## Alert Management, Photometry and Evaluation of Lightcurves (AMPEL)













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29.03.2019, Groningen



... much harder to achieve simultaneously

## Alert Management, Photometry and Evaluation of Lightcurves (AMPEL)









## The Zwicky Transient Facility (ZTF) alert stream





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"null"]. "name": "ssmaonr". "default": null, "doc": ' own solar system object if exists within 30 arcsec (usually V-band from MPC archive) [mag]"}, {"type": ["string", "null"], "name": "ssn , "doc": "name of nearest known solar system object if exists within 30 arcsec (from MPC archive)"}, {"type": ["float", "null"], "name' null, "doc": "Ratio: sum(pixels) / sum([pixels]) in a 5 x 5 pixel stamp where stamp is first median-filtered to mitigate outliers"}, {" ], "name": "maqapbiq", "default": null, "doc": "Aperture mag using 18 pixel diameter aperture [mag]"}, ("type": ["float", "null"], "nam ault": null, "doc": "1-signa uncertainty in nagapbig [nag]"), ("type": "double", "name": "ranr", "doc": "Right Ascension of nearest sou PSF-catalog; J2000 [deg]"), ("type": "double", "name": "decnr", "doc": "Declination of nearest source in reference image PSF-catalog; J ["float", "null"], "name": "sqmaq1", "default": null, "doc": "q-band PSF-fit magnitude of closest source from PS1 catalog; if exists wi {"type": ["float", "null"], "name": "srmag1", "default": null, "doc": "r-band PSF-fit magnitude of closest source from PS1 catalog; if c [mag]"}, {"type": ["float", "null"], "name": "simag1", "default": null, "doc": "i-band PSF-fit magnitude of closest source from PS1 c n 30 arcsec [nag]"}, {"type": ["float", "null"], "name": "szmag1", "default": null, "doc": "z-band PSF-fit magnitude of closest source

# 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  $\sim 10^{6-7}$  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







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



### 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  $\mathcal{S}(E_{\nu}, \Delta T, \Delta \Psi, \sigma) = \frac{1}{2\pi\sigma^2} e^{(\Delta\Psi)^2/(2\sigma^2)} \cdot \epsilon_{\text{sig}}(E, \theta, \gamma) \cdot Box(t_{start}, t_{end})$ Cut: TS > 1 Half Chi-Squared  $\mathcal{B}(E_{\nu}, \Delta T, \Delta \Psi) = \frac{\mathcal{P}(\sin \theta)}{2\pi} \cdot \epsilon_{\mathrm{BG}}(E, \theta)$ 100 ns = 110° 10<sup>-1</sup> 10<sup>-2</sup> ns = 0 $TS = -2\log\frac{\mathcal{L}(ns)}{\mathcal{L}(ns=0)} = -2\sum_{i=1}^{N}\log\left(1 + \frac{ns}{N}\left(\frac{\mathcal{S}}{\mathcal{B}} - 1\right)\right)^{\frac{1}{2}}$ 5.0 7.5 10.0 12.5 15.0 TS

## 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



OMMENTS
019 Feb 12 AMPELBOT [comment]: AMPEL Neutrino S 1 371
019 Jan 19 jesper [info]: I can still not see these spectra, re they available on marshall? "2019 Jan 18 kde [info]: He 10830 at ~ 20 000 km/s "
019 Jan 18 kde [info]: He I 10830 at ~ 20,000 km/s 019 Jan 14 jesper [comment]: Nice Ic spectrum, high elocities
019 Jan 14 jesper [comment]: Nice Ic
019 Jan 03 jesper [classification]: SN Ic
019 Jan 03 jesper [comment]: Finally some features,
oks like a SN Ic?
019 Jan 03 rsw [comment]: pysedm_report [view
ttachment]
018 Dec 28 jesper [info]: Any results from P200?
018 Dec 28 rsw [comment]: pysedm_report [view
ttachment]
018 Dec 28 rsw [comment]: pysedm_report [view
Itachment]
018 Dec 27 jesper [info]: still pretty blue and featureless
nectrum
018 Dec 27 rsw [comment]: pysedm_report [view
ttachment]
018 Dec 25 annaygho [info]: has this peaked already?
018 Dec 24 rsw [comment]: pysedm_report [view
Itachment]
018 Dec 24 jesper (redshift): 0.0429
018 Dec 24 jesper [info]: SEDM RCF p3

of T2 to

up programs



0.05

0.10

0.15

redshift z

0.25

0.30

0.20

Trigger spectra for classification

## 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%</p>
- 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





## T3: GROWTH Marshal and TNS server



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

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### Straightforward to achieve, in isolation...



#### Make full use of streams of data

Provenance / Repeatability



... much harder to achieve simultaneously