New Scientist: Where does the zero-point energy came from?

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ONE OF the more bizarre predictions of quantum theory, which describes the microscopic world of the atom, is that each cubic centimeter of apparently empty space contains an enormous amount of energy. Physicists call it the zero-point energy, because it exists even at the absolute zero of the temperature scale. But although their theories predict that it should exist, and their experiments also confirm that it does, physicists have not been able to answer the most fundamental of questions: Where does the zero-point energy come from? Harold Puthoff, of the Institute for Advanced Studies in Austin, Texas, has spent much time trying to find an answer. His calculations show that the spectrum of electromagnetic radiation that is associated with the zero-point energy can be self-generated in a process that, he says, is ‘not unlike a cat chasing its own tail’ (Physical Review A, vol 40, p 4857).

The zero-point energy is associated with all of nature’s fields of force, including the electromagnetic field. It appears quite naturally in the equations that describe the ‘quantized’ field as soon as physicists unify the theory of electromagnetism with quantum theory. Usually, though, the zero-point energy is unobserved.

Formally, physicists attribute an infinite amount of energy to this background. But, even when they impose appropriate cutoffs at high frequency, they estimate conservatively that the zero-point density is comparable to the energy density inside an atomic nucleus.

Because the numbers that describe the zero-point energy are so enormous, theorists have often questioned whether they should be taken seriously. Some have suggested that they may arise simply because the quantum theory has some defect, or because physicists are not interpreting it correctly. Usually, physicists argue over whether they should consider the fields associated with the zero-point energy as ‘real’ or ‘virtual’ – that is, necessary in the mathematics of quantum theory, although perhaps not physically real.

Despite such arguments, though, no one can doubt that the fields associated with the zero-point energy produce physical consequences which are measurable in the laboratory. One example is the Lamb shift of the spectral lines of an atom. Here, the fields slightly perturb an electron in an atom so that, when it makes a transition from one state to another, it emits a photon whose frequency is ‘shifted’ slightly from its normal value.

Another measurable consequence of the fields associated with the zero-point energy is the Casimir effect. This is an attractive force that appears between two metal plates that are closely spaced. The Casimir force is due to so-called radiation pressure from the zero-point energy of the background electromagnetic field. In effect, some wavelengths of the field are excluded from between the plates, so reducing the energy density compared with that of empty space. The imbalance results in the plates being pushed together.

When Puthoff considers the origin of the zero-point energy, he comes to the conclusion that it can have one of two explanations. The first explanation, which he discards, is that the zero-point energy was fixed arbitrarily at the birth of the Universe, as part of its so-called boundary conditions.

Puthoff believes instead that the zero-point energy may be generated by radiation from ‘quantum fluctuations’. According to quantum theory, the particles of matter can pop into existence, then pop out again, just as long as they do so for fleetingly small intervals, determined by the Heisenberg uncertainty principle. These ‘quantum fluctuations’ fill all of space and are the reason why physicists often refer to the ‘seething vacuum’.

Puthoff has calculated the properties of radiation from charged particles produced by quantum fluctuations throughout the Universe. All charged particles undergoing acceleration emit electromagnetic radiation. Such radiation drops off as the inverse square of the distance from the source. But, because the average volume distribution of such particles in spherical shells about any given point source is proportional to the area of the shell – that is, the square of the distance – the sum of contributions from the surrounding shells will yield a radiation field with a high energy density. Puthoff believes that the field associated with the zero-point energy is such a field.

One possibility is that the zero-point fields drive the motion of all particles of matter in the Universe, and that, in turn, the sum of the particle motions throughout the Universe generates the zero-point fields. This he regards as a ‘self-regenerating cosmological feedback cycle’.

His calculations assumed so-called inflationary cosmology, a currently popular theory of the origin of the Universe. He is able to predict the correct distribution of frequencies and the correct order of magnitude of the zero-point energy. His work supports the idea that the zero-point fields are generated dynamically.

The new calculations yield a bonus as well. Puthoff is able to derive an expression that relates the zero-point energy density to such factors as the average density of matter in the Universe and the size of the Universe. This expression also yields a precise expression for an observed ‘cosmological coincidence’, first pointed out by Paul Dirac, the English physicist. The coincidence is that the ratio of the strengths of the electromagnetic force between an electron and proton to the gravitational force between the same two particles is very close to the ratio of the Hubble distance – effectively the size of the Universe – to the size of the electron.

According to Puthoff’s findings, such a cosmological coincidence is simply a consequence of the cosmologically based mechanism which generates the zero-point energy. This is a neat linking of cosmological and atomic parameters and may solve the long-standing mystery.