Masters and students in Italian Physics between the 19th and 20th centuries: the Felici-Bartoli-Stracciati-Corbino case

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Abstract

In the second half of the 19th century, a special practice of research and training in physics took shape in Pisa, characterized by a particular attention to theoretical studies and to combining experimental activity with a profound mastery of mathematical tools. This peculiar approach, started by Carlo Matteucci and Ottaviano Mossotti, continued and spread by Riccardo Felici, Enrico Betti, Adolfo Bartoli and Vito Volterra, was quite an exception in the framework generally marked by strict experimentalism and positivist empiricism of the Italian physics cabinets of the time. The present paper highlights a special path connecting this tradition of the Pisan school to the scientific environment that was formed in the early years of the 20th century at the Royal Physical Institute in via Panisperna in Rome, through the interaction of Orso Mario Corbino with Volterra on one side, and the imprinting left on Corbino by Adolfo Bartoli and his student and collaborator Enrico Stracciati.

1. Introduction

When, in the context of the history of scientific thought, we speak of a "school", we usually have in mind an almost linear transmission process of a set of problems and methodologies that pass from a master to his own students thanks to a patronage that leads to the sharing of visions and research practices. It is therefore quite natural to associate the idea of a "school" with a specific place where this process may occur with some spatial and temporal continuity, often made transparent by the succession of students in the roles previously covered by the masters.
However, there are ways of dissemination of ideas and visions that do not necessarily follow this scheme and that, although obviously based on the existence of a personal relationship between teacher and pupil, may admit also important discontinuities and are therefore less easily recognizable. In such cases, there is not necessarily a clear continuity in the themes of research, and one should rather seek the evidence of the imprinting in the general approach that underlies the students' scientific practice.

The investigation on this peculiar type of scientific offspring cannot therefore disregard the search for links that are apparently weak, but in any case suggest the presence of a lasting influence and are therefore capable of showing observable effects over a long period. The case that we want to describe here is a significant example of the transmission of a particular scientific culture (that of Riccardo Felici's school in Pisa) to a very different context (that of Orso Mario Corbino's Physics Institute in Rome) through an academically underground path, of which we have reconstructed some non-marginal passages that had not been highlighted so far.

We will first sketch the main features of the way physics research and teaching were structured in Pisa and Rome, each with its own peculiar characters, differentiating them from the average practice of the discipline in Italian universities in the late 19th century. In the frame of this general background, we will then present the link between the Pisan tradition of blending theoretical and experimental approach and the scientific environment which developed in the early 20th century at the Physics institute in Rome, through the thin but significant threads connecting Felici to Corbino via Felici's scientific descendance of Adolfo Bartoli and Enrico Stracciati.

2. The Pisa school of physics in the second half of the nineteenth century

In the second half of the Nineteenth century, Pisa was one of the main places of training for university professors of experimental physics and mathematics in Italy [Reeves 1980, Rossi and Iurato 2018]. The University of Pisa was the first in Italy to be equipped with an independent building to house the Physics Institute, specially commissioned by the Grand Duke of Tuscany Leopoldo II under the scientific direction of Carlo Matteucci (1811-1868). Completed in 1844, the Institute had been conceived and built with the dual function of a place of research and scientific training, with a large auditorium for lessons and at least two rooms for laboratory experiences [Occhialini 1914]. The impact of the Pisa school may be measured by the number of its students who obtained professorships in experimental and technological physics. Among the students who graduated in physics and mathematical physics in Pisa between 1860 and 1882, sixteen became holders of a chair in an Italian University. If one considers that in 1894 the Italian chairs in experimental physics and mathematical physics were fifteen, it is evident how fertile appeared the Pisan school in those early years of Italian Kingdom. Scholars like Riccardo Felici (1819-1902), Antonio Pacinotti (1841-1912), Adolfo Bartoli (1851-96), Gregorio Ricci-Curbastro (1853-1925) and Vito Volterra (1860-1940) were trained at this school. A significant fraction of the credit for this concentration of talent in Pisa was due to the presence of the Scuola Normale Superiore, an institution originally founded by Napoleon Bonaparte in 1810

and depending entirely on the university for all its senior teachers. Although originally intended to give special training to excellent potential secondary school teachers, hence the very name of the School, in reality after the reorganization by Carlo Matteucci in 1863 and under the direction of Enrico Betti (1823-92), taking place in the years 1865-74 and 1876-92, the Scuola Normale quickly became an incubator for talented and research-oriented mathematicians and physicists. The science section focused on physics and mathematics and virtually excluded the natural sciences. The special courses for *normalisti* included additional training and exercises given by the same university professors who taught in ordinary courses, as well as by the internal school tutor. The *normalisti* had much more physics and chemistry labs than ordinary university students had, and advanced mathematics education frequently focused on the current research of professors. The candidates for the qualification, the *diploma* of the Scuola Normale, were required to prepare an original dissertation in addition to the degree thesis that the university required. Perhaps more than the University of Pisa itself, the reorganized Scuola Normale incorporated the ideals that had motivated Matteucci, Ottaviano Fabrizio Mossotti (1791-1863) and the chemist Raffaele Piria (1814-65) in their effort to establish a school of physical sciences in Pisa in the Forties. The *normalisti* were a small, selected group of students who were educated, thanks to the special programs of the Scuola Normale, to the research methods and to the careful analysis of the experiments that were considered necessary also for good teaching. At the turn of the Fifties and Sixties, the leading figures were Felici, internal tutor of sciences from 1853 to 1869 as well as professor of physics at the university, and Betti, since 1865 director of the Scuola Normale and professor of mathematical physics at the university, as Mossotti's successor. Under their joint guidance, the *normalisti* had access to a training that linked mathematical and experimental physics, and that was not available in any other Italian university until after 1880.

3. Pietro Blaserna and the new physics institute in Rome

It was necessary to wait almost four decades, indeed, before a second modern building aimed at housing a research school in physical sciences was erected in Italy: the Royal Physical Institute in via Panisperna, in Rome, inaugurated in 1881 by Pietro Blaserna (1836-1918)[1].

Trained as a physicist first in Vienna, with Andreas von Ettingshausen, and then in Paris, with Henri Victor Regnault, considered the greatest classical experimenter of the time, Blaserna had experienced the laboratories and schools of physics beyond the Alps

[1] On Blaserna and the creation of the new Physics Institute in via Panisperna see Focaccia 2016. A comprehensive history of physics at the University of Rome is Battimelli, Ianniello 2013.

and had further deepened his knowledge during a special trip made in 1872. In a pamphlet written in 1868, Blaserna claimed [Blaserna 1868]:

> *True teaching begins where the lesson ends, and must be done in the laboratory, at least for good students who have the desire to delve into science. Herein lies the difference between the Germans and us. We lecture in the amphitheater, they teach in the laboratory.*

Following the post-unitary university reform, around 1880 fourteen of the fifteen science faculties present in Italy offered a course entitled "Exercises in chemistry and physics". The existence of a laboratory course did not imply, however, that the young apprentices were made available in their respective physics institutes and cabinets with the spaces and the equipment necessary for advanced training and research. This was also the case of Pisa, for example, where only few advanced students and assistants were allowed to access the laboratories and use the experimental facilities. In the same 1868 pamphlet, Blaserna commented on the general status of Italian physical studies, identifying a specific "character" of Italy with respect to Germany, France and England:

> *This purely negative character is the lack of organization, or, as we may wish to say, of school. Even in the most inauspicious times, Italy has always had a number of physical science enthusiasts, and it would be easy, for example, to mention men as famous as the greatest physicists in Europe in our century. Now the most important fact that must be ascertained is this: that those illustrious names of which Italy is rightly proud, represent many generals and captains without soldiers. They have found ways to overcome all the difficulties, have made great discoveries and published beautiful works; but they did not leave behind them any student to continue and propagate the master's methods. This is the main flaw of our institutions and the reason why, among us, a real scientific life does not exist.*

Blaserna was referring to physicists of international stature such as Alessandro Volta (1745-1827), Leopoldo Nobili (1784-1835), Giovanni Battista Amici (1786-1863), Macedonio Melloni (1798-1854), who had produced results of very high scientific value, but no school or academic descent. It is interesting to note that in his 1868 pamphlet Blaserna admitted that some progress was underway, but an adequate higher education center in physics continued to be lacking in Italy: he meant a school aimed

at encouraging and preparing students to the experimental activity, which would allow free access to equipped laboratories for as long as desired by the practitioners.
The school founded by Blaserna in Rome deliberately drew inspiration from his Central European experiences and differed in many respects from the Pisan school. While in Pisa the attendance of the laboratories was limited to assistants and very few expert students, as we said, in *via Panisperna* all students participating in the general physics course - students of medicine, engineering, as well as physics and maths - were encouraged to practice as much time as possible in the labs. Furthermore, Blaserna had set up a "Practical school" (*Scuola pratica*), modelled on that of Stanislao Cannizzaro (1826-1910) in Palermo, which allowed students of the faculties of science or medicine to deepen experimental physics in the laboratory, beyond the regulatory university courses.
Blaserna had also established a special cabinet for the teaching of mathematical physics, which from 1891 was directed by Eugenio Beltrami (1835-1900) and then from 1900 by Vito Volterra, who therefore left his analogous position at the University of Turin. The arrival of the latter, an excellent pupil of the Scuola Normale and a man of exceptional foresight and political-organizational skills, gave further impetus to mathematical physics in the capital of young Italy [Guerraggio, Paoloni 2008].
In 1899 Blaserna managed to create at his institute a second chair of physics, aimed at introducing prospective future researchers to the advanced topics that were not included in the general course of experimental physics, addressed as it was to a wide audience of students of physics, mathematics, chemistry, natural sciences and medicine. In contrast to the rather discursive and qualitative character of the general course, the advanced course of *Fisica complementare* (*Complementary physics*), as the new chair was officially called, besides being quite up to date in the choice of the subjects covered, made extensive use of formalization. The first chair holder was Alfonso Sella (1865-1907), who had studied under Woldemar Voigt (1850-1919) in Göttingen, becoming an expert in crystallography and related mathematical tools, and one of the first Italian physicists to become actively involved in researches on radioactivity. The unusual mix of mathematical treatment and experimental approach characterizing the kind of teaching connected with the new chair was such that it was sometime referred to, in spite of its official designation, as "theoretical physics" [Battimelli 2013].

4. The general background of physical research and teaching in Italy

Certainly, the Pisan training put more emphasis on theoretical and mathematical education, while the Roman school preferred experimental practice, in line with the

transalpine and German schools in particular. These first two schools must however be considered against the background of the other experimental physics cabinets present on the national territory, often of ancient tradition such as those of Bologna, Naples, Florence and Padua, and also in comparison with the institutes of the most advanced European countries in the field of physics, i.e. France, Germany and England. Compared to these nations, the institutional status of physics in Italy in the second half of the XIX century - and still for a few subsequent decades - was very weak, especially when comparing the growth rate of the Italian physicist's community and the material resources available to them with those of other countries[2]. Historians Giuliani and Galdabini described that community as "*a small group of scientists facing formidable challenges with inadequate means (both cultural and material)*" [Galdabini and Giuliani 1988]. As highlighted by physicists such as Orso Mario Corbino (1876-1937), successor of Pietro Blaserna at the Royal Physical Institute of Rome, during the 1911 Rome meeting of the Italian Society for the progress of sciences (SIPS), the experimental sciences were being "neglected" or even "suffocated" in Italian universities, as they lacked the necessary financial and organizational means.

Alongside the economic-organizational aspect, however, there was also a deeply rooted cultural aspect. In the small community of Italian physicists, a widespread experimentalist approach prevailed, strongly inspired by positivism, which looked suspiciously at the intrusion of refined mathematical theories into the field of physics [Maiocchi 1991]. This attitude can be observed through the papers published in the most important Italian scientific journal of the time, *Il Nuovo Cimento*, founded in Pisa in 1855 by Carlo Matteucci and Raffaele Piria and since 1877 directed by Riccardo Felici and Enrico Betti (Felici until 1900, Betti until 1893) [Giuliani 1996]. During the years of Felici's and Betti's management, the magazine gradually transformed from a communication vehicle aimed at a regional audience to a nationally spread review, and from a general-purpose cultural magazine to a specialist magazine in the field of sciences. Between 1870 and 1899 the theoretical articles written by experimental physicists were about 90, thus 9% of the total papers published, and the main topics were electromagnetism (21%), thermodynamics (17%) and electricity (13%). The works published by mathematical physicists were, instead, one hundred (10% of the total), related to the study of elastic phenomena (21%), electricity (11%) and electromagnetism (10%) [Giuliani and Marazzini 1994]. As highlighted by Giuliani and Marazzini, even when the research area was the same, the topics studied were different, generally witnessing a poor interaction between physicists and mathematicians in the rather small Italian scientific community. Furthermore, in their

[2] On the general lines of the practice of physics in Italy between mid-19th and early 20th century, and the related institutional developments, see Dragoni 1989, Reeves 1980.

survey of the papers of *Il Nuovo Cimento*, Giuliani and Marazzini showed that in the last three decades of the XIX century, "*Italian physicists did not cultivate lines of research, experimental and theoretical, that later appeared to constitute the cornerstones of the new physics*", i.e. the statistical approach to thermodynamics, the black body radiation and the electrical discharge in rarefied gases. As an example, the only paper on topics related to black body radiation was the one published by Adolfo Bartoli on the pressure of thermal radiation in 1879 [Bartoli 1879], as we will see.

The widespread empirical vision translated into a research methodology dominated by the collection of measures and experimental data without the elaboration of an adequate theoretical and conceptual framework, in which to interpret them and plan new experimental tests. This approach contributed to slow down the penetration in our country of the new physical ideas, which were being developed beyond the Alps, in particular about the discrete nature of matter and radiation.

Bearer of the empiricist attitude was Francesco Rossetti (1833-85), a close friend of Blaserna and the first to hold the chair of physics in Padua, after that the region of Veneto became part of the Kingdom of Italy in 1866. Like Blaserna, he had worked at the University of Vienna and also in Paris with Regnault. He was an appreciated experimental physicist, member of the Italian Society for Sciences. As director of the cabinet of Physics in Padua, he enriched the instrument collection, but could not afford the plan of having a suitable new building. He obtained the addition of only a few rooms to serve as laboratories for selected students, for his assistants and himself. Among his students was Andrea Naccari (1841-1926), who brought the Padua experimental research tradition to Turin, giving rise in 1878 to an empirical-positivist school, which he successfully directed for forty years[3].

In his textbook *Introduction to the lessons of experimental physics* (1878), Naccari described with great clarity his experimentalist vision, in which the most fruitful activity of the physicist is considered that of measuring, of collecting data:

> *When he* [the physicist] *simply measures the intensity of a phenomenon […] it may seem that he does nothing but enrich the pages of a future treatise with a number. Nevertheless, it is to this continuous and modest work that physics owes its glorious triumphs [...]. From time to time the work done by many and distant experimenters around certain issues accumulates [...] finally, it appears to someone, or more adventurous or more ingenious, the idea that more facts can be gathered under the same law [...]. Then the work,*

[3] In the years 1881-1895, the physics institutes of Pisa, Rome, Padua and Turin produced 70% of the physics graduates of our country and the overwhelming majority of future university teachers in experimental physics and related fields, as well as most of the mathematics and physics teachers of the newly unified Italy [Reeves 1980].

> *perhaps obscure, of the many is immediately brought to light. Such is the sure way to prepare the path on which science proceeds in its slow and majestic progress.*

From this dominant empirical point of view, therefore, theoretical models were not deemed useful to provide guidelines for the investigator in his experimental explorations; it was instead supposed that the mere accumulation of measures over time would furnish the key to interpret natural phenomena. In this respect, the circumscribed experiences of the school of Pisa, at least in the incarnation of two of its relevant exponents - Riccardo Felici and his pupil Adolfo Bartoli, of whom we will speak in detail – represented an exception on a national level. Therefore, tracing and following the scientific descendants of these two masters takes on a particular interest, to observe how the theoretical approach did make its own way in Italy, along certain academic connections.

5. Riccardo Felici

Riccardo Felici (Pisa 11/6/1819 - Sant'Alessio di Lucca 20/7/1902), illegitimate son of the famed noble woman Isabella Roncioni [Ferrero 2014], spent his childhood and adolescence in Parma, in difficult personal conditions. In 1839, having moved to Pisa to attend the University, he became a pupil of Ottaviano Fabrizio Mossotti, professor of mathematical physics, and of Carlo Matteucci, professor of experimental physics. Felici graduated in 1843, in 1846 was appointed assistant to Matteucci, and in 1859 succeeded him on the chair of experimental physics [Battelli 1902; Pochettino 1930; Maiocchi 1996].

The double imprinting of his two masters was crucial in making him one of the most brilliant examples of balanced attention to theoretical and experimental aspects in the study of physical phenomena. This attitude found its maximum expression in his studies on the mathematical theory of electrodynamic induction (1854-1855), in which he accompanied an accurate experimental analysis of the induction phenomena with an adequate mathematical formalization, aimed at overcoming the conceptual limits of the theories of Franz Ernst Neumann (1798-1895) and Wilhelm Eduard Weber (1804-1891) [Agastra Selleri 2012, Rossi 2020].

This methodological approach was reflected also in the teaching of Felici, who was able to benefit from the simultaneous presence in Pisa of Enrico Betti, a very talented mathematician to whom he often entrusted his students for the preparation of their degree thesis. Antonio Roiti, one of Felici's most successful pupils and his assistant in 1868-71, would remember his former professor as a researcher convinced "*that*

physical studies separated from mathematical ones could come to very little". Felici also actively encouraged his colleagues in mathematics "*to occupy themselves with physical questions*" [Roiti 1902]. However, as we already mentioned, he was particularly reluctant to "*open the doors of the laboratory to students*" [Cantone 1920]. Michele Cantone (1857-1932), a mathematically oriented experimental physicist, commented Felici's attitude with these words:

> […] *in spite of the very great merits of this man as teacher and scientist, he was somewhat skeptical about the benefit that young people could derive from practical exercises* […].

Felici was the director, and actually the owner, of the magazine *Il Nuovo Cimento* (founded by Matteucci and Piria in 1855), the main Italian scientific journal, originally publishing all sort of scientific contributions and later, under Felici's direction, restricted to "experimental physics and mathematics". Upon his retirement in 1893, he kept the direction of the journal, sharing the task with his successor in Pisa, Angelo Battelli (1862-1916), and with Vito Volterra, the mathematical physicist who had graduated in Pisa as a student of Betti, and in 1893 had moved to a chair in Turin after being professor of mechanics in Pisa. Together with Volterra and Battelli, Felici was in 1897 among the founders of the Italian Physical Society; *Il Nuovo Cimento* became the official journal of the new institution, which gave solid identity to the Italian physics community.

An impressive number of Felici's students and collaborators got university chairs. Emilio Villari (1836-1904) taught experimental physics in Bologna (1871-1889) and later in Naples; Antonio Roiti (1843-1921) taught in Florence from 1880 to 1913; Giuseppe Poloni (1851-1887) became professor in Modena in 1885; Giuseppe Bongiovanni (1851-1918) got the physics chair in Ferrara in 1888; Oreste Murani (1853-1937) was full professor in Milan (*Politecnico*) since 1899; Adolfo Campetti (1866-1947) kept the chair in Catania from 1922 to 1929.[4] We should also mention the long list of mathematical physicists who got their education in Pisa, from Ernesto Padova (1845-1896) to Luigi Donati (1846-1932), from Gregorio Ricci-Curbastro to Vito Volterra and Carlo Somigliana (1860-1955). We shall however focus especially on Adolfo Bartoli.

6. Adolfo Bartoli

[4] It is however worth noticing that, mainly for accidental reasons, but possibly also because of some cultural bias, there were no university physicists belonging to a second generation of direct Felici's descendants. By the year 1920, almost all Italian physics professors were academic descendants of Blaserna or Nàccari.

Adolfo Bartoli (Florence 19/3/1851 - Pavia 18/7/1896), student of Felici at the University of Pisa and at the Scuola Normale, graduated on April 4, 1874 with a dissertation on the second principle of thermodynamics and obtained the qualification as *normalista* in the same year. Then he was assistant to Villari in Bologna for two years, succeeding Augusto Righi (1850-1920), who had moved to the local technical institute [Ronsisvalle 1896; Stracciati 1896; Gliozzi 1964; La Rana, Rossi 2019].
After teaching for two years at the technical institute of Arezzo in Tuscany, where he set up a meteorological observatory, and for less than a year at the University of Sassari in Sardinia, in 1879 he returned to Tuscany to succeed Ròiti as professor of physics at the technical institute of Florence, where Villari had also taught. This institution had a well-equipped physics cabinet (better than many universities had at the time), supported by the province rather than by the national government. Bartoli stayed there until 1886, even declining to accept the chair of mathematical physics in Palermo, for which he had won the competition in 1880. In 1886, he became professor of physics at the University of Catania. In 1893, he was called to succeed Giovanni Cantoni (1818-1897) in Pavia (Lombardy), on the chair that had been Volta's. He died less than three years later at the age of forty-five, having published more than sixty articles in his own name in twenty-five years and about sixty jointly with one or more colleagues.
Bartoli is still remembered (also in the Anglo-Saxon world) for a youthful work that he published in Florence in 1876 on the motions produced by light and heat, in which he analysed the working principles of a Crookes' radiometer. This article contained a historical account of the different points of view on the pressure of light and thermal radiation, as well as an experimental and theoretical investigation of the Crookes radiometer [Straneo 1922; Carazza, Kragh 1989; D'Agostino et al. 2008]. Bartoli demonstrated, perhaps for the first time, that the motion of the vanes was not due to the radiation pressure but to the behavior of the residual gas. The core of the work was Bartoli's theoretical demonstration, through an ideal experiment, that the second law of thermodynamics would have been violated if no work had been needed to compress a volume of radiation into a perfectly reflective cavity. An interpretation that Bartoli offered of this result was the fact that the radiation exerted pressure on the walls of the cavity, but since his experiments could not confirm the existence of this pressure, he advanced this hypothesis with suspicion and great reserve, and promised to discuss elsewhere various other hypotheses that would have led to the same result.[5]

[5] In a manuscript filed at the *Accademia dei Lincei* in 1882, Bartoli offered three other hypotheses, in addition to the radiation pressure, that could account for the purely thermodynamic result that work was required to compress radiation contained in a cavity in his thought experiment. When he published these hypotheses as an appendix to the 1884 article on radiant heat and the second principle of thermodynamics, however, he premised the observation that some hypotheses were not very probable and were therefore of more historical than scientific interest.

Bartoli's research did not derive from Felici's main interest in electrodynamics or from the interests of other professors in Pisa, but some elements of the style of his work on radiation resemble those of Felici. His work contained both experimental and theoretical sections, and in the theoretical sections the topic was developed with due skepticism towards mechanical hypotheses. It is worth noting that Bartoli's work on radiation thermodynamics was done while he was Villari's assistant in Bologna, and that Villari published a long article at the end of 1877, about the emission of different types of radiation from different bodies heated to 100º C.[6]

Only some years later, in 1883, Ludwig Boltzmann (1844-1906) combined Bartoli's thermodynamic arguments with the electromagnetic theory of James Clerk Maxwell (1831-1879), which had played no role in Bartoli's considerations. Boltzmann thus provided a theoretical derivation of the experimental law of Josef Stefan (1835-1893), concerning the proportionality of the radiant energy emitted by a black body to the fourth power of absolute temperature.

Bartoli's research activity revealed no coherent theme until 1877, when he began a series of systematic studies on galvanic polarization and its influence on electrolysis using weak electromotive forces. This work earned him the *Aldini Prize* of 1000 lire, offered by the Academy of Sciences of Bologna in 1879, and the following year the 3000 lire prize of the Ministry of Public Education, managed by the *Accademia dei Lincei*. In addition to starting a long series of studies[7] of electrochemistry, especially concerning organic synthesis by electrolysis, this work led Bartoli to develop a theory of electrolyte constitution, published in 1882-83, which some of his biographers claim to be substantially the same as the theory developed by Svante Arrhenius (1859-1927), which was not published until 1887. There was a precedent for Bartoli's work on electrolysis and electrochemistry, because Felici published an article in 1851 on galvanic polarization and the influence of heat on the passage of electric current through liquids. However, Ròiti remembered in his obituary of Felici that he had not been aware of this article [Ròiti 1902]. He was Felici's assistant until 1871, at the time when Bartoli and Poloni (another *normalista* and his peer) did their first work on electrolysis, published in 1871 when both were not yet graduated.[8] It is therefore not clear whether the work of Felici, twenty years old, had provided any direction or inspiration to Bartoli. As a matter of fact it is not possible to place electrolysis among the fields of a consolidated research tradition in experimental physics in Pisa. It cannot

[6] Later on, Villari engaged in a priority dispute with Ferdinand Kurlbaum (1857-1927) in 1900 on the credit for this type of research, which Kurlbaum had published independently in 1898.

[7] In many of his studies on electrolysis, Bartoli collaborated with Giorgio Papasogli, a chemistry assistant at the Institute of Higher Studies in Florence.

[8] It is worth recalling that also Ròiti, who was in Florence after 1880 (Bartoli was there at the technical institute from 1878 to 1886) published several articles on both electrochemistry and calorimetry.

however be ignored that already in the Thirties Matteucci had come to formulate the laws of electrolysis, independently of Michael Faraday (1791-1867).
Bartoli was better known in his time for his studies of calorimetry, which began in 1880 with a measure of the mechanical equivalent of heat with a new method. The calorimetric work included new high-precision measurements of the specific heats of various liquids and metals, and measurements of solar heat and its effects. For this work, Bartoli obtained the Royal Prize for physics of the *Accademia dei Lincei* for 1894, announced only in 1897, after his death. There seems to be no precedent in Pisa for Bartoli's work on calorimetry, neither in Felici's research, nor in that of Betti or in that of Paolo Tassinari (1829-1909), professor of chemistry, since Tassinari had not published anything since the mid Fifties. Many of Bartoli's experiments were conducted, in Florence and Catania and perhaps also in Pavia, in collaboration with Enrico Stracciati, a graduate of the Scuola Normale who like Bartoli had a significant role in the connection between the schools of Pisa and Rome.

7. Enrico Stracciati

Enrico Stracciati (Arezzo 29/12/1858 - Rome 3/4/1937) attended the Technical Institute of Arezzo until he obtained his license in the Physics-Mathematics Section on July 15, 1878, with generally good marks, but in particular with grades 10/10 in Physics. We emphasize that the teaching of physics at the Technical Institute of Arezzo was entrusted, exactly from 1876 to 1878, to Adolfo Bartoli, who certainly had the opportunity to appreciate the young Stracciati and was most likely the one who suggested him to continue his studies in Pisa and to compete for a place at the Scuola Normale.
Stracciati entered the Scuola in 1880 and stayed there until 1882. In Pisa he became friends with Vito Volterra, a little younger than him (Volterra was born on May 3, 1860), who graduated like him in physics in the same year 1882, and with whom Stracciati remained in close correspondence for his whole life[9] [La Rana 2019]. He graduated on December 1, 1882 with the thesis "On the demagnetization rapidity of iron when the inducing action of a voltaic spiral ceases". After graduating, he immediately started a scientific collaboration with Adolfo Bartoli, at the time (1879-1886) professor of Physics at the Provincial Technical Institute of Florence, and was appointed the position of *aiuto* for that same chair (literally *help*, a higher level of assistant). He then made some unfortunate attempts to participate in competitions for university professorships, including in particular the competition for the chair of

[9] Stracciati's correspondence with Volterra – dated in the period 1882-1928 - are stored among Volterra's Papers, in the library of the *Accademia dei Lincei*.

Physics of the University of Cagliari (October 1885). The Commission (Blaserna, Cantoni, Missaghi[10], Pacinotti, Villari) preferred Giuseppe Vicentini (1860-1944), Giuseppe Gerosa (1857-1910), Moisè Ascoli (1857-1921), Giovanni Guglielmo (1853-1935) and Pietro Cardani (1858-1924) (in this order) [La Rana, Rossi 2019], but Antonio Pacinotti recorded that he had voted also for Stracciati. In the competition for an experimental physics chair at the University of Sassari (again October 1885), the Commission (Blaserna, Cantoni, Garibaldi[11], Valente[12], Villari) produced the following "medallion":

> *STRACClATI Enrico. In 1882 he received his degree in physics from Pisa, was an assistant professor of physics at the technical institute of Florence; in 1885 he was appointed professor of physics at the Technical Institute of Arezzo. It presents exclusively the only note "On the delay in magnetization of iron produced by currents induced in its mass", which constitutes a diligently conducted work. The four memoirs made in collaboration with Professor Bartoli demonstrate activities for the part that concerns him.*

On these grounds, the Commission preferred Vicentini, Guglielmo, Aroldo Violi (unknown personal data), Battelli and Girolamo De Franchis (unknown personal data). For the record, Vicentini went to Cagliari and stayed there until 1889, then moved to Siena and later to Padua. Giovanni Guglielmo (1853-1935) went to Sassari but in 1891 passed to Cagliari, in the position left open by Battelli after his stay in 1889- 91.
Stracciati in the meantime had been recruited on October 1, 1885 as a professor in the Technical and Nautical Institutes, and had been assigned to the Technical Institute "Carlo Gemmellaro" of Catania as his first seat. In the following year 1886, he was joined by chance in Catania by Adolfo Bartoli, who was going to occupy the chair of experimental Physics, just left by Damiano Macaluso (1845-1932), who in his turn had moved to Palermo after a decade in Catania. Therefore Stracciati could easily start a remarkable collaboration, which in a few years (from 1884 to 1895) produced as many as 21 articles published in the *Nuovo Cimento* on various themes, ranging from calorimetry and other thermodynamic topics to astrophysics issues, related in particular to the measurement of solar heat. The relationship with Bartoli, however, could not last long due to the premature death of the latter in 1896. Furthermore, Stracciati already in 1892 had left Catania for Venice, where he taught for a year at the Technical Institute "Paolo Sarpi", and immediately afterwards for Rome, where from 1893 he taught at

[10] Giuseppe Missaghi, professore ordinario di chimica generale a Cagliari dal 1864 fino alla sua morte nel 1897.
[11] Pietro Maria Garibaldi (1823-1902).
[12] Lorenzo Valente (1850-1930).

the "Leonardo da Vinci" high school until his retirement in 1928. However as we shall see it was in that year that his ancient relationship with Orso Mario Corbino was ostensively resumed.

8. Orso Mario Corbino

The years when Stracciati was teaching at the Technical Institute "Carlo Gemmellaro" are linked not only to his collaboration with Bartoli, but also to his first interaction with the young Orso Mario Corbino (Augusta 30/4/1876 - Rome 23/1/1937), a student at the *Liceo* (high school) in Catania between 1887 and 1892 [Amaldi, Segreto 1983; Battimelli 2013b]. As he himself recalled many years later in a letter of 1911 to Stracciati, Corbino began to attend the Physics lessons by Stracciati and also those by Bartoli at the University, which fascinated him to the point of convincing him to enrol in the Degree Course in Physics in 1892. In Corbino's own words

> *As you may perhaps know, when I was a high school student, I stealthily attended your lectures at the Technical Institute of Catania, and also attended Bartoli's physics and mathematical physics lectures. Both have exerted on me a strong influence, pushing me to study physics. Since then I have had a religious veneration for your wonderful works*[13].

However, as a university student he could continue to benefit from Bartoli's lessons only for one year, because, as we have seen, in 1893 Bartoli moved to Pavia. Most likely Bartoli's departure was one of the reasons that prompted Corbino to move almost immediately to the University of Palermo, where he became a pupil of Damiano Macaluso, a former student of Blaserna in Palermo and later Blaserna's assistant in Rome. He graduated there and soon later became a teacher at the "Vittorio Emanuele II" high school. At the same time, he kept collaborating with Macaluso, and they discovered in 1898 the effect that bears their name (a great increase in the rotational power of sodium vapor in the magnetic field near the resonance lines). Macaluso and Corbino published jointly a first paper reporting the observation of the phenomenon and their experimental results, and soon after Corbino alone signed a second paper in which a theoretical explanation of the effect was given. It is reasonable to assume that, while the experimental skill shown by Corbino was the result of his apprenticeship under Macaluso, his peculiar attention to the theoretical side of the research was a legacy of his early interaction with Bartoli and Stracciati.

[13] "Come forse avrà saputo dopo, io, da studente di liceo, frequentavo furtivamente le sue lezioni all'Istituto Tecnico di Catania, e assistevo anche a quelle di fisica e di fisica matematica del Bartoli. Le une e le altre hanno esercitato una influenza grandissima attraendomi agli studi di fisica. E fin da allora io ho avuto una venerazione religiosa pei loro stupendi lavori" (Archivio Edoardo Amaldi, Physics Department, Sapienza University of Rome, Box 21, folder 7).

That work gave Corbino a quick reputation as an excellent researcher, so that already in 1905 he won a competition for a chair of experimental physics, and became full professor at the University of Messina, in Sicily. He did not stay there for long. In 1907 the chair of *Fisica complementare* in Rome was left vacant due to the premature death of Alfonso Sella, and Blaserna called Corbino to Rome to replace Sella. He reached Rome just after the devastating earthquake that destroyed Messina at the end of 1908. Though originally his move to Rome was meant to be a provisional one, he ended up staying in the Capital for the rest of his life, and when Blaserna died in 1918, he succeeded him on the main chair of experimental physics and as director of the Physics institute. As soon as Corbino landed in Rome, his open attitude towards experimental investigation guided by theoretical insight found a natural scientific partnership in Volterra's concern for mathematical research inspired by physical problems. Volterra entrusted Corbino with the task, which had been Sella's, of editing the *Rivista* section of *Il Nuovo Cimento*, where news of the development of the discipline and abstracts of the relevant papers published abroad were presented to the Italian physicists. By doing so, Volterra relied in Corbino's broad-minded attitude about the scope of physics, and on his sensitivity to, and knowledge of, the new ideas emerging at the time. Together, the mathematical physicist already enjoying a solid international reputation and the younger experimentalist with a feeling for theory were the pillars of the lively Rome section of the Physical Society, organizing series of public lectures where some of the recent developments in physics were discussed, from the atomic theory of matter to radioactivity, from the early quantum hypotheses to relativity.

Later on, only in 1926, Corbino succeeded in creating in Rome a chair officially labelled as "Theoretical physics", to be conferred notably to yet another *normalista*, Enrico Fermi (1901-1954)[14], who had graduated in Pisa in 1922 under the supervision of Luigi Puccianti (1875-1952)[15]. In spite of this late arrival, it is nonetheless fair to say that the ground in Rome for such an event had been laid long since; about twenty years earlier, the seeds disseminated from the days of Felici and Betti in Pisa, through the imprinting left by Felici's student Bartoli on Corbino, and Corbino's fruitful

[14] Corbino's choice was undoubtedly favored by the open-minded attitude of some of the Faculty's mathematicians. Among them we must recall Guido Castelnuovo (1865-1952) and Federigo Enriques (1871-1946), and especially Vito Volterra and Tullio Levi-Civita (1873-1941), who in 1925 had supported Fermi (with no success) in the competition for a chair in "Mathematical Physics" [Rossi 2019]. It is worth observing that Volterra was a *normalista* and Levi-Civita was a student and collaborator of Gregorio Ricci-Curbastro, another *normalista* and a student of Betti's; the first scientific papers by Fermi (concerning general relativity) were strongly inspired by Levi-Civita's work [Iurato and Rossi 2018].

[15] In this context it is worth mentioning that Luigi Puccianti, albeit being a student of Battelli (a pupil of Nàccari, devoted to purely experimental research), had been called to Florence by Ròiti (another *normalista*!) in 1900, and had been Ròiti's assistant and *aiuto* until 1907. Puccianti was a typical experimentalist, but he was also a devoted admirer of André-Marie Ampère (1775-1836) as a theoretician and a strong supporter of Felici's method and approach to physics [Puccianti 1939].

interaction with Betti's pupil Volterra, had prepared the environment allowing theoretical physics to land in full sweep on the Italian academic scene.

9. The unusual thread connecting Corbino and Stracciati

There is a further, more personal note to be mentioned here, a touching addition to the reconstruction of the devious thread linking Pisa to Rome via Sicily that we have sketched. As we have seen, of all the actors of our story only Stracciati never managed to get a university professorship. He ended up in Rome, where from 1893 he taught physics in a *Liceo*. We have quoted the letter that he received from Corbino in 1911, and that is the only documentary evidence of a contact between the two men in Rome in the twenty years dividing Corbino's arrival there in 1908 and Stracciati's retirement, at the age of 70, in 1928. In that very year 1928 the position of assistant to Corbino, that had been assigned to Franco Rasetti (1901-2001), was left temporarily uncovered due to the leave that Rasetti had requested in order to spend a period of study and research in the United States. Corbino proposed, and obtained from the Science Faculty[16], that Rasetti would be replaced by Stracciati; his old teacher was appointed temporary assistant in charge for the academic year 1928/29, and maintained that status also during the following year 1929/30, to cover the vacancy caused by the temporary absence of another assistant, Emilio Segrè (1905-1989), who was then engaged in the military service.

It is reasonable to think that Corbino could have made a different choice, were it to be dictated merely by scientific considerations of efficiency, or by the prospect of giving a young laureate a first opportunity of setting in an academic environment. None of these motives was obviously present in the case of Stracciati, by then an old high school teacher out of touch with modern developments in science. Corbino's choice was clearly dictated by a different kind of reason; and it is almost moving to see in this choice the signs of the profound affection and esteem for the ancient master, who evidently had left in Corbino a significant scientific imprinting.[17]

[16] We may recall here that also Vito Volterra, another good friend of Stracciati, was then a member of the Faculty.

[17] The quality of the relationship between Corbino and Stracciati impressed also Edoardo Amaldi (1908-1989) who, many years later, in the Fifties, arranged a meeting with Guglielmo Stracciati, Enrico's son, in order to get some first-hand information on his father.

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