Low-latency Selection of Gravitational-wave Event Candidates for EM Follow-up Observation

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for the LIGO Scientific Collaboration &
the Virgo Collaboration

GW and EM Multi-messenger Astronomy

Gravitational Waves:

» Bulk motion dynamics

» Luminosity distance

» Progenitor mass

» Direct probe of central engine

Light Curve & Spectrum:

» Host galaxy

» Gas environment

» Red shift distance

» Precise sky location

Combining these observations will also increase detection confidence, give a full picture of progenitor physics and allow a measurement of the local Hubble constant.

LIGO-G1100064-v5

Low-latency Event Selection Pipeline

The speed and sophistication of LIGO's data analysis methods and other infrastructure have developed to the point that we can now produce low-latency candidate GW detections for EM follow-up.
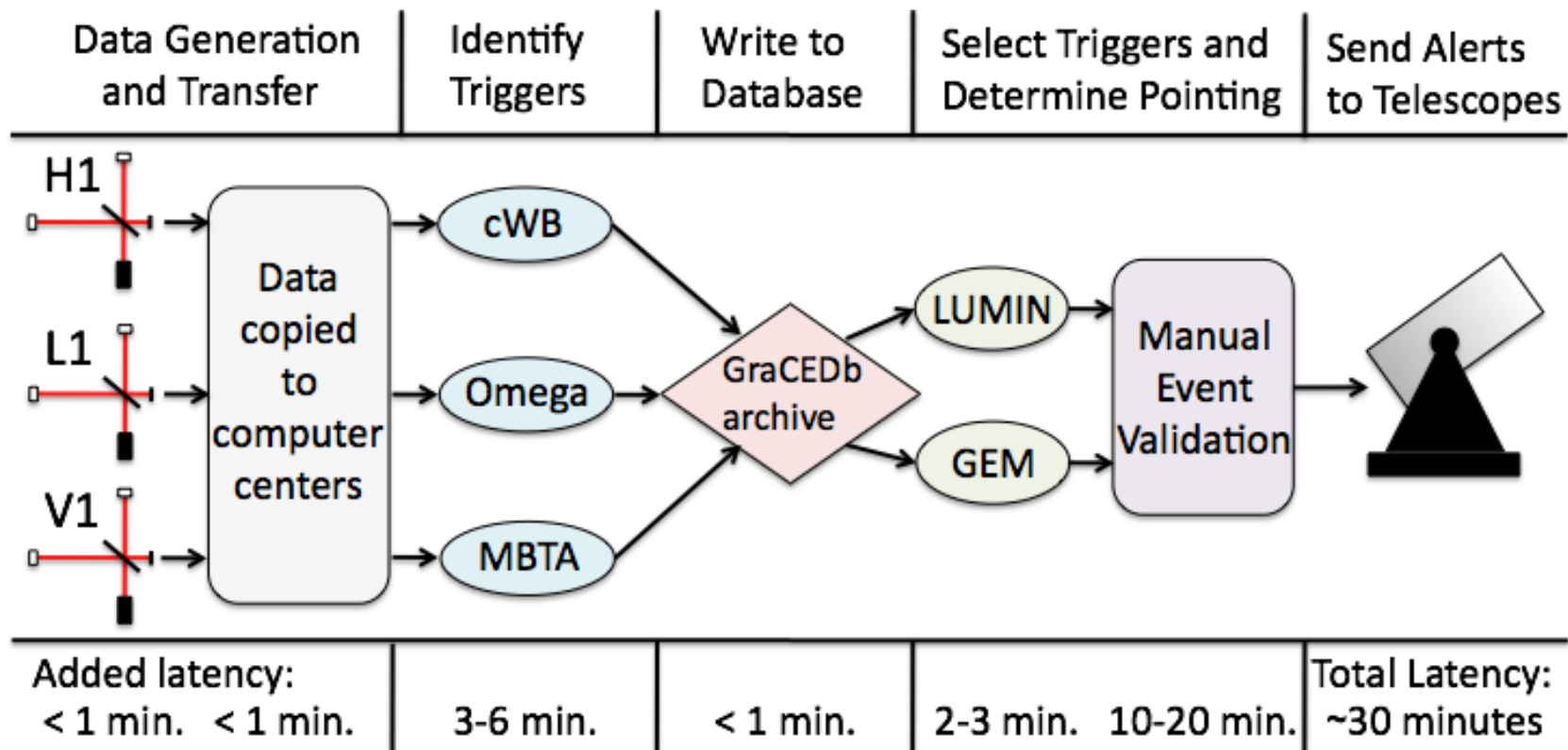
Data Analysis Methods

- ## Burst
    - » Coherent Waveburst – a coherent network algorithm based on constrained likelihood analysis; returns reconstructed signal and most likely source location map.
    - » Omega Pipeline – a multi-resolution time-frequency search for excess power on a single interferometer basis followed by a coherent follow-up to coincident candidate events, which generates a source likelihood map and the strength of the event.

- ## Compact Binary Coalescence
    - » MBTA (Multi-band Template Analysis) – 2nd order post-Newtonian matched filter inspiral search which searches between 1-35 $M_{\odot}$ and requires at least one mass to be consistent with a neutron star ($<3.5\ M_{\odot}$).

Source Localization and EM Partners

- Source localization up to 10s of square degrees.

- Partner with wide-field optical (FOV of several degrees), X-ray & radio telescopes and prioritize observations to areas with known galaxies within expected sensitivity range.

- LIGO & Virgo have run generating ToO observing requests during 2 periods of the last data run.

SkyMap
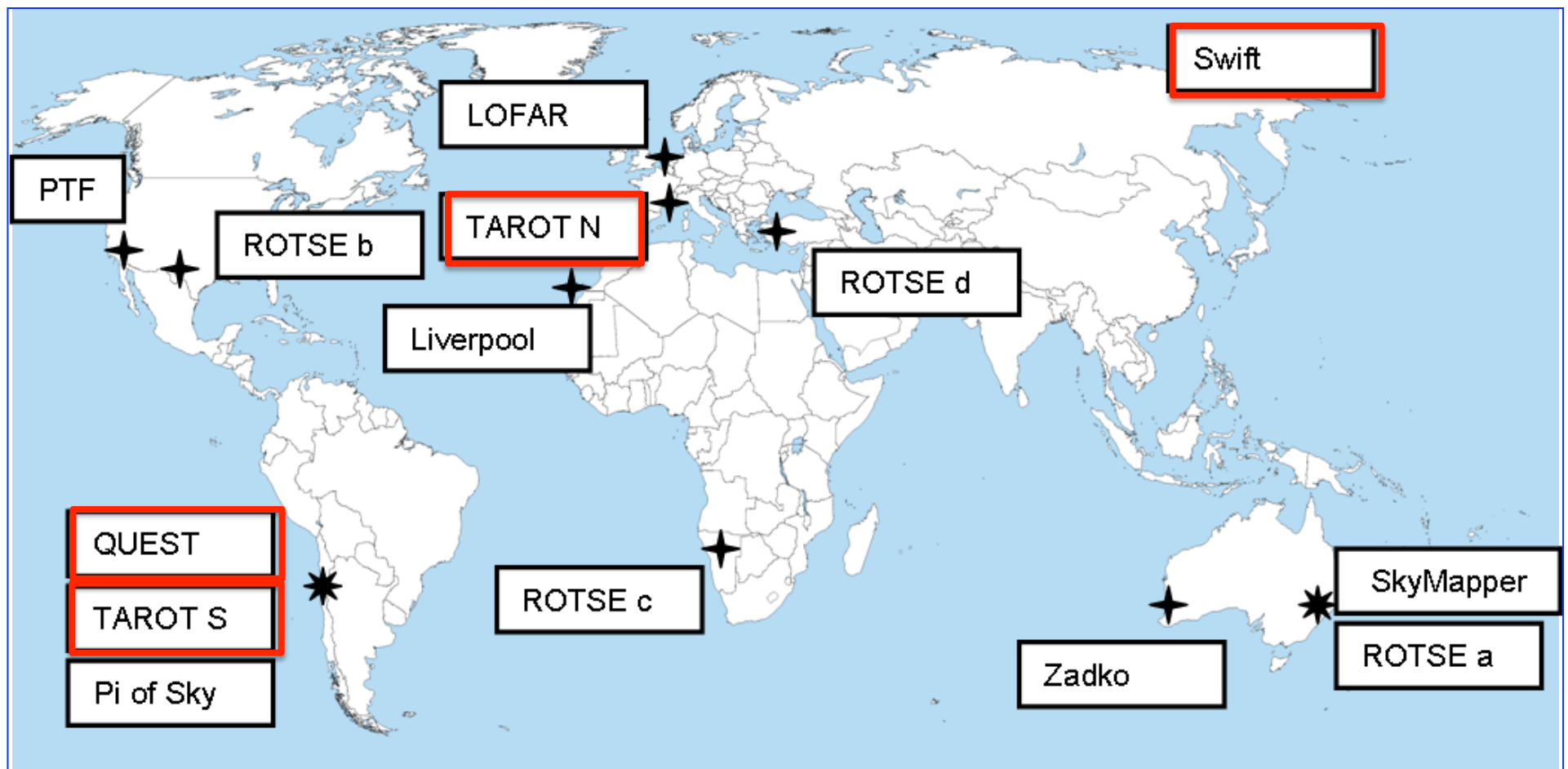
LIGO-G1100064-v5
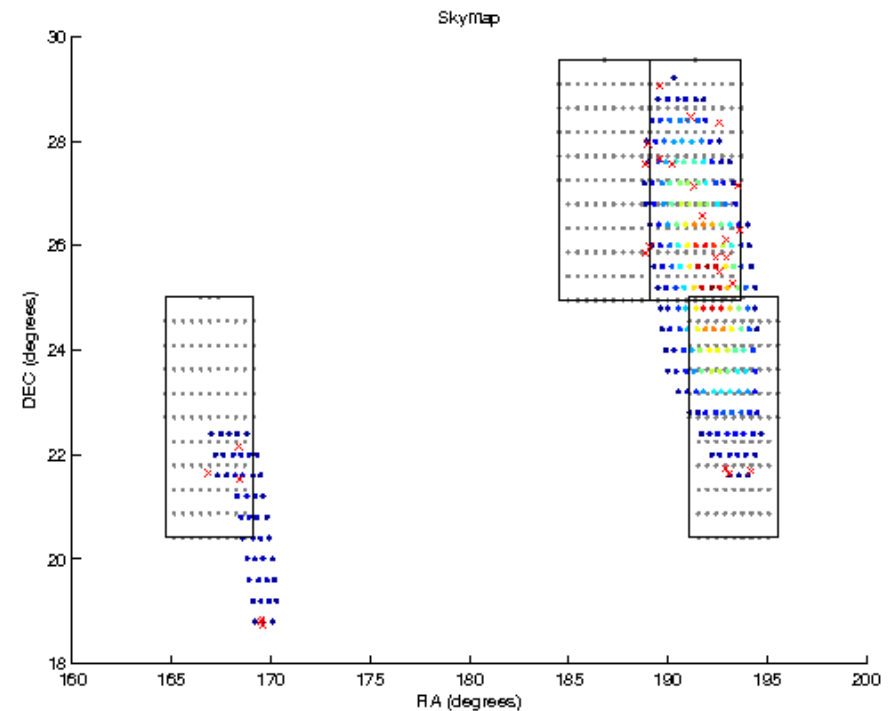
Telescope Network

Used in: [ ] winter '09 and autumn '10 run   [ ] autumn '10 run only

Human Vetting of Events

LUMIN Event Checklist Page

Welcome!

You are logged in as: amber.stuver@LIGO.ORG
You have shown some interest in the following event:

Age (Hr:Min)	Id	GPS	DQ	Energy	Event Rate	Frequency	Status	Scopes	View Times	Trigger Details	ETG
00:09	G19377	968654557.950	Clear	$\varrho = 4.338$	0.00 Events/day	176.3 Hz	alert	Text: Plot:	plot	Details	cwb classic

You should only request observations after performing the following checks:

- ☐ **Confirm the event ID starts with "G"**, not "T", in the table immediately above this checklist.
- ☐ **Confirm there are no undefined CAT 1, CAT 2 or INJECTION flags** by clicking the link in the DQ column above.
- ☐ **Get a "GO" message from the sanity check script** by using the button below. The script will check the event time is not too close to a lock loss, passes important data quality flags, and has a low KW glitch rate in H1 and L1.
- ☐ **Discuss via the permanent EVO session with all 3 control rooms** and confirm there are no obvious problems. If in a control room, look for obvious problems on the FOM screens and work with the operator to classify recent data as normal or unacceptable.
- ☐ **If the ETG column says cbc, check the lower mass is less than 3.5** for all 3 sites. Click on the event ID, and then click on event.log. Check that all three numbers in the M1 column are less than 3.5.
- ☐ **Check the event time on the 1 hour Omega-grams** for a glitch rate that is not dramatically elevated compared with the rest of the hour. If you are in a control room, just check this at your IFO and report on the EVO session if there is a problem.
- ☐ **Check that the View Times plot exists** by clicking on the link View Times column above. This plot should be generated about 5 minutes after you receive the alert.

Sanity Checks <---- Click here to run the sanity checks script and view the output.
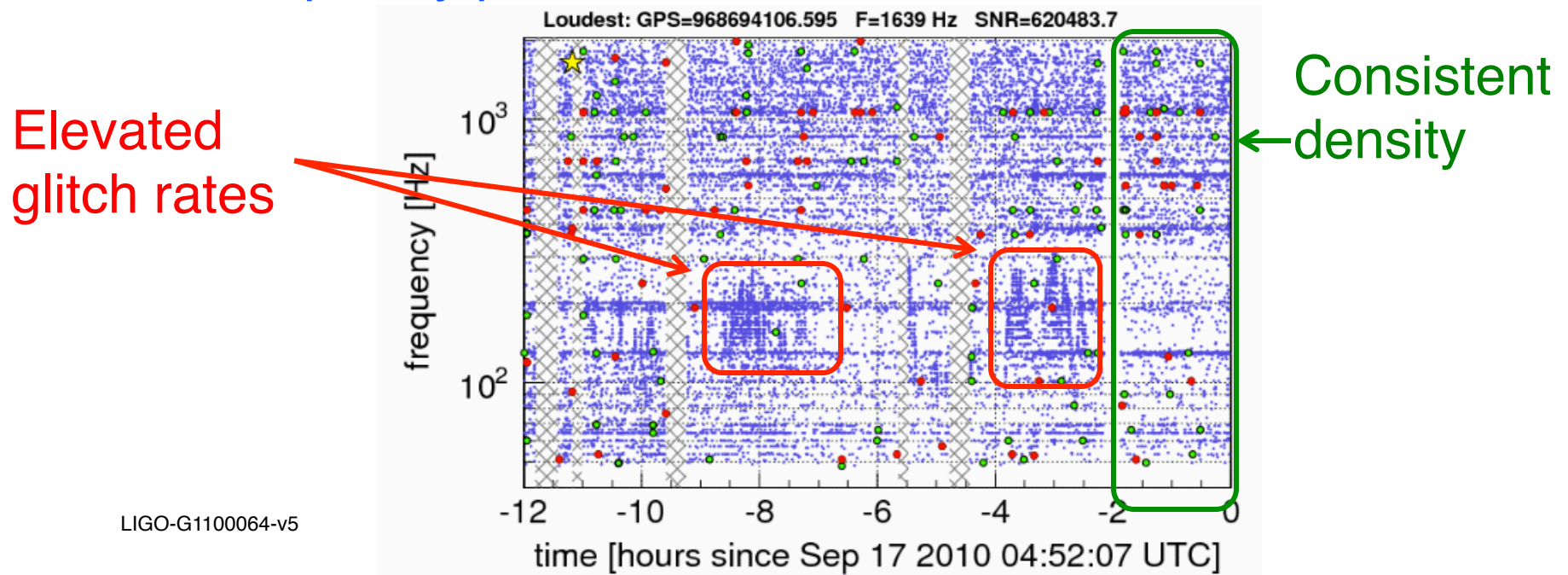
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Example Omega-gram

- Omega-grams are a reapplication of the Omega pipeline seeking noise transients (glitches).
- Consistent, low density is sought in the glitches on the time-frequency plot.

Loudest: GPS=968694106.595   F=1639 Hz   SNR=620483.7

Elevated glitch rates

Consistent density

frequency [Hz]

time [hours since Sep 17 2010 04:52:07 UTC]

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Example Event: The "Big Dog"

- In the early morning of 16 Sept. 2010, an exceptional event was seen in the LIGO-Virgo network localized within the Canis Major constellation.

- An alert was sent to human vetters for validation within 8 minutes and the event was sent out for ToO observation within 40 min.

- The areas of interest were first observed 44 minutes after event by TAROT (later by ROTSE, SkyMapper, ZADKO, and Swift).

- This event was later revealed to be a *blind injection*.

Continuing Work

- A methods paper for this work is being prepared for publication.

- The development of image analysis pipelines are being undertaken by a number of LIGO and Virgo collaborators.

  » This includes work to evaluate the efficiencies of these pipelines and to measure the background for each telescope.

- A results paper will be published in the future.