

Masters and students in Italian Physics between the XIXth and XXth centuries: the Felici-Bartoli-Stracciati-Corbino case

G. Battimelli

A. La Rana

P. Rossi

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 "philosophy" that inspires the students' scientific practice.

The investigation on this peculiar type of scientific "descent" 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 Felici's school in Pisa) to a very different context (that of 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.

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. The impact of the Pisa school may be measured by the number of its students who obtained professorships in experimental and technological physics. 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 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 Matteucci in 1863 and under the direction of Betti 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, Mossotti and Piria in their effort to

establish a school of physical sciences in Pisa in the Forties. The normalisti were a small, select group of students who were educated, thanks to the special programs of the Scuola, to the research methods and to the careful analysis of the experiments that were considered necessary also for good teaching. The leading teachers were Felici, internal tutor of sciences from 1853 to 1869 as well as professor of physics at the university, and Betti, director of the Scuola Normale from 1864 and professor of mathematical physics at the university. 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. Riccardo Felici

Riccardo Felici (Pisa 11/6/1819 - Sant'Alessio di Lucca 20/7/1902), illegitimate son of the famed noblewoman Isabella Roncioni, 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 (1791-1863) professor of mathematical physics, and of Carlo Matteucci (1811-1868), professor of experimental physics, to which he later succeeded as titular of the chair in 1959. 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 Neumann and Weber. 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 (1823-1892), a very talented mathematician to whom he often entrusted his students for the preparation of their degree thesis. Felici retired from teaching in 1893, while retaining the direction of the magazine *Il Nuovo Cimento* (founded by Matteucci and Piria in 1855), which he ceded to the newly formed Italian Physical Society, of which he was one of the founders in 1897.

4. Adolfo Bartoli

Adolfo Bartoli (Florence 19/3/1851 - Pavia 18/7/1896), student at the Scuola Normale, graduated on April 4, 1874 with a dissertation on the second principle of thermodynamics and obtained the qualification in the same year. Then he was assistant to Villari (a student of Felici's) in Bologna for two years, succeeding Righi, who had moved to the local technical institute. 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 in many universities 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 Cantoni 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, which contained a consideration of Crookes'

radiometer. This article contained a historical account of the points of view on the pressure of light and thermal radiation, as well as an experimental and theoretical investigation of the Crookes radiometer. 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 promised to discuss in another article various other hypotheses that would have led to the same result. In 1883, Boltzmann combined Bartoli's thermodynamic arguments with Maxwell's electromagnetic theory, which had played no role in Bartoli's considerations, in order to provide a theoretical derivation of Josef Stefan's experimental law, which established the proportionality of radiant energy emitted by a black body at the fourth power of absolute temperature.

Bartoli's early work 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 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 Svante Arrhenius' theory, which was not published until 1887.

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. Many of these experiments were conducted in collaboration with Enrico Stracciati, a graduate of the Scuola Normale, in Florence and Catania and perhaps also in Pavia. Bartoli had collaborated also with Giorgio Papisogli, a chemistry assistant at the Institute of Higher Studies in Florence, in many of its own electrolysis studies. 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 of the *Accademia dei Lincei* for physics 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, professor of chemistry, since Tassinari had not published anything since the mid Fifties. 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. 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. It is therefore not clear whether the work of Felici, twenty years old, had provided any direction or inspiration to Bartoli. If it is therefore not possible to place electrolysis among the fields of a possible consolidated research tradition in experimental physics in Pisa. It cannot however be ignored that already in the thirties Matteucci had come to formulate the laws of electrolysis, independently of M. Faraday.

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 three years later, at the end of 1877, on the emission of different types of radiation from different bodies heated to 100 C. By the way, Villari

engaged in a dispute over the priority with Ferdinand Kurlbaum in 1900 on the credit for this type of research, which Kurlbaum had published independently in 1898. Moreover 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. The center for calorimetric work in the seventies in Italy was Padua.

If Bartoli's research fields did not derive from Felici's main interest in electrodynamics or from the interests of other professors in Pisa, some elements of the style of work on radiation resemble those of Felici. This work contains both experimental and theoretical sections, and in the theoretical sections the topic was developed with due skepticism towards mechanical hypotheses. The suggestion of radiation pressure as a way to avoid violating the second law of thermodynamics was presented with great reserve. 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.

5. 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 (in the Volterra Fund his letters from 1882 to 1928 are now kept). 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 became a Help for that same chair. He then made some unfortunate attempts to participate in competitions for university professorships, including in particular the competition for the chair of Physics of the University of Cagliari (October 1885). The Commission (Blaserna, Cantoni, Missaghi, Pacinotti, Villari) preferred Vicentini, Gerosa, Ascoli, Guglielmo and Cardani (in this order), but Antonio Pacinotti recorded that he had voted also for Stracciati. In the competition for an experimental physics chair at the University of Sassari, the Commission (Blaserna, Cantoni, Garibaldi, Valente, Villari) produced the following "medallion":

STRACCIATI 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, Violi, Battelli and De Franchis. For the record, Vicentini went to Cagliari and stayed there until 1889, then moved to Siena and later to Padua. Giovanni Guglielmo, 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 "Gemmellaro" of Catania as his first seat. In the following year 1886, he was by chance reached in Catania by Adolfo Bartoli, who was going to occupy the chair of experimental Physics, just left by Damiano Macaluso, who 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 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 linked.

6. Orso Mario Corbino

The years when Stracciati was teaching at "Gemellaro" are linked also to his 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,

As he himself recalled many years later in a letter of 1911 to Stracciati, Corbino began to attend "stealthily" the Physics lessons by Stracciati and also those by Bartoli at the University, which fascinated him to the point of convincing him to enroll in the Degree Course in Physics in 1892. However, he could continue to benefit from Bartoli's lessons only for a 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 Macaluso. 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) and that gave Corbino an early fame. The contact between Stracciati and Corbino was never interrupted. In 1928 the position of assistant to Corbino, that had been assigned to Franco Rasetti, was left temporarily uncovered due to the leave that he had requested in order to spend a period of study and research in the United States. Stracciati, who was already retired, 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, who was then engaged in the military service.

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. A kind of experimental physics quite attentive to the quality of the theoretical interpretation was typical of a cultural heritage that was embodied in the person of Felici by the hybridization of the very different but equally remarkable experiences of his two masters Matteucci and Mossotti. It was then not by chance that Corbino wanted Enrico Fermi in Rome, having recognized in him not only his extraordinary intellectual qualities but probably also a similar imprinting already during their first meeting in 1922,

when Fermi had just graduated from Pisa. Fermi's results may therefore be seen also as the exaltation of a scientific method going back to the Galilean origins of modern physics and intrinsically capable of producing significant results.

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