letters

Solitons, numerical experiments, and that mysterious lady

The interesting article by Thierry Dauxois on "Fermi, Pasta, Ulam, and a Mysterious Lady" (PHYSICS TODAY, January 2008, page 55) relates the subject of solitons to that of the Fermi-Pasta-Ulam (FPU) problem. The term "soliton" was introduced by Norman Zabusky and Martin Kruskal[1] in 1965 because the nonlinear waves studied did not lose their identity after colliding. In a sense, they resembled particles. The study by Zabusky and Kruskal was a numerical one of the Korteweg–de Vries equation, but the motivation was to study the propagation of waves in a collisionless plasma containing a magnetic field. Fifty years ago John Adlam and I studied that problem[2] and found an analytical solution for strong, collision-free hydromagnetic solitary waves for Alfvén Mach numbers less than 2. The solution was not valid for faster, stronger waves. Further work in 1960 dealt with the excitation of a train of such waves;[3] that time the equations were solved numerically. The work with Adlam seems to have been largely overlooked until recently,[4] presumably because it predated the term "soliton."

References

1. N. J. Zabusky, M. D. Kruskal, *Phys. Rev. Lett.* **15**, 240 (1965).
2. J. H. Adlam, J. E. Allen, *Philos. Mag.* **3**, 448 (1958).
3. J. H. Adlam, J. E. Allen, *Proc. Phys. Soc.* **75**, 640 (1960).
4. F. Verheest, T. Cattaert, *Phys. Plasmas* **12**, 032304 (2005).

J. E. Allen
(john.allen@eng.ox.ac.uk)
University College, Oxford
Oxford, UK

Rediscovering Mary Tsingou's role in the Fermi-Pasta-Ulam problem is laudable. However, Thierry Dauxois is incorrect in calling the FPU problem "the first-ever numerical experiment" that marked the beginning of "computer simulations of scientific problems."

Lewis F. Richardson's landmark 1922 work on numerical weather prediction predated the FPU problem by more than three decades and far surpasses it in complexity.[1] The first successful numerical weather forecast was performed on the ENIAC computer in 1950 by a team of scientists that included John von Neumann.[2] Both of those numerical experiments were highly nonlinear in character and involved approximations of the Navier–Stokes equation. Dauxois's oversight confirms the statement that "meteorologists . . . are the Rodney Dangerfields of science. They get no respect from . . . physics and chemistry."[3]

References

1. L. F. Richardson, *Weather Prediction by Numerical Process*, Cambridge U. Press, Cambridge, UK (1922).
2. J. G. Charney, R. Fjörtoft, J. von Neumann, *Tellus* **2**, 237 (1950).
3. J. Fishman, R. Kalish, *The Weather Revolution: Innovations and Imminent Breakthroughs in Accurate Forecasting*, Plenum Press, New York (1994), p. 29.

John Knox
(johnknox@uga.edu)
University of Georgia
Athens

Dauxois replies: I did not attempt to present a complete history of the soliton concept, so all possibly relevant papers were not cited. However, I think the paper by Norman Zabusky and Martin Kruskal (J. E. Allen's reference 1) ought to be emphasized for several reasons. First, it dealt directly with the understanding of the puzzling observation made by Enrico Fermi, John Pasta, Stanislaw Ulam, and Mary Tsingou. Second, it highlighted the soliton, a concept of general interest[1] that goes beyond the observation of "collision free" wave interactions. Third, the suffix "-on" in the name emphasizes that those waves have properties of particles.

I know that using a computer to solve an equation was done before FPU-Tsingou. (Working in physical oceanography and having a wife in fluid mechanics, I do respect meteorologists!) Solving equations, with or without approximations, is different from conducting a numerical experiment, which asks the computer a physical question. One studies a system simpler than the real one in order to use the computer to test theories that could not have been tested with real experiments, affected as they are by uncontrollable effects and noise (see the epistemological paper in reference 2). I am not aware of any previous use of computers in that way, nor, apparently, was Ulam.[3]

References

1. T. Dauxois, M. Peyrard, *Physics of Solitons*, Cambridge U. Press, New York (2006).
2. R. Livi, S. Ruffo, M. Pettini, A. Vulpiani, *Giornale de Fisica* **26**(4), 285 (1985).
3. S. M. Ulam, *Adventures of a Mathematician*, Scribner, New York (1976).

Thierry Dauxois
(thierry.dauxois@ens-lyon.fr)
CNRS
Lyon, France

Water in trees

The Quick Study by Missy Holbrook and Maciej Zwieniecki (PHYSICS TODAY, January 2008, page 76), on the physics of transporting water to the tops of trees, invites an immediate agricultural query: Since, as the article describes, the extreme amounts of water that plants require are due to the low concentration of carbon dioxide in the atmosphere, why have we not developed enclosed growing systems with dramatically higher CO_2 concentrations?

For example, capturing coal-plant CO_2 effluent for use in adjacent growth enclosures—which requires almost no net energy consumption—would simultaneously reduce emissions and water consumption and provide abundant supplies of CO_2 for crops. Of course, that might require genetic reconfiguration of plants that have adapted to the low current CO_2 concentrations, but unlike other genetic modifications, those plants could pose no threat other than economic to normal crops, since they would not be viable in the outside world.

Furthermore, one can imagine enhanced growth rates, since the plants would need to expend considerably less of their vital resources on water transport.

Coal plant emissions and water supplies are matters of the utmost concern. In the American Southwest, for example, some 90% of water consumption goes to agriculture. Unfortunately, there seems to be no forum in which the necessary synergy might develop among energy companies, agribusinesses, and environmentalists.

Terry Goldman
(tgoldman@lanl.gov)
Los Alamos, New Mexico

I find PHYSICS TODAY a good source of information on physics in general. The Quick Study is usually interesting reading. However, the January 2008 Quick Study was an exception.

Granted, the topic of water transport to the tops of trees is a controversial one and the authors' description of the phenomenon, "life in a metastable state," pays little attention to the physical constraint of cavitation under high tension. The only reference given was from 1981, but new tools and techniques—for example, nuclear magnetic resonance imaging and pressure-probing techniques—have brought new insights on the topic in the past 27 years.

In a case like this, a warning to readers that scientists hold several different views on the topic and some reference to other perspectives would be welcome. In a more recent publication, Ulrich Zimmermann and coworkers provide access to more than 300 references on the subject.[1] They also give a well-documented description of a complex, multiforce, multistage, segmented xylem perspective on water ascent in trees.

I hope PHYSICS TODAY readers will eventually get a broader description than the "realm where water is transported in a metastable state," as the Quick Study authors call it.

Reference

1. U. Zimmermann, H. Schneider, L. H. Wegner, A. Haase, *New Phytol.* **162**, 575 (2004).

Jean Roy
(jeanroy_igp@videotron.ca)
Outremont, Quebec, Canada

Holbrook and Zwieniecki reply: Terry Goldman is correct in suggesting that providing plants with higher carbon dioxide concentrations can result in both water conservation and enhanced photosynthesis. Indeed, CO_2 fertilization is already used by many commercial growers. However, enclosed growing systems have huge energy costs associated with cooling and are thus unsuited for large-scale agricultural production.

On the planetary scale, we are currently conducting such an experiment, albeit in an uncontrolled fashion. Increased atmospheric CO_2 due to human activities such as fossil-fuel combustion and land clearing is estimated to have increased terrestrial photosynthetic output. However, at the same time, rising temperatures due to higher greenhouse gas concentrations increase the water demands placed on plants and are predicted to alter the frequency and intensity of precipitation events. Thus, although elevated CO_2 can improve the efficiency of photosynthesis, there appears to be no free lunch.

Jean Roy's letter suggests that our Quick Study on water transport in trees should "teach the controversy," so to speak. However, there is no scientific controversy regarding the cohesion-tension theory of water transport in plants. In the early 1990s, there was a short-term challenge to the theory due to discrepancies observed by Ulrich Zimmermann using a pressure probe. Subsequent refinements of that measurement technique by Zimmermann and others eliminated those concerns.[1] Since then no xylem water transport data have been found to be inconsistent with the cohesion-tension theory. Nor has any alternative mechanism been proposed that can explain the transport of water in plants. Publication of the reference Roy cites prompted 45 prominent plant biologists to protest.[2] The editor's response was that the paper by Zimmermann and coauthors should be perceived as representing the "views and opinions" of the authors and not as a review of the current state of knowledge appropriate for newcomers to the field.[3]

Finally, we stand by our citation of W. F. Pickard's 1981 work as an outstanding treatment of water transport in plants. That paper is particularly appropriate for the readers of PHYSICS TODAY because it assumes high literacy in the physical sciences rather than detailed knowledge of plant anatomy.

References

1. P. J. Melcher, F. C. Meinzer, D. E. Yount, G. Goldstein, U. Zimmermann, *J. Exp. Bot.* **49**, 1757 (1998).
2. G. Angeles et al., *New Phytol.* **163**, 451 (2004).
3. I. Woodward, *New Phytol.* **163**, 453 (2004).

N. Michele Holbrook
(holbrook@oeb.harvard.edu)
Maciej Zwieniecki
(mzwienie@oeb.harvard.edu)
Harvard University
Cambridge, Massachusetts

More light on the structure of nuclei

We agree with David Dean (PHYSICS TODAY, November 2007, page 48) that computational advances in solving many-body problems have led to important progress in understanding the structure of nuclei. However, we need to examine two of the five questions highlighted by the author, namely, the nature of the nuclear forces (beyond the well-understood long-range pion exchange) that bind nucleons in nuclei and the structure of neutron stars and dense cold nuclear matter. The answers to those two cannot be obtained within the mean-field approximation without probing the high-momentum component of the nuclear wavefunction. In the mean-field approximation and in the effective field theory approach, that component is hidden in the parameters of the effective interaction. At the same time, according to the most realistic calculations (see reference 1 and references therein), approximately 60% of the kinetic energy of nucleons in medium to heavy nuclei is due to the high-momentum component of the nuclear wavefunction.

In this respect we would like to mention recent significant progress in the investigation of the high-momentum nucleon–nucleon short-range correlations (SRC) that for years remained an elusive feature of the nuclei. The progress was made through the use of high-energy electrons at the Thomas Jefferson National Accelerator Facility and high-energy protons at Brookhaven National Laboratory.[2] Analyses of those data demonstrate that nucleons with momenta exceeding the Fermi momentum are present in medium and heavy nuclei with a probability of approximately 20–25%. The shape of the momentum distributions of the SRC does not depend on atomic number. Experiments also established that large nucleon momenta are balanced predominantly by one nearby nucleon with strong preference (by a factor of nine) for a proton momentum to be bal-