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Falling Stars, Instruments and Myths: Volta and the Birth of Modern Meteorology

E ben mi par degna questa bella parte
di Scienza, che più di tutto occupi
ogni Studioso della natural Filosofia.

Alessandro Volta, *Discorso sugli
strumenti meteorologici* (1793)

On September 11, 1784, at 6.55 am, a remarkably bright bolide darted across the clear skies of Turin, Italy. That rare and fascinating phenomenon was also witnessed by Anton Maria Vassalli, professor of philosophy at the Royal College of Tortona, and by his uncle Giuseppe Antonio Eandi, professor of experimental physics at the University of Turin.¹ There was no doubt that the meteor had been moving very high up in the sky since it had been seen not only in the Savoy region but also in Susa, Asti, Genoa, Modena and Milan. Vassalli was sent a number of reports on the event; some of them were very authoritative, such as Gardini's or Landriani's, and they all confirmed the most relevant facts about the sighting. In November 1784 Anton Maria Vassalli gave a report on the sighting during a meeting held by the Società Patria Letteraria. In March 1786 Vassalli wrote a paper, published by the Royal Printing-Office.²

Vassalli did not have any doubts about the nature of bolides, that could be nothing but electric, as had been indicated by his first physics teacher, Giambatista Beccaria, who had initiated him to the study of meteors. Anyway, there were many elements to prove the electric nature of the September 11 meteor, such as the speed of the bolide, although it had been lower than that of lightning; the apparent serenity of the sky, which in fact showed a certain rarefied cloudiness through the less-than-usual brightness of the stars and of Jupiter; the appearance of storm clouds; and the dull noise, similar to thunder, that had been heard by all who witnessed the event.³ In spite of this evidence, however, physicists continued to hold that most of the

¹ On the history of experimental science in Piedmont see CIARDI (1995); ID. (1998).

² VASSALLI (1786).

³ *Ibid.*, p. 38.

meteors that had been observed were manifested only “by inflammable matter that is almost always present in the upper part of the atmosphere and is largely collected by contrary winds, by vapours rising from the ground, by very electric clouds, or for other similar reasons”.⁴ But the thesis about vapours was easily nullified by the speed of the bolide.⁵ The nature of bolides, on the contrary, would not differ from that of falling stars, which Beccaria had eloquently written about in his letter to Le Roy dated 1775.⁶ For this reason “between falling stars and bolides” there was no difference “except for size”.⁷

Vassalli’s paper was very well received by Toaldo, Saussure and Senebier. On July 18, 1786 Vassalli then decided to send the paper to Volta. There is no doubt that Volta was not only one of the most distinguished scholars in electrical science, but also an authority in meteorological studies, as he openly stated in his immediate written reply to Vassalli on September 28. In fact, beginning from the mid-sixties, Volta had given an original explanation of electric phenomena based on the existence of short-range forces, forces that were different from universal attraction and that sometimes appeared to be difficult to detect, because of circumstances that prevented electricity from manifesting itself through perceptible signs, therefore making “any form of diligence vain” in all experiments. And Volta’s explanation also addressed the subject of “alterations occurring in bodies placed on the ground and alterations occurring in the atmosphere”.⁸ In spite of that, Volta provided Beccaria’s pupil with uncertain grounds. In fact, it was not by chance that Volta, although he praised Vassalli with regard to his attempt to refer meteoric phenomena to “Beccaria’s sentence”, which almost made him join “their sect”, and although he conceded that electricity could, at least in part, be said to rule aurora borealis, he was absolutely not in agreement with Vassalli about the electric nature of bolides and falling stars. According to Volta, they both showed every sign of being an “actual combustion of flammables”.⁹

Volta was very familiar with flammables and their reaction to electricity, as shown by the famous seven letters he sent to Carlo Giuseppe Campi.¹⁰ But, as a matter of fact, he was particularly interested in chemistry from before these letters, as we can easily understand when reading his *De vi attractiva*; in fact, he had stated that “chemical operations” manifested “other kinds of reciprocal forces everywhere, besides inertia of the mass and specific gravity”. And although the presence of “signs” due to electricity had been difficult to spot, one could not be certain that in chemical

⁴ *Ibid.*, p. 73.

⁵ *Ibid.*, p. 79.

⁶ BECCARIA (1775).

⁷ VASSALLI (1786), p. 90.

⁸ VOLTA (1769), pp. 64-5.

⁹ VOLTA (1786), pp. 10-4.

¹⁰ VOLTA (1777).

operations such signs could not be detected through more accurate experiments.¹¹ Therefore, in 1776, the interaction between electricity (both artificial and natural) and inflammable air had appeared to Volta as being the master-key to understanding many other phenomena that had not yet been adequately explained. Such interaction, in fact, could not only give an account of ignis fatuus phenomena, but it could also explain various “meteors”. It is interesting to note that Volta did not oppose Beccaria a priori, since on that particular occasion he had no problem recognising his merits, including the observation of other atmospheric phenomena.¹² Volta did not rule out the possibility that the electricity that was likely to be generated by falling stars could have originated larger meteors such as bolides through the ignition of a large mass of inflammable air. Naturally, Volta was aware of the risks involved in that speculation so, in his fifth letter, he immediately proposed a system of alliance and balance between the kingdom of electricity and that of inflammable airs.¹³

In spite of these precautions, on April 2 Volta received a letter by Barletti warning him that he should not overly extend the domain of inflammable airs. On April 18, 1777, Volta replied to Barletti saying that he disagreed about his system being unbalanced with regard to inflammable air, and he reminded his colleague that he had been “careful to warn” readers that the hypotheses contained in his fifth letter on earthquakes and aurora borealis were mere “fanciful ideas” that originated “more from fancy than from observation” and that were based on a bunch of “analogies and far removed possibilities”.¹⁴ In spite of all that, Volta confessed to Barletti that he considered “plausible” his “electric-aerial-inflammable theory” on falling stars. Nevertheless this theory was still lacking in explanation.¹⁵ In fact, it was difficult to explain how the electric spark that was supposed to give rise to the phenomenon would be generated. Furthermore, reports on that particular kind of meteors did not always describe phenomena that could be explained in terms of their supposed electric nature. However, Volta also quoted Musschenbroek, showing knowledge of theories that attributed the production of falling stars exclusively to the behaviour of atmospheric vapours. But Volta did not completely deny their electric nature either, as he hypothesised their mixed composition (fire plus electricity). And yet the question remained, how could one establish the exact characteristics of those meteors?

An acceptable solution began to make its way in Volta’s mind after his trip to Switzerland in September-November 1777, thanks to the possibility of highlighting the particular type of electricity that was regulated by forces undoubtedly different from gravitational ones, about which he had spoken in 1769 also referring to atmospheric phenomena. The objective of surveying atmospheric electricity was not

¹¹ VOLTA (1769), pp. 52 and 65.

¹² VOLTA (1777), 4th letter [Dec. 18, 1776], pp. 56-9.

¹³ *Ibid.*, 5th letter [Jan. 5, 1777], p. 62.

¹⁴ VOLTA (1777a), p. 43.

¹⁵ *Ibid.*, p. 44.

secondary within Volta's research programme, as was clearly outlined in his famous paper that he presented to the Royal Society on March 14, 1782.¹⁶ The main goal of the work was to give a report about a new tool to explore weak and imperceptible forms of atmospheric electricity, the "condenser" of electricity.¹⁷ According to Volta, the functions performed by the condenser could have opened unforeseen horizons in electrology, as he had found out in analysing an aurora borealis during the night of July 28-29, 1780.¹⁸ In fact, the condenser could be used to determine if heat, evaporation and fermentation could produce any degree of electricity, or any alteration in the natural dosage of electric fluid. Volta strongly stressed¹⁹ that he had already expressed the above mentioned idea, together with other "thoughts", in his *De vi attractiva* published in 1769,²⁰ when he had set out to discover a form of impalpable electricity by increasing the number of experiments and by devoting more attention and accuracy to them.²¹ He was indeed able to do that, in his opinion, during the famous experiments that he carried out with Lavoisier and Laplace in Paris, at the beginning of 1782.

To summarise: on the one hand, Volta had previously tried to formulate acceptable hypotheses in order to justify the nature of falling stars, and in so doing he had not excluded their electric origin. On the other hand, when he replied to Vassalli's paper in 1786, he had no more doubts about the issue, since he could then count on more evolved and refined survey tools. In his view, there would have been no point in "partisans of electricity" holding on to their theory by giving electricity "new characteristics and new extraordinary functions that were unrelated to its known nature". This is because even if "new and unusual functions" had been attributed to the electric fluid, it would have been impossible to admit that the electric fluid itself was no longer detectable by the best conductors available". In fact, Volta said, in spite of many "electric-meteorological observations" carried out in recent years by "many diligent observers", it was never the case that the atmospheric conductors that had been put up to allow for "discharge of electric clouds and to provide an outlet for lightning" had been hit by any falling stars. Instruments, then, had the final word in the question – at least with regard to the *pars destruens* of the problem, according to which shooting stars do not have an electric nature.²² Volta was not, however, in a position to provide a certain and clear answer about the origin of those unusual

¹⁶ VOLTA (1782); see the English translation in VOLTA (1782a).

¹⁷ VOLTA (1782a), p. VIII.

¹⁸ *Ibid.*, pp. XV-XVI.

¹⁹ *Ibid.*, p. XVIII.

²⁰ On Volta's *De vi attractiva* see now FREGONESE (1999), pp. 18-26 and 50-60.

²¹ VOLTA (1782a), p. XVIII: "Being persuaded of this theory, I thought that the electricity produced in those cases was not discovered, partly because of its small quantity, and partly because the insulation was almost destroyed by the vapours that rose, and I imagined, that by a greater accuracy, and by multiplying the experiments, I should some time or other discover it".

²² VOLTA (1786), p. 11.

meteors, as he agreed that the old explanation concerning a particular disposition of atmospheric vapours was not convincing either.

Anyway, the hypothesis on the electric origin of bolides was even less convincing, because it was truly inconceivable that “an enormous quantity of electric fluid” could travel “for many hundreds of miles through clear skies, instead of discharging itself into the ground”. Volta used the same examples as Vassalli’s to disprove him, such as the bolide that crossed the air over the Adriatic sea and was observed in Bologna by the famous scholar Montanari on March 31, 1676; the meteor observed in England on November 26, 1758, as described by Pringle; and the bolide that crossed the skies of Paris on July 17, 1771, described by Le Roy and Lalande, which was very similar to the bolide described by Vassalli in his paper. According to Volta, such phenomena were all characterised by matter that was “thick” and “subject to ignition”, i.e. by “actual combustion”.²³

After clarifying his thought, Volta once more presented the arguments he used in his conversations with Barletti in the late 1770s, attacking the “fanatic worshippers” of electricity, who even saw it as the cause of earthquakes, volcanic eruptions and phosphoric sea light.²⁴ Shortly after taking that standpoint, Volta repeated the necessity of establishing some solid elements and principles on which a new “meteorological Science, both applied and speculative”, could be founded. Current knowledge in that scientific field was still, in his opinion, “very imperfect in both respects” at the beginning of the 1790s.²⁵ Chemistry, on the contrary, already had its *Traité élémentaire*. Vassalli’s point of view was radically different, since he foretold the coming of a new Franklin, whose task would be to masterfully synthesise “air, fire, phlogiston, heat, light, and electricity”, which were well defined principles already (according to him).²⁶

The discussion with Vassalli undoubtedly had a role in stimulating Volta’s attempt to refine tools and equipment fit for surveying, measuring, and comparing electric phenomena, as one can easily understand from his famous correspondence with Lichtenberg, which he began soon after, in July 1787. The writings that Volta sent to Vassalli were something more than occasional commentaries, as he himself pointed out more than once, for example in his *Lettera prima sull’aurora boreale* addressed to Pietro Antonio Bondioli during the second half of 1791. In fact, not only had the topics dealt with by Volta in his paper on falling stars and on the 1786 bolide already been developed in an academic setting,²⁷ but later on they were to constitute the

²³ *Ibid.*, p. 12.

²⁴ *Ibid.*, p. 24.

²⁵ VOLTA (1791), p. 365.

²⁶ VASSALLI (1786), p. XXXVI.

²⁷ Volta was also able to use his letter to Vassalli (with appropriate modifications for the occasion) during a speech he made at the University of Pavia on June 12, 1790, at a graduation ceremony for two land surveyors. He did that in spite of the fact that there was now another “fanatical worshipper” to take into account, a new admirer of Beccaria, another one of the “many or few

follow-up²⁸ of his correspondence with Lichtenberg (nine letters, the last written in March-April 1790). But, as is well known, the tenth letter was never written. Volta was to explain in 1812 that the dialogue with the German scientist was interrupted “by the appearance of the so-called *Galvanic Electricity* that, thanks to its novelty and importance, and to the rich wealth of surprising discoveries that it allowed” kept him constantly busy “in 1792 and several years after that”. Anyway, 1794 was approaching and that was to be the decisive year when Chladni would produce his theory on the extra-terrestrial origin of meteorites, which Volta positively reviewed in 1812.

It was not by chance that Volta had given speeches during land-surveyor graduation ceremonies. He was well aware of the public importance of meteorology and about the advantages that meteorology could add “to Physics in general, to Agriculture, Medicine and Nautical Science”.²⁹ However, in order to be really useful in those fields, meteorology had to somehow purify itself of its connections with popular tradition and peasant life, astrology, and the myth of knowledge coming from ancient peoples, shared by many scientists as well.

On October 24, 1791 Vassalli sent Volta (some months before of the beginning of the controversy on animal electricity),³⁰ some of the works he had finished during the summer via the Vaccà-Berlinghieri brothers, asking for his advice. Among them was a paper on some conjectures about the ancients’ art of attracting lightning,³¹ that he had read three years before during a meeting of the Società Patria Letteraria. Vassalli was very familiar with the ancients, because during his academic studies he not only cultivated natural philosophy under the guidance of his uncle Eandi and of Beccaria, but he also read “specifically Hesiod, Homer and Virgil, both for the language and for the content, which described things that he included in an abstract to be later used for the History of Physics, as can be seen in many of his writings”.³² Certainly Vassalli’s trust in the ancients was also encouraged by Toaldo who was one of his meteorology teachers. In fact, although one must not overestimate “the incidence of ancient knowledge in Toaldo’s ideas, especially his typically Italian taste for erudition”, it is however true that Toaldo “considered the ancient naturalistic tradition to be valid as well”.³³ Such validity was surely acknowledged by Vassalli in 1791, when he tried to demonstrate that the ancients already knew the art of controlling lightning.

followers” of his, abbé Pierre Bertholon, who in 1787 had published a work bearing the eloquent title of *De l’électricité des météores*, see VOLTA (1790).

²⁸ VOLTA (1791a), p. 340.

²⁹ VOLTA (1793), p. 374.

³⁰ On the role of Vassalli in the controversy and his relations with Volta see BERNARDI (1992); ID. (2000); CIARDI (1995), pp. 82-8; ID. (1999).

³¹ VASSALLI (1791).

³² BERRUTI (1825), p. 10.

³³ CASATI (1990), p. 22. For a short history of meteorology and more bibliographical information see CASATI and CIARDI (1998), I, pp. 43-7. See also FELDMAN (1990).

In his work, appropriately opening with a quotation from Francis Bacon's *De sapientia veterum*, Vassalli took a stand about the topic of the wisdom of the ancients: although he surely mistrusted the "fanatics" that wished to attribute all truth to the ancients, including "the most recent discoveries", it was also natural for him to mistrust those who considered "our age the adult one of the world" and who thought the intellect of "men from remote times" to be like "the soil cultivated by early farmers: rough and wild, therefore inappropriate for good projects". In fact, it was well known that the ancients had reached "various forms of truth" that were later confirmed by the "moderns".³⁴ According to Vassalli, for instance, there was enough evidence to demonstrate that the ancients already knew the "admirable art of attracting lightning".³⁵

Various classical sources were used by Vassalli, among which are works by Marcus Manilius, Suetonius, Pliny, Ovid, and Livy. He also drew some interesting information from Herodotus, "the father of Greek history", whose works showed that during thunderstorms the Thracians used to shoot a great amount of arrows into the sky, as if they wanted to fight the divinity. That might well be proof that people already knew about the power of points with regard to lightning. The same is true about the fact that the temple of Jerusalem – both during its first construction by Solomon in 966 BC. and during its reconstruction – had been provided with innumerable metal points, golden plates and other types of conductors that started from the roof and reached all the way to the ground, proving once more that the ancients had knowledge of the subject. It is interesting to note that the question directly concerned Volta as well,³⁶ since he had supported Michaelis and Lichtenberg's "opinion" that "divine providence" had guarded that building, which had been built "without full cognition of the facts".³⁷ On the other hand, in Vassalli's view one could conclude that the ancients had been knowledgeable about "the main properties of electric fire". Such properties, held by many to be "the newest discoveries of the moderns", could in fact be considered new only because "they had been lost along with many others".³⁸

Volta's answer to Vassalli's memoir does not need any comments.³⁹ Although to Volta's mind the dissertation appeared to be "elegant, lively and scholarly", it still did not convince him of "the existence of facts"; actually, in his view the arguments presented were "specious, but nothing more". It was easy to find meanings in "the obscure sayings of the Oracles, in facts and mysterious expressions, in practices and ceremonies introduced by multiform pagan Superstition and in portentous Mythology". Somehow they were meanings that could be ascribed "to any modern discovery", but what certainty

³⁴ VASSALLI (1791), p. 4.

³⁵ *Ibid.*, p. 7.

³⁶ VOLTA (1787). Published as VOLTA (1788).

³⁷ VASSALLI (1791), p. 58.

³⁸ *Ibid.*, p. 40.

³⁹ Volta to Vassalli, autumn 1791, in *VE*, III, 902, pp. 127-8.

was there of that being the exact meaning intended by “the creators of those practices and ceremonies, and by the authors of those sayings and descriptions”?

Clearly, Volta did not completely disapprove of “the procedure, which was accepted by many scholars, according to which fairy tales and ancient rituals could be interpreted as symbols of some great natural phenomena”. However, even admitting that the ancients “really” intended “to symbolise those phenomena, and especially Meteors”, it was not possible to believe that they had gone beyond the description of “simple effects and appearances”, because “causes” turned out to be “difficult to understand and were not at the height of their knowledge”. Anyhow, where was the evidence that the ancients “had, or might have any knowledge of the electric agent, and of its presence inside clouds that were full of lightning”? And which and how many experiments would the ancients have to carry out in order to reach such conclusions? Taking this all into account, Volta ended his commentary to Vassalli’s *Conghietture* by taking the liberty of considering “the dissertation to be an erudite joke”.

It was necessary to leave the ancients’ fairy tales behind and to concentrate on the rather inadequate research done by the moderns. With regard to this subject, Volta could not help complaining about the fact that there were “few” meteorological observatories in Italy endowed “with a complete assortment of the right tools, or at least with the best Barometers and Thermometers”, which could effect the “systematic observations” that are necessary to determine at least “the annual and monthly average heat” and “the barometric average height”. This situation, in Volta’s words, was really “deplorable” because the experiments were usually “incomplete and disconnected” and were carried out using “not the best instruments”. This gap “in beautiful and learned Italy”, had been particularly revealed in “a work that was truly outstanding” by Richard Kirwan,⁴⁰ which was compiled “with great care and diligence” and had the merit of collecting “thermometric observations made with the type of accuracy, continuity and method that are necessary to derive average temperatures, representing more than forty cities and sites in England, Holland, France and Switzerland, in Germany, Sweden, Russia and Siberia, in Asia, Africa, America and in the Islands”. Unfortunately, in the case of Italy, Kirwan was able to get only the “proper observations” made in Padua, that he considered to be “well made and well recorded over a number of years”.⁴¹ The information had been collected by Poleni and Toaldo. It was true that “in Verona, Vicenza, Turin and Milan, and in some other cities” meteorological observations had been carried out and published for a number of years “in the form of monthly and yearly charts”, but they were “scanty and imperfect”. That was why in those years Volta not only encouraged the construction of meteorological observatories in Pavia, Mantua and Milan, but he also indicated very specific guidelines about

⁴⁰ See KIRWAN (1787); translated into Italian as KIRWAN (1790).

⁴¹ VOLTA (1791), pp. 366-7.

observation time and measurement of atmospheric data, so that uniform and, most importantly, comparable tabulations could be produced.⁴²

Volta's criticism of the Italian meteorological system did not hesitate to highlight the fact that the only international reference point in Italy was represented by Toaldo's observations. His appreciation of the work that the professor from Padua was carrying out, however, was limited to data collection, without entering the domain of lunar meteorology.⁴³ The time was not yet right for Volta to proceed towards a general theory of meteorological forecasting, since that discipline was not a science in the proper sense because it still had to formulate its fundamental components.

Volta always stressed his firm criticism of those naturalists, who insisted on using history and general principles instead of instruments and experiments to produce reliable scientific and quantitative results.

⁴² *Ibid.*, p. 365.

⁴³ On Toaldo see now PIGATTO (2000).

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