On the Noise of the Thunder

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CHOICE OF TEXT:

This very short text has drawn our interest for three reasons:

- It is a text that is apt for a layman and that explains the causes behind the thunder's noise; why, if a bolt of lightning is instantaneous, does the thunder that follows not materialize just as instantly? And why does it last a certain time?
- It stems from an expert – Coriolis – the father of important mathematical and physical formulas (the combined Coriolis and centrifugal forces, known as "Coriolis force"; physic's definition of the notion of "work"; the book on the physics of billiards ...) which he expresses in a language not easily accessible to all, while this text is quite different in this aspect.
- This text appears in the Paris Philo-Science Society's Journal, the Philo-Science Society was a society of scholars whose goal was the spreading of knowledge; and the text appears in the minutes of the society's meeting of Saturday, July 20, 1833.

Therefore, even if this text can perhaps not be considered as fundamental in the History of Science, the merging of these three ingredients has raised our interest about the popularization of sciences in the XIXth century.

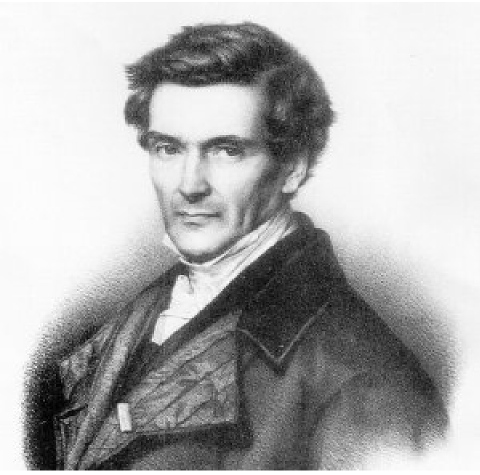
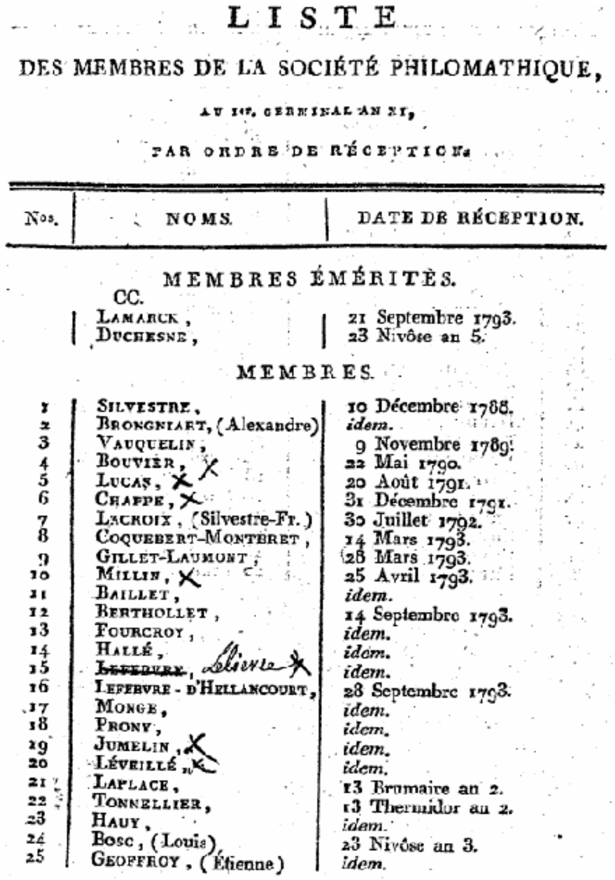


***Figure 1*: Portrait of Coriolis (1792-1843) by Roller.** *This scientist, a structural engineer, member of the Academy of Sciences, is as little known as his main discovery is: the combined centrifugal force (known as "Coriolis force"). Of unassuming character and delicate health, he dedicated his time to teaching and science, mainly at the Polytechnic School from 1817 up until his death.*

The Philo-Science Society of Paris

This society was created just before the Revolution, on December 10, 1788. From the very start, it welcomed the greatest scholars and experts of the time, and it was often considered as the antechamber of the Academy of Sciences.[1] Its structure imitated that of the Academy, with "sections" for each discipline; in this manner, the first section, to which Coriolis belonged, was dubbed "Mathematics, Astronomy and Geodetics". In an article dated in 1833, we can find, besides Coriolis, the names of such scientists as Binet, Liouville, Arago, Ampère, Poisson; in the second section, "General and Applied Physics", we may find Prony, Biot, Gay-Lussac, Hachette, Dulong, Navier…



LISTE

DES MEMBRES DE LA SOCIÉTÉ PHILOMATHIQUE,

AU 1er. GERMINAL AN XI,

PAR ORDRE DE RÉCEPTION.

Nos.	NOMS.	DATE DE RÉCEPTION.
	MEMBRES ÉMÉRITES.	
	CC.	
	Lamarck,	21 Septembre 1793.
	Duchesne,	23 Nivôse an 5.
	MEMBRES.	
1	Silvestre,	10 Décembre 1788.
2	Brongniart, (Alexandre)	*idem.*
3	Vauquelin,	9 Novembre 1789.
4	Bouvier,	22 Mai 1790.
5	Lucas,	20 Août 1791.
6	Chappe,	31 Décembre 1791.
7	Lacroix, (Silvestre-Fr.)	30 Juillet 1792.
8	Coquebert-Montbret,	14 Mars 1793.
9	Gillet-Laumont,	28 Mars 1793.
10	Millin,	25 Avril 1793.
11	Baillet,	*idem.*
12	Berthollet,	14 Septembre 1793.
13	Fourcroy,	*idem.*
14	Hallé,	*idem.*
15	~~Lefebvre~~,	*idem.*
16	Lefebvre-d'Hellancourt,	28 Septembre 1793.
17	Monge,	*idem.*
18	Prony,	*idem.*
19	Jumelin,	*idem.*
20	Léveillé,	*idem.*
21	Laplace,	13 Brumaire an 2.
22	Tonnellier,	13 Thermidor an 2.
23	Haüy,	*idem.*
24	Bosc, (Louis)	23 Nivôse an 3.
25	Geoffroy, (Étienne)	*idem.*

***Figure 2**: The list of the first twenty-five members in Germinal of year XI (seventh month of the French Republican calendar, corresponding to March of 1803). In the first and second position, we can see the names of the founders on December 10, 1788, Augustin-François Silvestre and Alexandre Brongniart.*

The Philo-Science Society (Société Philomatique in French)[2] will play a notably important role between August of 1793 and November of 1795. In effect,

1. Coriolis himself entered the Philo-Science Society in 1830, and the Academy of Sciences in 1836.
2. The etymology is in itself very interesting: "philo" (love, amateur), "matheme" (science, *cf.* "mathematics"). Philo-Science ("philomathe" or "philomate", it is written in both forms throughout the ages) is the amateur of science.

the Convention suppressed all the Academies in 1793, and they would not find their rightful place until two years later, in the form of "Institutes". The role played by Jean-Paul Marat, politician and scientist, was important as regards the elimination of the Academies (see boxed text). During this period, the Philo-Science Society replaced the Academy of Sciences, reuniting the same members and carrying on with the presentation of scientific works.

The Journal appeared under various names as of 1791: *Journal of the Philo-Science Society and its Correspondents* (from 1791 to 1797), *Journal of Sciences* (from 1797 to 1807, and from 1814 to 1824), *The New Journal of Sciences* (from 1807 to 1814, and from 1825 to 1835). One of the peculiarities of the Journal was to report what was said in the sessions of the Academy of Sciences because, up until 1835, there were no minutes of its works. The creation in 1835 of *The Minutes of the Academy of Sciences* by lifelong secretary Arago would finally translate into the publishing of the *Journal of Sciences*. In any event, the tradition of bringing knowledge to a wide audience by publishing in real time the contents of the sessions of the Academy of Sciences will persist, for example, in the *Journal of Debates*, in which Léon Foucault, a renowned "scientific journalist", wrote a chronicle in which he popularized the work of the Academy.

Marat and the Suppression of the Academies in 1793

Marat, the revolutionary, is well-known; Marat, the man of science, far less so. And for different reasons. Even if the suppression of the Academies was voted and approved in August of 1793, a month after Marat was murdered on July 13, it is unquestionable that he played an essential part in the conception and preparation of said decision.

Because, before the Revolution, Marat was a physician and – in a manner – a scientist; he had already participated in heated arguments with the Academy and, more particularly, with its leader, Lavoisier.

Always a virulent man, and a conflictive one, he believed he had made important discoveries concerning the theory of electricity and challenged Newton's optical theories. Current academician Jean-Pierre Poirier analyzed Marat's works in the following manner[3]:

3. *Marat, homme de science (Marat, Man of Science)*, J. Bernard, J.F. Lemaire, J.P. Poirier, Les Empêcheurs de penser en rond, 1993.

His manner of constantly questioning the most admired works can be interpreted more as a character trait than a scientific approach. By taking the opposite view of modern theories and, like all scientists who have not succeeded, presenting himself as a victim of the bigwigs.

In 1791, Marat published a small epistolary, *The Modern Charlatans*. In a vulgate well-known throughout time, and up to our days, he confronts the "isolated scientists", the only ones worth anything, with the Academicians, "fattened by the Government, lauded by the trumpets of fame". He addresses the reader in the curious epistolary style of an essay (letter III):

One must be astonished by this legion of scientists that the Government maintains at great expense, and by the limited progress that the sciences make.

According to him, the Academicians are like "children that make our ministers and kings proud". What he wrote concerning Lavoisier and Condorcet (both of whom died during the Terror of 1794, one on the guillotine and the second found dead in his cell) cannot but make us shiver in retrospect.

***Figure 3 :* Portrait of Marat (1743-1793) by Claessens** *(public domain image, Library of Congress collection)*

LIGHTNING AND THUNDER, "LIGHT & SOUND"

As of always, the phenomenon of lightning has fascinated humankind. And among others, scientists as well: studying this phenomenon may not have led to great discoveries, but it has resulted in great scientific intuitions. Several observations have been made during a storm, most notably:

- The luminous path of the lightning bolt, as seen outlined in the sky.

- The time delay between the observation of the lightning bolt and hearing the thunderclap.
- The duration of the thunderclap, in contradiction to the brevity of the light (a phenomenon explained by Coriolis in the *BibNum* text).

Concerning the first point, Galileo, in his *Two New Sciences* (1638), inferred the non-instant propagation of light as he observed a lightning bolt[4]:

> *We can make out the beginning* [...] *at a determined point between the clouds, before it propagates immediately afterward into the surroundings.*
>
> *Its movement occupies a certain time because, if illumination was instant and not progressive, I do not believe we would be able to distinguish its origin* [...] *from the extreme points of its expansion.*

***Figure 4 : Lightning bolt between clouds** (left);*
***lightning bolt clouds-ground** (right).*

In relation to the second point, we are aware of the delay between the speed transmission of sound and that of light, a million times faster. Therefore, we hear the beginning of the thunderclap seconds after seeing the lightning bolt: it is also an empirical manner of knowing the distance at which a storm is located, if it is approaching or moving away, as we count the seconds between the lightning bolt and the thunderclap; in this manner, if we count 9 seconds, the storm is about 3 kilometers away (9s $\times$ 340 m/s = near 3 kms).

As regards the third point, this is the subject of Coriolis' text.

4. As quoted by Jean Eisenstaedt, *Before Einstein. Relativity, Light, Gravitation (Avant Einstein, Relativité, lumière, gravitation)*, Seuil Science Ouverte, 2005.

The Noise of Thunder

Underline Attested Date

Coriolis does not in any way pretend to be the first to give an explanation for thunder's noise, as he says:

> *This explanation has already been put forward by several people, it is pointed out in Robinson's Physics, and M. Gay-Lussac speaks of it in his classes.*

We could also mention Monge, who put forward his Theory of Thunder in 1794. On another hand, Coriolis does not fail to date his observation: the *Journal* explains that "the idea came to him in 1815" (so, eighteen years earlier) and that "he discussed it with several persons over time". A subtle and elegant way of assuring the precedence of the idea.

The Sound Barrier

Following is an explanation of the cause itself of noise:

> *The force with which air is moved by electricity, and that with which it immediately replaces the void left by the flow, are sufficient to cause a strong detonation.*

This explanation was given by Monge several years earlier. We will not linger over outdated terms ("the electrical flow"), but we should note that this explanation is valid: when the air is displaced by a speed higher than that of sound, a shockwave and a detonation are created. This is the "breaking of the sound barrier", similar to the bang emitted by a supersonic plane or the crack of a whip.

The Length of a Thunderclap

However, it is at this point, in the last and lengthiest part of the text, that things get interesting. Just as Galileo, via Salviati, had pondered the visual path of the lightning bolt, Coriolis wonders about the sound path of the thunderclap. He asks himself why the rumble of thunder is prolonged in time – while the lightning bolt, the cause of the same, is practically instantaneous.

> *We must represent the lightning bolt as a series of points that form an irregular and even angular line in which all the points produce, at the same time, detonations of varying intensity. If all the points are at distances from the ear that do not differ significantly as regards the speed of sound, the lightning bolt will appear, to the observer, as one sole detonation; but, if the distances between all these points in relation to where the observer is placed, to the contrary, vary significantly as*

concerns the speed of sound, they translate into different time lapses, that is to say, that the detonations produced at the same time at different points arrive successively to the ear, breaking up the phenomenon to the observer.

In a manner that is easily comprehensible, Coriolis thus links the angular shape of the lightning bolt to the time lapses and the distance between the observer and the friction points propagating the lightning bolt.

To start with, we must point out that any part of the lightning bolt's path that remains roughly perpendicular to the radius vector starting at the observer will produce a strong detonation because, if all the points of that portion of the line are at the same distance from the observer, the shock waves that initiate at those points on the path will contribute their noises at the same time to the ear and, as the sound waves will be superimposed on each other, they will become larger and their effect on the ear will be that of a loud detonation, such as a cannon shot. On the contrary, the part of the lightning bolt's path that moves along the same path as the radius vector departing from the observer will produce a ripping sound to the ear, because the shock waves emanating from the different path points can only arrive at the ear successively.

So, when a lightning bolt strikes vertically (or to be more precise, perpendicularly to the line linking the observer to the lightning bolt's path), the noise is loud and almost instantaneous. However, when it strikes obliquely in the sky, whether it is approaching or growing further away, the detonation will last longer.

CONCLUSION

Even if it cannot be considered a scientific result in itself, this text edifies us about one way of propagating scientific knowledge in France in the XIXth century. In fact, this communication by Coriolis was judged sufficiently innovative to be published the next year in the work *Archives des Découvertes et inventions nouvelles faites dans les Sciences les Arts et les Manufactures tant en France que dans les Pays étrangers pendant l'année 1833 (Archives of Discoveries and New Inventions carried out in the Sciences of Art and Manufacturing in France and Abroad in 1833)*: and this is the kind of work that contributed to the spreading of scientific culture at the time.

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(May 2009)

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