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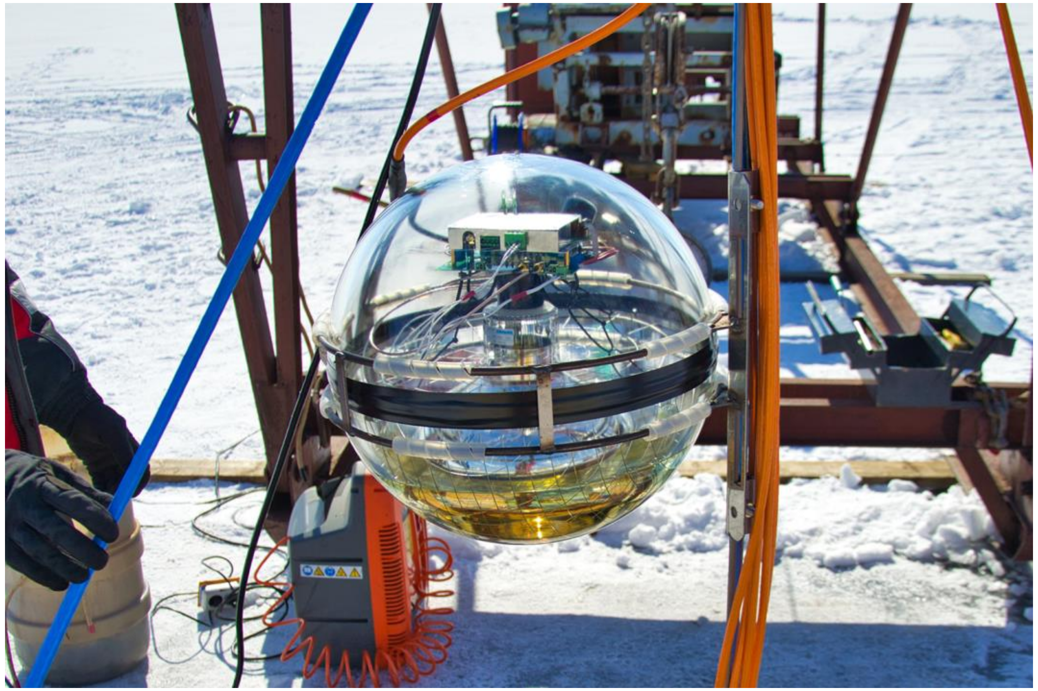
Investigating High-Energy Galactic Neutrino Flux with the Baikal-GVD Detector



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The Problem: The source of ultra-high-energy cosmic rays in our galaxy has remained unsolved for many years.

A possible way to solve it: Neutrinos!

- Neutrinos are light particles that barely interact with matter.
- They travel in straight lines, showing where they came from.
- They can pass through gas and dust without being stopped.
- They can show us the most „violent“ places in the universe!

Study Aim: To seek proof that many of the neutrinos we find, come from our galaxy, especially at very high energies.

How are neutrinos created?

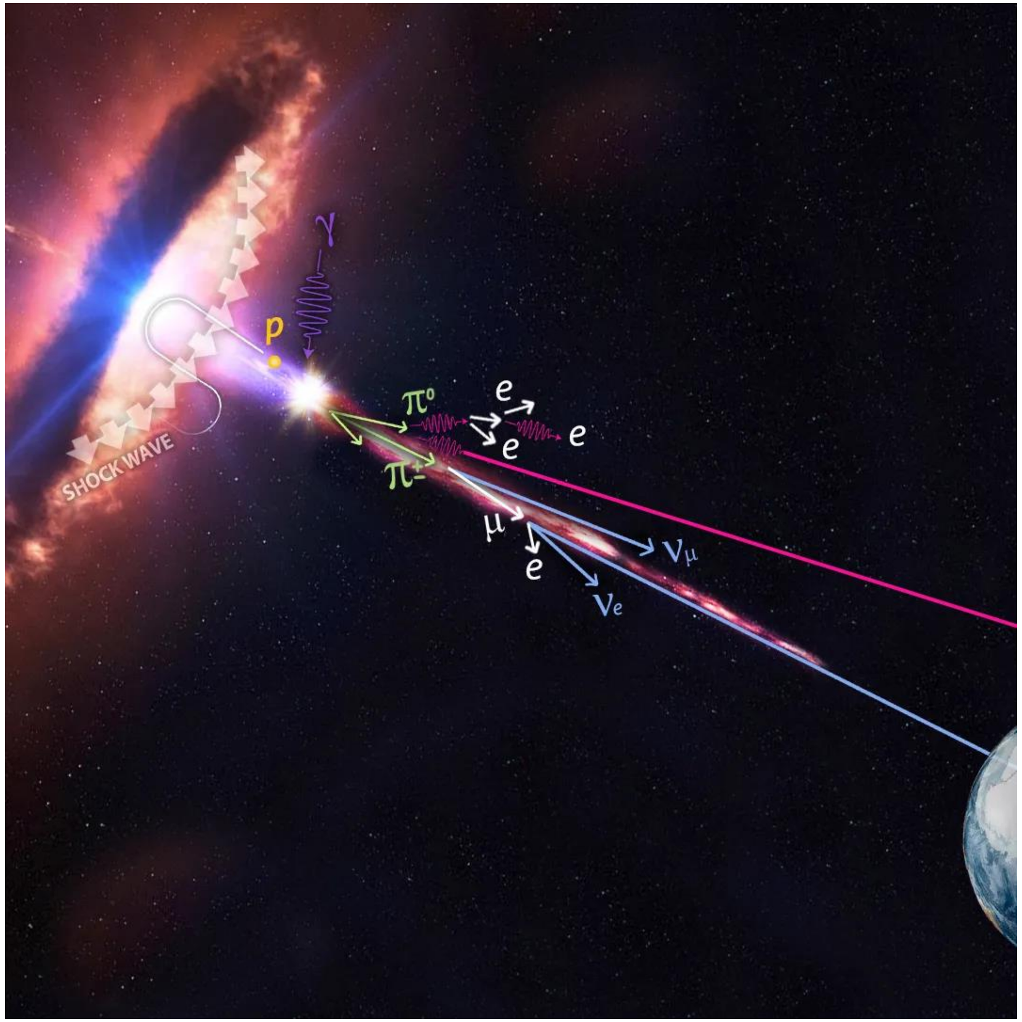
Cosmic rays (protons) from powerful sources (like exploded stars) move through space.

They hit gas in our Galaxy.

These crashes make particles called pions.

Neutrinos come from the decay of pions.

Finding these neutrinos helps us figure out where and how cosmic rays gain such high energies.

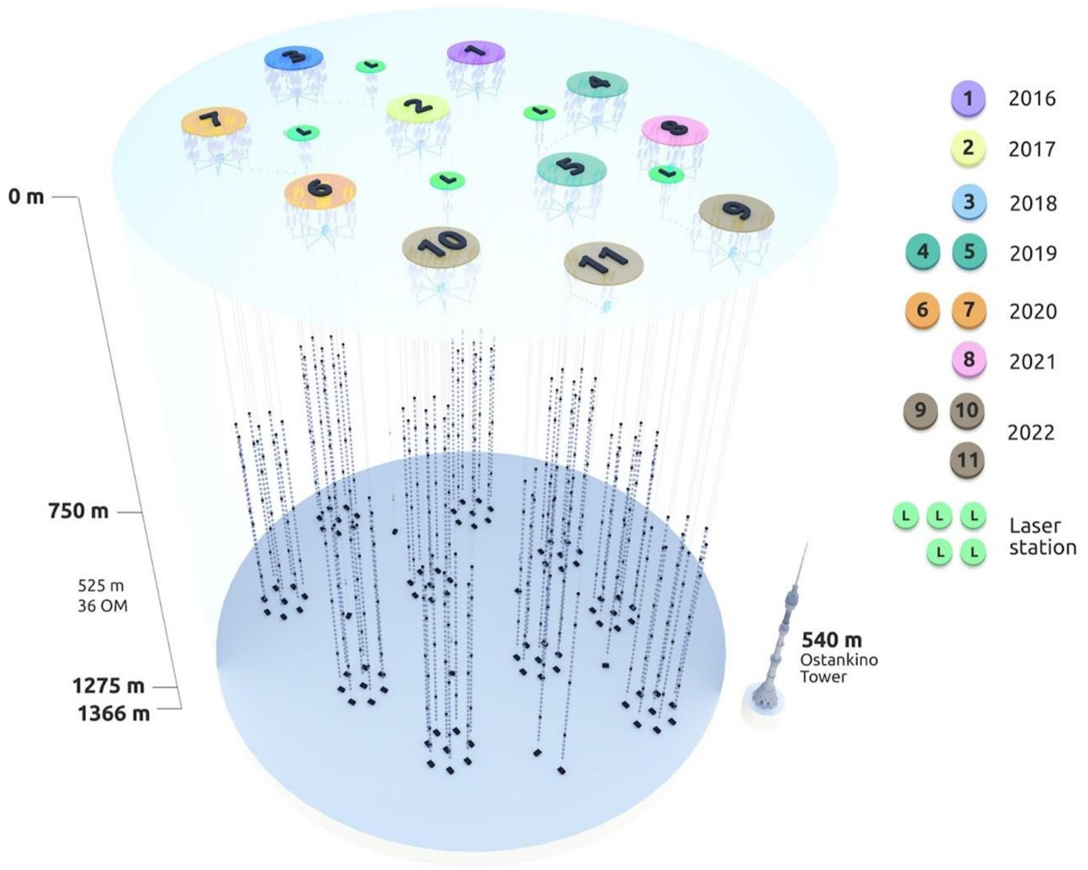


The Baikal-GVD Telescope - a large underwater telescope in Lake Baikal, Russia.

Telescope searches for faint flashes of light (Cherenkov radiation) made when a neutrino hits the water.

Cascades: Spherical flashes made by neutrino interactions are useful when measuring energy.

The Data: The study uses 6 years of collected data that shows cascade events with energies above 200 TeV(~ 100,000 times higher than the energy of protons in the LHC).



Methods

Scientists used a model-independent approach, without assumptions about the signal shape.

The analysis relied on a single non-parametric statistic test: the median Galactic latitude (|b|_med).

This test measures if events cluster near the Galactic plane (low |b|_med) or are spread out (high |b|_med).

Monte Carlo simulations generated thousands of random sky maps without a Galactic signal.

They calculated the p-value by comparing our observations to the simulation results.

Result 1 (The Baikal-GVD Finding)

The Baikal-GVD neutrinos are grouped near the Galactic plane.

The graph shows the median |b| from simulations. The actual number (red line) is far to the left, showing the found neutrinos are much closer to the plane.

What it means: There is only a 1.4% chance (or 2.5σ) that this grouping happened randomly. This supports a Galactic signal.

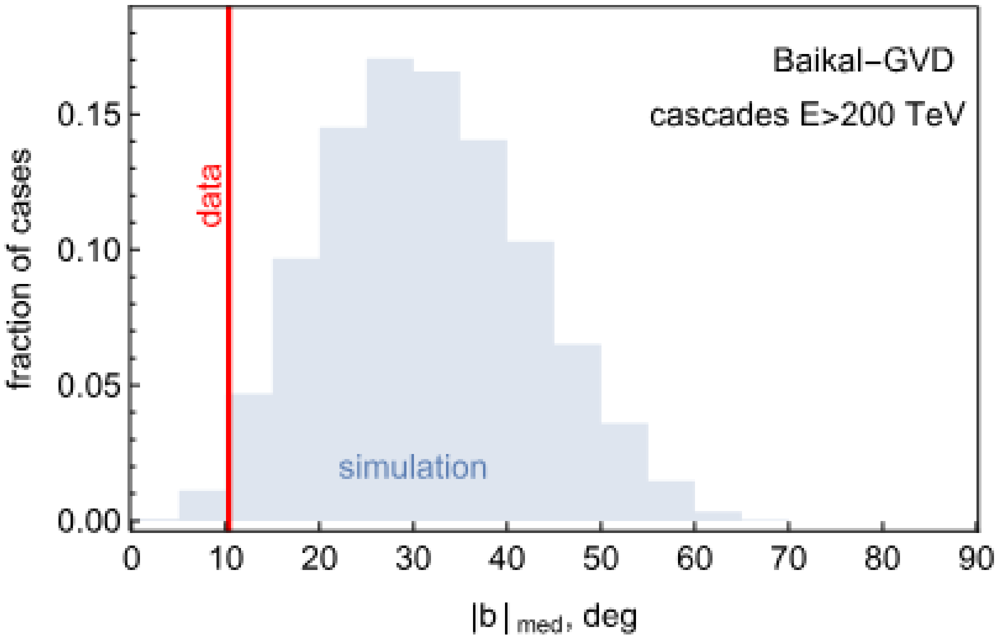


Figure 1. Distribution (shaded histogram) of the median $|b|_{med}$ in simulated sets of Baikal-GVD cascades with $E \geqslant 200$ TeV. The observed value of $|b|_{med}$ is shown by the vertical red line.

Result 2 (IceCube Data)

IceCube: A large neutrino telescope in the ice at the South Pole.

Both IceCube datasets also showed more events than usual from the Galactic plane!

Result: The combined data is even stronger.

There is only a 0.034% (3.6σ) chance that this is random.

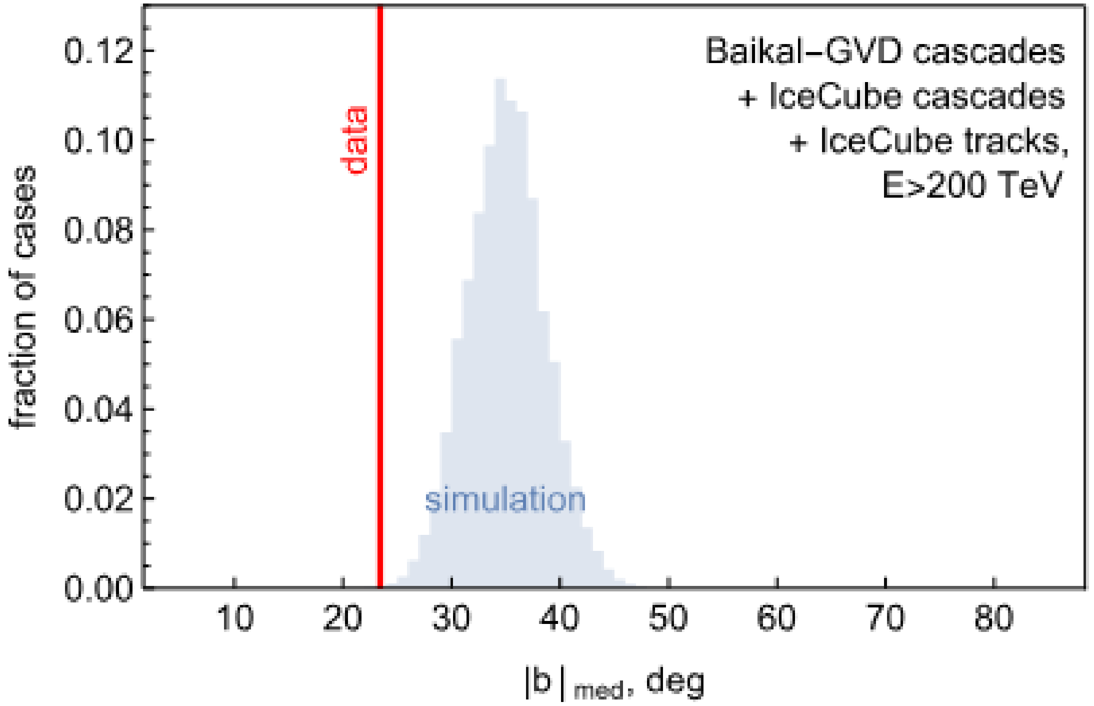


Figure 3. Distribution (shaded histogram) of the median $|b|_{med}$ in simulated combined sets of Baikal-GVD cascades, IceCube cascades, and IceCube tracks with $E \geqslant 200$ TeV. The observed value of $|b|_{med}$ is shown by the vertical red line.

Implications & Discussion

The Galactic neutrino amounts at these high energies are higher than expected.

The neutrino signal matches gamma-ray data from telescopes.

Source Clues: The neutrinos might come from specific spots in our Galaxy, like the Cygnus region.

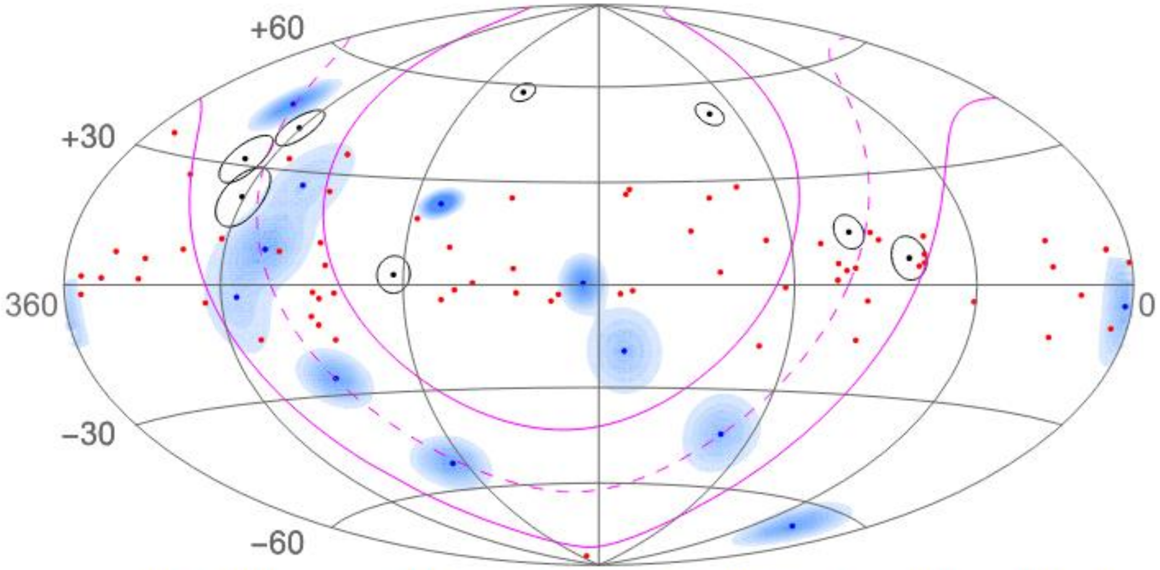


Figure 5. Arrival directions of Baikal-GVD (black projected circles of r_{90} radius) and IceCube (shading presenting the likelihood of the direction) cascade events, as well as IceCube track events (red dots) with $E \geqslant 200$ TeV in the sky map in equatorial coordinates. The dashed magenta line represents the Galactic plane, and two full magenta lines limit the zone $|b| < 20^{\circ}$.

Conclusions:

The Milky Way is a source of very high-energy neutrinos (>200 TeV).

Confirmed by two telescopes (Baikal-GVD and IceCube) using different ways to collect data.

There is still a mistery: the signal could be stronger and made up differently than predicted.

Future: More data from Baikal-GVD and other telescopes will show the exact sources and solve this puzzle.

Reference list

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Thank you for attention!