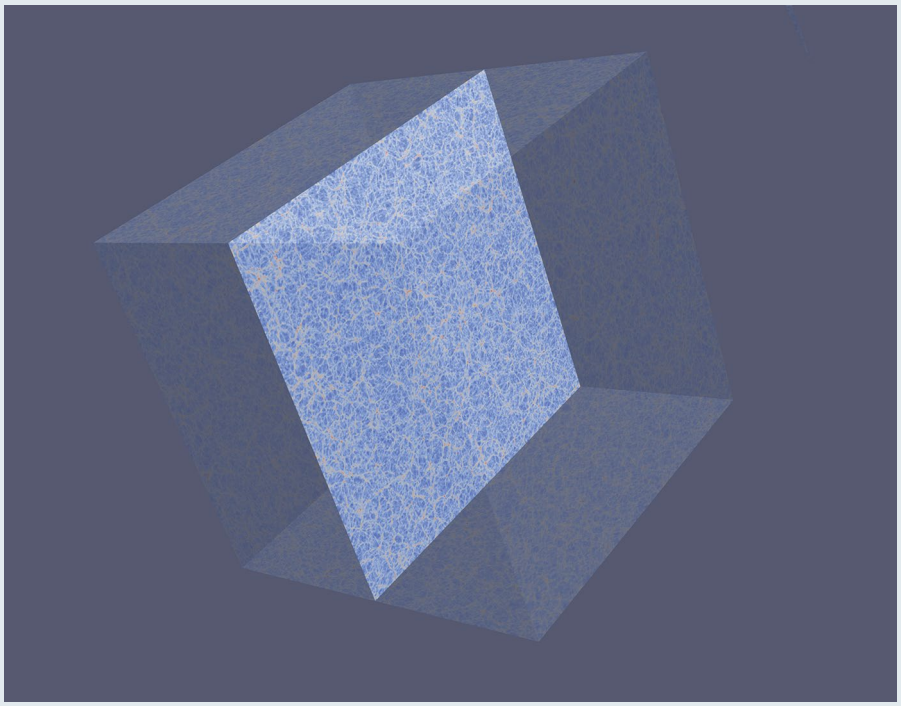
LARGE-SCALE STRUCTURE

Mass-producing universes

Revealing the nature of dark matter and dark energy and understanding their effect on the formation and evolution of present-day galaxies are two of the main open questions in observational cosmology today. Large-scale structure (LSS; for example, clusters, filaments and voids) is one of the key observables of dark matter accessible through large-scale optical and near-infrared surveys. LSS properties can be compared to time- and computation-intensive cosmological simulations to indirectly constrain the underlying cosmological parameters, including those describing dark matter and dark energy. Takahiro Nishimichi and collaborators (*Astrophys. J.* **884**, 29; 2019) present a new tool that can build a mock universe within seconds, greatly simplifying this comparison.

Machine learning has been increasingly used not only in analysing and understanding observational data, but also in expediting otherwise costly numerical simulations. Emulators are machine-learning tools that can be trained on numerical simulations to interpolate various quantities and therefore probe new parameter spaces not covered by the simulations used for their training. Nishimichi et al. used ATERUI II, the world's fastest astrophysical simulation supercomputer, to run 101 cosmological simulations to train their DARK emulator and then used the emulator to produce mock universes (an example pictured) to be compared with data from the Sloan Digital Sky Survey. The comparison indicates that the emulated universe can replicate the weak lensing signal of the LSS as well as the galaxy cross-correlation function to accuracies of 2% and 4%, respectively.



Credit: YITP

Unlike previous similar efforts, the DARK emulator is built to be highly modular: in effect it is made up of a series of emulators. This setup allows flexibility in the models that one may need to implement in the emulator — one example is the halo occupation distribution that links dark matter halos to observed galaxies — and the outputs one needs. The main outputs of the DARK emulator are the halo mass function and the halo-matter cross- and auto-correlation functions. ❐

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