The gravitational waves network within a global network of observatories

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• ground based gw detectors in the 2010s:
  efforts in US, Eu, Japan, Brasil (+ Au and Cina)

• LISA and beyond

• the need for networking gw detectors:
  sky, frequency and time coverage
  false alarms and confident detections
  direction & polarization of incoming gw

• violent events in the cosmos involving matter at extreme densities:
  a gw observatory within an international network for multimessenger searches

• imagining gw as one of the astronomies in 2025
  (assuming 2010s expectations fulfilled)
goals trends needs

• optimize performance of gw observatory
  >>> broaden the geographical distribution of the detectors, upgrade detectors to second (and third) generation, coordinate their on/off

• evolve from initial detections to steady observations
  >>> optimize directed searches: gw an astronomical tool

• solicit input from theory
  >>> accurate waveforms from numerical relativity to enhance SNR

• roadmap to second generation detectors
  LIGO adv-NSF, VIRGO adv-CNRS/INFN, GEO

• proposals for additional detectors
  Europe-EGO/ApPEC/ILIAS, Australia, Cina

• seeds for third generation detectors
  LSC-NSF, EGO-CNRS/INFN/MPG/PPARC

• studies on networking
  GWIC, ILIAS
  • coordination and collaboration between agencies worldwide to enhance and optimize trends
about “the role…”
(after all these considerations)

• one single detector cannot do much more than niche searches (e.g. continuous signals from a pulsar)
• a subset of detectors can give validated h(t), but only for a limited sky/frequency/on-time coverage
• only a global network of detectors, suitably arranged, with sufficient data analysis capabilities and input from theory, can give all sky, full on-time and wide frequency band h(t) and then enter gw data in the multimessenger astronomy arena
• the configuration of such a global gw observatory will be defined in the 2010 timeframe, but actions from projects/GWIC and agencies must start soon
The Gravitational Wave International Committee was formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave facilities world-wide. It is affiliated with the International Union of Pure and Applied Physics as a sub-committee of IUPAP's Particle and Nuclear Astrophysics and Gravitation International Committee PaNAGIC.

GWIC's Goals:

• Promote \textit{international cooperation} in all phases of construction and \textit{exploitation of gravitational-wave detectors}
• Coordinate and support \textit{long-range planning for new instrument} proposals, or proposals for instrument upgrades
• Promote the development of \textit{gravitational-wave detection} as an \textit{astronomical tool}, exploiting especially the potential for \textit{coincident detection} of gravitational-waves and other fields (\textit{photons, cosmic-rays, neutrinos})
• Organize regular, world-inclusive meetings and workshops for the study of problems related to the development of exploitation of new or enhanced gravitational-wave detectors, and foster research and development of new technology
• Represent the gravitational-wave detection community internationally, acting as its advocate
• Provide a forum for the laboratory directors to regularly meet, discuss, and plan jointly the operations and direction of their laboratories and experimental gravitational-wave physics
problems on the road to 2025  
(to be addressed by the agencies)

• undermanned/underwomened
  >>> long delays between data taking and finalization of results (OK for upper limits, but for detections one wants “real time”…)
  >>> slow progress in critical R&Ds for “advanced” and “third generation” instruments (materials, quantum optics, electronics, beyond “quantum limits,…)
  >>> frontier methods in data analysis with massive computing
  >>> numerical relativity

the gw field is blossoming in difficult times for hiring and giving steady jobs to young scientists (in most countries): agencies should have a special understanding of the problem

Need aggressive R&Ds for “advanced” instruments [LIGO the only one with a definite program, but need the others do their share too (EU is starting with 1 ifo + 1 acoustic, Japan is doing very well, but needs fundig approval)) (Australia…?) (Cina…?)]
  >>> agencies should try to coordinate efforts rather than compete
ground based gw detectors in the 2010s prospective: projects & trends

US
LIGO advanced ★★★
towards the limits of the facility

Eu
VIRGO ★ & GEO ★★ upgrades
sphere ★★ dual spheres design ★
third generation "observatory"
(one interferometer + one acoustic ?)

Brasil
sphere ★★

Japan
LCGT ★★

Australia (to fill up for sky coverage) and China (to cover the low frequencies in proximity of the "wall") may come up with one interferometer each
Intercontinental Network of Gravitational Waves Detectors

IGEC: International Gravitational Event Collaboration
Reduction in the burst amplitude sensitivity in respect to best orientation

- 4 interferometers (LIGO, VIRGO, TAMA GEO)
- 2 bars (AURIGA+25°, LSU−30°)
false alarm rate [$yr^{-1}$]

common search threshold [gw amplitude h]

AL-AU

AL-AU-NA
Final Results of the IGEC coincidence Search

Upper Limit on the Rate of gravitational waves bursts from the GALACTIC CENTER random arrival times and amplitude ≥ search threshold \( h \)


The Area above the blue curve is excluded with a coverage > 90%

search threshold \( h \)

\[ h \sim 2 \times 10^{-18} \quad \leftrightarrow \quad \Delta E \sim 0.02 \ M_\odot \text{ converted @ 10 kpc} \]
the need for networking (1)

sky coverage:
compensate for loss of sensitivity due to antenna pattern effects by operating in correlation a number of detectors

depth coverage:
advanced interferometers and dual spheres ???

time coverage:
coordinate detectors on/off periods (for maintenance, upgrade, relocation,...) so to maintain a uniform performance of the network
the need for networking (2)
false alarms and confident detections

obvious argument:
initial detections may be more convincing if from detectors of different make

• continuous and quasi-continuous signals: in principle single detector operation, but other detectors confirmation welcome

• stochastic background: correlation between at least two detectors distance determines frequency range

• bursts: false alarm rates decrease dramatically with the number of detectors in coincidence

  ➢ the gw observatory may need a maximum false alarm rate, say 1 ev/cy, to enter multimessenger searches with other observatories

  ➢ a useful exercise: the IGEC search
the need for networking (3)

detectors are noise dominated and gravity cannot be shielded:
what can be done beyond statistical and/or circumstantial evidence to identify confidently incoming gw signals and guess where they come from ???

get signatures
- from time evolution of signal (es: Doppler)
- get direction, polarization and versus
- test for c-velocity and Riemann tensor

solve “inverse problem” (various exercises for impulsive signals: 2 spheres, 6 bars, 3-4 ifos, 4 ifos+2bars, ifos+sphere,...) to get
  # Riemann-like tensorial properties as tracelessness, transversality, spin 2
  # c-velocity propagation within the network
  # direction, polarization and versus
  # measure the total burst energy with omnidirectional sensitivity
3000 attempts

Signal $10 \, h_{\min} \, S(\theta)$, linearly polarized $30^\circ$, R.A. $3^h 35^m 8^s$, S 320°18′

Antennae in "dodecahedron" configuration, same location, same pulse sensitivity $h_{\min}$

SNR of antennae are respectively 4.5, 6, 1, 9, 10, 1

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An exercise.....

Notice: The resolution is degrees!
Massimo(84) tells Annamaria he is considering to retire, after enjoying the wonderful findings of the multi-astronomy global observatory at work.