

The Ligo/Virgo/Kagra Low Latency Alert Generation Infrastructure

Einstein Telescope E-Infrastructure Board Workshop
Aachen, March 9-10 2023



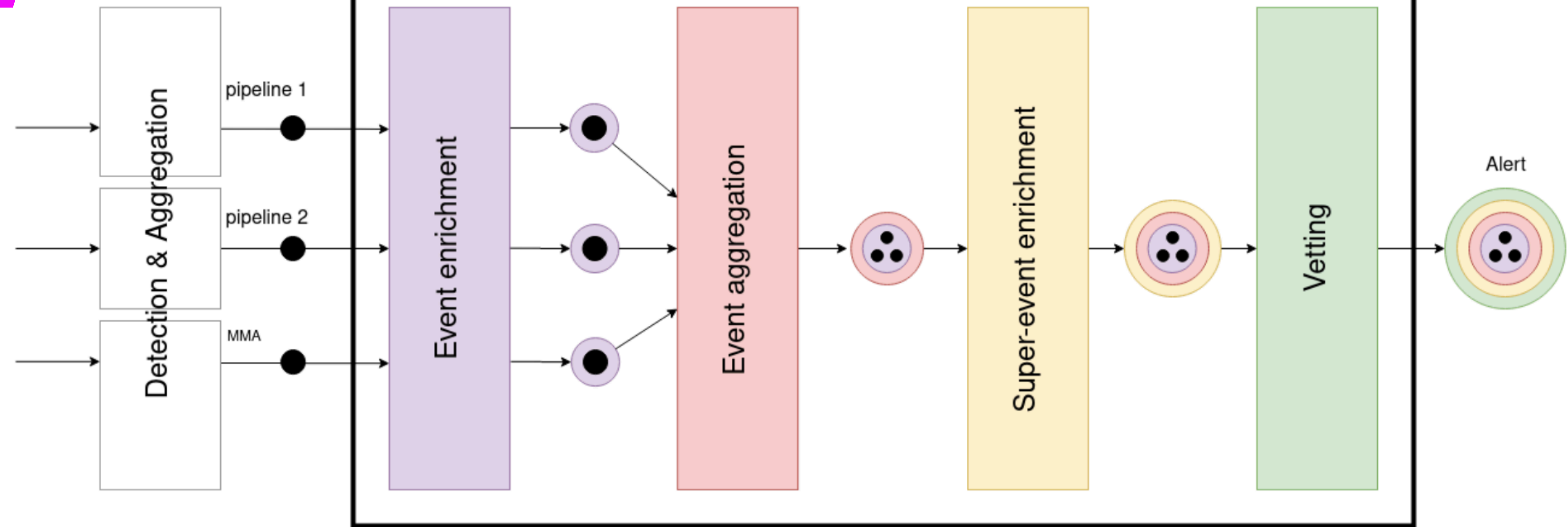
S. Vallerio - INFN Torino

The purpose

1. **Disseminate public alerts** of transient GW (and MMA involving GW) detections.
2. **Enable the discovery of EM and neutrino counterparts** to GWs (and vice versa) and assist the (common) source characterisation.
3. **Provide feedback to the instrument** teams by facilitating the diagnosing of detector problems via real-time analyses.

Workflow

- GW data
- EM data
- Neutrino data



• All-sky searches:

- no assumption on sky location or time of a transient
- Compact Binary Coalescence: modelled, matched-filtering
- Bursts: no assumption on signal morphology, time-frequency analysis
- no information from non GW sources
- also low significance alerts for early warning alerts (pre-merger)

• Multi-messenger searches:

- integrate information from EM or neutrino external triggers
- can be targeted to a region of the sky or a time identified by the external trigger (medium-latency)

• Event aggregation:

- grouping of events related to the same astrophysical (or not) cause into a *superevent*
- combining triggers across multiple pipelines but also from a given pipeline

• Superevent enrichment:

- source classification
- sky localisation
- data quality
- ...

• Vetting:

- human or automatic decision concerning the publication or retraction of the GW detection
- based on the enriched information available for the *superevent*

Public alerts

ALERT



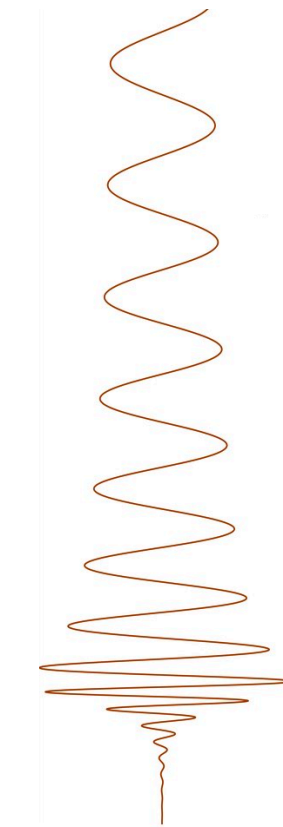
Scimma Hopskotch

<https://scimma.org/hopskotch.html>

Gamma-ray Coordinates Network (GCN)

<https://gcn.gsfc.nasa.gov/>

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{  "alert_type": "PRELIMINARY",
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  "urls": { "gracedb": "https://example.org/superevents/MS181101ab/view/" },
  "event": {
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    "far": 9.11069936486e-14,
    "significance": "low significance" # 2/day > FAR > (1/month CBC and 1/year BURST)
                      "significant"   # (1/month CBC and 1/year BURST) > FAR
    "instruments": [ "H1", "L1", "V1"],
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  },
  "external_coinc": null }
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EARLY WARNING

- Detect signal before the merger phase
- Dedicated pipelines
- Alert gamma-ray space telescopes

PRELIMINARY
PRELIMINARY
PRELIMINARY

- Up to 3 preliminary alerts with increasing significance

Human vetting

INITIAL ALERT/RETRACTION

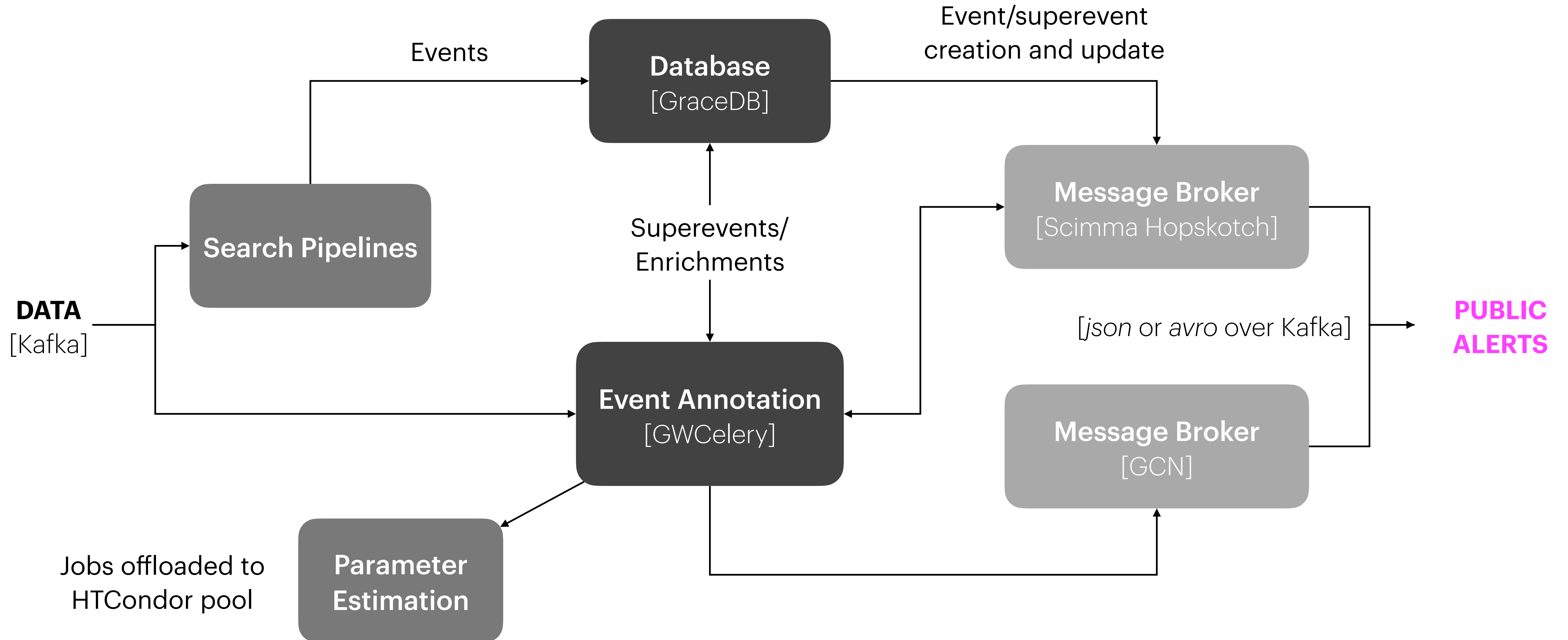
UPDATE
UPDATE

- improved calibration, de-glitching, or computationally deeper parameter estimation

...

- better significance
- better sky localisation

High-level architecture



GraceDB: the database

- Different deployments (tiers):
 - **Production**
 - **Playground:** designed for users to develop and test their own applications. It mimics the production instance, but events and associated data are not preserved indefinitely. Used in Mock Data Challenges
 - **Test:** designed for Quality Assurance (QA) testing and validation for GraceDB and electromagnetic follow-up developers. Software should meet QA milestones on the test instance before being moved to Playground or Production.
- **Web application:**
 - provides long-term storage for its inputs, outputs and by-products
 - accessible via GUI or API
 - relational database and local storage for persistence
 - deployed in replica 3 (each tier)

GraceDB (TEST) Public Alerts Latest Search Alerts Pipelines Documentation Admin Docs Logout									
Authenticated as: Sara Vallero									
MS230309I	EM_COINC	EM_Selected	EM_READY	9.110699364861297e-14	M30761	M30767 M30766 M30765	1362397199.376	2023-03-09 11:44:49 UTC	Sara Vallero
	PASTRO_READY	EMBRIGHT_READY	SKYMAP_READY			M30764 M30763 M30762			
MS230309k	DQR_REQUEST	GCN_PRELIM_SENT	ADVOK	5.176954877338635e-16	M30736	M30761 M30760 M30759	1362393223.659	2023-03-09 10:44:48 UTC	Sara Vallero
	DQR_REQUEST	ADVNO				M30758 M30757 M30756			
						M30755 M30754 M30753			
						M30752 M30751			
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						M30738 M30737 M30736			
						M30735			



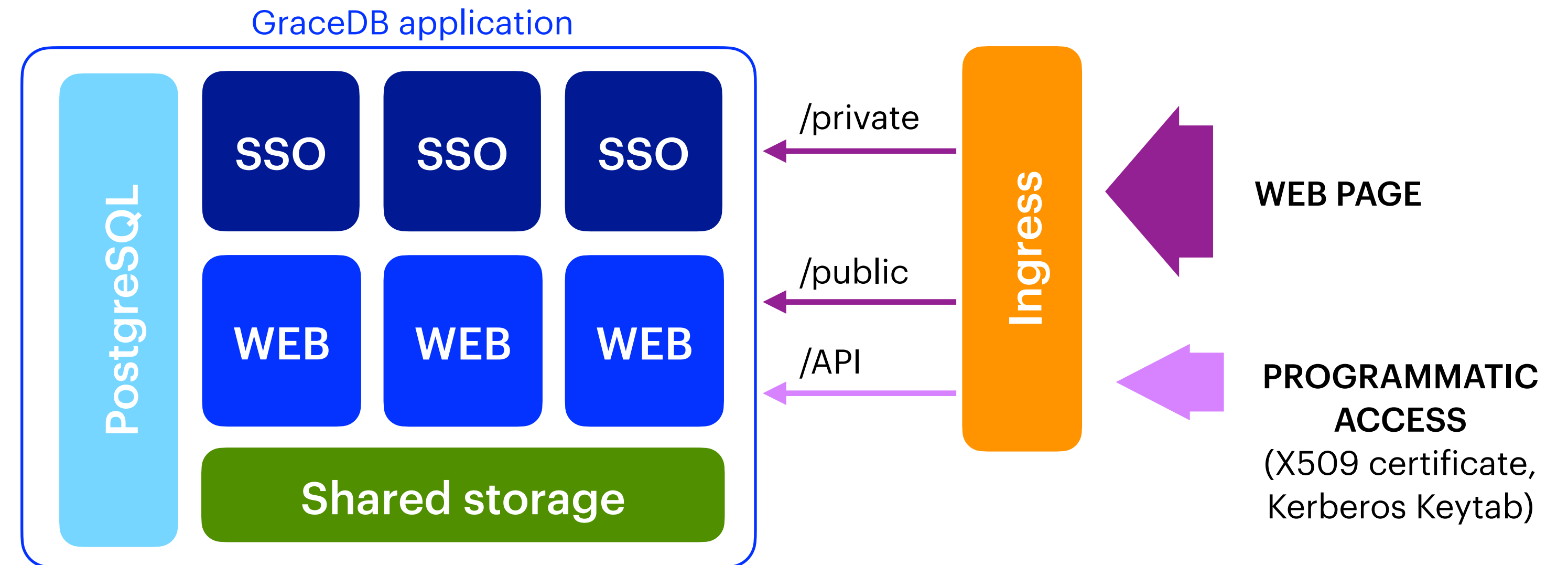
GraceDB: the database

Primary Authentication (Shibboleth):

- managing federated identities and providing a single sign-on (SSO) portal
- uses a metadata provider to collect user attributes from an attribute authority and put them into the user's session

Web application:

- **Django application:** GraceDB is written in Python and is constructed around the Django web framework.
- **Backend Webserver (Gunicorn):** Gunicorn is a lightweight Python webserver which interfaces directly with the Django service via the WSGI protocol.
- **Frontend Webserver (Apache):** used in concert with Gunicorn as an interface with Shibboleth. It is configured as a reverse proxy which gets authentication information from Shibboleth, sets that information in the headers, and then passes it on to Gunicorn.
- **Igwn-alert Overseer:** registers new events in Scimma



Shared storage:

- save event enrichment files (i.e. skymaps)
- relies on Amazon Elastic Block Store

Ingress:

- Traefik
- Redirects to different application components (Linux containers) according to url path

**Deployed with
Docker Swarm
on AWS.**

GWCelery: the event annotation service

<https://rtd.igwn.org/projects/gwcelery/en/latest/index.html>

- package for annotating and orchestrating LIGO/Virgo alerts
- built on the Celery distributed task queue and widely used opensource components
- different deployments (tiers), connected to corresponding GraceDB instances
- uses Redis to route and distribute Celery task messages and to store task results for later retrieval
- runs on dedicated VMs that also host Redis and offloads computing intensive tasks to a HTCondor cluster
- **GWCelery's responsibilities include:**
 - merging related candidates from multiple online LIGO/Virgo transient searches into *superevents*
 - correlating LIGO/Virgo events with gamma-ray bursts, neutrinos, and supernovae
 - launching automated follow-up analyses including data quality checks, rapid sky localisation, automated parameter estimation, and source classification
 - generating and sending preliminary and updated public Notices (machine readable)
 - automatically composing public Circulars (human readable)

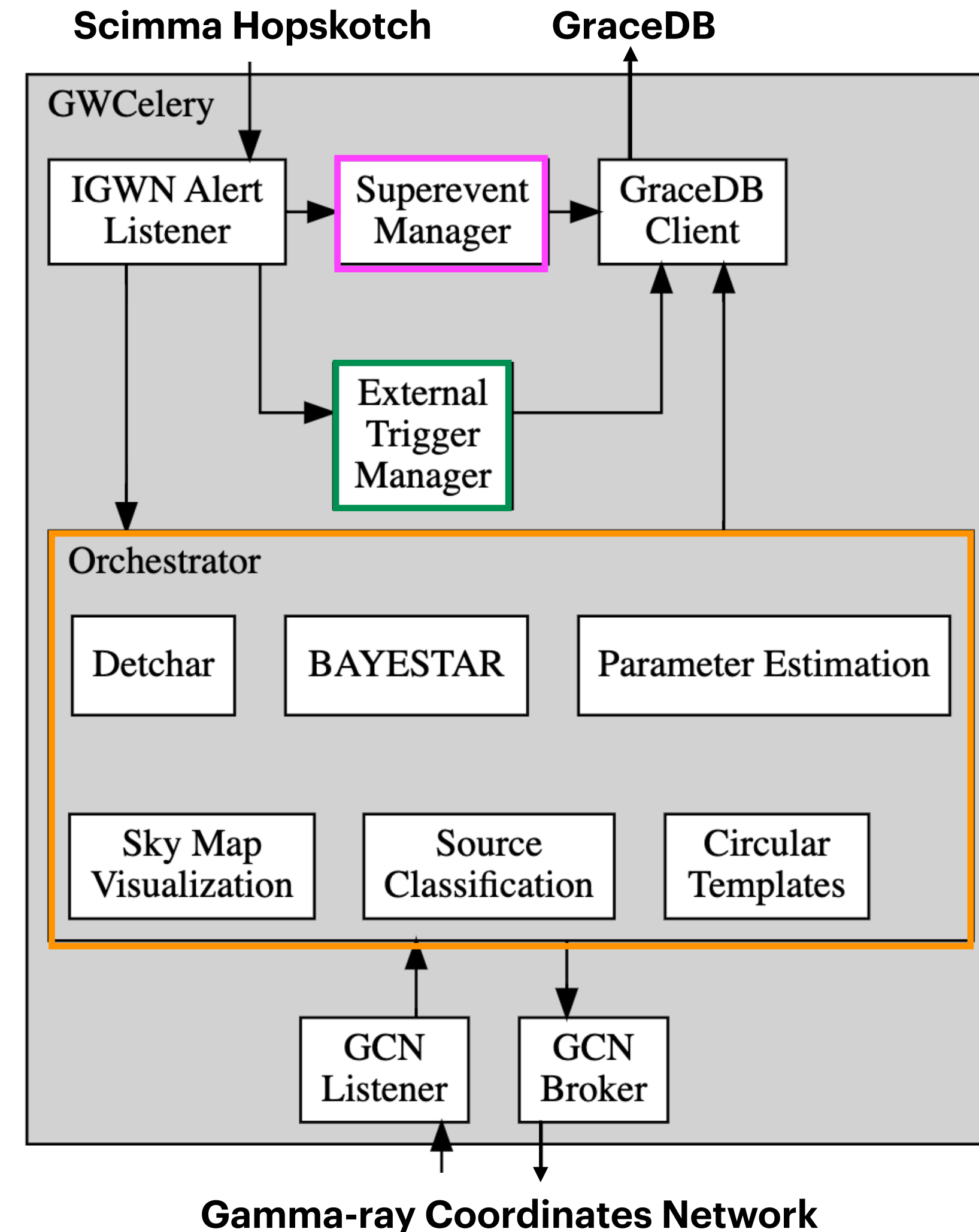
GWCelery: the event annotation service

Superevent Manager: clusters and merges related candidates into *superevents*

External Trigger Manager: correlates gravitational-wave events with GRB, neutrino, and supernova events

Orchestrator: executes the per-event annotation workflow

- these functional components are roughly mapped to Celery workers
- 1 Celery worker has been configured to accept only computationally intensive tasks that use OpenMP parallelism (HTCondor cluster)



Some considerations

- Elements in the critical path for latency:
 - Database
 - Annotation service
 - Data transfers (i.e. need data from other interferometers)
 - Search pipelines
- Latency is never “low enough”: consider early warning (negative latency) alerts
- Uniform running environment across experiments and within online/offline is desirable
- Asynchronous and distributed architecture of services is good