

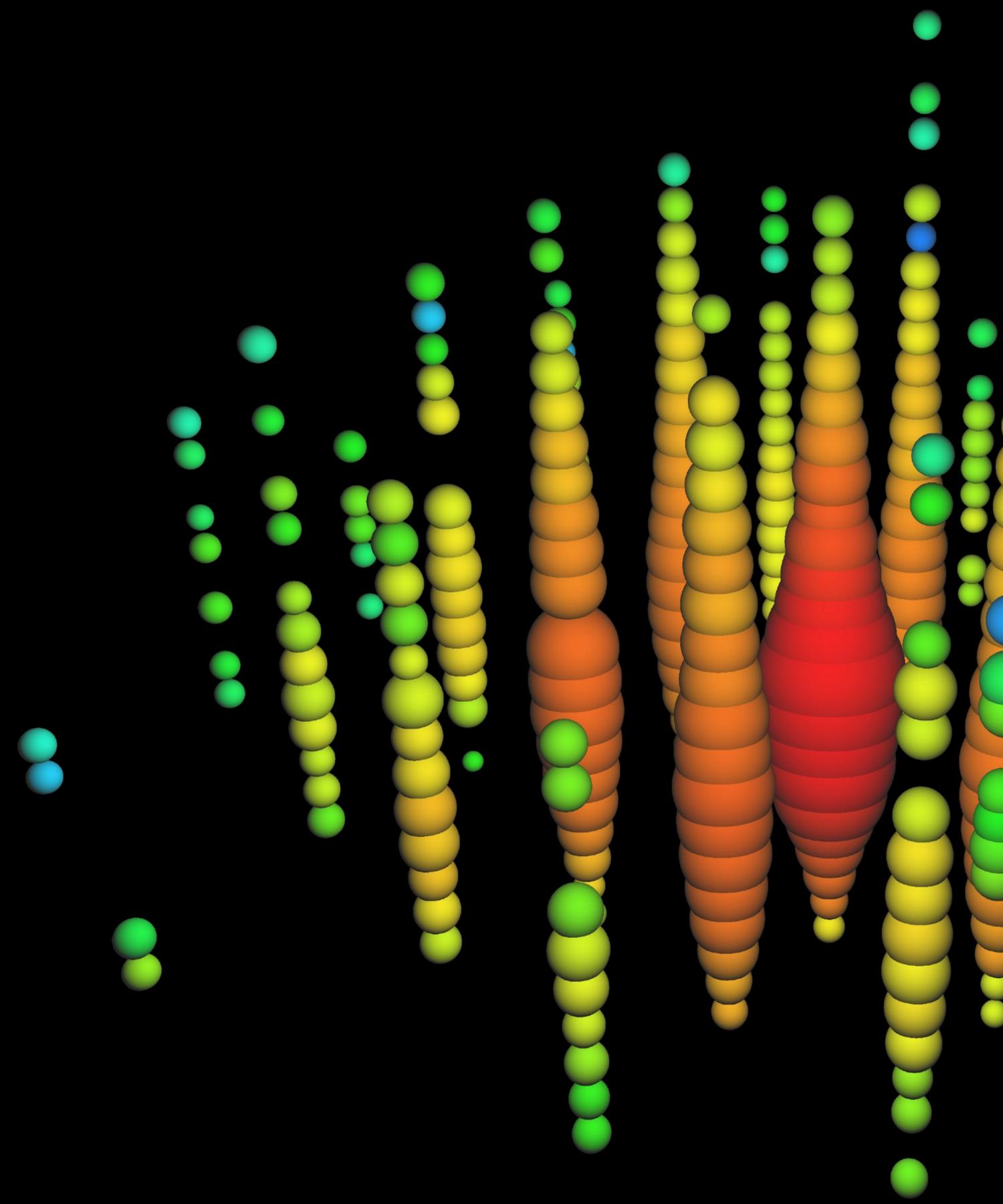
Astrophysical Neutrinos

Theoretical and Experimental Results

ICRC Discussion Session 39

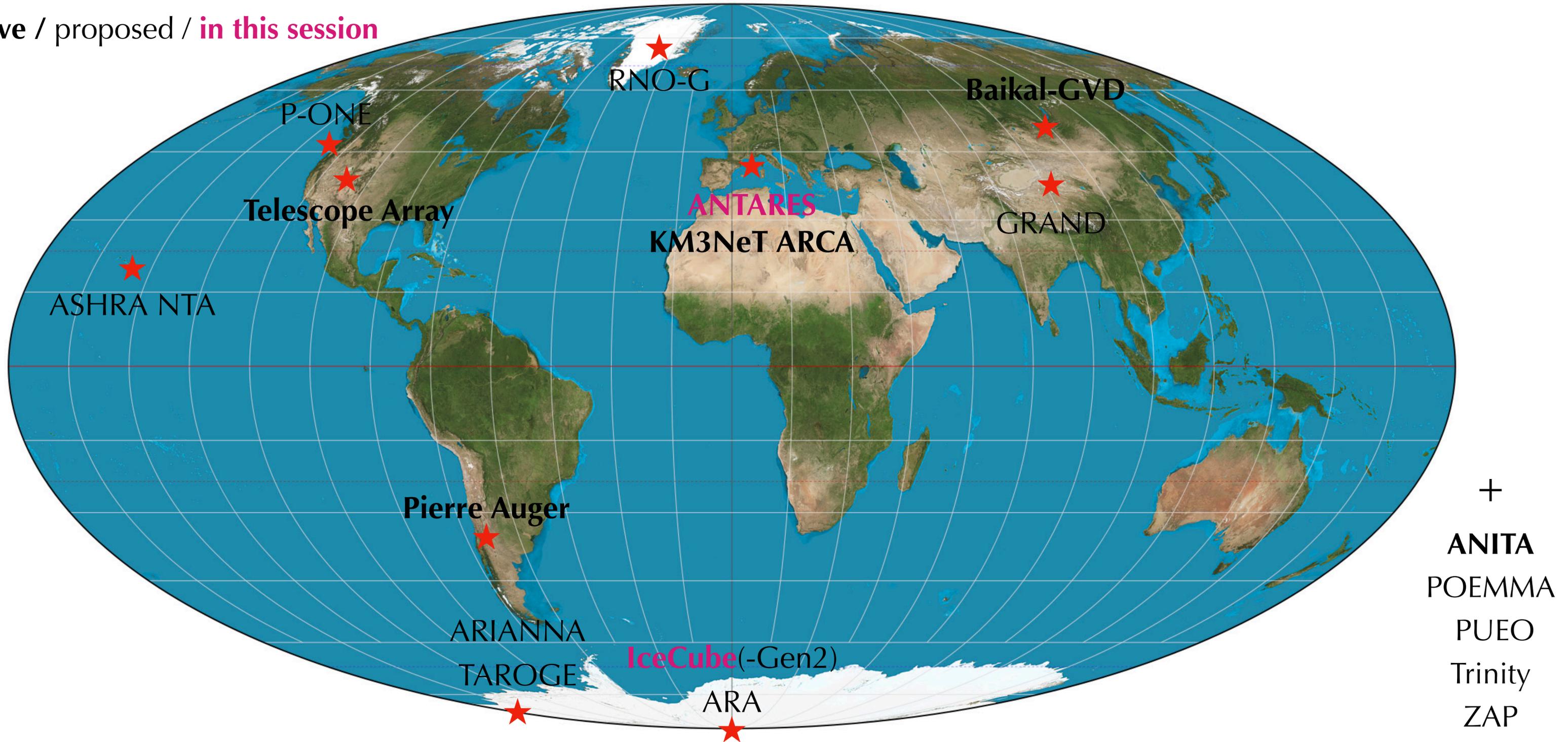
Introduction and Review

Markus Ahlers (NBI)



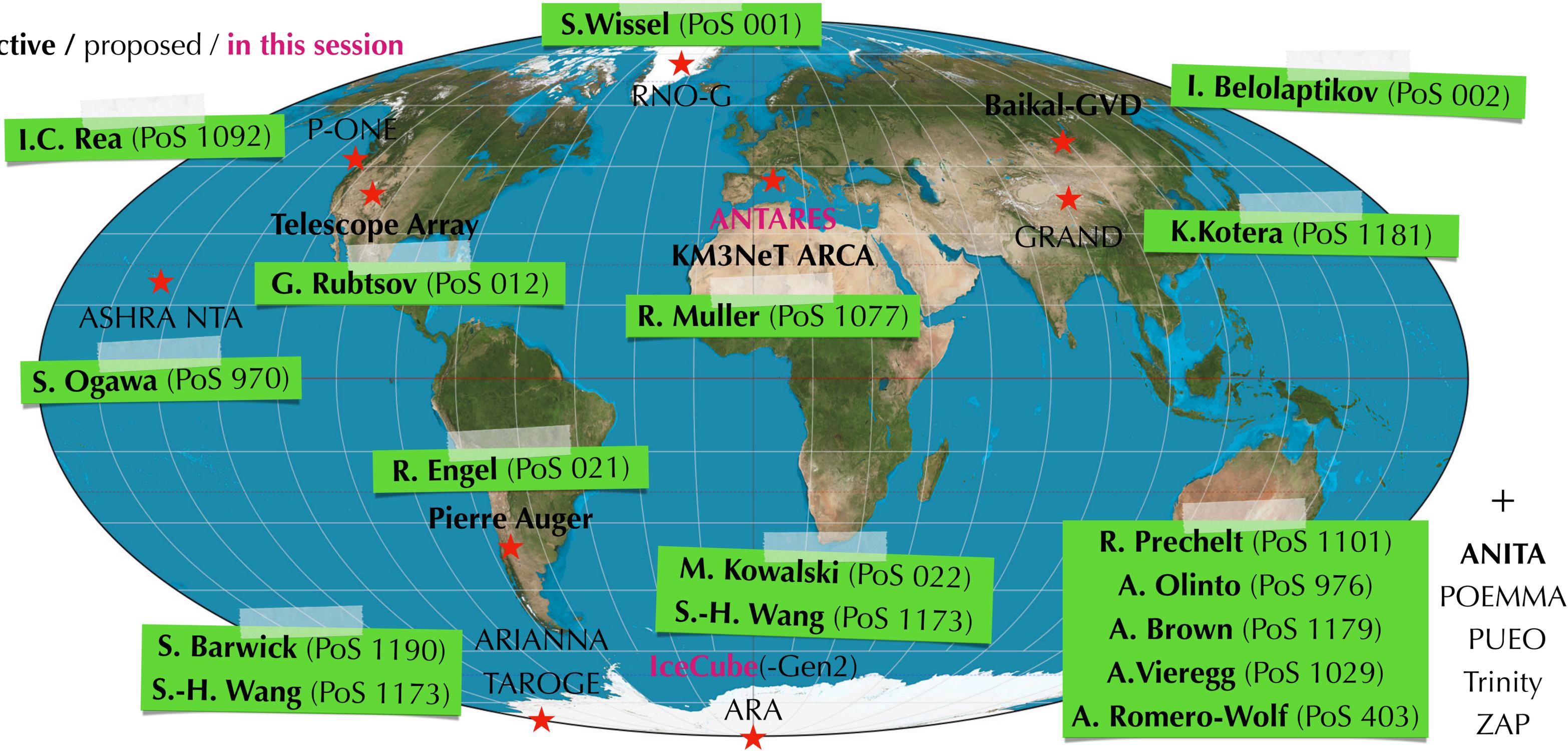
High-Energy Neutrino Observatories

active / proposed / **in this session**



High-Energy Neutrino Observatories

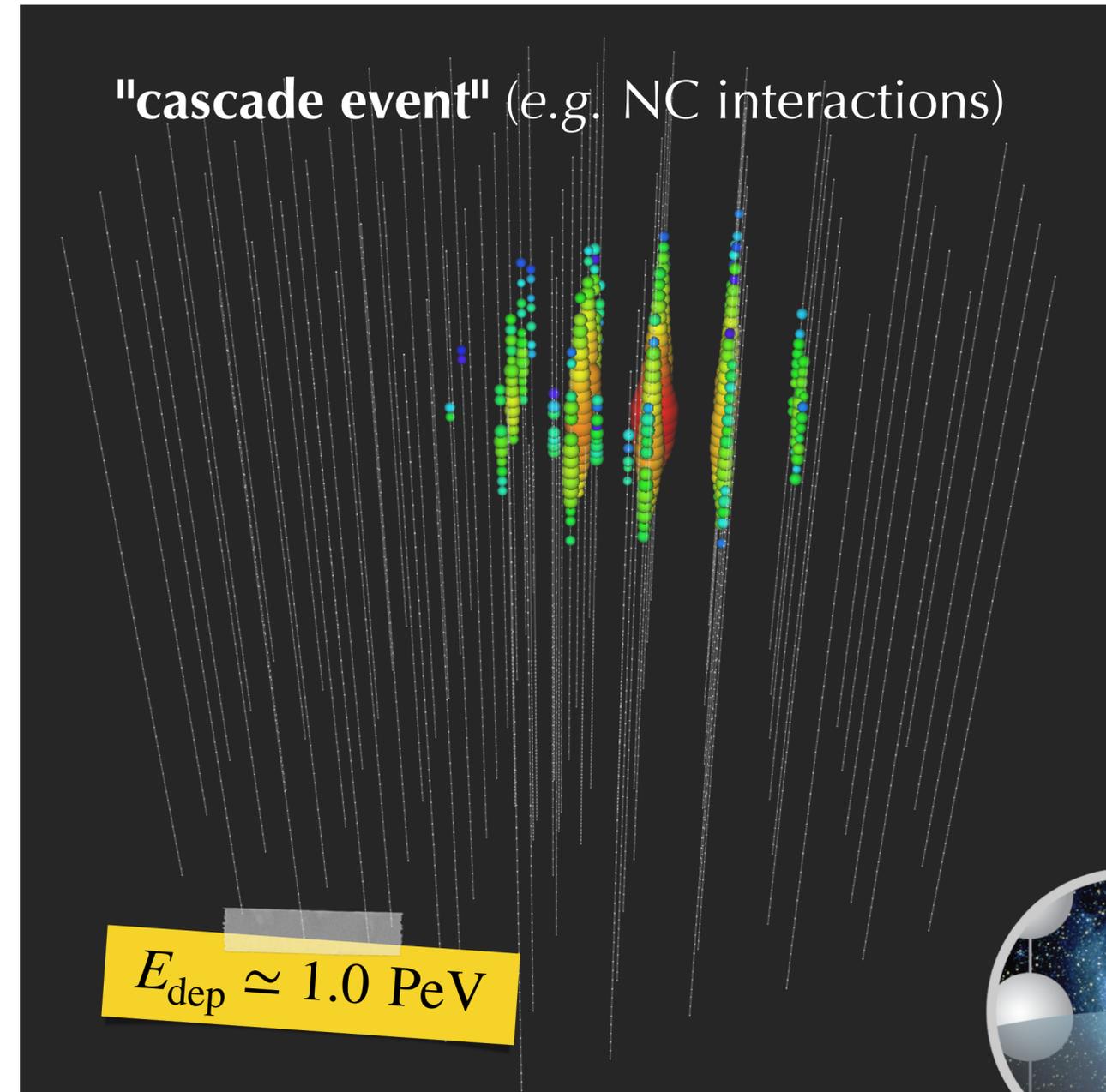
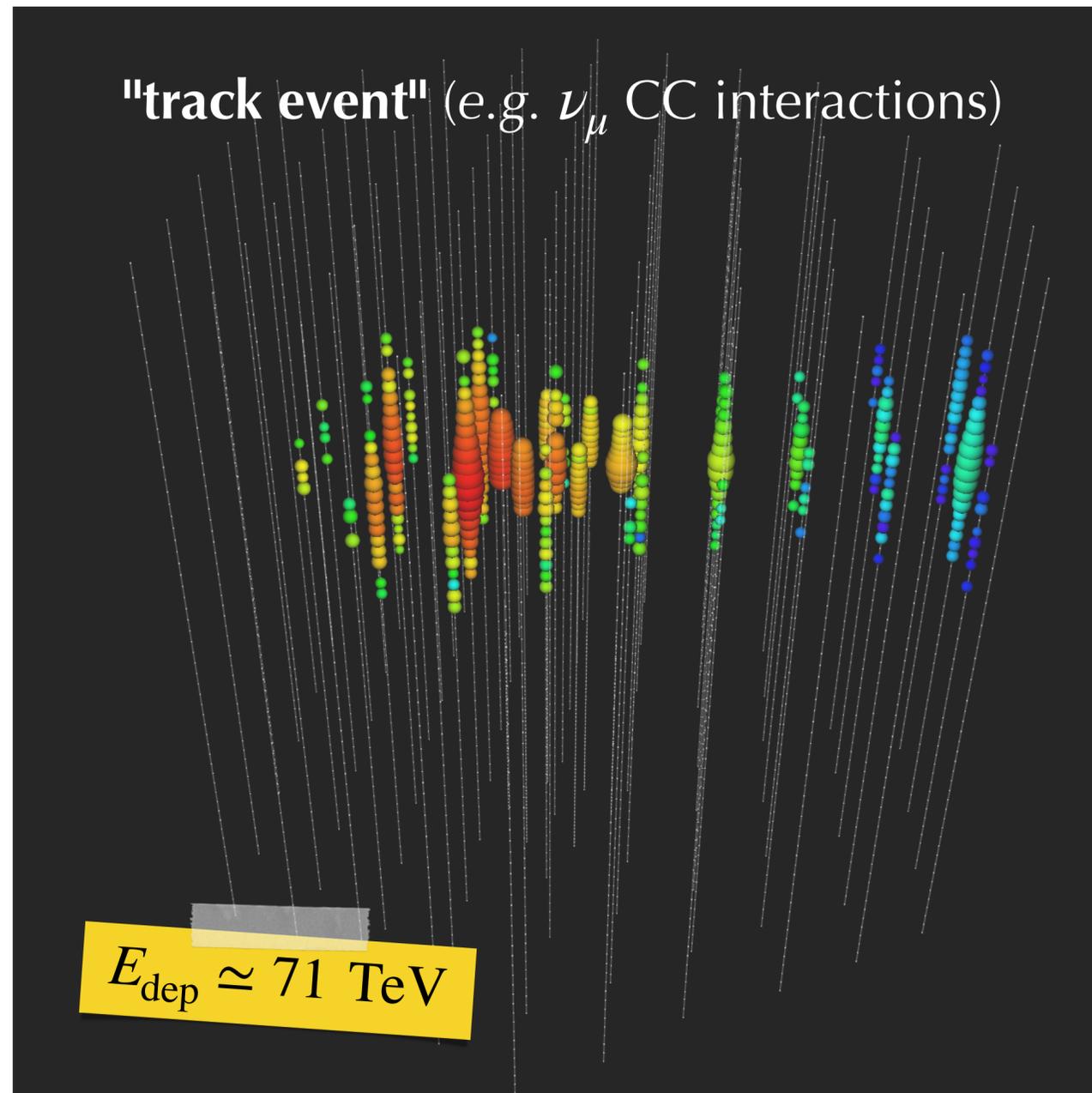
active / proposed / **in this session**



+
ANITA
POEMMA
PUEO
Trinity
ZAP

Astrophysical Neutrinos

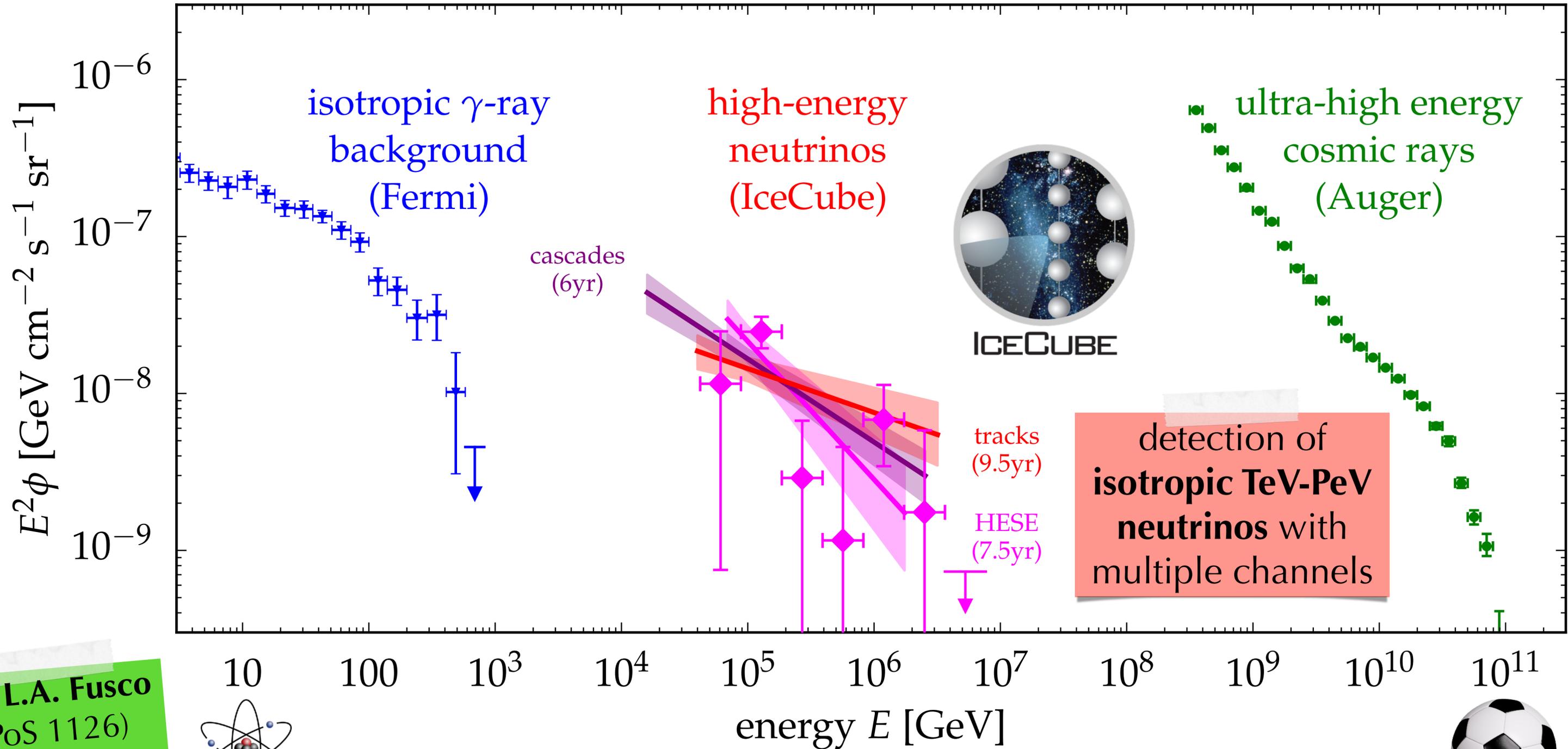
First observation of high-energy astrophysical neutrinos by IceCube in 2013.



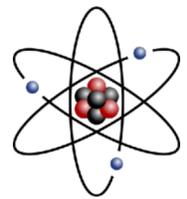
ICECUBE

(colours indicate arrival time of Cherenkov photons from **early** to **late**)

Multi-Messenger Panorama



see L.A. Fusco (PoS 1126) for ANTARES

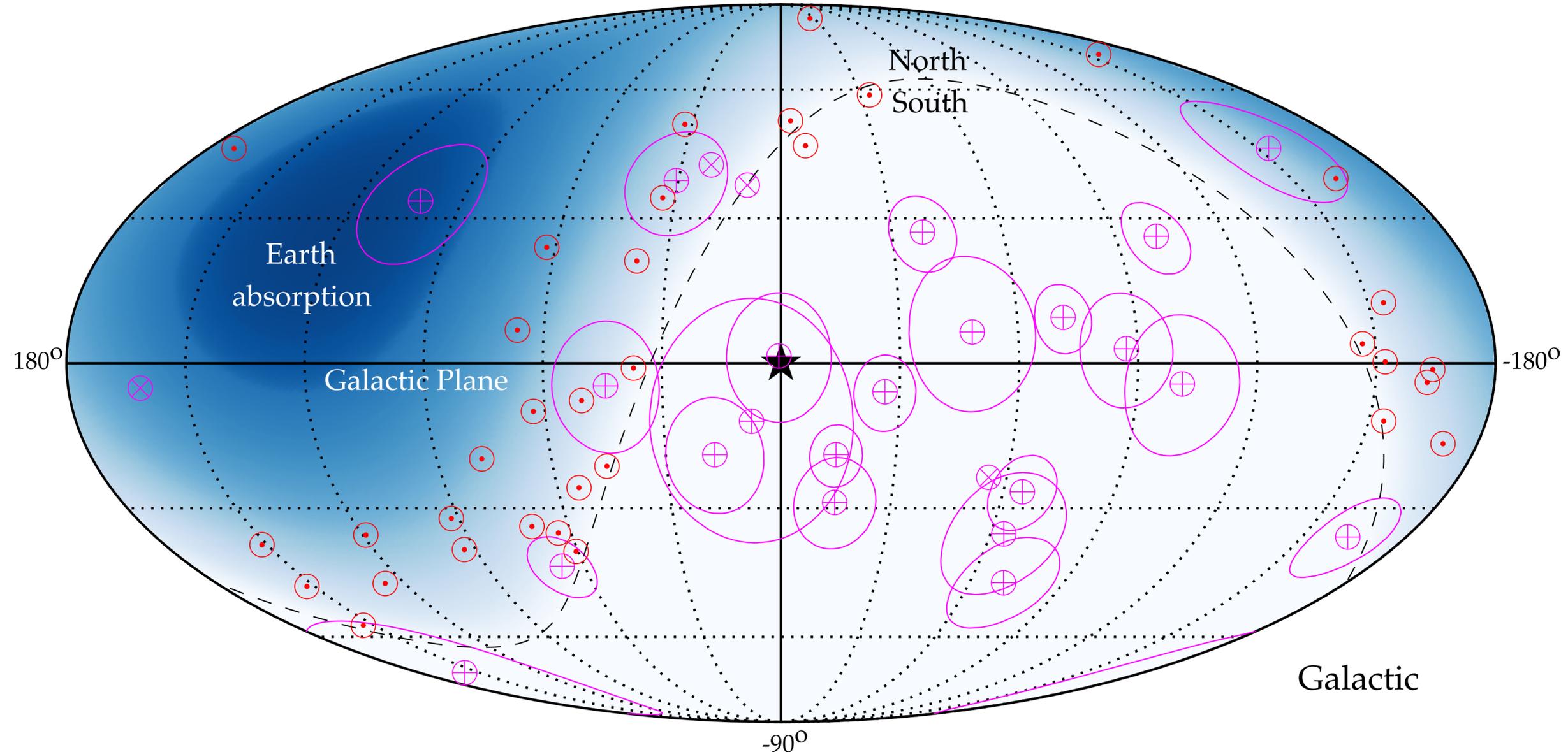


[IceCube, PRL 125 (2020) 12; PoS (ICRC2019) 1017; arXiv:2011.03545]



Status of Neutrino Astronomy

Most energetic neutrino events (HESE 6yr (magenta) & $\nu_\mu + \bar{\nu}_\mu$ 8yr (red))



No 5σ discoveries of steady or transient emission from known Galactic or extragalactic high-energy sources, but **several intriguing candidates**.

Where are the Sources?

Population of extragalactic neutrino sources can be visible as

individual sources

or by their

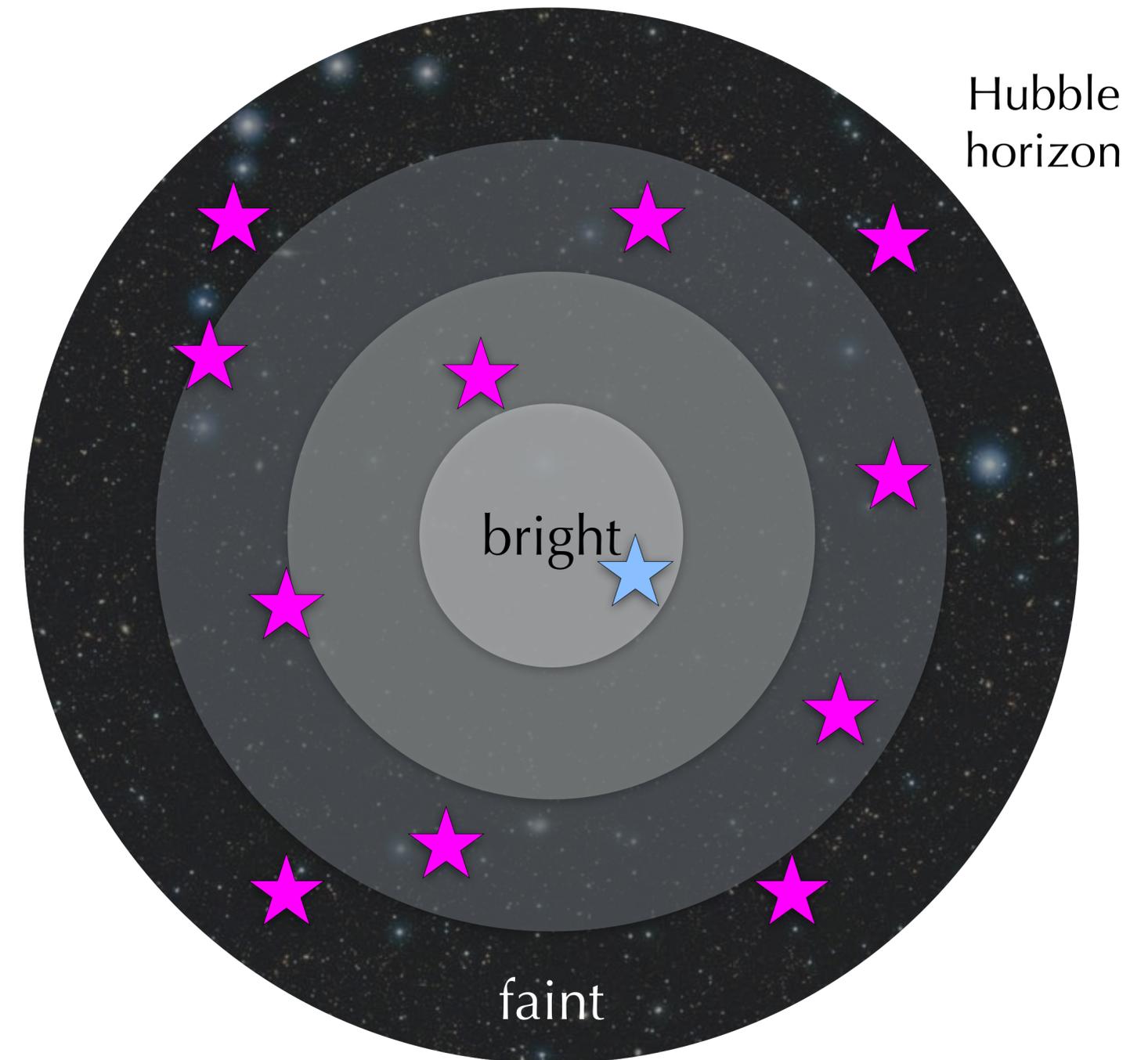
combined isotropic emission.

The relative contribution can be parametrized (*to first order*) by the average

local source density

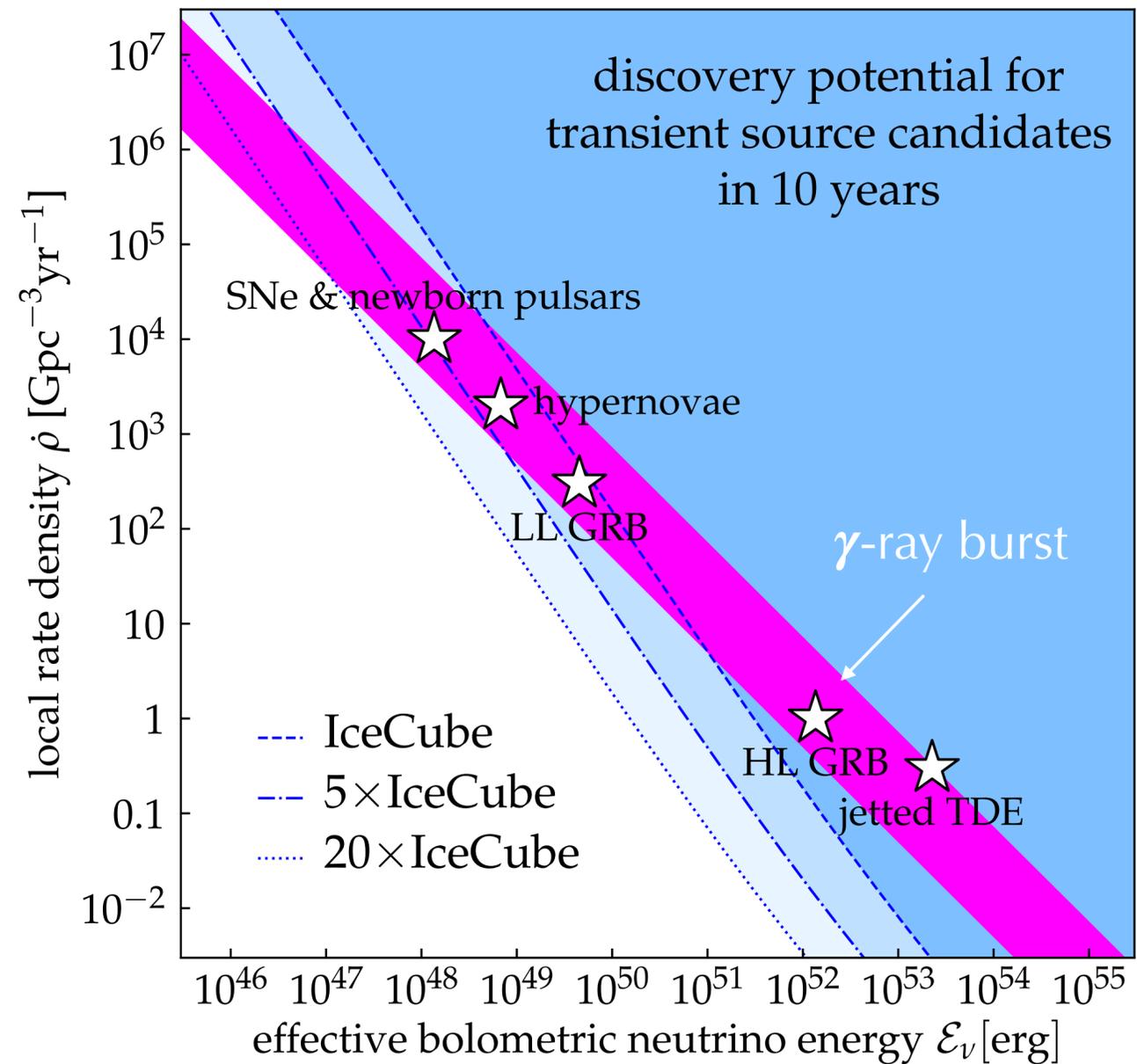
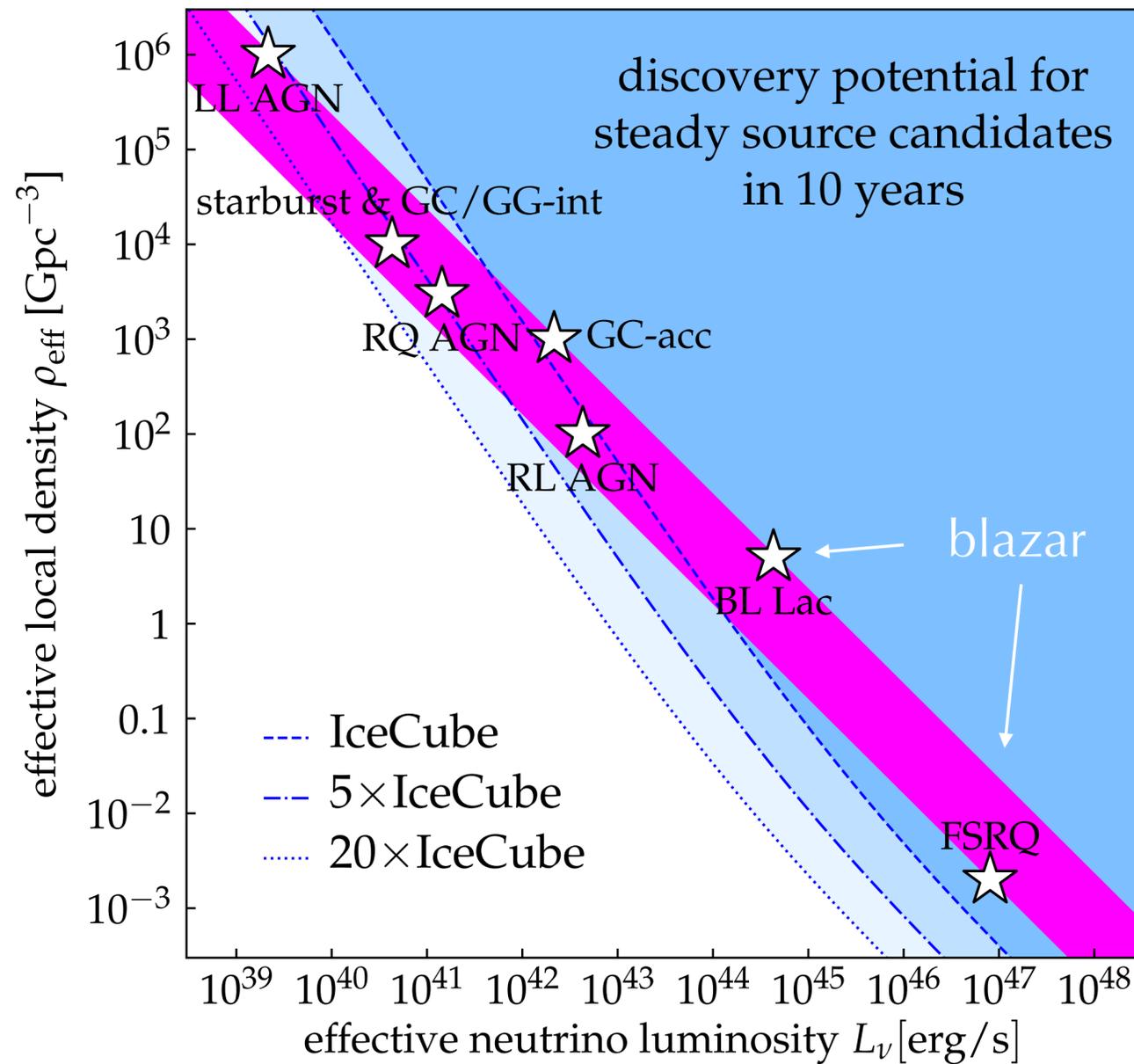
and

source luminosity.



“Observable Universe” with far (faint) and near (bright) sources.

Individual Sources vs. Isotropic Emission



[Murase & Waxman'16; Ackermann et al.'19]

Rare sources can not be the dominant sources of TeV-PeV neutrino emission (magenta band).

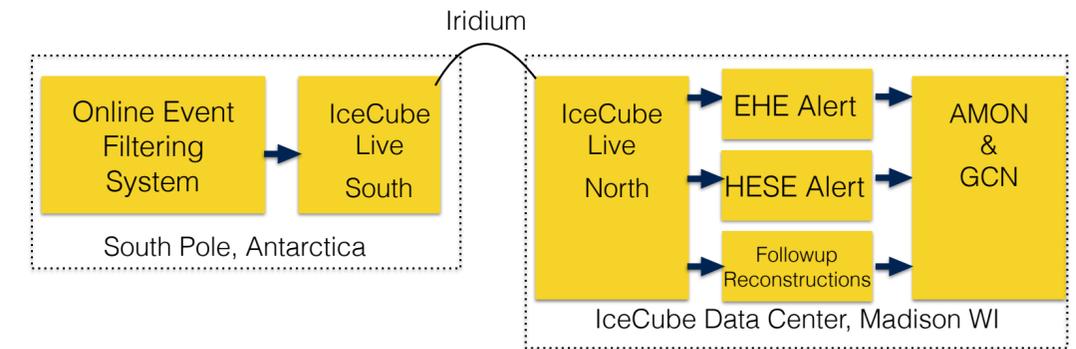
Consistent with results of IceCube analyses of GRBs and Fermi-LAT blazars.

[IceCube, ApJ 835 (2017) 45; ApJ 843 (2017) 2]

Realtime Alerts

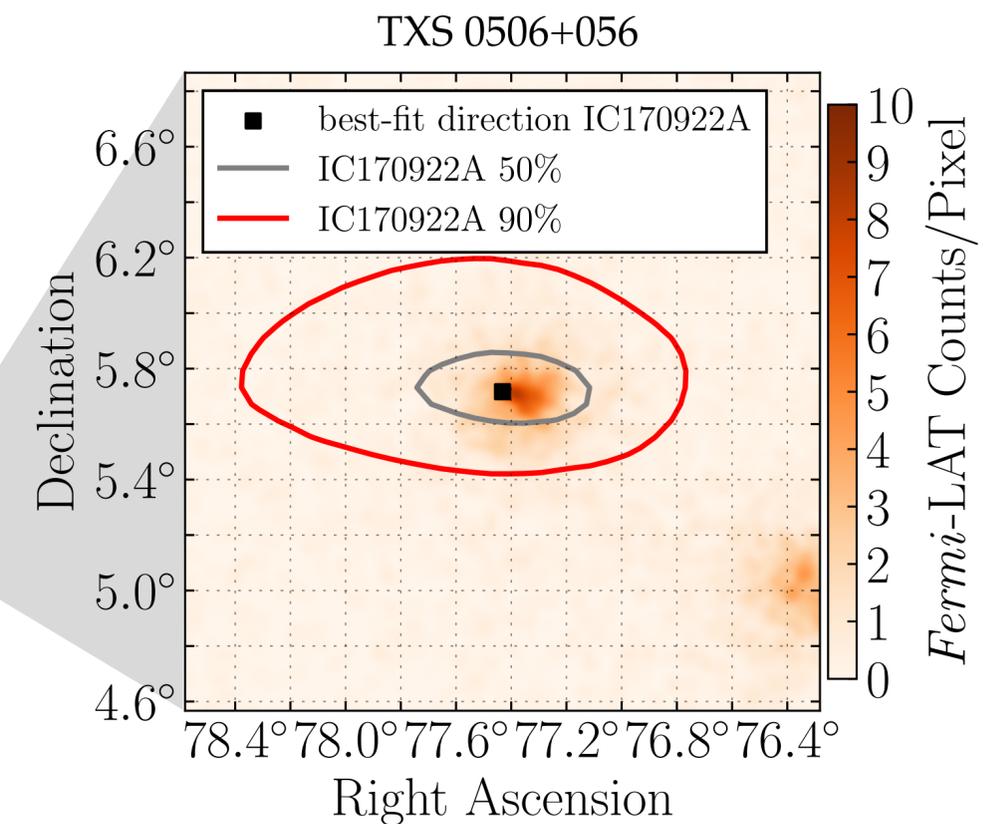
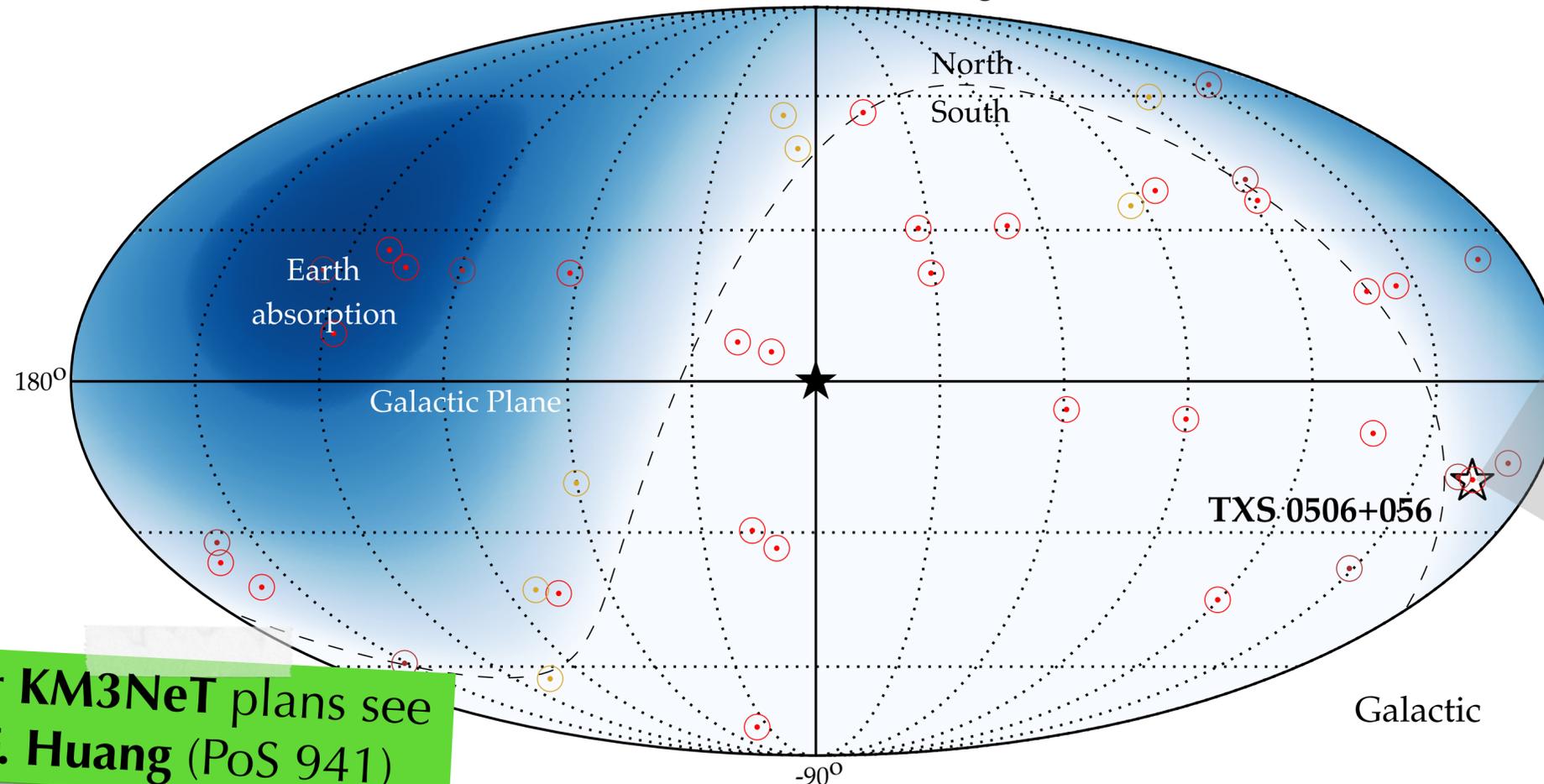
IceCube established a **low-latency** (<1min) **public neutrino alert system** in April 2016.

- ◆ **Gold alerts:** ~10 per year / >50% signalness
- ◆ **Bronze alerts:** ~20 per year / 30-50% signalness



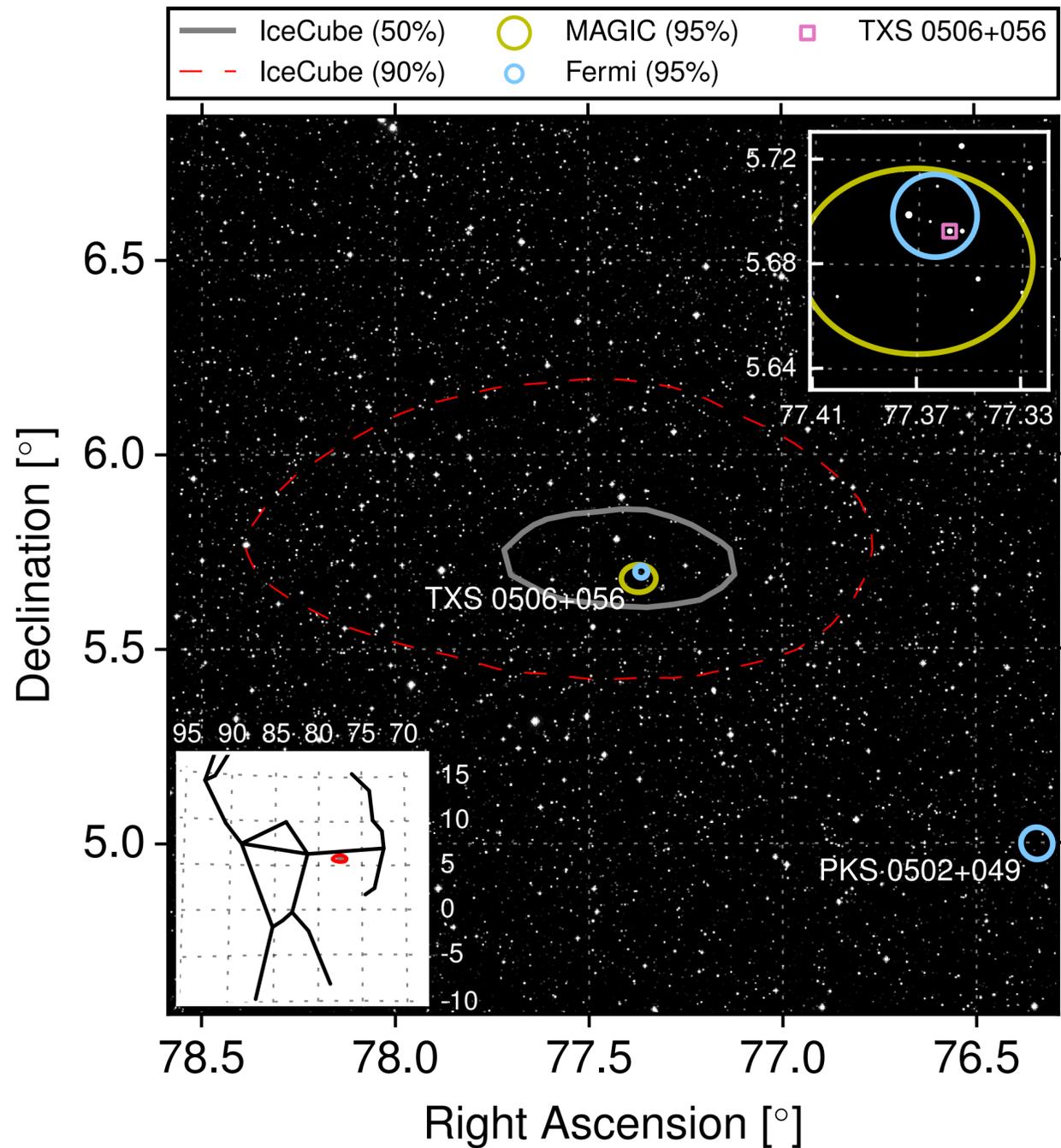
Median alert latency: 33 seconds

Neutrino alerts (HESE & EHE (red) / GFU-Gold (gold) / GFU-Bronze (brown))

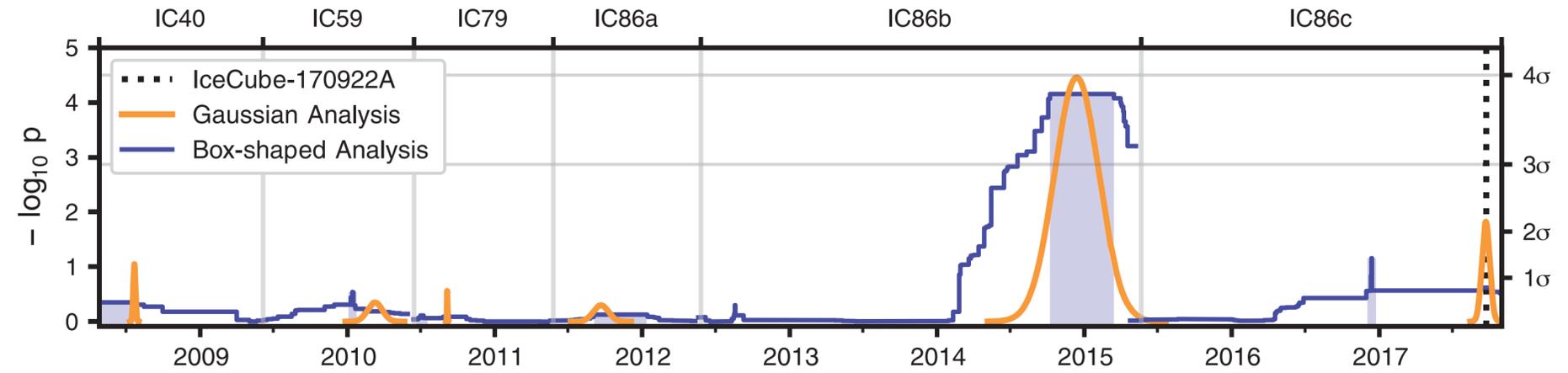


for KM3NeT plans see
F. Huang (PoS 941)

TXS 0506+056



[IceCube++, Science 361 (2018) 6398]



[IceCube, Science 361 (2018) 6398]

- IC-170922A observed in coincident with **flaring blazar TXS 0506+056**.
- Chance correlation can be rejected at the 3σ -level.
- In addition, independent 3.5σ evidence for a **neutrino flare** (13 ± 5 excess events) in 2014/15.
- In combination, **compelling evidence** for neutrino emission.

see also **F. Oikonomou** (PoS 030)

Tidal Disruption Events

Stars are pulled apart by tidal forces in the vicinity of supermassive black holes. Accretion of stellar remnants powers plasma outflows.

black hole

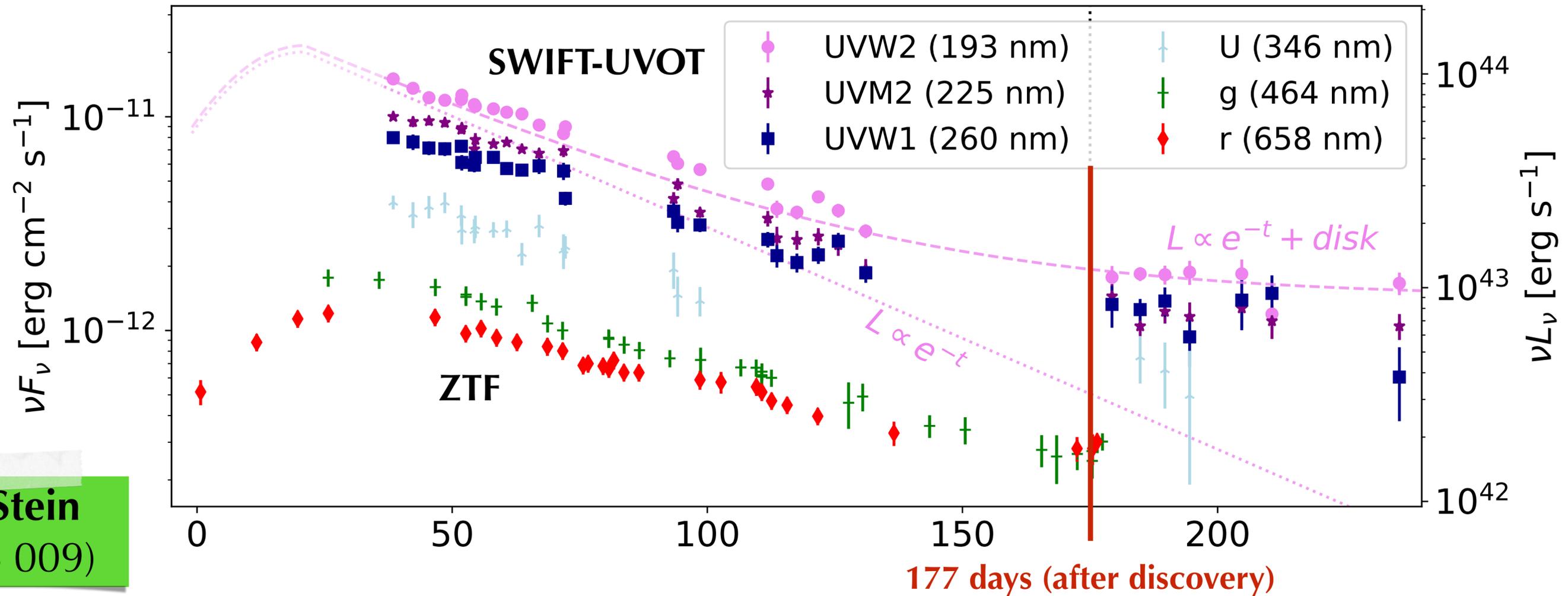
stellar debris

W. Winter & C. Lunardini
(PoS 997)

(relativistic) plasma outflow

[Credit: DESY, Science Communication Lab]

Tidal Disruption Events

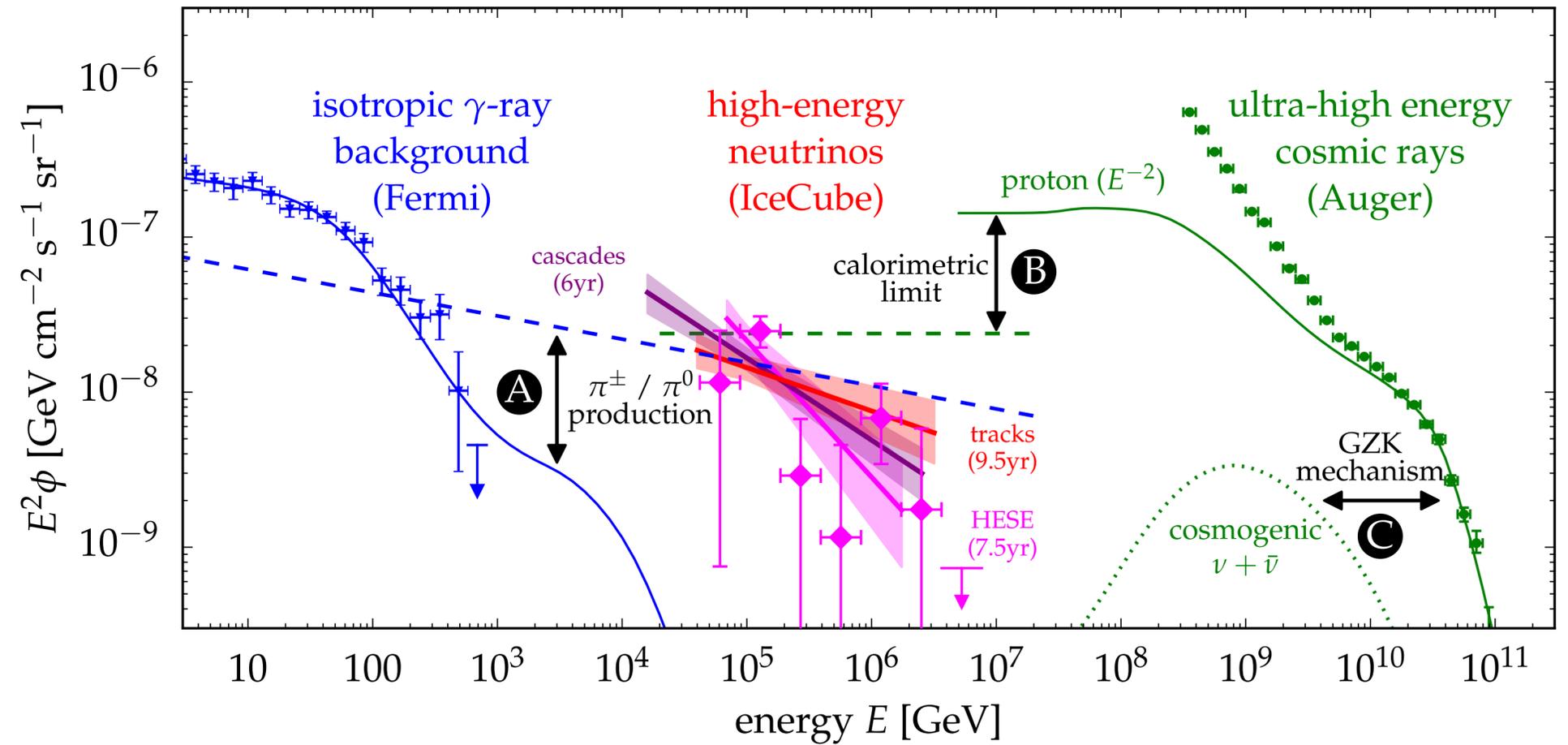
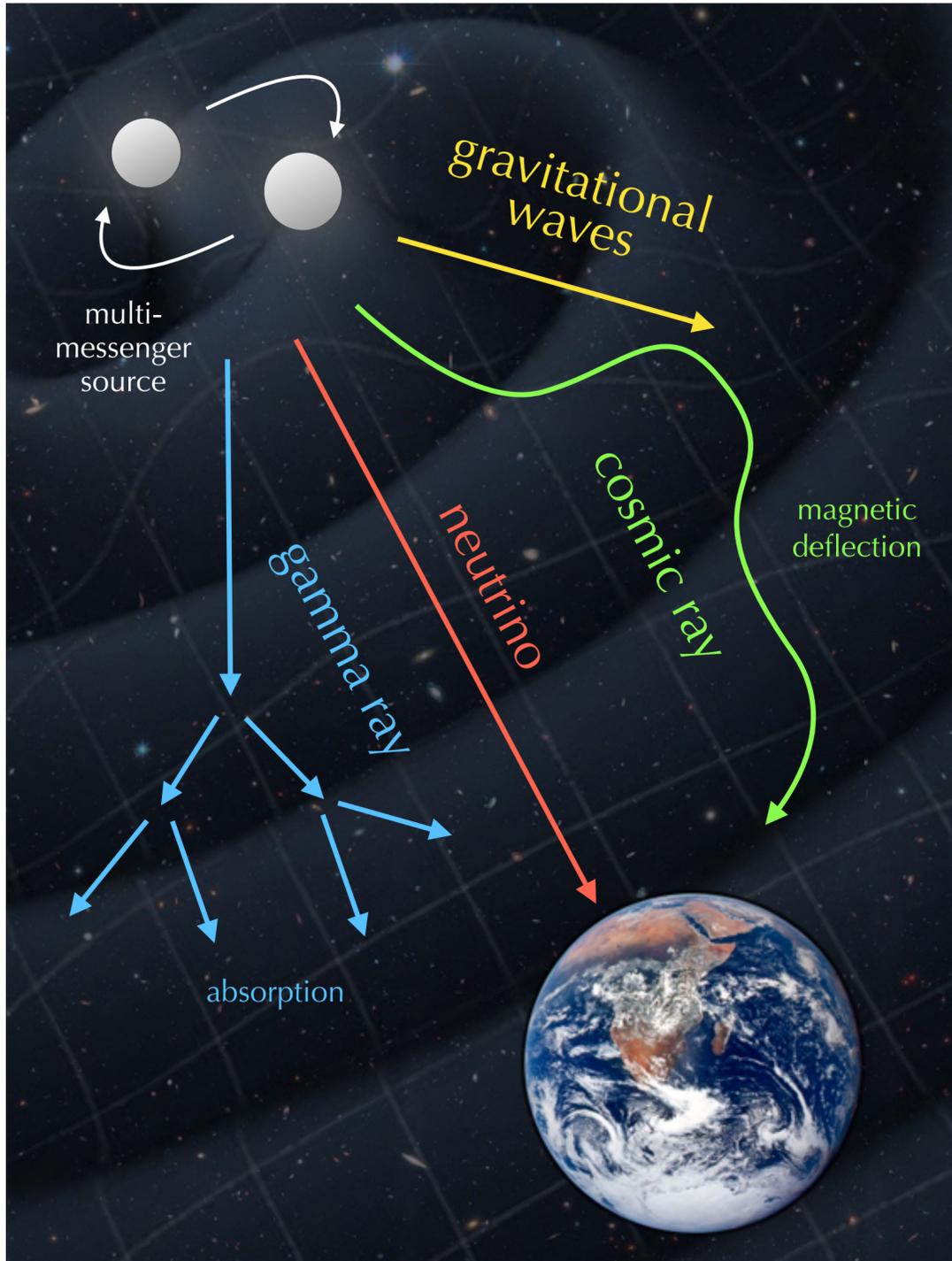


R. Stein
(PoS 009)

- Association of alert **IC-191001A** with radio-emitting TDE AT2019dsg
- Plot shows data from Zwicky-Transient Facility (ZTF) and SWIFT-UVOT.
- Chance for random correlation of TDEs and IceCube alerts is 0.5%.

[Stein, R., Velzen, S.v., Kowalski, M. et al., Nature Astronomy (2021)]

Multi-Messenger Interfaces



Strong relations between cosmic messenger provide **hints and constrains for model builders.**

For instance, IGRB observed by Fermi-LAT constrains hadronic γ -ray production and **suggests "hidden" sources.**

[Murase, MA & Lacki'13; Tamborra, Ando & Murase'14; Ando, Tamborra & Zandanel'15]
 [Bechtol et al.'15; Guetta, MA & Murase'16; Palladino et al.'19; Ambrosone et al.'20]

Session Outline

1) Theoretical Results

- **Viviana Niro** - Neutrinos from galactic sources
- **Ke Fang** - High-Energy Neutrinos from Non-Relativistic Shock-Powered Transients
- **Saqib Hussain** - High-Energy Neutrino Production in Clusters of Galaxies
- **Andrzej Smialkowski** - Very high energy neutrinos from Gamma Ray Bursts in dense clusters
- **Irene Di Palma** - Neutrino predictions from choked GRBs and comparison with the observed cosmic neutrino flux
- **Gibran Morales** - Unraveling the nature of GRBs progenitors through neutrinos

2) Experimental Results

- **Giulia Illuminati** - Searches for point-like sources of cosmic neutrinos with 13 years of ANTARES data
- **Julien Aublin** - Search for an association between neutrinos and radio-selected blazars with ANTARES
- **Hans Niederhausen** - A New Search for Neutrino Point Sources with IceCube
- **Sreetama Goswami** - Search for high-energy neutrino emission from hard X-ray AGN
- **Pablo Correa** - IceCube Search for High-Energy Neutrinos from Ultra-Luminous Infrared Galaxies
- **Chujie Chen** - Search for Astrophysical Neutrino Transients with IceCube DeepCore