Figure 1 Dark and cold — and probably icy (at least beneath the surface). This is a mosaic of images of the Moon's south pole, taken by the Clementine spacecraft. Clementine's radar detection of water ice at the lunar poles was controversial. The data on neutron fluxes, collected by Lunar Prospector and discussed here, are much more compelling.

The Moon isn't wet, but there is at least some water there. The latest and best evidence for water ice at the poles of the Moon comes from Feldman *et al.*¹ in a paper in *Science*. These findings may or may not make lunar bases more feasible, but they do represent a success for a new type of exploration for the US space agency NASA.

Although early astronomers called the vast, dark, circular patches of the Moon 'maria', thinking that they might be seas, water is scarce on the Moon. The amount of water in the samples returned by the Apollo astronauts is as low as 1 part per million, and most of that is probably contamination introduced during collection and processing². Some water should be brought to the Moon in asteroids and comets, and some should be created near the surface by the reduction of iron-bearing minerals by hydrogen in the solar wind. But these processes would put the water near to the lunar surface. With daytime temperatures approaching 400 K in the regions spacecraft have visited, that water has little chance of staying there.

There are, however, areas of the Moon that are permanently shadowed from sunlight. These regions of perpetual darkness, primarily the interiors of impact craters at very high latitudes, can stay very cold (<120 K), so water might be retained there^{3,4}. Such regions should also act as cold traps, and collect water that is released from other places on the Moon. The idea that the lunar poles might harbour ice gained more attention with radar studies in the early 1990s that presented evidence for the presence of ice in polar regions of Mercury⁵⁻⁷, the closest planet to the Sun, which experiences even higher equatorial daytime temperatures than the Moon. But the permanently shadowed regions of the Moon have never been visited by spacecraft, and are difficult to observe from Earth because the same crater walls that block the sunlight often block the view from Earth.

Less than two years ago, the Clementine mission made headlines when data it had collected showed indications of ice at the

lunar poles⁸. As in the case of Mercury, the evidence came from radar studies. Instead of looking at the radar return from a location, the Clementine studies consisted of analysing the scattering of the spacecraft's radio signal to Earth when it was bounced off the region of interest. Although they were exciting, the Clementine results were controversial, and later ground-based radar studies failed to confirm the presence of ice⁹.

Into the breach came the Lunar Prospector. It was built for only \$63 million, one to two orders of magnitude less than the planetary exploration spacecraft of the 1970s and 1980s, and was launched only 22 months after the decision to fly it was made¹⁰. Lunar Prospector is the first competitively selected mission (and the third overall) in NASA's Discovery Program, which emphasizes smaller, cheaper spacecraft with narrowly focused objectives. One of the reasons Prospector succeeded was because of a commitment to fly instruments that could meet specific goals (primary among them being the search for water at the lunar poles), rather than cutting-edge technology.

Lunar Prospector used a more direct approach to searching for ice than Clementine, and has achieved less ambiguous results. The detection was based on the measurement of the abundance and energy spectrum of neutrons coming from the interaction of galactic cosmic rays with the material in the uppermost metre of the lunar surface. As the lightest of the elements, hydrogen is uniquely capable of reducing the number of epithermal (moderate energy) neutrons. Feldman *et al.*¹ found a distinct lack of epithermal neutrons at each pole, strong evidence for the presence of hydrogen. Hydrogen will also reduce the number of neutrons with higher energies, but so will heavier elements, and these can mask the effects of hydrogen, if the hydrogen is buried. Because there was not a dramatic difference in the number of high-energy neutrons at the poles, Feldman *et al.* concluded that the hydrogen is buried, probably by 40 cm or more. A detection of hydrogen is not a detection of water; it could also be as H₂ or some other compound. But H₂O is by far the most

Daedalus

Worlds apart

Last week found Daedalus musing on Everett's 'many worlds' interpretation of quantum probabilities. If a quantum choice happens to go one way in our world, there is some other world in which it goes the other way. Thus everything that can possibly happen, does happen, in some world or other. Your wildest secret fantasy is actually coming true somewhere. Conversely, in some world or other, there is an individual for whom your ordinary humdrum life is *his* wildest fantasy.

Indeed, says Daedalus, that is why we have the fantasies we do, or enjoy mental creativity of any kind. The many Everett worlds are embedded in a set of equally valid vector subdivisions with mixed, non-physical quantum states: the 'spirit world', through which information can leak telepathically between the Everett worlds.

But Daedalus now reckons that physical communication may also be possible. A quantum event in this world, such as a radioactive decay, must have its counter-event in another world, to preserve the total sum of possibilities. Daedalus recalls the enigmatic Schmidt machine, whose electric lamps are lit at random by pulses from a radioactive source. Some people, it is claimed, can predict by ESP which lamp is going to light next. Some can even will a given lamp to light next. This telepathic ability to influence quantum states could signal to another Everett world, in which the complementary decay is occurring. Physicists there could read the message in the nonrandom decay pattern of their sample. They could even signal back in the same way.

Now one counting experiment on ⁶⁰Co and ¹³⁷Cs has found, against all expectation, that their decay was serially nonrandom¹. Someone, somewhere, is signalling to us! So Daedalus advocates a careful search for the lack of randomness in quantum events. Radioactive decay is an obvious example; electrical circuit noise is another; chaotic phenomena that rapidly amplify sub-Heisenberg irregularities to the macro scale are another. The field is vast and totally neglected; a positive outcome would be revolutionary. Many thinkers have imagined the likely form of coded messages from other civilizations — lists of prime numbers, the digits of π , and so on. They may be taken aback if the first signals seem to be descriptions of other people's fantasies.

David Jones

1. Anderson, J. L. & Spangler, G. W. *J. Phys. Chem.* 77, 3114–3121 (1973).