Jürgen Teichmann

Georg Christoph Lichtenberg: Experimental Physics from the Spirit of Aphorism

Lichtenberg was born on July 1st, 1742 in Ober-Ramstadt, a small town near Darmstadt, south of Frankfurt. All his scientific life he was professor of philosophy and experimental physics at the University of Göttingen, located in the Hannover electorate. The university was known as a young and forward-looking institution already at that time. One of its founders was the Swiss medical researcher, scientist and poet Albrecht von Haller. He also became professor at this university and founded the Göttingen academy of sciences in 1751. Lichtenberg died on February 24, 1799, in the very year Volta invented his battery.

Lichtenberg lived in Göttingen from the beginning of his university studies in 1763. He left the town only three times, all for extended journeys to England. There was a good reason for this: George IV, king of Great Britain was also Elector of Hannover. The English cultural influence on Lichtenberg was seen as unusual at that time in Germany because continental Europe in general was attracted towards France and also to Italy, in the wake of a rediscovery of classical Greek and Roman culture. The attraction of Italy, for example, is best shown by the famous and highly publicized Italian journeys of the German poets Lessing and Goethe. With Lichtenberg, Lessing and Goethe, the English influence on German poetry began to grow.

Today, Lichtenberg is famous in Germany as a writer of aphorisms.[1] He was not a poet, a dramatist or a novelist, but was well known in his own time for his satirical essays. He was also celebrated as an accomplished experimental physicist. His university lectures always included experiments and demonstrations, which was very unusual at that time. Many of his students later became famous scientists, mathematicians and personalities in Germany's cultural life; among them the mathematician Carl Friedrich Gauß, the naturalist/scientist and world traveller

[1] See W. PROMIES ed. (1968-92): vol. I and II for the first time are a complete edition of all entries in his waste books ("Sudelbücher"). The complete edition of his correspondence is JOOST and SCHÖNE eds. (1983-5). A complete edition of his other writings is still lacking. (The "Akademie der Wissenschaften" in Göttingen is working on an edition of his scientific writings). There are very few English translations of Lichtenberg's work, the newest is MAUTNER and HATFIELD (1959). Still the best all embracing reflection of Lichtenberg's life is MAUTNER (1968).

Alexander von Humboldt, and the romantic poet Novalis. The university had only about 400 students, but the lectures of Lichtenberg sometimes attracted more than 100! Lichtenberg knew many of the famous personalities of late eighteenth century: e.g. Goethe, Volta, William Herschel; they even visited him in Göttingen. With the philosopher Immanuel Kant and many other writers and academics he maintained a correspondence. In a letter of Lichtenberg to a friend he describes the visit of Volta at Göttingen in November 1784. Let me quote a few lines from it:

> He is an extraordinary man. DeLuc is right: he wrote me once "qu'en Electricité Volta voyoit avec les yeux de Newton". He is full of ideas and a raisonneur without peer. He had many instruments along; he unpacked them for me, and during his stay here I kept them in my own quarters. They are locksmith's work, but he accomplished everything with them. [...] He is a handsome fellow, and during some extremely uninhibited hours, at a supper at my place when we talked wildly till about one o'clock, I noticed that he has an expert knowledge of the electricity in girls. I remembered your double electroscope.[2]

After this last sentence Lichtenberg added a drawing of Volta which, I assume, is not found in the collection of Volta's portraits.

Ihr doppelter Elektrizitätsweiser

fiel mir dabei ein

Figure 1 Alessandro Volta as drawn by Lichtenberg ("I remembered your double-electroscope").

Lichtenberg was handicapped, with a big hump on his back. But this did not prevent him from being a socially active and an extraordinary lecturer. He was a very thorough,

[2] PROMIES ed. (1968-92), IV, pp. 585-6, in a letter from November 1784; also MAUTNER and HATFIELD (1959), pp. 167-8 (the last sentence, including the related drawing of Volta, only in the German version).

elegant but an unconventional thinker, showing great wit and humour and was very susceptible to beautiful things in life, like good wine and the charms of the opposite sex. From students attending his lectures we know that he came into the lecture room, always facing his audience – because he tried to hide his hump from the eyes of the students. "Small" and "big" Lichtenberg in this historical sketch is the construction of a "picture aphorism" by myself, along one of Lichtenberg's Baroque/Rococo maxims for research of the macrocosm (of the universe) and microcosm (of man's soul). He used this, with his competence and intimate understanding of instruments e.g. in the following remarks:

> If astuteness is represented by a magnifying lens then wit is by a reducing lens. To look into the telescope at the wrong end.[3]

Figure 2 Lichtenberg (sketch, probably from the 1790s, private collection).

These variations of ideas by way of an "experiment" are typically found in his aphorisms. These aphorisms remained unknown during his lifetime. They were kept as "waste books" using this word in the original English:

> The merchants have their Waste book; there they record from day to day everything they buy and sell, one after the other, without any order. From there the entries go into the Journal where everything is recorded more systematically, and finally it goes to the Ledger at double entrance. This should be imitated by the scholars. First, a book in which I write everything the way I see it or as my thinking tells me to. Then this can be copied into another where subjects are separated and arranged in better order; and the Ledger could then contain the various subjects in their connection and, following from it, their proper discussion.[4]

[3] PROMIES ed. (1968-92), I, D469; MAUTNER and HATFIELD (1959), p. 19.
[4] PROMIES ed. (1968-92), I, E46; MAUTNER and HATFIELD (1959), p. 12. Lichtenberg gives the terms "waste book", "Journal", "Leidger at double entrance" in English.

He declared that his entries were only "remarks which were thrown away" or what we may call in English "pithy remarks" (Pfennigwahrheiten). Certainly he would not have liked to see them published. Clearly, many of these notes – probably private – disappeared (maybe, because the family suppressed it).

Albrecht Schöne, the grand old man of Lichtenberg research in Germany, a retired professor of German literature, published a booklet in 1982: "Enlightenment out of the spirit of experimental physics – Lichtenberg's subjunctives".[5] Schöne started his interpretation with the observation that 30% of all sentences in Lichtenberg's "waste books" contained subjunctives. Within other writings of Lichtenberg we only find about ten percent of subjunctives. In one of his "waste books" there is a part called "mixed annotations in physics and mathematics" which contains 45% subjunctives, e.g.:

> Would you feel any heat if you caught the light of lightning with a big burning-mirror?[6]

Schöne concluded that Lichtenberg transformed scientific experimentation into a writing method for getting new insights into human life, intellect and soul. In Lichtenberg's words:

> We must experiment with ideas.[7]

In his interpretation of Lichtenberg, Schöne defined experiment as "a variation of possibilities". This maybe a too simple point of view – influenced by the interests of a researcher in literature. Other interpreters responded to Schöne's analysis by arguing that the use of subjunctives is more a play with hypotheses than real experimentation. Real scientific experiments can never anticipate results of observation. Results in real experiments are often totally unexpected, unforeseen by theory and they often refute the initial hypotheses. This, however, is not possible when playing with "ideas". But Lichtenberg's aphoristic experiments are often very open questions to nature without anticipating any results – as we learn from the burning mirror aphorism.[8]

Lichtenberg also went further and extended his way of experimenting with ideas to the construction of totally new experimental sciences, like experimental psychology:

For example:

> What effect it would have on me if I once had to sit in black clothing in a great room hung all in black, where even the ceiling was covered with black cloth and with black carpets, black chairs, black sofa and only a few wax candles, and was waited on by servants dressed in black![9]

On the other hand, experiment in the spirit of the 18th century involved a

[5] SCHÖNE (1982). In opposition to Schöne see RAPIC (1992), pp. 14-22.
[6] PROMIES ed. (1968-92), I, A177.
[7] *Ibid.*, I, K308; MAUTNER and HATFIELD (1959), p. 83.
[8] See *ibid.*, A177.
[9] *Ibid.*, I, F325; MAUTNER and HATFIELD (1959), p. 66-7.

broader sense of seeing and interpreting than the later science in the 19th century did. Experimentation in the 18th century for example included demonstration, experimental shows, and even tricks.

But in these demonstration, in the show and trick parts, the results are expected and subjunctives are no more usable. In general, the audience played an important role for the experimenter – at least still in electric science (see the famous study of Shapin/Schaffer about 17th-century experiments).[10]

We will stress this definition of experiment further on with Lichtenberg himself. Lichtenberg preferred to use his senses and emotions to explore nature. Therefore he concentrated on single natural phenomena, living beings, materials, instruments as objects for his research, using the methods of the physical sciences as a guide. He preferred this to any systematic theoretical reflection. On the other hand, he did not suppress critical philosophical reflection – in contrast to a pure empirical view of the world. The attempt to transfer this methodology (which included the thought experiment as a legitimate approach) into other branches of intellectual knowledge of the eighteenth century is not surprising in the age of enlightenment. Even in quantitative experimental science the non-mathematical language as a medium of communication remained a very powerful instrument, as powerful as scientific reasoning which guided all observation. Lichtenberg declared:

> Wit is the discoverer and reason the observer.[11]

Perhaps Lichtenberg achieved the best symbiosis of these two parts of the intellect within the physics of the 18th century.

The main interest of my paper is to invert the thesis of Schöne: Experimental physics was not the base on which Lichtenberg started his intellectual life. Rather the starting point was his predilection and love for expressing his ideas aphoristically. This predilection fitted well into the already existing "aphoristic" state of electricity of his time. Moreover, all his other experiments (including the biological ones) can be based on this interpretation. Maybe this interpretation can be extended partly to other centuries and the methodology of experimental physicists.

For Lichtenberg experimentation included:

1. Combining research and demonstration at the same time without differentiating between observational astronomy and experimental physics.
2. Making a performance to satisfy all the senses and providing a mythical background.
3. Presenting clever tricks and plays.
4. Narrating about nature.

These 4 aspects often are ingeniously mixed together.

[10] See SHAPIN and SCHAFFER (1985).
[11] *Ibid.*, II, J1620; MAUTNER and HATFIELD (1959), p. 16.

Elaborating on Point 1

Aspects of research and demonstration are almost always mixed in Lichtenberg: Getting new knowledge, experiencing aesthetic pleasure, criticising sensual experience, being aware of pedagogic interest and utility for society (in the sense of enlightenment philosophy) were one and the same task for him. This integrated view of science can be seen, for example, in his review of the colour theory of one of his predecessors, Tobias Mayer. He edited and commented on this theory, also for the use of painters, extended it by pedagogical considerations, and enriched it with practical experiments. He discussed it with Johann Heinrich Lambert, who was then the most famous scientist in this field. He also reflected the subjective physiological and psychological part of seeing colours:

> As far as coloured shadows are concerned you should know that it is still not clear, whether the colours of light are the same at different distances from the light emitting bodies...[12]

Because of his physiological and psychological interests he also was interested in the colour theory of the German poet and important scientific amateur Johann Wolfgang Goethe who tried to get some support for his ideas by the competent professor Lichtenberg. But as a passionate admirer of Newton, Lichtenberg more and more dissociated himself from Goethe's battle with the spectral theory of Newton. For Lichtenberg the phenomenon of spectral dispersion of light, with spectral colours as simplest parts of a white beam was reality. He just used it as metaphor for psychological observations:

> He could split a thought which everyone considered simple into seven others, as a prism splits sunlight; and each one of them always surpassed the one before. And then, another time he could collect a number of thoughts and produce the whiteness of sunlight, where others saw nothing but motley confusion.[13]

In his famous publication about electrostatic figures from 1777, published in the Transactions of the Göttingen Academy of Sciences, Lichtenberg often abandoned dry scientific language. For example, he compared his famous figures with milky ways, to the stars and to ice figures on a window-pane in winter. Pedagogic and aesthetic interests went hand in hand. In his eyes his big glass cylinders of his frictional electrical machines – which were built in London – possessed "very extraordinary beauty and magnitude".

At the beginning I mentioned his high estimation of Volta. Volta`s instruments looked like "locksmith's work" as compared to the elaborate ones owned by Lichtenberg. It is apparent that Lichtenberg experienced a sensual pleasure when he designed and used instruments that were not only practical but also beautiful.

He often used satirical elements in his experimental descriptions. When he was

[12] *Ibid.*, K368.
[13] *Ibid.*, I, J597; MAUTNER and HATFIELD (1959), p. 89.

asked as an expert what the best way was to prevent being struck by lightning he described a Faraday cage embracing the whole building and continued:

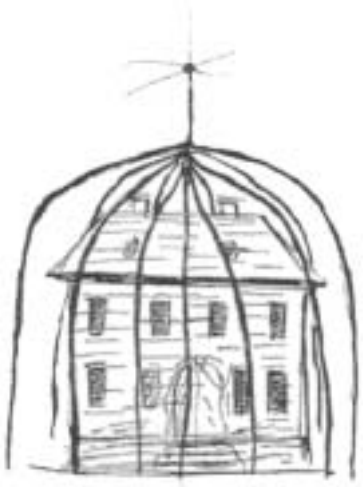

Figure 3 A Faraday-Cage, proposed by Lichtenberg.

> The iron cage could contain all kinds of decorations for example showing Jupiter, whose lightning will be put out by a pissing professor of physics.[14]

For Lichtenberg experiments were interventions by instruments in nature which really changed nature. But they were allowed because they were fruitful. This way of using outstanding instruments had made it possible for astronomy to become an exact science. Similarly, it would be necessary in meteorology and in other branches of the "physicque particulière" to develop and use exact instruments. This was normal reasoning – for Lichtenberg as well as for Volta.

Elaborating on Point 2

Beyond serving research and improving demonstration an experiment for Lichtenberg was also a show that proclaimed the power, glory and pathos of science in a most direct way:

> The world beyond the polished glasses is more important than that beyond the seas and is surpassed perhaps only by the one beyond the grave.[15]

And here is another example:

[14] *Ibid.*, IV, p. 726, in a letter from 18.2.1788.
[15] *Ibid.*, I, J937; MAUTNER and HATFIELD (1959), p. 91.

> Yesterday I showed in my lecture, before about 50 persons, one of my cylinders [for his frictional electrical machine]. When the cylinder was brought out of the box, there arose a noise, as in Naples, every time when the blood of the holy Januarius is presented.[16]

The use of metaphors of the Catholic Church such as the one in the second example leads, beyond the show, to the mythical dimension of science.

A "100% show" experiment for Lichtenberg was his discovery of what we today call electrical welding: a spring and the blade of a knife were welded together in pure oxygen (dephlogisted air) by a strong electric spark. Referring to such experiments he said:

> These are the most magnificent performances you can see.[17]

He did not reflect upon any technical use of this experiment but did speculate about what such things are as the claim made in the Old Testament about the extraordinary long lives of some, who may have breathed, he guessed, "purer" oxygen. Using a constructivist view of science we could say that Lichtenberg created this fact. It was not a simple discovery in nature, rather a part of Lichtenberg`s world of phenomena. He created it as a kind of magic performance and as a kind of a story, opening the way for other stories of science.

A strong mythical significance for him was any experiment from which new knowledge came in a very concentrated form – and not in a series of complicated steps of theory, detailed experiments, interpretations. Then

> the work of God is suddenly revealed to man's intellect![18]

Such concentrated experiments seemed to solve problems in one moment with finality. This is the power of myths! Another sign of a myth, the personification of a story or of a comparison, or of a metaphor, can often be found in Lichtenberg`s thinking. For example he compared Herschel's discoveries in the macrocosm with Leuwenhoek's research in the microcosm and ended with the question: "What results can be expected from Herschel's big new telescope?". We already mentioned the contrast between the microcosm and macrocosm used as a metaphor – see Volta's microelectroscope from 1782, that opened up, as Volta hoped, the microelectrical world in contrast to the large effects of the frictional electrical machines and batteries of condensers.

The most thoughtful and very critical reflection of scientific experimentation is Lichtenberg's short story "A dream".[19] He received a sphere from a spirit (maybe God) and placed in his hands, which he was asked to examine by experimentation.

[16] *Ibid.*, IV, p. 380, in a letter from 9.12.1779.
[17] *Ibid.*, p. 447, in a letter around the middle of June 1782.
[18] Unpublished manuscript of a university lecture. Cited from SCHÖNE (1982), p. 49.
[19] PROMIES ed. (1968-92), III, pp. 107-11: *Einige Betrachtungen über vorstehenden Aufsatz, nebst einem Traum*; MAUTNER and HATFIELD (1959), pp. 118-21.

He started the research by first smelling it, then tasting it, rubbing it to test for electrostatic property, cutting up a very thin piece for the chemical analysis, etc. But he could not find anything interesting. Then God returned and asked him what he had in his hands and told him what he had chemically destroyed was the earth itself. He just had cut down the highest mountains etc. "Oh Holy spirit", he answered, "enlarge a mustard seed to the thickness of the whole earth to so I can examine it". God replied: "How would that help you? In your own planet you already have a granule magnified, in your eyes, to the thickness of the earth. Make your test there". As a last attempt God gave him a pouch. He was asked to test the contents chemically. When he opened the pouch he found a book written in a language he could not understand. He did not know how to test it chemically. The content of the writing was its meaning, not the chemical composition of the printing ink. Suddenly things became clear in his mind – and at this moment he woke up. The conclusion we can draw is, that, apart from the meaning of the dream as an allegory, it is a description of the experiment concerned as the most essential part of scientific research. Moreover, the dream also made clear that it is difficult to know by experimentation alone about the relationship between matter and meaning, because there is no clear separation between the observer and the object observed.

Elaborating on Point 3

For Lichtenberg an experiment was sometimes a simple trick ("Kunststück" in German), or the playing out of pure pleasure. Sometimes he used it merely as an aperçu within a conversation. In his "waste books" he noted and described many such tricks (e.g. to balance two knifes at the rim of a glass) which he intended to examine scientifically or which he performed and described simply out of a sense of play or pleasure. In university lectures, he stated in a letter, it should be necessary to play. In fact if he did not play, a larger portion of his audience would fall asleep. These games, of course, he continued, opened up new points of view for the more clever students.[20]

Certainly, his experiments with electrical welding could be seen partly as play.

After the famous first flight of a Montgolfier balloon in Paris in 1783 he said he had experimented one year earlier with pig bladders (as did Tiberius Cavallo before him), filled with hydrogen, which rose in the air in his lecture room. For him this was mainly a trick to let these small balloons fly, and a pedagogically brilliant idea to show that hydrogen is lighter than air. He admired the French who had succeeded in transforming this trick to – for him again – a mythical dimension: to bring man nearer to heaven, now with his body and not only with his intellect.

An example of a pure aperçu is the experiment he had often performed with Volta. He asked him: What is the simplest method to produce a good vacuum in a wineglass without using an air pump? Just pour in wine! And what is then the best method to

[20] PROMIES ed. (1968-92), IV, pp. 438-9, in a letter from 10.6.1782.

allow the air to come back? Just drink the wine! This experiment will seldom fail![21]

Elaborating on Point 4[22]

For Lichtenberg experimentation was a specific form of narrating scientific knowledge. Mathematics, he said, is very important for the comfort of a physics "journey" – as a warm carriage is important for the comfort of a journey from Göttingen to Petersburg.[23] In principle it is possible to walk this distance on foot. In this latter case, we may interpret, the traveller has direct contact to all phenomena around him – by observation and experimentation and also has time to enjoy them. By experimenting, science narrates about nature in a special way. These special stories are immediately impressive (often for more than one, or two senses) as single events, shows, tricks, plays, but also in varying combination. Experiments seem to connect head and hand. They use another concept of beauty than theories. They open a direct way to the work of God.

Maybe the best example for this interpretation is his publication about electrostatic figures in 1778 – the only important physical discovery by him.

Basically it is a very careful scientific publication – written in Latin – looking at all aspects of electricity which were considered important at that time. Yet all facets of Lichtenberg's understanding of experiments, are ingeniously mixed together to impress his scientific, but at the same time Baroque-Rococo audience:

> When I saw for the first time an electrophorus I liked it immediately, not only because of its simple construction and large effects, but also because of the special composition of the materials that were necessary for its construction, which are easy to get everywhere [...].
>
> The occasion for the discovery of the phenomenon was the following: At the beginning of the spring, in 1777 [...] my room was still full of very fine dust of resin which had risen up during the planing and polishing the base of the instrument [...]. It happened [...] that the dust, lying at the base. [...] to my great pleasure formed at several places, small stars, which at the beginning could be seen only faintly and weakly. But when I scattered the dust on purpose with more vigour the stars became distinct and very beautiful and often looked like an elaborate and intricate piece of work. Sometimes there arose numerous small stars, whole milky ways and larger suns [...]. further on very pretty small branches, similar to those produced by frozen vapour on window panes [...]
>
> I don't doubt that my little machines – which is not a small recommendation – will be used in future by jugglers in addition to their stones and dice-boxes…
>
> In this respect we can also talk about a new kind of secret writing that I discovered by chance and which everybody who has some sense for such a pleasure, observing nature

[21] *Ibid.*, p. 613, in a letter from 3.2.1785.
[22] See also KEMPF (1992), pp. 3-13.
[23] PROMIES ed. (1968-92), IV, see f. n. 2.

gives to us, offers the most delightful performance.[24]

With this "secret writing" he can be seen as one of the predecessors of electrostatic copying. In fact the modern inventors at Xerox-Company honoured him by citing his electrostatic figures.[25]

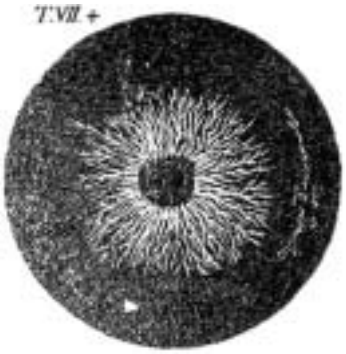

Figure 4 Lichtenberg's figures (Promies III, after p. 31).

For Lichtenberg an experiment really was a very important way to tell a story about nature. Indeed, Lichtenberg did not write a single book, He based his famous experimental lectures on a book, but of a predecessor of him (Erxleben), improving and extending it. (It was very successful in Germany). But at the beginning of his career as experimental lecturer he did not even want this much. He admired the English itinerant lecturer James Ferguson:

everything was done by experiments – he had not even chalk and sponge.[26]

Lichtenberg allowed his assistant to repeat the best of his experiments on Sundays between 10 and 11 o'clock. In fact the experiments were allowed to tell their own story. For Lichtenberg, the immediately impressive experiment performed with elaborate instruments was similar to the short sparkling witty language he loved so much.

He experimented without a systematic research programme and without being forced by any direct challenge from society. It was not necessary to perform experiments in university lectures – just the opposite was usual – and he was not

[24] *Ibid.*, III, pp. 24-34: "Von einer neuen Art die Natur und Bewegung der elektrischen Materie zu erforschen" [german translation from 1809]. A better translation gives D.N. Hasse in LICHTENBERG (1997), here pp. 143-67 (Latin and German). The original Latin title is: "De nova methodo naturam ac motum fluidi electrici investigandi", published in the *Transactions of the Göttingen Society*, class 8 (1778), pp. 168-80.
[25] CARLSON (1965), pp. 15-49, here p. 16.
[26] See footnote 18, here p. 52. About Lichtenberg and his relation to Ferguson and other itinerant lecturers' see HOCHADEL (1998), pp. 155-75.

interested in any technical application of them. Lichtenberg's experimenting should not be regarded as being unsystematic, but rather as anti-systematic:

> By aimless wondering, through the meandering of fantasy we often scare up wild game for which there is a need in the ordered world of philosophy.[27]

Or:

> I have the habit of putting down my ideas about all kinds of things, by no means in order to use them at some later time, but simply with the intention of trying out their connection with each other. For in writing down things, one notices a great deal which one is not aware of in mere meditation.[28]

It was this aphoristic anti-programme which made him immortal in literature. To be sure, he used his experiments in physics to transform them as a literary methodology to get new philosophical, psychological insights:

> The soul places the countenance round itself like a magnet does with iron filings.[29]

But scientific methodology was not the starting point for Lichtenberg. His experimental "anti-programme" originated in his character and at the same time came out of the still disorganized state of experimental physics of his time: in principle he wanted to continue from his "waste book" to the "Ledger at Double Entrance". But he found more single notes, more questions than systematic answers. He would have been able to perform systematic complex, mathematics-based research. This can be seen at the beginning of his career: his first writing, published as an invitation to his starting university lectures, treated a famous problem of the calculus of probability (today called the Petersburg problem).[30] He also did systematic geodetic research and made astronomical observations. Other researchers within the "physique particulière" were not so good at mathematics. For example Volta even had some difficulties with the shifting from conductance to the inverse concept of resistance.[31] Lichtenberg decided not to restrict his scientific interest to a special field but to extend it to all questions of man and the cosmos. He was a scientist and good enough to know that his broad interest mostly produced only questions, but no answers. Single experiments by themselves did not give continuous answers. This way to knowledge was long, uncomfortable and maybe dangerous. In another aphorism he compared experimental physics with politics:

> Experimental politics – the French Revolution![32]

[27] PROMIES ed. (1968-92), II, J1550.
[28] MAUTNER and HATFIELD (1959), pp. 12-3.
[29] PROMIES ed. (1968-92), I, B69.
[30] See *ibid.*
[31] See TEICHMANN (2001), pp. 53-80.
[32] PROMIES ed. (1968-92), I, L322.

For him this revolution led to a similar dangerous, sometimes chaotic, always non-systematic but exciting way to change society, as experimental physics tried to change our knowledge of nature.

With his preference to raising questions instead of finding new answers he sometimes also found very useful compromises for the big problems of his time: For example he declared – in his publication about the electrostatic figures – he would prefer the signs + and - for the theory of the electric matter, but not because he believed in Franklin's theory of only one kind of electric matter. This designation was simply superior to using the explicit concept of more or less electricity. *Plus* and *minus* could also be names for the two different electricities of the Anti-Franklin School and could be used as the beginning of a quantitative language.[33]

The science of electricity at this time fitted well to the anti-systematic, aphoristic programme of Lichtenberg's research. In optics, for example, Lichtenberg remained an obstinate defender of the corpuscular theory of light as it was developed by the successors of Newton. He used his wit and satire but still remained traditional in his basic beliefs. Here it was difficult to "hunt across country" as he sometimes characterised his anti-systematic programme. But in opposition to optics in electricity new knowledge exploded and again with Galvani's publications in 1791. But at this time Lichtenberg was no longer very active in research.

In electricity it was still possible and impressive to present "stage-effects". The boundaries between electricity and the other branches of science were still not clearly established: magnetism, meteorology, chemistry, physiology of senses ,medicine, and biology. More than this, playing, giving magic performances, making a mythical gesture were still a legitimate part of research. And instruments especially in electricity were part of the pleasure of research, from the cheapest ones to the very expensive ones like large frictional machines.

It maybe that the electrostatic figures of Lichtenberg became his only important discovery because they symbolized the great variety of electricity in the 18th century. The two rival theories of the century, one that postulated a single substance for electricity and the other two substances, could be demonstrated in this experiment in the simple manner of using + and - figures. But it was also a big mythical gesture: the two-dimensional analogue to lightning in the air. The explanation of lightning by physicists was the greatest success of electricity in the 18th century – at least as seen by the public. Lichtenberg's electrostatic figures are an essential part of "domesticating" lightning – and demonstrating it in the laboratory. Thus, for Lichtenberg research and demonstration went hand in hand.

It is very interesting that a later successor of Lichtenberg in Göttingen, Robert Wichard Pohl in the 20th century was able again to use a similar research programme. He is known as one of the founders of solid state physics. In contrast to Lichtenberg he did systematic research, and did not use an aphoristic approach. He

[33] NORDMANN (1999).

knew and liked Lichtenberg – but he also admired the systematic and pedantic Röntgen. Pohl preferred imagination to theory, mixed research, demonstration and play in a brilliant way. He departed from the "military road" (the German word used by Lichtenberg is "Heerstraße") of atomic physics "across country". For him an experiment was an essential part of narrating scientific knowledge. Theories come and go, experiments will stay, he declared.[34]

Such a research programme, may be especially fruitful in those new fields of science that develop in an explosive way and where it is still difficult to apply systematically new theories for explanation. But this has to be reflected on more thoroughly, at another time.

(Thanks to A. Stinner, Canada, for help in translation).

[34] TEICHMANN (1992), pp. 236-69; see also TEICHMANN (1988).

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