https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF3_NF2-CF7_CF1-TF9_TF8_Katori-073.pdf

New Physics with Astrophysical Neutrino Flavor

Test of neutrino properties
- Neutrino lifetime
- Number and nature of neutrinos
- Mass-varying neutrinos

Tests of signatures of a dark Universe
- Dark matter as source
- Dark matter as background
- Dark energy as background

Tests of fundamental physics:
- Non-standard interactions
- Neutrino self-interactions
- Long-range forces
- Modified neutrino-nucleus interactions
- Quantum decoherence
- Lorentz and CPT invariance violation
- Extra dimensions

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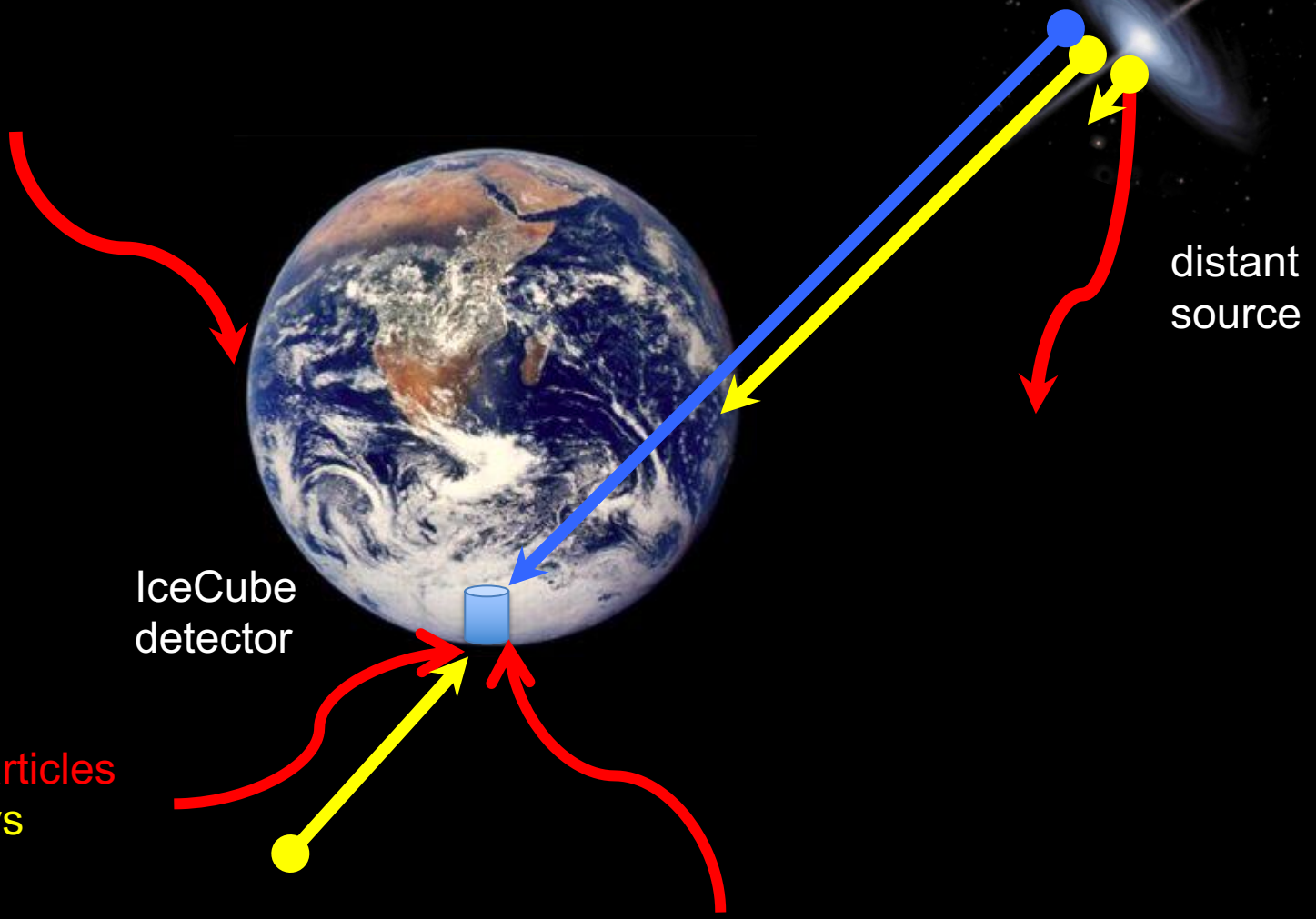
New Physics with Astrophysical Neutrino Flavor

High-energy astrophysical neutrinos have a unique role in Multi-messenger astronomy



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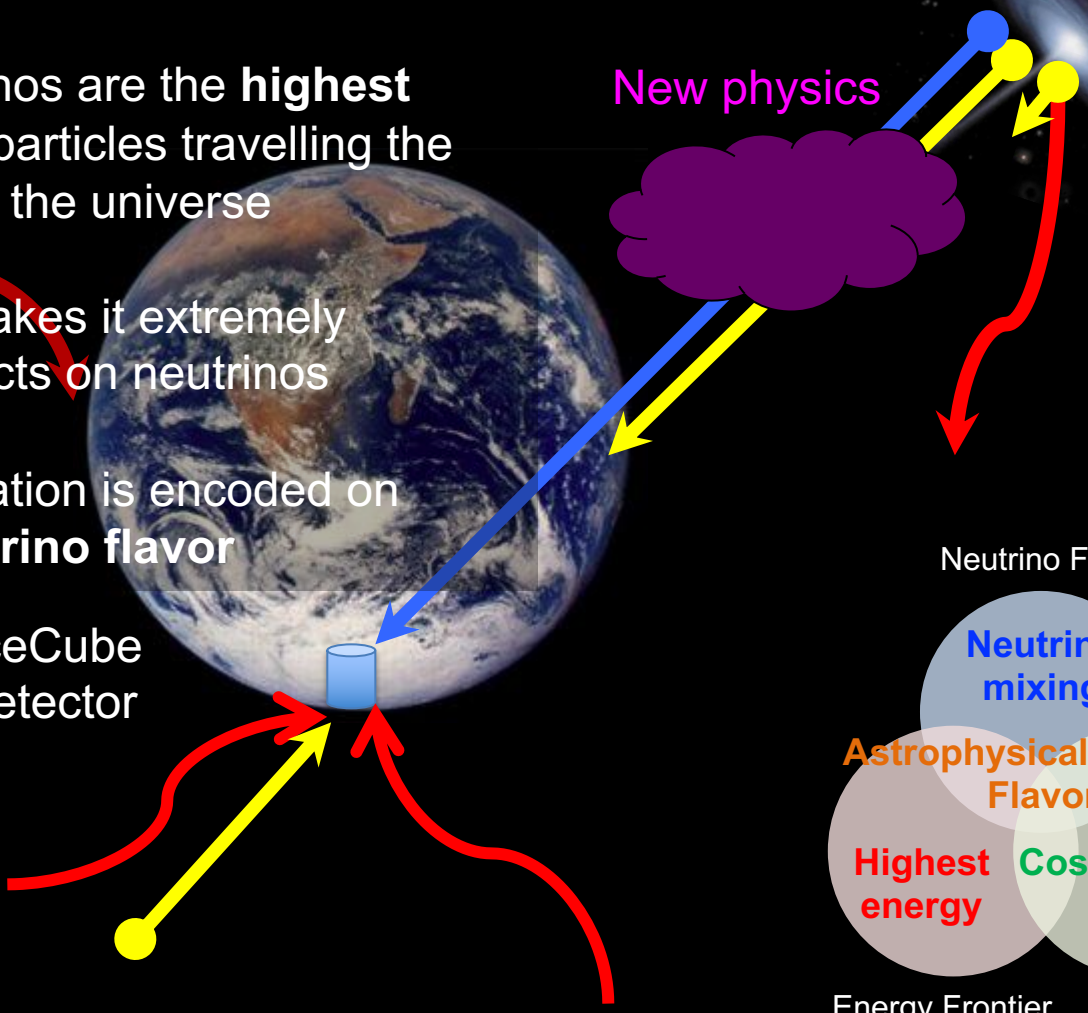
New Physics with Astrophysical Neutrino Flavor

High-energy astrophysical neutrinos have a unique role in Multi-messenger astronomy

Astrophysical neutrinos are the **highest energy** elementary particles travelling the **longest distance** in the universe

Neutrino mixing makes it extremely sensitive to any effects on neutrinos

New physics information is encoded on **Astrophysical neutrino flavor**



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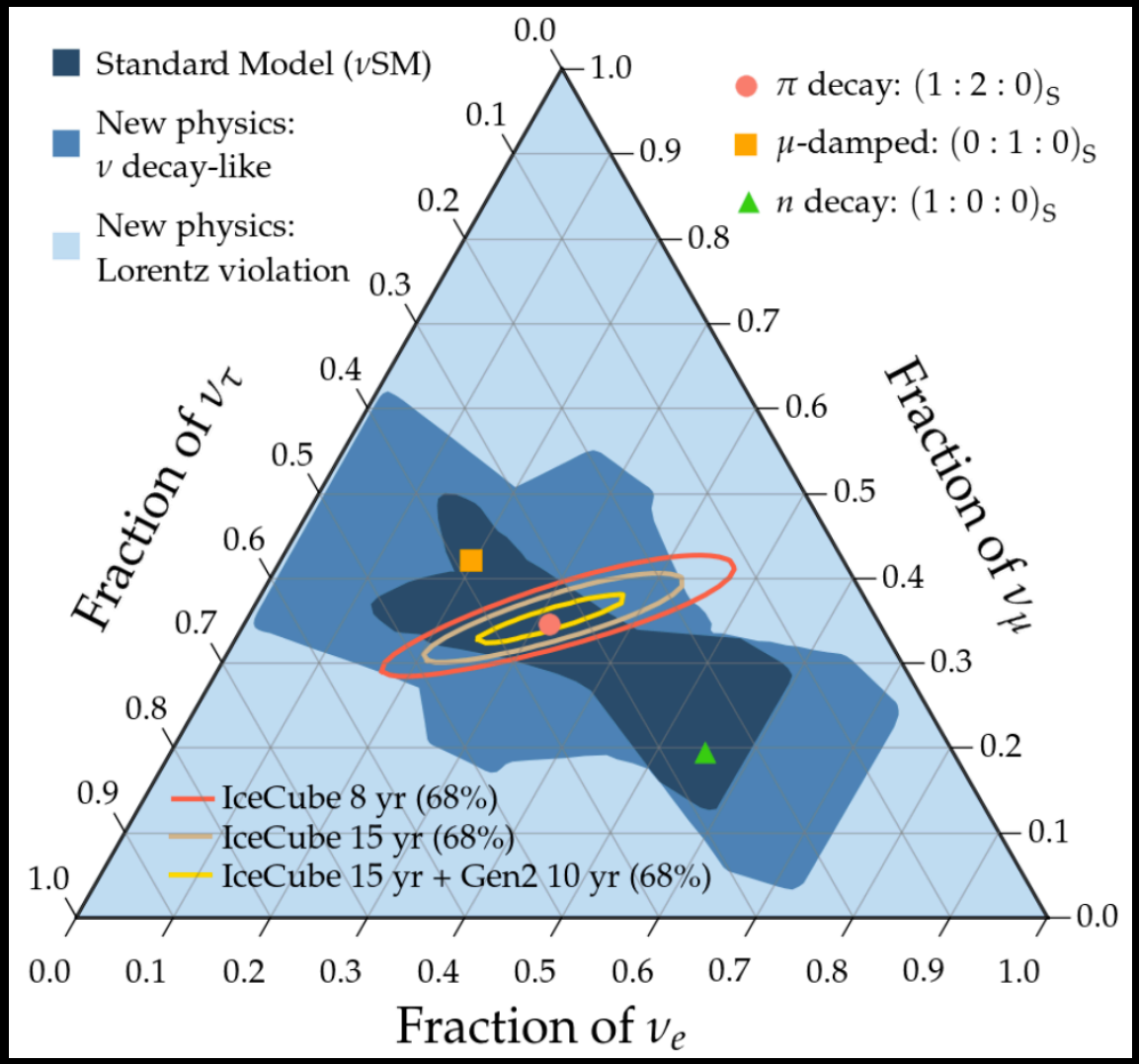
Flavor triangle ($\nu_e : \nu_\mu : \nu_\tau$)

Astrophysical neutrino flavor is measured as **flavor ratio**.

Standard neutrino mixing predicted observable flavor ratio within the dark blue region (~1:1:1).

Very small amount of new physics can deviate flavor ratio from 1:1:1.

Flavor ratio is extremely sensitive to new physics.



IceCube-Gen2, arXiv:2008.04323 (to be published, JPhysG)

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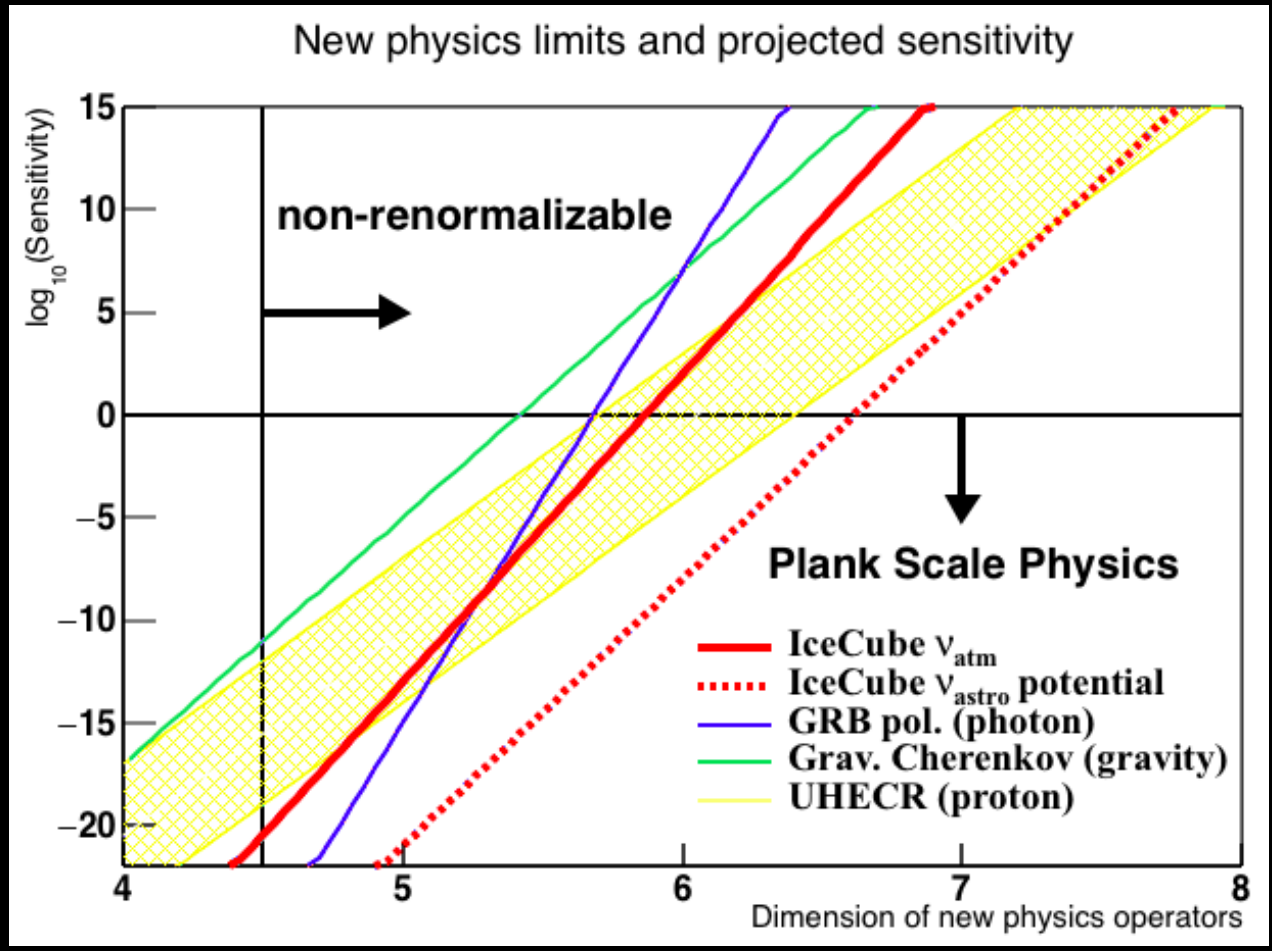
Effective operator sensitivity

$$\mathcal{H} = \mathcal{H}_{\nu SM} + \frac{\mathcal{O}^{(5)}}{M_{Pl}} E^2 + \frac{\mathcal{O}^{(6)}}{M_{Pl}^2} E^3 + \frac{\mathcal{O}^{(7)}}{M_{Pl}^3} E^4 \cdots$$

Assuming new physics is Planck scale origin, astrophysical neutrino flavor can reach discovery region

For example, sensitivity of astrophysical neutrino flavor to dimension-six vacuum operator is ~10^{-8} (10^{-46}GeV^{-2}), far beyond any other technology, from table to experiment to cosmology



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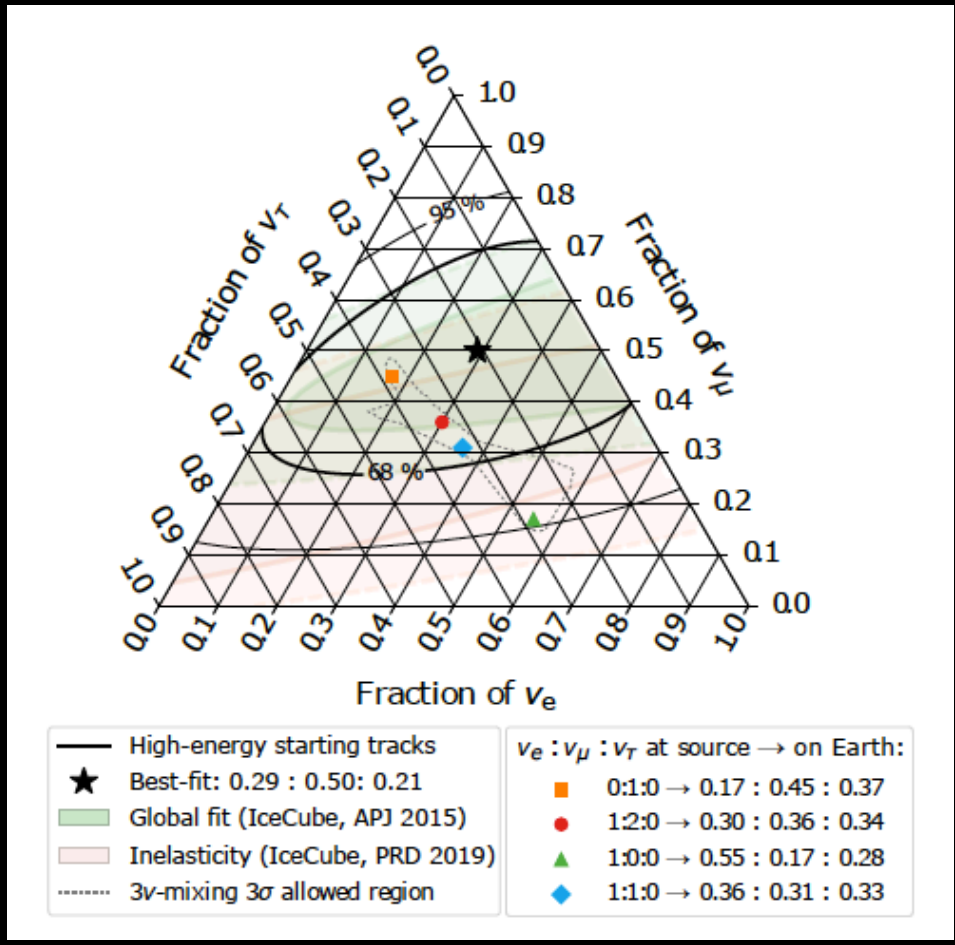
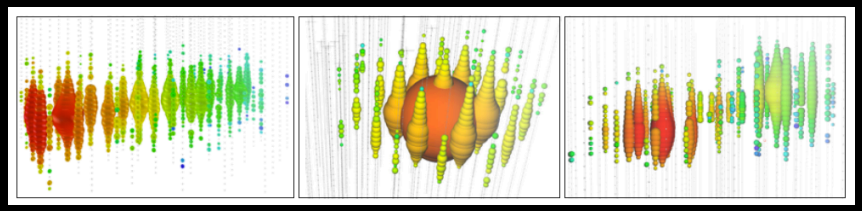
Flavor triangle ($\nu_e : \nu_\mu : \nu_\tau$) in IceCube

Astrophysical neutrino morphology
- Track: muon neutrino CC
- Cascade: electron, tau CC or NC
- Double cascade: tau

Current data statistics and systematics accept large area as astrophysical neutrino flavor ratio



ν_μCC ν_eCC,ν_τCC,NC ν_τCC



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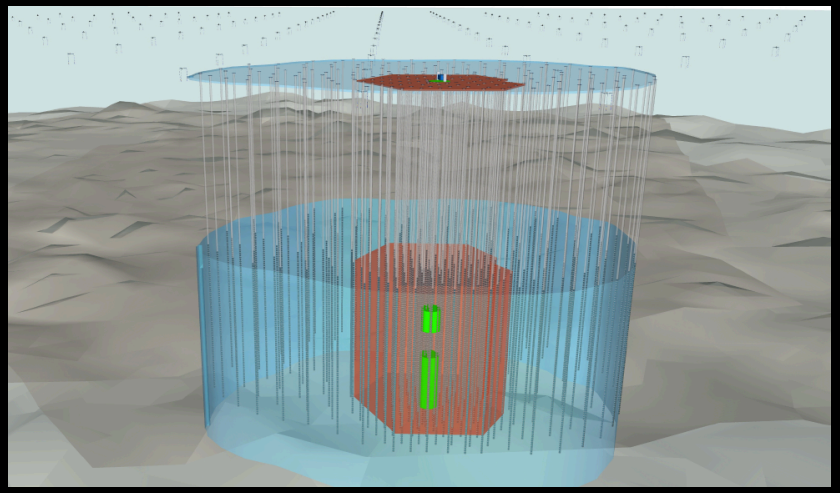
Flavor triangle ($\nu_e : \nu_\mu : \nu_\tau$) in IceCube-Gen2

Higher statistics with larger effective area

Improved particle identification
- Improved optical sensors
- New calibration
- New PID algorithm (machine learning, etc)



Higher energy neutrinos
- Larger effective area
- Radio arrays

More transient events
- Better constraint of production model

Astrophysical neutrino flavor physics is a new sub-field, it's an old idea but have been developed to the reality only in last few years. This approach uses the best of neutrino, energy, and cosmic frontiers, and it has a high discovery potential for many new physics models.

IceCube-Gen2, arXiv:2008.04323 (to be published, JPhysG)