Newsletter Interview

EGO AND THE FUTURE OF GRAVITATIONAL WAVES RESEARCH IN EUROPE

Interview with Massimo Carpinelli, professor at the University of Milan Bicocca and INFN researcher, director of EGO since January 1st, 2023

Founded in 2000 by INFN and CNRS Centre National de la Recherche Scientifique, the EGO Consortium, the European Gravitational Observatory, is now among the leading players on the international gravitational wave research scene thanks to the successes of the Virgo interferometer. EGO, in fact, is the site, just outside Pisa, of one of the three interferometers in the world that have observed to date the tiny vibrations of spacetime predicted by Albert Einstein in General Relativity and whose Nobel Prize-winning discoveries in 2017 led to the birth of gravitational and multimessenger astronomy, two completely new ways of studying the universe. EGO's mission is to ensure the operation, maintenance and upgrading of the Virgo interferometer, and to promote gravitational wave research in Europe. Over the years, the EGO consortium has built strong ties with the local area, thanks in part to its commitment to spreading scientific culture, particularly by welcoming the thousands of students who visit Virgo each year. Virgo will soon resume operations after major upgrading works. But looking even further ahead, the international gravitational wave community has launched a major new challenge: the construction in Europe of a third-generation gravitational wave detector, ET Einstein Telescope. After more than two decades of history, EGO will thus face decisive challenges in the coming years for the future of European and global gravitational physics, challenges on which the term of office of the centre's director, Massimo Carpinelli, professor at the University of Milan Bicocca and INFN researcher, who took office on 1 January 2023, succeeding Stavros Katsanevas, who died prematurely in November last year, will focus.

You have just taken over as director of EGO, succeeding Stavros Katsanevas, who had led it since 2018 and who left us prematurely shortly before the end of his term of office.

The enthusiasm with which Stavros Katsanevas approached his research activity and his entire life, which he knew was, in his last years, undermined by the illness that unfortunately took him away too soon, was admirable. In particular, two aspects of Stavros have always impressed me. The first is his distinctive ability to be able to look far ahead and always work with an eye on the future, never dwelling on today. The second, on the other hand, concerns the valuable contribution he made to gravitational wave physics. Stavros understood how important this field was not only for scientific knowledge, but also for the impact it can have on society. And he had understood the strong interest on the part of the public in learning about this kind of research, which is an incredible attractor for a range of other cultural, artistic and philosophical interventions.

What is EGO today? What issues and activities will the beginning of your term of office focus on?

The function and purposes of EGO have not essentially changed from the past, and focus on providing support, as a research infrastructure, for the Virgo gravitational interferometer. Our mission, therefore, which I will pursue in my role as director, continues to be that of ensuring that the detector's activities are carried out with the utmost sensitivity. EGO's responsibilities also include maintaining relationships with scientific institutions that are part of the consortium or would like to join it. One of the most important changes compared to the past concerns the Dutch National Institute for Subatomic Physics, Nikhef, becoming a member of the Consortium. Until recently, EGO was essentially an Italo-French enterprise. The two nations, through INFN and CNRS, contributed most of the necessary funding and, thanks to Adalberto Giazotto and Alain Brillet, to the ideas that led to the development of Virgo's technologies and the founding of the Consortium. Only in the past few years changes in EGO's articles of association have made it possible for other scientific institutions to join as members, enabling Nikhef's membership and an openness to all entities that would like to join in the future.

But, returning to the important contribution of those before me and to also building an active presence of EGO outside the field of gravitational wave physics, one of Stavros Katsanevas' legacies, which will certainly be carried forward in the near future, concerns the collaboration with research communities interested in using the environmental or anthropogenic noise data that we need to know in order to make gravitational wave observations possible.

The Virgo scientific collaboration is preparing for the new date-acquisition cycle after major interferometer upgrade works.

Virgo's new data-acquisition cycle, called O4, is expected to kick off before next summer. Currently, we are in what is called the commissioning phase, i.e., testing the technical and technological improvements already made on the interferometer. A job that takes place in parallel with that of the two U.S. LIGO detectors, which have also undergone upgrades in the past two years. This is because the alternation between periods of data acquisition and periods devoted to instrument improvement is now agreed upon by the worldwide collaboration to which Virgo, LIGO and the Japanese KAGRA interferometer belong. Many upgrades have been implemented on Virgo, including the installation of a more powerful laser source, an element needed to reduce a particular type of noise called shot noise. Other improvements have been achieved through the inclusion of an additional optical resonator, whose function is to allow recycling of the optical signal by increasing the bandwidth to which the detector will be sensitive. And the construction of up-to-date optics that can reduce the effect of so-called parasitic light, which is the scattering of light inside the interferometer. A network of sensors has also been implemented that aim to reduce the so-called Newtonian noise at low frequencies. Finally, the most technologically significant intervention involved squeezing, a quantum optical configuration that allows the coupling of noise due to radiation pressure and that due to the aforementioned shot noise to be minimised. All of these interventions will result in Virgo being able to probe space for coalescence events of binary systems consisting of black holes, neutron stars, or mixed pairs of these objects, at greater distances than before. This will obviously also lead to an increase in the volume of observable space and the number of signals that will be detected.

From the discovery of gravitational waves in 2015 to the present has been a succession of new measurements and observations. Gravitational wave research proves to be instrumental in advancing our knowledge. Why does this research make a difference?

As the resolution increases, we expect the rate of events recorded by Virgo to grow from the maximum of two a week to one a day. The growth in the number of events we expect to observe will be critically important because it will allow us to begin population studies of the sources involved. Moreover, a significant aspect affecting O4 is the decision to extend the data-acquisition period from one year to 18 months. One of the reasons was to be able to detect a multimessenger event again. Indeed, to date there has been only one observation of such an event, in which the associated gravitational wave has an electromagnetic counterpart. The event in question refers to the merger of two neutron stars observed by Virgo and LIGO in August 2017. Multimessenger physics is extremely interesting because it makes it possible to study these phenomena in various frequencies – not only through gravitational waves, but also in the bands of the electromagnetic spectrum – and to derive very accurate information about the type of sources. Multimessenger astrophysics thus represents a fundamental tool for shedding light on the still open questions concerning extreme astrophysical sources. This is an area in which INFN is also investing heavily, as evidenced by projects such as the KM3NeT undersea observatory, which will have among its goals to flank and complement the work of gravitational interferometers through the study of neutrinos, cosmic messengers that can carry information about astrophysical sources of interest.

The international scientific community is already working on the future third-generation ET interferometer. What are the main challenges that this new detector poses for its implementation?

Compared to second-generation detectors, ET should further improve resolution, especially at low frequencies. Indeed, gravitational observatories possess a sensitivity curve that varies with frequencies, which in turn are associated with different astrophysical phenomena. The low-frequency region is particularly interesting because, should we be able to explore it, we would be able to observe the so-called primordial gravitational waves, i.e., those that were produced in conjunction with the Big Bang. However, it is still a very difficult region to detect because low-frequency noise can have many sources; we are still studying to understand how to implement solutions to eliminate it. This will certainly be the main challenge for the implementation of ET which will require the development of new technologies to overcome it. We must also consider the aspect related to the engineering and construction difficulties that new detectors pose. Unlike current observatories, which are characterised by 3-kilometre-long arms, the forthcoming interferometers will have arms with lengths ranging from 10 to 20 kilometres, depending on the design, in order to increase sensitivity to medium and high frequencies. On the other hand, to explore low frequencies, our proposal to minimise ambient noise was to place ET underground.

You were Rector of the University of Sassari and during your term of office you were among the promoters of Sardinia's bid to host ET.

The idea that Sardinia is an ideal place to host a gravitational observatory is not a recent one: it can be traced back to the father of Virgo and gravitational interferometry, Adalberto Giazotto. Indeed, already at the time of my transfer from Pisa to Sassari, Giazotto asked me to promote the project, because he also felt that Sardinia was the right place. The reasons are still valid today and are the same as those behind the candidacy to host ET in the region: the limited seismic activity that characterises the area, among the lowest in Europe, and the equally limited presence of noise produced by human activities. In particular, the site subsequently identified, the former Sos Enattos mine, is located in the municipality of Lula, which has one of the lowest population densities in all of Europe. This is also in addition to the geological characteristics of the area, which lend themselves to the implementation of ET. The credit for first understanding that Sardinia could become the ideal place for observing and studying gravitational waves should therefore go to Giazotto, without whom the physics we are concerned with would not exist: he was the one to visionary propose the technique that made the birth of this field possible. Based on the suggestion that this great scientist gave me, once I became Rector of the University of Sassari, and thanks to the greater ability to interact with national and local institutions that the role granted me, I therefore began, thanks to INFN, which provided the scientific guidance, to submit the proposal. Albeit in the hope that ET will actually be able to be hosted in Italy, the mere fact that we were able to propose the candidacy was a not entirely obvious achievement, because the target area, precisely because of its low anthropisation, has certain logistical difficulties.

Why is it significant to host a large research infrastructure?

Studies have been conducted to assess the impact of a large international research infrastructure such as ET, and these have shown that for every euro spent, a six- or seven-fold return is expected, a part of which would remain in the territory. There would therefore be an immediate benefit in economic terms related to the ancillary revenue generated by the services needed to operate the research infrastructure. Perhaps an even more important aspect is that the implementation of ET in Sardinia would also ensure the overall growth of the entire local and national technological fabric, and of the skills capital, through the training that young researchers could receive not only in the field of gravitational physics, but also in all those scientific and application areas necessary to make the activities of an advanced research centre possible. The combination of all these factors could thus help slow down the phenomenon of depopulation that is affecting all depressed regions of Italy such as the areas of Sardinia chosen to host ET.

Regardless of where it will be built, EGO will be supporting the implementation of the ET project in Europe. What could its contribution to the new project be? And what could be the contribution of the Italian scientific community?

It must be said that the main contribution to the ET project concerns the unique role that EGO now plays in Europe as a centre for gravitational wave physics. The only centre in Europe where it is now possible for a young person to mature and acquire expertise in gravitational waves is Virgo: the only European laboratory where it is possible to acquire firsthand experience of this physics and to test the new technological solutions that future observatories will use. EGO and Virgo thus represent the school within which scientists working on ET will be trained. Sources of noise that can disturb gravitational wave detection at low frequencies can also be studied at our laboratory, and work is underway on technologies that will be developed for ET, such as vacuum, optics or suspension technologies. Finally, a key function that EGO and Virgo may play could be to accompany and keep the gravitational wave physics community active, so that it does not run the risk of dissipating, while waiting for the implementation of ET, which may take up to 15 years. At the end of the O4 and O5 data-acquisition periods already planned, we may in fact host an additional Virgo improvement, the Virgo Next project, which will be able to bridge the gap of the lengthy period that still separates us from the start of ET scientific activities.

Work is also underway in the United States on the next interferometer generation, Cosmic Explorer. Why is a global network of interferometers crucial to the success of this research?

The difference between the initial nascent phase of gravitational wave physics, in which the existence of these perturbations of spacetime was experimentally demonstrated, and the current phase, which is characterised by the in-depth study of gravitational signals, is the ability to precisely locate the sources of the observed events in space, thanks to multiple observers capable of triangulating the signals. In addition to providing information that is indispensable for the study of gravitational waves, having an extensive network of interferometers has a second important advantage, which is that, by working synchronously, interferometers can reduce background noise, increasing the overall measurement accuracy and sensitivity. This is why it would be necessary to start thinking about gravitational wave research as a globally coordinated activity that could optimise available and future resources, including the LISA space interferometer.

What do you foresee and hope for the future of EGO?

From the EGO perspective, one contingency-related aspect I am having to deal with is the return to normality after the pandemic. Therefore, I hope that in 2023 we can return to having a significant influx of researchers at our centre. Among the goals for my term of office is to make EGO even more hospitable in terms of logistics and available services.