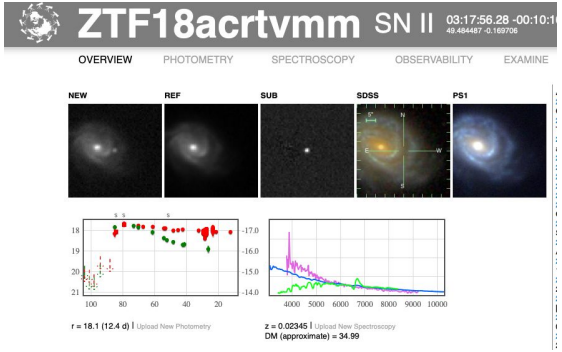
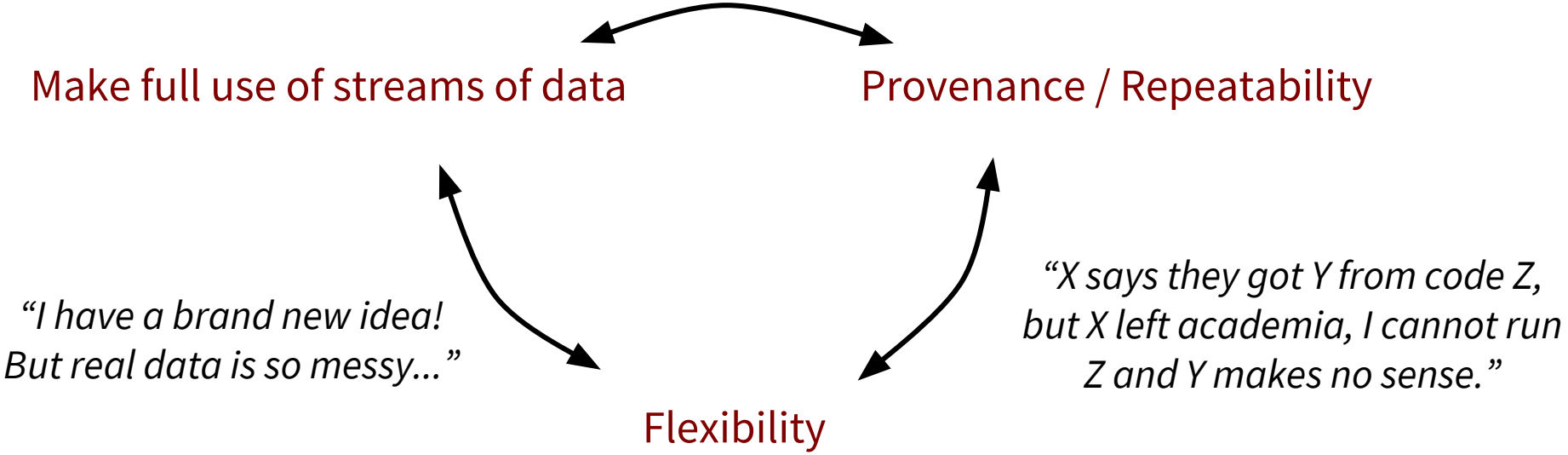
Alert Management, Photometry and Evaluation of Lightcurves (AMPEL)



Ludwig Rauch on behalf of Jakob Nordin

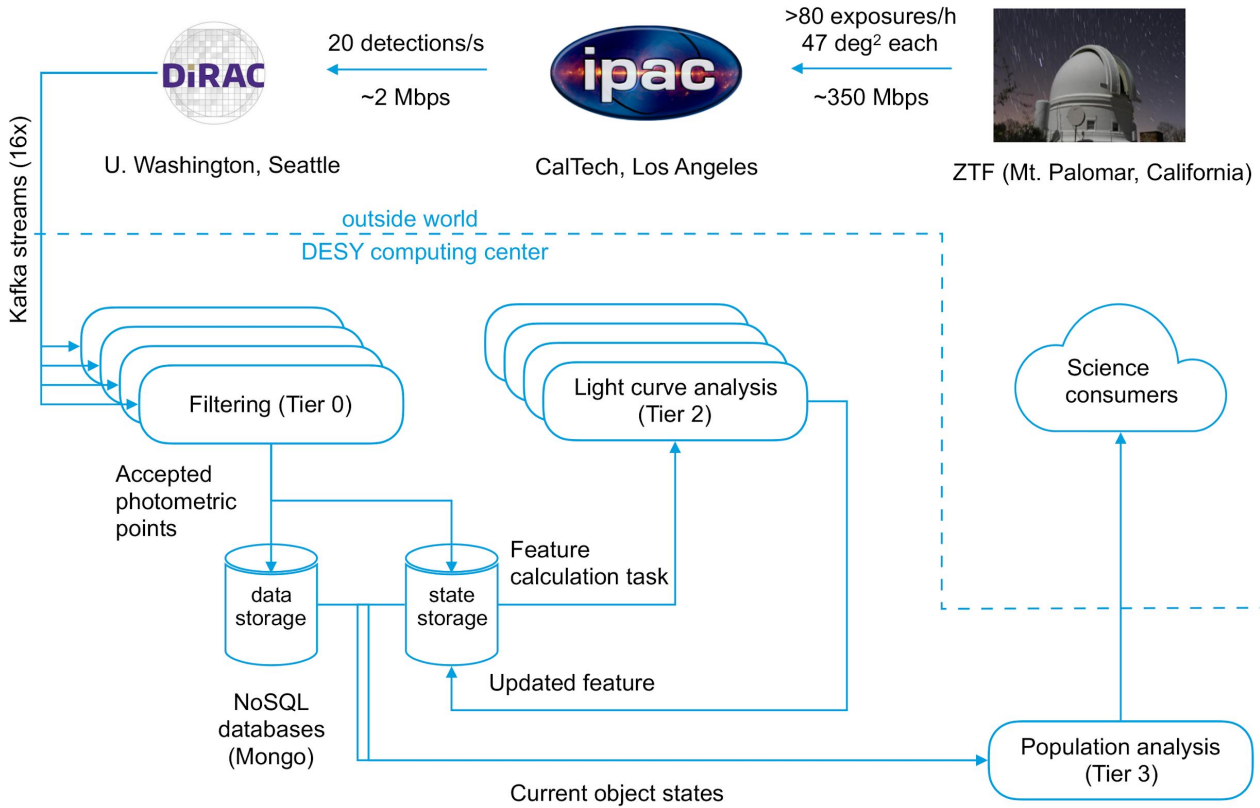
29.03.2019, Groningen

“Why did we not react to alert 5647342394746 at 5.32am Tue, three years ago?”



… much harder to achieve simultaneously

Alert Management, Photometry and Evaluation of Lightcurves (AMPEL)



The Zwicky Transient Facility (ZTF) alert stream

ZTF (Mt. Palomar, California)

>80 exposures/h
47 deg² each

~350 Mbps

CalTech, Los Angeles

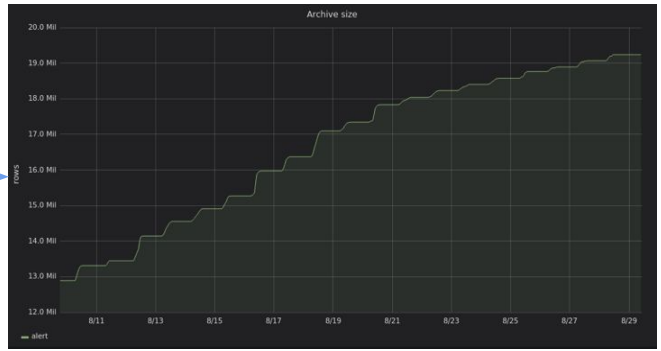
20 detections/s

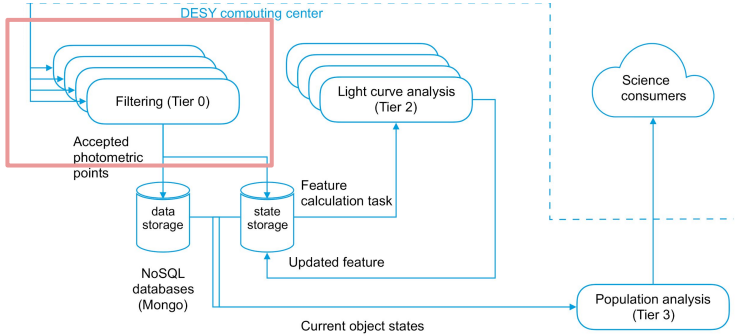
~2 Mbps

U. Washington, Seattle

Alerts

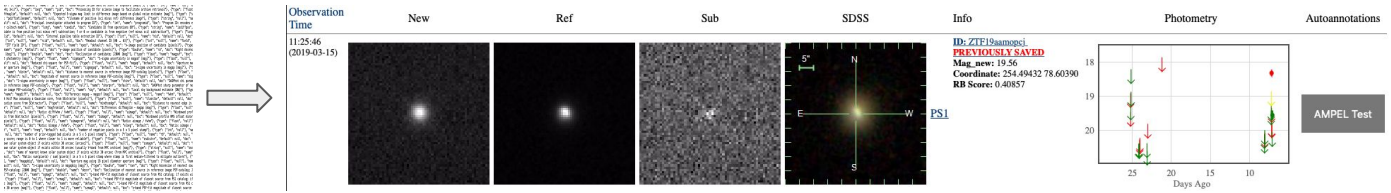
There is no central repository for transients, only a continuous stream of alerts.

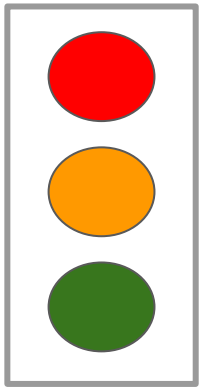


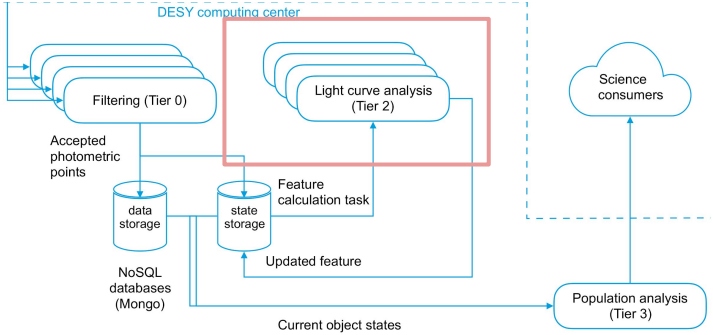


Primary filtering of data stream

- Enable primary filter of alerts targeted to science case
- Filter ~$10^{6\text{-}7}$ alerts per day to O(1000)





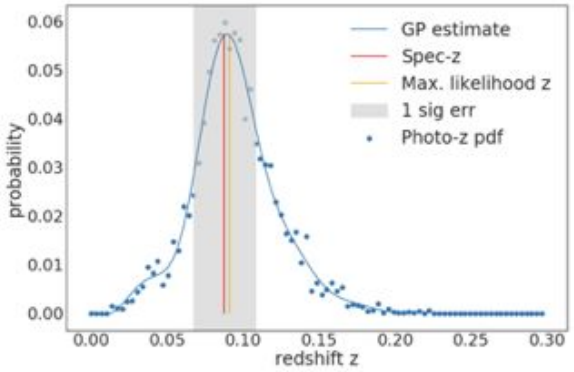


Python modules to compute properties based on transient data and position

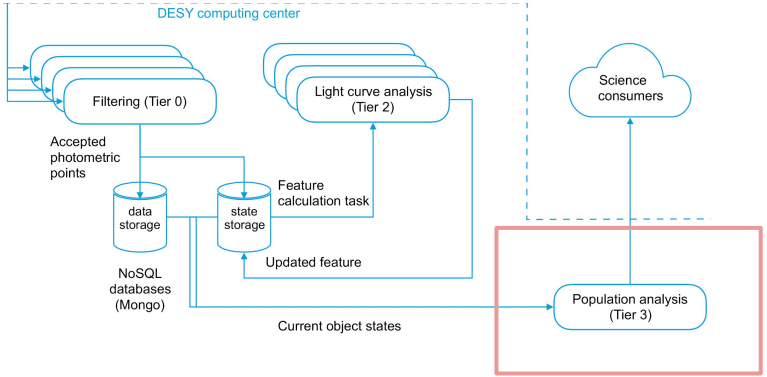
- Photometric redshift estimation
- SNcosmo template fitting
- Stream correlation
- Complex catalogue matching
- ...

Can be developed by users for specific science cases

T2: Real time photometric redshift estimate

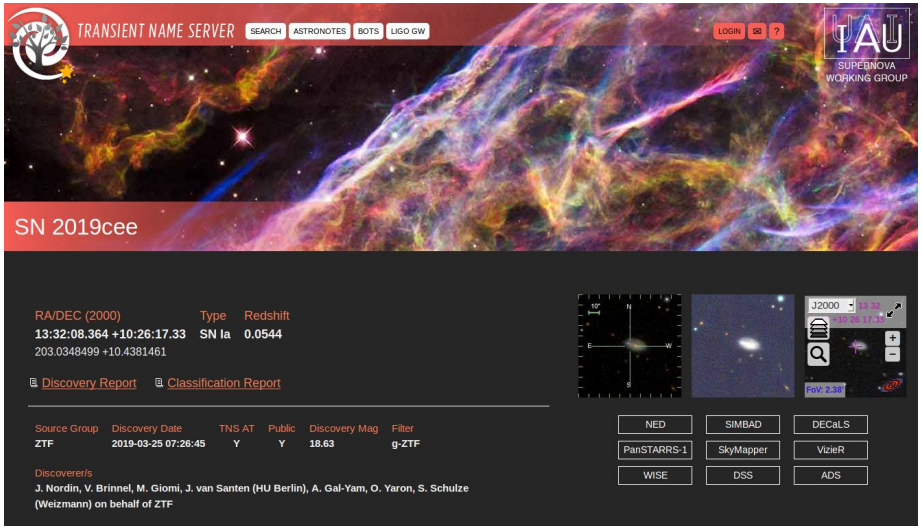


Respond



Use transient samples for:

- Automatic exchange of information to the outside of AMPEL: e.g. Transient Name Server publication, GROWTH network
- High level filtering and ranking based on all available information
- ...



Alert Management, Photometry and Evaluation of Lightcurves (AMPEL)

AMPEL achieves the initial three challenges through:

- Processing divided into four levels (tiers)according to type of input
  - Scientists are free to develop units within each tier (modularity).

- Alert process rate guaranteed through:
  - A database system specifically designed to quickly retrieve required tier data
  - Fully parallelizable (horizontal scaling)

- Provenance through:
  - Container framework incorporating also analysis units (for later rerun)
  - Automatic logging of unit input / output
  - Easy to use logging classes supplied to each unit

ZTF - AMPEL discovery statistics on TNS

Since December 2018 fully automatic reporting on the Transient Name Server (TNS):

Spectroscopically confirmed number of detected

ALL: SN: **389**

ZTF: 190 (49%)

ZTF - AMPEL automatic detections: 147 (38%) 

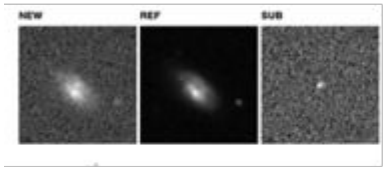
ATLAS: 120 (31%)

ASAS-SN: 40 (10%)

Other telescopes: 10%

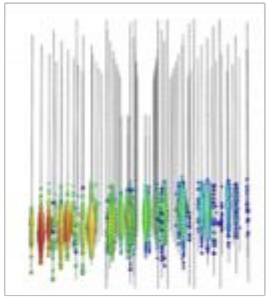
Example: ZTF - Ice Cube multi-messenger program

Transient positions from ZTF



AMPEL

Neutrino tracks from IceCube

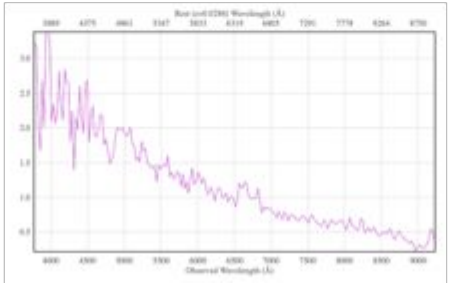


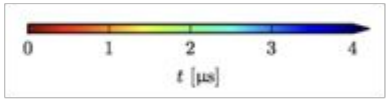
10^5 /d

1-2 /d

10^2 /d

Transient Spectrum





Filter: Primary data reduction applied to all alerts

Parameters

```
# number of previous detections
# minimum duration of alert detection history [days]
# maximum duration of alert detection history [days]
# real bogus score from machine learning
# sexctrator FWHM (assume Gaussian) [pix]
# Difference: magap - magpsf [mag]
# number of bad pixels in a 5 x 5 pixel stamp
# distance to nearest solar system object [arcsec]
# minium distance from galactic plane. Set to negative to disable cut.
#search radius for GAIA DR2 matching [arcsec]
# significance of proper motion detection of GAIA counterpart [sigma]
# significance of parallax detection of GAIA counterpart [sigma]
# min gmag for normalized distance cut of GAIA counterparts [mag]
# max gmag for normalized distance cut of GAIA counterparts [mag]
# maximum allowed noise (expressed as significance) for Gaia match to be trusted.
# maximum distance to closest PS1 source for SG score veto [arcsec]
# maximum allowed SG score for PS1 source within PS1_SGVETO_RAD
# reject alerts if the three PS1 sources are all within this radius [arcsec]
```

Information contained in alert

Automatic GAIA match

Automatic PanStarrs match

Calculate: Combination of two data streams

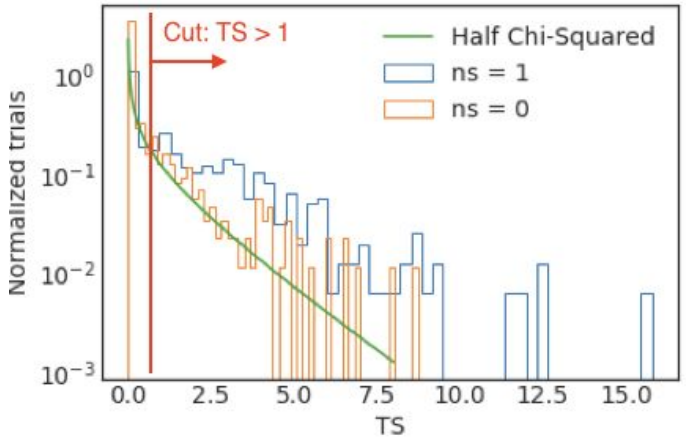
Maximum likelihood method

Position Energy Time

$$\mathcal{S}(E_\nu, \Delta T, \Delta\Psi, \sigma) = \frac{1}{2\pi\sigma^2} e^{(\Delta\Psi)^2/(2\sigma^2)} \cdot \epsilon_{\mathrm{sig}}(E, \theta, \gamma) \cdot Box(t_{start}, t_{end})$$

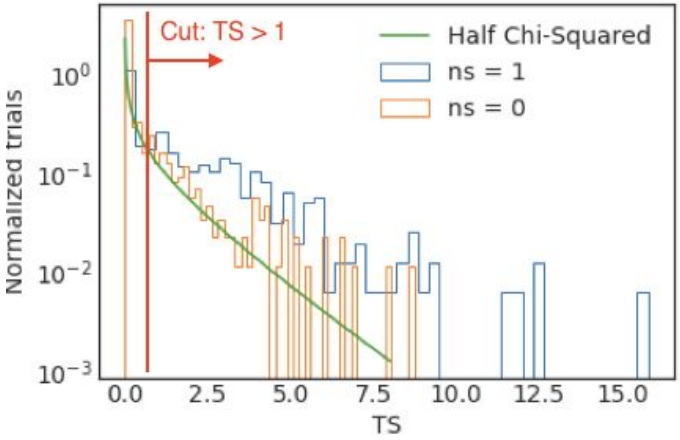
$$\mathcal{B}(E_\nu, \Delta T, \Delta\Psi) = \frac{\mathcal{P}(\sin\theta)}{2\pi} \cdot \epsilon_{\mathrm{BG}}(E, \theta)$$

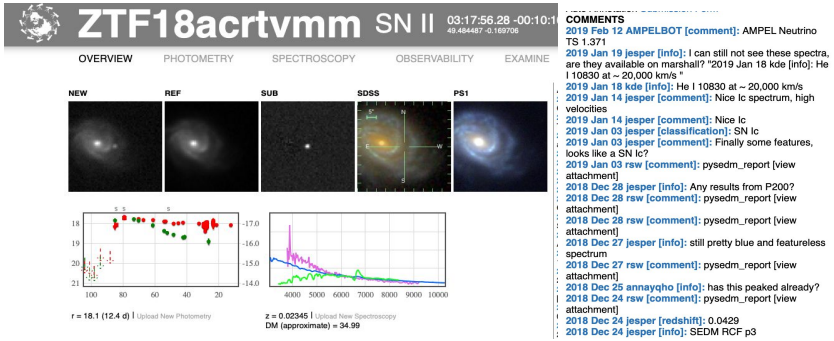
$$TS = -2\log\frac{\mathcal{L}(\mathrm{ns})}{\mathcal{L}(\mathrm{ns}=0)} = -2\sum_{\mathrm{i}=0}^{\mathrm{N}} \log\left(1 + \frac{\mathrm{ns}}{\mathrm{N}}\left(\frac{\mathcal{S}}{\mathcal{B}} - 1\right)\right)$$



T3: Ranking of transients

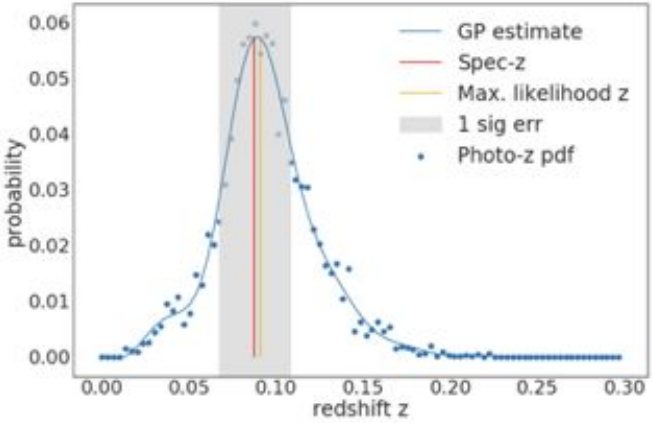
- Use TS values to rank transients
- Use photometric redshift to select close by objects
- Goal: Make a reproducible choice which transients are followed up





Trigger spectra for classification

Provide values of T2 to optimise follow up programs



Interested? How to get involved

Everything needed to start developing channels and units for Ampel available at:

https://github.com/AmpelProject/Ampel-contrib-sample

Anyone can get access to the optical ZTF public alerts through AMPEL

People:


Valéry Brinnel


Matteo Giomi


Jakob Nordin


Ludwig Rauch


Mickael Rigault


Robert Stein


Nicolas Miranda


JvS

Summary and Outlook

AMPEL: A system set up for complete analysis of streamed transient data

ZTF - IceCube program is a start of several multi messenger real time programs

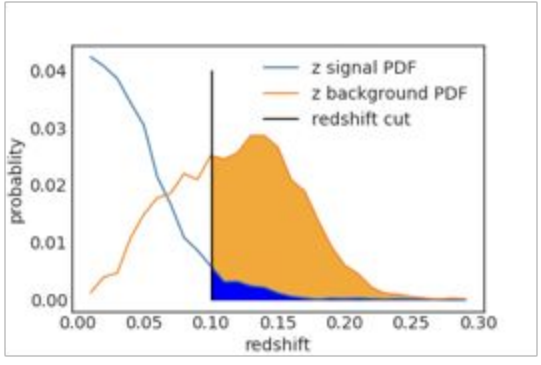
Paper coming soon: “**Transient processing and analysis using AMPEL: Alert Management, Photometry and Evaluation of Lightcurves”** (ask us for a copy)

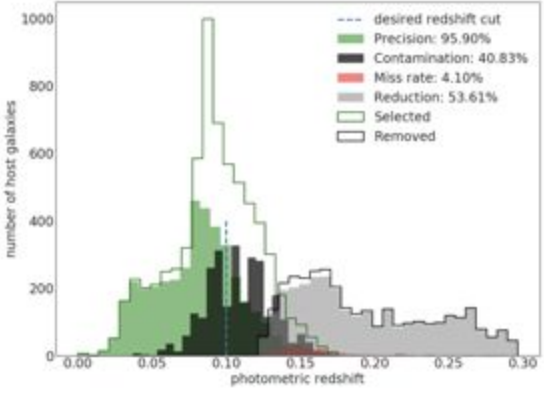
Joint analysis of MM alerts? In AMPEL through:

- A core SW+DB that is built to track the evolving state of transients
- A modular system that allows users to merge analysis code into the live transient processing carried out at a computer centre.

T2: Photometric redshift estimation

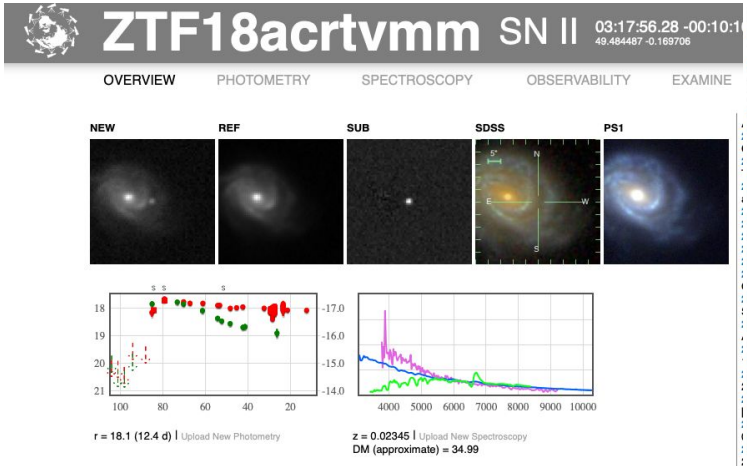
- Use photometric redshift for signal and background discrimination
- At redshifts larger than z=0.1:
  - Background: ~ 62 %
  - Signal < 5%
- Due to uncertainties of the redshift estimate we consider the error pdf
- Redshift cut on integral: Area of error pdf should be larger than 80% above a value of 0.1
- Using the area reduces the background rejection efficiency but minimises false negative rate

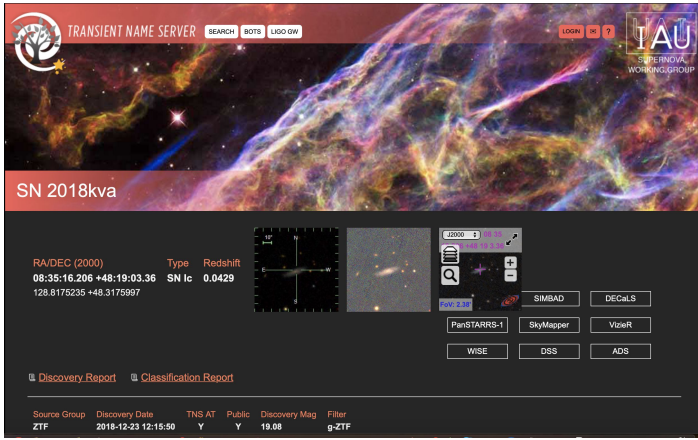




X

T3: GROWTH Marshal and TNS server





Trigger spectra for classification

Provide values of T2 to optimise follow up programs

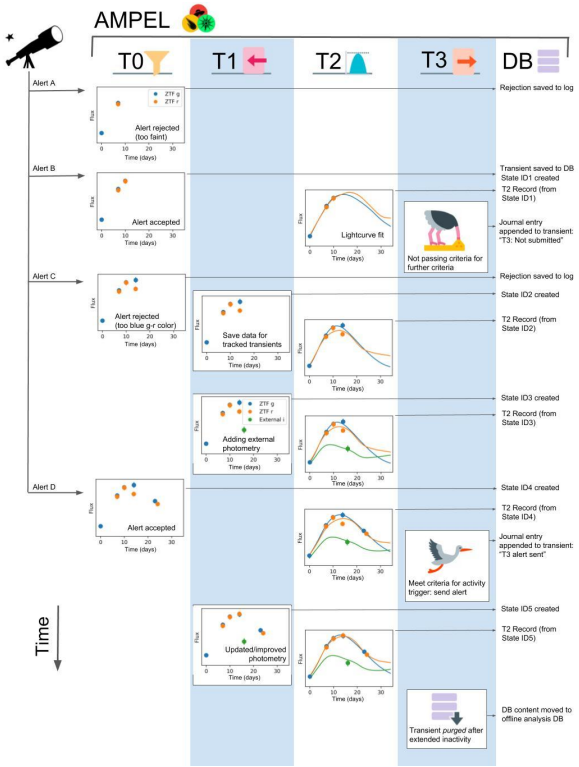
Automatic transient publication

Alert Management, Photometry and Evaluation of Lightcurves (AMPEL)

AMPEL our suggestion to how this can be done.

Processing divided into four tiers according to *type* of input

- Scientists are free to develop units within each tier.
- AMPEL supplies units with correct input / output



Goals for multi-messenger transient studies

Make full use of streams of data

- 1000+ alerts / s
- Parallel streams from different sources
- DIfferent data formats

Provenance / Repeatability

- Individual scientists cannot grasp full dataset
- Required to connect individual event to “the Universe”
- Create legacy datasets
- Acknowledge versions of data and software e.g. by using Docker

Flexibility

- Pick and choose among datasets: optical, γ-rays, x-rays, radio, IR, neutrino, GW...
- No single, predefined analysis; allow creativity
- Build on existing algorithms

Make full use of streams of data

- 1000+ alerts / s
- Parallel streams from different sources
- DIfferent data formats

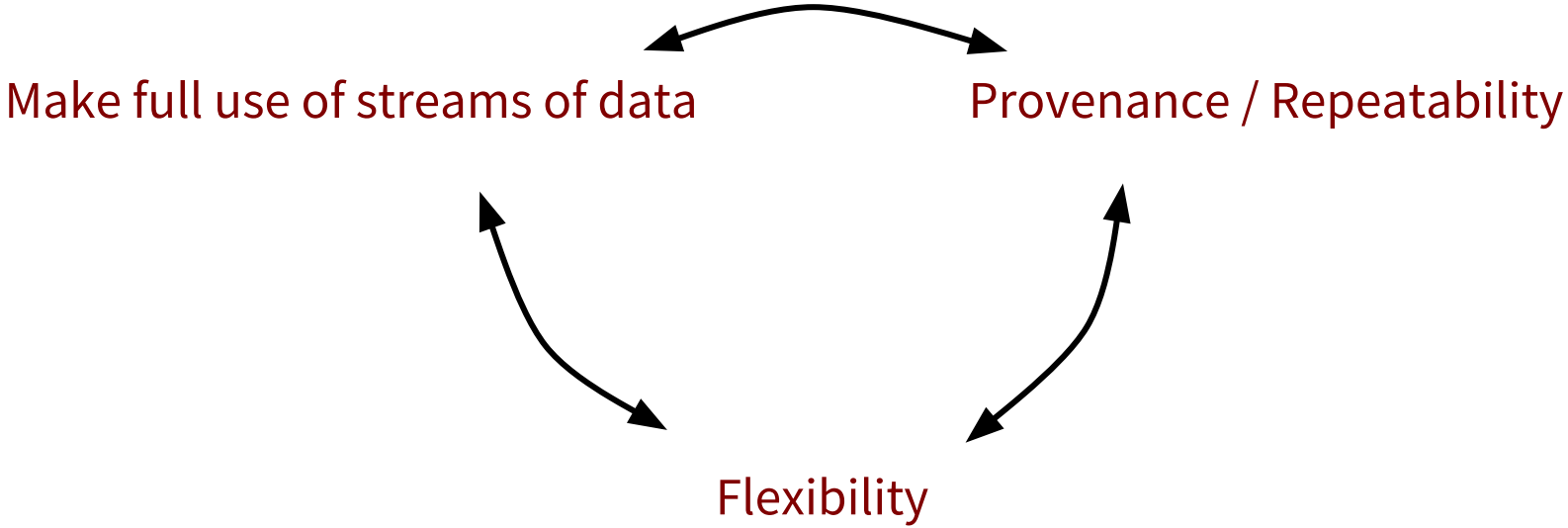
Provenance / Repeatability

- Individual scientists cannot grasp full dataset
- Required to connect individual event to “the Universe”
- Create legacy datasets
- Acknowledge versions of data and software

Flexibility

- Pick and choose among datasets: optical, γ-rays, x-rays, radio, IR, neutrino, GW...
- No single, predefined analysis; allow creativity
- Build on existing algorithms

Straightforward to achieve, in isolation...



… much harder to achieve simultaneously