SCIMMA: REAL-TIME ORCHESTRATION OF MULTI-MESSENGER ASTROPHYSICAL OBSERVATIONS

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1. ESTABLISHING THE INFRASTRUCTURE FOR A COLLABORATIVE MULTI-MESSENGER ECOSYSTEM
KEY COMPONENTS OF THE ECOSYSTEM: MESSAGING

- **Hopskotch** is an pub-sub system with identity and access management

- Use your own institutional sign-in (or ORCiD) with CILogon to sign up: [https://hop.scimma.org/](https://hop.scimma.org/)

- Public “topics” including LVK alerts in O4, AMON, GCN (over Kafka!), IceCube, SNEWS - get DOIs for discovery messages

- Private “topics” are fine too - you have to join the appropriate group

- Cloud-based on AWS - highly scalable (< 1s latency for us to process messages through Run O4) - **or stand up your own instance for your project**

- Granular permissions control, an easy-to-use [python client](https://github.com/hopskotch), all open-source

- Designed to handle high volume, high throughput streams for big surveys and experiments
HOW IT WORKS TODAY

1. Receive text alert/kafka message
2. What?!?
3. Trigger approved resources by filling out Phase II forms
4. Look up other resources available. Beg, plead, cajole for time. Form collaborations. Gather information from dozens of sources.
5. Download data from different archives and reduce it.
6. Communicate information to the community, via text.
HERMES: MESSAGING FROM YOUR BROWSER

- HERMES: Hopskotch-enabled Realtime Message Exchange Service
- Where Hopskotch serves big groups, Hermes serves users and small teams working on follow-up
- Nothing to install - [https://hermes.lco.global/](https://hermes.lco.global/) use your SCIMMA credentials and you are ready to go
- Connects with TNS/GCN – one stop shop to submit a discovery
- Messages are human-readable AND machine-parseable, all form fields are validated, neat API
CONTROVERSIAL CLAIM #1:
MESSAGING INFRASTRUCTURE IS NOT THE CHALLENGE ANYMORE
2. ESTABLISHING THE INFRASTRUCTURE FOR A COLLABORATIVE MULTI-MESSENGER ECOSYSTEM
SELECT TOP 1000000 g.objID, g.htmID,
g.cmodelMag_u, g.cmodelMag_g, g.cmodelMag_r, g.cmodelMag_i, g.cmodelMag_z,
g.cmodelMagErr_u, g.cmodelMagErr_g, g.cmodelMagErr_r, g.cmodelMagErr_i, g.cmodelMagErr_z,
g.fracDeV_u, g.fracDeV_g, g.fracDeV_r, g.fracDeV_i, g.fracDeV_z,
g.extinction_u, g.extinction_g, g.extinction_r, g.extinction_i, g.extinction_z,
s.bptclass,
s.lgm_tot_p2p5, s.lgm_tot_p16, s.lgm_tot_p50, s.lgm_tot_p84, s.lgm_tot_p975p5,
z.z, z.z_err, z.z_warning,
z.v_disp, z.v_disp_err,
z.subclass,
z.sn_median, z.reliable
INTO mydb.GalaxyInfo from GalaxyTag as g
INNER JOIN galSpecExtra as s
ON s.specObjID = g.specObjID
INNER JOIN galSpecInfo as z
ON z.specObjID = s.specObjID
WHERE g.clean=1;
DES - MIX OF PUBLIC/PRIVATE

DES internal access to all data products + community compute on catalogs through NOIRLab
Data Management System Vision

Raw Data: 20TB/night
Sequential 30s images covering the entire visible sky every few days

Prompt Data Products
- Alerts: up to 10 million per night
- Results of Difference Image Analysis (DIA): transient and variable sources
- Solar System Objects: ~ 6 million

Data Release Data Products
Final 10yr Data Release:
- Images: 5.5 million x 3.2 Gpx
- Catalog: 15PB, 37 billion objects

Access to proprietary data and the Science Platform require Rubin data rights

Rubin Science Platform
Provides access to Rubin Data Products and services for all science users and project staff

Community Brokers
Alert Filtering Service
Rubin DACs (USDF & Chile)
Independent DACs (iDACs)

 Rubin Science Platform (RSP)
A set of integrated web applications & services deployed at Data Access Centers (DACs) through which the scientific community will access, visualize, subset and perform next-to-the-data analysis of Rubin Data products.

- **Portal Aspect**: exploratory analysis and visualization of the Rubin archive
- **Notebook Aspect**: in-depth ‘next-to-data’ analysis and creation of added-value data products
- **API Aspect**: remote access to the Rubin archive via industry-standard APIs

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**Rubin Science Platform (RSP)**

- **Portal**
- **Notebooks**
- **WEB APIs**

**Components**

- **Data Releases**
- **Alert Filtering Service**
- **User Databases**
- **User Files**
- **User Computing**
- **Software Tools**
WE ARE MISSING SCIENCE BECAUSE WE AREN’T EFFICIENTLY SHARING INFORMATION

Slide Credit: Andy Howell
VISION FOR GRAVITATIONAL WAVE FOLLOWUP OF THE FUTURE

1. Receive alert

2. Telescopes automatically observes target, negotiates priorities, data access

3. Data are automatically reduced, instantly made available to community

4. Machines and humans make inferences based on all available data, repeat

\[ p_{\text{dist}} (R.A., \text{decl.}, D) = N_{\text{dist}} (R.A., \text{decl.}) \cdot e^{-\frac{(D - \mu_{\text{dist}}(R.A., \text{decl.}))^2}{2\sigma_{\text{dist}}^2(R.A., \text{decl.})}} \]
BUILDING A COLLABORATIVE MMA ECOSYSTEM

- Requires interoperability between components
- Improving messaging – HOPSKOTCH & HERMES (Andy Howell)
- Improving data acquisition & management – TOMs: Target & Observation Managers (Rachel Street)
- Improving telescope infrastructure – AEON & Open Observatory Control System (Bryan Miller)
- Improving searches by information sharing & visualization – Treasure Map (Sam Wyatt in the afternoon session)
HOPSKOTCH/TOM INTEGRATION

- Hopskotch carries GCNs and other public alerts
- Pulls machine readable info into a database with an API
- SCIMMA and LCO are making modules for the TOM Toolkit to display and filter GCNs
- This should work with future message formats
- Ultimately, also want to connect with AEON facilities this way (and ACROSS!)
- SCIMMA’s Hopskotch can be used to provide real-time observatory status and instrument availability information to users
X-ray sources are reported by Swift in GCN notices.

When a GCN notice is carried through Hopskotch, the X-ray sources are extracted into a database.

Treasure map queries this database via API to report X-ray sources.

Building the connections with TOM Toolkit and AEON automagically means we can keep Treasuremap updated in real-time.
Rubin Auxiliary Telescope (AuxTel)

- AuxTel is a 1.2m telescope that will provide spectroscopic observations to improve photometric calibration of the LSST.
- AuxTel uses the same services and software stack as the primary telescope, so it will be useful to prototype a ToO pipeline prior to deploying during LSST.
- Mock observing runs twice a month.
Prototype design: SCiMMA-Rubin client

- Use hop-client API to receive LVK alerts via SCiMMA and reformat into appropriate schema
- Send alerts to Rubin scheduling database for parsing
- Use alerts from the scheduling database as target-of-opportunities for AuxTel

- Working with Tiago Ribeiro (Rubin Telescope+Site team and scheduling systems)
RESEARCH PLATFORMS IN THE CLOUD ARE COMING

Live Alerts & Notifications

Observatories & Surveys

Multimessenger Trigger

Sharing Streaming & Filtering

IAU Transient Name Server

HERMES

ARCHIVE & DATABASE

HOPSKOTCH

NASA GCN

Space-based Followup

NASA

https://hermes.lco.global/

https://hop.scimma.org/

https://github.com/scimma/hop-client
THE DATA LAKE
WHAT SUCH INFRASTRUCTURE MIGHT LOOK LIKE
COLLABORATIVE ECOSYSTEMS NEED PEOPLE TALKING

- OpenLVEM is a tremendous resource for the community, but it is time to grow it beyond the original LVK beginnings

- SCIMMA is working with OpenLVEM to begin hosting the community forum in the next few months

- A joint slack for all groups, liaisons between OpenLVEM and surveys so users have a channel to feedback

- Port the OpenLVEM Wiki and git repo - Same SCIMMA credentials for Hopskotch/ Hermes also work for the forum

Welcome to the OpenLVEM web

This is the community forum on multi-messenger observations connected to Gravitational Wave (GW) interested can join. This open forum started in January 2018. The LIGO-Virgo-KAGRA Collaboration

- Get started
- LIGO-Virgo-KAGRA documentation and resources
- Other resources
- Telecons
- Townhall Meetings
- Other links
- OpenLVEM Web Utilities

Get started

Sign up to the OpenLVEM Forum at gw-astronomy.org: approval and subscription to the openlvem@gw-astronomy.org address (for help on this topic, email gcastro-help@cgca.uwm.edu). Information about observing runs via OpenLVEM mailing list.

The OpenLVEM forum will also organize occasional teleconferences and in-person meetings to foster observations connected to gravitational waves. If you would like to make a presentation, please submit

LIGO-Virgo-KAGRA documentation and resources
3. ESTABLISHING THE INFRASTRUCTURE FOR A COLLABORATIVE MULTI-MESSANGER ECOSYSTEM
CONTROVERSIAL CLAIM #2:

THE BIG VISION SHOULD BE A COLLABORATIVE ECOSYSTEM FOR SCIENCE

THIS IS GOING TO REQUIRE JOINT AGENCY FUNDING AND A MANDATE THAT NEW EXPERIMENTS WORK WITH THE "CENTER"
FIN