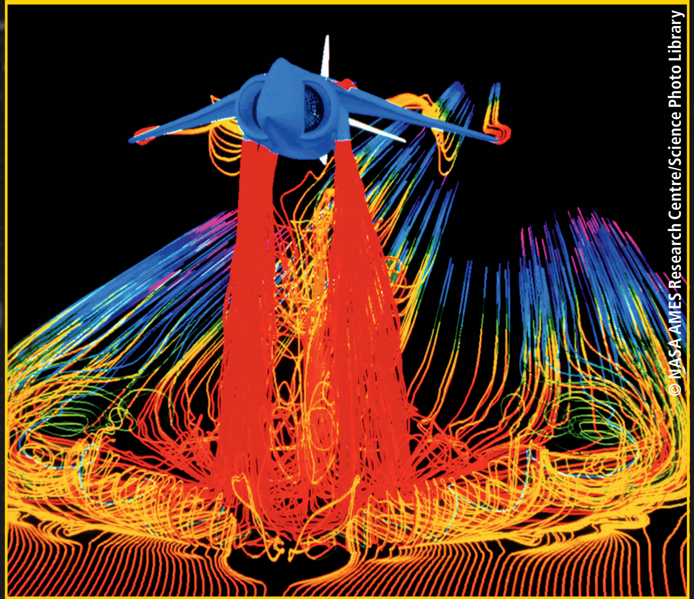
Supercomputer simulations

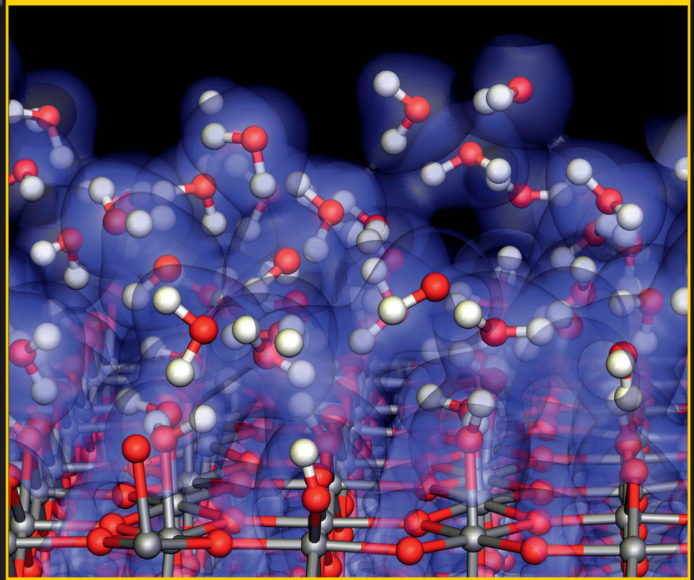
1 Supercomputer simulation of a Harrier jump jet hovering over a runway, showing the airflow from the aircraft's engines. The colours show the temperature of the air, from red (highest) to purple (lowest)



The equations that govern fluid dynamics are very complicated, non-linear, differential equations that are impossible to solve analytically for real-world problems, so computer simulations play an important role in understanding the behaviour of fluids (1).

Fuel cell technology produces electricity from hydrogen-rich fuels. An important aspect of the way in which fuel cells function is the transfer of protons through the cell. How this works at the molecular level is complex, and supercomputer simulations can provide valuable insights into the processes (2).

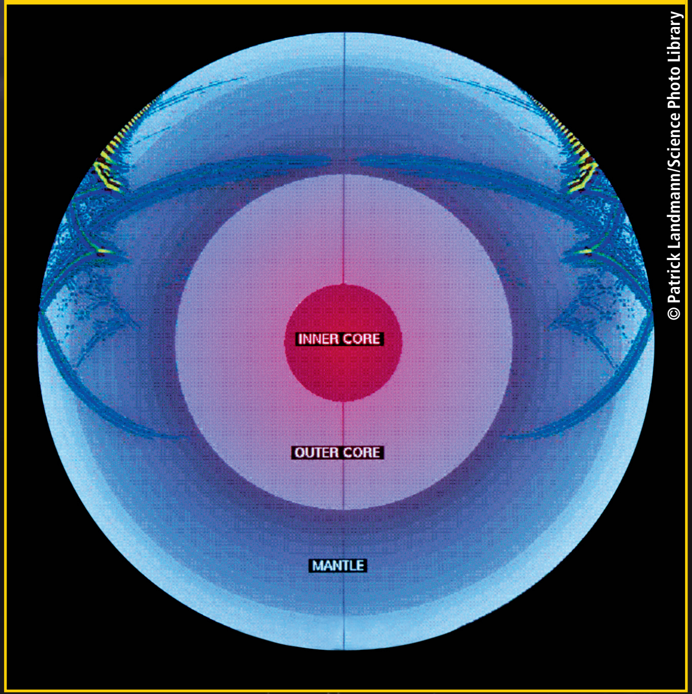
2 Simulation of the charge density (purple) of water, across the centre of the image, on a titanium dioxide surface, produced on the *Jaguar* supercomputer at Oak Ridge National Laboratory in the US. The model has successfully simulated proton transfer in solar cells and fuel cells



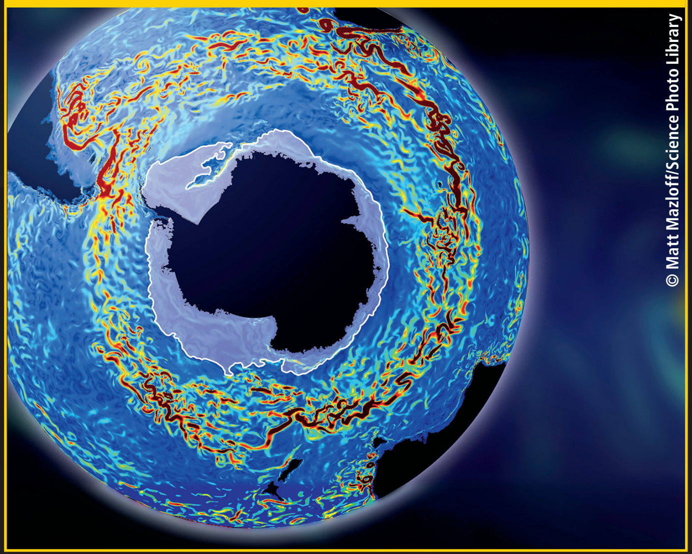
Seismic waves travel through Earth as the result of earthquakes, and analysing them tells us about the inner structure of our planet. We cannot see inside Earth, so computer models are important in understanding how seismic waves propagate through and around the planet (3).

Seismic waves are not the only things propagating around the Earth. Supercomputer simulations using data from satellites, floating drifters and radio-tagged marine animals can show simulations of ocean currents (4).

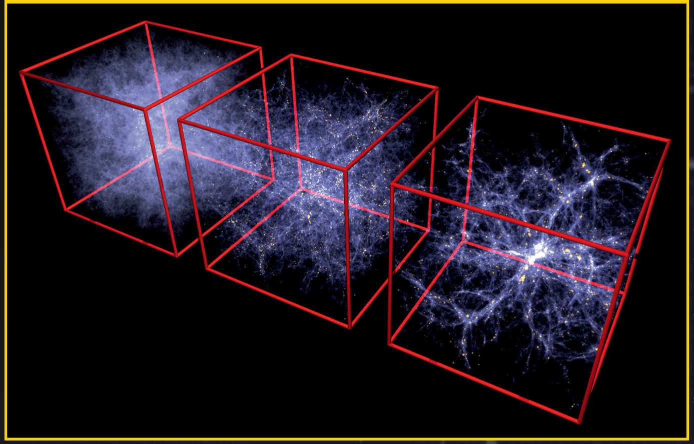
3 Simulation of the propagation of seismic waves through Earth during an earthquake. In strong earthquakes seismic waves can run several times around the planet before dying away



4 Computer model of the Antarctic circumpolar current in the Southern Ocean, the largest ocean current in the world, which travels clockwise around Antarctica



5 Supercomputer model of the formation of galaxies and clusters of galaxies from the contraction of a homogeneous cloud (left). Models such as this can help to estimate the amount of dark matter in the universe by seeing whether they produce results that look like the real universe



A new area of experimental physics is the detection and analysis of gravitational waves. These waves are a prediction of Einstein's general theory of relativity, involving another set of very complex non-linear differential equations that are impossible to solve analytically in most real situations. Supercomputer simulations can now be generated, for example modelling the merging of black holes, and compared with experimental data.

Understanding our universe over vast time and distance scales, and understanding its evolution, relies on simulations because we cannot easily make observations over billions of years. Simulation of galaxy formation, for example, relies on the presence of dark matter, whose gravitational attraction clumps matter together, leading eventually to the formation of stars and galaxies (5).

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