



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

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On behalf of the SCIMMA team:

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OAC-1841625
OAC-1934752
OAC-2311355



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

KEY COMPONENTS OF THE ECOSYSTEM: MESSAGING

3

- ▶ [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
- ▶ 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

 **Scimma-Alert-Bot** APP 4:19 AM
Alert Type: EARLYWARNING
Superevent ID: S230918aq
Group: CBC

Event Time: 2023-09-18T11:19:41.162Z
Alert Time: 2023-09-18T11:19:36Z
FAR [1/yr]: 1.7098958325494311
Detectors: ['H1', 'L1']

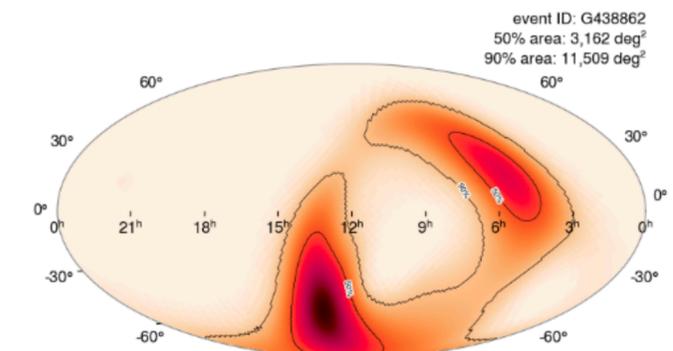
Terrestrial : 0.209
BNS: 0.791
NSBH: 0.000
BBH: 0.000

Has NS: 1.000
Has Remnant: 1.000
Has Mass Gap: 0.000

Distance (Mean): 118.825 +/- 45.273 Mpc
Distance modulus: 35.375

Join related channel: [#s230918aq](#)
[Skymap Link](#) | [Grace DB](#)

(114 kB) ▾



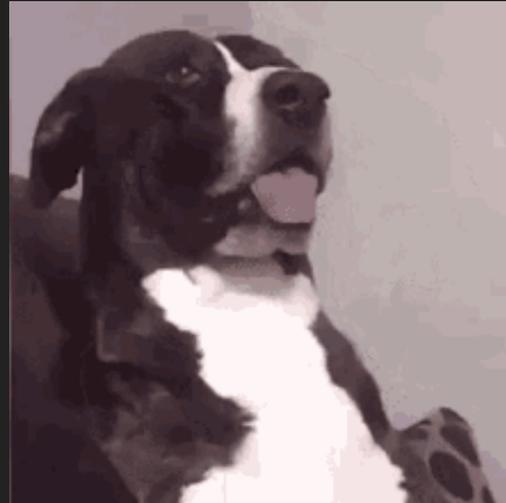
HOW IT WORKS TODAY

skymap <https://gracedb.ligo.org/api/superevents/S231017bj/files/bayestar.muliorder.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

DOW	Date	Dark	Tel#	Principal	Observers	Location	InstrAcc	Institution	OA	SA	NA	ProjCode
Tue	Jan-01	80	1	Masters	Masters, (CIT), J. Cohen, (CIT), Hermitschek, (CIT), Stanford, (UCB)	CIT/UCB	LRIS-ADC(9)	NASA	JA	ARoc		N044
Tue	Jan-01	80	2	G. Fuller	K. Rubin, (UCSD), Coli, (UCSD), Vaught, (UCSD), Burchett, (UCSC)	UCSD/UCSC	KCW(8)	UCSD	JR	LRoc		U090
Wed	Jan-02	88	1	Crystal, Martin	Crystal, Martin, (UCSB)	UCSB	LRIS-ADC(1)	UCSB	JA/CW	JW	SJ	U136
Wed	Jan-02	88	2	G. Fuller	K. Rubin, (UCSD), Coli, (UCSD), Vaught, (UCSD), Burchett, (UCSC)	UCSD/UCSC	KCW(8)	UCSD	JR	LRoc		U090
Thu	Jan-03	96	1	S. Kulkarni	Burdge	HQ	LRIS-ADC(2)	CIT	CW	JW	SJ	C323
Thu	Jan-03	96	2	J. Cohen	J. Cohen, (CIT), Hermitschek, (CIT)	CIT	ESI(1)	CIT	JR/JP	RC	SJ	C253
Fri	Jan-04	100	1	PrinceRavi	Burdge/Burdge	HQ	LRIS-ADC(3/3)	CIT	CW	JW	SJ	C322/C327
Fri	Jan-04	100	2	J. Cohen	J. Cohen, (CIT), Hermitschek, (CIT)	CIT	ESI(1)	CIT	JP	RCoc	SJ	C253
Sat	Jan-05	100	1	J. Cooke	Foran, (Swin), Prichard, Mestric, J. Cooke, S. Webb	Swin/HQ	LRIS-ADC(4)	Swinburne	CW	JW	SJ/JLP	W247
Sat	Jan-05	100	2	Fassnacht	Fassnacht, (UCD), G. Chen, (UCD)	UCD	ESI(2)	UCD	JP	JL	SJ/JLP	U122
Sun	Jan-06	98	1	Dressing	Isaacson, (UCB), Pelgura, (CIT)	UCB/CIT	HIREs(1)	UCB	CW/TR/AAR	GD	JLP	U096
Sun	Jan-06	98	2	Ono	Ono, Itoh	HQ	DEMOS(4)	Subaru	JP	AR	JLP	S347
Mon	Jan-07	90	1	Dressing	Isaacson, (UCB), Pelgura, (CIT)	UCB/CIT	HIREs(1)	UCB	TR (AAR)	GDoc	JLP/TKC	U096
Mon	Jan-07	90	2	Hu	Hu, L. Cowie	HQ	DEMOS(5)	UH	JP/HH	AR	JLP/TKC	H239
Tue	Jan-08	83	1	Redfield	Farrin, Swain, Redfield	HQ	HIREs(7)	NASA	TR (AAR)	GD	JLP/TKC	N192
Tue	Jan-08	83	2	Mawet/Hu	Mawet, (CIT), Echeverti, (CIT), S. Ragland/Hu, L. Cowie	CIT/HQ	NIRSPAC-NGS+NIRC2-NGS(5)/DEMOS(5)	CIT/UH	HH/AH	CA	JLP/TKC	C315/H239
Wed	Jan-09	76	1	M. White	Khee-Gan, Lee, Ata	HQ	LRIS-ADC(5)	UCB	TR (AAR)	JW	TKC	U095
Wed	Jan-09	76	2	Skemer/Hillenbrand	Sallum, (UCSC)/Hillenbrand, Okopiec	UCSC/HQ	UCSC/CIT	UCB	TKC	TKC		U128/C272
Thu	Jan-10	69	1	S. Valentini/M. White	Bostroem, (UCD)/Khee-Gan, Lee, Ata	UCD/HQ	LRIS-ADC(6/6)	UCD/UCB	TR/CJ (AAR)	JW	TKC	U099/U095
Thu	Jan-10	69	2	Skemer/M. Cooper	Sallum, (UCSC)/M. Cooper, (UCI), Fillingham, (UCI), Wimberly, (UCI), Baxter, (UCI)	UCSC/UCI	NIRC2-NGS(6)/NIRSPEC(4)	UCSC/UCI	HH (AH)	CA	TKC	U128/U053

```

////////////////////////////////////
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.
    
```

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/> 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

Submission Form API View Text View

Title: Topic:

Event ID: ? Authors: ? Submit to TNS
 Submit to GCN

Targets

	Name	RA	Dec	New Discovery		
0	SN2023oct	08:56:11.620	-03:19:32.05	<input checked="" type="checkbox"/>	<input type="button" value="+"/>	<input type="button" value="🗑"/>

Photometry

	Target	Observation Date	Telescope	Instrument	Band	Brightness	Units	Error		
0	SN2023oct	10/17/2023	CTIO4m	DECam	r	19.5	AB mag	0.02	<input type="button" value="+"/>	<input type="button" value="🗑"/>

Spectroscopy

Spectroscopy Datum 0 Target: ? Obs Date: ?

Flux: Error: Wavelength:

Flux Units: Wavelength: Flux Type:

CONTROVERSIAL CLAIM #1:

**MESSAGING INFRASTRUCTURE IS NOT THE
CHALLENGE ANYMORE**

2. ESTABLISHING THE INFRASTRUCTURE FOR A COLLABORATIVE MULTI-MESSENGER ECOSYSTEM



Context MyScratch Table (optional) Task Name

DR16 default GalaxyMags Gal-Spec Cross Match

Samples Recent Clear

Syntax Plan Quick Submit

```
1 SELECT TOP 1000000 g.objID, g.htmID,
2   g.cmodelMag_u, g.cmodelMag_g, g.cmodelMag_r, g.cmodelMag_i, g.cmodelMag_z,
3   g.cmodelMagErr_u, g.cmodelMagErr_g, g.cmodelMagErr_r, g.cmodelMagErr_i, g.cmodelMagErr_z,
4   g.fracDeV_u, g.fracDeV_g, g.fracDeV_r, g.fracDeV_i, g.fracDeV_z,
5   g.extinction_u, g.extinction_g, g.extinction_r, g.extinction_i, g.extinction_z,
6   s.bptclass,
7   s.lgm_tot_p2p5, s.lgm_tot_p16, s.lgm_tot_p50, s.lgm_tot_p84, s.lgm_tot_p97p5,
8   z.z, z.z_err, z.z_warning,
9   z.v_disp, z.v_disp_err,
10  z.subclass,
11  z.sn_median, z.reliable
12 INTO mydb.GalaxyInfo from GalaxyTag as g
13   INNER JOIN galSpecExtra as s
14   on s.specObjID = g.specObjID
15   INNER JOIN galSpecInfo as z
16   ON z.specObjID = s.specObjID
17 WHERE g.clean=1;
```

SDSS - CATALOG QUERIES VIA SQL

Community access to SDSS images, spectra, catalogs + nice interfaces and API. Query but not compute.



DES Labs

- [Home](#)
- [People](#)
- [Projects](#)
- [? Help](#)

DESaccess web



DES cutouts



DESDM Services status



External Links

Science Server



Astro Data Lab



CosmoHub



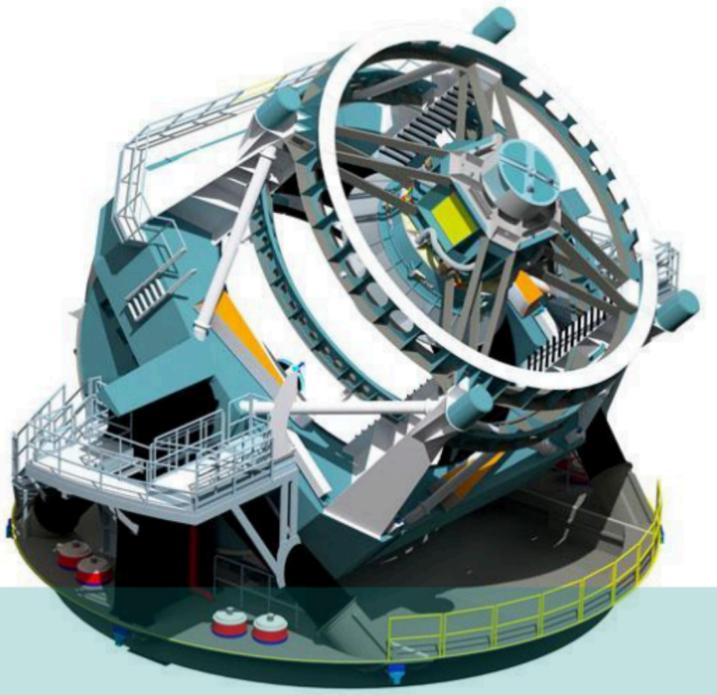
DES – MIX OF PUBLIC/PRIVATE

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

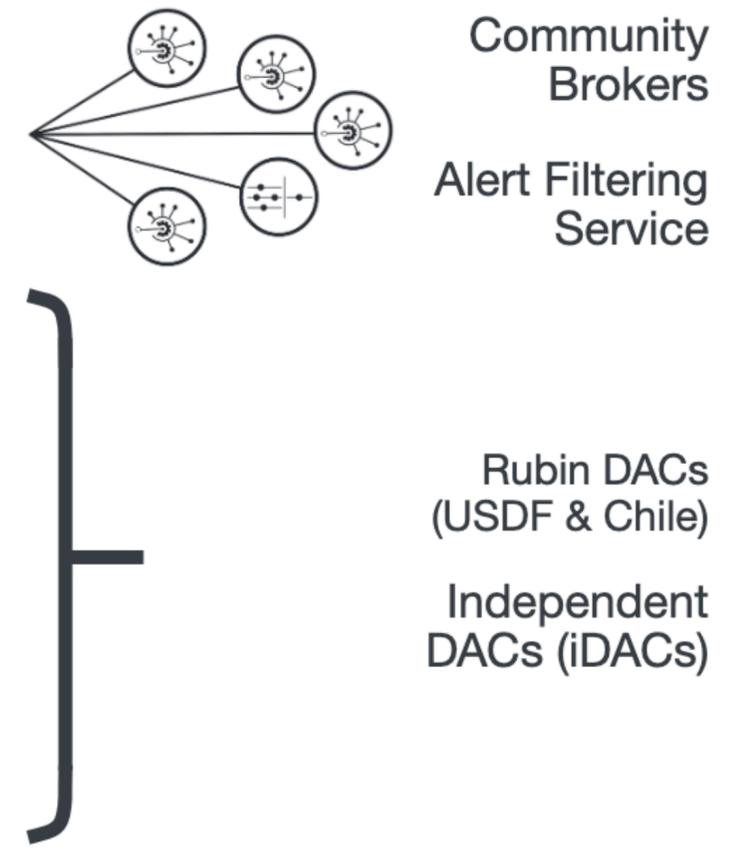
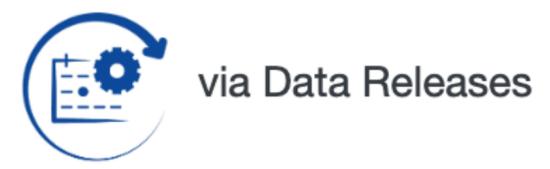
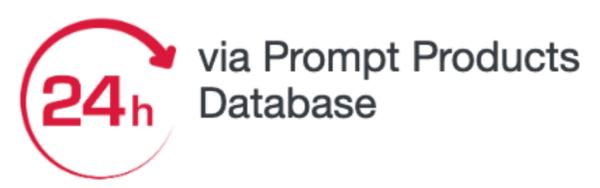
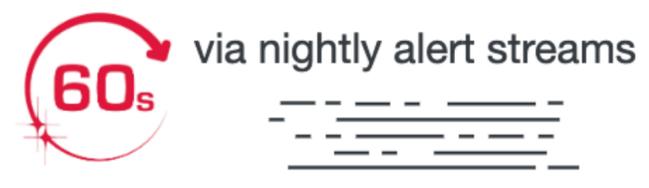
Alerts: up to 10 million per night

Results of Difference Image Analysis (DIA): transient and variable sources

Solar System Objects: ~ 6 million

Data Release Data Products

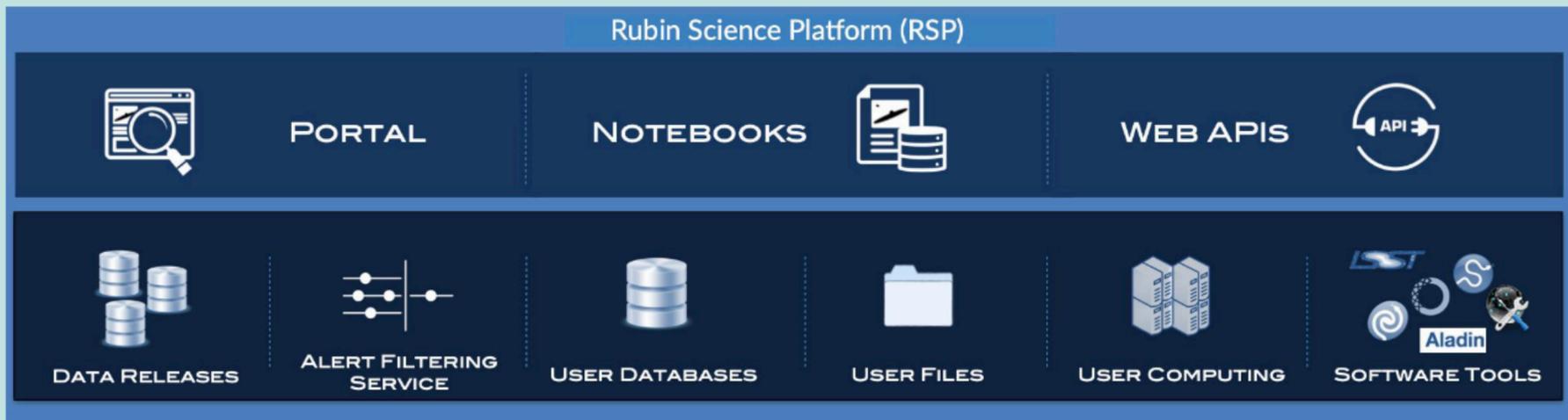
- Final 10yr Data Release:
- Images: 5.5 million x 3.2 Gpx
 - Catalog: 15PB, 37 billion objects



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



Science Platform

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



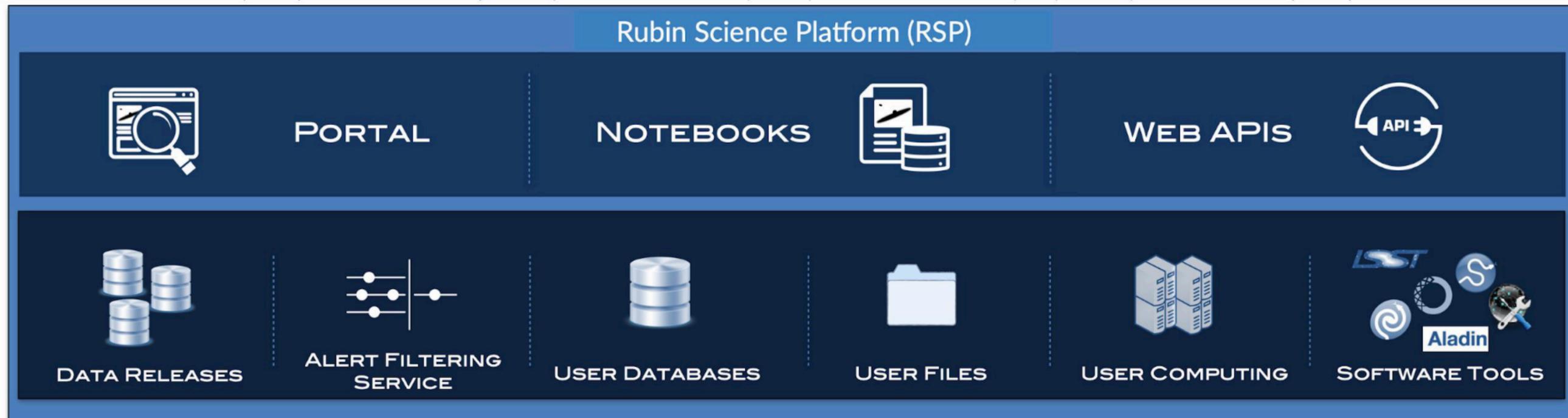
Notebook Aspect

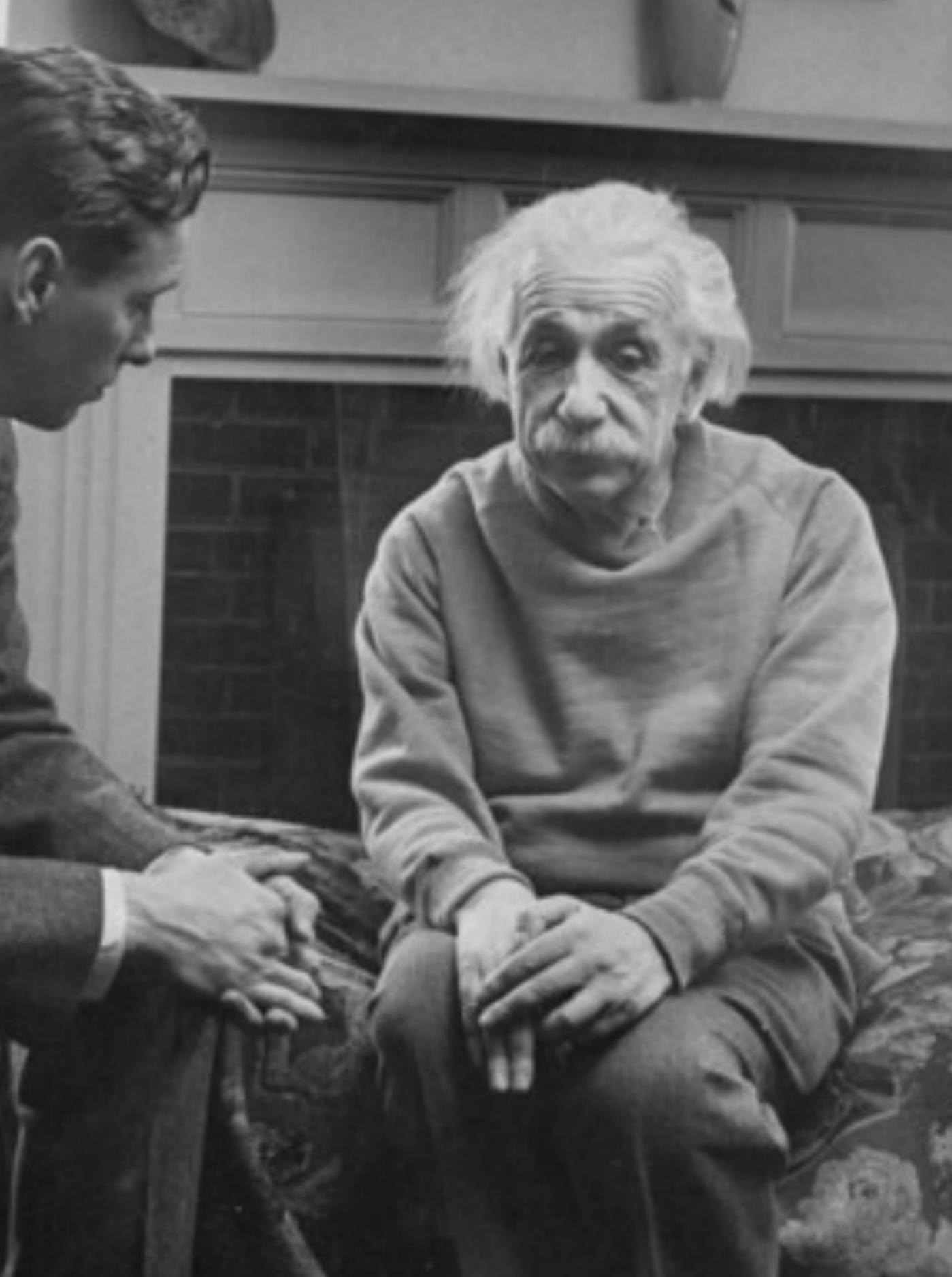
in-depth 'next-to-data' analysis and creation of added-value data products



API Aspect

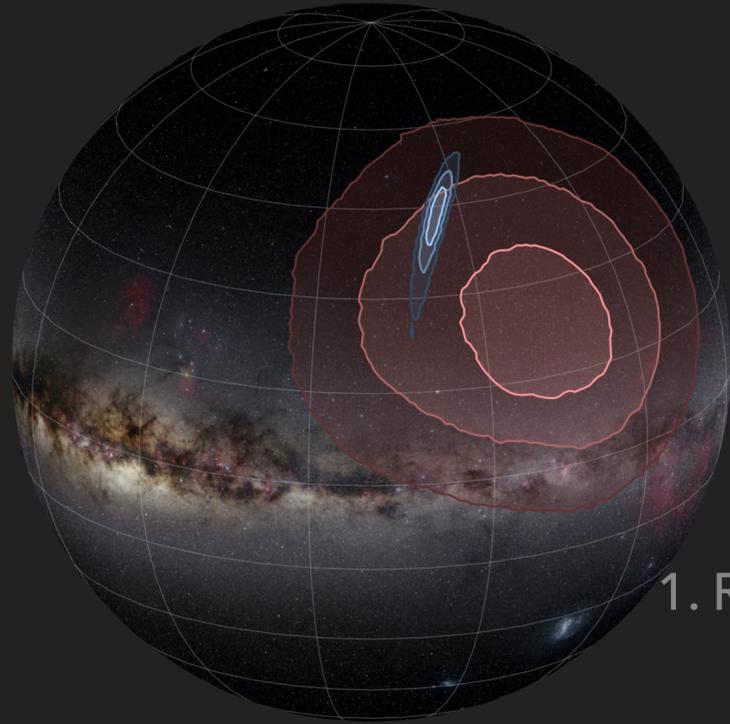
remote access to the Rubin archive via industry-standard APIs





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

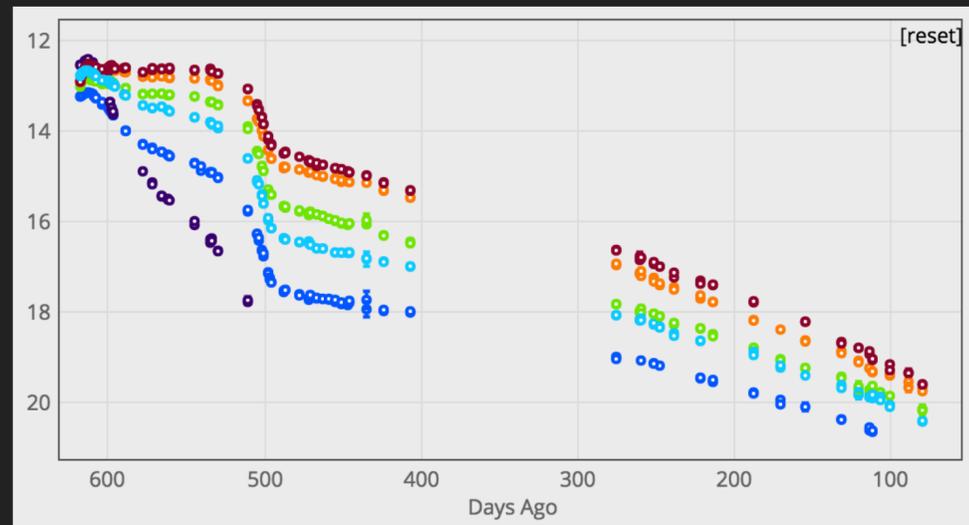
VISION FOR GRAVITATIONAL WAVE FOLLOWUP OF THE FUTURE



1. Receive alert



2. Telescopes automatically observe target, negotiate priorities, data access



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

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

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

- ▶ 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

TOM Toolkit Home Targets Alerts Observations Data Users Admin User (admin) Logout

SCIMMA Alerts

SCIMMA

Keyword Search: S190426

Right Ascension: Declination: Radius:

Start Date → End Date

Create targets from selected

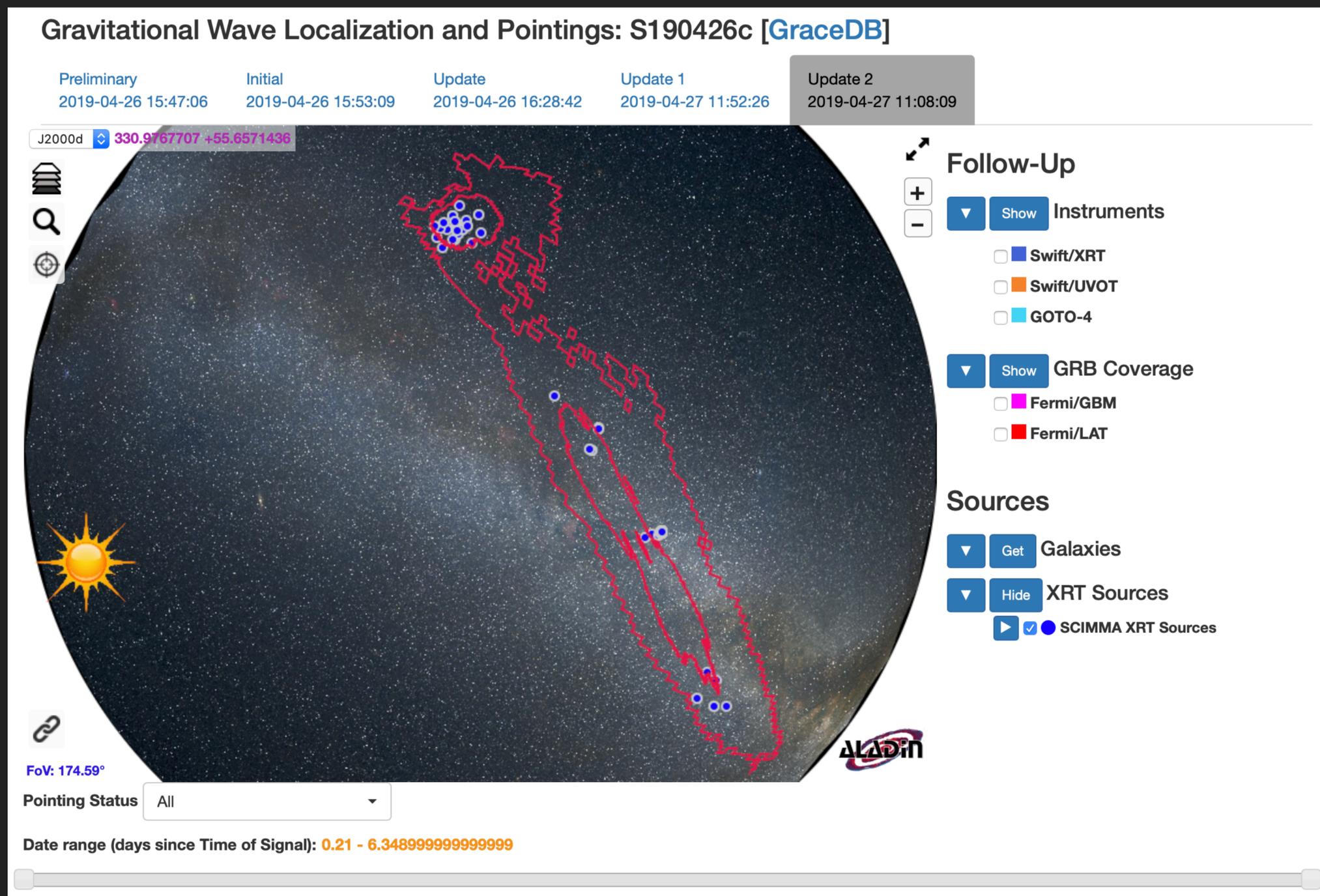
	Alert Identifier	Counterpart Identifier	Right Ascension	Declination	Rank	Comments
<input type="checkbox"/>	S190426_X5	1SXPS J144850.8-400845	14:48:50.784	-40:08:45.6	4	MAY match a known transient, will be checked manually.
<input type="checkbox"/>	S190426_X41	3XMM J195917.2+404514	19:59:17.88	40:45:03.24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

« < 1 > »

TREASURE MAP – HOPSKOTCH INTEGRATION

Wyatt et al. 2020, ApJ, 894, 127

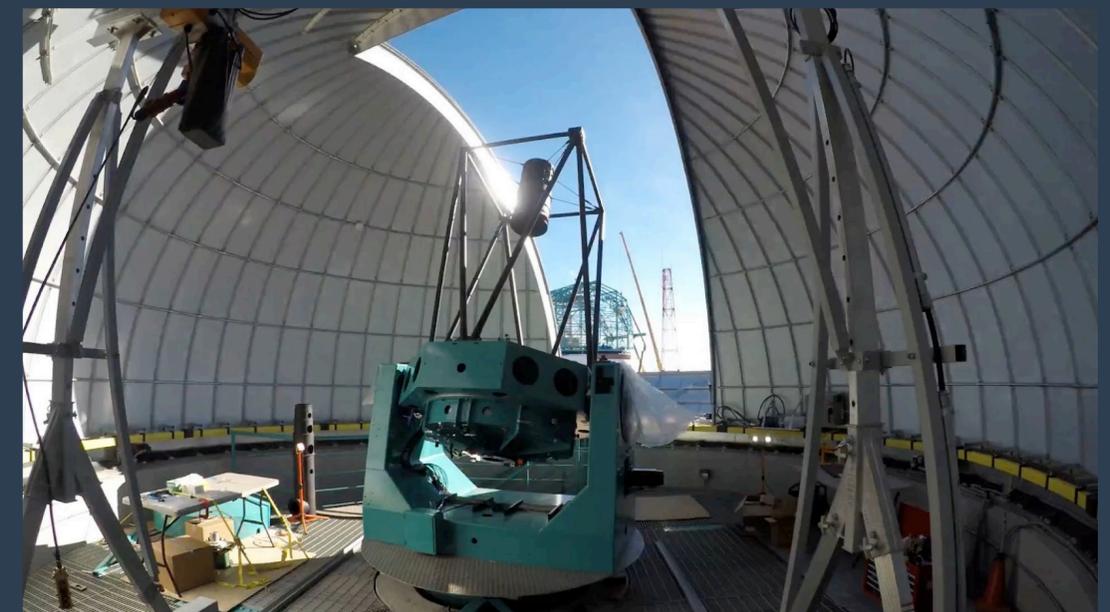
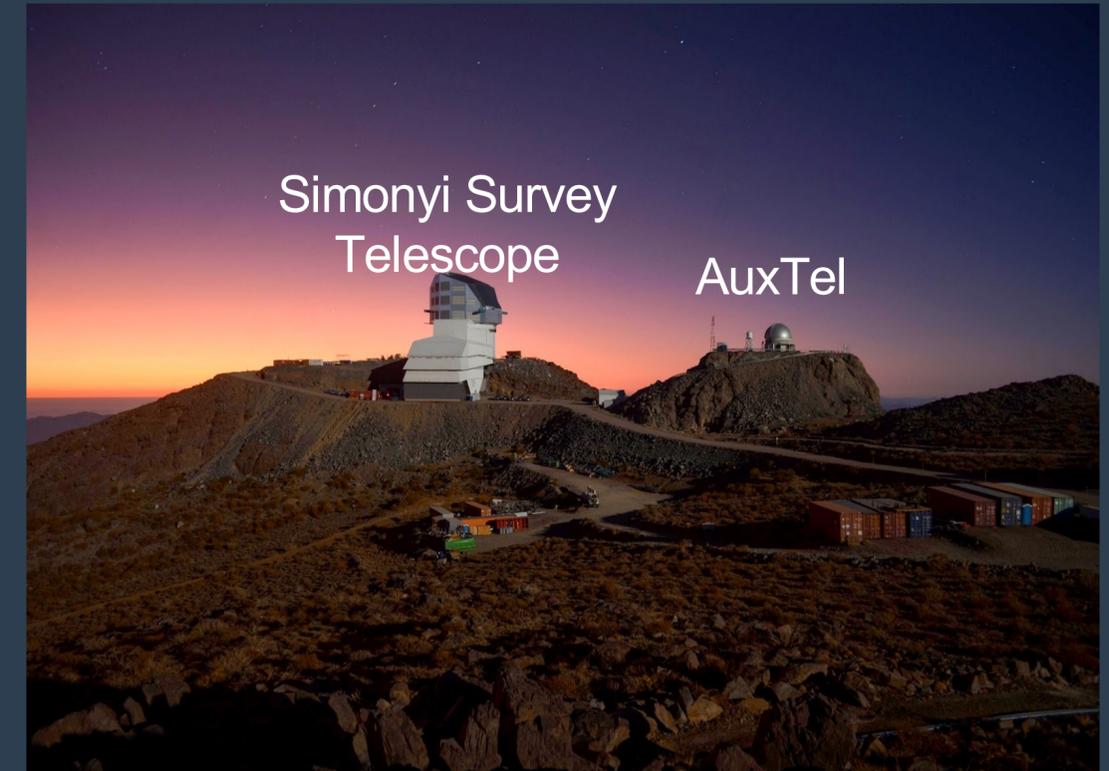
treasuremap.space



- ▶ 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.

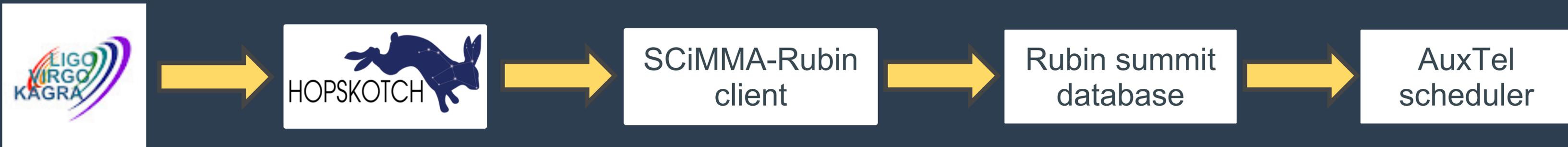
Rubin Auxiliary Telescope (AuxTel)

- 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

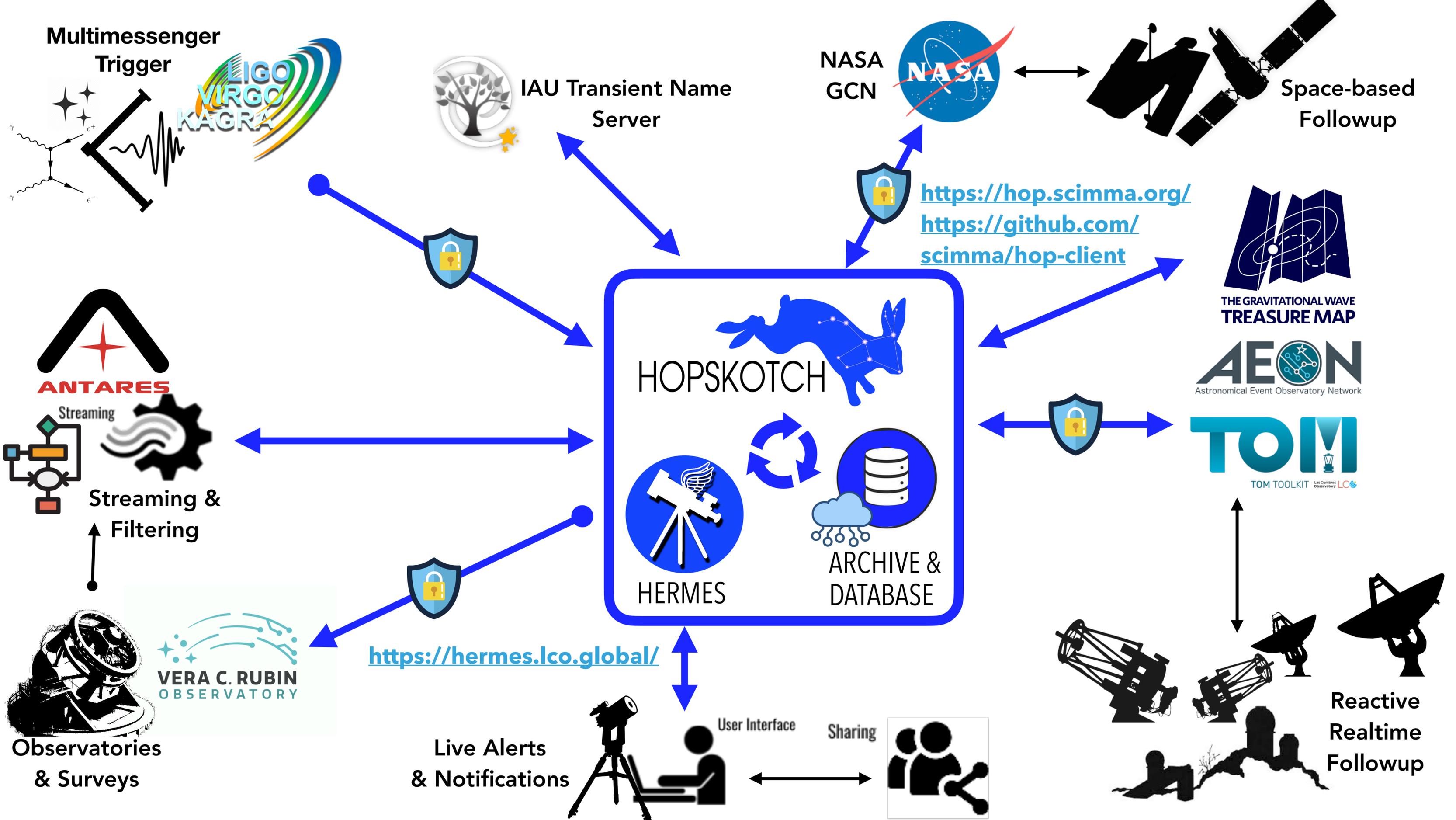
- Use hop-client API to receive LVK alerts via SCiMMA and reformat into appropriate schema
- Send alerts to Rubin scheduling database for parsing
- Use alerts from the scheduling database as target-of-opportunities for AuxTel

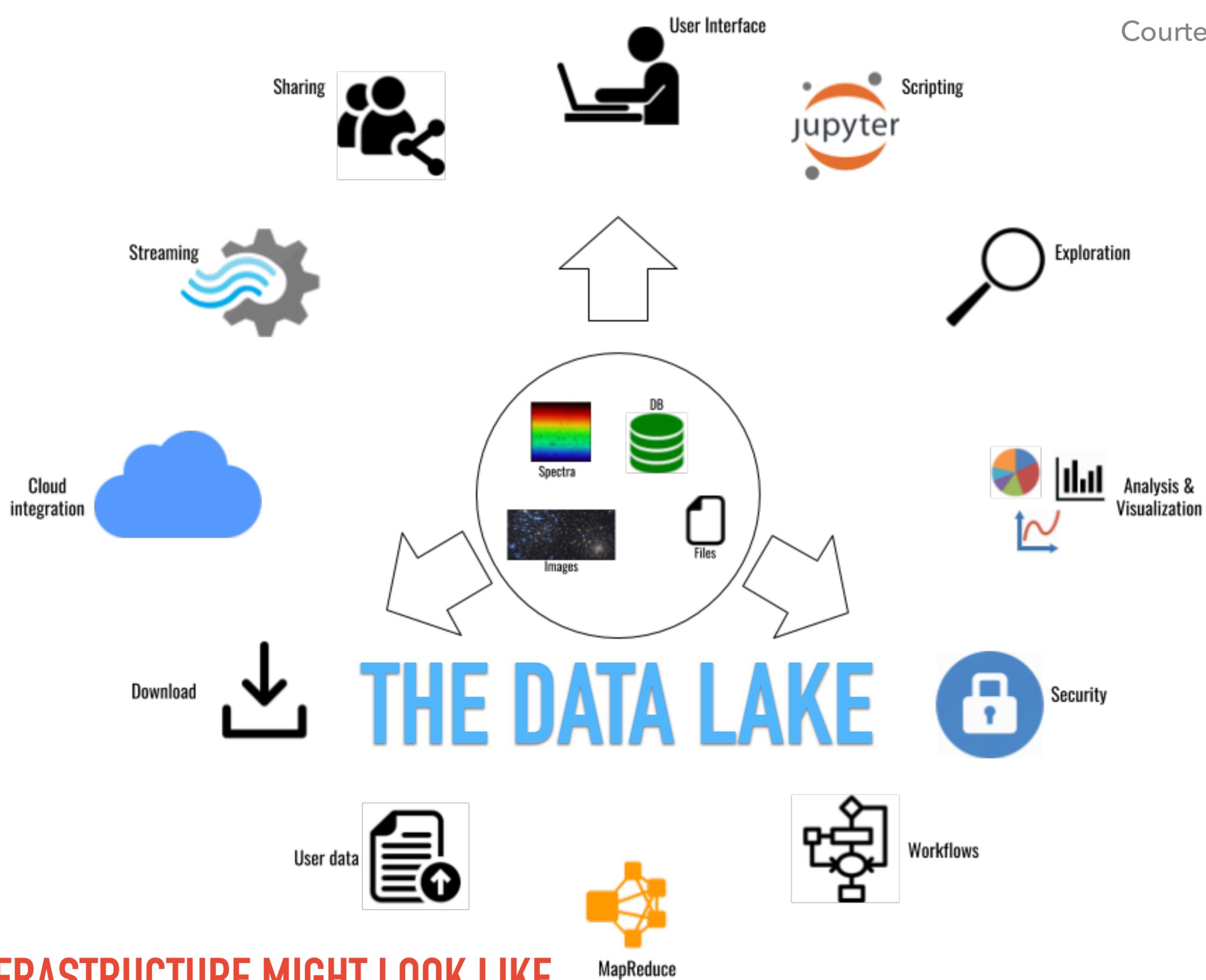


- Working with [Tiago Ribeiro](#) (Rubin Telescope+Site team and scheduling systems)



Tiago Ribeiro
Scheduler Scientist @ T&S group





WHAT SUCH INFRASTRUCTURE MIGHT LOOK LIKE

- ▶ 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 gwastro-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-MESSENGER~~ 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