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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. ■