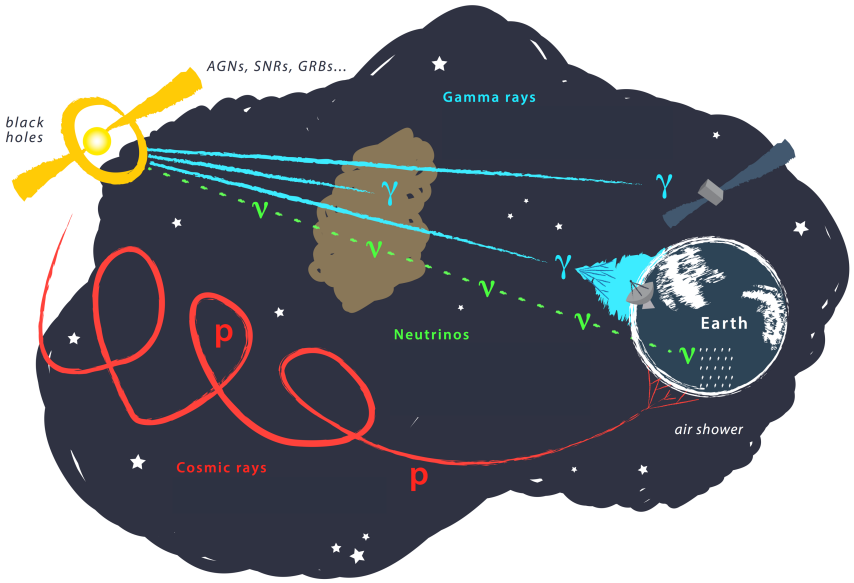
Multi-Messenger Astronomy in the Era of the Zwicky Transient Facility (ZTF)



Ludwig Rauch

THE NEW ERA OF MULTI-MESSENGER ASTROPHYSICS CONFERENCE 2019
Groningen, 28.03.2019

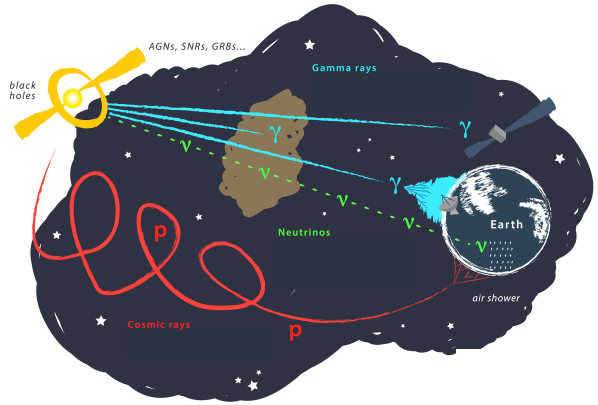
HELMHOLTZ Young Investigators

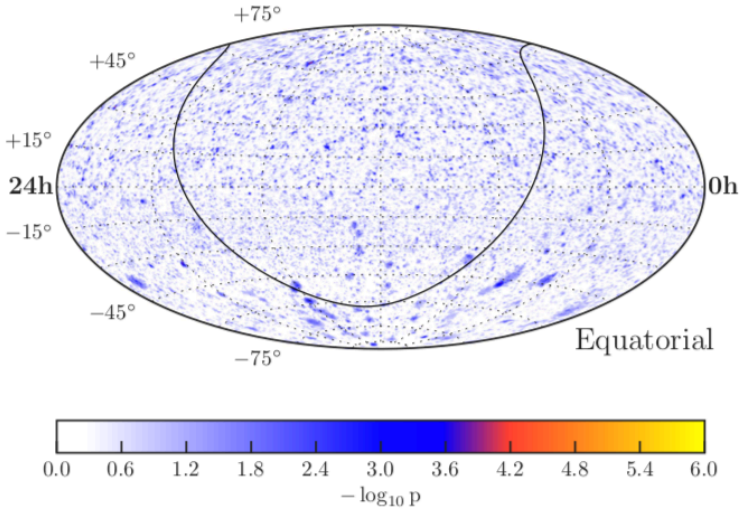
IceCube South Pole Neutrino Observatory

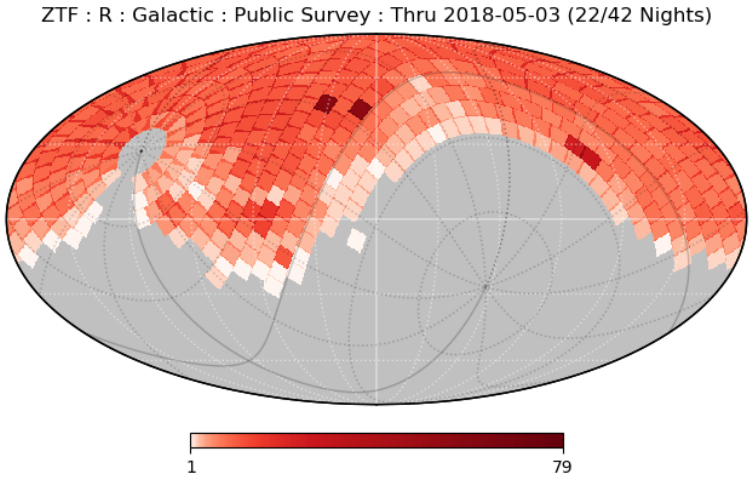
ZTF

DESY.

The Idea in Short

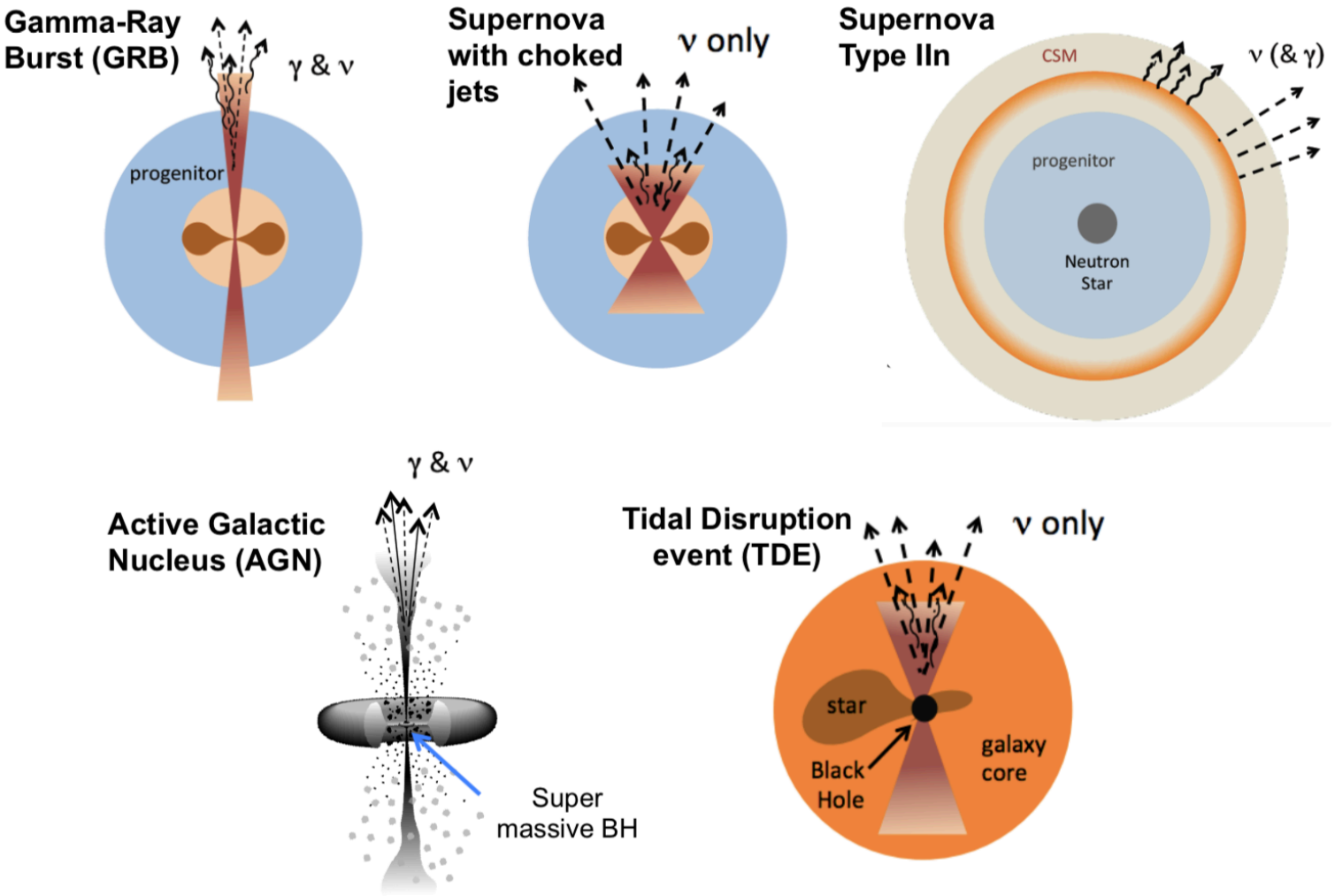






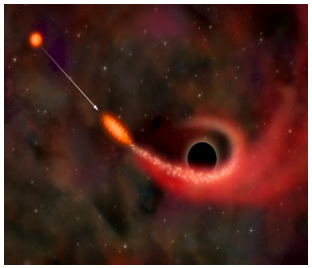
Combine two northern sky surveys in realtime

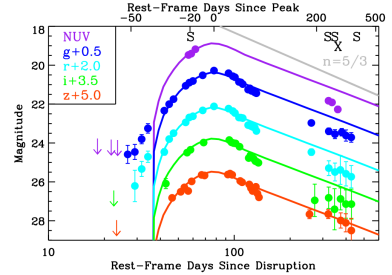
Neutrino Source Candidates



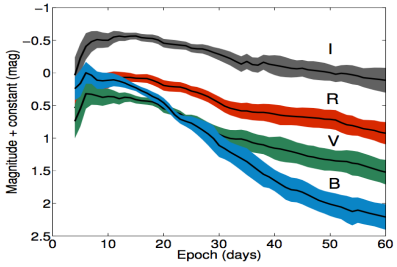
Expected Time Scales of Transients

Tidal disruption events ~1d - 100d

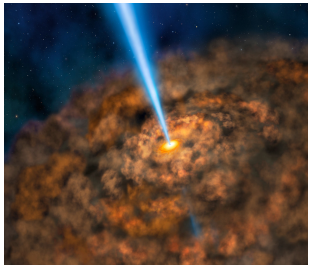


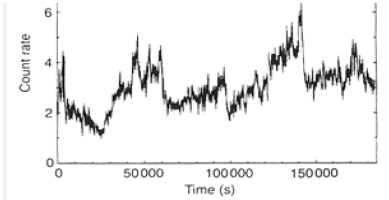


Supernovae ~100d

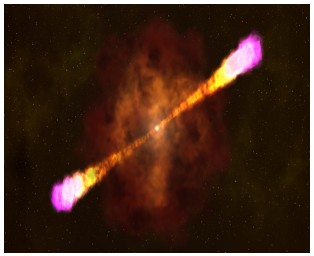


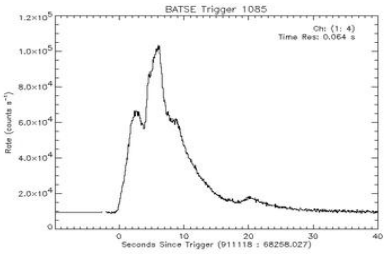
Active galactic nuclei ~1h - 100d





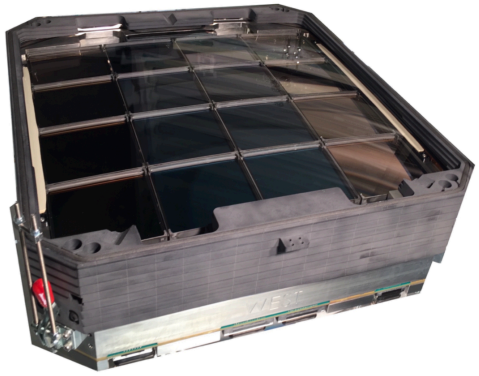
Gramma ray bursts ~10s -100s





DESY.

Zwicky Transient Facility (ZTF)



Roger Smith/Michael Feeney, Caltech Optical Observatories

P48
survey
telescope

P200
Spectroscopic
follow-up

P60
classification

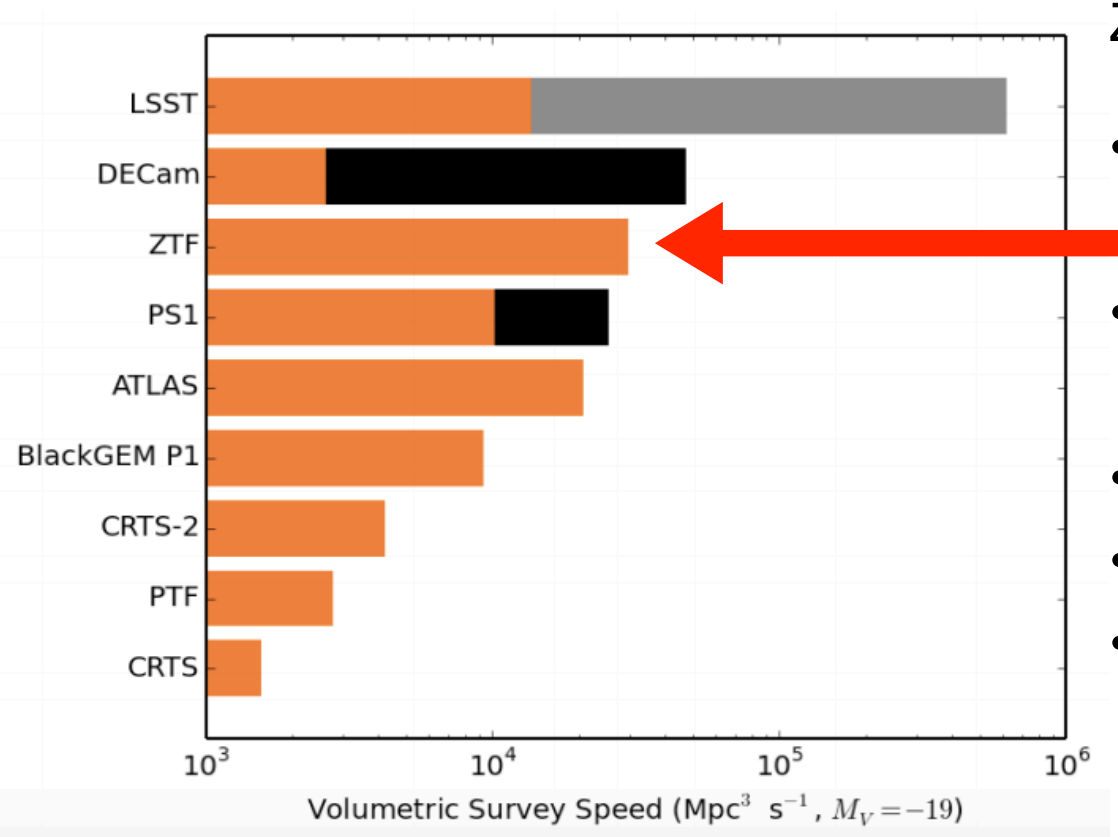
Caltech (PI: Shri Kulkarni)
University of Maryland
University of Washington
University of Wisconsin-Milwaukee
Los Alamos National Lab

Lawrence Berkeley National Lab
Oskar Klein Centre, Stockholm
Humboldt-University Berlin/DESY
Weizmann Institute, Israel
TANGO Consortium, Taiwan

Current / Future Optical Surveys

ZTF can scan the entire Northern sky every night to 20.5 mag

ZTF Spectroscopically-Accessible Transients



ZTF provides:

- Unprecedented catalogue of transients up to ~20.5mag
- Complete set of lightcurves for source identification
- All-sky coverage (3π in 8h)
- Cadence approx. 3 days
- On site spectrograph (SED-machine)

Spectroscopically-accessible

ZTF discoveries on TNS since June 2018

Spectroscopically confirmed supernovae reported to the Transient Name Server (TNS) since June 2018:

- All SN found: 1214
- **ZTF detected SN: 556 (46%)**
- ATLAS: 363 (30%)
- ASAS-SN: 157 (13%)
- GaiaAlerts: 60 (5%)
- Other Telescopes (6%)

ZTF is very competitive in detecting optical transients!

Great potential for multi-messenger astronomy

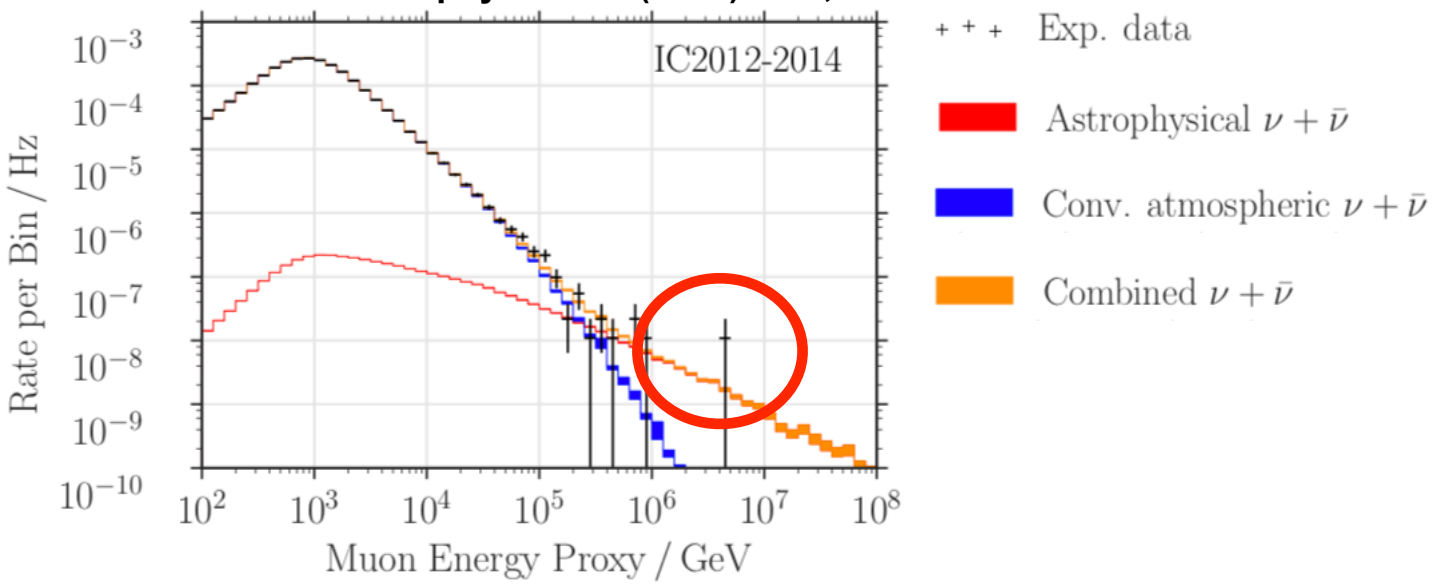
Optical Follow-Up Program of High-Energy Neutrinos

Target of Opportunity

- Follow-up of high-energy neutrinos (TeV, PeV) for early time information of transient
- Track events: (~1 deg, ~10 (28)/year with at least 50% (30%) signalness)

  ~1 pointing of ZTF covers the neutrino error circle

Astrophys.J. 833 (2016) no.1, 3



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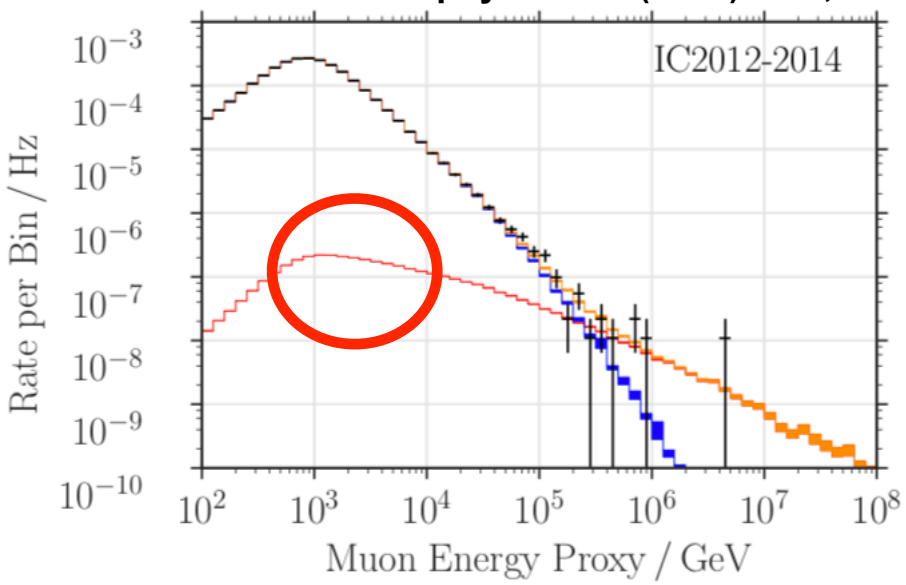
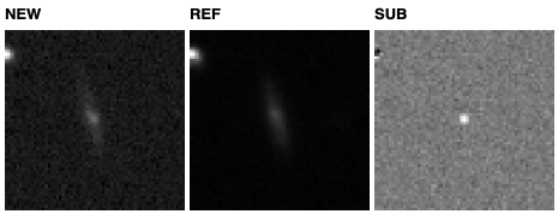


Real-Time Correlation

- Use stream of IceCube muon track neutrinos with energies of several 100 GeV
- Matching algorithm will consider:
  - Position and error circle of candidates
  - Neutrino Energy
- Stacking of signal from many sources

Real-time Neutrino Correlation with IceCube

Transient positions from ZTF



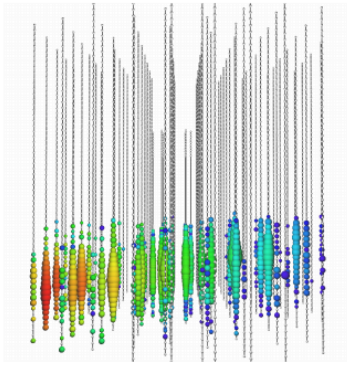
10^5 /d

AMPEL

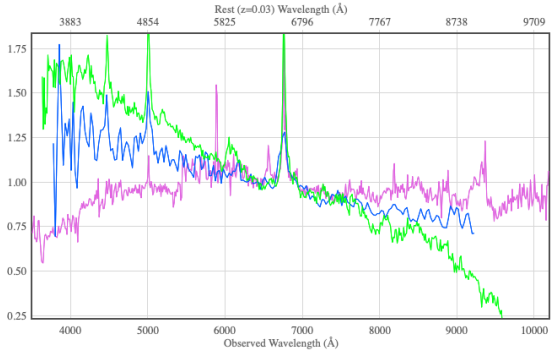
Trigger
1-2 /d

10^2 /d

Neutrino tracks from IceCube



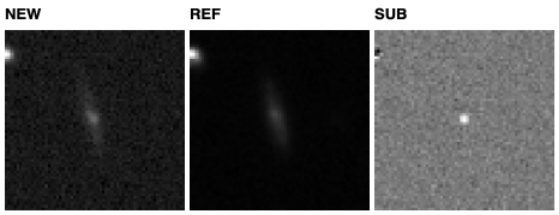
Transient Spectrum



Real-time Neutrino Correlation with IceCube

Dedicated talk tomorrow

Transient positions from ZTF



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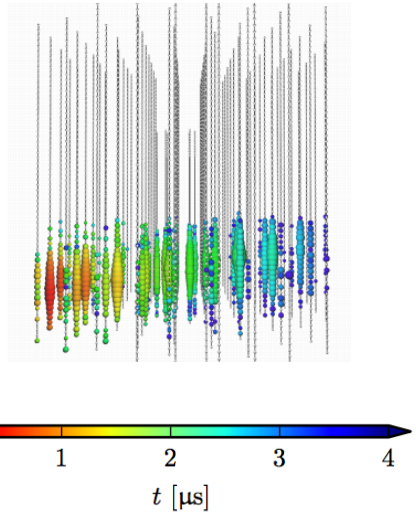
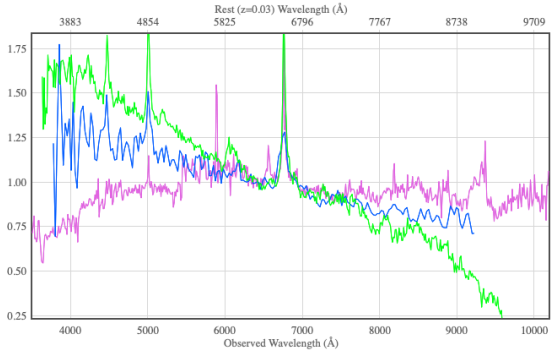
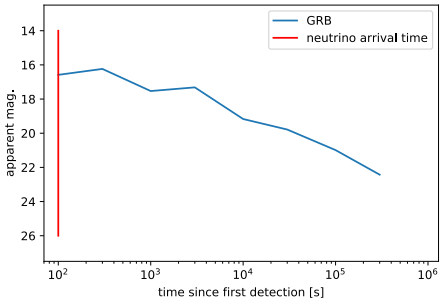


Transient Spectrum

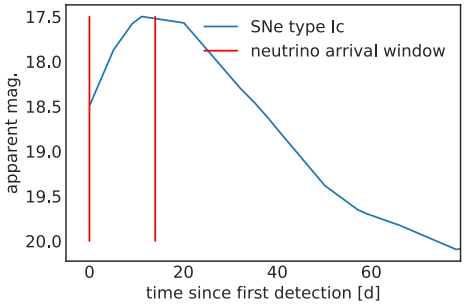


Real-time Neutrino Correlation: Primary Transient Selection



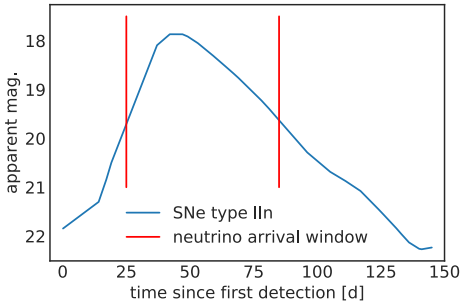
Short transients (GRB-like)

- More than 2 optical detections in < 12h
- Falling lightcurve
- Realtime maximum likelihood calculation of test statistic
- Neutrino signal at explosion time



Medium length transients (SN Ic, Kilonova)

- Time window of 2 weeks
- More than 3 optical detections
- Neutrino signal within ~100s of explosion time



Long transients (SN IIn, SLSN,TDE, AGN)

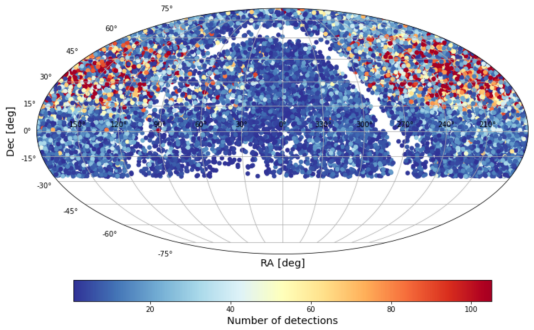
- Time window of 8 weeks
- More than 5 optical detections

Real-time Neutrino Correlation: Goal

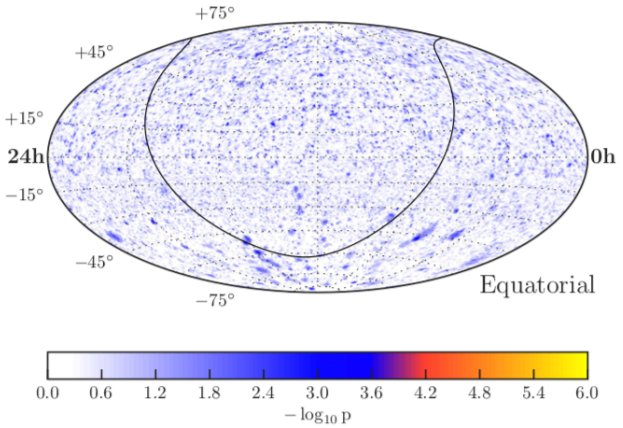
Offline Stacking Analysis

- ZTF transient catalogue:
  - Complete (magnitude-limited) catalogue
  - Fast-fading transients can be detected
  - Well-sampled lightcurves
  - Spectroscopical classification available
- IceCube neutrino sky map
  - Large statistics of high-energy neutrino events

ZTF transient catalogue



IceCube neutrino sky map



Summary

- ZTF features a 47 deg^2 field-of-view and high-cadence observations
- High classification capabilities with onsite spectrograph
- AMPEL: Software developed to manage large data streams and real-time analysis framework

<u>ZTF starts a new era for real-time multi-messenger astronomy</u>

HELMHOLTZ
Young Investigators

DESY.