Dark matter, dark energy, dark… magnetism?
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Notes

Billions of years from now, only a huddle of nearby galaxies will be left. This is because space is expanding ever faster, allowing far-off regions to slip across the boundary from which light has time to reach us. We call the cause of this expansion dark energy. Might the culprit be a repulsive force that emerges from the energy of empty space, or perhaps a modification of gravity at the largest scales? Each option has its charms, but also profound problems.

But what if that mysterious force making off with the light of the cosmos is an alien echo of light itself? That is the bold notion of two cosmologists who think that such an echo could also account for the mysterious magnetic fields that we see in the emptiest parts of our universe. Smaller versions could be emanating from black holes within our galaxy.

The discovery of the run away universe came from observations in the 1990s of supernovae that were dimmer, and so further away, than was expected, and earned its discoverers the Nobel prize in physics in 2011.

A possible cause of dark-energy is the cosmological constant, an unchanging energy which might emerge from the froth of short-lived, virtual particles that according to quantum theory are constantly present in otherwise empty space.

Dark energy would need to have an energy density of about half a joule per cubic kilometer of space to account for the acceleration we see.

However, when physicists try to calculate the energy of all those virtual particles, the answer comes to either exactly zero, or an inconceivably enormous 120 orders of magnitude.

Other researchers argue that in dark energy we are seeing an entirely new side to gravity. At distances of many billions of light years, it might turn from an attractive to a repulsive force.

In 2008 at the Complutense University of Madrid, Spain, Jose Beltrán and Antonio Maroto were playing with a particular version of a mutant gravity model called a vector-tensor theory, which they had found could mimic dark energy. Then came a sudden realisation. The new theory was supposed to be describing a strange version of gravity, but its equations bore an uncanny resemblance to some of the mathematics underlying electromagnetism.

Beltrán and Maroto call their idea dark magnetism (arxiv.org/abs/1112.1106).

Photons are massless, chargeless particles carrying fluctuating electric and magnetic fields that point at right angles to their direction of motion.

This description, comes from quantum electrodynamics or QED, and can explain a vast range of phenomena, from the behaviour of light to the forces that bind molecules together. QED has arguably been tested more precisely than any other physical theory, but in addition to the commonly understood definition of the EM field, it predicts two other anomalous fields, with their photon variants.

The first is a wave in which the electric field points longitudinally, rather than at right angles as it does with ordinary photons. The second, called a temporal mode, has no magnetic field. Instead, it is a wave of pure electric potential, or voltage.

As these fields and photons have never been observed, physicists found a way to hide them using a mathematical fix called the Lorenz condition, which means that all their attributes are always equal and opposite, cancelling each other out exactly.

Beltrán and Maroto's theory looked like electromagnetism without the Lorenz condition. The strange waves normally banished by the Lorenz condition may come into being as brief quantum fluctuations - virtual waves in the vacuum - and then disappear again. In the early moments of the universe, there is thought to have been an episode of violent expansion called inflation, which was driven by very powerful repulsive gravity. The force of this expansion grabbed all kinds of quantum fluctuations and amplified them hugely.

Inflation could also have boosted these new electromagnetic waves. Beltrán and Maroto found that this process would leave behind vast temporal modes: waves of electric potential with wavelengths many orders of magnitude larger than the observable universe. These waves contain some energy but because they are so vast we do not perceive them as waves at all. So their energy would be invisible, dark... perhaps, dark energy?