Global Coordination of Third-generation Ground-based Gravitational-wave Detectors

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The current situation

- A network of ground-based GW detectors has succeeded spectacularly
- We see the science potential of a major step forward
- The astronomy world is awakened to the potential of GW by a network that 'points'
  - » It is the ***network*** that has broad community impact

  → We need to be proposing a ***network*** of 3G instruments

- **This is the right time to be formulating the next generation of instruments**

Timelines for Detectors

- E.g., Initial LIGO → ~20 years from 'green fields' to Observatories
  - **1983** MIT and Caltech jointly present results of the km-scale interferometer study to NSF. Receive endorsement by NSF committee on new large programs in physics.
  - **1990** The US National Science Board (NSB) approves the LIGO construction proposal, which envisions Initial LIGO followed by Advanced LIGO.
  - **1994-1995** Site construction begins at the Hanford and Livingston locations.
  - **2002** The first coincident operation of Initial LIGO interferometers with the GEO600 interferometer.
- Advanced LIGO → ~15 years (but the infrastructure was there)
- 3G detectors are 3-10x 'larger' projects (not *necessarily* longer…)

- Current infrastructures aging
- Sister project LISA launching in 2030's – multiband detections

- **Yet more reasons to be active now.**

LIGO-Virgo-KAGRA history

- First generation GW interferometers were independently designed and constructed.
  - NSF's LIGO, Virgo (joint French, Italian), GEO (joint German, UK)
- Second generation GW detectors had some elements of coordination …
  - NSF's Advanced LIGO had US, UK, German, Australian contributions
  - Virgo/LIGO Trades of technical solutions, leadership headaches
- … but by and large were independently designed and built
- We now collaborate on the analysis of GW data; LIGO-Virgo agreement (2007), LV pre-agreement with KAGRA (2013)
- LIGO Laboratory and India have initiated a joint project to build a third LIGO interferometer 'LIGO-India' in India by the mid 2020s to expand the capabilities of the existing GW network

- **We already see the strong advantages – and scientific necessity – of cooperation and collaboration.**

3G = MegaScience

- The scale of the project (at least two 10+ km class interferometers) may require coordination across collaborations/projects to take advantage of 'economies of scale'
- Advantages of coordination
  - (At least partial) homogeneity in design and construction; 'best of' solutions, efficient design and build phase, reduced cost
  - Coordinated site selection for optimal network design
  - Makes best use of distributed expertise
- Disadvantages of (or challenges in) coordination
  - Requires establishment of robust management structure, necessitating giving up some control by partners
  - Schedules can be pinned to the slowest/poorest partner
  - Requires robust system engineering, establishment of standards, interface control, quality assurance program, …

Likely Steps to funding a 3G network

- Current instruments should reach design sensitivity
  - to have design input for the 3G detectors
  - to demonstrate to funding agencies that we can deliver
- The science case for 3G detectors must be clear
  - Compelling to a broad audience, well beyond GW/GR
- Prepare funding agencies that big projects are being planned
  - E.g., It can take 5 years to get a project 'queued up' in the USA
- The concepts need to pass scientific/technical/organization reviews
- The International planning and coordination of the network needs to be determined, established, and robust
- Need support and advocacy from a large, broad, vocal outside community
  - They will support GW science because it adds to their science
  - Astrophysicists, astronomers, nuclear physicists, cosmologists
  - → **Need to be generous with GW data!**

Open Questions

- What should the 3G network look like?
  - How many? Where? What topology? homogeneous or mixed?
- How to map science case onto detector design?
  - Eg, 40 km arm length put FSR at 3.75 KHz, in the range of signals produced by BNS mergers
- How much coordination is needed?
  - N different detectors, N similar detectors, N identical detectors?
- What is the role of the 2nd gen detectors in the 3G eras?
- How should we be reaching out to other communities to make them aware and, then, advocate?
  - Transient and high energy astronomy; numerical GR, nuclear physics; atomic, molecular, optical physics, high energy physics, cosmology; string/quantum theory…
- How should the ground-based GW community interact with the Astro2020 Decadal survey (US) and APPEC Roadmap (EU)?

How to get from Here to There?

GWIC (Gravitational Wave International Committee)

Body formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities world-wide

- Affiliated with the International Union of Pure and Applied Physics
  - From 1999 until 2011, GWIC was recognized as a subpanel of PaNAGIC (IUPAP WG.4).
  - In 2011, GWIC was accepted by IUPAP as a separate Working Group (WG.11).
- Links to the:
  - International Astronomical Union (IAU)
  - International Society for General Relativity and Gravitation (ISGRG)

Of what is GWIC made?

The membership of GWIC represents all of the world's active gravitational wave projects*, as well as other relevant communities, covering gravitational wave frequencies from nanohertz to kilohertz. Each project has either one, two, or four members on GWIC depending on size.

Einstein Telescope Michele Punturo

European Pulsar Timing Array Michael Kramer

GEO 600 Karsten Danzmann, *Sheila Rowan (Chair)*

IndIGO/LIGO-India Bala Iyer, Somak Raychaudhury

KAGRA Takaaki Kajita, Yoshio Saito

LIGO Dave Reitze, David Shoemaker

LISA Kelly Holly-Bockelmann, Bernard Schutz, Ira Thorpe, Stefano Vitale

NANOGrav Maura McLaughlin

OzGrav Matthew Bailes, David McClelland

Theory Community Luis Lehner

Virgo Jo Van den Brand, Fulvio Ricci

IUPAP AC2 (ISGRG) Beverly Berger

IAU D1 Marica Branchesi

Executive secretary : David Shoemaker
Co- secretary: Stan Whitcomb

*no CMB community membership

GWIC's role in coordinating 3G detector development

GWIC Subcommittee on Third Generation Ground-based Detectors (charged in November 2016)

GWIC 3G subcommittee Purpose and Mission:

With the recent first detections of gravitational waves by LIGO and Virgo, it is both timely and appropriate to begin seriously planning for a network of future gravitational-wave observatories, capable of extending the reach of detections well beyond that currently achievable with second generation instruments.

The GWIC Subcommittee on Third Generation Ground-based Detectors is tasked with examining the path to a future network of observatories/facilities

Committee Membership

Michele Punturo – ET (co-chair)
David Reitze – LIGO (co-chair)
Jo van den Brand – NikHef
Takaaki Kajita – KAGRA
Vicky Kalogera – Northwestern
Stavros Katsanevas – EGO
Harald Lueck – AEI
David McClelland – OzGrav
Sheila Rowan – GWIC Chair
Gary Sanders – TMT
Sathyaprakash – Penn State
David Shoemaker – Secretary

- **Overall committee meets biweekly to conduct business**
- **Subcommittees carry out the charge**
- Web Site https://gwic.ligo.org/3Gsubcomm/

3G Subcommittees

- 3G Science Case
- R&D Coordination
- Community Networking
- Agency Interfacing
- Investigation of Governance Structures

Science Case Subcommittee

Mission: Commission a study of ground-based gravitational wave science from the global scientific community, investigating potential science vs architecture vs. network configuration vs. cost trade-offs, recognizing and taking into account existing studies for 3G projects (such as ET) as well as science overlap with the larger gravitational-wave spectrum.

Goals

- Develop a robust science case unique to GW observations for the next generation of ground-based detectors
  - ➢ build the case based on refereed publications
  - ➢ could influence and impact position papers for national and international studies and surveys

e.g. APPEC and ESFRI roadmaps in Europe, Astro2020 US decadal survey

Science Drivers

Seed black holes	**Multi-messenger observations**
Neutron star structure	**Extreme gravity**
Compact binaries	**Analytical and numerical relativity**
Cosmology, early Universe	**Detector networks**
Supernovae	

Science Case Team

- An open call to join the 3G SCT Consortium in July 2017
- ~ 210 researchers from around the world have joined the consortium
  - » members can join and contribute to as many science working groups as they wish
  - » the nine working groups each have between 20 to 40 members
- Meeting in Potsdam 1-2 October 2018

R&D Coordination Subcommittee

- Mission: Develop and facilitate coordination mechanisms among the current and future planned and anticipated ground-based GW projects, including identification of common technologies and R&D activities as well as comparison of the specific technical approaches to 3G detectors. Possible support for coordination of 2G observing and 3G construction schedules.

- **Activities**:
  - Review current R&D levels of activity and of collaboration amongst detector groups
  - Evaluate subsystem designs and interdependencies
  - Identify technology shortfalls

Light sources (Lasers + squeezers)

Coatings

Low Frequencies (NN) + site requirements

Simulations & Controls

Facilities & infrastructure

Cryogenics

Suspensions and Isolation

Core optics

Aux optics

Quantum noise + Configurations

Networking Subcommittee

Overseen by co-chairs Michele Punturo and Dave Reitze; provides a coordinating function

Mission: organize and facilitate links between planned global 3G projects and other relevant scientific communities, including organizing:

- town hall meetings to survey the community
- dedicated sessions in scientific conferences dedicated to GW physics and astronomy
- focused topical workshops within the relevant communities

Agency Interfacing and Advocacy Subcommittee

Overseen by Sheila Rowan, as GWIC Chair

Mission: identify and establish a communication channel with funding agencies who currently or may in the future support ground-based GW detectors; communicate as needed to those agencies officially through GWIC on the scientific needs, desires, and constraints from the communities and 3G projects (collected via 1) – 3) above) structured in a coherent framework; serve as an advocacy group for the communities and 3G projects with the funding agencies.

- Presentation at APPEC General Assembly, Barcelona (Dec 2017)
- Telecon with GWAC – Gravitational Wave Agencies Correspondents
  - https://www.nsf.gov/mps/phy/gwac.jsp

GWAC

- *"This group's main purpose is to create a direct channel of communication between funding agencies to coordinate the use of existing and explore new funding opportunities for the gravitational wave science community."*
- **Member Agencies**
  - » Australian Research Council (ARC)
  - » Canada Foundation for Innovation (CFI)
  - » Centre National de la Recherche Scientifique (CNRS)
  - » Conseio Nacional de Ciencia y Tecnología (CONACYT)
  - » Deutsche Forschungsgemeinschaft (DFG)
  - » Indian Department of Atomic Energy (DAE)
  - » Indian Department of Science and Technology (DST)
  - » Istituto Nazionale di Fisica Nucleare (INFN)
  - » National Aeronautics and Space Administration (NASA)
  - » National Science Foundation (NSF)
  - » Netherlands Organisation for Scientific Research (NWO)
  - » Science&Technology Facilities Council (STFC)

Governance Evaluation Working Group

- **Mission:** By applying knowledge of the diverse structures of the global GW community, propose a sustainable governance model for the management of detector construction and joint working, to support planning of 3rd generation observatories.

- Evaluating governance structures of existing large scale, international scientific enterprises. Their strengths, weakness, and relevance to 3G GW
- Will provide evaluations and make recommendations to the GWIC 3G subcommittee

Governance Evaluation Working Group Status

Examining governance structures for 21 existing/planned projects/facilities

ALMA	ITER
AUGER	KAGRA
CERN	KM^3
CTA	LHC Experiments
DUNE	LIGO
EGO/VIRGO	LSC/VIRGO
ELI	LSST
ELT	SKA
ESS	SNOLab
IceCube	TMT
ILC	

Time Scales for Completing 3G Subcommittee's Work

- Subcommittees will assemble their reports to have a preliminary report and set of recommendations by the 2018 GWIC meeting (Chicago, July 2018).
- 'Dawn IV' Workshop, Amsterdam August 30-31 discussion of interim results
- Preliminary report will be broadly circulated for comment and input among the relevant communities.
- Interim report not later than December 2018 delivered to relevant communities and GWAC
- Final report sometime in mid-2019

- **Contact Michele Punturo or Dave Reitze to engage**
  - michele.punturo@pg.infn.it, reitze@ligo.caltech.edu