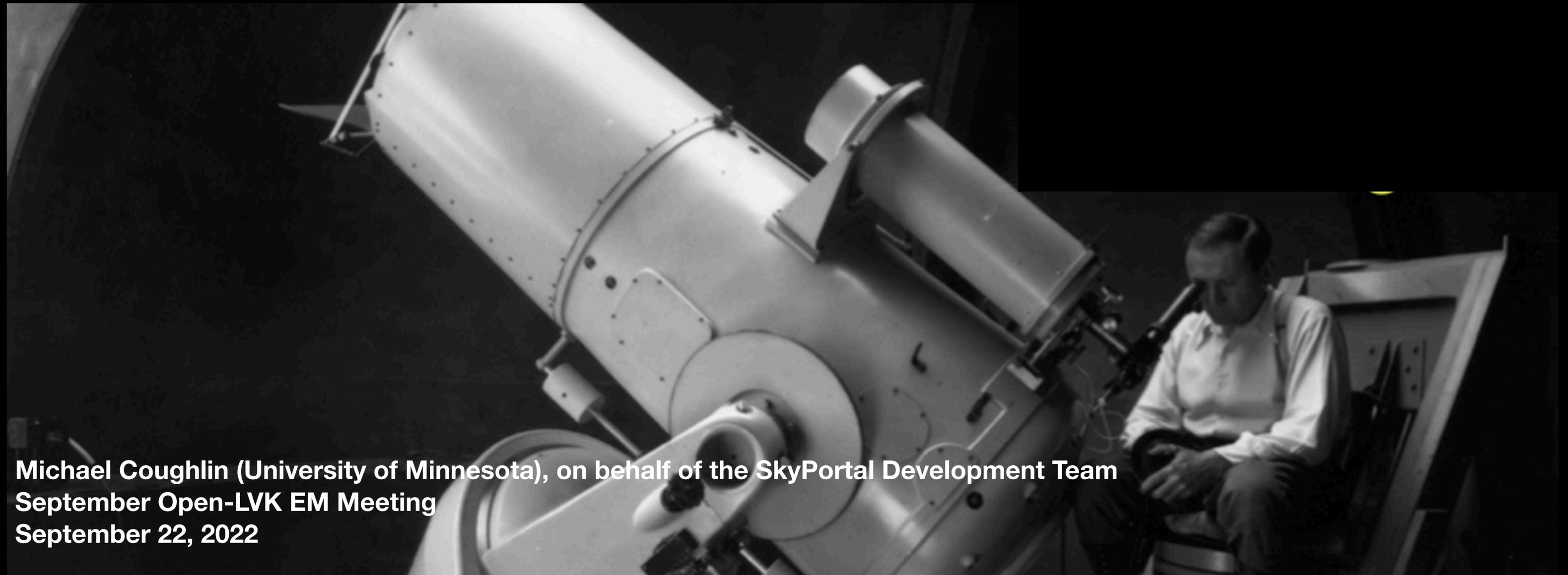




Towards a multi-messenger data science platform for the MMA era



**Michael Coughlin (University of Minnesota), on behalf of the SkyPortal Development Team
September Open-LVK EM Meeting
September 22, 2022**

The History

O3 showed us how hard follow-up can be, and O4 is not going to get easier, as our interferometers remain at quite different sensitivities (plus the unfortunate situation with KAGRA's sensitivity).

However, because O3 was challenging, we built/adapted many, many quality tools both during the run and afterwards to analyze the results.

iCARE, gwemopt, simsurvey, POSSIS, gwemlightcurves/nmma, NIMBUS, various annotation pipelines, the GROWTH ToO-Marshal, the GROWTH Marshal, etc.

Table 2. Summary Statistics for O3, O4, and O5.

Run	BNS	NSBH	BBH
Median 90% credible area (deg ²) ^a			
O3	1672 ⁺⁹⁴ ₋₁₁₀	1970 ⁺¹¹⁰ ₋₁₁₀	1069 ⁺⁴³ ₋₄₁
O4	1820 ⁺¹⁹⁰ ₋₁₇₀	1840 ⁺¹⁵⁰ ₋₁₅₀	335 ⁺²⁸ ₋₁₇
O5	1250 ⁺¹²⁰ ₋₁₂₀	1076 ⁺⁶⁵ ₋₇₅	230.3 ^{+7.8} _{-6.4}
Median 90% credible co-moving volume (10 ⁶ Mpc ³) ^a			
O3	6.62 ^{+0.97} _{-0.97}	44.1 ^{+7.4} _{-5.2}	217 ⁺²³ ₋₁₆
O4	44.8 ^{+6.4} _{-6.5}	191 ⁺²⁰ ₋₂₇	216 ⁺¹⁶ ₋₂₀
O5	125 ⁺²¹ ₋₁₂	448 ⁺⁶¹ ₋₄₄	538 ⁺²³ ₋₂₄
Median luminosity distance (Mpc) ^a			
O3	176.1 ^{+6.2} _{-5.7}	337.6 ^{+10.9} _{-9.6}	871 ⁺³¹ ₋₂₈
O4	352.8 ^{+10.3} _{-9.8}	621 ⁺¹⁶ ₋₁₄	1493 ⁺²⁵ ₋₃₃
O5	620 ⁺¹⁶ ₋₁₇	1132 ⁺¹⁹ ₋₂₃	2748 ⁺³⁰ ₋₃₄
Sensitive volume (10 ⁶ Mpc ³) ^{ab}			
O3	17.5 ^{+1.4} _{-1.3}	101.1 ^{+6.4} _{-6.1}	1047 ⁺⁵⁰ ₋₄₉
O4	109.0 ^{+6.7} _{-6.5}	558 ⁺²⁶ ₋₂₆	4450 ⁺¹³⁰ ₋₁₃₀
O5	590 ⁺²⁹ ₋₂₈	2787 ⁺⁸⁹ ₋₈₇	19950 ⁺³¹⁰ ₋₃₁₀
Annual number of detections ^{cd}			
O3	5 ⁺¹⁴ ₋₅	13 ⁺¹⁵ ₋₉	24 ⁺¹⁸ ₋₁₂
O4	34 ⁺⁷⁸ ₋₂₅	72 ⁺⁷⁵ ₋₃₈	106 ⁺⁶⁵ ₋₄₂
O5	190 ⁺⁴¹⁰ ₋₁₃₀	360 ⁺³⁶⁰ ₋₁₈₀	480 ⁺²⁸⁰ ₋₁₈₀

The Vision

We have also seen our team evolve (both in terms of people coming and going, as well as career stages). Even during these 1+ year runs, these aspects change as well.

For this reason, we have set out to use SkyPortal as our one-stop-shop where many of these analyses should be available. This enables us to both save ourselves both in time and energy; the run is grueling (but obviously potentially incredibly rewarding) and limiting single points of success* is important. Even if in principle more than one person knows how to do something, it can be often the case that basically one person knows how to do it, and that's a tough spot to be in.

* A Patrick Brady special

Meet the Team



Sarah Antier



Joshua Bloom



Michael Coughlin



Matthew Graham



Theophile Jegou du Laz



Mansi Kasliwal



Jada Lilleboe



Don Neill



Guy Nir



Leo Singer



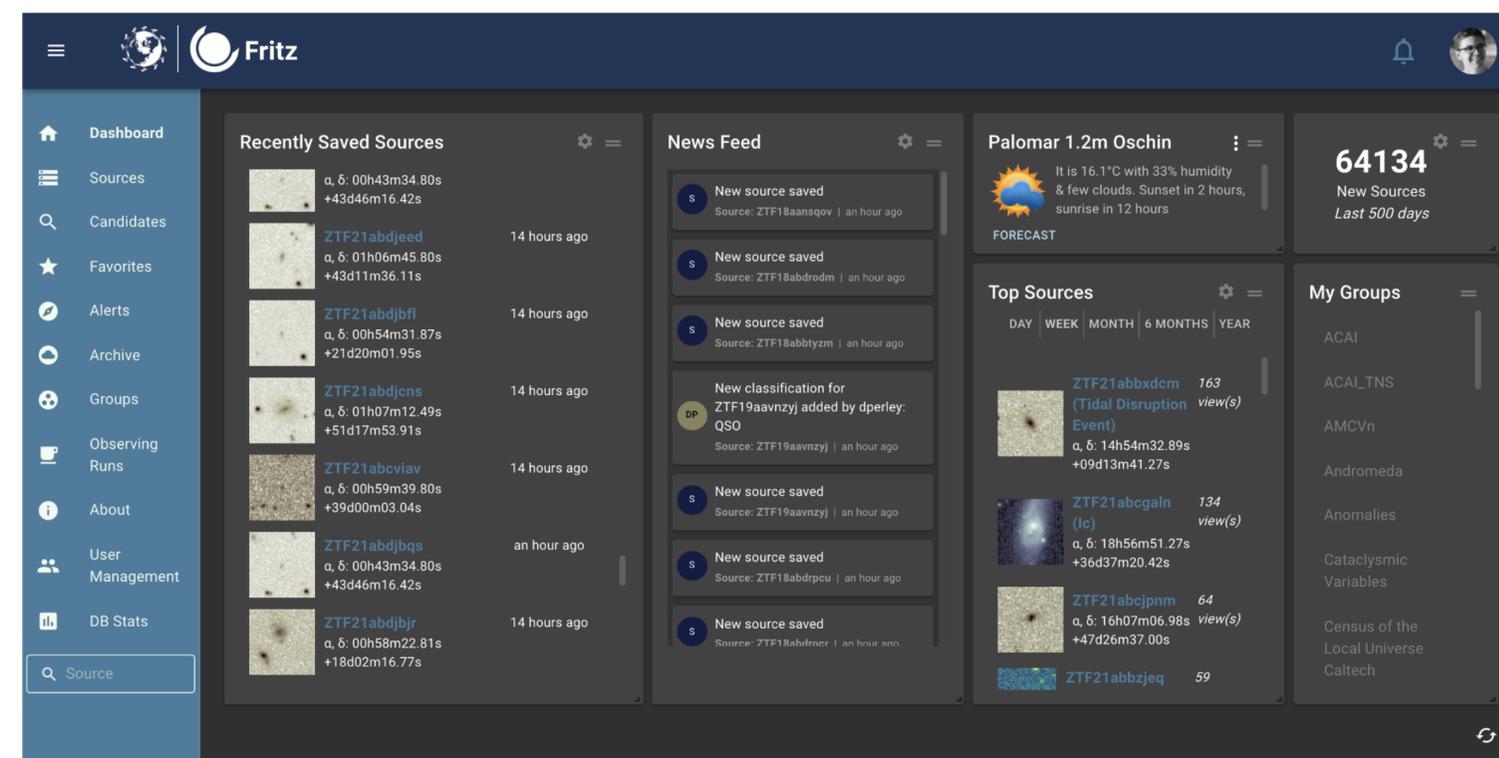
Stéfan van der Walt

SkyPortal is jointly developed at Caltech, UC Berkeley, the University of Minnesota, and the Observatoire de la Côte d'Azur. It is in active use by ZTF/GROWTH, GRANDMA, DESI, amongst others, and will be in use by more than 60 telescopes during O4.

SkyPortal

- Open source (free to use, modify, and distribute)
- Scalable, [API-first](#) system, with [fine-grained access control](#) on every data point (important for complex collaborations)
- Multi-survey data archive and alert broker
- Interactive, mobile-friendly collaborative platform for transient, variable, and Solar system science cases
- Workhorse for ML applications: classification and labeling at scale
- Follow-up observation management: robotic and classical facilities
- Well-tested, extensive docs, CI/CD

Initiated in Feb 2020
Beta up in Sep 2020
MVP live in Nov 2020



Stability/Scaling

Roadmap

(In brief)

MMA (04)

3rd Party Analysis

2.1M
Source Views

247
Users

1.8M
Annotations

1.5M
Sources

4.6M
Candidates

173M
Photometry Points

97k
Comments

**7.4M/
2.3Gb**
Thumbnails

Building the plane while we fly it...

...and (trying to) squash bugs big and small.



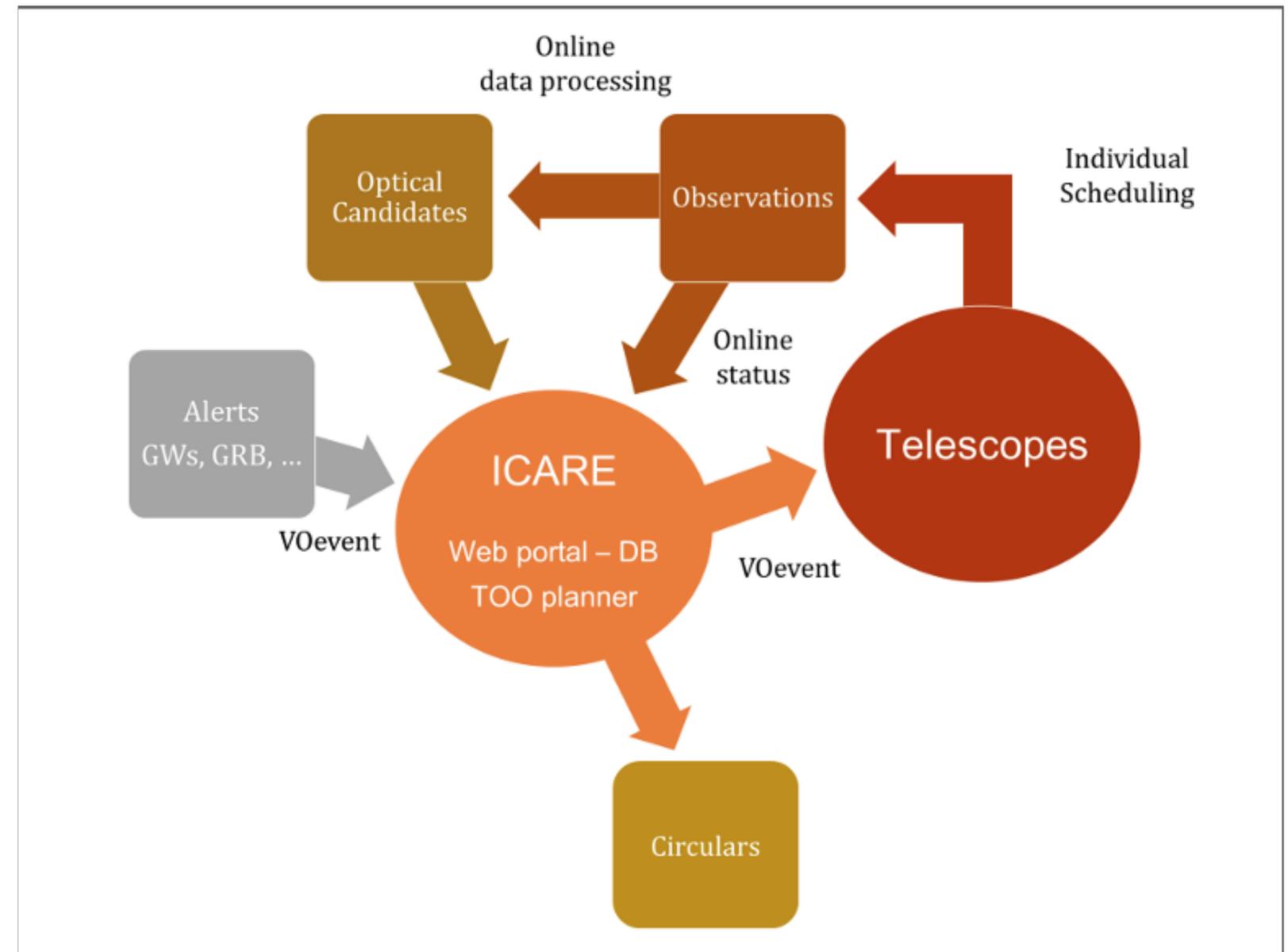
MMA Infrastructure for O4

Inherits from two very successful projects during O3 and beyond: GRANDMA's iCARE and GROWTH's ToO Marshal

Events

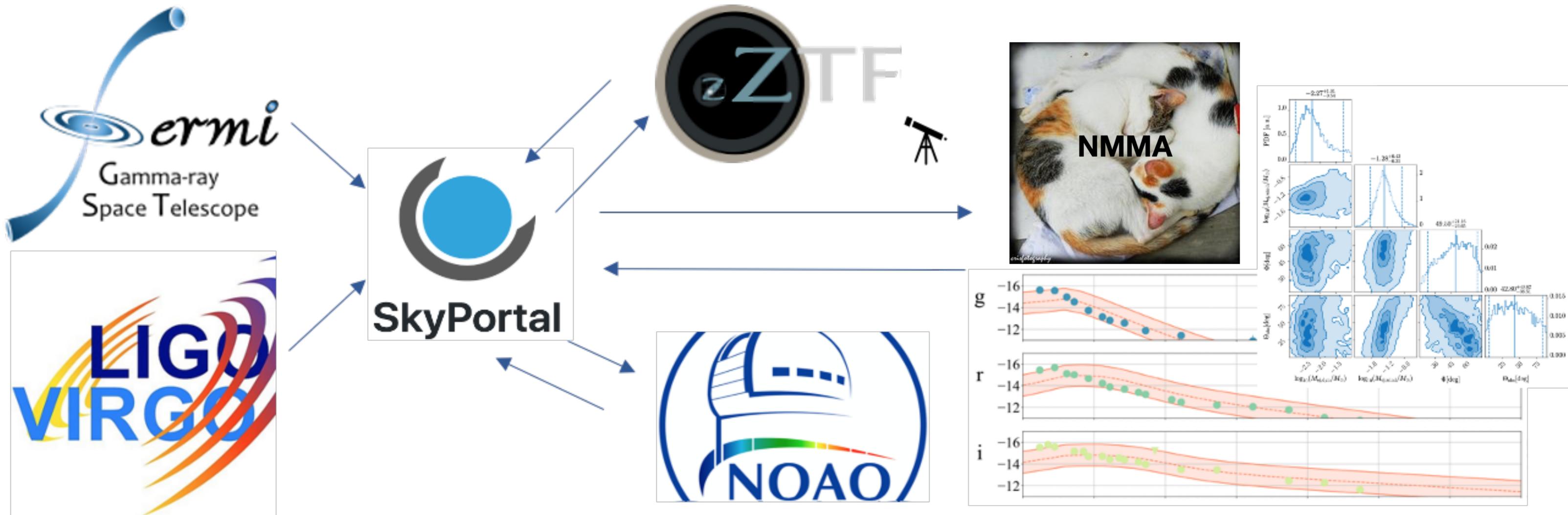
AMON AllSky BBH BNS Fermi GRB GW HighMass IMBH
 LVC MDC MassGap NSBH Terrestrial long retracted short
 transient

210511 20:51:24 (18 hours ago)	Fermi GRB
210511 11:26:39 (a day ago)	Fermi long GRB
210511 10:58:57 (a day ago)	Fermi long GRB
210510 19:20:01 (a day ago)	Fermi short GRB
210509 13:53:40 (3 days ago)	Fermi GRB
210509 12:15:04 (3 days ago)	Fermi short transient
210508 22:27:35 (3 days ago)	Fermi GRB
210508 21:37:25 (3 days ago)	Fermi short transient
210508 21:30:44 (3 days ago)	Fermi short transient
210507 19:01:51 (4 days ago)	Fermi GRB



Ahumada et al. 2105.05067, Anand and Coughlin et al. 2009.07210, Andreoni and Goldstein et al. 1910.13409, Antier et al: 1910.11261, 2004.04277, Coughlin et al.: 1907.12645, etc.

A vision for the O4 workflow



Goal: Inform follow-up decisions

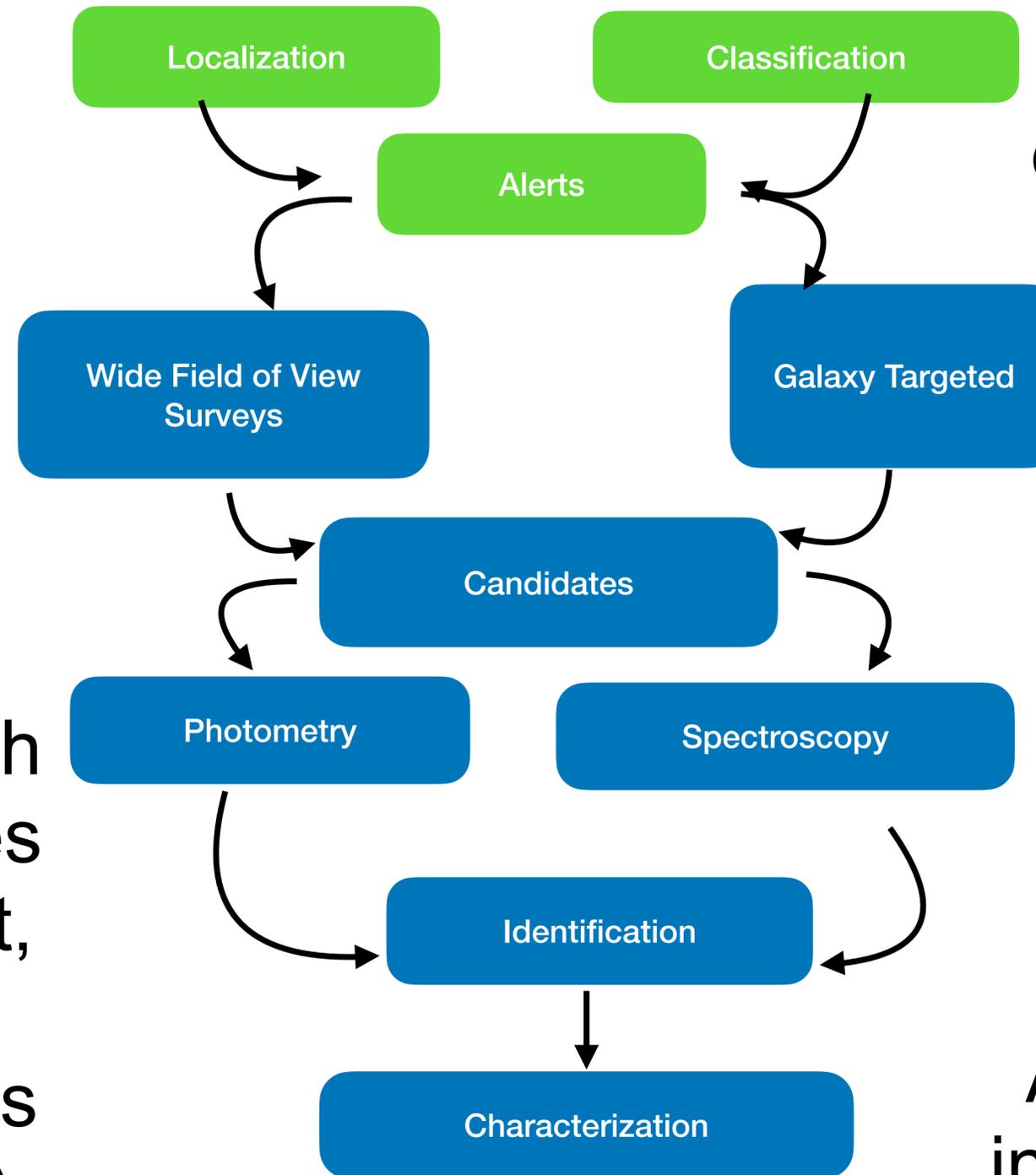
Goal: Remove difference between code we use to vet candidates in low latency and code we use to do science

What is available now in SkyPortal

Ingestion by gcn-kafka

Network-level scheduling using gwemopt. Validation using simsurvey.

API interactions with follow-up telescopes (SEDM, LCO, Swift, NICER, etc.) and photometry services (ATLAS, ZTF, etc.)



Notification framework by email, SMS, slack, phone etc. Time-zone cognizant shifts.

Cross matching of filter streams with skymaps. Automated summaries for distribution through GCN.

Analysis framework to interact with light curve / spectroscopy fitting frameworks

Integration with Bayesian Inference toolkits: The Nuclear Multi-messenger Astrophysics Framework

- Generalized EM-GW Bayesian inference infrastructure
 - gravitational-wave data analysis using parallel bilby
 - kilonova modelling with various models (Bulla, Kasen, etc.)
 - gamma-ray burst afterglow fits (as well as other fast transient models to perform model selection)
 - chiral effective field theory to simulate the neutron-star EOS
 - neutron-star maximum mass and NICER constraints, fits to relate ejecta parameters to progenitor parameters using numerical relativity
- Used for [Ahumada, Singer, et al.](#), [Dietrich, Coughlin, et al.](#), [Tews, Pang, et al.](#), etc.

What (else) do I hope is available by O4?

- **Light curve fitting:** fit to supernova, kilonova, GRB, etc. models with the click of a button. *(Done, but how to properly scale?)*
- **Follow-up prioritization suggestion.** *(Fast-transient simulation sets, still need a working agent).*
- **Creation of space-time MOCs** (for ease of internal and external observation distribution). *(How to deliver to the community?)*
- **Improved scheduling with M4OPT.** MIP-based scheduling (rather than heuristics).
- **Upperlimits/efficiency assessment:** integration of NIMBUS to quote physics constraints based on upper limits. Updated version of simsurvey for speed.
- **Sharing.** Can we more easily streamline the posting of data between instances of SkyPortal?

How to Engage

- Document Issues on the SkyPortal GitHub
- Contribute code via pull requests - we're happy to onboard you!
- Lots of (unique) learning opportunities in development and operations
- YouTube Channel: <https://tinyurl.com/skyportal-demos>
- User Survey: <https://forms.gle/5vnYiWJSkqngP9G27>

Thank you!