farther north in Asia than Zhoukoudian, the huge limestone cave in central China used by the famous "Peking Man" nearly 500,000 years ago. "What Mochanov may be seeing at Diring is part of a south-north migration pattern," suggests Robert E. Ackerman, an archeologist at Washington State University in Pullman, who visited Diring 4 years ago. "Perhaps this is part of a movement north out of China during a warming trend." However, scientists have little data about the paleoclimate of Siberia, and there is as yet no way of knowing how cold or warm the Diring peoples' environment really was. Waters suspects the site is at a high enough latitude that, even during a warm interglacial period, the climate would be similar to the climate today—and that can be chilly indeed. At Yakutsk, just north of Diring, the mercury falls as low as ⁻45 degrees Farenheit in January.

The ability to cope with cold at that time in human prehistory also figures in the peopling of the Americas. "For those who've wanted to see an earlier date for the peopling of the Americas this [500,000-year-old] date is a cause for celebration," says Stanford. He notes that critics have always argued that people did not have sophisticated enough technologies to survive in the Arctic until very recently. "But if people were dealing with the cold that far north in Siberia 500,000 years ago, then a little bitty ice age like the Wisconsin isn't going to stop you from getting to America," he says.

No one, however, is going to push Diring as evidence for early American pilgrims until the twin issues of the environment and dating are much more settled. Mochanov has found no *erectus* fossils, which would clinch the case for the site as an *erectus* habitat, or animal fossils, which would go a long way toward clearing up questions about just how cold it was back then. "Those are the kinds of questions that have to be answered before we can explain the Diring peoples' behavior," says Potts. "We need to know what the survival strategies were of other animals in the area. If they were all cold weather-adapted, then you'd have to say these hominids made a real breakthrough—one that no others were doing."

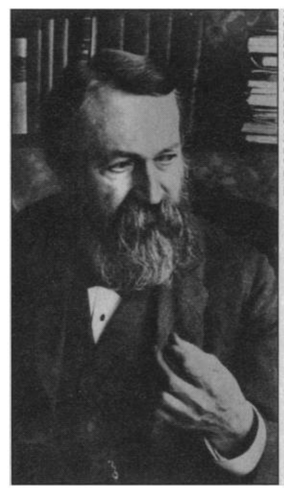
As for the 500,000-year-old date, there is still at least one scientist who is dissatisfied with it—Mochanov. He doesn't think it is old enough, and he is still sticking to his 3-million-year-old claim. "That is preliminary work," he says of the TL date, adding that he wants to wait for Waters' and Forman's final report, which is due by the end of this summer. "If we find we have a mistake [with the earlier date]," says Mochanov, "then we will correct it." At least his North American colleagues have already begun to correct their notion that Diring is a dud.

–Virginia Morell

PHYSICS

Inertia: Does Empty Space Put Up the Resistance?

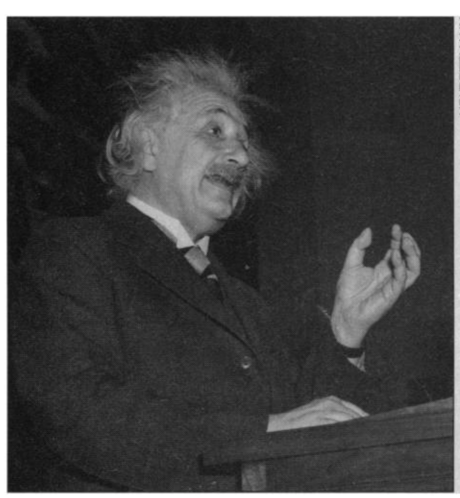
As a child, the Nobel Prize–winning physicist Richard Feynman asked his father why a ball in his toy wagon moved backward whenever he pulled the wagon forward. His father said that the answer lay in the tendency of moving things to keep moving, and of stationary things to stay put. "This tendency is called inertia," said Feynman senior. Then, with uncommon wisdom, he added: "But nobody knows why it is true."


THE GRANGER COLLECTION

Seeking a reference frame. Mach defined inertia with respect to the distant stars.

That's more than even most physicists would say. To them, inertia does not need explaining, it simply "is." But since the concept was first coined by Galileo in the 17th century, some scientists have wondered if, perhaps, inertia is not intrinsic to matter at all, but is somehow acquired. Those who have tried to come to grips with inertia include Feynman junior, once he had grown up, and Albert Einstein, who tried—and failed—to show that inertia was related to the arrangement of matter in the universe.

Now three researchers think they have found the source of inertia—and it turns out to be much closer to home. Inertia, they say, comes from the apparently empty space that surrounds us all—or rather, from the buzz of activity that, according to quantum theory, fills even a perfect vacuum, where subatomic particles are being created and annihilated in the blink of an eye. It is this ever-present sea of energy that the researchers believe resists the acceleration of mass, and so creates inertia.


UPI/BETTMANN

Another try. Einstein tried to incorporate Mach's principle into general relativity.

Reaching this conclusion took more than just a simple application of quantum theory for Bernhard Haisch of the Lockheed Palo Alto Research Laboratory, Alfonso Rueda of the California State University at Long Beach, and Hal Puthoff at the Institute for Advanced Studies at Austin, Texas. Their idea, published in the 1 February issue of *Physical Review A*, is based on an esoteric mathematical treatment of the vacuum and a long-forgotten attempt by the Soviet theorist and dissident Andrei Sakharov to explain another great mystery, gravity. These unfamiliar foundations, together with the new proposal's boldness, would be more than enough to stir up controversy. But the paper raises an even more provocative notion: that inertia, once understood, might be controlled.

It is a bit too early to be talking about building inertia-free starships, the researchers say, but they maintain that there may soon be hard evidence supporting their claim, from experiments that will search for changes in the mass of electrons when they are exposed to powerful laser beams. Certainly many of their colleagues are intrigued. Says Stanford University astrophysicist Peter Sturrock, "No one would say that it's the last word, but I think it may really be one of the first words in what could be a very interesting approach."

One inspiration for the effort was a much earlier try, by the German philosopher-physicist Ernst Mach. In 1872, Mach argued that acceleration—and hence inertia—is not absolute, but only has meaning within a frame of reference. For Mach, that frame of reference consisted of the other matter in the universe: After all, in utterly empty space, how do you know you are moving? Einstein later tried and failed to work that notion into general relativity. Haisch and his colleagues also invoke a frame of reference: not the distant stars, but the quantum vacuum.

The seething activity of the vacuum is an upshot of Heisenberg's uncertainty principle, one of the key results of quantum theory. The principle is best known for setting limits to the accuracy with which it is possible to measure simultaneously certain attributes of a particle, such as its position and momentum. But the flip-side of this uncertainty is that a particle and a matching antiparticle can spontaneously appear out of thin air, so long as they recombine and annihilate each other so fast no one would know. During their fleeting existence, these "virtual particles" make their presence felt in many ways, including slight shifts in the spectrum of hydrogen, the irreducible electronic noise in semiconductors and, Haisch and his colleagues now claim, inertia.

Meeting with resistance. Their argument draws on a curious quantum vacuum phenomenon first described by the British physicist Paul Davies (now at the University of Adelaide in Australia) and William Unruh of the University of British Columbia in the mid-1970s. If you move at a constant speed through the quantum sea of virtual particles, it looks the same in all directions. But as soon as you start to accelerate through it, theory predicts that the vacuum gives the appearance of being a tepid "sea" of heat radiation.

Although far too small to measure, the Davies-Unruh effect led Haisch, a high-energy astrophysicist, and Puthoff, a quantum theorist, to wonder independently about a connection with inertia. Could it be that accelerating through the vacuum produces other effects, too—like the resistance to acceleration that we call inertia? While still mulling over the idea, Haisch met with Rueda, an electrodynamics theorist with considerable experience in the techniques needed to attack such a question. When they learned of Puthoff's similar ideas, Haisch and Rueda decided to join forces with him.

In their analysis, the trio set aside conventional quantum theory. Instead, they opted for an approach known as stochastic electrodynamics (SED), which accepts the existence of the vacuum fluctuations *a priori*, then applies an entirely classical (i.e., nonquantum) approach to particles and electromagnetism. Since the 1960s, a number of theorists, including Rueda, have shown that SED can give a perfectly accurate account of bizarre quantum effects without becoming embroiled in complex quantum theory.

In their intensely mathematical paper, Haisch and his colleagues wield SED to argue that inertia results from a Lorentz force, familiar to physicists as the force that deflects a charged particle moving through a magnetic field. For inertia, it is the vacuum fluctuations that produce the magnetic field, and it is the charged subatomic particles making up objects that feel the Lorentz force. The larger the object, the more particles it contains, and hence the stronger the resistance, and the greater the object's inertia.

Predictably for a grand claim based on obscure theory, peer reaction is mixed. On the one hand is Stanford's Sturrock, who calls it "very interesting, and potentially very important." On the other is Peter Milonni, a specialist on quantum vacuum processes at the Los Alamos National Laboratory, who says, "I don't think much of the work," complaining "I see a lot of claims being made that are just not backed up."

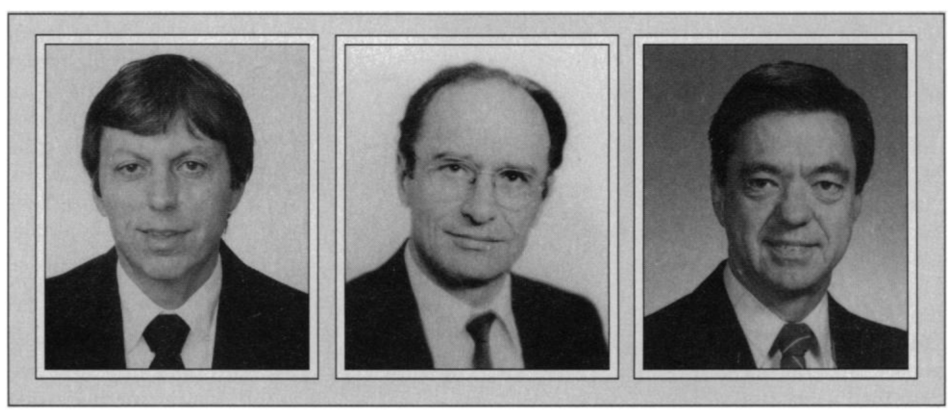
Cosmologist Paul Wesson of the University of Waterloo, Canada, an authority on the links between the subatomic and cosmic worlds, is "glad that someone is trying to return to the question of inertia again." But he is concerned about "the astrophysical and cosmological implications" of the work. Wesson's concerns center on the cosmological constant, best known as an add-on to Einstein's equations of general relativity that endows free space with extra energy and gives it a gravitational effect. Einstein eventually dropped the constant because it was inelegant, but some cosmologists would like to resurrect it because it would solve some of their most intractable problems, such as the age of the universe and its missing mass (*Science*, 5 November 1993, p. 846).

The new vacuum-based theory of inertia devised by Haisch and his colleagues does just that: It requires an energy-rich vacuum, which implies a cosmological constant. The problem is that the constant implied by the new theory is much bigger than the one required to solve the other problems of cosmology. Says Wesson: "The vacuum has so much energy associated with it that it would have negative astrophysical implications. Those would have to be cleared up."

Overcoming inertia. Haisch and his colleagues agree that there is a problem and suggest an answer, in the form of a controversial theory of gravity proposed by Sakharov in the late 1960s. One consequence of Sakharov's theory is that vacuum energy can't generate a gravitational field—and so cannot create a problematic cosmological constant. Solving one unconventional theory's problems by invoking another unconventional theory is unlikely to win many converts, and Haisch agrees that the team's work needs refining. But he hopes to do it with the help of other researchers, who might be lured by the tantalizing implications of the theory—among them the possibility that by altering the properties of the vacuum, researchers might control inertia.

Physicists have known for years that the quantum vacuum can be manipulated. In the so-called Casimir effect, two metal plates brought close together distort the quantum vacuum, which responds by producing an attractive force between the plates. If the quantum vacuum could be distorted on a larger scale, says Haisch, "then we open a door on a way of perhaps someday controlling inertia—and we had no inkling that was even possible in principle before."

Experiments slated for later this year at the Stanford Linear Accelerator Center (SLAC) may provide Haisch and his colleagues with the evidence they need to convince skeptics. Physicist Kirk McDonald of Princeton University and colleagues from a number of other universities plan to expose high-energy electrons produced at SLAC to a terawatt beam from a neodymium-YAG laser. Testing the inertia theory isn't the main aim of the experiment. But if the theory is correct, the intense electromagnetic field experienced by the electrons as they enter the beam will affect their interaction with the quantum vacuum's own field—and so change their inertia.



A new tack. Haisch, Rueda, and Puthoff, shown from left to right, think they have found the source of inertia in the fluctuations of the quantum vacuum.

A favorable outcome, Haisch thinks, might be just what he and his colleagues need to overcome any resistance—or is it inertia?—they are meeting in the scientific community. "If nothing else," he says, "controlling inertia is a possibility that might just encourage others to dig deeper."

–Robert Matthews

Robert Matthews writes for The Sunday Telegraph *in London.*