The figure and the work of Riccardo Felici

Paolo Rossi – Dipartimento di Fisica – Università di Pisa

Abstract

Riccardo Felici (1819-1902) was Professor of Experimental Physics at the University of Pisa from 1859 to 1893. However, his main scientific contributions go back to the Fifties of the XIX century, when he studied the electromagnetic induction phenomena both from an experimental and a theoretical point of view. His formulation was very rigorous, probably the best of his time, and it was quite appreciated also by J.C. Maxwell. His school of physics was the most important and influential in Italy for the best part of the XIX century, and he gave also a substantial contribution to the formation of the Italian Physics community, especially through his direction of the journal *Il Nuovo Cimento* and his participation in founding the Italian Physics Society.

1. Felici's biography

According to some sources and to the literature, Riccardo Felici was born in Parma on 11 June 1819, but the circumstances of his birth are somewhat uncertain, since there is no trace of his birth in original Parmesan documents, while there is an act of baptism[1] [requested by Felici himself, and attesting the birth in Pisa, on that same date, of Rinaldo Felice (*sic*), son of unknown parents. Some circumstances lead us to believe that Felici was the illegitimate son of the Pisan noblewoman Isabella Roncioni, whose stormy biography would make the hypothesis plausible. Certainly, there is a "fraternal", albeit cautious, correspondence with Enrichetta Bartolommei, Isabella's daughter[2], and the choice of Isabella's name for Felici's only daughter does not seem casual either.

Certainly, however, he spent his apparently uneasy childhood and adolescence in Parma, and he enrolled first, on November 30, 1838, at the local University - where he followed, among others, the teachings of Elementary Mathematics, Sublime Mathematics and Elements of Astronomy, Mechanics applied to Architecture, Statics and Hydrodynamics, Theoretical and Practical Physics, Experimental Physics - until when Professor Michele Leoni (1776-1858), who had been a lover of Roncioni in the past, prompted him to move, the following year, to the degree course in Mathematical Sciences at the Faculty of Sciences of the University of Pisa, as a pupil of Filippo Corridi, Vincenzo Amici, Luigi Pacinotti, Ottaviano Fabrizio Mossotti and Carlo Matteucci.

In his articulated study plan both Physics and Mathematics teachings appeared, together with various other technical and scientific subjects, up to his degree on July 12th, 1843, achieved in just three years instead of the usual four of the ordinary course of studies.

In 1846, having already published some scientific works, Felici was appointed as assistant to the Chair of Experimental Physics held by Matteucci, as well as examiner and preparer for the exams.[3]

From 1848 to 1849, he took part, with the rank of lieutenant, in the First War of Independence, fighting valiantly in Curtatone.[4]

---

[1][ARF] 1. Fede di nascita di Rinaldo Felice

[2] [ARF] 16. Lettera a Michele Leoni a firma Enrichetta Passerini (nata Bartolommei); 21. Sonetto a stampa a Isabella Bartolommei (Il ritratto); 86. Una incisione: "la nobil Donna la Signora Marchesa Isabella Bartolommei" (F. de Fournier d'Ajaccio); 88. Biglietto da visita della contessa Enrichetta Passerini

[3] [ARF] 35. Nomina ad aiuto per due anni (1846) (estratto); 36. Proroga dell'ufficio di aiuto (1848) (estratto); 37. Conferma per un biennio nel posto di aiuto (1849) (estratto); 38. Incarico delle lezioni e del gabinetto di fisica (1849); 39. Conferma nel posto di aiuto per un biennio (1850) (estratto); 40. Approvazione che l'aiuto dia le lezioni di fisica (1850) (estratto)

[4] [ARF] 57. Congedo dall'Armata del Quartiere Generale Toscano (1848); 58. Passaporto del Ministro Residente di Toscana a Torino; 59. Medaglia commemorativa per la campagna 1848 (1866); 60. Medaglia commemorativa per la campagna 1848 (1867); 83. G. Nerucci: "appendice ai ricordi storici, etc"; 84. Memorie del Battaglione Universitario

On his return to Pisa, due to his political ideas, he was opposed by the Church in resuming his post as assistant at the university, and it was only through the intercession of Professor Silvestro Centofanti, with whom he shared many political ideas and maintained friendly relations, who soon succeeded in restoring his initial academic role.
In 1852, he held both courses and seminars at the Scuola Normale Superiore in Pisa, and in 1853 he was appointed repeater.[5] In 1854 he became adjunct professor[6] and married Elisa Frullini, from Pisa[7]; their only daughter, Isabella, was born in 1856 and married Carlo Paladini.[8]
In 1859, due to the increasing political commitments of Matteucci, Felici became a full Professor and took over the Chair of Experimental Physics - also holding the annexed Cabinet.[9]
It is worth noticing that his salary went down twice, in 1862 and 1865[10], and it kept increasing every five years only starting from 1873.[11]
In 1868 he was appointed as an extraordinary member of the Higher Council of Public Education.[12]
In 1873 the Ministry proposed him to be appointed as a professor at the Higher Institute of Florence, but he finally rejected the offer.[13]
In 1870/71 and in 1882/83, Felici was also Rector of the University of Pisa, taking on various other organizational and managerial positions - including the presidency of the Faculty of Sciences and the position of councilor of the Scuola Normale Superiore - that brought him to abandon active physical research. At the end of 1893 he left university teaching,[14] and a few months later, in 1894, he was appointed professor emeritus of the University of Pisa.[15]
He friendly relationships and collaborations with several Italian scientists of the time, as well as with scientists from other European countries. In 1897, together with several other university professors (including Battelli, Ròiti, Blaserna, Righi and Beltrami) he proposed the establishment of the Italian Physical Society and was the director of his main magazine "*Il Cimento*" (founded in 1844, and then, since 1855, renamed "*Il Nuovo Cimento*").

---

[5] [ARF] 41. Autorizzazione a supplenze alla Scuola Normale (1852-53) (scritto anonimo); 42. Disposizioni per le lezioni dell'A.A. 1852 (estratto); 43. Nomina aripetitore per la Scuola Normale (1853) (estratto).
[6] [ARF] 44. Nomina aprofessore aggregato (1854)
; [7] [ARF] 2. Certificato di nascita di Elisa Frullini; 3. Certificato di matrimonio di Riccardo Felici ed Elisa Frullini (5 agosto 1893); 4. Certificato di matrimonio di Mario Frullini e A. Ceccarelli; 5. Certificato di battesimo di Elisa Frullini; 6. procura di Mario Frullini a Riccardo Felici; 7. Dichiarazione di pensione civile per Mario Frullini; 8. Certificato di liquidazione pensione a Mario Frullini; 9. Decreto di pensione vedovile a A. Ceccarelli; 10. Disdetta di capitale preso in prestito (Elisa Frullini)
[8] [ARF] 11. Contratto di sponsali e costituzione di dote Isabella Felici – Carlo Paladini; 12. Inventari–valutazione del corredo di Isabella Felici; 13. Nota di spesa di T. Tizzoni per nozze Felici-Paladini; 14. Nota di spesa di O. Papasogli per nozze Felici-Paladini; 15. Imprestito fruttifero di R. Felici a C. Paladini
[9] [ARF] 45. nomina a professore aggregato del Governo di Toscana (1859); 46. nomina a professore di Fisica e direttore (1859) (estratto)
[10] [ARF] 47. decreto di riduzione dello stipendio (1862) (estratto); 48. decreto di riduzione dello stipendio (1865) (estratto)
[11] [ARF] 49. decreto di aumento di stipendio (1868) (estratto); 50. decreto di aumento di stipendio (1873); 51. decreto di aumento di stipendio (1878) (estratto) decorrenza dal 1883; 52. decreto di aumento di stipendio (1883); 53. decreto di aumento di stipendio (1888) decorrenza 1893; 54. decreto di aumento di stipendio (1893)
[12] [AUP] 1. Nomina del cav. Felici Riccardo a membro straordinario del CSPI (21/11/1868)
[13] [AUP] 4. Proposta di nomina del prof. Felici all'Istituto Superiore di Firenze (16/11/1873); 5. Relazione della seduta del dì 4 dicembre della Facoltà di Scienze (4/12/1873)
[14] [AUP] 7. (MPI) Prof. Riccardo Felici (31/3/1893); 8. Collocazione a riposo (22/5/1893); 9. Documenti di nomina (20/8/1893); 10. (MPI) Stato di servizio (1893); 11. (MPI) Collocamento a riposo del prof. Riccardo Felici (30/9/1893). [ARF] 55. decreto di collocamento a riposo (1893); 74. minuta manoscritta di Riccardo Felici con la carriera e gli uffizi per la liquidazione della pensione; 75. 75. decreto della Corte dei Conti di liquidazione della pensione di Riccardo Felici
[15] [AUP] 12. (MPI) Nomina del Comm. Felici a professore emerito (30/12/1893); [ARF] 56. 56. decreto di conferimento di professore emerito (1894)

Many were also the acknowledgments for his career: he was a member of various other Italian and foreign scientific societies and academies, including the Italian Society of Sciences of Modena (1861), the Physical Society of London (1868), the *Academy of Sciences* of Bologna (1873), the *Physicalisch-Medicinische Gesellschaft* of Wurzburg (1874), the *Accademia dei Lincei* (1875), the *Istituto Veneto* (1875), the *Academy of Sciences* of Turin (1881), the *Lombard Institute of Sciences and Letters* (1882), the *Academy of Sciences, Letters and* Arts of Lucca (1883),[16] as well as various honors by chivalry orders [cavaliere dell'Ordine Civile di Savoia, cavaliere dell'Ordine dei Ss, Maurizio e Lazzaro, cavaliere, ufficiale, commendatore e Grand'Ufficiale dell'Ordine della Corona d'Italia.[17] He also got official invitations by Italian and foreign associations among which, in 1899, the *Royal Institution of Great Britain.*[18]
He died in the locality of Sant'Alessio di Lucca, on July 20, 1902 [AUP 14]. His body was then buried at the monumental Camposanto of Pisa.

Felici was one of the best Italian researchers and professors of experimental physics in the second half of the nineteenth century, educated at the first Italian school of physics in the nineteenth century, the Pisan one, which had as its main masters Mossotti, Luigi Pacinotti and Matteucci, who was the first to give an experimental character to the school, also by his pioneering research work. There is often a certain continuity of methods and views within a school of thought, even more so in the scientific field, but this this cannot be said of Felici with respect to his teacher Matteucci.
In fact the peculiarities of Matteucci's character were undoubtedly at the origin of this many and rapid initiatives taken both in the political, organizational and institutional context as well as in the practice of research, where his trend was often towards the immediate experimental discovery, while he showed much less interest in the theoretical and mathematical formalization.
Quite different was Felici's temper, described by Pochettino as «[...] of a calm, modest, constant character; methodical spirit, crystalline, ingeniously sharp and disciplined, cautious, balanced, sometimes even skeptical, and balancing the experimental and the mathematical element in his research. A man of reasoning, Felici did not tie his name to a phenomenon he discovered; but his fundamental researches on the induction currents were conducted with such perfection of method that they deserved the honor of being included in the *Klassiker der exakten Wissenschaften* collection published by Ostwald[19]»

---

[16] [ARF] 61. diploma di nomina a uno dei quaranta della Società Italiana delle Scienze di Modena (1861); 62. nomina a socio corrispondente dell'Accademia delle Scienze di Bologna (1873); 63. diploma a socio corrispondente della Physicalisch-Medicinische Gesellschaft di Würzburg (1874); 64. lettera di accompagnamento del diploma n° 63 (in tedesco); 65. nomina a socio nazionale dell'Accademia dei Lincei (1875); 66. nomina a socio corrispondente dell'Istituto Veneto (1875); 67. lettera di Q. Sella dell'Accademia dei Lincei; 68. diploma a socio corrispondente della R. Accademia delle Scienze di Torino (1881); 69. nomina a socio corrispondente del R. Istituto Lombardo di scienze e lettere (1882); 70. diploma a socio corrispondente dell'Accademia Lucchese di scienze, lettere ed Arti (1883); 71. lettera di nomina a socio nazionale della R. Accademia delle Scienze di Torino; 72. diploma di nomina a socio nazionale della R. Accademia delle Scienze di Torino; 73. nomina a uno dei 12 "Honorary Fellows" della Physical Society of London (1868)

[17] [AUP] (MPI) 2. Nomina a cavaliere dell'Oridne della Corona d'Italia del prof. Felici (10/1/1869); 3. (MPI) Onorificenze ai professori Felici e Meneghini (22/7/1870); 6. (MPI) Onorificenza (1875); 13. Ringraziamenti del prof. Felici per la nomina a Grand'Ufficiale (26/5/1894). [ARF] 28. diploma a Riccardo Felici di grande ufficiale dell'ordine della Corona d'Italia; 29. lettera ministeriale di trasmissione del precedente diploma; 29a lettera rettoriale di trasmissione del diploma al n. 28

[18] [ARF] 22. Royal Institution (Centenary of fundation); 23. the nature and objects of Royal Institution; 24. traduzione di una lettera di Federico Bramwell; 25. inizio di traduzione del documento n° 23; 26. traduzione della lettera di Silvano Thompson; 27. elenco con descrizione dei n° 22, 23, 24, 25, 26 ed altri

[19] [ARF] 78. R. Felici: "Ueber die Matematische Theorie der Elektrodynamischen Induction" in astuccio con incisa dedica della S.I.F.; 78a. Lettera di accompagnamento del n. 78 firmata Roiti. 79. Fascicolo omaggio rilegato in pergamena.

2. The scientific work of Riccardo Felici

His first physics works date back to the years immediately following his graduation, with a first memoir, dated 1844, in which he expressed his critical considerations, basically on theoretical grounds, regarding research conducted by the French physician, biologist and physiologist Henri Dutrochet on some hydrodynamic phenomena that he explained by introducing ad hoc a new force, while Felici brought them back to the action of capillary forces.
Appointed as Matteucci's assistant in 1846, Felici was immediately able to make use of direct experimentation, supported by the precious work of the laboratory technician Mariano Pierucci, in support of his theoretical considerations, for which he published, in 1846, a more experimental work in 1846 on some phenomena of thermoelectricity of the mercury, it shows that the electrolytic conductivity could be established not only in the presence of a thermal gradient but in any case in conjunction with phenomena of ionization of the conductive substance.
The following year, continuing with studies and research on electrochemical phenomena, he published a third work on electrical circuits formed by galvanic elements, while, in 1850, he published a work on the propagation of electric current inside a spherical conductor, then , in 1851, in continuation of what has already been done in the previous ones, he published another work on electrochemistry in which he also studied the effect of thermal phenomena on electrical conduction in liquids, arriving, for the first time, to determine the mode of variation with the temperature of the polarization emf. These were purely experimental works, with the addition of non-formal theoretical considerations. In the same year 1851 a first work was also published focusing on the explanation of electrodynamic induction phenomena, later translated into French and republished the following year in the famous *Annales de chimie et de physique*, and also known to Maxwell. This last publication marked the beginning of the main sequence of works on electrodynamic induction, which would end in the early 1860s, consecrating Felici among the great masters of the discipline.
In the early 1950s, therefore, Felici undertook a study of electromagnetic phenomena according to an experimental approach similar to that used in the 1920s by André-Marie Ampère in studying the phenomena of attraction and repulsion between linear elements of electrical circuits. Felici began with a series of experiences in which he systematically investigated the possible variations in the intensity of inducing and induced currents with the variation of nature, greatness, relative position and shape of inducing and induced electric circuits, thus reaching a new theory of electromagnetic induction that contributed much to complete the theoretical framework in which to place the phenomena of electromagnetic induction, to which contributed above all M. Faraday, F.E. Neumann, W.E. Weber and H.F. Lenz, in addition to numerous others ..
But what most distinguishes the work of Felici from the certainly noticeable contributions of the other authors, is the working method with which it reached the formulation of its theory. Indeed, the theories of Neumann, Lenz and Weber were based on particular *ad hoc* hypotheses, having more *a priori* nature and justification than a reasonable physical motivation.
Instead, on the preliminary basis of simple and elementary but crucial physical experiments, Felici, similarly to the method followed by Ampère in the 1920s, arrived at the formal construction of a general theory of electromagnetic induction, avoiding recourse to prior hypotheses artificial, not experimentally proven. His main experimental results are the following:
1. The induced electromotive force is proportional to the inducing current intensity;
2. The induction caused by n currents of intensity i/n is the same as that caused by a single current of intensity I ;
3. A conductor’s effects is the same as the summation of the effects of the elementary cur rents into which it can be decomposed;

4. He induced electromotive force is proportional both to the number of coils of the inductor and the number of the induced circuits;
5. The currents originated in a moving closed circuit is equal to the difference of the currents that would be induced in that same circuit if, open, it was closed in its original or final position;
6. The mutual induction of two identical, coaxial, circular circuits is proportional to their diameter,
7. The current induced in a closed circuit from a solenoid (or a magnet) depends only on the relative position of the circuit's and of the solenoid's (or magnet's) extremities;
8. If the axis of a solenoid (or a magnet) forms a closed loop, then its induction is zero unless the circuit is concatenated with the axis.

Felici's law, according to which "it is possible to calculate the total charge that passes in a circuit subject to an induced current as the difference between the final flux of the magnetic field and the initial one divided by the electrical resistance of the circuit", was then resumed from J.C. Maxwell in constructing his general theory of electromagnetism, as also from A. Roiti, L. Puccianti and G. Polvani, which further confirmed many aspects of Felici's work.

Thanks to these important results, Felici became, in 1859, full professor of experimental physics.

And precisely during the period in which these pioneering researches on the induction currents were conducted, Felici published works in which he explained, through the delay of electromagnetic induction, the presence of certain lack of symmetry in mechanical actions intervening between a given rotating conductive sphere and a magnet placed perpendicular to the axis of rotation of this solid conductor, in the case where the angular velocity increased considerably. And it is precisely from these studies, even admitting hypotheses not directly linked to experimental facts - and this was the only case of a mathematical rather than theoretical treatment of an empirical problem by Felici - he came also to an ingenious theory of diamagnetism.

From the early 1960s onwards, he directed his interests towards other questions of electromagnetism, acoustics and optics. With the work of the years between 1862 and 1866, Felici prepared, on the basis of previous work on the subject, laboratory experiments for estimating the speed of electric current, succeeding, at the same time, in describing some details of the phenomenology of electric sparks, their nature and duration, through congenial technical-experimental apparatuses prepared by himself. In the same years he published, on the basis of what his teacher Carlo Matteucci had already begun, some works concerning some laboratory experiences - building, for this purpose, his own special electromechanical system based on a torsion balance - on the physical behavior of dielectrics in the presence of other electrified bodies, with particular attention to the case of the insulating material inserted between the two conductors of a capacitor, as also published other remarkable works on the possibility of having dielectric polarization phenomena, the latter hypothesis already advanced by Amedeo Avogadro, then taken up and further developed by G. Belli, M. Faraday and above all by Mossotti but from a more theoretical than empirical point of view, thus leaving numerous questions incomplete to which Felici's experimental work, which lasted until the last years of his research activity, responded with acumen and originality, thus bringing the polarization of the dielectrics from a simple ad hoc hypothesis to experimentally assessable physical reality, confirming however many theoretical aspects of Mossotti's physical-mathematical theory.

Some memories are then recalled published between the 1960s and the early 1970s on the determination of the geometric shape of some surfaces of liquids modeled by the action of capillary forces. Thus, in the mid-1970s, for the study of the demagnetization law of certain ferromagnetic materials (a more complicated case than that of diamagnetic and paramagnetic substances), Felici thought and conceived, together with the technique of the Mariano physical laboratory Pierucci, a special switch that produces rapid intermission (at intervals of 1 / 20,000 seconds) in the currents induced between two concentric solenoids in which to insert an iron cylinder (FIG. 2). One battery

was connected to one solenoid, the other a galvanometer, so that, by closing the circuit of the battery, the iron would magnetize, thus inducing an electric current in the other solenoid connected to the galvanometer.
The switch prepared by Felici, with the technical support of Pierucci, thus made it possible to adjust the opening and closing times of these two circuits specifically so as to be able to estimate and adjust the magnetization and demagnetization times of the iron rod, then evaluate the intensity of the various currents in play, which obeyed laws of for −ma A exp (-αt) with A and α numerical constants.
These experiences, which will also be taken up and extended by some of Felici's students can be considered historically as forerunners of subsequent research and theories on the demagnetization of ferromagnetic materials, which are mainly based precisely on the use of alternating magnetic fields of decreasing intensity, made this last necessary since the occurrence of magnetic hysteresis phenomena.
Finally we recall some minor works, carried out between the 70s and the 80s, related to laboratory experiences: i) for the study of the potential of a moving conductor under the influence of a magnetic field; ii) on the theory of the propagation of electricity in a homogeneous conductive sphere when the electrodes are placed on its surface; iii) to investigate other phenomenological aspects of electromagnetic induction; iv) for the study of electromagnetic phenomena of moving fluids; v) on the "Amperian forces"; vi) for the study of string vibrations, as well as some memoirs on thermodynamics, acoustics and optics, many of which constituted the thesis topic of his students and students.
From a retrospective examination of the list of his works, we note that a special attention was paid by Felici to the particular and indissoluble relationship between mathematics and physics, not seen from an axiomatic perspective of a physical-mathematical type, such as was assumed for example by Neumann , Weber and Lenz in their research on electrodynamic induction, but rather from a more properly physical-theoretical perspective, took the moves from theoretical hypotheses with a clear and precise experimental basis and not formulated in a priori way. This epistemological position of Felici probably arose from a fruitful combination of the teachings received from Mossotti and Matteucci, from which he matured a sure, firm and profound conviction in the necessary union between mathematics and physics, more according to the Galilean prescriptions for modern physics than from the axiomatic perspective typical of mathematical physics.
Felici renewed the Galilean tradition in its most typical methodological aspects of study, research and experimentation, starting above all from the work on electromagnetic induction, and with this gave birth to a true school of Pisan Physics alongside the contemporary birth of a equally important school of mathematical physics - that of Enrico Betti and Vito Volterra, who were very much affected by the influence of Felici.
Faced with the limited number of publications by Felici (almost all of them, however, having a character of completeness), one cannot certainly forget, alongside the figure of the researcher, that of a teacher: indeed for many years, in Italy of that period, as Pochettino writes: "there was only one physical Institute, that of Pisa, directed by Felici, and the school could not have been better because from him, equally eminent both from the mathematical point of view and from the experimental point of view, the youth could well learn to know the true way of working in the field of physics; that is, to balance the theoretical element with the experimental one in a proper measure, so that the inappropriate over-dominance of one over the other does not lead to either abstruse metaphysics or disordered empiricism ".
Despite this, Felici's pioneering work did not have a direct academic following in Pisa, partly due to Felici's own motives and dispositions, which led to a sort of diaspora of his students in many parts of the country, resulting in some discontinuity in some way rectified only in 1917 with the call of

Luigi Puccianti, who always held in great esteem the teaching of Felici, his studies and his researches. He explicitly attests that, with Felici, the school of Physics in Pisa reached the highest level of scientific research, thus renewing the great Galilean tradition. Recalling the famous maxim of Saggiatore ["philosophy is written in this great book ..."], Puccianti writes that

... perhaps no modern physicist like ours has ever conformed to the famous Galileo maxim with equal severity. [...] But if it is easy to admire the profound truth contained in this maxim, and to see in it a general and invariable norm of the method, it is very difficult to follow it rigorously, without being discouraged by the logical abstractness of those pure mathematical entities, or allowing oneself to be led to transform them with fantasy (as too often happened in the history of science) into fictitious physical entities, attributing to them an imaginary concreteness, which gives them the comforting illusion of treating real things by treating them: from which precisely it refused the mentality of R Felici, who [...] while sitting in the chair of experimental physics was no less a mathematician than an experimenter.

References

Archivio Riccardo Felici, Sistema Bibliotecario di Ateneo, Pisa [ARF]

Archivio storico dell'Università di Pisa [AUP]

A.Roiti, *Commemorazione del socio prof. Riccardo Felici*, Atti della R. Accademia dei Lincei, Vol. XI, II semestre, pp. 285-295 (1902) [ARF 82]

A.Battelli, *Riccardo Felici*, Il Nuovo Cimento Serie V, Tomo Iv, pp. 233-246 (1902)

A. Occhialini, *Notizie sull'Istituto di Fisica sperimentale dello Studio pisano,* Pisa 1914

L.Puccianti, *Fisici dell'Università pisana alla guerra del 1848,* Il Nuovo Patto n. 3 anno II (1919)

A.Pochettino, *Riccardo Felici*, L'Elettrotecnica, XVII, pp. 487-488 (1930)

L.Puccianti, *Il contributo della scuola di Pisa alla fisica italiana,* SIPS Roma 1939 [ARF 77]

R.Maiocchi, *Felici, Riccardo*, Dizionario Biografico degli Italiani, Vol. 46 (1996)

R. Vergara Caffarelli, *I sette lustri della direzione di Riccardo Felici*

G. Ferrero, *Riccardo Felici. Un enigma nella vita dello scienziato*, E.T.S. Pisa (2014)

B. Reeves Buck, *Italian Physicists and their Institutions* (thesis), pp. 288-320 (1980)

E.Agastra and S.Selleri, *J.C.Maxwell's Forerunners: Riccardo Felici*, IEEE Antennas and Propagation Magazine, Vol. 54,N.3, pp. 250-257 (2012)

P.Rossi, G.Iurato, *La Scuola pisana di Fisica (1840-1950),* pp. 61-96, Pisa University Press (2018)