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Neutrino Oscillations in Extreme Astrophysical Laboratories: Insights from GRBs

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Astronomy has entered a new era of multi-messenger observation with the early detection of neutrinos from SN1987A and the recent discovery of gravitational waves. Neutrinos serve as an effective detection channel for various astrophysical sources. This research focused on neutrino propagation through multiple media, including central engines within gamma-ray bursts (GRBs) and environments with strong magnetic fields. We studied how these neutrinos interact with and are affected by their surroundings. Our findings show that neutrino propagation highly depends on the medium's properties, such as density profiles and magnetic fields. In environments with non-isotropic density distributions, we demonstrated that neutrino propagation is essential in understanding the energy extraction mechanisms at work near GRB central engines.
Furthermore, our findings indicate that neutrino oscillation probabilities can vary significantly with changes in propagation latitude and energy, allowing for potential differentiation between GRB progenitors. The implications of our studies extend beyond theoretical understanding. They pave the way for multi-messenger astrophysics, aiding in identifying the sources of observed neutrino flux. These findings are crucial for the future of neutrino astronomy and the development of next-generation neutrino detectors, and they promise to enhance our ability to investigate the universe's most energetic events.

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