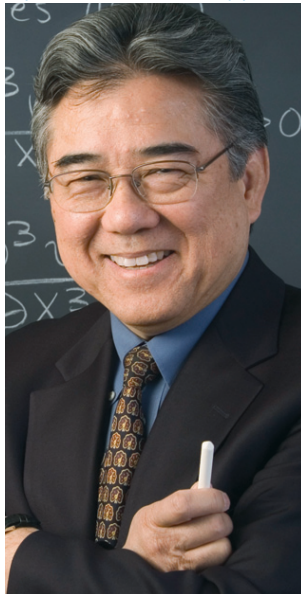


# Pursuing Solitons

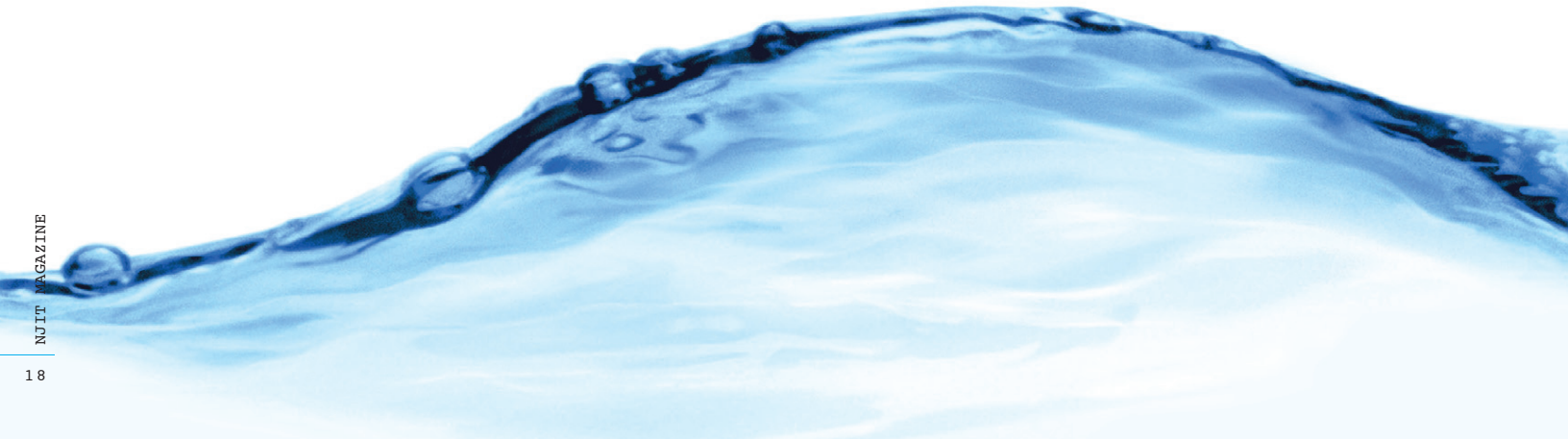
IT ALL BEGAN BY CHANCE ON AN AUGUST DAY IN 1834, NEAR EDINBURGH, SCOTLAND. THAT'S WHEN A KEENLY OBSERVANT ENGINEER, JOHN SCOTT RUSSELL, SAW A SINGLE UNUSUAL WAVE RISE ON THE SURFACE OF THE UNION CANAL AS A BARGE CAME TO A SUD-DEN STOP. RUSSELL PURSUED THE WAVE ON HORSEBACK FOR A MILE OR TWO UNTIL HE "LOST IT IN THE WINDINGS OF THE CHANNEL."



Professor Robert M. Miura

The first to view this phenomenon with the eye of a scientist, Russell called it the “wave of translation.” Now widely referred to as a “soliton,” it’s a wave that has since rippled strongly through time, stirring the imaginations of researchers whose related discoveries are of great importance in fields as diverse as fiber-optic communications and the human genome. One of these researchers is Robert M. Miura, professor of mathematical sciences and biomedical engineering at NJIT. In 2006, Miura shared the prestigious Leroy P. Steele Prize for Seminal Contribution to Research awarded by the American Mathematical Society, an honor closely linked to Russell’s very significant wave.

Miura, who is also acting chair of the Department of Mathematical Sciences, has clearly met the Steele criteria of producing a paper reporting work of “fundamental or lasting importance in its field, or a model of important research.” The paper accorded this recognition is titled “Korteweg-de Vries Equation and Generalizations:



VI. Methods for Exact Solution.” Published in 1974, it was co-authored with Clifford S. Gardner and Martin D. Kruskal, both mathematicians, and John M. Greene, a nuclear physicist.

#### From Scotland to KdV

To appreciate the significance of the contribution made by Miura and his colleagues in the 20th century, it’s necessary to once again look back in history. Russell, who distinguished himself as an engineer during a long career, spent quite a bit of time pondering the wave that he noticed in 1834. He even built a tank 30 feet long in his garden in an attempt to duplicate such waves, believing they might be of fundamental significance in studying a wide range of physical phenomena. After he published on the topic, Russell also sparked considerable controversy. Some scientists of the day said that solitary waves with the characteristics Russell ascribed to them couldn’t possibly exist.

But two mathematicians working at the end of the 19th century did not share this bias. In 1895, Diederik Johannes Korteweg and Gustav de Vries took a key step toward the mathematical understanding of Russell’s wave by formulating what came to be known as the Korteweg-de Vries equation, or the KdV equation for short. They showed how self-reinforcing solitary waves can arise from partial differential equations describing shallow-water motion.

NJIT’s Miura first encountered the KdV equation as a research challenge in the mid-1960s at the Princeton Plasma Physics Laboratory, where he was a postdoctoral associate investigating the complexities of nonlinear wave propagation. In addition to MA and PhD degrees in aerospace and mechanical sciences from Princeton,

Miura had earned a BS and MS in mechanical engineering from the University of California at Berkeley. Raised in rural central California, the course of Miura’s life includes elementary education in a two-room schoolhouse and an encounter with a high-school teacher who recognized his talent and encouraged him to work towards a career in engineering. Miura would have another very important chance encounter at the plasma physics lab in Princeton, this time with Gardner, Greene and Kruskal.

#### Time to study solitons

“Every day came with the time to think deeply about new ideas,” Miura says of his Princeton postdoctoral experience. Some of this time was dedicated to building on Kruskal’s earlier work with the physicist Norman Zabusky. They had applied the power of computers, then becoming available, to gain more insight into the wave phenomena at the heart of the KdV equation. Discerning that the waves in their approximate solutions of the KdV equation also had the behavioral qualities of particles, Kruskal and Zabusky coined the term soliton for this type of wave.

Shortly thereafter, Miura and his colleagues took the study of solitons to a new and remarkable plateau of understanding. They showed how it is possible to derive exact solutions of the nonlinear KdV equation by applying inverse scattering theory from quantum mechanics — principles governing the interaction among waves or particles as understood by the middle of the 20th century. Over the years leading up to the

Steele prize in 2006, their work has been the basis of theoretical and practical progress in many areas. This progress includes insights relevant to the transport of data in fiber-optic cables, the formation of tornadoes and oceanic waves (possibly tsunamis), high-speed optical computing, plasma physics, and magnetohydrodynamics. Some researchers even postulate a link between solitons and the Great Red Spot on Jupiter.

### Thinking East

By the time the paper that won Miura the Steele prize was published, he had moved further along in a career that has included teaching and research at New York University and at Vanderbilt University. In 1975, he began a 26-year association with the University of British Columbia, where he explored problems in neurophysiology. Through synergistic interaction with investigators in physiology and pharmacology, he came to focus on how mathematics can serve as an essential tool for research in the biological sciences, with his specialty

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being quantitative neuroscience. Miura's achievements in the field have earned him wide recognition. A Fellow of the John Simon Guggenheim Foundation and the Royal Society of Canada, he was named a Fellow of the American Association for the Advancement of Science in 2005, one of only five mathematicians so honored that year.

A member of the NJIT faculty since 2001, Miura's journey back to the United States began with a letter from Professor Daljit Singh Ahluwalia, then chair of the university's Department of Mathematical Sciences and presently acting dean of the College of Computing Sciences. Ahluwalia had contacted Miura as an academic colleague in mathematics to solicit his thoughts on a professional matter. Since he had already been thinking about teaching once again in the U.S., Miura added a postscript to his response, asking Ahluwalia to let him know when he heard of any suitable openings on the West Coast. Ahluwalia answered with a succinct "Think East."

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One measure of this prominence is the substantial funding that members of the department continue to receive from sources such as the National Science Foundation, the National Institutes of Health and the National Aeronautics and Space Administration.

Especially notable among recent awards is the million-dollar grant from the Howard Hughes Medical Institute given to NJIT, Rutgers-Newark, and the University of Medicine and Dentistry of New Jersey (UMDNJ) for an innovative graduate program in quantitative neuroscience. The grant to the three schools will support their vision of an interdisciplinary doctoral program that will prepare neuroscientists to work on research frontiers where, increasingly, success requires integrating the biomedical, physical and computational sciences. The program will be co-directed by Miura along with Joshua Berlin of UMDNJ-New Jersey Medical School and James Tepper of Rutgers.

Only ten schools out of the 132 that applied received one of these grants to promote interdisciplinary graduate studies. Miura notes that NJIT is in good educational company in this group, with some of the other institutions being Brandeis, Carnegie Mellon, Johns Hopkins, the University of California, the University of Chicago, and the University of Pennsylvania.

"The Howard Hughes grant is indicative of the maturity of our program in mathematical biology and how highly regarded that program is across the country," Miura says. "But it's also exciting that we have equally promising programs in areas like fluid dynamics, with younger faculty members just starting out on what I am sure will be outstanding careers as educators and researchers." In fluid dynamics, as in many other fields, the understanding of solitons and the KdV equation that Miura and his colleagues helped to advance will undoubtedly be of lasting importance. ■

**Department of Mathematical Sciences:** <http://math.njit.edu>

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