What is light? An overview of XIX and XX centuries theories of light

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> Im Anfangs schuf Gott Himmel und Herde. Und die Herde war ohne Form und Lehrer, und Finsternis war auf der Fläche der Tiefe.
> […] Und der Geist schwebte auf der Fläche der Wasser, und Gott spracht: Es werde Licht! Und es war LICHT” (Gn 1,2-3).
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> It is not bodies that generate sensations, but sensations complexes instead which form bodies (Ernst Mach).

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My study concerns the historical problem of an alleged distinction between light and our vision of an illuminated earth and skies. Johannes Kepler, the XVII century celebrated astronomer, thought that vision was the effect of its alleged cause, the *lumen*. The cause-effect relationship interested scientists in the XVIII century, representing one of the main objects of their research. In this paper, I limit my considerations to the XIX century contributions of renowned scientists such as Helmholtz, Maxwell and Hertz, and to Lorentz’s and Zeeman’s spectroscopic analysis. Their demonstrations of the measured light’s high velocity required very deep theoretical skills. When Albert Einstein abolished Lorentz’s ether, an ether-less theory of electromagnetism and light was accepted by a majority of physicists. The velocity of light is today accepted as one of the universal constants of nature. I argue that Einstein’s revolutionary relativity theories took the role of centuries long debates on an ethereal support of light.

In his 1611 *Dioptrics*, Johannes Kepler studied what he considered the external agent of vision, the *lumen* (Ronchi 1952). Kepler’s view of lumen, as a light’s material support, represented the birth of a new paradigm on the existence of various levels of light’s supporters. Kepler’s overthrow of the Middle Age conception of fire as the unique supporter was also confirmed by Galileo’s observations with his telescope (Bartellini 2010). Kepler’s theory of vision, based on the concept of rays propagating from luminous and illuminated object is still accepted as an elementary theory, although Kepler prudently admitted the difficulty of explaining virtual images (Ronchi 1982). The so-called *camera obscura*, a devise used by painters in the XVII century, represented a convincing model for the lumen interpretation of vision. As is known, Kepler limited his approach to the study of white light, but Newton maintained that colours are its spectral fundamental ingredients. Huygens’ and Newton’s opposite views on the essence of light, concerned a distinction between particles and waves. Newton's convinced his followers physicists that light consisted of special particles, although nobody never saw the particles, whereas light clearly behaved as a wave, no less than in its mirrors reflections and refractions. In the 1820s, Augustine Fresnel convinced his hard minded compatriot Laplace that light is a transversal wave, and its source is in the ether, a supporting staff, a lumen very much dissimilar from ordinary materials. An analogy with acoustics and sound was the implicit model because a vibrating string is the causal source of music and sounds. But, the source of light could not be assimilated to the string elasticity. A great difficulty was presented when it was proved that light's velocity was higher than any terrestrial velocity. XIX century physicists and mathematicians worked very hard in order to find answers. Maxwell's electromagnetic theory of light was one of the highest achievements in a field theory, but owed its success to Maxwell's recourse to the action at a distance theory of Karl Fredrik Gauss and Wilhelm Weber, clearly contrasting with his field program. Ten years afterwards, Heinrich Hertz managed electric currents from a Rumkorff coil, and afforded the first controlled production of electromagnetic waves (D'Agostino 1998). Hertz's master, Hermann von Helmholtz, and the international opinion – Poincarè excepted – welcomed Hertz's discovery. The discovery of X rays extended the concept of something later on identified as of very high frequency electromagnetic waves. But the spirit of a glorious science did not last for more than a few years. Ernst Mach doubted that what we really experience as a vision of a coloured world and an alternation of colours and darkness are really the effect of an unknown entity we call light, or it is just that we attribute our perceptions to something, a so-called light, that nobody has ever seen (Ronchi 1952). Mach's sceptical views have an historical precedent in the philosopher Berkeley, Mach's type paradox of vision as a feedback paradox. As a secure guarantee for science's objective knowledge, Helmholtz referred to the regularity of physical laws, and to their almost secure prediction of our perceptions (Helmholtz 1956). I find that many questions debated by physicist would receive a deeper understanding by a serious historical approach. By its nature, science is a very complex affair: who could have imagined that the very assertor of an indubitable truth in scientific law was destined to contradict Maxwell and Hertz on the wavelike nature of light? It is well known that Planck discovered that a light wave included energy packets, the today well-known photons.

I have very drastically exemplified a long and complex history of light and vision. I am here concerned with XIX century contributions to theories on the velocity of light by Maxwell, Hertz, Lorentz and Helmholtz. I included above Heinrich Hertz's theoretical and celebrated experimental contributions to a domestic creation of light waves. A comparison between Hertz's reflective criticism on his conception of the *a priori* assumption of physics theory, and, on the other side, Lorentz justification for the success of empirically well supported theory, represent in my view a suitable introduction for an understanding of the imminent next conceptual storm: the advent of Albert Einstein's special and general relativity.

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