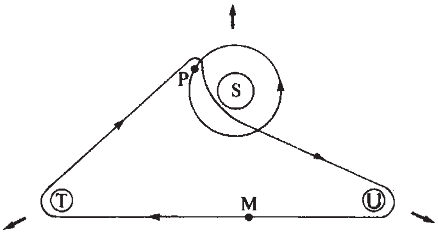
could occur for four point particles constrained to lie on a line and colliding elastically. The process involves an infinite number of energy transfers, happening ever more rapidly: conservation of energy does not rule out such escapes.

Gerver argues that in the (planar or three-dimensional) five-body problem, non-collision singularities should exist. The proposed mechanism is ingenious. Imagine three massive 'stars' S,T and U represented by point masses. Make S slightly heavier than T and U. Arrange all three stars in a triangular constellation with an obtuse angle at S, and start them out in such a way that the triangle expands at a uniform rate while maintaining its shape. Add a tiny 'meteorite' M, which orbits round the outside of all three, approaching them very closely (see figure).

As M passes each star it undergoes the same 'slingshot' effect that was used for the Voyager spacecraft journeys through the



Solar System. As a result, M gains a small amount of kinetic energy from star S, which it can then share with T and U to increase their speeds (and its own). If only there were a way also to increase the energy of S, it would be possible to make the triangle expand at an ever increasing rate, disappearing to infinity in a finite time.

Of course, conservation of energy forbids this — but there is a way out. Place a fifth 'planet', P, in a roughly circular orbit round S. Now make M gain its energy at the expense of P and transfer some of it to S via a 'zig-zag' slingshot path. Otherwise proceed as before. Now, as time increases, the triangular constellation expands ever faster but does not change its shape, M moves ever more rapidly in its triangular orbit, and the orbit of P descends ever closer to S. As a result, all five bodies escape to infinity in a finite time.

This scenario requires a very delicate balancing act. For example, planet P must be in a suitable position for the zig-zag slingshot not just at the first pass, but at every pass; its orbit must stay roughly circular; and the triangle of stars must stay stable. Furthermore, the energy transfers must be handled in such a way that the increase in the speed of the meteorite as it traverses the constellation is greater than the rate at which the constellation grows, so that the orbital period of the meteorite shrinks. Gerver argues plausibly (but heuristically) for the existence of a set of initial conditions that keeps all of these problems under control. He adds that a calculation "nearly one hundred pages long" give a rigorous proof that the 'Great Escape' does occur in an analogous model problem, in which some particles are massless and the meteorite undergoes elastic collisions instead of slingshots. The full result might be proved in "hundreds of pages of calculations". A better approach might be to seek new methods to make the arguments more rigorous.

In the real Universe, of course, additional bodies would interfere with this delicate scenario, and relativistic effects would change the results. But Gerver's idea is a bold and imaginative thrust at the heart of a celebrated problem, and a challenge to the current mathematical techniques. Isaac Newton would have loved it. □

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Radiocarbon dating

New World colonized in Holocene

from Richard Burleigh

A PAPER by J.L. Bada *et al.* on page 442 of this issue describes the application of the new accelerator mass spectrometric (AMS) technique of radiocabon dating to human skeletal remains from California. The dating of the remains to the Holocene is important for two reasons: first, it adds to the increasing body of evidence placing the human colonization of the New World in this period; and second, with much wider relevance, it provides a striking demonstration of the power of AMS.

The time of first arrival of humans in the New World has long been a matter for controversy. During the earlier decades of this century any claims for the antiquity of apparently early human skeletal remains discovered in the Americas were hotly contested, notably by the physical anthropologist Ales Hrdlička. At their most vehement, Hrdlička's views would not allow the presence of humans there for more than a few millennia, although eventually he was prepared to concede a possible time of arrival of 10,000–15,000 yr ago. The most widely accepted view today is that human groups first entered North America some 12,000–13,000 yr ago after the ice had begun to retreat at the end of the last glaciation. They most probably came across a land bridge from Asia (Beringia) rather than by a coastal (sea) route. On this model, if human remains very much older than about 12,000 yr before the present (BP) were to be found in the Americas, it would suggest that entry had occurred during the previous interglacial, some 70,000–100,000 yr BP; there is no fossil or lithic (artefact) evidence in support of this. In other words, the first people probably arrived in the Holocene (postglacial) rather than during the Pleistocene. Conventional radiocarbon dating over the past 25 years has contributed support for this time scale for the appearance of humans in North America and for their subsequent very rapid spread southwards.

Racemization dates of up to 50,000 or even 70,000 yr BP, obtained by Bada and his colleagues at the Scripps Institution in the mid-1970s for amino acids extracted from human skeletal remains from California (notably those from Del Mar and Sunnyvale), were therefore in immediate conflict with accepted views of the antiquity of the human population of North America deduced from radiocarbon evidence. On the other hand, although these dates seemed incredible they could not be lightly dismissed. The measurements were carefully made, apparently independently 'calibrated' by a radiocarbon date of 17,000 yr (UCLA-1233A) for a human skull from Laguna Beach, California (itself an unexpectedly early date), and, above all, were direct analyses of the skeletal remains themselves.

The opportunity to test the validity of these results comes with the successful development over the past seven years of the AMS technique of radiocarbon dating (Hedges, R.E.M. & Gowlett, J.A.J. *Nature* **308**, 403; 1984) which requires only a few milligrams of sample, in contrast to conventional radiocarbon techniques, where gram quantities are needed. In their current work, Bada *et al.* have used the AMS technique to date aliquots of the original amino acid extracts used to obtain the racemization dates. Their new results (which are well-supported by some conventional ^{14}C measurements of related acid-insoluble extracts) clearly show that all the remains, including the Laguna skull, are of Holocene age. This agrees with the date reported by Stafford *et al.* (*Nature* **308**, 446; 1984), of less than 4,000 yr BP obtained using AMS for a human burial from Yuha, California, that had previously been assigned a racemization age of some 24,000 yr. Using these new results, the cranium of Los Angeles Man, previously dated by the conventional radiocarbon technique to greater than 23,600 yr BP (UCLA-1430; Berger, R. *World Archeol.* 7, 174; 1975), is most probably also of Holocene age. These new results remove a puzzling anomaly that was in conflict not only with a model built very carefully over a long period from many independent (archaeological, geological, environmental and climatic) lines of evidence, but also with the observation that these human skeletal remains are essentially modern in appearance and show few if any of the traits that might be expected in the representatives of earlier populations. □

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