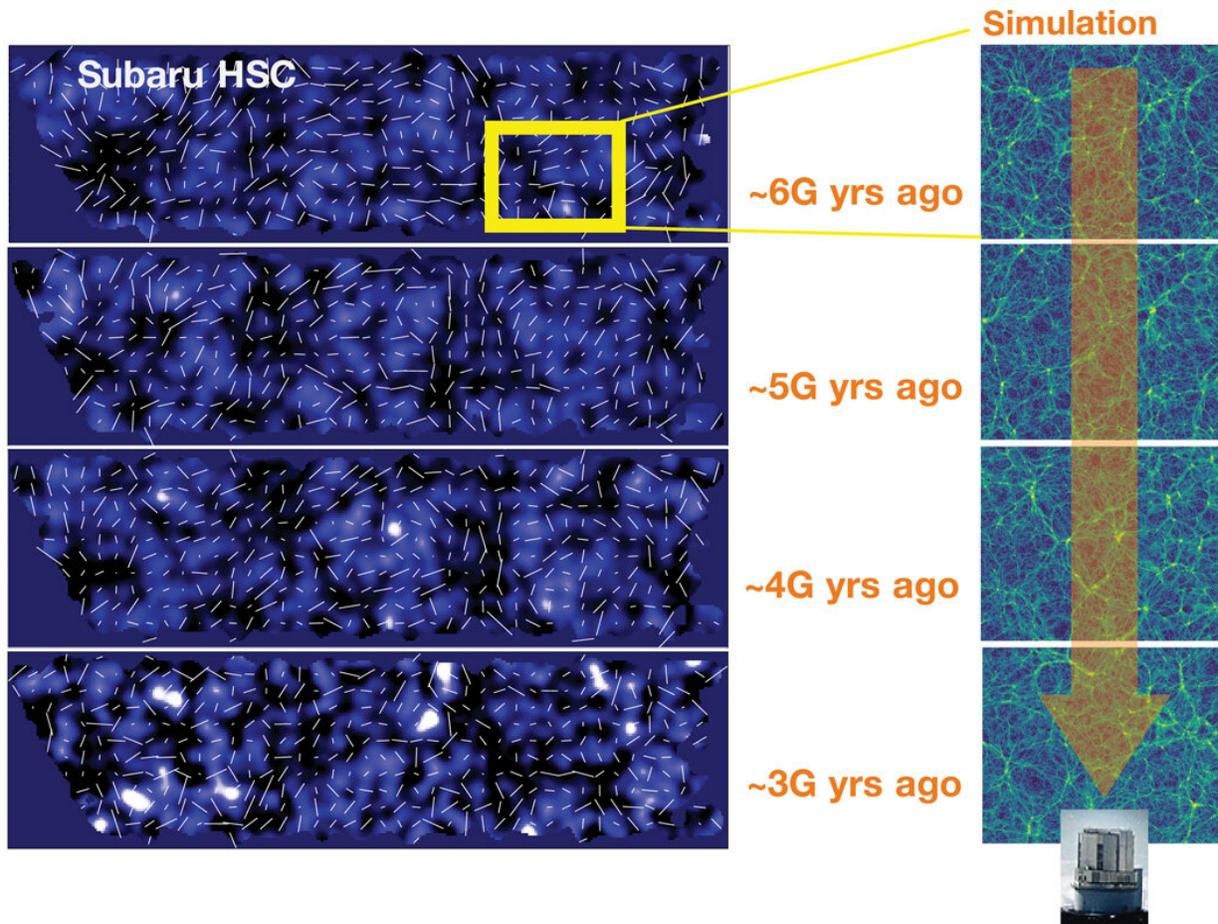


Mapping historical changes in dark matter

February 13 2019



(Left) The 3-dimensional dark matter map of the universe inferred from one of the six HSC observation areas is shown in the background with various shades of blue (brighter areas have more dark matter). The map was inferred from the distortions of shapes of galaxies in the HSC data which are indicated by white sticks. The stick lengths represent the amount of distortion and the angle of the stick corresponds to the direction of the distortion. (Right) The measurements are enabled by the light from distant galaxies that travels through the universe

and gets deflected by matter at different epochs in the universe, before reaching the Subaru telescope. Credit: HSC Project/UTokyo

Combining Einstein's theory of relativity with one of the most powerful telescopes in the world has helped an international team of researchers measure where and how dark matter structures grow in the universe. Their analysis suggests cosmic structures might be evolving more slowly than previously predicted.

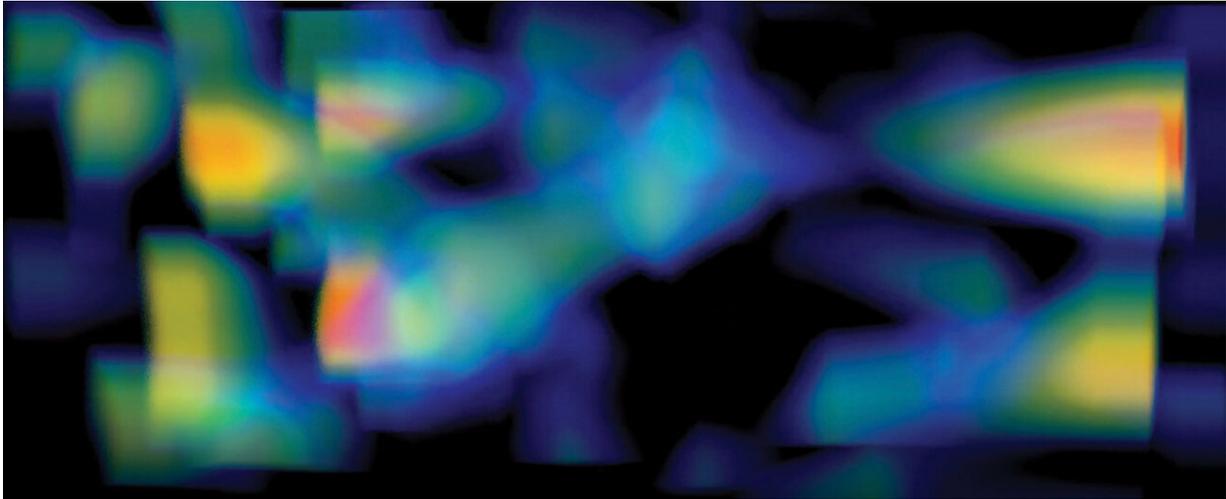
A team led by the Kavli Institute for the Physics and Mathematics of the Universe constructed a map of [dark matter](#) throughout the history of the universe by analysing images of more than ten million galaxies. The results appear to challenge current understanding of the fundamental laws of physics.

"If further data shows we're definitely right, then it suggests something is missing from our current understanding of the Standard Model and the general theory of relativity," says physicist Chiaki Hikage.

According to Einstein's [general theory of relativity](#), gravity warps space and time. To date, this theory has successfully predicted the expansion of the universe, the existence of black holes, and the bending of light from distant stellar objects. If cosmologists confirm that the observed universe is evolving more slowly than the theory predicts, it would mean an entire branch of physics has not yet been discovered.

Dark matter is responsible for the formation of galaxies, and [dark energy](#) is responsible for accelerating the ongoing expansion of the universe. Together, they make up 95 percent of the universe. Mapping the density of dark matter in today's universe and reconstructing historical maps of dark matter going back 13 billion years could help study changes in dark

matter over time. Such a comparison could also elucidate how dark energy has influenced dark matter's growth in the universe.



A still shot from the short "HSC Mass Map" video from Kavli IMPU showing a 3D map of how mass, including dark matter, is distributed throughout the universe. Like this still shot shows, the areas with more mass are represented by brighter red and yellow colours, and less mass represented by blue and black. Credit: HSC Project

Dark matter is not visible, but its effects can be seen on the shape of galaxies. Since the gravity of all matter, including invisible dark matter, bends the path of light, far away galaxies appear distorted to observers on Earth. Researchers can calculate how the dark matter is distributed in the universe through the distortions of galaxies.

Hikage and his team analysed images of ten million galaxies from the Hyper Suprime-Cam (HSC) Survey. This 870 [megapixel camera](#), attached to the 8.2 metre Subaru telescope at the summit of Maunakea, Hawaii, surveys the sky, drawing a detailed map of the universe. It is

enabling researchers to study galaxies billions of [light years](#) from Earth. These [galaxies](#) existed billions of years ago, but their light is only reaching Earth today, making it possible for researchers to study the universe from its infancy.

Using the information from these images, the researchers were able to make the most detailed three-dimensional map of dark [matter](#) in the universe to date. The map was consistent with past studies. However, it also suggests cosmic structures might be evolving more slowly than predicted by other research teams.

Hikage explains that more data is needed. "With a little more work, if we can get better accuracy, we might be able to find something concrete. This is a big motivating factor for me."

The researchers will continue to analyse more HSC Survey data, bringing them closer to discovering whether science needs to rewrite its rules about the [universe](#).

Provided by Kavli Institute for the Physics and Mathematics of the Universe

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