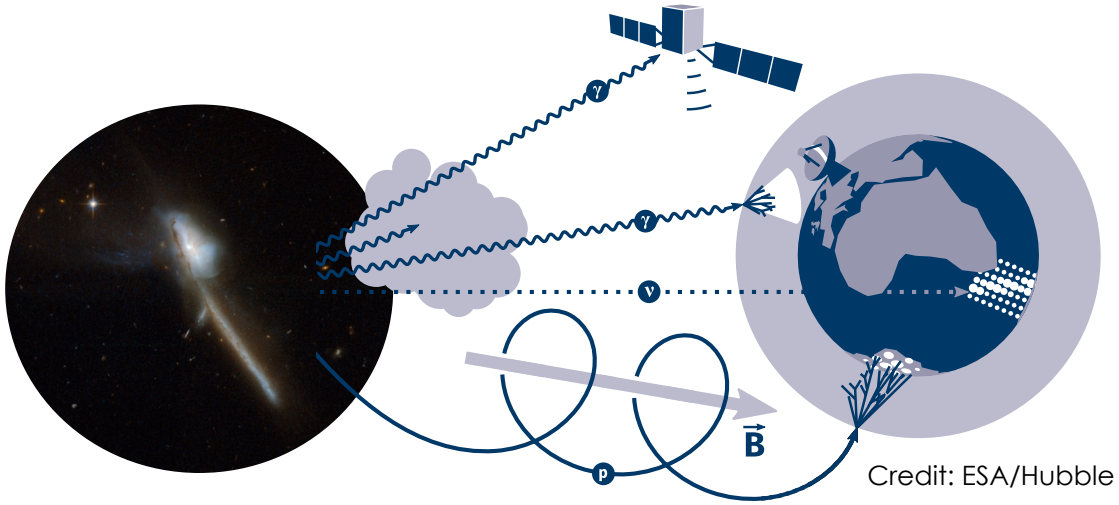


Credit: ESA/Hubble & C. Raab

IceCube Search for High-Energy Neutrinos from Ultra-Luminous Infrared Galaxies

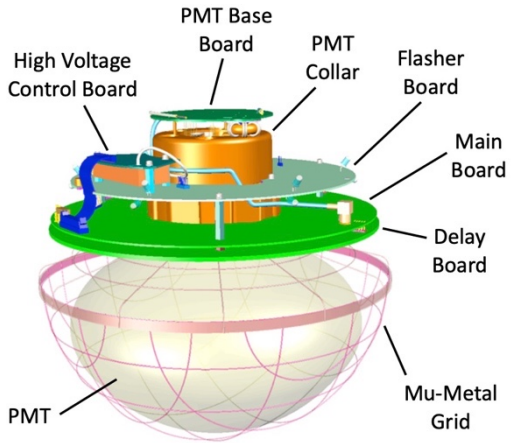
HEP@VUB Seminar
19 November 2020

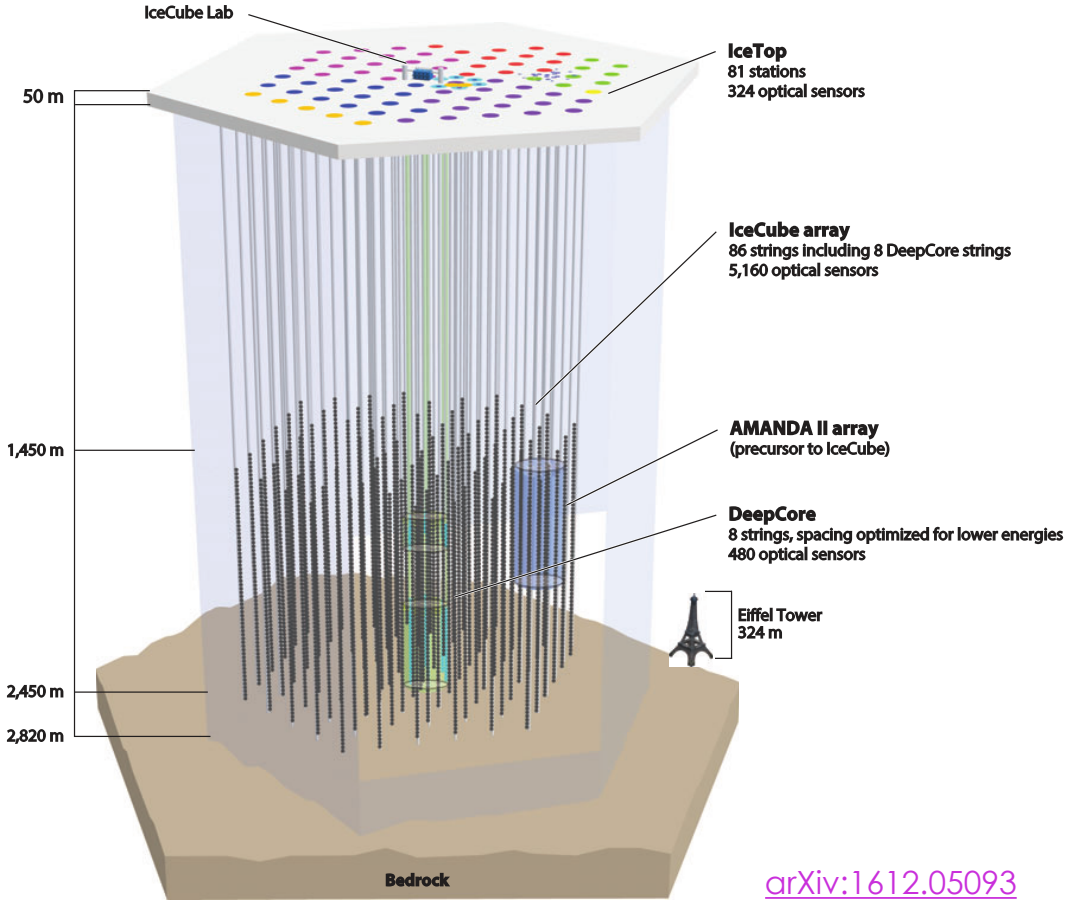
Pablo Correa
pabcorcam@gmail.com

IceCube South Pole Neutrino Observatory
iihe Bruxelles Brussel
VUB Vrije Universiteit Brussel
High-Energy Physics Research Centre
fwo

The IceCube Neutrino Observatory

- 1 km^3 detector at the South Pole
- 5160 digital optical modules (DOMs)
- 86 strings down to 2.45 km depth



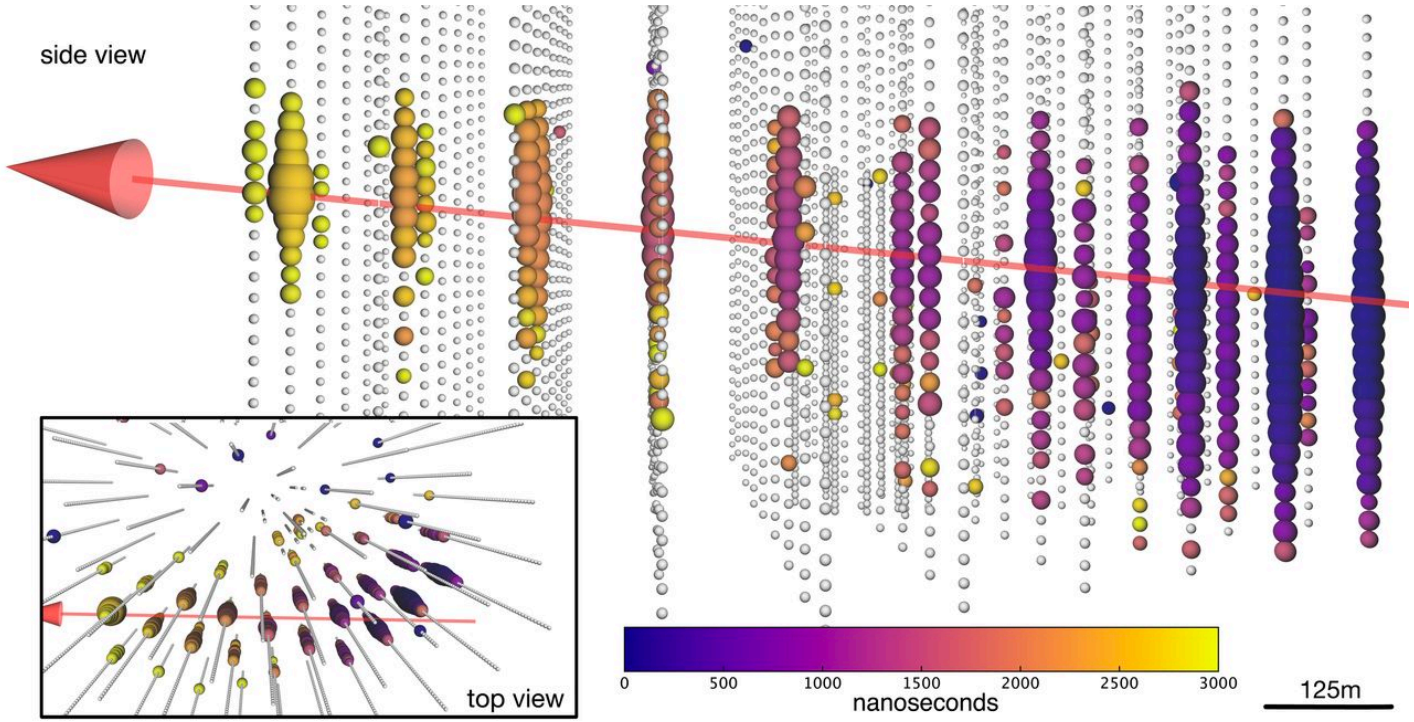


arXiv:1612.05093

Detecting Neutrinos with IceCube

- Neutrinos can interact with the ice surrounding IceCube
- Secondary charged particles produce Cherenkov radiation
- Muons leave track signatures in the detector
  - Median angular resolution $\lesssim 1^\circ$ for muon energy $\gtrsim 1$ TeV

IC170922A



doi:10.1126/science.aat1378

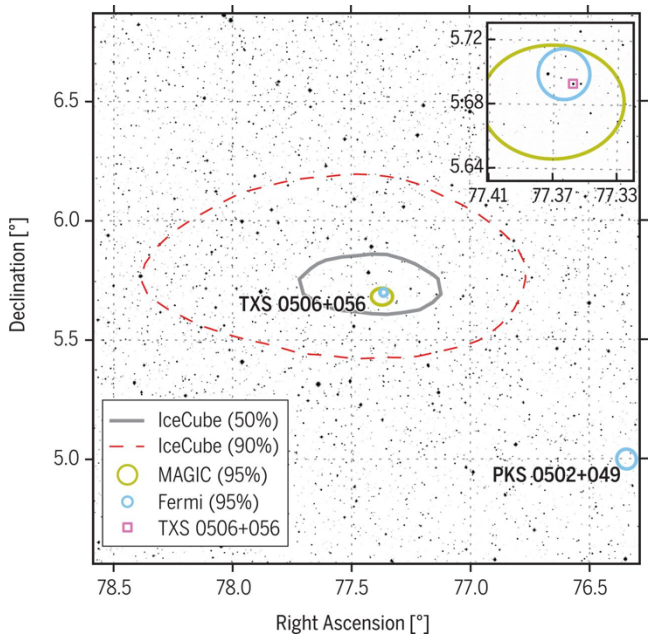
Check out the IceCubeAR app!

Available on the App Store link

GET IT ON Google Play link

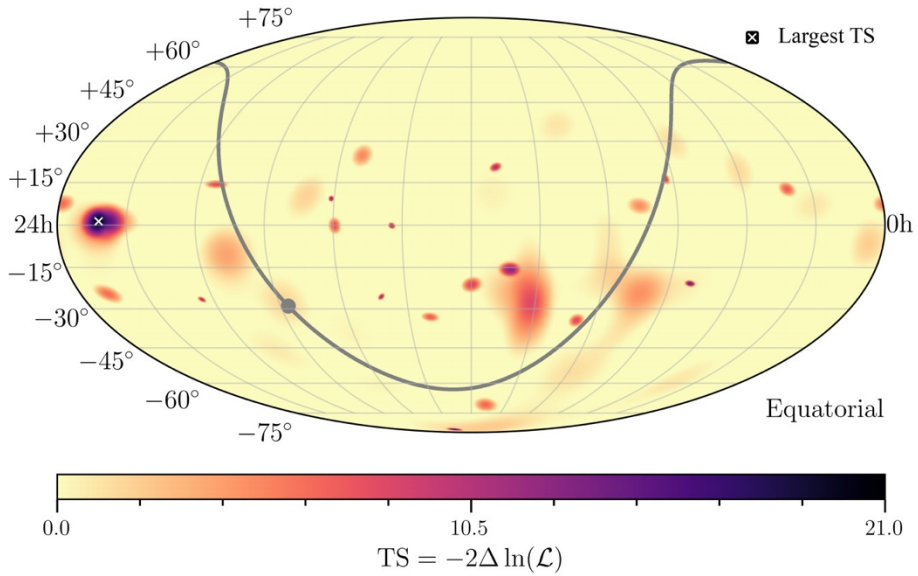
Neutrino Astronomy with IceCube

- Diffuse astrophysical neutrino flux observed since 2013
- Origin remains largely unknown
  - TXS 0506+056 is the only neutrino source identified so far thanks to multimessenger astronomy



doi:10.1126/science.aat1378

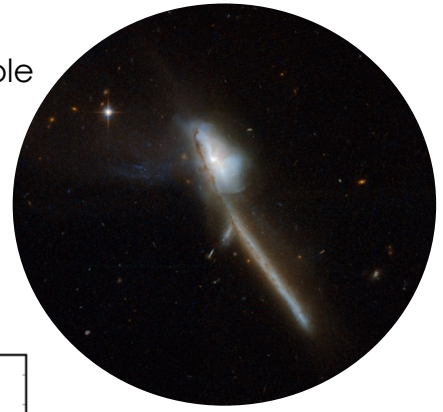
The sky in 7.5 years of astrophysical neutrinos



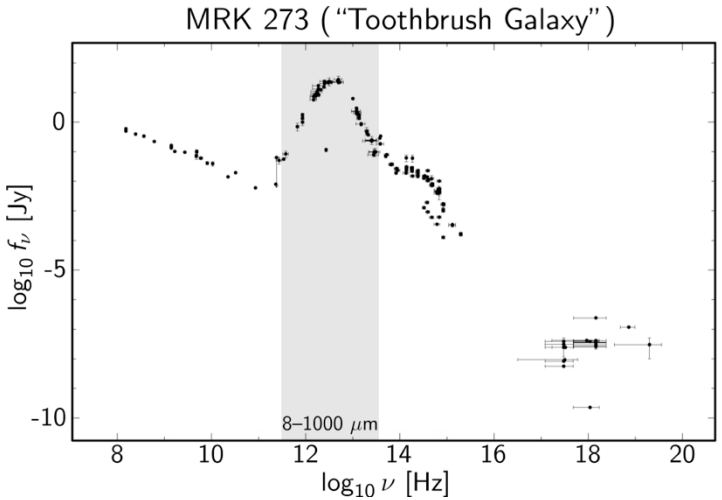
arXiv:2011.03545

Ultra-Luminous Infrared Galaxies

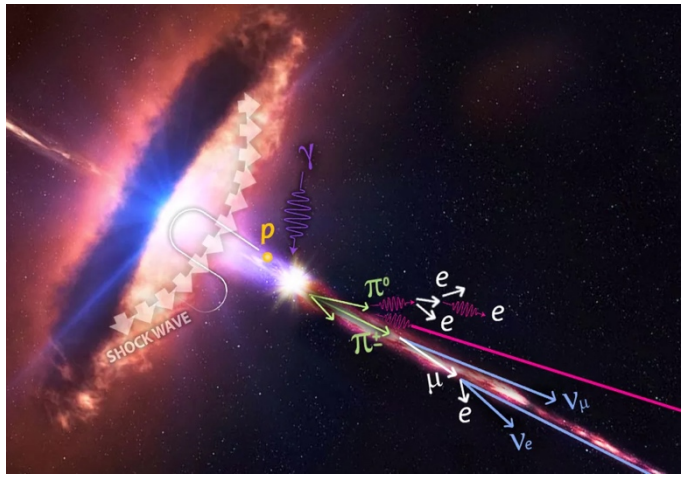
Credit: ESA/Hubble



- The most luminous objects in the IR sky
  - $L_{IR} \geq 10^{12}\ L_{\odot}$ between 8–1000 micron
  - Typically interacting galaxies
- Plausible hadronic accelerators
  - ULIRGs are mainly powered by starbursts
  - Possible contribution from active galactic nuclei
- Plausible neutrino sources
  - Smoking-gun signature of hadronic acceleration



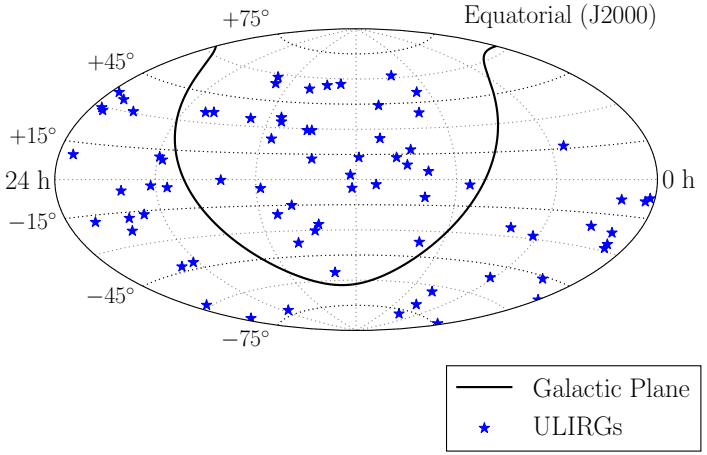
Credit: NASA/IPAC Extragalactic Database



Credit: NASA/IceCube

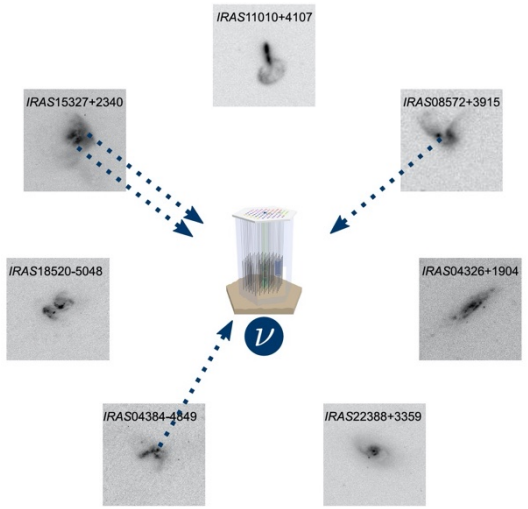
IceCube Stacking Search for Neutrinos from ULIRGs

- Select ULIRGs for a point source analysis
  - From catalogs based on IRAS satellite data
  - Complete sample of 75 ULIRGs (redshift $z \leq 0.13$)
- Stack ULIRGs to enhance sensitivity



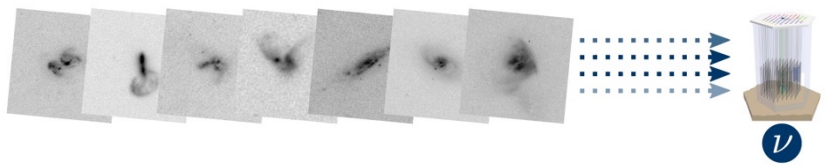
arXiv:astro-ph/0306263
arXiv:astro-ph/9806148
arXiv:1003.0858

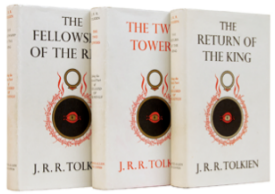
arXiv:1406.4509



Stack

Increasing IR flux

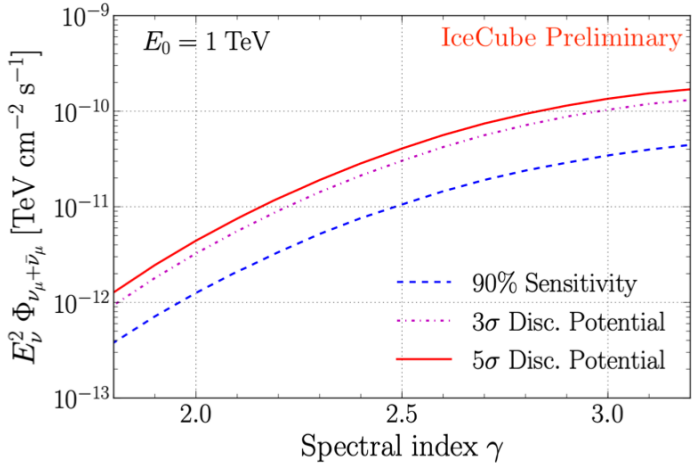


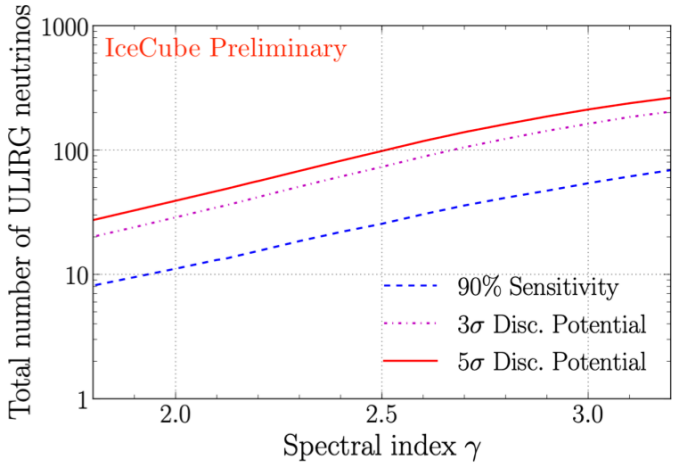


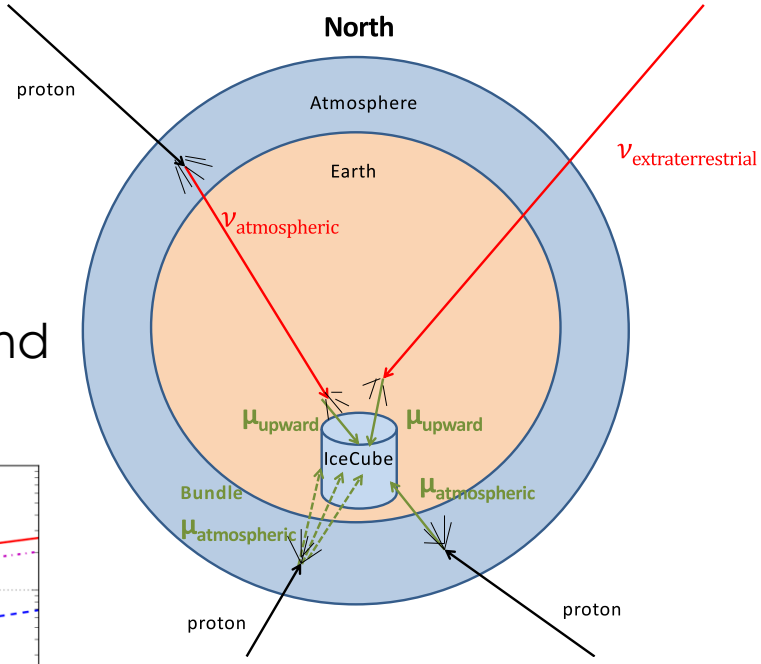
Stack

Sensitivities & Discovery Potentials

- Maximum likelihood analysis with 8 years of data
  - Background: atmospheric muons and atmospheric neutrinos
  - Search for an excess of neutrinos from ULIRG locations
- Test analysis performance for $E^{-\gamma}$ spectrum
  - Steeper spectra are more difficult to separate from background
  - Reflected in this analysis







Credit: J. Kunnen

Results & Upper Limits on Source Population

arXiv:2004.03435

- Analysis consistent with background hypothesis
  - Obtained p-value = 1.0
- Set upper limits on flux from our 75 ULIRGs
  - Extrapolate to limits on full ULIRG source population
- ULIRGs cannot be sole sources of the IceCube diffuse neutrino flux

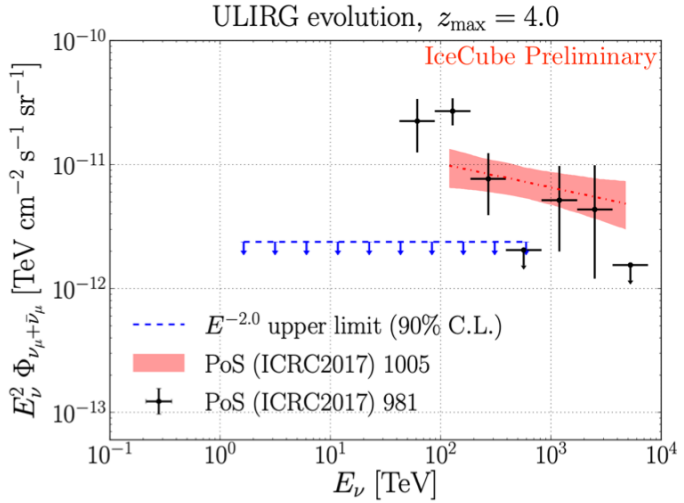
$$\Phi^{\text{all ULIRGs up to } z=z_{\max}}_{\nu_\mu+\bar{\nu}_\mu} = \frac{\xi_{z=z_{\max}}}{\xi_{z=0.13}} \Phi^{\text{all ULIRGs up to } z=0.13}_{\nu_\mu+\bar{\nu}_\mu}$$

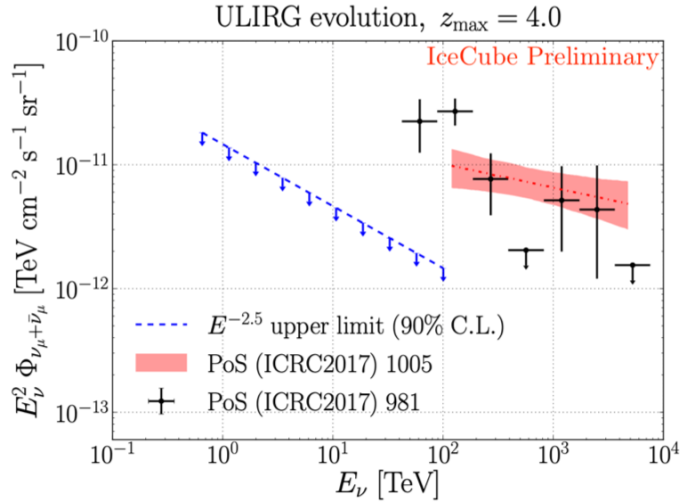
$$\xi_z = \int dz \, \mathcal{H}(z)$$

$$\mathcal{H}(z) = \begin{cases} (1+z)^4 & z \leq 1 \\ \text{flat} & z > 1 \end{cases}$$

ULIRG redshift evolution

$E^{-2.0}$ limits





$E^{-2.5}$ limits

Results & Upper Limits on Source Population

arXiv:2004.03435

- Analysis consistent with background hypothesis
  - Obtained p-value = 1.0
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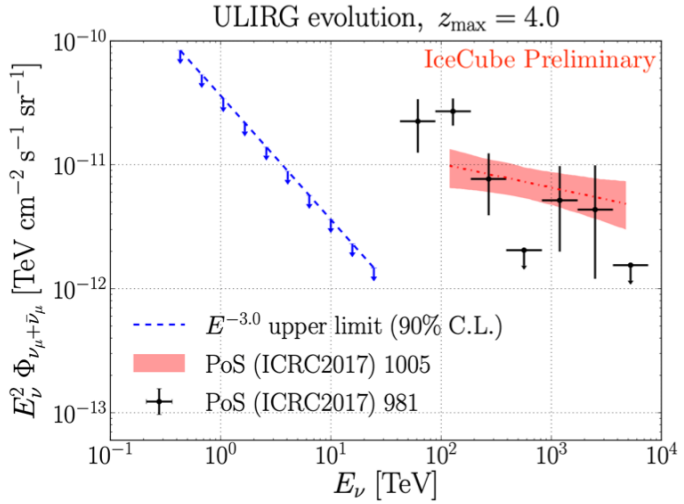
$$\Phi^{\text{all ULIRGs up to } z=z_{\max}}_{\nu_\mu+\bar{\nu}_\mu} = \frac{\xi_{z=z_{\max}}}{\xi_{z=0.13}} \Phi^{\text{all ULIRGs up to } z=0.13}_{\nu_\mu+\bar{\nu}_\mu}$$

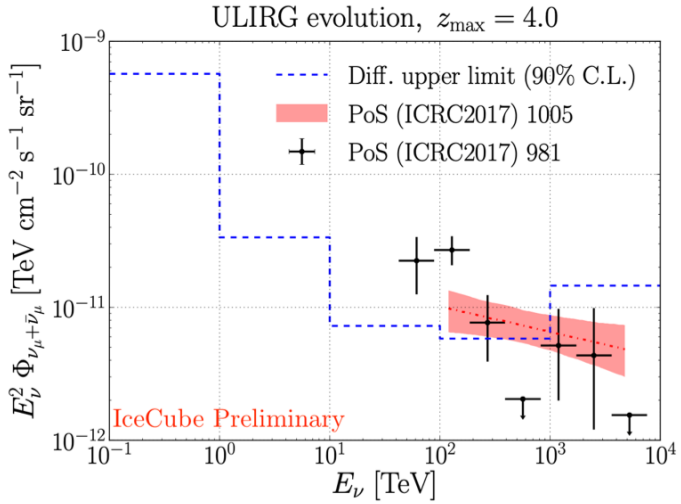
$$\xi_{z=z_{\max}} = \int dz \, \mathcal{H}(z)$$

$$\mathcal{H}(z) = \begin{cases} (1+z)^4 & z \leq 1 \\ \text{flat} & z > 1 \end{cases}$$

ULIRG redshift evolution

$E^{-3.0}$ limits

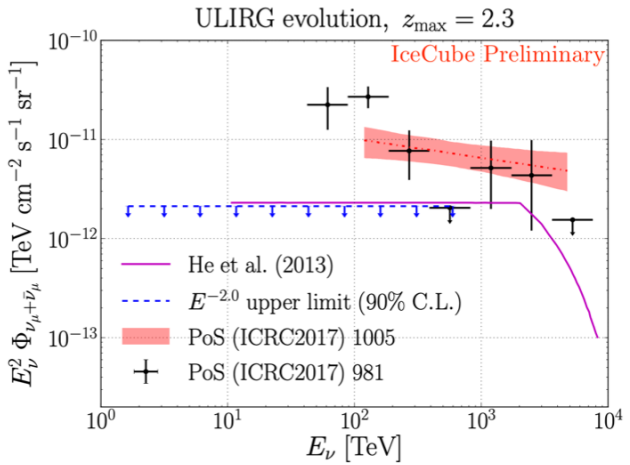


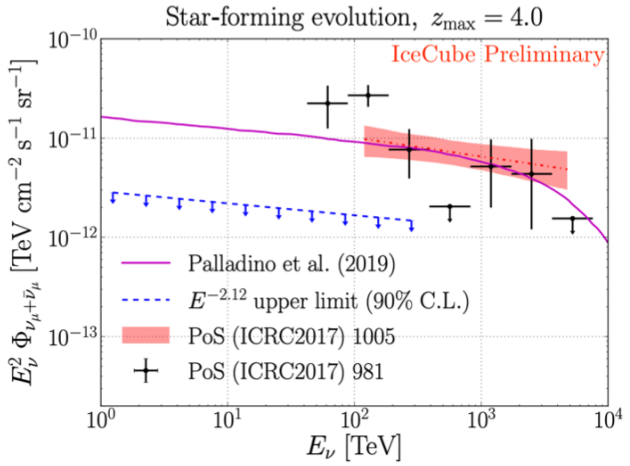


Differential limits

Comparison with Model Predictions

- He et al, 2013 (arXiv:1303.1253)
  - In tension with limits
- Palladino et al, 2019 (arXiv:1812.04685)
  - ULIRGs excluded as sole contributors
- Vereecken & de Vries, 2020 (arXiv:2004.03435)
  - Baryonic loading constrained: $f_e = L_e/L_p \gtrsim 10^{-3}$





Conclusions & Future Prospects

Summary

- Performed IceCube stacking search for neutrinos from ULIRGs
- No astrophysical signal identified
- Set upper limits on ULIRG source population
- Constrained model predictions

Outlook

- Write an IceCube paper on this analysis
- Future studies will focus on gamma-ray dim neutrino sources
  - Subclass of (U)LIRGs?
  - Compton-thick active galactic nuclei?
  - Follow Yarno Merckx' MSc thesis work!