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» INTERVIEW

THE PHYSICS OF GRAVITATIONAL SIGNALS AMONGST THE L'ORÉAL-UNESCO 2021 AWARDS

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Although the field of research dedicated to the study of gravitational waves is already preparing to launch a new season with even more powerful detectors, it continues to produce fundamental results, such as the one published in June by the Virgo, LIGO and KAGRA collaborations, dealing with the observation of the first signals generated by two mixed binary systems comprising a black hole and a neutron star. The work carried out by the many female scientists in this area of research is essential and indispensable for the achievement of such successes. This year they are in the spotlight of "Per le Donne e la Scienza" Italia, an international prize promoted by the L'Oréal foundation in collaboration with UNESCO, which since 2002 has aimed to raise public awareness of the problem of gender inequality in science, thus enhancing and supporting the work of young female researchers in the field of STEM disciplines (Science, Technology, Engineering and Mathematics) and encouraging new generations of women to embark on a scientific career. One of the six grants awarded in the 2021 edition of the prize went to Ornella Juliana Piccinni, a researcher at INFN Rome 1 division, at the Amaldi Research Centre of the Università Sapienza in Roma and a member of the Virgo collaboration, thanks to a project aimed at modelling and identifying the gravitational signals produced by magnetars, neutron stars with an extremely intense magnetic field.

How are the research projects of the L'Oréal prize selected and what kind of prize do the winners receive?

Since 2002, L'Oréal Italia, in collaboration with the UNESCO commission, has annually selected the six most interesting research projects proposed by women under 35, in the field of life sciences, physical sciences and sciences relating to matter, including engineering and technological sciences. The "L'Oréal Italia Per le Donne e la Scienza" prize consists of a €20,000 scholarship for a 10-month project at a

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research centre in Italy. The six best proposals from over 300 applications were selected by a jury of experts in the various research fields covered by the award and chaired by Lucia Votano, researcher at INFN, who also led the INFN Gran Sasso National Laboratories. In addition to the proposed project, the jury also took into account the candidates' curricula and any experience abroad.

Did you expect to be among the winners and what did you think and feel when you received the news?
Definitely not! For me it was a surprise, and what's more, it came at a fairly decisive time in my career. I remember that at that moment I was in the kitchen just about to drain the pasta, so I wasn't prepared at all. The first thing I did was to tell my family and colleagues, who had been telling me to try for years (and every time I found an excuse not to), so it was a great satisfaction.

Your project concerns the research dedicated to the study of gravitational waves, which has achieved a number of incredible results in recent years. Can you tell us more about your project proposal?
The research project I presented proposes a new line of analysis for a type of gravitational signal, not yet detected, which we call continuous gravitational waves. Typically, this signal is emitted by an isolated, asymmetric neutron star that is rotating rapidly on itself. So far there are several groups, even outside the LIGO-Virgo-KAGRA collaboration, that are trying to detect this signal, which is much weaker than the signal emitted during the merger of two black holes, two neutron stars or binary systems composed of both these bodies. So let's say there is a lot of competition, because many of us expect this to be the new surprise in gravitational astronomy. In detail, my project focuses on a particular type of neutron star, also known as a magnetar which has an extremely high magnetic field. In general, these objects can be formed following a merger between two compact objects, at least one of which is a neutron star, or else following the explosion of a supernova. The signal emitted by this particular system differs from what we would expect from a typical neutron star with a "normal" magnetic field, for example, in its duration, which we expect to be much shorter. Furthermore, the presence of extreme magnetic fields makes the star much more "asymmetrical" than a stable neutron star, and this in general relativity means that the star is theoretically capable of emitting a larger amount of gravitational energy. In general, even the very existence of magnetars, despite the confirmations coming from various studies, does not totally convince the entire scientific community. To date, there are about twenty known magnetars, others may be electromagnetically silent, which is why it is necessary to study these objects also through gravitational waves.

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What are the scientific objectives of your proposal and how do they fit into the future study of gravitational signals?
We are currently in a crucial phase of gravitational astronomy. To date, several sources are missing from the detection list, including continuous waves generated by neutron stars. There is a great deal of excitement about this potential next discovery, because at the end of the ongoing upgrade phase the detectors themselves will have reached a level of sensitivity that enables them to pick up this particular signal, at least according to the estimates. In parallel, various research groups have significantly improved their search algorithms. So, we could definitely be on the verge of a first detection, which could once again prove Einstein right, if all the models we have considered so far are valid. If, in the next data run of the LIGO-Virgo-KAGRA collaboration, which is due to start next year, we don't actually manage to measure these signals, then it means that we have to start rethinking the models we have been using up until now, and this, after all, is still a way of helping to expand our boundaries of knowledge. In practical terms, I will have to work on a data analysis algorithm, optimised for finding signals from magnetars. The most exciting thing is to know that in case of detection we will be able to observe how matter behaves in conditions of extreme gravity and density, because I remember that neutron stars reach densities comparable with that of the atomic nucleus. To reproduce such an experiment on Earth with the technology available to us today would clearly be quite risky. Moreover, a possible detection could contribute to the observation of magnetars from the multi-messenger astronomy point of view, exactly as it happened with the first merger between two neutron stars (GW170817), we would also have gravitational waves available to study these objects that, to this day, we can only possibly observe through their electromagnetic emission.

What was your study background and what motivated you to get involved in such a young field of research as gravitational waves?
I always liked mathematics as a child and then astrophysics in high school. I enrolled in the three-year degree course in astronomy and astrophysics in Rome, but after a few months I switched to physics because there were too many interesting subjects and I wasn't sure of my path yet, so much so that my three-year dissertation was on a mathematical physics subject, i.e., tsunamis. Then, during my master's degree, the same thing happened, I attended astrophysics courses for a few months and then I switched to physics again, but this time I decided to include exams in my curriculum such as “General Relativity” and from then on it was love at first sight, it was the subject that perfectly combined my passion for mathematics with astronomy and astrophysics. I had decided that this was the subject that I was going to work on as my degree project, although initially I wanted to do something purely theoretical. In the

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meantime, I had won an Erasmus grant for Germany in Hannover, so I plunged into this new adventure, under the guidance of Prof. Fulvio Ricci, former Virgo spokesperson and lecturer in the "experimental gravitation" course at Sapienza. In Hannover, I completed my master's thesis project at the Max Planck Institute for Gravitational Physics, in collaboration with the group of Dr. Maria Alessandra Papa, then a member of LIGO, with a project on gravitational waves emitted by neutron stars. After my master's thesis dissertation, it became natural for me to get in touch with the Virgo group in Rome where I did my PhD, this time in Astrophysics, working with Prof. Sergio Frasca and with the colleagues in Rome, continuing my research projects here.

How do you evaluate the numbers of women in your research sector? Do you think that female researchers today have the same opportunities as their male colleagues or are there still inequalities related to career opportunities?
Fortunately, I have always had the opportunity to work with women as well, but I do not deny that even looking at the situation in the Physics Department of Sapienza University, the percentage of female professors is drastically lower compared to their male colleagues.
The same is true if we look at large numbers: in the LIGO-Virgo-KAGRA collaboration, there are women but the most important roles, in most cases, are held by male colleagues. However, I recognise that at least part of the scientific community is beginning to address this gender gap in a serious way. In theory, the opportunities are available to all, but given the data on hand, many female students decide not to go on to higher degrees of education (starting with doctorates), and this clearly means that even fewer women get into positions of greater power, worsening an already alarming situation. There are some striking cases, even recent ones, of doctoral programmes consisting exclusively of male doctoral students. I would say that there are still disparities today, and that they mainly weigh on the most important period of a female or male scientist's career, and are very difficult to take up later. Certainly, in my opinion, this is a cultural problem that cuts across the different nations, so I would not speak of an exclusively Italian cultural problem. We grow up with models that do not fully represent us and that also direct us towards educational paths typically designed "for girls" and that do not necessarily provide access to higher education.

What would you advise a young girl to do if she wanted to study physics or astrophysics after finishing secondary school?
I would definitely say that it is the right choice and that there are no careers that are more or less suitable for one's gender identity. That she should never be discouraged or feel uncomfortable when

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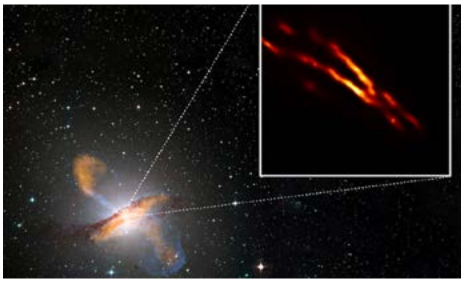
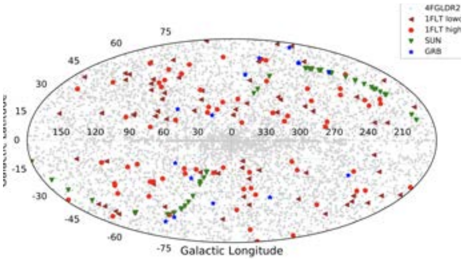
she enters the classroom and realises that she is one of the few girls on the course, and that in no way this should be a burden on her career. In short, I would tell her that she can definitely do it.



RESEARCH

EHT: A LOOK INTO THE HEART OF THE CENTAURUS A GALAXY

An international team of scientists from the Event Horizon Telescope (EHT) collaboration has combined observations from several radio telescopes around the world, using the same technique that produced the famous image of the black hole at the centre of the M87 galaxy, to photograph the heart of the nearby Centaurus A radio galaxy in unprecedented detail at a wavelength of 1.3 mm. The team, including researchers from the INFN, the National Institute for Astrophysics (INAF), and the University of Naples Federico II, identified the position of the central supermassive black hole revealing the birth of a giant jet. Surprisingly, the experts found that only the outer edges of the jet appear to be emitting radiation. This observation challenges the predictions of current theoretical models. The study was published today in the Nature Astronomy journal. The EHT data originates from the 2017 observation campaign. Compared to all previous high-resolution observations, the jet launched from Centaurus A was observed in radio band at a frequency 10 times higher, providing images with 16 times sharper resolution than those available so far. Thanks to the EHT's resolution power, researchers are able to locate the source of the radio signal that extends far beyond the galaxy, in a portion of the sky equal to 16 times the apparent diameter of the Moon.
The article on Nature Astronomy *"Event Horizon Telescope observations of the jet launching and collimation zone in Centaurus A"* ■



SPACE

FERMI-LAT PROVIDES THE FIRST MAP OF EXTRAGALACTIC TRANSIENT SOURCES

The first list of extragalactic transient sources has been obtained. These sources correspond to a particular class of extreme astrophysical objects characterised by a non-continuous and variable emission of gamma rays, i.e., photons at high energies. The results, published in early September in the Astrophysical Journal Supplement, are the fruit of a study led by Italian researchers from INFN and ASI Italian National Space Agency, as part of the international Large Area Telescope (LAT) collaboration. One of the two detectors on board NASA's Fermi Gamma-ray Telescope, the LAT detector, has allowed to extract a completely new catalogue compared with those published so far, and it is called the Fermi-LAT Long Term Transient Catalog (1FLT), which could help scientists shed light on possible dark matter candidates.

To find the 142-point sources in 1FLT that radiate very high-energy light for even short periods of time, the researchers compared the observations in the source catalogue obtained from 10 years of Fermi-LAT data.

Most of the new gamma-ray transient sources detected by Fermi-LAT are associated with blazars, active galaxies with supermassive black holes at their centre. The remaining ones, for which no counterpart could be found in other wavelengths and are therefore unknown, are of great astrophysical interest, because they could be an important clue to the presence of dark matter, thus helping scientists to understand the characteristics and behaviour of this mysterious and widespread component of the universe. ■

PUBLIC ENGAGEMENT

GRAVITATIONAL WAVES AT THE VENICE ARCHITECTURE BIENNALE

Gravitational waves and large research infrastructures that serve to host the instruments for their observation, such as the future Einstein Telescope project, are among the protagonists of the cultural proposal of the 2021 Architecture Biennale.

From 7 to 10 September 2021, in the spaces of the *Italian Pavilion - Resilient Communities*, at the Arsenale of Venice, a series of events will take place in support of the installation Gravitational Waves Architecture, which is set in the pavilion. The installation is curated by Eugenio Coccia, Massimo Faiferri, Giancarlo Mazzanti, Michele Punturo with Lino Cabras and Fabrizio Pusceddu, starting from the results of the summer school “ILS 2019 Landscapes of Knowledge” of the Department of Architecture, Design and Urbanism of the University of Sassari.

A series of meetings in the name of interdisciplinary dialogue, organized by INFN, GSSI - Gran Sasso Science Institute, EGO - European Gravitational Observator and ecourbanlab, the research laboratory of the Department of Architecture, Design and Urban Planning of the University of Sassari.

Architects, physicists, economists will discuss the contact points of their respective fields of investigation, in relation with large present and future research infrastructures, analyzing their impact not only from a scientific point of view but also from industrial, economic and social ones.■

TAKE PART IN

INFN AT THE ARCHITECTURE BIENNALE 2021 - RESILIENT COMMUNITIES

The events will be hosted in the spaces of the Italian Pavilion - Resilient Communities, live broadcasted on the *“Comunità Resilienti” Facebook page*, and relaunched on the involved institutions Facebook pages.

7 SEPTEMBER - PHYSICS, ARCHITECTURE, ECONOMICS

Italian Pavilion, Spazio Genoma – Arsenale di Venezia

14.30-15.30: GREAT RESEARCH INFRASTRUCTURE, RESOURCE FOR COMMUNITIES AND TERRITORIES

With Martina Dal Molin, GSSI researcher, Massimo Faiferri, University of Sassari, architect, Antonio Zoccoli, INFN physicist, moderated by Matteo Massicci, INFN.

15.30-16.30: LANDSCAPES OF KNOWLEDGE, ARCHITECTURE AND APPRENIDMENT

With Massimo Faiferri, University of Sassari, architect, and Giancarlo Mazzanti, El Equipo Mazzanti, architect.

17.30-18.30: A NEW IDEA OF SPACE: A DIALOGUE BETWEEN PHYSICS AND ARCHITECTURE

With Eugenio Coccia, GSSI physicist, Gonçalo-Byrne, GB Arquitectos, architect, Stavros Katsanevas, EGO physicist, moderates Vincenzo Napolano, EGO.

10 SEPTEMBER - GRAVITATIONAL WAVES, ARCHITECTURES, TERRITORIES

Italy Pavilion, Peccioli Space - Arsenale di Venezia

11.00 - 12.00: EINSTEIN TELESCOPE: SCIENCE, ARCHITECTURE AND SOCIO-ECONOMIC IMPACT

With Marica Branchesi, GSSI astrophysicist,, Luca Deidda, University of Sassari, economist, Fernando Ferroni, GSSI physicist, Michele Punturo, INFN physicist, moderated by Francesca Scianitti, INFN.

FROM OCTOBER 12 UNCERTAINTY. INTERPRETING THE PRESENT, PREDICTING THE FUTURE

Palazzo delle Esposizioni, Rome

The exhibition curated by INFN dedicated to the theme of uncertainty and to the methods and tools that science has developed over time to address and manage it in different contexts, will be inaugurated on 12 October: from aspects of fundamental physics to the description of epidemics, from climate forecasts to big data and our universe destiny. The exhibition *Uncertainty. Interpreting the present, predict* the future is created by Azienda Speciale Palaexpo in collaboration with INFN and is part, with the *Ti con Zero* and *La Scienza di Roma* exhibitions, of the broader cultural project promoted by Roma Culture and Azienda Speciale Palaexpo *Three stations for Art-Science* .■

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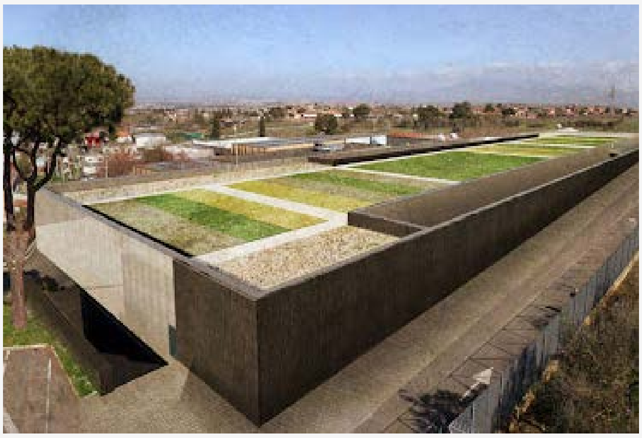

EUPRAXIA: PLASMA ACCELERATION AMONG NEXT EUROPEAN RESEARCH CHALLENGES

EuPRAXIA is a future multidisciplinary experimental research infrastructure based on the use of plasma acceleration - an innovative particle acceleration technique - and intended for basic research and applications in physics and other scientific sectors. It is one of the two international projects, with the Einstein telescope, which the INFN, and Italy, with the MUR Ministry of Universities and Research, has successfully nominated for the 2021 Roadmap of the ESFRI European Strategy Forum on Research Infrastructure, the European strategic forum that identifies the future major research infrastructures in which to invest at the European level.

One of the main challenges for future accelerators is to achieve increasingly higher energies in order to explore new realms of matter. As stated in the Conceptual Design Report, funded with €3 million under the Horizon 2020 program and *published* at the end of 2019, the EuPRAXIA project consists in the creation of a new generation of accelerators, capable of achieving higher energies than those reached by current accelerators, but with reduced costs and size.

The EuPRAXIA acceleration technique entails using an ionised gas excited by laser or particle beams as a means of accelerating the electrons injected into it. This new technique promises to revolutionise the field of accelerator machines, not only by boosting their performance in terms of energy, but also by making them more powerful, compact (at least 10 times shorter) and hence cheaper. One of the factors that most limits the application of plasma accelerators is the energy spread that the beam accumulates during acceleration in the plasma module. An experiment conducted by researchers of the SPARC_LAB group at the INFN Frascati National Laboratories demonstrated, for the first time, that it's possible to solve this problem and thus accelerate a beam of high-quality electrons. The result, *published on Nature Physics in January,* was obtained using an innovative technique and it paves the way for future developments in particle accelerators based on plasma technology.

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Obtaining more performative and smaller accelerators would have an important impact not only in the field of basic research in high-energy physics, but also in other areas: it would allow, among other things, the construction of compact sources of X-ray laser radiation (free-electron lasers), useful, for example, in diagnostic imaging, in various industrial sectors and in applied research, including the possibility of investigating the structures of bacteria and viruses, and thus providing valuable information for the development of therapies and vaccines. The aim of EuPRAXIA is thus to demonstrate the functionality of a plasma accelerator and, at the same time, to make a free-electron laser available to users from international universities and research centres. The compact size of these machines will also enable them to be installed in small research centres, such as those in universities, hospitals or industries.
The commitment made by the MUR to host this new infrastructure at the INFN Frascati National Laboratories, as established by the international community that supports its realisation, and to start its construction is supported by the formal expressions of commitment at the Government level of four other EU countries (United Kingdom, Portugal, Czech Republic and Hungary). The construction of the infrastructure, scheduled for 2028, will involve hundreds of young scientists and engineers with experiences across plasma physics, accelerators, lasers and the most advanced electronic and computer technologies. ■

* EuPRAXIA was proposed by a consortium of over 40 institutes from ten European countries (Italy, France, Germany, Portugal, Poland, United Kingdom, Czech Republic, Sweden, Switzerland, Hungary), as well as 10 other observatory institutions from China, Israel, Russia and the United States, and a number of industrial partners. Italy is taking part with INFN, the Italian National Research Council, the Universities of Roma Sapienza and Tor Vergata, ENEA and Elettra Sincrotrone Trieste.

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Italian National Institute for Nuclear Physics

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