# Optimization Simulations for Kilonova Detections in Optical and Near Infrared

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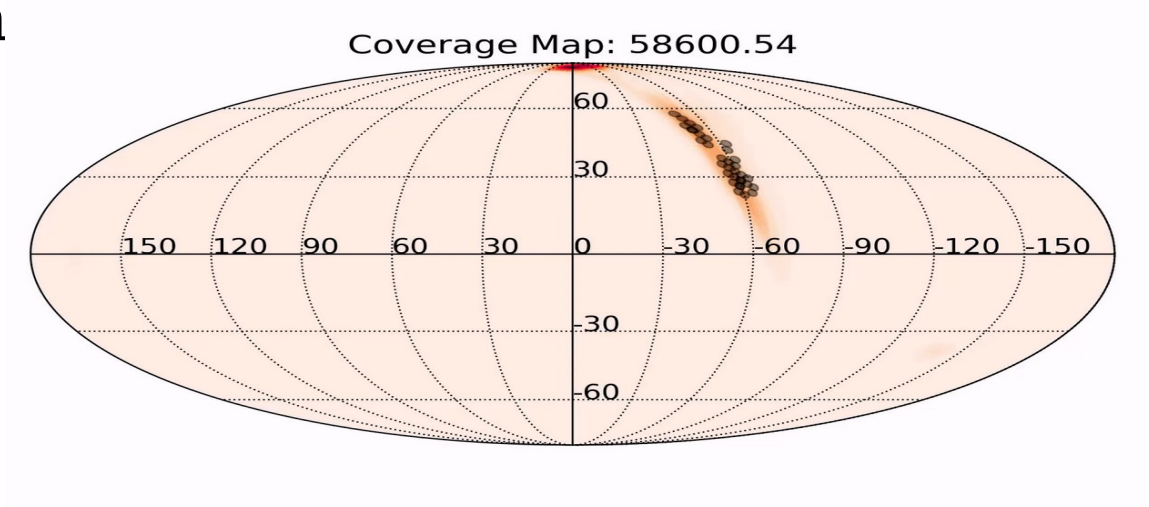
# General Overview

- **Important to strategize detection of kilonovae:**
  1. **through follow-up of GW events**
  2. **serendipitously (during regular surveys)**
- **We used *Gwemopt* (GW-EM optimization), a code that creates observing plans and evaluates their efficiency for ZTF detections.**
- **We used LSST packages and metrics to simulate surveys in 6 photometric filters.**
- **We have considered several observing factors and schemes: past failed observations, dynamic vs. fixed exposures, optical vs. near-infrared, etc.**

# SuperScheduler algorithm

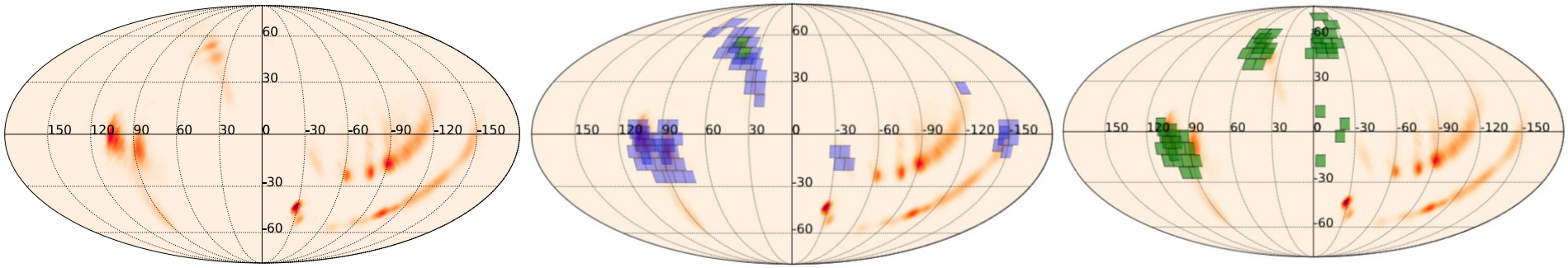
- **SuperScheduler can take into account past observations and *dynamically* schedule new ones.**
- **Some fields are not observed due to wea**




***Three rounds of scheduling with three telescopes.***
***Unobserved tiles after each round are shown in***

# Filter Balancing

- Difficulties in scheduling multi-epoch observations for large maps with multiple “lobes”.
- Implemented a way to schedule each of these lobes by splitting them up in right ascension.



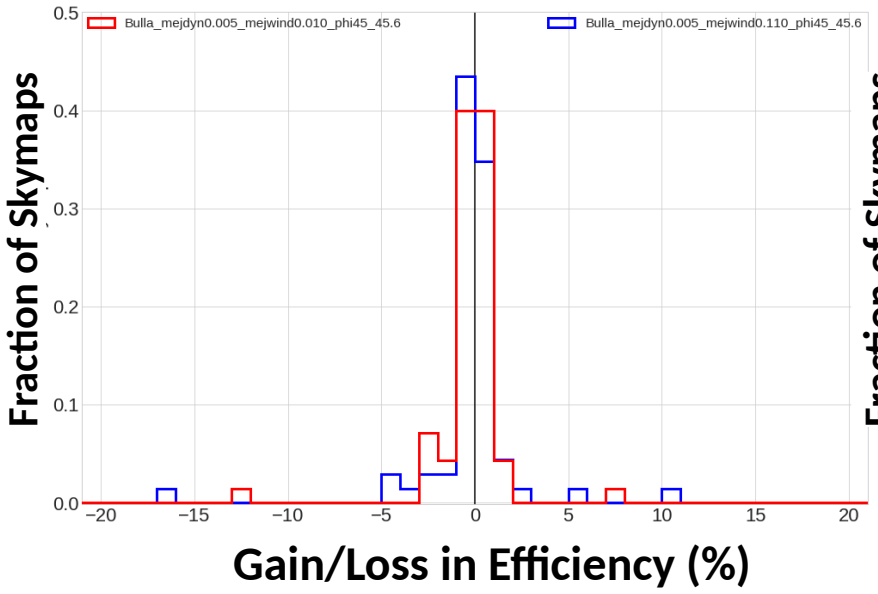

***Before and after the new implementations. Fields in green have had all requested obs. scheduled, while those in violet have not.***

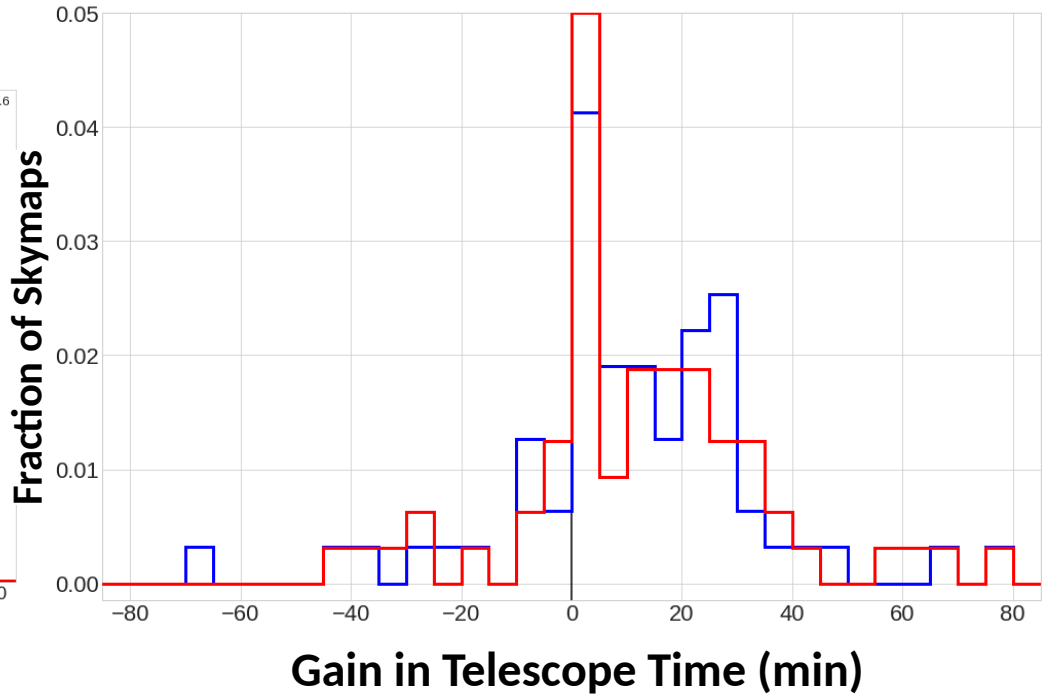
# Dynamic Exposures

- **Set Exposure (standard) technique:**
  - **short exposures ☾ increase in skymap coverage, useful for skymaps with large localization regions.**
  - **long exposures ☾ reaches greater depth (limiting magnitude), useful for candidates with high luminosity distances.**
- **For maximum efficiency, we need the right balance between coverage and depth/distance.**
- **Exposure time of each field is calculated using the skymap's 3D probability**

# Dynamic Exposures (cont'd)

- **We find that by using Dynamic Exposures over Set Exposures, we <u>save 20 (median) minutes of telescope time</u> (6-8 % of observing time, roughly) without compromising efficiency.**

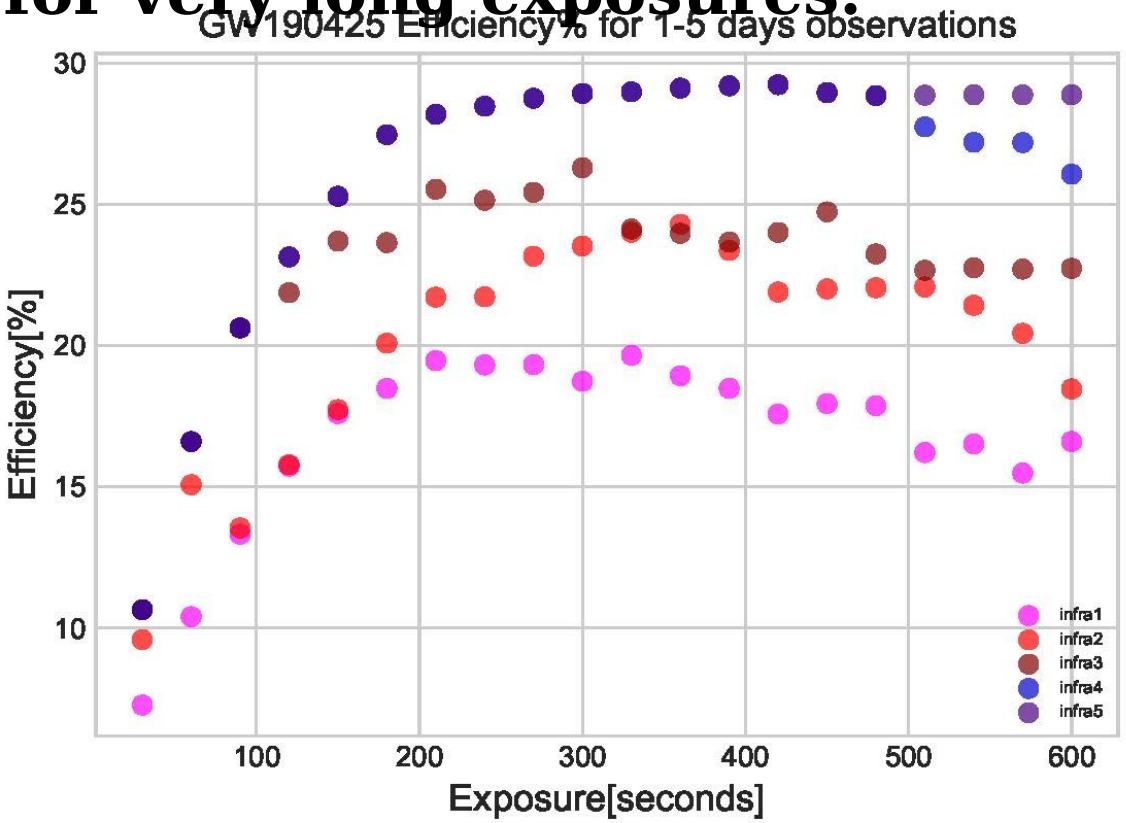


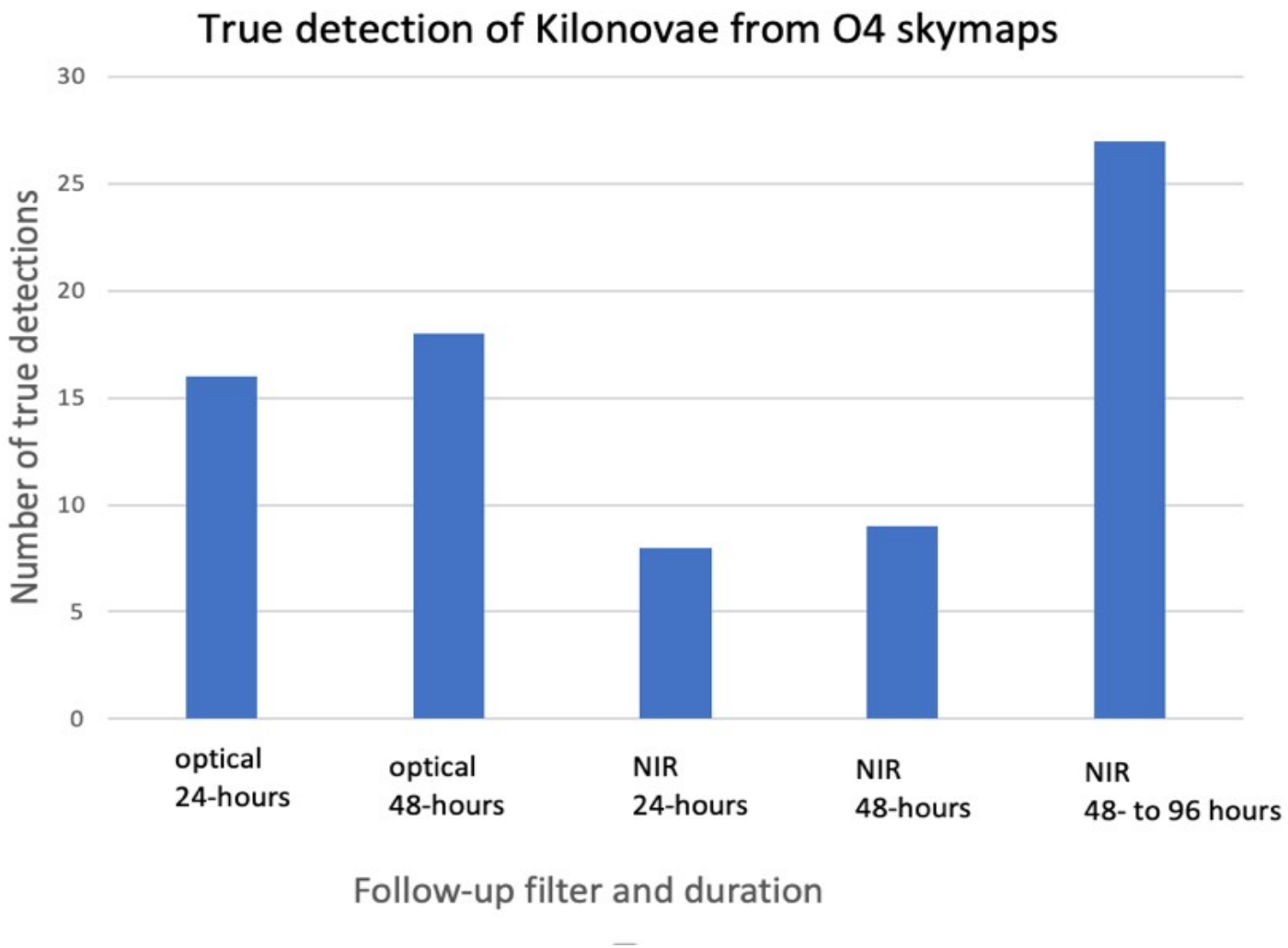
# Optical vs. Near-Infrared Observations

- **KNe are expected to last longer in NIR compared to the 72-hour follow-up strategies for Optical.**
- **We ran simulations using ZTF configurations in Optical (g- and r-bands) and NIR (J- and K-) with GW190425 skymaps and light curve models from the literature.**
- **We used exposures of 30 to 600 seconds for observations up to 120 hours.**

- **In Optical, maximum efficiencies are obtained with exposures of less than 100s.**
- **In NIR, best exposures are 200 to 400s for each tiling, reaching 25% after 48 h, decreasing for very long exposures.**



- **Also, number of detections for O4 skymap follow-ups in Optical and NIR for different time periods (post GW signal):**

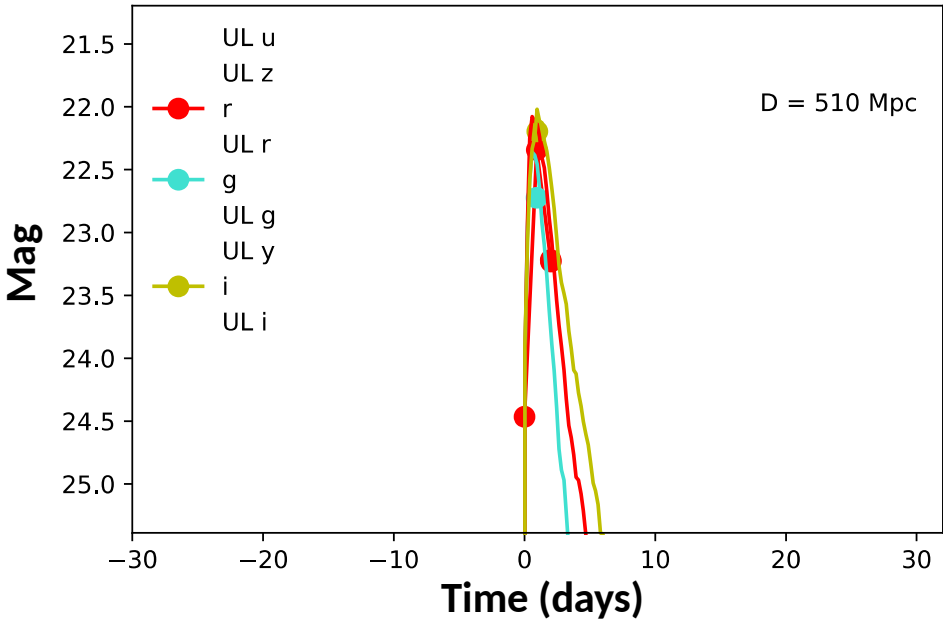


# VRO/LSST Filter Selections

- **We used LSST packages and metrics to simulate surveys in 6 photometric fi**

| Filter | u | g | r | i | z | y |
|---|---|---|---|---|---|---|
| ✦ (nm) | 305.3 - 408.6 | 386.3 - 567.0 | 536.9 - 706.0 | 675.9 - 833.0 | 802.9 - 938.60 | 908.0 - 1100.0 |

- **GW170817 kilonova light curves were injected into the simulations.**
- **Kilonova model parameters:**
  - $M_{dyn} = 0.005M_{\odot}$
  - $M_{wind} = 0.050M_{\odot}$
  - Viewing angle (☋) = 25.8🏭
  - Half lanthanide-rich composition opening angle (☊) = 30🏭

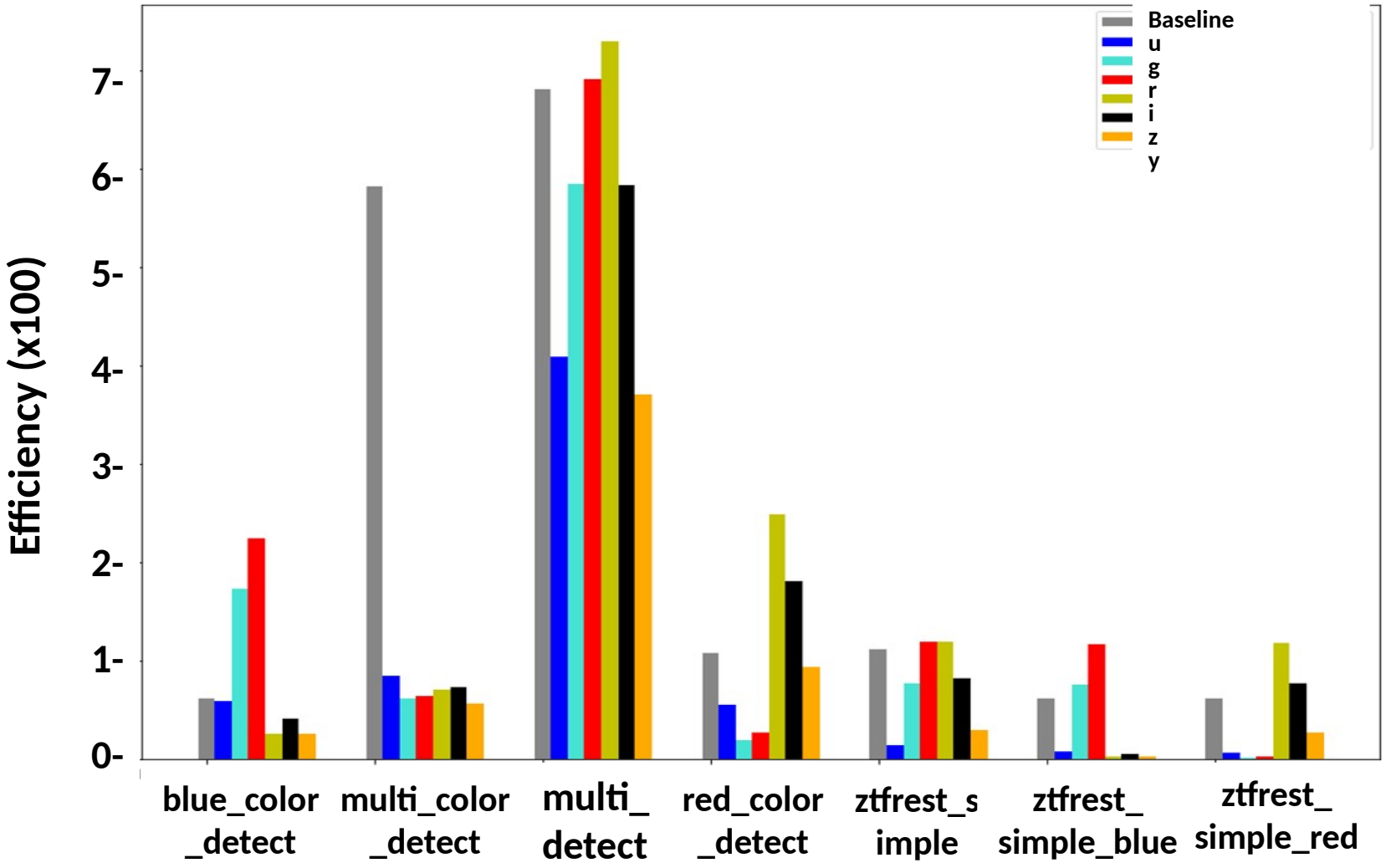


A metric gives the detection criteria for each event injected in our simulations:

- **multi-detect:** 2 transient detections.
- **multi-color detect:** 2 color detections.
  - **multi-detect red:** red filters only (i, z, y).
  - **multi-detect blue:** blue filters only (u, g, r).
- **ztfrest simple:** Rising faster than 1 mag day$^{-1}$ and fading faster than 0.3 mag day$^{-1}$.
  - **ztfrest simple red:** red filters only (i, z, y)
  - **ztfrest simple blue:** blue filters only (u, g, r)

# Results: Detections and Recovery Efficiencies

## (500,000 events injected into the simulations)



# Results: Detections and Recovery Efficiencies

**(500,000 events injected into the simulations)**

- **ztfrest_simple rates are much lower than the multi_detect because of the KN discovery criteria.**
- **Efficiency rates show that i- and r-band filters proved to be the best optimal filters for kilonova and transient detection alike.**
- **While kilonovae appear red and fade slower in redder/near-infrared bands, the y- and z-bands performed worse than expected due to VRO's lower**

# Conclusions

- **Using *gwemopt*, we have simulated observational scenarios (cadences, exposure lengths, Optical and NIR filters, etc.) for O4 skymaps on ZTF in the aim of optimizing KN detections.**
- **Using LSST survey strategies, we have simulated and investigated filter selections (in particular).**
- **We have published our main results, some of which may be surprising.**
- **Along with the GRANDMA observational campaigns that prepare for the upcoming O4 events, we believe**