The scientific community lost a deeply original individual with the passing of Steven Alan Orszag on May 1, 2011. He had a profound influence in fluid mechanics where he tackled challenging problems in turbulent flow using of mathematical and computational methods.

Steve was born in New York in 1943 and at 19 obtained his B.S. in Mathematics from MIT. He spent the academic year 1962-63 as a Henry Fellow at St John's in Cambridge University where he did Part III of the Mathematical Tripos (now a Masters degree program). Having obtained a strong mathematical foundation for the study of fluid flows he went to Princeton as a National Science Foundation graduate fellow where in three years he completed his PhD in the Department of Astrophysical Sciences, a summer of which he spent as a fellow in the Geophysical Fluid Dynamics Program in Woods Hole. Already as a graduate student his work was characterized by a combined approach of mathematical foundation and computational exposition to capture the reality of complex flow phenomena. Indeed, his mentors, Martin Kruskal, Lyman Spitzer and Bengt Strömgren, provided a blend of theory and observation into which Steve's numerical predictions ideally dovetailed. His earliest paper on the atmospheres of neutron stars used state of the art computing but the evident intransigence of astrophysical flows quickly led him to examine underlying fluid mechanisms governed by the Navier-Stokes equations. His thesis, "Theory of Turbulence", led to a series of papers with Kruskal and Robert Kraichnan over the next several years while a member of the Institute for Advanced Study and as a visitor at the National Center for Atmospheric Research.

His growing understanding of both the mathematical foundation and broad relevance of turbulent flow provided the rostrum for his research at MIT where he was an applied mathematics professor from 1967-84 and a Sloan Foundation Fellow. There he and Carl Bender conceived of lecture courses out of which their widely used text "Advanced Mathematical

Methods for Scientists and Engineers" emerged. It should be appreciated that in the UK the *style* of research in fluid mechanical phenomena at the time Steve returned from Cambridge was rather distinct from that in North America. In Oxbridge fluid mechanics was, and is still, part of the mathematics curriculum whereas in North America it resided in application subareas (astrophysics, engineering, geophysics and superfluids). Steve fused the mathematical approach with numerical methods.

Fluid flow is governed by nonlinear partial differential equations. Therefore, a foundation in ordinary and partial differential equations, solution methods, scaling and asymptotic methods provides the tools for quantitative description of the nonlocal nonlinear processes in fluids. The degree of nonlinearity is commonly measured by the Reynolds number. When it is large, the flow is strongly turbulent and displays an enormous range of scales. Capturing this numerically is a major challenge; not only does one need to store a great deal of information (scaling roughly as the nine-fourths power of the Reynolds number), but one needs very efficient algorithms with the highest possible precision. These impediments were central to progress in the field until Steve developed, in a series of papers beginning in 1969, the transform methods now called "spectral methods" which exploit Fourier decomposition (or a generalization thereof) and Fast Fourier transforms. Spectral methods provide the strongest evidence that the three-dimensional Navier-Stokes equations remain well-posed and hence free of singularities for all times, and make practicable many real world flow problems. Some forty years later the methods and codes Steve created are central to progress.

With this evolving global perspective and detailed knowledge of both mathematics and computation he returned to Princeton in both Engineering and Applied and Computational Mathematics and was the Director of the Princeton Supercomputing Center. There his interests broadened; embracing the renormalization group and testing it against simulations and multiple scales analysis, studying chaotic and unstable shear flows, studying concepts from the field of cellular-automata, boundary integral methods, the Rayleigh-Taylor instability and becoming actively involved in electromagnetic theory with an eye towards photolithography. Steve developed still widely used turbulence closures, such as the Eddy Damped Quasi-Normal Markovian approach, unplagued by primal pathologies such as negative energies. These were simultaneously sufficiently simple and versatile to allow many applications. Through all of this he stayed at the core of contemporary High Performance Computing.

He arrived at Yale in 1998, was the Percey F. Smith Professor of Mathematics and Directed the Applied Mathematics Program for four years. Early in his tenure at Yale he drove research with many colleagues in Lattice-Boltzmann models of both turbulent fluids and granular materials. Such approaches are based on the discrete Boltzmann equation of statistical mechanics and reduce the number of particles with which one must deal. Steve envisioned this approach as an ideal method to study complex fluid flows without the requirement of solving the full Navier-Stokes equations, the difficulties of which he knew as well as any applied mathematician. Indeed, the approach can be so powerful that many geometrically complex flows can be solved readily. Most recently Steve was involved in problems wherein the solidification of a two-component liquid (such as salt water) and the associated fluid flow adjacent to it must be solved simultaneously thereby coupling two nonlinear problems. The setting foremost on his mind was developing rigorous methods for ice growth in the polar oceans which underlies important issues in climate change.

Steve's contributions to this broad swath of fields have been widely recognized. In addition to what has been described above, he was awarded the American Institute of Aeronautics and Astronautics Fluids and Plasmadynamics Prize in 1986, he was a John Simon Guggenheim Fellow in 1989 and won the Otto Laporte Award of the American Physical Society in 1991 along with the G. I. Taylor Medal of the Society of Engineering Science in 1995. He was named a *Highly Cited Author* by the ISI Web of Knowledge.

Always keen on showcasing the power of computing Steve most recently began to teach calculus using computational pedagogy. He was a key intellectual framer for a company that uses lattice Boltzmann methods and very-large eddy turbulence models as the core technology. It is a rare mathematician who authors engineering turbulence models, and Steve's became a part of a design cycle used everywhere in industry.

Steve's constant contact with computers and methods for improving scientific computing were an active love affair. He recently built a GPU machine from the component parts for a PhD student. From mathematics to hardware Steven Orszag was a constantly evolving renaissance man who did not care where someone came from, but only what they brought to the discussion at hand. He cared immensely for his family, collaborators, students and friends.

With his passing, vast areas of the landscape of the thought will lose a brilliant and energetic thinker, a wise advisor and a cherished friend. He is survived by his wife of 47 years Reba, his son Michael Orszag; his son Jonathan Orszag and his wife Rica; his son Peter Orszag and his wife Bianna Golodryga; his grandchildren Leila and Joshua Orszag; and his sister Myrna Baron.

Carl Bender, *Washington University*
Hudong Chen, *Exa Corporation*
Uriel Frisch, *CNRS, Nice*
Alexander Smits, *Princeton University*
Katepalli Sreenivasan, *New York University*
Sauro Succi, *AC-CNR, Rome*
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