Chapter 2
The Active Ether

Abstract During most of the nineteenth century the existence of an all-encompassing ether as a substitute for a true void was taken for granted. According to the successful electromagnetic ether theory based upon Maxwellian electrodynamics, the ether was endowed with energy and hence very different from nothingness. Oliver Lodge thought that its energy density was enormous, about 10^{33} erg cm^{-3}. The active ether of the fin-de-siècle period was in some respects surprisingly similar to the later quantum vacuum, yet it was based fully on classical physics.

Keywords Ether · Electromagnetism · Vortex theory · Oliver Lodge

In spite of the opinion of Boyle, many later natural philosophers assumed the existence of a rare and penetrating "subtle matter" that was present also in a void. Although some physicists accepted the vacuum as a passive nothingness, this was not the generally held view. The period from Newton to Maxwell saw a bewildering variety of ethers which in many cases were introduced for specific purposes, such as explaining electricity, magnetism, light, gravitation, nervous impulses, and chemical action (Cantor and Hodge 1981). In an article on the ether for the *Encyclopaedia Britannica*, Maxwell (1965, p. 763) noted that "To those who maintained the existence of a plenum as a philosophical principle, nature's abhorrence of a vacuum was a sufficient reason for imagining an all-surrounding æther." The fact that some of these phenomena were easily transmitted in empty space indicated that their associated ethers were part of even a perfect vacuum. Maxwell continued: "Æthers were invented for the planets to swim in, to constitute electric atmospheres and magnetic effluvia, to convey sensations from one part of our bodies to another, and so on, till a space had been filled three or four times with æthers."

As he implied here, the many hypothetical ethers were *ad hoc* and therefore unsatisfactory from a methodological point of view. Yet Maxwell was himself not only a believer in the ether; his field theory of electromagnetism was instrumental in introducing a new and unified kind of ether, one which was electrodynamical rather than mechanical in nature. Since the early decades of the nineteenth century the ether had become increasingly associated with optics and seen as the medium in

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which light propagated. Following the pioneering work of Thomas Young in England and Augustin Fresnel in France, by the 1820s the corpuscular theory of light was abandoned and replaced by a theory of transverse waves. The new "luminiferous" ether pervaded the universe and, according to most physicists, behaved like an elastic solid that—strangely—did not interact with other matter. Although it had the form of a solid, and was sometimes likened to steel, the planets and comets passed through it without noticing any resistance. Strange indeed!

In a postscript to an 1864 article titled "A dynamical theory of the electromagnetic field," Maxwell (1864), Maxwell even wondered whether the electromagnetic ether might in some way be responsible for the force of gravitation. His idea seemed to be that by "screening" each other from a portion of this energetic medium, massive bodies might be driven together as if they were accelerating under the influence of a new force. After noting that the energy of the ether is everywhere positive, and attempting to obtain a lower limit on its density, he concluded:

> The assumption, therefore, that gravitation arises from the action of the surrounding medium... leads to the conclusion that every part of this medium possesses, when undisturbed, an enormous intrinsic energy, and that the presence of dense bodies influences the medium so as to diminish this energy wherever there is a resultant attraction.
>
> As I am unable to understand in what way a medium can possess such properties, I cannot go any further in this direction in searching for the cause of gravitation.

This is a remarkable anticipation, not only of the zero-point energy of quantum theory some 50 years later (Chap. 4), but also of attempts by some modern unified-field theorists to account for gravitational interactions as a Casimir-type byproduct of electromagnetic zero-point fields.[1]

Much ingenuity and mathematical effort was put into the construction of ether theories by theoretical physicists such as George Green, Gabriel Stokes, and James MacCullagh (Schaffner 1972). Ethers of the elastic-solid type were developed until the 1880s, often without connection to phenomena of electrodynamics. With the gradual acceptance of Maxwell's electromagnetic theory of light, as fully expounded in his monumental *Treatise on Electricity and Magnetism* from 1873, the ether came to be seen as inextricably associated with electromagnetism. Through the works of Hendrik A. Lorentz, Joseph Larmor, Oliver Heaviside, Max Abraham and many other theorists, Maxwell's field theory was developed into a sophisticated theory of the electromagnetic ether. Characteristically, when the German physicist Paul Drude in 1894 wrote an advanced textbook of Maxwellian electrodynamics, he chose to entitle it *Physik des Aethers* (Physics of the Ether). Whatever its precise nature, the ether was considered indispensable. Another German physicist and specialist in electrodynamics, August Föppl, suggested that space without ether would be a contradiction in terms, like a forest without trees.

Late nineteenth-century physics consisted of the physics of matter and the physics of the electromagnetic ether. To avoid the unwanted dualism, the trend was to identify matter with ether, rather than the other way around. In the early years of the twentieth

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[1] The original idea for such a theory is usually credited to in Sakharov (1968). In its most compelling form it has been developed under the name "stochastic electrodynamics" by Haisch et al. (1994).

century it became common to regard the new electron as a concentration of or singularity in the ether; or, what was about the same, electromagnetic fields. This was a basic assumption of the so-called electromagnetic world picture that held a strong position in theoretical physics. But the views concerning space, ether, and vacuum differed. In a lecture of 1909 at Columbia University, Max Planck said: "In place of the so-called free ether there is now substituted the absolute vacuum,.... I believe it follows as a consequence that no physical properties can be consistently ascribed to the absolute vacuum" (Planck 1915, p. 119). He regarded the speed of light not as a property of the vacuum, but a property of its electromagnetic energy: "Where there is no energy there can be no velocity of propagation." Two years later Planck would initiate a development that led to the modern view of a true vacuum endowed with physical properties.

It is possible to trace the concept of dark energy far back in time, say to the days of Newton (Calder and Lahav 2008) or even to the *pneuma* of the Stoic philosophers. However, if one wants to point to pre-quantum and pre-relativity analogies to dark energy, a more sensible arena might be the ethereal world view of the late nineteenth century. The general idea that cosmic as well as terrestrial space is permeated by an unusual form of hidden energy—a dark energy of some sort—was popular during the Victorian era, where space was often identified with the ether. The generally accepted ethereal medium existed in many forms, some of them assuming the ether to be imponderable while others assumed that it was quasi-material and only differed in degree from ordinary gaseous matter in a highly rarefied state.

The ether was sometimes thought of as a very tenuous, primordial gas, perhaps consisting of ether atoms of the incredibly small mass 10^{-45} g. On the other hand, according to the popular vortex theory, which was cultivated by British physicists in particular, the discreteness of matter (atoms) was epiphenomenal, derived from stable dynamic configurations of a perfect fluid. This all-pervading fluid was usually identified with the continuous and frictionless ether. The highly ambitious vortex theory invented by William Thomson, the later Lord Kelvin, was not only a theory of atoms, it was a universal theory of ether (or space) and matter, indeed of everything (Kragh 2002).

The point is that by the turn of the nineteenth century few physicists thought of "empty space" as really empty. Rather it was filled with an active ethereal medium. This ether was widely seen as "a perfectly continuous, subtle, incompressible substance pervading all space and penetrating between the molecules of all ordinary matter, which are embedded in it" (Lodge 1883, p. 305). Lorentz and other physicists in the early twentieth century often spoke of the ether as equivalent to a vacuum, but it was a vacuum that was far from nothingness. Although Lorentz was careful to separate ether and matter, his ether was "the seat of an electromagnetic field with its energy and its vibrations,... [and] endowed with a certain degree of substantiality" (Lorentz 1909, p. 230). On the other hand, the popular belief in a dynamically active ether was rarely considered in astronomical or cosmological contexts.

Among the firm believers in the ether as a storehouse of potential energy was the English physicist Oliver Lodge (Fig. 2.1), a devoted follower of Maxwell who has been called a "remote ancestor" of the modern quantum vacuum. Peter Rowlands, a

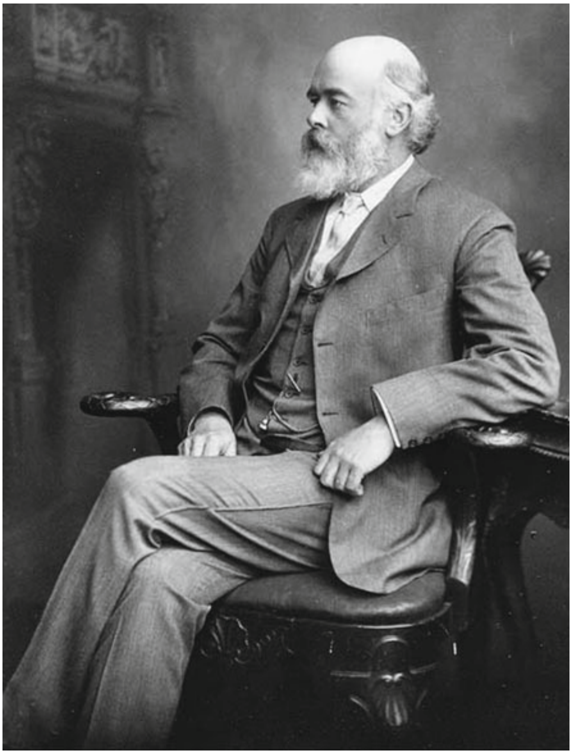

Fig. 2.1 The English physicist Oliver Lodge (1851–1940), a pioneer in radio telegraphy and a life-long advocate of the electromagnetic ether

biographer of Lodge, comments: “The infinite energy density of the zero-point vacuum field fluctuations is almost indistinguishable from the infinite elasticity of the universal ethereal medium” (Rowlands 1990, p. 285). Lodge was indeed an enthusiastic protagonist of the active Victorian ether, which he considered incompressible and a reservoir of an immense amount of energy. This energy was not directly testable, but it could be calculated. In one such calculation, dating from 1907, he estimated the minimum etherial energy density to be “something like ten-thousand-million times that of platinum.” In the words of Lodge (1907, p. 493):

> The intrinsic constitutional kinetic energy of the æther, which confers upon it its properties and enables it to transmit waves, is thus comparable with 10^{33} ergs per c.c.; or say 100 foot-lbs. per atomic volume. This is equivalent to saying that 3×10^{17} kilowatt-hours, or the total output of a million-kilowatt power station for thirty million years, exists permanently, and at present inaccessibly, in every cubic millimetre of space.

The energy density of Lodge’s ether, if transformed to a mass density by means of $E = mc^2$, corresponded to about 10,000 tons cm^{-3}. In a later chapter on the possible granular structure of the ether, he repeated the estimate of 10^{30} to 10^{33} erg cm^{-3}, adding that “the ether may quite well contain a linear dimension of the order 10^{-30}

to 10^{-33} centim." (Lodge 1920, p. 171). Although not more than a curiosity, it is worth pointing out that the linear dimension of Lodge's ether happened to be in the same range as what would later become known as the Planck length,

$$\sqrt{\frac{Gh}{c^3}} = 4 \times 10^{-33}\,\text{cm}. \tag{2.1}$$

A length scale of the same order appears in modern unified theories of the fundamental interactions, such as string theory.

As another example, perhaps an even more dubious ancestor, consider the French psychologist and amateur physicist Gustave LeBon, the discoverer of the illusory "black light" and author of the best-selling *The Evolution of Matter*. In this time-typical and hugely popular book, LeBon (1905, pp. 313–315) pictured electrons and other charged particles as intermediates between ordinary matter and the ether. His cosmic scenario started with "a shapeless cloud of ether" which somehow was organized into the form of energy-rich atomic particles. However, these would be radioactive and slowly release their energy. They were "the last stage but one of the disappearance of matter," the last stage being represented by "the vibrations of the ether." Matter formed by electric particles would eventually radiate away all their stored energy and return to "the primitive ether whence they came... [and which] represents the final nirvana to which all things return after a more or less ephemeral existence."

The analogy between some forms of the classical ether and the presently discussed vacuum energy has not been lost on modern physicists, who sometimes refer to the resurrection or "transmogrification" of the ether (Sciama 1978). Even before the discovery of the cosmic microwave background, Robert Dicke at Princeton University wrote: "One suspects that, with empty space having so many properties, all that had been accomplished in destroying the ether was a semantic trick. The ether had been renamed the vacuum" (Dicke 1959). According to Paul Davies (1982, p. 582), late-nineteenth century physicists "would surely have been gratified to learn that in its modern quantum form, the ether has materialised at last." Similarly referring to the role of virtual particles in modern quantum field theory, Nobel laureate Frank Wilczek suggests that the ether—"renamed and only thinly disguised"—plays a most important role in physics (Wilczek 1999; see also Barone 2004). Tempting as it may be to consider the classical ether as an anticipation of modern vacuum energy, we need to emphasize that it is at most a crude analogy and that the historical connection between the two concepts is largely a reconstruction with little support in actual history. Vacuum energy is a quantum phenomenon and to find its historical origin we need to look at the early development of quantum theory.

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