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


GAUTHAM NARAYAN

On behalf of the SCIMMA team:
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Lindy Lindstrom, Andrew Manning, Curtis McCully, Jon Nation,
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and a long list of collaborators and affiliates



OAC-1841625
OAC-1934752
OAC-2311355

# 0. WHAT THE HECK IS THIS SCIMMA THING

# I.E. WHY DO YOU EVEN EXIST?

# HOW IT WORKS TODAY

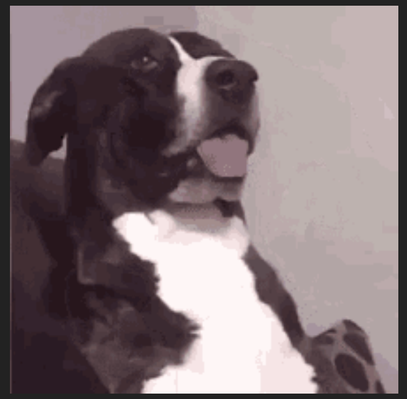
skymap https://gracedb.ligo.org/api/superevents/S231017bj/files/bayestar.multiorder.fits,0

gracedb https://gracedb.ligo.org/superevents/S231017bj/view/

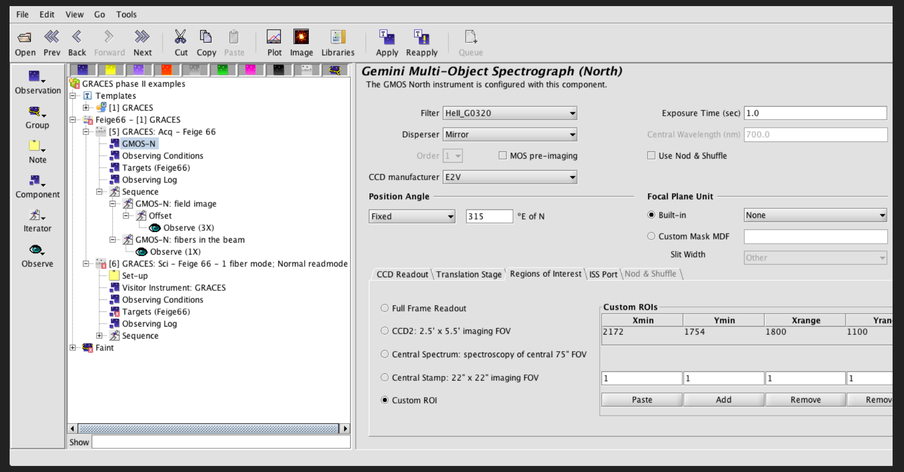
EVENT KEYPAIRS ≡

| Key | Value |
|---|---|
| far | 0.00000526891153640463 |
| time | 2023-10-17T13:28:29.537Z |
| group | CBC |

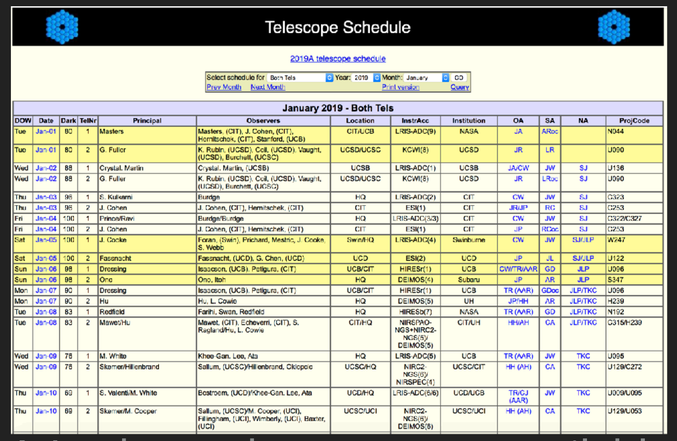
1. Receive text alert/kafka message



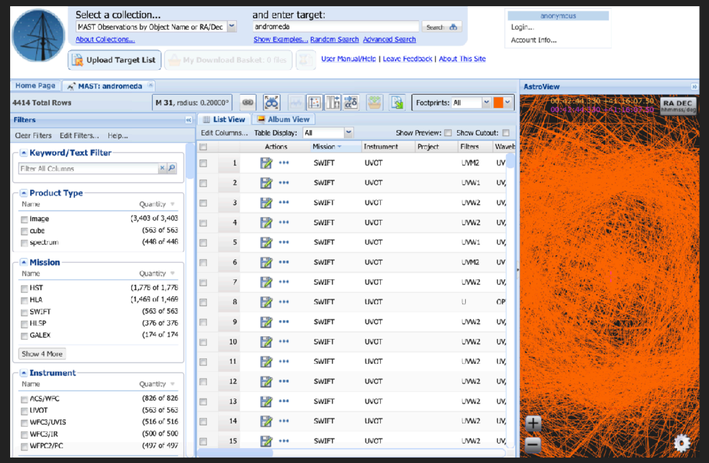
2. What?!?




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.

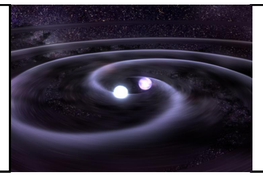
```
////////////////////////////////////////////////////////////////////////
TITLE:   GCN CIRCULAR
NUMBER:  21538
SUBJECT: LIGO/Virgo G298048: Las Cumbres Observatory Detection of The Possible Optical Counterpart in NGC 4993
DATE:    17/08/18 04:06:31 GMT
FROM:    Iair Arcavi at LCOGT  <iarcavi@lcogt.net>

I. Arcavi, D. A. Howell, C. McCully, G. Hosseinzadeh, S. Vasylyev (UCSB/Las
Cumbres Obs), M. Zalzman, D. Poznanski (TAU), L.P. Singer (NASA/GSFC), S.
Valenti (UC Davis), T. Piran (HUJI), D. Kasen, J. Barnes (UC Berkeley) and
W-f. Fong (UA) report an independent detection of the possible optical
counterpart reported by Coulter et al. (LVC GCN 21529), Chornock et al.
(LVC GCN 21530), Valenti et al. (LVC GCN 21531) and Melandri et al. (LVC
GCN 21532).

In the course of Las Cumbres Observatory galaxy-targeted LIGO followup we
observed NGC 4993 from one of our 1-meter telescopes at the Cerro Tololo
Inter-American Observatory in Chile. An imaging 5-minute exposure starting
at 2017-08-18 00:15:23 UT in the w (=g+r+i) filter clearly shows the
candidate.

Analysis of the image is ongoing and followup is planned when the field
becomes visible to our Siding Spring telescopes starting at 2017-08-18
08:32 UT.
```

6. Communicate information to the community, via text

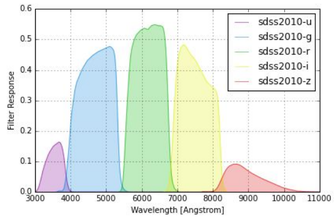
Slide Credit: Andy Howell

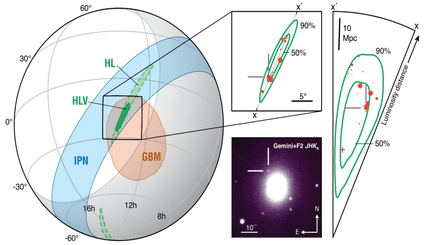
# WHY IS IT BAD IF WE DON'T COMMUNICATE? MMA EVENTS ARE RARE

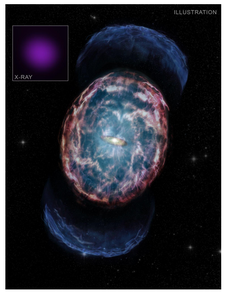
Sample BNS masses



Sample merger distance




LVK Detectable?

LIGO VIRGO KAGRA

Passband transmission

Survey mag threshold

Kilonova

yes

yes

Sample / Compute SED model parameters

SED Approximation

Synthetic SED

Synthetic light curve

EM Survey Detectable?

WEBB SPACE TELESCOPE

DECam

HUBBLE SPACE TELESCOPE

VERA C. RUBIN OBSERVATORY

no

SciPy

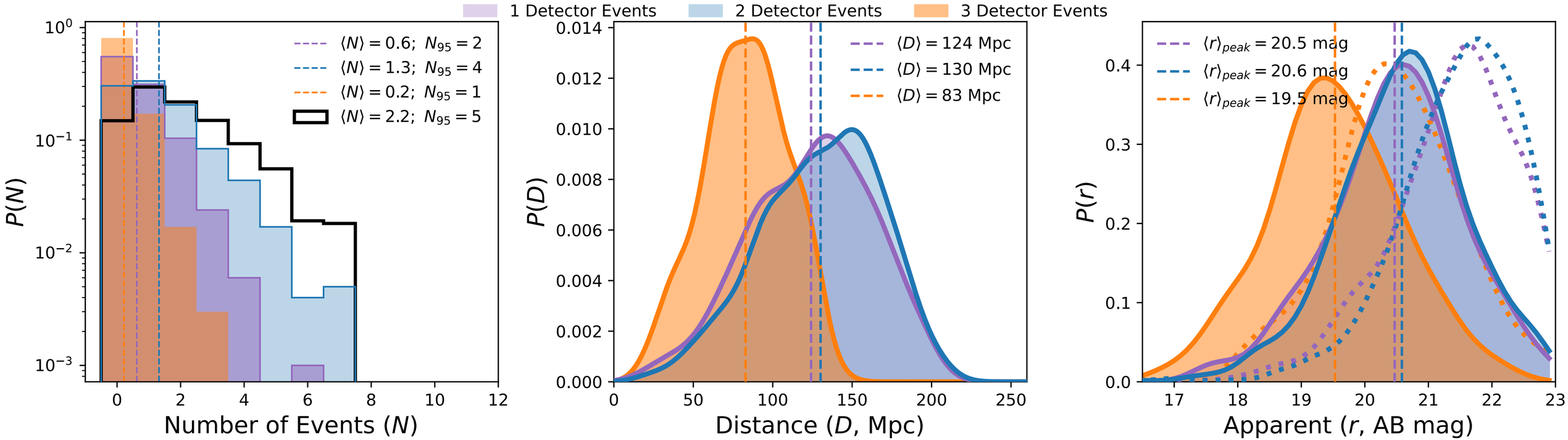
Bulla SED Grid

Sample coordinates, extinction, and redshift and treat SEDs

No EM Counterpart

Shah et al., 2023

# WHY IS IT BAD IF WE DON'T COMMUNICATE? MMA EVENTS ARE RARE



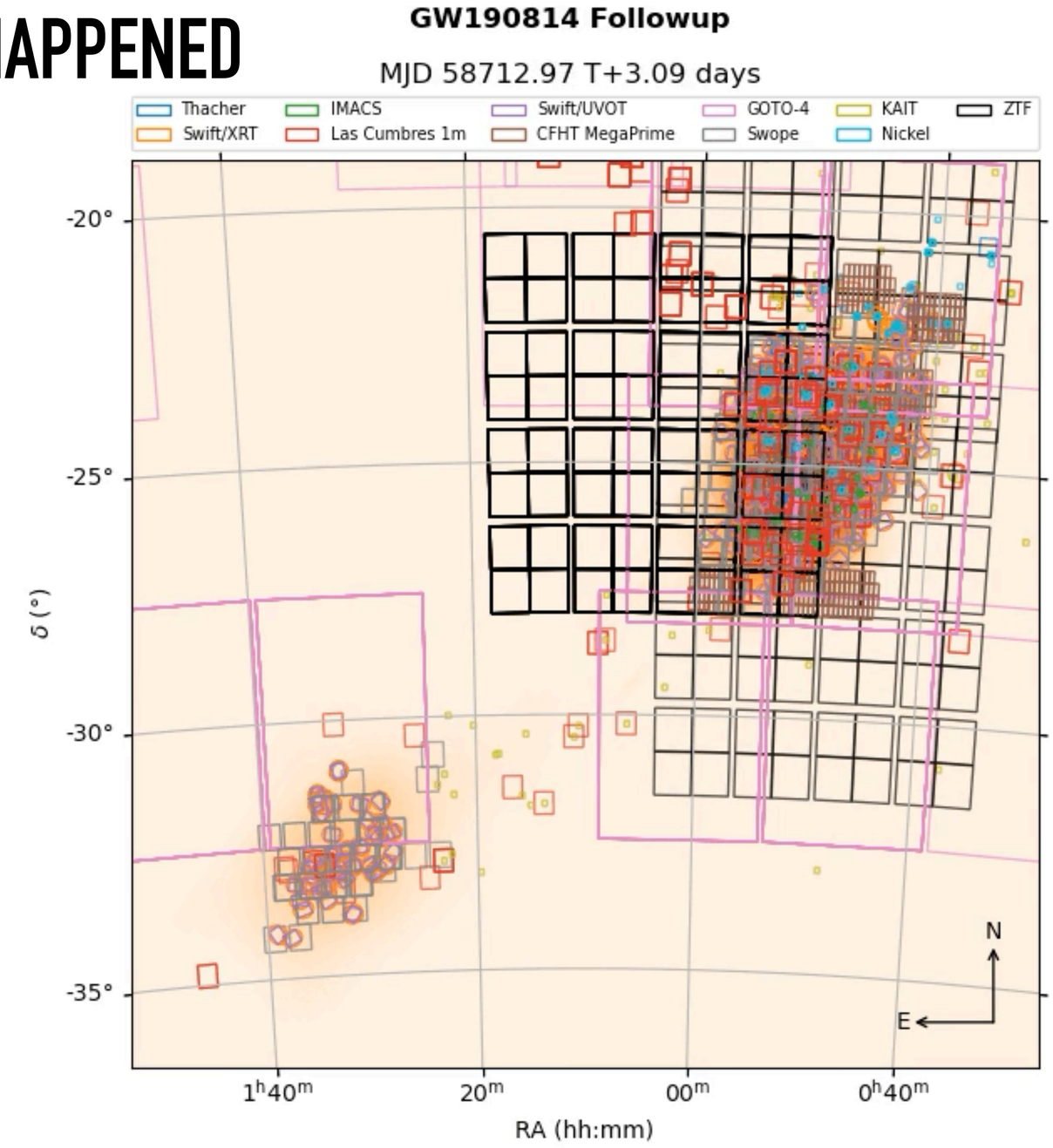

**The number of MMA events we should expect in O4 is ~1. In the most optimistic scenarios, 4.**

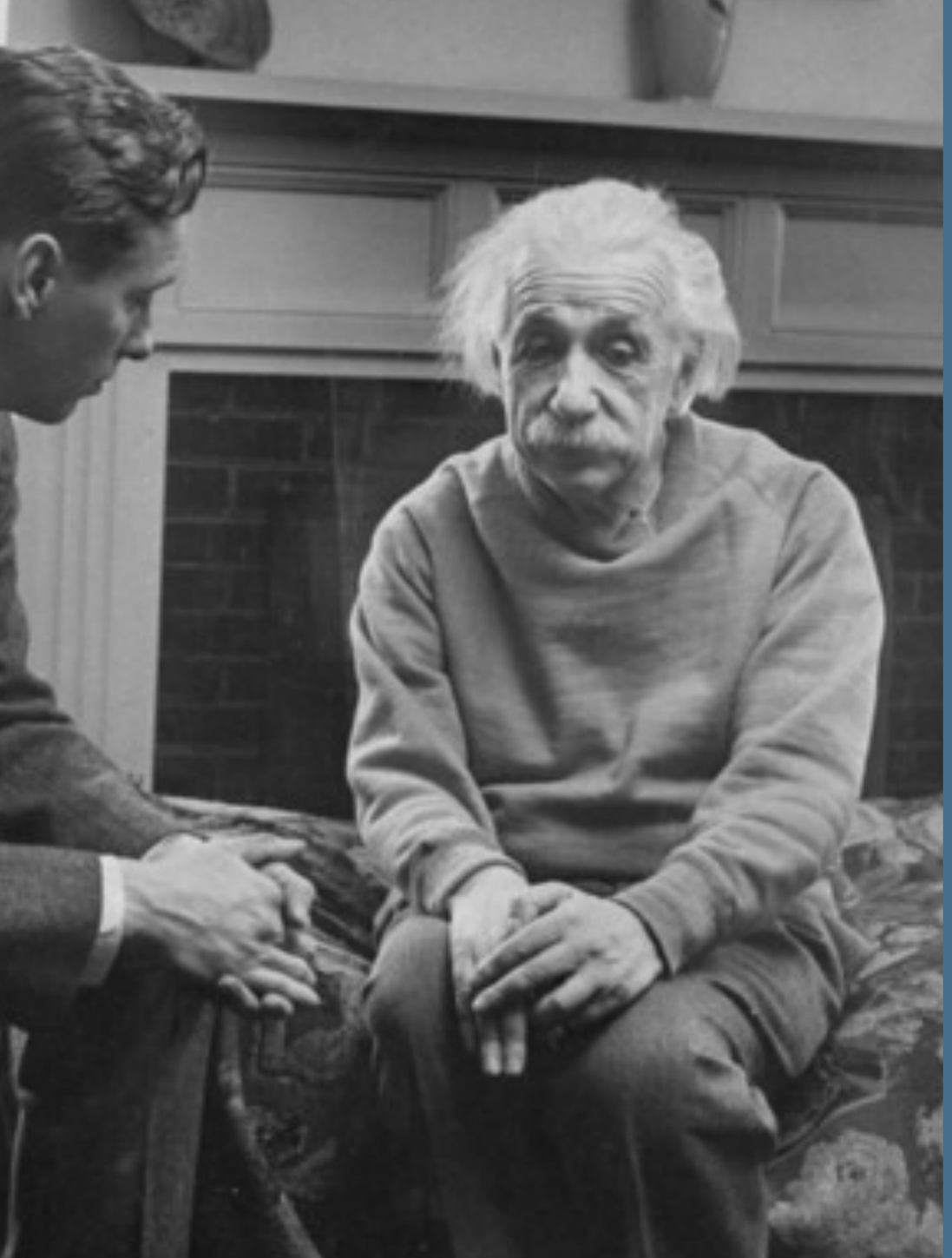
**If we do not coordinate, we will miss the second**

Shah et al., 2023

# THIS HAS ALREADY HAPPENED







# WE ARE MISSING SCIENCE BECAUSE WE AREN'T EFFICIENTLY SHARING INFORMATION

Slide Credit: Andy Howell

# 1. ESTABLISHING THE INFRASTRUCTURE FOR A COLLABORATIVE MULTI-MESSENGER ECOSYSTEM

# KEY COMPONENTS OF THE ECOSYSTEM: MESSAGING



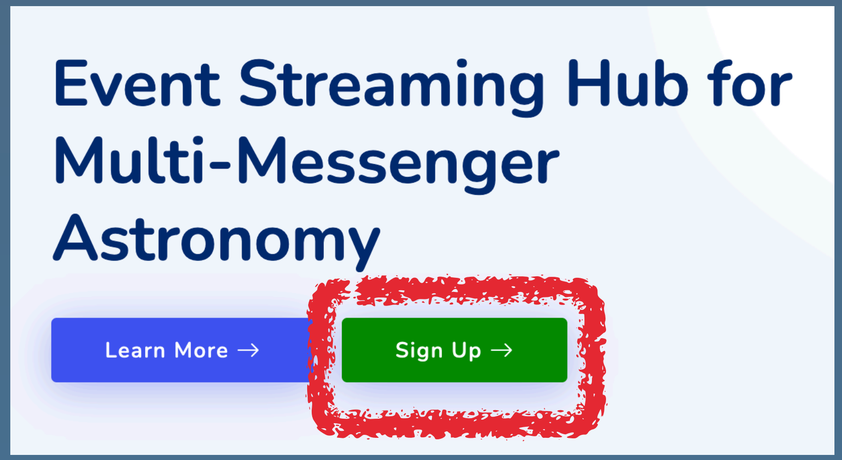
- Hopskotch is an pub-sub system with identity and access management
- Use your own institutional sign-in (or ORCiD) with CILogon to sign up: https://hop.scimma.org/
- Public “topics” including LVK alerts in O4, AMON, GCN (over Kafka!), IceCube, SNEWS - get DOIs for discovery messages
- Private “topics” are fine too - you have to join the appropriate group - message us to create a new survey with you as the PI
- 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, all open-source
- Designed to handle high volume, high throughput streams for big surveys and experiments

# 2. SIGNING UP FOR SCIMMA & HERMES (DEMO)

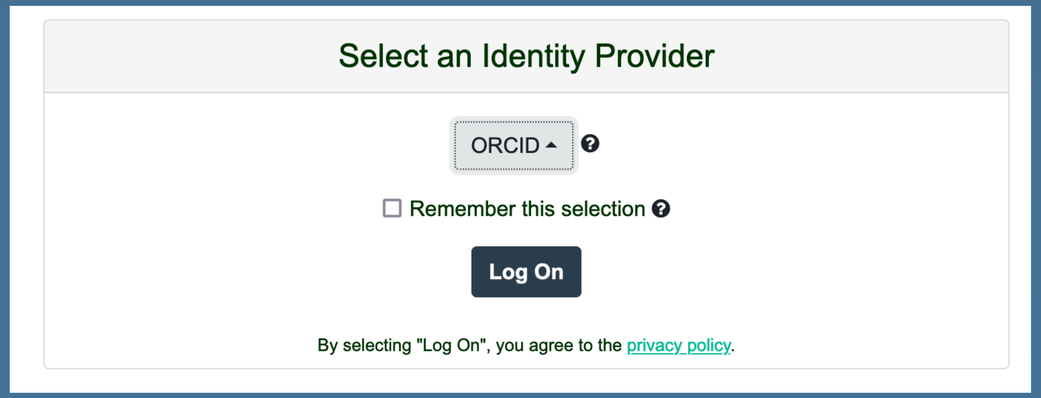
# SIGNING UP FOR SCIMMA P1



- As promised, use your own institutional sign-in (or ORCiD) with CILogon to sign up: https://hop.scimma.org/



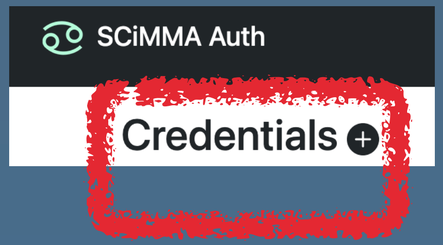

- Pick your identity provider (the reason we do this is so you don't have to go get an endorsement from someone to verify that you are who you are) - strongly suggest using ORCiD!



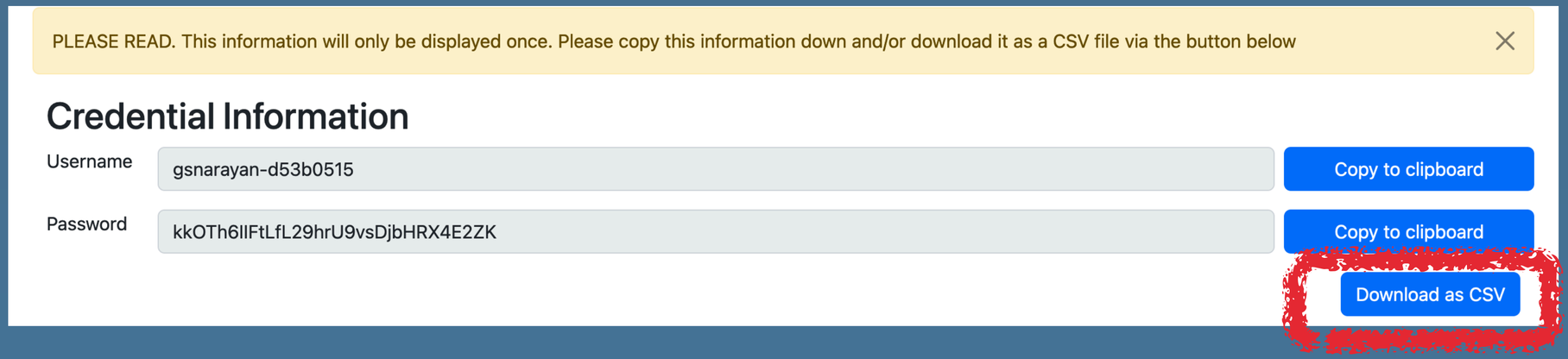
# SIGNING UP FOR SCIMMA P2.



- Click the + next to Credentials to create this and enter some description - you can have more than one for e.g. different surveys



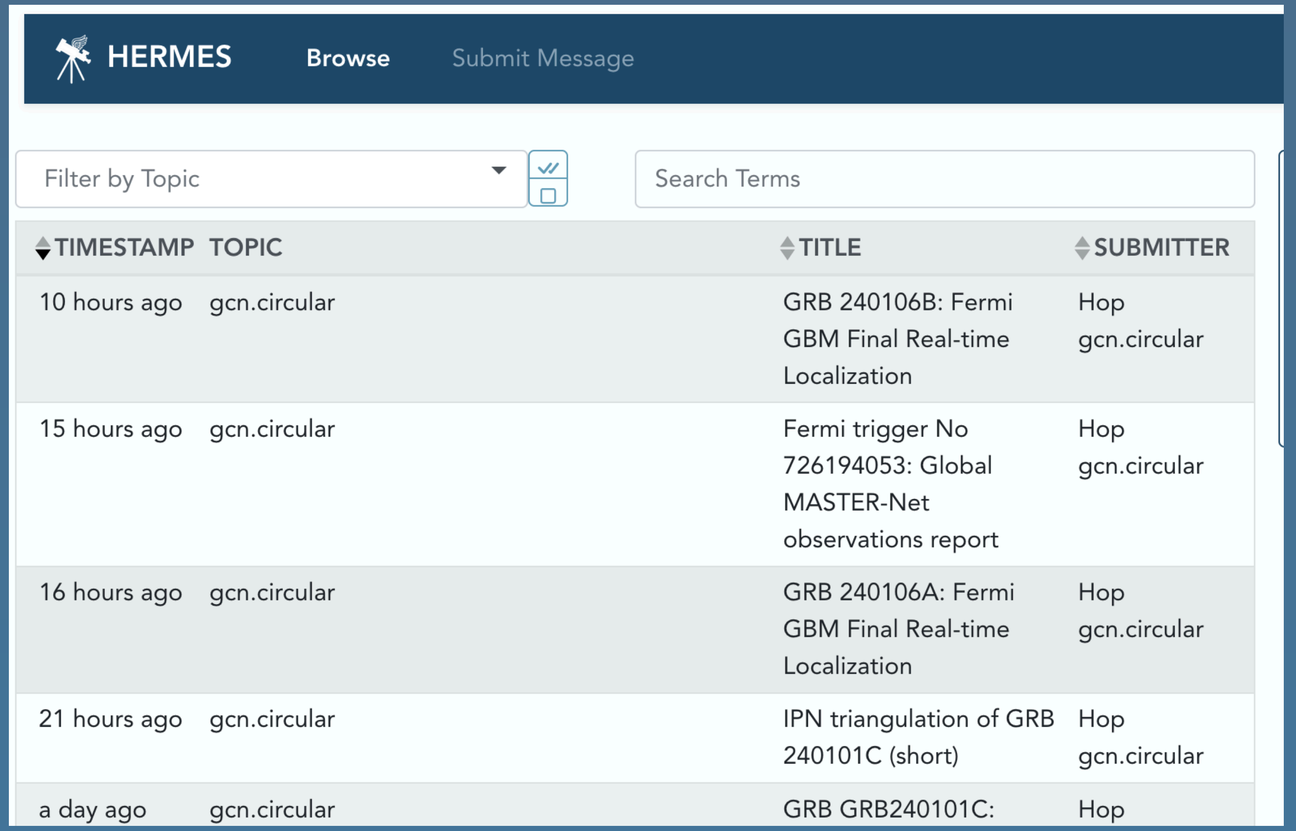

- hop.scimma.org will autogenerate a username and password for you - IMPORTANT - DOWNLOAD AS CSV! Save this someplace!



# SIGNING UP FOR SCIMMA P3.



- Your hop account will let you use HERMES - https://hermes.lco.global
  - Under the hood, HERMES will create a hop credential with your hop account, allowing it to post and read, which you can see back at https://hop.scimma.org - it says created by HERMES.
  - You can also have your TOM Toolkit do the same exact thing - so you can post e.g. TNS circulars from your TOM Toolkit



HERMES Browse Submit Message Stream Status: About gsn@illinois.edu

igwn.gwalert ×

Search Terms

| TIMESTAMP | TOPIC | TITLE | SUBMITTER |
|---|---|---|---|
| 2 days ago | igwn.gwalert | S240104bl - UPDATE | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104bl - INITIAL | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104bl - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104bl - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104ao - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104ao - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104ah - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104ah - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104ae - PRELIMINARY | cody.messick-30d512c8 |
| 2 days ago | igwn.gwalert | S240104ae - PRELIMINARY | cody.messick-30d512c8 |

« ‹ 1 2 3 4 … › »

Show: 10

# S240104bl - INITIAL

Message ID: c6f1cc7a

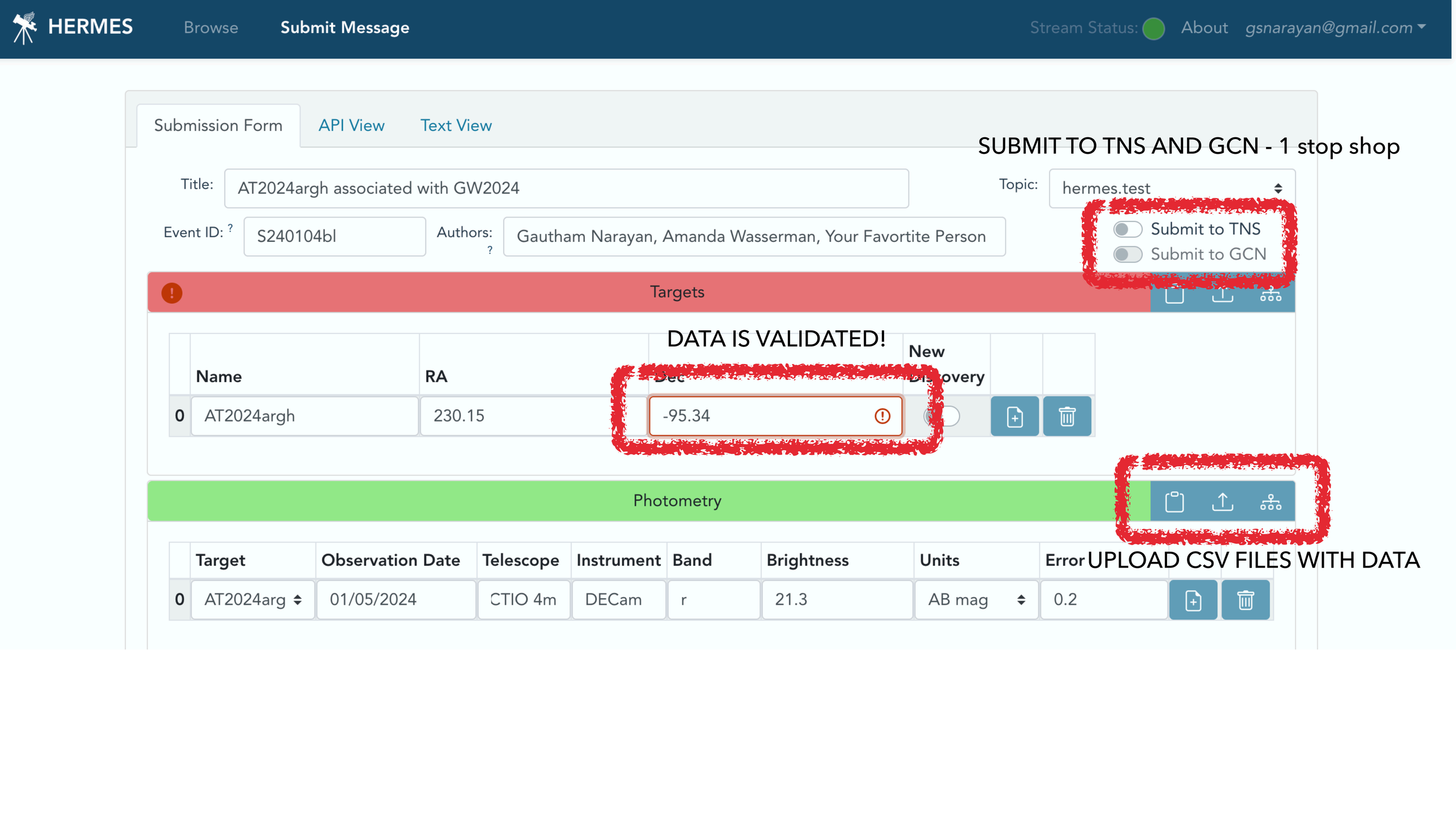
Superevent Messages: S240104bl

## URLS KEYPAIRS ≡

| Key | Value |
|---|---|
| skymap | https://gracedb.ligo.org/api/superevents/S240104bl/files/bayestar.multiorder.fits,1 |
| gracedb | https://gracedb.ligo.org/superevents/S240104bl/view/ |

## EVENT KEYPAIRS ≡

| Key | Value |
|---|---|
| far | 3.554967487258808e-17 |


HERMES
Browse
Submit Message
Stream Status:
About
gsnarayan@gmail.com
Submission Form
API View
Text View
SUBMIT TO TNS AND GCN - 1 stop shop
Title:
AT2024argh associated with GW2024
Topic:
hermes.test
Event ID:
S240104bl
Authors:
Gautham Narayan, Amanda Wasserman, Your Favortite Person
Submit to TNS
Submit to GCN
Targets
DATA IS VALIDATED!
Name
RA
Dec
New Discovery
0
AT2024argh
230.15
-95.34
Photometry
UPLOAD CSV FILES WITH DATA
Target
Observation Date
Telescope
Instrument
Band
Brightness
Units
Error
0
AT2024arg
01/05/2024
CTIO 4m
DECam
r
21.3
AB mag
0.2

# 3. INTEGRATING THIS WITH YOUR PIPELINES (DEMO)

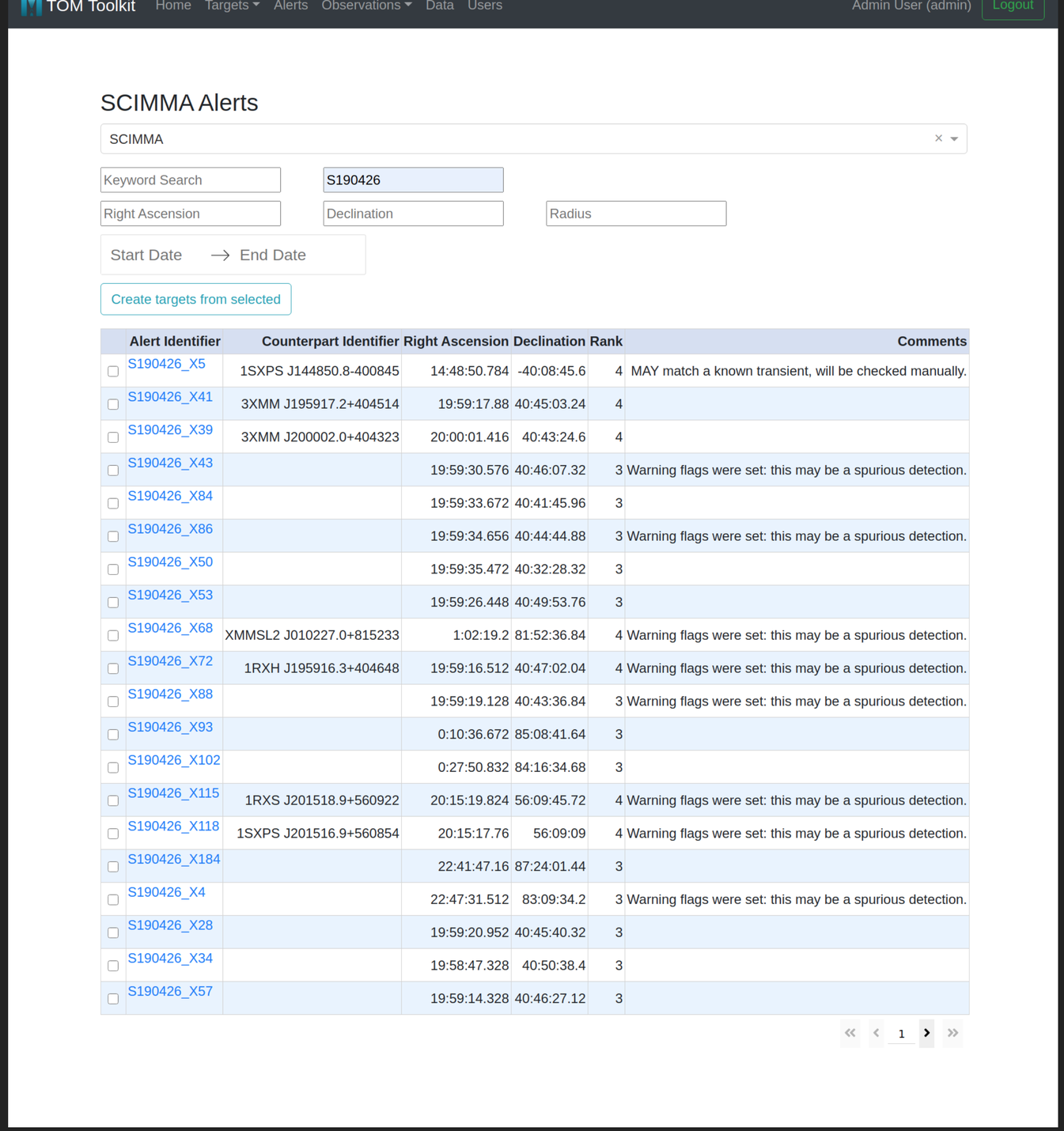
# SIGNING UP FOR SCIMMA P4 - HOPSKOTCH



- conda create --name hop-venv python=3.10
- conda activate hop-venv
- conda install -c conda-forge hop-client
- hop auth add
- (add your username and password)
- for hostname - you can listen to ANY kafka server e.g. kafka.scimma.org
- hop list-topics kafka://kafka.scimma.org
- hop subscribe kafka://kafka.scimma.org/gcn.circular
- hop subscribe kafka://kafka.scimma.org/igwn.alert

# 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



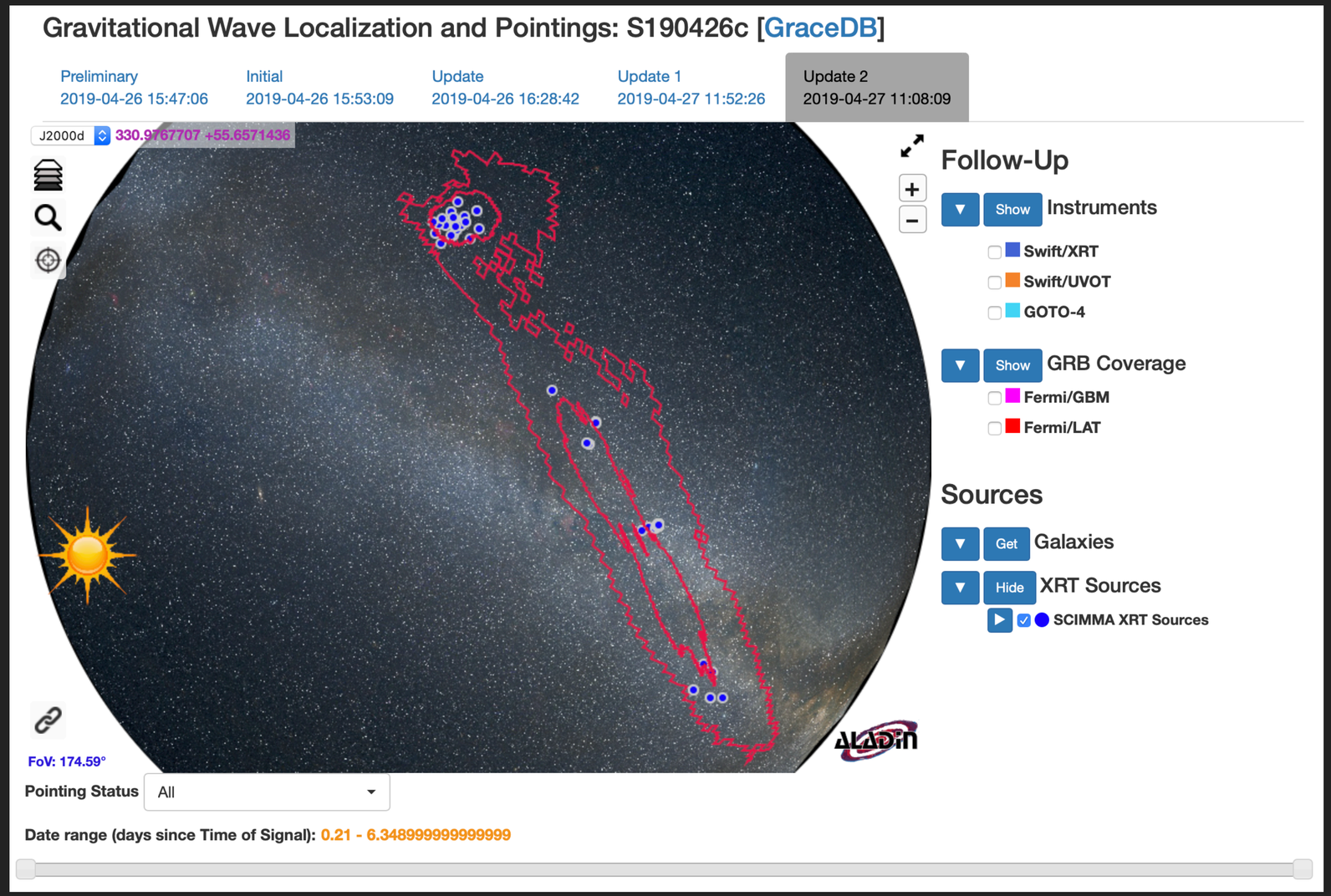

| | Alert Identifier | Counterpart Identifier | Right Ascension | Declination | Rank | Comments |
|---|---|---|---|---|---|---|
| ☐ | S190426_X5 | 1SXPS J144850.8-400845 | 14:48:50.784 | -40:08:45.6 | 4 | MAY match a known transient, will be checked manually. |
| ☐ | S190426_X41 | 3XMM J195917.2+404514 | 19:59:17.88 | 40:45:03.24 | 4 | |
| ☐ | S190426_X39 | 3XMM J200002.0+404323 | 20:00:01.416 | 40:43:24.6 | 4 | |
| ☐ | S190426_X43 | | 19:59:30.576 | 40:46:07.32 | 3 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X84 | | 19:59:33.672 | 40:41:45.96 | 3 | |
| ☐ | S190426_X86 | | 19:59:34.656 | 40:44:44.88 | 3 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X50 | | 19:59:35.472 | 40:32:28.32 | 3 | |
| ☐ | S190426_X53 | | 19:59:26.448 | 40:49:53.76 | 3 | |
| ☐ | S190426_X68 | XMMSL2 J010227.0+815233 | 1:02:19.2 | 81:52:36.84 | 4 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X72 | 1RXH J195916.3+404648 | 19:59:16.512 | 40:47:02.04 | 4 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X88 | | 19:59:19.128 | 40:43:36.84 | 3 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X93 | | 0:10:36.672 | 85:08:41.64 | 3 | |
| ☐ | S190426_X102 | | 0:27:50.832 | 84:16:34.68 | 3 | |
| ☐ | S190426_X115 | 1RXS J201518.9+560922 | 20:15:19.824 | 56:09:45.72 | 4 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X118 | 1SXPS J201516.9+560854 | 20:15:17.76 | 56:09:09 | 4 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X184 | | 22:41:47.16 | 87:24:01.44 | 3 | |
| ☐ | S190426_X4 | | 22:47:31.512 | 83:09:34.2 | 3 | Warning flags were set: this may be a spurious detection. |
| ☐ | S190426_X28 | | 19:59:20.952 | 40:45:40.32 | 3 | |
| ☐ | S190426_X34 | | 19:58:47.328 | 40:50:38.4 | 3 | |
| ☐ | S190426_X57 | | 19:59:14.328 | 40:46:27.12 | 3 | |

« ‹ 1 › »

# TREASURE MAP – HOPSKOTCH INTEGRATION

Wyatt et al. 2020, ApJ, 894, 127

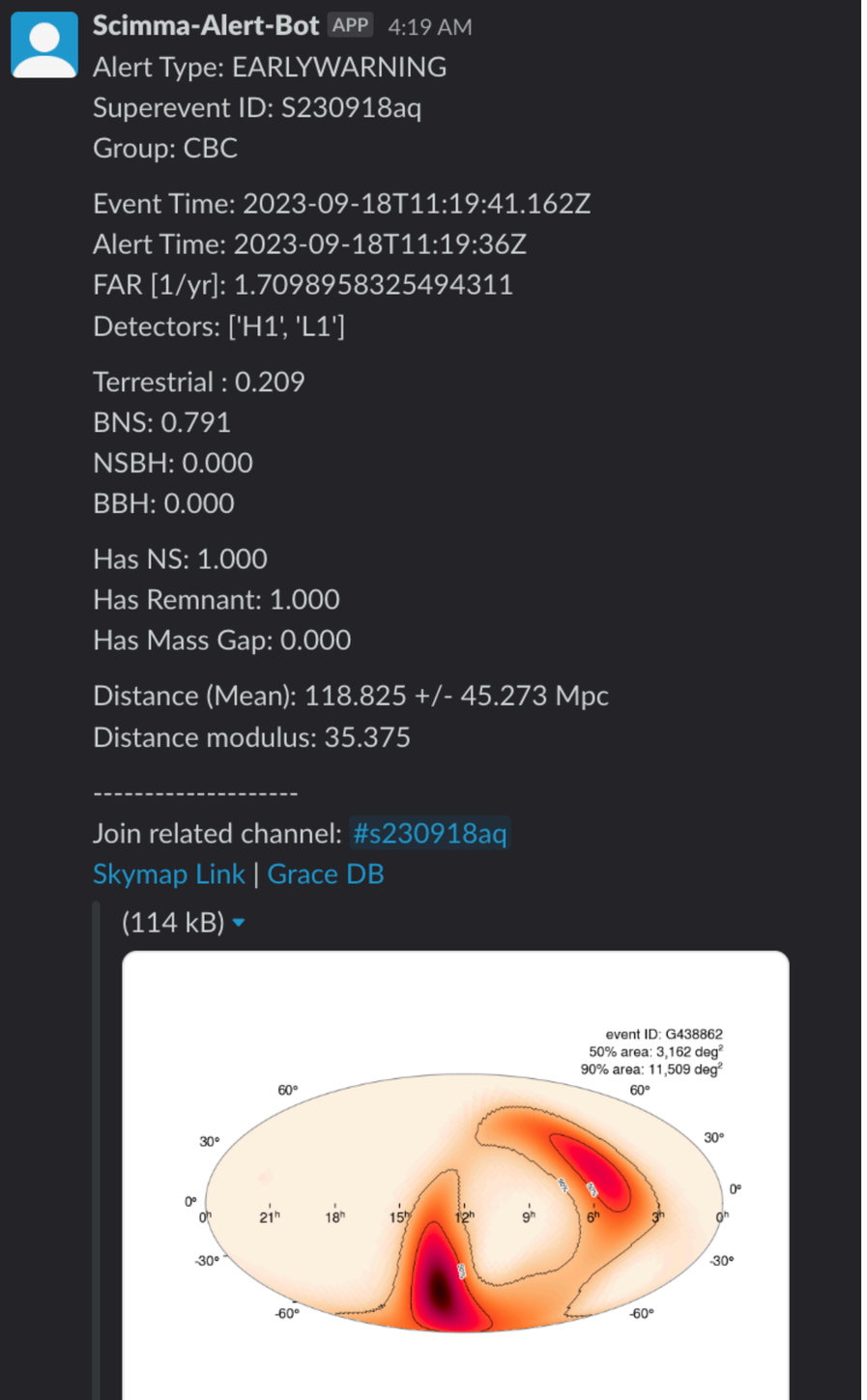
https://treasuremap.space/



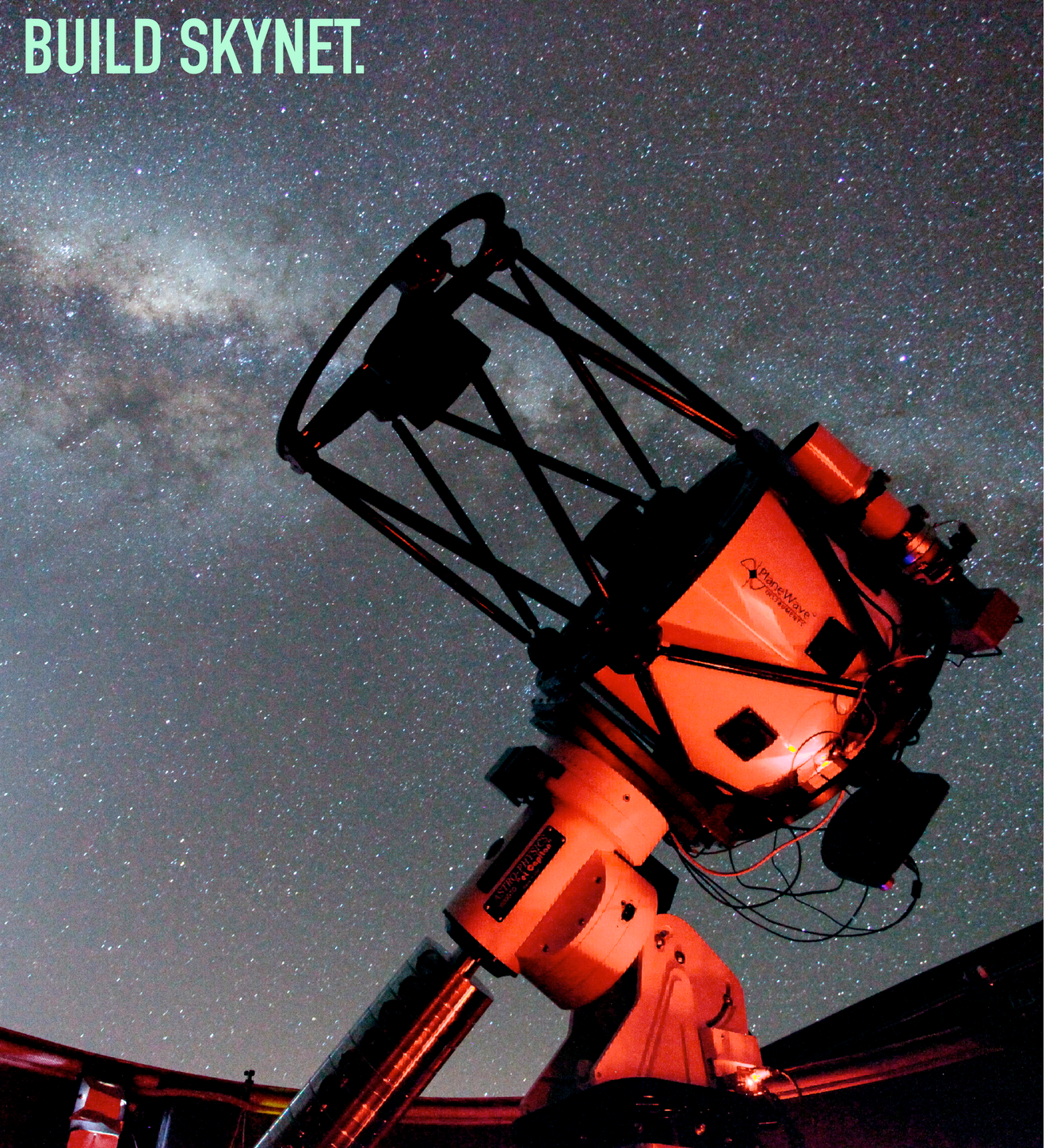

- X-ray sources are reported by Swift in GCN notices.
- When a GCN notice is carried through Hopskotch, the X-ray sources are extracted into a database
- Treasure map queries this database via API to report X-ray sources.
- Building the connections with TOM Toolkit and AEON automagically means we can keep Treasuremap updated in real-time.

# BUILDING YOUR OWN APP AROUND HOPSKOTCH – A SIMPLE EXAMPLE

https://github.com/scimma/hop-slack-app

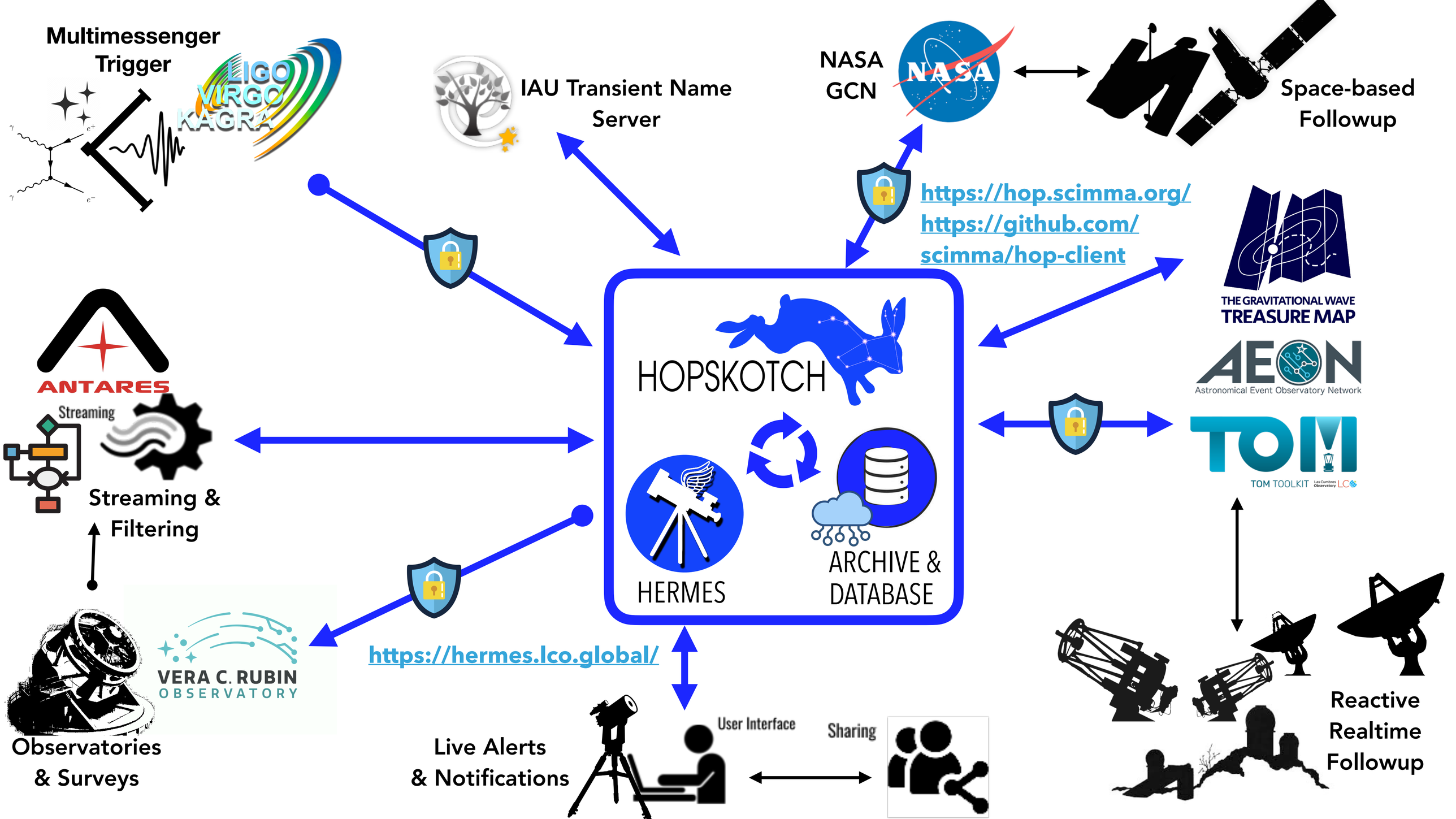



- It's now functionally possible to listen to Kafka messages with Hopskotch (e.g. LVK)
- Trigger the TOM Toolkit to get more photometry
- Report your followup observations to TNS, GCN and again as Kafka message on Hopskotch/HERMES
- Your colleague can listen to your messages, and trigger spectroscopic followup on Gemini






- Hopskotch can carry ANY message - not just science data - e.g. observatory status for your robotic telescope
- We're not. far away from:
  - Listen to survey alerts from e.g. Rubin through a broker e.g. ANTARES (https://antares.noirlab.edu)
  - Use a RNN/CNN classifier to find, filter and characterize objects - send a hop message
  - Have your robotic telescope broadcast it's status as a hop message
  - Setup your TOM Toolkit to automatically trigger followup on your robotic telescope - broadcast a hop message when it's done
  - Trigger your pipeline to reduce and process the data - send a hop message
  - Use GPT4 to write a circular, submit to HERMES/ TNS/GCN, and start an overleaf project.


Multimessenger Trigger
LIGO VIRGO KAGRA
IAU Transient Name Server
NASA GCN
NASA
Space-based Followup
https://hop.scimma.org/
https://github.com/scimma/hop-client
THE GRAVITATIONAL WAVE TREASURE MAP
AEON
Astronomical Event Observatory Network
TOM
TOM TOOLKIT
ANTARES
Streaming
Streaming & Filtering
HOPSKOTCH
HERMES
ARCHIVE & DATABASE
https://hermes.lco.global/
VERA C. RUBIN OBSERVATORY
Observatories & Surveys
Live Alerts & Notifications
User Interface
Sharing
Reactive Realtime Followup

FIN