GWIC- Advocacy in the Science Community; Outreach

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Community Networking Subcommittee

- Planning for the development of a 3G global GW detector array is a complex effort that requires strong community input.
- **The Community Networking Subcommittee within the GWIC 3G Planning Committee is charged with organizing and facilitating communications between 3G projects and the relevant scientific communities who will utilize and benefit from the operation of those detectors**
  - to raise awareness of the ongoing planning efforts
  - to effectively communicate the progress on planning and development
  - to establish means for input and feedback from the constituencies in the planning process, and iterate with the communities as plans evolve.
- Need a **communication and outreach plan** for engaging with and rallying the relevant communities into the 2020s, as the roadmap toward a 3G detector network is finalized and executed.
- It will be critically important to **maintain a highly visible profile** for 3G detectors through continued communication of the planning and progress as it occurs.

1. Scientific stakeholders / constituencies

- **Who are the scientific stakeholders and to what degree those stakeholders will benefit from and contribute to the scientific output of a 3rd generation global array?**
    - The community of gravitational-wave ‘users’ has grown rapidly over the past decade and will likely continue to grow into new domains now that the field is delivering scientific results.
    - The scientific stakeholders will be the strongest advocates for making the case for building an operating the next generation of interferometers.
        - Each interferometer node in the detector array is very likely to cost more that the entire existing generation of gravitational-wave observatories. As such, new GW facilities will come directly into competition with other planned large-scale scientific infrastructure projects, each with their own group of scientific proponents.

The Ground-based Gravitational-wave Community

- The primary 'user' base for ground-based gravitational-wave detectors.

- The key to the success of the existing ground-based gravitational-wave observatories – LIGO, Virgo, GEO600 – has been the **tight integration of their scientific teams** and the collaborative structures that have developed and grown among the projects over the past 25 years (the LIGO Scientific Collaboration and Virgo Collaboration)

- The existing collaborative framework among LIGO, Virgo, and GEO600 has been designed to grow and incorporate new 2nd generation gravitational-wave observatories – KAGRA and LIGO-India – as they come online. This **'collaboration of collaborations'** framework already provides the necessary structures and communication pathways for engagement and communication with the GWIC 3G Committee. Collectively, these existing ground-based detector collaborations are made up of more than 1600 researchers who are a natural and powerful advocacy group.

    - While the 'collaboration of collaborations' model will be an effective structure for communicating, it will very likely not scale to become a governance model for a 3rd generation global detector array.

- In February 2018, the Einstein Telescope (ET) project formally established a collaboration to support the development of the 3rd generation ET detector in Europe. Likewise, a collaboration is expected to develop around the US-based Cosmic Explorer (CE) effort in the future.

Other Gravitational-wave Communities

- **Laser Interferometer Space Antenna (LISA)**
  - LISA is the L3 ‘large class’ mission of the European Space Agency with NASA support currently under negotiation, currently slated for launch in 2034. It will be sensitive to mHz GW frequencies.
  - LISA will primarily focus on different GW sources (intermediate or light supermassive black hole mergers, galactic white dwarf binaries) but will have overlapping science goals with 3G detectors. Collaborating and coordinating with the LISA community of ~ 850 researchers will be beneficial. LISA is a member of GWIC, thus a natural channel already exists for coordination to take place.
    - E.G.: BBH sources will be detected by LISA months to years before merger. Thus LISA can serve as an ‘early warning’ alert to the 3G global network and electromagnetic/particle observers for interesting and/or novel BBH events.
- **Radio telescope Pulsar Timing Arrays (PTAs)**
  - GW detection via radio telescope pulsar timing arrays extends the search for gravitational waves down to the nanoHertz range. Primarily focusing on supermassive black hole (SMBH) mergers.
  - Though perhaps not as directly connected to ground-based community as LISA, synergies exist with the PTA community. As with LISA, the pulsar timing community (NANOGrav, the European Pulsar Timing Array, and the Parkes Pulsar Timing Array Collaborations) are members of GWIC.

Transient Astronomy and High-energy Astrophysics

- The detections of BBH and BNS mergers by LIGO and Virgo have dramatically raised awareness of communities that traditionally were not in direct contact with the ground-based GW community
  - especially true of BNS merger GW170817, with the discovery of an optical counterpart to GW170817 and the subsequent massive follow up campaign by a large fraction of the transient astronomical community comprising over 2000 astronomers and astrophysics.
- **Electromagnetic astronomy and ground-based GW communities now have very strong overlapping scientific interests in the arena of GW sources containing matter, and the transient astronomy and high-energy astrophysics communities will be a very important scientific constituency for future GW detectors**
  - A large fraction of the high energy astrophysics community, from gamma ray to radio astronomers, are eager to receive alert from LIGO-Virgo as well as to collaborate on selected science targets.
- **Localization** of the GW source is critical: the ability to provide well-defined error regions on rapid (minute) timescales will be one of the important pillars for the science case of a 3G global network, and in particular for building three widely separated 3G detectors.

Cosmology, Fundamental Gravity, Dark Matter, and Dark Energy

- **Cosmology and Fundamental Gravity**
    - 2G detectors will produce more precise measurements of the Hubble constant and put more stringent limits on GR in the dynamical strong field regime.
    - A 3rd generation network will deliver vastly improved measurements and open up new avenues for investigation. For instance: measuring the post-merger black hole ringdown to definitively answer the question 'are black holes really bald?'
- **Dark Matter and Dark Energy**
    - The limits on the difference between the speed of light and the speed of gravity from GW170817 have already ruled out some exotic dark matter and dark energy models. 3G detectors will potentially be able to constrain the dark energy equation of state independently of current methods using electromagnetic observations.
    - Similarly, the first gravitational-wave detections have produced theoretical models conjecturing that LIGO-Virgo black holes may be a component of dark matter. While the connection between gravitational waves and dark matter is very preliminary and speculative at present, there is clear interest in understanding how gravitational-wave searches can shed light on the nature of dark matter.
- **These aspects of gravitational-wave science touch upon many communities, including cosmology, numerical relativity and analytical relativity.**

Nuclear and High Energy Physics

- **Nuclear Physics:**
  - GW170817 demonstrated new insights into ‘r-process’ nucleosynthesis of heavy elements derived from observing the kilonovae produced by BNS collisions and measurements of the equation of state of neutron stars.
  - More speculatively, the discovery of exotic stars (e.g., quark, electroweak, or bosonic stars) by GW observations could reveal completely new high-density states of matter.
- **High Energy Physics:**
  - **Scientific** synergies on common and contiguous research items exist
    - For example, CERN is investing growing resources into research of dark matter particle candidates like axions both within in LHC and in other apparatuses (e.g. the CERN Axion Solar Telescope). The impacts of axion like dark matter could be investigated in the coalescence of black holes and in the propagation of gravitational waves.
  - **Technologies** developed by the experimental HEPP community can be adapted and adopted into the realization of the future GW observatories.
    - Areas of obvious overlap include large volume UHV vacuum systems, development of low noise cryogenics, high performance computing, and large underground infrastructure development.

2. Engaging with Major Road Mapping Exercises

- Two major community Road Mapping exercises are currently underway and will continue for the next few years:
    - **ESFRI**: the European Strategy Forum on Research Infrastructures Roadmap
        - a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach, to support a coherent approach to policy-making on RI in Europe, and to facilitate multilateral initiatives leading to the better use and development of RIs.
    - **Astro2020**: the US National Academies Astronomy and Astrophysics Decadal Survey, commissioned by NASA, NSF, DOE
        - to consider the past and current research of the field and provide consensus recommendations for the direction of the field over the next decade. Astro2020 charter specifically calls out gravitational-wave observations in the broader context of astronomy, specifically.
- Additional, more specific exercise:
    - **ESPP**: the European Strategy for Particle Physics is a roadmapping exercise for particle physics carried out by CERN, to be updated sometime in 2020.
        - Although ESPP is addressed to a specific research sector, there are opportunities to submit plans for synergistic GW research in that roadmap. It will be important to develop the interaction mechanism with the HEPP community in order to exploit the possible synergies.

Recommendations

1. The ground-based GW community should actively participate in **scientific conferences in the constituent communities**, to interact with and inform them on 3G-enabled science.
    - GWIC should take an active role in identifying appropriate conferences and reaching out to conference organizers to facilitate participation by the ground-based communities.

2. The major **roadmapping exercises** underway in the US and Europe present critical opportunities for Einstein Telescope and Cosmic Explorer.
    - GWIC should facilitate the submission of white papers by relevant projects as well as follow up by playing a coordinating role as these roadmapping exercises go forward.