Plans Shape Up for a Revolutionary New Observatory to Explore Black Holes and the Big Bang

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University of Birmingham physicists, with scientists from all over the world, present their design for the Einstein Telescope – Europe's next-generation detector that will 'see' the Universe in gravitational waves.

A new era in astronomy will come a step closer when scientists from across Europe present their design study for an advanced observatory capable of making precision measurements of gravitational waves – minute ripples in the fabric of spacetime – predicted to emanate from cosmic catastrophes such as merging black holes, collapsing stars and supernovae. It also offers the potential to probe the earliest moments of the Universe just after the Big Bang, which are currently inaccessible.

The Einstein Observatory (ET) is a so-called third-generation gravitational-wave (GW) detector, which will be 100 times more sensitive than current instruments. Like the first two generations of GW detectors, it is based on the measurement of tiny changes (far less than the size of an atomic nucleus) in the lengths of two connected arms several kilometres long, caused by a passing gravitational wave. Laser beams passing down the arms record their periodic stretching and shrinking as interference patterns in a central photo-detector.

The first generation of these interferometric detectors built a few years ago (GEO600, LIGO, Virgo and TAMA) successfully demonstrated the proof-of-principle and constrained the gravitational wave emission from several sources. The next generation (Advanced LIGO and Advanced Virgo), which are being constructed now, should make the first direct detection of gravitational waves – for example, from a pair of orbiting black holes or neutron stars spiralling into each other. Such a discovery would herald the new field of GW astronomy. However these detectors will not be sensitive enough for high precision studies of the GW sources.

The design study, which will be presented at the European Gravitational Observatory site in Pisa, Italy, outlines ET's scientific targets, the detector layout and technology, as well as the timescale and estimated costs. A superb sensitivity will be achieved by building ET underground at a depth of about 100 to 200 metres to reduce the effect of the residual seismic motion. This will enable higher sensitivities to be achieved at low frequencies, between 1 and 100 hertz (Hz). With ET, the entire range of GW frequencies from astronomical sources that can be measured on Earth – between about 1 Hz and 10 kHz – should be detected. An important aim is to provide GW information that complements observational data from telescopes detecting electromagnetic radiation (from radio waves through to gamma-rays) and other instruments detecting high-energy particles from space (astroparticle physics).

The Birmingham Gravitational Wave Group is centred on the observation of the universe in the gravitational wave band, and on testing gravity at new scales. The group is a member of the GEO collaboration and the LIGO Scientific Collaboration with a central role in data analysis and the instrumental upgrade of LIGO to Advanced LIGO. It is also part of the LISA-Pathfinder team providing flight hardware for the proposed NASA / ESA mission to detect gravitational waves from space. The group has played a leading role in the design of the next generation of detectors - Advanced Virgo and the Einstein Telescope. Dr Andreas Freise, from the University of Birmingham's School of Physics and Astronomy, who leads the optical design of the Einstein Telescope said, 'The Einstein Telescope is an amazing instrument. It combines many new ideas and technologies custom built to create the most sensitive instrument to listen to the faint echoes in the fabric of space and time. I helped to build the GEO 600 and Virgo detectors and later had the chance to contribute to the optical design for Advanced Virgo. Now leading the optical design of the Einstein Telescope has been a great opportunity, using hands- on experience to design something completely new.'

Professor Alberto Vecchio, who leads the LIGO activities at the University of Birmingham, said, 'We expect to achieve the first direct detection of gravitational waves with Advanced LIGO, to which our group has made direct contributions. As new ideas mature the Einstein Telescope becomes the next natural step in the quest for observing the universe with new "eyes", and a bold step beyond Advanced LIGO: with its exquisite sensitivity the Einstein Telescope will enable us to produce precise maps of black holes, unveiling many of their mysteries, and possibly peek into the first moments of cosmic history after the Big Bang.'

The strategy behind the ET project is to build an observatory that overcomes the limitations of current detector sites by hosting more than one GW detector. It will consist of three nested detectors, each composed of two interferometers with arms 10 kilometres long. One interferometer will detect low-frequency gravitational wave signals (2 to 40 Hz), while the other will detect the high-frequency components. The configuration is designed to allow the observatory to evolve by accommodating successive upgrades or replacement components that can take advantage of future developments in interferometry and also respond to a variety of science objectives.

The European Commission supported the design study within the Seventh Framework Program (FP7-Capacities) by allocating three million Euro. 'With this grant the European Commission recognized the importance of gravitational wave science as developed in Europe, its value for fundamental and technological research, provided a common framework for the European scientists involved in the gravitational wave search and allowed for a significant step towards the exploration of the Universe with a completely new enquiry instrument', says Federico Ferrini, director of the European Gravitational Observatory (EGO) and project coordinator of the design study for the Einstein Telescope.

ET is one of the 'Magnificent Seven' European projects recommended by the ASPERA network for the future development of astroparticle physics in Europe. It would be a crucial European research infrastructure and a fundamental cornerstone in the realisation of the European Research Area.

Notes to Editors

Further information, images and movies:
URL: **www.et-gw.eu (http://www.et-gw.eu)**

• The School of Physics and Astronomy at the University of Birmingham is one of the largest in the country and has shown a strong performance in the most recent Research Assessment Exercise (2008). The scientists are active in wide range of research fields including Astronomy, Condensed Matter Physics, Nanoscale Physics, Nuclear and Particle Physics as well as Theoretical Physics.

• The Einstein Telescope Project (ET) is a joint project of eight European research institutes, under the direction of the European Gravitational Observatory (EGO). The participants are EGO, an Italian French consortium located near Pisa (Italy), Istituto Nazionale di Fisica Nucleare (INFN) in Italy, the French Centre National de la Recherche Scientifique (CNRS), the German Albert Einstein Institute (AEI) in Hannover, the Universities of Birmingham, Cardiff and Glasgow in the UK, and the Dutch Nikhef in Amsterdam. Scientists belonging to other institutions in Europe, as well as the US and Japan, actively collaborated in the realisation of this design study.
URL: **www.et-gw.eu (http://www.et-gw.eu/)**

• The direct detection of gravitational waves – predicted by Einstein's theory of gravity, the General Theory of Relativity – is one of the most important fundamental research areas in modern science. Apart from verifying General Relativity, especially for extreme gravitational fields found in the vicinity of a black hole, GW detection could allow us, for the first time, to look back at the earliest moments of the Universe just after its birth. Cosmological observations are currently limited to those using electromagnetic waves and cosmic-rays (high-energy particles such as protons). This information can reach us from the past, but from a time no earlier than 380,000 years after the Big Bang. Before then, light and matter continually interacted, so that the Universe was rendered opaque. The Universe became transparent only when matter and light separated during this epoch. Cosmological epochs dating further back have thus far remained hidden, so it has not been possible to verify from observations the various theories about their nature. The direct measurement of gravitational waves may allow us "to listen" back as far as the first trillionth of a second after the Big Bang. This would give us totally new information about our Universe.

• GW research is a global effort because the full information about many GW sources can be obtained only with several interferometers working simultaneously in different places. Therefore, the US (LIGO), German-UK (GEO600), Italian-French and Dutch (Virgo) scientific communities have been working together closely for a long time. They share technology R&D and theoretical advances, as well as data-analysis methods and tools. The joint European project ET will help to improve further this worldwide collaboration.

The current observatories:

• GEO600, is a German-UK detector located near Hannover, Germany, and is operated by researchers at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute/AEI) in Hannover, and at the Universities of Glasgow, Cardiff and Birmingham in the UK. It is funded by the Max Planck Society, the state of Lower Saxony, the Volkswagen Foundation and the UK Science and Technologies Facilities Council (STFC). GEO works in close cooperation with the cluster of excellence, QUEST (Centre for Quantum Engineering and Space-Time Research), in Hannover.
URL: **www.geo600.de (http://www.geo600.de/)**

• Virgo is a 3-kilometre arm interferometer at Cascina, near Pisa, Italy. This project accomplished the additional goal of making low-frequency measurements at around 10Hz. Initially, Virgo was funded by the CNRS (Centre National de la Recherche Scientifique) and the INFN (Istituto Nazionale di Fisica Nucleare) but has now expanded to include Dutch, Polish and Hungarian research groups.
URL: **www.virgo.infn.it (http://www.virgo.infn.it/)**

• The US LIGO detectors consist of 2-kilometre and 4-kilometre instruments at Hanford, Washington, and a 4-kilometre instrument at Livingston, Louisiana. The LIGO project has been developed and is operated by the California Institute of Technology (CalTech) and the Massachusetts Institute of Technology (MIT), and funded by the National Science Foundation (NSF).
URL: **www.ligo.caltech.edu (http://www.ligo.caltech.edu/)**

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