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Current and future status of gravitational wave astronomy - gravitational wave facilities

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Abstract. Currently a network of interferometric gravitational wave detectors is in operation around the globe, in parallel with existing acoustic bar-type detectors. Searches are underway aimed at the first direct detection of gravitational radiation from astrophysical sources. This paper briefly summarizes the current status of operating gravitational wave facilities, plans for future detector upgrades, and the status of the planned space-based gravitational wave detector *LISA*.

Keywords. gravitational waves

1. Introduction

Gravitational waves are strains in space-time caused by the acceleration of mass, as predicted by Einstein's General Theory of Relativity. Sources of astrophysical interest include black hole and neutron star coalescences, low-mass X-ray binaries, supernova explosions and rotating asymmetric neutron stars (Hough *et al.* 2005). Predicted astrophysical signals are at a level where detectors with strain sensitivities of 10^{-23} or better are required.

2. Status of gravitational wave detectors

2.1. *Current detectors*

Currently a gravitational wave detector network exists based on sensing the changes, induced by gravitational waves, in the relative arm lengths of large interferometers. The US LIGO project (Waldman *et al.* 2006) comprises two 4 km long detectors, one in Hanford, WA, and one in Livingston, LA. A 2 km detector exists inside the same evacuated enclosure at Hanford. The 3 km long French/Italian VIRGO detector (Acernese *et al.* 2006) near Pisa is close to completing commissioning and the 300 m long Japanese TAMA 300 detector (Takahashi *et al.* 2004) is operating at the Tokyo Astronomical Observatory. The German/British detector, GEO600 (Hild *et al.* 2006), through use of novel technologies is expected to reach a sensitivity at frequencies above a few hundred Hz close to those of VIRGO and LIGO in their initial operation. Complementing the interferometers is a network of cryogenic bar detectors, running continuously with amplitude spectral densities of less than 10^{-21}. Links to projects can be found at: <http://gwic.gravity.psu.edu/>.

Four science data taking runs have been completed with the LIGO detectors. Three of these involved the GEO and TAMA detectors. New 'upper limits' have been set on the strength of gravitational waves from a range of sources, see for example, publications available at <http://www.ligo.org/results/>. The 5th LIGO science run started on 4th Nov 2005 with GEO having joined in January 2006. Ongoing searches for gravitational wave signals are at a level where it is plausible that a detection could be made.

3. Planned upgrades to detectors

However, detection with initial systems is not guaranteed; a ten times improvement in sensitivity is needed to reach levels where many signals are expected. Thus plans for an upgraded LIGO, 'Advanced LIGO', are already mature (Fritschel 2003). The upgrade is approved by the National Science Board with the start of US construction funds from the NSF account for large projects (MREFC) anticipated in 2008, construction expected to start in 2010, and with initial operation by 2014. Contributions from the UK (PPARC) and Germany (MPG) are already approved. Around the same time, an upgrade to VIRGO is planned along with the rebuilding of GEO as a detector with high sensitivity at kHz frequencies, and the building of an underground detector, LCGT (Kazuaki *et al.* 2006), in Japan. In Australia, the ACIGA consortium operates an 80 m interferometric testbed and has plans for a future full-scale interferometer. The advanced technology planned for the 'DUAL' acoustic-type detector could allow it to have a sensitivity equal to that of interferometers at high frequencies.

Ongoing laboratory research will complement the proposal in Europe of a design study for a 3rd generation interferometric detector, aimed at the European Community Framework 7 funding call.

4. *LISA*

LISA is a space-based interferometric gravitational wave detector proposed jointly by a US/European team (Danzmann & Rüdiger 2003), aimed at signals in the region of 10^{-4} Hz to 10^{-1} Hz. A demonstrator mission '*LISA Pathfinder*' is in phase C/D, preparing for launch in 2009. A US study to prioritize the launches of the *LISA*, *Con-X*, and *JDEM* missions is imminent. On the ESA side, final commitment to *LISA*s implementation will be influenced by the success of LPF. However, work is underway before *LPF* launch to define the *LISA* mission and prepare the invitation to tender for the implementation phase. With NASA's selection in FY 2009 and ESA's final commitment, *LISA* is expected to enter the implementation phase in 2011, with launch in the 2015 to 2016 timeframe.

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