BUILDING THE TIME-DOMAIN ECOSYSTEM WITH RUBIN

GAUTHAM NARAYAN @gsnarayan

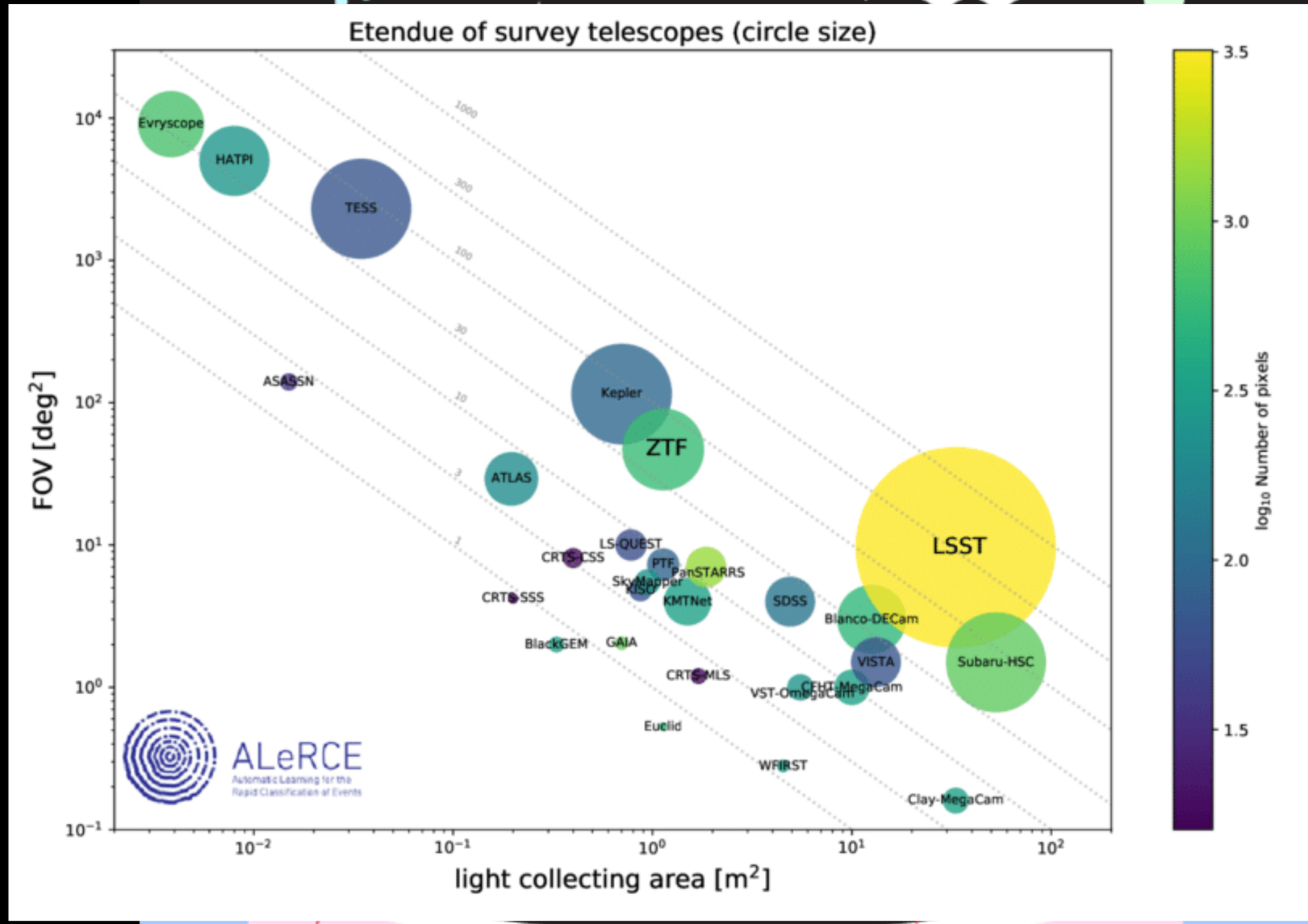
Simonyi-NSF CAREER Fellow

UNIVERSITY OF ILLINOIS, URBANA-CHAMPAIGN

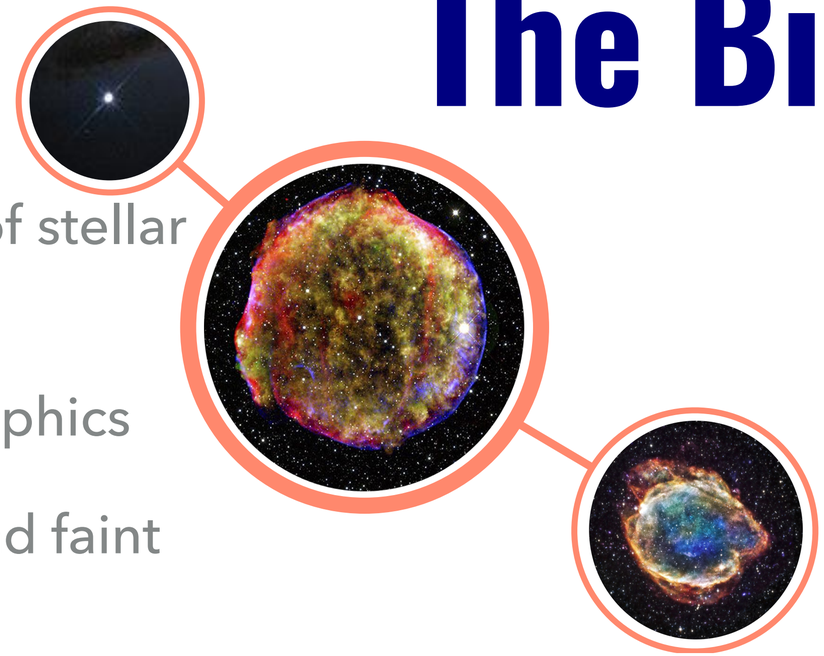
Artwork by Sandbox Studio, Chicago with Ana Kova

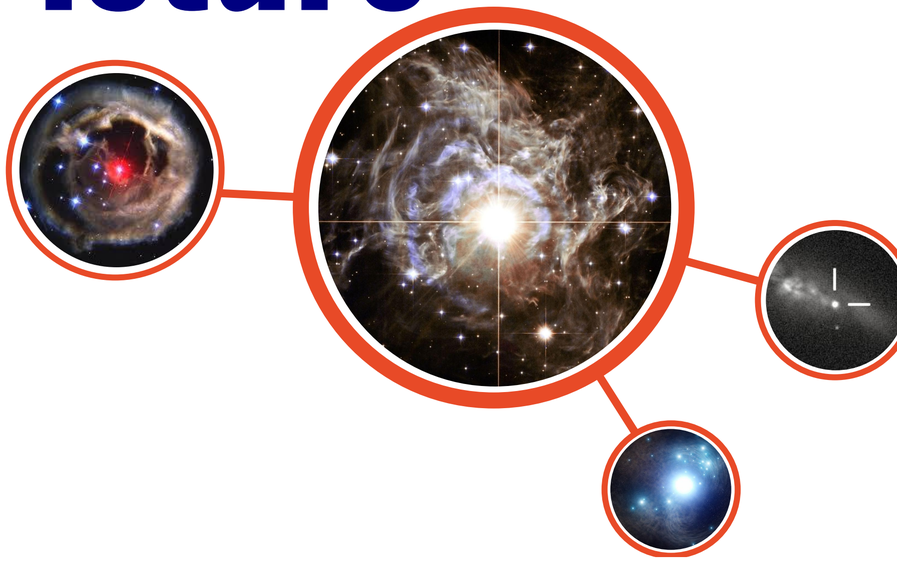
ETENDUE ENABLES TIME-DOMAIN ASTROPHYSICS

- With a 8.4m primary mirror…
- and a unique f/1.23 optical design giving it a very large FoV…
- Rubin Obs. has the largest etendue of any ground-based optical telescope
- leading to ~10 million transient alerts, every night



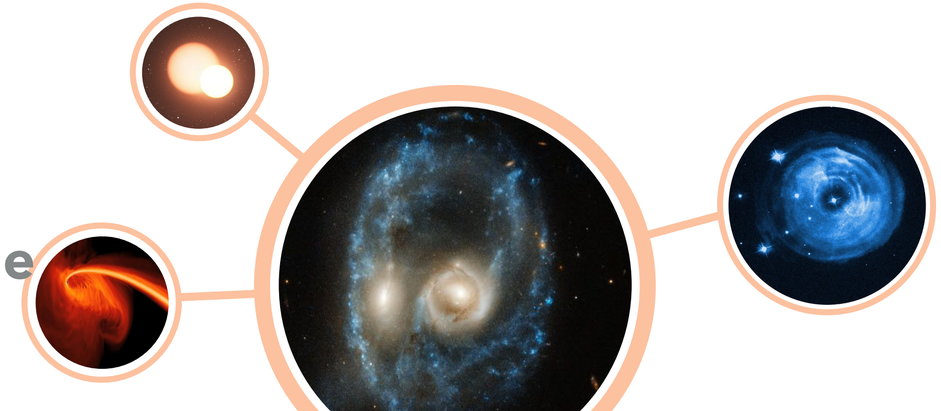
The Big Picture





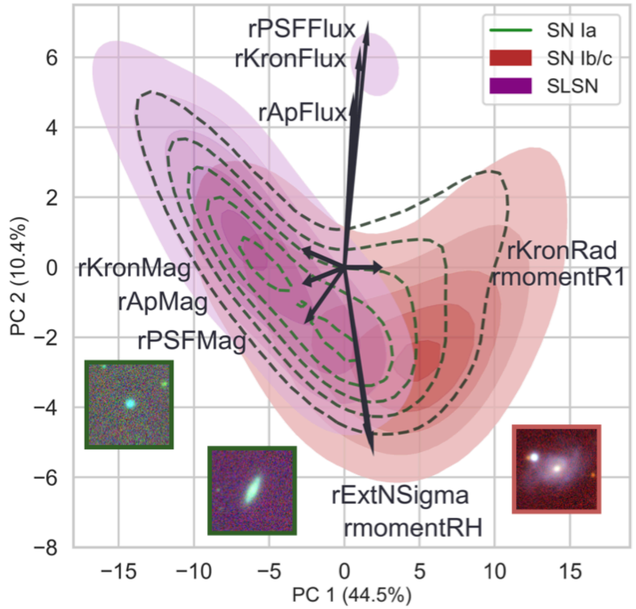
- Understand the physics of stellar death
- probe transient demographics
- discover the most rare and faint sources
- map the covariance between transients and their host environment, and their evolution with redshift
- **study the Hubble constant tension, dark energy and its evolution over over cosmic time**

LSST ALLOWS US TO EXAMINE SEVERAL OPEN QUESTIONS

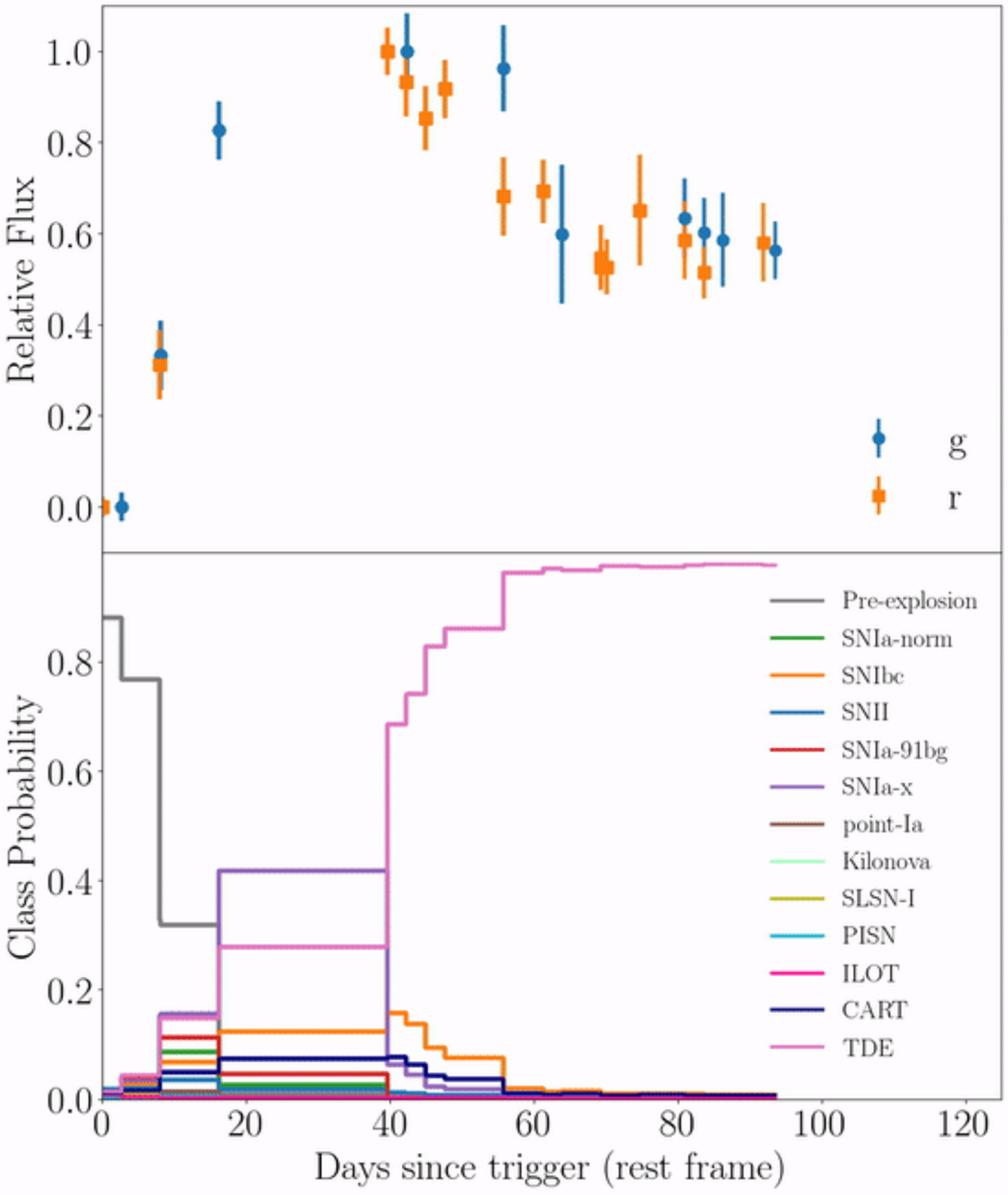


LSST DESC
Dark Energy Science Collaboration

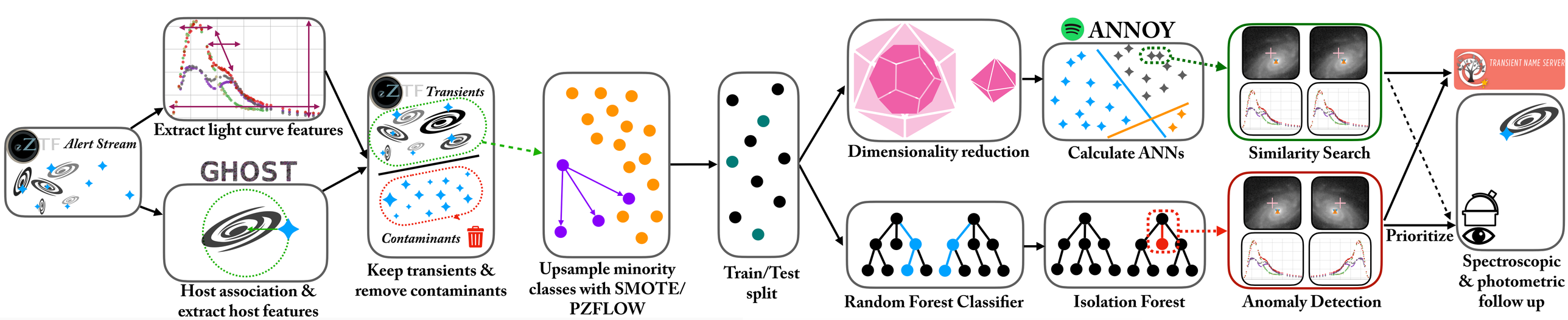
THE ROLE OF AI WITH LSST

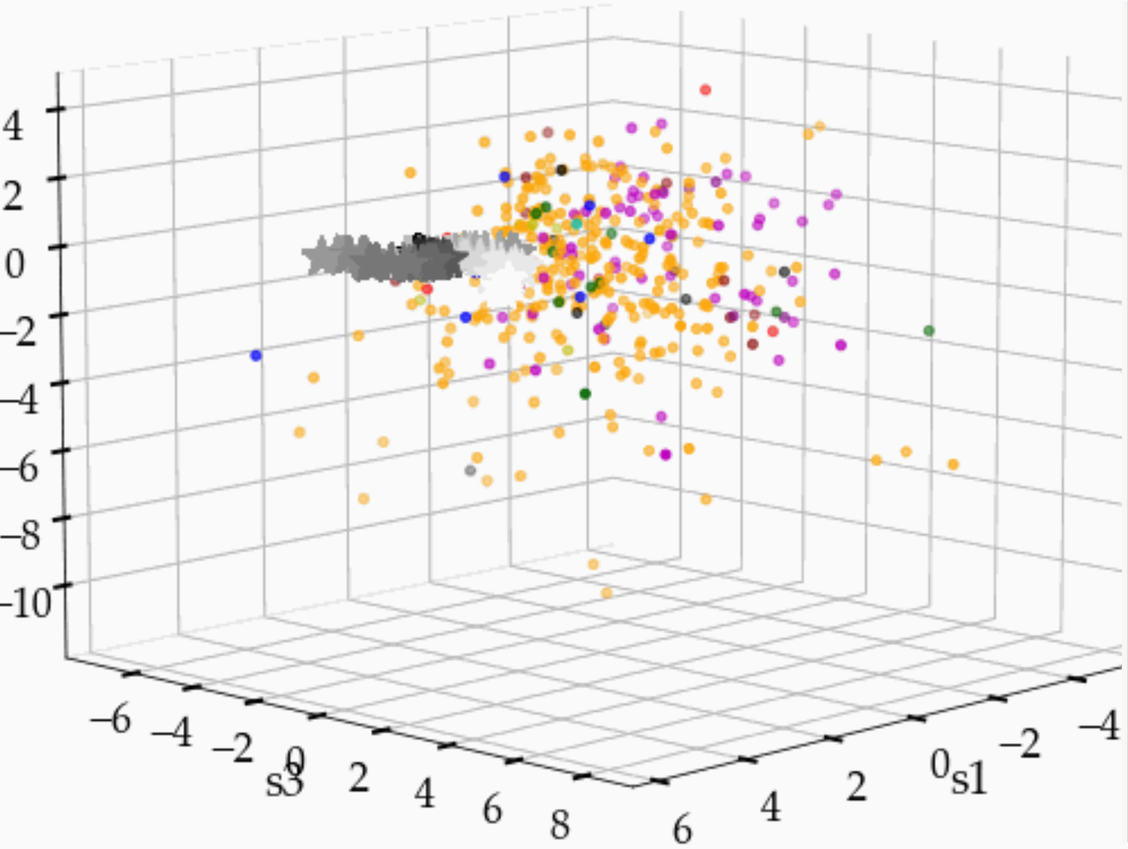


RAPID (Right, Muthukrishna, Narayan+19) uses real-time alerts to classify objects, while GHOST (left, Gagliano, Narayan+21) uses only host-information to classify SNe



- The key challenge is how to enable a community with diverse interests to use the vast quantity of data
- For the time-domain, need to process real-time streams to characterize events quickly - implies AI/ML
- The primary goal is to whittle 10 million/alerts per night into something manageable for your science case





ZTF22aaezyos

Num. Alerts: 133

Num. Mag. Values: 105

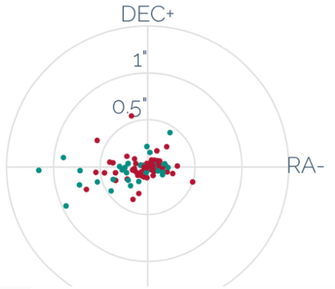
Associated Tags:

- iso_forest_anomaly_detection
- lc_feature_extractor
- extragalactic
- high_amplitude_transient_candi…
- high_flux_ratio_wrt_nn
- young_extragalactic_candidate

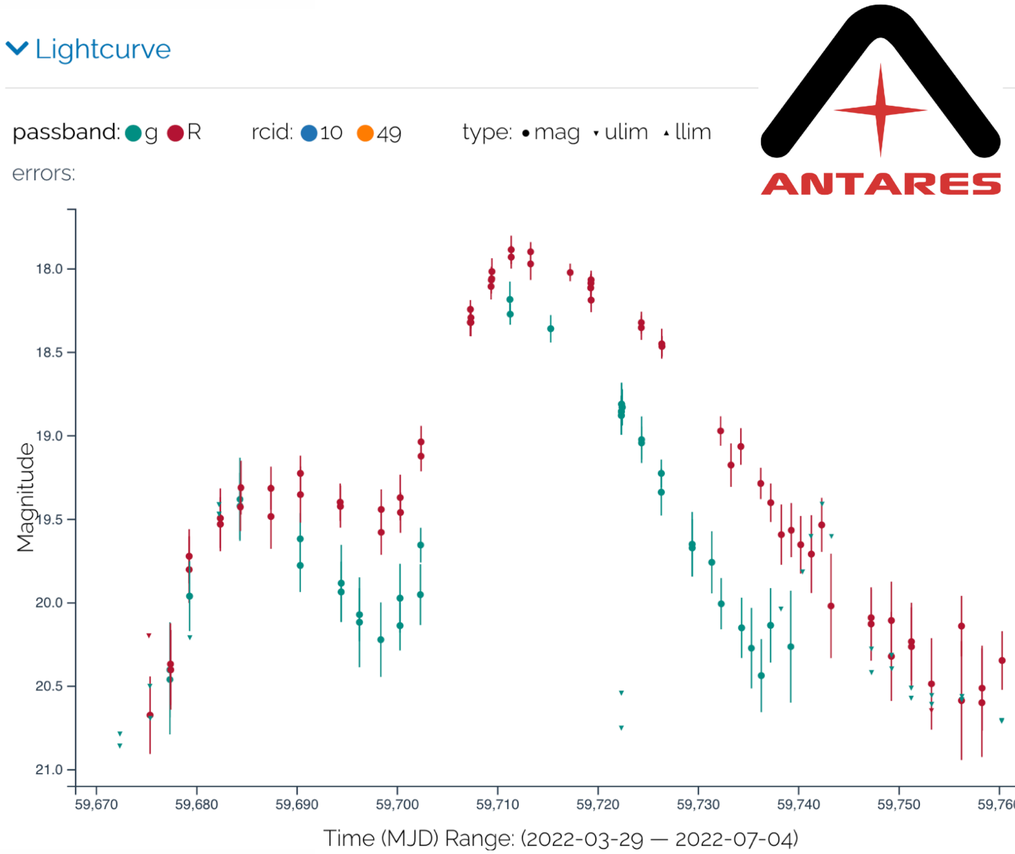
Alert Brokers: ALeRCE

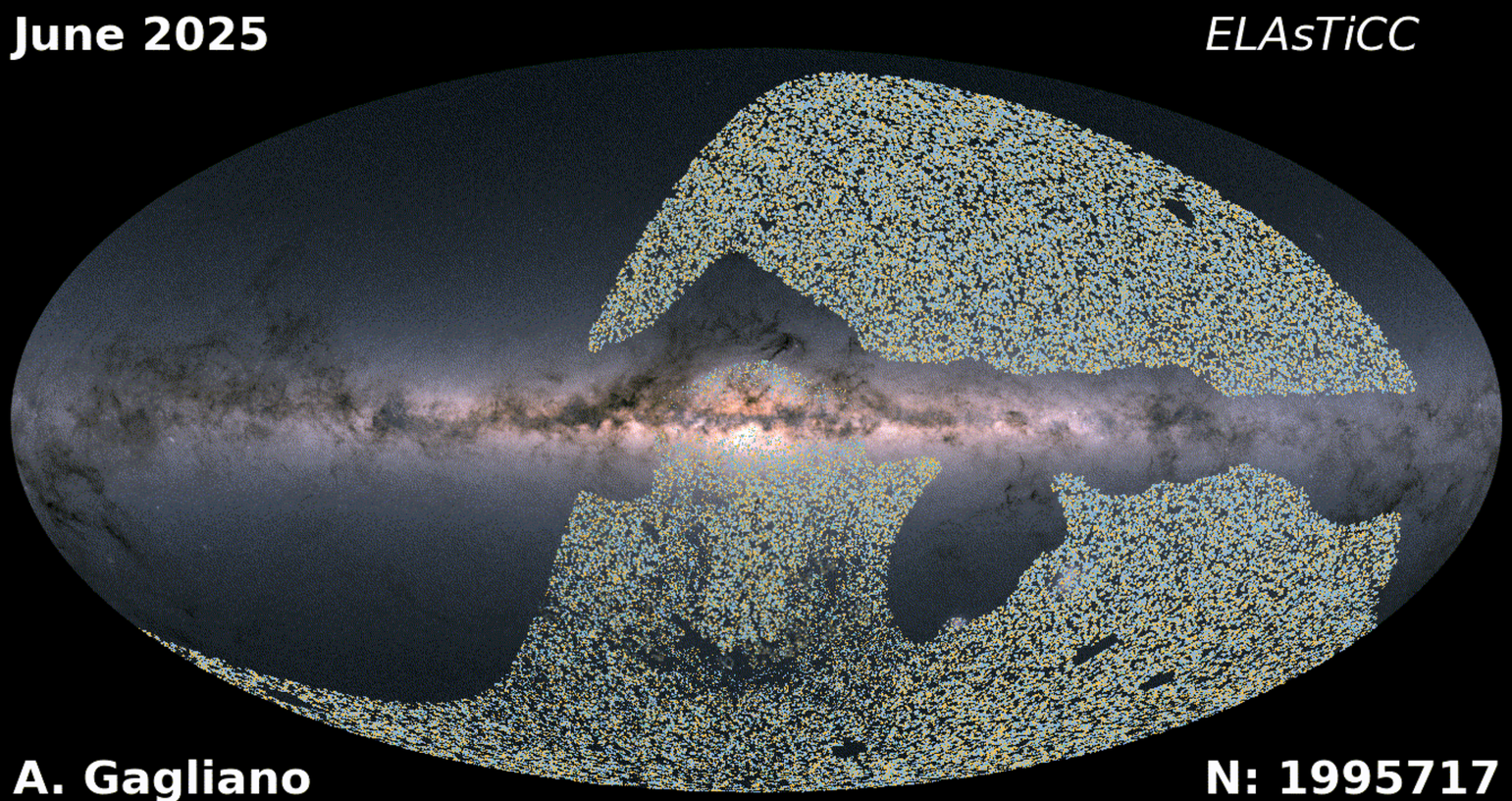
External Services: IPAC, NED, SIMBAD, SNAD, TNS, VizieR

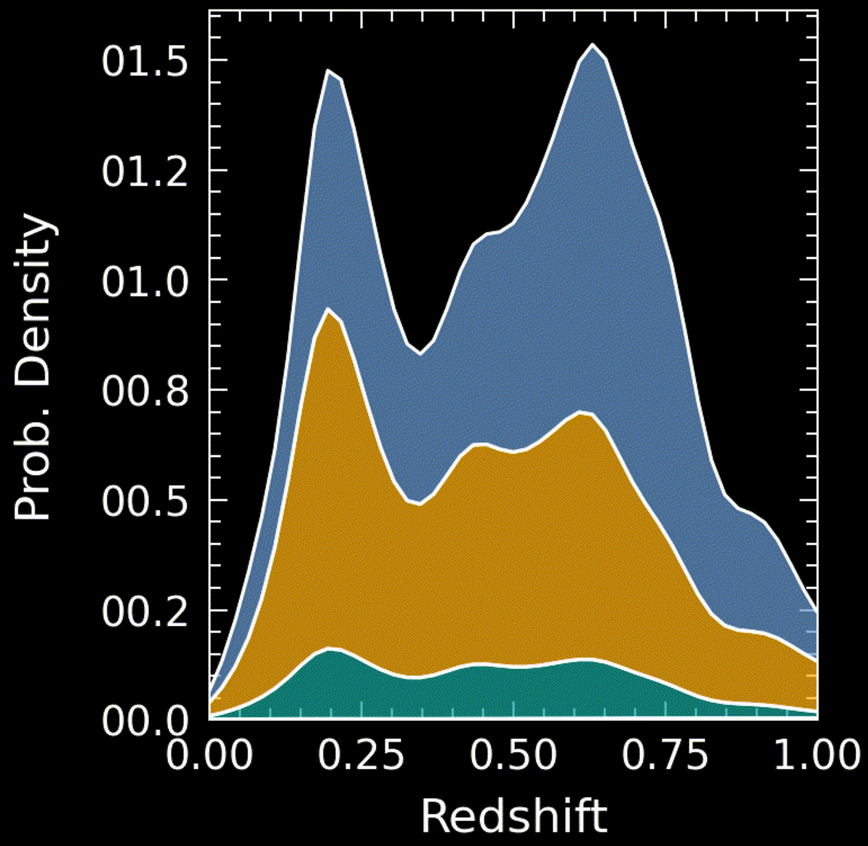
Finder Chart



Lightcurve





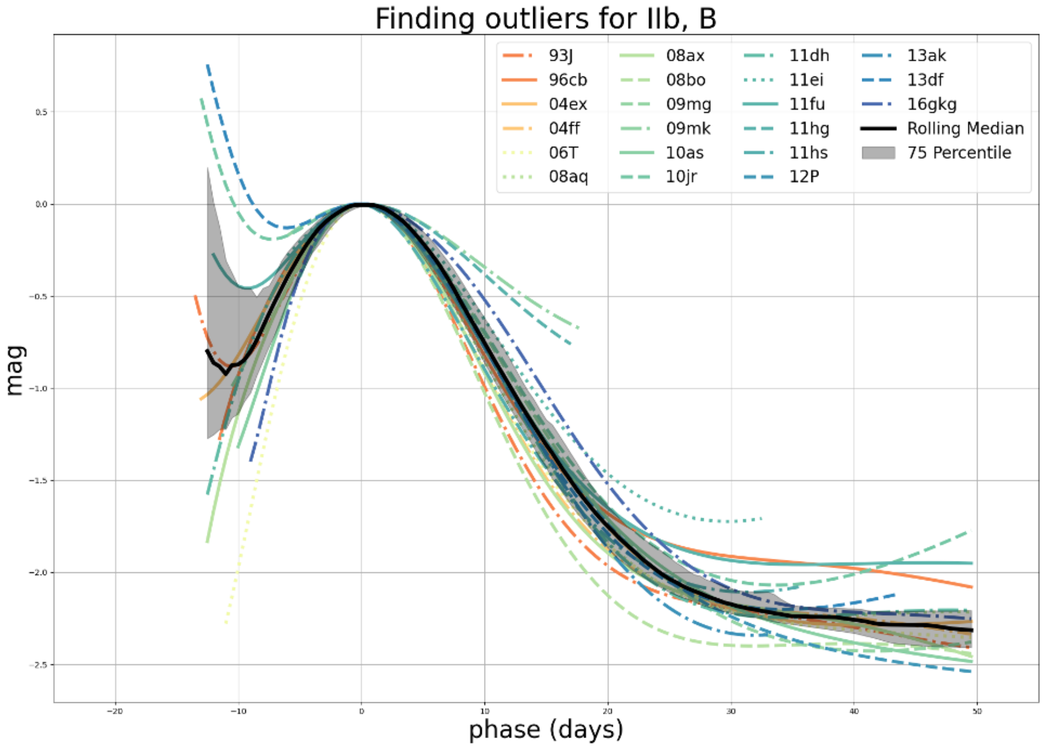


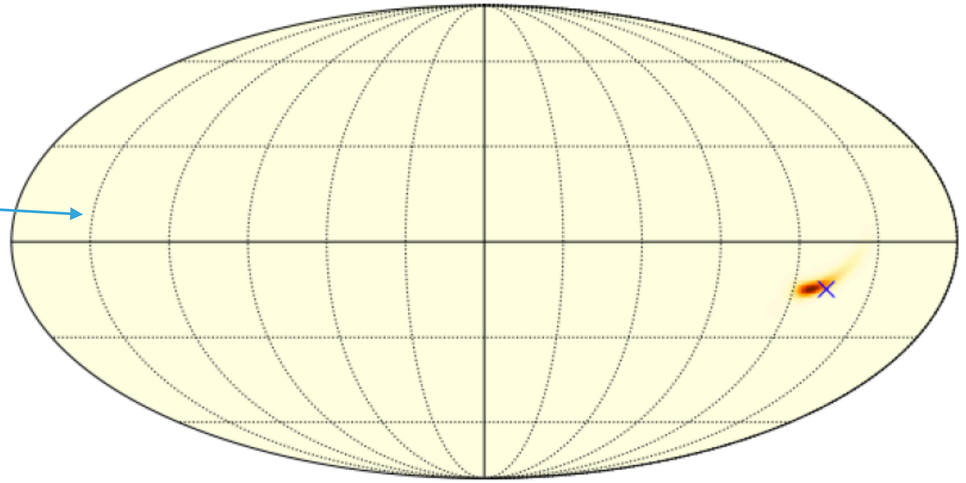
SN Ia : 921142 SN II : 854271 SN Ib/c : 183741 SLSN : 9864

- Preparing AI for LSST requires detailed simulations of the time-domain sky - beyond DP2 together with connecting with machine learning-based “brokers” such as ANTARES (Narayan+’18, Matheson+’21)
- Current best realization of these simulations is the Extended LSST Astronomical Time-series Classification Challenge (ELAsTiCC) - Round 2 starts at the end of August!
- **December 2023 - NASA effort (Leads: Michael Troxel, Rachel Mandelbaum, Mike Jarvis) to create pixel level simulations of Rubin+Roman sky**

ELAsTiCC has a rich diversity of models

- *New:*
  - delta Scuti, Cepheids (K. Malanchev)
  - dwarf novae and changing look AGN (Q. Cheng)
  - + others we've snuck into test data but not in training data
- *Updated:*
  - more diverse SNe Ib & c (M. Vincenzi)
  - M-dwarf flares (V. Shah)
  - KNe (V. Shah, D. Chatterjee)
    - **+ synthetic LVK O4 alert skymaps**



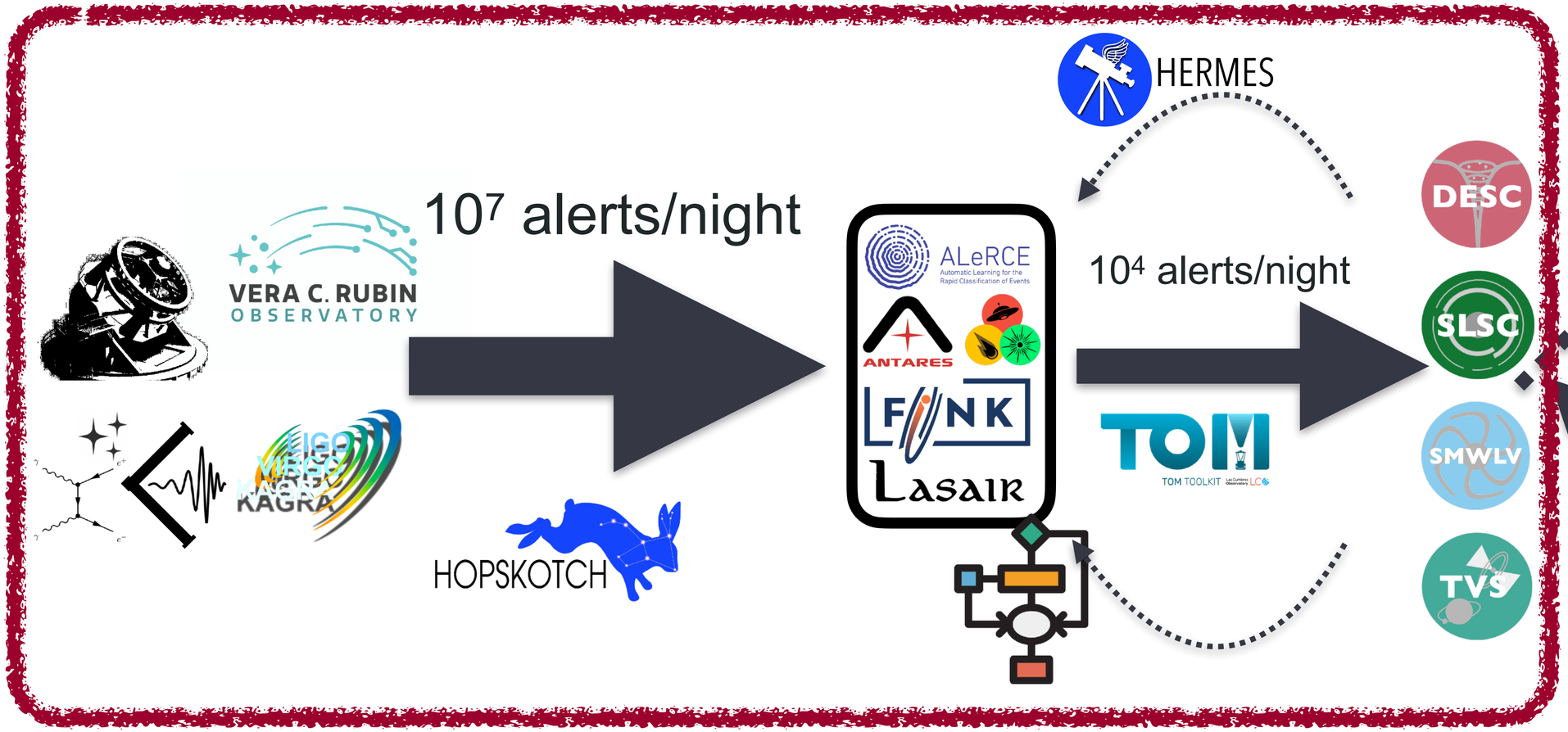




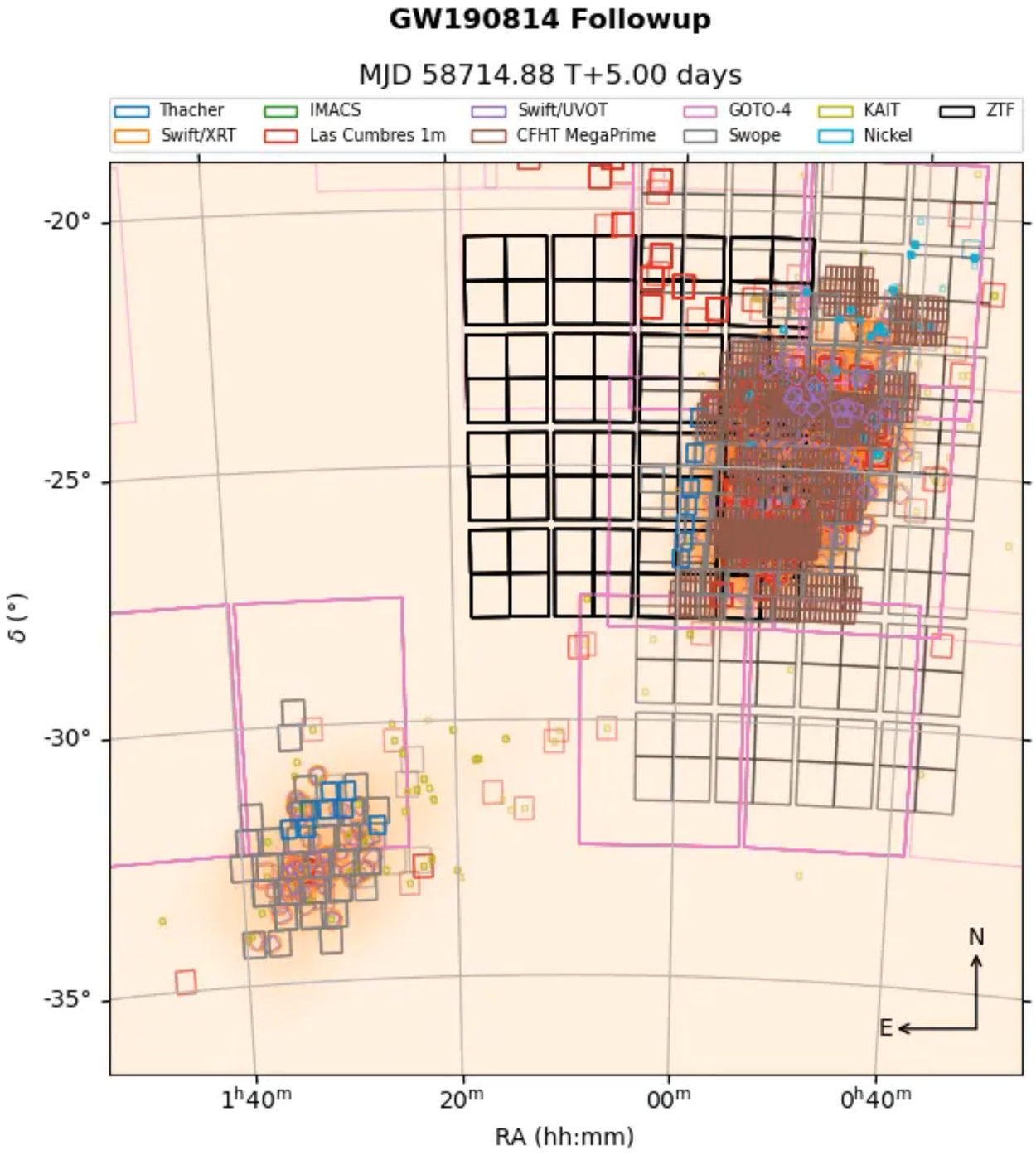


What is ELAsTiCC?

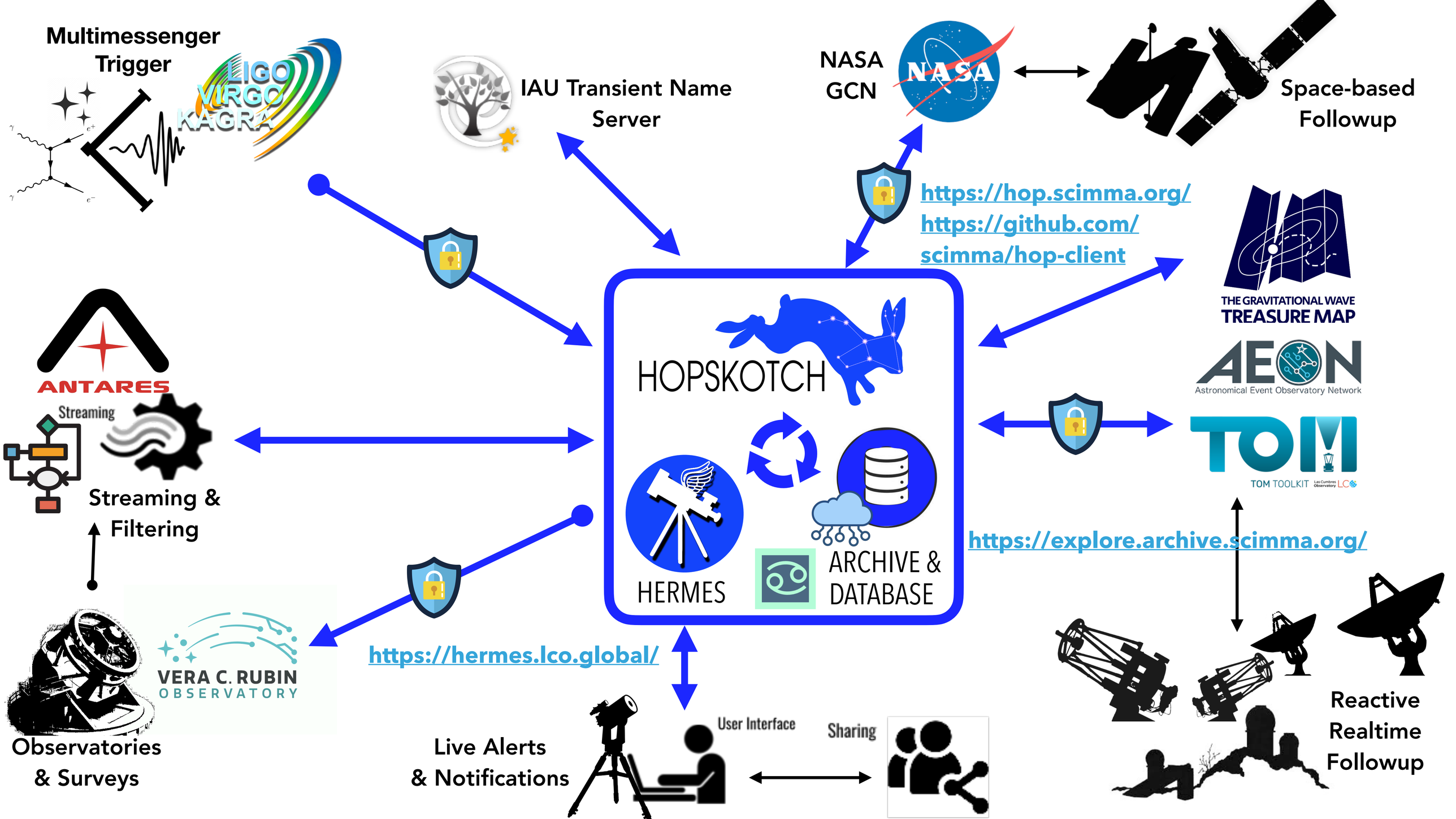
Big infrastructure challenge with multiple potential points of failure along chain. ELAsTiCC simulates the entire chain to identify these.



https://portal.nersc.gov/cfs/lsst/DESC_TD_PUBLIC/ELASTICC/



- LSST does not operate in isolation!
  - Critical to coordinate with other optical surveys such as the Young Supernova Experiment (YSE), Roman, Euclid, DESI2 as well as MMA experiments - LVK, IceCube, CTA, CMB-S4 to identify rare, faint and fast sources
- **This needs an interconnected ecosystem for time-domain astrophysics**
- This is the goal of the NSF CSSI-funded Scalable Infrastructure for Multi-Messenger Astrophysics team (SCiMMA)
  - Need new features? Let's talk!


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://explore.archive.scimma.org/
https://hermes.lco.global/
VERA C. RUBIN OBSERVATORY
Observatories & Surveys
Live Alerts & Notifications
User Interface
Sharing
Reactive Realtime Followup

- Rubin Observatory will revolutionize our knowledge of the time-domain sky
- Time-domain and multi-messenger astrophysics requires a complex, interconnected ecosystem of services
  - DESC and SCiMMA are building this infrastructure and the datasets to prepare for LSST
  - We’re happy to work with you and share code/add new models/features! Let’s talk!