Gravitational waves carry unique information about the origins of our Universe and studying them could provide important insights into the evolution of stars, supernovae, gamma-ray bursts, neutron stars and black holes.

Directly detecting these waves would, therefore, be an enormous scientific breakthrough and UK scientists are playing an important role in this worldwide effort.

**DETECTING A RIPPLE THROUGH SPACE-TIME**

Gravitational waves are produced by an accelerating mass - be it the coalescence of a neutron star binary system, or a person running for a bus, although the amount produced in the latter case is infinitesimally small. Unfortunately, detecting gravitational waves isn’t easy. Although they interact with particles, this interaction is extremely weak. Gravitational waves from a supernova in the Milky Way, for example, would create a ripple in space which would distort a ring of particles of 1km diameter placed on Earth by no more than one ten-thousandth the size of an atomic nucleus. Fortunately, this ripple can travel huge distances across space and so scientists should be able to detect gravitational waves from, for example, the coalescence of neutron star or black hole binary systems or perhaps a supernova.

Gravitational wave detectors use a technique called laser interferometry. Beams of laser light are reflected between effectively freely suspended mirrors forming two arms at right angles to each other, and the differences in arm...
length caused by a passing gravitational wave are searched for. The ground-based detectors can cover large areas of the sky – more than 40% - at any one time.

**UK EXPERTISE ADDS TO THE CHASE**
STFC supports a number of international projects on gravitational waves including GEO600, Advanced LIGO and indirectly, LISA Pathfinder.

The British-German GEO600 detector has arm lengths of 600m and is based near Hannover in Germany, operated by the Leibniz Universität Hanover, and the Universities of Glasgow and Cardiff. The detector is currently being upgraded to ‘GEO-HF’ for increased sensitivity at higher frequencies.

On the ground, LIGO and UK scientists from Rutherford Appleton Laboratory, and the Universities of Cardiff, Birmingham, Glasgow and Strathclyde, have contributed to the upgrade of the LIGO hardware to form a newer, even better Advanced LIGO facility, aiming to increase the detector sensitivity more than tenfold. This consists of interferometers of 4 km arm length at Hanford in Washington State and at Livingston Louisiana, partially funded by the STFC. The UK collaboration supplied advanced quadruple suspension systems, electronic systems for suspension control and silica blanks for the main mirrors of one Advanced LIGO interferometer. The new facility is now undergoing commissioning and first observations are planned for 2015. Recently the LIGO international collaboration agreed to relocate one of the Advanced LIGO interferometers from the LIGO Hanford Observatory in the US to India, which will significantly extend the scientific reach of the detector array.

The GEO600 experiment and Advanced LIGO is part of the LIGO Scientific Collaboration which uses an international network of detectors to search for gravitational waves. The different projects share data and perform joint analyses.

The UK has played a leading role in the development of instruments and systems for the European Space Agency (ESA) LISA Pathfinder mission. Funding for the development is currently provided by the UK Space Agency to groups at the Universities of Glasgow and Birmingham, and Imperial College. Launch of LISA Pathfinder is planned for mid-2015. LISA Pathfinder will test technologies for a future gravitational wave detector in space, with arm lengths of a million km. This incredibly challenging project has taken many years to be realized and relies on extremely accurate interferometric measurement, space-positional awareness and state-of-the-art technologies for test mass release and monitoring.

A full gravitational waves mission (known at various points as LISA, eLISA, or NGO) was proposed by European scientists for the first large scale (L1) mission of ESA’s Cosmic Vision Programme. The science case for the mission was rated very highly, but programmatic considerations led to its non-selection by ESA. Technology developments in preparation for the full mission are being pursued across Europe, funded both nationally and by ESA, and a revised proposal will be made to the forthcoming ESA L2/L3 call. Selection as L2 would result in a launch in the late 2020s. STFC funded groups at the Universities of Birmingham, Cardiff, Cambridge, Glasgow and Southampton have contributed to data analysis techniques and the study of potential sources of gravitational waves that could be detected by a future space-based gravitational waves mission.

**WIDER TECHNOLOGY IMPACT**
Technology developed in the UK is already proving useful outside the field of gravitational waves.

- The improved coatings for highly reflecting mirrors have applications in inertial navigation and time/frequency standards.
- The oxide bonding technique for silicon carbide and other materials is leading to developments in the optics and engineering industries.
- The novel interferometric sensor, EUCLID, from the University of Birmingham is now being commercialized.
- A collaboration with a US company aims to apply suspension technology to the oil industry.

wiDergo technology impact
Technology developed in the UK is already proving useful outside the field of gravitational waves.