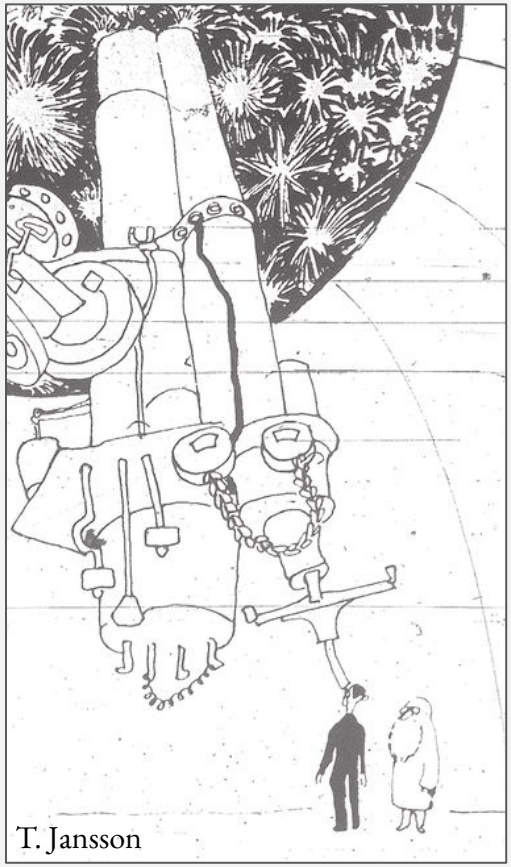
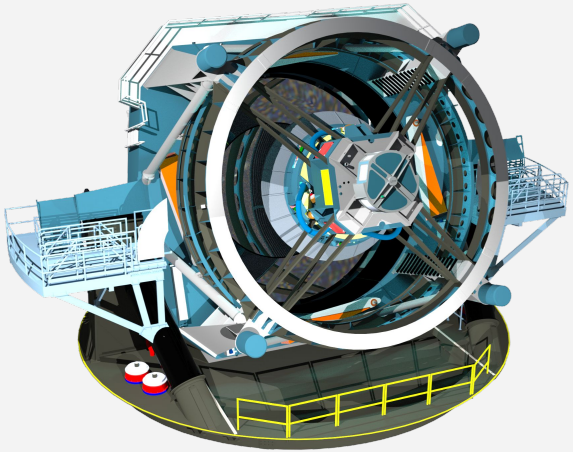


LSST, Brokers, Multi-messenger programs

- VRO -> Brokers
- AMPEL MM workflow
- Looking ahead

The LSST survey at the Vera Rubin Observatory

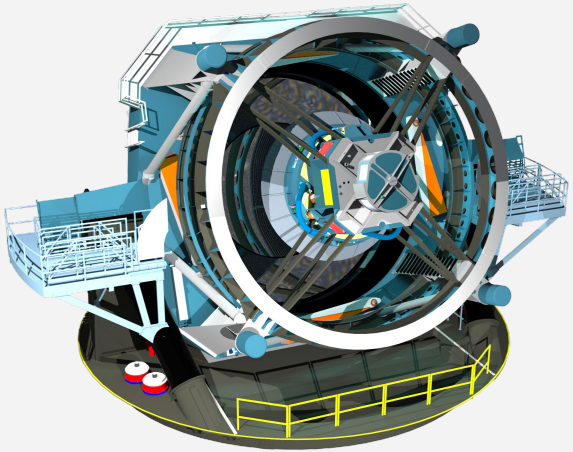


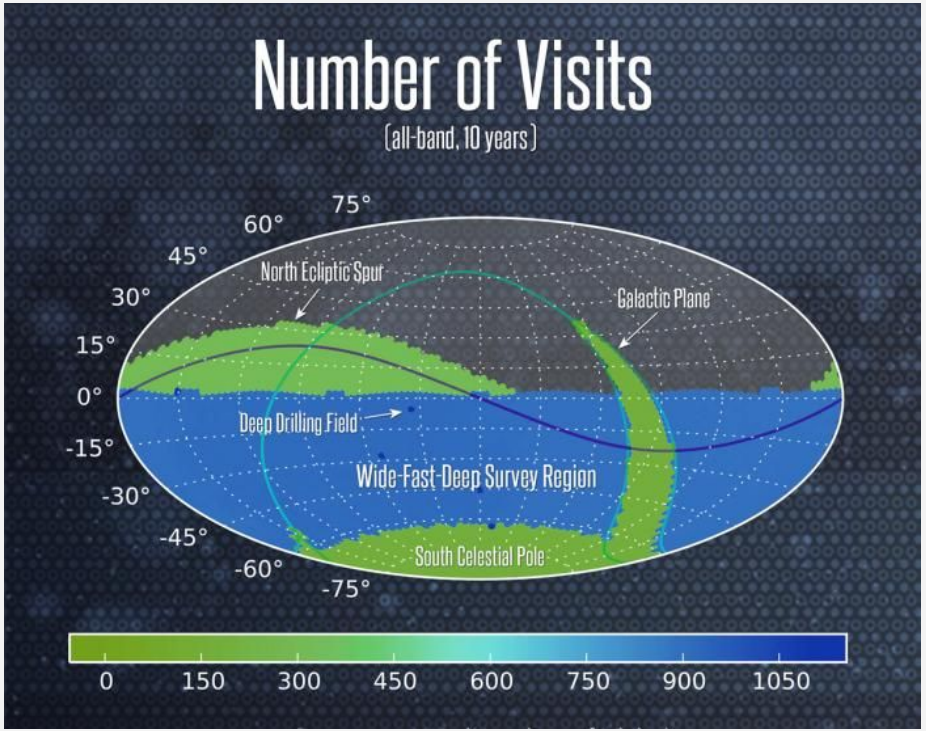
... will be many things, but for time-domain multi-messenger science:

- Characterization of slowly varying transients (TDE, ... ?).
- Discovery machine for young, faint & distant transients.

Follow-up observations required.

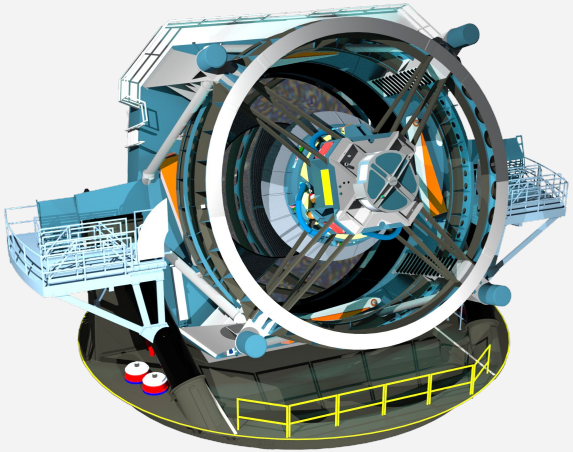
The LSST survey at the Vera Rubin Observatory





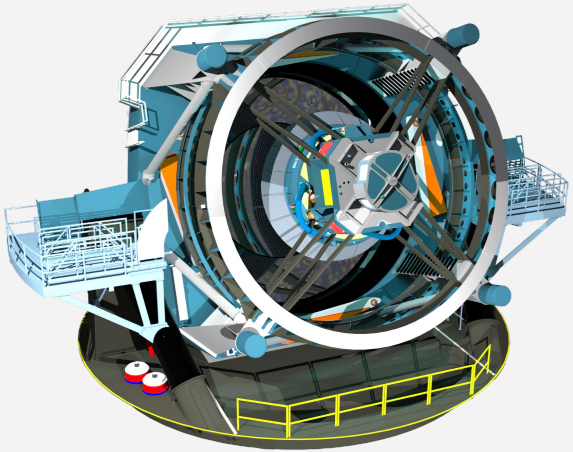
Mostly low cadence

The LSST survey at the Vera Rubin Observatory



	ZTF	LSST
Effective Aperture	1.2 m	6.7 m
Field of View	47 deg^2	9.6 deg^2
Median Image Quality	2.0”	0.7”
Filters	g, r (i)	u, g, r, i, z, y
Single exposure magnitude range (r)	13.5-20.5	16-24.7
Areal survey speed	3760 deg^2 hr^{-1}	840 deg^2 hr^{-1}
Average yearly observations per field	290	82
Survey dates	2018-2020	2022-2032

The LSST survey at the Vera Rubin Observatory



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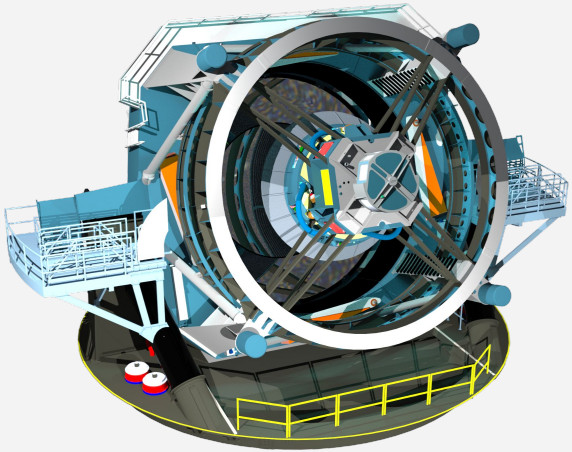
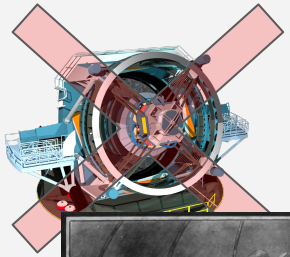
Most detections too faint for small telescopes

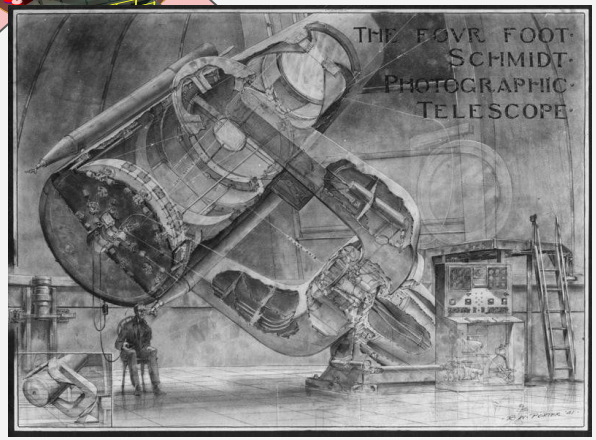
The LSST survey at the Vera Rubin Observatory



	ZTF	LSST
Number of detections	1 trillion	7 trillion
Number of objects	1 billion	37 billion
Nightly alert rate	1 million	10 million
Nightly data rate	1.4 TB	15 TB
Alert latency	< 20 minutes	60 seconds

The LSST survey at the Vera Rubin Observatory





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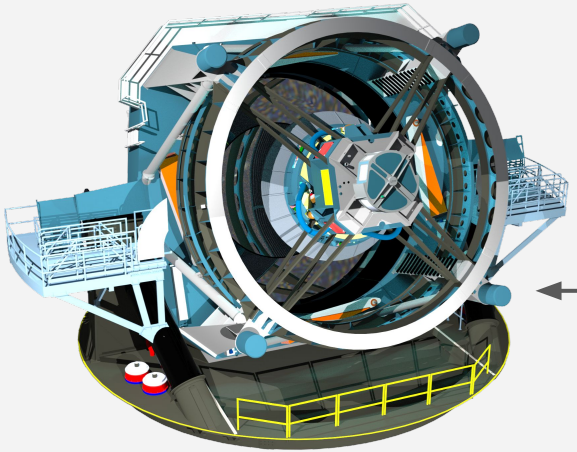
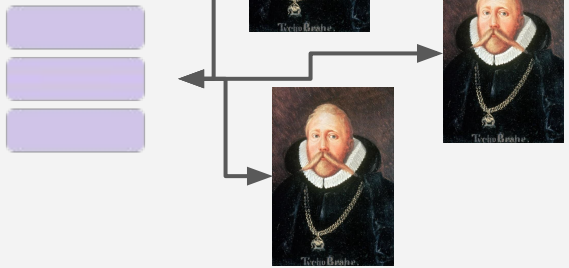
Already in the LSST “era” - throwing away most data

The LSST survey at the Vera Rubin Observatory

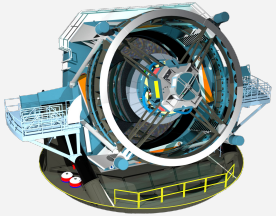


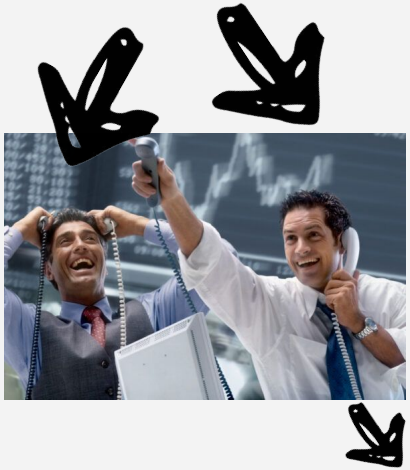
No real-time access through DB access:



Would cause large data volumes & unpredictable requests

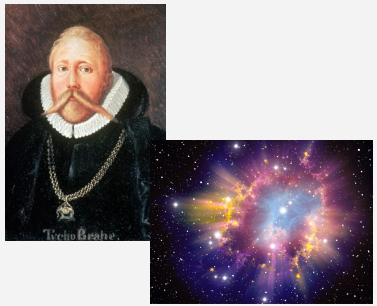
Brokers to the rescue





Detections distributed as unidirectional alert stream to fixed endpoints.

Brokers provide interesting alerts to scientists.



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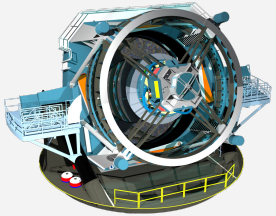


Detections distributed as unidirectional alert stream to fixed endpoints.

- **Six+ brokers selected.**

ANTARES

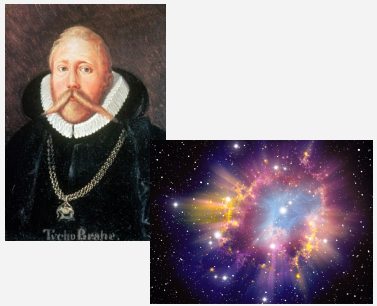
FINK

BABA·MUL

Pitt

- **Access points for filtered alerts.**
  - **Cross match**
  - **Classification**

Brokers provide interesting alerts to scientists.



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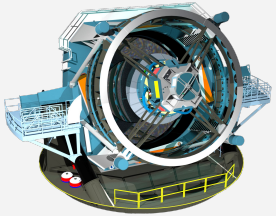


IceCube

LIGO VIRGO

- Six+ brokers selected.

ANTARES

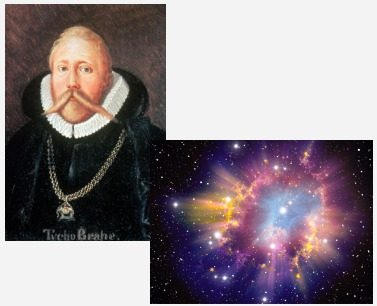
FINK

ZTF BABA-MUL

Pitt

- Access points for filtered alerts.
  - Cross match
  - Classification
- Conceptually easy to add new streams (MM)

Brokers provide interesting alerts to scientists.



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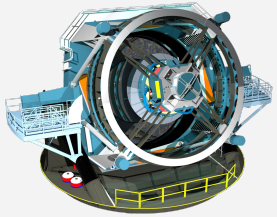
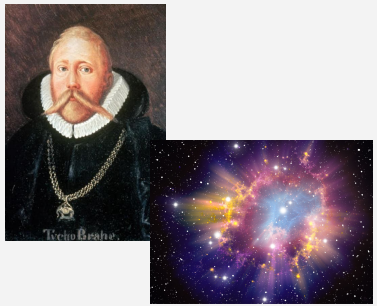


IceCube

LIGO VIRGO

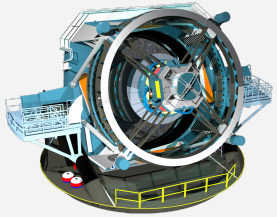
Brokers provide interesting alerts to scientists.



However:

- Should we trust brokers?
- What just happened?
- Will they last?

Brokers to the rescue



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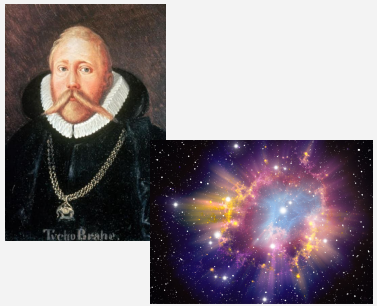
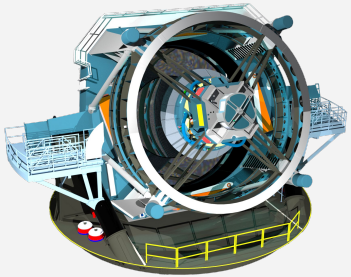


- Who knows how to select?
  - ... not broker teams!
  - Change with time
- Provenance
  - Reproducibility
  - Statistics
- Stability
  - Funding unclear
  - Single point of failure
  - No common interfaces

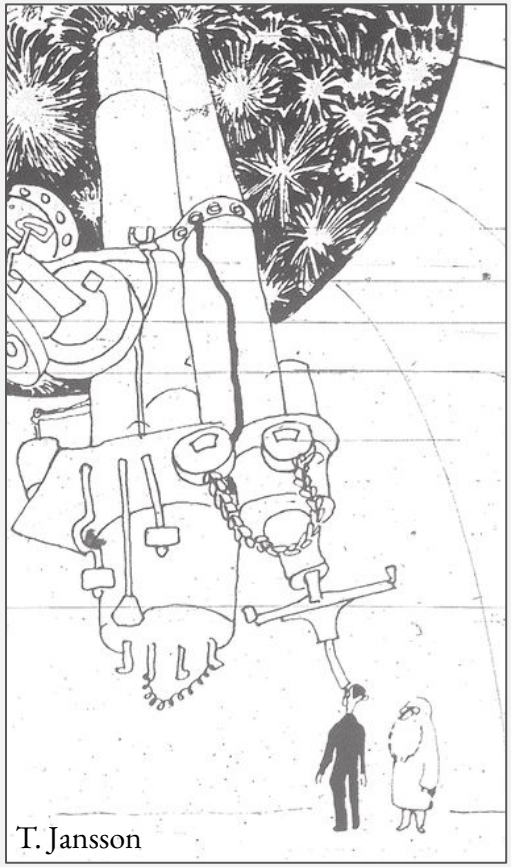
The European Broker Initiative



...

- Different architectures with different focus.
- Initiative started to use each others strengths and jointly develop missing pieces.
- Part of unfunded ACME proposal...

Hopefully continued!



LSST, Brokers, Multi-messenger programs

- VRO -> Brokers
- AMPEL MM workflow
- Looking ahead

Science analysis encoded as job for flexible execution

Distributed, stored & orchestrated.

AMPEL

Analysis and workflow framework for high throughput time-domain astronomy.

Scalable.

DB designed for (evolving) knowledge of transients.

Use astronomers tools: python / catalogs / ...

Realizes code-to-data in astronomy.

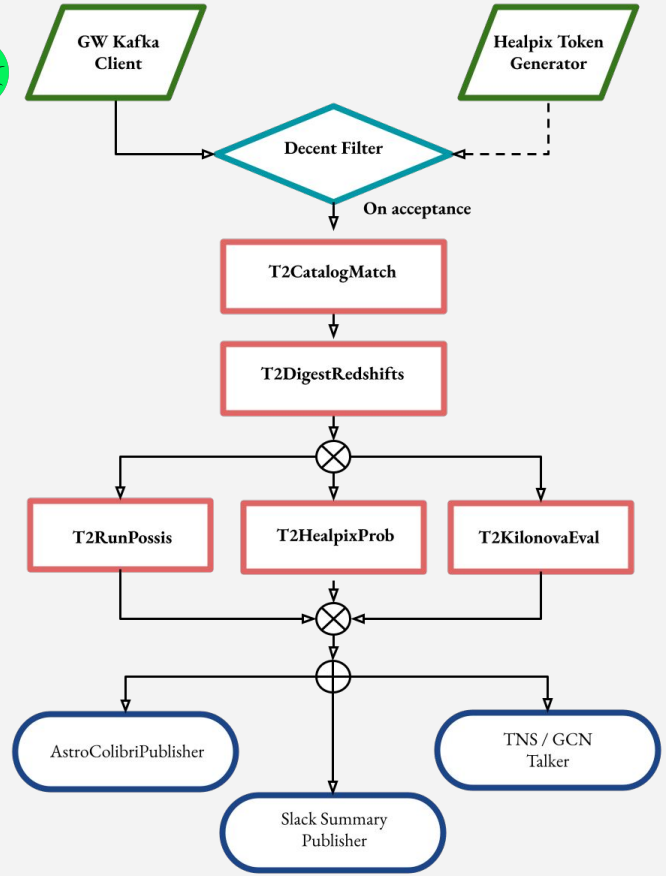
https://github.com/AmpelAstro

A sample MM workflow

```yaml
name: ligo-kilonova
parameters:
- name: map_url_var
  value: https://gracedb.ligo.org/api/superevents/S231102w/files/bayestar.fits.gz,1
- name: map_name_var
  value: S231102w.fits.gz,1
- name: map_token_var
  value: S231102w.fits.gz,1_token
- name: trigger_jd_var
  value: 2460250.8038889
- name: export_fmt
  value: csv
- name: transienttable_path
  value: ./TransientTable.csv

mongo:
  prefix: S231119u
  reset: true

channel:
- name: remote
  access: [ZTF, ZTF_PUB, ZTF_PRIV]
  policy: []

task:

- title: token
  unit: T3Processor
  config:
    raise_exc: true
    execute:
      - unit: T3PlainUnitExecutor
        config:
          target:
            unit: HealpixTokenGenerator
            config:
              pvalue_limit: 0.9
              chunk_size: 1000
```

- Retrieve healpix map (GraceDB, GCN)
- Retrieve ZTF alerts within t-range from event time (~25000).
- Filter for new transients.
- Match position to catalogs and redshift.
- Fit optical+GW data to POSSIS models.
- Combine all information into one kilonovaness ranking.
- Post candidates (AstroColibri)

https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml



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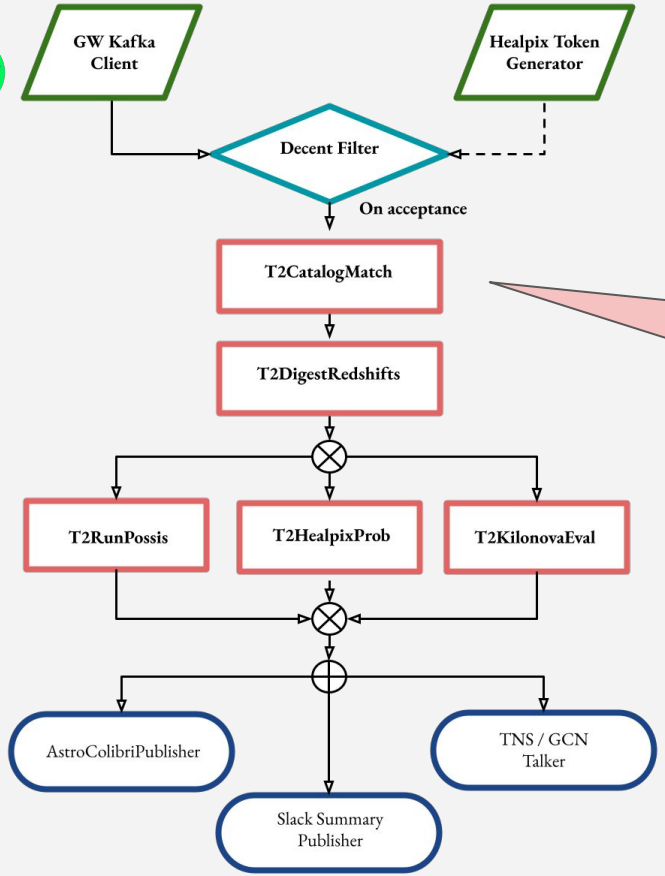
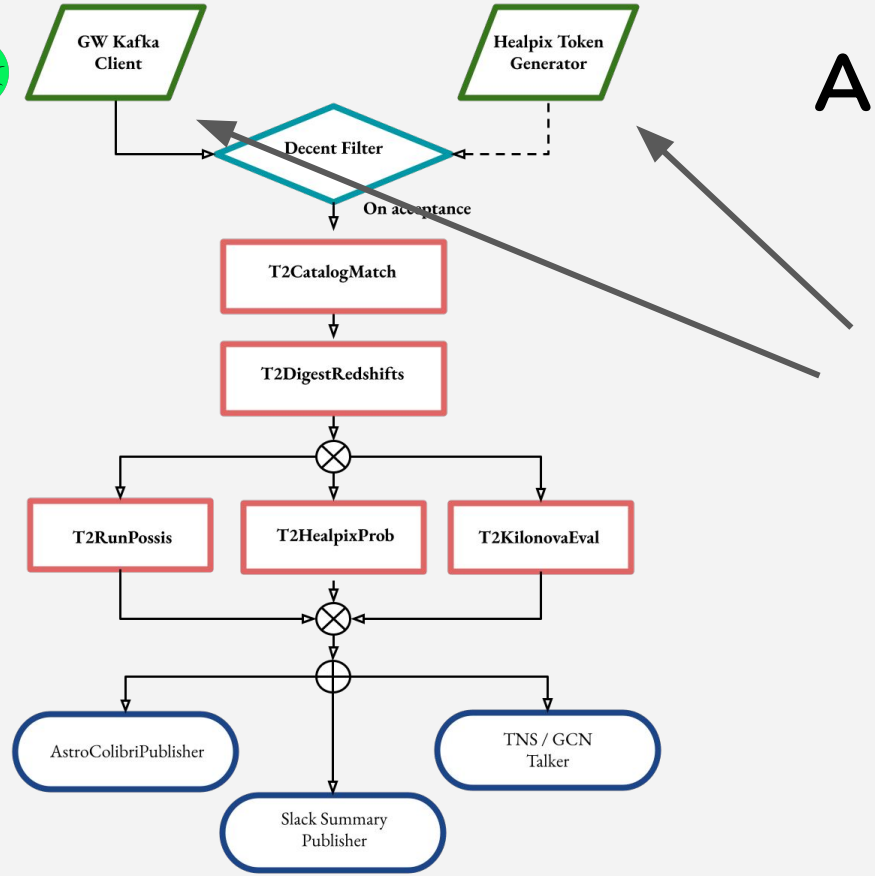


Each unit is a public python module:

https://github.com/AmpelAstro/Ampel-ZTF/blob/master/ampel/ztf/t2/T2CatalogMatch.py

https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml

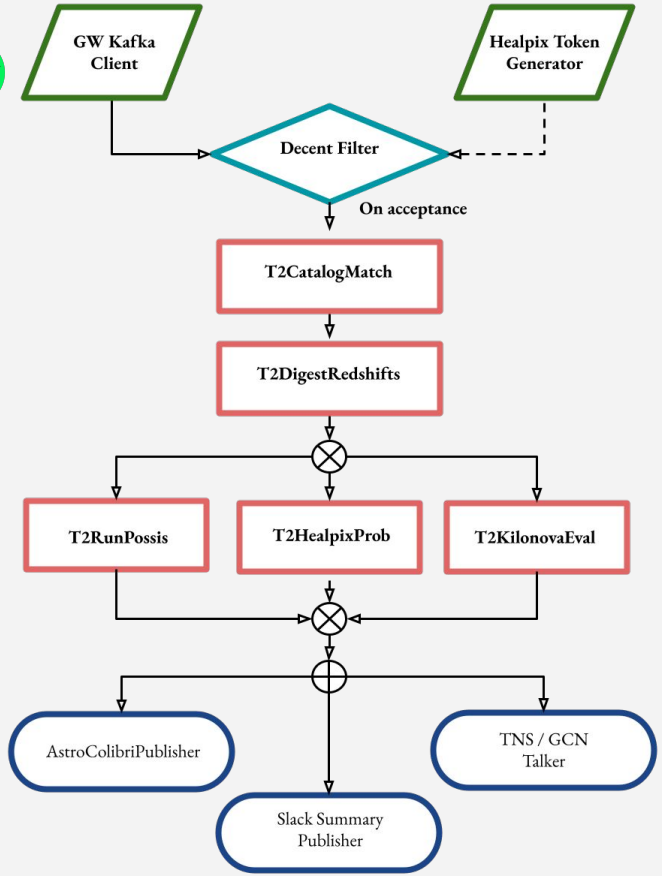
A sample MM workflow



Identical structure for autonomous alert reaction, simulation studies and archive runs.

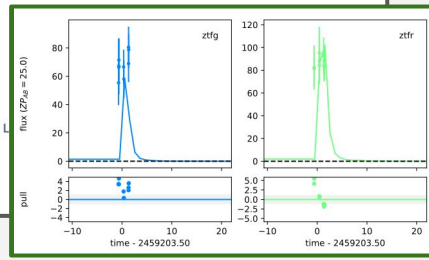
https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml

A sample MM workflow



Consistent use of theoretical models

```
30
31  class T2RunPossis(T2RunSncosmo):
32      """
33      Load a POSSIS kilnova model and fit to a LightCurve object as process is called.
34
35      Load one of the POSSIS models and create an sncosmo_model
36      model for fit by T2RunSncosmo.
37      :param possis_base_url: str, path to (github) possis repository
38      :param model_gen: str, name of model generation (subfolder)
39      :mej_dyn: float, Possis parameter
40      :mej_wind: float, Possis parameter
41      :phi: int, Possis parameter
42      :cos_theta: float, Possis parameter
43
44      Dynamically fix model explosion time
45      :param explosion_time_jd: Union[None, float, L
46
47
48      """
49
```



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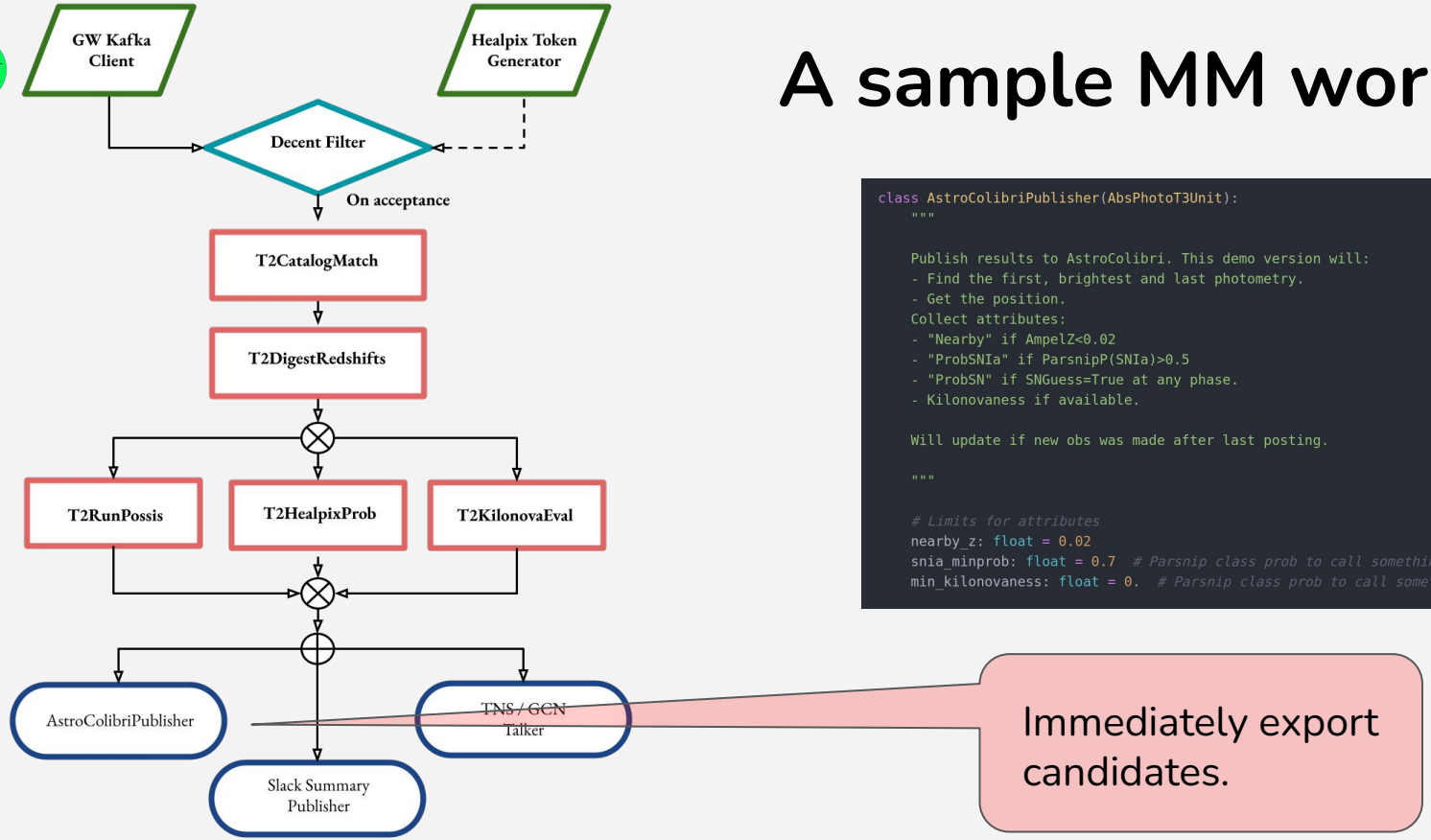
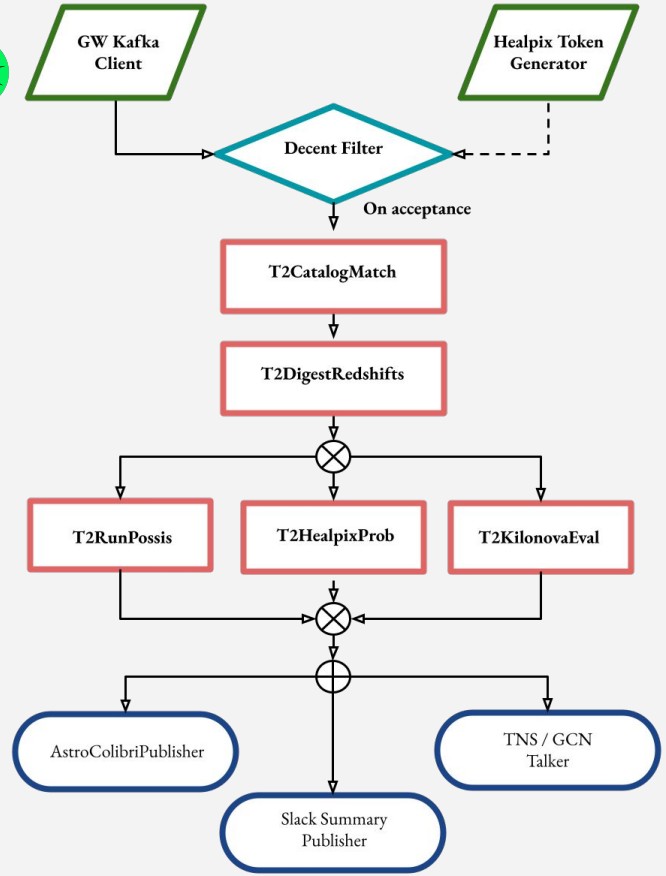



```python
class AstroColibriPublisher(AbsPhotoT3Unit):
    """

    Publish results to AstroColibri. This demo version will:
    - Find the first, brightest and last photometry.
    - Get the position.
    Collect attributes:
    - "Nearby" if AmpelZ<0.02
    - "ProbSNIa" if ParsnipP(SNIa)>0.5
    - "ProbSN" if SNGuess=True at any phase.
    - Kilonovaness if available.

    Will update if new obs was made after last posting.

    """

    # Limits for attributes
    nearby_z: float = 0.02
    snia_minprob: float = 0.7  # Parsnip class prob to call something SNIa
    min_kilonovaness: float = 0.  # Parsnip class prob to call something SNIa
```

Immediately export candidates.

https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml

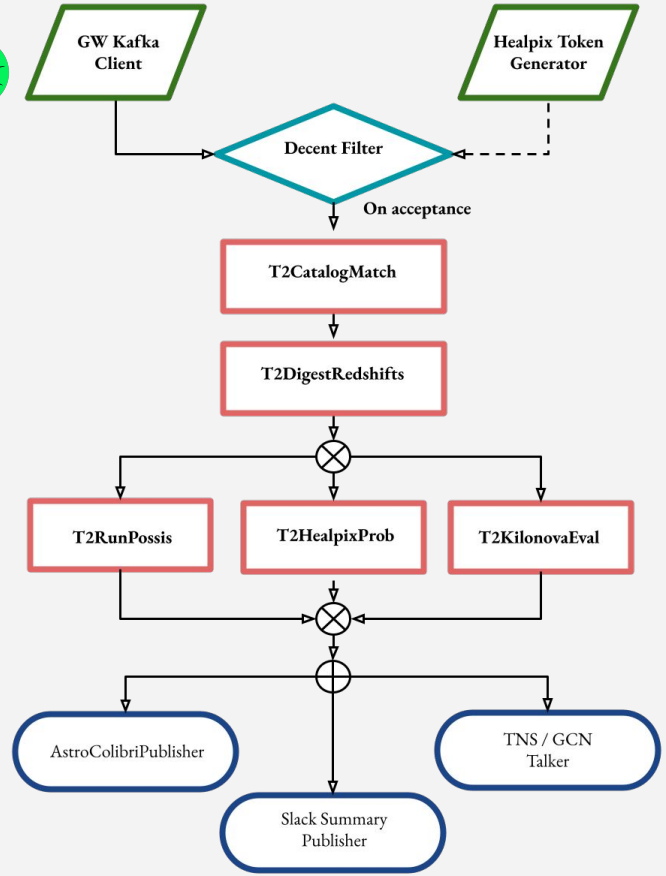


A sample MM workflow

Reproduce locally, scale at CS, co-develop and publish.

```
jnordin@kol: ~/github/ampel83m3/Ampel-HU-astro/examples
(ampel83m3) jnordin@kol:~/github/ampel83m3/Ampel-HU-astro/examples$ ampel job --config ../ampel_conf.yaml
--secrets ../../../ampel83/vault.yaml --schema ligo_healpix_dynashape.yml

2023-05-07 13:24:08 JobCommand:323 INFO [pid=56534]
 Running job ligo-healpix
 ------------------------

2023-05-07 13:24:09 AmpelDB:280 INFO
 Creating dumpme -> stock [('localhost', 27017)]
   Creating index: {'index': (('stock', 1), ('channel', 1)), 'args': {'unique': True}}

2023-05-07 13:24:10 AmpelDB:280 INFO
 Creating dumpme -> t0 [('localhost', 27017)]
   Creating index: {'index': [('id', 1)], 'args': {'unique': True}}
   Creating index: {'index': [('stock', 1)], 'args': {'sparse': True}}

2023-05-07 13:24:10 AmpelDB:280 INFO
 Creating dumpme -> t1 [('localhost', 27017)]
   Creating index: {'index': [('stock', 1)]}
   Creating index: {'index': [('channel', 1)]}
   Creating index: {'index': [('code', 1)], 'args': {'sparse': True}}

2023-05-07 13:24:10 AmpelDB:280 INFO
 Creating dumpme -> t2 [('localhost', 27017)]
```

https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml



A sample MM workflow

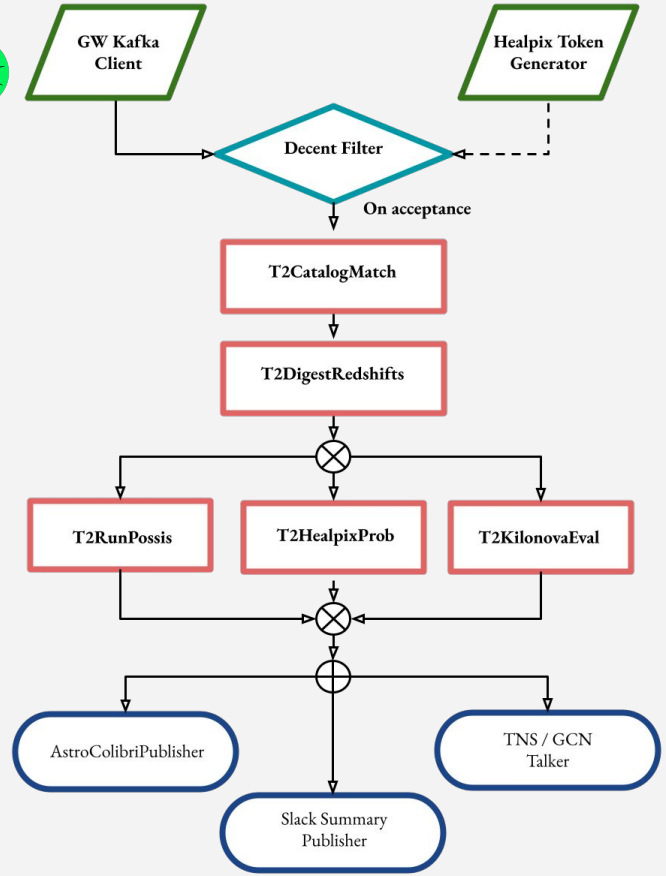
Modular (“code-to-data”):

- Develop/run locally, scale at CS.
- Add interfaces to domain specific software.
- Optimize parameters for science.

Provenance:

- Workflow can be shared/published.
- Analysis repeatability.
- Logging built into the system.
- Map to IVOA provenance model.

https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml



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- Map to IVOA provenance model.

It works, but flexibility -> modularity -> abstract -> non-intuitive

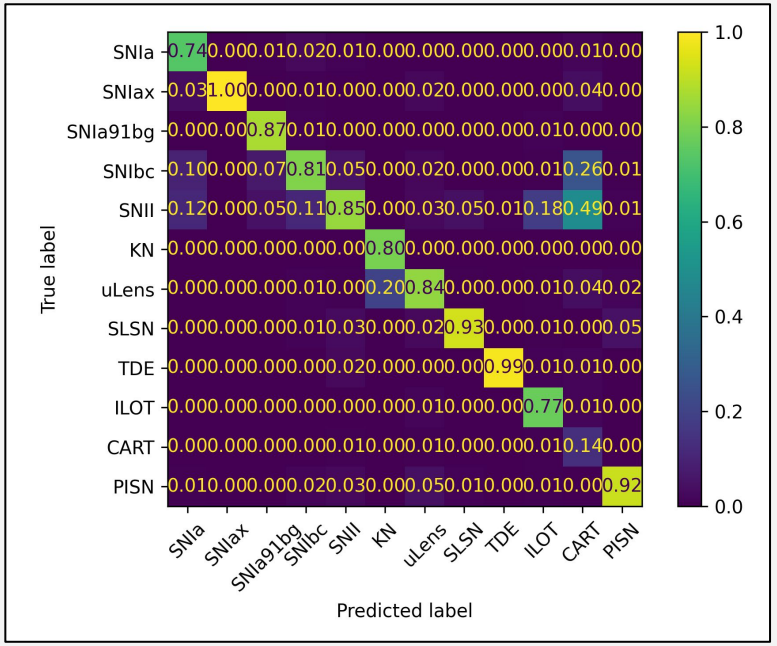
https://github.com/AmpelAstro/Ampel-HU-astro/blob/9b4faed7700b39a91b12bf45e2dbabf2304580f8/examples/remote/lvk_S231102w.yml

ELAsTiCC LSST simulation

Working with VRO/LSST will be *hard*.

DESC-created ELAsTiCC data challenge showed AMPEL classification schema to work better than expected.

Time-domain challenging, but possible with significant preparation.

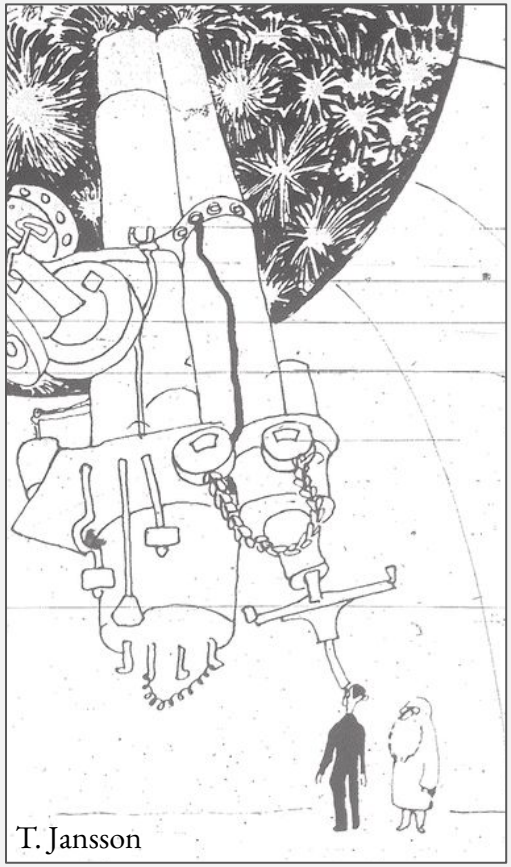


How to run workflow locally:

Create a python 3.10 environment w. poetry and:

- `git clone https://github.com/AmpelAstro/Ampel-HU-astro.git`
- `cd Ampel-HU-astro/`
- `git checkout ampelgw04`
- `poetry install -E "ztf sncosmo extcats notebook"`
- `ampel config build -out ampel_conf.yaml >& ampel_conf.log`
- `ampel job --config ampel_conf.yaml --schema remote/lvk_S231102w.yml --secrets vault.yaml`

[Get access token to put in vault from JN.]



LSST, Brokers, Multi-messenger programs

- VRO -> Brokers
- AMPEL MM workflow
- Looking ahead

Data irreversibility & FAIR standards

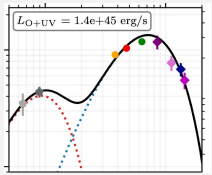
Universe does *stuff*

Sensor *happens* to point.

A real-time *algorithm* triggered.

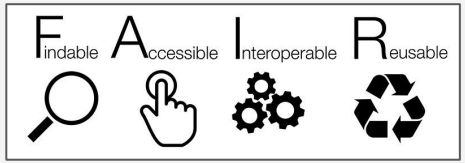
A *human* pressed a button.

A... number?



How do we go from a measurement back to the Universe?

Irreversible, complex, stacked steps.

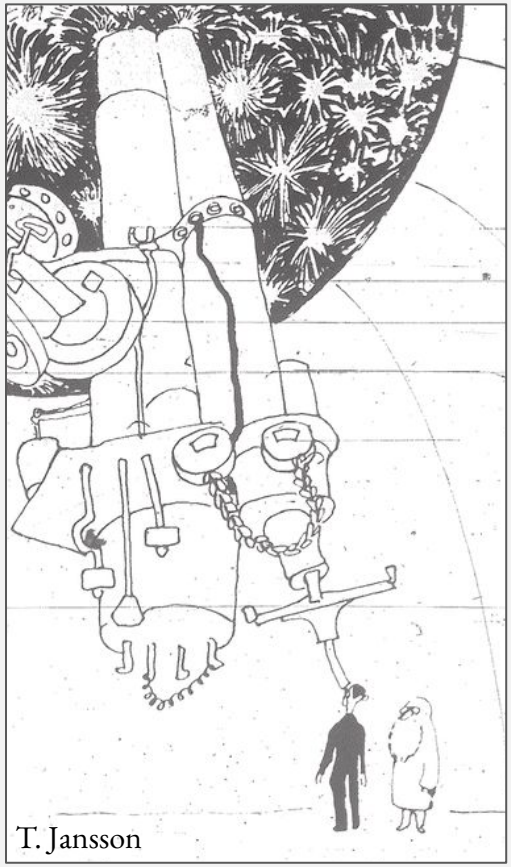


Preparation is key

"Inverted" work order:

1. Get some data
2. Develop analysis (software)
3. Conclude based on results

3. Define project hypothesis
2. Develop and test model
1. Connect to data streams



Summary:

Brokers will be a critical component of real-time infrastructure, but will not and should not do the science.

Path ahead:

- (im)possible?
  - Funding incentives for scientific computing
  - Require reproducible publications and data release
- This week
  - Interfaces (filters, software modulers, alerts)
  - What workflows will we want?
- Take home (yes, you!)
  - Inverted work order
  - Talk to broker teams early in the process
  - Program maintenance