Francesco Algarotti explains Newton's prism experiment to Ladies

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ABSTRACT

In the 18th century, a "new science" flowed in Europe. One of the primary elements of Enlightenment was the rise of the public sphere excluding women and lower classes. *Les Philosophes* introduced the public to many scientific theories, in particular–Newtonianism by Voltaire and Émilie du Châtelet. Some works are more formal, but the popular works were written in a discursive style. Articles on scientific topics appeared in popular women's magazines and books designed to introduce women to scientific disciplines. Noted examples of this popular new genre include Francesco Algarotti's *Newtonianism for Ladies or Dialogues on light and colours*. This book was an 18th century best seller and was one of the main channels through which Newtonian ideas reached the public in continental Europe. The text explained the principles of Newton's *Opticks* while avoiding much of the mathematical rigor of the work in favour of a more "agreeable" text. Algarotti presented Newton as a follower of the Galilean tradition and the first modern philosopher. The description of some of Newton's experiments on the nature of light and colours in the form of a gentle dialogue has great educational value, because it does not demand any geometrical or algebraic knowledge.
In this article, the authors want to underline the importance of Algarotti's book for the dissemination of Newton's ideas that until then had been shared only by scholars.
Algarotti's book today is testimony to women's interest in science during 18th century.

KEYWORDS Optics, Colour, Enlightenment, Algarotti

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1. Introduction

In the 18th century, Enlightenment's principles inspired a new genre of painting, music and the "new science" flowed in Europe. One of the primary elements of the culture of Enlightenment was the rise of the public sphere. The word "public" implies the highest level of inclusivity – the public sphere should be open to all. However, this sphere was only public to relative degrees. Additionally, most institutions of the public sphere excluded both women and lower classes. An important development was the popularization of science among an increasingly literate population.

Les Philosophes (Philosophers) introduced the public to many scientific theories, most notably through the Encyclopédie and the popularization of Newtonianism by Voltaire and Émilie du Châtelet.

Some works were more formal and included explanations of scientific theories for individuals lacking the educational background to comprehend the original scientific text. The popular works were written in a discursive style, which was laid out much more clearly for the reader than the complicated articles or treatises. Articles on scientific topics appeared in popular women's magazines and books designed to introduce women to scientific disciplines. Noted examples of this popular new genre include Francesco Algarotti's *Newtonianism for Ladies or Dialogues on Light and Colours* (1737). This book was an 18th century best seller and was one of the main channels through which Newtonian ideas reached the public, not only women, in continental Europe.

The widespread use of the book was also due to the fact that Algarotti was well introduced in the English and French as well as in the Italian cultural circles.

Algarotti frequented the salon of Elisabeth Montagu where he met Elizabeth Carter who translated the *Dialogues.* Later, Algarotti became a great friend of Frederick the Great.

The book brings together both groups of women, the amateur and the learned scientists. Algarotti illustrated the book with an engraving of Émilie du Châtelet and himself set in a bucolic scene. The text explained the principles of Newton's *Opticks* while avoiding much of the mathematical rigor of the work in favour of a more "agreeable" text. In the book, Algarotti presented Newton as a follower of the Galilean tradition and the first modern philosopher. The distinguishing feature of the book is that he presents the theory about the nature of light and colours by means of Newton's experiments. He shares. with Galileo and Locke, the same idea about the scientific value of experience, in antithesis with the Cartesian method. The description of some of Newton's experiments on the nature of light and colours in the form of a gentle dialogue has great educational value, because it does not demand any knowledge of geometry or algebra. From this point of view, the literary quotes are always totally justified and meaningful. Algarotti writes the verses in the beginning "o, of the golden sevenfold light the myriad ardent, mixed and glorious colours," in honour of Laura Bassi, professor of Philosophy and Physics at the University of Bologna. This quote shows his attention to the Experimental Method and recalls the period in which Algarotti himself studied Physics at the University of Bologna.

In this article, the authors want to underline the importance of Algarotti's book for the dissemination of Newton's ideas that up to that time had been shared only by scholars. In the 18th century, as pointed out, the salons where literature and science conversations were held were also very important. The conversations were held also by women, despite not being able to attend schools, who had to know and talk about the latest discoveries.

So, Algarotti's book explains Newton's theory in a simpler and less formal way with rhetorical figures and literary verses. Therefore, Algarotti's book is witness to women's interest in science in 18th century.

2. Importance of Decomposition of White Light in Eighteenth Century

In 18th century there is a reassessment of the connections between practical techniques, philosophical ideas and the cultures in which they resided. The production of dyes, pigments and glazes were well established industries. Colour was a subject of systematic experimental and theoretical investigations in the sciences. Colour brought philosophical ideas close to everyday experience. In books and lectures directed at popular audiences, colour was used to illustrate connections between methods and theories, emphasizing the familiarity and practicality of colour making techniques. The characterization of Chemistry in eighteenth century as under fledged in comparison to Physics meant that mainly Mathematics, Mechanics, Optics and Dioptrics were present in discussions of colour practices. Reference to Newton, Descartes, Gassendi and even Aristotle were obligatory in practical writing intended for publication. Colour was part of a developing art or tangential to science.

The expanded place of the sciences in public and private life explains the interest in learning the book of nature, that the sciences provided with exemplary systems, visible or invisible as the laws of motion or mathematics. There were many strategies for disseminating information. The transfer could be purely verbal, as in *Conversazioni* or lectures, or by means of a combination of verbal and visual strategies (Fig.1). Colour was a topic with clear connection to science. It suggested visible and tangible opportunities to join theories and practice, providing a unitary focus for systematic conjecture and experiment. (Lowengard, 2005).

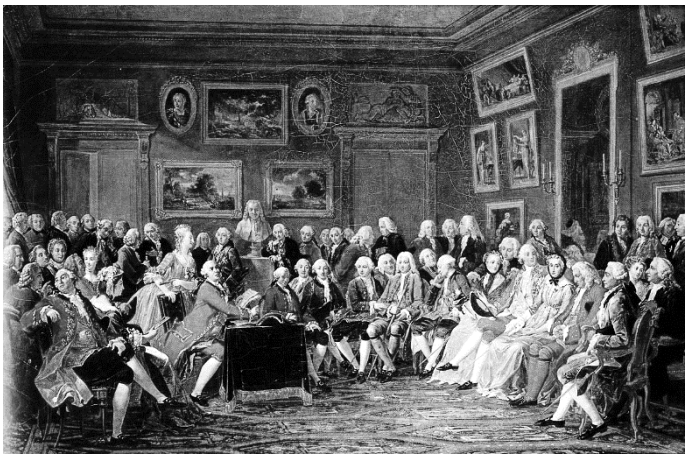

Fig. 1. Conversazioni or lectures

3. Newton Prism Experiment

Between 1665 and 1666, Isaac Newton realized a series of experiments with the prism that radically transformed traditional ideas about the nature of light and colours. He made a small hole in the window of his perfectly darkened room. He caused a prism to intercept the ray of light that penetrated from the small opening, projecting the image onto a wall several meters away, on which he observed a non-circular, but elongated spectrum in which all the colours of the iris were revealed. Newton also showed the reversibility of the experiment: by projecting the polychrome spectrum on a converging lens, the white light beam was in fact regenerated. From these experiments he deduced that the colours were not, as Descartes had assumed from Aristotle, accidental modifications of white light. The latter no longer appeared as an elementary but heterogeneous substance: the product, that is, of mixing different colours. Newton correctly stated that the spectrum appeared elongated because the various colours have different indices of refraction. He derived from this discovery the idea of the reflecting telescope, capable of considerably attenuating the annoying effects of chromatic aberration. The results of this research were published by Newton in the Philosophical Transactions of the Royal Society in 1672 and 1675. The Newtonian theory of light and colour stirred lively debate. The comparison with the wave theory of light supported by Huygens was particularly lively.

Experiment's description (Newton, 1704)
Place a prism (whose angle *fbd* is about 60°) in a dark room in which the Sun passes only through a small round hole *k* and holding it near the hole *k* so that the rays being equally refracted in *n* and in *h*, project *rstv* colours on the opposite wall (Fig. 2).
The colours are refracted forming an oblong shape bounded in the sides *r* and *s* by straight lines. The amplitude *rs* is 2 1/3 inches, their length about 7 or 8 inches and the distance of the centres of red and blue (*p* and *q*) are about 3 inches. The distance of the *rstv* wall from the prism is 260 inches (about 6.70 meters).[1]
In another experiment, Newton took a prism on a face of which he placed a sheet of paper with different bands parallel to the edges of the prism and placed at a regular distance.
Passing through these cracks, the sunlight, collected on a screen near the prism, produced a coloured line at each slot. However, as soon as the screen moved away, white formed in the central part of the spectrum. If the screen was placed at an even greater distance, the whole spectrum reappeared.

Fig. 2 - Newton's experiment drawing (drawing by authors of this text)

4. Francesco Algarotti: a Venetian Polymath

Count Francesco Algarotti (1712–1764) was an eclectic scholar: philosopher, poet, essayist, art critic and art collector. He was a man of broad knowledge, an expert in Newtonianism, architecture, music and a friend of most of the leading authors of his age. Voltaire, Jean-Baptiste de Boyer, Pierre-Louis de Maupertuis, Lord Chesterfield, Thomas Gray, Metastasio, Benedict XIV and Heinrich von

Brühl were among his correspondents. Algarotti was born in Venice as the son of a rich merchant. Unlike his older brother Bonomo, he did not step into the company, but decided to become an author. Francesco studied natural sciences and mathematics in Bologna under Francesco Maria Zanotti and in 1728 he experimented with optics.

At the age of twenty, he went to Paris, where he became friendly with Voltaire and Émilie du Châtelet.
The first French introduction to Newtonianism and the *Principia* was *Eléments de la philosophie de Newton*, published by Voltaire in 1738.
Émilie du Châtelet's translation of the *Principia*, published after her death in 1756, helped to spread Newton's theories beyond scientific academies and the university. Bernard de Fontenelle's *Conversations on the Plurality of Worlds* (1686) was the first significant work that expressed scientific theory and knowledge expressly for the laity, in vernacular and with the entertainment of readers in mind. The book was produced specifically for women with an interest in scientific writing and it inspired a variety of similar works and pushed Algarotti to write his book about Newton's Optics during his stay in Cirey, guest of Voltaire and du Châtelet.
When he was in London, he was made a fellow of the Royal Society and joined the friends' circle of Lady Mary Wortley Montagu.
Among them there was Elisabeth Carter, the poet, linguist and polymath, who later translated his book. In 1737, Algarotti left for Italy and finished *Neutonianismo per le dame* (Newtonianism for Ladies), dedicated to Bernard le Bovier de Fontenelle, a work intended for the popularization of Newtonian philosophy and addressed to women.
Algarotti wrote *Il Newtonianesimo per le dame, ovvero Dialoghi sopra la Luce e i Colori* as a series of six dialogues.
First dialogue: Introduction; a general Idea of Physics, and an Explanation of the most remarkable Hypothesis concerning Light and Colours.
Second dialogue: That Qualities, such as Light, Colours, and the like, are not really in Bodies. Metaphysical Doubts concerning our Sensations of them. Explication of the general Principles of Optics.
Third dialogue: Several Particulars relating to Vision, Discoveries in Optics, and a Confutation of the Cartesian System
Fourth dialogue: Encomium on Experimental Philosophy, and an Exposition of the Newtonian System of Optics
Fifth dialogue: Exposition of the Newtonian Philosophy continued
Sixth dialogue: Exposition of the Newtonian universal Principle of Attractions and Application of this Principle to Optics. (Algarotti, 1737)

5. Newtonianism for Ladies

Algarotti began his book with the following sentence

I am putting the last touches to my Dialoghi, which have found grace in the eyes of the belle Émilie and the savant Voltaire. I try, when near them, to acquire those choice terms, that charming turn of speech with which I should like to embellish my work.

Algarotti illustrated the book with an engraving of Émilie and himself set in a bucolic scene, which represented the Cirey gardens with the château on the right.


IL NEWTONIANISMO
PER LE DAME
OVVERO
DIALOGHI
SOPRA
LA LUCE E I COLORI.
——— quæ legat ipsa Lycoris.
Virg. Egl. X.
IN NAPOLI
MDCCXXXVII

Fig. 3. source Linda Hall Library of Science, Engineering & Technology

The marquise was highly flattered at being placed at the head of the work to represent "*wit, grace, imagination, and science*." The book was published with a title that did not refer to women, leading some to believe that the female branding of the book was a ploy to avoid censorship. Algarotti had to make changes, certainly not improving the text, in the most famous editions following the first. The changes are both in the content and in the expressive form, in order to avoid a further condemnation, or the accusation of harmful work to morals of young people. He eliminated any reference to sensationalist gnoseology and praise of experimental philosophy, every positive judgement of ancient atomism, and every expression deemed excessively free and polemical. The "tone" of research, of direct investigation, the language so close to the daily use of the things, which we find in the first edition of the "Dialogues", is less in the following ones. The civil tension and the true will of renewal, which is easy to detect in the first edition—emphasizes experimental philosophy as a methodology valid in every field, from natural research to political practice—which are lost in a "neutral" dissemination of the only scientific results of Newton.

Condemned by decree of April 1739, the book appeared in the 1744 edition of the *Index Librorum Prohibitorum* (List of Prohibited Books). From 1746, the new prints presented a revised title (the last was *Dialogue on the Neutonian Optics*) and significant variations. Algarotti added a new dialogue, which he envisages to happen several years after the others, and an appendix containing some scientific dissertations. From 1750, Algarotti replaced the Proemio, originally dedicated to Fontenelle, with another dedicated to Frederick II, King of Prussia in which his literary style became more austere and academic. (Salvadé, 2010)

The distinguishing feature of *Newtonianism for Ladies* was that Algarotti presented theory about the nature of light and colours according to Newton's experiments. Algarotti shares, with Galileo and Locke, the same idea about the scientific value of experience, in antithesis with the Cartesian method. In the book, he presented Newton as a follower of the Galilean tradition and the first modern philosopher.

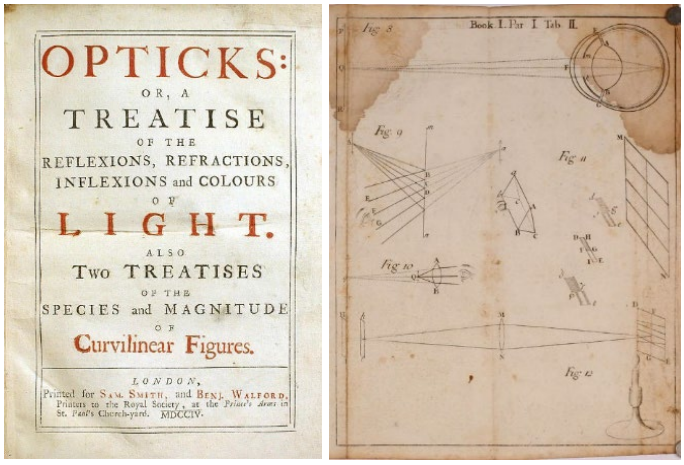

Fig. 4. Newton's Opticks

The description of some of Newton's experiments on the nature of light and colours in the form of a genteel dialogue has great educational value, because it does not demand any geometrical or algebraic knowledge. From this point of view, the literary quotes are totally justified and meaningful.

At the beginning of the first dialogue, Algarotti turns to the Marquise declaiming the following verses:

The sevenfold light
Whence ev'ry pleasing charm of colour springs,
And forms the gay variety of things

From the composition of these seven colours in a direct ray from the Sun arises the white or rather golden colour of Light: that if this direct Ray from the Sun is refracted by a certain Glass called a Prism, these rays of which is composed differing in colour and differ also in degrees of refrangibility.

In fact, Algarotti intends to speak about Optics and in particular wants to explain to the Marquise how light, according to Newton's opinion, is not simple and pure but like each ray of sun is a bundle composed of red rays, some orange colour, yellow, green, indigo and violet.

Algarotti then also explains reflexion and refraction. Reflexion happens by a collision of the globules of light with the solid part of bodies, these globules are repelled back again as a ball rebounds when it is struck against the Earth.

Refraction is caused when the globules of light passing through air, water, glass, meet with the pores and cavities of these bodies, so that the ray, which is only a chain of globules, breaks and turns out of its proper path and takes a different direction from what it had before.

He tells the Lady to think she is in a room, completely in the dark except for a narrow, round glimmer from which a ray of sunshine comes.

At a certain distance from the glimmer, there is a glass prism, which receives through it that glimmer of light.

The prism must be situated so that a face is looking at the ceiling of the room, another face at the glimmer and the third face at the wall facing the glimmer. One of the edges must face the floor.

The ray of the sun, which penetrates the face that looks at the glimmer, comes out of the face that looks at the wall so that the prism refracts it and sends it straight over the wall of the room that faces the glimmer.

The luminous trace is no longer that which the straight beam impressed on the floor.

The trace is white and almost round, while the second is five times longer than the width, it is four-sided and rounded at the ends and the light is broken down into seven colours.

The colours are arranged as follows: first red, then orange, then yellow, green, blue and indigo and finally purple.

Turning the prism, a little around itself the ray of sun becomes more or less oblique to the face on which it falls. Thus, the order of refraction can be changed and the coloured image can be seen rising or falling from the wall. Stop the prism when the emitting ray is equally inclined to the faces of the prism. Then the colours are even more beautiful and bright.

Né il superbo pavon si vago in mostra,
spiega la pompa dell'occhiute piume,
né l'iride si bella indora e innostra.
Il curvo grembo e rugiadoso al lume [2]

6. Conclusion

In Italy, Francesco Algarotti was the first author of a text popularizing Newton's theories. Following the Principles of

Enlightenment, Algarotti, by literary quotes or his own verses, achieved the purpose of disclosing scientific culture to women and lower classes.The civil tension and the true will of renewal, which is easy to detect in the first edition—emphasizes experimental philosophy as a methodology valid in every field, from natural research to political practice—which are lost in a "neutral" dissemination of the only scientific results of Newton. Even today, Algarotti's method of dissemination could help pupils to understand principles of Newton's physics.

7. Conflict of interest declaration

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9. Short biography of the authors

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Notes

[1] 1 inch=38 centimeters.

[2] Neither the superb peacock wanders in the exhibition, explains the pomp of the eyed feathers, nor the iris is beautiful and gilds it with its own. The curved womb is dewy by the light

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