



# Alert Distribution System

**Mario Juric, Eric Bellm, Maria Patterson,  
Zach Golkhou, Ben Rusholme, and the ZTF  
Partnership**

*University of Washington*

*DIRAC Institute  
IPAC / CalTech*



DATA INTENSIVE RESEARCH IN  
ASTROPHYSICS AND COSMOLOGY

CHARLES AND LISA SIMONYI FUND  
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# Zwicky Transient Facility

Systematic Exploration of the Dynamic Sky



- > 1000 images/night, 576 mpix
- > 300 M detected sources/night
- > 1 billion objects, 75-250 mea/obj/year
- > 1 M alerts/night



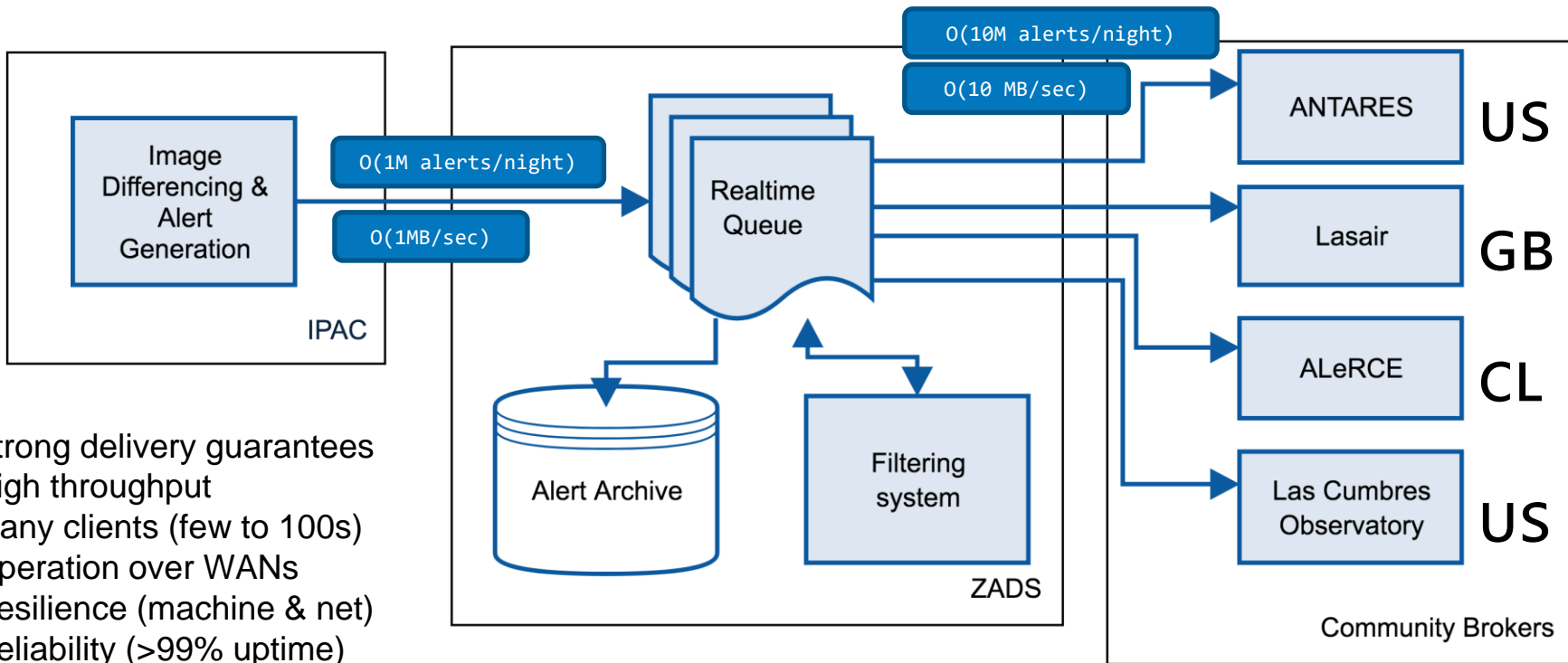
ZTF is a candidate discovery machine. These candidates need to be *contextualized*, *distributed*, *classified*, and *followed up*.

This talk is about a scalable framework for distribution that enables (pluggable) classification.



Public-Private Partnership.  
40% obsv. on LSST-like cadence,  
immediately public!

# Why is Real-Time Alert Distribution Hard?



Strong delivery guarantees  
High throughput  
Many clients (few to 100s)  
Operation over WANs  
Resilience (machine & net)  
Reliability (>99% uptime)

# Standing on the Shoulders of (Tech) Giants

Rich history and very useful prior experiences with alerts from VO / GCN / PTF / IPTF... **The main new challenge is *scalability and robustness*.**

The industry has the same problem. There are billions of events flowing through compute systems of the largest companies (Google, Facebook, Amazon, Microsoft, ...) that need to be serialized, transmitted, streams fused, results classified, acted upon, ...

*Alert distribution discussions circa 2015*

*Maria*



No thanks!

*Mario*



We are too busy

*et al.*



*Things have changed since...*



Maria Patterson  
UW (formerly 🐼)

# Serialization

# Distribution



<https://kafka.apache.org>

<https://avro.apache.org>

Open source, Apache 2.0 licensed

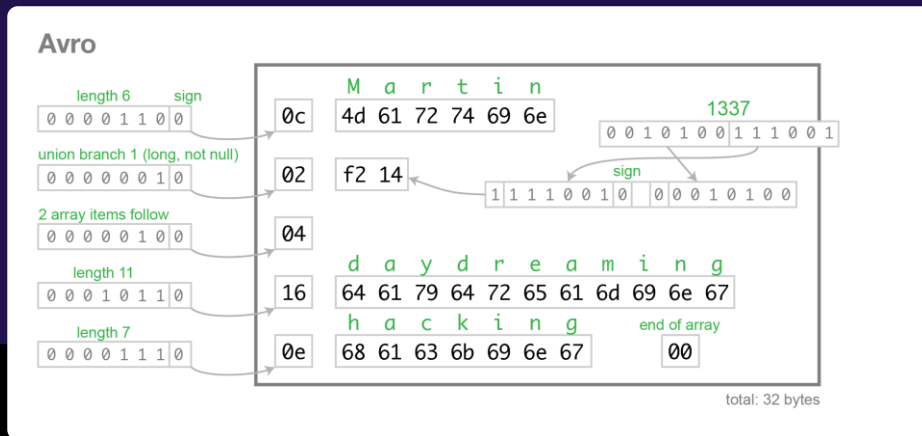


# Serialization: Apache Avro

JSON encoding is 82 bytes

```
{  
  "userName": "Martin",  
  "favouriteNumber": 1337,  
  "interests": ["daydreaming", "hacking"]  
}
```

```
{  
  "type": "record",  
  "name": "Person",  
  "fields": [  
    {"name": "userName", "type": "string"},  
    {"name": "favouriteNumber", "type": ["null", "long"]},  
    {"name": "interests", "type": {"type": "array", "items": "string"}}  
  ]  
}
```



Encoded to 32 bytes

Fast parsing  
Serializing byte streams  
Schema evolution

# ZTF Alert Schema

Schema Definition: <https://zwicky.tf/4t5>

- With each alert, we transmit meas. + **context**:
  - Identifiers
  - Photometry
  - Nearest neighbors (PS1 and Gaia)
  - Detection metadata (real-bogus score, S/G, etc.)
  - Image cutouts (science, template, difference)
  - Detections and upper limits over the previous month
- Schema version at v3.1
  - All updates were fwd/backwards compatible.

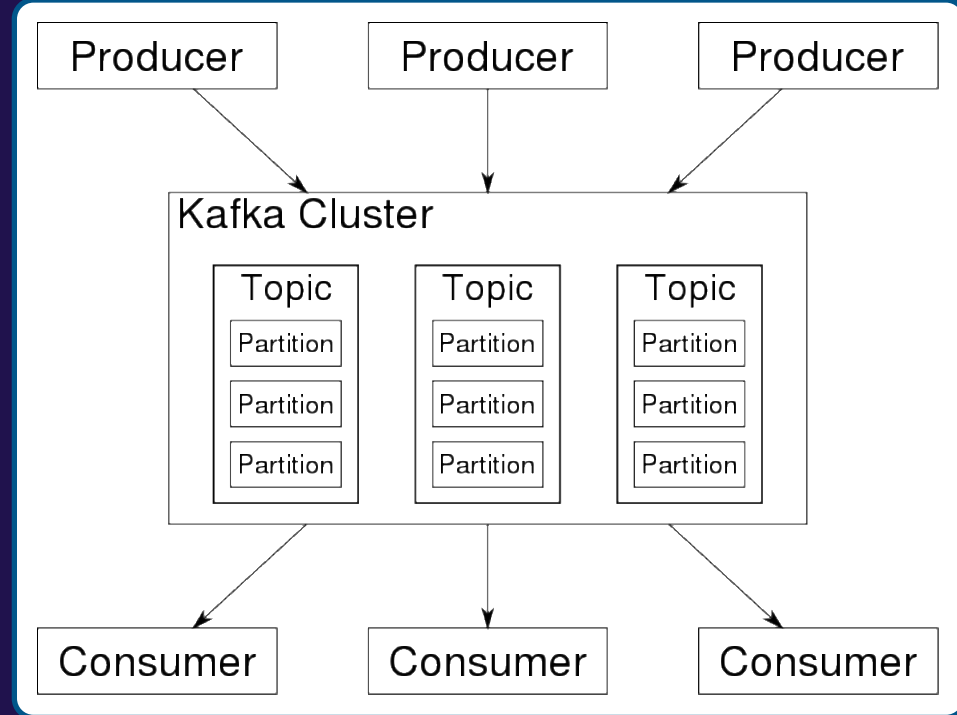
( Not using the VOEvent data model at present; providing feedback for future versions. )

Field	Type
objectId	long
candid	long
candidate	ztf.alert.candidate
candidate.fid	int
candidate.ra	double
candidate.dec	double
candidate.magpsf	float
candidate.distnr	float or null
candidate.magnr	float or null
candidate.classtar	float or null
candidate.rb	float or null
prv_candidate	array of ztf.alert.candidate
cutoutScience	ztf.alert.cutout or null
cutoutTemplate	ztf.alert.cutout or null
cutoutDifference	ztf.alert.cutout or null

**Typical alert size: 60kB**

# Apache Kafka

- **Fault-tolerant, scalable, high-throughput, low-latency platform for handling real-time data feeds. Backed by Confluent.**
- Implements a publish/subscribe paradigm: producers publish messages into a topic, consumers read messages from topics they're subscribed to.
- Allows for at least once and exactly once delivery semantics
- Good Python and C++ client support





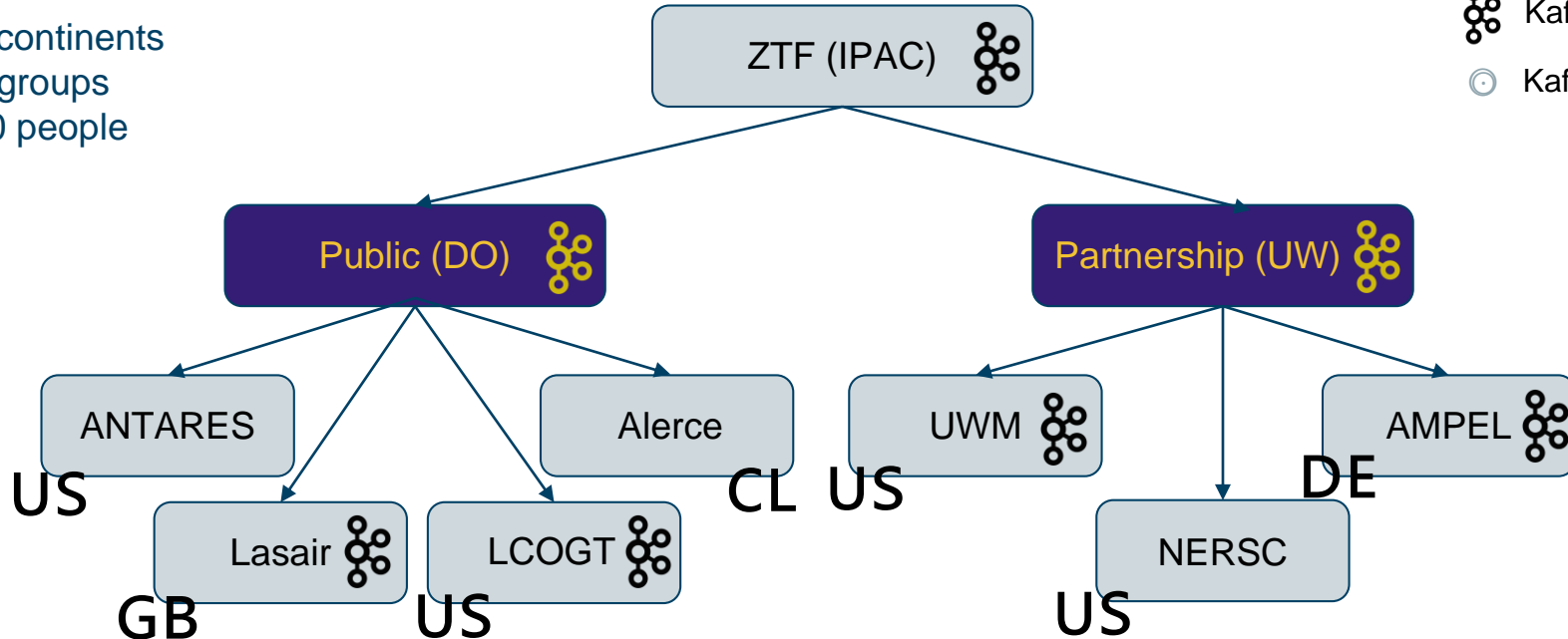


# ZTF Alert Network



3 continents  
> 8 groups  
> 20 people

 Kafka broker  
 Kafka client





# ZTF Alert Network Implementation

- Running Kafka 1.0+ brokers
- Configured to keep the last ~7 days of alerts (some keep more).
  
- Each night is a separate Kafka topic: e.g. `ztf_20180725_programid1`
- Authentication: IP Based (pwd auth planned)
- Encryption: None at present (SSL planned)
  
- Deployment w. Terraform (and Docker)
- Monitoring w. Prometheus/Grafana

# Clients

- Any number of out-of-the-box Kafka clients will work
  - For example, `kafkacat` (`conda install -c conda-forge kafkacat`)
- Demo (Python) client (<https://zwicky.tf/mrs>)
  - A thin fork of the LSST alert streaming client.
  - Useful as a basis for custom client development.
- `kcp` client (<https://github.com/mjuric/kcp>)
  - A cmdline tool for stream consumption and format conversion (“netcat for Kafka/Avro”)
  - Investigating VOEvent <-> Avro conversion (should be possible)



# ZTF Alerts Archive

Archive is also created by consuming the Kafka stream.

ZWICKY TRANSIENT FACILITY ALERT ARCHIVE

## Opening a real-time window into the time-variable Universe.

DATA ACCESS   ZTF @ UW   ZTF @ CALTECH

A PUBLIC SERVICE OF THE ZTF PARTNERSHIP AND THE UNIVERSITY OF WASHINGTON DIRAC INSTITUTE

<https://ztf.uw.edu>

ZTF ALERT ARCHIVE

**What is included?**

Below you will find compressed tar archives of ZTF event alerts (observations detected in image differences). Each tar file contains events collected in the given night (UTC-based), with each alert stored in a separate file in the FITS format. To get you alerted, we offer a repository with few basic utilities for reading FITS-related data, as well as an overview figure workflow.

**Why this service?**

We are providing this archive as a step-goo measure until public event brokers capable of receiving and redistributing the ZTF alert stream come online. We expect this to be the end of 2018.

**Known caveats**

- The data provided on this site is generated automatically, has not yet been optimally calibrated or fully characterized, and uses evolving algorithms. It is best suited for searches of relatively bright transients.
- The files provided contain a LUT, unlabeled, 5-sigma alert stream. Depending on your access case, you may wish to improve the purity of your sample by filtering the data on the included attributes such as the signal-to-noise ratio or the real-time score.

Name	Last modified	Size
ztf_public_20180605.tar.gz	1 day ago	342M
ztf_public_20180604.tar.gz	2 days ago	5.4G
ztf_public_20180603.tar.gz	3 days ago	3.3G
ztf_public_20180602.tar.gz	4 days ago	8.9G
ztf_public_20180601.tar.gz	5 days ago	6.8G
ztf_public_20180531.tar.gz	6 days ago	3.3G
ztf_public_20180530.tar.gz	8 days ago	3.1G
ztf_public_20180529.tar.gz	8 days ago	4.1G
ztf_public_20180528.tar.gz	9 days ago	2.5G
ztf_public_20180527.tar.gz	10 days ago	1.9G
ztf_public_20180526.tar.gz	11 days ago	2.5G

<https://ztf.uw.edu/alerts/public/>

ZTF PARTNERSHIP SURVEY ALERT ARCHIVE

**Reminder: These are private data, not to be shared outside of the ZTF Partnership. If you are not a member of the ZTF Partnership, you may still use the public survey data.**

**What is included?**

Below you will find compressed tar archives of ZTF event alerts (observations detected in image differences). Each tar file contains alerts collected in the given night (UTC-based), with each alert stored in a separate file in the FITS format. To get you alerted, we offer a repository with few basic utilities for reading FITS-related data, as well as an overview figure workflow.

**Known caveats**

The data provided on this site is generated automatically, has not yet been optimally calibrated or fully characterized, and uses evolving algorithms. It is best suited for searches of relatively bright transients.

The files provided contain a LUT, unlabeled, 5-sigma alert stream. Depending on your access case, you may wish to improve the purity of your sample by filtering the data on the included attributes such as the signal-to-noise ratio or the real-time score.

These are only alerts from observations taken in the ZTF Partnership survey time. Observations from public (BSF) survey are available here.

Name	Last modified	Size
ztf_partnership_20180605.tar.gz	1 day ago	49
ztf_partnership_20180604.tar.gz	2 days ago	19G
ztf_partnership_20180603.tar.gz	3 days ago	16G
ztf_partnership_20180602.tar.gz	4 days ago	15G
ztf_partnership_20180601.tar.gz	5 days ago	6.1G
ztf_partnership_20180531.tar.gz	6 days ago	3.4G
ztf_partnership_20180530.tar.gz	7 days ago	7.3G
ztf_partnership_20180529.tar.gz	8 days ago	4.8G
ztf_partnership_20180528.tar.gz	9 days ago	2.8G
ztf_partnership_20180527.tar.gz	10 days ago	2.0G

<https://ztf.uw.edu/alerts/partnership/>



# LCO Interface to Public Alerts

<https://mars.lco.global>

MARS - Las Cumbres Observa x Mario

Secure https://mars.lco.global

Apps Bookmarks zwicky.tf Shorten Welcome to Spark... UW Libraries Proxy... Spark Picasa Web Albums... ClipConverter! Rerouting VPN Traf... Other Bookmarks

**LCO** **MARS**  
Make Alerts Really Simple Help Contact

MARS provides access to all public alerts issued by ZTF since the start of the public alert stream on June 1, 2018. Subsets of the alerts, filtered by selectable constraints, may be identified and downloaded, either through this webpage or using the underlying API. Alerts are ingested as they are generated by the ZTF survey and are made available immediately, which is reflected by the "Latest Alert" value below. Users are advised to limit their request frequency to a reasonable time period, preferably allowing at least 5 minutes between requests. In addition to our own [help](#) page, users should refer to the [ZTF website](#) and the [ZTF Alert Archive](#) for documentation on ZTF and the generation of alerts.

The following table lists ZTF alerts in descending order by JD. Use the filters on the right to narrow down the results to interesting candidates. When the results look good, add `?format=json` to the url. You can now access this url to retrieve the full data and use it in your scripts. You can access an alert's previous alerts by visiting `/<id>/` where id is the value of the lco\_id key in the json view or by clicking the id link in the table.

See the [help](#) page for descriptions of the table values and available filters.

Select Reset Prev Next Results: 5841854 Pages: 58419 Latest Alert: 2018-08-04 07:20:49 UTC

Sort By time

Sort Order Descending

objectid

candid

time (lower) yyyy-mm-dd

time (upper) yyyy-mm-dd

jd

id	objectId	time	filter	ra	dec	magpsf	magap	distnr	Δmaglatest	Δmagref	rb
<a href="#">6121378</a>	ZTF18ablonfj	2018-08-04 07:20:49	g	269.91461	66.96017	18.26	18.76	6.367			0.290
<a href="#">6121764</a>	ZTF18abloniq	2018-08-04 07:20:49	g	265.89783	66.70604	18.78	18.98	5.880			0.290
<a href="#">6121943</a>	ZTF18ablonlr	2018-08-04 07:20:49	g	257.63087	68.18566	18.12	18.56	11.711			0.270
<a href="#">6121964</a>	ZTF18aakvzfc	2018-08-04 07:20:49	g	256.65589	67.64165	18.00	18.26	0.588	0.12	-2.66	0.497
<a href="#">6121989</a>	ZTF18aaoechd	2018-08-04 07:20:49	g	273.53155	70.73565	16.75	16.84	0.452	-0.06	-1.31	0.560
<a href="#">6121998</a>	ZTF18aamyhuq	2018-08-04 07:20:49	g	257.13025	68.88617	16.77	16.88	0.596	0.18	-2.96	0.330
<a href="#">6122003</a>	ZTF18aapsnka	2018-08-04 07:20:49	g	257.34833	67.93375	19.63	19.76	0.535	0.20	-2.47	0.690
<a href="#">6122022</a>	ZTF18ablonlq	2018-08-04 07:20:49	g	271.74009	69.55966	18.34	18.76	4.095			0.353

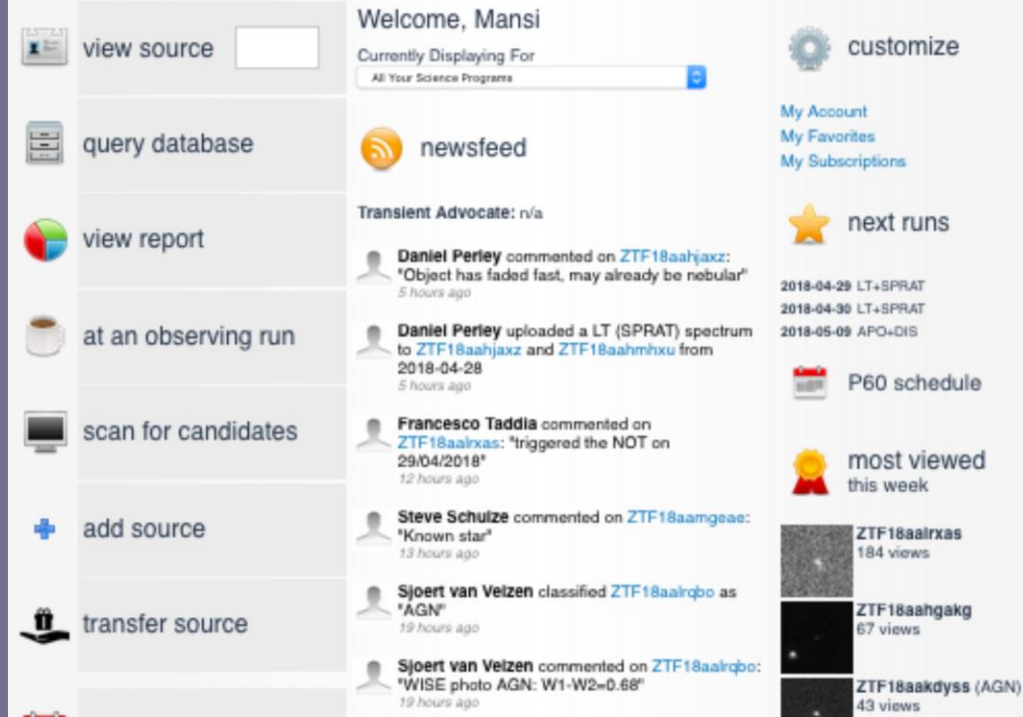
# GROWTH Followup Marshal

# GROWTH Followup Marshal

<http://growth.caltech.edu/>

*This is where most of the filtering happens right now (but that's another talk...)*

*Kasliwal et al., *subm.**



The screenshot shows the GROWTH Followup Marshal web interface. On the left is a navigation menu with icons and labels: 'view source', 'query database', 'view report', 'at an observing run', 'scan for candidates', 'add source', and 'transfer source'. The main content area is titled 'Welcome, Mansi' and includes a dropdown menu for 'Currently Displaying For' set to 'All Your Science Programs'. Below this is a 'newsfeed' section with a 'Transient Advocate: n/a' and several user comments on ZTF objects. On the right, there are links for 'customize', 'My Account', 'My Favorites', and 'My Subscriptions', followed by a 'next runs' section with a star icon and a 'P60 schedule' section with a calendar icon. At the bottom right, there is a 'most viewed this week' section with three small image thumbnails and their view counts.

view source

query database

view report

at an observing run

scan for candidates

add source

transfer source

Welcome, Mansi

Currently Displaying For  
All Your Science Programs

customize

My Account  
My Favorites  
My Subscriptions

newsfeed

Transient Advocate: n/a

next runs

2018-04-29 LT+SPRAT  
2018-04-30 LT+SPRAT  
2018-05-09 APO+DIS

P60 schedule

most viewed this week

ZTF18aaairxas  
184 views

ZTF18aaahgakg  
67 views

ZTF18aaakdyss (AGN)  
43 views

Daniel Perley commented on ZTF18aaahjaxz: "Object has faded fast, may already be nebular" 5 hours ago

Daniel Perley uploaded a LT (SPRAT) spectrum to ZTF18aaahjaxz and ZTF18aaahmxxu from 2018-04-28 5 hours ago

Francesco Taddia commented on ZTF18aaairxas: "triggered the NOT on 29/04/2018" 12 hours ago

Steve Schulze commented on ZTF18aaamgeae: "Known star" 13 hours ago

Sjoert van Velzen classified ZTF18aaairqbo as "AGN" 19 hours ago

Sjoert van Velzen commented on ZTF18aaairqbo: "WISE photo AGN: W1-W2=0.68" 19 hours ago



# Experiences, ~9 months in

# Key Question: Is it Enabling Science?

[ Previous | Next ]

## ePESSTO spectroscopic classification of optical transients

ATel #12175; *M. Berton (FINCA), E. Congiu (Padova), S. Benetti (Padova), A. Fiore (Padova), A. Pastorello (Padova), A. Reguitti (Padova), N. Elias-Rosa (IEEC, ICE-CSIC), J. Lyman (Warwick), T.-W. Chen (MPE), C. Inerra (Southampton), E. Kankare (QUB), K. Maguire (QUB), S. J. Smartt (QUB), D. R. Young (QUB), O. Yaron (Weizmann), I. Manulis (Weizmann)*  
 on 6 Nov 2018; 15:00 UT

Distributed as an Instant Email Notice Supernovae  
 Credential Certification: *Andrea Pastorello (andrea.pastorello@oapd.inaf.it)*

Subjects: Optical, AGN, Supernovae, Transient

Tweet Recommend 51

2015, A&A, 579, 40; <http://www.pessto.org> ), reports the following classifications. One target was supplied by the Zwicky Transient Facility (<https://www.ztf.caltech.edu/>; Kulkarni et al. 2018, ATel #11266) data stream processed through the Lasair broker (<http://lasair.roe.ac.uk/>). Targets

All observations were performed with the ESO New Technology Telescope at La Silla on 2018 November 6 (UT), plus EFOSC2 and Grism 13 (3985-9315Å, 18Å resolution). Classifications were done with SNID (Blondin & Tonry, 2007, ApJ, 666, 1024) and GELATO (Harutyunyan et al., 2008, A&A, 488, 383). The classification spectra and additional details can be obtained from <http://www.pessto.org> (via WISEREP) and the IAU Transient Name Server.

DRAFT VERSION SEPTEMBER 10, 2018  
 Typeset using L<sup>A</sup>T<sub>E</sub>X two-column style in AASTeX02

### The first tidal disruption flare in ZTF: from photometric selection to multi-wavelength characterization

SIOBERT VAN VELZEN,<sup>1,2</sup> SUVU GEZARI,<sup>3,4</sup> S. BRADLEY CENKO,<sup>5,4</sup> ERIN KARA,<sup>3,6,4</sup> JAMES C. A. MILLER-JONES,<sup>7</sup> TIARA HUNG,<sup>8</sup> JOE BRIGHT,<sup>8</sup> NATHANIEL ROTH,<sup>3,4</sup> NADEJDA BLAGORODNOVA,<sup>9</sup> DANIELA HUPPENKOTHE,<sup>10</sup> LIN YAN,<sup>11</sup> ERAN OFEK,<sup>12</sup> JESPER SOLLERMAN,<sup>13</sup> SARA FREDERICK,<sup>7</sup> CHARLOTTE WARD,<sup>4</sup> MATTHEW J. GRAHAM,<sup>3</sup> ROB FENDER,<sup>8</sup> MANSI M. KARLWAL,<sup>9</sup> CHRIS CANELA,<sup>9</sup> ROBERT STYEN,<sup>14</sup> MATTEO GHOMI,<sup>15</sup> VALEWY ERINEN,<sup>15</sup> JAKOB VAN SANTEN,<sup>14</sup> JAKOB NORDIN,<sup>15</sup> ERIC C. BELL,<sup>10</sup> RICHARD DEKANY,<sup>16</sup> CHRISTOFFER FREMLING,<sup>9</sup> V. ZACH GOLKHOV,<sup>10,17</sup> THOMAS KUPFER,<sup>18,19,9</sup> SHRINIVAS R. KULKARNI,<sup>9</sup> RUSS R. LAHER,<sup>20</sup> ASHISH MAHALAL,<sup>9,21</sup> FRANK J. MASCI,<sup>22</sup> ADAM A. MILLER,<sup>23,24</sup> JAMES D. NEILL,<sup>9</sup> REED RIDDLE,<sup>10</sup> MICKAEL RIGAUDT,<sup>25</sup> BEN RUSHOLME,<sup>22</sup> MAAYANE T. SOUMAGNAC,<sup>26</sup> AND YUTARO TACHIBANA (後永剛博)<sup>27,28</sup>

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<sup>14</sup>Deutsches Elektronen-Synchrotron, Platanenallee 6, D-15738, Zeuthen, Germany

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<sup>19</sup>Department of Physics, University of California, Santa Barbara, CA 93106, USA

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02608v1 [astro-ph.HE] 7 Sep 2018

The first TDE in ZTF (+ N more in the pipeline....)

... and also being used through public endpoints.



# Performance

- Throughput

- Producing 600k – 1.2 million alerts per night
- Typical alert size is ~60 kB; nightly volume can amount to over 70GB
- Ran > 2M alerts/night w/o issues
- Demonstrated transfer rates of up to 80MB/s (80k alerts/minute)

4 GB	2 vCPUs	80 GB	4 TB	\$20/mo \$0.030/hr
------	---------	-------	------	-----------------------

- Latency

- 20 minutes end-to-end latency, entirely dominated by data reduction time.
- Packaging latency: 6 seconds
- Kafka-to-Kafka single-packet transmission latency: ~10s of ms (entirely bandwidth limited)

# Operations

- Deployment
  - Started with a 3-node (Docker based) Kafka cluster
  - Found the system reliable enough to simplify the config to a single-node “cluster”
  - Now running on a 6-core/16 GB RAM/320 GB VM (note: 2-core/4GB entirely sufficient!)
- Reliability
  - Very stable: no public endpoint downtime since June 1<sup>st</sup> launch.
  - Shaky in the commissioning period (some hardware issues, configuration mismatches)
  - One instance of data corruption when “exotic” configurations were attempted (1:20M event)
- Effort
  - ~6 FTE-months (would be a ~week now)

# Lessons Learned

- **9 months in, the system is performing beyond expectations. Excellent reliability!**
- The learning curve is steep.
  - A consequence of the Confluent's' business model
  - A number of configuration settings are correlated, easy to deploy the system inconsistently w/o realizing.
  - But we now know how to do this.
- Kafka was initially conceived as an “intra-company” technology. Some features are still in their infancy (user management, accounting, etc.)
- Monitoring could be better.
- On-the-wire format could be made even more compact.
- Swatting 1-in-20M heisenbugs is hard, but not impossible.



# Implications beyond ZTF

- The same technologies are baselined to be used for distribution of LSST alerts.
- **At-scale, fault-tolerant, reliable alert distribution for LSST is within reach.** We've already observed throughputs of up to 60% of LSST's predicted alert rate (~40% in terms of bytes transferred).
- **We hope that ZTF experiences can inform the evolution of standards in this area.**

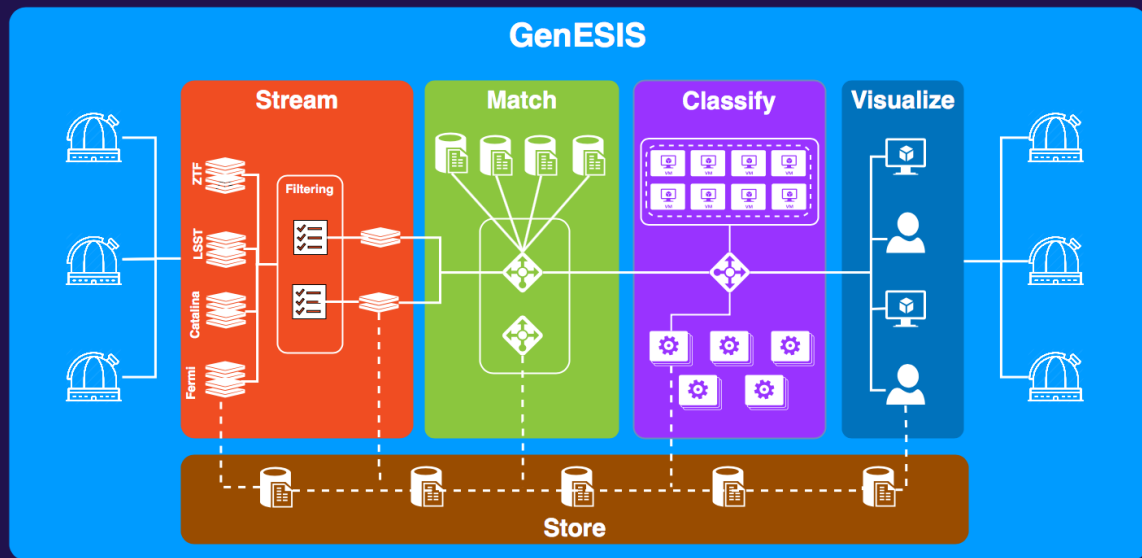
*Details in Patterson et al., in press (PASP special issue on ZTF)*

# Looking Ahead: GenESIS: General Event System for Inference in Science



A cloud-native platform for searching through millions of astronomical events or sources, combining these sources with our existing knowledge, classifying the events, and storing and updating our knowledge of the astronomical nature of the event.

Coming in 2019.



# Join Us!

## *DIRAC Data Engineering Group*

*We're a collaborative incubator that supports people and communities researching and building next generations of software technologies for astronomy.*

*We emphasize cross-pollination with other fields, the industry, and delivering usable, community supported, projects.*



DATA INTENSIVE RESEARCH IN  
ASTROPHYSICS AND COSMOLOGY

## Research Associate- Zwicky Transient Facility

In this position, you will develop new tools for the ZTF alert stream, use them in your own scientific research, and help others to do the same. You will contribute to open-source software packages and facilitate hackathons and data challenges. An interest in developing expertise in cloud computing, real-time stream processing, and distributed databases is welcome.

<https://zwicky.tf/nzs>

+ **two DIRAC Postdoctoral Fellows** to expand the frontiers of astronomical systems and algorithms.

<https://zwicky.tf/0cz>

UNIVERSITY *of* WASHINGTON

# Backups



# Serialization: Apache Avro



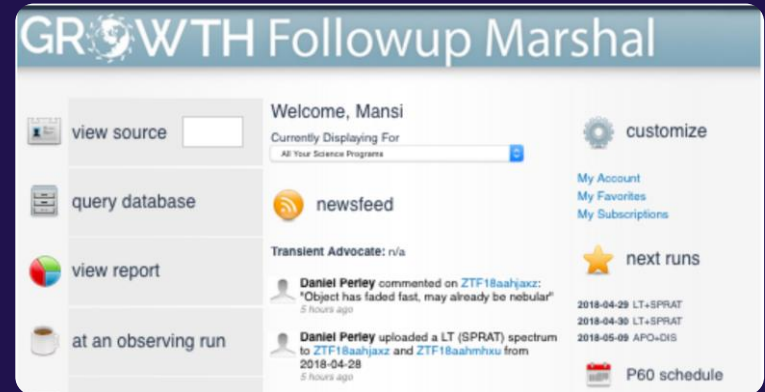
**Fast parsing with structured messages**  
**Strictly enforced schema (with evolution)**

**Allows transport of arbitrary data (incl. images)**  
**Schema always included with data when at rest**



# Some More Observations

- **9 months in, the system is performing beyond expectations. Excellent reliability!**
- This should be considered a backend technology. Most *humans* will not be interacting with the streams directly.
- Example: no user should interact with Avro-formatted data directly.
- Human interaction and organization through “marshals” (aka. “TOMs”, Target-Observation Managers). This is a whole different talk...



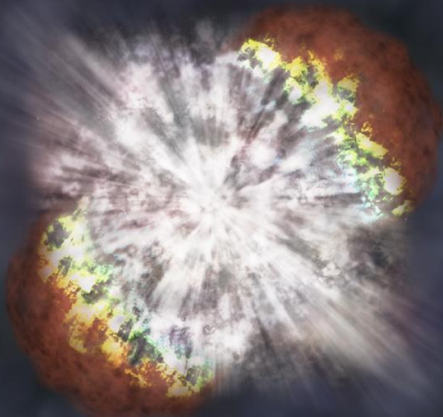
*Kasliwal et al., subm.*

# Gamma-ray bursts



NASA/GSFC

# Superluminous Supernovae



NASA/CXC



# Interstellar Objects



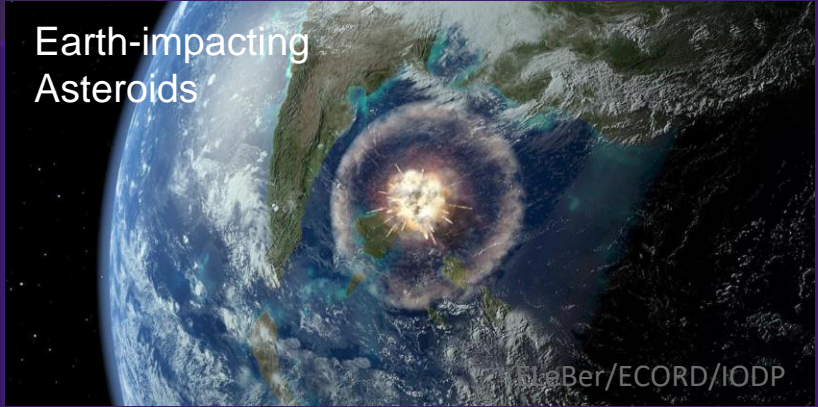
ESO/M

# Tidal Disruption Events



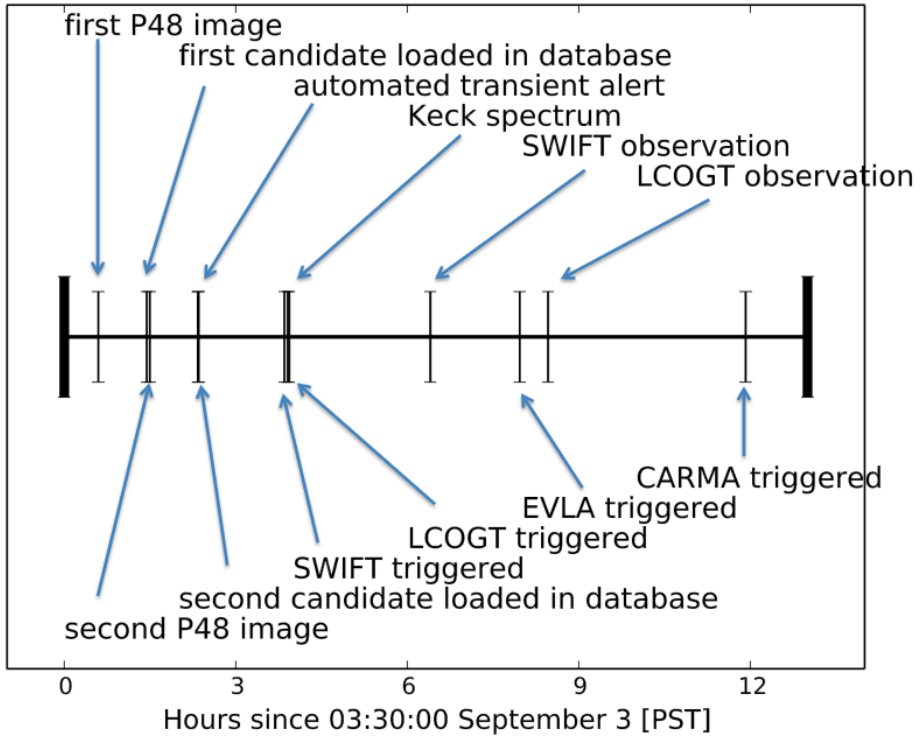
NASA/CXC

# Earth-impacting Asteroids



MaBer/ECORD/IODP

# Discover and Follow-Up



ZTF is a candidate discovery machine. These candidates need to be *contextualized, distributed, classified, and followed up*.

This talk is about a scalable framework for distribution that enables (pluggable) classification.

