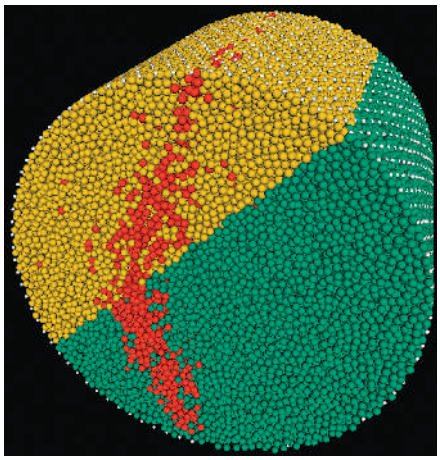
Shear light refraction



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Sand is solid — you can walk on it. But you can also pour it as a fluid, which makes predicting the motion of granular media so difficult. When the grains flow in response to external stress, most of the bulk remains solid-like in blocks, which slide past one another. The sliding planes are known as shear zones: the weakest structural link.

Tamás Unger has modelled and simulated shear flow in layered granular media. His analysis is based on a long cylindrical drum filled with two layers of polydisperse grains (yellow and green in the picture), each with a different coefficient of friction. The interface is parallel to the axis of the cylinder. As the cylinder is cut in two along its long axis, and each half slides away from each other, the grains inside experience shear stress. By minimizing the rate of energy dissipation, Unger found that the shear zones separating the moving parts of the grains (shown in red) are refracted by the interface. Moreover, the angle of refraction follows Snell's law from geometric optics. Thus the surface of the shear zone, which minimizes dissipation, represents the path of least resistance, analogous to Fermat's principle.

Bunches of bosons

Nature **445,** 402–405 (2007)

When photons are detected from a beam of narrow spectral width, correlations can be seen between photons arriving at the same time in different locations. This means that, provided the separation between two detectors is sufficiently small, the probability of joint detection is higher than merely adding the probabilities of statistically independent detection events. Robert Hanbury Brown and Richard Twiss were the first to describe this 'bunching' effect, in *Nature* in 1956, triggering the development of modern quantum optics.

Bunching was later also seen with massive bosons, in ensembles of cold atoms. But Tom Jeltes and colleagues go a step further and compare the Hanbury Brown–Twiss effect for bosonic and fermionic atoms in the same apparatus. They use the two helium isotopes — any differences in the behaviour of the two species can be assigned to pure quantum effects. For bosonic helium-4 atoms, Jeltes *et al.* observe bunching once the detectors are separated by less than about 1 mm. Fermionic helium-3 atoms, however, interfere destructively over the same distance — consistent also with the Pauli principle, which excludes two identical fermions occupying the same spot.

Stars as fossils

Mon. Not. R. Astron. Soc.
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Just as archaeologists use fossils to study the past, astronomers use stars to reconstruct galaxy formation and evolution. As galaxies evolve, stars change composition and mass, thereby providing a traceable chemical history. Roberto Cid Fernandes and co-workers have sampled 84,828 star-forming galaxies to reconstruct their histories, and arranged them according to mass or chemical abundance of their nebulae. From there, they worked out the stellar mass and heavy-metal content over time.

Of course such fossil methods are not new. But by using integrated spectra with vastly improved statistics, the authors were able to resolve the conditions of stellar evolution. Stars form within warm interstellar media (ISM). The authors found that for nebulae rich in heavy metals, the observed stars gained mass and finished their chemical evolution quickly — surpassing the heavy-metal content of our Sun billions of years ago. By contrast, in low-metallicity ISM, the stars formed so slowly that in their last 10^8 years of evolution they had only reached a third of the Sun's metallicity level.

Recognition to order

Opt. Express **14,** 13095–13100 (2006)

Optical tweezers — which enable particles ranging in size from micrometres to tens of nanometres to be manipulated using focused laser fields — provide a powerful tool for studying living cells. The difficulty in using them to manipulate more than a handful of particles at a time, however, limits their wider potential use. Some success has been achieved in the development of passive optical trapping systems that create an array of optical traps to sort and filter particles by size or composition. But for more complex tasks that demand 'closed-loop' control (using feedback to more actively manipulate multiple particles), continuous human intervention is usually required.

Stephen Chapin and colleagues have developed a holographic optical tweezer system for controlling many particles at once , which avoids the need for a human operator in the active control loop. Using computer-based real-time feature recognition to accurately locate and control the position of twenty five individual silica particles suspended in fluid, they can automatically arrange the particles into a variety of ordered patterns — including into a 5×5 array, and into letters to spell 'LUX'.

Nanosense and sensibility

Nature Nanotech. **2,** 114–120 (2007)

The microcantilever is arguably the most ubiquitous and commercially successful of all micromechanical devices. It is the principal sensing element of both the accelerometers used in all car airbag systems and of the atomic force microscope (AFM). Extending the potential and sensitivity of cantilever-based sensors to other applications requires that their size be reduced to nanoscale dimensions. But finding a method of measuring a nanocantilever's deflection in a way that could sensibly be implemented in a mass-produced device has proved challenging. Doing so capacitively, as in an accelerometer, is too susceptible to noise and parasitic effects.

And doing so optically, as in an AFM, requires external optics that are bulky and inconvenient.

To overcome these limitations, Mo Li and colleagues have developed a self-sensing nanocantilever whose deflection is measured using the piezoresistive response of a thin metallic layer that coats it. Not only is the device more amenable to large-scale production and deployment than previously demonstrated nanocantilevers, but it is also less strongly affected by operation under ambient conditions than conventional microcantilevers, and hence potentially more useful for biological and chemical sensing applications.

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