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The Dark Side Of Cosmology: Dark Matter And Dark Energy

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Abstract

Both the dark matter and dark energy issues are considered essential for a deeper understanding of the evolutionary universe. According to studies, dark matter and dark energy have had a strong influence on the structure and evolution of the universe. A theory about the way dark energy affects the expansion of the universe exists already, but it remains unknown what exactly dark energy is, except that it comprises almost sixty-eight percent of the universe. In addition, dark matter makes up almost twenty-seven percent of the universe, with the remaining five percent being baryonic matter. It is not known exactly what dark matter is, and in order to explain the missing mass of the universe it is commonly accepted that the study of dark energy and dark matter lies at the forefront of modern research and is considered of paramount importance for the development of 21st century physics. The phenomenon that scientists hypothesise is causing the universe to expand at an ever-faster rate. No-one knows anything about dark energy, except that it could be, somehow, blowing pretty much everything apart. Meanwhile, dark energy has an equally shady cousin – dark matter. This invisible substance appears to have been clustering around galaxies, and preventing them from spinning themselves apart, by lending them an extra gravitational pull. Such a clustering effect is in competition with dark energy's accelerating expansion. Yet studying the precise nature of this competition might shed some light on dark energy.

'Many dark energy models are already ruled out with current data,' said Dr Alexander Mead, a cosmologist at the University of British Columbia in Vancouver, Canada, who is working on a project called Halo modelling. 'Hopefully in future we can rule more out.'

Keywords: Expansion of the universe, Dark Energy, Dark Matter, Black Holes

Gravitational lensing

Currently, the only way dark matter can be observed is by looking for the effects of its gravitational pull on other matter and light. The intense gravitational field it produces can cause light to distort and bend over large distances – an effect known as gravitational lensing. By mapping the dark matter in distant parts of the cosmos, scientists can work out how much dark matter clustering there is – and in principle how that clustering is being affected by dark energy. The link between gravitational lensing and dark matter clustering is not straightforward, however. To interpret the data from telescopes, scientists must refer to detailed cosmological models – mathematical representations of complex systems.

Dark Matter

By fitting a theoretical model of the composition of the universe to the combined set of cosmological observations, scientists have come up with the composition that we described above, ~68% dark energy, ~27% dark matter, ~5% normal matter. What is dark matter? We are much more certain what dark matter is not than we are what it is. First, it is dark, meaning that it is not in the form of stars and planets that we see. Observations show that there is far too little visible matter in the universe to make up the 27% required by the observations. Second, it is not in the form of dark clouds of normal matter, matter made up of particles called baryons. We know this because we would be able to detect baryonic clouds by their absorption of radiation passing through them. Third, dark matter is not antimatter, because we do not see the unique gamma rays that are produced when antimatter annihilates with matter. Finally, we can rule out large galaxy-sized black holes on the basis of how many gravitational lenses we see. High concentrations of matter bend light passing near them from objects further away, but we do not see enough lensing events to suggest that such objects to make up the required 25% dark matter contribution.

However, at this point, there are still a few dark matter possibilities that are viable. Baryonic matter could still make up the dark matter if it were all tied up in brown dwarfs or in small, dense chunks of heavy elements. These possibilities are known as massive compact halo objects, or "MACHOs". But the most common view is that dark matter is not baryonic at all, but that it is made up of other, more exotic particles like axions or WIMPS (Weakly Interacting Massive Particles).

Dark matter is a form of matter postulated to exist in the field of astronomy and cosmology. Scientists know that dark matter behaves differently than ordinary matter, such as planets, stars and galaxies (this matter is classified as baryonic matter and its most fundamental unit is an atom). For instance, dark matter, unlike normal matter, does not interact with electromagnetic energy. Thus, it neither emits nor absorbs electromagnetic radiation at any level making it difficult to spot. Its existence is inferred only from the gravitational effect it has on observable matter. Dark matter is estimated to be about 23% of the cosmic energy density, as it seems to outweigh visible matter approximately five to one. Normal matter accounts for around 4%. According to computer simulations, dark matter could be everywhere; hence, the Earth could be encountering a mass of dark matter particles as it revolves around the sun.

Although most scientists accept the existence of dark matter, no one knows the true nature of dark matter. To unfold this puzzle, dark matter candidates are divided into two broad categories, baryonic and non-baryonic. Baryonic candidates considered include Massive compact halo objects (Machos). Machos are objects that make up the halos around galaxies, but are hard to spot because they have very low luminosities. Such objects include brown dwarfs, neutron stars, black holes or just dim stars called white dwarfs. Apart from space telescopes, gravitational lensing is a technique used to detect the presence of Machos. Albert Einstein (1919) had proved that gravity bends light rays (gravity curves spacetime, and the path of any passing radiation including visible light would be deflected, as a result). He predicted that if a star lined directly behind the sun, the gravitational field of the sun would bend light rays from the star towards an observer. As a consequence of lensing light rays, an observer can observe an image or images of the star. When a black hole passes between a galaxy or star and an observer on the Earth, gravitational lensing occurs and astronomers can deduce the presence of a Macho. Circling stars could also suggest the presence of a Macho object such as a black hole. Black holes have a gravitational influence on objects surrounding them. Thus, when scientists see stars circling something invisible, they suspect a black hole. In early 1995, a team of Japanese and American astronomers announced the existence of a massive black hole with a mass 36 million times that of our sun. Although the announcement was significant in its own way, research has not turned up enough Machos to account for all the dark matter in the universe. In an effort to explain dark matter, particle physicists theorize the existence of non-baryonic particles that rarely interact with ordinary matter. The leading candidates for these particles include Weakly Interactive

Massive Particles (WIMPs) (Panek, 2011). These yet to be discovered particles are thought to have mass, but they interact so weakly with ordinary matter that they are hard to detect. Particle physicists argue that if these particles interacted with ordinary matter, detectable radiations could be emitted. Such interactions, however, are extremely rare. Some of these particles include Axions, Photinos. Most scientists concede that both non-baryonic WIMPs and baryonic MACHOs could make up dark matter.

Dark Energy

More is unknown than is known. We know how much dark energy there is because we know how it affects the universe's expansion. Other than that, it is a complete mystery. But it is an important mystery. It turns out that roughly 68% of the universe is dark energy. Dark matter makes up about 27%. The rest - everything on Earth, everything ever observed with all of our instruments, all normal matter - adds up to less than 5% of the universe. Come to think of it, maybe it shouldn't be called "normal" matter at all, since it is such a small fraction of the universe. One explanation for dark energy is that it is a property of space. Albert Einstein was the first person to realize that empty space is not nothing. Space has amazing properties, many of which are just beginning to be understood. The first property that Einstein discovered is that it is possible for more space to come into existence. Then one version of Einstein's gravity theory, the version that contains a cosmological constant, makes a second prediction: "empty space" can possess its own energy. Because this energy is a property of space itself, it would not be diluted as space expands. As more space comes into existence, more of this energy-of-space would appear. As a result, this form of energy would cause the universe to expand faster and faster. Unfortunately, no one understands why the cosmological constant should even be there, much less why it would have exactly the right value to cause the observed acceleration of the universe.

Another explanation for dark energy is that it is a new kind of dynamical energy fluid or field, something that fills all of space but something whose effect on the expansion of the universe is the opposite of that of matter and normal energy. Some theorists have named this "quintessence," after the fifth element of the Greek philosophers. But, if quintessence is the answer, we still don't know what it is like, what it interacts with, or why it exists. So the mystery continues.The thing that is needed to decide between dark energy possibilities - a property of space, a new dynamic fluid, or a new theory of gravity - is more data, better data.

Dark energy is a mysterious force, mostly thought as a repulsive force that accelerates the expansion of the universe. Over the years, theorists have suggested a number of possibilities to calculate dark energy. Many theories, however, do not pass stringent local tests, and if they pass, they fail to apply a metric structure to energy momentum conservation or gravity. The cosmological constant, regarded as vacuum energy density, is the most preferred candidate for dark energy. If cosmological constant originates from vacuum fluctuations, its energy scale is incredibly larger than the current dark energy density. Hence, this energy scale needs to be reconciled with observations. However, scientists are yet to find the correct mechanism to do this. As a result, modified gravity models that explain cosmic acceleration without dark energy have been proposed.

Black Hole

A black hole is anything but empty space. Rather, it is a great amount of matter packed into a very small area - think of a star ten times more massive than the Sun squeezed into a sphere approximately the diameter of New York City. The result is a gravitational field so strong that nothing, not even light, can escape. In recent years, NASA instruments have painted a new picture of these strange objects that are, to many, the most fascinating objects in space.

The idea of an object in space so massive and dense that light could not escape it has been around for centuries. Most famously, black holes were predicted by Einstein's theory of general relativity, which showed that when a massive star dies, it leaves behind a small, dense remnant core. If the core's mass is more than about three times the mass of the Sun, the equations showed, the force of gravity overwhelms all other forces and produces a black hole. Scientists can't directly observe black holes with telescopes that detect x-rays, light, or other forms of electromagnetic radiation. We can, however, infer the presence of black holes and study them by detecting their effect on other matter nearby. If a black hole passes through a cloud of interstellar matter, for example, it will draw matter inward in a process known as accretion. A similar process can occur if a normal star passes close to a black hole. In this case, the black hole can tear the star apart as it pulls it toward itself. As the attracted matter accelerates and heats up, it emits x-rays that radiate into space. Recent discoveries offer some tantalizing evidence that black holes have a dramatic influence on the neighborhoods around them - emitting powerful gamma ray bursts, devouring nearby stars, and spurring the growth of new stars in some areas while stalling it in others.

One Star's End is a Black Hole's Beginning

Most black holes form from the remnants of a large star that dies in a supernova explosion. (Smaller stars become dense neutron stars, which are not massive enough to trap light.) If the total mass of the star is large enough (about three times the mass of the Sun), it can be proven theoretically that no force can keep the star from collapsing under the influence of gravity. However, as the star collapses, a strange thing occurs. As the surface of the star nears an imaginary surface called the "event horizon," time on the star slows relative to the time kept by observers far away. When the surface reaches the event horizon, time stands still, and the star can collapse no more - it is a frozen collapsing object.

Even bigger black holes can result from stellar collisions. Soon after its launch in December 2004, NASA's Swift telescope observed the powerful, fleeting flashes of light known as gamma ray bursts. Chandra and NASA's Hubble Space Telescope later collected data from the event's "afterglow," and together the observations led astronomers to conclude that the powerful explosions can result when a black hole and a neutron star collide, producing another black hole. “This is one of the first instances where we can really see how magnetic fields and interstellar matter interact with each other,” noted Joan Schmelz, Universities Space Research Center astrophysicist at NASA Ames Research Center in California’s Silicon Valley, and a co-author on a paper describing the observations. “HAWC+ is a game-changer.”

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