EM Partnerships and Multi-Messenger Astronomy: What Did and Did Not Work in O1

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(my views, but with some material from
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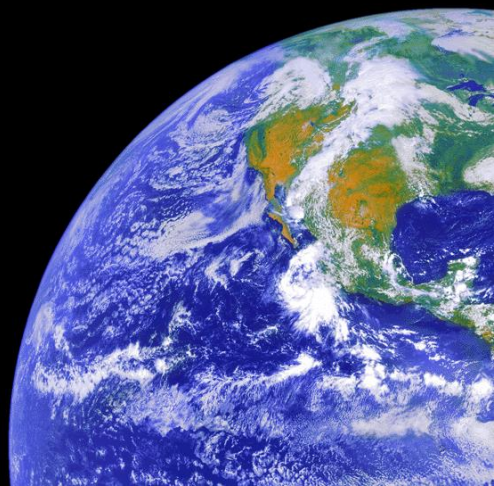
GW DAWN Meeting – July 7, 2016

LIGO-G1601458-v2



GOES-8 image produced by M. Jentoft-Nilsen, F. Hasler, D. Chesters (NASA/Goddard) and T. Nielsen (Univ. of Hawaii)

Prior to O1…

https://wiki.ligo.org/DAC/ExtCollabProposals

We had done several types of *externally triggered* GW searches and *joint* searches

CBC, Burst	GRBs, magnetar flares – using	public (GCN) and	private info
Burst	High-energy neutrinos		private
	Radio transients [in progress]		private
	Supernovae [in progress]	public	
	Pulsar glitch (Vela)		private
CW	Known pulsars	public	private
CBC	Offline follow-up with satellite	public γ/X-ray data	[methods paper only]

We had carried out an *EM follow-up program* during S6/VSR2+3

About a dozen partner groups, with a variety of communication protocols

Sent alerts for 14 GW triggers; images obtained for 8, including Big Dog

Image analysis results published in one big paper after a few years of work

We had worked out a new framework for EM follow-up partnerships

And enrolled 74 (!) partner groups under a standardized MOU

ExtTrig and Joint Analyses for O1

Partnerships continuing for access to private (and public) info

- GRBs: Interplanetary Network (IPN) detected bursts
- High-energy neutrinos: IceCube and ANTARES partnerships ongoing
- Radio transients: Continuing MOU with Parkes group (others?)
- Pulsars: Timing solutions from radio astronomers
- Sub-threshold analysis of Fermi GBM data around GW event candidates

➔ **Relationships tend to persist**

- Even when we've reached formal end of MOU scope, in some cases
- Based on common interest and trust
- Expert guidance is helpful even in cases where data is publicly available

For O1 and beyond, how strict should we be about MOUs? e.g.:

- Partners willing to continue informally with new data
- EM follow-up partners willing to supply information from their surveys for ExtTrig or joint analysis

EM follow-up program - O1 run

- **Three alerts** sent to 65 groups of astronomers with observational capabilities
- **About 40 groups followed-up at least one alert** giving a broadband coverage of the sky maps and the rapid characterization of the candidate counterparts

GW150914

2 days → **Alert!** *Initial sky maps* → 19 days → **Update** *BBH nature* → 4 months → **Updates:** *Final FAR and sky map*

G194575

6.5 hrs → **Alert!** *Initial sky maps* → 29 days → **Update** **Noise event** **Retraction**

GW151226

1.6 days → **Alert!** *Initial sky maps* → 15/17 days → **Updates:** *Redshift Final FAR* → 23 days → **Updates:** *Final sky map*

WWaDNW: Establishing Partners

Good:

- Clear criteria for eligibility
- Got lots of applications, and the vast majority were eligible
- MOU conditions evidently did not scare away (many) potential partners

Not Good:

- LV-EM Forum registration system needed lots of babysitting
- Failed to maintain regular communication (email, telecons) to have a meaningful *Forum*; the occasional messages were fairly impersonal
- Subscribing to private GCN Notices and Circulars were extra steps, overlooked by some partners, and often requiring iterating with Scott Barthelmy

Outlook:

- Most active partners are set up now, but registration system and GCN distribution configuration still need manual intervention regularly. Trying to keep communication threads going in the Forum.

WWaDNW: Identifying GW Candidates

Good:

Low-latency analyses ran reliably and reported triggers

Triggers were vetted quickly, and junk triggers were rejected

Not Good:

BBH deliberately excluded from low-latency CBC search at first

GCN Retraction Notice mechanism was not fully implemented and tested, so it wasn't used during O1; made us extra cautious about sending alerts

Outlook:

Re-implementing software to be more robust, to deal better with multiple triggers from the same transient in the GW data, and for better monitoring. Would like to minimize alert latency by changing role of human vetting to be after sending the initial alert, and issue a retraction if needed.

WWaDNW: Communicating About Candidates

Good:

Standardized communication route with private GCN worked

GraceDB access for partners and EM Bulletin Board worked pretty well

Not Good:

Alerts delayed by 1-2 days due to needing to seek approvals

Some initial technical issues with private GCN

Concerns about secrecy and protocol led to not sharing important info from the GW analysis until much later; led to inefficient observing and frustration; they did not feel like they were being treated as trusted partners

Some confusion from providing multiple sky maps

Outlook:

O1 was all special cases; did not have a chance to settle into a routine. Will do better with experience and reduced pressure. Should agree on guidelines and then be able to act without bureaucratic overhead.
Will provide more information in future: binary classification, distance.

WWaDNW: Follow-Up Observations

Good:

Much enthusiasm, even for the first event candidate!

> *"G184098 is an unvetted event of interest,… There are important caveats associated to this event: * It occurred before the initiation of the planned observing run; * The detectors were not in their final O1 configuration; * Calibration is not finalized. In particular, calibration uncertainties may imply systematic errors in sky localization.*
>
> *Nevertheless, the trigger is of sufficient interest to present an important opportunity to exercise the EM follow-up process,…"*

Many astronomers willingly shared information about their observations

Not Good:

Edo Berger's frank assessment: the observations had shortcomings in terms of depth and/or sky coverage (Edo's GWPAW talk: https://emvogil-3.mit.edu/gwpaw2016/presentations/gwpaw2016_berger.key)

Outlook

Astronomers may become more selective about following up events

WWaDNW: Findings from Observations

Good:

- The astronomers analyzed their own data and have written many papers
- Potential counterparts were considered rationally and published, or not
  - Many optical transients were classified spectroscopically and dismissed
  - Intriguing, controversial Fermi GBM weak transient was published and is being critiqued by the community
- Good give-and-take on optical transient PS15dpn with position-constrained parameter estimation from the GW data, firmly establishing that the redshift was inconsistent
- Established a streamlined “partner paper check”
- Formerly private GCN Circulars were added to the public GCN archive

Not Good:

- Partner paper check turn-around was inconsistent in crush around Feb 11

Outlook:

- Will there be appropriate cases for true joint analyses & papers?

About Open Alerts

LIGO+Virgo declared:

> "…the LSC and Virgo will begin releasing especially significant triggers promptly to the entire scientific community… after the Collaborations have published papers (or a paper) about 4 GW events, at which time a detection rate can be reasonably estimated. The releases will be done as promptly as possible, within an hour of the detected transient if feasible. Initially, the released triggers will be those which have an estimated false alarm rate smaller than 1 per 100 years….
>
> Partners who have signed an MoU with the LSC and Virgo will have access to GW triggers with a lower significance threshold and/or lower latency…"

Even MOU partners will be able to publish immediately, before any final word from the GW analysis

General feeling that we should make this transition after O2

- For concreteness more than technical reasons
- Discussion point: should/can we attempt to reserve the first NS binary event?

Some will choose to continue as MOU partners, others will not ?

See Also

From the March LVC meeting:

LIGO-G1600630: “Lessons learned from O1. How to do it better O2?”

LIGO-G1600674: “EM Follow-up Plans for O2”

From the May 12 LV-EM Forum telecon:

LIGO-G1601066: Summary of O1 run

LIGO-G1601085: “O2 Lessons Learned”

From recent conferences:

LIGO-G1601314: “LIGO-Virgo Forum on Hunting GW Counterparts”

LIGO-G1601387: Marica’s slides for the RICAP conference