The Process for Claiming a First Detection

Introduction

The LIGO and Virgo gravitational wave instruments and collaborations have matured sufficiently, both in the sensitivities of the detectors and in the ability to analyze data, that first detection is now a real possibility. This note outlines a step-by-step process by which the LIGO Scientific Collaboration (LSC) and Virgo collaboration can validate that event candidate or analysis result can be claimed to be a gravitational wave. This note is not intended to present the technical details of validating an event candidate. However, it is unrealistic to assume that everything will be done as outlined here, and a certain degree of flexibility to react to the actual circumstances surrounding a possible detection claim is essential.

This note is based on discussions that have taken place at LSC-Virgo Collaboration meetings, within the Data Analysis Council (DAC), and within the LSC-Virgo Detection Committee (DC). In this document, "LIGO/Virgo leadership" is defined as the LSC Directorate and the Virgo spokesperson. The major steps of the process are presented below. A chart summarizing the process is presented at the end of this document.

By adopting this process, the collaborations affirm that their highest research priority is the first detection. All persons who accept a role in this process will be expected to give the validation of the detection claim sufficient attention to move the process along at the pace outlined below.

Step 0: Getting ready for a discovery

To make the whole process as smooth and fast as possible, it is important that the needed procedures be in place and validated before an observation run starts. These procedures and the responsible parties include:

- Carrying out thorough reviews of search pipelines, at least for the main search types. This will be taken care of by the search groups review committees.
- Establishing detection checklists, in order to verify the sanity both of data analysis results and of the state of the instruments. The checklists will be prepared by the search groups and detector characterization groups and will be reviewed by the DC.
- Establishing procedures to ensure that state of the observatories and the activities going on at the time of a possible event can be documented and recorded rapidly in response to a possible (transient) detection. The LIGO Observatory Heads and a person to be designated by the Virgo Spokesperson are responsible for defining and implementing these procedures.
- Establishing a policy about the level of significance required to claim a detection. This policy will be proposed by the DAC and the DC for approval by the collaborations.
- Establishing procedures for folding the results of any electro-magnetic follow-up observations of a candidate in the assessment of the significance of that event.

These procedures will be proposed by the EM forum for approval by the collaborations.

- Preparing detection paper outlines for the main expected first detection source types. These paper outlines should be prepared by the search groups and be reviewed by the search group review committees, the DC and the editorial boards. This review should examine whether or not key issues likely to arise in a detection claim are addressed in the outlines, to ensure that necessary expertise has been engaged prior to the start of Step 1. The collaborations should agree on a target journal for the discovery paper.
- Reviewing, and revising if necessary, the procedures for communication with the media and the general public about the discovery as established by the two collaborations. These procedures are the responsibility of the LSC spokesperson, the LIGO executive director, the GEO Data analysis coordinator, and the Virgo spokesperson.
- Establishing criteria for cross-checking a detection claim with a second independent pipeline, as required by the multiple-pipelines policy (provide reference). The DAC and the DC will review the cross-check procedures described by the search groups in their search plans.

In the weeks leading up to an observing run, the DC chairs will ask each of the responsible parties listed above to report on the status of each preparation and will report the status of each to the collaborations.

Step 1: Initial steps toward a possible discovery case

As soon as hints for a discovery are observed in any of the search groups, the co-chairs of the group(s) will inform the LSC and Virgo Data Analysis Coordinators, the DC chairs, the Observatory Heads, the Detector Characterization and Instrument Leads, the LSC spokesperson, the LIGO executive director and the Virgo spokesperson.

The search group continues work to build the case, interacting with its review committee, using its protocols and detection checklists. The co-chairs of the search groups will remind all involved scientists that confidentiality must be observed.

During this stage:

- The search groups and review committees initiate an in-depth *technical* check of the correctness of the analysis.
- The search group performs cross checks / consistency checks with other search groups, under the supervision of the DAC.
- The search groups define if there is a case, and what this case is, for a detection.
- The Observatory heads activate the process for capturing the complete state of the observatories and the activities there for the time of the event (assuming a transient event).
- The detector characterization groups and instrument scientists collect and bring forward complete information on instrument state and data quality at the time of the possible detection.
- The search groups and detector characterization groups put the case in writing through technical notes and maintaining an up-to-date web site for the event(s).
- The EM follow-up group will seek the results of any follow-up observations that

might have been performed in response to alerts issued by L-V.
- The DC is informed about the case. The DC begins its work by reviewing the work of the detector characterization groups and instrument scientists in documenting the state of the interferometers and in assessing data quality.

Step 2: Consolidating the case

Based on the results of Step 1, the LIGO/Virgo leadership decides whether to continue to proceed with the case. If their assessment is favorable, then:
- The Review Committee will complete its review of the search and its result.
- The DC will complete its review of the data quality and the instrument state.
- The Spokespersons will appoint two co-chairs of a team to coordinate the preparation of the detection case to the collaboration and to coordinate the writing of the detection paper; one of the co-chairs will be a Chair of the relevant Search Group, and the other will be a leader of the instrumental work. The co-chairs will work with the Spokespersons to engage the contributions of appropriate experts in all relevant areas, including data quality, significance estimation, parameter estimation, and the EM follow-up (if appropriate). The Spokespersons should also take steps to ensure the highest level of clarity and style in the paper. Drafts of the paper will be shared with all interested members of the Collaborations, who are in turn invited to comment and suggest improvements.
- The LSC Spokesperson and the Virgo Spokesperson notify the collaborations of the possible detection via a spectrum of methods, including:
  - an L-V Spokesperson e-mail to the collaborations
  - convening a telecon open to all LSC and Virgo members to present and discuss the initial information about the event
  - maintaining up-to-date information on the web, including up-to-date drafts of the detection paper.
- The outreach committees are informed and charged with preparing material for communicating with the general public about the detection

Step 3: Preparing for the decision

When the outcomes of Step 2 are available, the LSC/Virgo leadership will convene a meeting including the chairs of the relevant search group(s), the chairs of the DAC, the chairs/representatives of the Detector Characterization/instrument teams, the chairs of the Paper Coordinating Team, and the DC chairs. This group will discuss the case as it is understood at that time, and decide whether to take it forward and make the case to the DC and the collaborations.

At this time, the Paper Coordinating Team must provide the draft of the paper that describes the discovery and detailed material supporting the evidence for detection.

The LSC/Virgo leadership will formally charge the joint DC to review the claim. The DC plays the role of an independent investigator, asking broader and different questions than the people doing the analysis may have asked themselves and examining the case with fresh eyes/perspective different from the previous stages. In essence, the DC plays the Devil's Advocate, providing an opportunity for the wider Collaboration to form their own

opinion. This stage may be *somewhat* adversarial but will certainly involve multiple and closely coupled interactions with the search group, detector characterization groups, and instrument scientists.

During this stage, the search groups and their review teams, Detector Characterization and instrumental team, the DAC, the Paper Coordinating Team, and the DC *may* carry out the following activities:

- Deeper and/or broader review of the detection case and the draft detection paper,
- Consideration of analyses that may take longer to complete than allowed by the previous steps (e.g., parameter estimation)
- Additional analysis with different parameters to assess the robustness of the data analysis
- Audit of the detector hardware and/or software to test that the configuration is known
- Repeat measurements of detector calibration and response to hardware injections,
- Literature searches to assess the astrophysical predictions concerning sources of this type,
- any further checks and actions, if necessary.

Input from the Collaborations concerning any aspects of the detection claim and the paper will be welcomed and considered.

Step 4: Making the decision

Once the DC has substantially completed its evaluation, its assessment of the candidate is communicated to the collaborations' managements and the collaborations. Here, the DC provides the spokespersons its evaluation of the proposed discovery. The Spokespersons will circulate the DC report executive summary and final draft of the paper to the collaborations. The spokespersons will remind the collaborations that confidentiality is paramount during this process.

At the earliest possible time after the collaborations have had time to read and evaluate the paper, an L-V collaboration meeting will be held, either in person or by teleconference. During this meeting, the search group will summarize the case for the candidate, and the DC will present their recommendation to the collaborations. Following this, a discussion by the members of the LSC and Virgo Collaboration will take place on the merits of the case. At the end of that discussion, the members of the collaboration will formally consider whether *or not to submit the detection claim paper for publication*. A strong consensus from both the LSC and Virgo Collaboration to submit the paper is necessary for the paper to go forward. If necessary, a vote may need to be performed, but a decision to claim a detection will require that the vote be overwhelmingly positive.

If the collaborations' decision is positive, a blind injection check is performed. If a blind injection was present for this type of event, the spokespersons/director opens the "envelope". If no blind injection occurred, then the hardware injection channels are crosschecked for unrecorded or malicious injections to ensure that the event is truly valid.

If the event is certified, the paper is submitted and the discovery announcement goes out.

	Step 1 (2 weeks)	Step 2 (4 weeks)	Step 3 (4 weeks)	Step 4 (3 weeks)
Search Group	**Notice, notify, launch studies of significance, PE**	**Organize info for paper; continue signif./PE studies**	On call	Answer questions
DetChar + Instrumentalists	**Evaluate DQ and instrument state**	**Present DQ / instrument to DC**	On call	Answer questions
Reviewers	**Review search procedure**	**Review search result**	On call	Answer questions
Paper Coordinating Team		**Assemble case for presentation to DC; Coordinate writing of paper**	**Present Detection Claim, paper to DC**	Present to Collaborations
Detection Committee	Look in on DQ	**Review DQ**	**Review Detection Claim**	Present to Collaborations
EM follow-up	**Search for counterpart**	**Interpret observations**	On call	Answer questions
DAC	Facilitate communication	**Convene presentations, collect questions**	**Convene presentations, collect questions**	Prepare Collaborations meetings
Collaborations	Ask questions	Ask questions	Ask questions	**Make judgment**
Spokespersons	**Keep process moving**	**Appt. Paper Coordinating Team**	**Keep process moving**	**Plan publication, publicity**

Notes:

- Spokespersons are responsible for actively managing the process to make sure that process moves forward correctly and promptly. They (or their designees) will attend meetings of all "rows" in the process, and will arrange for overlapping memberships to facilitate flow of information.
- The times shown above are targets, to be adhered to if possible; however, if complications occur, then the Collaborations will adjust the timeline as necessary.