From the Historian

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Diffraction: The First Recorded Observation

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Forward

[This article, sent to me by Professors Cecchini and Pelosi, concerns perhaps the earliest known discovery of diffraction. I found the article most interesting, and hope that others will take the opportunity to send us similar articles on any significant part of electromagnetic theory and associated subjects, either ancient or modern.

My personal knowledge of Francesco Maria Grimaldi was limited to astronomy. This came about in the 1960s when my laboratory, NASA Langley, undertook close-up photography of the moon, the Lunar Orbiter Project. If you are interested, I am certain that NASA public affairs can provide readers copies of those lunar maps.

Perhaps one day I will be able to visit Italy, meet the authors, and also pursue my love of painting and sculpture. WFC]

> *Geometrical optics, the oldest and most widely used theory of light propagation, fails to account for certain optical phenomena called diffraction* [1].
>
> J. B. Keller

Probably, diffraction is one of the phenomena more familiar to the members of the electromagnetic community, and this, also, thanks to the success of the Geometrical Theory of Diffraction. What perhaps is not so well known is the etymology of the word, the first observation of the phenomenon, and its discoverer.

What we would like to do in this short paper is just to contribute to the diffusion of this knowledge, which, we think, could interest the readers of this *Magazine*.

Of course, everything we are saying is generally recognized by science historians, but we believe that the iconographic material, some of which is extremely rare, has never been gathered in one place before.

De Lumine

Even if the first hints about the diffraction phenomenon can be found in the works of Leonardo da Vinci, its discovery is unanimously accredited to the Jesuit, Francesco Maria Grimaldi [2] (Figure 1). He described the experiments which led to its discovery in the book *De Lumine* [3]—first published in Bologna in 1665, two years after the author's death Figure 2—and gave the phenomenon the name by which it is still called. The etymology of the word is from the Latin verb *diffringere* (*dis* + *frangere*), which means "to break in different directions" [4].

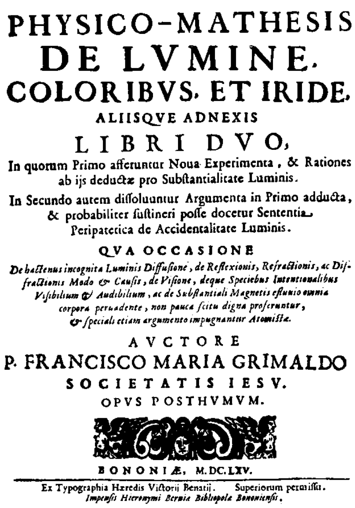
The book *De Lumine*—in Latin, as that was the official language of the scientific community in those times—with its strange mixture of modern experimental spirit and old scholastic philosophy, is a very important testimony to the philosophical and scientific renaissance of those years. This was a process which was strongly opposed by an extremely conservative milieu, averse to every form of innovation. A careful reading reveals the didactic and scientific authoritarianism which still ruled in the higher education fields and, at the same time, the advance of the modern Galilean principles against the old Medieval dogmatism.

In the two parts of his book, Grimaldi presents two possible hypotheses about the nature of light: *substance* or *accident* (i.e., a quality of another substance) even if his preferences, as can be deduced from the Preface, are for the second one. However, even if the two parts contain contrasting views about the nature of light, in both Grimaldi opposes the corpuscular theory of light. He is deeply convinced that light is a fluid (a substance or accident of some other fluid substance), and that colors are a modification of it. The phenomenon of diffraction is the main point in favor of this hypothesis.

Figure 1. Francesco M. Grimaldi (courtesy of the Picture Gallery of the University of Bologna).

Grimaldi's Life

Grimaldi lived in the years which saw the rise of modern science: a transitional period, in which strong remnants of the Medieval mentality coexisted with the new way of thinking and working. The situation was worsened by religious struggles: the Council of Trent (Counter Reformation) was held from 1545 to 1563.



PHYSICO-MATHESIS
DE LVMINE.
COLORIBVS. ET IRIDE.
ALIISQVE ADNEXIS
LIBRI DVO,
In quorum Primo afferuntur Noua Experimenta, & Rationes ab ijs deductæ pro Substantialitate Luminis.
In Secundo autem dissoluuntur Argumenta in Primo adducta, & probabiliter sustineri posse docetur Sententia Peripatetica de Accidentalitate Luminis.
QVA OCCASIONE
De hactenus incognita Luminis Diffusione, de Reflexionis, Refractionis, ac Diffractionis Modo & Causis, de Visione, deque Speciebus Intentionalibus Visibilium & Audibilium, ac de Substantiali Magnetis effluvio omnia corpora peruadente, non pauca scitu digna proferuntur, & speciali etiam argumento impugnantur Atomistæ.
AVCTORE
P. FRANCISCO MARIA GRIMALDO
SOCIETATIS IESV.
OPVS POSTHVMVM.
BONONIÆ, M.DC.LXV.
Ex Typographia Hæredis Victorij Benatij. Superiorum permissu.
Impensis Hieronymi Bernia Bibliopolæ Bononiensis.

Figure 2. The title page of *De Lumine*.

These are just a few dates to help the reader to set his work and life against their historical background.

1600. Giordano Bruno was burned at the stake.
1609. Kepler published *Astronomia Nova*, in which he expounds his theory about the ellipticity of planetary orbits.
1632. Galileo Galilei published his *Dialogo Sopra i Due Massimi Sistemi del Mondo*.
1633. After a trial by the Holy Office, Galileo recanted his theories.
1687. Isaac Newton published his fundamental work *Philosophiae Naturalis Principia Mathematica* in London.

Most of the information about the life of Father Grimaldi come from the *Elogium perbreve* (a brief panegyric) written by Father G. B. Riccioli at the end of *De Lumine*. His father was a silk merchant who worked in Bologna, where he was born in 1618, fourth of six children. Grimaldi entered the Society of Jesus in 1632, studied in Parma and Ferrara, then settled in Bologna, where he died of consumption in 1663 at the age of 45. He first taught Philosophy and then Mathematics in the College of Santa Lucia, where he earned a great reputation as a teacher and scientist. His many scientific activities were theoretical and experimental (Father Riccioli tells that he used to build his own instruments): from astronomical observations – he originated the practice of naming lunar regions after astronomers and physicists; some still bear his names – to anatomy, physiology, geography, and optics. Perhaps his more important contribution to the astronomical sciences is a selenograph of the moon [5]

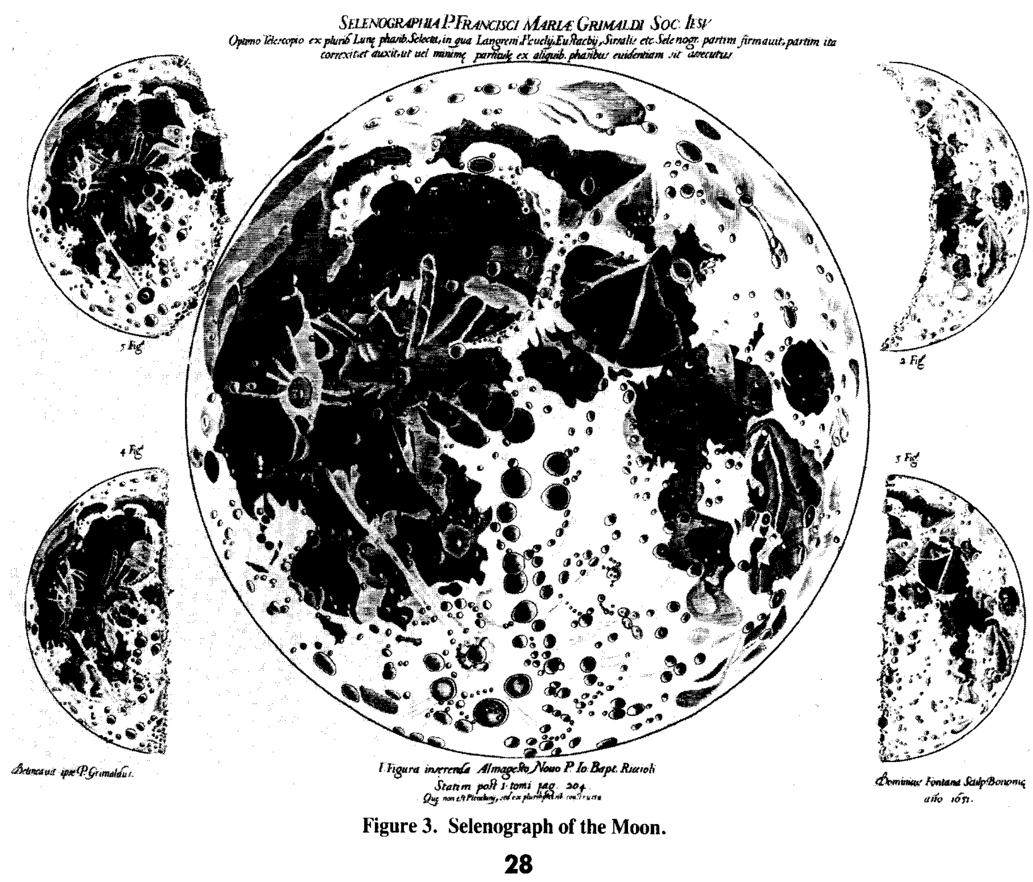


Figure 3. Selenograph of the Moon.

(Figure 3), which was surprisingly accurate for its times.

Experimental Observations

Grimaldi was extremely conscious of the importance of the phenomenon discovered, as can be seen by the relevance he gave to it in *De Lumine*. Actually, he began his book with these words:

PROPOSITIO I.

Lumen propagatur seu diffunditur non solùm Directè, Refractè, ac Reflexè, sed etiam alio quodam Quarto modo, DIFFRACTE'.

(The light propagates or scatters not only directly, by refraction and reflection, but also in a fourth way, by diffraction).

The phenomenon is demonstrated by two experiments whose results sharply contrast with the fundamental principle of geometrical optics: the principle of the rectilinear propagation of light. These two experiments, and the author's subtle arguments to exclude reflections or refractions from the possible causes, occupy the first 11 pages (of 535!) of *De Lumine*, and constitute his main contribution to the science of Optics.

In the first experiment (Figure 4a, from *De Lumine*, as is the following one), Grimaldi described the anomalous shadow (according to the geometrical optics principles!) cast by a small opaque body (EF), in a sun ray, from a very small aperture (AB), in a closed window. In the regions CM and ND he noticed the diffraction fringes, which he called *seriae lucidae* – the name *fringes* was used by Newton some years later [6].

In the second experiment (Figure 4b) he found that a cone of light through two very small apertures (CD and GH) produces, on a white screen, a spot (IK) much larger than the one predicted by the theory of geometrical optics (ON).

Grimaldi even tried to formulate a theoretical explanation of the phenomenon. Of course the scientific knowledge available in his day was insufficient: the true explanation of the phenomenon would only come from A. Fresnel, 150 years later.

The Use of the Term *Diffraction*

Newton was familiar with Grimaldi's work, and even if he only quoted him in his book *Opticks* [7], he probably knew it well before [8]. Unfortunately, the phenomenon of diffraction conflicted with his theory of the corpuscular nature of light and, in this case, his behavior was not very scientific: he ignored the Jesuit's findings! Specifically, he made many very clever experiments which confirmed and perfected Grimaldi's results, but he attributed the causes of the diffraction fringes (a term introduced by him) to reflections and refractions at the borders of the objects in the ray path: exactly what Grimaldi had excluded by a long series of considerations (in Proposition One of Book One). Moreover, Newton ignored the name Grimaldi had given to this new phenomenon – he used the word *inflexion* instead [9] – and the word *diffraction* disappeared from use for the duration of his

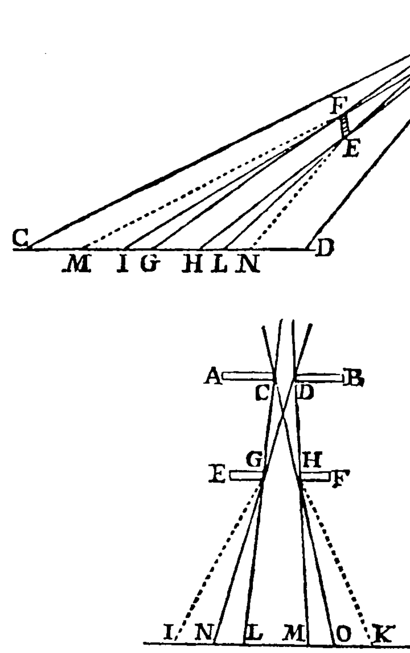


Figure 4. Grimaldi's experiments.

dominion over Optics [10].

We'll have to wait 'till the second decade of the XIX century, when Augustin Fresnel will explain the phenomenon with his theory on the wave nature of light, to see Grimaldi's term used again [11].

Acknowledgements

We would like to thank Dr. A. Lumini of the Central National Library of Florence for her precious help in bibliographic research.

References and Notes

[1] Joseph B. Keller, Geometrical Theory of Diffraction," *J. Opt. Soc. of America*, vol. 52, no. 2, pp. 116-130, 1962.

[2] For an exhaustive review of Grimaldi's life and works – including the ones not related to diffraction – see the entry in Charles C. Gillispie, ed., *Dictionary of Scientific Biography*, Charles Scribner's Sons, New York (1970-1980), and the references therein.
Another useful work is C. Sommervogel, *Bibliothèque de la Compagnie de Jésus*, Seconde Partie: Historie, Oscar Schepens, Bruxelles (1892).

[3] *Dis* is a prefix which denotes separation, interruption (see the Greek *δια*). *Frango* means to break (in a physical and moral sense), and its roots can be found in the Gothic *brikan* and the Sanscrit word *bhanakti*. The verb *diffringere* is used by various authors, mainly with reference to things. The first testimonies about its use in a literary text are in Plautus – the author of comedies who lived in the III - II century B.C. (see *Thesaurus Linguae Latinae*, Lipsiae: B. G. Teubner, 1910).

[4] The complete title is *A physico-mathematical treatise on light, colors and the rainbow, and other re-*

lated topics in two books, in the first new experiments are described and arguments are deduced from them in favor of the substantiality of light. In the second, however, the arguments introduced in the first are confuted and it is shown that the Peripatetic theory of the accidentality of the light might be true.

[5] The selenograph is a table in the *Almagestum Novum* by G. B. Riccioli, with the title *Selenographia P. Francisci Mariae Grimaldi Soc. Iesu*, signed: "Delineavit ipse P. Grimaldus at Dominicus Fontana Sculp. Bononiae ano 1651." As a curiosity, the isolated black crater on the extreme left bears Grimaldi's name.

[6] Isaac Newton, *Opticks*, New York: Dover, 1979 (based on the fourth edition of 1730).

[7] Isaac Newton, *Ibid.*, p. 317.

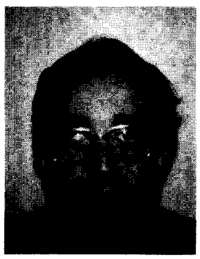
[8] *De Lumine* was reviewed in *Philosophical Transactions of the Royal Society of London*, vol. 6, no. 79, pp. 3068-3070, 1672.

[9] The term inflexion was used for the first time by Hooke, who performed his first experiments on diffraction in 1672, after the review of Gimaldi's work in the *Philosophical Transactions*.

[10] For Grimaldi's influence on Newton's theory of diffraction, see Roger H. Steuer, *Isis*, vol. 61, p. 188-205, 1970.

[11] Augustin J. Fresnel, *Ann. Chim. et Phys.*, vol. 1, no. 2, p. 239, 1816.

About the Authors



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Roberto Cecchini was born in Pisa, Italy on July 7, 1951. In 1975 he received the Laurea degree in Physics from the University of Florence. He first worked in the field of theoretical High Energy Physics, and then in private industries. At present, he is the Director of the Computing Center of the Department of Physics of the University of Florence. His main interests are in the fields of Symbolic Computation and Image Processing. R. Cecchini is a member of the IEEE and of the ACM.

Giuseppe Pelosi was born in Pisa, Italy, on December 25, 1952. He received the Laurea (Doctorate) degree in physics (*cum laude*) from the University of Florence, Florence, Italy, 1976. He first collaborated with the Department of Physics of the University of Florence, and then joined the Department of Electronics Engineering of the same university in 1979, where he is at present an Associate Professor. He has been involved in research related to solid state physics, radar systems, and asymptotic and numerical techniques in electromagnetic scattering. G. Pelosi is a member of the IEEE and of the Italian Electrical and Electronic Association (AEI).

Allen Love Named Engineer of the Year

Rockwell International's Satellite and Space Electronics Division has named Allan Love their 1990 Engineer of the Year. He has been recognized for his distinguished contributions to the electromagnetic sciences, specifically in the fields of antennas and propagation as applied to radar, radio astronomy and spacecraft communications. A past President of AP-S, Allan Love is currently Chairman of the AP-S Awards and Fellows Committee.