GW-EM follow-up program: Key points and issues for discussion

LIGO Scientific Collaboration and Virgo Collaboration

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Thank you for your interest in receiving prompt alerts of gravitational-wave (GW) event candidates from LIGO and Virgo. Members of the LIGO Scientific Collaboration (LSC) and Virgo Collaboration (together, "LVC") have prepared this document as an overview of the program as we currently see it, and to highlight some of the details and issues that we plan to settle using input from the meetings in Amsterdam and Chicago. The LSC and Virgo governing councils will approve the program details and MOU template text later this Fall.

1. **Background.** 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 (electromagnetic or "EM") astronomy. However, GW astronomy is a new field, and the first direct detection 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. We appreciate your understanding, and we look forward to many discoveries from fruitful partnerships.

   In 2012, the LSC and Virgo approved a statement[1] which broadly outlines LVC policy on releasing gravitational wave "triggers" (partially-validated event candidates). Initially, triggers will be shared promptly only with astronomy partners who have signed an MOU with LVC. After four gravitational wave 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.

2. **Rationale for this policy.** Our main goal is to ensure that the GW data supporting the first direct detections of gravitational wave 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 expect 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. **What information will we provide?** We expect to distribute alerts of gravitational wave event candidates as VOEvents over a *private* communication network using established protocols such as GCN/TAN, VOEventNet, SkyAlert. Alerts will include the time of the candidate and the *source position* estimate in the form of a (posterior probability) skymap (HEALPix format in FITS file), along with the *significance* expressed as a false alarm rate and some other information that could influence observing strategy. There will probably be human validation steps after the automated processing that identifies candidates, so we expect to send alerts out after $\sim$ 30 minutes. We may send updated information about candidates after the initial alert, *e.g.* refined position reconstruction or refined significance estimate.

4. **What do we expect from partners?** We expect partners to bring observational resources, and to use them appropriately to observe GW indicated sky regions for electromagnetic counterparts. We expect partners to analyse their data promptly. All partners will share information with all other partners and LVC about what observations they make and any possible counterparts they find, using something like a "private ATel" (maybe just a mailing list). All partners retain ownership of their own data. They are responsible for analyzing and interpreting their own data, or else ensuring that

[1] Available at https://dcc.ligo.org/LIGO-M1200055/public and also at https://tds.ego-gw.it/itf/tds/index.php?callContent=2&callCode=9370

it is done promptly by someone competent. All partners should choose a *liaison* from their team for reliable communication with the LVC.

5. **Modes of participation.** We plan to offer **two modes of participation**:

   - **Independent partners** who entirely decide their own observing strategy
   - **Coordinated partners** who, with selected LVC members, jointly determine a coordinated follow-up strategy

6. **Details of the Coordinated mode.** Coordinated partners and interested LVC members form a sort of consortium or joint working group. The group establishes observing strategies and recommends when and where to point the telescopes/instruments which are part of the consortium, *e.g.* to cover a large GW sky region and to coordinate multi-band photometry and/or spectroscopy for possible counterparts. The group (or a steering committee) may assign one of its members to serve as the *event advocate* for a candidate event, keeping track of what has been done and recommending (with input from others) when to activate premium facilities such as large telescopes and orbiting observatories. How exactly the group should operate will need to be worked out once it is formed. Advance preparations and testing will likely be needed to make the Coordinated observing effort run smoothly.

   The consortium model of the Coordinated group will likely have implications for the authorship of papers about the observations. For instance, participating observers may earn authorship on a paper even if the event was found somewhere other than where they were assigned to observe. This is an issue to be worked out.

7. **Publications.** A GW event discovery paper will not typically include EM data and authors (but will reference related papers). However, a joint paper is possible by mutual agreement if the science calls for it, such as if the EM observations greatly strengthen the GW result. We expect that the LVC will take around 3 months to complete the analysis and write the first GW detection paper. Any separate paper describing an EM counterpart to a GW event must be released *after* the GW discovery paper. (Similar for talks at conferences, etc.) This restriction is considered fundamental by the LVC.

   There may be several companion EM follow-up papers including one (?) from the Coordinated group and others from Independent observers. The LVC reserves the right to be co-authors on EM follow-up papers. The LVC only asks to review statements about the GW data and interpretation in such papers. However, if the EM data analysis is crucial for verifying or interpreting the GW event, the LVC may ask to review the analysis of the EM data which will be shared with the LVC.

   No restrictions are intended on publication of EM transients which are not associated with a GW candidate event, or for which no association is claimed. 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.

8. **MOU details.**

   This is a preliminary list of items we expect to include in the MOUs. The precise details will be decided following discussions at the Amsterdam and Chicago meetings.

   - Indicate whether your group will be Independent or Coordinated
   - Tell what observing resources you plan to use
   - Keep the trigger information confidential.
     How this principle applies to shared facilities, *e.g.* if another observer would have to be asked to obtain a spectrum, is an issue to be worked out. Some observatories have open data policies by default; when requesting time at such a facility, ask for confidentiality.
   - Use the trigger information only for the purpose of making follow-up observations
   - You are responsible for analyzing and interpreting your own data
   - Tell LVC and other EM partners promptly what observations you have made and what your findings are

- Don't announce or publish anything about your observations of a GW trigger until after LVC validates it and announces the detection to the world
- Authorship guidelines

9. **Steps toward signing MOUs and getting started.** We appreciate all the letters of interest we received, and they have helped define our vision for the EM follow-up program. This Fall, once we have finalized the standard MOU template, we will invite all members/teams in the astronomy community (whether or not they sent a letter of interest in response to the Summer 2013 call) to submit a somewhat more structured application to become an official partner. We expect to limit this program to professional astronomers with demonstrated experience, and will 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.

   The dates are tentative, but we hope to begin accepting applications this October or November with a deadline in January 2014, perhaps. MOUs should be approved and signed by the end of March 2014. Thereafter, we expect to accept applications and sign MOUs in cycles, at least once per year. Once signed, an MOU lasts indefinitely until ended by one of the parties.

10. **Notes.**

    In the case of a qualified observer who will depend on a pending or future telescope time allocation, LVC will accept them conditionally and let them participate in the planning, etc. But if they do not get telescope time, we will not send them GW triggers, since it only makes sense to send triggers to partners who have some chance of observing them.

    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. If they both go ahead with overlapping observing proposals, it will be up to the facility's time allocation committee to choose one (or both, or neither).

    Based on the letters of interest, we know that several partner groups will include LVC members contributing to the EM follow-up observations. This is allowed, but LVC members receive no special preference—all partner groups participating in the EM follow-up program will be treated equally. Aside from the GW alerts and related information that will be shared with all partners, LVC members are reminded that they are prohibited from revealing any other private LVC information to non-members of LVC.

    Partners are free to end their participation at any time. Partners who, for one reason or another, are unable to make a useful contribution to the follow-up program, will be asked (without ill feelings) to end their participation. They can reapply at a later time.