Astronomers Gravitate Toward Einstein's Telescope

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The gravity of galaxy cluster Abell 2218 bends and focuses the light from galaxies that lay behind it in this Hubble Space Telescope image. The effect distorts multiple images of the background galaxies into long, faint arcs. Image: NASA, A. Fruchter and the ERO (STScI), STScI-PRC00-08

Scientists are harnessing the cosmos as a scientific 'instrument' in their quest to determine the makeup of the universe.

The University of Chicago's Evalyn Gates calls the instrument "Einstein's telescope." The instrument is actually the phenomenon of gravitational lensing, which acts as a sort of natural telescope. Gates's new book, Einstein's Telescope: The Hunt for Dark Matter and Dark Energy in the Universe, explains how it works.

Although based on Albert Einstein's general theory of relativity, the

effect is easily demonstrated. Look at a light through the bottom of a wine glass, Gates recommends, and see the resulting light distortion.

“Einstein’s telescope is using the universe itself as a lens through which we can seek out galaxies that would otherwise be too faint to be seen,” says Gates, Assistant Director of the University’s Kavli Institute for Cosmological Physics.

Einstein’s first inklings

Long ago Einstein recognized the potential existence of gravitational lensing, a consequence of his theory of general relativity. According to general relativity, celestial objects create dimples in space-time that bend the light traveling from behind.

Einstein realized that the gravitational influence of a foreground star could theoretically bend the light of another star sitting almost directly far beyond it, producing two images of the background star.

“Gravitational lensing magnifies things as well as making multiple images and distorting the shape of images, so you can actually use it as a magnifying glass,” Gates explains.

But, assuming that the effect would be too weak to detect, Einstein immediately dismissed its significance. “What he didn’t anticipate, among other things, were the incredible leaps forward in telescope technology,” Gates says.

Seeing the invisible

Astronomers now use gravitational lensing to look for dark matter and the imprint of dark energy, two of the greatest modern scientific

mysteries.

Dark energy, which acts in opposition to gravity, is the dominant force in the universe.

“We can’t see dark energy directly by any means, but we’re looking for how it has sculpted the matter distribution of the universe over the past few billion years, since it’s been the dominant factor, and also how it has affected the rate at which the Universe is expanding” Gates says.

And gravitational lensing is essentially the only method astronomers have for tracing out the web of dark matter that pervades the Universe, and determining how dark energy has impacted the evolution of this web. “It’s really hot scientifically,” she says.

Like dark energy, dark matter is also invisible. It accounts for most of the matter in the universe, but exactly what it is remains unknown. Scientists only know that dark matter differs significantly from normal matter (which is essentially composed of protons and neutrons) that dominates everyday life.

“What we’re made of is just about five percent of everything that’s in the universe,” Gates says.

In 1990s scientists wondered if a significant quantity of dark matter in the halo consisted of MACHOs (Massive Astrophysical Compact Halo Objects) - faint objects such as dim stars, Jupiter-sized planets or stellar-mass black holes that are all composed of normal matter but hard to see.

Gates and her collaborators were among the researchers who used gravitational lensing to search for MACHOs within the halo of the Milky Way galaxy. “We have seen MACHOs - but what we found is that they make up at most a small fraction of the galactic halo,” Gates said.

A look into galaxies past

Scientists also use galaxy clusters as gravitational lenses to probe 13 billion years back into the history of the universe. “They’re seeing some of the very first galaxies,” she says.

Gravitational lensing offers astrophysicists a tool comparable to magnetic resonance imaging and computing tomography, which have provided health professionals with unprecedented new views of the human body.

“Gravitational lensing is going to allow us to image the universe in ways that wouldn’t have been possible even 50 years ago,” she says.

During the 20th century, quantum mechanics and general relativity radically altered scientists’ view of the universe, Gates says. Investigations of dark matter and dark energy may do likewise.

“It may lead us to another revolution in our understanding of the most fundamental aspects of the universe, time, matter, and energy.”

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