almost 15 years of operation of the surface detectors, 1600 water tanks that observe the cosmic ray shower when it hits the Earth's surface, and of the 27 fluorescence telescopes distributed around the surface detector grid which, on the other hand, collect the flashes of fluorescence light produced in the air by the charged particles of the shower, thus observing their longitudinal development along the direction of origin. The Observatory's data include raw data, obtained directly from these instruments, as well as data generated from detailed analyses. Sample codes for reading it, derived from those used to obtain the results published by the Collaboration, are released along with the data. Part of the data is routinely shared with other observatories to allow analysis with coverage of the entire celestial sphere and to facilitate multi-messenger studies.

The Pierre Auger Observatory is managed by an international collaboration of over 400 scientists from 18 different countries in which INFN has always played a major role. Italy is participating with groups from the Universities and INFN divisions of Catania, Lecce, Milan, Naples, Rome Tor Vergata, Turin, the Universities of L'Aquila and Palermo, the Polytechnic of Milan, the Gran Sasso National Laboratories, GSSI and with the INAF groups of the Astrophysical Observatory of Turin and the Institute of Space Astrophysics and Cosmic Physics of Palermo.

The data is available at www.auger.org/opendata ■

PUBLIC ENGAGEMENT

MASTERCLASS ITALY: HIGH SCHOOL STUDENTS UNVEIL THE MYSTERIES OF PARTICLE PHYSICS

Almost 2000 high school students from all over Italy are participating in the 17th edition of the International Masterclasses organised by the International Particle Physics Outreach Group (IPPOG) and coordinated in Italy by INFN, despite the difficulties of this year due to the COVID-19 pandemic.

They began on 11 February and will end on 27 March. The initiative, which this year involves 25 locations in Italy, is an opportunity for students to discover how research in particle physics works and to analyse real data from the LHC and BELLE II experiments at CERN and at the KEK laboratory in Japan, respectively. Each location organises one or more days of lectures and seminars on fundamental topics in particle physics, followed by computer-based exercises. At the end of each day, just like in a real international research collaboration, there is a videoconference with CERN and the young Masterclass participants from all over the world to discuss together the results of the exercises.

The Masterclasses take place simultaneously in 60 different countries, involving more than 200 of the most prestigious research institutions and universities worldwide and more than 13,000 high school students. ■

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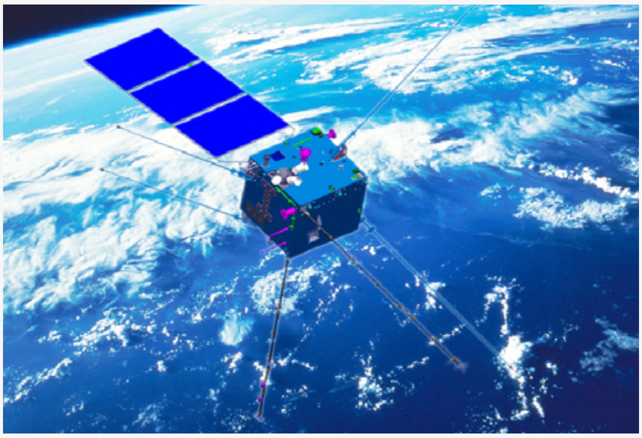

CSES-LIMADOU AND ITS FIRST THREE YEARS OF FLIGHT

Three years after its launch on 2 February 2018 from the Chinese Jiuquan Satellite Launch Center in the Gobi Desert in Inner Mongolia, the CSES (China Seismo-Electromagnetic Satellite)-Limadou satellite mission, dedicated to Earth observation, takes stock of its first scientific results.
Stemming from a collaboration between the Chinese Space Agency (CNSA) and the Italian Space Agency (ASI), with the important scientific contribution of INFN*, CSES-Limadou aims to develop new methods for the study of geophysical phenomena, such as earthquakes and volcanic eruptions, on a global scale. And, to accomplish its mission, it can count on as many as nine scientific instruments set up on board the satellite, practically all the main sensors needed to study the ionosphere, magnetosphere and their possible coupling with the lithosphere, including the made-in-Italy HEPD (High Energy Particle Detector), dedicated to the observation of high energy particles and nuclei.
In these three years of flight, HEPD and the set of instruments created for the study and characterisation of the plasma and the perturbations induced by solar activity, have transmitted a large amount of data that has been analysed by a highly interdisciplinary Italian collaboration**. The convergence in a single team with diverse scientific expertise, including seismology, particle physics and astrophysics, allowed important results to be obtained, presented at the most important international conferences and published in prestigious scientific journals.
In particular, in this first phase of the experiment, HEPD has also proven to be an excellent detector of space weather-related phenomena, recording one of the rare geomagnetic storms that has occurred in recent years, on 25 August 2018. For the first time in low orbit (approximately 500 km from Earth), the instrument also recorded low-energy cosmic protons in the period 2018-2020, measuring their flux with high precision. These measurements have provided an important contribution to our understanding of the interplanetary magnetic field. HEPD data on electrons and protons at energies in the order of the MeV

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or tens/hundreds of MeVs cover the most scientifically interesting range, and the capabilities of HEPD will be very useful to the international scientific community, especially in view of the completion of the Van Allen Probes mission that will study the Van Allen Radiation Belt.

Thanks to the high sampling rate of its instruments, the CSES-Limadou mission has also made it possible to identify high-frequency fluctuations in the electric field at the entrance to the auroral oval, where charged particles interact with the Earth's ionosphere. At low latitudes, the extraordinary sensitivity of the EFD (Electric Field Detector) and LP (Langmuir Probe) instruments have led to the identification and study of important phenomena associated with abrupt reductions in plasma density (plasma bubbles). In addition, the low-energy electron and electric field data, together with the information collected by the other instruments, have, for the first time, made it possible to highlight all the elements underlying the co-seismic coupling mechanism between the lithosphere and magnetosphere in the presence of an earthquake. During a seismic event, the movement of the Earth's surface (solid or liquid) activates a gravito-acoustic wave, observable by satellite, which, having reached the ionosphere, induces the emission of low frequency electromagnetic waves (hundreds of Hz) which alter the magnetic field, influencing the motion of particles trapped in the Van Allen belts. In order to describe this mechanism in a coherent manner, the MILC (Magnetospheric-Ionospheric-Lithospheric Coupling) model was developed. This model has been verified in all its components with measurements taken by CSES and other satellites during the Bayan earthquake (2018). The application of this model to the study of other earthquakes observed in the last two years is now being developed, expanding the study to the time interval adjacent to the time of the earthquake.

The CSES-Limadou mission, which is scheduled to continue to operate until 2023, therefore promises many interesting results and, in line with what has been produced in this first phase, will continue to provide us with valuable information to improve our knowledge of the geophysical phenomena that characterize our planet.

* INFN Divisions of Bologna, Perugia, Rome Tor Vergata, Naples, Trento TIFPA National Center and Frascati National Laboratories.

** The Italian data analysis collaboration, in addition to INFN, consists of INAF National Institute for Astrophysics-IAPS, INGV National Institute for Geophysics and Volcanology, CNR National Research Council-IFAC and of the Universities of Bologna, Trento, Rome Tor Vergata and Uninettuno International Telematic University (UTIU). ■

Italian National Institute for Nuclear Physics

COORDINATION:
Francesca Scianitti

EDITORIAL BOARD
Eleonora Cossi
Matteo Massicci
Francesca Mazzotta
Francesca Scianitti
Antonella Varaschin

GRAPHIC DESIGN:
Francesca Cuicchio

TRANSLATION:
ALLtrad

ICT SERVICE:
Servizio Infrastrutture e Servizi Informatici Nazionali INFN

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Making of the Medaglia Galileo Galilei, © INFN

CONTATTI
Ufficio Comunicazione INFN
comunicazione@presid.infn.it