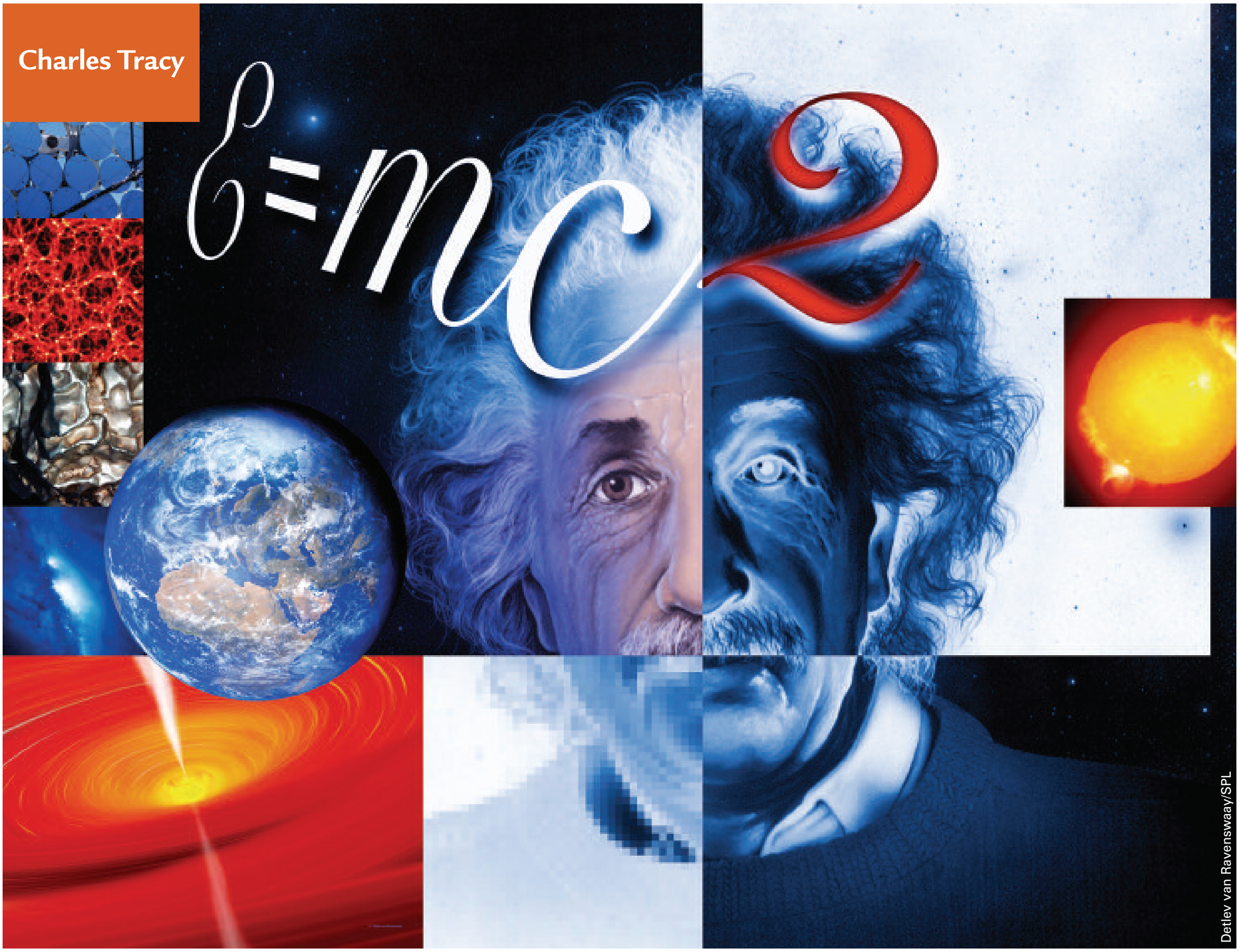
Charles Tracy



Detlev van Ravenswaay/SPL

Physics connections

Last year we celebrated the International Year of Physics — also known as Einstein Year. In the century since Einstein's annus mirabilis *(see* CATALYST *Vol. 16, No. 1) there has been a revolution in the study of physics. This article explores the links between some of the architects of this revolution.*

GCSE key words
Gravity
Alpha particle scattering
Nuclear fission

Einstein did not become instantly famous in 1905; it took several years before he became a global icon. In 1915, while Europe was caught up in the First World War, **Einstein** broadened his special theory of relativity. His **general theory of relativity** predicted the effects of gravity on space, time and light. In particular, it described how space becomes distorted near a massive object such as a star, so that light follows a curved path rather than travelling in a straight line (Figure 1).

Its publication in wartime and the fact that it was written in German meant that few people read it. However, one person who did read it was the British astronomer **Arthur Eddington**. The story goes that it was Eddington who brought Einstein to the world's attention — though Einstein might have disagreed.

Eddington was a conscientious objector. As such, he should have spent the war in jail. Instead, he got official permission to prepare for a trip to observe a total eclipse of the Sun — a rare event. His intention was to verify Einstein's general theory of relativity. Einstein felt that no such verification was needed, but

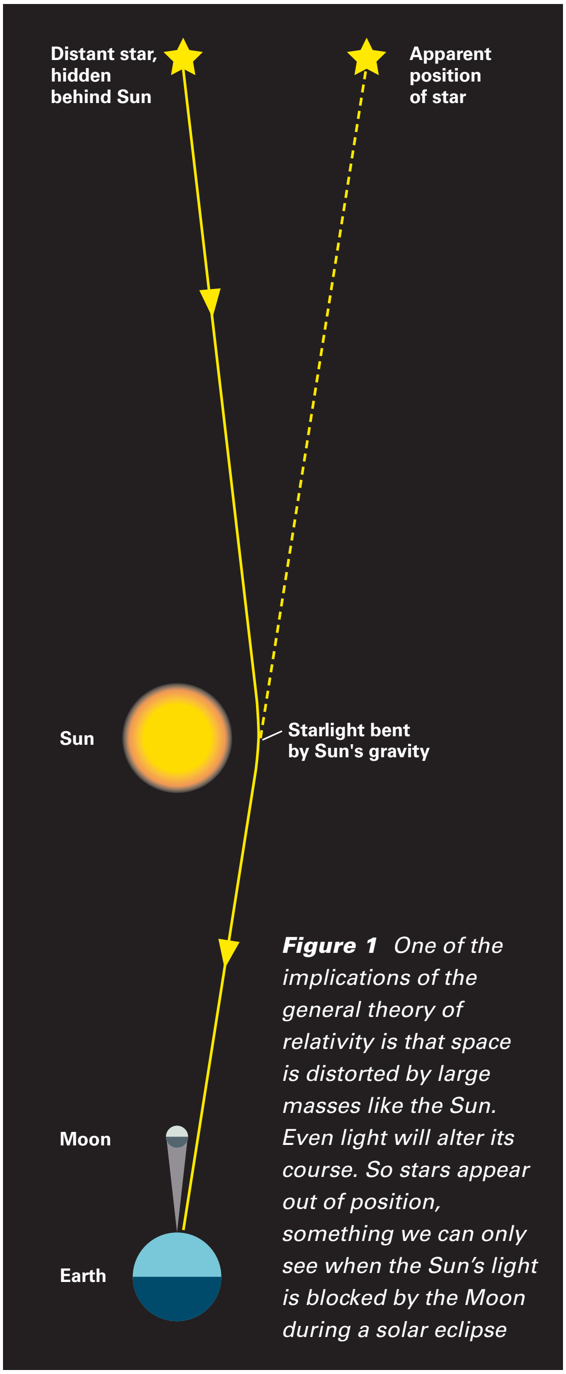


Figure 1 *One of the implications of the general theory of relativity is that space is distorted by large masses like the Sun. Even light will alter its course. So stars appear out of position, something we can only see when the Sun's light is blocked by the Moon during a solar eclipse*

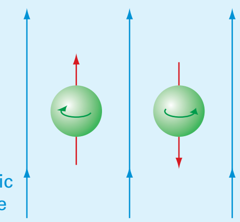
Eddington went ahead as planned in 1919. During the eclipse, Eddington measured the apparent shift in the positions of stars that were beyond the Sun, as their light rays were curved by its gravity. His results were in close agreement with Einstein's predictions.

The international press were captivated. One reporter suggested to Eddington that he was one of only three men who understood Einstein's theory. Eddington replied, possibly ironically: 'I am trying to think who the third person is.'

Predicting particles

That person could well have been **Satyendra Bose**, the Indian physicist who translated Einstein's paper on the general theory of relativity from German into English. In 1924, Bose devised a theory for photons

Figure 2 *An electron has spin. In a magnetic field, it can either spin clockwise (spin up) or anti-clockwise (spin down)*



and black body radiation. The theory came from a mistake he made in a lecture: while trying to show that theory could *not* predict the behaviour of photons, he accidentally showed that it *could*.

After some correspondence with Einstein, Bose developed a new type of statistics that described the behaviour of photons and similar particles. These particles, which have whole-number values (0, 1, 2 etc.) of a property called spin, are now known as **bosons** after Satyendra Bose.

Photons **are the particles which carry the energy of electromagnetic radiation. Einstein used the idea of photons to explain the photoelectric effect.**

Particles that are not bosons are called **fermions**. They have a spin of ½, 1 ½, 2 ½ and so on. This family of particles includes protons, neutrons and electrons (Figure 2), and takes its name from **Enrico Fermi**, the Italian American physicist who built the first **nuclear chain reactor** in a Chicago squash court in 1942. This was 4 years after he had escaped from the fascists at the time of his Nobel prize ceremony. After collecting his prize – for work on creating radioactive isotopes through neutron bombardment – Fermi slipped out of the Stockholm Institute and made good his escape.

In his *annus mirabilis*, Einstein published three papers. Their contents initiated modern cosmology and quantum mechanics – the foundations of modern physics.

Physics and facism

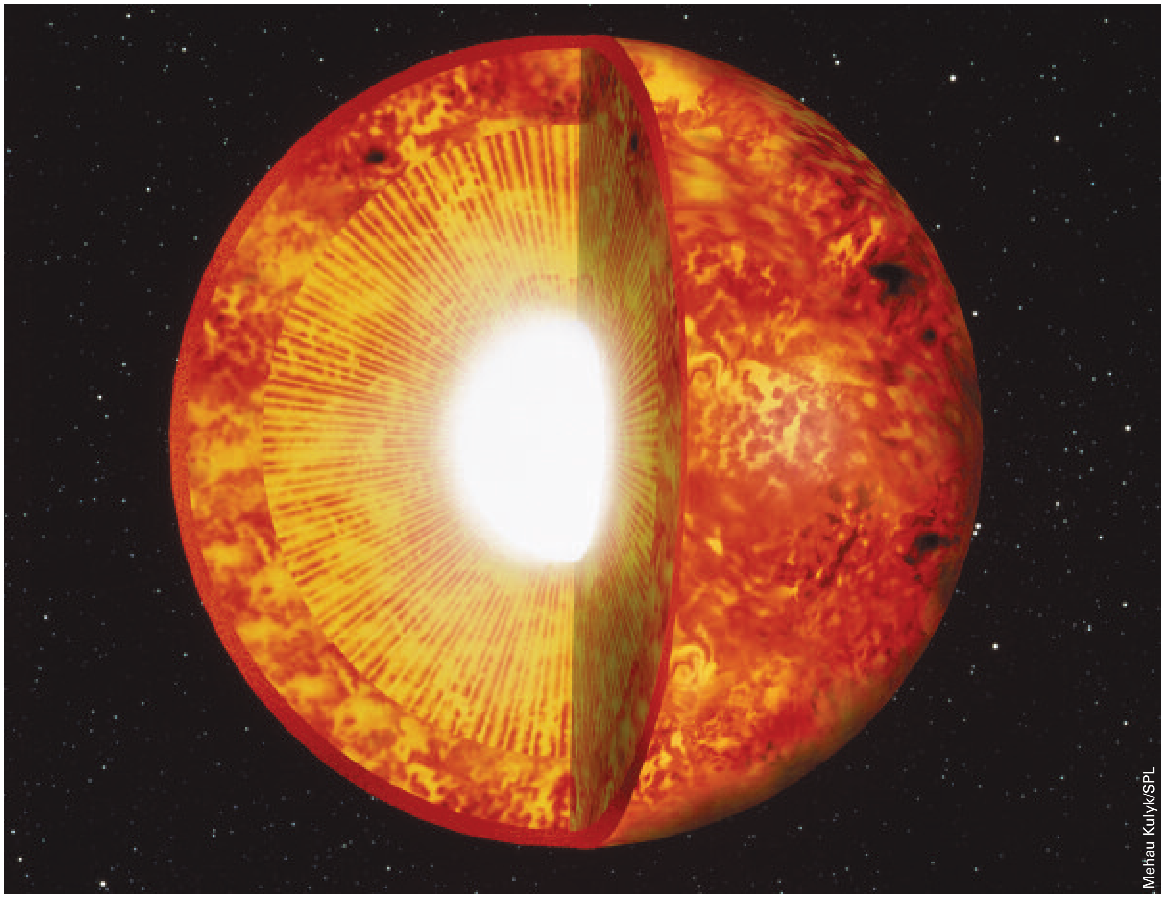
Another scientist who fled the fascists was **Niels Bohr**. Bohr stayed in his native Denmark for 3 years of the Nazi occupation. But, in 1942, he escaped via Sweden to England in the empty bomb rack of a British plane. He made his way to America and joined Fermi and others in the Manhattan Project, building America's **atomic bomb**.

Before he left, Bohr had had a secret meeting with his former pupil, the German physicist **Werner Heisenberg**. In the 1920s, Heisenberg had developed a mathematical method to describe the behaviour of atoms. This was one of the foundations of quantum mechanics, the basis of much of today's physics. Later, during the Second World War, he was a member of the **Uranium Club** – the German group trying to develop a fission weapon. In 1941, he travelled to Copenhagen to meet his old friend Bohr and they went for a stroll after dinner. Their discussion remains a mystery. Did Heisenberg pass information to Bohr, or did he try to enlist Bohr's help with the Uranium Club? We may never know for sure.

Classical mechanics, developed by Newton and others, is used to describe large-scale phenomena. It does not work on the scale of atoms – quantum mechanics must be used instead. It is the basis of semiconductors and therefore much of our technological world.

The Uranium Club also included the German physicist **Hans Geiger**. During the Second World War, Geiger was an enthusiastic Nazi. This was totally at odds with the vehemently anti-fascist views of his

Right: *Computer graphic of the interior of the Sun. Scientists now know that the Sun is a massive nuclear fusion reactor*



The Hot Big Bang theory, generally accepted by scientists today, says that the universe exploded into existence, emerging from a single point, about 14 billion years ago.

former tutor, **Ernest Rutherford**, for whom he had performed the famous alpha particle scattering experiments during 1908. In 1933, Rutherford had set up the Academic Assistance Club to help Jewish scholars escape the rising hatred in Germany.

Another of Rutherford's students, **James Chadwick**, could have used some help in the previous war. Chadwick left Manchester in 1914 to work with Geiger in Berlin. Unfortunately for him, the assassination of Archduke Ferdinand on 28 June 1914 led to the outbreak of the First World War. He was trapped in Germany and spent 4 years interned in the stables of a German racecourse. On his return home, he joined Rutherford at the Cavendish Laboratory in Cambridge where his work led to the discovery of the **neutron** in 1932.

The age of the Sun

The following year, the Russian physicist, **George Gamow**, escaped a different tyranny by defecting from Stalin's Soviet Union to America. Gamow worked on many things (including the genetic code), but is renowned for his description of the **Hot Big Bang**. The paper, which he wrote with his student **Ralph Alpher**, was published in 1948. When he heard that **Hans Bethe** was in town, Gamow could not resist a little radiation joke: he asked Bethe to add his name to the paper which became the Alpher, Bethe, Gamow (α,β,γ) paper.

Hans Bethe is best remembered for developing a theory that describes the nuclear processes inside the Sun. His theory explained, at last, how the Sun could stay so hot and have lasted so long — 4.5 billion years, long enough for life to evolve on Earth. Only 50 years earlier, **William Thomson** (**Lord Kelvin**) had estimated the age of the Sun as about 20 million years — 200 times too small.

Kelvin had described the Sun as an incandescent rock that had gained all its energy from ancient meteor impacts. Somewhat boldly, in 1900 he had stated that: 'There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.' Had Kelvin waited 5 years — for Einstein's influential papers — he might have been more cautious.

Physics, past and future

Hans Bethe died in 2005, the year in which we celebrated 100 years of astute, committed and often brave people who made the century of physics. Their stories are as much about human endeavour, strength and frailty as of laboratories and brassware. The physics they have developed would be unrecognisable to Kelvin. Physics is still changing. Who knows what will happen in the next 100 years?

Charles Tracy *is a schools adviser in Hertfordshire and develops physics teaching resources.*

- **Visit www.physics.org/evolution/evolution.asp for an animated history of physics.**