Enlightening Towers

Public Opinion, Local Authorities, and the Reformation of Meteorology in Eighteenth Century Italy

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In the spring of 1777 Piazza del Campo at Siena became the site of a collective experiment. One year earlier the Grand Duke of Tuscany, Pietro Leopoldo, ordered that a lightning rod be affixed to the tower of the town hall, the very heart and symbol of the city. His decision prompted the heated reaction of a Siena nobleman, the marquis Alessandro Chigi, who published an attack against the theory that lightning was an electrical phenomenon, claiming that metallic conductors would be ineffective in preventing damages to building and people during thunderstorms.[1] Chigi's opposition to lightning rods found quite a few supporters, and when, on April 18, 1777, black clouds darkened the sky above Piazza del Campo, a large crowd gathered in the square to observe the effects of the conductor erected on top of the tower. They saw a bolt of lightning strike the tower and be conducted safely into the ground, channeled by the metallic rod. The professor of physics at the University of Siena, Domenico Bartaloni, examined the tower and the conductor after the storm. Although "the incredulous" expected "a completely different result, almost wishing to see the tower flashing, so as to expose to ridicule the holy laws of physics," Bartaloni declared the complete success of the conductor in protecting the tower. His official report was published in the transactions of the Academy of Siena as well as in the local newspaper. The collective witnessing of the experiment sanctioned the success of lightning rods in the public sphere.[2]

The Siena episode highlights typical elements that characterized eighteenth century debates on the effectiveness of lightning rods: the involvement of public opinion, the role of local authorities, the experts' engagement in the popularization of their views, and the spectacularly visible setting of the experiments. Towers were main protagonists of the early history of lightning rods. Highly tangible symbols of political, religious, or financial power, towers had always been frequent targets for the fiery meteor of lightning. From the mid-eighteenth century, they became favorite sites for experimenting with lightning conductors. Not only in Siena but also in Florence, Pisa, Milan, Turin, Venice, Genoa, Bologna as well as in smaller towns south of the Alps, natural philosophers affixed metallic conductors on top of the towers of churches, city halls, castles, and palazzi.[3] In the philosophers' opinion, the pointed conductors would slowly draw the electric fire from thunderclouds and channel it into the ground, thereby preventing huge discharges that would damage buildings. Or, they would attract lightning, forcing it to pass through the metal, with the same result. Yet because of their visibility and symbolic significance in the everyday life of Italian cities, towers also became highly debated experimental sites that attracted the inhabitants' attention and made the debate over lightning rods a public concern.

This essay shows that before lightning rods became marketable commodities, they were experimental devices used to substantiate or criticize Franklin's theory of electricity, which held that the matter of lightning and that of artificially produced electric sparks were one and the same. The study of the nature of lightning contributed to the reformation of Aristotelian meteorology in terms of the new science of electricity: each flash of lightning that struck a metallic conductor created the experimental setting for electricians to study the behavior of such a disruptive natural "meteor." The reports of their observations made up a sort of transnational repository of experimental results on which lightning rods advocates relied to support their arguments. Because of their unusually visible setting, however, such experiments acquired a public dimension that obliged electrical experimenters to confront public opinion and local authorities. In some cases, this confrontation brought electricians to engage in campaigns of popularization of electrical science, which aimed at highlighting the public benefits deriving from the installation of lightning rods and from the study of electrical meteorology. Yet the electricians' attitude to public opinion was not unanimous. Marsilio Landriani, for example, who in 1784 published a complete list of lightning conductors affixed on private houses, powder magazines, and public buildings in Italy and the rest of Europe, in his *On the Usefulness of Electrical Conductors* declared that he was "convinced that examples and authority have more effects than reasons on people's dispositions."[4] Nonetheless, if Pietro Leopoldo's decision was clearly an authoritative example, it did not seem to suffice to sedate controversies that characterized debates over lightning rods throughout the century.[5]

This essay explores the multifaceted interactions between local authorities and lightning rods advocates in three different experimental sites where three experts of electricity experimented with lightning conductors, each with different fortune. The fragmentation of the Italian peninsula into several states made of each site a unique combination of the electricians' aspirations with the pressures exerted by local decision makers. Yet active interest in the practical applications of electricity linked together the Italian experimenters who worked with lightning conductors. Each of the three cases highlights the dynamics that affected the fortunes of lightning rods at the local level; taken together, they offer an analysis of the emergence of atmospheric electricity as a new branch of experimental philosophy that redefined the ancient science of meteorology, implementing the Enlightenment rhetoric on the usefulness of science. Pointing upward to the sky, lightning rods provided new means, both theoretical and practical, to interpret the nature of the meteors that fell from the heavens onto the ground. In doing so, they contributed to taming unruly atmospherical phenomena with the Enlightenment ideal of a law-obeying universe.

The Tower of the Istituto delle Scienze in Bologna: Giuseppe Veratti, the Pope, and the Fear of Lightning Rods

In 1752 at Marly, France, the French electrician Thomas François Dalibard performed a crucial experiment. Following Franklin's directions, he erected a pointed, long metallic rod toward a group of thunderclouds. Approaching the rod with another conductor near the ground, he managed to extract sparks that appeared identical to those produced by artifice by means of electrical instruments. "Natural" and "artificial" electricity, he concluded, were one and the same thing. When news of the experiment reached Bologna, the town's leading electrician, Giuseppe Veratti, hurried to replicate it. Veratti was a lecturer of anatomy at the university and a member of the Bologna Institute of Sciences. A few years earlier, he was one of the main actors in a controversy of international resonance over the healing properties of electricity; his work, *Physico-Medical Observations on Electricity*, published in Bologna in 1748 was translated into French and was well known in the republic of letters. With Laura Bassi, his more famous wife, he set up a laboratory of experimental philosophy in their house where they both offered demonstrations to students and visitors. Electricity figured prominently in their experimental activity.[6]

Veratti performed the experiment with lightning conductors on top of the observatory tower of Palazzo Poggi, the building that hosted the Istituto delle Scienze. Founded at the beginning of the century by Gen. Luigi Marsili, who envisaged his institution as a new "House of Solomon," the Istituto complemented the range of lectures offered by the university. Contrary to other contemporary scientific academies, such as the *Royal Society* and the *Académie des Sciences*, it was intended primarily as a site for experimental research: located at walking distance from the city center, in the elegant Palazzo Poggi, its rooms were all equipped with the necessary instruments for the members to lecture and carry out their research. It also included a library and an observatory (fig. 2.1). Each of the rooms for experiments was dedicated to one branch of natural philosophy and was directed by a member. Veratti was in charge of the physics room.[7] The Institute of Sciences was Bologna's most prestigious scientific institution; it hosted large collections of instruments, wax models, and natural specimens, and it was a destination that learned travelers would not miss. In 1740, when the Bolognese cardinal Prospero Lambertini became pope Benedict XIV, the Istituto could boast of a very powerful patron who added expensive items to its scientific collections and supported its research activities.

Veratti's choice to carry out the experiment on top of the observatory tower of Palazzo Poggi was an obvious one. The observatory was a tall building conveniently located just a few floors above the physics room where Veratti kept his electrical instruments. He sought the collaboration of two fellow members of the Institute of Sciences, the astronomer Petronio Matteucci and his assistant Tommaso Marini. Together they erected a metallic rod on top of the observatory tower. The rod was sixteen Parisian feet high (about five meters) and half a digit wide, and it was connected to a metallic chain that allowed them to test the electric state of the rod without climbing the tower.[8]

When thunderclouds appeared in the sky Veratti repeated Dalibard's experiment as it was described in the gazettes: he approached the chain connected to the conductor with a metallic key and observed strong sparks that issued from it. In drawing conclusions on the nature of such sparks he relied on his experience as an electrical experimenter, making use of his senses and of his own body. The color of the sparks and the "disagreeable sensation" that they produced on the body did not leave any doubt as to their similarity with those produced by artifice with common electrical instruments, even though the strength with which they shocked the experimenters' arms and legs indicated that the quantity of electricity involved was exceedingly greater. The physiological effects of the shock did not differ from those produced by the Leyden jar, an instrument that enjoyed international popularity because of the strong shock that it could provoke when discharged through one's body. In his practice as a medical electrician, Veratti, as well as his fellow colleagues in the rest of Europe, used the Leyden jar also as a medical remedy against paralysis and other ailments. The electric phenomena revealed by the lightning conductor disappeared after a few minutes, when rain started to fall, just as electrical experiments lost their vigor in humid weather. The experimenters then climbed the tower to examine the rod, convinced that they would not observe anything interesting for the rest of the day. However, when a bolt of lightning struck nearby, Matteucci and Marini, who were touching the iron bar, experienced a terrible shock, as if they had been struck by lightning. They recovered completely after a few hours of convalescence and even resumed the experiments, but their accident did not go unnoticed.[9]

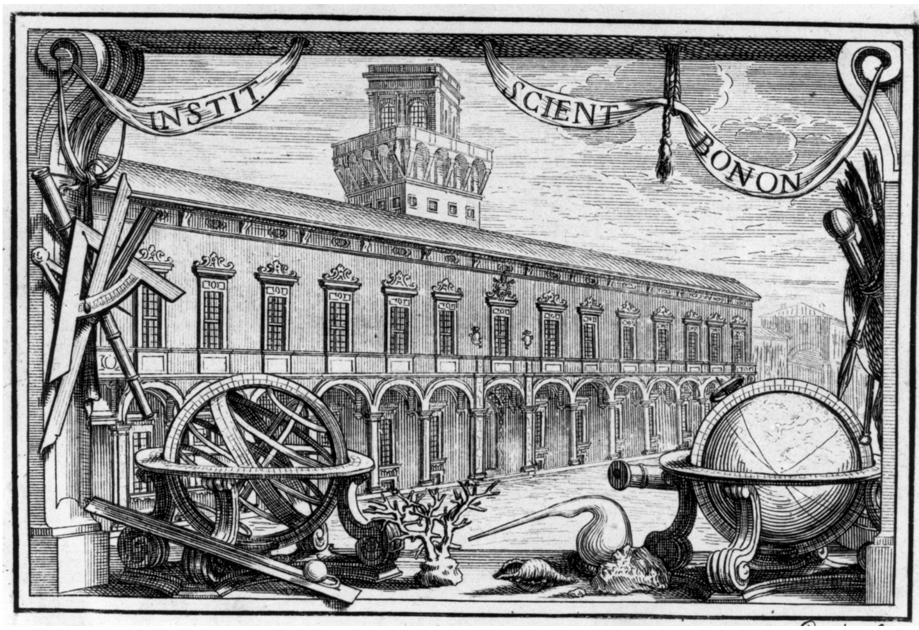

Figure 2.1. The Bologna Institute of Sciences and the Observatory Tower.
De Bononienis Scientiarum et Artium Instituto atque Academia Commentarii. Tomus Septimus (Bologna, 1791)

The local gazette praised Veratti, who had equaled experimenters in Philadelphia and Paris and confirmed the "hypothesis of those who believe that by this means lightning can be pushed away from those places, where iron bars are erected above resinous or sulphurous substances." With a view toward highlighting the expertise of the experimenters, the anonymous author of the article referred his readers to Veratti's work on medical electricity and informed them of his recent success in the treatment of a paralytic arm that was restored to its normal state after seven minutes during which the physician extracted sparks from it.[10] Electric sparks, the author seemed to imply, were not dangerous if properly managed, as Veratti was able to do. However, the experiments at the observatory tower did not elicit unanimous approval. Upon hearing of the terrible shock experienced by Matteucci and Marini, the people who lived near the Institute of Sciences protested that the experiment demonstrated that the metallic rod attracted the electric matter from the clouds and was therefore dangerous. Their vociferous complaints reached the Assunteria d'Istituto, the board of magistrates (*assunti*) who legislated on matters related to the Institute of Sciences. Although the magistrates were surprised by the hostility that such experiments engendered among the Bolognese and did not intend to comply with what they regarded as unreasonable fears, as a cautionary measure they decided to suspend

Veratti's work at the observatory tower, ordering him and his colleagues to remove the apparatus from the tower.[11] The secretary of the Institute of Sciences, Francesco Zanotti, was distressed about the resolution to put an end to the "wonderful electrization" and bitterly commented that vulgar fears had infected even the learned. From his point of view, the Istituto delle Scienze would miss the opportunity of making important discoveries in a field of research that, being relatively new, promised to yield interesting results.[12] The ensuing tension between a number of members of the Institute of Sciences and its magistrates prompted the assunti to inquire about the opinion of Benedict XIV, patron of the Istituto. They explained to the pope that in light of popular hostility against erecting metallic conductors on top of the observatory tower, they had resolved to wait and "see the results of the experiments that will be done elsewhere, without jeopardizing a piece of art as valuable as the Institute."[13] The pope declared that although he was "little inclined to believe the dissipation of thunderstorms" he "praised the experiments" and disapproved the assunti's endorsement of "popular fears, especially after the example of the experiments [on atmospheric electricity] carried out by the French at the presence of Their King." The pope believed that the French would not have exposed the King's "life to any danger."[14] However, Benedict XIV's criticism had little to do with the advocacy of lightning rods. In fact, the pope was not enthusiastic about the electrical craze of the age that had already exposed the Istituto to international ridicule and wanted to express to the assunti his disappointment about his latest donations to the Istituto (a collection of statues and anatomical tables, plus Campani's optical instruments) that had not yet been displayed in Palazzo Poggi. The pope did not take any measure to invite the assunti to withdraw the ban on lighting rods because he worried that other experiments with metallic conductors would further delay the proper collocation of his donations.[15]

Although Tommaso Marini erected a metallic conductor on the roof of his house and carried out experiments there while Veratti discussed Franklin's *Experiments and Observations* with the members of the Istituto,[16] de facto the assunti's decision prevented the installation of lightning rods in Bologna until the turn of the nineteenth century.[17] In 1770 Laura Bassi told the musician Charles Burney, who was touring Italy, that since her husband replicated the Marly experiment on the observatory tower, demonstrating soon after Franklin the identity between lightning and the electric spark, "no lightning rods have been erected in this town."[18] In 1783 Marsilio Landriani, who was compiling an inventory of all the lightning rods erected in Europe, asked Sebastiano Canterzani, physics professor and new secretary of the Institute of Sciences, to provide him with a list of the conductors that had been affixed in Bologna and surrounding areas, recalling the priority of the institute's members in replicating the Marly experiment. Canterzani had to admit

> with regret and confusion . . . that in Bologna and surrounding areas, as far as I know, there is no building equipped with electric conductors. This will probably do little honor to Bologna, and to the Bolognese. But this is the spirit of the nation: we are as easy in picking up whimsical foreign clothing fashions and behavior, as we are slow at implementing the new methods, useful to citizens' health and safety. I believe that the reason of this inconvenience lies in the coincidence, that new methods promptly find many opponents, and also many scoffers, who feed on disputes and controversies, whereas those few who perceive their reasonability and value, are peace-lovers, and they do not want to become the subject of the debate, and maybe also of the mockery of the many.[19]

Canterzani's complaint about local indolence toward new scientific ventures was partly informed by the Enlightenment cliché attacking the opponents of the new science as vain people, but in part it expressed the Institute's frustrated ambition of being protagonist of an important discovery in the field of electricity. To Landriani's surprised request of further explanations about the absence of lightning rods in Bologna, Canterzani mentioned the suspension of Veratti's experiments in 1752, and commented that probably the Senate's decision "has then taken away from physicists the courage to propose the use of conductors in Bologna."[20]

If Bologna remained without lightning rods for the remaining of the eighteenth century, the Institute of Sciences and its members maintained an active interest in the study of the electricity of the atmosphere. Only two years after Veratti's experiments, the Institute supported the experimental activity of Giambattista Beccaria, professor of physics at the University of Turin and author of *Natural and Artificial Electricity* (Turin, 1753). Beccaria traveled to Bologna and performed experiments on the electricity of the atmosphere in the countryside together with a group of members of the Institute of Sciences who encouraged his research and offered to publish his next work in Bologna. Indeed, his letters on natural electricity, addressed to Jacopo Bartolomeo Beccari, former president of the Institute, were published in Bologna in 1758.[21]

The suspension of experiments with metallic conductors separated the study of the electricity of the atmosphere from the history of lighting rods in Bologna. Given the Institute's long-lasting interest in electricity, the suspension also played the crucial role of diverting the members' attention from public safety to public health, with physicians and electricians focusing on the role of electricity in the animal frame. It is a singular coincidence that in the 1780s Luigi Galvani, a student of Veratti and a reader of Beccaria, performed some of his celebrated experiments by testing the effects of the electricity of the atmosphere on a dissected frog. At a time when the identity of artificial and natural electricity was an undisputed result, for the Bolognese it was still a matter of experimentation. Galvani's experimental set-up was curiously similar to Veratti's apparatus on the observatory tower.[22]

The "Electric Observatory" in Turin: Giambattista Beccaria and the Formulation of the New Meteorology

The relationship between Beccaria and the Institute of Sciences of Bologna was to last a long time. Even after the publication of his *Letters to Beccari*, Beccaria continued to work with Bassi, Veratti, and Beccari in Bologna. In 1758 he decided to address the letters forming his *On Atmospheric Electricity* to the president of the Institute of Sciences because, as he explained to Franklin, "the others, and mostly this part of experimental physics, are cultivated there."[23]

Beccaria's interest in maintaining good relations with electricians outside Piedmont was no exception for a member of the republic of letters. Yet the circumstances of his appointment as the physics professor of the University of Turin played a crucial role in directing his research interests toward electricity and in his keeping an extensive network of foreign correspondents. In 1748, when the chair of physics was offered to him, the kingdom of Piedmont-Sardinia had entered a period of peace after several decades of war. The king, Carlo Emanuele III, concerned with building up the kingdom's economy, encouraged his magistrates to plan a new system of education that would link the centers of learning to the state. To implement the project, the king was aware that it was necessary to render the university independent from the control of the Minims, the clerical order that had colonized the university during the previous decades.[24] Beccaria's appointment was one of the steps that the reformers undertook in this respect. Beccaria, still a cleric, did not belong to the order of the Minims. Hence, he worked in a hostile environment in which his colleagues, looking with suspicion at the attempts of the reformers to limit their power, tried to discredit his work.[25] Aware of these hostilities, one of the reformers, the marquis Giuseppe Morozzo, upon reading in the newspapers of the Marly experiment, advised Beccaria to replicate it and to investigate the subject further.[26] The ambitious professor realized that the experiment could lead to a reformulation of the ancient science of meteorology: "I cannot tell how much enthusiasm of the most cheerful [giocosissima] confidence took my heart when I read of the greatest experiment. Here, I said to the most honorable Mr. Marquis, has been opened a new and very wide field for the investigation of nature's most wonderful effects; here is the way from which to proceed to the very important study . . . of meteorology."[27]

The connection between electrical research and meteorology informed Beccaria's experimental work on "natural" electricity. Soon after Morozzo's communication, he set up the apparatus on the roof of his house, and on July 2, 1752, he was the first Italian to extract sparks from a conductor pointed to the sky. In the course of the following months he collected experimental results, studied Franklin's experiments and observations, and published his first work, *Natural and Artificial Electricity*, a work in two volumes dedicated to the king.[28] The first systematic exposition of Franklin's theory of electricity, the text gained Beccaria fame and reputation in the international community of electricians. He was elected a member of the Bologna Institute of Sciences and a fellow of the Royal Society.[29] The king was so pleased with Beccaria's achievements that he awarded him an increase in salary, the first of a series of rewards.[30] He also required Beccaria to affix a lightning rod upon the Royal Palace.

Whereas in his *Natural and Artificial Electricity* Beccaria only conjectured that the electric fluid could play a role in the operations of nature, in his *Of Atmospheric Electricity: Letters to Beccari*, published in 1758, he proposed a comprehensive theory of the role of the electric fluid in the natural world. Not only lightning, but also earthquakes, whirlpools, whirlwinds, auroras borealis and falling stars, Beccaria argued, could be explained in terms of the motion of the electric fluid. His program linked the new science of electricity to meteorology, reshaping the Aristotelian science in terms of contemporary experimental philosophy. To carry out his electrometeorological observations, Beccaria conceived of an "electric observatory": a place where he could measure, on a daily basis, the electric state of the air. The experimental apparatus was a simple one: he placed a pointed metallic conductor on the roof and connected it by means of a long insulated metallic wire (which he called "exploratory wire") to an electrometer placed in a room. Extra wires, which he called "safety wires" (*fili di salute*), grounded the apparatus to avoid the risk of being struck by lightning. The electric observatory was a mobile experimental site where Beccaria would "live day and night" recording measurements: it could be the tower of a church, castle, or private house "in which the deferent wire brings electricity to me, and subjects it for me to a delicate electrometer."[31] In the course of two decades he set up electric observatories on the tower of the Valentino castle, at his house in Mondovì, and on the hills of Superga and Garzegna, near Turin. In his electrical observatory, he studied the electricity of the atmosphere in different meteorological situations: clear sky, rain, fog, dew, hail, and thunder.[32] With this apparatus he replaced Franklin's kites, which he noted could not be used in the absence of wind. By recording humidity, pressure, and temperature of the air together with its "quantity of electricity" he investigated whether there was any relation between the electric state of the atmosphere and the weather, becoming among the first in Europe to weave together electricity and meteorology.[33] It was a self-conscious program, which he intended as a new foundation of meteorology based on electrical experiments. If in his laboratory practice he was able to "verify the artificial circulation of the new and very active element," then by means of his electric observatory he was able to "discover, and draw the right lines of its natural circulation." He proudly claimed that he was one of the first to "find by experiment and to demonstrate that such an element [electricity] is present also in the air," and that he could show that "the exterminatory instantaneous fire is the main cause of the various watery meteors." In sum, he boldly reminded his patron, "I discovered, and made plain, the true principle of a very important science: meteorology."[34]

Beccaria's reference to meteorology contributed to a new understanding of electrical science, which began in the late 1740s with the first attempts to apply the electric fire to medical therapies, in terms of one of the Enlightenment themes: the usefulness of science. At a time in which meteorologists claimed that knowledge of the weather could have useful applications to agriculture and medicine, its connection with meteorology gave electrical research new relevance, and it made electricians fit the new image of natural philosophers as experts in the service of the state.[35] Beccaria had acted in this function soon after his appointment, when he worked on the standardization of weights and measures to be used for commerce in Piedmont, and on the design of canals that would channel water from the river Po to the fields inland.[36] His work with lightning rods was part of this program. He was involved in the construction and design of lightning conductors to be affixed on powder magazines and private buildings in various sites in Piedmont, and he was asked to supervise the lightning rod to be affixed on the Duomo in Milan.[37]

To respond to the objections against the usefulness of lightning conductors, Beccaria focused on the nature of lightning and on the examination of the path that it followed when it struck houses, towers, or other buildings. His empirical observations shifted his attention from the shape of the conductors' terminations to the best method to make the electric fire disperse into the ground. He noticed that a bad junction between the conductor's elements could cause sparks that, issuing from the conductor, could set fire to inflammable substances. On the basis of Henry Cavendish's experiments of the conductivity of water (that demonstrated that water conducted less than iron), he observed that when the electric fire reached the water, it could gush back to the ground with the same, disruptive results. Hence, he suggested that no lightning rods should be affixed on powder magazines, but that they should rather be erected in front of them, at a safe distance.[38]

His experimental observations of lightning strokes informed his recommendations about conductors' shape, material, and insulation, and his work attracted the attention of younger electricians involved in the lightning rod campaign. Felice Fontana from Tuscany and Giuseppe Toaldo from the Republic of Venice both corresponded with Beccaria when their governments requested them to supervise the construction of lightning rods to be affixed upon public buildings.[39] From the 1770s onward, enlightened governments as well as individuals invested consistent sums into the display of their faith in scientific progress: lightning rods became symbolic icons of that faith. In 1784, when Landriani published his catalogue, there were more than eighty lightning rods on top of private houses south of the Alps, and three dozen distributed evenly between public edifices, churches, and powder magazines.[40] The business of making lightning conductors proved profitable. For the construction of three lightning rods to protect the powder magazine at the Tortona castle near Turin, Beccaria and his assistants estimated expenses of 1,600 *lire*, which at the time very few people could afford. For a comparison: Beccaria's annual salary, when he was first appointed, was 1,200 lire. But lightning rods could be tailored to different pockets, as Beccaria himself noticed while giving advice on which materials to choose to make lightning rods: "Gold would be a very performing conducting material, but because of its price it has no other place than the premises of the greatest kings, otherwise copper, which resists better to the weather, but if it is too expensive, iron is good too, also because, not costing too much, one can easily make a thick conductor."[41]

The price of lightning rods was one of the issues that Giuseppe Toaldo, the most famous advocate of lightning rods south of the Alps, addressed in his numerous pamphlets in favor of lightning rods.

The Padua Observatory Tower: Giuseppe Toaldo, the Expert and the People

When he became involved in the lightning rod campaign, Toaldo was professor of "Astronomy, Geography and Meteors" at the University of Padua. In the long list of objections and replies that made up his *Of the Use of Conductors: New Apology* (1774), he argued that costs could be consistently reduced if decorations were left out and, in any case, no expense could be regarded as excessively dear for the safety of the people. He advocated the necessity of lightning conductors to protect public buildings such as theatres, and reminded his readers that a conductor would cost twenty or thirty *scudi*, which, compared to the hundreds of thousands of *scudi* required to build a theatre, was as inexpensive as it could be.[42]

Contrary to Beccaria's relatively private work on lightning conductors, Toaldo made the "information of the people" his mission. Aware of popular resistance against lightning rods, he envisaged in the popularization of electrical science and of the numerous cases in which conductors had preserved buildings from disasters the path toward a better reception of lightning rods. Arguing that "authority is worth nothing when it comes to physics," his view on how to gain popular consensus was different from Landriani's insistence on authoritative examples as more effective means to forge the people's opinions. He was aware that local authorities needed to be educated just as ordinary people. The case of Bologna demonstrated that even magistrates could concede to popular fears:[43]

"In order to extend the use of conductors, we need to educate Magistrates and people of the administration, we should not talk only to the learned, we need to enlighten the people of the world, dissolve their prejudices, and reassure them about their fears."[44]

Toaldo, who was a Catholic priest, subscribed to the French amateur electrician Barbier de Tinan's view on the popularizing mission of the enlightened philosopher; his texts were conceived as "information to the people" that, while spreading natural knowledge, attempted also to combine enlightened natural philosophy and Catholicism. His works in favor of lightning rods were distinctively marked by the intention to spread knowledge about natural electricity and its role in meteorological events. When he was archpriest in Montegalda, a small village near Padua, Toaldo realized that multiple observations in time and space were necessary to find the "causes" of meteorological changes.[45] His work on meteorology was imbued with the conviction that better knowledge of the weather would result in improvements in agriculture and medicine, and Beccaria's theory of natural electricity fit perfectly with his idea of researching the natural causes of meteorological events. With the intention to sedate popular fears about lightning rods by offering a rational understanding of the nature of lightning, in his *Meteorological Essay* (Padua, 1770) he embraced Beccaria's view of the electric fire as "the great instrument of nature, the principle of evaporation, winds and thunderstorms, earthquakes, aurorae borealis and, above all, *lightning*."[46] All these, together with snow, fog, hail, and rain, were "meteors" whose motions could be explained in terms of the natural tendency of the electric fire to reach balance; the climatic features of geographically different places resulted from the interactions between such meteors. Thanks to the new meteorology, the weather was no longer to be seen as unpredictable or resistant to rational understanding. If the place and time where lightning would strike were still beyond exact predictions, meteorologists could foretell the likeliness of events based on meteorological records, observations, and measurements. All meteors behaved according to a pattern that meteorologists could decode; thereby their work would help people not to be passive victims of the weather. "Toaldo gives me rain on the 4th, and on the 4th it rained; I did the same on the 13th, 20th and 26th and rain fell. Everyone is amazed and stood bewitched, and they all shout; bravo Toaldo."[47]

Padua, just like Siena, Toaldo argued, was particularly exposed to lightning. Its towers were notoriously favorite targets for bolts of lightning; therefore conductors were highly recommended.[48] In the course of the 1770s, when he looked after the construction of a new, well-equipped observatory for the University of Padua, Toaldo designed a lightning rod to be affixed on top of the tower. The new observatory was completed thanks to the pressures that the professors of the university exerted on the Venetian Senate. The university where Galileo once taught was in visible decline, and the new observatory, to become the most mod-

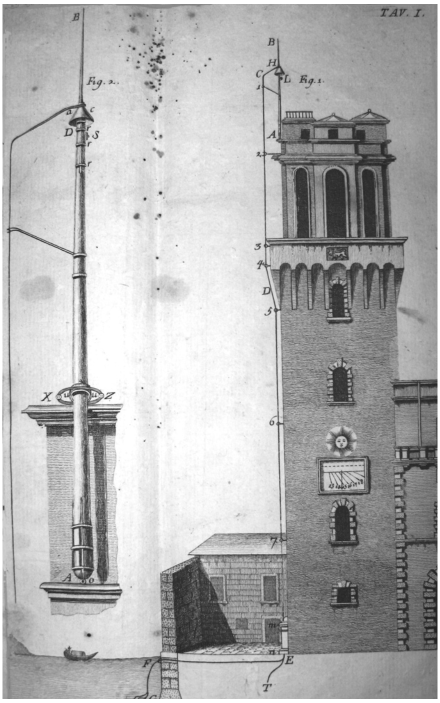

Figure 2.2. The Padua observatory tower with its lightning rod. Giuseppe Toaldo, "Dell'uso dei conduttori" (Padua, 1774). Franklin Collection, Yale University Library.

ern south of the Alps, was presented by Toaldo as the essential step toward the renovation of the university.[49] A lightning rod on its top, the first conductor in the Veneto affixed on a public building, would crown—symbolically and physically—the progressive inclinations of the university and of its institutional supporter, the Venetian Senate. When a bolt of lightning struck the observatory tower in 1772, it caused damages of 500 Venetian lire. One year later, on September 28, 1773, a lightning rod appeared on top of the observatory.[50] It cost a little less than 200 *ducati* (1,600 lire).[51]

The lightning rod on the observatory tower was the first of many others that Toaldo would design. Wealthy individuals asked him to design lightning rods for their own palaces and, given the number of people who died struck by lightning every year, the senators of the Republic became sensitive to Toaldo's appeal to public safety. Toaldo could count on firsthand information on the damages caused by lightning in the Venetian countryside. He had arranged a network of meteorological observers spread in the domain who sent him barometric and thermometric measurements together with records about occasional yet meaningful events. Deaths by lightning and the damages caused by severe weather were among them, and in 1787 his correspondents urged him to petition the Senate for a ban against bell-ringing during thunderstorms.[52]

In Toaldo's advocacy, expertise was essential in the making of conductors. The death of the physics professor Georg Richman at St. Petersburg (1753) demon-

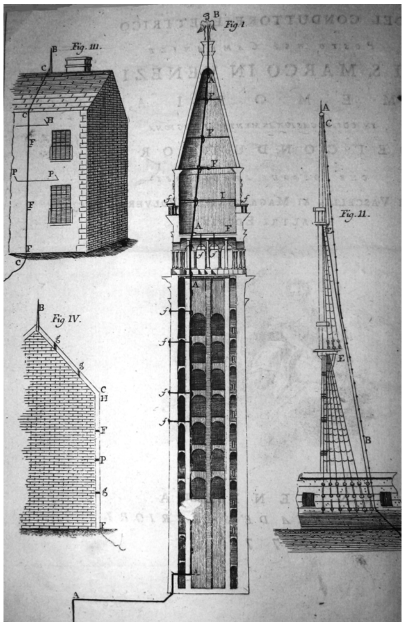

Figure 2.3. The lightning rod that Toaldo designed for the church of San Marco in Venice. GiuseppeToaldo, "Del conduttore elettrico posto nel campanile" (Padua, 1776). Franklin Collection, Yale University Library.

strated the risks of inexpert management of the electric fire. Toaldo argued that "conductors are God's gifts to preserve human life, but, like medical remedies, they have to be well prepared."[53] It was on the basis of their observations of the marks left by bolts of lightning upon conductors or other materials that electricians, such as Beccaria and Toaldo, had drawn their conclusions on how to make lightning conductors. Expertise derived from practical knowledge and familiarity with facts, not from abstract theory: "We can well ignore the intimate nature of this fire: it is not necessary to know the nature of materials to make use of them."[54] Indeed, theory could be revised on the basis of the evidence that new facts offered. Each bolt of lightning that struck towers with or without conductors left signs that electrical experts could decode and use to improve the design of lightning rods. The public, by witnessing the results of such observations, could partake of expert knowledge. Toaldo published the reports of the effects of lightning upon conductors to educate "the class of people that is not much dedicated to studies, and that is less versed in physical erudition."[55]

For those who could not go to Padua and see with their own eyes, Toaldo's *Of the Use of Conductors: New Apology* offered a detailed description of the lightning rod on top of the observatory, together with some notions on the electric nature of lightning. Similarly, after his supervision of the lightning rod that was affixed on the bell tower of San Marco in Venice, he felt it his "duty" to account for his work to the senators who ordered it, and to the public.[56] Aware that lightning rods engendered controversies on both sides of the Alps and the Atlantic among "the people not yet philosophical,"[57] Toaldo's strategy was to popularize the recent discoveries in the science of electricity so as persuade these people that preserving edifices from the effects of lightning was now possible, just as it was possible to prevent floods by means of embankments.[58] The government responded sympathetically to his activity. On May 9, 1778, the Venetian Senate ordered that lightning rods should be affixed on all the powder magazines of the Republic, and eight years later, in 1786, it extended the order to all bell towers.[59]

Conclusion: Lightning and the Enlightened Philosopher

Brandished like sharp swords against threatening thunderclouds and wrapped in a scabbard of controversies, lightning rods symbolized the enlightened philosopher's victorious campaign against superstitious beliefs about the nature of lightning. "What else is left to say about the ancient opinion that lightning froze wine, which, while melting, provoked death, or furor? And what about the modern one, that lightning dissipates wine without offending its barrel? If not that, the malice of drunken servants has contrived them and has imposed them upon ignorant masters, who, after exaggerating the real effects, have then been abused by all these kinds of oddities to deify lightning. Thus they have reciprocally deceived the deceitful people and oppressed them under the yoke of blind superstition."[60]

Popular culture had interacted with lightning since antiquity. It had produced notions on the nature of lightning and of its relation to divine agency, and it had devised methods to prevent lightning's disruptive power. If the habits of ringing bells and firing cannons during thunderstorms were relatively recent, that of burning laurel dated back to ancient times. Laurel and olive trees were commonly held to be immune from lightning strikes, and people used to place laurel leaves or branches of olive trees on top of their houses, around their fields, or on their beds.[61] Enlightened philosophers like Toaldo did not confront such traditions with sarcasm. On the contrary, Toaldo engaged in the reformulation of popular beliefs in terms of Franklinian electrical science. Confused and uncertain, he argued, popular opinions were nonetheless rooted in observation and practical knowledge, and they could be explained by experimental physicists on more authoritative grounds.[62] Because of the resinous nature of plants such as laurel or olive trees, he explained, lightning abhorred them, and indeed, experience showed that they were only rarely struck.[63]

Throughout history, lightning terrified not only because of its disruptive nature but also because of its relation with the godhead. In monotheistic religions as well as in pagan traditions, it was perceived as the manifestation of the most awe-inspiring form of divine power: wrath. Enlightened philosophers who belonged to a clerical order, such as Beccaria and Toaldo, engaged in the task of readdressing popular beliefs and containing people's fears, showing the compatibility between Catholicism and faith in scientific progress. According to Scriptures, neither evil spirits nor sorcerers have in themselves the evil power to rouse lightning, thunder, hail, or storming winds; all such effects are produced by the powers of nature, preordained by God with infinite knowledge and benevolence.[64]

By his own admission, Beccaria was not the first who stated that no human being could produce lightning: he quoted extensively from the bishop of Lyon, Agobard, who in the eleventh century wrote against "the silly opinion of the people about hail and thunder." Beccaria invited those who were in charge of "educating the clergy" to read Agobard's works. A properly educated priest would reassure the people and would make them "admire the immensity of nature's operations and its Creator's omnipotence" instead of letting them be prisoners of their superstitious fear.[65] The demonstration that lightning was one and the same with artificial sparks and that the electric fire was responsible for the "unusual operations of nature" left no room for supernatural powers, if not those of a benevolent, omnipotent being.

The appeal to education as a means through which to emancipate the people from ignorance and superstition in the name of enlightened Catholicism was also a refrain in Toaldo's campaign in favor of lightning rods. He was familiar with traditional beliefs about the powers of certain people to attract lightning. Pliny recorded that Numa Pompilio, the Roman emperor, mastered the art of evoking lightning. Tullio Ostilio, his successor, died struck by lightning while trying to steal the secret. The Etruscans were also acquainted with the art of attracting lightning. A traditional folk tale told the story of a monster that, after periodically ravishing the peoples who lived around the lake of Bolsena, was eventually killed by a flash of lightning called on for that purpose.[66]

Toaldo did not intend to support such beliefs, yet he wanted his readers to appreciate that the eccentric behavior of lightning could be explained in terms of the main tenets of Franklin's electrical philosophy: the electric fire's natural tendency toward balance and its predilection for metals.[67] With this in mind, it was possible that humans could artificially attract lightning. By linking the earth with the sky, metallic conductors attracted the electric fire and forced it through themselves, preventing it from setting fire elsewhere. However, the modern Prometheuses who stole fire from the sky acknowledged that lightning rods were God's gifts: if they snatched lightning from Jupiter's hands, it was to remit it in God's. In Toaldo's work, modern meteorology was to be seen as a human attempt blessed by divine benevolence and not as a new, presumptuous Icarus flight.

Debates on lightning rods prompted educational campaigns whose goal was to advocate a new alliance between Catholic faith, popular beliefs, and enlightened natural knowledge. The new meteorology advocated by Beccaria and Toaldo domesticated the terrifying meteor of lightning within a philosophical system in which the apparently unpredictable did not undermine the ideal of a

God-ordained, law-obeying universe. With a lightning rod on top, towers now symbolized the power of the new science of meteorology to tame the unpredictable forces of nature. On their part, towering above ancient beliefs, lightning rods pointed to the real direction of Enlightenment.

Notes

1. Alessandro Chigi, *Dell'elettricità terrestre-atmosferica* (Siena, 1777).

2. Domenico Bartaloni, "Relazione dello stato della Torre colpita da fulmine," *Giornale Letterario di Siena* 3 (1777): 267–68.

3. For an analysis of the debates on lightning rods in the English context see Trent A. Mitchell, "The Politics of Experiments in the Eighteenth Century: The Pursuit of Audience and the Manipulation of Consensus in the Debate over Lightning Rods," *Eighteenth-Century Studies* 31 (1998): 307–31; for the French context see Jessica Riskin, *Science in the Age of Sensibility: The Sentimental Empiricists of the French Enlightenment* (Chicago: University of Chicago Press, 2002), ch. 5; for the American, James Delbourgo, "A Most Amazing Scene of Wonders. Electricity and Enlightenment in North America" (Cambridge, MA: Harvard University Press, 2006), ch. 4; for the Italian, Ferdinando Abbri, "La 'spranga elettrica': Frisi e l'elettricità," in *Ideologia e scienza nell'opera di Paolo Frisi (1728–1784)*, vol. 1, ed. Gennaro Barbarisi (Milano: Franco Angeli, 1987), 161–99; Stefano Casati, "Storie di folgori: il dibattito italiano sui conduttori elettrici nel Settecento," *Nuncius* 13 (1998): 493–512; and Antonio Pace, *Benjamin Franklin and Italy* (Philadelphia: The American Philosophical Society, 1958), ch. 2.

4. Marsilio Landriani, *Dell'utilità dei conduttori elettrici* (Milano, 1784), unpaginated dedication.

5. Pace, *Franklin and Italy* (cit. n. 3), 28–30.

6. See Paola Bertucci, "Sparking Controversy: Jean Antoine Nollet and Medical Electricity South of the Alps," *Nuncius* 20 (2005): 153–87; and *Viaggio nel paese delle meraviglie. Scienza e curiosità nell'Italia del Settecento* (Turin: Bollati Boringhieri, 2007). On Laura Bassi there is an extensive literature that is impossibile to list here: see at least Marta Cavazza, "Laura Bassi e il suo Gabinetto di Fisica Sperimentale: realtà e mito," *Nuncius* 10 (1995): 715–53; and Paula Findlen, "Science as a Career in Enlightenment Italy. The Strategies of Laura Bassi," *Isis* 84 (1993): 440–69.

7. On the history of the Institute of Sciences, see Annarita Angelini, ed., *Anatomie Accademiche*, vol. 3: *L'Istituto delle Scienze e l'Accademia* (Bologna: Il Mulino, 1987); and Marta Cavazza, *Settecento Inquieto* (Bologna: Il Mulino, 1990).

8. Giuseppe Veratti, *Osservazione fatta in Bologna l'anno MDCCLII dei fenomeni elettrici nuovamente scoperti in America, e confermati a Parigi* (Bologna, 1752).

9. Ibid., 2. On the most popular electrical experiments in the eighteenth century see Paola Bertucci "Sparks in the Dark: The Attraction of Electricity in the Eighteenth Century," *Endeavour* 31 (2007), 88–93; for an overview of eighteenth century electricity, John L. Heilbron, *Electricity in the 17th & 18th Centuries. A Study of Early Modern Physics* (Berkeley and Los Angeles: University of California Press, 1979).

10. [anon.; untitled article] *Bologna* (August 1752): 31, p. 1. On Veratti's involvement in medical electricity, see Bertucci, "Sparking Controversy" (cit. n. 6). On electrical experiments on the human body, see Paola Bertucci, "The Electrical Body of Knowledge," in *Electric Bodies: Episodes in the History of Medical Electricity*, ed. Paola Bertucci and Giuliano Pancaldi (Bologna: CIS, University of Bologna, 2001), 43–68.

11. Archivio di Stato, Bologna (hereafter ASB), *Assunteria d'Istituto, Lettere dell'Istituto* 3 (Institute to the Ambassador, August 2, 1752).

12. Gino Rocchi, ed., *Carteggio tra Giambattista Morgagni e Francesco M. Zanotti* (Bologna: Zanichelli, 1885), 404 (Zanotti to Morgagni, August 4, 1752).

13. ASB, *Assunteria d'Istituto, Lettere dell'Istituto* 3 (Institute to the Ambassador, August 19, 1752). On the pope's donations to the Institute, see Angelini, *Anatomie Accademiche* (cit. n. 7), 215–38.

14. ASB, *Assunteria d'Istituto, Lettere all'Istituto* 4 (Fulvio Bentivoglio to the Institute, August 9, 1752 and August 12, 1752). .

15. On the pope's attitude to electricity see my "Sparking Controversy" and *Viaggio nel paese delle meraviglie* (cit. n. 6).

16. Tommaso Marini, *Esperienze sulla Elettricità che chiamano celeste* (Bologna, 1748). See also Giorgio Tabarroni, "La torre dell'Università di Bologna e l'elettricità atmosferica," *Coelum* 34 (1966): 1–14.

17. On Bassi's and Veratti's physics laboratory, see Cavazza, "Laura Bassi" (cit. n. 6).

18. Charles Burney, *The Present State of Music in France and Italy, or The Journal of a Tour through Those Countries* (London, 1771), 75.

19. Biblioteca Universitaria, Bologna (hereafter BUB), *Lettere di Landriani a Canterzani*, Cod. 2096, busta V: draft of a reply by Canterzani to Landriani dated September 15, 1783.

20. Ibid., draft of a reply by Canterzani to Landriani dated June 15, 1784.

21. Giambattista Beccaria, *Dell'elettricismo: Lettere di Giambattista Beccaria dirette a Giacomo Bartolomeo Beccari* (Bologna, 1758).

22. On Galvani's laboratory, see Marco Bresadola, "Exploring Galvani's room for experiments," in *Luigi Galvani International Workshop* (Bologna: CIS, University of Bologna, 1999), 65–82; and Marco Piccolino and Marco Bresadola, *Rane, torpedini e scintille: Galvani, Volta e l'elettricità animale* (Turin: Bollati Boringhieri, 2004).

23. American Philosophical Society Library (hereafter APS), Beccaria Papers, B B385, No. 12 undated, although it was written after Beccari's death (1766) and in the course of Franklin's supervision of the English translation of Beccaria's *Artificial Electricity* (London, 1773). Beccaria's book referred to in the quote was printed twice in 1758. The two editions differ only in the title: the first is *Dell'elettricismo: Lettere di Giambattista Beccaria dirette a Giacomo Bartolomeo Beccari* (Bologna, 1758), and the second edition is *Elettricismo atmosferico: Lettere di Giambattista Beccaria* (Bologna, 1758).

24. See Tommaso Vallauri, *Storia delle Università degli studi del Piemonte*, 3 vols. (Torino: Stamperia Reale, 1845). Also Marco Ciardi, "Medicina, tecnologia civile e militare, filosofia naturale. L'insegnamento della fisica nel Regno di Sardegna," *Studi Settecenteschi* 18:217–47.

25. See Heilbron, *Electricity in the 17th & 18th Centuries* (cit. n. 9), 362–72; Pace, *Franklin and Italy* (cit. n. 3), 50f.

26. APS, Beccaria Papers, B B385, No. 36, f. 1 (Osservazioni fatte in Torino nell'anno 1752).

27. Ibid., No. 36, f. 1.

28. Giambattista Beccaria, *Dell'elettricismo artificiale e naturale. Libri due* (Torino, 1753).

29. On the Italian fellows of the Royal Society in the eighteenth century, see Marta Cavazza, "The Institute of Science of Bologna and the Royal Society in the Eighteenth Century," *Notes and Records of the Royal Society* 56 (2002): 3–25.

30. Antonio Maria Vassalli-Eandi, *Memorie Istoriche intorno agli studi del Padre Giambattista Beccaria delle Scuole Pie* (Torino, 1783), 37.

31. Giambattista Beccaria, *Dell'elettricità terrestre atmosferica a ciel sereno* (Turin, 1775), p. 12.

32. APS, Beccaria Papers, B B385, Nos. 15, 19.

33. Joseph Priestley gave ample credit to Beccaria for his observations on the electricity of the atmosphere and on the "unusual appearances" in nature, remarking that many of his experiments were performed prior to those of other electricians in other countries. See Priestley, *History and Present State of Electricity* (London, 1767), 366–97.

34. Giambattista Beccaria, *Elettricismo atmosferico* (Bologna, 1758), unpaginated dedication.

35. On the new role of natural philosophers as civil servants, see Giuliano Pancaldi, *Volta: Science and Culture in the Age of Enlightenment* (Princeton, N.J.: Princeton University Press, 2003), ch. 2. For the case of Piedmont, see Vincenzo Ferrone, *La Nuova Atlandide e i Lumi: Scienza e politica nel Piemonte di Vittorio Amedeo III* (Torino: Meynier, 1988), especially ch. 1. Studies on eighteenth-century meteorology are still sparse; for the British context, see Jan Golinski, *British Weather and the Climate of Enlightenment* (Chicago: University of Chicago Press, 2006).

36. Vassalli-Eandi, *Memorie Istoriche* (cit. n. 30), 12f.

37. APS, Beccaria Papers, B B385, No. 31.

38. Ibid., No. 33. This and the following examples demonstrate that debates on lightning rods in the Italian states did not verge on the controversy about pointed vs. blunt terminations analyzed by Mitchell (see note 3) and R. W. Home in this volume. Indeed, the Italian electricians themselves acknowledged that the debate was confined to England.

39. Ibid., Nos. 31, 35.

40. Landriani, *Dell'utilità* (cit. n. 4), 285–93.

41. APS, Beccaria Papers, B B385, No. 35, f. 1v.

42. Giuseppe Toaldo, *Dei conduttori per preservare gli edifizj da' fulmini*, ed. Stefano Casati (Firenze: Giunti, 2001; 1st ed. Venice, 1778), 207. This work was a collection of all his previous works on the subject.

43. Giuseppe Toaldo, "Dell'uso dei conduttori: Nuova apologia" in Toaldo, *Dei conduttori* (cit. n. 42), 115.

44. Barbier de Tinan, *Nuove considerazioni sopra i conduttori* in Toaldo, *Dei conduttori* (cit. n. 42), 162.

45. On Toaldo's work as a metereologist, see Giampiero Bozzolato, *Giuseppe Toaldo: Uno scienziato europeo nel Settecento veneto* (Padova: Brugine, 1984); also Luisa Pigatto, ed., *Giuseppe Toaldo e il suo tempo nel bicentenario della morte. Scienze e lumi tra Veneto e Europa* (Padova: Cittadella Bertoncello artigrafiche, 2000).

46. Giuseppe Toaldo, *La Meteorologia applicata all'Agricoltura* (Venezia, 1775), 21.

47. Tragin della Bastia to Toaldo (Brescia, September 5, 1784), quoted in Bozzolato, *Giuseppe Toaldo* (cit. n. 45), 108.

48. Giuseppe Toaldo, "Del conduttore elettrico posto nel campanile di San Marco in Venezia" (Padova, 1776), in Toaldo, *Dei conduttori* (cit. n. 42), 154.

49. On the attempts to renovate the University of Padua, which included a plan to set up an autonomous press, see Bozzolato, *Giuseppe Toaldo* (cit. n. 45). In 1744 Toaldo published the Padua edition of Galileo's works, which included the first authorized reprint of the *Dialogue on the Two Chief World Systems* (in the Index of Forbidden Books since 1633).

50. Archivio Antico Osservatorio Astronomico, Padova (hereafter AOP), Cod. I, *Osservazioni meteorologiche. Padova 1766–1804* (September 17, 1772; September 28, 1773). Also Toaldo, *Dei conduttori* (cit. n. 42), 100f.

51. Toaldo, *Dei conduttori* (cit. n. 42), 114f.

52. AOP, *Lettere a Toaldo*, fasc. 43, 47.

53. Giuseppe Toaldo, "De' conduttori, o parafulmini," in Toaldo, *Dei conduttori* (cit. n. 42), 211.

54. Toaldo, *Dei conduttori* (cit. n. 42), 96.

55. Giuseppe Toaldo, *Tre lettere sul conduttore elettrico*, in Toaldo, *Dei conduttori* (cit. n. 42), 198.

56. Toaldo, "Del conduttore elettrico posto nel campanile" (cit. n. 48), 125–58.

57. Ibid., 128.

58. Giuseppe Toaldo, *Informazione al Popolo*, in Toaldo, *Dei conduttori* (cit. n. 42), 74.

59. AOP, Cod. I., Toaldo, *Osservazioni meteorologiche: Padova 1766–1804* (July 1786); Toaldo, *Dei conduttori* (cit. n. 42), 67.

60. APS, Beccaria Papers, B B385, No. 20, Libro VI (addressed to Priestley).

61. Toaldo, *Dei conduttori* (cit. n. 42), 70.

62. See Giuseppe Toaldo's prize-winning *Meteorologia applicata all'agricoltura, memoria che ha riportato il premio della società reale di Montpellier* (Venezia, 1775).

63. Toaldo, *Dei conduttori* (cit. n. 42), 70.

64. APS, Beccaria Papers, No. 20, Libro III (to the Bishop of Mondovì).

65. Ibid.

66. Toaldo, *Dei conduttori* (cit. n. 42), 69.

67. Jessica Riskin interprets this attitude toward the explanation of natural phenomena as "sentimental empiricism"; see Riskin, *Science in the Age of Sensibility* (cit. n. 3), especially chs. 3 and 5.