In search of the energy inside a vacuum

Physics can show there is energy in a vacuum, but will we be able to tap into it, asks **Nigel Hawkes**

A perfect vacuum is the absence of everything, unless you are a quantum physicist. Then you know that empty space is actually filled with particles which wink in and out of existence too rapidly to be seen. Even at absolute zero, a vacuum is sweating energy at every pore, unlikely as it seems. Some bolder spirits, touched by millennial fever, have even claimed that this "zero-point energy" is the fuel of the future which will generate electricity, replace crude oil and propel mankind across the vast emptiness of space.

At a laboratory near Austin in Texas, rather grandly called the Institute for Advanced Studies — an echo of the better-known institution at Princeton where Einstein spent his final years — a small team led by the physicist Dr Harold Puthoff is testing the claims of inventors who say that they can tap into zero-point energy. Over the past decade, Dr Puthoff has examined at least ten devices and found none that works.

To mainstream scientists, the effort smacks of cold fusion. But unlike that débâcle, in this case at least the energy is real, as physicists have recently shown in experiments which confirm quantum theory's predictions to a nicety. While this brings us no closer to exploiting zero-point energy, or even to knowing how much of it there is, it is always satisfying when a long-standing prediction is proved true.

But first, why should zero-point energy even exist? The simplest explanation comes from Heisenberg's uncertainty principle, which declares that it is impossible to know simultaneously both the position and the momentum of a particle. At absolute zero, this principle would be violated if particles were absolutely still, since then both position and momentum would be known. So they must continue to jiggle about, even when they no longer have any thermal motion. The same rule applies to energy. That means that even in empty space, energy continues to exist; and because energy and mass are equivalent, the vacuum energy must be able to create particles which flash briefly into existence, then disappear. Such ephemeral events are called fluctuations.

In 1948 the Dutch physicist Hendrik Casimir outlined a way of detecting this vacuum energy. He argued that it should manifest itself as a tiny force acting between two flat reflecting plates held very close together, but not touching, in a vacuum. If the gap were small enough, he reasoned, it would form a channel so narrow that only certain wavelengths of light, and their respective particles, could be contained within it.

In empty space, particles wink in and out of existence

Just as driving into a tunnel cuts off a radio signal, so the narrow channel would cut off some of the wavelengths of light. But outside the channel would be photons of all wavelengths. The discrepancy would result in a force pushing the plates together — a force no bigger than a speck of dust falling on the top plate but still, in theory, detectable.

Last year the physicist Steven Lamoreaux, of Los Alamos National Laboratory, measured the Casimir force for the first time. His experimental arrangement was more complex than Casimir envisaged, consisting of two gold-coated quartz bars and a gold-plated sphere, arranged close together so that the effect of the Casimir force was to cause one bar, hanging on a wire, to twist. He then measured the force needed to restore it to its original position. It agreed with Casimir's prediction to within 5 per cent. "We're excited; it confirms a very basic prediction of quantum electrodynamics," said Ed Hinds of Sussex University.

Last month Umar Mohideen and Anushree Roy, of the University of California at Riverside, went a step further, using an atomic force microscope to position an aluminium-coated sphere less than a thousandth of a millimetre away from a plate and to measure the force between them. After correcting for errors, they concluded in *Physical Review Letters* that the force they measured was within 1 per cent of the predicted value. And by enlarging and cooling the ball, "we are confident that we can improve the accuracy by a factor of 1,000", Dr Mohideen said.

So yet again, quantum theory has triumphed over common sense; the world really is an oddly constructed place. But is zero-point energy just a curiosity, or does it underlie some of the large-scale structure of the Universe? Can it ever be put to use? Here is where enthusiasts such as Dr Puthoff and most of the rest of the physics community part company.

> To many scientists, the effort smacks of cold fusion

Even calculating how much energy there might be presents awkward problems. In theory, any volume of empty space could contain an infinite number of fluctuations, and hence an infinite amount of energy. That energy would in turn generate gravitational fields out of all proportion to anything we observe in the Universe around us. Even if simplifications are made to eliminate the infinities, the number remains dauntingly large — according to the Nobel Prize-winning physicist Steven Weinberg, ten to the power of 120 times larger than the observed expansion of the Universe allows. "This must be the worst failure of an order-of-magnitude estimate in the history of science," he says.

If so, there must be a lot less vacuum energy than the equations suggest. There might be enough, perhaps, to contribute to an anti-gravity effect, observed in the accelerating expansion of the Universe described in last week's Science Briefing. Certainly Dr Lamoreaux's experiments do not indicate a huge untapped reservoir of energy waiting to be exploited. His experiment extracted 10-15 joules, a piffling quantity. He resents having become a hero to a group for whom he has little time. "The zero-point energy community is more successful at advertising and self-promotion than it is at carrying out *bona fide* scientific research," he told *Scientific American*.

None of this worries Dr Puthoff. He believes that zero-point energy provides the force that stops electrons in atoms spiralling down until they hit the nucleus: and also suspects that inertia, the reluctance of objects to be accelerated, is caused by the drag of moving through a zero-point field. If so, he argues, then it would be worth trying to manipulate the field to reduce inertia, which would enable a rocket to go much faster, and hence much farther, on the same fuel load. Nasa, the American space agency, convened a meeting at which this idea was discussed, to the disgust of some physicists.

Although it is never wise to declare a possible source of energy moonshine — as Lord Rutherford once did of nuclear power — the prospect of civilisation subsisting on a vacuum seems improbable in the extreme.

Even in a quantum universe, with its Alice in Wonderland quality, that would be too close to getting something for nothing.