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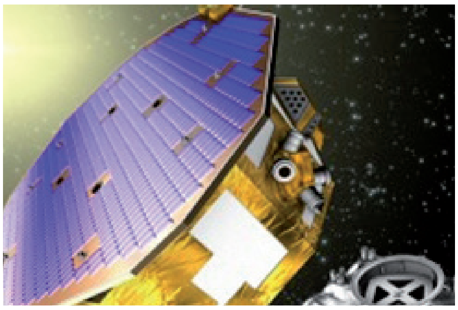
NEWSLETTER 20

Italian National Institute for Nuclear Physics

NEWS



RESEARCH
THE LISA PATHFINDER CUBES FLOAT FREE

Launched on 3 December last year and in its operating position since 22 January, at approx. 1.5 million km from Earth in the direction of the Sun, at the beginning of February the LISA Pathfinder probe completed the first step of its delicate scientific mission. Technological forerunner of the gravitational wave space observatory planned by ESA as the third big mission in its Cosmic Vision scientific programme, LISA Pathfinder aims to test the concept of detection of gravitational waves from space, showing that it is possible to control and measure with extremely high precision the movement of two masses in gravitational free fall. From 3 February, and over the following two days, the two test masses contained in the probe, two gold and platinum cubes with 46 mm side, were freed from the eight "fingers" that kept them firmly still during the preparation, launch and entry into orbit procedures of the probe and in the 6-week voyage to its operating position. Since then, the two cubes are floating in the heart of the spacecraft, in free fall a few millimetres from the walls of the compartment and at a distance of 38 cm from each other, connected only by a laser beam controlling their position. The inertial sensors, high precision instruments that envelop the test masses and control their position, were built by the Italian Space Agency based on the scientific design of researchers at the University of Trento and the National Institute for Nuclear Physics. ■

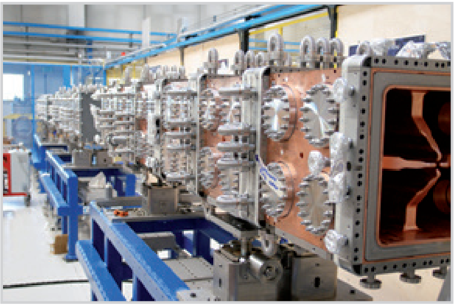
INSTITUTIONS
PRIME MINISTER RENZI AND MINISTER GIANNINI VISIT THE GRAN SASSO NATIONAL LABORATORIES

The Prime Minister Matteo Renzi has paid a visit to the INFN Gran Sasso National Laboratories (LNGS), accompanied by the Minister of Education, University and Research, Stefania Giannini.
"We often talk about the brain drain, the Gran Sasso Laboratories, with 30% Italian and 70% foreigner researchers are, on the other hand, an example of the brain attraction", said the Prime Minister during his visit. "In the coming weeks and months we will allocate 60 million euros for LNGS, for infrastructure improvements instrumental to maintaining leadership in the search for dark matter with important industrial implications. I confirm", added Renzi, "what I have already stated during my visit to CERN in Geneva: we need to free the most prestigious research institutes, such as INFN, from the bureaucracy of public administration, which need", concluded the Prime Minister,"simpler rules". ■

AWARDS
"BRUNO PONTECORVO" 2016 AWARDED TO GIANPAOLO BELLINI

The Italian physicist Gianpaolo Bellini has won the prestigious "Bruno Pontecorvo" 2016 international prize, awarded annually by the *Joint Institute for Nuclear Research* (JINR) in Dubna. The prize jury - chaired by Alexander Olshevskiy and comprising Samoil Bilenky, Luciano Maiani (Pontecorvo Prize winner in 2014), Arthur McDonald (Nobel Prize 2015) and Yoichiro Suzuki - awarded Bellini this important recognition "For his outstanding contribution to the development of low-energy neutrino detection methods, their implementation in the Borexino detector and the important results on solar neutrinos and geo-neutrinos obtained by this experiment". The Pontecorvo Prize in the past has already been awarded to another four Italian scientists: Ugo Amaldi, Antonino Zichichi, Luciano Maiani and Ettore Fiorini.

Among the successes of Borexino is the first measurement of solar luminosity with neutrinos - a result nominated among the "Top Ten Breakthroughs in 2014" by the British Institute of Physics -, the measurement of neutrino oscillation in a vacuum and of solar streams from all the nuclear reactions active in the Sun, results which have allowed us to confirm the predictions of the Standard Solar Model. Finally, measurement of geo-neutrinos with probability exceeding 99.9999993%. Currently, Borexino is working to obtain a new important measurement concerning massive stars and to test the existence of a fourth neutrino: the so-called sterile neutrino. ■



INFRASTRUCTURES
ACCELERATOR BUILT BY INFN HAS LEFT FOR JAPAN

A high-intensity accelerator built by INFN for the prototype of the International Fusion Material Irradiation Facility left in mid-February from the National Laboratories of Legnaro (LNL) headed for Japan. The accelerator, designed and built by a team of physicists and engineers from LNL and the INFN sections of Padua, Turin and Bologna, will produce extremely intense neutron streams in Japan, which will hit the critical components of future nuclear fusion power plants to test their resistance to these impacts. This is an RFQ, radio frequency quadrupole, a very advanced system to obtain the maximum intensity of the accelerated particle beam. Legnaro is one of the few laboratories in the world with the technology and skills available to build accelerators of this type.
This RFQ represents Italy's main contribution to an international project in which our country is participating together with France, Spain and, of course, Japan, where the site that will host the tests in the coming years has been built. It was funded by the Ministry of Education, with a special allocation of 25 million euros to the National Institute for Nuclear Physics.
After the design and production of the prototypes and of the most complex parts, implemented within the INFN, the construction has been awarded, under the supervision of INFN, to specialised companies via international tenders, in which Italian companies obtained particularly encouraging results. ■

» INTERVIEW

WHISPER OF THE COSMOS HEARD. THE DISCOVERY OF GRAVITATIONAL WAVES NARRATED BY ONE OF THE PROTAGONISTS

Interview with Fulvio Ricci, spokesperson of the VIRGO international Collaboration

It is the scientific news of 2016. The discovery, awaited for a century, of the gravitational waves predicted by Albert Einstein in his Theory of General Relativity . A revolutionary milestone, which changes our outlook on the universe.
The important result was achieved, thanks to the data of the twin detectors LIGO (Laser Interferometer Gravitational-wave Observatory), by the LIGO Scientific Collaboration (which includes the GEO600 Collaboration, the Australian Consortium for Interferometric Gravitational Astronomy) and VIRGO, part of the European Gravitational Observatory (EGO), founded by the National Institute for Nuclear Physics (INFN) and the French Centre National de la Recherche Scientifique (CNRS).
We asked one of the protagonists of this scientific enterprise, Fulvio Ricci, spokesperson of the VIRGO Collaboration, to tell us how this result was achieved, and how our understanding of the cosmos will change from now on.

The first direct gravitational wave signal was captured on 14 September 2015 after a century-long wait. Can you describe your feelings on that day?
I remember having received the first news of the signal via an email from Marco Drago, a young researcher trained in Italy by INFN and since one year in Germany, at the Max Planck Institute in Hannover. My first reaction was one of scepticism and incredulity. Then, analysing in more detail the first checks, my conviction that we were facing something particularly interesting grew. I must say, though - perhaps because I have been working in this field for many years now and have seen a few false alarms in the past - that my change of heart was slow. And, for sure, it was influenced by the reactions of my colleagues, particularly by the younger generation, who instead immediately reacted with greater enthusiasm. Now, we are all aware of the fundamental importance of the step we have taken.

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What does this discovery tells us?
We have managed to see, indeed it is more correct to say hear, a high-energy collision between two black holes with masses of about 36 and 29 solar masses, which collide at an astounding speed, about half the speed of light. A collision with an energy at the centre of the mass frighteningly higher than what we see at the LHC, the super accelerator at CERN in Geneva. An extraordinary result of great satisfaction. These black holes are extraordinary cosmic objects, the simplest that can be described with General Relativity: spin, mass and charge are in fact enough. Today we have in hand a coalescence signal between black holes that we can follow starting from 20Hz. But the fact of being sensitive to such low frequencies is due to the intuition of Adalberto Giazotto, one of the "fathers" of VIRGO. The progress of gravitational wave physics can, in fact, be considered a construction with many bricks. For example, the American LIGO interferometer, unlike VIRGO, opened the low frequency window only very recently, with Advanced LIGO. And it was immediately able to hear the gravitational waves.

Once again, therefore, Einstein was right...
Certainly he was right. But, even though it is often thought that one person alone can determine a cultural revolution, Einstein was not alone. Just think of the valuable contribution to the mathematical formulation of General Relativity of the Italians mathematicians Luigi Bianchi, Gregorio Ricci Curbastro and Tullio Levi-Civita.
Moreover, in the history of the search for gravitational waves, there are those who affirmed that the waves would never be seen. Even Einstein himself was of this opinion. This recent discovery shows, however, that on this aspect he was wrong.

What is the role of Italy and INFN in this important scientific enterprise?
INFN has been and is the entity in Europe that has invested more than anyone else in this area, and has been doing so since 1980. Only the American National Science Foundation (NSF) has invested more worldwide. INFN has, for example, trained many researchers scattered around the world who are making a crucial contribution to LIGO. The list of Italian scientists trained at the INFN gravitational wave school is, in fact, very long, so much so that the project leader of the LIGO Collaboration recently timidly apologised for having taken away from us some extremely valid physicists trained by INFN. Many Italians have, in fact, leading roles, such as the LIGO run coordinator Elisa Barsotti from MIT, or Gabriele Vaiente, from Caltech, who has made a decisive contribution to the characterisation of the detector, or Marco Cavaglià, deputy of the LIGO Scientific Collaboration (LSC), and Laura Cadonati, data analysis coordinator at LIGO.

How does this discovery change our outlook on the universe?
This result represents a milestone in the history of physics, but even more it is the beginning of a new chapter in astrophysics. Observing the cosmos through gravitational waves, in fact, radically changes

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our possibility of studying it. Gravitational waves are an entirely new messenger, which allows us to study phenomena invisible to electromagnetic radiation. Phenomena that hitherto it has been impossible to analyse.
The potential of this discovery is enormous. We will be able, for example, to study the behaviour of matter in extreme temperature, pressure and compactness conditions of objects, unrepeatable in the laboratory. It is not yet known, for example, what there is inside a neutron star, characterised by very high density in which several solar masses are concentrated in just 10 km of diameter. There are many models that predict the presence of free quarks. The gravitational wave probe, in this regard, will provide us with basic information on the state of matter in these cosmic objects. Until now, in fact, it is as if we had looked at the cosmos through radiography X-rays, while now we can do an ultrasound scan of our universe.

The discovery also represents the first direct observation of a black hole
On this there are still conflicting opinions. Observations of the wind of charged particles that emit X-rays in binary systems in which a companion seems to be a black hole have already been made. What we can say with our discovery is that it is the first time we hear a system of two black holes.

Will it also be possible to capture the primordial gravitational waves emitted just after the Big Bang?
Terrestrial interferometers, in principle, can measure background cosmic radiation of gravitational origin. But, if the background is solely due to gravitational radiation envisaged by the Theory of General Relativity, at the frequency characteristics of these interferometers the enterprise is more difficult, almost prohibitive. Their sensitivity would need to be further improved, even if there are a number of models, such as string theory, that make more optimistic forecasts.
There is, however, another difficulty: the need to distinguish the wave signals from the background noise of all the astrophysical coalescence phenomena, for example between black holes or between neutron stars. The combination of all these coalescences is like the roar of all the fans shouting in a stadium or the sound produced by many fireworks going off together.

Can these signals become commonplace in the future?
Theoretical models have a very wide range of estimates of the percentage of these events. With the current sensitivity levels, and with those we will already achieve in the next scientific runs, I believe there is the possibility of gathering at least a dozen events in one year of observation. ■

» FOCUS ON

EUROPEAN SYNCHROTRON RADIATION FACILITY - THE EXTREMELY BRILLIANT SOURCE PROJECT

The ESRF-EBS (European Synchrotron Radiation Facility –Extreme Brilliant Source) is a major project that aims to create a new generation of synchrotrons with performances that are unique in the world. The ESRF-EBS is a major challenge requiring state-of-the-art accelerator technology to realise a very innovative relativistic electron beam dynamics design. The project sees the collaboration between France and Italy with INFN at the heart of the development of breakthrough technologies. This unique ESRF-EBS project is supported by the 21 partner nations of the ESRF, including France, the host-country, and Italy whose contributions to the ESRF amounts to 27.5% and 13.2% respectively. The principal aim of this project is to construct and commission the new 844 m circumference ESRF-EBS storage ring, over the period 2015-2022.
On the 8th of February, in Grenoble, the Director General of ESRF, Francesco Sette, the Chairman of the Council of the ESRF, Bertrand Girard, and the President of INFN, Fernando Ferroni, signed a collaboration agreement in the presence of the Italian and French Ministers, Stefania Giannini, Minister for Education, Universities and Research, and Thierry Mandon, Minister of State for Higher Education and Research. The agreement represents a key step in the construction and installation phases of the ESRF-EBS new storage ring that will be 100 times brighter than the existing source. It will result in an exchange of expertise and a strengthening of technical assistance between ESRF and INFN.
The collaboration between ESRF and INFN dates back to the very beginning of the ESRF, started in the 1980s. Nowadays, since 2011, collaboration between ESRF and INFN-LNF (INFN Frascati National Laboratory) has further strengthened with the conception and engineering design of the new revolutionary ESRF-EBS storage ring. INFN, with its pioneering work on DAFNE (the first accelerator made almost entirely with aluminium vacuum chambers) at the INFN-LNF, has helped in all aspects of the design and construction of the ESRF-EBS vacuum system. The high value

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brought in the project by the DAFNE experience and by the innovative study related to the electron-positron SuperB project - abandoned before construction due to budget constraint – is related to an innovative solution invented in Frascati and aimed at improving the performances of accelerators. To push the limits of accelerating machines, in fact, an alternative way than raising the current is to make the beam pipe smaller, in order to increase the amount of events in the collision point. The way to make beams as narrow as possible has been proposed in Frascati by the former INFN director of accelerators Pantaleo Raimondi who has been later appointed director of the ESRF's Accelerator and Source Division. Nowadays, the innovative solution represents an effective match between the two laboratories and as the DAFNE aluminium vacuum chamber is a good model for ESRF–EBS, the design of the beam pipes for ESRF–EBS has being established under the responsibility of INFN. ■

ITALIAN NATIONAL INSTITUTE FOR NUCLEAR PHYSICS

CONTACTS

Communications Office
comunicazione@presid.infn.it
+ 39 06 6868162