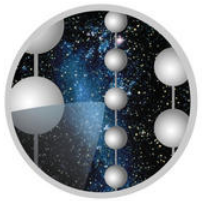
Search for High Energy Neutrinos from Populations of Optical Transients

Asterics Multi-Messenger Conference

Robert Stein
For the IceCube Collaboration

HELMHOLTZ
Young Investigators

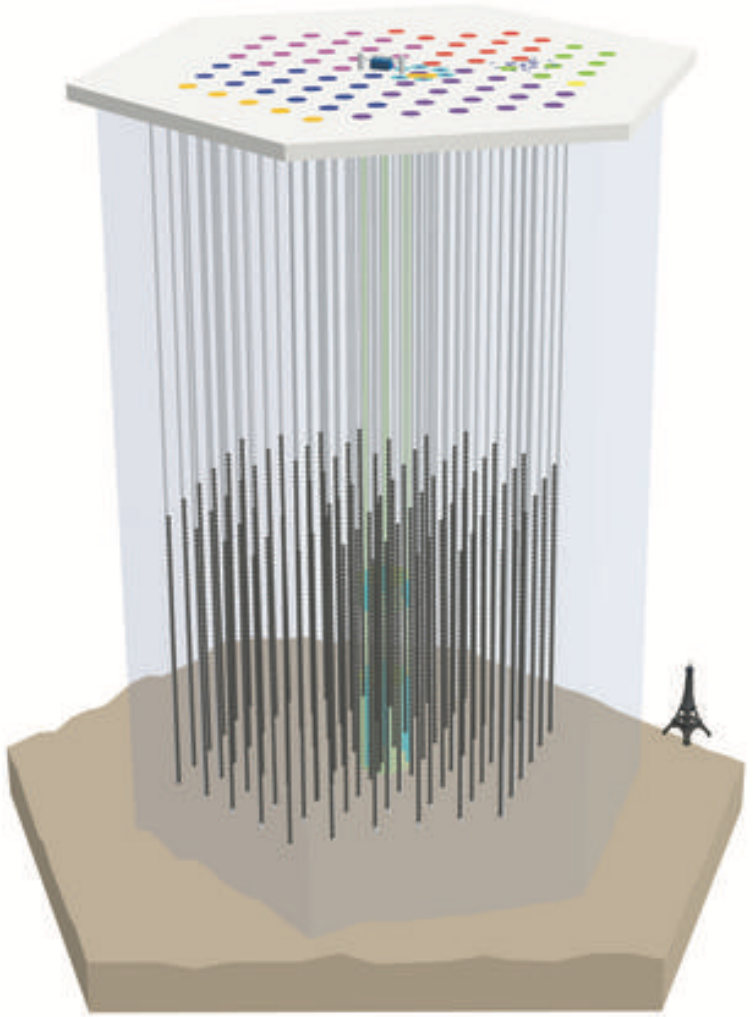


IceCube
South Pole Neutrino Observatory

DESY.

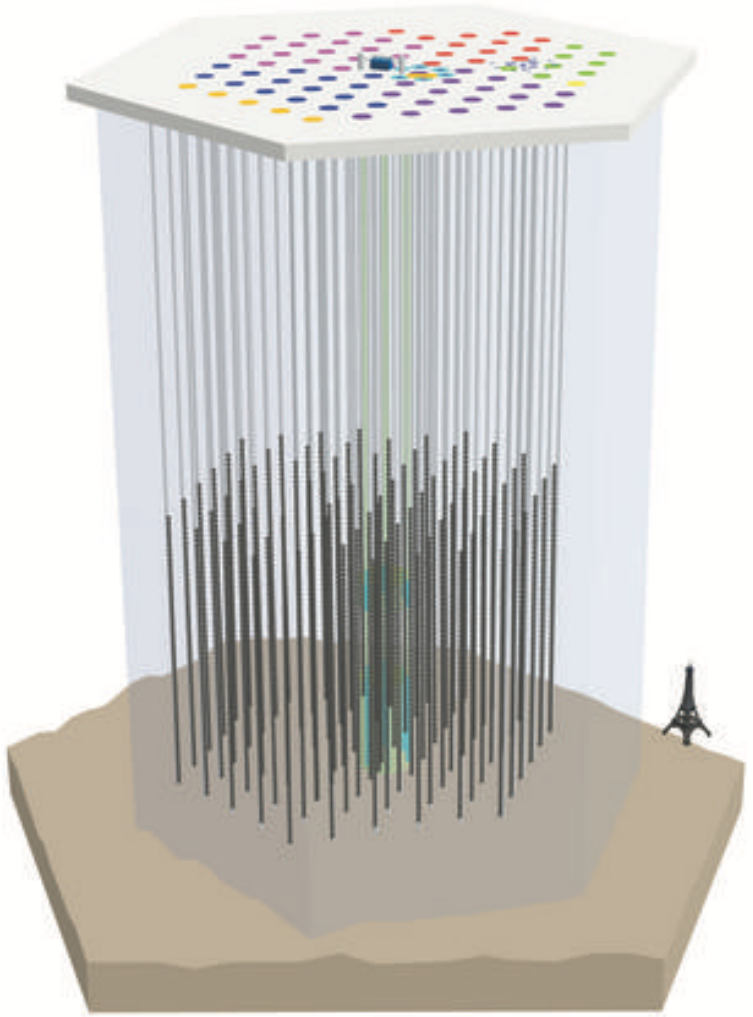
What do we know after a decade of IceCube?

- **There is a diffuse flux of astrophysical neutrinos**



What do we know after a decade of IceCube?

- **There is a diffuse flux of astrophysical neutrinos**
- **There is compelling evidence that the blazar TXS 0506+056 is a neutrino source**
- **At the same time, the cumulative flux of neutrinos from all Fermi blazars is limited to less than 30% of the total**
- **The remaining neutrinos have to come from somewhere else**



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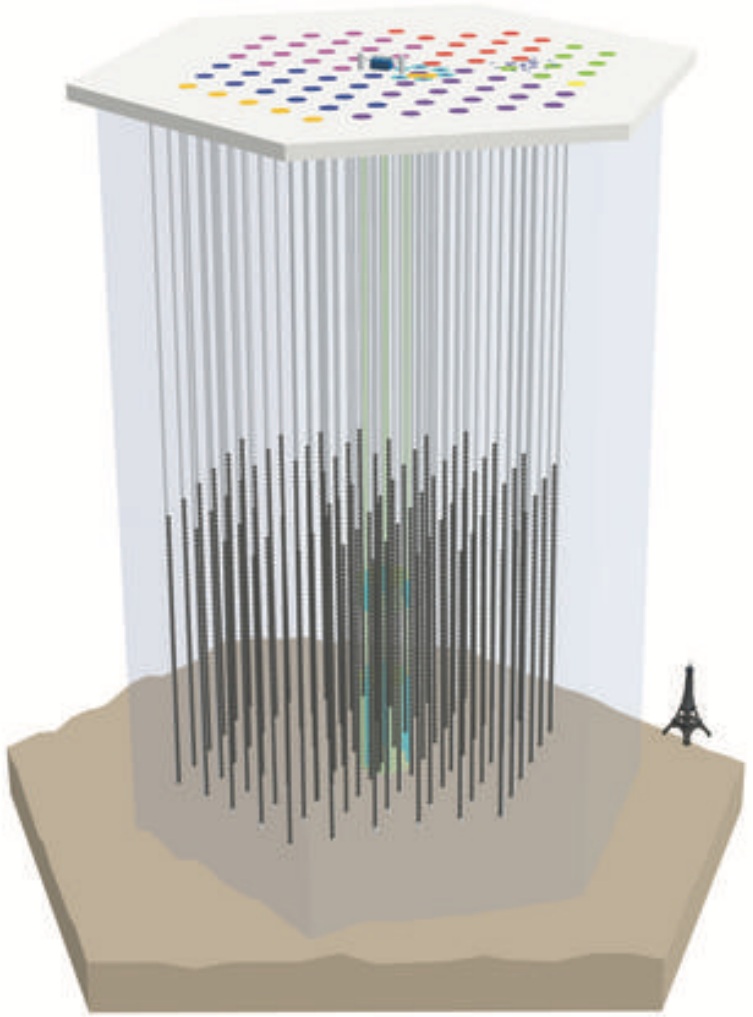
- **Neutrino astronomy is difficult**



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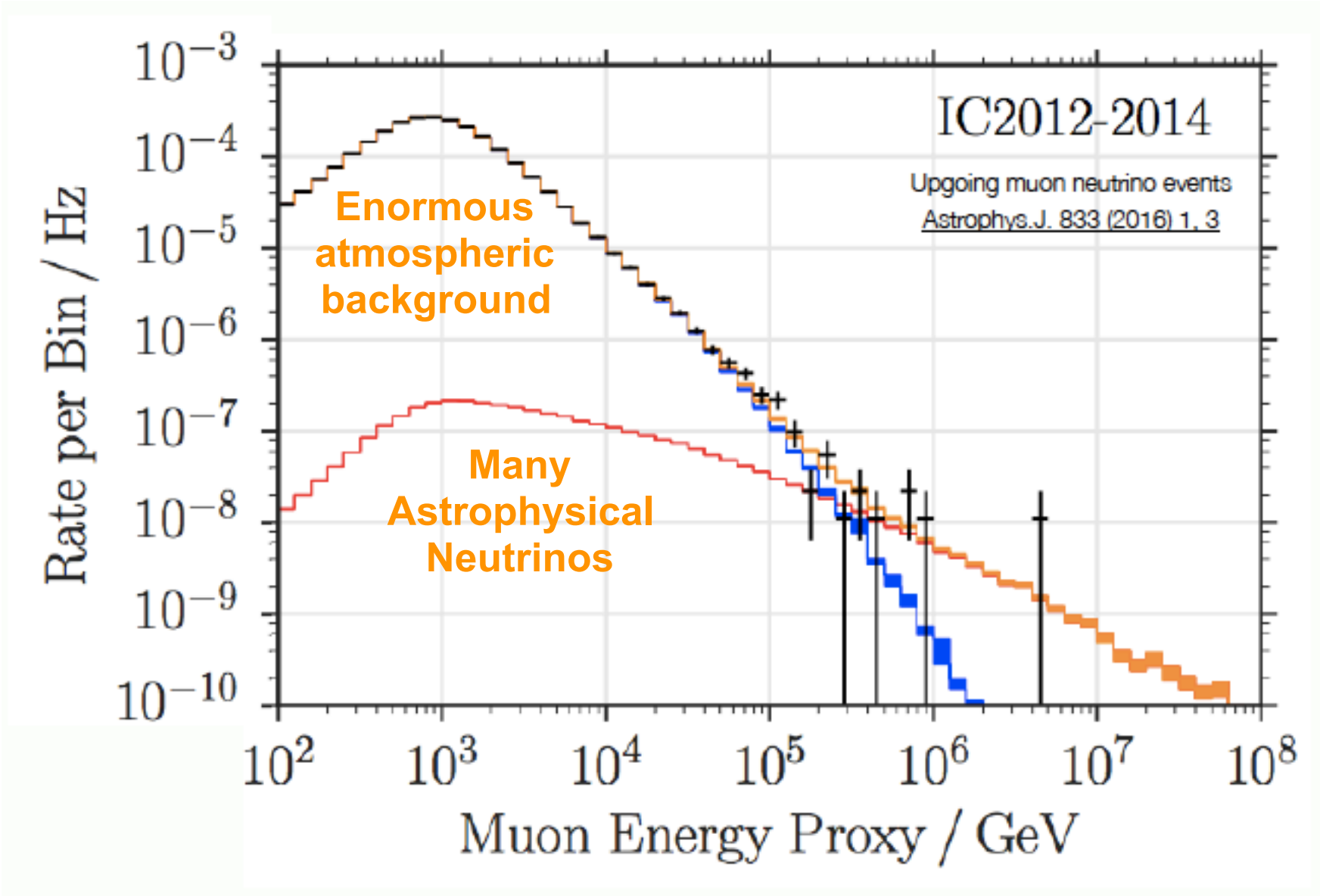

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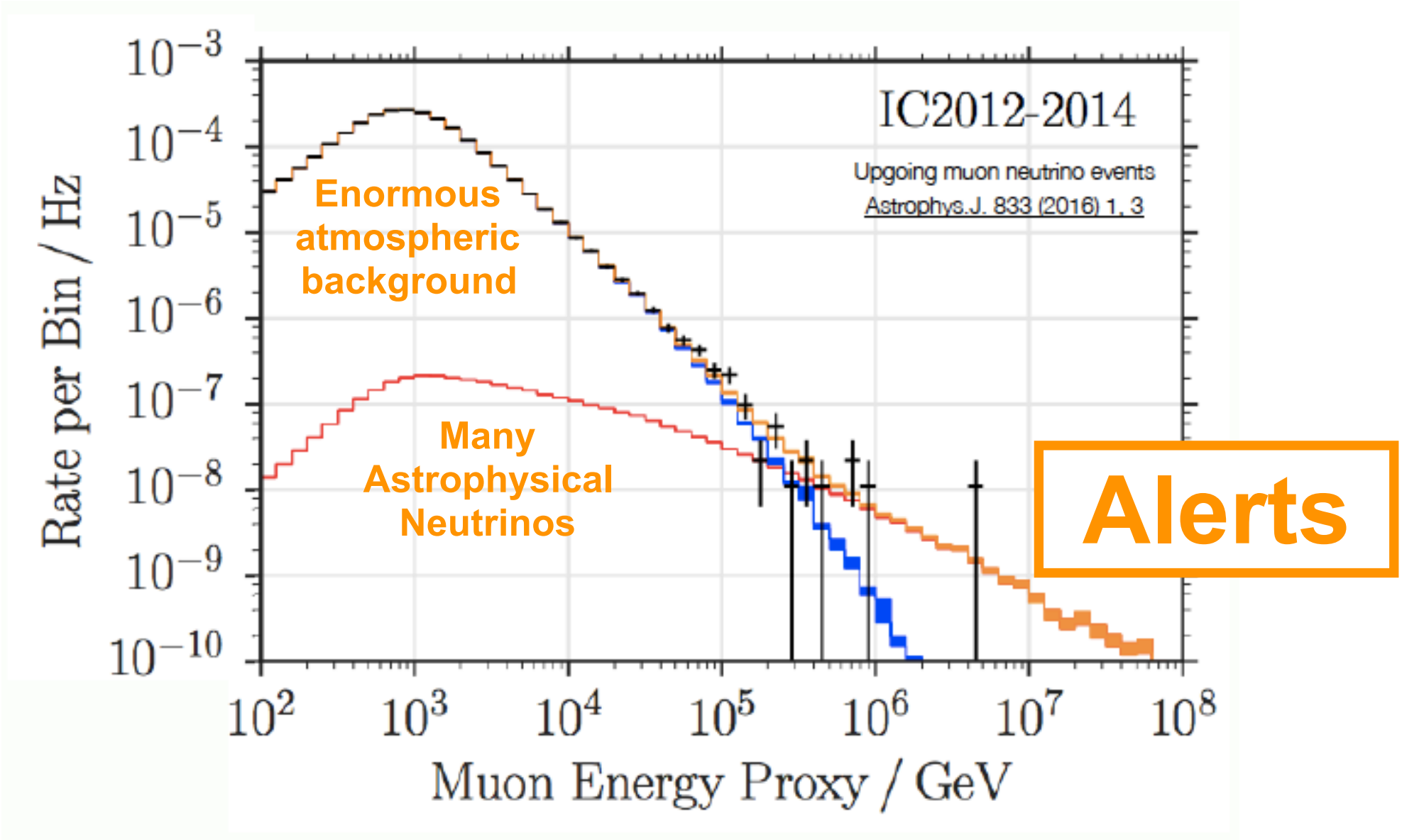

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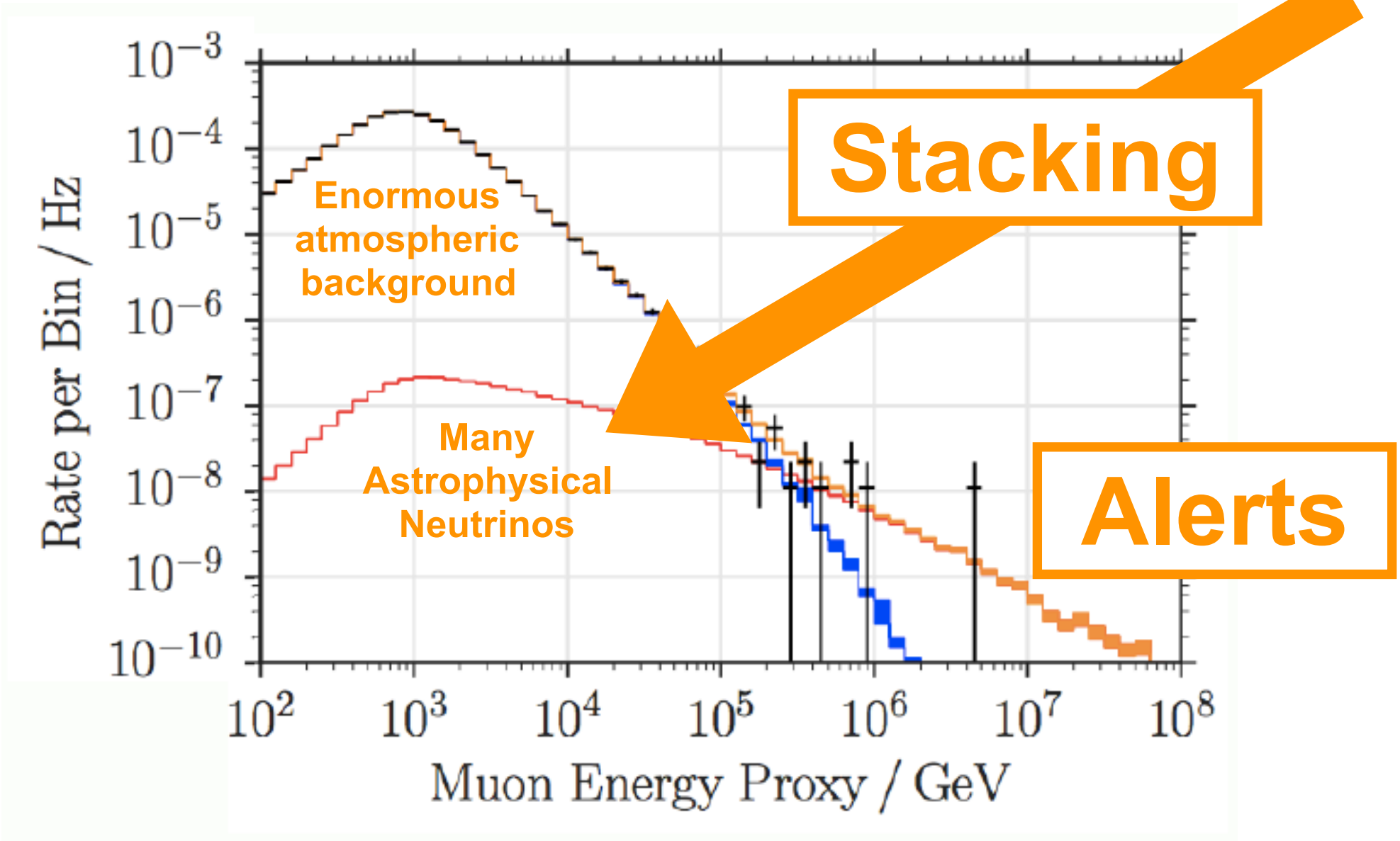
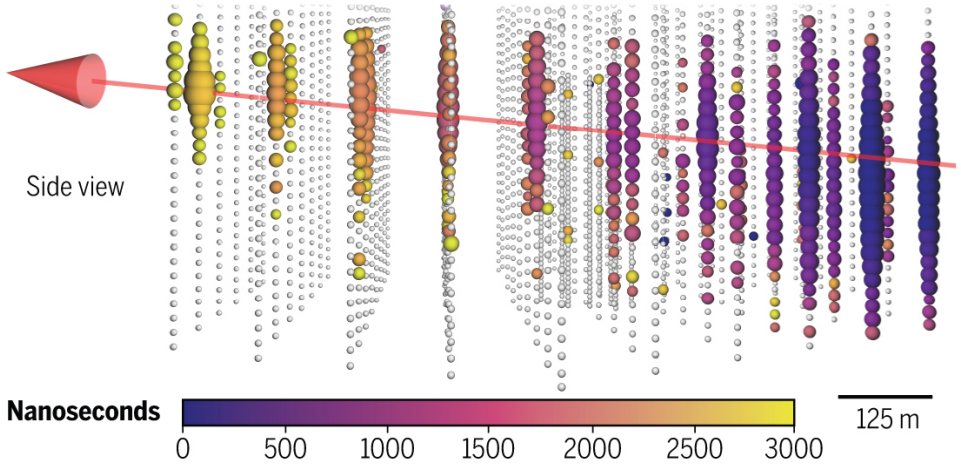


IceCube Realtime Alerts

- **High-purity neutrino filters identify neutrinos of likely astrophysical origin in realtime, then sent out via GCN to astronomers**
- **We search for counterparts, hoping for contemporaneous multi-wavelength observations of variable/transient sources**
- **IC170922A is an excellent example of this**



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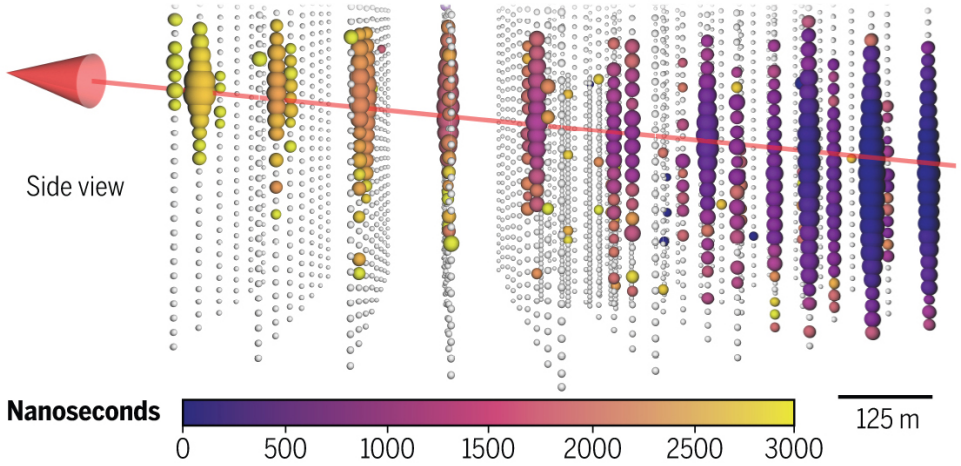

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- **However, we expect many neutrinos to come from unresolved sources. For example, of CCSNe neutrinos, only 20% are expected to come from "detectable counterparts".**

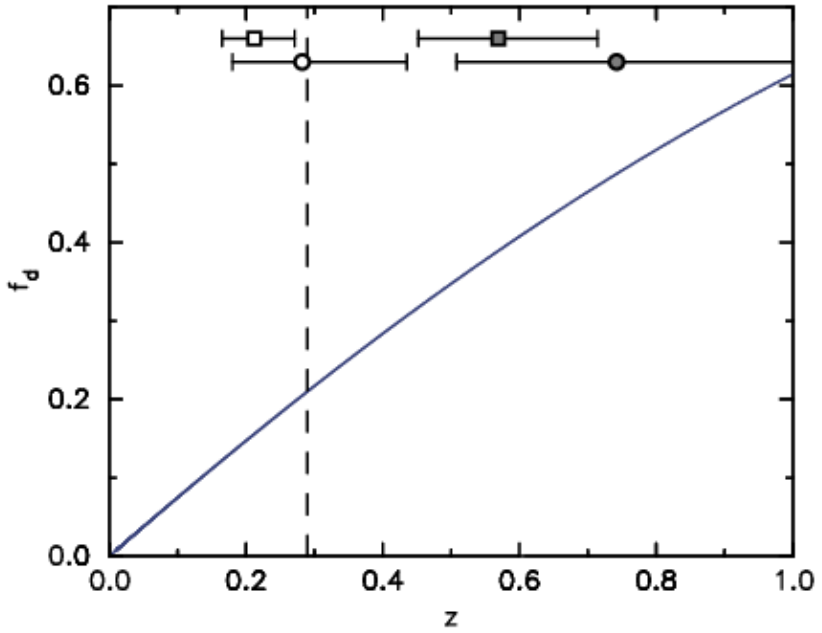


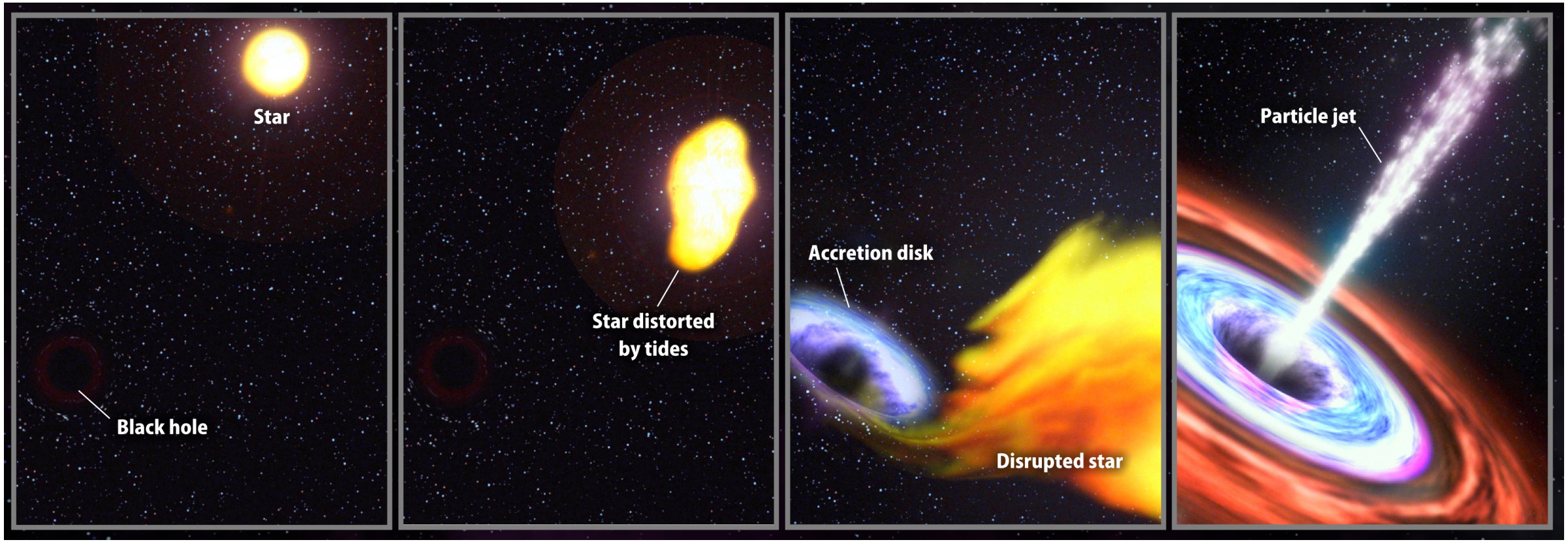
Fig. 6. Cumulative fraction of astrophysical neutrino sources with a single high-energy neutrino detection in IceCube, accumulated as a function of source redshift, assuming they follow the SFR (Madau & Dickinson 2014) given standard cosmology. The redshift of PS16cgx is marked with a vertical line. The maximum distance ranges where a normal Type Ic (squares) and Type Ic-BL (circles) SNe can be detected in rise are indicated assuming negligible line-of-sight extinction, ignoring K-corrections, and adopting 1σ distribution of the SN peak magnitudes, for image depths of 22.5 and 25 mag (white and grey symbols, respectively).

https://arxiv.org/pdf/1901.11080

Leveraging the lower-energy neutrinos

- **“Stacking analyses” are used to identify neutrino emission from a population.**
- **Search for cumulative neutrino emission from many sources, rather than needing one bright individual source.**
- **The central problem in neutrino astronomy is “too much background”. Knowing where and when to look can help us!**
- **We need good multi-messenger observations to constrain search windows.**
- **We can access the many lower-energy neutrinos, enabling statically-significant statements on populations.**

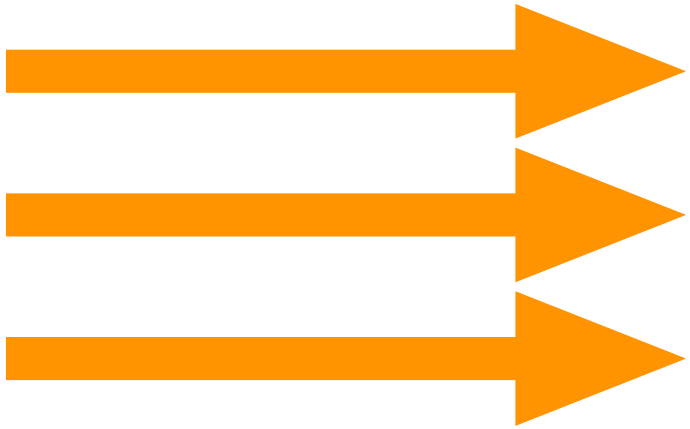
What are Tidal Disruption Events?



1 2 3 4

But what is a TDE? And what is not?

Nuclear Transients



TDEs

AGN

Nuclear SNe

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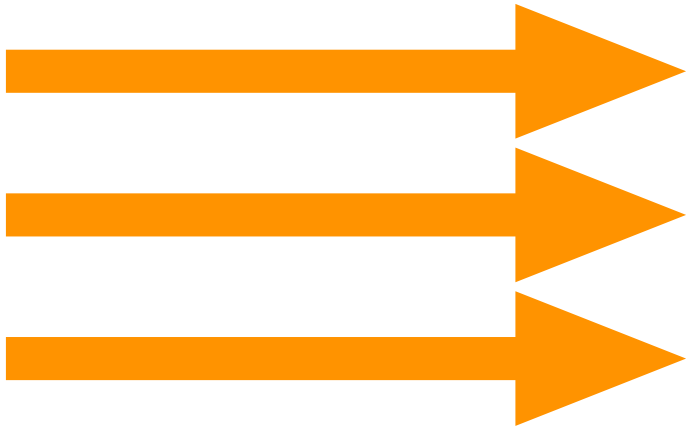
Nuclear Transients



TDEs

AGN

Nuclear SNe

Stacking analyses rely on the assumption that the sample is not contaminated.

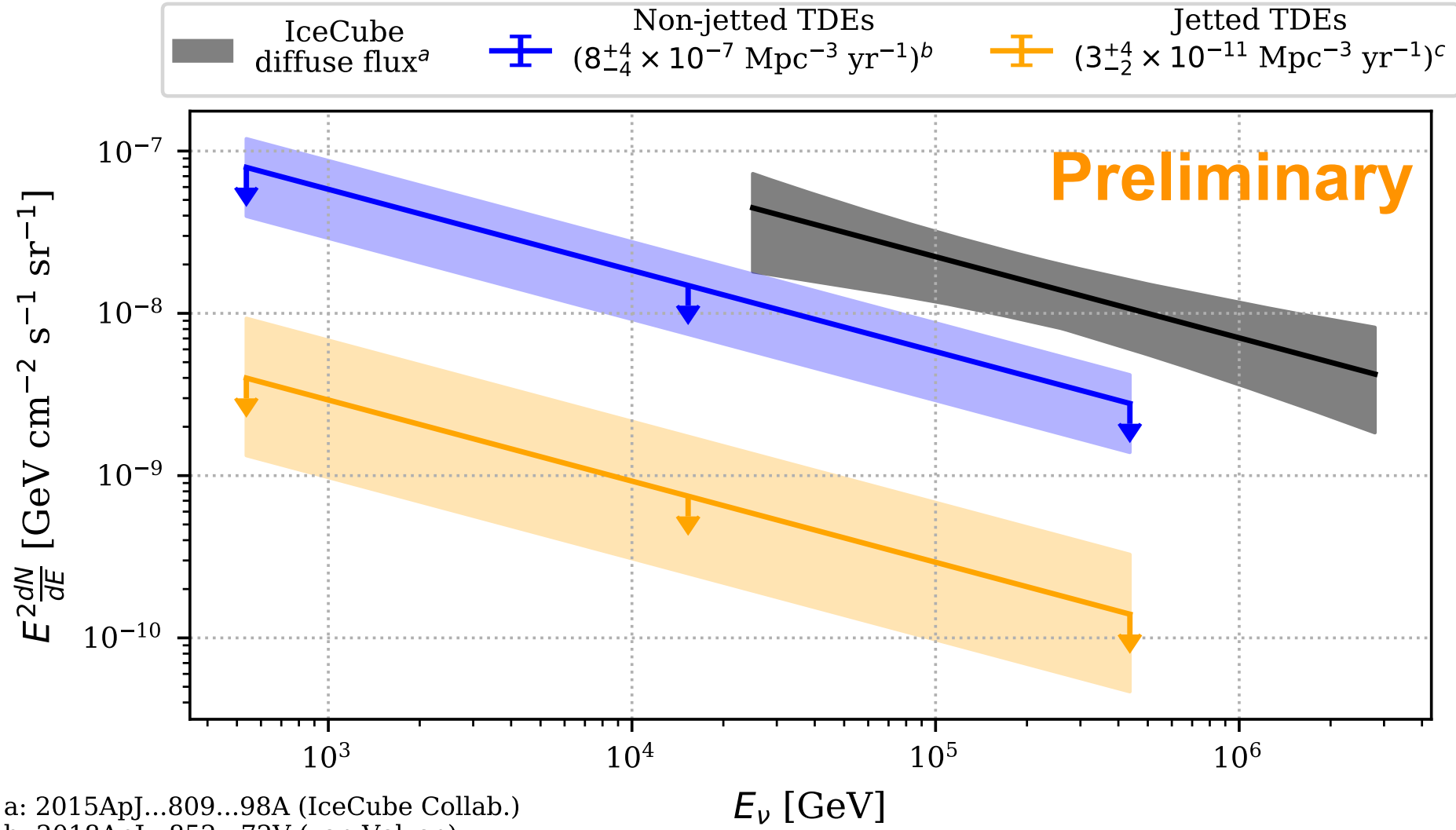
Robust TDE classification requires multi-epoch spectroscopy + photometry

Only ~a dozen non-jetted TDEs meet this requirement, and 3 jetted TDEs, out of ~60 "TDE candidates" in the literature.

Makes rate estimation extremely difficult!

Constraints on TDE neutrino emission

NEW RESULT!



a: 2015ApJ...809...98A (IceCube Collab.)
b: 2018ApJ...852...72V (van Velzen)
c: 2015ApJ...812...33S (Sun et al.)

With evolution from Sun et al.[c]

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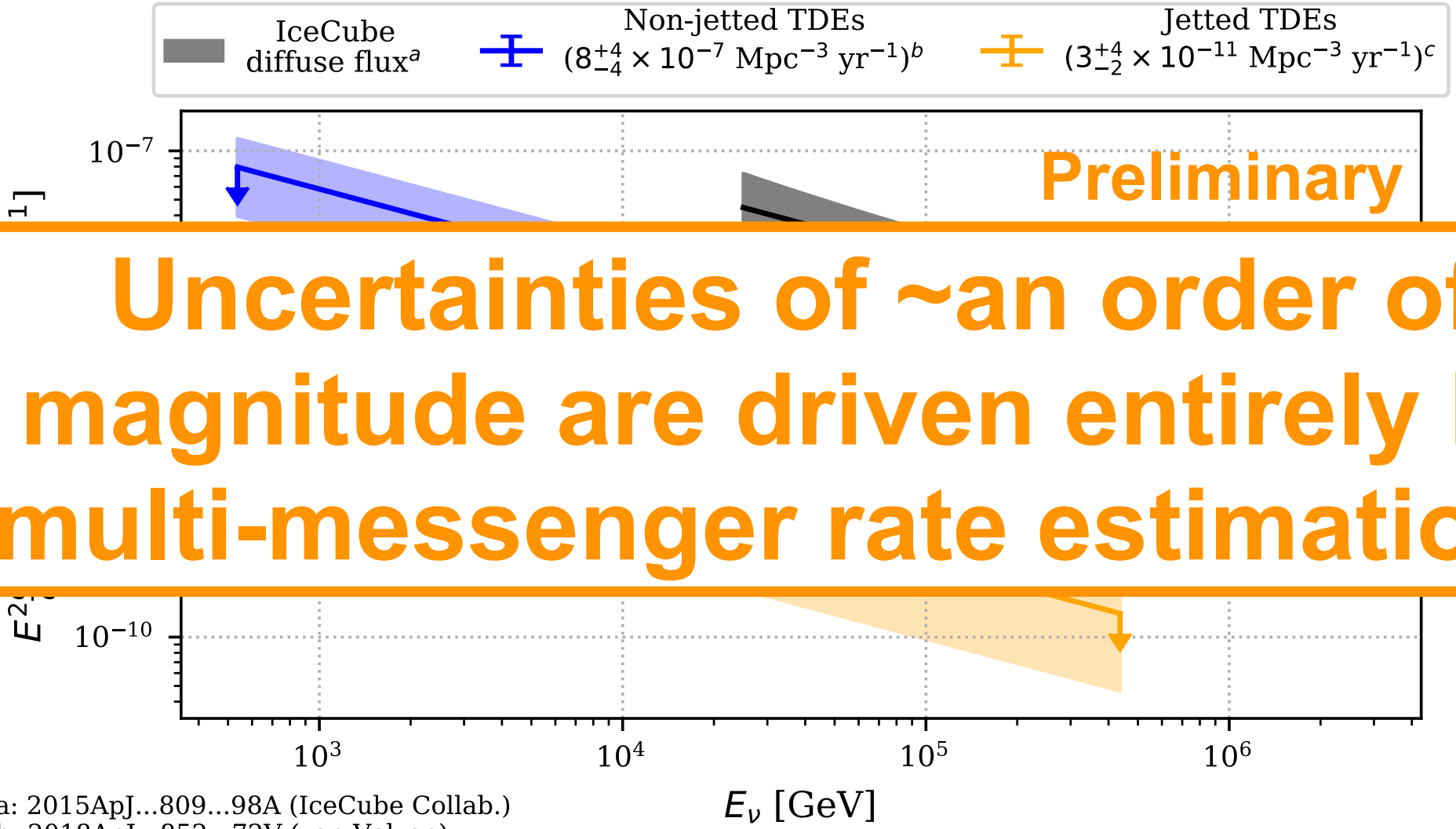

Uncertainties of ~an order of magnitude are driven entirely by multi-messenger rate estimations

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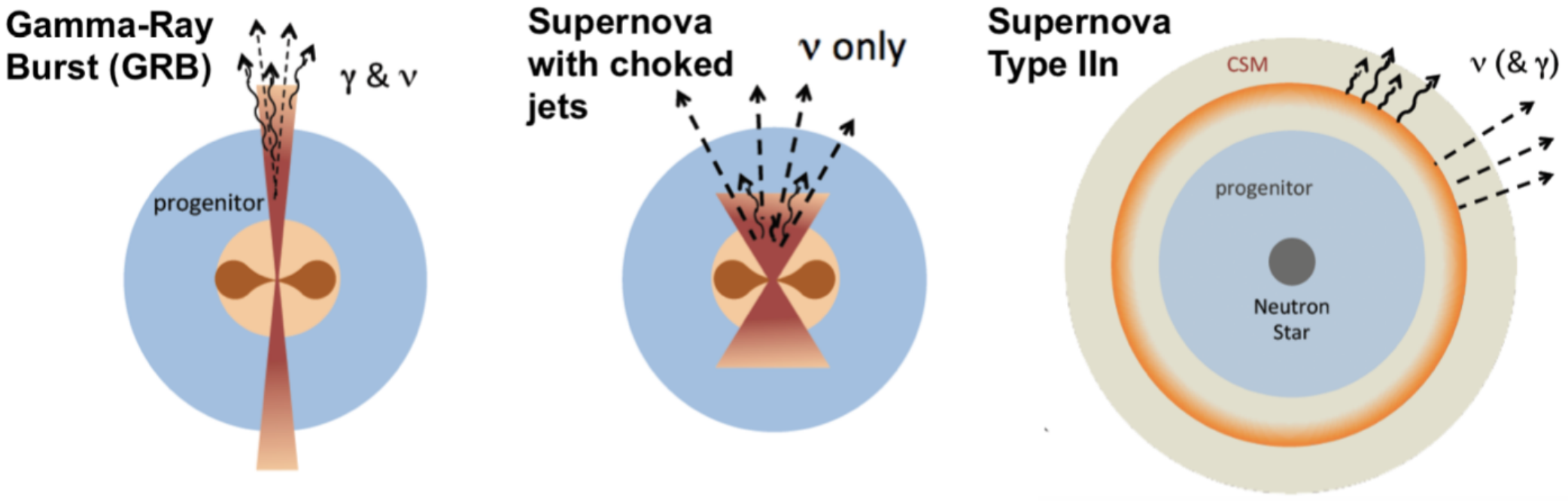
Neutrinos from Supernovae



<1%

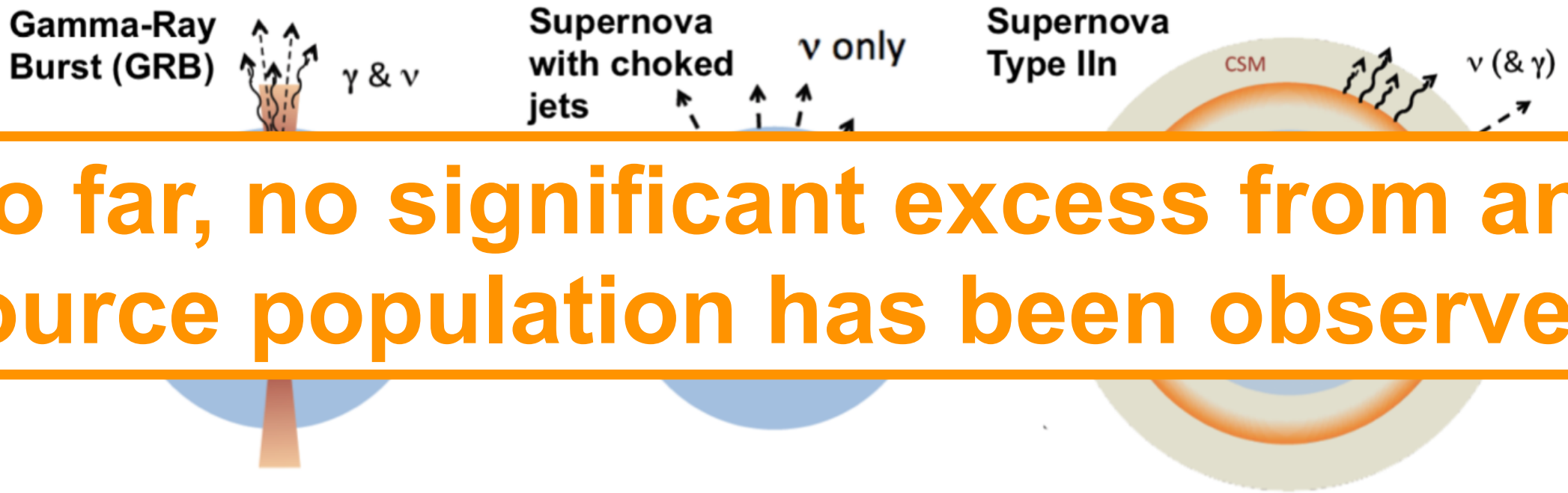
<13%

<28%

https://arxiv.org/abs/1601.06484

Preliminary (Publication in prep)

Neutrinos from Supernovae



So far, no significant excess from any source population has been observed.

<1%	<13%	<28%

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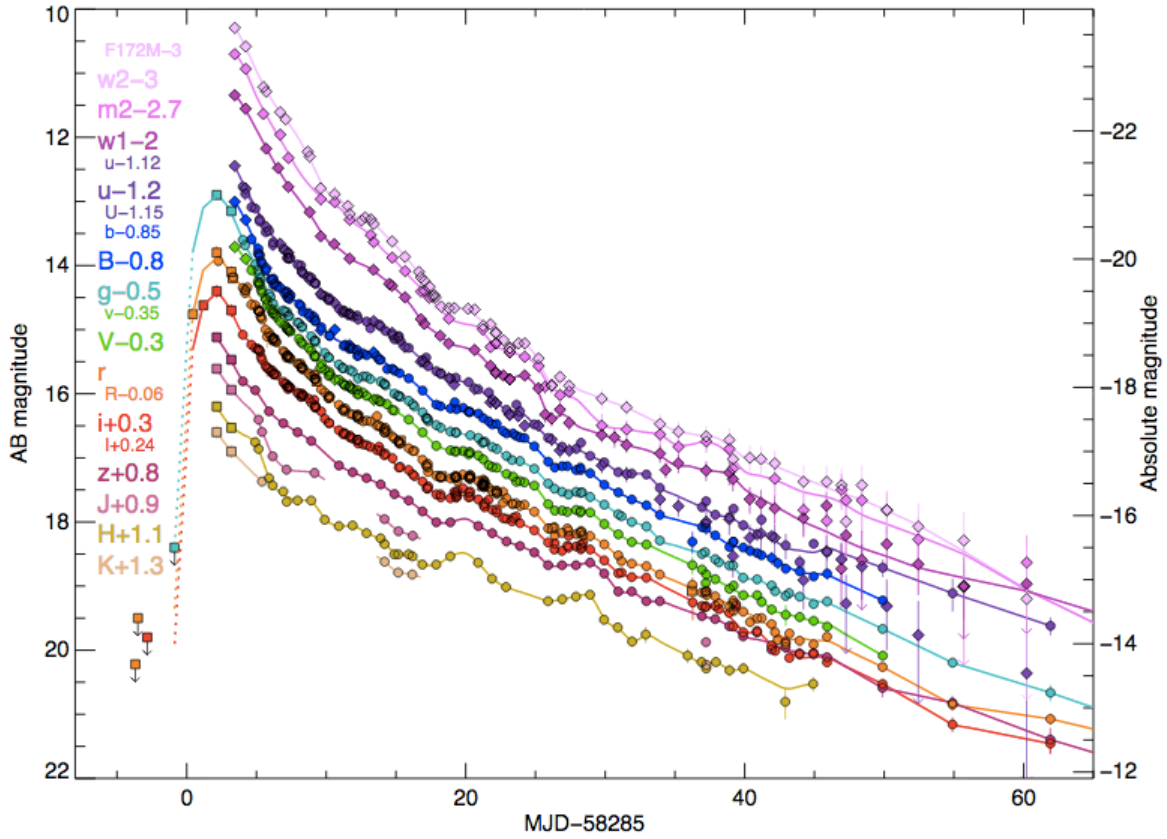
The universe has surprises in store for us!

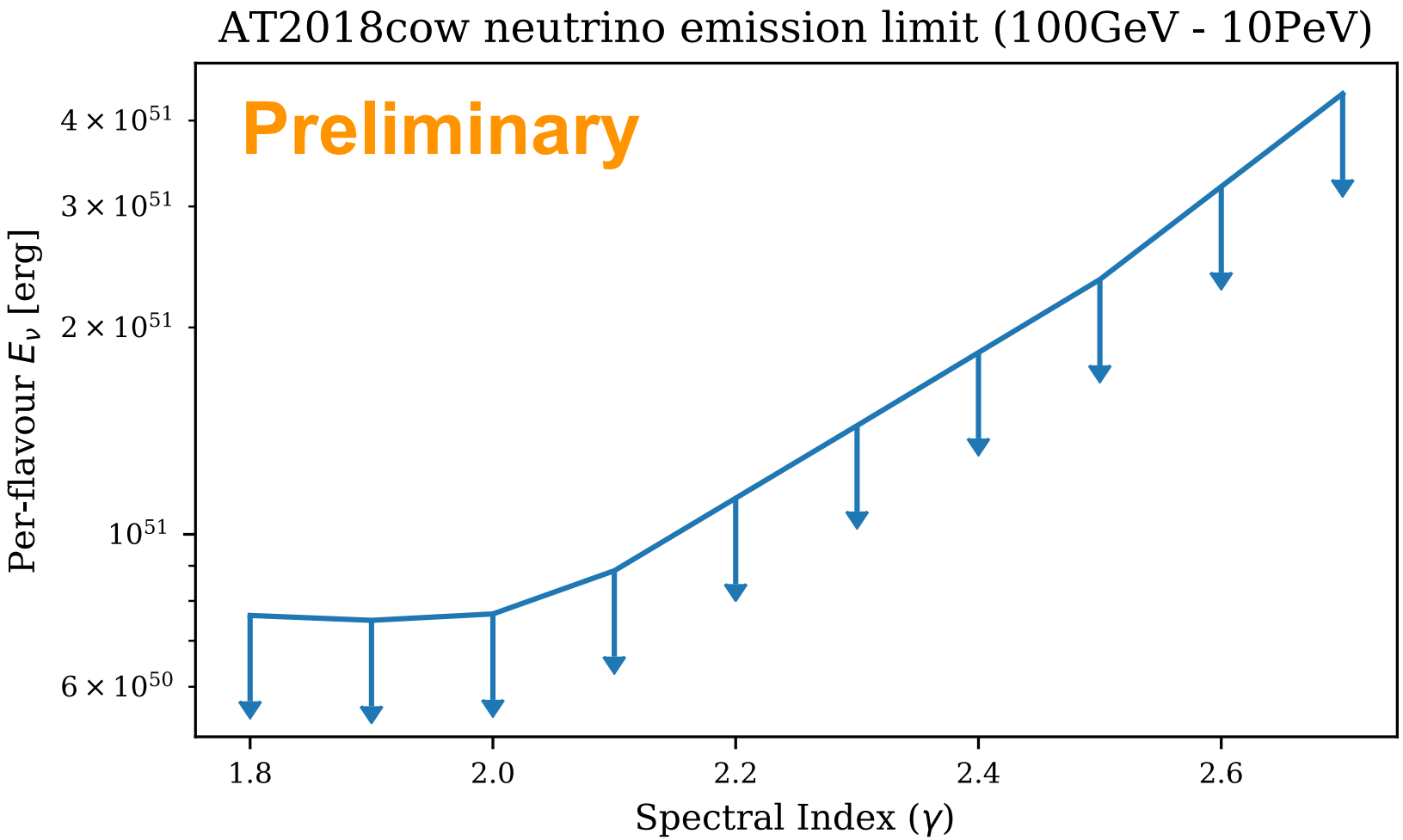
AT2018cow



Extraordinary fast bright blue transient.
Potential nearby example “FBOT”, candidate TDE

Latest IceCube results…

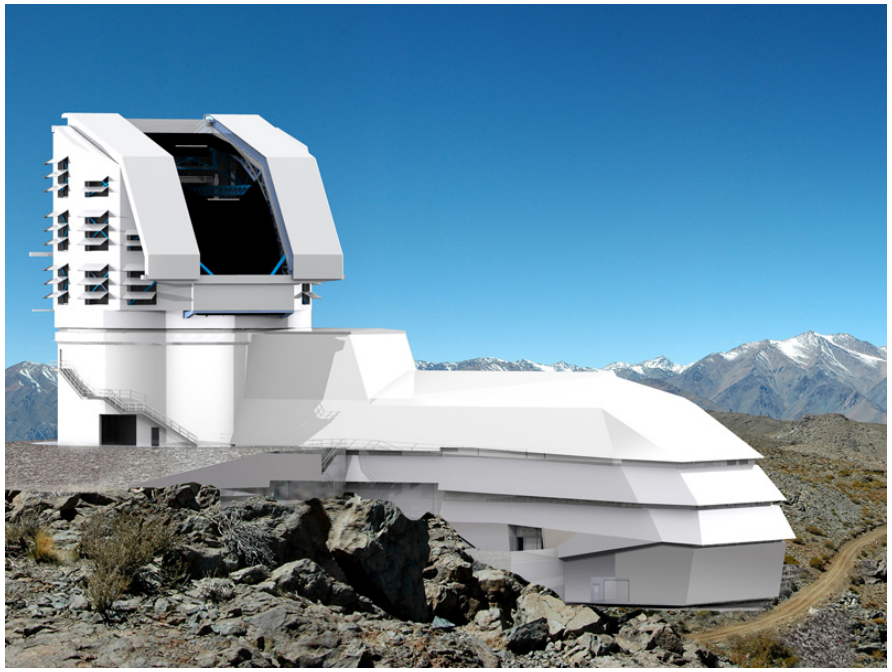
NEW RESULT!



(Time-integrated emission in 130-day window)

How can multi-messenger observations help?

- **Discover more transients!**
  - **Better limits with more sources**
- **Better light curves.**
  - **High cadence observations can greatly reduce background.**
- **Reliable classification.**
  - **TDE study limited by small ‘contamination-free" sample**
- **Better rate estimation**
  - **Deeper surveys constrain evolution, untargeted surveys more complete.**



Summary

- **An identified neutrino source population remains elusive**
- **Transients provide an opportunity for searches with much-reduced background.**
- **No significant neutrino emission found from TDEs, as well as CCSNe.**
- **Multi-messenger observations are key to reducing uncertainty in limits, and more sensitive analysis.**
- **New surveys such as ZTF, and upcoming surveys such as LSST, mean multi-messenger datasets available will improve dramatically in the near future**