Physicists investigate lower dimensions of the universe

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(PhysOrg.com) -- Several speculative theories in physics involve extra dimensions beyond our well-known four (which are broken down into three dimensions of space and one of time). Some theories have suggested 5, 10, 26, or more, with the extra spatial dimensions "hiding" within our observable three dimensions. One thing that all of these extra dimensions have in common is that none has ever been experimentally detected; they are all mathematical predictions.

More recently, physicists have been theorizing the possibility of lower dimensionality, in which the universe has only two or even one spatial dimension(s), along with one dimension of time. The theories suggest that the lower dimensions occurred in the past when the universe was much smaller and had a much higher energy level (and temperature) than today. Further, it appears that the concept of lower dimensions may already have some experimental evidence in cosmic ray observations.

Now in a new study, physicists Jonas Mureika from Loyola Marymount University in Los Angeles, California, and Dejan Stojkovic from SUNY at Buffalo in Buffalo, New York, have proposed a new and independent method for experimentally detecting lower dimensions. They've published their study in a recent issue of Physical Review Letters.

In 2010, a team of physicists including Stojkovic proposed a lower-dimensional framework in which spacetime is fundamentally a (1 + 1)-dimensional universe (meaning it contains one spatial dimension and one time dimension). In other words, the universe is a straight line that is "wrapped up" in such a way so that it appears (3 + 1)-dimensional at today's higher energy scales, which is what we see.

The scientists don't know the exact energy levels (or the exact age of the universe) when the transitions between dimensions occurred. However, they think that the universe's energy level and size directly determine its number of dimensions, and that the number of dimensions evolves over time as the energy and size change. They predict that the transition from a (1 + 1)- to a (2 + 1)-dimensional universe happened when the temperature of the universe was about 100 TeV (teraelectronvolts) or less, and the transition from a (2 + 1)- to a (3 + 1)-dimensional universe happened later at about 1 TeV. Today, the temperature of the universe is about 10^{-3} eV.

So far, there may already be one piece of experimental evidence for the existence of a lower-dimensional structure at a higher energy scale. When observing families of cosmic ray particles in space, scientists found that, at energies higher than 1 TeV, the main energy fluxes appear to align in a two-dimensional plane. This means that, above a certain energy level, particles propagate in two dimensions rather than three dimensions.

In the current study, Mureika and Stojkovic have proposed a second test for lower dimensions that would provide independent evidence for their existence. The test is based on the assumption that a (2 + 1)-dimensional spacetime, which is a flat plane, has no gravitational degrees of freedom. This means that gravity waves and gravitons cannot have been produced during this epoch. So the physicists suggest that a future gravitational wave detector looking deep into space might find that primordial gravity waves cannot be produced beyond a certain frequency, and this frequency would represent the transition between dimensions. Looking backwards, it would appear that one of our spatial dimensions has "vanished."

The scientists added that it should be possible, though perhaps more difficult, to test for the existence of (1 + 1)-dimensional spacetime.

“It will be challenging with the current experiments,” Stojkovic told *PhysOrg.com*. “But it is within the reach of both the LHC and cosmic ray experiments if the two-dimensional to one-dimensional crossover scale is 10 TeV.”

Lower dimensions at higher energies could have several advantages for cosmologists. For instance, models of quantum gravity in (2 + 1) and (1 + 1) dimensions could overcome some of the problems that plague quantum gravity theories in (3 + 1) dimensions. Also, reducing the dimensions of spacetime might solve the cosmological constant problem, which is that the cosmological constant is fine-tuned to fit observations and does not match theoretical calculations. A solution may lie in the existence of energy that is currently hiding between two folds of our (3 + 1)-dimensional spacetime, which will open up into (4 + 1)-dimensional spacetime in the future when the universe’s decreasing energy level reaches another transition point.

“A change of paradigm,” Stojkovic said about the significance of lower dimensions. “It is a new avenue to attack long-standing problems in physics.”

More information: Jonas Mureika and Dejan Stojkovic. “Detecting Vanishing Dimensions via Primordial Gravitational Wave Astronomy.” *Physical Review Letters* 106, 101101 (2011). DOI: 10.1103/PhysRevLett.106.101101 permission of PhysOrg.com.