Open call for partnership for the EM identification and follow-up of GW candidate events

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LIGO and VIRGO open a call to sign Memoranda of Understanding (MOUs) with astronomers in order to enable a program of electromagnetic (EM) follow-up observations of gravitational-wave (GW) event candidates. While each MOU represents an agreement between LIGO, VIRGO and a single astronomy group, it is an agreement for participation in the program as a whole, which requires sharing information with other partners as well. We have discussed the issues, consulted with astronomers, and settled on a framework for the EM follow-up program that we believe facilitates the science that can be done and will be fair to all participants. The purpose of this document is to provide background on LIGO and VIRGO and outline some of the important details of the GW-EM follow-up program that partners are invited to participate in.

Contents

1 Background on LIGO and VIRGO

LIGO and VIRGO are separate entities operating separate GW detectors, but they cooperate closely and are committed to sharing and analyzing GW data together to maximize the information that can be obtained.

"LVC" is a shorthand designation for the LIGO and VIRGO collaborations together.

1.1 LIGO

LIGO (`http://www.ligo.org`) denotes hereafter the LIGO Laboratory and the LIGO Scientific Collaboration (LSC).

LIGO was built under a Cooperative Agreement between the National Science Foundation (NSF) and Caltech signed in May 1992 (No. PHY9210038). LIGO is a system of three interferometric Fabry-Perot antennas possessing 4 kilometer arm lengths, aimed at the simultaneous detection of GWs in the frequency range 10-6000 Hz. LIGO observatories have been built in Hanford, Washington and in Livingston Parish, Louisiana (USA) and began observations in the year 2002. An additional LIGO observatory in India is planned. The design and construction of LIGO was carried out by the California Institute of Technology

(Caltech) and the Massachusetts Institute of Technology (MIT). Caltech and MIT jointly operate LIGO Laboratory for the NSF under a Cooperative Agreement between NSF and Caltech, with MIT participating through subaward from Caltech. The LIGO Oversight Committee supervises the realization and exploitation of LIGO.

The LSC is composed of approximately 900 individuals from more than 70 institutions worldwide, including scientists and engineering personnel from the LIGO Laboratory. LSC membership includes all of the scientists and engineers in the GEO project (described below).

The LSC Charter establishes the functions, organizational structure and responsibilities of the LSC as well as its role in the research of the LIGO Laboratory, and the release of scientific results. The LIGO leadership consists of a Directorate that includes the LIGO Executive Director, the LIGO Laboratory Deputy Director, and the LSC Spokesperson.

The German/British Collaboration for the Detection of Gravitational Waves (GEO) has built a detector of arm length 600 m (GEO600) near Hannover in Germany, with the purposes of joining in a worldwide search for gravitational radiation from astronomical sources and of developing advanced interferometric and suspension technologies for later GW detectors. The design, construction and operation of the GEO600 system is being carried out by scientists and technologists at the University of Hannover, the University of Glasgow, and the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Hannover and Golm. Data acquisition and analysis are carried out by the Albert Einstein Institute (AEI), Cardiff University, the University of Glasgow and Birmingham University. The project is funded in Germany by the State Government of Niedersachsen, the Max Planck Gesellschaft (MPG), and the Bundesministerium für Bildung und Forschung (BMBF) in Germany, and by the Science and Technologies Facilities Council (STFC) in the UK.

1.2 VIRGO

VIRGO (`http://www.virgo.infn.it`) denotes the Virgo Collaboration and the European Gravitational Observatory (EGO) consortium.

CNRS and INFN signed an agreement on 27 June 1994 concerning the realization of a three kilometer Fabry-Perot interferometric antenna aimed at the detection of GWs in the frequency range 10-10 000 Hz, named Virgo, located at Cascina, Italy. This agreement was superseded by the Agreement between CNRS and INFN, founding the "European Gravitational Observatory" Consortium under Italian law (EGO), signed on 11 December 2000, completed by the agreement signed with the Nikhef on July 2009, the Netherlands becoming an associated member.

The main purpose of EGO is to ensure the end of the construction of the Virgo antenna, its commissioning, its operation and its upgrade, as well as to promote an open co-operation in R&D. The Consortium is supervised by the EGO Council.

The Virgo collaboration is composed of approximately 200 scientists and technicians coming mainly from CNRS and INFN laboratories, which have signed an Agreement on 19 December 2001, as well as from EGO, the Netherlands, Poland and Hungary. Decisions are taken by its steering committee. The overall scientific exploitation of the Virgo antenna is under the responsibility of the Virgo Collaboration

1.3 Estimated observing schedule

The LVC has made public a plausible scenario for the operation of the LIGO-Virgo network over the next decade [1]. The first three observing periods are scheduled in 2015 (3 month duration; with two LIGO detectors at early advanced sensitivity while Virgo is still in commissioning with a chance to join the run), 2016–17 (6 month duration; with both LIGO and Virgo at first stage sensitivity) and 2017–18 (9 month duration; with both LIGO and Virgo at second stage sensitivity). The LIGO and Virgo detectors are expected to operate at full sensitivity beginning in 2019. Note that unexpected problems could slow down the commissioning progress and may change the scheduling and length of those observing periods.

2 Application instructions and eligibility conditions

An application form can be downloaded from `http://www.ligo.org/science/GWEMalerts.php` and should be submitted online in PDF format by **Feb 16, 2015 – 23:59 UTC**.

We are limiting this program to professional astronomers with demonstrated experience, and require that a partner bring some useful observing resource(s), not just astronomy expertise, to participate. Our intent is to accept and sign MOUs with all qualified applicants.

GW triggers will be sent to groups that are in position to make observations. LVC will conditionally accept qualified observers who depend on a pending or future telescope time allocation or facilities that are expected to be operational in the course of next science runs circa 2015–2017 [1, 2]. In those cases, we will send GW triggers once the telescope time is allocated or when the facility has come online.

2.1 Duration of the agreement

Agreements resulting from this open call will terminate on June 1st 2017. We expect to issue calls for additional partners annually, and will naturally accept renewal applications from any partners whose MOUs are expiring.

Any party can discontinue participation in program at any time. However the rules about confidentiality, communications and publications continue to apply to all information exchanged while participating in the program.

A future significant change in the GW detector network, such as the addition of the Japanese KAGRA or LIGO-India detectors when they attain comparable sensitivity, will likely require all MOUs to be ended and re-established.

3 Overview of the GW-EM follow-up program

3.1 Guiding policy

We, the LVC, wish to enable multi-messenger observations of astrophysical events by GW detectors along with a wide range of telescopes and instruments of mainstream astronomy. However, GW astronomy is a new field, and the first direct detections of GW signals after so many years of effort is a particularly sensitive matter. We are striving to find a good balance between making information about GW candidates promptly available to astronomers while keeping control of how our first handful of GW detections are announced to the world.

In 2012, the LSC and Virgo approved a statement [2] which broadly outlines LVC policy on releasing GW "triggers" (event candidates). Initially, triggers will be shared promptly only with astronomy partners who have signed an MOU with LVC. After four GW events have been published, further event candidates with high confidence will be shared immediately with the entire astronomy community (and the public), while lower-significance candidates will continue to be shared promptly only with partners who have signed an MOU.

In making this policy, our main goal is to ensure that the GW data supporting the first direct detections of GW signals are very carefully validated, interpreted and presented **by the LVC**. We will be thrilled if those events are also seen by EM observers, but we cannot allow rumors or unsupported statements hinting at LIGO-Virgo GW detections to reach the news media and general public before we have completed a very thorough validation of the GW data and announce/publish the results. Until that point, we require confidentiality for shared information about GW observations and any EM observations associated with them. (Things will probably relax later, after GW detections are well established.)

3.2 GW event candidate alerts

LVC intends to do rapid searches for GW transient sources including compact binary coalescences and burst signals whenever two or more detectors with comparable sensitivity are collecting science-quality data. LVC will make its best effort to report the significance and sky probability map for each candidate event, although position accuracy is limited, particularly when only two detectors are operating.

LVC will deliver GW candidate information ("alerts") as soon as practical to all partners enrolled in this program. There may be multiple alerts for a given event:

- Preliminary alert: as soon as an event candidate is identified based on its apparent signal significance, but before any additional checks
- Confirmed alert – when validated
- Withdrawn alert – in case the GW event is discarded after detailed inspection
- Revised alert(s)

LVC and EM observers acknowledge that the threshold for generating a GW alert is deliberately being set low, so that most (hopefully not all!) GW candidates reported at least in early advanced science runs will likely be noise fluctuations.

3.2.1 Blind Injections

Before there is an astrophysical gravitational wave observation confirmed by the LVC, there will be tests during science runs including "blind injections". These tests involve the injection in the data of a simulated gravitational wave, with the time and parameters of the injection only known to a small group of LVC members. These injections may lead to GW candidate alerts shared with partners, depending on their significance. No LVC members (aside from the few people entrusted to carry out the program in secrecy) or EM partners will know that those events are fake until after they have been fully vetted by LVC (see Sec. 3.7), and this may naturally impact publication plans.

The number of these injections will be low, comparable to astrophysical expectations, probably 0-1 per run (or per year for multi year observations), but certainly not more than 3 per run or per year. The exercise tests possible biases in the interpretation of the data, as well as readiness and timeliness for arriving at final conclusions consistent with the injected waveform. This exercise has proved to be very useful in the past - see references to these injections in [3, 4]. When the result about the analysis of a candidate or of a run is vetted and ready to be presented to the public, but before it is made public, the time and parameters of the injections (if any) will be revealed, so they can be taken into account in the final result. MOU partners will be informed of any known injections at the same time than LVC collaboration members are informed.

3.3 Planning and carrying out follow-up observations

Each EM observer plans and carries out their own observations, although they can coordinate with others to the extent they wish.

If two (or more) partners intend to apply for time at the same facility, LVC will not attempt to choose between them, but will simply alert them to each other's plans. We have been advised that time allocation committees do not take kindly to receiving multiple proposals for the same science, but the LVC is not in a position to choose between competing proposals. If two (or more) groups go ahead with overlapping observing proposals, it will be up to the facility's time allocation committee to decide what to do.

The LVC plans to assign an *event advocate* to each GW event. He/she will keep track of what has been done and try to make sure (with input from others) that appropriate observing resources have been activated.

3.4 Preparations and tests

LVC will generate and distribute test alerts to allow EM observers to develop and test their response tools and procedures before actual alerts are generated from science-mode GW data.

3.5 Information sharing

EM observers should choose a *liaison* from their team for reliable communication and information exchange with the LVC.

GW alert messages — LVC will send GW alerts to partners in a machine-readable format and will also store alert information in a database.
EM follow-up reports — EM observers are required to report to the LVC and other partners the times and coordinates of their observations related to each GW candidate as soon as practical (and within 12 hours), so that others can plan their observations with that knowledge. EM observers are expected (even if not required) to share relevant information about any candidates found (or null searches) with other partners, in the interest of maximizing the scientific return.
GW-EM notices — All partners will share information with all other partners and LVC using a dedicated communication channel. Details remain to be worked out, but something like a private "ATel" (Astronomer's Telegram) or GCN/TAN circulars email-based service is envisioned. For now, we will refer to this as *GW-EM notices*. The GW-EM notices regarding a given GW event candidate will be authored, time-stamped and archived. The sequence of the GW-EM notices will be released to the public when that event is published, to reveal the record of which observer reported the event first, etc.

All partners retain ownership of their own data. This specifically applies to the contents of GW-EM notices. Once public GW-EM notices are citable, similarly to GCN circulars.

3.6 Confidentiality

The basic idea of the GW-EM follow-up program is to enlist a group of trusted partners with whom the LVC can share proprietary information. The partners, too, commit to sharing information with the LVC as well as with each other. All together, it forms a kind of "bubble" within which information can be exchanged freely to maximize the effectiveness of follow-up observations and the resulting science. However, the data and information still belong to the individual groups who collect and analyze it, and this must be respected by everyone who receives the information.

Publications and presentations must not use proprietary information without explicit permission from the owner(s), and possibly co-authorship or other proper acknowledgment, even if that information has been shared within the bubble. In other words, participants will know proprietary information from other groups but are not allowed to use it in a publication without consent, if it has not yet been properly published by the owner(s). The goal of this policy is to protect the ability of each contributor to be the one to properly publish their own observations and findings.

The *embargo* on information about a given GW candidate event and any possible EM counterpart ends with the publication release (in the form of arXiv, media announcement or journal acceptance) of that event. At this point, all of the "private ATel" notices will be made public, so the record will be clear about the sequence of observations and reported findings. Those notices will be citable.

To be concrete, we can distinguish three types of shared information:

- **Unrestricted information** may be stated by a participant in public (e.g., in a paper, poster or talk) at any time. The existence and general nature of the GW-EM follow-up program, and the types of facilities involved, are unrestricted information. We expect to describe such things in conference talks and on the LVC web site, for instance. Observers may freely state that they are participating in the GW-EM follow-up program and may describe their own observational capabilities and strategies, if they wish. Once LIGO-Virgo data collection begins, the fact that alerts are being generated is not a secret.

- **Embargoed information** is restricted, but can be cited in papers, posters and talks, accompanied by a reference to the publication or notice where that information is publicly released once the embargo has ended. The ID number, date, and time of the GW event candidate are embargoed. Similarly, the finding of a possible EM counterpart consistent with the GW skymap is embargoed.

- **Proprietary information** cannot be used by others in papers, posters or talks without the explicit consent of the owner(s) before it has been properly published or released. If it is to be used, the owner(s) should be offered co-authorship, in accordance with usual publishing etiquette. The significance, skymap, and other properties of the GW candidate are proprietary. (This information will be included in the publication announcing the GW event detection.) Similarly, the detailed properties of observed EM transients and counterparts are proprietary. Once the details have been published in the

regular literature by the owner(s), then the information can be used in other papers and talks with proper citation.

These confidentiality regulations apply to the use of public facilities (which may not normally keep data confidential and which may not have signed a partnership agreement with the LVC). The EM partner must impress on any observers or staff who are needed to assist that the observations and data must be kept confidential. This extends as well to the case where help from a non-partner is requested, e.g., asking the current observer at a facility to take a spectrum, if that person gives their assurance to respect the confidentiality of the information and data. We understand that some facilities will require details to be shared supporting a proposal for time in such facility; these details should be kept in confidence by the staff reviewing proposals (and this should be explained in the proposal itself). If observation time is granted in a facility that makes their pointing public, the pointing may be known to be triggered by a GW observation - this is consistent with the confidentiality agreement, assuming that no details are shared about the sky position probability derived from the GW detectors, or any details about the candidate that triggered the observation. The observation results obtained with the facility should follow data policies for the corresponding facility.

3.7 Publishing

Authorship of each paper will be based on the scientific content of the paper following the usual standards of the community. Specifically, if a paper only uses another party's data or findings that are fully contained in a previous (or coordinated simultaneous) publication, then the source should be cited as a reference; while if any use is made of unpublished data, analysis or findings, co-authorship should be offered. To implement those general principles, it is essential that LVC and EM observers share in advance drafts of all publications associated with the GW-EM follow-up program.

The baseline plan is to publish the GW discovery paper standalone, followed by companion papers for the results of the EM follow-ups. However, if the science calls for it, we may mutually agree to opt for a joint publication.

GW publications — LVC will only publish as "detections" or "strong evidence" GW candidates which have a sufficiently low estimated false-alarm rate based on the GW data. We expect that the LVC will take around 3 months to complete the analysis and its internal review. The paper will be ready to be released after approval by the collaborations and the unblinding of blind injections.

LVC may also publish papers describing lower-significance event candidates without claiming them as detections. Those will be published after the run has finished with again a 3 month delay to complete the analysis.

EM publications — No restrictions are intended on the publication of EM transients which are not triggered by a GW alert. For instance, normal survey detection and EM follow-up of short GRBs can be published as such. If a GW counterpart to the GRB is found by LIGO-Virgo, that happy occurrence will be published after being fully validated.

Clearance to promptly publish any EM transient found in observations triggered by a GW alert, but clearly not related to that GW candidate event, can be requested from the LVC. Unless there are questions about a transient being a possible counterpart, the request is expected to be approved. The LVC will consult with the EM observers to identify the typical cases where rapid response is needed. On this basis, the LVC will put a procedure in place to provide decisions swiftly.

Joint GW-EM publications — This option will typically be considered when the EM data analysis is crucial to validate the astrophysical nature of the GW event. The LVC may ask to review the analysis of the EM data which will be shared with the LVC. Reciprocally, the EM observer partners may require to review the analysis of the GW data, as a condition for publishing a joint paper.

References

[1] J. Aasi et al. Prospects for Localization of Gravitational Wave Transients by the Advanced LIGO and Advanced Virgo Observatories, 2013. arXiv:1304.0670 – LIGO-P1200087, VIR-0288A-12.

[2] LIGO Scientific Collaboration and Virgo Collaboration. LSC and Virgo policy on releasing gravitational wave triggers to the public in the advanced detectors era. `https://dcc.ligo.org/LIGO-M1200055/public` and `https://tds.ego-gw.it/ql/?c=8986`.

[3] J. Abadie et al. All-sky search for gravitational-wave bursts in the first joint LIGO-GEO-Virgo run. *Phys. Rev. D*, 81:102001, 2010.

[4] J. Abadie et al. Search for gravitational waves from low mass compact binary coalescence in LIGO's sixth science run and Virgo's science runs 2 and 3. *Phys. Rev. D*, 85:082002, 2012.