» FOCUS ON

ADVANCED VIRGO: TO THE LIMIT OF TECHNOLOGY FOR GRAVITATIONAL WAVE RESEARCH

Exactly a century has passed since Albert Einstein, in 1916, predicted the existence of gravitational waves with his theory of general relativity. Capturing these space-time ripples, produced by masses in accelerated motion, is difficult, but not impossible. Due to their infinitesimal amplitude, to increase the detection sensitivity it was necessary to push the technologies of laser interferometers, the detectors used for gravitational wave research, to the limit.
The INFN physicists, already engaged with their American and European colleagues in analysing the data of the Advanced LIGO (Laser Interferometer Gravitational-Wave Observatory) detector, are finalising the construction of Advanced Virgo, a 2nd generation interferometer at EGO (European Gravitational Observatory), in the countryside around Pisa, which will start taking data in the second half of 2016. Advanced Virgo is an upgrade of Virgo, the giant first-generation interferometer consisting of two 3 km-long perpendicular arms, situated in Cascina, near Pisa, and inaugurated in 2003. Each of the two arms of Virgo is traversed by a laser beam which, before overlapping with the other, is reflected back and forth several times in order to virtually lengthen the arms, thereby increasing the sensitivity of the instrument. When a gravitational wave passes through the interferometer, the length of the arms varies and the interference pattern created by the overlapping of the laser beams is modified: the measurable variation is related to the wave amplitude. Funded by INFN, by CNRS, the French Centre National de la Recherche Scientifique and with the particpiation of NIKHEF, the National Institute for Nuclear Physics and High Energy Physics in Amsterdam, the Polish Academy of Science and the Hungarian Wigner Institute, Advance Virgo will increase the sensitivity of Virgo by about 10 times, thus extending the volume of the observable universe by 1000 times.
Officially approved in December 2009, Advanced VIRGO constitutes, with the two Advanced LIGO in the US, a worldwide network of interferometric detectors that operate as one big detector, sharing the data collected, analysing it jointly and publishing together the scientific results. Joint observation

» FOCUS ON

with three interferometers allows the direction of the sources of gravitational wave to be identified via the tiny differences in arrival times of the wave in the different devices. Locating the source in the sky subsequently allows the terrestrial and space telescopes to be pointed, looking for an electromagnetic counterparty, in the spectrum from radio waves up to high energy gamma rays.
The Pisa interferometer, subjected to profound improvements, has several features that are the result of years of intensive technological research. The optical design, the quality of the mirrors, the power of the laser, the thermal aberration compensation system, the seismic isolation and mirror control, as well as the vacuum, stray light reduction and environmental monitoring systems. The new mirrors, in particular, have double the mass of the previous one and are made of synthetic quartz, with purity and homogeneity at the frontier of technology, so much so that surface irregularities are reduced to the level of a few angstrom, a few tenths of a billionth of a metre. Thanks to this level of purity, in addition to the presence of advanced systems for the control of all aspects of the experiment, Advanced VIRGO is capable of measuring variations in the length of the arms, due to the passage of a gravitational wave, a billion times smaller than the diameter of a hydrogen atom.
The Virgo partnership, which manages the project together with EGO, currently consists of over 250 researchers - about half of which INFN - from 19 laboratories of 5 European countries: Italy, France, Holland, Poland and Hungary. ■