How to realize MM studies

1. Previous results
2. The Ideas that led to them
3. Plumbing

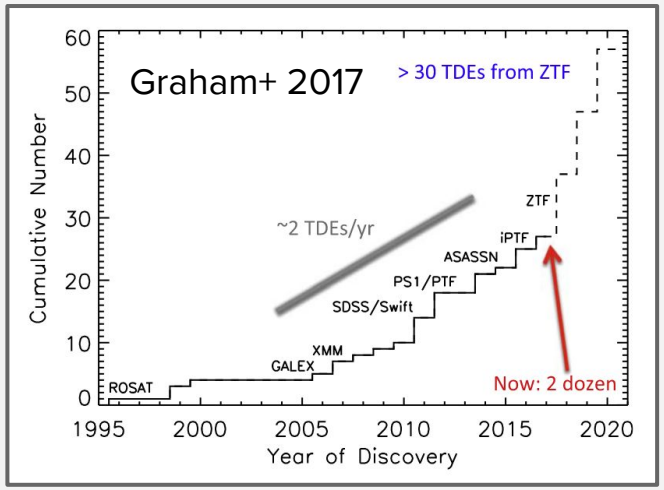
 AMPEL

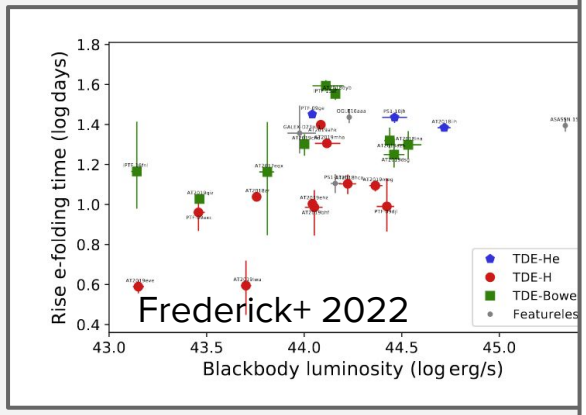
1 Results

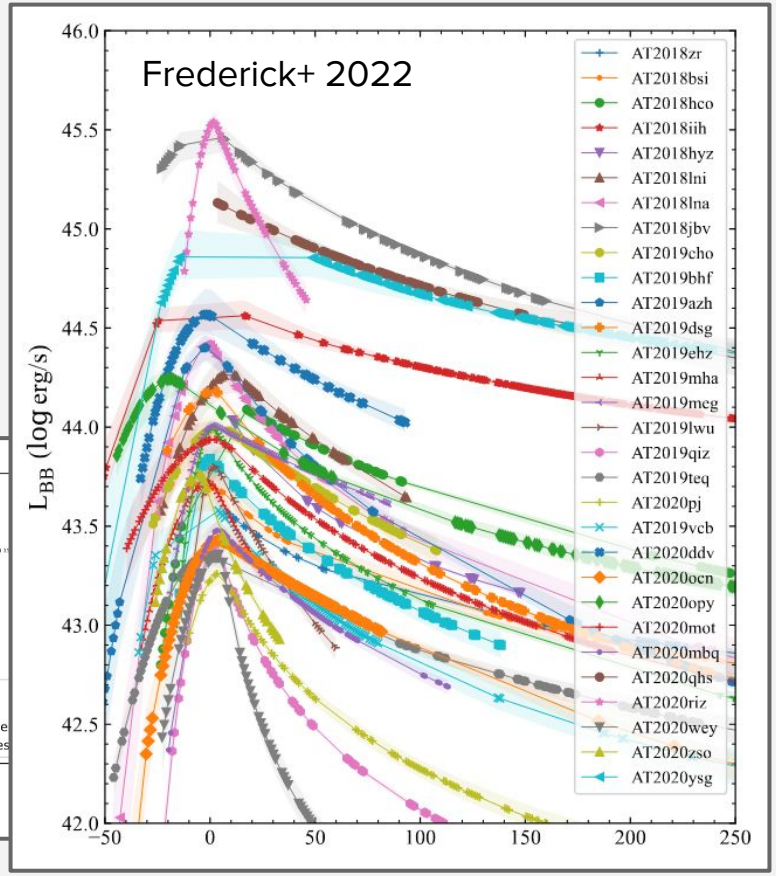
1.1 Tidal Disruption Event Samples

1.1 Tidal Disruption Event Samples

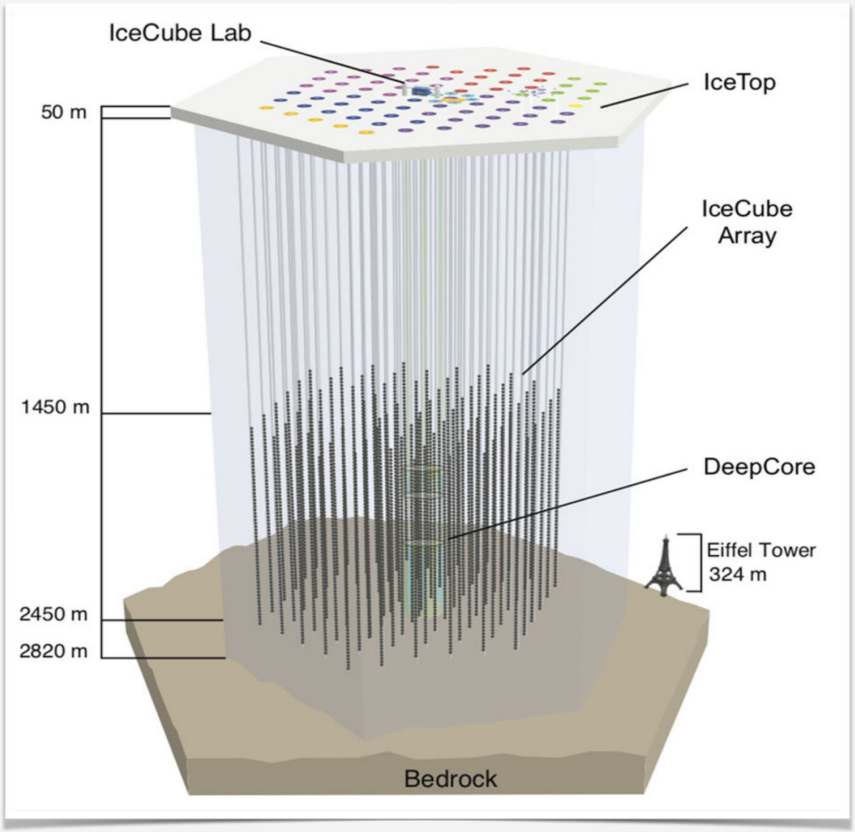
From single objects to population studies.



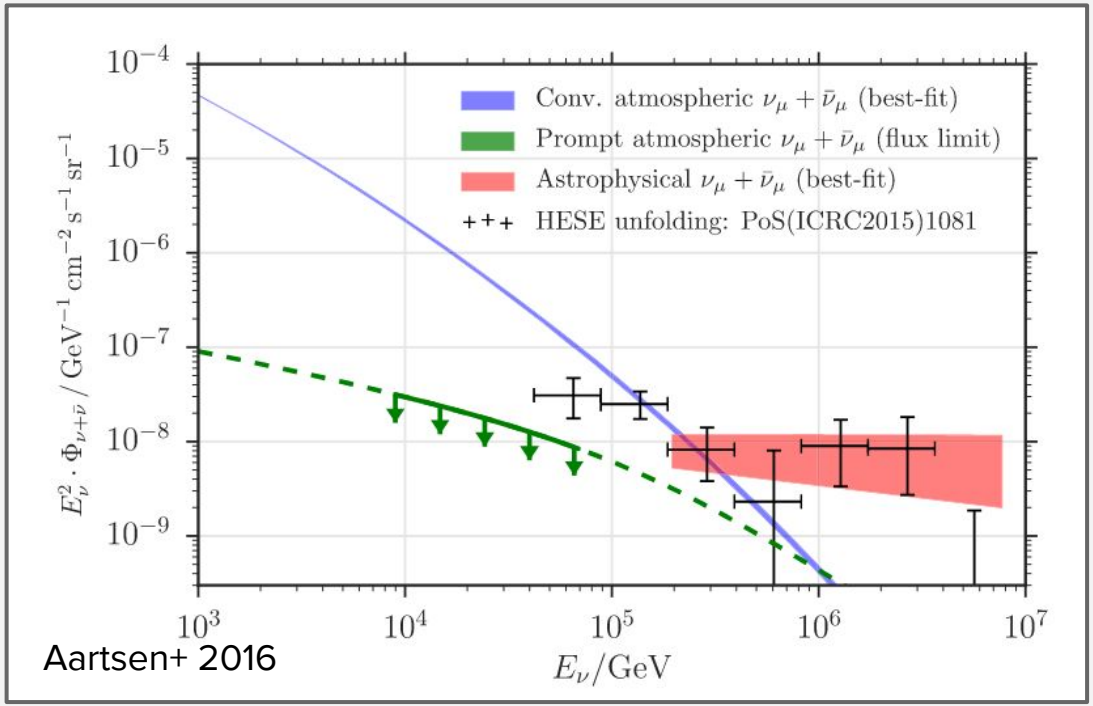




1.2 Sources of Extragalactic Neutrinos



Flux excess at high energies.



Aartsen+ 2016

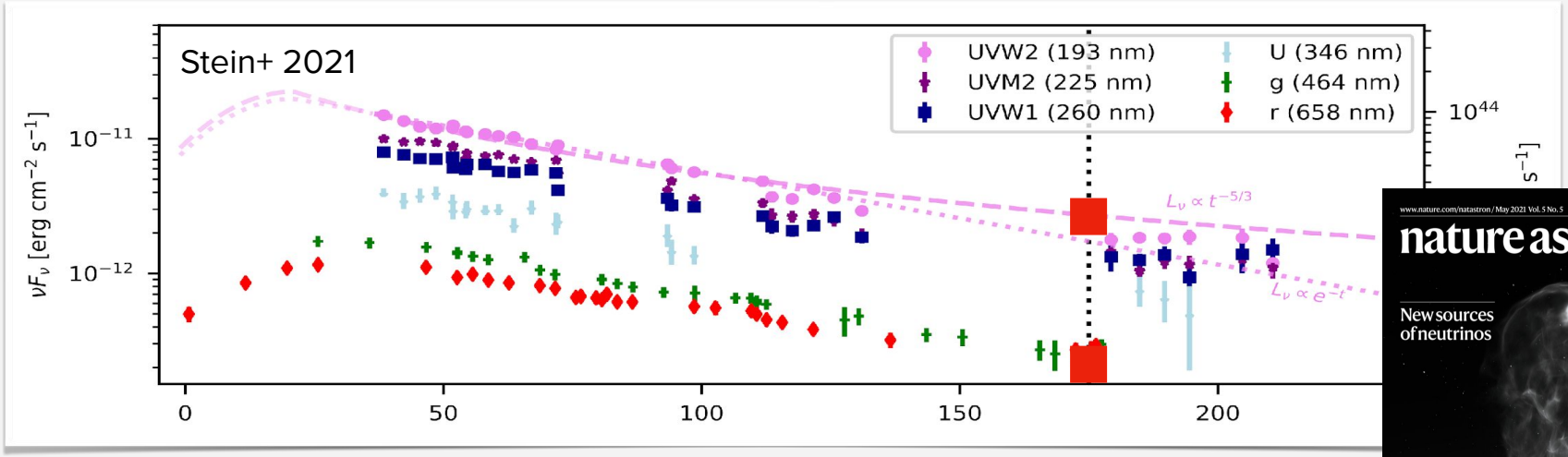
1.2 Sources of Extragalactic Neutrinos

```
TITLE:   GCN CIRCULAR
NUMBER:  25929
SUBJECT: IceCube-191001A: Candidate Counterparts with the Zwicky Transient Facility
DATE:    19/10/02 21:47:19 GMT
FROM:    Robert Stein at DESY  <robert.stein@desy.de>

Robert Stein (DESY), Anna Franckowiak (DESY), Jannis Necker (DESY), Suvi Gezari (UMd), Sjoert van Velzen (UMd/NYU) report,
On behalf of the Zwicky Transient Facility (ZTF) and Global Relay of Observatories Watching Transients Happen (GROWTH) collaborations:

We observed the localization region of the neutrino event IceCube-191001A (Stein et. al, GCN 25913) with the Palomar 48-inch telescope, equipped with the 47 square
degree ZTF camera (Bellm et al. 2019, Graham et al. 2019). We started obtaining target-of-opportunity observations in the g-band and r-band beginning at
2019-10-02T03:32:47.200, approximately 7.4 hours after event time. Excluding chip gaps, we covered the entire reported localisation region of the neutrino. Each
exposure was 300s with a typical depth of 21.0 mag.

The images were processed in real-time through the ZTF reduction and image subtracti
AMPEL (Nordin et al. 2019) was used to search the alerts database for candidates. We
apply machine learning algorithms to remove bogus subtractions (Mahabal et al. 2019)
and highlight four that are particularly interesting.

+---------------------------------------------------------------------------+
| ZTF Name     | IAU Name  | RA (deg)    | DEC (deg)   | Filter | Mag   | MagErr |
+---------------------------------------------------------------------------+
| ZTF19aapreis | AT2019dsg | 314.2623825| +14.2045431 | g      | 19.79 | 0.05   |
| ZTF19abzkexb | AT2019qhl | 320.5502682| +11.5600861 | g      | 19.13 | 0.03   |
| ZTF19acbpqfn | AT2019rsj | 316.0854222| +12.9171434 | g      | 21.00 | 0.14   |
| ZTF19acbxbjq | AT2019rsk | 318.6378536| +14.1469459 | g      | 20.32 | 0.08   |
+---------------------------------------------------------------------------+

ZTF19aapreis is a Tidal Disruption Event approximately 150 days post peak, previousl
of a handful of radio-detected TDEs, as reported in ATEL #12798, making it a particu

Additional Swift TOO observations as well as VLA observations have been submitted fo
this source.

In addition, three unclassified transients were found within the localisation region
days ago and is clearly offset from its host. It shows a rising light curve resembli
supernova that is a few days post peak. It is offset from its host. ZTF19acbxbjq, fi
consistent with the center of the host galaxy.
```

Search and publication of potential counterparts.

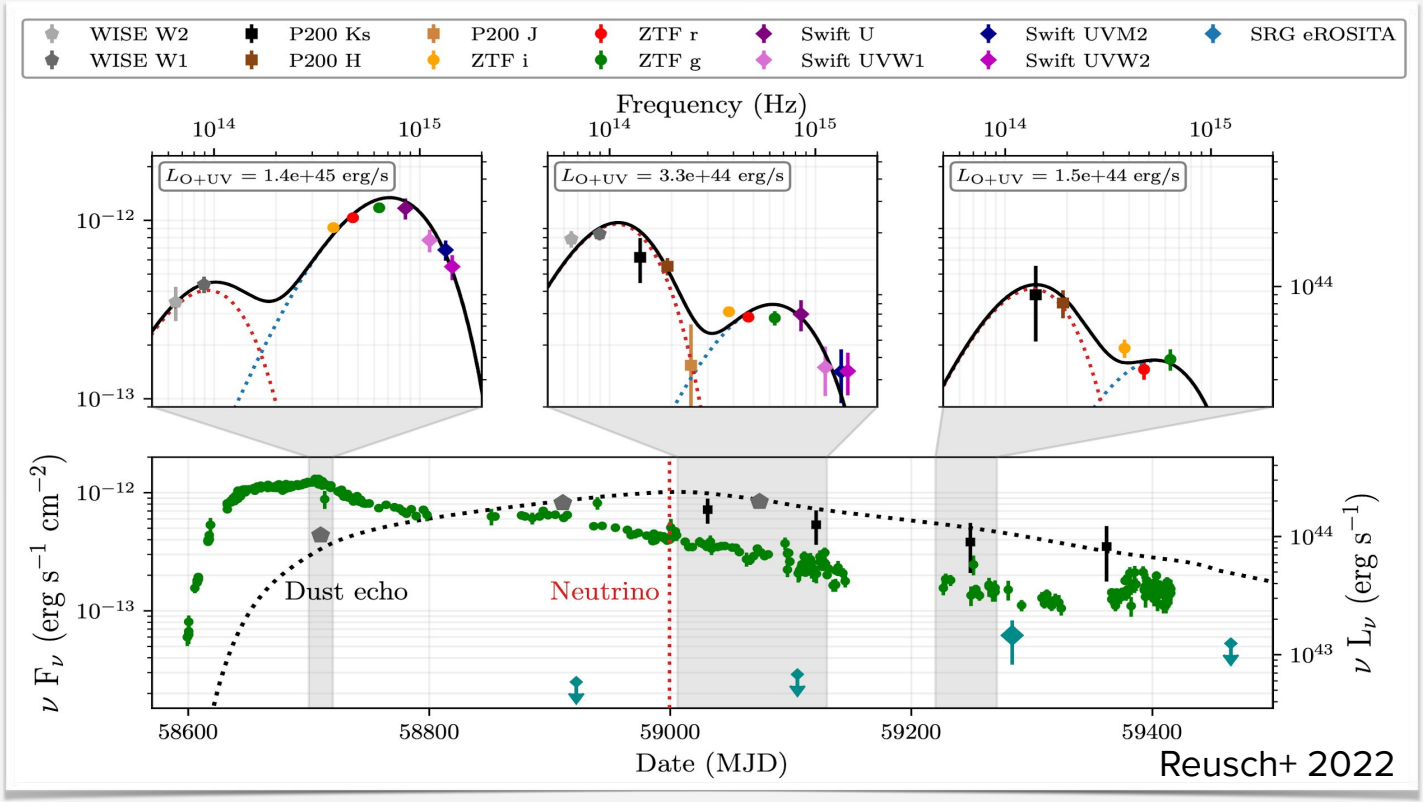
```
TITLE:   GCN CIRCULAR
NUMBER:  29461
SUBJECT: IceCube-210210A: Two Candidate Counterparts from the Zwicky Transient Facility
DATE:    21/02/10 16:59:54 GMT
FROM:    Simeon Reusch at DESY  <simeon.reusch@desy.de>

Simeon Reusch (DESY), Sven Weimann (Ruhr University Bochum), Robert Stein (DESY), Micheal Coughlin (UMN) and Anna Franckowiak (DESY/Ruhr University Bochum) report,

On behalf of the Zwicky Transient Facility (ZTF) and Global Relay of Observatories Watching Transients Happen (GROWTH) collaborations:

We observed the localization region of the neutrino event IceCube-210210A (Lagunas et. al, GCN 29454) with the Palomar 48-inch telescope, equipped with the 47
square degree ZTF camera (Bellm et al. 2019, Graham et al. 2019). We started observations in the g- and r-band beginning at 2021-02-10 12:07 UTC, approximately 0.2
hours after event time. We covered 2.1 sq deg, corresponding to 78.6% of the reported localization region. This estimate accounts for chip gaps. Each exposure was
300s with a typical depth of 21.0 mag.

The images were processed in real-time through the ZTF reduction and image subtraction pipelines at IPAC to search for potential counterparts (Masci et al. 2019).
AMPEL (Nordin et al. 2019, Stein et al. 2020) was used to search the alerts database for candidates. We reject stellar sources (Tachibana and Miller 2018) and
moving objects, and apply machine learning algorithms (Mahabal et al. 2019). We are left with two high-significance transient candidates from our pipeline, both
lying within the 90.0% localization of the skymap.

+---------------------------------------------------------------------------+
| ZTF Name     | IAU Name   | RA (deg)    | DEC (deg)   | Filter | Mag   | MagErr |
+---------------------------------------------------------------------------+
| ZTF21aajxjrv | AT2021clu  | 206.9855020 | +05.3138660 | r      | 21.03 | 0.13   |
| ZTF21aajxjry | AT2021clv  | 207.3743696 | +04.9786236 | r      | 21.47 | 0.19   |
+---------------------------------------------------------------------------+

Both candidates are possible transients, with no prior detections, that have not yet been spectroscopically classified. Additional target-of-opportunity
observations with ZTF are planned for 2021-02-11 as part of our neutrino follow-up program (Stein et al. 2020).

Based on observations obtained with the Samuel Oschin Telescope 48-inch and the 60-inch Telescope at the Palomar Observatory as part of the Zwicky Transient
Facility project. ZTF is supported by the National Science Foundation under Grant No. AST-2034437 and a collaboration including Caltech, IPAC, the Weizmann
Institute for Science, the Oskar Klein Center at Stockholm University, the University of Maryland, Deutsches Elektronen-Synchrotron and Humboldt University, the
TANGO Consortium of Taiwan, the University of Wisconsin at Milwaukee, Trinity College Dublin, Lawrence Livermore National Laboratories, and IN2P3, France.
Operations are conducted by COO, IPAC, and UW.
GROWTH acknowledges generous support of the NSF under PIRE Grant No 1545949.
Alert distribution service provided by DIRAC@UW (Patterson et al. 2019).
Alert database searches are done by AMPEL (Nordin et al. 2019).
Alert filtering is performed with the AMPEL Follow-up Pipeline (Stein et al. 2020).
```

1.3 TDEs as possible neutrino sources



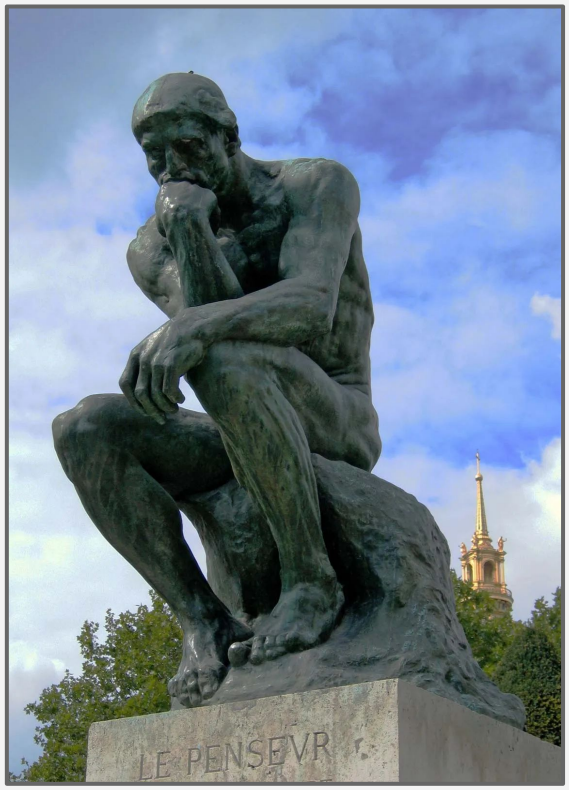
A neutrino potential counterpart turned out to be an independently detected TDE.

1.3 TDEs as possible neutrino sources



... and then another one!

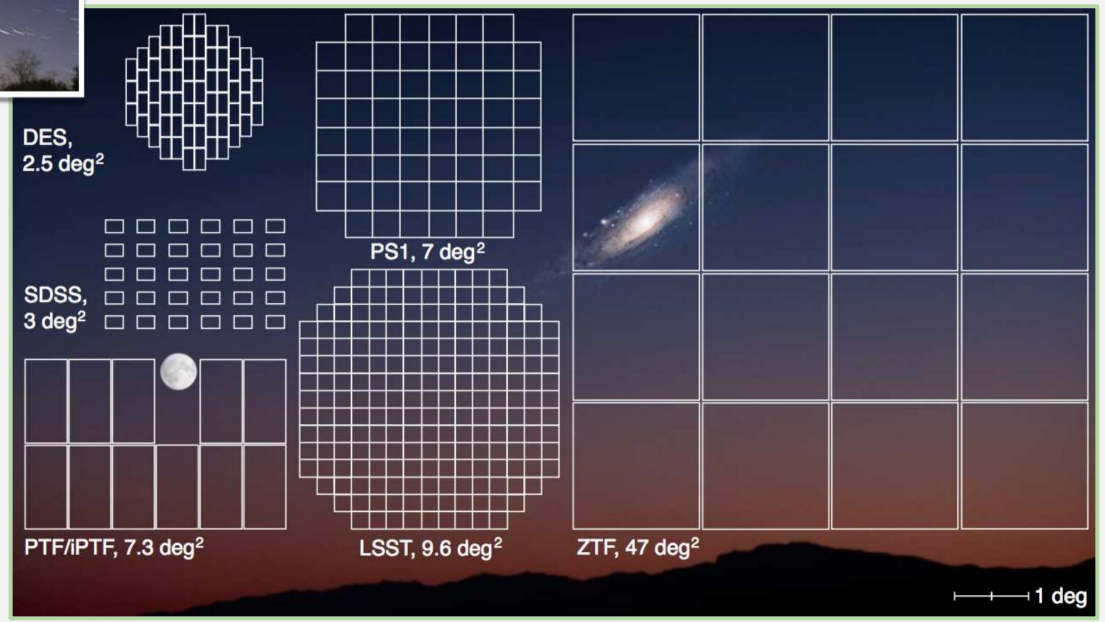
2 Ideas



What lead to these results

2.1 Tidal Disruption Event Samples

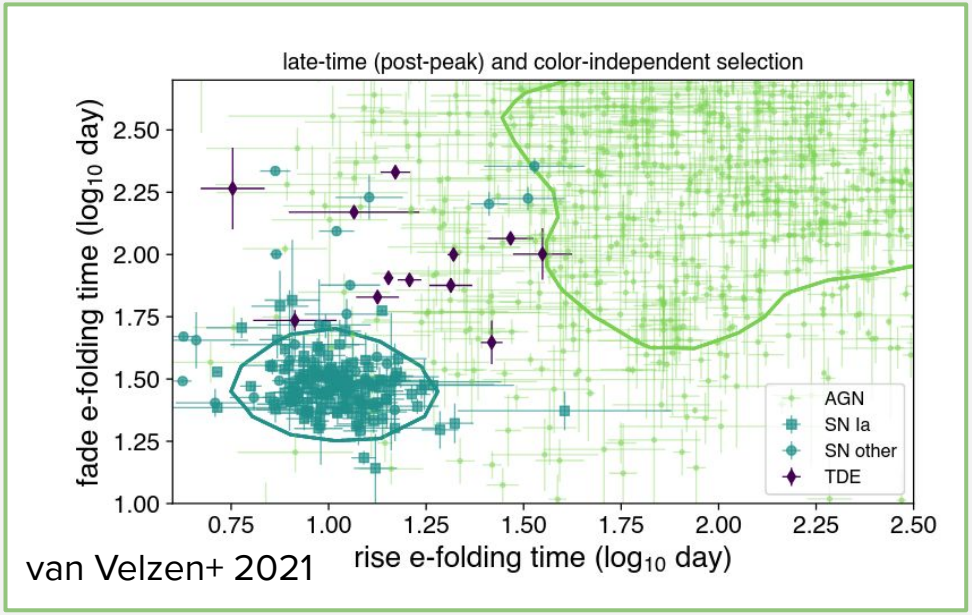
Wide field optical surveys efficiently sample large volumes.



2.1 Tidal Disruption Event Samples

$$L_\nu(t) = L_{\nu_0\ \mathrm{peak}} \frac{B_\nu(T_0)}{B_{\nu_0}(T_0)} \times \begin{cases} e^{-(t-t_{\mathrm{peak}})^2/2\sigma^2} & t \leq t_{\mathrm{peak}} \\ e^{-(t-t_{\mathrm{peak}})/\tau} & t > t_{\mathrm{peak}} \end{cases}$$

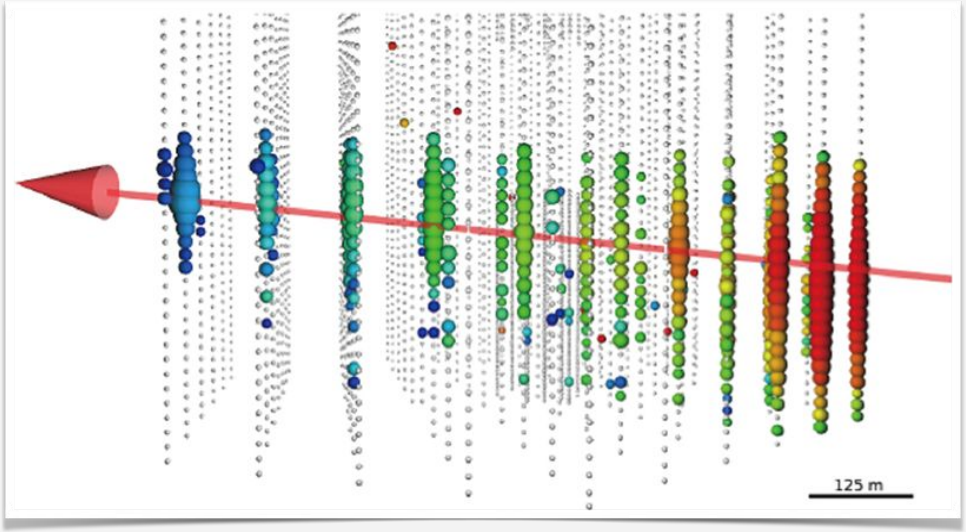
First TDE observations allowed a physical model to be constructed.



van Velzen+ 2021

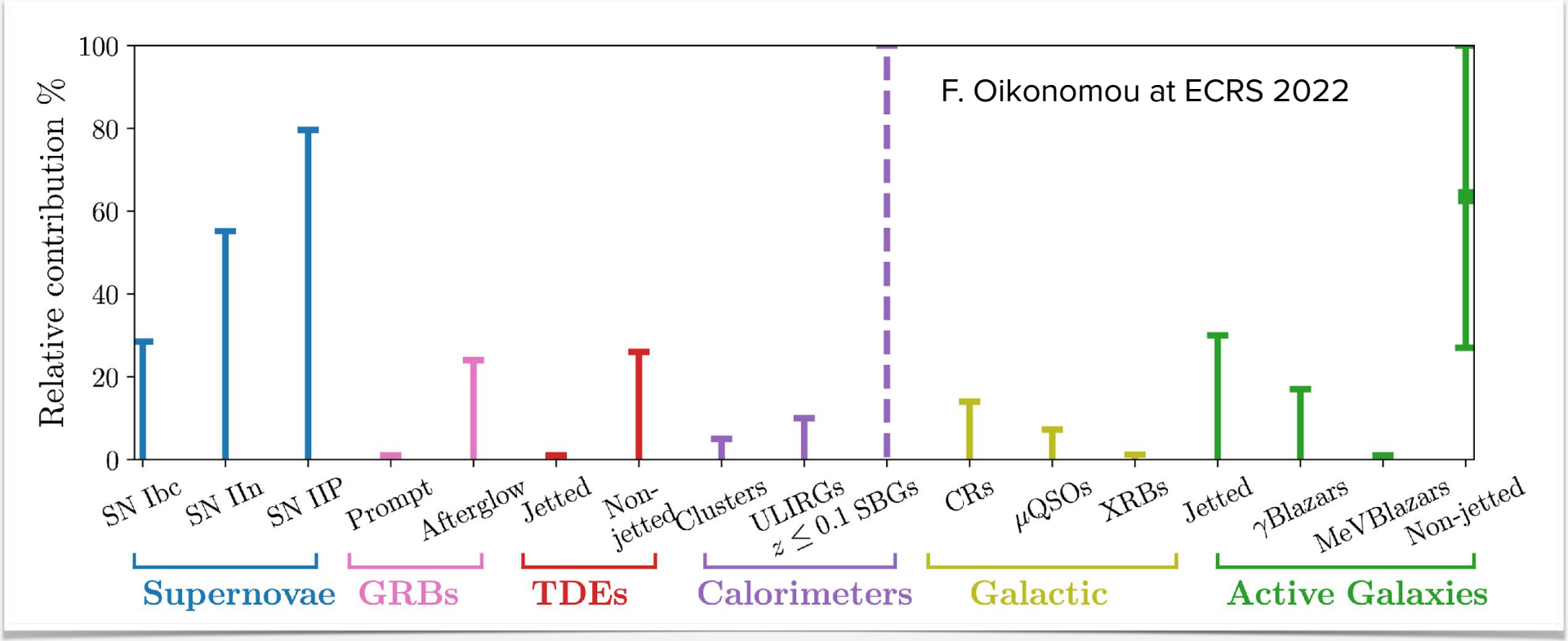
2.2 Sources of Extragalactic Neutrinos

Neutrino event direction
covered by ZTF observations.



IceCube Event view IC170922

2.3 TDEs as possible neutrino sources



Several potential source classes identified, TDEs one of them.

3 Plumbing

What was hard?

What can we learn?

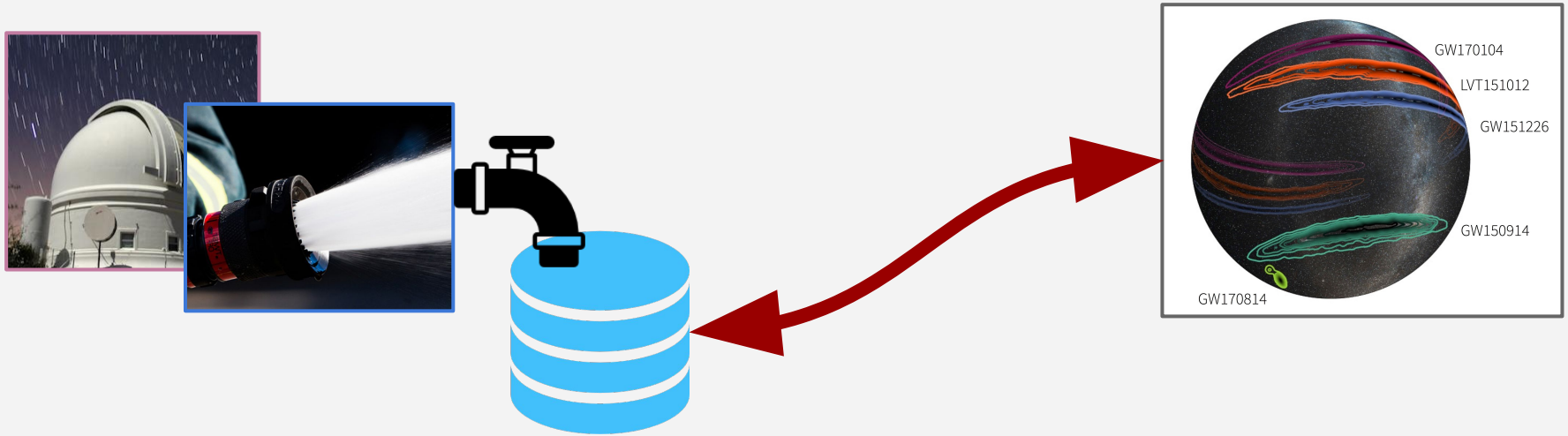
3.1 Tidal Disruption Events

Apply *function* to high throughput data streams

$$L_\nu(t) = L_{\nu_0\ \mathrm{peak}} \frac{B_\nu(T_0)}{B_{\nu_0}(T_0)} \times \begin{cases} e^{-(t-t_{\mathrm{peak}})^2/2\sigma^2} & t \le t_{\mathrm{peak}} \\ e^{-(t-t_{\mathrm{peak}})/\tau} & t > t_{\mathrm{peak}} \end{cases}$$

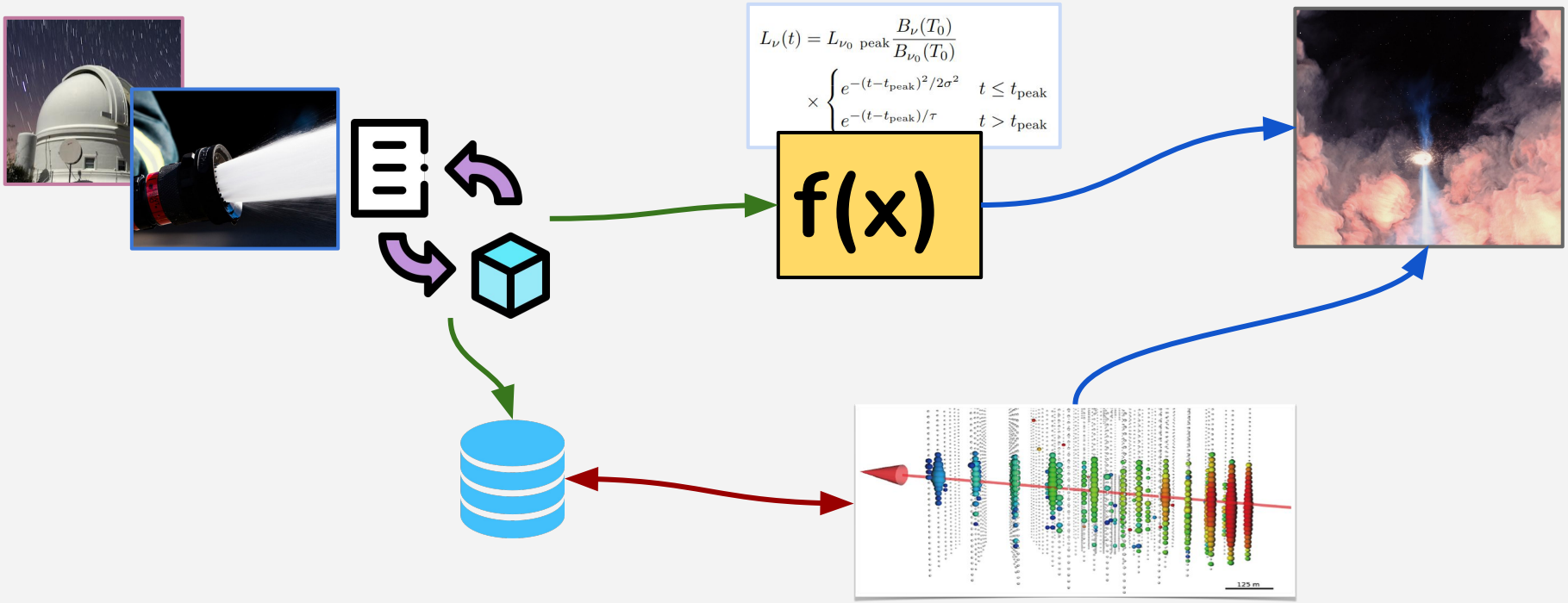
3.2 Extragalactic neutrinos

Efficient matching with large collections.



3.3 TDEs as possible neutrino sources

Modularity: Using algorithms produced by experts.



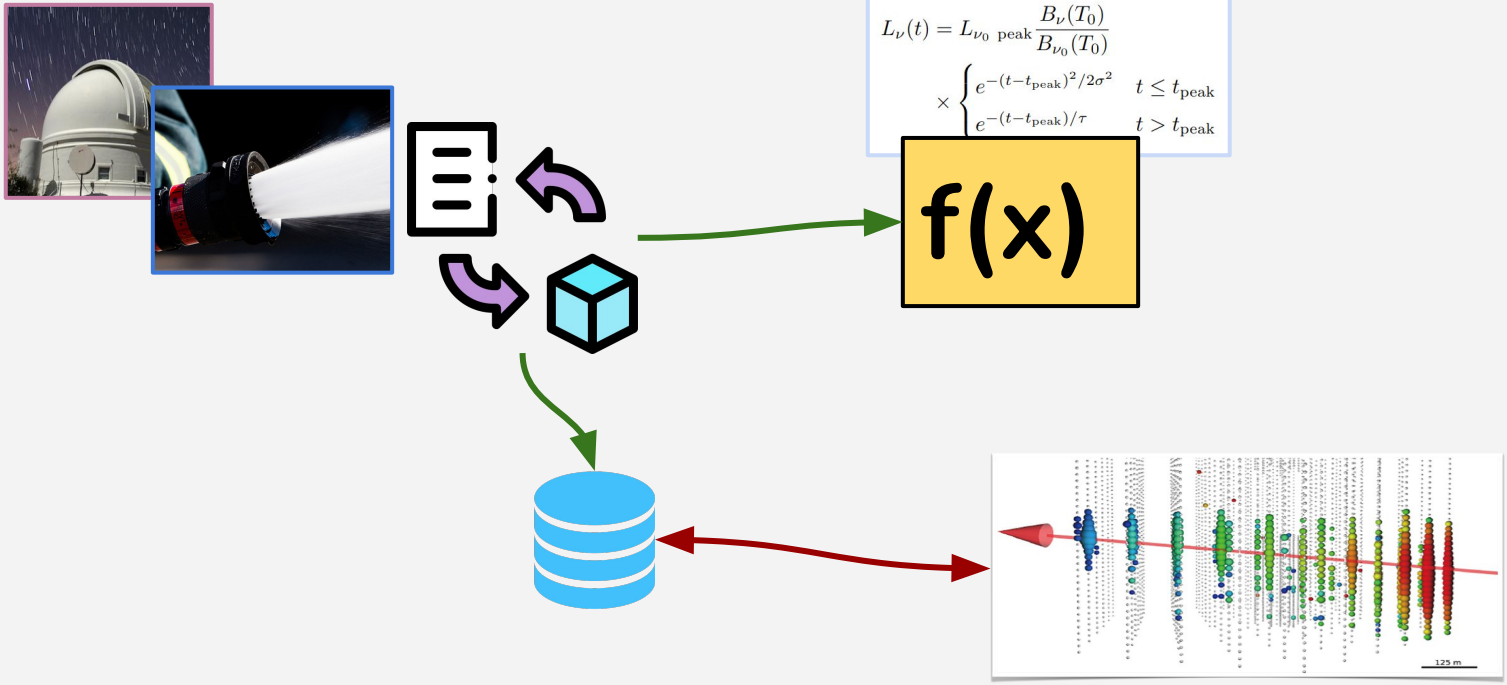
My takeaway

What would be good to have?

- Modular workflows
- Provenance
- Software development encouraged
- Code-To-Data

What would be good to have?

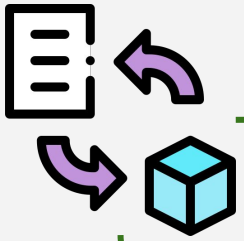
Modular workflows



What would be good to have?

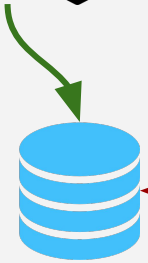
Modular workflows

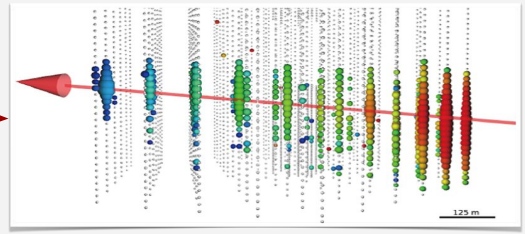
VERA C. RUBIN OBSERVATORY



$$L_\nu(t) = L_{\nu_0\ \mathrm{peak}} \frac{B_\nu(T_0)}{B_{\nu_0}(T_0)} \times \begin{cases} e^{-(t-t_{\mathrm{peak}})^2/2\sigma^2} & t \le t_{\mathrm{peak}} \\ e^{-(t-t_{\mathrm{peak}})/\tau} & t > t_{\mathrm{peak}} \end{cases}$$

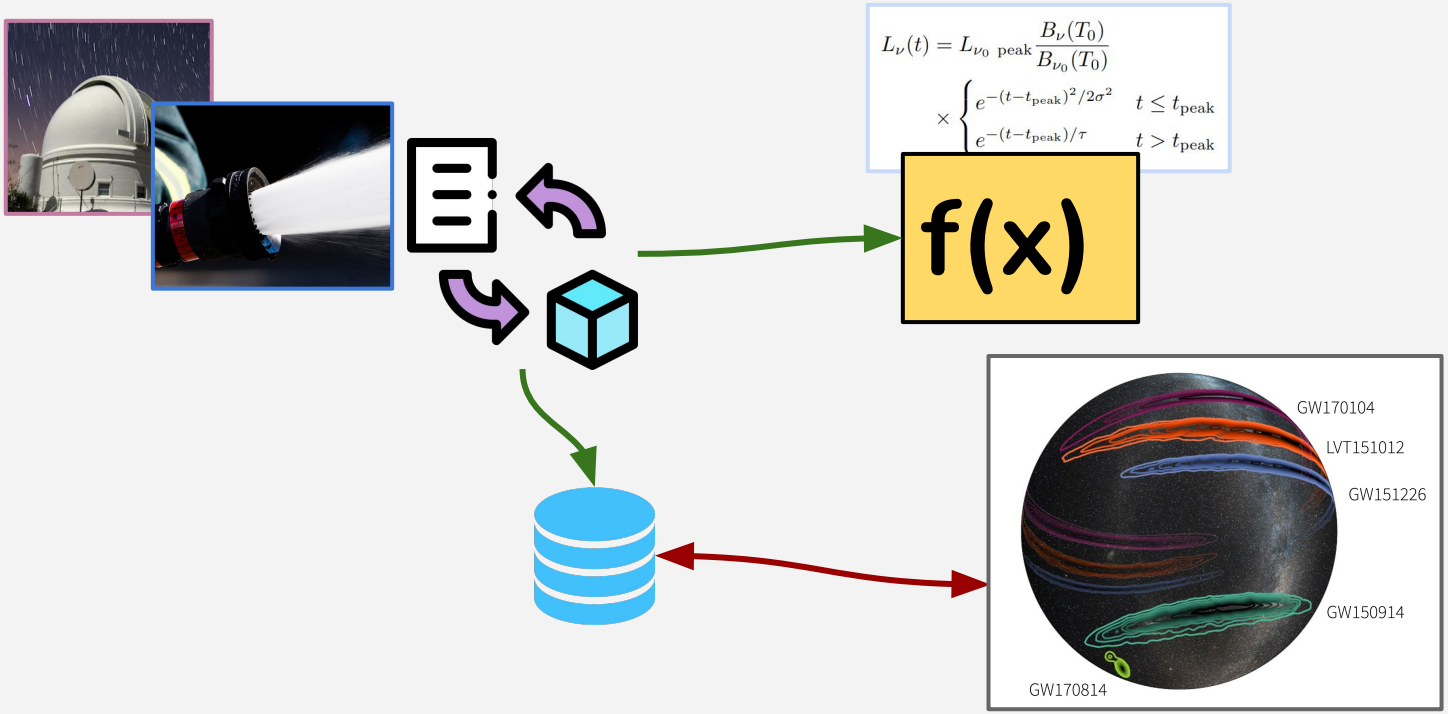
f(x)





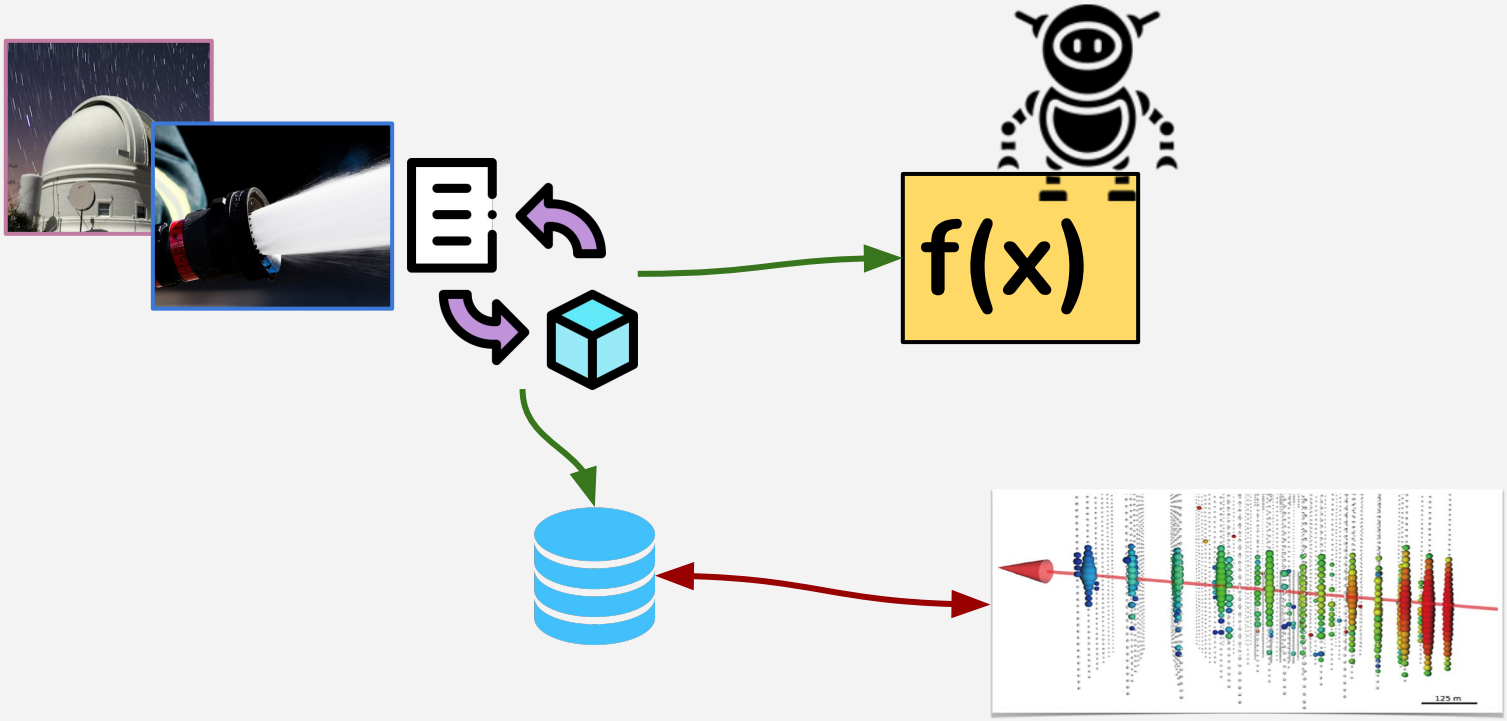
What would be good to have?

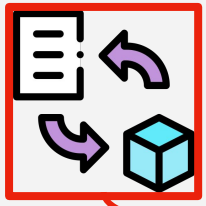
Modular workflows

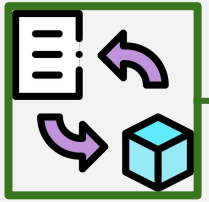


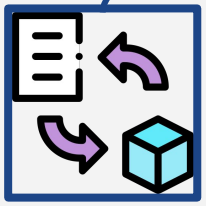
What would be good to have?

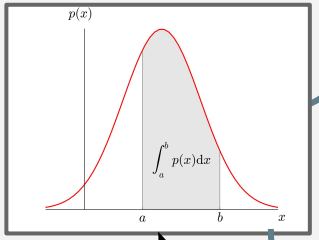
Modular workflows

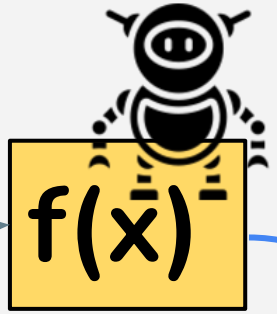


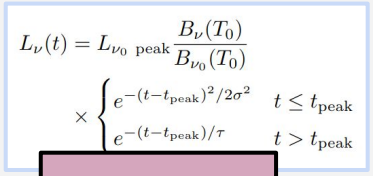


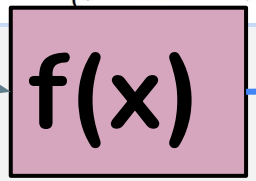


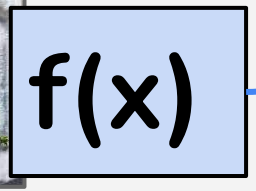



p(x)
$\int_a^b p(x)\mathrm{d}x$
a
b
x


f(x)


$L_\nu(t) = L_{\nu_0\ \mathrm{peak}} \frac{B_\nu(T_0)}{B_{\nu_0}(T_0)}$
$\times \begin{cases} e^{-(t-t_{\mathrm{peak}})^2/2\sigma^2} & t \le t_{\mathrm{peak}} \\ e^{-(t-t_{\mathrm{peak}})/\tau} & t > t_{\mathrm{peak}} \end{cases}$


f(x)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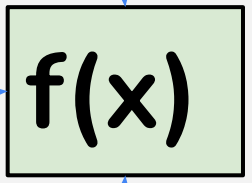

f(x)

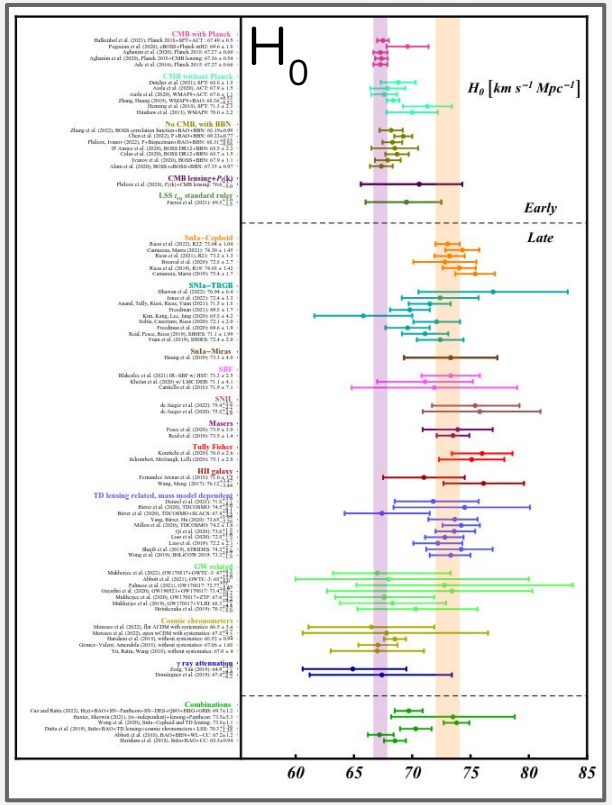

LSST
DESC
Dark Energy Science Collaboration

What would be good to have?

Provenance

- Only one Universe
- Already in sigma “hell”

Reproducibility will be key!

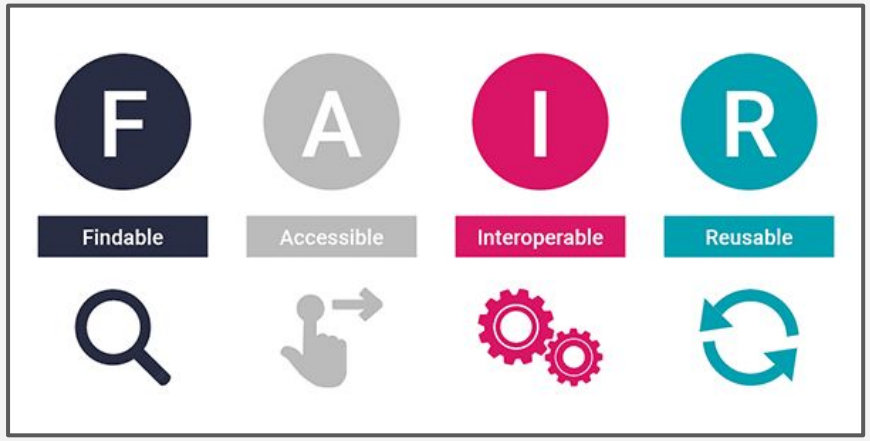


Perivolaropoulos+ 2022

What would be good to have?

Code-To-Data

Only way to manage FAIR principles and efficient resource usage!



AMPEL

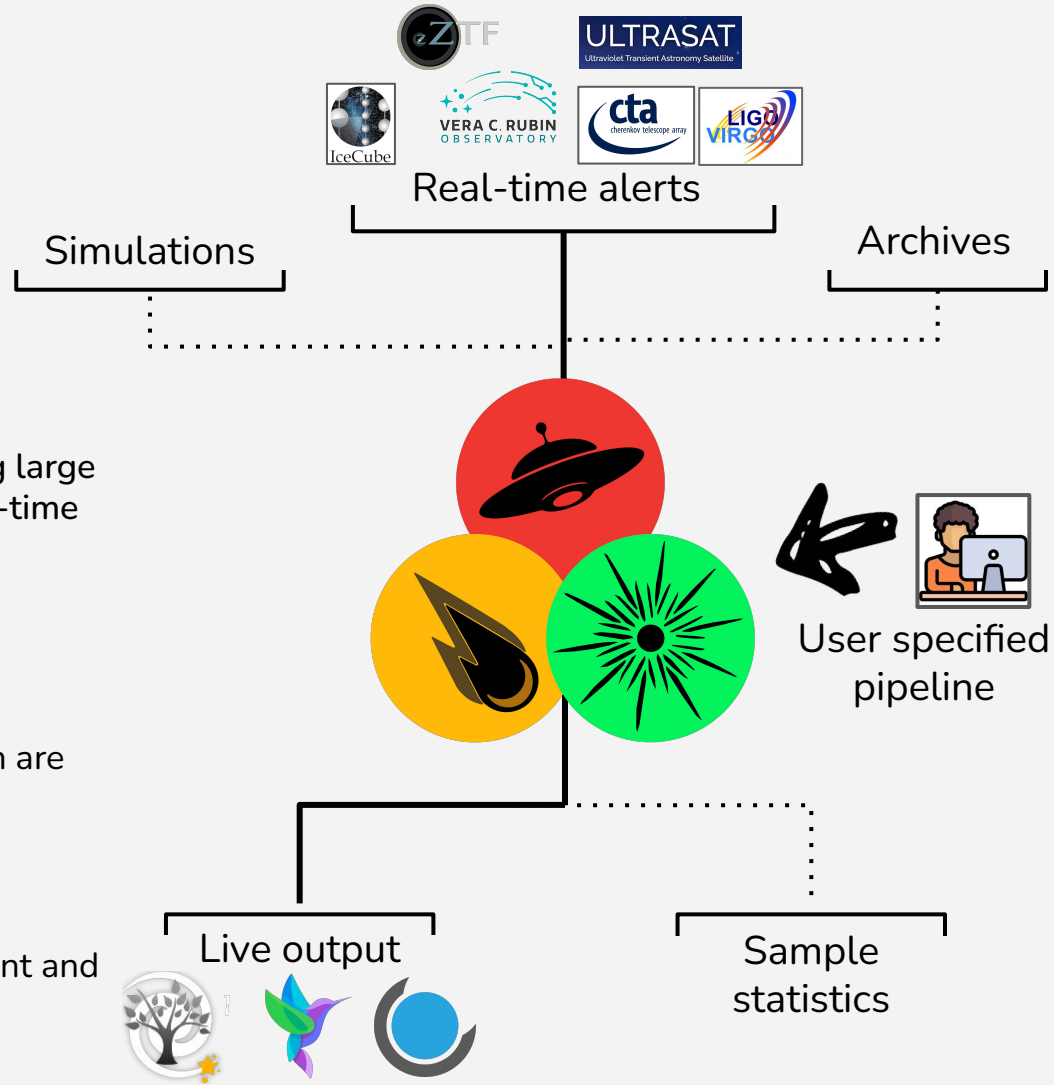
AMPEL

AMPEL is a *modular* and *scalable* platform with explicit *provenance* tracking, suited for systematically processing large - possibly complex and heterogeneous - datasets in real-time or not.

This includes selecting, analyzing, updating, combining, enriching and reacting to data.

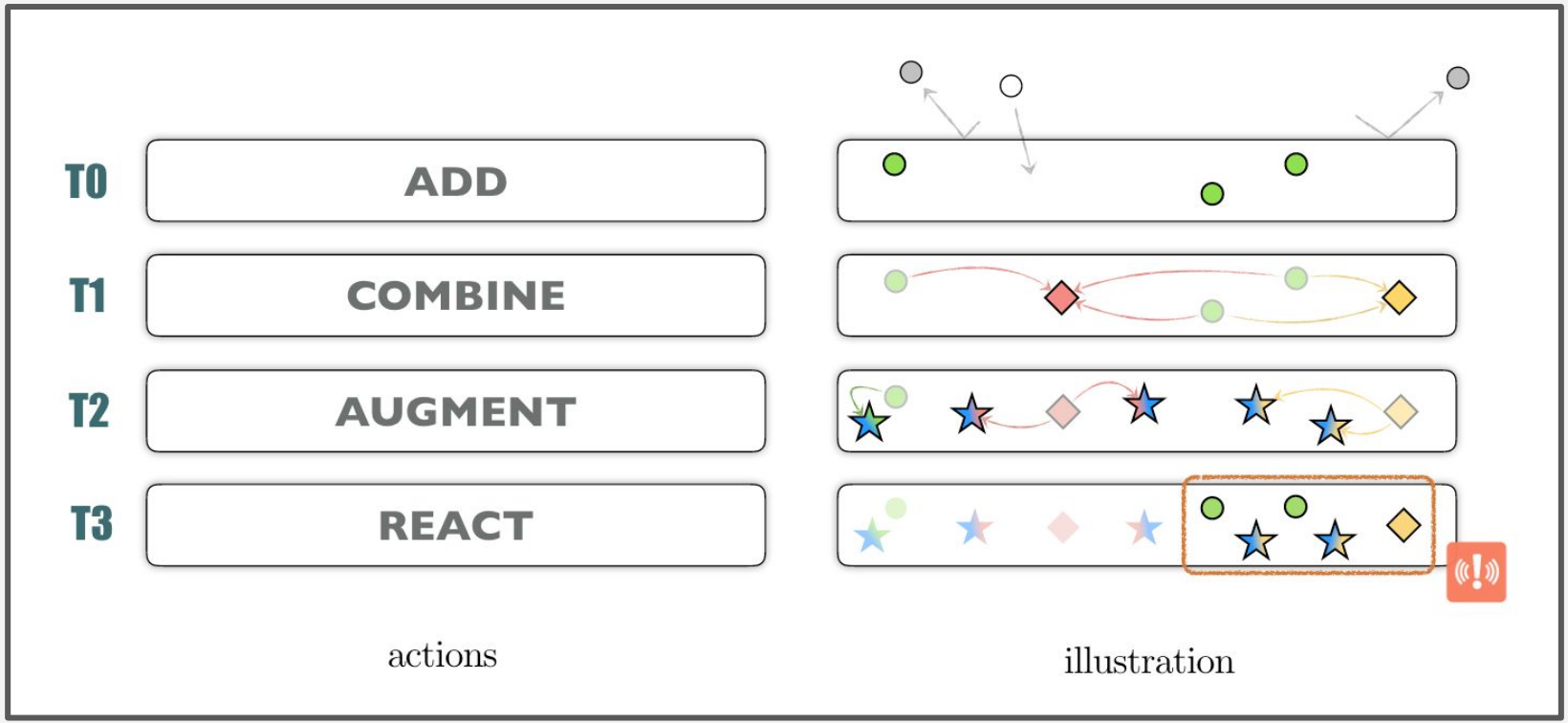
Code-To-Data: Teams develop analysis algorithms which are hosted by AMPEL and exposed to data streams in a high performance computer center.

A public AMPEL instance is hosted at DESY Zeuthen (ampel-info@desy.de), code is public for local development and alternate instances (ampelproject.github.io/).



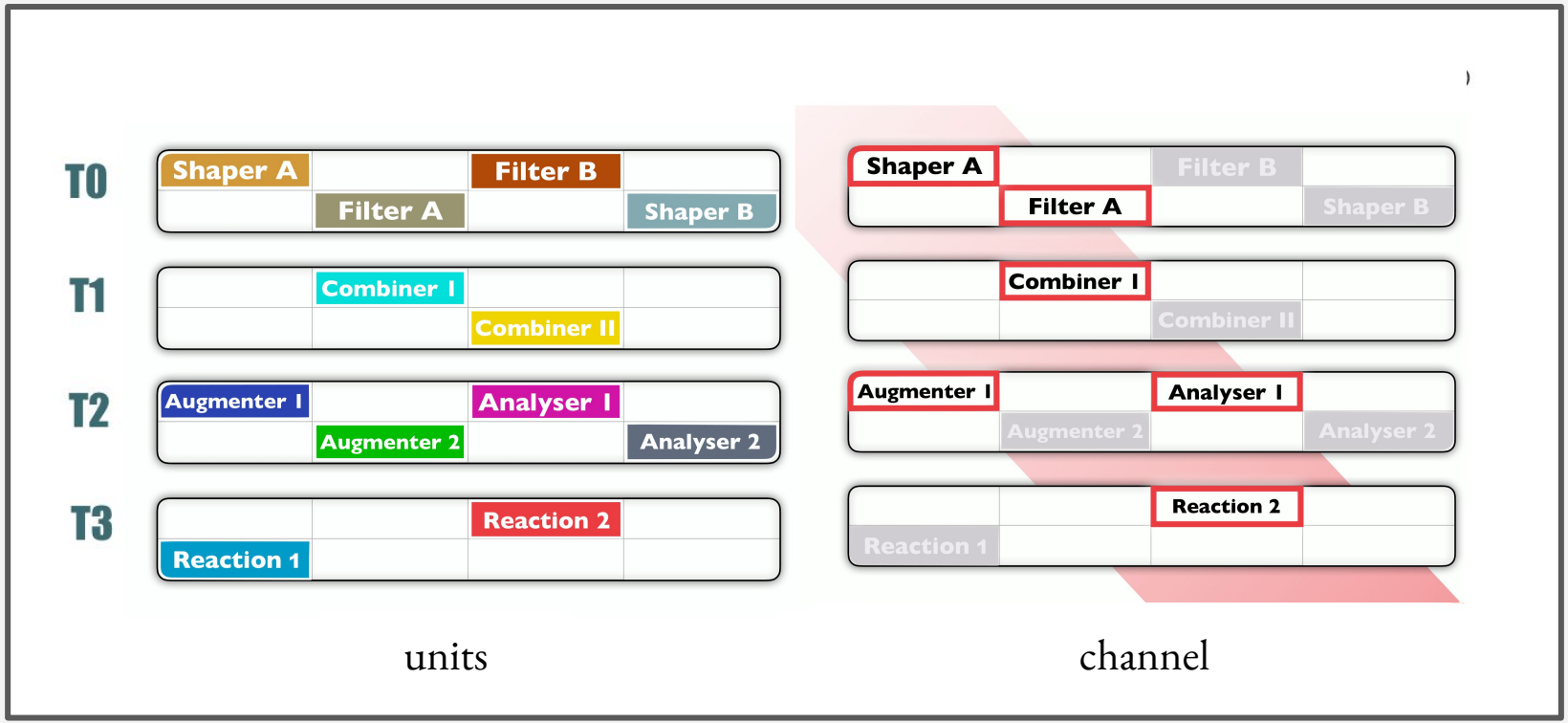
Methodology for modularization

Data processing divided into four execution layers



Methodology for modularization

An analysis *channel* is created by selecting *units*.



Provenance built in

A channel *jobfile* can be used to distributed and used to recreate an analysis sequence.

System journals and logs record all real-time activity.

```yaml
name: fastDecliningVoevent
task:
- unit: AlertConsumer
  config:
    iter_max: 1000000
    supplier:
      unit: ZiAlertSupplier
      config:
        loader:
          unit: ZTFArchiveAlertLoader
          config:
            archive: https://ampel.zeuthen.desy.de/api/ztf/archive/v3
            stream:
              ztf_name: ZTF22abhrjld
    directives:
    - channel: Demo
      filter:
        config:
          min_ndet: 2
          min_gal_lat: 14
        unit: SimpleDecentFilter
      ingest:
        mux:
          combine:
          - state_t2:
            - unit: T2FastDecliner
              config:
                min_declinerate: 0.1
- unit: T3Processor
  config:
    execute:
      - unit: T3FilteringStockSelector
        config:
          t2_filter:
            unit: T2FastDecliner
              match:
                fast_decliner: true
            stage:
              execute:
                - unit: VOEventPublisher
                  config:
                    why_schema:
                      T2FastDecliner:
                        "Decline-rate g-band":
                          - g
                          - decline_rate
                        "Decline-rate R-band":
                          - R
                          - decline_rate
```

github.com/AmpelProject/Ampel-HU-astro/examples/fastDeclining_voevent.yml

Software development

Software modules contributed by domain/software experts. Integration through abstract classes.

Being used requires being *“developable”*.

Recognition for software engineers and maintainers: can directly quote how often modules are requested.

```python
class AbsPhotoT3Unit(AbsT3ReviewUnit[TransientView], abstract=True):
    """
    Parametrized abstract class for T3 units receiving TransientView instances
    (and potentially LightCurve instances as well)
    """
    _View = TransientView
    pass
```

```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.

    Will update if new obs was made after last posting.

    """

    trigger_id:str = 'AMPEL.test'
```

Code-To-Data in practice

Workflows developed locally:

```
git clone https://github.com/AmpelProject/Ampel-HU-astro.git
cd Ampel-HU-astro/
poetry install -E "ztf sncosmo extcats notebook elasticc"
poetry run ampel config build -out ampel_conf.yaml >& ampel_conf.log
poetry run ampel job --secrets vault.yaml --config ampel_conf.yaml --schema examples/fastDeclining_voevent.yml
```

Uploaded to compute center for real-time or archive processing. ZTF instance running at DESY Zeuthen.

Technical stuff

- Using type hinting for job verification.
- Execution layers + MongoDB allows for excellent horizontal scaling.
- Every configuration stored as hash - possible to backtrack exact software responsible for what operation.
- Shapers and tabulators allows for combination of different data streams.
- Workflow execution through Argos.
- Data access regulated at individual datapoint level and propagated through all operations.
- Operations/data are deduplicated for efficiency.

Summary

- Exciting decade for real-time MM astronomy!
- Often limited by infrastructure rather than lack of ideas.
  - Modular frameworks + code-to-data will be necessary for efficient data, energy and manpower use.
  - Provenance / Reproducibility will be key to navigate claims.
- AMPEL was designed as both a ***methodology*** for (de)constructing MM workflows as well as a ***live engine*** for executing these.