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Physics in Perspective

Identifying and Understanding Historical Scientific Instruments: The Case of the Physics Cabinet of the University of Bologna

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This paper reconstructs the process of identification and understanding of an ensemble of historic physics instruments carried out between 2021 and 2022 at the Department of Physics and Astronomy "Augusto Righi" of the University of Bologna. The ensemble of 244 instruments is part of the Collection of Physics of the University and corresponds to the main core of the nineteenth-century Cabinet of Physics of the University of Bologna. After a brief recollection of the complex history of the cabinet the paper brings into light the different aspects involved in the identification and understanding of a scientific instrument. The various challenges concern the use of the resources available, the role of the experts, the study in situ and the use of original archive sources. In addition, a contextualization of the present study in the current literature on material culture studies and history of scientific instruments will bring to light the importance of the analysis of historical and trade catalogues, both for retracing the trajectories of a specific artefact and for the study of its relationships with users, donors, collectors, previous owners, and other objects.

Key words: Nineteenth-century physics cabinet; History of physics; History of scientific instruments.

In recent years, cabinets of physics have been a major theme of research within the field of the history of scientific instruments. Careful studies on their constitution, enrichment and dispersion have allowed scholars to reconstruct the practise of research and teaching in many universities and institutes in various periods.[1] Collections researched, preserved, and included in published catalogues are essential primary sources for a full account of the past practice of science.[2]

The literature on material culture has shown how artefacts have assumed a central role in the study of the beliefs—according to Jules David Prown understood as ideas, values, attitudes, and assumptions—of a particular society at a given time.[3] Objects are material things that persist and allow access tp the history

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of people; examining objects traces the cultural context in which they were created and in which they have evolved. David Fontijn compares Igor Kopytoff's concept of biographies with that used by Hadas Weiss and Hans Peter Hahn of itineraries, both metaphors that give intrinsic qualities to the objects themselves: "biographies colour the perception of objects with the quality of human life, itineraries with the quality of routes and paths."[4] While Kopytoff's concept places emphasis on the emic meaning of artefacts, the concept of itineraries is best suited to describe what happens to an artefact with regard to ethics. The trajectories of objects, which acquire more meaning and identity from interactions with donors, collectors, and previous owners also offer historians of science the opportunity to study the wider cultural movement at play in the museum.[5]

In our case, analysis of the contextual and specific histories of the Cabinet of Physics has allowed the identification of apparatuses. At the same time, the collected instruments constitute primary sources that illuminate the institutions they have belonged to—scientific academies, research institutes, religious schools, corporations, and universities—and the people involved in the processes of manufacture, trade, purchase, and use. Among the literature on material culture studies and the history of scientific artefacts, particularly meaningful for the present study have been the works of Paolo Brenni and Alexi Baker, due to their focus on the objects seen at the intersection among several scholarly fields and the required interplay of knowledge, expertise, and in-depth research for its understanding.

This paper aims not only to enrich the current literature with a case study of the Cabinet of Physics in Bologna but also to focus on an aspect so far mostly neglected: the complexity of the process of identification and understanding of historical apparatuses which, in various forms and disguises, may appear within a cabinet.

The task will be accomplished by firstly outlining the history of the Cabinet of Physics of the University of Bologna. Spanning from the beginning of the eighteenth century to the late-nineteenth century, this history reveals the path through which modern physics progressively entered and established within the ancient, traditionally-oriented University of Bologna.

After this, the core aspects of the paper will be discussed. Between 2021–22, a thorough identification and understanding of the apparatuses belonging to the nineteenth-century Cabinet of Physics has been carried out with the help of an internationally recognized expert in the field, the late scholar Paolo Brenni. The present study illustrates the many aspects involved in this process: it discusses the use of scarce sources and catalogues, the importance of the analysis in situ and the role of expertise within the process. Next, the results of the identification carried out with expert supervision will be compared with three historical catalogues of the nineteenth-century Physics Cabinet from 1835, 1865, and 1870 recently found in the University archives; it is shown how not only, as expected, the historical catalogues can provide help in the understanding of the instruments but also how the new, reliable, authoritative inventory provided a guide in the reading and interpretation of historical sources. The overall work with an expert led to the finding of a replica of a seventeenth-century microscope by Giuseppe Campani which turned out to be particularly interesting and for which a specific in-depth study has been initiated.

A Brief History of the Cabinet of Physics at the University of Bologna

As with for other Italian and European cases, the proliferation of modern science at the University of Bologna was not straightforward. As remarked by many historians, a new culture boosted by the Renaissance first and by the scientific revolution after did not originate within universities, nor was it celebrated there. Instead, Cloisters, chancelleries, courts, academies, and free assemblies of scholars were the centres of new knowledge.[6] In these places outside the university context the original ancient texts of Archimedes and the early naturalists were rediscovered, which were to become essential tools for the new science.

Notable examples in this context are the Royal Society in London and the Académie des Sciences in Paris, which gave a strong boost to scientific research from the seventeenth to the nineteenth centuries, dealing with the realization of scientific experiments, the store of collections, and the publication of original works such as, in the case of the Royal Society, Newton's *Principia Mathematica*.[7] Throughout the eighteenth century, Newtonian physics was cultivated mostly amongst those associated with academies, and it is to these institutions that the organization and dissemination of modern scientific knowledge in Europe is due.

Following the trend, the cradle for the cultivation of modern science in Bologna was not the ancient *Studium* or University whose roots are traced back to the eleventh century, but rather an independent institution: the Institute of Sciences and Arts of Bologna. The Institute was founded by a member of the local aristocracy, Luigi Ferdinando Marsili, with a military and diplomatic career behind his shoulder and a cultivated passion for and direct practice of science. Once returned from his service to the Habsburg family, Marsili managed to get the support from the senate of the city for the foundation of a new institute that could promote progress in the astronomical, historical, military and physical fields.[8] In addition, an agreement with the *Studium* made the Institute a place accessible to students who, after the regular morning lessons, could attend the new laboratories and follow experimental activities and lessons given by the scientists. In this way, Marsili began modern reforms of the *Studium* that became more substantial towards the end of the eighteenth century when, within the reforms in education introduced during the Napoleonic age, the Institute and the *Studium* were integrated in a single entity: the modern University of Bologna.

Marsili's initiative entailed not only scientific imagination and political ability, but also private donations. The different laboratories of the Institute were initially fed by an ample supply of precious objects and scientific apparatuses, collected by

Marsili himself in years of travels. On January 11, 1712 the donation of the Marsili's collection to the Senate for the foundation of the Institute was ratified.[9] It is still possible to recognise the list of apparatuses devoted to the "Chamber of Physics" which, in 1745, would be renamed the "Cabinet of Physics." This first nucleus, nowadays completely lost, included optical instruments like telescopes and microscopes, a magic lantern, various mirrors and lenses; various types of thermometers and barometers and an air-pump; scales and apparatuses for the study of equilibrium and statics and an entire workshop for the construction and reparation of the apparatuses.[10] Marsili's donation included other objects and equipment devoted to other disciplines studied at the Institute such as natural history, the art of war, antiquities, painting and sculpture. As the Institute grew, other fields of studies such as chemistry, anatomy, obstetrics, geography and nautical science were added and for each of these, specific professors were assigned to give lectures on fixed days, showing the instruments and objects, and giving practical demonstrations to students and colleagues.[11]

The official foundation of the Physics Cabinet in 1745 coincided with a second sustained donation of apparatuses by the patron of the Institute who took the lead after Marsili's death: the cardinal Prospero Lambertini, who had been Pope Benedict XIV since 1740. Almost fifty new apparatuses entered the Cabinet many of which were made by the famous Dutch instrument-makers Pieter van Musschenbroek and Willem Jacob's Gravesande. Amongst these were apparatuses to show the decomposition of light, together with instruments to study elasticity and to demonstrate hydrostatics and hydrodynamics. Among the highlights there was a pressure-cooker by Denis Papin and a globe-electrostatic machine by the design of Francis Hauksbee.[12] Within two years, the Pope managed to provide the Cabinet with another remarkable acquisition: the optical laboratory of the celebrated lens and instrument-maker Giuseppe Campani, active in Rome in the second half of the seventeenth century. The Physics Cabinet therefore acquired various bronze wheels for the grinding of the different types of lenses, together with various lenses signed by Campani himself. Among these was a telescope that Campani had built for French First Minister of State Jean-Baptiste Colbert, which is nowadays a piece of particular historical value.[13]

A third and last acquisition of almost 400 apparatuses completes the growth of the Cabinet of Physics during the eighteenth century.[14] Thanks to a third patron, Cardinal Andrea Gioannetti, the Physics Cabinet was enriched by the collection of scientific instruments of the late William Cowper who, although mostly known for being an art collector, owned a selection of apparatuses built by instrument-makers such as George Adams, Peter Dollond, James Ferguson, Edward Nairne, and Thomas Blunt. These instruments were in the fields of electricity, magnetism, mechanics, pneumatics, thermology, hydrostatics, and optics.[15]

The work of collecting instruments carried out by Cowper fits into the context of the luxury markets of eighteenth century. As pointed out by Alexi Baker,[16] during this period optical, mathematical, and philosophical instruments were produced in greater number and varieties, in large part due to the expansion of consumerism. The market for instruments has been defined "threefold" by the American historian Silvio Bedini,[17] since the customers were either "men of science"—like philosophers using instruments for the performance of experiments—"dilettanti"—usually gentlemen buying the latest model of instrument for amusement purposes or to impress their hosts—or "mathematical practitioners"—using instruments for practical purposes in everyday life. London was the centre of production, sale, and purchase of these instruments, which could represent different things according to the people who acquired them, and communicate several meanings, from fashion and wealth to cutting-edge professionalism. The collection of Cowper, which was an expression of great interest in natural philosophy and a desire to patronise scientists and instrument-makers, certainly added a certain prestige to the figure of the politician, showing that he was in step with the trends of the time.

Of the all instruments mentioned so far, only a small part survives in 2023. Less than fifty in number, the instruments are preserved and exhibited together with the tools of the Campani workshop at the museum of Palazzo Poggi of the University of Bologna. Though interesting, they do not constitute the focus of the present paper which, instead, will pivot on another conspicuous ensemble of instruments not yet studied so far that entered the Cabinet of Physics in the nineteenth century. Numbering 244, these apparatuses have been collected in a period that goes from the beginning of the so-called Napoleonic age in Italy (1796) and throughout the all the nineteenth century, a period of political, social, and economic turmoil during which the Italian peninsula saw occupation, revolution, and eventual unification in 1861.[18] At the same time, the apparatuses were collected and used in a century in which the University assumed its modern shape—with organized and official courses, textbooks of reference, and disciplinary institutes[19]—so their study is particularly important for retracing the establishment of physics within the University itself.

Of particular interest to the present study are some original sources recently found in the University archives. These are three catalogues dated 1835,[20] 1865,[21] and 1870.[22] Despite showing some level of continuity they also display important differences; while the second and third are in the form of a simple list, the first reports very accurate descriptions of each instrument and a brief historical introduction by the physics professor Silvestro Gherardi. The 1835 catalogue is not only more accurate but also more populated. From this, it is possible to conclude that the well-known spoliations carried out by the French authorities on Italian heritage did not affect the Physics Cabinet. In fact, the 1835 catalogue reports that a great enrichment of the Cabinet which is observed in this period was due to the many apparatuses confiscated from the congregations and religious institutions suppressed by order of Napoleon. In 1835 these apparatuses amounted to 1,786, to which 163 new objects were added in the following four years.

As it is possible to read from the preface of the 1835 catalogue:[23]

> It was by chance that Professor Aldini was destined to collect the objects of natural science scattered in the suppressed corporations, since with another choice perhaps our Cabinet would not have been enriched. Perhaps it would not have been given so many machines, some of which were also later left to it, and it still possesses them; for example: the great annular electric machine, according to that of the Venetian Maggiotto, with the closet that encloses it; the Atwood machine for the fall of the bodies, according to Brisson; the compass for measuring the sphericity of the lenses and optical plates, of the Priest Anderlini; and other machines that, like the above, belonged to the Serviti Fathers.

Identifying the Instruments: A Multi-Level Operation

The contemporary study and inventory of the nineteenth-century physics instruments was carried out between September 2021 and February 2022 at the Department of Physics and Astronomy of the University of Bologna "Augusto Righi."* The 244 apparatuses were not on display for the public but preserved in storage together with some descriptive notes, but not a real inventory. The study developed in several steps that included: firstly the taking of multiple photographs of each apparatus and the collection of the data available such as captions or notes accompanying the instrument (often tied with a string or stored in the instrument box); secondly the collection of the available paper and online sources potentially useful for the identification and study of the instruments: these sources were historical textbooks, online and printed catalogues of other nineteenth-century

* With the establishment in 1907 of the new Institute of Physics on Via Irnerio under Augusto Righi, the Cabinet instruments were transferred to the new headquarters of the foundation of the Royal Museum of Physics. Then there were further changes in the collection, among which was the addition of the didactic and experimental equipment of Augusto Righi and that of Quirino Majorana. The First and Second World Wars, particularly the Second, were detrimental to the Museum. It is probable that many apparatuses reported in the nineteenth-century catalogues and no longer present today were lost at that juncture, whether destroyed, sold as scrap metal or thrown away during renovations of laboratories and school buildings. This was a time when historical instruments were considered bulky and obsolete artefacts. To date, the instruments of the Physics Collection owe their preservation to the recovery and restoration operations that began in the 1970s and are nowadays continued by the University Museum Network of the University of Bologna.

* Among the textbooks and catalogues, of particular interest have been the famous textbook *Elementary Treatise on Experimental and Applied Physics and Meteorology* by Adolphe Ganot, the catalogue of *Fondazione Scienza e Tecnica* of Florence (https://www.fstfirenze.it/gabinetto-di-fisica/collezione-del-gabinetto-di-fisica/), the catalogue of French instruments on the website of the *Association de Sauvegarde et d'Etude des Instruments Scientifiques ed Techniques de l'Enseignement* (http://www.aseiste.org/), the catalogue of the Physics Cabinet of the *Liceo Sarpi* of Bergamo (http://www.museovirtualesarpi.it/home.html), and the catalogue of the old Physics Cabinet of the *Liceo Foscarini* (http://museo.liceofoscarini.it/virtuale/index.html).

Cabinets of Physics and the mentioned archive sources concerning the Physics Cabinet of Bologna;* thirdly the corroboration of information regarding the instruments, when present, with the specialised knowledge of an expert of historical scientific instrument: this third point turned to be essential since, in most cases, the correspondence between objects and written sources turned out to be problematic, either because some apparatuses were not directly traceable in the available catalogues or because the few datapoints at our disposal (like captions close to the instruments) turned out to be inaccurate.

Among the sources useful for the comparison and the collection of information about the instruments, there were also trade catalogues from nineteenth century, like Rudolph König's *Catalogue des Appareils D'Acoustique* (1889). These kinds of sources, which have long been treated as trivial in the study of history of science and scientific instruments, have proved to be invaluable aids providing important information about "instruments design, industry trends, commercial demands, maker techniques and specialism, and even clues to the instrument business's social context."[24]

All along this work, we had the privilege of being assisted by the expertise of the late Paolo Brenni, a leading scholar in the field of historical instruments who, due to the Covid situation, shared his invaluable knowledge remotely. This not optimal situation nevertheless allowed the authors of the present paper to examine the apparatuses under the guidance of an expert. Between September and November 2021, once a week, the photographs of the instruments were taken and a draft of the inventory was made. At the same time, the instruments were searched for in modern existing catalogues[25] and, as advised by the expert, in the nineteenth-century textbook by Adolphe Ganot.[26] The results of this preliminary study were then discussed with the expert, amendments were made, and observations in situ were performed. Only after identification by the expert, the new so-called "ex-novo" inventory was compared with the historical catalogues. The reason for this last choice lays in the fact that, while modern catalogues are relatively easy to consult, historical catalogues needs to be studied and understood, more than simply consulted: they present a different subdivision in physics sections and instruments are not always listed with the name that one is expected to find. After the identification of the expert, consultation of historical catalogues has been feasible and more rewarding.

In the next three sections, the identification process will be summarised by grouping the cases into four major categories: a) notorious nineteenth-century apparatuses which needed only to be recognised in existing catalogues and for which, in most cases, some videos on their use were available online;** b) instruments accompanied by captions that reported incorrect, partial, or

** A particular mention in this respect goes to the videos created by Paolo Brenni and Anna Giatti at the *Fondazione Scienza e Tecnica* in Florence: https://www.youtube.com/@florencefst.

misleading information: in some cases the instruments had been correctly identified in their general name but still presented inconsistencies in some details that could only be resolved with a closer look (see the distinction between the polarimeter and saccharimeter discussed below) or with tests; c) defective or incomplete apparatuses; d) "mysterious objects" which had to be identified from scratch on the basis of the specific knowledge of the expert.

The identification process led the three of us to a revelation that one of the pieces studied was a reproduction of an instrument that was in fact unexpectedly rare and valuable from a historical point of view, giving space for a more in-depth understanding that will be discussed later in the paper.

Apparatuses Recognisable in Existing Catalogues

A significant number of the instruments examined belong to the typical objects of a nineteenth-century physics cabinet, made by famous instrument-makers of the time and today belonging to many museums and collections. For this reason, such objects have been studied and catalogued by many experts; the identification of these instruments has therefore been quicker thanks to the rich existing bibliography.

Among the optics instruments, the optical bench can undoubtedly be considered an important piece, since it reproduced all the new discoveries of interference and diffraction, based on the discoveries of Thomas Young and Étienne-Louis Malus. The optical bench, stored in the Physics Collection of the University of Bologna with its accessories, is signed by Jules Duboscq, who was the successor of Jean-Baptiste-François Soleil and became the best-known manufacturer of optical apparatuses of the time, and includes a support with a slot for the insertion of accessory boards, a micrometric slit, and a Fresnel mirror system.*

A special example of a milestone instrument of the nineteenth century is the catadioptric microscope of Gian Battista Amici (Figure 1), which highlights the transition between the use of non-achromatic lenses and the introduction of achromatic lenses. Designed by Amici around 1812, the instrument combined a system of mirrors and lenses that eliminated achromatic aberrations. Although, due to the spread of achromatic lenses, it fell into disuse towards the end of the 1820s, the catadioptric microscope was very successful throughout Europe and also entered the physics cabinets.**

* An optical bench similar to the one kept at the Physics Collection in Bologna can be found in the Physics Museum of Liceo Foscarini in Venice, having belonged to the physics cabinet of the school.

** Today several museums and collections preserve a specimen of this instrument, including the *Fondazione Scienza e Tecnica* of Florence and the Museum for the History of the University of Pavia (https://www.bibliotecadigitale.unipv.eu/handle/20.500.12460/439).

Fig. 1. The catadioptric microscope of the Physics Collection of Bologna, signed by Amici. *Credit*: University Museum Network, University of Bologna

The microscope of the Physics Collection in Bologna bears the engraving "Amici Modena" and can therefore be considered one of the most valuable pieces of the collection; Amici's signature and comparison with the catadioptric microscopes kept in other museums made the identification unequivocal.

Among the benches, an instrument that spread widely among the physics laboratories of the late-nineteenth century, and that is still kept in several physics museums including in Florence, Rome, Milan, and Turin, is the bench by Macedonio Melloni. Designed to perform studies on radiant heat, the Melloni bench helped demonstrate that infrared radiation behaves exactly like visible light. The instrument at the Physics Collection in Bologna is signed by the well-known German instrument maker Heinrich Ruhmkorff, and is stored along with its accessories.

A last example of a milestone instrument is the compass of the sines and of the tangents, which allowed the user to measure the intensity of current. The compass of the sines was conceived around the 1840s by Claude S. M. Pouillet and was later perfected by Heinrich Ruhmkorff, who was the manufacturer of one of the two compasses of the sines belonging to the Collection of Bologna, as shown by the engraved signature (Figure 2).*

These milestones of the nineteenth-century cabinets of physics are often found in trade catalogues of the time, with illustrations and details of the prices at which they were purchased. Brenni reports on the research conducted on the prices of

* A precise account on the structure and functioning of this instrument can be found both in Ganot's treatise and in nineteenth-century commercial catalogues.

Fig. 2. One of the two compasses of the sines and of the tangents of the Physics Collection of Bologna. The instrument bears the signature of Heinrich Ruhmkorff. *Credit*: University Museum Network, University of Bologna

some popular physics instruments that were sold in Europe and the United States in the nineteenth century, and among them is the Melloni bench with accessories.[27] According to information provided by Brenni, this apparatus was sold in the 1860s by several Parisian makers, Pixii, Molteni, Salleron, Deleuil, Lerebours et Secretan and Breton, at prices ranging from 650 to 700 francs.

Apparatuses to be Re-interpreted: Correction of Errors, Tests, Incomplete Apparatuses, Mysterious Objects

Particularly interesting for the purposes of this paper are the devices found in the collection that, consisting of an optical tube, needed to be distinguished between telescopes, saccharimeters, or polarimeters.

The object shown in Figure 3, for example, was captioned "Reflector Poggendorff Scale" which made us think that it was a reading *cannocchiale* used in the method introduced by the German physicist J. C. Poggendorff in 1826. In order to perform measurements of small angular deviations in the mobile parts of

Fig. 3. One the optical tubes in the Physics Collection of Bologna, captioned as "Reflector Poggendorff Scale" but identified instead as a saccharimeter. *Credit*: University Museum Network, University of Bologna

instruments such as magnetometers or galvanometers, a mirror is attached to the mobile element of the instrument and observed through a telescope. Perpendicular to the axis of the telescope, above it, is placed a rule with zero at the centre. On the mirror a beam of light is sent so that it is reflected on the scale, on which a very bright spot is visible. When the mobile element moves, the light beam is reflected to the right or left of the zero of the scale. If the mirror rotates by a certain angle, the rays reflected on the scale have double angular deviation (Figure 4).

However, the expert pointed out that on closer examination the optical tube contains a case tube which is the container for an optically active solution. The detail allowed us to identify the instrument as a saccharimeter since the task of a saccharimeter is to determine the concentration of sugar solutions through the polarization of light which passes through, and to this purpose the optical tube contains a prism and quartz plates.

Moreover, this error in the caption led us to trace the real "Reflector Poggendorff Scale" in the Bologna Physics Collection (Figure 5). The instrument does not have the scale, but can be equipped with one.*

The presence of a smaller tube to contain the solution also allowed us to correct a second imprecision related to the distinction between a saccharimeter and a polarimeter. A second apparatus with such characteristics bore the caption "Polarimeter of Laurent." As explained by the expert, the tube for the solution

* A particularly useful tool in this respect has been the online catalogue of the Physics Museum of the Physics Department of La Sapienza University in Rome where a telescope equipped with axis and scale to perform the Poggendorff method is preserved (https://web.uniroma1.it/museofisica/cannocchiale-e-scala).

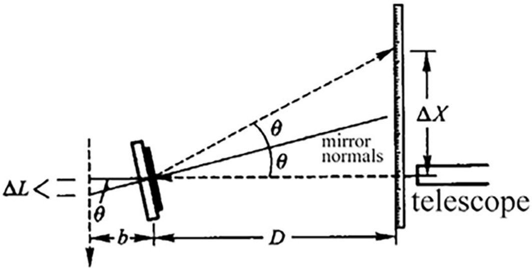

Fig. 4. Functioning of the Poggendorff method

makes the saccharimeter a particular type of polarimeter, so the caption could be elucidated in a saccharimeter designed by Léon Louis Laurent in 1874.

Four more instruments that had been misinterpreted by previous curators and required in-depth expertise to be fully identified were: an induction electrostatic machine, captioned as a Holtz type but actually designed by Robert Voss;* a Grenet battery previously captioned as "Leclanchè battery";** a Peltier's atmospheric electrometer and a simple gold-leaf electroscope whose captions had been inadvertently exchanged.***

For a series of instruments, Brenni suggested some tests to verify their functioning and use, such as in the case of the instrument captioned as "Electromagnetic signal from Deprez" (Figure 6); from the picture, the expert hypothesized that it could have been a vibrating pen to mark a sinusoid, tracing a zigzag curve on a rotating cylinder covered for example with smoked paper; a close inspection of the instrument and a small test confirmed the presence of two coils (green), a circuit, and a nib connected to a spring.****

* The machine by Robert Voss, a German manufacturer who introduced this new design in 1880, combines the Holtz and Toepler machines. Unlike the Holtz machine, the Voss machine does not need an external charge to trigger. At the *Fondazione Scienza e Tecnica* in Florence, both machines are stored and the difference is explained (https://www.fstfirenze.it/macchina-elettrostatica-di-holtz/; https://www.fstfirenze.it/macchina-elettrostatica-di-voss/).

** Both batteries were introduced in the second half of the nineteenth century, are made of glass, and contain an electrolytic solution. The Grenet battery contains two carbon electrodes and one zinc plate while the Leclanchè one has a single zinc electrode and a porous cylinder inside.

*** The Peltier's electrometer has a cupper "hat" that acts as a screen and two needles inside, one fixed and one mobile and whose deviation is measured through the graduated scale.

**** Similar models of this instrument are kept, for example, at the Museum of the History of Psychological Instrumentation at Montclaire State University (http://tomperera.com/psychology_museum/museum.htm) and at the Department of Psychology of the University Bicocca in Milan (https://www.aspi.unimib.it/).

Fig. 5. The reflector Poggendorff scale of the Physics Collection of Bologna. *Credit*: University Museum Network, University of Bologna

Fig. 6. Electromagnetic signal from Deprez of the Physics Collection of Bologna. *Credit*: University Museum Network, University of Bologna

Other instruments will require more accurate measurements and small experiments in a laboratory space. This is the case of a phosphoriscope and of a series of vials with liquid dyes, used in spectroscopy, and with powders, used in microscopy.

Fig. 7. Incomplete apparatus for the comparison of the vibrations of two air columns of the Physics Collection of Bologna. *Credit*: University Museum Network, University of Bologna

Among the series of well-known and easily-identifiable acoustics instruments there was one that turned out to be largely incomplete and therefore problematic. It appeared as a system of two simple organ pipes with the caption: "Two acoustic tubes: Fa4, Do4." The presence of a box on which the tubes are fixed has been fundamental to correctly identify the apparatus. A joint use of the two tubes in a common experiment is suggested, specifically the comparison of the vibrations of two air columns (Figure 7).

The incompleteness can be readily realised from recent catalogues[28] and historical catalogues[29] that show how the acoustic pipes are a part of an integrated system including rotating mirrors (present among the Collection), and a system of manometric capsules with membranes, tubes, and gas spouts (Figure 8). The transduction work done by the capsules when tuned with the rotation of the mirror creates a stable image of the superposition of the two sounds and their harmonics. The expert pointed out a relevant detail: the presence of a "worn area" on the right barrel may suggest the existence of a sliding-door that might have been used for

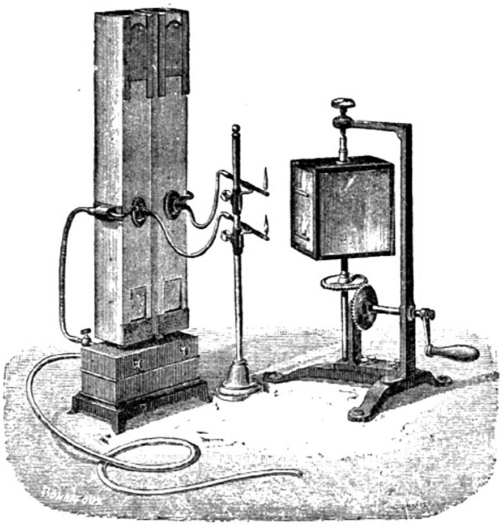

Fig. 8. Complete apparatus for the comparison of the vibrations of two air columns. *Source*: König's *Catalogue des Appareils D'Acoustique*

modifying the frequency of the emitted sound. The guess is confirmed by the figure of the complete apparatus reported in the *Catalogue des Appareils D'Acoustique* by König (Figure 8).[30]

The process of identification brought to light the existence of mysterious objects that could not be traced in any of the existing catalogues or in the treatise of Ganot. Among these was a "polytrope"—an apparatus to demonstrate the effect of Earth's rotation on the movement of a rotating body such as a gyroscope—which Brenni pointed out to have been designed by Georges Etienne Sire, who presented it at the Paris Academy of Sciences in 1859.*

The second case was a vertical galvanometer of Leopoldo Nobili described in the second volume of the "Memoirs and Observations Published and Unpublished by the Knight Leopoldo Nobili" of 1834. The instrument was designed exclusively for the didactic demonstrations that took place during lessons in experimental physics, which Nobili held in Florence. The dimensions of the instrument are indeed very large in comparison to those for a more sensitive galvanometer used for research.**

* After Brenni's indication, we found the only other model of this instrument described on the website of the National Museum of American History (https://americanhistory.si.edu/).
** The information and documents concerning this vertical galvanometer were found during the staging of a 1984 exhibition on Leopoldo Nobili in Reggio Emilia, for which Paolo Brenni was part of the Scientific Committee.

Linking the Ex-Novo Identification with Historical Catalogues

The work of identification showed that the nineteenth-century section of the Physics Collection consists of a total of 244 apparatuses which can be divided into specific areas: optics, geodesy, electrical and magnetic physics, acoustics, mechanics and thermology and thermodynamics.

The identification has been then compared with the historical catalogues found at the archive of the University Library dating back to 1835, 1865, and 1870. This has allowed us to locate the apparatuses examined and retrace when they entered the collection of the Cabinet. This research has also allowed us to highlight the existence of rare and precious apparatuses, in particular a seventeenth-century microscope by Campani.

Dating the Apparatuses: Comparison Between the 1835, 1865 and 1870 Catalogues and Inventories

The comparison between the new inventory and the lists of the 1835 and 1865 catalogues (and a successive update of 1870) has allowed us to reconstruct part of the history of the Cabinet of Physics of Bologna. To this purpose, particularly useful was the catalogue of 1865 where on the first column of each entry, the inventory number of the 1835 catalogue is reported.

A comparison between this catalogue and the current collection has allowed us to find out that about a hundred of the 244 apparatuses identified and inventoried with the expert are present in the catalogues of 1835 and 1865, and so were acquired before these dates. Among the apparatuses identified by the expert (and reported in the ex-novo inventory) which appear in both catalogues, there are: the Atwood machine, the apparatus for the study of elastic collisions, the apothecary scale, a violin bow, some barometers and thermometers, the pneumatic lighters, the Peltier electrometer, the gold leaf electroscope, the Leiden bottles, the electrophores, some galvanometers, the Volta battery, the glass battery, the declination compass, the catadioptric microscope of Amici, a solar microscope, various types of prisms and lenses, and a Duboscq magic lantern.

Other apparatuses of the ex-novo inventory do not appear in the 1835 and 1865 catalogues but in the 1870 inventory which is an update of the 1865 document. Examples are the phosphoriscope of Becquerel, a big Fresnel lens with annular sections, and a set of crystals to be used with the polarimeter.* Finally, other instruments of the ex-novo inventory are mentioned only in the catalogues of 1835 and of 1865, and not in the inventory of 1870, such as the catadioptric microscope by Amici. It can be assumed that in the drawing up of such an inventory they were

* The 1870 catalogue also includes a generic reference to two spectroscopes ("two of which one bad") whereas the Collection currently includes six of them.

intentionally omitted or by mistake, or because for some reason they were not at that time present in the Physics Cabinet.

In the appendix of the present paper, a comparison between the ex-novo inventory and the historical catalogues is reported for the sections of mechanics and optics.

Intercepting Rarities: Seventeenth-Century Microscopes

The analysis of the instruments brought to light the existence of objects that will pave the way to more in-depth research. One of those objects, a microscope, turned out to be particularly interesting because it is signed by Campani, a famous lens- and instrument-maker of the seventeenth century (Figure 9, on the left). In spite of the signature, the manufacture of this object is more recent, and this is particularly evident in the type of screw used, which is different from the types common in the seventeenth century: the piece is indeed a reproduction dating back to the 1980s of the original model kept at the Museum of Palazzo Poggi (Figure 9, on the right).*

Even though it turned out to be a replica, the instrument aroused the curiosity of the authors. In fact, even the original object signed by Campani has a history which is neither clear nor easy to retrace.

In the 1835 catalogue of the Physics Cabinet, two items concerning Campani can be found: ”Three hand microscopes with two wooden and leather tubated lenses, one large, another mediocre, and one small: that one is by the famous Campani”;[31] “Two miliary lenses mounted in brass (one with an ivory handle) to serve as a simple microscope: the one in brass is by Campani.”[32]

Of the five microscopes mentioned in previous entries in the catalogue, two are from Campani. The first, a small microscope with wood and leather tubated lenses are reminiscent of the type of microscopes for which Campani became famous and which are found nowadays in museums.[33] According to the 1835 catalogue, one such microscope must have been part of the Cabinet in the past. Unfortunately, this apparatus is no longer present in the collection. The second reference hints to a couple of microscopes in which two miliary lenses—one for each microscope—are mounted. The first, with an ivory handle, is also not present in the collection. However, the second, which is entirely made of brass, appears to be the the

* An interview with the professor formerly responsible of the collection, Giorgio Dragoni, has confirmed that the artefact is a replica realised by a former technician of the Physics Department and museum collaborator, Antonio Grilli.

Fig. 9. Modern reproduction of the apparatus signed by Campani, found among the nineteenth-century instruments of the Physics Collection of Bologna (on the left), and of the original apparatus kept at the Museum of Palazzo Poggi (on the right). The engraving reads: "Giuseppe Campani in Roma." *Credit*: University Museum Network, University of Bologna

instrument whose replica has been found in this study and whose original is kept at Museum of Palazzo Poggi, even though the lens is not present anymore.

The information derived from the catalogue can be refined by looking at the literature on Campani. In fact, the microscope on display at the Poggi museum has been described in an authoritative and recent publication by the American historian Silvio Bedini.[34] In the book, a photograph of the microscope is shown together with the following description taken from a printed price list for Campani's optical instruments reported in Klaute's "Diarium Italicum" (1699): "The microscope of just one crystal, of artisanal line, which serves to observe transparent objects, and the fluids, it magnifies admirably with clarity, it is worth ten shields."[35]

To conclude, the present research shows that, even though the attribution to Campani is undeniable, the entry of this object into the collection needs further research which, as pointed out by the quoted literature, will involve different scholarly fields. The field of provenance research on the one hand, by carefully re-inspecting the act of donation of the Campani workshop to the Institute of the Sciences or following Bedini's suggestion to check whether the microscope could have entered the collection later and perhaps be attributed to some Bolognese scholars. On the other hand, the availability of a replica of the instrument allows us to consider replication studies and experiments in order to recreate the admirable observational conditions mentioned in Campani's trading list.

Conclusions

The aim of the present paper has not been a full description of the items which are present in one of the many European Cabinets—the Physics Cabinet of Bologna—but rather the reconstruction of the process of identification and understanding of a not-yet-studied ensemble of nineteenth-century apparatuses, as well as indicating some of the further research that may develop from the identification process and close study of the objects.

In particular, the paper has highlighted the interplay between several elements that turned out to be important to the task: one is the nowadays available sources based on the extensive literature and the work done within the historical research community on scientific instruments, textbooks, and catalogues. However, two more elements can be described as decisive. The finding of three historical catalogues on the Bologna Physics Cabinet and the role of the expert, in this case the late Paolo Brenni, a leading scholar in the field of scientific instrumentation.

Another consideration concerns the methodology of the research. The basic steps described in the present work—picture taking and draft inventory, collection of available sources (paper and online), close look at the instruments with the assistance of an expert—are quite regular of any work of this type. What is more peculiar of this specific research is the authoritativeness and precision of the expert Paolo Brenni which went far beyond descriptive catalogues or books, and made it possible to have a full new inventory and a fresh snapshot of the present state of the collection.

This allowed the researchers to postpone the comparison of the new inventory with the historical catalogues, tracing the single items and the information they carried. This way of proceeding proved to be effective especially due to the big changes occurring between the Physics Cabinet of the Napoleonic age and the present one: from a total of 1,786 instruments listed in the 1835 catalogue, through the 2,450 of the 1865 one and the 757 of the 1870 inventory to the 244 of nowadays, the Cabinet changed its face a number of times to the point that the vertiginous lists do not so much help us to understand the current situation but more the current situation makes the lists of the catalogues clearer.

The inspection of the historical catalogues with the new inventory at hand has allowed us to conclude that more than a half of the present apparatuses have been added to the collection after 1870 whereas about a hundred of them were acquired before 1865 or 1835: among the instruments acquired in the early nineteenth century a special mention goes to the Atwood machine, the apparatus for the study of elastic collisions, the Oersted piezometer, the Leiden bottles, the declination compass, the catadioptric microscope of Amici, and a solar microscope; among the ones acquired during the first half the nineteenth century there are for example the phosphoriscope of Becquerel, a big Fresnel lens with annular sections and a set of crystals to be used with the polarimeter.

With regard to the current literature, the paper has confirmed what has been pointed out by many scholars: that historical documents from museum archives and trade catalogues have a special role in reconstructing the itineraries of objects, improve provenance research, and show how instruments, in certain historical periods, contributed to the nations and institutions they belong to.

The study of the nineteenth-century instruments has moreover brought into light the intriguing case of a replica of a small seventeenth-century microscope by Campani. In this respect, the present paper has drawn the contours of a new research topic which will be developed in an upcoming study.

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Data availability

The authors declare that all the data used in the paper are available.

Appendix

See Table 1.

Table 1. Comparison between the instruments mentioned in nineteenth-century catalogues and those still present in the mechanics and optics section of the current collection of the University of Bologna

Object of the Present Physics Collection in the Ex-Novo Inventory	Catalogue of 1835	Catalogue of 1865	Inventory of 1870
Mechanics (8 instruments)	3 instruments	6 instruments	8 instruments
Polytrope			Foucault gyroscope
Simple catetometer		Catetometer	Catetometer
Borda pendulum		Borda absolute pendulum	Borda pendulum with iron tools and length meter
Morin cylinder		Morin apparatus for the falling bodies	Morin cylinder
Atwood machine	Beautiful complete Atwood machine, with its weights in mahogany box Another Atwood Machine described by Brisson (incomplete)	Beautiful Atwood machine	Atwood machine
Apparatus for the study of elastic collisions	Similar machine of jujube, with straight graduated scale of metal, and with four ivory balls hanging	Great beating machine with 7 ivory balls Similar machine of jujube with 4 balls of ivory	Apparatus for the pendulum laws
Analytical scale			Scale with lower suspension Small scales
Apothecary scale with small weights	Merlin's beautiful scale, with all its Florentine weights Small scale with its weights in mahogany box, which also serves as a foot to the same	Small scales with copper plate Small scale with its weights in box	Precision scale with respective weights box
Optics (42 instruments + 4 possible simple microscopes, 2 of which belonging to the eighteenth-century collection, traceable in the historical catalogues = 46)	16 instruments + 4 possible microscopes (simple and compound) = 20	20 instruments + 6 possible microscopes (simple e compound) = 26	38 instruments
Two lenses of large and different sizes			Large antique lenses

Table 1 continued

Object of the Present Physics Collection in the Ex-Novo Inventory	Catalogue of 1835	Catalogue of 1865	Inventory of 1870
Six prisms for light dispersion	Four Dutch prisms decorated with brass axes and mounted on Dutch oak frames Four English prisms decorated in brass and mounted on black wooden frames Three other prisms disassembled, of crystal of Venice	Four Dutch prisms Four English prisms Three more prisms disassembled, of Venice crystal	Prisms
Polyprism		Polyprism formed of four consecutive parts of different materials, to show the difference in refractive index and dispersion of solid bodies	Polyprism
Convex flat lens with holder, diameter 50 cm	Large convex-convex lens, and flat mirror with frames, on mahogany foot: they serve together to enlarge, to show vertically the views and objects studied Large convex-convex crystal lens, with brass frame: it is pivoted in a brass semicircle, therefore a stem that can slide vertically into the jujube column that serves as a foot to the lens Another beautiful convex-convex hand lens with mahogany frame and handle Two lenses similar to the previous one, but mounted on a black wooden foot, and in a brass semicircle	Large convex-convex lens	Antique spherical lenses
Three prisms for liquids			Glass prism Ancient horizontal prisms

Table 1 continued

Object of the Present Physics Collection in the Ex-Novo Inventory	Catalogue of 1835	Catalogue of 1865	Inventory of 1870
Ophthalmic box with glasses			Glasses with red and green glass
Spectroscope with direct vision Spectroscope Hoffmann-Duboscq type spectroscope			Spectroscopes two, one of which bad
Variable angle prism (parchment prism), liquid holder			Water prism with variable angle
Solar microscope	Another ordinary solar microscope	Solar microscope Solar microscope adaptable to the light holder (Cabinet No. 2), or to the aforementioned Lantern by Duboscq, and equipped with holder-objects included in the smaller of the two mahogany drawers	Modern/Antique/ Vertical/ Horizontal Solar Microscope
Light holder without microscope with 5 diaphragms for light beams (optical experiences)		Light holder, adaptable to Duboscq lantern Light holder	Light holder
Two bellows cameras			Pocket camera
Magic lantern Projection apparatus of Duboscq	Magic lantern: the views are in the adjacent box (missing)	Duboscq lantern with electric controller	Duboscq lantern with magic lantern lenses
Phosphoriscope of Becquerel			Phosphoriscope of Becquerel

Table 1 continued

Object of the Present Physics Collection in the Ex-Novo Inventory	Catalogue of 1835	Catalogue of 1865	Inventory of 1870
Silver and oxidized concave mirror, diameter 40 cm	Six large metal mirrors: two are slightly concave on one side, not wrought on the other, and with a simple black wooden frame; four are wrought in the two sides, and more or less convex-concave: three of these are mounted on a black wooden foot with an iron semicircle; the fourth, greatest of all, is hinged on a semicircle of gilded iron, which semicircle is then hinged on a wooden foot covered with gilded stucco		Concave mirrors
Silver and oxidized mirror, diameter 35 cm			Mirrors, one concave the other convex
Concave mirror with support, diameter 46 cm			Large concave mirror
Silver and oxidized mirror, diameter 35 cm		Large convex-convex lens, and mirror	Concave mirror
Fresnel lens with holder, diameter 48 cm			Lens “a gradinate”
Iceland spar			Rhombohedra spar
Press to show accidental polarization of glass (equipment for bending and compressing glass)			Equipment for compressing the glass
Polariscope reflector of Malus		Malus apparatus for polarization	Polariscopes
Tourmaline tweezers		Tourmaline tweezers Tweezers with foils of tourmaline	Tourmaline tweezers
Apparatus for showing Newton rings with black centre and white centre		Newton disc apparatus for coloured rings	Apparatus for Newton’s rings
Nörremberg polarimeter		Nöremberg apparatus	Nöremberg apparatus

Table 1 continued

Object of the Present Physics Collection in the Ex-Novo Inventory	Catalogue of 1835	Catalogue of 1865	Inventory of 1870
Foils used for projection or interference			Pieces of tempered glass
Crystals to be used with polarimeter			Birefringent crystals
Silbermann apparatus for the study of light refraction Mirror Polarizer by Duboscq	Wonderful apparatus to demonstrate the variety of refraction in the variously dense air: it consists of a brass prism with two faces of beautiful crystal, with a syringe to condense, and to rarefy the air in the prism, and with two crystal manometers to be inserted in the base of the prism opposite to that to which the syringe is applied: everything can be closed in the mahogany box, from which the instrument sticks out	Wonderful apparatus to demonstrate the variety of refraction in the air	Apparatus for polarization and reflection
Optical bench for diffraction and interference Accessories for optical bench		Bench for diffraction and interference experiments, with mahogany box containing all the diaphragms necessary for the experiments	Diffraction bench, with accessories for diffraction and interference experiences
Three Hartnack compound microscopes, cylindrical Zeiss compound microscope	Two antique cylindrical microscopes sliding along vertical rod; with wooden and leather tubes, one of which by Marshall in London Two compound microscopes of the famous Dollond mounted in their respective cases, one pyramidal, the other parallelepiped	Two ancient cylindrical microscopes	
Simple microscope		Three hand microscope	
Simple microscope		Nice one lens microscope	
Homberg microscope		Another hand microscope?	

Table 1 continued

Object of the Present Physics Collection in the Ex-Novo Inventory	Catalogue of 1835	Catalogue of 1865	Inventory of 1870
Campani microscope	Two miliary lenses mounted in brass (one with an ivory handle) to serve as a simple microscope: the one in brass is by Campani	Two miliary lenses	
Catadioptric microscope of Amici	Catadioptric microscope of the famous Amici, with small wooden board of slate, and with the relative memory of the author	Catadioptric microscope of the famous Amici	
Heliostat	Heliostat (wooden model) for all latitudes Another brass heliostat (small model)		
Part of an electric eudiometer	Four eudiometers of Volta Eudiometer of Landriani Two Magellan Eudiometers (one defective) Eudiometer of Fountain Eudiometer of Jaubert	Eudiometer of Landriani Two Magellan Eudiometers Eudiometer of Fountain Eudiometer of Jaubert	Eudiometers

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