modulus, a defining characteristic of a solid.

Until Kim and Chan, however, no one had had much luck in finding experimental evidence for supersolidity. Their torsional oscillator was a rather simple piece of apparatus. They attached a 'bob' containing the helium sample to the end of a torsion rod. A torque applied to the bob caused it to twist and rotate back and forth, with an oscillation period set by the ratio of the bob's moment of inertia (a measure of the amount and distribution of mass being rotated) to the torsional stiffness of the rod. If some of the material in the sample stops participating in this rotation, the moment of inertia of the bob decreases, and the period drops. This is precisely what happens with liquid ^{4}He, which is a well-known superfluid: as the temperature is reduced below that at which the superfluid forms, the superfluid component stops rotating and the oscillator's period drops. Kim and Chan's same result[1,2] with solid ^{4}He has now been reproduced in at least four other laboratories.

A supersolid can exhibit other anomalies, for instance in the speed at which sound passes through it. Sound speed depends on the shear modulus of the solid, as well as the density of the superfluid component. To assess why the solid behaves in the way it does, it is thus important to measure the shear modulus independently of the superfluid density. This is precisely what Day and Beamish have now done with solid helium.

Again, the authors' experiment[3] is conceptually simple. They placed solid ^{4}He between two parallel plates, known as piezoelectric shear transducers. They moved one plate, the driving transducer, in a direction parallel to the second plate. The solid helium transmits the resulting elastic shear stress between the plates, and this is measured by the second transducer. Day and Beamish find[3] that the shear modulus of helium rises by up to 10% as the temperature is reduced from 0.2 to 0.02 kelvin. More significantly, the temperature dependence of this large increase in shear modulus closely tracks the changes in period in the torsional-oscillator experiments.

When these results were first presented at a small workshop on the supersolid state of matter in Minnesota in late July 2007, the reaction of some of us in the audience was that the large change in the shear modulus might be the primary phenomenon, and the much smaller change in the period of the torsional oscillator a related side effect. The various torsional-oscillator experiments are now being re-examined, to estimate the shear stresses and strains that occur within and between the various parts of the assemblies, and to ask if changes in shear stiffness of the helium might cause the observed changes in the oscillation period[5].

So what might be the root cause of the observed effects? It has long been known that a solid's strength and shear modulus are not set solely by the intrinsic nature of a perfect crystalline solid, but also depend strongly on defects such as dislocations and grain boundaries. The same seems to be true for the torsional-oscillator experiments: the results depend on the quality of the crystal, with the largest effects seen in the most defective samples.

Day and Beamish[3] explain their results very plausibly as the behaviour of dislocations and trace ^{3}He impurities in the solid ^{4}He: when dislocations can move in response to a shear stress, they relax the stress and so lower the shear modulus. Impurities of ^{3}He are thought to bind weakly to dislocations in solid ^{4}He at low temperatures and so restrict their motion. As the temperature is increased, the trace ^{3}He atoms unbind from the dislocations, allowing the dislocations to move more freely. The observed dependence of the shear modulus on the concentration of ^{3}He is consistent with this idea. This is not to say that supersolidity must have no role: careful simulations[6] and modelling[7] find superfluid flow along dislocation lines in solid ^{4}He.

It seems clear now that both the earlier torsional-oscillator experiments[1,2] and Day and Beamish's new experiment[3] are probing the quantum-mechanical behaviour of structural defects in imperfect helium crystals. But a thorough understanding of the measured effects remains elusive. Are we studying supersolidity, the quantum properties of dislocations, both — or perhaps something else entirely?   ∎

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RELATIVITY

Still special

Giovanni Amelino-Camelia

Is special relativity a clapped-out classical theory, to be replaced by a shiny new quantum model as soon as possible? On the contrary, it would seem: the theory still has a youthful ability to surprise us.

Since Albert Einstein introduced it to the world in 1905, the special theory of relativity has embodied the journey of modern physics from an 'intuitive' description of the world to a deeper level of understanding — an understanding at first profoundly baffling to established ways of thinking. Concepts such as the equivalence of mass and energy, embodied by the formula $E = mc^2$; the existence of an unbreakable speed barrier, the speed of light *in vacuo*, c; and the paradox of two twins who, by dint of experiencing different accelerations through space, can age by different amounts, have all stamped themselves on the public's consciousness (Fig. 1, overleaf). At the same time, special relativity has provided a reliable description for an ever-growing list of physical phenomena.

Writing in *Physical Review Letters*, Cubero *et al.*[1] add to that list, establishing how special relativity affects certain equilibrium properties of a gas of idealized particles. The work is symbolic of special relativity's odd position in the pantheon of modern physics theories: continuously tested and always successful; yet also disparaged as not really 'belonging' in the grander scheme of things. To physicists, special relativity was only really ever a fundamental theory for 11 years: in 1916, it ceded that title to Einstein's general theory of relativity. General relativity incorporates special relativity's maximum-speed principle into a comprehensive theory of gravitational phenomena, and through that arrives at a description of gravitational acceleration as a consequence of the curvature of space-time.

Special relativity is thus a humble 'effective theory', valid only as an approximation under certain conditions — specifically, that gravitational effects such as the curvature of space-time can be ignored. But, as luck would have it, physicists have devoted most of the century since Einstein first dreamt up his relativity to studying the quantum properties of particles in just such cases. The particle physicist at a laboratory such as CERN does not need to worry about the local topology of space-time when smashing particles together: particle physics' ultra-successful 'standard model' is built on the special, not the general, theory of relativity.

Since the end of the 1990s, however, the blanket application of special relativity in these instances has come under renewed attack. The reason for this is that gravity, in its general-relativistic description, is the only one of the four fundamental forces of nature that is still described using the rules of classical mechanics. Pursuing the hypothesis of a 'quantum
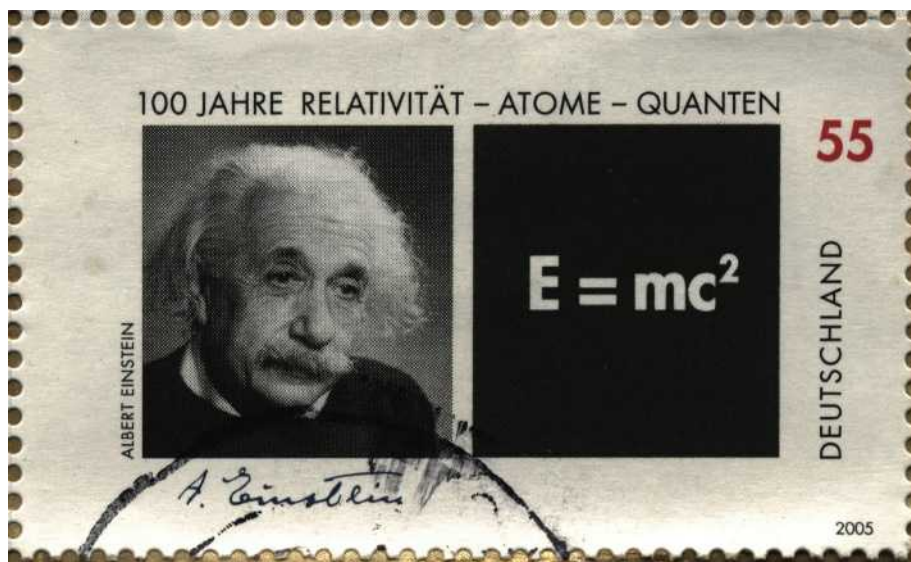
gravity', one encounters the possibility of small, but non-negligible quantum-curvature effects, even where the average curvature is zero.

This could have practical implications for, say, the observation of objects in the distant Universe. The particles that we observe from so far away (mainly photons of light) propagate for billions of years, and quantum-curvature effects, although individually tiny, could accumulate to an appreciable effect that might, for example, affect our estimates of the objects' distance. But in all the astrophysical tests so far performed to test this hypothesis, special relativity comes out tops, with no evidence of deviations from its predictions. A more definite picture will emerge only after other crucial tests are performed, such as γ-ray observations soon to be conducted with NASA's GLAST space telescope. But at present even I — a researcher deeply involved in all the quantum-curvature speculation — must admit that special relativity seems in remarkably rude health.

In fact, rather than discovering regimes to which special relativity does not apply, we are actually learning how to use it to describe even more areas of physics. Cubero and colleagues' analysis[1] of the special-relativistic equilibrium properties of a gas of particles is a case in point. Although Einstein's original formulation provided straightforward prescriptions for attributing special-relativistic properties to each particle in such a multi-particle system, it has not always been easy (and has sometimes been terribly hard) to derive from these properties a macroscopic, statistically valid description of the system.

The authors find a clever and reliable way to simulate numerically a dilute, one-dimensional gas consisting of two species of particle, and study macroscopic properties such as temperature and the velocity distribution of the particles. The statistical distribution of the particle velocities in the gas that emerges clearly favours a description proposed[2] on the basis of a maximum-entropy principle that has been criticized for lacking explicit compatibility with relativity. The authors also succeed in introducing a concept of 'proper' temperature such that, in agreement with the principles of special relativity, observers moving differently with respect to the gas will agree on the temperature's value.

As so often happens in the development of young theories — at 100 years old, special relativity is still looking remarkably youthful — these results clarify some issues, but also present new challenges. In particular, the authors' analysis must be generalized from one to three spatial dimensions, the number we really care about. This will require getting rid of the simplification introduced by the authors that the point particles in the gas interact only when they actually touch. In one dimension, touching collisions are rather frequent, and this approximation is appropriate; but in three dimensions, contact collisions would not be frequent enough to allow the establishment of

a definite temperature. For a complete description, interactions at a distance must also be considered.

Such caveats do not detract from the success, exemplified by Cubero and colleagues' work[1], of special relativity in characterizing the properties of complex systems. Even those of us speculating about a quantum version of the theory, and at present concentrating on very simple systems, might do well to take a lesson

Figure 1 | Einstein equals most celebrated, squared. The equation embodying mass–energy equivalence has become, along with its creator, the most recognizable symbol of modern physics — here on a German stamp to commemorate the 2005 'Year of Physics', the 100th birthday of special relativity.

from that — this theory's retirement might be some time coming yet. ■

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CANCER

Immune pact with the enemy

Cornelis J. M. Melief

Progress comes from the latest investigations into a long-standing question in immunology — the role of the immune system in maintaining small, potentially cancerous lesions in a state of dormancy.

The current belief about treating cancer is that tumour cells need to be eradicated as quickly as possible, so as to halt tumour growth and spread, and to prevent or delay the death of the patient. The startling results of Koebel *et al.*[1] (page 903 of this issue) demonstrate that considering cancer as a fatal disease is not always appropriate*.

The authors show in mice that induction of cancer by methylcholanthrene (MCA), a tar component of the kind found in cigarette smoke, causes an initial wave of deadly tumours affecting many animals, after which the surviving mice show no evidence of growing tumours. Deceptively, however, dormant tumours still exist in these apparently healthy mice, and these are kept in check by

*This News & Views article and the paper concerned[1] were published online on 18 November 2007.

the immune system. This state can be fatally disrupted by suppression of the immune system, allowing the dormant tumours to wrest themselves from immune control and grow, spread and kill their host.

The concept of tumour dormancy, or latency, has a long history, and is well documented in animal studies and in anecdotal clinical observations[2–5]. Also, it has long been suspected that immunosuppression can activate dormant tumours. For example, a cancer — malignant melanoma — developed in the recipient of a kidney transplant from a donor who had been treated for melanoma 16 years earlier, and was considered cured[5]. The cancer in the recipient was found to be of donor origin: apparently, the immunosuppression required to prevent the recipient's rejection of the kidney triggered regrowth of the cancer