What Is the Universe Made Of

Every once in a while, cosmologists are dragged, kicking and screaming, into a universe much more unsettling than they had any reason to expect. In the 1500s and 1600s, Copernicus, Kepler, and Newton showed that Earth is just one of many planets orbiting one of many stars, destroying the comfortable Medieval notion of a closed and tiny cosmos. In the 1920s, Edwin Hubble showed that our universe is constantly expanding and evolving, a finding that eventually shattered the idea that the universe is unchanging and eternal. And in the past few decades, cosmologists have discovered that the ordinary matter that makes up stars and galaxies and people is less than 5% of everything there is. Grappling with this new understanding of the cosmos, scientists face one overriding question: What is the universe made of?

In the dark. Dark matter holds galaxies together; supernovae measurements point to a mysterious dark energy.

This question arises from years of progressively stranger observations. In the 1960s, astronomers discovered that galaxies spun around too fast for the collective pull of the stars' gravity to keep them from flying apart. Something unseen appears to be keeping the stars from flinging themselves away from the center: unilluminated matter that exerts extra gravitational force. This is dark matter.

Over the years, scientists have spotted some of this dark matter in space; they have seen ghostly clouds of gas with x-ray telescopes, watched the twinkle of distant stars as invisible clumps of matter pass in front of them, and measured the distortion of space and time caused by invisible mass in galaxies. And thanks to observations of the abundances of elements in primordial gas clouds, physicists have concluded that only 10% of ordinary matter is visible to telescopes.

But even multiplying all the visible "ordinary" matter by 10 doesn't come close to accounting for how the universe is structured. When astronomers look up in the heavens with powerful telescopes, they see a lumpy cosmos. Galaxies don't dot the skies uniformly; they cluster together in thin tendrils and filaments that twine among vast voids. Just as there isn't enough visible matter to keep galaxies spinning at the right speed, there isn't enough ordinary matter to account for this lumpiness. Cosmologists now conclude that the gravitational forces exerted by another form of dark matter, made of an as-yet-undiscovered type of particle, must be sculpting these vast cosmic structures. They estimate that this exotic dark matter makes up about 25% of the stuff in the universe—five times as much as ordinary matter.

But even this mysterious entity pales by comparison to another mystery: dark energy. In the late 1990s, scientists examining distant supernovae discovered that the universe is expanding faster and faster, instead of slowing down as the laws of physics would imply. Is there some sort of antigravity force blowing the universe up?

All signs point to yes. Independent measurements of a variety of phenomena—cosmic background radiation, element abundances, galaxy clustering, gravitational lensing, gas cloud properties—all converge on a consistent, but bizarre, picture of the cosmos. Ordinary matter and exotic, unknown particles together make up only about 30% of the stuff in the universe; the rest is this mysterious antigravity force known as dark energy.

This means that figuring out what the universe is made of will require answers to three increasingly difficult sets of questions. What is ordinary dark matter made of, and where does it reside? Astrophysical observations, such as those that measure the bending of light by massive objects in space, are already yielding the answer. What is exotic dark matter? Scientists have some ideas, and with luck, a dark-matter trap buried deep underground or a high-energy atom smasher will discover a new type of particle within the next decade. And finally, what is dark energy? This question, which wouldn't even have been asked a decade ago, seems to transcend known physics more than any other phenomenon yet observed. Ever-better measurements of supernovae and cosmic background radiation as well as planned observations of gravitational lensing will yield information about dark energy's "equation of state"—essentially a measure of how squishy the substance is. But at the moment, the nature of dark energy is arguably the murkiest question in physics—and the one that, when answered, may shed the most light.

–CHARLES SEIFE

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