In the name of god

دانشگاه صنعتی خواجه نصیرالدین طوسی

Clustering of dark matter in the cosmic web as a probe of massive neutrinos

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Introduction

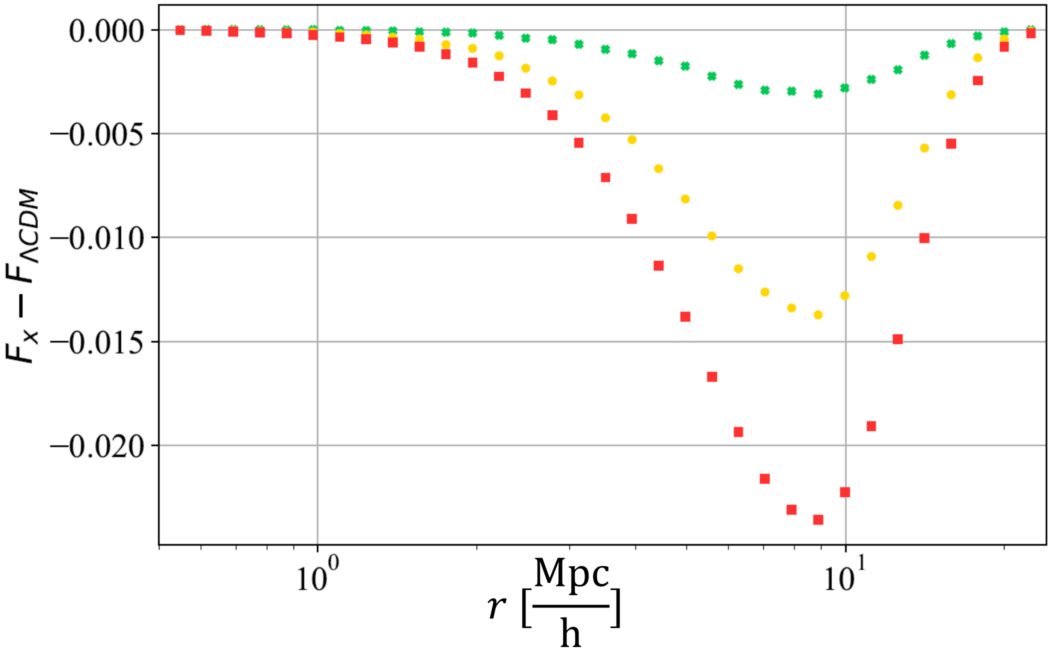
- The vast expanse of the universe holds mysteries, including the nature of dark matter and the mass of the neutrino. Dark matter, invisible yet dominant, shapes the cosmic web – a network of filaments and voids. Neutrinos, low mass particles barely interacting with matter, are abundant but difficult to detect.
- This research explores a novel approach to unveil the neutrino's secret: **using the cosmic web and dark matter clustering as a probe**. By studying how massive neutrinos influence the distribution of dark matter, we can gain insights into their properties. This investigation sheds light on the dark universe and paves the way for a deeper understanding of these fundamental particles.

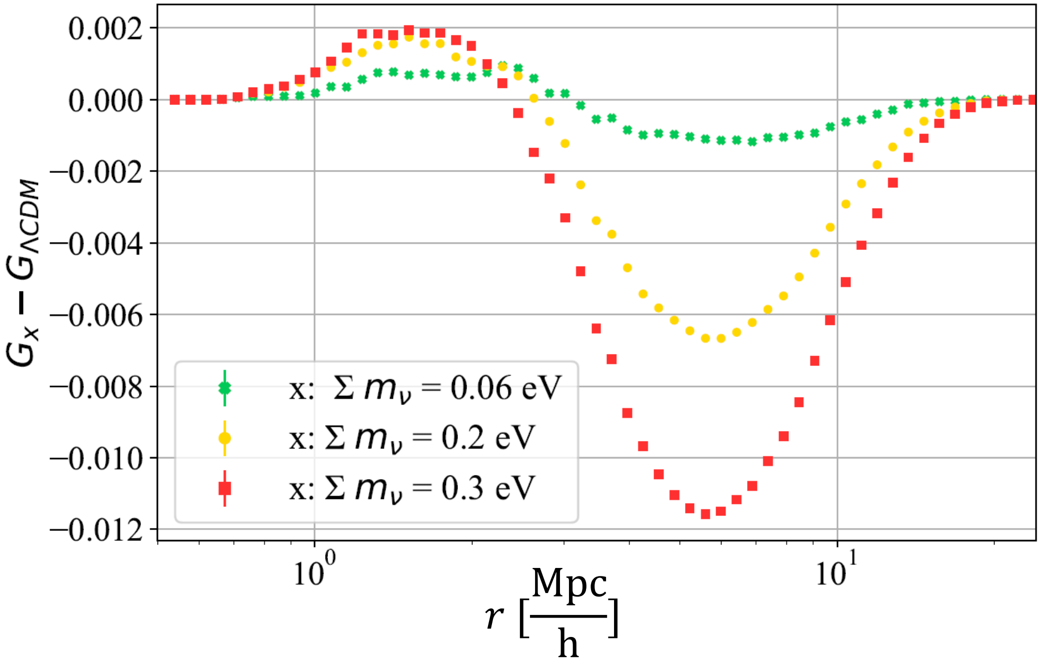
K-nearest neighbor

- To tackle this challenge, we employ a powerful technique called the **k-Nearest Neighbor (k-NN)** method within the context of the cosmic web.
- The k-NN method is a statistical approach that works by identifying the closest neighbors – in our case, dark matter halos – within the vast cosmic web. By analyzing the statistical properties of these neighboring halos and their relation to neutrino mass, we can gain valuable insights into the properties of these particles. This approach offers a novel perspective on neutrino mass, leveraging the large-scale structure of the universe to probe the unseen.
- Previous studies suggest that similar approaches can significantly improve the detectability of neutrino mass. [Uhlemann et al. 2020, Abel et al. 2021].

Results

The impact of sum of neutrino mass on F(r) and G(r);
F(r) is the cumulative distribution function of nearest neighbor distance of a random chosen point.
G(r) is the cumulative distribution function of the nearest neighbor distance of a dark matter halo.





Simulations: Gevolution [Adamek et al. 2017]

M. Khoshtinat, MA, F. Hassani, S. Baghram (2024)

Results

- We successfully applied the k-Nearest Neighbors (k-NN) method to analyze dark matter halo clustering in simulations that incorporated varying **neutrino masses**.
- Our analysis revealed a **distinct signature** of neutrino mass in the simulations. This signature manifests as a deep and then a peak in the G(r) which can be used as a unique identifier (fingerprint) of neutrinos within dark matter cosmic web data.
- Furthermore, increasing the **total neutrino mass** resulted in a larger deviation from the standard Lambda-Cold Dark Matter (ΛCDM) model.
- We also find that the mass of neutrinos might be more readily detectable in **high-redshift** (high-z) cosmological data.

Future remarks

- **Refining the Technique**: Further research is ongoing to optimize the k-NN method for real-world cosmological data analysis.
- **Synergy with Observations**: By combining this technique with upcoming large-scale structure surveys, we aim to place tighter constraints on neutrino mass.
- **A New Window on the Dark Universe**: This research paves the way for a deeper understanding of massive neutrinos and their role in the evolution of the cosmos.