European Science Foundation
**Standing Committee for Physical and Engineering Sciences (PESC)**

## ESF PESC EXPLORATORY WORKSHOP

# Toward a 3rd generation European Gravitational Wave Observatory

**Perugia, Italy, 20-23 September 2005**

**Scientific Report:**
**Michele Punturo** [3]

## *Executive Summary*

The workshop was convened by Dr. Michele Punturo (INFN-Sezione di Perugia, Italy) and Prof. Flavio Vetrano (Università degli Studi di Urbino, Italy) and organized in the conference infrastructures of the Hotel Giò, Perugia, Italy. All the logistic information to the participants have been given trough a dedicated web server that contains also all the relative documents:

http://esf-gw.pg.infn.it

The workshop has been mainly supported by the European Science Foundation (EW04-112 (PESC)), but some of the participants preferred to use personal research funds for the travel reimbursement. The arrival of the majority of the participants occurred the 20th of September 2005; few participants anticipated their arrival because few parallel working meetings have been organized around this ESF event. The official sessions started the 21st morning.

The meeting brought together a number of distinguished physicists working in the gravitational wave detection field. At the meeting were present representatives of all the detectors build in Europe (and in USA). The workshop started with the status report of the active ground based detectors, Virgo, LIGO, GEO, Auriga, Nautilus and Explorer and with the presentation of the status of the advancement of the design of the future, space based, interferometer LISA.

Then we had a talk, "*Scientific case for advanced detectors*", presented by B.S. Sathyaprakash that given the theoretical framework and justification of the following talks about the technologies for future detectors. In the long list of these talks, has been presented also the collaboration experience made in USA between the LIGO scientific collaboration and an *high tech* industry (Frequency Device).

After the partial views given by the talks on advanced technologies, the presentation of the advancement status of future detectors projects given the global view of the needed progresses.

The final part of the workshop has been dedicated to the technologies for the 3rd generation observtory and finally to the discussion of a possible European common project to be submitted to the European Commission.

## *Scientific Content*

The 1st generation of gravitational wave (GW) interferometric detectors, LIGO in USA, TAMA in Japan, GEO600 in Germany, VIRGO in Italy, is currently in operation. Because of their limited sensitivity, their capability of detecting GW signals is restricted to a few MPc distance from the astronomical source.

A second generation of interferometric detectors is under study in USA and in Europe to reach a promising detection probability. Research and development and preparatory work for the second generation have been going on for almost a decade now. The European GEO600 detector, testing some of such 2nd generation technologies, is now operating very successfully. The design for the 2nd generation upgrade of the US antenna, the so-called Advanced LIGO, is based on that technology to improve the current LIGO sensitivity about 10 times in amplitude. The European VIRGO (Italy-France collaboration) detector is in the commissioning phase right now. It already incorporates some advanced solutions and should achieve a low-frequency sensitivity somewhere between LIGO and Advanced LIGO. An upgrade to an Advanced VIRGO will be implemented in 2009-2011. As Advanced LIGO and Advanced VIRGO go into construction, GEO600 will be converted into a high-frequency detector. Resonant bars detectors (AURIGA, EXPLORER and NAUTILUS) have just demonstrated the possibility to enlarge their bandwidth up to 100 Hz. In a few years these bars will also be upgraded to an advanced version, by the use of quantum limited readouts and materials with higher cross section to GW. The MINIGRAIL spherical detectors, at present under construction in Holland, will soon start operation and in the future will also be upgraded with quantum limited readouts.

The plans for the upgrade of the existing LIGO and VIRGO facilities are based on sound engineering practices and no major scientific breakthroughs are required. The leap forward from simple GW detection to GW astronomy requires to design a new observatory that:

- Is able to routinely detect compact binary in-spiral and merger several times per week, up to a distance equivalent to a redshift z = 2. This will help measure the rate of star formation and give clues to the nature of stellar evolution in the early Universe. Working with gamma-ray observatories, it may provide detailed information, at high signal-to-noise ratios, of the events that produce gamma ray bursts. High-redshift supernova observations have revealed that 70% of the Universe is dark energy. This is yet to be confirmed by observing the rate of expansion beyond z = 1. Black Hole binaries serve as standard candles and

therefore one can combine the detections of Black Hole mergers, possibly in coincidence with detectors in America or Japan, (which would provide the sky position and luminosity distance) and optical observations of host galaxies (which measure the redshift) at $z > 1$ to infer the rate of expansion of the Universe in the early epochs and hence infer the nature of dark energy. This should ascertain if dark energy is indeed due to a cosmological constant or if there is an even deeper mystery behind these observations.

- Is capable of inferring the presence of a relic radiation from the early Universe at the level of 10-10 of the closure density (or 10-11, if in coincidence with a similar third-generation detector in America or Japan), more than a million times fainter than the cosmic microwave background radiation. At this level most of the cosmic string models for the early universe could be ruled out, providing stringent constraints on theories of fundamental physics.
- Allows detection of (r-mode) instabilities in rapidly rotating, newly born neutron stars in the Virgo super-cluster with a signal-to-noise ratio of more than 100. Supernovae in Virgo may be as frequent as twice a month, but most are hidden and are not found in optical surveys. A 3rd generation GW observatory could detect them, and in addition it would study the details of the cooling of the Neutron Stars after they form, since the rate of emission of gravitational radiation from r-modes is temperature-sensitive.

A 3rd generation Gravitational Wave Observatory will be built using new European technology. It will develop and apply a number of important technologies that are not used in the first- and second-generation interferometers and resonant detectors: Non-classical light, Quantum Non-Demolition position sensing, advanced lasers emitting 100W of continuous power, novel signal enhancing techniques, interferometry using diffractive optics, cryogenic cooling of critical optical components, monolithic suspensions for the optical components and Quantum Limited amplifiers. Spin-offs of these new technologies are foreseen in different fields, like

- high sensitivity position sensing and control
- signal extraction from noise
- advanced optics equipment

## *Assessment of the result and future developments*

Very promising has been the final discussion on the future developments. The representatives of the two interferometric detectors, GEO and Virgo, expressed the intention to present a common project for a 3rd generation observatory to the European Commission in the next FP7 program. The resonant detector collaborations evaluated that the FP7 design study tool don't fit with their time and size constrain for the upgrade of their detectors, and expressed the intention to support this initiative. A program of future meetings for the realization of this 3rd generation observatory design study will be organized by some of the workshop participants.

## *Participants final list*

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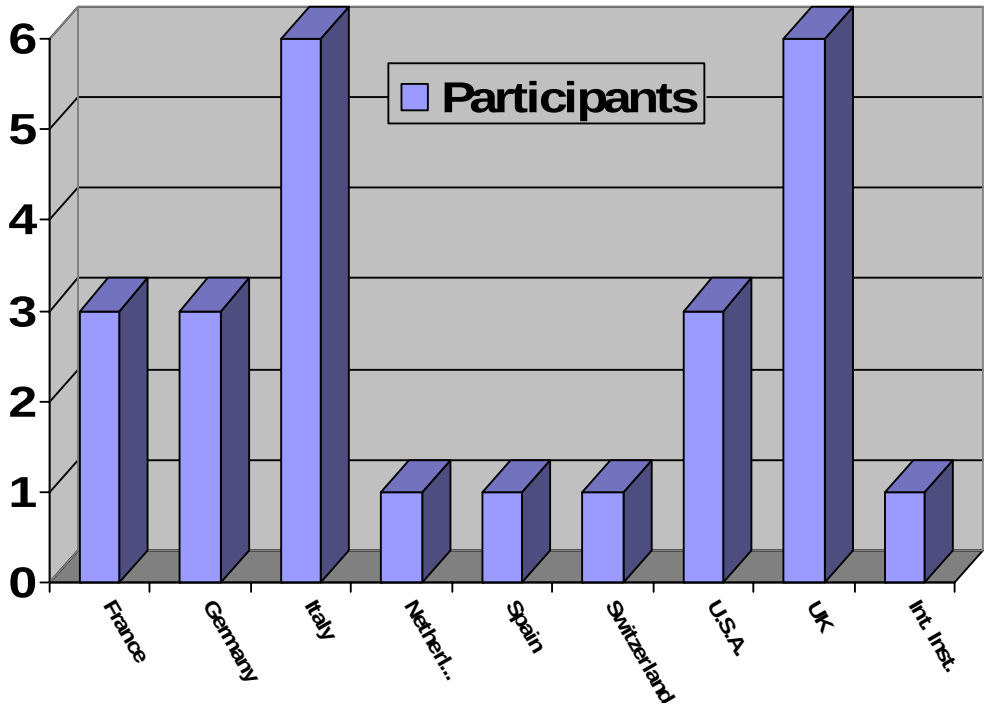
## *Statistical information*

**The full number of participants was 25, with a country distribution reported in the following histogram (Int. Inst means international Institution). In the Italian participants have been accounted the convenors and in the British participants the ESF representative. Not all the participants have been fully supported by ESF, but few of them have partially used their own travelling founds.**



# *Final Programme*

## Wednesday 21 September 2005

09.00 – 11.00 Registration

*Welcome Coffee Break*

### Opening Talks

Chairman: M.Punturo

11.15 – 11.30 Welcome talk **F. Vetrano**

11.30 – 11.45 **Presentation of the European Science Foundation (ESF)** **Ian Butterworth** (Standing Committee for Physical and Engineering Sciences)

### Status of the experiments

Chairman: F.Vetrano

11.45 – 12.15 Status of VIRGO **B. Mours**

12.15 – 12.45 Status of GEO **B. Wilke**

*Lunch*

### Status of the experiments

Chairman: B.Mours

15.00 – 15.30 Status of LIGO **G.Mueller**

15.30 – 16.00 Status of Auriga **M. Cerdonio**

16.00 – 16.30 Status of Explorer and Nautilus **M.Visco**

16.30 – 17.00 Status of Minigrail **G. Frossati**

*Coffee Break*

17.00 – 17.30 LISA **K. Danzmann**

## Scientific case for advanced detectors

Chairman: K.Danzmann

17.30 – 18.00 Scientific Case for 2nd and 3rd generation detectors **B.S. Sathyaprakash**

## Technologies for advanced detectors

18.00 – 18.15 Electrostatic actuators: from the GEO experience to the 2nd generation requirements **H. Lueck**

# Thursday 22 September 2005

## Technologies for advanced detectors

Chairman: G.Cagnoli

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|---|---|
| 09.00 – 09.20 | Low noise FS suspension: from the GEO experience to the 2nd generation requirements **G. Cagnoli** |
| 09.20 – 09.40 | Collaboration between industry and research institution: the *Frequency Devices-LIGO* case **Don Carolan** |
| 09.40 – 10.00 | Low noise controls and electronics **B. Mours** |
| 10.00 – 10.10 | Discussion and other contributions on: Low noise controls in suspended optics |
| 10.10 - 10.30 | New materials and cooling techniques for test masses **G. Frossati** |
| | *Coffee break* |

Chairman: J.Hough

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|---|---|
| 11.00– 11.30 | Mirrors for advanced interferometers: substrate and coating requirements **S.Rowan** |
| 11.30 – 12.00 | High power lasers **B. Wilke** |
| 12.00 - 12.20 | Input Optic requirements and components for High Power lasers **G. Mueller** |
| 12.20 – 12.40 | Thermal compensation: the GEO and LIGO experience and the requirements for the advanced detectors **G.Harry** |
| | *Lunch* |

## Technologies for advanced detectors

Chairman: A.Giazotto

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|---|---|
| 15.00 – 15.20 | Signal Recycling: from the GEO experience to the 2nd generation detector requirements **H. Lueck** |

**Advanced Detector Project Status**

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|---|---|
| 15.20 – 15.40 | Highlighs on the EGO R&D program **F. Menzinger** |
| 15.40 – 16.00 | GEO HF project status report **H. Lueck** |
| 16.00 – 16.20 | Advanced Virgo project status report **M. Punturo** |
| 16.20 – 16.40 | Advanced LIGO project status report **G. Harry** |
| | *Coffee break* |

Chairman: E.Coccia

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|---|---|
| 17.00 – 17.20 | Advanced Spherical detector **E. Coccia** |
| 17.20 – 17.40 | Dual **M. Cerdonio** |
| 17.40 – 18.00 | Readout SQUID based and Quantum Limit **G. Prodi** |
| 18.00 – 18.20 | Discussion and other contributions on:<br>• Quantum limited resonant readouts<br>• Optical readouts for resonant detectors |
| 20:00 | *Social dinner* |

## Friday 23 September 2005

### Technologies for 3rd generation detectors

Chairman: M.Cerdonio

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|---|---|
| 09.00 – 09.20 | 3rd generation detectors: thermal noise & Co.: Strega project **G. Cagnoli** |
| 09.20 – 09.40 | Capabilities of advanced resonant spheres **M. Maggiore** |
| 09.40 – 10.00 | Quantum noise observation and control **A. Heidmann** |
| 10.00 – 10.20 | All reflective ITFs **A. Giazotto** |
| 10.20 – 10.30 | Discussion and conclusive remarks (**ALL**) |