Eur. Phys. J. H (2025)50:20
https://doi.org/10.1140/epjh/s13129-025-00106-w

THE EUROPEAN PHYSICAL JOURNAL H

Regular Article

Alessandro Serpieri and his seismographs: innovations in late nineteenth-century Italian seismology

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Received 17 February 2025 / Accepted 11 July 2025
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Abstract The paper examines the historical development and context of several seismographs preserved in the *Physics Laboratory and Museum of Science and Technology* at the University of Urbino Carlo Bo. In the second half of the nineteenth century, these instruments were used by Alessandro Serpieri (1823–1885), a Scolopian priest and a pioneer of Italian seismology. Following a brief biographical overview of the scientist, the study examines three principal instruments currently on display in the museum: the "protoseismograph" by Michele Stefano De Rossi (1878) and two seismographs designed by the Urbino-based instrument-maker Achille Scateni (c. 1882). In addition to these surviving instruments, the study also discusses a seismograph invented by Serpieri in 1873, known only through contemporary descriptions and illustrations. This study re-examines their history and mechanical functioning using archival documents, publications from the period, and direct analysis of the instruments, focusing on Luigi Palmieri's influence on Serpieri's seismograph design. It highlights the scientific heritage of Urbino's Physics Laboratory and the pivotal collaboration between Serpieri and Scateni, locating their advancements in Italian instrumental seismology within the context of the birth of quantitative seismometry which complemented continuing observational methods in the late nineteenth century. In particular, it suggests how the interplay between local instrumental innovation and national scientific networks fostered the development of modern seismometry in Italy.

Keywords Alessandro Serpieri · History of seismology · Scientific instruments · Seismograph · Instrumental innovation · Quantitative seismometry · Scientific networks · Late nineteenth-century Italy

1 Introduction

The Physics Laboratory and Museum of Science and Technology of the University of Urbino Carlo Bo[1] houses a notable collection of nineteenth-century scientific instruments (Mantovani 1996). Among these, several were employed by Alessandro Serpieri (1823–1885), a Scolopian priest and scientist, in his pioneering studies on earthquakes (Grianti et al., 1990). Serpieri's initial investigations into seismology were motivated by the violent and extensive earthquake that struck central Italy on 12 March 1873 (Serpieri 1873a). The seismic event, distinguished by its intensity, prompted Serpieri to design a new model of seismograph. This apparatus, which appears to have been inspired by a component of a complex electromagnetic seismograph devised in Naples some years earlier by Luigi Palmieri, was remarkable for its simplicity of construction, low cost, and capacity to record both the time and direction of the "initial seismic impulse". Unfortunately, no example of this model described by Serpieri in 1873 has survived. Three other seismic instruments associated with Serpieri survive in good condition, although some components have been lost over time. The first is the "protoseismograph" designed by the Roman scholar of Earth sciences Michele Stefano De Rossi (1834–1898), whose history is thoroughly documented in an extensive exchange of letters between De Rossi and Serpieri. The other two instruments were designed and built by Achille Scateni, a technician based in Urbino, who was likely commissioned by Serpieri. The first is a sensor for horizontal movements (Scateni seismograph), which was originally part of a seismograph with a recording system that has since been lost (Scateni 1883). The second is a "mechanical seismograph for vertical movements" and was designed and built

[1] Its official name is *Physics Laboratory: Urbino Museum of Science and Technology* (see https://physlab.uniurb.it/Museum.html). Henceforth, it will be referred to as PLUMST.

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Published online: 10 October 2025

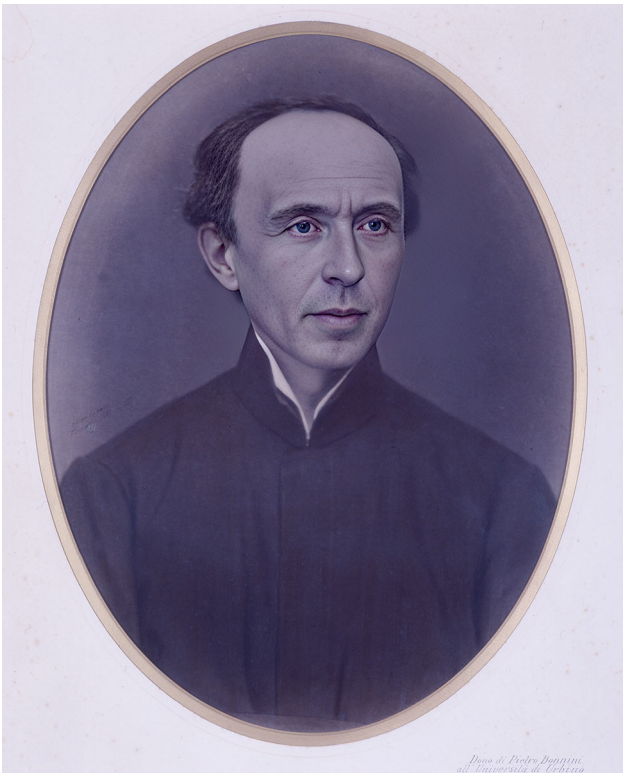


Fig. 1 Photographic portrait of Father Alessandro Serpieri. *Source*: PLUMST, University of Urbino Carlo Bo

by Scateni. While the sensor is described in a contemporary account, no descriptions of the second instrument exist, either in print or manuscript form. These instruments are not unique: similar models are preserved in Rome ("CREA" Historical Collection) and Pesaro ("Valerio" Observatory). This study aims to reconstruct the history and functioning of the instruments used by Alessandro Serpieri, drawing on archival documents, contemporary publications, and direct examination of the surviving instruments. In particular, it examines how the interplay between local instrumental innovation and national scientific networks contributed to the development of modern seismometry in Italy. By contextualizing these innovative instruments within the emergence of seismometry in the last quarter of the nineteenth century, the present analysis offers new insights into their role within the broader transformation of scientific practices during this period.

2 Between teaching and research: some biographical notes on Alessandro Serpieri

The Scolopian Alessandro Serpieri (Fig. 1) was the foremost nineteenth-century scientist at Urbino University and a major figure in Italian science in the second half of the nineteenth century. His scientific training was grounded in the intellectual tradition of the Scolopians, a religious order that played a pivotal role in advancing science in Italy between the eighteenth and nineteenth centuries, operating in both secondary schools and universities. Serpieri was born in San Giovanni in Marignano (in the province of Rimini on the border with the Marche region) on 31 October 1823. After receiving his early education in Rimini, he moved to Urbino and attended the College of Nobles, an institution run by the Fathers of the Pious Schools since 1699. In 1840, Serpieri moved to Florence to continue his studies at the *Specola Ximeniana* (now the Ximeniano Observatory), a centre of scientific excellence at the time. There, he was mentored by leading figures of the Florentine Scolopian tradition, such as Giovanni Inghirami (1779–1851), a renowned geodesist and astronomer of European fame, and Giovanni Antonelli (1818–1872), a respected scientist. The young Serpieri remained in Florence until 1843, a decisive three-year period during which he acquired his scientific and intellectual skills, marking the beginning of his career in academia and scientific research. In November 1843, with the support of Giovanni Inghirami, Serpieri began his long career as a teacher and educator, which would continue uninterrupted until his death. He was appointed professor of mathematics and philosophy at the prestigious Scolopian College Tolomei in Siena, then one of the leading educational institutions in Italy. During his three years at the Tolomei college (1843–1846), he worked alongside the physicist Santi Linari (1777–1858), known for his studies on the electricity of torpedo fish. This

environment broadened his scientific interests, which were further enhanced by frequent visits to the Meteorological Observatory at the University of Siena, then directed by Giuseppe Pianigiani (1805–1850). It was in this context that his interest in meteorology arose, a field he would study with lasting dedication. In November 1846,[2] at the urging of Father Tommaso Pendola, Serpieri was appointed to the chair of physics and philosophy at the *College of Nobles* in Urbino, an institution that would be renamed *Raphael College* in 1865, partly as a result of his initiative. Just two months after his appointment, the papal authorities conferred on him the title of university professor. At only twenty-three years of age, Serpieri thus became a professor of physics at both the College and the University of Urbino, roles that he held continuously until 1884. The university appointment also entailed the direction of the Physics Laboratory, which underwent a period of extraordinary development under his leadership, partly due to the collaboration of a skilled machinist as well as to the foundation of a Meteorological Observatory. During his tenure (1846–1884), the *Physics Laboratory* was enriched with new instruments, thanks in part to the technical expertise of the machinist Achille Scateni. As of today, more than six hundred instruments from the laboratory have been recovered; most of these have been catalogued and restored, providing invaluable evidence of the scientific fervour of that period. On 2 July 1848, Serpieri took his vows in the Scolopian order and was ordained a priest on 27 August of the same year. From then on, and for nearly the rest of his life, he devoted himself to teaching and scientific research in Urbino, publishing numerous highly original works. A significant testimony to his vigorous scientific engagement is provided by his epistolary collection, which includes 1113 letters addressed to Serpieri by Italian and foreign scientists[3] (Mantovani and Vetrano 1991). In 1884, following the secularization of *Raphael College* and the schools in Urbino in a context of growing anticlericalism, Serpieri decided to leave the city despite being offered the opportunity to continue teaching. On 21 October of the same year, also upon the advice of his superiors, he left Urbino for the Badia Fiesolana (near Florence), where he died on 2 February 1885.[4] Serpieri distinguished himself as an ethical and intellectual educator and a versatile and eclectic scientist. Following the interdisciplinary approach typical of scholars of his time, he successfully dedicated himself to various scientific fields. In addition to seismology, he worked in physics, astronomy, meteorology, and natural sciences. His contributions to physics were both theoretical and experimental, as evidenced by his studies of the telephone and the Crookes apparatus. Among his educational and popular works are *La forza considerata nelle sue principali trasformazioni* (Serpieri 1868a, 1–72), *Il potenziale elettrico nell'insegnamento elementare della elettrostatica* (Serpieri 1882, X-172), and *Le misure assolute meccaniche elettrostatiche ed elettromagnetiche* (Serpieri 1885, X-90). In particular, the treatise on electric potential was groundbreaking in Italy, making the concept accessible to students at high schools and technical institutes through a simplified approach that avoided infinitesimal calculus.[5] His contributions to astronomy focused mainly on the study of shooting stars, zodiacal light, and, to a lesser extent, aurora borealis, comets, planets, eclipses, and solar prominences. His work was greatly appreciated by Angelo Secchi and Giovanni Schiaparelli, as evidenced by his extensive correspondence with these two scientists. Serpieri contributed significantly to affirming Schiaparelli's theory on the cometary origin of shooting stars through a rigorous analysis presented in his article *Sulla teoria fisica delle stelle cadenti* (Serpieri 1868b). Even more important were his studies of zodiacal light and aurora borealis. He proposed a "cosmic-atmospheric" theory according to which the zodiacal light shared the same nature as the aurora borealis, a hypothesis that preceded modern explanations of these luminous phenomena (Serpieri 1876a, 1876b). In meteorology, Serpieri founded the first observatory in the Italian region of Marche in 1850 and began observations on 1 May of that year. The observatory has remained active without interruption to this day. In 1852, Serpieri was the first in Italy to propose applying telegraphy to meteorology, a project realized in 1856 by Angelo Secchi with a network of telegraph stations in the Papal States, marking the first example of such meteorological communication in Europe (Mantovani 2010, 16). Finally, in natural sciences, Serpieri made contributions to plant and animal phenology. He studied the flowering and fruiting cycles of wild and cultivated plants, anticipating modern scientific approaches, and observed bird migration phenomena and insect behaviour, in relation to agricultural activities. His systematic observations of annual biological rhythms demonstrate an interdisciplinary approach involving botany, zoology, and meteorology. These studies were published and used as the basis for subsequent surveys of the regional flora.

[2] The certainty of Serpieri's presence in Urbino is confirmed by a letter dated 18 November 1846, in which he requests the purchase of scientific instruments valued at between sixty and seventy scudi, intended for the Physics Laboratory of the University of Urbino (Mantovani 1998, 67).

[3] This correspondence is supplemented by 36 letters sent by Serpieri to Father Filippo Cecchi (1822–1887) of the Osservatorio Ximeniano in Florence. The University of Urbino has also recently acquired from the Pontifical Gregorian University 55 digital letters written by Serpieri to the Jesuit scientist Angelo Secchi.

[4] The Scolopian Giovanni Giovannozzi authored the primary historical account of Father Serpieri's life (Giovannozzi 1887, 5–134). Other biographical works include those by Federico Mici (1886, 1–36), Geronte Cei (1885, 4–27), Gaetano Dehò (1885, 1–32), and Costantino Bonini (1885, 4–22).

[5] A more detailed analysis of Serpieri's contributions to physics will be presented in a forthcoming article by the present author in this topical collection (Between Physics and Earthquakes: Scientific Development and Instrumental Innovation in Modern Italy, and the Legacy of Alessandro Serpieri).


SULL' OSSERVATORIO METEOROLOGICO
DEL COLLEGIO DEI NOBILI IN URBINO
AL SIG. CONTE DOMENICO PAOLI
DI PESARO
MEMBRO TITOLARE DELL' ISTITUTO DI AFFRICA, SOCIO DELL' ISTITUTO DI VENEZIA, DELLA SOCIETÀ GEOLOGICA DI FRANCIA, DELL' ISTITUTO DELLE SCIENZE DI BOLOGNA, E DELLE ACCADEMIE DI MEDICINA DI PARIGI, DELLE SCIENZE DI TORINO, DI SCIENZE LETTERE ED ARTI DI MODENA, DI SCIENZE ED ARTI DI MARSIGLIA, DE' GEORGOFILI DI FIRENZE, DELLE SCIENZE DI PADOVA, DE' FISIOCRITICI DI SIENA, ECC. ECC.
RELAZIONE
DI ALESSANDRO SERPIERI
delle Scuole Pie
Prof. di Fisica nella Pontif. Università di Urbino e di Matematiche nel Collegio
URBINO
30 MAGGIO 1850

Fig. 2 Title page of the printed report sent by Serpieri to Count Domenico Paoli of Pesaro in May 1850 (left); turret of the Meteorological Observatory at the Raffaello College in Urbino, from an early twentieth-century photograph (right). *Source*: PLUMST, University of Urbino Carlo Bo

3 The meteorological observatory and the emergence of seismic studies

It was only in the mid-nineteenth century that seismic science, which until then had relied on descriptive and observational analyses, began to adopt appropriate instruments and effective methodologies for analysing data from seismic events**,** such as the first seismoscopes and electric seismometers. During the second half of the nineteenth century, an extensive scientific debate developed, seeking to investigate the causes of earthquakes through theoretical studies and systematic observations conducted with increasingly sophisticated instruments. Italy played a leading role in this process, both theoretically and instrumentally, thanks to the contributions of a scientific community that, by establishing regular observations and designing increasingly effective detection instruments, decisively contributed to the formation of a new, autonomous, and professional scientific discipline. A seminal figure in this transformation was Alessandro Serpieri, whose contributions to earthquake studies were significant, both methodologically and theoretically.[6] His involvement in seismic studies began with the establishment, in 1850, of a small Meteorological Observatory in a turret (Fig. 2) of the Collegio dei Nobili in Urbino (later known as *Raphael College,* and today designated as *Palazzo degli Scolopi*). The Observatory, located at an altitude of 451 m above sea level, was initially equipped with a Fortin barometer, indoor and outdoor thermometers, a Six-Bellani maximum-and-minimum thermometer, hygrometers, a rain gauge, and an anemoscope. This was the first Observatory in the Marche region, and it became a reference point for scientific observations in the Montefeltro area. Serpieri publicly announced its establishment in a publication (Fig. 2) dedicated to Count Domenico Paoli[7] (1783–1853) of Pesaro (Serpieri 1850). The Urbino Meteorological Observatory began its observations on 1 May 1850 and has been operating continuously ever since (Mantovani 2010). For over three decades, Serpieri meticulously recorded the most significant meteorological parameters of Urbino's climate on a daily basis (temperature,

[6] Among his most significant contributions was the introduction of the 'seismic radiant'. This theoretical insight enabled a better understanding of seismic wave propagation and contributed to explaining the differential damage sustained by urban buildings based on their orientation relative to the wave direction.

[7] Paoli was an esteemed naturalist, chemist, and physicist, a follower of the theories of the Italian scientist Ambrogio Fusinieri (1775–1853) and a staunch proponent of speculative dynamical physics. Starting in 1844, he initiated systematic meteorological observations in Pesaro, taking over this role from Count Giuseppe Mamiani della Rovere (Mamiani 1845). He maintained frequent contact with Serpieri, whose scientific expertise he deeply admired. Upon his death, it was Serpieri himself who delivered his eulogy.

pressure, humidity, rainfall, and wind), assuming personal responsibility for acquiring and updating the equipment and managing its operation. Only on rare occasions did he receive support from the State, and, in later years, small municipal subsidies. In addition to meteorological parameters, Serpieri diligently documented many other natural phenomena daily in the "*Observatory Journal*", including earthquakes, auroras, shooting stars, and ball lightning. According to his own account, from May 1850 to 12 March 1873, the date of the first strong earthquake felt in Urbino, a total of seventy-nine reports of seismic events observed in Urbino and its surrounding areas were documented (Serpieri 1873c, see Cap. XII, 34–36). His initial interest in seismology is also attested to by Michele Stefano De Rossi, one of the fathers of Italian seismology and a prominent figure who, from 1874, edited the *Bullettino del Vulcanismo Italiano* (*BVI*), considered the world's first geodynamics journal. De Rossi is credited with being among the first to encourage Serpieri to undertake studies on earthquakes. The occasion arose from an exchange of views on volcanic seismic activity, which had occurred in the province of Rome on 19 January 1873. From that moment, the two scientists began a productive correspondence that continued until 1884.[8] In these letters, the two scientists addressed various aspects of seismology, including instrument design, data interpretation, theories regarding the origin of earthquakes, and the coordination of seismic studies in Italy. De Rossi recalls that it was with Serpieri's endorsement that he decided, in 1874, to begin publishing his famous *BVI* (De Rossi 1890, 29). This journal became a reference point for seismology scholars in Italy and abroad, contributing significantly to the development and dissemination of this discipline. Serpieri published his first studies on seismology following the severe earthquake that struck central Italy on 12 March 1873. On this occasion, he made an innovative proposal: transforming telegraph offices into temporary stations to collect immediate data on seismic events (Serpieri 1873c, 37). This pioneering idea was approved by the National Telegraph Directorate and led to the creation of the first *Telegraphic Seismic Correspondence Service* in Italy. In the aftermath of that event, he designed a new model of seismograph.

4 Collecting and interpreting: the earthquake of march 1873

On the evening of 12 March 1873, a severe earthquake struck the city of Urbino. The telegraph clock stopped at 9:04:44 p.m. (local mean time). Serpieri described the event as follows: "*The tremors were very rapid and gradually increased in energy over a prolonged period, making it an extraordinary earthquake in terms of both intensity and duration for our region. The fear was immense: some people turned pale and fell silent, others ran to safety, and some, terrified, began to scream. Then the undulations slowed significantly, or even, as it seemed to me, for a moment, ceased altogether. But suddenly, they returned with greater violence and force, unlike anything our hill had experienced in this century.*" (Serpieri 1873a, 4). The next day, Serpieri developed a systematic analysis of the earthquake, relying on an innovative theoretical idea centred on the concept of "seismic radiant" (Fig. 3) and adopting a data collection methodology that differed significantly from contemporary practices. He sent a circular to over a hundred Italian observers, scientists, and friends, requesting detailed information on the event. The circular included a questionnaire soliciting precise data regarding the exact time and minute of the first tremor, the types of tremors, their directions and orientations, their intensity, the duration of the phenomenon, and any pauses between tremors (Serpieri 1873b, 3–5). Through repeated epistolary exchanges, Serpieri collected ninety-seven reports. However, the responses revealed numerous uncertainties, especially regarding the exact start time of the phenomenon in different locations and the direction and orientation of the first seismic waves. The time discrepancies stemmed from the failure to specify the time standard adopted (true solar time, local mean time, or Rome mean time). The scientist addressed this timing issue in a subsequent circular, requesting observers to clarify the temporal references used in their reports. However, an even more significant challenge emerged: determining the direction and orientation of the initial wave motion from the collected data. The submitted reports often contained contradictory information about the shock wave's direction of propagation. This parameter was crucial for locating the epicentre, yet it was particularly difficult to establish accurately in the immediate aftermath of the seismic event, due to time constraints. For example, geographically close stations such as Viterbo and Orvieto, as well as Rome and Anagni, provided contradictory information regarding the direction of shock wave propagation. In this regard, Serpieri observed that these difficulties were compounded by the lack of sufficiently precise instruments for accurately detecting the dynamic parameters of seismic waves. As he stated: "*Tracing the paths of such fleeting wave motions of the Earth's surface is perhaps more difficult than tracing the orbits of comets through space.*" (Serpieri 1873b, 4). Consequently, Serpieri excluded the parameter "direction of propagation" from his dynamic analysis of the initial seismic waves, concentrating exclusively on their direction: *I ask you to consider that this point [i.e. the direction of propagation] is exceedingly difficult to establish, either because it is generally not given special attention, or because it is not truly intended to be expressed when indicating the direction of the tremors, or because more often than not, by the time one begins observing them, a few seconds have already passed since they started*. Moreover, concerning the "origin of tremors", he noted: "*We are still far behind in our methods*

[8] The *Archivio Provinciale Scuole Pie Toscane* contains 36 letters sent by De Rossi to Serpieri.

Fig. 3 Seismographic map of the earthquake of 12 March 1873 in Italy, drawn by Lieutenant-Colonel Luigi Gatta (1875, map at the end of the book). The map was based on data collected by P. Serpieri and his concept of the "seismic radiant". Using an astronomical analogy, Serpieri compared the central zone of the earthquake (in red on the map) to a radiant point from which seismic waves propagated like the trajectories of shooting stars during a meteor shower. *Source*: Gatta 1875, 57–58

of observation, and a remedy must be found" (Serpieri 1873c, see Cap. V, 18). To address this methodological shortcoming, Serpieri proposed a new, simple, inexpensive seismograph capable of recording both the direction and the orientation of the initial horizontally propagating seismic wave. This device had the advantage of being easily constructed from locally available materials and was designed to provide an instantaneous record of an earthquake's fundamental parameters. As we shall see, the instrument was likely inspired by an earlier modular model—a more complex apparatus, incorporating electromagnetic components, designed several years earlier in Naples by Luigi Palmieri.

5 A new seismograph: genesis, structure, operation

The first description of the new seismograph appeared in Serpieri's concluding work on the 1873 earthquake, specifically in Chapter XIII of the *Report*, entitled "*On a Very Simple Seismograph That Provides the Direction, the Initial Point of Departure, and the Time of the Tremor*" (Serpieri 1873c, see Cap. XIII, 37). This work is dated "Urbino, 2 August 1873". Thus, the seismograph was designed and built before this date, but precisely when? To establish the construction date, it is pertinent to note that the new apparatus was also designed to

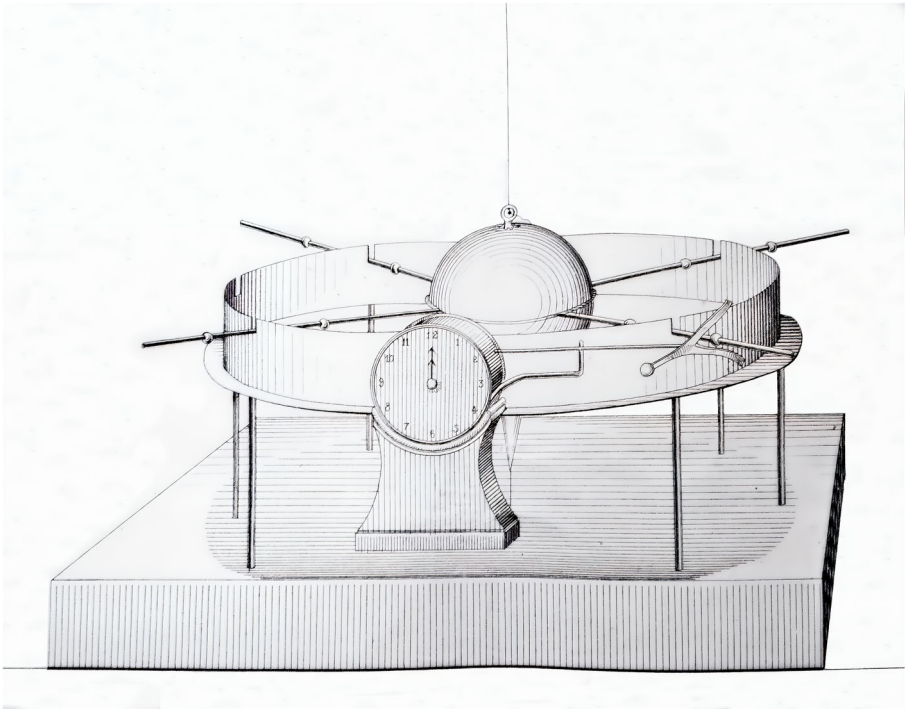
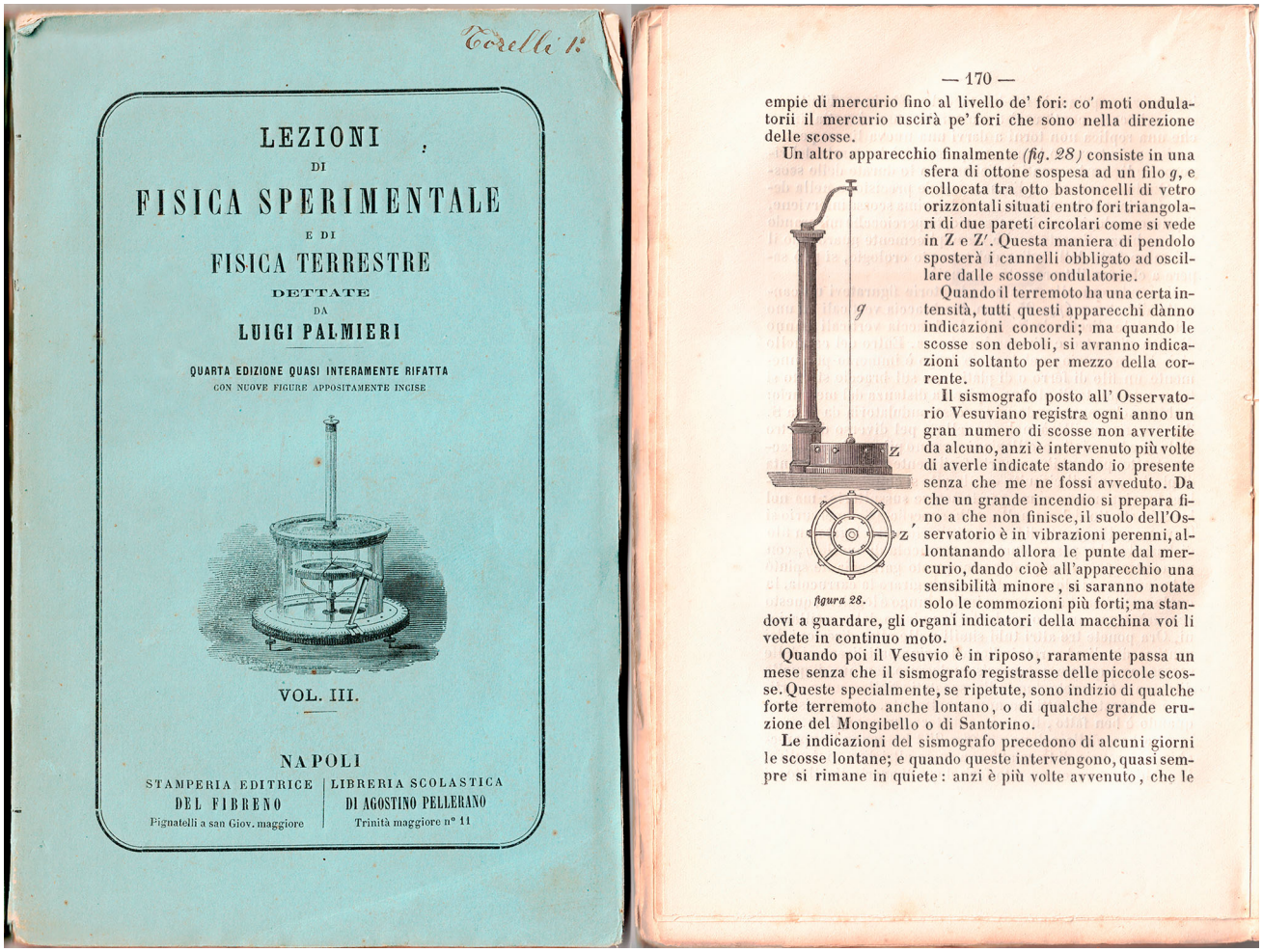


Fig. 4 Original engraving of the mechanical seismograph designed by Father A. Serpieri. *Source*: Serpieri 1873c, Fig. 6

record the exact time of the first seismic tremor. In his initial publication on the 12 March earthquake, dated 19 March 1873, Serpieri, in relation to the beginning of the earthquake, stated: "*The telegraph clock clearly marked the time because the tremors stopped its movement*" (Serpieri 1873a, 15). In Chapter XII of the final *Report*, Serpieri presents a historical catalogue of earthquakes felt in Urbino, including brief descriptions up to July 1873. Within this list, the earliest reference to the new seismograph is found in a note dated 19 April 1873: "At *4:03 p.m., two small undulatory tremors occurred with an interval of about 2 min. The seismograph gave the direction from W to E. The tip of the 1.48 m-long pendulum left a trace of only 2 mm. The first shock lasted about 2 s, the last 5 s* (Serpieri 1873c, 36). These documents suggest the instrument was constructed between 12 March and 19 April 1873. Father Denza stated that the instrument was placed in *Raphael College* "*within a niche carved into a large main wall, which rises from the ground floor of the college to the level of the observatory—approximately 26 m above ground level—and is guarded and protected against wind ingress and accidental disturbance by a locked crystal door*" (Denza 1875, 367). Unfortunately, despite careful research, all traces of the original seismograph have been lost. However, an engraving (Fig. 4) and several accurate descriptions (Serpieri 1873c, see Cap. XIII, 37; Denza 1875, 365–367; Gatta 1875, 10–11) enable a detailed reconstruction of the instrument. The instrument was notable for its simple design and low construction cost—features that rendered it easily replicable and accessible for practical and educational applications. It was designed to record the point of origin, time, and direction of the first seismic tremors with horizontal motion. The main component of the apparatus was a metal sphere, 10 cm in diameter, suspended from a 135-cm-long wire. Extending from the lower part of the sphere was a metal tip that lightly contacted and traced a groove in a layer of lycopodium powder. Attached to the sphere's equatorial band was a small metal ring that supported four metal rods, which were aligned with the cardinal points. A thin, circular, vertical metal plate, 35 cm in diameter and concentric with the sphere, provided secondary support for these rods through grooves. A portion of each rod protruded beyond the plate's outer edge. Small sliding lead weights on the rods created a slight imbalance, favouring the inner space of the instrument. The seismic movement caused one rod to topple outward, while simultaneously pushing the opposite and lateral rods inward, thereby enabling the determination of both the direction and the orientation of the earthquake's initial horizontal impulse. A simple mechanism, activated by a falling side rod, started an adjacent pendulum clock. The time of the shock was determined by comparing the clock triggered by the initial shock with the observer's own timekeeping device. Information about the event was further supplemented by the direction of the trace left by the sphere's tip on the lycopodium powder, the length of which was proportional to the intensity of the tremor. Finally, one last issue merits discussion: how did Serpieri conceive the idea for this instrument? Serpieri does not give a direct answer. However, it is known that a few years earlier, the Neapolitan scientist Luigi Palmieri (1807–1896)—who had been Director of the Vesuvius Observatory in Naples since December 1855, the first geodynamic observatory in the world—had designed a very similar apparatus. We propose here that Palmieri's device may have inspired


Torelli 1.

LEZIONI
DI
FISICA SPERIMENTALE
E DI
FISICA TERRESTRE
DETTATE
DA
LUIGI PALMIERI

QUARTA EDIZIONE QUASI INTERAMENTE RIFATTA
CON NUOVE FIGURE APPOSITAMENTE INCISE

VOL. III.

NAPOLI
STAMPERIA EDITRICE DEL FIBRENO — Pignatelli a san Giov. maggiore
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— 170 —

empie di mercurio fino al livello de' fori: co' moti ondulatorii il mercurio uscirà pe' fori che sono nella direzione delle scosse.

Un altro apparecchio finalmente *(fig. 28)* consiste in una sfera di ottone sospesa ad un filo *g*, e collocata tra otto bastoncelli di vetro orizzontali situati entro fori triangolari di due pareti circolari come si vede in Z e Z'. Questa maniera di pendolo sposterà i cannelli obbligato ad oscillare dalle scosse ondulatorie.

Quando il terremoto ha una certa intensità, tutti questi apparecchi dànno indicazioni concordi; ma quando le scosse son deboli, si avranno indicazioni soltanto per mezzo della corrente.

Il sismografo posto all' Osservatorio Vesuviano registra ogni anno un gran numero di scosse non avvertite da alcuno, anzi è intervenuto più volte di averle indicate stando io presente senza che me ne fossi avveduto. Da che un grande incendio si prepara fino a che non finisce, il suolo dell'Osservatorio è in vibrazioni perenni, allontanando allora le punte dal mercurio, dando cioè all'apparecchio una sensibilità minore, si saranno notate solo le commozioni più forti; ma standovi a guardare, gli organi indicatori della macchina voi li vedete in continuo moto.

figura 28.

Quando poi il Vesuvio è in riposo, raramente passa un mese senza che il sismografo registrasse delle piccole scosse. Queste specialmente, se ripetute, sono indizio di qualche forte terremoto anche lontano, o di qualche grande eruzione del Mongibello o di Santorino.

Le indicazioni del sismografo precedono di alcuni giorni le scosse lontane; e quando queste intervengono, quasi sempre si rimane in quiete: anzi è più volte avvenuto, che le

Fig. 5 Title page of Luigi Palmieri's treatise published in 1869 (left); engravings of Palmieri's mechanical sensor for horizontally propagating shocks (right). *Source*: Palmieri 1869, 170

Serpieri, who subsequently partially modified it. The apparatus in question functioned as a mechanical sensor for medium and strong tremors and was part of a more complex, sophisticated electromagnetic seismograph featuring continuous recording capabilities. Designed by Palmieri around the end of 1855 to monitor the seismic activity of Mount Vesuvius, it was particularly adept at detecting tremors imperceptible to human senses (the so-called instrumental tremors). Of this exceptional seismic apparatus, considered at the time the most sophisticated ever built,[9] only a few modified models were ever developed by its creator. Its first description appears in the inaugural issue of the *Annals of the Vesuvian Observatory* (Palmieri 1859, 20–24), a journal founded by Palmieri himself in 1859 and edited by him until 1873. A second description (Palmieri 1869, see Lesson XI, titled "Terremoti. Descrizione del Sismografo elettromagnetico" 165–171) appears in Volume III of *Lezioni di Fisica Sperimentale e di Fisica Terrestre*, published by Palmieri in 1869. This description includes an engraving (Fig. 5) of the mechanical sensor, which may have served as a model for Serpieri's seismograph design. This sensor, now preserved in the Museum of the Royal Vesuvius Observatory in Naples (Fig. 6, centre and right), shows remarkable similarities to Serpieri's seismograph. It belongs to the sensor system of the electromagnetic seismograph designed by Palmieri, the only complete specimen still extant today, made in 1864 by Giovanni Bandieri, a Neapolitan scientific instrument maker.[10] This seismograph (Fig. 6) comprises a recording unit and a seismic sensor unit that integrates various

[9] The device incorporated all methods of seismic motion detection that, up to that point, had been employed in other instruments. Although the seismograph was highly regarded, its high cost limited its dissemination. Palmieri also designed a portable version of his instrument.

[10] The Bandieri family were scientific instrument makers who operated in Naples throughout the nineteenth century. The known members include Bonaventura, his son Giovanni, and Giovanni's son Giuseppe. In 1849, Giovanni inherited the mechanical workshop and the machinist position at the royal court from his father. After the unification of Italy, Giovanni worked as a machinist for the University and participated in the Universal Exhibitions in London (1862) and Vienna (1873).

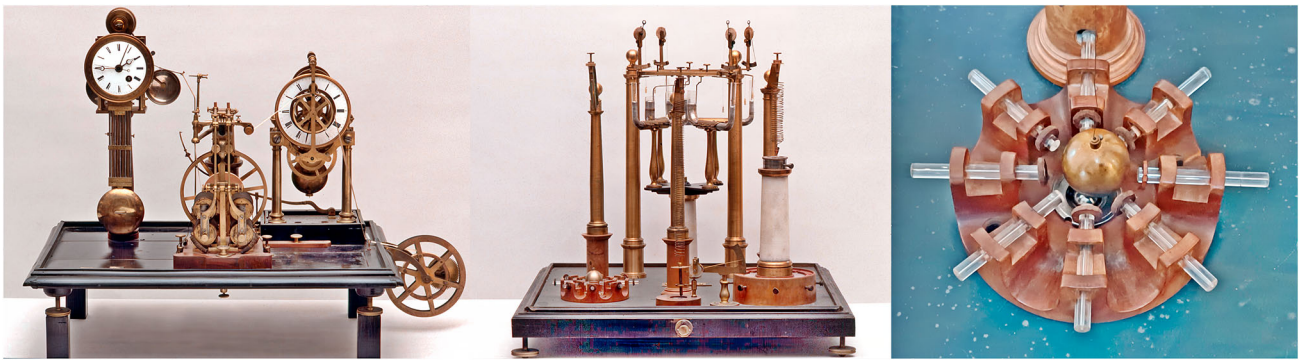

Fig. 6 Luigi Palmieri's electromagnetic seismograph, built by Giovanni Bandieri in Naples in 1864, and currently preserved in the Museum of the Royal Vesuvius Observatory in Naples (left and centre); close-up view of the mechanical pendulum sensor used to detect horizontal shocks (right). *Source*: INGV – Osservatorio Vesuviano, Naples

sensors designed to detect vertical ("sussultatory") and horizontal ("undulatory") tremors, as explicitly stated by its creator. Among these sensors, the mechanical types were designed to record tremors of medium or high intensity and served as a reference for the more sensitive current-operated sensors, which were suitable for detecting shocks of lower intensity. Figure 6 (right) shows the mechanical sensor preserved in the *Vesuvian Observatory Museum*. Although it lacks a timekeeping mechanism, this apparatus bears a striking resemblance to Serpieri's seismograph. The sensor consists of a brass sphere suspended from a steel wire and positioned between eight small horizontal glass rods arranged at the four cardinal points and at intermediate positions. Each rod can slide with minimal friction through a pair of holes in a wooden support and is horizontally constrained by a coaxial leather disc. The horizontal oscillation of the ground imparted motion to the pendulum and the brass sphere, which in turn displaced the glass rods outward. This mechanism enabled the visual recording of precise information about the direction and orientation of the earthquake's initial impulse.

6 The De Rossi protoseismograph

Serpieri's second seismograph for his earthquake studies was the "protoseismograph", an instrument designed and so termed by Michele Stefano De Rossi. As De Rossi himself declared, it was "conceived" in 1874 and "repeatedly modified *and described in Meteorologia Endogena (vol. II, p.152) and in the BVI (vol. X, p. 101)*" (De Rossi 1886, 79). Between 1874 and 1876, De Rossi designed several electric recording seismographs, comprising "pendulums equipped with loosely tensioned tie-wires" and pendulums using "spirals".[11] These devices represented a major innovation, enabling more precise and detailed recordings than earlier models. At present, although incomplete, the De Rossi protoseismograph is preserved in the PLUMST, University of Urbino Carlo Bo (Fig. 7). The history and chronology of this instrument have been carefully reconstructed on the basis of five letters sent by De Rossi to Father Serpieri, dated between 7 December 1877 and 7 April 1878. In a letter dated 7 December 1877, De Rossi, responding to Serpieri's request for information regarding the purchase of an efficient seismograph, wrote:

> "For the most strictly seismological applications, and specifically for the recording of microseismic maxima alone, the best among my instruments is the one I have called the protoseismograph, whose excellent performance I can fully guarantee on the basis of my experience. One such instrument is available, exceptionally well built and equipped with a high-quality clock, which is a particularly significant feature of this apparatus. It is located in Rome at the workshop of the mechanic Ermanno Brassart and costs 400 Italian lire."[12]

Eleven days later, De Rossi sent Serpieri the drawings of the apparatus. On 24 January 1878, in a subsequent letter, he reported verbatim:

[11] De Rossi used the following seismographs: the economic hourly autoseismograph; the economic seismograph, which recorded vertical (sussultatory), wave (undulatory), and hourly movements; the protoseismograph; and, finally, the microseismograph. De Rossi tested them in his observatory at Rocca di Papa (near Rome). They were designed to detect even the smallest movements of the Earth's crust.

[12] Michele Stefano De Rossi, letter to Serpieri, December 7, 1877. Archivio Provinciale Scuole Pie Toscane in Florence, MS, Religious Register 472.

Fig. 7 Michele Stefano De Rossi's protoseismograph, built in Rome by Ermanno Brassart in 1878 and currently preserved in the University Museum of Urbino. *Source*: PLUMST, University of Urbino Carlo Bo

> "I showed your letter to a mechanic named Brassart, who informed me that he accepts the conditions you proposed for purchasing the protoseismograph, to which he will add the necessary batteries. He is currently working on constructing those batteries and preparing the entire instrument."[13]

The apparatus arrived in Urbino on April 7, 1878. Brassart[14] had equipped the instrument with two iron brackets for wall mounting, twelve paper rolls for the clockwork mechanism at an extra cost of 12 lire, and "extremely fine natural silk thread", which was integral to the detection unit. Although the instrument is generally well-preserved, a number of mechanical components are missing, including the clockwork movement, the metal anchors, and a sliding cylinder. A brief description of this rare apparatus (Fig. 8) follows. It consists of two main components: a detection unit and a recording mechanism. The recording device comprises a spring-wound clock, which drives a strip of paper, pressing it between two cylinders, and four pairs of electromagnets electrically connected in parallel to one pole of a battery. Each pair of electromagnets operates a metal anchor with a pointed tip at the end, which is positioned above the paper strip. The detection unit includes a pendulum (now missing), which, suspended from a stable support, oscillated in response to seismic movements. The pendulum's motion, triggered by the initial impulse of an earthquake, was amplified by four loosely tensioned silk tie-threads (i.e., yielding ligatures kept at low pretension so their effective length can vary under motion). These threads originated from a single point on the pendulum and were connected to four fixed points aligned with the cardinal directions. At the midpoint of each thread was a metal needle, electrically connected to the other pole of the battery and suspended above a small metal cup containing mercury. These cups, arranged at the corresponding fixed points, were connected by electrical wires to the four pairs of electromagnets. The first shock was recorded because each small horizontal half-oscillation of the pendulum corresponded to a noticeable vertical descent of the metal needles. As a needle dipped into the mercury below, it closed the electric circuit and activated the corresponding pair of electromagnets. This pair of electromagnets lowered the corresponding pointed anchor tip, producing a hole in the paper strip (De Rossi 1877, 285–286). Through this mechanism, the instrument recorded the pendulum's half-oscillations as individual dots, thereby allowing the detection of individual pendular signals and enabling the identification of the direction of the initial horizontal seismic impulse. Despite this important functionality, the instrument could not determine the tremor's duration or intensity. This limitation led De Rossi to name the instrument the "protoseismograph". Nevertheless, it was awarded an "*honorary diploma*" at the 1881 Paris International Electrical Exhibition (De Rossi 1882, 143–146).

[13] Michele Stefano De Rossi, letter to Serpieri, January 24, 1878. Archivio Provinciale Scuole Pie Toscane in Florence, MS, Religious Register 472.

[14] In 1859, Ermanno Brassart and his brother Emilio established a mechanical workshop in Rome at Via S. Agostino 1, which operated until 1885. The workshop specialized in seismological and meteorological instruments and produced electrical devices, particularly electro-medical equipment. One of their most notable achievements was the construction of the famous Meteorograph for Father Secchi. This pioneering automated meteorological station won a gold medal at the Paris Universal Exhibition in 1867. From 1881 to 1895, Brassart was the official manufacturer of the *Central Office of Meteorology and Geodynamics*.

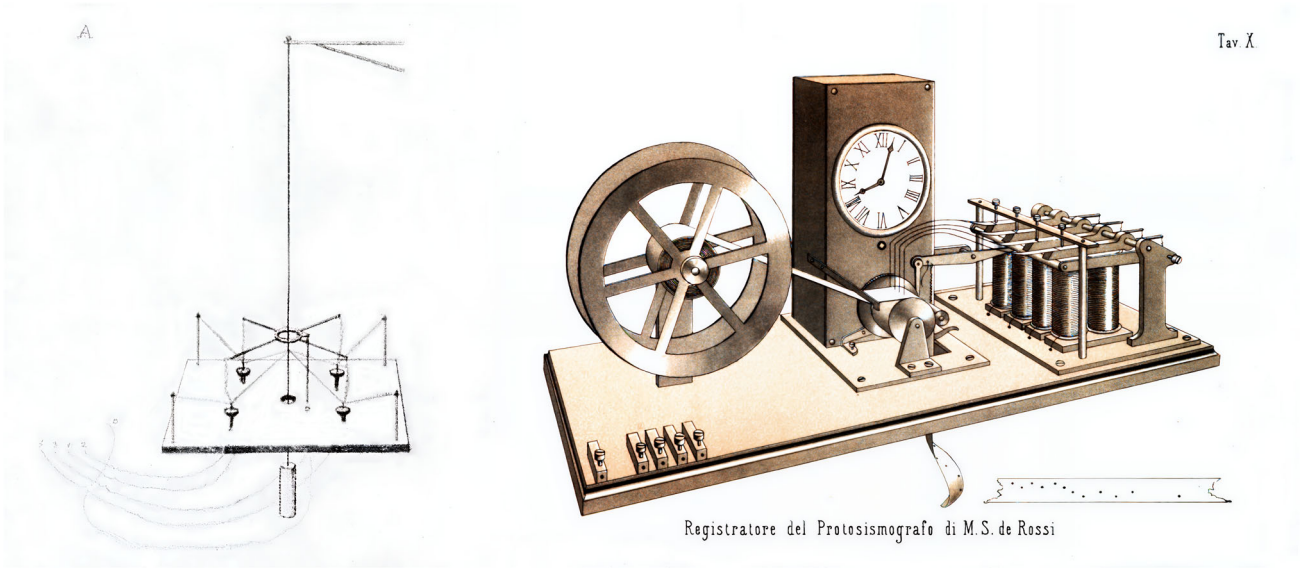

Fig. 8 The De Rossi protoseismograph: original drawing of the detector apparatus (left) and the recording apparatus (right). *Sources*: PLUMST, University of Urbino Carlo Bo; De Rossi 1877, Table X

7 A skilled local instrument maker, Achille Scateni

Documents in our possession clearly indicate that the final seismographs utilized by Alessandro Serpieri in his research were designed and constructed by his mechanical assistant at the Physics Laboratory, Achille Scateni. Little is known about the life of this skilled and meticulous maker of scientific instruments, who, as was customary in physics laboratories of the period, served as a machinist. According to available documentation, he initially worked as a watchmaker, describing himself as having been trained in the "Genevan school". In 1860, he was appointed both caretaker of the university building and, concurrently, assistant to the Physics and Chemistry Cabinets, roles he held with unwavering dedication and competence until 1890 (Pesaro State Archives 1860; Scateni c. 1880). Under Serpieri's supervision, Scateni was responsible for the maintenance and repair of the scientific apparatus in the Urbino laboratory for three decades. A document from 1865, located in the archives of the University of Urbino, entitled "*List of Works Carried Out by the Undersigned [Scateni] for the Physics Cabinet on the Orders of Prof. A. Serpieri*", attests to his primary activities. He was tasked with the construction of new apparatus, the repair of defective instruments, and the manufacture of missing supports and accessories. These functions, vital for the operation of the *Physics Laboratory*, required considerable expenditure, particularly for the procurement of specialized components. It was only around 1865 that Scateni fully assumed his technical duties, owing to the increased resources and financial backing secured by Serpieri for his *Physics Laboratory*. This period marked the advent of a phase of heightened productivity and innovation for the technician, who not only undertook maintenance but also distinguished himself through the design and construction of novel scientific apparatus of remarkable precision, some of which are still preserved today in the PLUMST collection at the University of Urbino.[15] In particular, from the early stages of his career, Scateni distinguished himself by manufacturing precision balances. Documents show, for example, that he completed the construction of a balance in 1868. This instrument, now in the collection of the PLUMST (Fig. 9), received a highly favourable technical assessment from the *Consultative Commission of Weights and Measures* in Florence the following year. This commendation formed part of a wider context, typical of the period, characterized by competition between Italian manufacturers in the production of precision instruments.[16] Further recognition came in 1873 from Pietro Blaserna, director of

[15] Among the various pieces bearing the "Scateni" signature, notable examples include an Atwood machine, a pair of precision analytical balances, a Deleuil model air pump, and a large 1863 Winter model electrostatic machine. The latter was built according to precise instructions from both Serpieri and Father Filippo Cecchi. Another remarkable Atwood machine, also signed "Scateni", is preserved in the Physics Cabinet of the Istituto d'Istruzione Superiore "Raffaello" in Urbino.

[16] On the basis of this judgement, the Minister of Public Education, in a note dated 12 February 1869, granted Achille Scateni the sum of 200 lire "as an encouragement" for his excellent work. A circular was also sent to the *Engineering Schools* of Milan, Turin, Palermo and Padua, as well as to the *Polytechnic Institute* of Milan (with the Commission's report attached), to inform them of the possibility of purchasing the balance, the cost of which was estimated by its creator at around 3,000 lire.

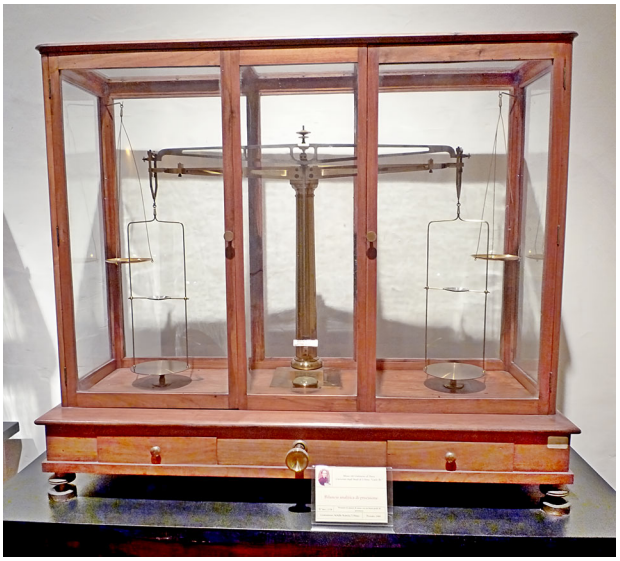

Fig. 9 Long-beam analytical balance, dated 1868 and signed "Achille Scateni Urbino". *Source*: PLUMST, University of Urbino Carlo Bo

the Physics Institute of the Royal University of Rome, who certified the purchase of a precision balance made by Scateni, valued at 1,750 lire, which had been requested by Professors G. Cantoni and P. Brusotti. Blaserna praised the fine craftsmanship of Scateni's balance, describing it as meeting the scientific standards of the time. He expressed his astonishment at Scateni's ability to construct such a highly accurate instrument, given the extremely limited resources at his disposal[17] (Scateni c. 1880, 7–8). In 1880, the same Florentine Advisory Commission reiterated its positive assessment of some of the Urbino manufacturer's precision balances, judging them to be of such exceptional craftsmanship that they could compete with those produced by the most prestigious foreign workshops (Scateni c. 1880, 8). This recognition highlights Scateni's remarkable skill in the manufacture of precision instruments and his ability to contribute to complex scientific projects. Following this success, the last instruments he made that survive today are the two seismographs that he likely began designing in 1882, which will be discussed shortly. After his death (around 1890), several mechanical assistants succeeded him at the Physics Laboratory: first Filippo Cangini, then Giuseppe Basili from 1908 to 1937, followed by Fausto Santini, and finally Pasquale Logli from 1945 to 1963. His legacy remains tangible in the numerous instruments still preserved at the PLUMST.

8 The Scateni recording seismograph for horizontal movements

Between 1882 and 1883, Scateni, presumably at the specific request of Father Serpieri, designed and constructed a new seismograph intended to "*better meet the needs and fulfil the requirements of science compared to those hitherto known*". He reported this accomplishment in a brief publication dated May 1883, where he referred to certain defects in existing seismographs[18] and highlighted the features, operation, and innovative aspects of his apparatus (Scateni 1883, 1–4). The instrument offered a new indication system to precisely register the time, duration, direction, and other phases of seismic phenomena. The apparatus consisted of two separate parts, which could be placed "*adjacent in the same room or at any distance from each other*". Unfortunately, of these two

[17] In 1876, Blaserna sent a photograph of this balance to the *International Exhibition of Scientific Instruments* held at the South Kensington Museum in London (Catalogue of the Special Loan 1877, 1073). The instrument is now preserved in the Museum of the Physics Department at La Sapienza University in Rome.

[18] Scateni points out that seismographs, which were based on the movement of pendulums or the movement of mercury in vessels, transmitted the seismic movements of the ground to the various display and recording mechanisms with some shortcomings. For example: the ordinary pendulum, once set in motion, did not easily return to rest, causing oscillations that did not necessarily correspond to the actual movements; tubes or other vessels filled with mercury had defects of uncertainty and instability in their oscillations, which did not guarantee an accurate measurement of seismic tremors.

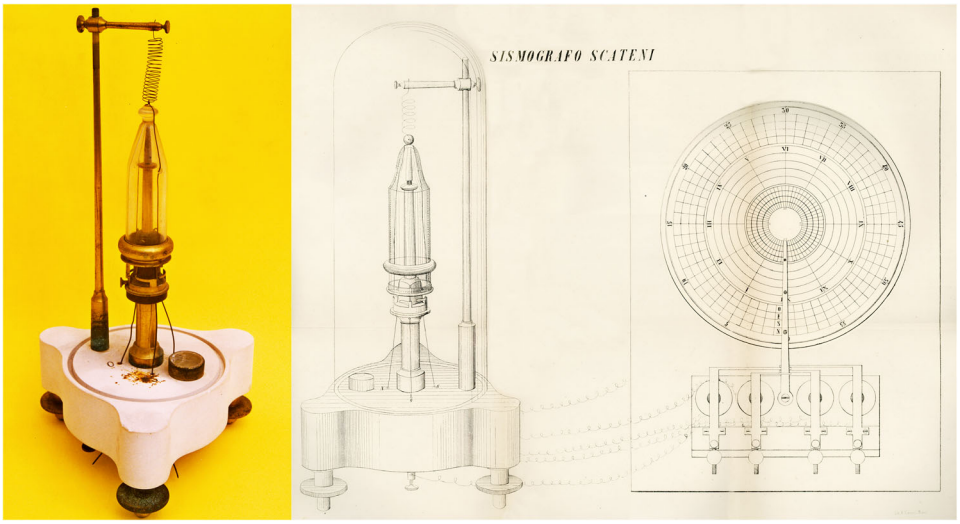

Fig. 10 Detector apparatus of Achille Scateni's seismograph, built around 1882 (left); original engraving of the Scateni seismograph (right). *Sources*: PLUMST, University of Urbino Carlo Bo; Scateni 1883

parts, only the detector apparatus—which has survived largely intact and in good condition—remains and is now kept in the PLUMST. A brief description is given below. The Urbino detector (Fig. 10, left) consists of a cylindrical glass bell, 11 cm in height and 3 cm in diameter, inverted and balanced on the tip of a steel rod placed inside and coaxial with the bell. A screw terminal positioned under the base connects the rod to one pole of a battery. A sliding ring (now missing) was placed on the bell, allowing adjustments to modify the system's centre of gravity, thereby calibrating its sensitivity. The lower rim of the bell is internally lined with platinum and is electrically connected to the other pole of the battery. The base of the steel rod supporting the bell has four metal wires rigidly attached at right angles and oriented along the cardinal directions, each of which was linked to the indicator-recorder apparatus. Finally, a rotary switch located beneath the bell enabled the combination of the four separate contacts corresponding to the cardinal points into a single contact. The initial impulse of an earthquake set the bell into oscillation; as the bell struck one of the four wires attached to the rod, it closed the circuit, transmitting its movement to the indicator-recorder. Of this second part of the device, only an explanatory drawing (Fig. 10, right) and the following description remain extant:

> "It consists of a balance-wheel clock equipped with three concentric dials, designed to indicate, moving from the outermost to the innermost, the first for minutes, the second for hours, and the third for seconds. The hand is fixed in this clock, while the dials rotate in the opposite direction to that of conventional clock hands. Four distinct rods, stacked one on top of the other and corresponding to the four wires of the bell pivot, serve as indicators and are moved by the arms of four electromagnets. Four zones corresponding to the four cardinal points are inscribed on each of the three dials. The rods, which act as indicators, are each equipped with three points designed to leave, on each dial and in their respective zones, marks indicating the Earth's movements. The entire system of indicators and points is designed so that each rod can operate independently of the others by allowing its points to pass through those of the rods below without any contact" (Scateni 1883, 3).

Scateni thus highlighted the responsiveness, accuracy, and ease of recording seismic movements offered by his seismograph and the possibility of deploying several devices at different locations and networking them for remote monitoring of earthquakes. The instrument was received positively, earning a flattering assessment from De Rossi: "*The recording device has a special importance because it achieves a highly practical and useful result: the indication of the hour, minute, and second, visible at a glance without the inconvenience of extensive paper unwinding. Therefore, I believe that, rather than limiting it to Scateni's seismograph alone, it would be well-suited to an observatory rich in instruments as a general recorder for all apparatus*" (De Rossi 1883, 138). Finally, it should be noted that Scateni, in his printed description, stated that the detector system was capable of "*receiving and transmitting ground movements of any kind*" (Scateni 1883, 2), encompassing not only horizontal seismic movements but also vertical ones. While Scateni did not elaborate on the mechanism for vertical detection, observation of the instrument suggests the spring supporting the inverted bell likely served this

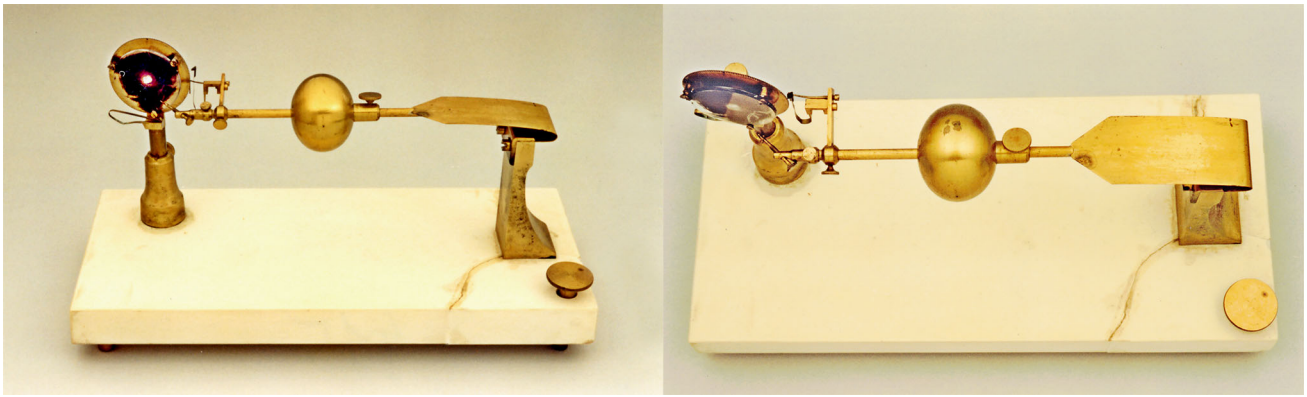

Fig. 11 Achille Scateni's mechanical seismograph for vertical shocks, viewed from the side and from above. Built around 1882. *Source*: PLUMST, University of Urbino Carlo Bo

function, acting as a qualitative sensor. However, at the 1884 *Turin General Exhibition*, this instrument[19] was presented under the name "*Recording seismograph, Scateni system, for undulatory ground motion*" (L'Esposizione Generale 1884, 14), and upon analysing its construction, this classification appears to be technically accurate.

9 The Scateni mechanical seismograph for vertical movements

Scateni also presented a second apparatus at the Turin Exhibition, which has survived and is currently preserved in the PLUMST (Fig. 11). This apparatus was a mechanical graphic recorder designed to measure vertical seismic movements and was listed in the Exhibition's official catalogue as "Vertical Seismic Sensor, Scateni system" (L'Esposizione Generale 1884, 14). No printed or handwritten notes or descriptions have been found for this piece, presumably also designed and built between 1882 and 1883. The instrument consists of two vertical brass supports rigidly connected to a marble base. The left support holds a toothed wheel that, in turn, supports a disc on which the smoked paper was mounted. On the right side of the instrument, a flat spring is attached to a horizontal brass rod fitted with a sliding spherical mass used to calibrate the oscillation thresholds. The end of this rod is equipped with a metal nib and a mechanism that engages with the toothed wheel. Vertical movements, including those caused by earthquakes, set the instrument in motion, activating the nib and allowing it to record the tremor on the smoked paper. The two instruments were honourably displayed in the "geodynamic section" of the Turin Exhibition and were awarded a bronze medal (Elenco dei premi 1884, 193). In August 1884, the University of Urbino purchased the two seismographs from Scateni for 250 lire (Scateni 1884). In October of the same year, Serpieri left Urbino and relocated to Badia Fiesolana; the Observatory and Physics Laboratory directorships were subsequently assigned to the physicist and meteorologist Giuseppe Martinotti, who held these positions until 1897. In July 1885, under pressure from Scateni, Martinotti submitted a proposal to the *General Directorate of Agriculture* in Rome to adopt Scateni's recording seismograph—defined as a "seismic monitoring apparatus"—for use in observatories within the Italian seismic network. The apparatus was examined in 1886 by the *Royal Geodynamic Commission of the National Geodynamic Service* in Rome (1884–1887). The Commission, chaired by the seismologist Giulio Grablovitz (1846–1928), issued a negative opinion on Martinotti's proposal (Ferrari 1992, 99). This judgement effectively precluded any real possibility of the instrument's widespread adoption. As evidence of this, only a small number of specimens similar to the Urbino seismograph have been documented to date. One such specimen, a detector apparatus for horizontal movements, is currently preserved at the "Valerio" Observatory in Pesaro. The museum collection of Meteorology, Seismology, and Hydrobiology at the "CREA"—Food and Nutrition Research Centre (formerly UCEA) in Rome, on the other hand, preserves four pieces originating from the Scateni family: two sensors—one for horizontal movements and one for vertical movements—closely resembling those from Urbino; an incomplete recording apparatus; and, finally, a conspicuously modified sensor for horizontal movements. These instruments were loaned by Scateni's widow in 1906 for display at the International Exhibition in Milan, which included a retrospective exhibition on seismometry—the first historical exhibition of its kind ever organized in Italy—curated by the *Royal Central Office of Meteorology and Geodynamics* in Rome (Cavazzana 1906, 363).

[19] The Exhibition Catalogue specifies that "*only a part of this instrument, namely the recording section, is displayed in drawings*" (Esposizione Generale 1884, 14).

Funding Open access funding provided by Università degli Studi di Urbino Carlo Bo within the CRUI-CARE Agreement.

Declarations

Conflict of interest The author declares no conflict of interest and no relevant financial or non-financial interests to disclose.

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