

DOMINATED BY UNSEEN MATTER

We live in a universe dominated by unseen matter, and on the largest scales, galaxies and everything they contain are concentrated into filaments that stretch around the edge of enormous voids.

Thought to be almost empty until now, a group of astronomers based in Austria, Germany and the United States now **believe these dark holes could contain as much as 20% of the 'normal' matter in the cosmos** and that galaxies make up only 1/500th of the volume of the universe. The team, led by **Dr Markus Haider** of the Institute of Astro- and Particle Physics at the University of Innsbruck in Austria, publish their results in a new paper in Monthly Notices of the Royal Astronomical Society.

Looking at cosmic microwave radiation, modern satellite observatories like COBE, WMAP and Planck have gradually refined our understanding of the composition of the universe, and the **most recent measurements suggest it consists of 4.9% 'normal' matter (i.e. the matter that makes up stars, planets, gas and dust), or 'baryons', whereas 26.8% is the mysterious and unseen 'dark' matter and 68.3% is the even more mysterious 'dark energy'.**

Complementing these missions, ground-based observatories have mapped the positions of galaxies and, indirectly, their associated dark matter over large volumes, showing that they are located in filaments that make up a 'cosmic web'. Haider and his team investigated this in more detail, using data from the Illustris project, a large computer simulation of the evolution and formation of galaxies, to measure the mass and volume of these filaments and the galaxies within them. **Completed in late 2013, Illustris is using a state of the art numerical code and a comprehensive physical model built on several years of effort by members of the collaboration and represents an unprecedented combination of high resolution, total volume, and physical fidelity.**

Illustris simulates a cube of space in the universe, measuring some 350 million light years on each side. It starts when the universe was just 12 million years old, a small fraction of its current age, **and tracks how gravity and the flow of matter changes the structure of the cosmos up to the present day.** The simulation deals with both normal and dark matter, **with the most important effect being the gravitational pull of the dark matter.**

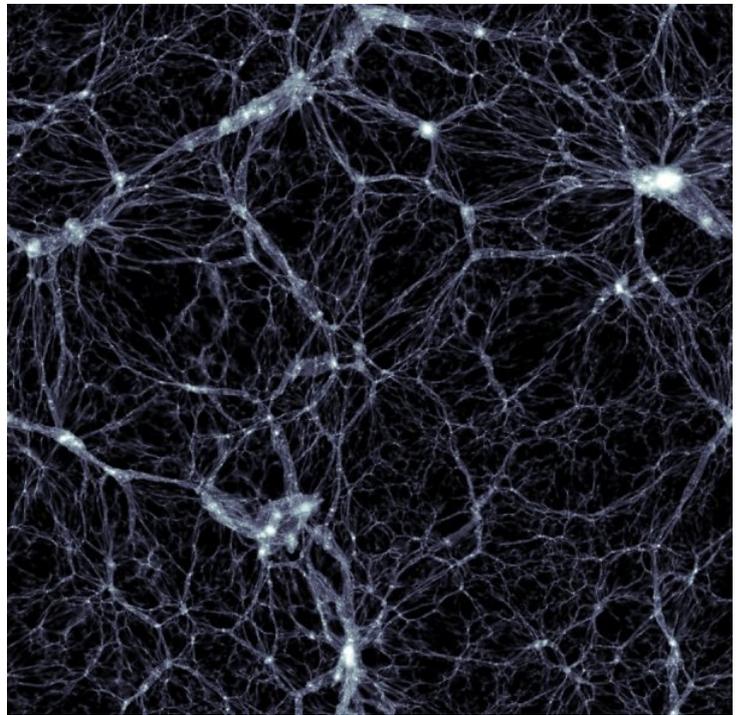
When the scientists looked at the data, they found that **about 50% of the total mass of the universe is in the places where galaxies reside, compressed into a volume of 0.2% of the universe we see, and a further 44% is in the enveloping filaments. Just 6% is located in the voids, which make up 80% of the volume.**

But Haider's team also found that a surprising fraction of normal matter -- 20% -- is likely to have been transported into the voids. The culprit appears to be the supermassive black holes found in the centres of galaxies. Some of the matter falling towards the holes is converted into energy. This energy is delivered to the surrounding gas, and leads to large outflows of matter, which stretch for hundreds of thousands of light years from the black holes, reaching far beyond the extent of their host galaxies.

Apart from filling the voids with more matter than thought, the result might help explain the missing baryon problem, where astronomers do not see the amount of normal matter predicted by their models.

Illustris is now running new simulations, and results from these should be available in a few months, with the researchers keen to see whether for example their understanding of black hole output is right. Whatever the outcome, it will be hard to see the matter in the voids, as this is likely to be very tenuous, and too cool to emit the X-rays that would make it detectable by satellites.

Galaxy Zoo is now arguably the world's best-known online citizen science project, and is certainly the one with the largest number of publications based on citizen scientists input. It all started back in July 2007, with a data set made up of a million galaxies imaged by the Sloan Digital Sky Survey, who still provide some of the images in the site today. With so many galaxies, it was assumed it would take years for visitors to the site to work through them all, but within 24 hours of launch some 70,000 classifications were received every hour. In the end, more than 50 million classifications were collected by the project during its first year, contributed by more than 150,000 people. Having galaxies classified is a great help with new cosmological solutions.



Distribution of matter, with a width and height of 350 million light-years and a thickness of 300000 light years. Galaxies are found in the small, white, high-density dots.