

 MILESTONE 4

# Light is special

At the dawn of the twentieth century, light was thought to propagate through 'aether', a medium at absolute rest with respect to the fixed stars and transparent to the motion of celestial bodies. "There can be no doubt that the interplanetary and interstellar spaces are not empty but are occupied by a material substance or body, which is certainly the largest, and probably the most uniform", wrote James Clerk Maxwell in 1878. A clear proof of the existence of aether, however, could not be found.

In 1887, Albert Michelson and Edward Morley published the results of arguably the best known attempt to detect aether. Their idea was that if light propagated along the direction of motion of the Earth, its speed would change owing to the velocity

of our planet with respect to the aether. They used an interferometer purposely designed by Michelson that had sufficient resolution to detect any expected effect. The result, however, was unequivocally null.

Explanations of the negative result reported by Michelson and Morley would introduce more complications. This bothered, not least, Albert Einstein, who trusted that natural laws obey a universal harmony. From the failure to detect any variation in the speed of light in a vacuum,  $c$ , he concluded that this ought to be a constant, regardless of the velocity with which the light source moved. He also assumed that the laws of physics should be the same in reference frames moving with uniform translation with respect to one

another. These two postulates were the basis of the theory he published in June 1905, which is now known as special relativity.

Einstein derived the transformations of space and time coordinates between inertial reference frames, and reproduced equations that George FitzGerald and, independently, Joseph Larmor and Hendrik Lorentz had found to make Maxwell's equations consistent with Newtonian mechanics (which governs the laws of dynamics when velocities much lower than  $c$  are involved, as in everyday experience). The paper Einstein published in June 1905 was followed by a shorter one in September of the same year, which featured the celebrated equivalence between energy and mass,  $E = mc^2$ . The speed of light became the upper limit that no body having finite mass at rest can reach, as it would need infinite energy.

As far as aether was concerned, special relativity made it vanish. As Einstein wrote in the opening of his original paper, "The introduction of a 'luminiferous ether' will prove to be superfluous inasmuch as the view here to be developed will not require an 'absolutely stationary space' provided with special properties".

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**ORIGINAL RESEARCH PAPERS** Maxwell, J. C. in *Encyclopaedia Britannica* 9th edn Vol. 8 (1878) | Michelson, A. A. & Morley, E. W. On the relative motion of the Earth and the luminiferous ether. *Am. J. Sci.* **34**, 333–345 (1887) | Einstein, A. On the electrodynamics of moving bodies. *Ann. Phys.* **17**, 891–921 (1905) | Einstein, A. Does the inertia of a body depend upon its energy content? *Ann. Phys.* **18**, 639–641 (1905)