Research Article

Objectivity and Honesty in Science: The case of Light Interference Phenomena

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1. Independent researcher

In his book *La Valeur de la Science* published in 1905, French scholar Henri Poincaré (1854-1912) claimed: 'Scientists have to deserve the truth; this is the unique goal Science is worthy of'.[1] And he completed: 'In order to achieve this goal, the scientist must get rid of his emotions and preconceptions; he must attest an unconditional sincerity'.[2]

But scientists are human beings animated by their own psychology and their own feelings. Power, pre-eminence, pride, ambition, career, revenge, rancour, jealousy, hypocrisy, disappointment, scandalmongering, friendship, cupidity, this list being non exhaustive, blur their judgments. Furthermore, most of the time they belong to a group and they have to follow their mentor's ideas not to be rejected. Therefore, the very significance of Science, its aim and its method are often biased by their lack of objectivity and by their lack of intellectual honesty.

History of Science reveals several such circumstances in which Science and human behaviours are intricately linked. This is illustrated with a case study: beginning of the nineteenth century, the question of propagation of light raised once again by light interference experiments. After a short recall of the scientific and historical background, an analysis of the correspondences between the principal characters allow to portray them quite accurately. This leads to an interpretation of the situation that the sole reading of their published papers cannot provide. And it demonstrates that paradoxically but also obviously, Science is not only built up with Science

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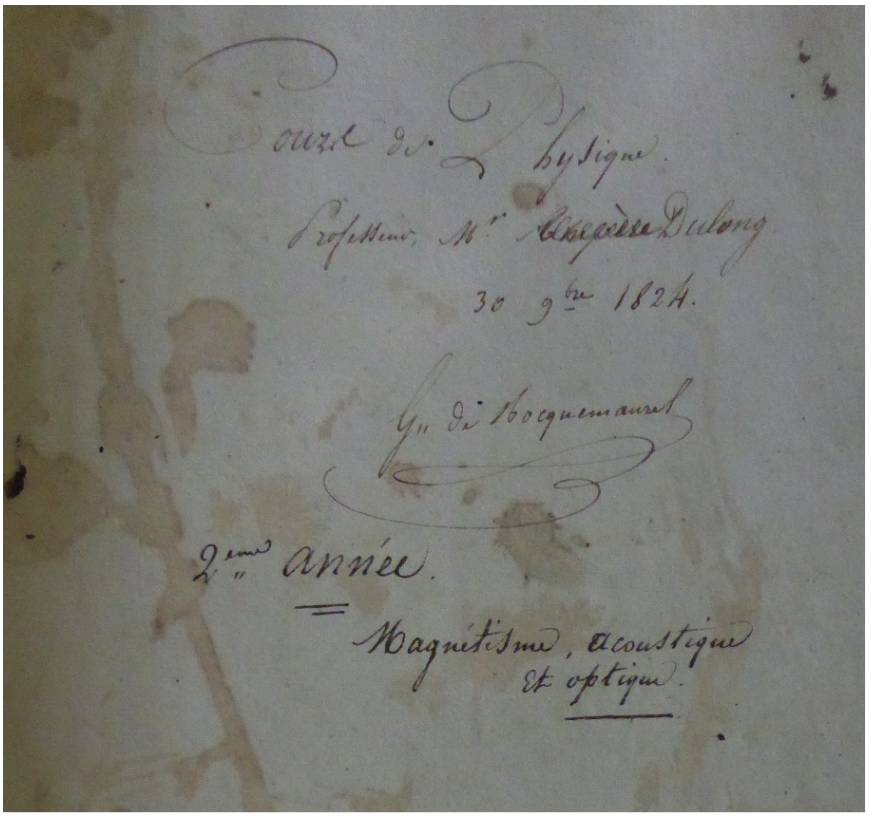
Introduction

Today, the name of Thomas Young (1773-1829) is famous and for most physicists, it is associated with light interference phenomena.[3] However, when Young made his first experiments and published them

in the *Philosophical Transactions of the Royal Society* at the beginning of the nineteenth century, he was strongly criticised and even attacked.[4] Young's conclusions about propagation of light had raised once again controversies in the scientific community. According to him, his experiments could only result from the wave system: light had to travel like a wave through an ethereal fluid. But at this time most scholars were fervent advocates of the emission theory: light consists of a stream of particles to which Newtonian mechanics can apply; these particles can travel because of attractive and repulsive forces one exerts on to the others.

About a decade later, in 1816, on the other side of the channel, Young's discovery was relayed by young French engineer and physicist Augustin Fresnel (1788-1827). Famous astronomer François Arago (1786-1853), secretary of the French Royal Academy of Science at this time, read Fresnel's first memoir and he noticed a similarity between Young's and Fresnel's experiments.[5] Then he initiated a Franco-Britannic epistolary exchange between the two scientists. And Fresnel was the winner of the Competition proposed by the French Royal Academy of Science in 1819, for his conceptions and explanations of light propagation in the wave system.[6] His demonstration was based on light interferences. As a mark of recognition, from 1821 the interference phenomenon was even included in the program of the French most prestigious school 'Ecole polytechnique'.[7] Young's experiments were taught straightaway. Young's name was mentioned several times in the lessons of optics given by Pierre-Louis Dulong (1785-1838).[8] (Figure 1) When such an event occurs, isn't it a step to celebrity?



Cours de Physique.

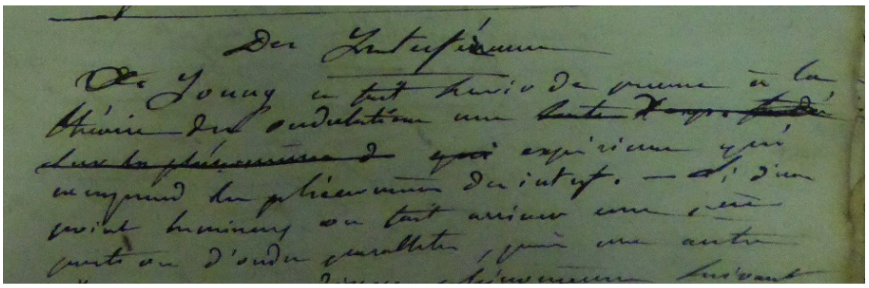
Professeur M.r Gaspard Delong

30 9.bre 1824.

Y.n de Bocquemaurel

2.ème année.

Magnétisme, acoustique
Et optique.



Des Interférences

M.r Young a fait servir de preuve à la théorie des ondulations une [illegible] sur les phénomènes [illegible] qui expliquent les phénomènes de interf. — Si d'un point lumineux on fait arriver une certaine quantité d'ondes circulaires, qui se [illegible]

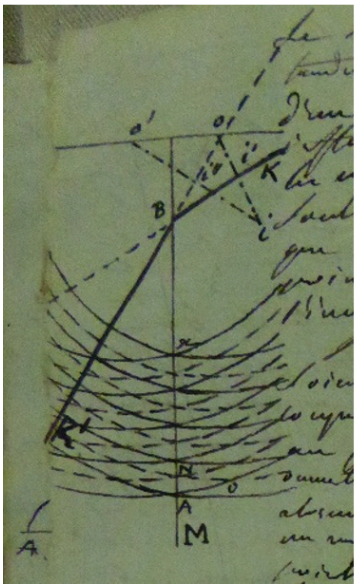


Figure 1. Lesson of Optics at 'Ecole Polytechnique' in 1824. Pierre-Louis Dulong professor of Physics. Notes taken by student Roquemaurel.Found in the Archives of the Library of 'Ecole Polytechnique'.

Fresnel was elected member of the French Royal Academy of Science in 1823, in the class of Physics. Later on, in June 1825, he became foreign corresponding member of the Royal Society and in June 1827, he was honoured with the Rumford's Medal... he died less than a month later![9] As a reciprocal political honour, in August of the same year 1827, Young became one of the eight foreign associates of the French Royal Academy of Science.[10] He passed two years later in 1829.

Astronomer John Herschel would write around 1830: 'We must not separate them and assign to each his share would be as impracticable as invidious so intimately are they blended together throughout every part of the [wave] system'.[11] (Figure 2.) The acceptance of their theory was inevitable though still a question about the speed of light in different substances had to be answered ... the *experimentum crusis* was performed in 1862![12]

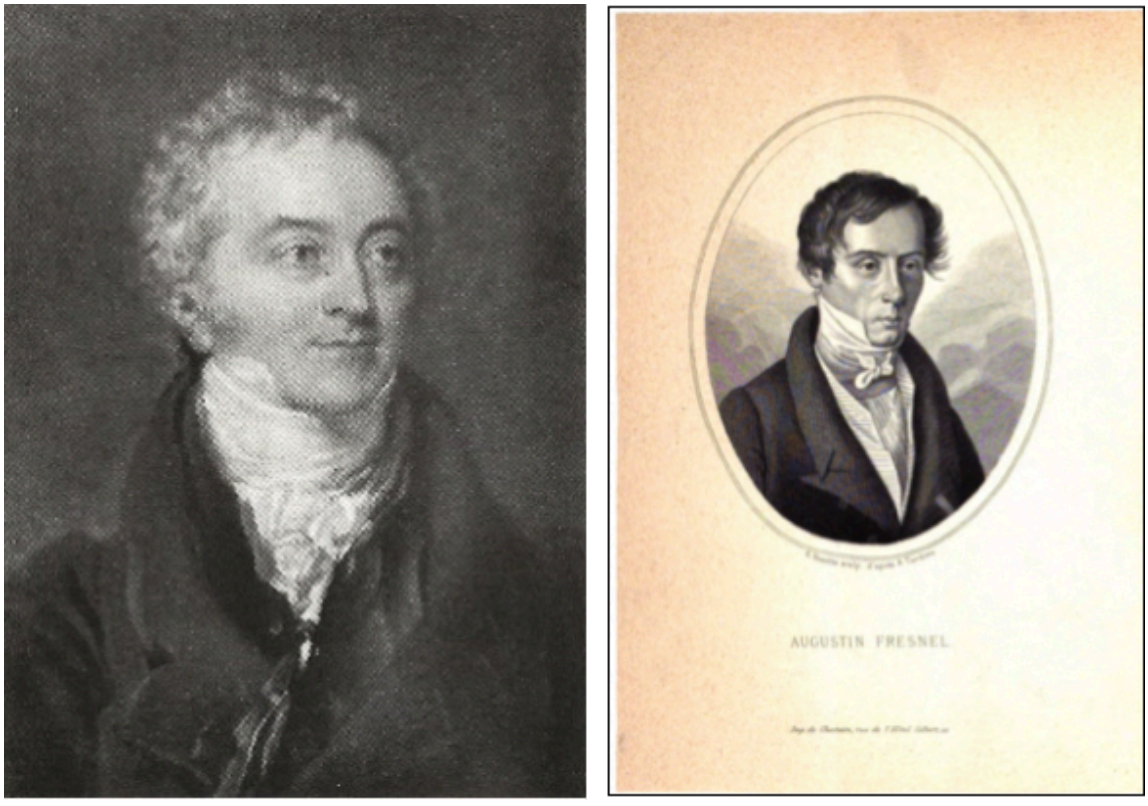


Figure 2. Thomas Young and Augustin Fresnel

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However as Arago claimed in his obituary: 'Fresnel and Young were buried without receiving any honour in their own country'.[13] Their works were published much later: Young's in 1855 and Fresnel's from 1866 about four decades after his death.[14] But this is another story.[15]

This short evocation gives a partial view of the situation. It is undoubtedly a simplification of the story since it neglects the complexity of the relationships between the characters and their psychology. Nevertheless it raises several interrogations: why was Young attacked in Great Britain? Was it really for scientific reasons? Could he have convinced French scientists by himself, without Fresnel's help and Arago's implication? Was their correspondence fructuous? Did it allow to establish a faithful collaboration between those physicists? Did it lead to Fresnel's fragile success? What were Arago's role and interest? Why were both protagonists, Young and Fresnel, if not totally forgotten for decades, not praised? And why were their works published much later? An investigation to answer these relevant questions will prove that behind this story, a variety of human feelings are hidden: revenge, hypocrisy, career, notoriety, ambition, pre-eminence, disappointment, friendship etc.

Through this case-study, about the question of light propagation, I intend to show that History of Science must absolutely be embedded in a whole social context: it must not only take into account policy or economic situation of a country, it must also consider human feelings and relationships between people among a community. A discovery must not be taken independently of this broader context. The sole analysis of the published papers provides a truncated image of the story. If available, the correspondence allows to improve this image and to understand the reasons why a theory or an invention are rejected.

The scientific background of this case-study is recalled in the first Section of this paper. In the second Section, I analyse the reception of Young's experiments and conjectures in England and I show that Young's failure to convince his peers was not only a matter of Science. Young was contacted by Arago in 1816. His welcome by the French school dominated by Pierre-Simon Laplace (1749-1827) was no more successful. I examine the principal reasons in the third Section. Once again, objections to his theory were not exclusively scientific. In the fourth Section, I recall how Augustin Fresnel got the opportunity to study optics and I analyse some of his exchanges with Young. In the following Section, I intend to clarify the role of Arago and to guess his feelings about the wave system. Finally, I draw a conclusion about the situation and the behaviour of those scientists.

Scientific Context

How does light travel, from the sun to our eyes, from a furnace, from a fire? At the beginning of the nineteenth century, most scientists, in Europe, were convinced that light propagation consisted of a stream of particles forming 'rays'.[16] Those particles follow Newton's laws of mechanics, which means that attractive or repulsive forces, expressed in terms of the square of their distances, cause their movement. This is the so called emission theory.[17] Note that Newton himself was a bit sceptical and did not attest this conception.[18]

However, with the emission theory, different phenomena discovered during the seventeenth century still remained unexplained: inflexion of light also called diffraction, double refraction and colours of thin plates... and even why did light travel with such a high speed? [19] In his *Treatise on Light* published in 1690, Christian Huygens (1629-1695) who examined the behaviour of the Iceland spar, following the interrogations of Erasmus Bartholinus (1625-1698), conjectured that light could travel like a wave.[20] Robert Hooke (1635-1703) had made the same hypothesis before him, in his *Micrographia* published in 1665 when he aimed to explain the colours of thin films or plates.[21] But as sound propagates through the air, as water waves, shaped for example when a pebble is thrown, propagate through water, light has to travel through a media: the aether. The very constitution of this media raised another question.[22] It seems that Newton had been stopped by this problem and dared not assume the existence of an aether, proper to light transmission.[23] Nevertheless, several historians of Science pretend that Newton adopted a dualistic theory, emission of particles and wave system, depending on the phenomenon to be explained.[24]

During the eighteenth century, Leonhard Euler (1707-1783) raised several objections against the emission theory, one of the principal being, how if there are many particles of light, travelling in different directions, one does not bother the others and modify their trajectory?[25] And he preferred the idea of a vibrating media.

Despite these arguments against the emission theory, the wave system was not even thought of at the beginning of the nineteenth century. Thomas Young appeared to be the first physicist to have raised once again the controversy after he had made his experiments.

At this stage, the question is why a conception or a scientific theory should be preferred to another one? Why should the emission theory of light be adopted rather than the undulatory one? Several

scholars, at the beginning of the nineteenth century, have attempted to answer this question. In order to initiate the thinking and to give a flavour of how much the answer is far from being obvious, I propose to quote three main trends which appear relevant for this paper.

First of all, according to crystallographer René-Just Haüy (1743-1822), a theory must be able to explain the different phenomena. Experiments must be linked by this theory. Scientists aim to harmonize the laws of Nature. Haüy gave his own definition of physics that he distinguished from natural sciences:

> Physics aims to know the natural phenomena and the laws that govern them. It clearly differs from natural history which reduces to a description of the organisms and a list of their characteristics which allow one to recognise and distinguish them. The naturalist compares and classifies. Unlike the physicist who gathers observations in order to tie them together into a single theory.[26]

When talking about the wave system, Fresnel adopted the same idea: 'A theory for which the basic hypothesis is true, no matter how difficult it is to represent mathematically, should provide some relations between different observations or phenomena, that would have remained unknown in the other system'.[27] But he added the notion of traducing the theory mathematically, the difficulty being not relevant.

Arago did not agree at all since he claimed: 'A mathematical law is more important than an ordinary discovery as it is by itself a source of new discoveries'.[28] A theory should be able to forecast new phenomena, and this point is subject to the possibility of traducing it into mathematical equations.

Thomas Young's Reputation in Great Britain

In this section, I propose to analyse the reception of Young's experiments and conjectures in England. Why were the critics so virulent? Were they only based on scientific considerations?

Thomas Young was undoubtedly an erudite. Though several opportunities were offered to him, promising a brilliant career as a lawyer, he chose to study medicine. He obtained his grade in 1795 from Göttingen University. Nevertheless, his publications testify that he was also involved in almost 'everything', physical sciences and mathematics, as well as philosophy, foreign ancient or modern languages, he began the deciphering of the Rosetta stone later completed by Jean-François Champollion, music and painting.[29] He wrote papers dealing with tides, atmosphere, eclipses,

spiders, bridges or grammar. He was also skilful. He did not hesitate to design by himself a microscope when, adolescent, he wanted to observe the pistils of flowers. He also invented the 'Eriometer' for measuring the average size of small particles such as red corpuscles present in the blood of several mammals. And his friend Arago did call him 'bibliothèque vivante'.[30] Although, he was not isolated from the rest of the Society. He did not live like a monk but he frequented fashionable London assemblies.

Young thought of himself primarily as a physician. The first two memoirs he wrote for the *Philosophical Transactions* concerned vision.[31] The second paper led Young to his election as a Fellow of the Royal Society the following year, in 1794: he was only twenty one. He suggested that the curvature of the crystalline lens could adapt to the distance. Experiments and mathematical proofs sustained his theory. But he was not successful in convincing people. Arago would write:

> Physiologists did not even read his paper, since it required much more mathematical knowledge than it is usually delivered in the universities. Physicists also rejected it because in their oral courses as well as in their textbooks, people ask for superficial notions within the reach of anyone and not brain consuming with difficult mathematics.[32]

In his second paper, he explained that color perception requires only the ability to discern between blue, green, and red. As a physician, Young appeared too rigorous since he wanted to explain every disorder, to check every effect of every drug he delivered to his patients, giving them the impression that he was a beginner.

Young became professor of Natural Philosophy at Cambridge University between 1796 and 1799 and at the Royal Institution of Great Britain from 1801 to 1803. It took him more than three years to write his *Lecture Notes on Natural Philosophy* which completed his courses at the theatre of the Royal Institution.[33] At the beginning of the first volume, he mentioned:

> In the department of physical optics, ..., some new cases of the production of colors have been pointed out, and have been referred to the general law of double lights, by which a great variety of the experiments of former opticians have also been explained; and this law has been applied to the establishment of a theory of the nature of light, which satisfactorily removes almost every difficulty that has hitherto attended the subject.[34]

He described and discussed in this volume the experiment named today Young's slits.[35] (Figure 3.) That is the manner in which two portions of colored light, admitted through two small apertures, produce light and dark stripes, or fringes, by their interference, proceeding in the form of hyperbolas; the middle ones are however usually a little dilated.[36]

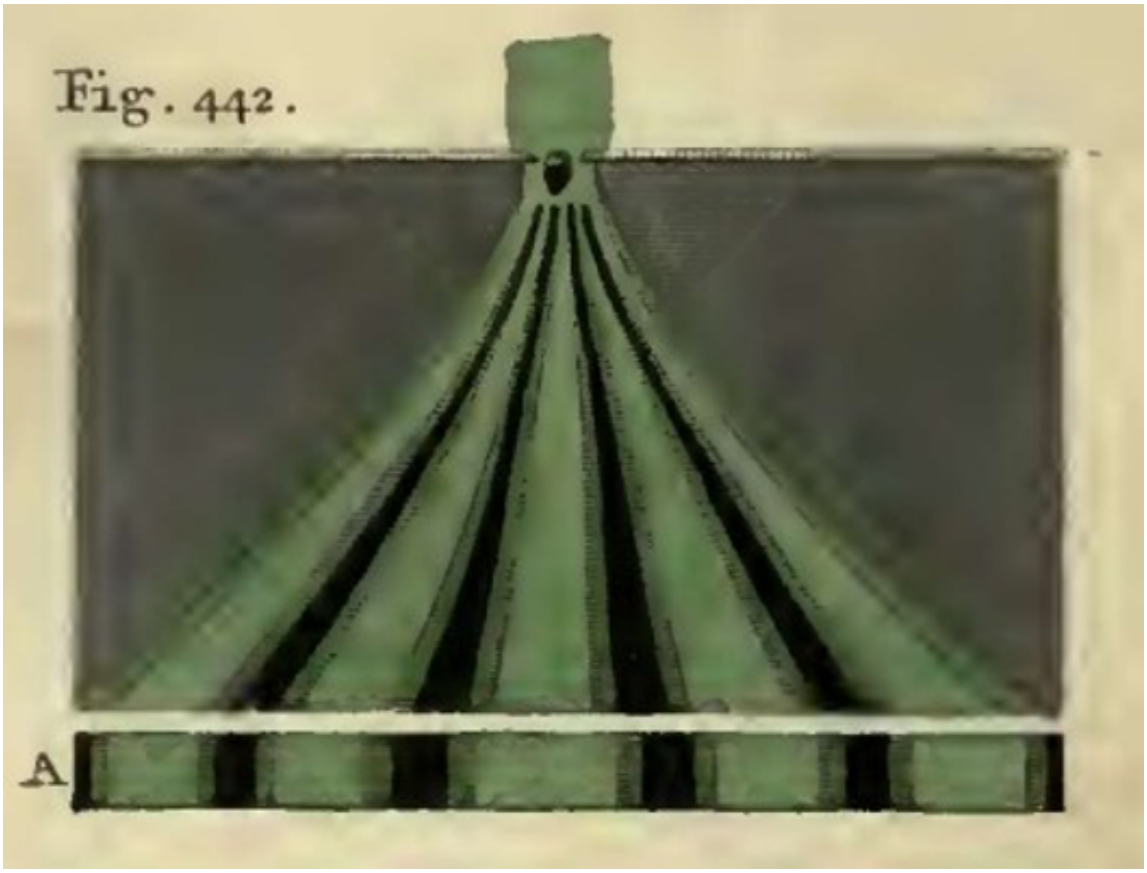

Figure 3. Light Interferences from Thomas Young, *Lecture Notes on Natural Philosophy and the Mechanical Arts*, London: Joseph Johnson, 1807. Plate XXX, Fig. 442.

Between 1801 and 1804, he published three papers related to sound, fluid and light in the *Philosophical Transactions*. In particular, he discussed the analogy between sound and light from the beginning.[37] Young's mind had already begun to grapple with the evidence to the wave theory of light.[38] His major discovery came from what Arago called a 'game for children'.[39] He was intrigued by the different colours the bubbles of soap present and he explained that they were caused by minute variations of thickness. When a tiny region of the bubble appears black, absence of light, he pretended that rays of light reflected by the outer face encounter rays reflected by the inner one and destroy them. He gave to

this conflict: the name of *interferences*. And this famous sentence from Arago: 'Who could have ever imagined that light added to light could result into darkness? '.[40] Young concluded that this phenomenon would be impossible if light travelled as streams of particles. He concluded that the wave theory was the only suitable explanation.

In spite of his calculations and in spite of his measurements which were rigorously transcribed in his papers, in 1804, Henry Peter Brougham (1778-1868), editor of the *Edinburgh Review* strongly attacked him. Most historians of Science concluded that since Lord Brougham was a fervent advocate of the emission theory of light, these critics were due to Young's wave conception.

The periodical was launched in 1802. The learning of the new journal, its talent, its spirit, its writing and its independence were all new.[41] Moreover, the editor was known as a scientist, he had published three articles in the *Transactions*, articles related to optical sciences and mathematics.[42] It seems that at this time, as a politician he had already reached a pretty high position.[43] The public not only admired the periodic but trust the writings. Three articles appeared in the *Edinburgh Review,* between 1802 and 1804, revising Young's contributions. Though anonymous, Young traced them to Brougham and Brougham himself never contested. These were some of the words in the first article about Young's first Bakerian Lecture:

> As this paper contains nothing which deserves the name, either of experiment or of discovery, and as it is in fact destitute of every species of merit, we should have allowed it to pass among the multitude of those articles which must always find admittance into the collection of a Society which is pledged to publish two or three volumes every year.[44]

The second article criticised Young's paper 'On the Theory of Light and Colours':

> We cannot conclude our review of these articles without entreating, for a moment, the attention of that illustrious body, which has admitted of late years so many paltry and unsubstantial papers into the Transactions.[45]

And the third article was about Young's third paper 'An account of some cases of the production of Colors not hitherto described':

> We now dismiss for the present, the feeble lucubration of this author, in which we have searched without success for some traces of learning, acuteness, and ingenuity that might compensate his evident deficiency in the powers of solid thinking, calm and

> patient investigation, and successful development of the laws of Nature, by steady and modest observation of her operations.

With that conclusion: 'From us, however, he cannot claim any portion of respect until he shall alter his mode of proceeding or change the subject of his lucubration'.[46]

Arago would write about this attack: 'the erudite, the writer, the mathematician, the experimenter, was attacked with such a vehemence, with such a bitterness of expression nearly impossible to find in scientific debates'.[47] Unfortunately, the audience adopted the reporter's claims. And Arago concluded: 'When they are written by people who are known in the field, the scientific newspapers have a dreadful impact on certain things'.[48]

The revenge

Clearly, Brougham was an advocate of the emission theory of light. But did he provide any constructive comments on Young's scientific procedure? He contented himself with some gratuitous and abject remarks. No one in the public, except scientists, would verify and would be encouraged to look at the papers. So is it possible that the critics were not scientifically founded? Actually, they might be a revenge which have had a dramatic impact on Young's career and notoriety.

In 1800, Young published an essay in the *British Magazine* about cycloidal curves.[49] In particular, he referred to a paper printed in 1798 in the *Philosophical Transactions*. He wrote:

> When we see an author exerting all his ingenuity in order to avoid every idea that has the least tincture of geometry, when he obliges us to toil through immense volumes filled with all manner of literal characters, without a single diagram to diversify the prospect, we may observe with the less surprise that such an author appears to be confined in his conception of the most elementary doctrines and that he fancies he has made an improvement of consequence, when in fact he is only viewing an old subject in a new disguise.[50]

Though he did not name the author, he gave some hints:

> [...] and its equation is to be found in a work no less common than Emerson's Fluxions, nearly in the same form as that which is published as new, in the ***Philosophical Transactions*** for 1798. We find in the same paper a new method for dividing an elliptic

> area in a given ration; but the curve which the author calls a cycloid is the companion of a trochoid, and is only a distortion of the figure by which Newton had very simply and elegantly solved the same problem.[51]

Young went on with sarcasms. In fact, he was advocating the use of geometry rather than calculus. He even dared denounce the French mathematical school in such words:

> To say nothing of the needless encumbrances of new methods of variations, of combinatorial analysis, and of many others similar innovations, the strong inclination which has been shown especially on the Continent, to prefer the algebraical to the geometrical form, of representation, is a sufficient proof, that, instead of endeavouring to strengthen and enlighten the reasoning faculties [...] at best only serves the office of a book of tables, in facilitating computations, but which often fails even of this end, and is at the same time the most circuitous and the least intelligible.[52]

Brougham could be annoyed and he certainly waited for a revenge.

Young's behaviour

Young joined Emmanuel College in 1797. He was admitted as a Fellow Commoner on 18 March 1797, privileged to sit at the same table with the Fellows, and to enjoy their conversation.[53] When the Master introduced him to his tutors, he said: 'I have brought you a pupil qualified to read lectures to his tutors'. [54] About his behaviour, the Tutor of the College at this time reported:

> In his manners he had something of the stiffness of the Quaker remaining; and though he never said or did a rude thing, he never made use of any of the forms of politeness. Not that he avoided them through affection: his behaviour was natural without timidity, and easy without boldness. He had a few friends of his age. They did not like to admit the superiority of anyone in ***statu pupillary*** and he would not converse with anyone but as an equal.[55]

Young seemed to be too frank and he had neglected diplomacy in human relationships. He was self-confident. Although he was an erudite, very clever, this behaviour might have annoyed several scientists. Despite his response to Lord Brougham, Young had not and never been able to gain success in England.[56]

Young and the French school

Summer 1798, Young wrote to a friend of him that he had read some works of the contemporary French and German mathematicians:

> I have been studying not the theory of the winds, but of the air, and I have made observations which I believe are new. Several circumstances, unknown to the English mathematicians which I thought I had first discovered, I since find to have been discovered and demonstrated by the foreign mathematicians; in fact Britain is very much behind its neighbours in many branches of the mathematics; were I to apply deeply to them I would become a disciple of the French and German school; but the field is too wide and too barren for me.[57]

And to another friend: 'I am ashamed to find how much the foreign mathematicians for these forty years have surpassed the English in the higher branches of the sciences'.[58]

He had the opportunity to know the French mathematical school and he was rather aware of its advance, compared to the English school. Dynamics was dominated by the analytical tradition of eminent mathematician Joseph-Louis Lagrange (1736-1813), according to whom the subject was reduced to a matter of mathematics only. Pierre-Simon Laplace (1749-1827) reacted against this approach and returned instead to the earlier Newtonian tradition with the notion of force as one of the irreducible element of the subject. His name is associated with the mechanico-molecular tradition in physics.[59]

Young's attempt to convince French scientists 1817

After Arago and Gay Lussac's visit in London in 1816, Young felt he had a new opportunity, he could convince French scientists about the wave system. Could he really succeed? Was the French school entirely objective?

At this time, French scientific community was undoubtedly led by Marquis de Laplace. He was pretty respected because of both his political and academic positions. He could adapt to the different political regimes, French Revolution, first Empire or Monarchy and therefore he has never been bothered.[60]

Unfortunately, Laplace was one of the most fervent advocate of the emission theory of light.[61] He had presented his philosophy entitled *Système du monde* which was absolutely coherent with Newtonian

mechanics: every object in nature, from giant star to minuscule particle, follows the gravitation law. And every new discovery was to be consistent with this theory.[62] *A forciori,* every newly discovered light phenomenon was to be interpreted with respect to the emission theory. Another reason favoured this theory: it could be easily translated to analytical equations, preferred to geometry at this time. And this was very important especially in the French academic community.

Young decided to send a letter to Laplace in 1817. But prior to this, he wanted Arago to give him some advice.[63] This was a friendly letter ending with compliments to Mrs Arago and Mrs Biot he had certainly met in Paris. French physicist Jean-Baptiste Biot (1774-1862), was a fervent follower of Laplace.[64]

Laplace replied in French, rather quickly, in October 1817.[65]

First of all, in order to close the subject definitively, and to insist on the fact that a demonstration had to be made using the tools of calculus rather than with those of geometry, Laplace wrote:

> Though ingenious, I can only consider your demonstration as an outline and not as a geometrical proof. I still believe that up to now, the problem of wave propagation when they travel through different substances has never been solved and it is far beyond the potentials of calculus.[66]

To be more precise, the discussion was about Snalus law of refraction that Young wanted to retrieve within the undulatory framework. Laplace adopted a disdainful attitude, but this was his usual manners. He claimed that thanks to Newton, a mathematical explanation of the phenomenon had already been made.

> Hence, the conjectures (about light) made by Descartes as well as several insights from Kepler about the system of the world, have been verified by calculus: but the value of the discovery of a certainty belongs entirely to whom proves it; I admit that some new light phenomena are still very difficult to explain; but after studying them very carefully, in order to discover the rules that govern them, someone would discover that new properties are hidden in the particles of light that will provide a mathematical explanation. From the phenomena, one has to look back to the laws, and from the laws to the kinetic forces, this is as you know it, the right way Natural Philosophy should proceed.[67]

Full stop! Laplace had other concerns such as probability theory, the length of the pendulum etc. and he ended his letters skipping to these questions.

Young's reaction

Young seemed very annoyed by Laplace's answer. As a matter of fact, Sir David Brewster (1781-1868) reported to Young:

> When I mentioned to Mr Biot, about a year ago, your demonstration, that the undulation propagated through a minutely stratified substance, in which the density is greater in one direction than in another, was spheroidical, he replied that both Laplace and Poisson were of opinion that, in the present state of mathematical analysis, the simplest case of undulation could not be calculated; and therefore that the above theorem was not capable of demonstration.[68]

And attesting his consideration, he followed: 'I am exceedingly interested on this point and am therefore anxious to know if you are yourself satisfied with the accuracy of the demonstration'.[69]

Less than one month later, Young replied:

> I conclude that Mr Biot had the candour to tell you that he had read none of my papers whatever: he promised me that he would attempt it in the course of the summer, but I dare say he has not found leisure. Mr Laplace has now arrived at so happy a pre-eminence in science that he thinks it sufficient to assert where others would assign their reasons; and having once asserted, he is not very impatient to retract.[70]

And about his demonstration of Snalus' law of refraction, Young contested: '...instead of admitting it [my demonstration], or endeavouring to point out its deficiency, he tells me that it is only an 'aperçu', a sketch, or a presumption'.[71] Note that Huygens had performed such a demonstration in his *Treatise on Light*.[72] Young concluded that he did not want to spare more time 'entering in any further controversy on such a subject with such a person'.[73] And even, he argued: 'With respect to Mr Poisson, when we know how repeatedly and how deeply he has committed himself in praising and in imitating some of Mr Laplace's least successful speculations, we cannot be surprised at his bearing him out on this point'.[74]

Brewster reported in a letter to Young that Biot would have told him: 'Any experimental law of double refraction that I had discovered must be erroneous unless they agree with those given by Laplace'.[75]

Supremacy and pre-eminence! Laplace was the leader of the French school. He had a strong power. And most French scientists, if they aimed to succeed in their career, had to follow him and to agree with his philosophy not to be rejected. And even if they did not agree, they had to show that he was right. Malus' behaviour is emblematic of the community Laplace had created. Either you belong to it or you are excluded. That means that debates are not welcome. And Science becomes like a dogma or a belief. Young might have been naïve to believe that his ideas would be examined with objectivity.

Malus price

In 1809, Etienne-Louis Malus (1775-1812) was the winner of the competition proposed by the French Institute. The subject concerned double refraction and aimed to provide a mathematical theory of this phenomenon. But when Malus observed a peculiar modification of light behaviour after reflection by a glass window, for a certain angle of incidence, in order to be consistent with the emission theory, he imagined that the particles of light reacted like small magnets. This is the reason why he named this phenomenon *polarisation*. Because of the apparition of poles after reflection, they adopted a same direction.[76] Malus became a member of the 'Société d'Arcueil', a private association created by chemist Claude-Louis Berthollet (1728-1822) and by Laplace. People would meet regularly at the house of Berthollet in Arcueil, a suburb situated in the south of Paris, where they would discuss about science. Malus was elected member of the French Institute on 13 August 1810 and then he was honoured with the medal of Rumford.

Young was well aware of these experiments and he even reviewed Malus' work.[77] He also wrote a short paper about Malus' life.[78] Concerning the Rumford Medal, Young commented:

> It has been creditable to the Royal Society to have conferred this distinction in the time of a war between the two countries; but if any credit were due for only doing justice conscientiously, it would attach, on this occasion, to those members of the Council, who saw their own optical speculations in great danger from the new mass of evidence, which appeared likely to overthrow them, at least in the public opinion, and who were still the most active in offering this tribute of applause to the more fortunate labours of a rival.[79]

And he laughed at the promotion Malus obtained in his own profession as a military man. 'And this not for services performed in the field, nor even in a difficult and dangerous expedition to unknown regions, but for experiments made with safety and tranquillity in his own closets'.[80]

Young's comments about Laplace's works

As Young was foreign secretary at the Royal Society, he had to examine and comment the foreign writings. He also knew the 'Société d'Arcueil' and he dared give his own opinion about this community.[81] He published some comments about Laplace's works related to optics.[82] In 1809, he had analysed Laplace's manuscript about double refraction. Let me quote the very first sentence of this review:

> The few who have arrived, in the different departments of learning and science, at such a degree of eminence, as to be almost without a second or without a judge, have not only the advantage of being able to propagate real knowledge with uncontrolled authority, but also the less enviable prerogative of giving to error the semblance of truth, whenever accidental haste or inattention may have led them into those inaccuracies from which no human intelligence can be wholly exempt.[83]

And Young added that the critic must:

> watch with redoubled care the steps of those who are the most likely to lead other astray if they happen to follow a wrong path: and while the ultimate decision always remains with the public, as with a jury, the judge is bound to state, as fully and impartially as possible, the whole mass of the evidence before him; not fearing to adduce all such reasoning as can tend to the support of the weaker side, when there is any danger of its being oppressed by the authority and respectability of the stronger.[84]

He was well aware that Laplace read the *Transactions* as he mentioned it and even though he attacked him for his perseverance on calculations 'presuming that the principles, on which they were founded, were capable of being applied, with greater precision to the phenomena in question…'.[85] He employed the expressions 'hasty adoption of a general law without sufficient evidence' and even 'inversion of the method of induction equally unwarrantable with any of the paralogisms of the Aristotelian school' and he concluded that Laplace was: 'not allotting to the observations of different authors their proper share of originality'.

Want of candour... In this last sentence, Young referred to Wollaston's publications for 1802 that he considered to transcribe 'the most accurate experiments' of double refraction in crystals and atmosphere.[86] He continued:

> But it seems to be one of the attributes of a great nation to disregard, on all convenient occasions, the rights of its neighbours. [...] Who is capable of directing public opinion on subjects respecting which very few will form an opinion of their own, as a philosopher like Mr Laplace whose works are sure of commanding universal attention, and almost sure of inforcing implicit belief? [..] Mr Laplace has been a little superficial in his arguments and extremely precipitate in his conclusions... rage for abstraction.[87]

Young clearly preferred geometrical methods with sketches rather than algebra and calculations

About the extraordinary refraction and Laplace's comments, he wrote:

> A Turk laughs at an Englishman for walking up and down a room when he could sit still; but Mr Laplace may walk about, and even dance, as much as he pleases, in the flowery regions of algebra, without exciting our smiles, provided that he does no worse than return to the spot from which he sat out: but when in the rapidity of his motion, his head begins to turn, it is time for the spectators to think of their own safety.[88]

Therefore in those conditions, Young had no chance to convince French scholars. Arago claimed in his obituary:

> A physicist is glorious when he can announce some astonishing result far from common ideas; but he must, quickly, follow it with proofs (mathematical) otherwise he risks to be assimilated to those oriental writers that charmed the Sultan Schahariar for thousand and one nights with their fantastic daydreams.[89]

And several decades after his death, people could still think that his demonstrations were not in the trend of French scientists, not rigorous enough for them. French physicist Émile Verdet would write in 1866, in his introduction to Fresnel's works:

> Young has neglected the art of presenting his discoveries. He contented himself with a rough explanation of the phenomena without comparing rigorously the experiments to the theory, which would have been the unique manner of guarantying the truth. The

> interferences between the two rays of light was due to a mysterious phenomenon, as mysterious as the inflexion of light in the shadow of bodies impervious to light that his predecessors had observed, and the advocates of the old system [emission] could attest that the interferences were a particular case of diffraction.[90]

But this is not the only reason why Young was rejected by the French school. Laplace had certainly feelings of rancour against him. Hence, it might not only be a question of science, because even for the emission theory, with a mechanistic approach, the mathematical formalism failed to explain every phenomenon.

Augustin Fresnel's opportunity to study optics

Augustin Fresnel joined the 'Ecole Polytechnique' in 1804, he was only sixteen years old, after a selective exam in mathematics. This school was created in 1794, just after the French Revolution, to gather the most brilliant young men and deliver a high level in sciences especially in mathematics. They would be the elite of the Nation.[91] Professors were eminent scientists. Arago had also studied in this prestigious school between 1803 and 1805. There was an 'esprit de corps' between the students. This has to be underlined because when Arago received Fresnel's memoir, he certainly wanted to encourage and to support him. But as I shall discuss in the next section, the thoughts of Arago about light propagation were ambiguous.

After his studies, Fresnel became a civil engineer. He was in charge of building roads in the Alps, bridges in Paris, Lourcq channel, Cherbourg harbour.[92] In France, he was said to be the inventor of 'Fresnel's lenses' for lighthouses.[93] But in 1814, he participated to a demonstration in La Palud (Normandie) and he was fired for a while. Feeling weakened, he was obliged to stay at home. He took benefits of that spare time to study…optics. Because he had heard of polarisation of light, he asked his uncle to provide the most recent writings on the topic. Then he started to study light inflexion.

Fresnel was not a scholar so that he could examine the question with an independent mind. He was not obliged to adopt a preconception. He needed neither to please nor to convince anybody. He owned the privilege to be independent and hence free. He sent a first memoir to the 'Institut de France' in 1815. And according to him, the inflexion of light could only be explained in the wave system.

Arago who was secretary, examined it and noticed a similarity between Young's experiments about interferences and Fresnel's about diffraction, experiments which seemed absolutely inconsistent with

the emission theory of light. With his friend chemist Gay-Lussac, they decided to meet Young in London. Then, they aimed to initiate an epistolary relationship between Young and Fresnel.

The relationships between Young and Fresnel

A series of letters is provided in both Young's works and Fresnel's: ten letters written by Fresnel (first dated 24 May 1816 and last 4 September 1825) and five letters from Young (first dated 16 October 1819 in French and last 18 June 1827 in English).[94]

Clearly, Fresnel tried to find an ally while Young claimed the priority for his discovery and its anteriority. Furthermore, Young went to Paris in 1817 but he did not meet or even tell Fresnel.[95] They never took the opportunity to meet. Also as I had mentioned it in the previous Section, Young had written to Laplace in 1817, without consulting Fresnel as if he wanted to act alone.

In the first letter Fresnel addressed to Young, the French scientist wrote that he did not know about Young's experiments before Arago had told him. Then, he had decided to delate some parts of his memoir concerning diffraction, a slight correction he had made about coloured fringes excepted.[96] He was aware that there were few new experiments in his memoir. But he was proud to have met such an eminent scientist.

> Though I have not the advantage of being the first, it comforts me to have met such a scholar who has enriched physics with so many significant discoveries, and at the same time, it contributes to increase my conviction in the theory I have adopted.[97]

In July 1816, Arago sent Young copies of Fresnel's memoir, with the mention of Young's anteriority for the interferences.[98] Though it is worth noticing that the experiment made by Fresnel was slightly different: instead of using two slits which caused diffraction phenomena because of their edges, as most scientists reproached to Young, Fresnel used two mirrors in order to observe interferences only. This is beyond the scope of this paper. In the same letter, Arago announced that he had also inserted in the *Annales* two notes referring to Young's contributions in the *Transactions of the Royal Society* for 1803. This was a step to knowing Young in France. And he concluded:

> I cannot imagine how the advocates of the emission theory of light could explain the curved trajectories of the diffracted strips; I guess they will doubt about this fact or even they will not talk about it at all, in order to follow the path they have chosen. [...]

> If the enormous book just published by Mr Biot, entitled ***Treatise of Experimental Physics and Mathematics*** has already been translated in English, you would have noticed how pathetic are his arguments to prove, against your opinion, that a ray of light can never impact another one.

Arago and Biot were friends, at 'Ecole Polytechnique'. They had participated to the measure of the meridian in the Pyrénées and around 1811, they had experimented together chromatic polarisation. Their friendship would have been probably broken if Biot had ever known![99] Otherwise, this would mean that Arago showed a kind of hypocrisy.

Young replied to Arago on 12 January 1817:

> I am sincerely delighted with the success that has attended Mr Fresnel's labours, qa I beg you will tell him; and I think some of his proofs and illustrations very distinctly stated; but I cannot fully adopt your expression in the letter…that his memoir may be ***considéré comme la demonstration de la doctrine des interferences*** for neither I nor any of those few who were acquainted with what I have written can find a single new fact in it of the least importance: nothing certainly half so important as your experiments of the colours seen in transmitted light … Now you are well aware that this was known to Newton himself.[100]

He followed:

> Mr Fresnel has repeated some of Mr Dutour's experiments on small cylinders, and has very truly observed that the spectra move with the cylinders. This was the reason that I never considered these experiments as of any value, the circumstance having been noticed by several authors, and, among the rest by Mr Brougham in 1796.[101]

And we know how much Young hated Lord Brougham! Certainly, Fresnel had never known this comment as he had still considered Young as a collaborator and trust him. Was Young jealous? Did he initiate a kind of competition when he wrote to Laplace? Fresnel was not aware of it. He thought it was rather a sincere teamwork.

Fresnel was elected member of the French Royal Academy of Science in 1823, in the class of Physics. He was very upset since he was the second in the list, the first being Dulong. He addressed a letter written in French to Young on 18 February 1823. He claimed his disappointment in such words: 'Sir,

you see that I have not been lucky with the wave theory; nevertheless, I do not give up and I follow my research in Optics with even more enthusiasm'.[102]

One of the remaining question would be to examine the reasons why Fresnel won the Competition in 1821. The price was unanimously given, though in the selection committee there were Laplace, Poisson, Biot, Arago... Fresnel transcribed the interference phenomenon into mathematical equations and then, he could deduce the explanation of diffraction. A taste of it is displayed. (Figure 4.)

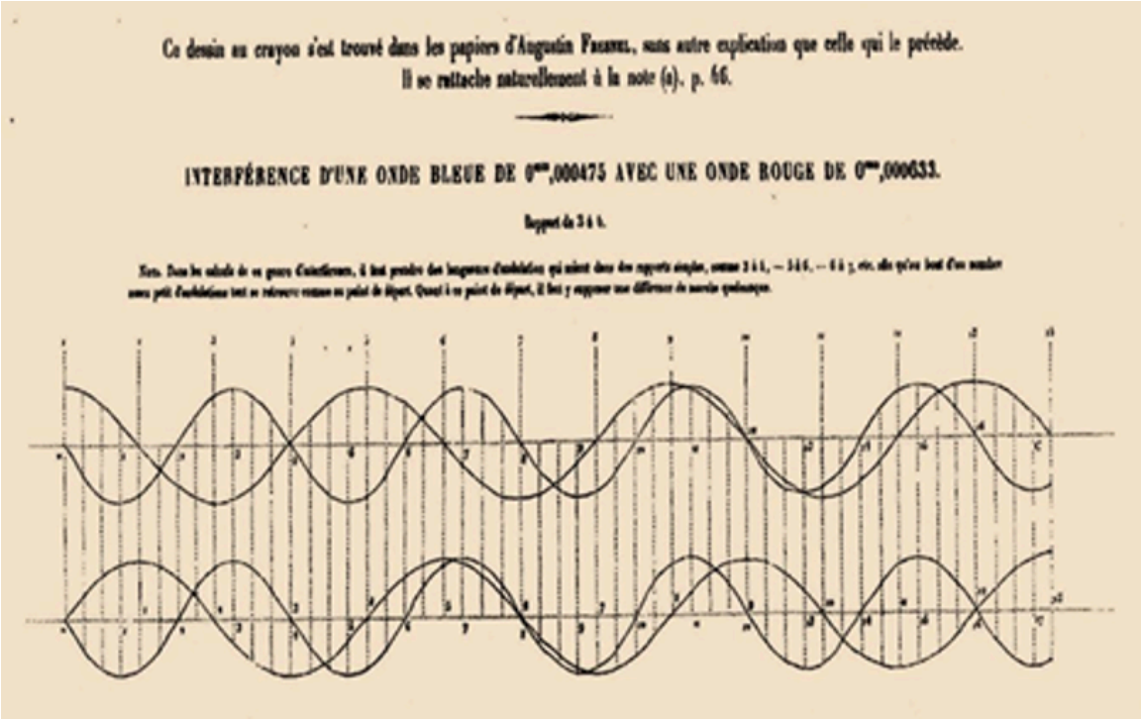

Figure 4. Fresnel's representation of the interferences between a blue and a red light. This illustration was found in Fresnel's notes with the manuscript of his memoir 'De la lumiere".

He conjectured the structure of the ethereal fluid, the way the wave travelled and he could retrieve the different optical phenomena. It is well known that when Simeon-Denis Poisson (1781-1840), member of the selection committee, had predicted the intensity of light at the centre of the shadow of a disc, as a consequence of his mathematical settings, Fresnel could display the result with his experiment. In 1818, Fresnel had reported to his brother Léonor: 'I talked to Poisson recently and he confessed that the Newtonian theory needed too many hypothesis so that it reduced its faith in it'.[103] Though Poisson and Arago seemed to follow their mentor Laplace, they seemed to doubt about the emission theory of light.

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Fresnel convinced or 'seemed to convince' because of mathematics. Rigorous analytical proofs sustained his experiments and his conception. He calculated the distances between the fringes, but also where the different intensities of light from bright to dark appear. He also calculated the pattern for any number of light rays etc. In order to determine the intensity of diffracted light, Fresnel used integrals formula.

Poincaré reported that Laplace had said that the wave theory was too complicate for mathematics, therefore it could not be true. And Fresnel would have replied: 'Nature does not care about mathematics!'[104]

Arago's Thoughts

In 1818, Arago confessed to Young that he was a proselyte of the wave system.[105] He seemed not to be shared any longer between both conceptions: emission theory and wave system. He thought of his own career and this might be the principal reason why he dared not attempt to declare that in France. Nevertheless, he wanted to keep an eye on Fresnel's work. He advised him and he provided the necessary devices for his experimentations. But he did not publish a single paper about the wave theory of light.

Arago started to care about the speed of light around 1830: how to estimate speed in the air and compare it to speed in the water. This would allow to decide definitely between both theories.[106]

Conclusion

Throughout this paper, I intended to demonstrate that a variety of human behaviours and a variety of human feelings could have a drastic impact on Science. Or to be more precise, on scientific choices. I have considered a particular controversy, for which the common conclusion seemed obvious. But I have adopted another point of view to show that the winning conception was not only a matter of Science. Even if in this case, there was no financial challenge, career, revenge, rancour, jealousy, hypocrisy, disappointment, scandalmongering, friendship have certainly altered the rationality which was required to take a decision, and if no decision could be taken in the time period, because the *experimentum crusis* was lacking, at least Young and Fresnel could have been considered much better during their life.

Young was dishonoured in his own country by Brougham. This broke his career. But it was not only due to his conceptions about light propagation. It might have been a revenge. And the question still remains: did Young break Brougham's scientific career with his critics and his lack of diplomacy? On the other side of the channel, Laplace was the leader of the French School. Either a scientist followed his conceptions: he could be admitted in the community, for example in the very private circle 'Société d'Arcueil'. He could gain protection and help in order to embrace a nice career. Or he did not share the mentor's ideas and he could not pretend to any recognition. Young tried to act on his own, though he had asked Arago's advice. He expected to gain Laplace's goodwill as a scientist thinks that his sole experiments and reasoning could convince or at least arouse a certain interest. Instead, Laplace reacted with condescendence. And the British physicist could not have been successful in France without Fresnel's contribution... and Arago's support. He needed an intermediary able to adapt his discoveries to the scientific French spirit prevailing during the nineteenth century. The experiments had to be sustained by mathematics and particularly by calculus, and analytical demonstrations. And Fresnel could do it as a former student at the 'Ecole Polytechnique'. But Fresnel based his entire theory on the interferences of light and Young was the discoverer of this phenomenon. Fresnel was independent and did not enter in those considerations of pleasing anybody. He was a scientist as Poincaré defined it. But even if he won the Competition of the French Royal Academy of Sciences, he was neither elected the first in 1823 nor accepted to be professor of Physics at 'Ecole Polytechnique'. He was so disappointed. Dulong was preferred though as Fresnel mentioned it, he could have been elected at the Academy as a chemist. Fresnel was naïve thinking that he could be admitted in the community. He certainly expected an academic recognition. Concerning Arago, he had his career to care of, and he did not mean to participate to the controversy, which would have irritated his mentor Marquis de Laplace. Soon he will break with his friend Biot. He supported Fresnel as if he dared not give his own opinion. He stayed on the backstage.

Surprisingly or not, let me point out that Laplace passed in 1827, the year Fresnel died. That same year, Young was elected as foreign associate of the French Royal Academy. Arago started to think about a proof of the wave system: speed of light should be slower in water than in the air. This experiment was made about thirty years later. And as Arago became blind at the end of his life, he left young Foucault make it.

Acknowledgements

I would like to thank Mr Olivier Azzola, in charge of the Archives at the Library of 'Ecole polytechnique', for his fructuous help.

Footnotes

[1] Henri Poincaré, *La Valeur de la Science*, Paris: Bibliothèque de Philosophie scientifique, Flammarion, 1905, p. 1. The French sentence is: 'La recherche de la vérité doit être le but de notre activité [la science] ; c'est la seule fin qui soit digne d'elle'.

[2] Poincaré, op. cit. p. 3. The French sentence is: '... il faut s'efforcer d'affranchir complètement son âme du préjugé et de la passion, il faut atteindre à l'absolu sincérité'.

[3] Alexander Wood, *Thomas Young Natural Philosopher*, Cambridge: Cambridge University Press, 1954.

[4] Thomas Young, 'Outlines of Experiments and Inquiries respecting Sound and Light', *Philosophical Transactions* for 1800, in a letter addressed to Edward Whittaker Grey, read January 6 (1800); Thomas Young, 'On the Theory of Light and Colors', *Philosophical Transactions* for 1802, a Bakerian Lecture read November 12 (1801); Thomas Young, 'An account of some cases of the production of Colors not hitherto described', *Philosophical Transactions* for 1802, read July 1 (1802). These three memoirs can also be found in George Peacock D. D., *Miscellaneous Works of the late Thomas Young*, Vol. 1, London: John Murray, Albemarle Street, 1855, pp. 64-98, pp. 140-169, pp. 170-178 respectively.

[5] The French Royal Academy of Science was closed by the National Convention on 8 August 1793, then the 'Institut de France' opened on 26 October 1795. When the Monarchy was re-established in 1816 (King Louis XVI) the old name was reused on 21 March 1816.

[6] 'Procès –Verbal, March 17th 1817 of the French Royal Academy of Science', *Annales de chimie et physique*, Vol. 4, Paris: Crochard, 1817, p. 303. Physicist Jean-Baptiste Biot (1774 - 1862) and famous Pierre-Simon Laplace (1749 - 1827) announced this Competition in Physical Sciences for 1819. The subject concerned diffraction (also called inflexion) of light. Fresnel gave explanations about this phenomenon but moreover he fixed several principles about propagation of light in the wave system. Augustin Fresnel, 'Mémoire sur la diffraction de la lumière, couronné par l'Académie des Sciences', *Œuvres Complètes*, Vol. 1, Paris: Imprimerie Impériale, 1866, pp. 247 – 364.

[7] Carole Esther Nahum, 'Teaching physics to adolescents in France during the second half of the eighteenth century', *Journal of the History of Education Society*, Vol. 51, Issue 4, 2022, pp. 453-478. The historical context and the circumstances which led to the creation of the 'Ecole polytechnique' are analysed. This school opened on 26 November 1794. 'Programme de l'enseignement de l'École polytechnique pour l'année scolaire 1821-1822', Paris : Imprimerie Royale, Décembre 1821, p. 36.

[8] Dulong is generally associated with Petit (1791-1820). They are known for their works in chemistry, relative to heat. For example, see Alexis-Thérèse Petit, Pierre-Louis Dulong, 'Recherches sur quelques points importants de la théorie de la chaleur', *Annales de chimie et physique*, Vol. 10, Paris: Crochard, 1819, pp. 395-413. In 1820, Dulong became professor of Physics at 'École polytechnique' replacing his friend and collaborator.

[9] Peacock, op. cit., p. 408. This announce was made by Young in a letter addressed to Arago dated 29 March 1827. A few months later, on 18 June 1827, Young would write to Fresnel who passed on 14 July.

[10] Peacock, op. cit., p. 410. A letter dated 6 August 1827 from Arago announced to Young this good news.

[11] Wood, op. cit., p. 204.

[12] William Tobin, *The man who proved the World turned round*, Cambridge: Cambridge University press, 2002. (French adaptation James Lequeux, *Léon Foucault*, Les Ulis: EDP Sciences, 2002).

[13] François Arago, *Éloge historique du Dr Thomas Young*, 1832, p. c. Arago read this obituary before the French Academy of Science in 1832, on 26 November, three years after Young's death.

[14] Peacock, *op. cit.*; Fresnel, *Œuvres Complètes d'Augustin Fresnel*, Paris: Imprimerie Impériale, Vol. 1, 1866, Vol. 2, 1868, Vol. 2, 1870.

[15] Crystallographer Henri de Senarmont (1808 – 1862) had started gathering Fresnel's articles. He was followed by crystallographer Emile Verdet (1824 – 1866) who achieved the publication. Both of them had been professor of physics at 'Ecole polytechnique'.Young was rehabilitated in England for his works about the human perception of colours. In his paper devoted to colours, James Clerk Maxwell referred several times to Young's works on vision. James Clerk Maxwell, 'Experiments on Colour, as perceived by the Eye, with remarks on Colour Blindness', read 19 March 1855, *Transactions of the Royal Society*, 1857, p. 279, p. 283, p. 288. He speaks of Young in laudatory terms: 'Young, who made the next great step in the establishment of the theory of light, seems also to have been the first to follow out

the necessary consequences of Newton's suggestion on the mixture of colours…', p. 279. It seems that in 1852, H. Helmholtz and even J. D. Forbes from 1849, had quoted the name of Young. H. Helmholtz, 'LXXXI On the theory of compound colours', *The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science*, Vol. 4, Issue 28, 1852, pp. 519-534; J.D. Forbes, 'Classification of Colours', *Philosophical Magazine*, Series 3, Vol. 34, n^{o} 228, 1849, pp. 161-178.

[16] I insist here: the question is not the nature of light, how it is produced or what it consists of, but rather how light travels.

[17] A. I. Sabra, *Theories of Light from Descartes to Newton*, Cambridge: Cambridge University Press, 1981.

[18] Isaac Newton, *Traité d'optique,* (1722), Paris: Gauthier-Villars, 1955; Isaac Newton, *Opticks, or a Treatise about Reflections, Refractions, Inflexions and Colours of Light*, reprinted from the 4th edition London 1730, London: 1931.

[19] Sabra, op. cit., p. 185. These phenomena were discovered by Francesco Maria Grimaldi (1665), Erasmus Bartholinus (1669) and Robert Hooke (1665) respectively. An accurate estimation of the speed of light using Jupiter's satellites, was performed by Ole Roemer (1676). The dates in parenthesis are those of their writings.

[20] Christian Huygens, *Treatise on Light*, rendered into English by Sylvanus Thompson, London: MacMillan and Co., 1912. Forgotten book's Classic reprint series, 2012.

[21] Robert Hooke, *Micrographia*, London: 1665.

[22] Edmund Taylor Whittaker, *A History of the Theories of Aether*: from the age of Descartes to the close of the nineteenth century, Dublin: University Press Series, 1910, pp. 1-28 and pp. 99-133.

[23] Léon Bloch, *La philosophie de Newton*, Paris: Félix Alcan, 1908, pp. 549-642.

[24] André Chappert, *L'édification au 19ème siècle d'une science du phénomène lumineux*, Paris: Librairie philosophique J. VRIN, 2004, p. 24. The author underlined that Newton thoughts are often simplified. He supposed that particles of light moved along a straight line in a transparent and uniform medium and that they exerted forces one on to the others: he explained light refraction. But he introduced the idea of something periodical in his theory of 'fits' in order to explain the colours of thin plates. See also Sabra, op. cit., pp. 319-342.

[25] Chappert, op. cit., p. 25.

[26] Precisely, this was the introduction of his first lesson of physics at the 'Ecole Normale de l'an III' which was given on January 20, 1795. See Nahum, op. cit., p. 466. The original French sentence is: 'La physique a pour objet les connaissances des phénomènes de la nature et des lois dont ils dépendent. Elle diffère de l'histoire naturelle, dont le but est de décrire les êtres et d'indiquer les caractères qui peuvent servir à les reconnaître et à les distinguer les uns des autres. Le naturaliste cherche dans l'aspect des individus des points de comparaison propres à établir leur classification ; le physicien, par le rapprochement des faits observés, parvient à les lier ensemble dans une même théorie'.

[27] Fresnel, op. cit., Vol. 2, p. 6. The original article is 'De la lumière', *Comptes-rendus de l'Académie des Science*s, June 1821, and was reproduced pp 3-146. The French sentence is : ' La théorie dont l'hypothèse fondamentale est vraie, quelque rebelle qu'elle soit d'ailleurs à l'analyse mathématique, indiquera même entre les faits les plus éloignés, des relations intimes qui seraient toujours restées inconnues dans l'autre système'.

[28] Fresnel, op. cit., Vol. 3, 1870, p. 485. Arago claimed that in the obituary he read, 'Eloge historique d'Augustin Fresnel, lu en séance publique de l'Académie des Sciences le 26 juillet 1830' which is reproduced pp. 475-526. The French sentence is : 'Une loi mathématique a plus d'importance qu'une découverte ordinaire, car elle est elle-même une source de découvertes'.

[29] Wood, op. cit. For a relevant and complete biography.

[30] Arago, op. cit., p. xcj. This French expression could be translated literally by 'living library'.

[31] Thomas Young, 'Observations on Vison', *Philosophical Transactions for 1793*, vol. lxxxiii, p. 169, read 30 May 1793, Peacock, op. cit., pp 1-11; Thomas Young, 'On the Mechanism of the eye', *Philosophical Transactions for 1801*, vol. xcii, p. 23, read 29 November 1800, Peacock, op. cit., pp 12-63. See Wood, op. cit., pp. 22-23 for the reception of those papers and the circulation of a damaging rumor pretending that Young's paper had been suggested by John Hunter.

[32] Arago, op. cit., p. lxvij. The original French sentence is: 'Les physiologistes ne lisent pas son beau mémoire, car il suppose plus de connaissance mathématique qu'on en cultive ordinairement dans les facultés ; les physiciens l'ont dédaigné à leur tour, parce que, dans les cours oraux ou dans les ouvrages imprimés, le public ne demande plus guère aujourd'hui que ces notions superficielles dont un esprit vulgaire se pénètre sans aucune fatigue…'.

[33] Thomas Young, Lecture Notes on Natural Philosophy and the Mechanical Arts, London: Joseph Johnson, 1807.

[34] Ibid, Vol. 1, p. viii.

[35] Ibid, pp. 786-787. See Plate XXX, Fig. 442. Young discussed the experiment on p. 465.

[36] Eugene Hecht, *Optics*, San Francisco, Boston, New York: Addison Wesley, 2002, p. 570. The presentation of this experiment as it is taught today is given in Hetcht's book. After a unique source of light has traversed two very narrow slits made in a paper, peculiar patterns appear on a screen: high intensity fringes and dark fringes. A careful observation would show that there are different light intensities ranging from dark to bright. If the experiment is made with white light, a variety of colours appear on the screen. This phenomenon can be simply explained as follows: two rays of light are formed because of the slits. Each one takes a slightly different path before reaching the screen. Depending of the length of their respective path, they may destroy one another causing darkness on the screen, add one to the other causing brightness or partially add causing a variety of intensities of light. Moreover, the location on the screen where the rays destroy one another depend on the colour of the light. If the light is red the location is not identical to the location for green light. Therefore if the light is white, there are some locations for which red rays destroy but green rays remain present. I recall that white light is composed of monochromatic lights which means lights of different colours, red, green, blue etc.

[37] Peacock, op. cit., Vol. 1, pp. 64-98, pp. 140-169, pp. 170-178.

[38] Wood, op. cit., p. 66. I employ Wood's expression here.

[39] Arago, op. cit., p. lxxiij. Arago's words are: 'jeu d'enfants'.

[40] Arago, op. cit., p. lxxvj. French sentence: 'Qui se fût imaginé qu'on en viendrait à supposer que l'obscurité pouvait être engendrée en ajoutant de la lumière à de la lumière?'.

[41] Henry Cockburn, *Life of Lord Jeffrey*, 1852. Also in Wood, op. cit., p. 169.

[42] Henry Peter Brougham, 'Experiments and observations on the inflection, reflection, and colours of light', *Philosophical Transactions of the Royal Society* (86), 1796; Henry Peter Brougham, 'Farther Experiments and Observations on the Affections and Properties of Light', *Philosophical Transactions of the Royal Society* (87), 1797; Henry Peter Brougham, 'General Theorems, Chiefly Porisms, in the Higher Geometry', *Philosophical Transactions of the Royal Society* (88), 1798.

[43] Member of the Parliament in 1810, he would become Lord Chancellor in 1830 and this same year Baron Brougham and Vaux.

[44] *Edinburgh Review*, (1), October 1802-January 1803, p. 450. Also in Alexander Wood, op. cit., p. 169.

[45] *Edinburgh Review*, (1), p. 459. Also in Wood, op. cit., p. 170.

[46] *Edinburgh Review*, (V), October 1803-January 1804, p. 103. Also in Wood, op. cit., p. 170.

[47] Arago, op. cit., p. cj. French sentence : ' ... l'érudit l'écrivain, le géomètre, l'expérimentateur avec une véhémence, avec une âpreté d'expressions presque sans exemple dans les débats scientifiques'.

[48] Arago, op. cit., p. cj. French sentence : 'Les journaux de sciences, quand ils sont rédigés par des hommes d'un mérite reconnu, acquièrent ainsi, sur certaines matières, une influence qui souvent devient funeste'.

[49] Thomas Young, 'An essay on cycloidal Curves', *Miscellaneous Works of the late Thomas Young*, (1), op. cit., pp 99-114. Peacock indicated in a not that this essay appeared in the British Magazine for 1800. It was the third of a series entitled: 'The Leptologist', p. 99.

[50] Peacock, op. cit., p. 100.

[51] Peacock, op. cit., p. 101.

[52] Peacock, op. cit., p. 100. I shall discuss that point in the next section.

[53] Wood, op. cit., p. 60. The author discussed the choice of this College and also related the friendship between Dr Brocklesby and the Master, Richard Farmer, Fellow of the Royal Society, one of Young's supporters when he was elected to the Fellowship of the Royal Society in 1794.

[54] Wood, op. cit., p. 62. These words were reported by the Tutor or the College.

[55] Wood, op. cit., p. 62, from George Peacock, *Life of Thomas Young*, London: John Murray, 1855, pp 118-119. I recall that pupils in *statu pupillary* are usually those under the rank of BA.

[56] Peacock, op. cit., Vol. 1, pp 192-215. Dr Young's reply to the animadversions of the Edinburgh reviewers, on some papers published in the *Philosophical Transactions*.

[57] George Peacock, *Life of Thomas Young*, op. cit., p. 127. Young wrote to Dr Bostock in June 1798. Peacock added that it would have been fortunate for his scientific character, and it would have greatly aided the ready reception of his subsequent discoveries if he had been tempted, at this early period of his career to study systematically in this school of mathematics, and had adopted the elegance of form and completeness of development for which the works of Euler, La Grange and La Place are so justly distinguished.

[58] Ibid, p. 127.

[59] J. W. Herivel, 'Aspects of French Theoretical Physics in the nineteenth century', *The British Journal for the History of Science*, Vol. 3, 10, 1966, pp. 121-122. I borrow Herivel's words here.

[60] Herivel, op. cit., p. 112.

[61] W. W. Rooue Ball, *A short Account of the History of Mathematics*, Third Edition, London: McMillan and Co., 1901, pp. 423-431. For comments and critics of Laplace's philosophy. The author wrote:'The *Méchanique céleste* is not only the translation of the *Principia* into the language of the differential calculus, but it completes parts of which Newton had been unable to fill in the details', p. 427.

[62] Laplace's works were published in seven volumes by the French government in 1813-7; and a new edition with considerable additional matter was issued at Paris in six volumes, 1878-84.

[63] Peacock, op. cit., pp. 385-386. Letter dated 15 September 1817. I did not find Arago's answer.

[64] Biot assisted Laplace in revising it for the press, sayd that Laplace himself was frequently unable to recover the details in the chain of reasoning, and, if satisfied that the conclusions were correct, he was content to insert the constantly recurring formula, `Il est aisé à voir', which means: 'It is easy to see'. This was reported by Rouse Ball. See Rouse Ball, op. cit., p. 427.

[65] Peacock, op. cit., pp. 373-374. The letter was dated 6 October 1817.

[66] Peacock, op. cit., p. 374. French sentence: 'Quelque ingénieux que soit ce raisonnement, je ne puis le regarder que comme un aperçu, et non comme une démonstration géométrique. Je persiste à croire que le problème de la propagation des ondes, lorsqu'elles traversent différents milieux, n'a jamais été résolu et qu'il surpasse peut-être les forces de l'analyse'.

[67] Peacock, op. cit., p. 374. French sentence: 'Ainsi les suppositions de Descartes (about light) comme plusieurs aperçus de Kepler sur le système du monde, ont été vérifiés par l'analyse : mais le mérite de la découverte d'une vérité appartient tout entier à celui qui la démontre ; je conviens que de nouveaux phénomènes de la lumière sont jusqu'à présent très difficiles à expliquer ; mais en les étudiant avec un grand soin, pour découvrir les lois dont ils dépendent, on parviendra peut-être un jour à reconnaître dans les molécules lumineuses des propriétés nouvelles qui donneront une explication mathématique de ces phénomènes. Remonter des phénomènes aux lois, et des lois aux forces, est comme vous le savez la vraie marche des sciences naturelles'.

[68] Peacock, op. cit. p. 370. In a letter addressed to Young, dated 17 October 1817.

[69] Peacock, op. cit. p. 371.

[70] Peacock, op. cit. p. 371. Letter dated 9 November 1817.

[71] Peacock, op. cit. p. 371.

[72] Huygens, op. cit., pp. 34-38.

[73] Peacock, op. cit. p. 371.

[74] Peacock, op. cit. p. 371.

[75] Peacock, op. cit. p. 220. This is a note by the Editor. The letter dated January 1818 is not provided.

[76] André Chappert, Etienne Louis Malus et la théorie corpusculaire de la lumière, Paris: Vrin, 1977.

[77] Peacock, op. cit., Vol. 1, pp 260-278. The title of the paper is 'Review on Malus, Biot, Seebeck, and Brewster on light'. It appeared in *Quarterly Review*, April 1814, Vol. xi p. 42

[78] Peacock, op. cit., Vol. 2, pp. 581-596. The paper is entitled 'Life of Malus'.

[79] Ibid, p. 583.

[80] Ibid, p. 595.

[81] Peacock, op. cit., pp 234-259. Original title 'Mémoires de physique et de chimie de la société d'Arcueil' Vols I and II, *Quarterly Review* for May 1810, Vol. iii, p. 462.

[82] Thomas Young, 'Review of Laplace's Memoir sur la loi de la réfraction extraordinaire dans les cristaux diaphanes, lu dans la première classe de l'Institut à sa séance du 30 janvier 1809, Journal de Physique Janvier 1809', *Quarterly Review* for November 1809, Vol. ii, p. 337. Also in Peacock, op. cit., pp. 220-233.

[83] Peacock, op. cit., p. 220.

[84] Peacock, op. cit., pp. 220-221.

[85] Peacock, op. cit., p. 221.

[86] Peacock, op. cit., p. 222. For example, report to William Hyde Wollaston, 'On double images caused by atmospheric refraction', read before the Royal Society on 6 March 1800. *Philosophical Transactions of the Royal Society*, 1800.

[87] Peacock, op. cit., p. 229.

[88] Peacock, op. cit., pp. 226-227.

[89] Arago's obituary, op. cit., p. lxxvj. French sentence : 'Un physicien est justement glorieux quand il peut annoncer quelque résultat qui choque à ce degré-là les idées communes ; mais il doit, sans retard, l'étayer de preuves démonstratives, sous peine d'être assimilé à ces écrivains orientaux dont les fantasques rêveries charmèrent mille et une nuits du Sultan Schahariar'.

[90] Fresnel, op. cit., Vol. 1, pp. XXV- XXVI. French sentence: 'Young a ignoré ou négligé l'art de présenter ses découvertes. Il s'est contenté d'expliquer en gros les phénomènes sans instituer entre l'expérience et la théorie cette comparaison minutieuse qui garantit seule la possession de la vérité... Les deux rayons qu'il faisait interférer lui étaient fournis par un phénomène aussi mystérieux que pour ses prédécesseurs, l'inflexion de la lumière dans l'ombre des corps opaques, et les partisans de l'ancien système [émission] pouvaient soutenir avec quelque apparence de raison, que les interférences n'étaient qu'un cas particulier des phénomènes de la diffraction'.

[91] Nahum, *op. cit.*; Ambroise Fourcy, 'Livre premier : 1794 – Création de l'École ', *Histoire de l'École Polytechnique'*, Paris: École polytechnique, 1828.

[92] These events were reported by Arago. 'Eloge historique d'Augustin Fresnel', Séance publique de l'Académie des Sciences, read 26 July 1830. The speech can be found in Fresnel, op. cit., 1870, pp. 475-526. A biography of Fresnel was provided. Moreover, Arago gave his analysis of the improvements made in optical sciences during the first three decades of the nineteenth century.

[93] It seems that Brewster had claimed the paternity of this invention but that discussion is beyond the scope of the present article.

[94] Peacock, op. cit., Vol. 1, pp. 359-411. Nine letters from Fresnel to Young and two from Young to Fresnel were reproduced. Fresnel, op. cit., Vol. 2, a letter written by Fresnel in 1819 (the precise date was not indicated) being the answer to Young's 16 October 1819, p. 755 and three other letters written by Young, November 1823, p. 759, October 1824, p. 765 and November 1824, p. 767.

[95] An allusion to that visit is made in a letter Young addressed to Arago dated 22 April 1817. Peacock, op. cit., p. 384.

[96] *Annales de chimie et physique*, 1816. The series was created by Arago and chemist Gay-Lussac.

[97] Peacock, op. cit., Vol. 1, p. 376. The French sentence is: 'Mais si quelque chose pouvait me consoler de n'avoir pas l'avantage de la priorité, c'était de m'être rencontré avec un savant qui a enrichi la physique d'un si grand nombre de découvertes importantes, et cela n'a pas peu contribué en même temps à augmenter ma confiance dans la théorie que j'avais adoptée'.

[98] Peacock, op. cit., Vol. 1, p. 379. Letter dated 13 July 1816. French sentence: 'Je ne vois pas trop en effet comment les partisans du système de l'émission pourront expliquer les trajectoires courbes des bandes diffractées ; ou plutôt, je devine déjà que pour ne pas abandonner la route qu'ils ont suivie jusqu'à présent, ils révoqueront ce fait en doute, ou s'abstiendront d'en parler'. [...] 'Si le volumineux ouvrage que M. Biot vient de publier sous le titre *Traité de Physique expérimentale et Mathématique* est déjà parvenu jusqu'en Angleterre, vous aurez eu l'occasion de remarquer par quels arguments pitoyables il prétend prouver, contre votre opinion que deux faisceaux lumineux n'exercent jamais l'un sur l'autre aucune influence sensible'.

[99] François Arago, *Histoire de ma jeunesse*, Bruxelles and Lepzieg: Kiesslig, Schnée and Co., 1854.

[100] Peacock, op. cit., Vol. 1, p 380-381. Though the letter was written in English, thi expression in italic letters was in French. It can be translated by 'considered as being the proof of the interferences principle.

[101] Peacock, op. cit., Vol. 1, p 382.

[102] Peacock, op. cit., p. 396. The French sentence is: 'Vous voyez Monsieur, que la théorie des ondulations ne m'a point porté bonheur; mais cela ne m'en dégoute pas et je me console de ce malheur en m'occupant d'optique avec une nouvelle ardeur'. Fresnel wrote three times to Young during this year 1823. Young replied only once at the end of the year.

[103] Fresnel, op. cit., Vol. 2, p. 849. The French sentence is: 'Dans une conversation que j'ai eue dernièrement avec Poisson, il m'a avoué que la multiplicité des hypothèses que nécessite la théorie newtonienne diminuait beaucoup sa confiance en elle'.

[104] Henri Poincaré, *La Science et l'Hypothèse,* Paris: Champs Flammarion, 1968, p.161. The original writing was entitled: *Rapports présentés au congrès international de Physique*, Vol. 1, Paris, 1901.French sentence : 'La nature ne soucie pas des difficultés analytiques'.

[105] Peacock, op. cit., Vol. 1, p. 386.

[106] Speed of light versus density or elasticity of the substance, this was crucial to decide between the two conceptions.

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