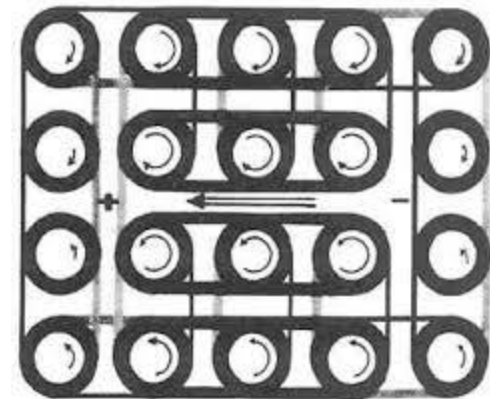
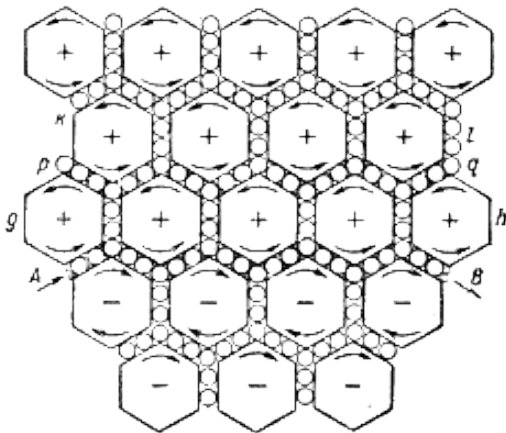


# A BIG QUESTION OF NINETEENTH-CENTURY PHYSICS:

# WHAT IS THE ETHER?



## BIG QUESTIONS OF NINETEENTH-CENTURY PHYSICS

Definition: an important question that most physicists long regarded as open.

False positive: Academy prize questions, nature of light, heat, and electricity.

Oxford meeting of the British Association, Lord Salisbury, 1894

The Salisburian mysteries: ultimate structure of matter, **the ether**, origin of life.

*The mystery of the ether remains even more inscrutable than before.*

Lamé 1863: *I have long ago arrived to two novel conclusions: first, that future science will recognize in the ether the true king of physical nature; second, that we would much delay its solid installation if we hurried to crown it today.*

Hertz 1889: *We are more and more inclined to think that the question of the nature of the ether overcomes all other questions, that knowing the ether not only explains the nature of our old imponderables but also the nature of our old matter and of its properties: gravitation and inertia.— Today's physics is no longer far from answering the question: Is every existing thing made of the ether?*

## THE ETHER, A CERTITUDE

even for sober French scientists

Lamé 1834: *Fresnel's works seem to have removed any doubt about the existence of a universal fluid in which luminous waves propagate.*

Lamé 1852: *The existence of the ethereal fluid is incontestably proven. . . It is not possible to arrive at a complete, rational explanation of physical nature without taking this inevitable agent into account.*

Bertrand 1878: *No hand has yet touched the ether; no eye has seen it, no balance has weighed it. We deduce it, we do not exhibit it; and yet it is as real as the air, its existence is just as certain; if I dare say, its existence is more certain.*

Exceptions: Comte (1835: *éter = hypothèse anti-scientifique sur la nature intime des phénomènes*) et Duhem (1895: *optique physique = système d'équations symboliques* ).

## THE ETHER, A CERTITUDE

Maxwell 1873: *The vast interplanetary and interstellar regions will no longer be regarded as waste places in the universe, which the Creator has not seen fit to fill with the symbols of the manifold order of His kingdom. We shall find them to be already full of this wonderful medium; so full, that no human power can remove it from the smallest portion of Space, or produce the slightest flaw in its infinite continuity. It extends unbroken from star to star; and when a molecule of hydrogen vibrates in the dog-star, the medium receives the impulses of these vibrations, and after carrying them in its immense bosom for several years, delivers them, in due course, regular order, and full tale, into the spectroscope of Mr. Huggins, at Tulse Hill.*

Maxwell 1878: *Whatever difficulties we may have in forming a consistent idea of the constitution of the aether, 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 body of which we have any knowledge.*

J.J. Thomson 1909: *The ether is not a fantastic creation of the speculative philosopher; it is as essential to us as the air we breathe. . . The study of this all-pervading medium is perhaps the most fascinating and important duty of the physicist.*

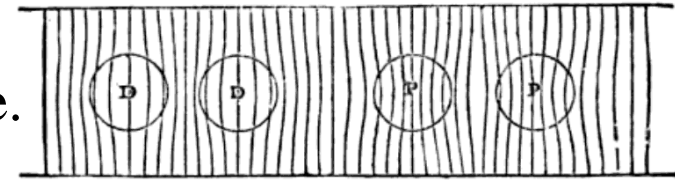
## EXISTENCE PROOFS AND DOUBTS

Young 1800s, Fresnel 1820s: Wave theory of light.

Acoustic analogy, mechanism, and grammar → There is a medium

Lord Salisbury 1894: *For more than two generations the main, if not the only, function of the word ether has been to furnish a nominative case to the verb 'to undulate.'*

Faraday 1840s: No mechanical ether, only lines of force.



Poincaré 1888: *It matters little whether the ether really exists; that is the affair of the metaphysicians. The essential thing for us is that everything happens as if it existed, and that this hypothesis is convenient for the explanation of phenomena. After all, have we any other reason to believe in the existence of material objects? That, too, is only a convenient hypothesis; only this will never cease to be so, whereas, no doubt, some day the ether will be thrown aside as useless.*

Emil Cohn 1900: The electromagnetic fields are real entities sui generis.  
(Cohn refers to Mach, although Mach not hostile to the ether)

## MODELS OF THE ETHER

Mechanical medium compatible with transverse waves and Fresnel's laws.

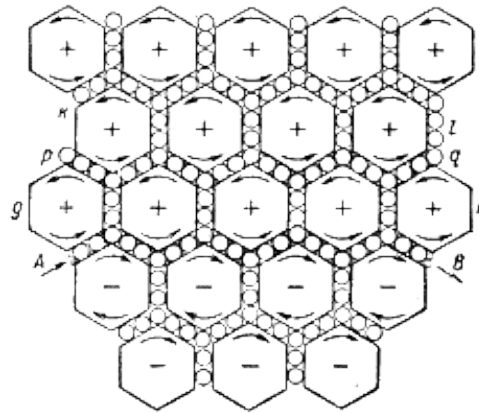
Many elastic-solid theories, the two best being:

MacCullagh's rotational ether (1839)  $V = \frac{1}{2} K (\nabla \times \mathbf{u})^2$

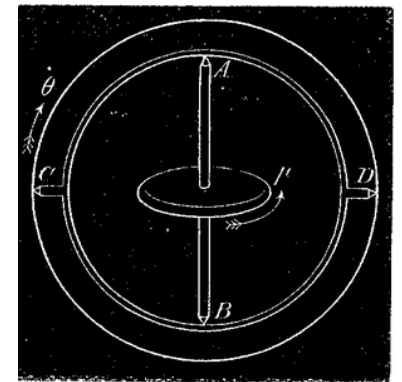
Cauchy (1839), Kelvin (1888)  $V = \frac{1}{4} K' (\partial_i u_j + \partial_j u_i)(\partial_i u_j + \partial_j u_i) + \frac{1}{2} K'' (\partial_k u_k)^2$

labile ether

with  $2K' + K'' \rightarrow 0$



Maxwell's electromagnetic ether  
with molecular vortices (1862),  
then Lagrangian (1865)



Larmor's ether (1890s): MacCullagh plus singularities (electrons).

Heaviside, Hertz, many Germans, and Poincaré: agnostics.

Hertz 1890: *Maxwell's theory is Maxwell's system of equations.*



## ETHER AND MATTER

### 1) *The presence of matter affects the propagation of light:*

Optical index, anisotropic propagation, dispersion, optical rotation

Explained in the 1880s by ionic or electronic vibrators in the ether by Helmholtz, Lorentz, and Larmor.

### 2) *The motion of matter affects the propagation of light*

Motion of the earth: causes stellar aberration (Bradley 1720), but no effect on terrestrial experiments from Arago 1810 to Michelson-Morley 1887.

Running water: partial drag of the waves (Fizeau 1850).

How can the earth move through the ether?

- Young, Fresnel, Lorentz, Larmor: porous matter (Young's wind and grove)
- Stokes: fully dragged ether.

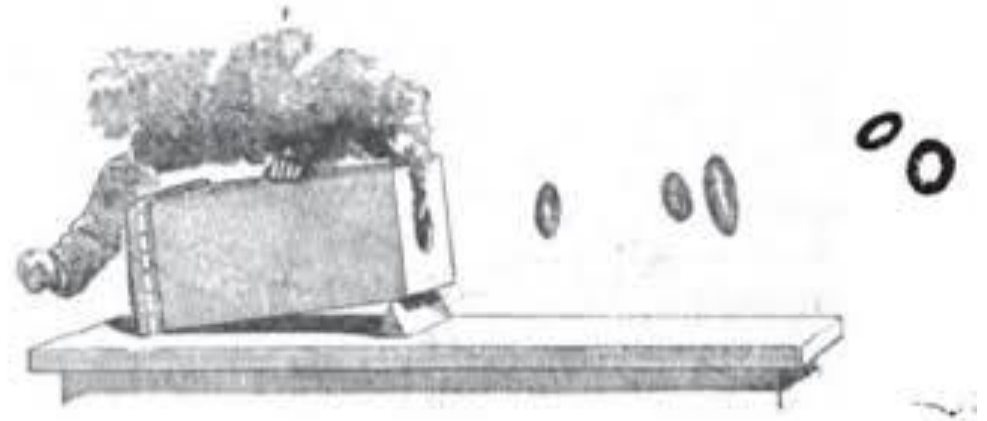
Fresnel: aberration evident, Arago and Fizeau ad hoc

Lorentz: aberration evident, Arago and Fizeau deduced, MM' ad hoc

Stokes: aberration ad hoc, Arago and MM' immediate, Fizeau ad hoc.

## THE UNIVERSAL ETHER

William Thomson: vortex atoms in ether as perfect liquid (1867-1887) and effective optical rigidity by small-scale turbulent motion (1887)



FitzGerald 1885-1900: Vortex sponge.

Larmor 1890s: singularities in rotational ether

Turn of the century: The electromagnetic worldview of Wien, Wiechert, Abraham, Sommerfeld, Langevin...

Ether and life: Stewart & Tait (*The unseen universe*, 1875), Ernst Haeckel (*Der Monismus*, 1893), Louis Bourdeau (*Le problème de la vie*, 1901).



## QUESTIONS ABOUT THE BIG QUESTION

How do we decide an entity is real?

Could some of our big questions turn out to be about fake entities?

Was the ether an obstacle to progress or was it a useful, temporary, heuristical device (a scaffold)?

Is there anything useful left from nineteenth-century physicists' struggle with the ether?

Paul Valéry (1931): *L'homme a conquis toute l'étendue habitable: la terre, la mer, l'air et la nuit lui appartiennent, et jusqu'à l'éther, - si éther est un nom qui convienne encore à l'espace ondulatoire.*

Barak Obama (2005, The daily show): *See I don't have a television, so...I'm not sure what's getting out there into the ether.*

Lorentz 1906: I cannot but regard the ether, which can be the seat of an electromagnetic field with its energy and its vibrations, as endowed with a certain degree of substantiality, however different it may be from all ordinary matter.

Duhem 1894: Rompant franchement [...] avec la loi que Descartes a voulu imposer à la physique et que, depuis deux siècles, la physique cherche à secouer par des efforts sourds et inconscients, nous ne voulons voir dans la lumière qu'une qualité et dans l'optique physique qu'un système d'équations symboliques dont le but est de figurer et non d'expliquer les caractères que l'analyse expérimentale nous signale en cette qualité.

Comte 1835: On ne conçoit pas mieux, en réalité, la propriété lumineuse des corps, après l'avoir attribuée à leur faculté incompréhensible de lancer un fluide fictif ou de faire vibrer un éther imaginaire. " hypothèses anti-scientifiques sur la nature intime des phénomènes"