Another central issue in the field of nanomechanical-resonator cooling is the small amplitude of the zero-point fluctuations once the resonator is in its ground state. For the cantilever assumed above, this amplitude would be as low as 5×10^{-13} m, 1,000-fold smaller than the radius of a ground-state hydrogen atom. Once again, the strong coupling between the spin and the oscillator enables a convenient read-out of this motion. The magnetic-field gradient of the tip causes a Zeeman shift of the electron spin of the nitrogen vacancy. This shift is proportional to the amplitude and to the magnetic-field gradient. Close to the tip, the gradient can be about 10^{7} T m^{-1}, yielding a shift of 100 kHz. As the electron-spin linewidth is only a few kilohertz, such a shift can be easily read out on a millisecond timescale. Once prepared near its ground state, the oscillator can be coherently controlled by means of its coupling to the spins. This brings the full beauty of coherent spin control known from techniques such as NMR to the field of mesoscopic quantum physics.

Although the physical parameters of the coupled spin–cantilever system are technically demanding, the system meets the requirements for ground-state cooling and coherent control. And this technique certainly has the potential to cross-fertilize other areas of science, such as single-spin magnetic-resonance force microscopy.

A further asset of the proposal is that it points towards another intriguing aspect of the coupled cantilever–spin system. A vital element of the spin-mechanical cooling scheme is the outstanding properties of the diamond electron spin such as a long decoherence time of several milliseconds. Thus, the idea could be modified to use a spin (of an electron in a diamond nitrogen vacancy, for example) at the tip of the cantilever to achieve strong coupling — that is, entanglement — to an immobilized spin. This second spin could be another defect-centre electron spin in a diamond substrate. By moving the cantilever this entanglement can be transferred to another electron spin at a distant location. This would enable the creation of quantum-correlated spin states over macroscopic distance, an as yet unexplored version of Schrödinger's cat. ❐

Jörg Wrachtrup is at the 3rd Institute of Physics, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany.
e-mail: wrachtrup@physik.uni-stuttgart.de

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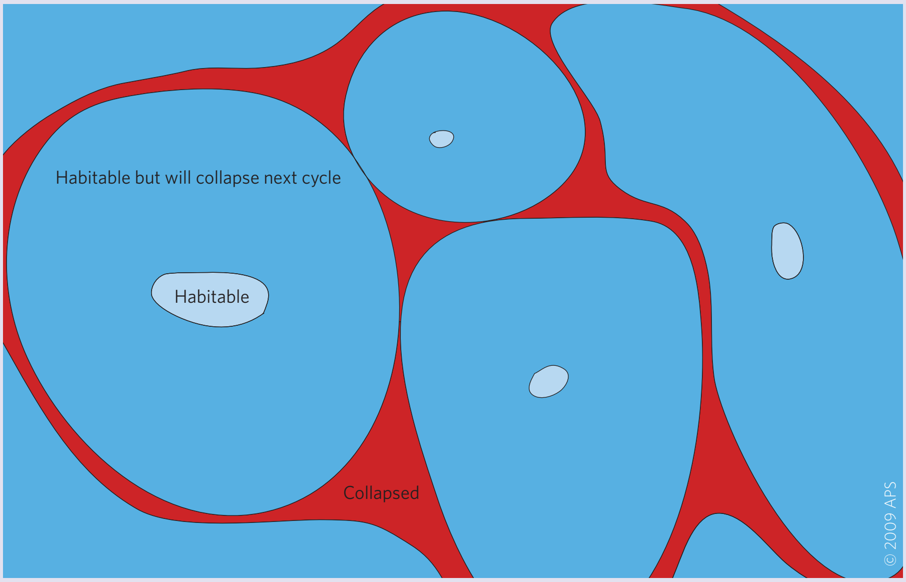
COSMOLOGY

Can the Universe survive a cosmic crunch?



Forget the credit crunch, there could be a far bigger crunch to come — one in which most of the Universe could be lost forever. Jean-Luc Lehners and Paul J. Steinhardt suggest that only a tiny seed of the old might survive, to arise, phoenix-like, from the ashes and expand into a new universe (*Phys. Rev. D* **79,** 063503; 2009).

According to cyclic models, the Universe is undergoing repeated phases of expansion and contraction punctuated by a big crunch and a big bang. In the basic formulation, using a single scalar field, all of the Universe passes through the crunch/bang transition and enters the next cycle of expansion and contraction.

Data from NASA's WMAP satellite, indicating the flatness of the Universe, have constrained the picture: the period of contraction before each crunch must be slow and follow an equation of state $w \gg 1$ — what is known as 'ekpyrotic' contraction. And (for the moment, at least) the best way to engineer ekpyrotic contraction alongside other necessary features of the model is to allow for two scalar fields, not one, evolving on a steep potential through the contraction.

This does, however, have a side-effect: it makes it easy for quantum fluctuations to knock huge chunks of the Universe off the necessary trajectory for passing through the crunch/bang and hence they do not survive into the next phase. Unless, that is, the period of contraction is preceded by at least 600 billion years of dark-energy-driven expansion — then a chunk with the same characteristics as our Universe would survive (as shown here in the authors' lava-lamp-like representation of the two-field cyclic universe), and it would even grow in volume from one cycle to the next. Furthermore, the level of spatial variation in dark energy in the Universe (if it could ever be detected) would be an effective 'cosmic clock' — higher in early cycles, lower in later ones (for a cyclic model that does actually have a beginning).

Whether the Universe is cyclic or not could be decided in the next few years by data from ESA's soon-to-launch Planck satellite, through a definitive measurement of the non-Gaussianity of the cosmic microwave background radiation.

ALISON WRIGHT