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MILESTONES

MILESTONE 1

Physics is set spinning

> “…it would take nearly three decades for this ‘anomalous Zeeman effect’ to be explained…”

“It was not simply out of a spirit of contradiction that I exposed a light source to a magnetic field,” so said Pieter Zeeman, on receiving the 1902 Nobel Prize in Physics with Hendrik Lorentz.

The effect of a magnetic field on light had been studied years before, most notably by Michael Faraday: in 1845, he showed that when light passes through certain materials immersed in a magnetic field, the plane in which the light oscillates is rotated — now known as Faraday rotation, this was the first experimental evidence of a connection between light and electromagnetism. Later in his life, Faraday wondered whether a magnetic field could have a direct influence on a light source — specifically, on the light emitted by atoms or molecules when excited in a flame. This investigation was the last experiment recorded in his laboratory notebook, but the result was negative: on 12 March 1862, Faraday wrote that there was “not the slightest effect demonstrable”. Possibly referring to this experiment, James Clerk Maxwell stated in 1870, on the subject of light-emitting particles, that “no force in nature can alter even very slightly either their mass or their period of oscillation”. This statement, “coming from the mouth of the founder of the electromagnetic light theory and spoken with such intensity”, greatly troubled Zeeman.

Motivated by his own studies of the magneto-optic Kerr effect (a phenomenon closely related to the Faraday effect, but measured for light reflected from a magnetized medium), Zeeman decided in 1896 to revisit Faraday’s last experiment. Two recent technical advances proved useful. The first was the invention, by Henry Augustus Rowland, of diffraction gratings consisting of mirrors ruled with a large number of parallel lines; Rowland’s gratings offered unprecedented spectral resolution. The second was the steady development of photography, which brought with it the possibility of capturing spectra and analysing them later.

Zeeman was soon able to show that, for a sodium flame placed in an electromagnet, there was a broadening of the sodium D-lines when the magnet was switched on. The effect was reportedly far from conspicuous; however, firm support was provided by the observation of characteristic polarization effects. This confirmed predictions made by Lorentz — immediately after seeing the first results produced by Zeeman, he had proposed a model of electrons vibrating within the light-emitting particles. In 1897, Zeeman reported much clearer splittings in the blue line of cadmium. Although Lorentz’s theory did explain the most elementary splitting patterns, it was not long before numerous exceptions were found, as more elements were studied in greater detail.

“Nature gives us all, including Professor Lorentz, surprises”, concluded Zeeman. He might have been surprised to know that it would take nearly three decades for this ‘anomalous Zeeman effect’ to be explained fully — when it was realized that the splitting is a consequence of spin (Milestone 3).

Andreas Trabesinger, Senior Editor, Nature Physics

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