Multimessenger Astronomy

4th APC meeting

10.11.2021

Marek Kowalski for the Gamma and Neutrino groups

Multimessenger Astronomy @ DESY

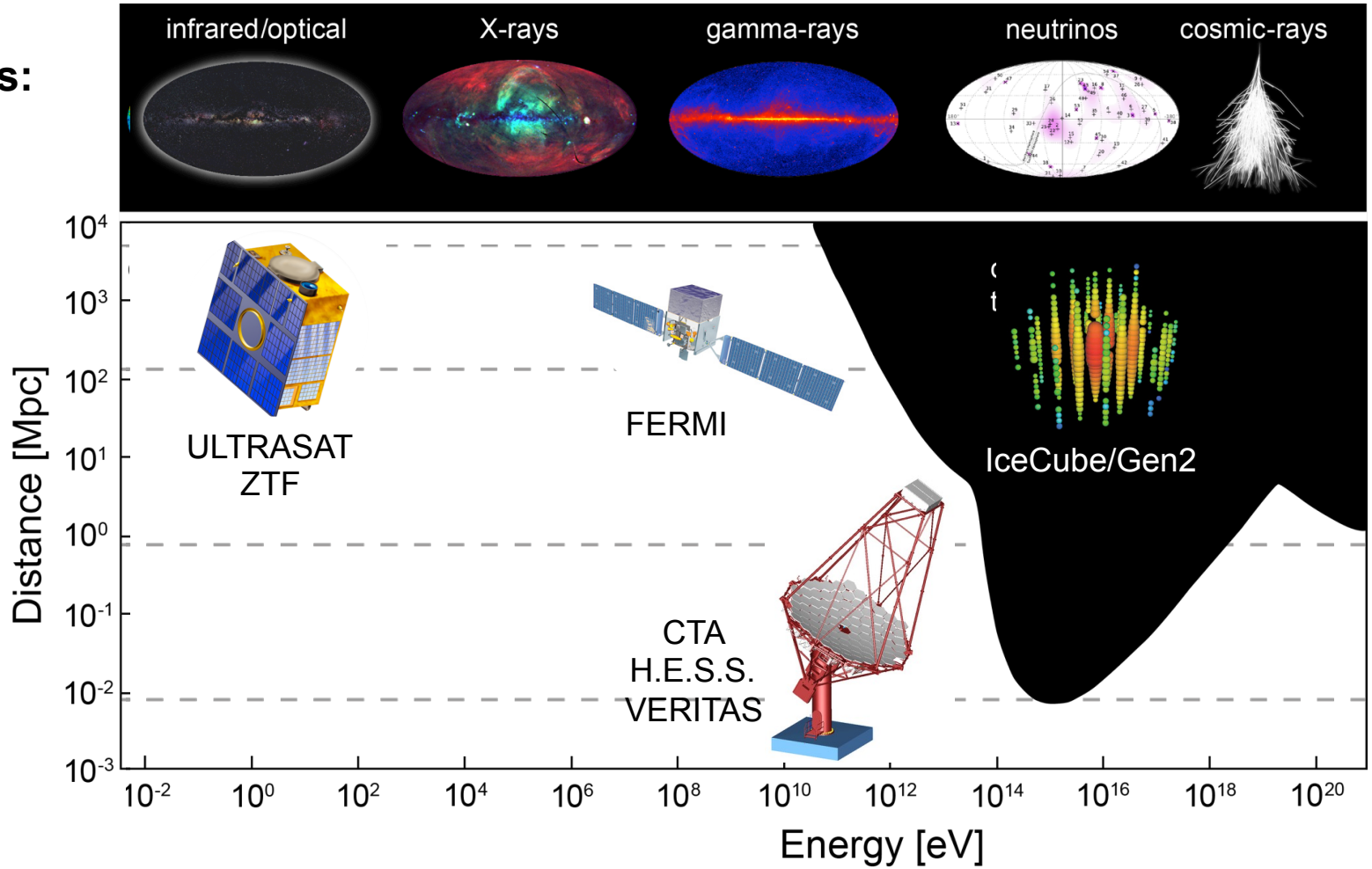
Exploring the High-Energy Universe

Focused research program at DESY based on strong observational pillars:

- Gamma-ray astronomy
- Neutrino astronomy
- (future GW astronomy)

Multimessenger Astronomy connects all and promises (and delivered) many novel discoveries.

Besides our main research directions, we invest into auxiliary data (e.g. ZTF, ULTRASAT) and tools (e.g. AMPEL) to maximize our impact.



Science Highlights

An example: another TDE in coincidence with an IceCube neutrino

- Paper on first TDE (AT2019dsg, arXiv:2005.05340) currently under review.
- Meanwhile, we have a second coincidence:
  - AMPEL detected object in ZTF stream:

2019TNSTR.771....1N 2019/05

ZTF Transient Discovery Report for 2019-05-13

Nordin, J.; Brinnel, V.; Giomi, M. *and 4 more*

  - Neutrino coincidence identified through AMPEL:

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TITLE:   GCN CIRCULAR
NUMBER:  27872
SUBJECT: IceCube-200530A: Candidate Counterparts from the Zwicky Transient Fa
DATE:    20/05/31 14:13:01 GMT
FROM:    Simeon Reusch at DESY  <simeon.reusch@desy.de>
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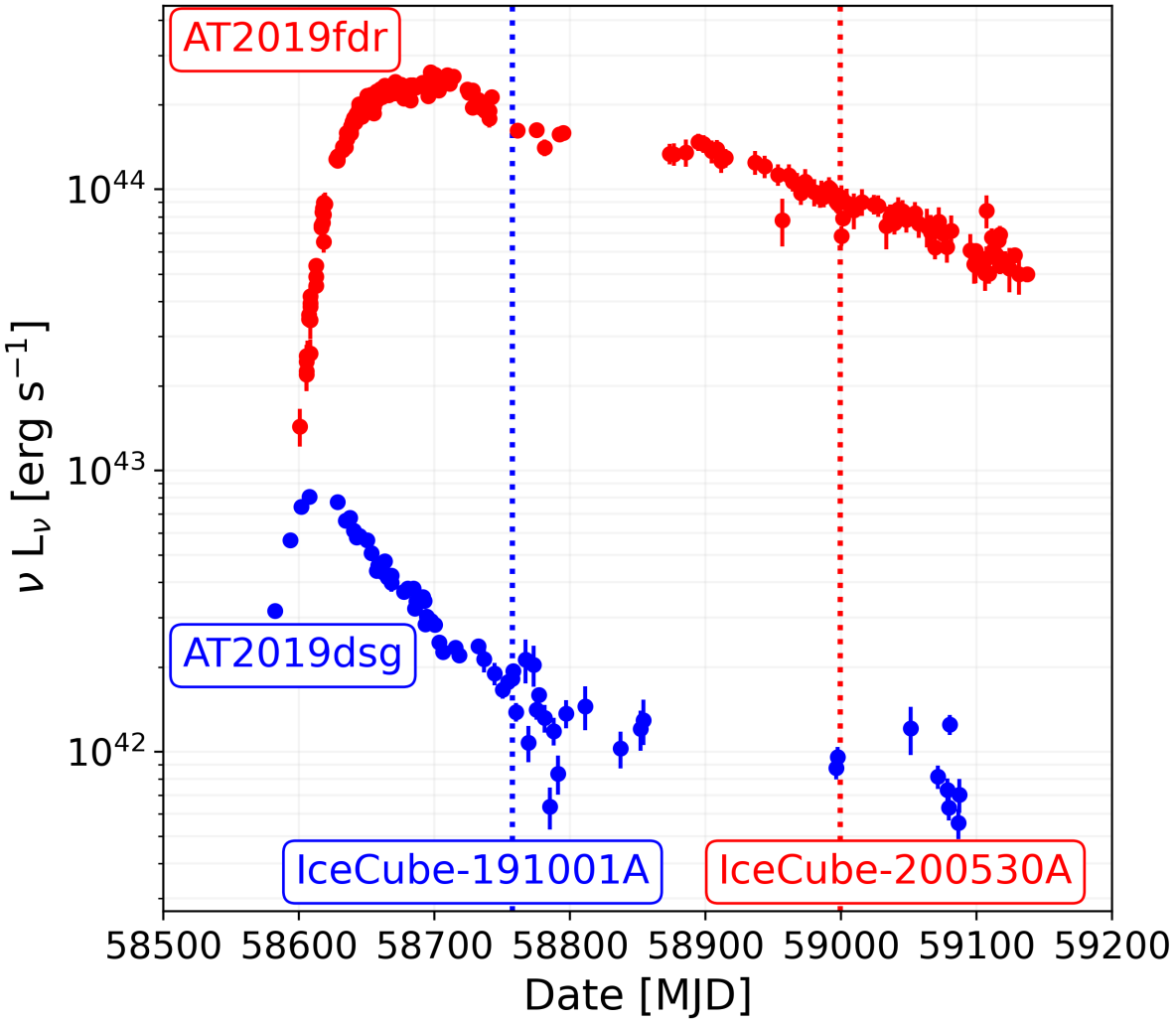
  - Classification by ZTF a likely TDE (2010.08554)
  - Paper in preparation (S. Rauch et al.), with modeling contributions by K. Murase and Walter Winters groups.

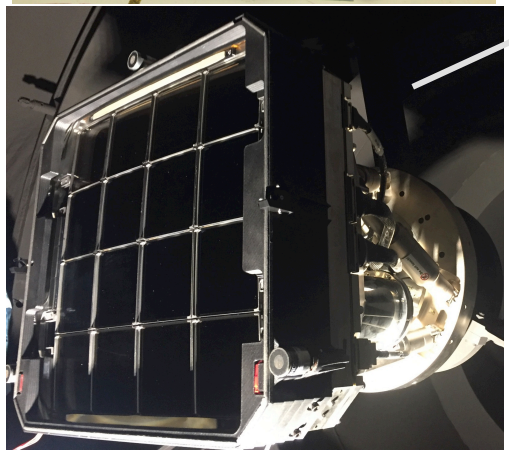


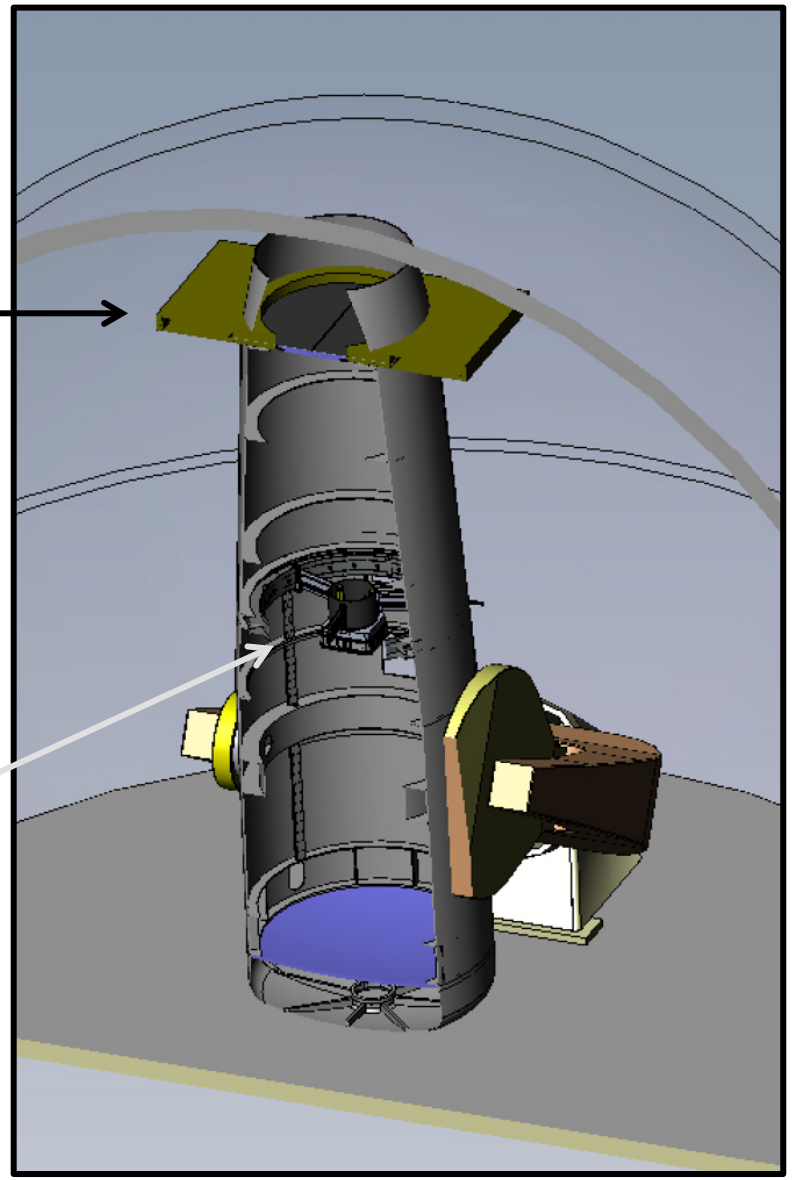
For more context, see talk by R. Stein tomorrow morning.

Zwicky Transient Facility I

DESY in-kind:
largest shutter
ever build

a new camera
with 576 Mpixels
and **47deg²** FoV

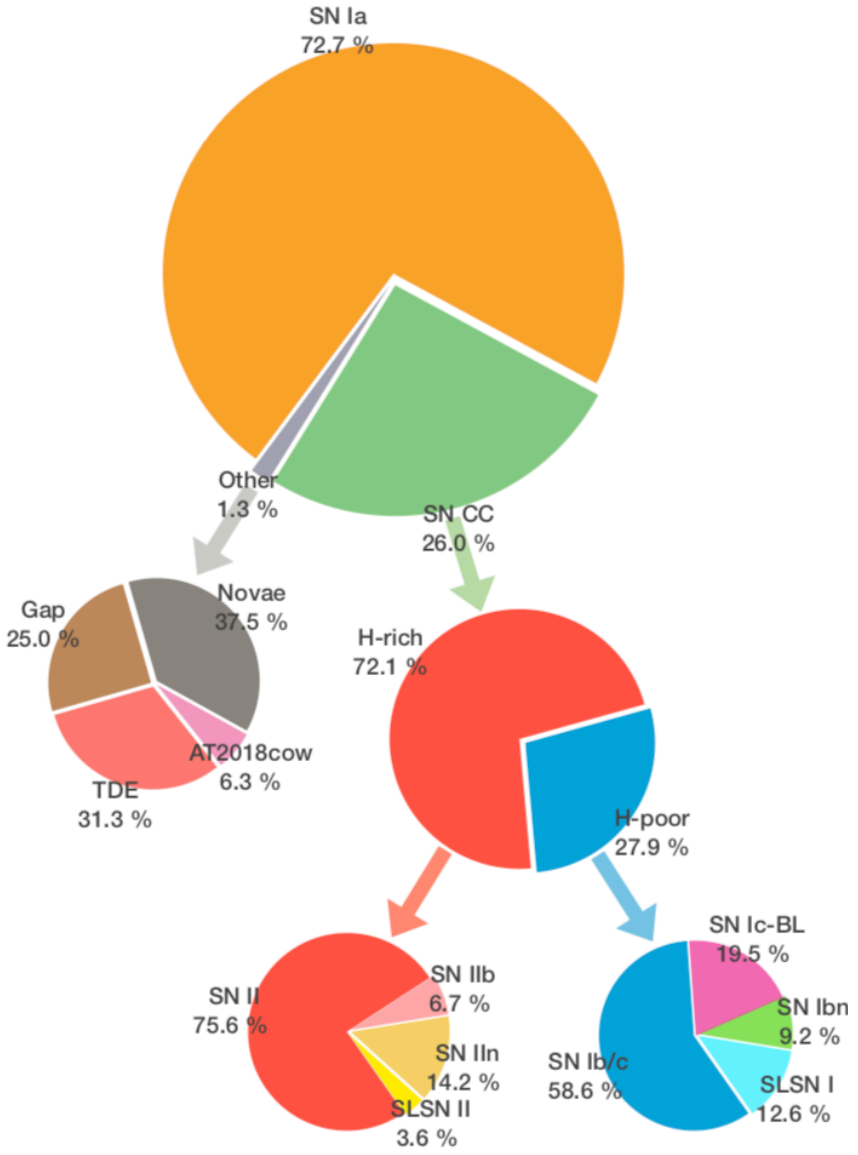




Zwicky Transient Facility I

Survey: March 17, 2018 – Sept 30, 2020

- 929 nights – data taken on 734
- 380,000 exposures
- 300 million alerts
- 3 Data Releases: 5.6B sources (gri)
- > 90 publications – 1800 citations, 5200 reads
- Almost 5000 SNe, > 3000 Ia, > 1000 II; > 2000 in TNS
- 25 TDE, 10 CLAGN, Neutrino from TDE
- 19 ultracompact double degenerate binaries (4 / 8 < 15 min)
- Asteroids (e.g. 180 NEAs), comets (16 outbursts, 4 detected)
- Atiras, Vatira, but no Planet 9
- No NS-NS or BH-NS EM counterpart but a BH-BH?



Flux-limited survey, Perley et al 2020

Summary by M. Graham, Project scientist, https://sites.astro.caltech.edu/~srk/ZTF/CSAC_2020.html

Zwicky Transient Facility II

Survey: Oct 1, 2020 – Sept 30, 2023

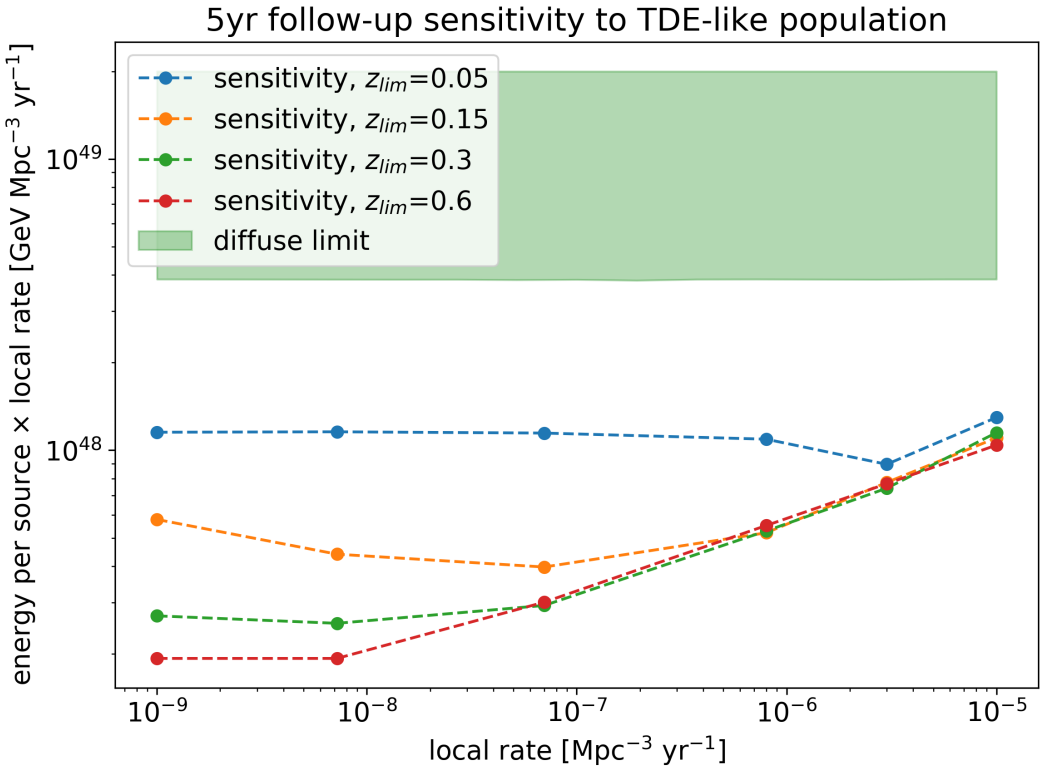
"*I soon became convinced... that all the theorizing would be empty brain exercise and therefore a waste of time unless one first ascertained what the population of the universe really consists of*" – *Fritz Zwicky*

- Discovery is purely a function of technology & algorithms -> very efficient through automatization
- Much of the hardware (P48+P60 SEDM) and software exists! Public part (50%) funded through a $5M NSF MSIP grant
- In addition, private survey (30%) by the partnership:
  - Weizmann Institute of Science, Israel
  - Oskar Klein Centre, Sweden
  - Humboldt University & DESY, Germany
  - INP23, France
  - Trinity College Dublin, Ireland
  - University of Maryland, College Park
  - University of Wisconsin, Milwaukee
  - Lawrence Livermore National Laboratory • IPAC
  - Caltech
  - TANGO, Taiwan

ULTRASAT

Strategic developments beyond the instrumentation

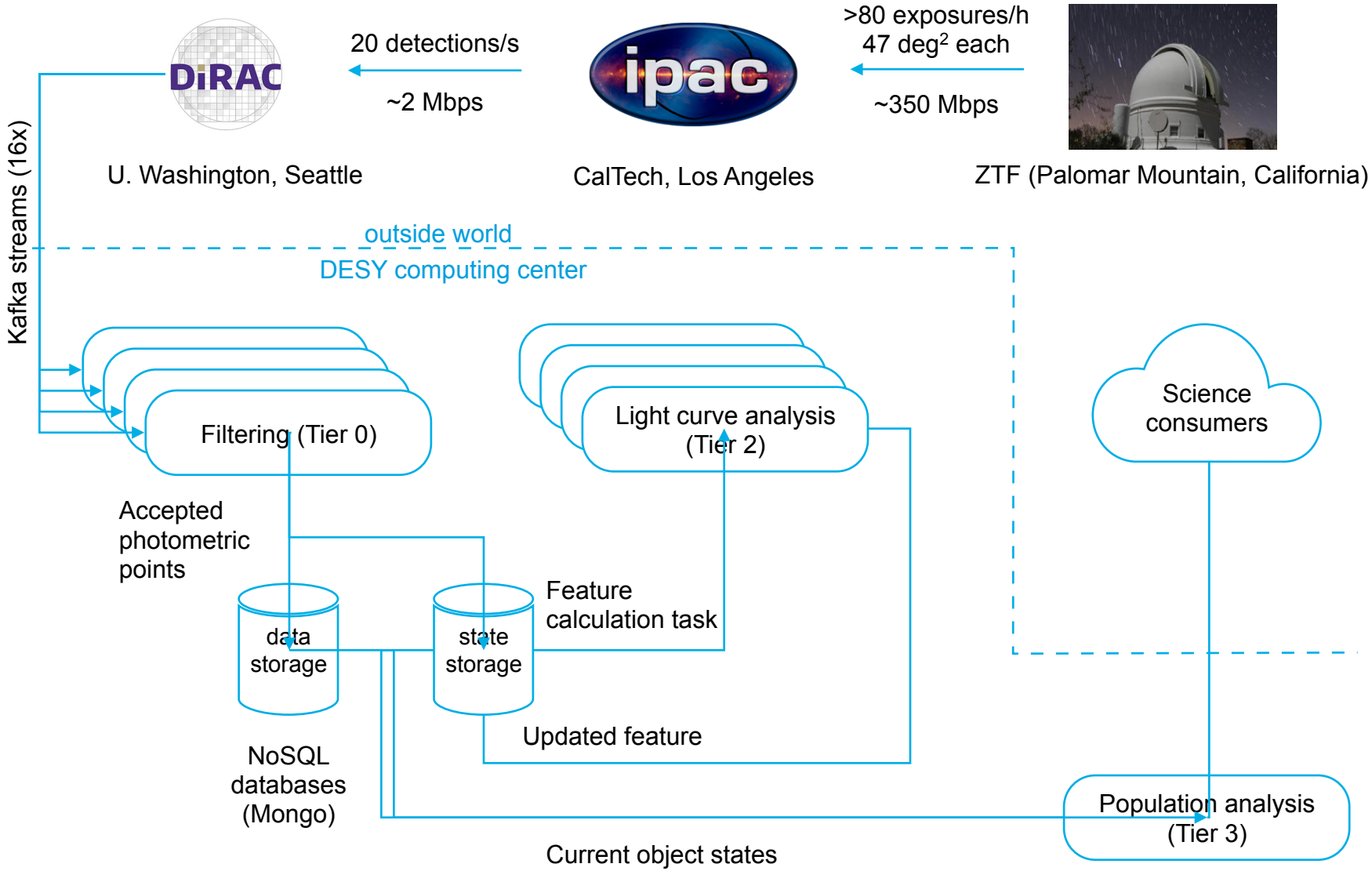
- Science Board (incl. Berge, Kowalski) currently establish working groups to further develop science case and survey.
- Currently admitting Israelian members based on proposed contributions.
- US participation in ULTRASAT is being negotiated with NASA LSST part of package, incl. two LSST PI-slots @DESY
- DESY groups are currently preparing a document summarizing the key science opportunities, including
  - Neutrino sources
  - GW sources
  - GRBs
  - AGN variability
  - Cosmology
  - …



Neutrino follow-up sensitivity of ULTRASAT (red line) to TDEs

AMPEL @ DESY

Real-time analysis of Zwicky Transient Facility data



AMPEL:

- identified thousands of SNe and tens of TDEs through dedicated ZTF filters.
- Automated follow-up for very young SNe within 30 min now routine
- Allowed systematically search for GW and neutrino counterparts (e.g. Kasliwal et al, arXiv:2006.11306)

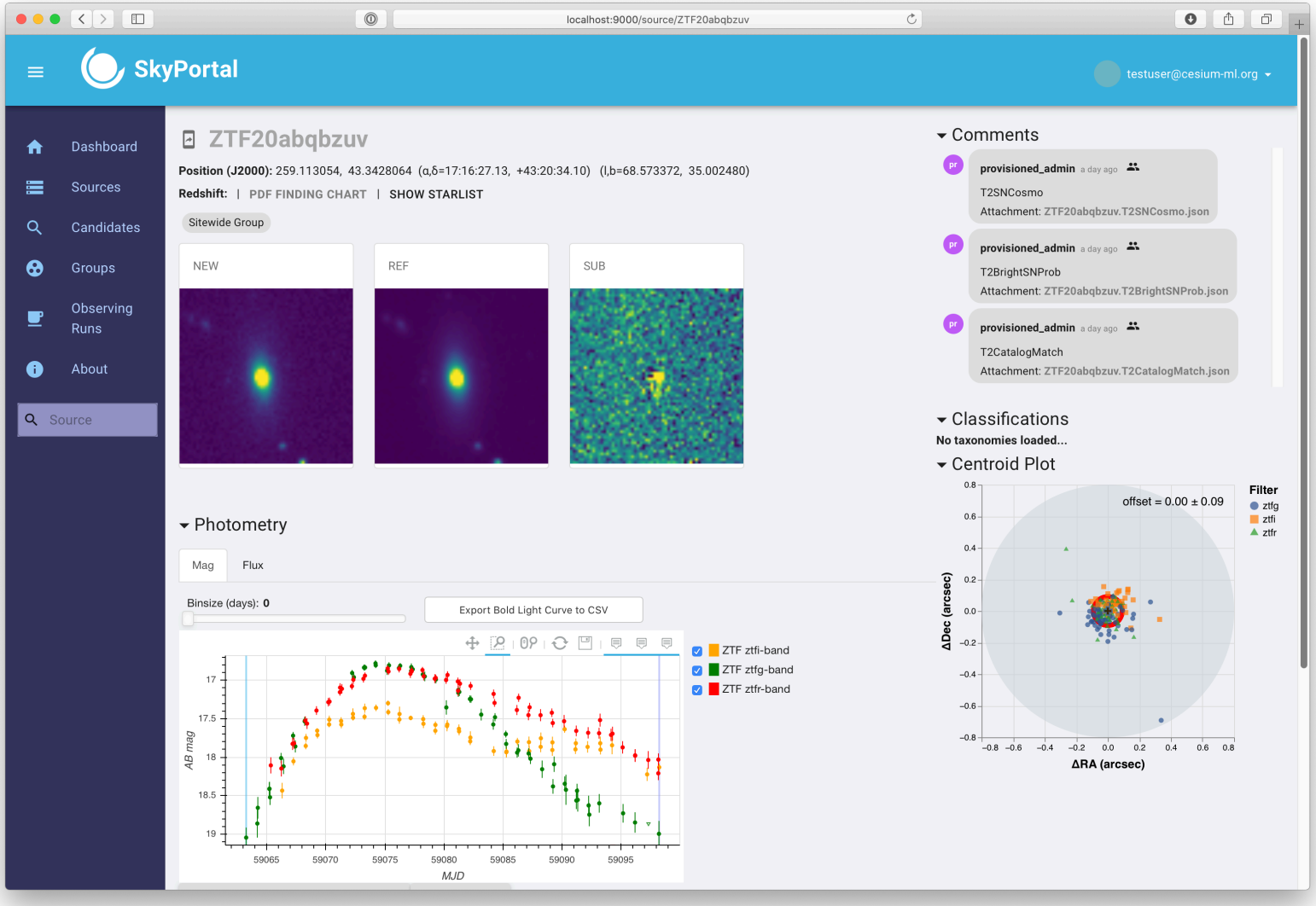
Major upgrade of AMPEL framework

Applying lessons learned in ZTF I

Ampel v0.6		Ampel v0.7
Single-instrument alert streams	Generality	Heterogenous alert streams
Low-level data handling specific to ZTF-like photometry		ZTF- and photometry-specific components cleanly separated
Light curve analysis	Flexibility	Analyze individual data points, collections; chain computations
Configuration at run-time	Usability	Robust configuration system with ahead-of-time validation
Operating since June 2018		*In pilot phase since November 1*

AMPEL integration with SkyPortal

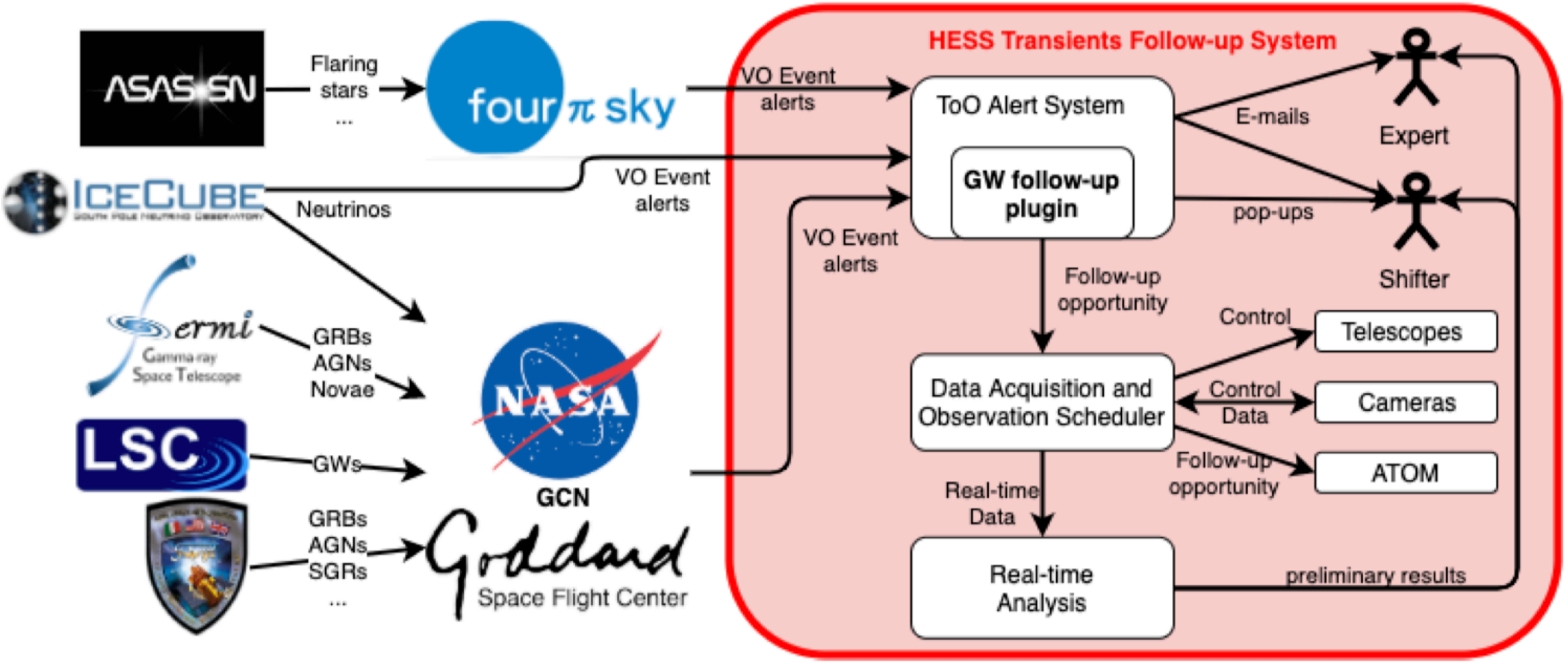
Visualization of AMPEL output



This appears to be a good solution for ULTRASAT and LSST as well.

Other Multimessenger Software: GW follow-up with H.E.S.S.

https://arxiv.org/abs/2010.16172



System will also be the basis for the CTA transient handler system, which DESY is signed up to deliver to CTA

Adjusting multimessenger astronomy at DESY

Anna Franckowiak moved to Bochum 1.10.2020

- Anna Franckoiwak is now building up a large research group at U. Bochum (several University positions + significant start-up funds). The majority of her research topics remain of strategic importance to DESY.
- Experience at DESY remains broad, topics mostly covered by existing staff, as well as new hires (at the postdoc level).
- We are continuing to work closely with AF group on multiple areas. Members of her group are contributing to ULTRASAT and AMPEL, while we are supporting her group in the development of a LAST node (a small, robotic wide field optical observatory) for the CTA site.
- In the longer term we would like to strengthen the science harvest through tenure(-track) hires; we have started to informally explore and search for suitable candidates.

Some points for discussion

Personnel

- The AMPEL effort is lacking people. Currently ~< 1 FTE for software and operation support
- A postdoc has been hired to improve the situation (starting early next year), and a PhD graduate student position could be filled soon. A proposal to advance GW science (HILAGRO) between IN2P3 and Helmholtz was not successful, which would have helped AMPEL and allowed for GW follow-up activity
- Propose AMPEL+SkyPortal as a broker for ULTRASAT, as well as LSST public broker, and expand into the GW domain. This will require longer term support.
- Adjust to AFs move to U. Bochum – short term solution has being implemented. To fully exploit the opportunities from combining ULTRASAT, CTA and IceCube, we would profit from more senior expertise

Question: How to best improve our prospects given limited resources: E.g. expand on AMPEL, focus more on GW events in preparation of ET, look for astronomers that fit our instruments or rather our current science interests (e.g. TDE, NS merger)?