regression of samples that have experienced a different geological history to obtain a supposedly meaningful age.

The trondhjemite mineral data are taken to define an age close to the time of emplacement for the reasons given in the original paper[1]. However, the whole-rock Sm–Nd and Pb–Pb ages of 2,800 and 3,000 Myr are considered to represent the age of 'their source', not of 'the mantle source'. The latter phrase was not present in our final submitted manuscript, but appeared as an editorial change which we unfortunately failed to notice on the proofs.

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Energy partitions

SIR — John Maddox (*Nature* **374**, 11; 1995) discusses results by Y. Du *et al.* (*Phys.Rev. Lett.* **74**, 1268–1271; 1995) of a one-dimensional array of particles which undergo inelastic collisions: inelasticity implies a loss of energy, and thus energy is fed at a bounding wall to maintain steady state. Energy is not equipartitioned: it decays as one moves away from that wall.

Maddox calls the situation "tantalizing"; he believes that the result may be an artefact of the one-dimensional assumption: "So where is the snag? . . .It will be interesting to learn what the two-dimensional simulations . . . will show. A similar result would indeed be subversive. That outcome seems improbable . . ."

That outcome has been found by people who were looking at large-size particles such as found in hoppers, chutes and the like. But we first discuss a simple problem with an ideal gas, where the same result is obtained.

Consider a long tube containing an ideal gas, hotter than the surrounding ambient, so that energy is lost by heat transfer. The latter is equivalent to collision inelasticity in that it allows energy to be lost. Steady state is maintained by supplying heat at one wall. Temperature will decay as one moves away from the heated wall, and energy is not equipartitioned. All it takes is: a mechanism for loss of energy; and a steady supply of energy at one position to balance the energy loss.

J. T. Jenkins and S. B. Savage (*J. Fluid Mech.* **130**, 187–202; 1983) and others have analysed the statistical mechanics of a granular material with inelastic collisions. Vigorously shake a bottle of pills: the pills have a significant kinetic energy of oscillation, which may be kept constant if the shaking mechanical energy input exactly balances the energy loss due to inelasticity. That collisions are inelastic is shown by the fact that, as soon as shaking ceases, it will take very little time for all the pills to set down on the bottom and have a zero "temperature".

Application of the Jenkins–Savage theory to some simple flow of granular materials quickly shows that fluctuation energy is not equipartitioned. Michael Faraday (*Proc. R. Soc.* **A121**, 299–340; 1831) reported on the flow of a mound of particles sitting on a vertically vibrated plane. The same experiment was done again by Savage (*J. Fluid Mech.* **194**, 457–478; 1988), who has correctly interpreted the results in terms of an inelastic collision flow theory.

There is nothing surprising about the Du *et al.* results. What is surprising is that, in rarefied gases, collisions are so precisely elastic that equipartition of energy occurs. What Maddox calls a "deliciously schooltextbook notion", the coefficient of restitution, has to be exactly unity for equipartition to occur. Should it be less than unity, no matter by how small an amount, equipartition would not occur except in very special cases. Maddox does not need to wait for the "implicitly promised" two-dimensional simulations. Energy will not be equally partitioned.

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Complementarity and uncertainty

SIR — Storey *et al.*[1] claim to have shown that, in any scheme for detecting the way of a particle through a Young's double-slit interferometer, the interference pattern is destroyed because the detector transfers momentum to the particle. The authors then conclude that the principle of complementarity is simply a consequence of Heisenberg's uncertainty relation and not a more fundamental concept. We disagree. The principle of complementarity is much deeper than the uncertainty relation, although it is frequently enforced by $\delta x \delta p \geqslant \hbar/2$. We show here (1) that the general arguments by Storey *et al.* cannot be right in the face of a recent experiment; and (2) that their specific criticism of our analysis of the quantum-optical which-way detectors is invalid because the calculation is incomplete. The complete detailed calculation[2] confirms our original statement[3] that it is the presence of which-way detectors, not Heisenberg's uncertainty relation, that enforces complementarity.

A which-of-two-ways-type experiment based on photons scattered from two atoms had been proposed by Drühl and M. O. S.[4] and realized by Eichmann *et al.*[5]. In this experiment, photons emitted from a source reach a screen after being scattered off two ${}^{198}\mathrm{Hg}^+$ ions held firmly at rest in a linear Paul trap. This resonant scattering occurs in two steps. First, the incoming photon is absorbed and one of the two ions is excited from its $6s^2S_{1/2}$ ground state to the $6p^2P_{1/2}$ state; then a photon is emitted and this ion returns to the ground state. Both the ground state and the excited state have two Zeeman sublevels with $m_J = +\frac{1}{2}$ and $m_J = -\frac{1}{2}$, which is the key element in the which-way experiment. The incoming photons are linearly polarized. Therefore, if one observes fluorescence photons with the same linear polarization, the final state of the scattering atom is identical with the initial one. In this case, which-way information is not available and an interference pattern is observed. By contrast, if one observes fluorescence photons that are circularly polarized, then the scattering atom ends up in a different Zeeman level from the one it was in initially. Consequently, which-way information is available in this case and no interference pattern can be observed.

The disappearance of the fringes cannot be blamed on a change in the external motion of the photon — as Storey *et al.* would conclude — because the observation of the interference for linear polarization definitively excludes the excuse of a substantial momentum kick. We thus have here a clear experimental counter-example to the notion that the enforcement of Bohr's principle of complementarity in two-slit experiments is always a consequence of Heisenberg's uncertainty relation.

Storey *et al.*[1] present their argument in a longer paper[6] to which we have already replied[2]. In Fig. 1 of ref. 6, Storey *et al.* incorrectly place the which-way detectors between the double slit and the screen. The correct location is depicted in Fig. 3 of ref. 3, where the atoms traverse the which-way detectors before reaching the slits. At this early stage, the precision with which the position has to be determined must only suffice to distinguish the upper partial beam from the lower one. The avoidance of a position measurement is a decisive advantage of our scheme[3]. Storey *et al.* correctly find that the final centre-of-mass wave function $\psi_f(x) = \psi_i(x)\, g(x)$ is the product of the initial one, $\psi_i(x)$, and a function $g(x)$ that is determined by the geometry of the resonator. In the figure we show the $g(x)$ function used by Storey *et al.* and a typical initial wavefunction $\psi_i(x)$. Note that $\psi_i(x)$ is well localized, and therefore $g(x)$ matters only where $\psi_i(x)$ is