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GCN Listener Service

 [Brief overview presentation](#)

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Personnel

Project Lead and Primary Contact: Alex Urban**Core Contributors:** Alex Urban, Patrick Brady, Leo Singer, Roy Williams

Description

Given the very rapid (~seconds to hours) timescale over which gamma-ray bursts (GRBs) and their X-ray and optical afterglows occur, good multimessenger astronomy requires collaboration between LIGO, Virgo and astronomer colleagues to happen as quickly as possible. Very low latency searches for gravitational waves (GWs) from compact binary mergers, for example, have a demonstrated ability to provide triggers within ~10 seconds of the coalescence time, while GRB notices are provided directly from satellite observatories over the Gamma-ray Coordination Network (GCN) within ~1 minute of a typical GRB. For the purpose of both the low-latency coincidence search with external triggers and the medium-latency triggered coherent searches, a pathway through the GCN over which such external

triggers may be supplied is mission-critical. Such a pathway exists in the form of the GCN Listener service, where users may subscribe for real-time alerts in the event of something like a GRB trigger. In LIGO's case, this service is used to upload electromagnetic events to GraceDB and trigger the aforementioned searches for associations with GW candidates. Information uploaded with these events includes observatory, event time, sky location, figures of merit (including an SNR based on gamma-ray counts), and position of the Sun, among other things.

Please see the [GRB search plan](#) for more information.

Software Location

GCN listener code currently lives in the GRINCH (Gravitational-wave Candidate Event Handler) git repository, which is hosted on LIGO-VCS at

```
ligo-vcs.phys.uwm.edu:/usr/local/git/grinch.git
```

and is visible on the LIGO-VCS [cggit](#). Code relevant for this piece of the GRB infrastructure lives under the `gcn_listener` subdirectory, and the script that filters events is called `eventcatch.py`.

Note: The GraceDB Processor service will eventually be the subject of its own code review.

Event Cache

The listener service is run from the `gdb_processor` account on the Nemo cluster at UWM. A file cache for all saved events, including files with information that does *not* get uploaded to GraceDB (e.g. pointers to light curves), is stored on-disk at

```
UWM: ~gdb_processor/working/gcn_listener/cache/.
```

These are further indexed by the `role` that appears in the corresponding VOEvent file; for all *bona fide* GRBs, this `role` variable has the value "observation."

All events that were saved prior to September 2014 are visible under

```
UWM: ~gdb_processor/Users/aurban/gracedb-voevent/comet/comet/cache.
```

Software Dependencies

Outside the standard, cluster-wide system installations of LIGO-specific software such as LALSuite, the GCN Listener has the following dependencies:

- Twisted, an event-driven networking engine in Python (Version 14.0; [link](#))
- Comet, a scalable HTTP-based event routing bus ([link](#))
- Zope, an Open Source web application server ([link](#))
- LXML, an XML toolkit and Pythonic binding for the C libraries `libxml2` and `libxslt` ([link](#))

An up-to-date version of all these dependencies is installed locally on the `gdb_processor` account at UWM, and could easily be migrated to another cluster. (The service also depends rather strongly on

VOEventLib, an Open Source XML-parsing Python module useful in parsing the VOEvent (Virtual Observatory Event) alerts containing GRB information, but this software is installed cluster-wide.)

After switching to pygcn, this section will look thusly:

Outside the standard, cluster-wide system installations of LIGO-specific software such as LALSuite, the GCN Listener has the following dependency:

- PyGCN, an anonymous GCN/TAN client for receiving GCN notices in XML format (Version 0.1.4; <https://pypi.python.org/pypi/pygcn>)

An up-to-date version of `pygcn` is installed locally on the `gdb_processor` account at UWM, and could easily be migrated to another cluster. (The service also depends rather strongly on VOEventLib, an Open Source XML-parsing Python module useful in parsing the VOEvent (Virtual Observatory Event) alerts containing GRB information, but this software is installed cluster-wide.)

Event Streams

The GCN listener connects to a hard-coded set of *streams*, each one corresponding to a specific observatory. At present, the streams we connect to are for Swift (where alerts come from the Swift Burst Alert Telescope instrument), Fermi (where alerts come from the Fermi Gamma-ray Burst Monitor instrument) and SNEWS (i.e., the Supernova Early Warning System, a network of neutrino detectors designed to provide rapid notices of galactic and nearby supernovae). The listener is currently plugged in to the following alert nodes:

1. `68.169.57.253:8099` (Primary GCN node at NASA GSFC)
2. `voevent.phys.soton.ac.uk:8099` (Southampton University)
3. `voevent.transientskp.org:8099` (LOFAR)

In the case of Swift, bursts arrive already having been classified as a GRB (that is, with an official designation as "GRB 141117A" or the like). In the case of Fermi, however, assigning a designation can take a good deal more time, and at any rate a designation is not typically available when we ingest an alert. Fermi triggers are sub-classified by their probable source, which is captured within the code by a variable called `Fermi_Likely`.

The `Fermi_Likely` variable may take the following values:

0. An error has occurred
1. `UNRELIABLE_LOCATION`: Location not trusted
2. `PARTICLES`: Local particles, equal rates in opposite detectors
3. `BELOW_HORIZON`: Distant particles, assumed to come from the horizon
4. `GRB`: Burst with good localization
5. `GENERIC_SGR`: Soft Gamma Repeater (except 1806-20)
6. `GENERIC_TRANSIENT`: Astrophysical transient of unknown class
7. `DISTANT_PARTICLES`: Particles at a distance
8. `SOLAR_FLARE`: This is a Solar Flare event
9. `CYG_X1`: This trigger came from SGR 1806-20

10. GROJ_0422_32: This trigger came from GRO J0422-32
11. unrec_value: Unrecognized value
12. TGF: Terrestrial Gamma Flash

Finally, in the case of SNEWS, all alerts are accepted but there is some question as to whether they're actually being *broadcast* from the observatories themselves.

Parsing VOEvents and Alert Types

The following links are maintained by NASA and the GCN system overlords, and are organized by observatory:

- [Swift](#)
- [Fermi](#)
- [SNEWS](#)

These are the documentation pages that detail the various alert types, as well as what kind of information is contained in the VOEvent file that gets received by our listener. In brief, we are interested in six types of event notice:

Instrument	Notice Type	Latency	On-sky Precision	Description
Swift	61 (BAT_GRB_Pos)	7-30 seconds	~arcminutes	A significant trigger from the <i>Swift</i> Burst Alert Telescope, whose position has been determined with on-board software
Fermi	110 (GBM_Alert)	~5 sec	(No Localization)	A significant trigger from the <i>Fermi</i> Gamma-ray Burst Monitor, and its timestamp has been identified
Fermi	111 (GBM_Flt_Pos)	~10 sec	~15 deg.	A localization has been calculated with in-flight software
Fermi	112 (GBM_Gnd_Pos)	20-300 sec	1-10 deg. (+3 deg. systematic)	A better localization has been calculated with automated on-the-ground software
Fermi	115 (GBM_Fin_Pos)	~2 hr	1-3 deg. (+3 deg. systematic)	The best available localization has been calculated with a human-in-the-loop
SNEWS	N/A	N/A	N/A	A significant trigger from the Supernova Early Warning System (SNEWS) network of neutrino detectors

In terms of information content in these VOEvent packets, our event filter utilizes the following pieces of information (for more information, see Pseudocode, below):

- The IVORN
- The event `role`
- The official designation (e.g. GRB 150304), if there is one

- The trigger time, in ISO 8601 format (which is measured to millisecond precision)

Note the IVORN and role are used to identify an event portfolio on-disk, the designation is used to select a more useful file name, and the trigger time is used to identify other bursts in GraceDB at the same time. Fermi notices of type 111 and 112 also use the `Fermi_Likely` variable.

Pseudocode

Here is an outline of the algorithm used to filter alerts that come in over the GCN.

To begin with, what is fed to the event catcher script (`eventcatch.py`) is a GCN Notice: a real-time alert announcing some recent event. Notices can be either wholly new events, or updates to Notices from existing events with new information (e.g. light curves or better sky localization). The Notice is ingested as an XML-parsable string in the VOEvent (Virtual Observatory Event) format, and passed through `eventcatch.py`.

When the event string is ingested, it is processed by the following algorithm:

1. Parse the VOEvent string.
2. Grab this event's IVORN (International Virtual Observatory Resource Name), which acts as a key to the registry that stores actual information and behaves like a standard URL. For example, the IVORN `ivo://nasa.gsfc.gcn/SWIFT#BAT_GRB_Pos_618673-699` would resolve to something like an FTP server (`nasa.gsfc.gcn/SWIFT`) where `/BAT_GRB_Pos_618673-699` is a physical location.
 - A. IF the IVORN is of an illegal form OR the IVORN is from a stream other than Swift, Fermi or SNEWS, THEN reject this event immediately.
3. Grab this event's `role`, which classifies its science status (possible values are `observation`, `utility` and `test`).
 - A. IF the `role` is `utility` OR (the `role` is `test` and not from SNEWS), THEN reject this event immediately.
4. Grab this event's packet type:
 - A. IF the stream is Swift THEN:
 - i. IF packet type is 61, THEN it is a `BAT_alert`. Flag for saving/sending to GraceDB!
 - ii. ELSE: This alert is not interesting to us or is a test of some kind. Reject this event.
 - B. IF the stream is Fermi THEN:
 - i. IF packet type is 110, THEN it is a `GBM_Alert`. Flag for saving/sending to GraceDB!
 - ii. IF packet type is 111, THEN it is a `GBM_Flt_Pos`. Flag for saving/sending to GraceDB! AND print `Fermi_Likely`.
 - iii. IF packet type is 112, THEN it is a `GBM_Gnd_Pos`. Flag for saving/sending to GraceDB! AND print `Fermi_Likely`.
 - iv. IF packet type is 115, THEN it is a `GBM_Fin_Pos`. Flag for saving/sending to GraceDB!
 - v. ELSE: This alert is not interesting to us or is a test of some kind. Reject this event.
 - C. IF the stream is SNEWS THEN:
 - i. It could be a test, but flag for sending to GraceDB!
5. Now, find all previous VOEvent portfolios cited by this event. Does it cite one we've already

captured?

- A. IF yes THEN flag it for saving on disk and find the portfolio it cites.
 - B. ELSE: Start a new event portfolio in the file cache!
6. Does this event already have an official designation (e.g. GRB 141117A)?
- A. IF yes THEN make that designation the filename of this Notice on disk (e.g. GRB141117A.xml).
 - B. ELSE: Well, that's unfortunate! Because now the filename will be the full event descriptor, which is rather long (e.g. nasa.gsfc.gcn_Fermi#GBM_Flt_Pos_2014-11-15T06:12:00.03_437724723_58-041.xml).
7. IF this event has been flagged as an interesting one that ought to be stored on disk, THEN save its VOEvent file (in the appropriate portfolio within the file cache and with the appropriate filename).
8. IF this event has been flagged for sending to GraceDB THEN:
- A. IF it coincident in time within 1 second of an event that's already been uploaded, THEN send it as an update to that event.
 - B. ELSE: Send it as a new event.

Unit Tests

For unit testing, a directory called `~gdb_processor/Users/aurban/gcn_unit_tests` was set up on the `gdb_processor` account at the UWM cluster. A tarball of the directory is at [tar.gz](#). A simple script in this directory called `test_gcn_end2end.py` with the following contents was used to call an instance of the `EventCatcher()` class:

Toggle line numbers

```

1 import sys
2 from comet.utility import xml # Needed to pass a VOEvent to the
event filter
3 from comet.plugins.eventcatch import EventCatcher # Class that
filters GCN notices
4
5 # Pass a VOEvent file as a positional command line argument
6 args = sys.argv[1:]
7 filename = args[0]
8
9 # Convert the contents of that VOEvent to an instance of the class
xml_document
10 with open (filename, "r") as f:
11     data = f.read()
12 voevent = xml.xml_document(data)
13
14 # Call the event catcher
15 EventCatcher().__call__( voevent, test=True )

```

This script is then run from the command line as `python test_gcn_end2end.py [voevent.xml]`.

A simulated VOEvent file (emulating the behavior of real alerts) was then prepared to test each of the alert types LIGO is interested in. In particular, the files

```
[gdb_processor@pcdev2:~/Users/aurban/gcn_unit_tests] $ ls Swift/*.xml
Swift/Swift_BAT_Alert.xml
```

```
[gdb_processor@pcdev2:~/Users/aurban/gcn_unit_tests] $ ls -l Fermi/*.xml
Fermi/Fermi_Fin_Pos.xml
Fermi/Fermi_Flt_Pos.xml
Fermi/Fermi_GBM_Alert.xml
```

test each alert type in turn, while the associated log files

```
[gdb_processor@pcdev2:~/Users/aurban/gcn_unit_tests] $ ls Swift/*.xml
Swift/Swift_BAT_Alert.out
```

```
[gdb_processor@pcdev2:~/Users/aurban/gcn_unit_tests] $ ls -l Fermi/*.xml
Fermi/Fermi_Fin_Pos.out
Fermi/Fermi_Flt_Pos.out
Fermi/Fermi_GBM_Alert.out
```

contain the results of running the above script on each one, organized by gamma-ray observatory. For evidence that the GCN listener passes the unit tests suggested by the review team, please consider the output of these log files, as well as some purposefully "wrong" VOEvent files (to come).

Open Issues

This space is reserved for open issues related to the code and its use.

Other Important Links

- [Webpage](#) of the International Virtual Observatory Alliance (IVOA).
- [Documentation page](#) for the Comet package used by the listener.
will be removed after switching to PyGCN
- [Documentation page](#) of the Gamma-ray Coordination Network (GCN) at the NASA Goddard Space Flight Center.
- [Archive](#) of GCN *circulars*, which are plaintext followups of the Notices from the wider astronomical community. In particular, T90s and X-Ray, optical and radio afterglow observations are all typically reported via GCN circulars.
- [Latest](#) events in GraceDB
- [All Swift events](#) in GraceDB
- [All Fermi events](#) in GraceDB