v_s, compared with c, the velocity of light. The spatial soliton has velocity less than c and can be Lorentz-transformed to a coordinate frame in which it is solely a function of position and is typically determined by initial-value conditions. The temporal soliton is faster than c and can be transformed to a frame where it is solely a function of time and is typically specified by boundary conditions. McKinstrie and Dubois call triple solitons types A, B and C, depending on the soliton velocity, v_s, relative to the group velocities of the two laser beams, v_1 and v_2, and the plasma wave, v_3. They recommend a type B ($c > v_1 > v_2 > v_s > v_3$) spatial soliton for beat-wave acceleration. On the other hand, we (Mima, K. *et al. Phys. Rev. Lett.* **57**, 1421; 1986) have previously suggested a triple soliton for beat-wave acceleration but specified type A ($v_s > v_1 > v_2 > v_3$) with v_s matched to c.

For the particles not to outrun the soliton before significant acceleration occurs, v_s has to be close to c. McKinstrie and Dubois also imply that the temporal soliton ($v_s > c$) is not physically relevant because it carries no information: the only usable solitons for acceleration are types A and B spatial solitons. They further infer that because the type A spatial soliton runs into a stiff condition $c > v_1 > v_2 > v_s > v_3$ and $c - v_3 << c$, the soliton becomes very short and the envelope approximation may break down. This is why they prefer the type B spatial soliton.

There are several points worth discussing about this choice. The first is the physical realizability of solitons faster than the speed of light; the second is the relative merits of type A and B solitons; and the third is the stability of solitons. A triple soliton propagates with speed v_s that transforms transverse electromagnetic energy into the longitudinal electrostatic wave and back again to the transverse state without transmitting energy at that speed. It propagates by using the energy invested ahead of it. Therefore, surprisingly, a soliton with $v_s \geqslant c$ does not violate the special theory of relativity. A similar situation arises in a series of linear-accelerator klystrons that are charged up and then fired in sequence so that the propagating electromagnetic wave has any desired phase velocity. Temporal or spatial solitons can be made by choosing appropriate boundary or initial conditions.

According to the theory of nonlinear wave interaction, if the parent wave has a higher frequency ω_1 than the daughter waves ω_2 and ω_3, energy exchange from parent to daughter can be complete (the decay-instability), whereas if ω_1 is less than ω_2 and ω_3 only a partial exchange of energy from parent to daughters takes place (simple frequency mixing). Now because in type A, ω_1 is the parent ($\omega_1 > \omega_2 > \omega_3$), and in type B, ω_2 is the parent, the energy-exchange process should be more spontaneous in type A.

An exciting new avenue is opening up in accelerator physics as a result of this work. Plasmas are often too unstable to sustain a stable structure with intense fields. But potentially much more efficient and coherent particle acceleration may be achieved if the self-binding properties of triple solitons and their self-induced transparency can be exploited; two laser beams and a plasma wave, appropriately tailored, can reinforce each other. Such investigation may have applications in optical fibre soliton research in telecommunications, where the idea is to send a pulse of photons without disintegration over long distances. The new phenomenon of nonlinear accelerating structures could be used for accelerators in the ionosphere; this self-binding structure may propagate stably and efficiently in the ionosphere plasma, where external control is difficult. □

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Animal behaviour

Leatherback turtle off scale

N. Mrosovsky

MURMERS of surprise at a recent meeting* greeted the announcement by Scott Eckert (University of Georgia) that a leatherback sea turtle had dived to a depth of 1,200 m. In fact the recording device, a combination of a tiny light on a pressure-sensitive arm and a rotating film, had been pushed off the scale. Calibration allowed the 1,000 m mark to be specified accurately and by extrapolating from the relationship between depth and duration of other dives, Eckert and his colleagues estimated that the turtle had dived to a depth of 1,200 m. This is deeper than the 1,140 m for a sperm whale and is probably a record

for an air-breathing vertebrate[1]. The same turtle went deeper than 1,000 m on two occasions. In earlier studies Eckert *et al.* had found[1] maximum depths of 475 m. The same pressure-sensitive apparatus, used successfully by G.L. Kooyman (Scripps Inst. of Oceanography) on various animals besides turtles, will now require modification for leatherbacks.

The leatherback turtle, *Dermochelys coriacea*, is a remarkable reptile in other ways. It is the largest living turtle, with maximum weight exceeding 600 kg, and is also the most widely distributed reptile in the world. In the summer it routinely penetrates temperate or cooler waters. It has been reported from Newfoundland to Argentina, from Norway to South Africa, from Russia to Tasmania, and is not benumbed but active in such waters. Measurements on an animal captured off Nova Scotia show[2] that leatherbacks are capable of maintaining a body temperature of at least 18°C above an ambient level of 7.5°C. It remains to be determined whether they are warm blooded mainly on account of their size and thermal inertia, or whether they actively regulate their temperature, as suggested by the existence of countercurrent heat exchangers at the junction of flippers and body[3].

This thermal physiology is expressed both in the migration of the turtle from the tropics to far northern or southern latitudes and in its deep dives off its nesting beaches. At a depth of 500 m off the Virgin Islands, where Eckert *et al.*[1] did their work, the temperature is 12–15°C, not so very different from the surface temperature in the summer in the northern parts of its range. The reason for the leatherback's excursions, be they far or deep, may also be similar — to feed. This huge animal subsists largely on jellyfish, which are patchily and unpredictably distributed. Whether the leatherback is also feeding when it dives remains to be discovered.

Medusivory raises another question about this already remarkable animal: how does it withstand the toxins it ingests? But the leatherback's feeding habits are not without problems; they frequently mistake floating plastic bags for jellyfish. Sometimes the gut becomes blocked and the turtle dies in an emaciated condition. Elsewhere I have estimated[4] from data on stomach contents that today 44 per cent of adult leatherbacks have some plastic in their guts. A reptile that can keep itself warm in cold water, travel for thousands of kilometres, dive to more than a thousand metres and gulp down a Portuguese man-of-war, does not necessarily survive eating an inert plastic bag. □

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