Supercomputer turns back cosmic clock

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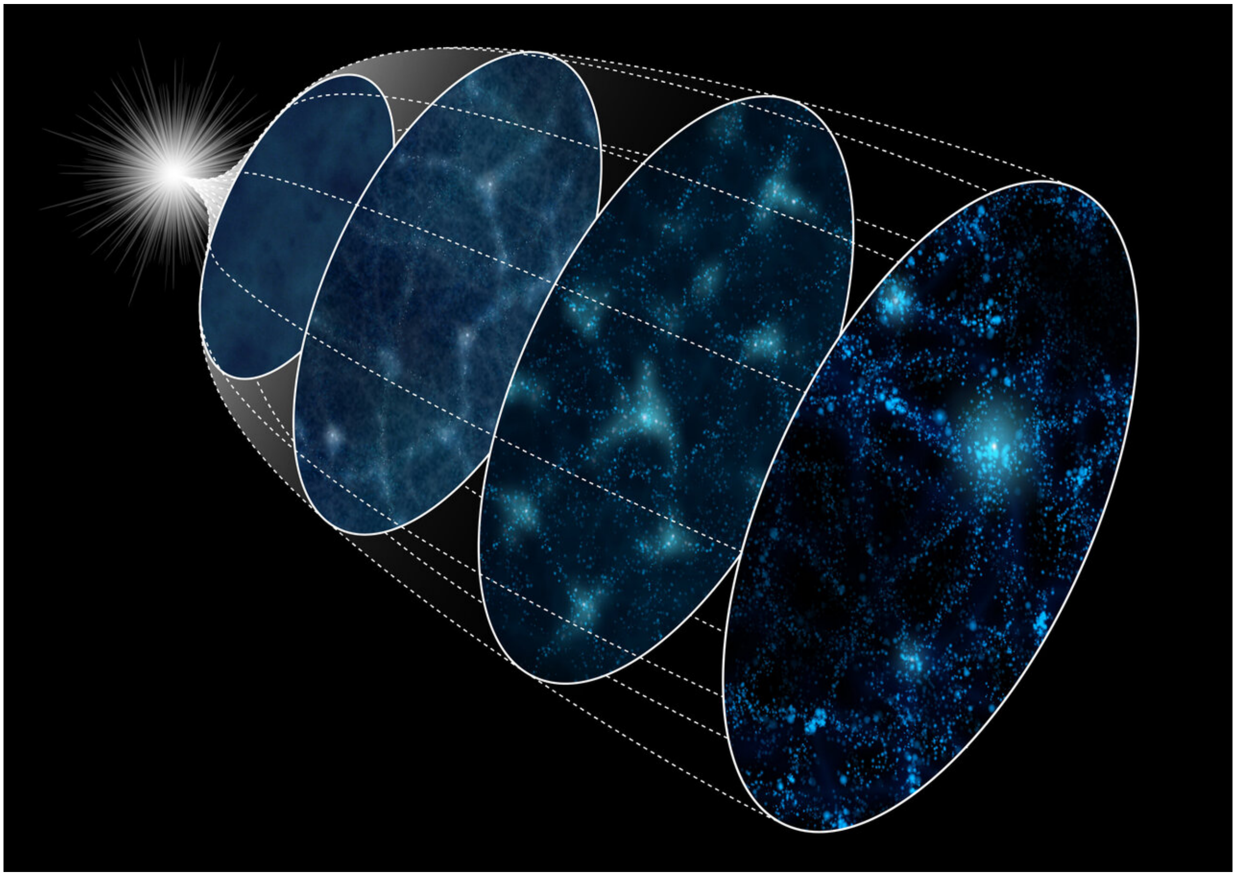

Figure 1: Schematic diagram of the evolution of the universe from the inflation (left) to the present (right). The reconstruction method winds back the evolution from right to left on this illustration to reproduce the primordial density fluctuations from the current galaxy distribution. Credit: The Institute of Statistical Mathematics

Astronomers have tested a method for reconstructing the state of the early universe by applying it to 4000 simulated universes using the ATERUI II supercomputer at the National Astronomical Observatory of Japan (NAOJ). They found that together with new observations, the method can set better constraints on inflation, one of the most enigmatic events in the history of the universe. The method can shorten the observation time required to distinguish between various inflation theories.

Just after the universe came into existence 13.8 billion years ago, it suddenly increased more than 1 trillion trillion times in size in less than a trillionth of a trillionth of a microsecond, but no one knows how or why. This sudden inflation is one of the most important mysteries in modern astronomy. Inflation should have created primordial density fluctuations that would have affected the distribution of galaxy development. Thus, mapping the distribution of galaxies can rule out models for inflation that don't match the observed data.

However, processes other than inflation also impact galaxy distribution, making it difficult to derive information about inflation directly from observations of the large-scale structure of the universe, the cosmic web comprising countless galaxies. In particular, the gravitationally driven growth of groups of galaxies can obscure the primordial density fluctuations.

A research team led by Masato Shirasaki, an assistant professor at NAOJ and the Institute of Statistical Mathematics, applied a reconstruction method to turn back the clock and remove gravitational effects from the large-scale structure. They used ATERUI II, the world's fastest supercomputer dedicated to astronomy simulations, to create 4000 simulated universes and evolve them through gravitationally driven growth. They then applied this method to see how well it reconstructed the starting state of the simulations. The team found that their method can correct for the gravitational effects and improve the constraints on primordial density fluctuations.

"We found that this method is very effective," says Shirasaki. "Using this method, we can verify inflation theories with roughly one-tenth the amount of data. This method can shorten the required observing time in upcoming galaxy survey missions such as SuMIRe by NAOJ's Subaru Telescope."

These results appeared as Masato Shirasaki et. al. "Constraining Primordial Non-Gaussianity with Post-reconstructed Galaxy Bispectrum in Redshift Space," in *Physical Review D* on January 4, 2021.

More information: Masato Shirasaki et al. Constraining primordial non-Gaussianity with postreconstructed galaxy bispectrum in redshift space, *Physical Review D* (2021). DOI: 10.1103/PhysRevD.103.023506

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