# 10 impossibilities conquered by science

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What is truly impossible? To accompany **Michio Kaku**'s article on the physics of impossibility, we have rounded up 10 things that were once thought scientifically impossible. Some were disproved centuries ago but others have only recently begun to enter the realm of possibility.

#### 1. Analysing stars

In his 1842 book *The Positive Philosophy*, the French philosopher Auguste Comte wrote of the stars: "We can never learn their internal constitution, nor, in regard to some of them, how heat is absorbed by their atmosphere." In a similar vein, he said of the planets: "We can never know anything of their chemical or mineralogical structure; and, much less, that of organized beings living on their surface."

Comte's argument was that the stars and planets are so far away as to be beyond the limits of everything but our our sense of sight and geometry. He reasoned that, while we could work out their distance, their motion and their mass, nothing more could realistically be discerned. There was certainly no way to chemically analyse them.

Ironically, the discovery that would prove Comte wrong had already been made. In the early 19th century, William Hyde Wollaston and Joseph von Fraunhofer independently discovered that the spectrum of the Sun contained a great many dark lines.

By 1859 these had been shown to be atomic absorption lines. Each chemical element present in the Sun could be identified by analysing this pattern of lines, making it possible to discover just what a star is made of.

#### 2. Meteorites come from space

Astronomers look away now. Throughout the Renaissance and the early development of modern science, astronomers refused to accept the existence of meteorites. The idea that stones could fall from space was regarded as superstitious and possibly heretical – surely God would not have created such an untidy universe?

The French Academy of Sciences famously stated that "rocks don't fall from the sky". Reports of fireballs and stones crashing to the ground were dismissed as hearsay and folklore, and the stones were sometimes explained away as "thunderstones" – the result of lightning strikes.

It was not until 1794 that Ernst Chladni, a physicist known mostly for his work on vibration and acoustics, published a book in which he argued that meteorites came from outer space.

Chladni's work was driven by a "fall of stones" in 1790 at Barbotan, France, witnessed by three hundred people.

Chladni's book, *On the Origin of the Pallas Iron and Others Similar to it, and on Some Associated Natural Phenomena*, earned him a great deal of ridicule at the time. He was only vindicated in 1803, when Jean-Baptiste Biot analysed another fall of stones at L'Aigle in France, and found conclusive evidence that they had fallen from the sky.

**3. Heavier-than-air flight**

The number of scientists and engineers who confidently stated that heavier-than-air flight was impossible in the run-up to the Wright brothers' flight is too large to count. Lord Kelvin is probably the best-known. In 1895 he stated that "heavier-than-air flying machines are impossible", only to be proved definitively wrong just eight years later.

Even when Kelvin made his infamous statement, scientists and engineers were closing rapidly on the goal of heavier-than-air flight. People had been flying in balloons since the late eighteenth century, and by the late 1800s these were controllable. Several designs, such as Félix du Temple's *Monoplane*, had also taken to the skies, if only briefly. So why the scepticism about heavier-than-air flight?

The problem was set out in 1716 by the scientist and theologian Emanuel Swedenborg in an article describing a design for a flying machine. Swedenborg wrote: "It seems easier to talk of such a machine than to put it into actuality, for it requires greater force and less weight than exists in a human body."

Swedenborg's design, like so many, was based on a flapping-wing mechanism. Two things had to happen before heavier-than-air flight became possible. First, flapping wings had to be ditched and replaced by a gliding mechanism. And secondly, engineers had to be able to call on a better power supply – the internal combustion engine. Ironically, Nicolaus Otto had already patented this in 1877.

**4. Space flight**

From atmospheric flight, to space flight. The idea that we might one day send any object into space, let alone put men into orbit, was long regarded as preposterous.

The scepticism was well-founded, since the correct technologies were simply not available. To travel in space, a craft must reach escape velocity – for vehicles leaving Earth, this is 11.2 kilometres per second. To put this figure into perspective, the sound barrier is a mere 1,238 kilometres per hour, yet it was only broken in 1947.

Jules Verne proposed a giant cannon in his novel *From the Earth to the Moon*. However, such a sudden burst of acceleration would inevitably kill any passengers instantly, and calculations have shown *that* no cannon could be powerful enough to achieve escape velocity.

The problem was effectively cracked in the early 20th century by two rocket researchers working independently – Konstantin Tsiolkovsky and Robert Goddard. Tsiolkovsky's work was ignored outside the USSR, while Goddard withdrew from the public gaze after scathing criticism of his ideas. Nonetheless, the first artificial satellite, Sputnik, was eventually launched in 1957, and the first manned spaceflight followed four years later. Neither Tsiolkovsky nor Goddard lived to see it.

**5. Harnessing nuclear energy**

On 29 December 1934, Albert Einstein was quoted in the *Pittsburgh Post-Gazette* as saying, "There is not the slightest indication that [nuclear energy] will ever be obtainable. It would mean that the atom would have to be shattered at will." This followed the discovery that year by Enrico Fermi that if you bombard uranium with neutrons, the uranium atoms split up into lighter elements, releasing energy.

Einstein's scepticism was, however, overtaken by events. By 1939, nuclear fission was better understood and researchers had realised that a chain reaction – one that, once started, would drive itself at increasing rates – could produce a huge explosion. In late 1942, such a chain reaction was produced experimentally, and on August 6 1945 the first atomic bomb used aggressively exploded over Hiroshima. Ironically, Fleet Admiral William Leahy allegedly told President Truman: "This is the biggest fool thing we've ever done – the bomb will never go off – and I speak as an expert on explosives."

Then, in 1954, the USSR became the first country to supply some of its electricity from nuclear power with its Obninsk nuclear power plant.

**6. Warm superconductors**

This is a strange case: a phenomenon can be observed and measured, but should not be happening. According to the best theories of superconductivity, the phenomenon of superconductivity should not be possible above 30 kelvin. And yet some superconductors work perfectly well at 77 K.

Superconductors – materials that conduct electricity with no resistance – were first discovered in 1911. To see the effect, a material normally has to be cooled to within a few degrees of absolute zero.

Over the next 50 years, many superconducting materials were discovered and studied, and in 1957 a complete theory describing them was put forward by John Bardeen, Leon Cooper and John Schrieffer. Known as "BCS theory", it neatly explained the behaviour of standard superconductors.

The theory states that electrons within such materials move in so-called Cooper pairs. If a pair is held together strongly enough, it can withstand any impacts from the atoms of the material, and thus experiences zero electrical resistance. However, the theory suggested that this should only be true at extremely low temperatures, when the atoms only vibrate slightly.

Then, in a classic paper published in 1986, Johannes Georg Bednorz and Karl Alexander Müller turned the field upside-down, discovering a material capable of superconducting at up to 35 K. Bednorz and Müller received the Nobel Prize for Physics the following year and more high-temperature superconductors followed. The highest cutoff temperature yet observed (admittedly under pressure) is 164 K. Yet, quite how this is all possible remains a topic of intense research.

**7. Black holes**

People who think of black holes as a futuristic or modern idea may be surprised to learn that the basic concept was first mooted in 1783, in a letter to the Royal Society penned by the geologist John Michell. He argued that if a star were massive enough, "a body falling from an infinite height towards it would have acquired at its surface greater velocity than that of light… all light emitted from such a body would be made to return towards it by its own proper gravity."

However, throughout the 19th century the idea was rejected as outright ridiculous. This was because physicists thought of light as a wave in the ether – it was assumed to have no mass, and therefore to be immune to gravity.

It was not until Einstein published his theory of general relativity in 1915 that this view had to be seriously revised. One of the key predictions of Einstein's theory was that light rays would indeed be deflected by gravity. Arthur Eddington's measurements of star positions during a solar eclipse showed that their light rays were deflected by the Sun's gravity – though actually the effect was too small for Eddington's instruments to reliably observe, and it was not properly confirmed until later on.

But, once relativity was established, black holes became a serious proposition and their properties were worked out in detail by theoreticians such as Subrahmanyan Chandrasekhar. Astronomers then began searching for them, and accumulated evidence that black holes are common with one at the centre of many galaxies (including our own) and the biggest ones being responsible for high-energy cosmic rays.

Perhaps the debate has not been entirely settled, though. Some controversial calculations, published in 2007, suggested that as stars collapsed into black holes, they would release a great deal of radiation, reducing their mass so that they do not form "true" black holes after all.

**8. Creating force fields**

This classic of science fiction went from wild speculation to verifiable fact in 1995 with the invention of the "plasma window".

Devised by Ady Hershcovitch from the Brookhaven National Laboratory, the plasma window uses a magnetic field to fill a small region of space with plasma or ionised gas. The devices, developed by Hershcovitch and the company Acceleron, are used to reduce the energy demands of electron beam welding.

The plasma window has most of the properties we associate with force fields. It blocks matter well enough to act as a barrier between a vacuum and the atmosphere. It also allows lasers and electron beams to pass through unimpeded and will even glow blue, if you make the plasma out of argon.

The only drawback is that it requires huge amounts of energy to produce plasma windows of any size, so current examples are very small. In theory, though, there is no reason they could not be made much bigger.

**9. Invisibility**

Invisibility is another staple of fantasy fiction, appearing in everything from Richard Wagner's opera *Das Rheingold* to H. G. Wells' *The Invisible Man*, and of course *Harry Potter*.

There is nothing in the laws of physics to say invisibility is impossible, and recent advances mean certain types of cloaking device are already feasible.

The last few years have seen a rash of reports concerning experimental invisibility cloaks, ever since a basic design for one was produced in 2006. These devices rely on metamaterials to guide light around objects. The first of these only worked on microscopic objects and with microwaves.

It was thought that modifying the design for visible light would prove very challenging, but in fact it was done just one year later – albeit only in two dimensions and on a micrometre scale. The engineering challenges involved with building a practical invisibility cloak remain formidable.

**10. Teleportation**

This is a word with a long and rather dubious history. It was coined by the paranormalist writer Charles Fort in his book *Lo!* and was subsequently seized on by legions of science fiction writers; most famously as the "transporter" in *Star Trek*.

Despite its fantastical origins, physicists have achieved a kind of teleportation thanks to a bizarre quantum phenomenon called entanglement. Particles that are entangled behave as if they are linked together no matter how wide the distance between them. If, for example, you change the "spin" of one entangled electron, the spin of its twin will change as well.

Entangled particles can therefore be used to "teleport" information. Performing the trick with anything larger than an atom was once thought impossible, but in 2002 a theoretical way to entangle even large molecules, providing *that* they can be split into a quantum state known as superposition, was described.

More recently, an alternative idea, dubbed "classical teleportation", was proposed for making a beam of rubidium atoms effectively disappear in one place and reappear elsewhere. This method would not rely on entanglement, but transmitting all the information about these atoms through a fibre optic cable so that they can be "reconstructed" somewhere else.