European Review, Vol. 15, No. 4, 531–544 © 2007 Academia Europæa
doi:10.1017/S1062798707000518 Printed in the United Kingdom

'Our Friend of Brilliant Ideas': G. F. Fitzgerald and the Maxwellian Circle

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From the late 1870s until his death in 1901, the Irish physicist G. F. Fitzgerald was one of the most active and influential proponents of Maxwell's theory of the electromagnetic field. Along with Oliver Lodge, Oliver Heaviside, Heinrich Hertz, and other 'Maxwellians', Fitzgerald took the lead in extending Maxwell's theory, clarifying its expression, and subjecting it to experimental test. The surviving correspondence of this Maxwellian circle provides a window into the workings of late Victorian physics and into the private side of scientific communication.

In January 1901, George Francis Fitzgerald wrote to his good friend Oliver Lodge, who had recently been appointed principal of the new University of Birmingham. His digestion had been troubling him again, Fitzgerald said, and he suspected he had found the cause. 'I don't like to think it', he said, 'but I am rather afraid these attacks begin with questions that run in my head for a week or so. If I have to give up this continuous thinking I am afraid I cannot do much more in the rest of my life; but I hope I may be wrong in my hypothesis. Anyway just now I am under doctor's orders not to think at all'.[1] Fitzgerald could no more stop thinking than he could stop breathing, however, and he went on to fill the rest of his letter with incisive remarks about some of the most recondite questions in electromagnetic theory.

Deeply worried, Lodge wrote to various of their mutual friends to beg them not to trouble Fitzgerald just then. 'I am afraid', he wrote to Joseph Larmor at Cambridge, 'that people get in the way of writing to him about all sorts of questions', knowing he would offer insightful suggestions; Fitzgerald was always generous with his time and attention, even when the effort wore him out.[2] One of the physicists Lodge wrote to about Fitzgerald was Oliver Heaviside; together, the three men had formed the core of the group of 'Maxwellians' who, over the preceding two decades, had revised, extended, and clarified James Clerk Maxwell's theory of the electromagnetic field and helped to establish it as one of the cornerstones of modern physics. Writing from his home in Devon, Heaviside told Lodge that he was 'grieved to hear of the illness of our friend of brilliant ideas'; he was dismayed by Lodge's report, he said, and hoped Fitzgerald would soon recover his usual vigour.[3] It was not to be. Fitzgerald's condition worsened, and on 22 February 1901 his doctors felt compelled to attempt an operation. They succeeded in removing an ulcer, but Fitzgerald sank under the strain and died a few hours later. He was 49 and left a widow and eight children.

The Maxwellian correspondence

Fitzgerald had long been the 'glue' of the Maxwellian group, and many of his most important contributions to science came in letters to or conversations with other Maxwellians. The members of the group were geographically scattered – Fitzgerald in Dublin, Lodge mainly in Liverpool before his move to Birmingham, Heaviside in London and then Devon, Heinrich Hertz in Germany, Joseph Larmor in Cambridge, with more peripheral members sprinkled around Britain and elsewhere. In the 1880s and 1890s, long before email and with long-distance telephone calls still an expensive luxury, the Maxwellians communicated almost entirely by post; moreover, being good Victorians, they saved most of the letters they received. Hundreds of these letters are still preserved, and together with the Maxwellians' other surviving papers, they provide a rich trove of material for historians. The large collection of Lodge papers at University College London holds about 185 letters from Fitzgerald, 135 from Heaviside, and 160 from Larmor; although most of the many letters Lodge sent to Heaviside have been lost, the Heaviside collection at the Institution of Engineering and Technology in London holds 60 letters from Fitzgerald and 18 from Larmor; the Larmor collection at the Royal Society of London holds about 100 letters from Lodge, 75 from Fitzgerald, and eight from Heaviside; and the Fitzgerald collection at the Royal Dublin Society holds about 90 letters from Lodge, 45 from Heaviside, and 60 from Larmor. Smaller collections of letters to and from the various Maxwellians can be found in other archives in Britain and elsewhere; a particularly important set of letters to Hertz, including three from Lodge, five from Fitzgerald, and nine from Heaviside, is held by the Deutsches Museum in Munich.

The Maxwellians' surviving letters enable us to reconstruct in remarkable detail the workings of their group, the paths by which ideas passed back and forth within it, and something of the personalities of its members.[4] Through the letters, we can trace not just the thinking of one or two individuals, but the course of the collaborative conversation from which the new Maxwellian synthesis emerged.

Maxwell's theory and the Maxwellian group

James Clerk Maxwell had laid the foundations for the treatment of electromagnetic phenomena in terms of fields in his *Treatise on Electricity and Magnetism* (1873), but many readers found that rich but sprawling work to be almost impenetrable. Maxwell never made much effort to promote his theory, and it had made relatively little headway among other physicists before he died in 1879 at the age of 48. The task of refining and advancing the theory was thus left to a younger generation of Maxwellians, few of whom had ever had more than the most passing personal contact with Maxwell himself. Between the late 1870s and the early 1890s, this group of physicists took up Maxwell's theory, mastered its intricacies, recast it into a simpler and more usable form, and then proceeded to apply it to an ever widening range of phenomena, above all the generation and propagation of electromagnetic waves and the passage of energy across the electromagnetic field. In the process they transformed the original theory – what Heaviside called 'Maxwell *as he was wrote*' – into something significantly different: *Maxwellian* theory.[5] It was the latter that passed into general circulation in the late 1880s and early 1890s and that has remained the most widely used formulation of electromagnetic theory ever since.

The rise of Maxwellian theory was, in important ways, driven by the rise of the Maxwellian group. The first and, on a personal level, the strongest bond in the group was that between Fitzgerald and Lodge. Both were born in 1851, Fitzgerald the son of a Dublin academic and clergyman who later became a bishop of the Church of Ireland, Lodge the son of prosperous Staffordshire clay merchant. Both excelled in their studies, Fitzgerald at Trinity College Dublin and Lodge at University College London, and by the mid-1870s both were embarking on promising scientific careers. They first met in August 1878 when the British Association for the Advancement of Science came to Dublin for its annual meeting. The two young physicists found they had much in common, including a shared enthusiasm for Maxwell's theory and a conviction that all electromagnetic phenomena could ultimately be traced to the strains and motion of the all-pervading ether. They soon struck up an active correspondence and, after Lodge took up a new Professorship at University College Liverpool in 1881, began to exchange regular visits across the Irish Sea. Their friendship became close and strong, and is reflected in the mix of jokes, academic gossip, and high science that filled their letters. (Fitzgerald's are written in an admirably clear hand; Lodge's, regrettably, are in an almost indecipherable scrawl.) After about 1890, they began to address and sign their letters to each other with Greek initials, 'φ' for Fitzgerald and 'Λ' for Lodge. They consulted closely on scientific matters of all kinds, and although they occasionally led one another astray – in 1879 an error of Fitzgerald's led him to steer his friend away from a line of work that, had it been pursued, might well have made Lodge the first to produce and detect electromagnetic waves experimentally – their exchanges of ideas and advice were generally remarkably productive. Lodge felt Fitzgerald's death deeply, writing in an obituary that 'It is right that such a man should be honoured for his great learning, high powers, and bright achievements, on which so many from various points of view can speak; but it is right also that he should be lamented on his human side by one who loved him as a brother'.[6]

The third of the core members of the Maxwellian group was certainly the oddest. Oliver Heaviside was born into very modest circumstances in London in 1850, and after a brief career as a junior telegraph engineer near Newcastle, he 'retired' at the age of 24, partly for health reasons and partly because his prickly personality made it difficult for him to work with others. He spent the next 20 years living with his parents, first in London and later in Devon, devoting all of his time to the mathematical exploration of electrical problems, particularly those related to the propagation of signals along telegraph lines. In the late 1870s he began to delve deeply into Maxwell's *Treatise*, drawing out its implications and recasting its contents into a form he found easier to use. It was in fact Heaviside who, in the mid-1880s, rewrote the long list of fundamental electric and magnetic relations Maxwell had given in his *Treatise* into the compact and symmetrical set of four vector equations now universally known as 'Maxwell's equations'. Throughout this period, Heaviside worked in almost complete isolation, publishing dozens of papers in the *Journal of the Society of Telegraph Engineers and Electricians*, the *Philosophical Magazine*, and the weekly trade journal *The Electrician*, but coming into very little contact with anyone outside his immediate family. Looking back years later, he said that 'There was a time indeed in my life when I was something like old Teufelsdröckh in his garret, and was in some measure satisfied or contented with a mere subsistence. But that was when I was making discoveries. It matters not what others may think of their importance. They were meat and drink and company to me'.[7]

Heaviside finally acquired intellectual company of another kind in 1888, when he first began to correspond with Lodge and Fitzgerald. Although he would meet Lodge face to face only once, and Fitzgerald only twice, the ties Heaviside developed with the two men – ties that were kept up almost entirely by post – became among the most important in his life. (Heaviside's handwriting is admirably legible, perhaps reflecting his time as a telegrapher.) In 1896, the London electrical engineer John Perry mentioned to Heaviside that his own high opinion of Heaviside's work was based largely on the praise he had heard of it from Fitzgerald. Perry was, he later told Fitzgerald, 'simply astonished at [Heaviside's] reply: he said he felt so proud and so honoured at your thinking well of him and he used much affecting language!'[8]

Bath 1888

Heaviside was brought into contact with Fitzgerald and Lodge in 1888 by a remarkable confluence of events that also served to vault Maxwellian theory into sudden prominence. There were four main threads to this story, all of which converged at the Bath meeting of the British Association in September of that year. The first was a controversy over the proper place of electrostatic and vector potentials in Maxwell's theory, and whether changes in such potentials were felt instantaneously across space or instead propagated at finite speed. The key figures in this dispute at Bath were Fitzgerald and Sir William Thomson (later Lord Kelvin); Heaviside, though not at the meeting, played an important role from off stage. The second thread concerned a bitter dispute between Heaviside and W. H. Preece, chief engineer of the British Post Office telegraph system, over the effect of self-induction on signals passing along telegraph and telephone wires. Preece held that self-induction was an evil to be eliminated wherever possible, whereas Heaviside argued, on theoretical grounds, that adding the right amount of extra self-induction – for instance, by inserting coils at proper intervals – could actually aid the clear transmission of signals. This dispute did not break into the open at Bath, but it lay behind some of the sharpest conflicts there. The third thread centred on lightning protection. In March 1888, Lodge had delivered a series of lectures at the Royal Society of Arts in which he used sudden electrical discharges to illustrate the effects of lightning. According to Lodge, these experiments showed self-induction to be as important a factor as simple conductivity in the design of effective lightning conductors. Preece objected, maintaining that existing methods of lightning protection were perfectly adequate, and at Bath he and Lodge faced off in a formal debate that turned out to focus as much on questions of the relative value of practice and theory as on niceties in the design of lightning conductors. The fourth and most important thread at Bath grew out of Hertz's experiments in Germany on electromagnetic waves in air. The Maxwellians had long believed in the reality of such waves, but had been unable to point to direct evidence of their existence. Hertz's experiments now provided that evidence, and Fitzgerald in particular used it at Bath to press the case for acceptance of Maxwellian theory.

The dispute between Heaviside and Preece went back to 1887, when Oliver and his brother A. W. Heaviside, a prominent Post Office telegraph engineer, had sought to publish a joint paper on the use of added self-induction to improve the transmission of telephone signals. Preece used his authority as A. W. Heaviside's boss to block publication of the paper in the *Journal of the Society of Telegraph Engineers and Electricians*, and was apparently also behind the abrupt cancellation later that year of Oliver Heaviside's long-running series of mathematical articles in *The Electrician*. Heaviside was furious at being silenced in this way and frustrated by his seeming lack of recourse; working as he did in total isolation, he had no scientific allies to call upon. The winter of 1887–88 was a dark time for Heaviside, and he did not know where to turn for help. He thus looked upon it 'as a sort of special Providence', he later said, when Lodge, whom he did not then know, went out of his way in his March 1888 lecture on lightning protection to remark on 'what a singular insight into the intricacies of the subject, and what a masterly grasp of a most difficult theory, are to be found among the eccentric, and in some respects repellant, writings of Mr. Oliver Heaviside'.[9] The reservations about his writing style aside, Heaviside was grateful for the attention and soon wrote to Lodge to seek to enlist him in the battle against Preece. For his part, Lodge was happy to have the support of such a deeply knowledgeable electrical theorist, for his own claims about self-induction and lightning conductors were coming under heavy fire, and through the summer of 1888 he and Heaviside exchanged a series of long letters on a mix of theoretical and strategic questions.

Lodge's experiments with sudden electrical discharges did not really mimic the effects of lightning as closely as he thought, but they had the great merit of leading him toward the discovery of electromagnetic waves. In fact by the spring of 1888 he was actually producing such waves; although Lodge's waves travelled along wires rather than across empty space, they subsisted primarily in the field surrounding the conducting wire and in most fundamental ways were no different from waves in open space. Indeed, the waves Lodge sent surging along his wires produced a glow in the surrounding air, faintly visible in a darkened room, and he was able to measure their wavelengths and show that they behaved just as Maxwellian theory predicted they should; Heaviside, it turned out, had worked out the complete theory of such waves in his papers on telegraphic propagation.

As the summer approached, Lodge looked forward to presenting his new findings at the upcoming British Association meeting; he felt sure they would make a nice splash. As he was heading off for a hiking holiday in the Alps, however, he happened to read on the train the latest issue of the *Annalen der Physik* and there saw that Heinrich Hertz of Karlsruhe had already made much more striking experiments with electromagnetic waves in air, reflecting them off walls and displaying the resulting interference patterns. 'The whole subject of electrical radiation seems working itself out splendidly', Lodge wrote from Cortina, though he could see that his own hopes for scientific acclaim were quickly slipping away.[10]

The president of the Mathematical and Physical Section for the Bath meeting was Fitzgerald, and no one could have been better prepared to appreciate the importance of Hertz's experiments or their value in advancing the Maxwellians' larger aims. Brushing past any ambiguities in Hertz's results – and there were

https://doi.org/10.1017/S1062798707000518 Published online by Cambridge University Press

several in his experiments as initially reported – Fitzgerald used his 6 September presidential address to hail them as a direct and successful test of Maxwell's central claim that electromagnetic forces are not exerted directly from a distance, but instead act through a medium. 'The year 1888 will be ever memorable', Fitzgerald declared, 'as the year in which this great question has been experimentally decided by Hertz in Germany, and, I hope, by others in England'; the last clause being a clear allusion to the recent work of his friend Lodge.[11]

Hertz's experiments greatly strengthened the Maxwellians' hand, especially when combined with Lodge's own experiments and Heaviside's theoretical investigations. As Heaviside later put it, 'the very slow influence of theoretical reasoning on conservative minds was enforced by the common-sense appeal to facts', and after Fitzgerald and others drew attention to Hertz's experiments, Maxwellian field theory acquired a new and far more receptive audience.[12] Fitzgerald's address attracted wide notice in the British press (to the extent that it was sometimes said that news of Hertz's discoveries reached Germany via Britain), and the Bath meeting came to be seen as marking a watershed in the fortunes of Maxwellian theory and its proponents. The disputes that had recently divided the electrical world did not all suddenly disappear, but after Bath the balance had clearly tipped in the Maxwellians' direction. Preece was forced to give ground on the issue of self-induction, and though he and others would keep up a rearguard action for years to come, there was increasing recognition after 1888 that 'theory' as well as 'practice' might have something to contribute to the progress of electrical technology.

Heaviside never attended scientific meetings, but he read the published accounts of the Bath meeting closely and was greatly pleased. He was even moved to burst into verse, at least in his private notebook:

> Self-induction's 'in the air',
>   Everywhere, everywhere;
> Waves are running to and fro,
>   Here they are, there they go.
> Try to stop 'em if you can
>   You British Engineering man![13]

The Bath meeting marked a striking reversal in Heaviside's own fortunes. A few months before the meeting, he had been completely isolated, blocked from publishing even in a weekly trade journal; at the meeting, his name was repeatedly invoked, the journal *Engineering* reporting that, when questions of high theory came up, 'everybody expressed regret at the absence of Mr. Heaviside, and kept on his guard'. Just a few months after the meeting, Sir William Thomson, the grand old man of Victorian electrical science, devoted much of his presidential address to the Institution of Electrical Engineers (as the Society of Telegraph Engineers

https://doi.org/10.1017/S1062798707000518 Published online by Cambridge University Press

and Electricians had just been renamed) to praise for Heaviside's theory of telegraphic propagation.[14] Heaviside was subsequently invited to resume writing for *The Electrician*; his earlier papers were collected and (on Lodge's recommendation) issued in two stout volumes by Macmillan; and in 1891, with backing from Fitzgerald, Lodge and Thomson, he was elected a Fellow of the Royal Society. He still lived with his parents, having moved with them in 1889 from London to Devon, where they lived above his brother Charles's music shop in the seaside town of Paignton, and he still had no job and no real income. Nonetheless, within the space of two or three years, Heaviside had risen greatly in the scientific world, carried upward by the successes of the entire Maxwellian programme. Hertz, too, was carried upward after 1888 and for a time was drawn into close contact with the British Maxwellians. He exchanged a number of letters with Fitzgerald, Lodge and Heaviside, mainly between 1888 and 1890, and though he never adopted the full Maxwellian emphasis on tracing flows of energy through the field, in other ways Hertz moved close to the Maxwellians' views.[15] The Royal Society awarded Hertz its prestigious Rumford Medal in 1890 and he came to London that November to accept it. There he met Fitzgerald, Lodge, and many other British physicists and electrical engineers. He apparently gave some thought to making a side trip to Devon to meet Heaviside, but Heaviside dissuaded him, insisting that there were far more important people for him to see without going so far out of his way.[16] Hertz died of blood poisoning just over three years later at the early age of 36; he and Heaviside would never meet.

The murder of ψ and the origins of the Fitzgerald contraction

There is one last thread from the Bath meeting for us still to pick up, and it is in some ways the most fascinating of all. The controversy over the proper place of the potentials in Maxwell's theory is worth close attention, not just for its intrinsic interest, but because it offers an especially clear look at the inner workings of the Maxwellian group and the way questions and ideas passed back and forth among its members. Moreover, the episode culminated in the formulation of Fitzgerald's contraction hypothesis, certainly the most famous of the many brilliant ideas proposed by 'our friend of brilliant ideas', and tracing the roots of that hypothesis will illuminate the role Fitzgerald played within the Maxwellian group. What Fitzgerald called the 'murder of ψ' debate (ψ being Maxwell's symbol for the electrostatic potential) got its start when Thomson presented a paper at Bath on a 'Simple hypothesis for electro-magnetic induction of incomplete circuits'. Although Thomson had helped get Maxwell started on the study of electromagnetism more than 30 years before, he had never accepted important parts of Maxwell's theory, and his 'Simple hypothesis' called for lopping off what he regarded as its most objectionable feature: the displacement current. As the

Maxwellians at the meeting soon made clear, however, Maxwell's displacement current was not just a dispensable appendage to the theory, but its keystone; remove it, and the whole structure would collapse. Moreover, without displacement currents, electromagnetic waves, the very waves whose discovery by Hertz had just been hailed by Fitzgerald, could not exist. In fact, word of Hertz's experiments caused Thomson to waver in his opposition; whereas in the draft of his 'Simple hypothesis' he had dismissed Maxwell's notion of a displacement current as 'wholly untenable', in delivering the paper he softened this to say only that it 'seems to me not wholly tenable'.[17] For the rest of the meeting, Lodge reported, Thomson could be seen going about 'with the second volume [of Maxwell's *Treatise*] under his arm, every now and then appealing to Fitzgerald to explain a passage'. For his part, Fitzgerald said that 'Most of these refined points would probably be found mathematically treated somewhere in the writings of Mr. Heaviside'.[18]

The discussion at Bath soon came to focus on the potentials and whether they should be regarded as reflecting the true state of the field, or as little more than mathematical artifices. Heaviside had long made his own view clear: only the electric and magnetic field intensities **E** and **H** (and their associated fluxes **D** and **B**) referred to anything real, and the potentials deserved to be murdered. He had in fact eliminated them completely from his 'redressed' version of Maxwell's equations. The apparent implication in Maxwell's *Treatise* that changes in the electrostatic potential would be felt instantaneously across space was an error, Heaviside said, arising from a mistaken formalism; once one shifted attention to the electric and magnetic intensities, one saw that all disturbances propagate through the field at the speed of light. Fitzgerald reached essentially the same conclusion, and at the Bath meeting he went back through his notebooks, correlating the field equations with the workings of a model of the ether he had devised several years before. He clarified the relationship between the potentials and the field intensities, and beside one important equation (describing what would now be called a gauge condition) he scrawled 'Very important. 9.9.88. Must be all in O. Heaviside'.[19]

After reading accounts of the discussions at Bath, Heaviside declared the whole question of the propagation of the electrostatic potential to be 'metaphysical' – it could never, he said, be tested experimentally, even in principle.[20] Thomson disagreed, saying one could imagine moving an electric charge to and fro and watching for any time lag in the response of sensitive electrometers set at different distances.[21] Heaviside responded by tackling a problem no one before him had ever fully solved: finding the exact field around a charge moving with any speed. Previous calculations, including Heaviside's own, had been limited to slow motions, in which the electrostatic field could be treated as moving rigidly with the charge, with an additional term for the magnetic effect of the electric current arising from the motion of the charge. According to Maxwell's theory, however, the motion of the resulting magnetic field would produce a further electric field, whose changes would produce a further magnetic field, and so on. At first Heaviside despaired of arriving at anything more than an unwieldy infinite series, but in December 1888 he found that the expression converged to a surprisingly simple result. In effect, the ordinary radial electric field of a point charge is compressed along its line of motion by a factor of $\sqrt{(1 - v^2/c^2)}$, where v is the speed of the charge and c the speed of light. Heaviside was delighted with this result, declaring it simple enough 'to take a place in text-books'.[22] He sent a brief note off to the *Electrician* and a longer paper to the *Philosophical Magazine*; in letters to Fitzgerald, Thomson and Hertz, he also made a point of drawing attention to his striking new formula, and to the way it illustrated the propagation of electric force from a moving charge with no need for the electrostatic potential to make itself felt instantaneously across space.

On 8 February 1889, just a few days after receiving Heaviside's letter on this question, Fitzgerald happened to be in London and arranged to call on Heaviside. He had some trouble finding the Heavisides' house, but when he did, the two physicists sat down to talk for an hour or two about moving charges and changing fields, among other subjects. A few weeks later Lodge, too, visited what he later called Heaviside's 'dismal lodgings at Kentish Town'.[23] We have no record of their conversation, but it was no doubt a mix of high talk about electromagnetic theory and low grumbles about W. H. Preece.

Lodge had just taken up the problem of 'aberration', or the way motion through the ether affected electric, magnetic, and optical phenomena. In particular, he was brooding over the puzzling result of an 1887 experiment in which the American scientists A. A. Michelson and E. W. Morley had split a beam of light, sent its two parts bouncing back and forth at right angles to each other, and then recombined them to produce an interference pattern. According to Maxwell's theory, or indeed any plausible form of the wave theory of light, the motion of the Earth should have produced a slight but detectable shift in the phase of the waves of light, and so of the interference fringes, but Michelson and Morley had found no shift at all. This result, Lodge said in 1889, stood as one of the 'outstanding problems' facing Maxwellian theory; Heaviside later said it confronted the accepted laws of light and electromagnetism with 'a flat contradiction'.[24]

About two months after Fitzgerald's visit to Heaviside, and only a few weeks after Lodge's, Fitzgerald made one of his periodic visits to Lodge in Liverpool. As they were mulling over Michelson and Morley's puzzling null result, Fitzgerald was struck by one of his characteristic 'brilliant ideas' – in Lodge's later words, it suddenly 'flashed on' him as they sat in Lodge's study at 21 Waverley Road.[25] What if, Fitzgerald asked, the motion of a body through the ether caused it to change in size by just the amount – a tiny fraction of a millimetre – needed to mask the effect Michelson and Morley had been looking for? What if the laws governing the structure of matter and the propagation of light conspired to hide the effects one would expect motion through the ether to produce? The suggestion was not nearly as implausible as it might first appear, for if material bodies are held together by electromagnetic forces, or by other forces that also act through the ether, it made perfect sense that motion through the ether might affect those forces and so alter the size of a body. Moreover, Heaviside's formula for the field around a moving charge, then fresh in Fitzgerald's mind, showed that electromagnetic forces would be altered by just the factor involving v^2/c^2 needed to explain Michelson and Morley's result, by causing the body either to contract along its line of motion or expand laterally to it.

Fitzgerald ordinarily sent notes of his bright ideas to the *Proceedings of the Royal Dublin Society*, but he had had a falling out with the Society not long before, and so instead sent a letter describing his hypothesis to the New York journal *Science*, apparently choosing it because Michelson and Morley were Americans. It appeared there in May 1889 but Fitzgerald never saw it in print and his letter remained almost wholly unknown until Stephen Brush unearthed it in 1967.[26] Although Fitzgerald did not cite Heaviside's moving charge formula directly in his letter, which was brief and elementary, he clearly had it in mind when he said that 'we know that electric forces are affected by the motion of the electrified bodies relative to the ether, and it seems a not improbable supposition that the molecular forces are affected by the motion, and that the size of a body alters consequently'.[27] As Fitzgerald told Lodge, if all bodies change in size as they move through the ether, then Michelson and Morley's experiment was one of the few ways to show that change – ironically, by showing no result at all.[28]

Fitzgerald mentioned his hypothesis in his lectures at Trinity College, and Lodge included a brief account of it in a paper on aberration problems he published in 1893, but it drew little other attention or support until after it was incorporated into a comprehensive electron theory of matter. Fitzgerald's friend and fellow Irishman Joseph Larmor developed such a theory in 1894 (largely in response to suggestions from Fitzgerald himself) and later became a leading proponent of the contraction hypothesis.[29] It was the Dutch physicist H. A. Lorentz, however, who did most to bring the contraction hypothesis into prominence. He had begun to develop his own version of electron theory in the early 1890s, and in 1892 he independently hit on the contraction hypothesis. After coming across Lodge's aberration paper and its reference to the idea as Fitzgerald's, Lorentz wrote to Fitzgerald in 1894 and received a characteristic reply. Fitzgerald said he was not sure his letter to *Science* had even been published, and he apologized for not having written 'any special article about it as I ought to have done for the information of others besides my students here'. In any case, he said, he was happy to let Lorentz take all the credit.[30] Lorentz was nonetheless careful to mention Fitzgerald in his later writings on the subject, which is how the hypothesis came to be known as the 'Fitzgerald–Lorentz contraction'. By 1900 it was widely accepted by theorists, and it later gained new and greater prominence, though with a very different interpretation, as part of Einstein's theory of relativity.

Conclusion

The story of the origins of the Fitzgerald contraction illustrates the different parts Heaviside, Lodge, and Fitzgerald played in the Maxwellian group, and especially Fitzgerald's role as their 'idea man'. Fitzgerald continually generated new ideas, but rarely followed any of them through to completion. As Heaviside wrote shortly after Fitzgerald's death:

> He had, undoubtedly, the quickest and most original brain of anybody. That was a great distinction; but it was, I think, a misfortune as regards his scientific fame. He saw too many openings. His brain was too fertile and inventive. I think it would have been better for him if he had been a little stupid – I mean not so quick and versatile, but more plodding. He would have been better appreciated, save by a few.[31]

The ingredients of scientific fame are often elusive; the race is not always to the swift, and there is often much to be gained by steady plodding. Had Fitzgerald put more of his energies into completing a comprehensive theory or carrying out a great experiment, or even into publishing some of the bright ideas he tossed off in letters to his friends, he might be better remembered today. The real lesson of the Maxwellian story, however, is not so much what Fitzgerald, Lodge or Heaviside accomplished or failed to accomplish individually, but how their differing personalities and abilities meshed to enable them jointly to produce one of the great scientific syntheses of their time.

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