TRANSPORT METHODS AND APPLICATIONS

CONQUERING THE SEVEN-DIMENSIONAL MOUNTAIN

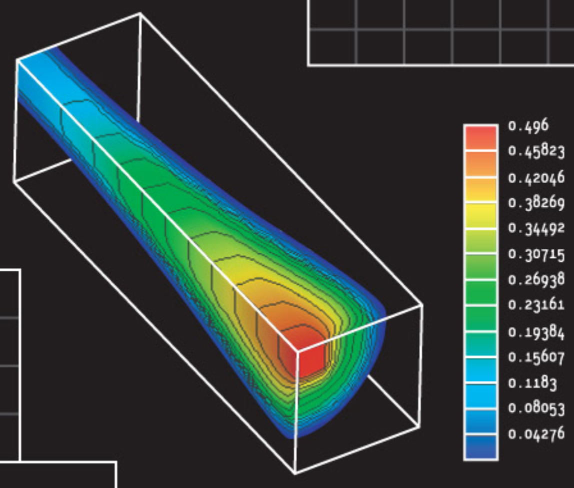
The Transport Methods Group develops computational tools that simulate the transport of radiation, including neutrons, photons, neutrinos, and charged particles. Examples of applications include studying the life cycles of stars, simulating nuclear reactors, and maximizing the treatment of tumors with radiation beams.

The complex (seven-dimensional) nature of the mathematical equation for modeling radiation transport problems requires that we use mathematical approximations, parallel supercomputers, and advanced algorithms to make the problems tractable. These problems would otherwise be difficult, if not impossible, to solve.

To reduce the complexity of the seven-dimensional calculation, we often use lower-dimensional approximations. The resulting simplified models are much less expensive to solve but less accurate. The group develops algorithms that can divide big problems into thousands of small problems so that radiation transport problems can be solved more efficiently with modern parallel computers.

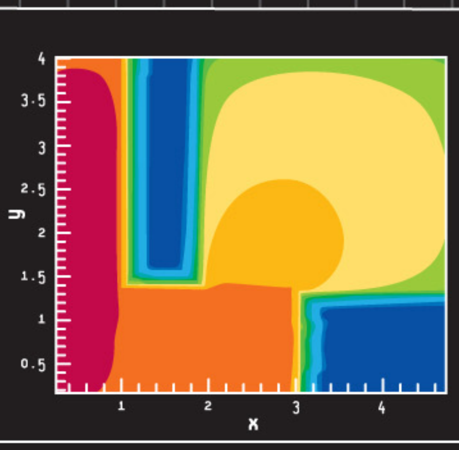
We solve the transport equation with deterministic methods (direct solution of discrete equations), stochastic methods (tracking individual particles), or a combination. Recent developments in these methods have reduced solution times dramatically.

We continue to develop new radiation transport methods and computer programs that provide more accurate solutions in less time.



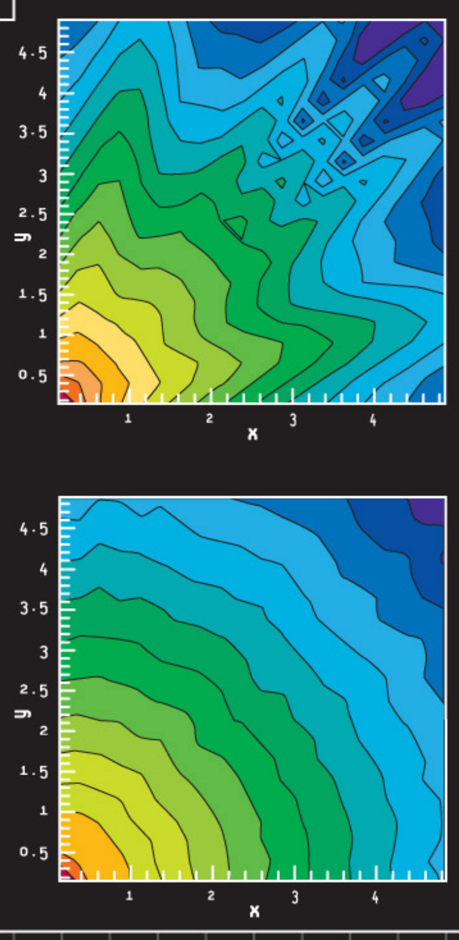
Reducing simulation complexity

A deterministic radiative transfer code uses energy independence and spherical harmonics approximations to simulate the transmission of a radiation beam down a pipe. The accuracy of the solution demonstrates our ability to model radiation flow using only four dimensions (three for space, one for time). This approximation dramatically reduces solution times when compared with the full seven-dimensional problem (three dimensions for position, two for direction, one for energy, and one for time).



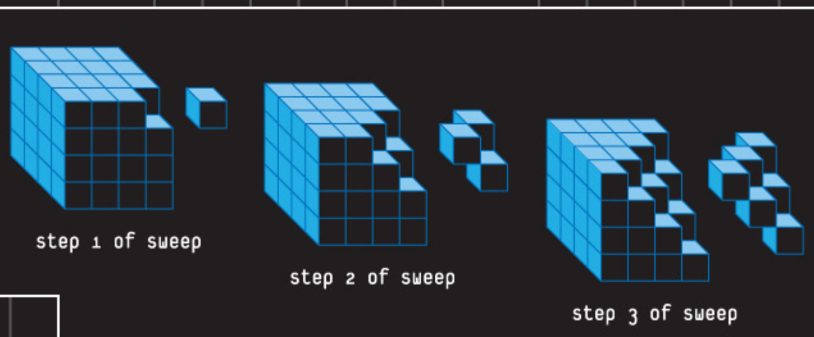
Using advanced algorithms

Diffusion synthetic acceleration (DSA) is a physics-based preconditioner that reduces computational effort by eliminating long-wavelength errors. In this neutron dose problem, DSA reduces the simulation solution time by a factor of 28 compared with standard Richardson iteration without acceleration.



Hybrid algorithms

Discrete-angle deterministic methods introduce nonphysical rays into the solution (top). We reduce this ray effect significantly by precomputing the uncollided portion of the solution with a stochastic method and then allowing the deterministic code to solve the remainder of the solution (bottom).

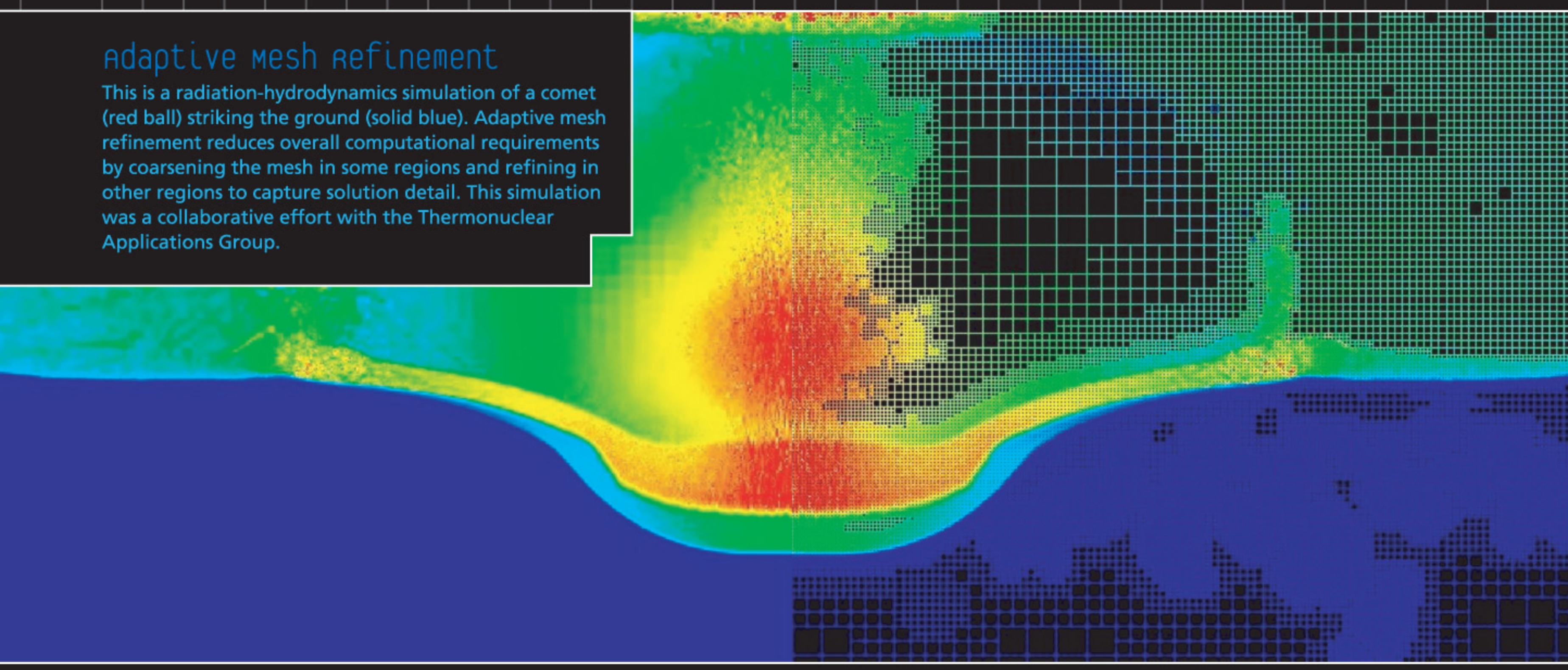


Algorithms for massively parallel supercomputers

The Los Alamos KBA (Koch, Baker, and Alcouffe) algorithm takes advantage of structured meshes to decompose the whole problem into nearly equal portions. Each small block in the diagonal plane represents a portion of the problem given to a processor. This "divide and conquer" algorithm makes efficient use of the capabilities of modern parallel supercomputers to reduce solution times.

Adaptive mesh refinement

This is a radiation-hydrodynamics simulation of a comet (red ball) striking the ground (solid blue). Adaptive mesh refinement reduces overall computational requirements by coarsening the mesh in some regions and refining in other regions to capture solution detail. This simulation was a collaborative effort with the Thermonuclear Applications Group.



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