



**Acoustics'08  
Paris**  
June 29-July 4, 2008  
[www.acoustics08-paris.org](http://www.acoustics08-paris.org)

## The marvellous sound world in the '*Phonurgia Nova*' of Athanasius Kircher

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Athanasius Kircher, a Jesuit, was born in Geisa, Thüringen, in 1608. He spent a large part of his life in Rome, where he died in 1680. He was active in many different topics, ranging from geology to philosophy. He was the author of many books, among them the *Musurgia Universalis*, written in 1650, and the *Phonurgia Nova*, of 1673. Whilst the *Musurgia Universalis* has gathered wide attention, his *Phonurgia Nova*, which means “a new method of sound production”, has only recently been rediscovered. In this paper the original Latin version of the *Phonurgia Nova*, which comprises two different books, i.e. the “*Phonosophia nova*” and the “*Phonosophia anacamptica*”, is analyzed. The first book deals with the influence of music on human beings, whereas the second book analyses sound propagation in enclosed spaces. This book reveals some interesting acoustic apparatuses for sound production and propagation, such as the “*tuba stentorophonica*” (the “loud trumpet”), and the “*statua citofonica*” (the “talking statue”). Some of these phonic apparatuses are described, analyzed and commented on.

## 1 Introduction

The literary production of Athanasius Kircher is vast, spanning almost every branch of knowledge. The title of the literary work here analysed, contains the neologism “*Phonurgia*” [1], meaning “New modality of the sound production”. This treatise was written during the dispute with the contemporary English engineer Samuel Morland [2], who claimed responsibility for the invention of the *tuba stentorophonica*, a “trumpet with a strong sound”: this musical instrument aroused great interest among many contemporary scientists, due to its incredible sound emission potential. Kircher declared that he was the first to have invented it. He provided the evidence for this claim in his previous work, the *Musurgia Universalis* [3], written twenty years before, in which the ‘tuba’ had been already described. Besides the polemical intention, in the *Phonurgia* Kircher wished to enrich and widen the knowledge already existing in the field of musical acoustics. The *Phonurgia* was written in Latin, and only a few studies about it still exist. It is characterised by an original mixture of Baroque sound and aesthetics, which could be called “the *meraviglia*”.

After an initial humanistic subordination from classical sources, in the last decades of the 16<sup>th</sup> Century the growing scientific revolution imposed a radical turning point: the rediscovery of the conic section and the study of the burning glasses of Archimede, the study of sound propagation moved from an undulatory approach to a ray-tracing approach, as related to light.

The Venetian Ausonio began the geometrical approach to acoustics, soon followed by Giovanni Battista Della Porta (who wrote the *Magia naturalis*, Napoli, 1589) and by Giuseppe Biancani (author of a *Sphaera mundi*, Bologna, 1635), with consequently first attempted to focus on sound and to modify the musical scale. The first mathematic development along such lines was due to Bonaventura Cavalieri (*De speculo utorio*, Bologna, 1632), who was the first to affirm that (..for the sound, instead of to rays of light) during the design, it is necessary to take into account a phenomenon, called, in the optical field, “diffraction”.

The study of the musical world, based on exact laws of physics, has interested a large part of eighteenth-century culture. Kircher, for his part, revealed a logic-rational approach towards any occurrence of musical phenomenon.

In chapter one of the first book of *Phonurgia nova*, Kircher tackles the problem of the nature of sound: it is

defined as a sensitive phenomenon, which is perceptible by hearing: it is a movement of bodies, which are in contact with each other by means of a portion of air interposed among them. For the Jesuit, therefore, the movement of bodies was the fundamental presupposition of every acoustic manifestation.

Kircher’s definition of sound is based on Aristotle and Boezio. Aristotle defined sound as “a determined movement from two bodies, which crash one against the other” (*Musurgia Universalis*); Boezio, similarly, believed that the sound was a movement, which broke up the air and afterwards reached the ear.

For Kircher, however, the sound was not simply a physical phenomenon, as it was for the two aforementioned authors, but also something that was deeply connected with human nature. Kircher’s conception of sound was not yet influenced by the modern theory of oscillations, which was formulated later thanks to the researches of Galilei and Newton, but it already considered the deep relationship between the number of the oscillations (frequency) and the pitch of the sound.

The *Phonurgia nova* is subdivided in two books. The *Phonosophia nova* represents the more anthropological part: here Kircher analysed the causes of influence of music on the human mind, inclined towards various types of “affections”. He also developed the idea that the art of sound making can be used effectively for therapeutic purposes. A remarkable case is the “*tarantolati*”, a special kind of mad people, which could heal, thanks to the execution of particular types of melodies and rhythms.

In the *Phonosophia anacamptica*, Kircher was extensively interested in the prodigious phenomenon of echo, which he considered as founded on sound waves, which, after having hit some *obiecta phonocamptica*, or “obstacles”, they propagated in the air or in the water and therefore producing reverberation. In the same book, he deals with sound which propagates in tubes of various shapes and typologies, of sound strengthened in natural caves re-emerging at the surface with increased force, about how to listen to other people’s conversations while remaining in a concealed room, with the aid of tubes and hidden devices, and how to exchange coded messages by the use of special trumpets.

Finally, Kircher accurately described amazing cars and contraptions, that he himself had often invented, in order to astonish and amaze people: speaking statues, channels in which sounds and noises were spread, musical instruments with internal mechanisms that generated unexpected harmonies, playing by themselves depending on the direction of the wind.

## 2 The mechanics of the magnificent

Kircher's works express the typical Baroque vision of the "marvellous world". All the machines that he invented reveal the strong alliance between science and magic. He wished to amaze, to convince people of improbable things and, finally, to explain the arcane that lies between hermetism and exact science. From the point of view of the traditional history of science, the inventions of the German Jesuit remained a provocative source of perplexity. Such inventions could hardly be included into "experimental science". Nevertheless, at that time, Kircher's museum benefited greatest splendour. The Kircherian inventions and all the items collected in his museum reveal his audience was strictly selected. The marvellous items that he conserved in the museum belonged to a large variety of branches of learning, from mechanics to metallurgy, distillation to cosmetics, and magnetism to aerology.

## 3 Sound Entertainments for the Aristocracy

### 3.1 The talking statue

Among all the machines of Kircher's creation, in the XI charter of the first Book, there is the description of a strange and curious mechanics invention, the "talking statue".

Kircher's talking statue caused a great amount of discussion: some people, following principles of studies on occult sciences, believed that the statue could have been realized with no problem. They declared that Alberto Magno built a man's head, which could perfectly pronounce articulate sounds. Moreover, Kircher declared that he had already fully demonstrated in his work, *Oedipus Aegyptiacus*, that the Egyptians had also built some statues that were able to speak. Nevertheless, many people asserted that this idea was in contrast with natural laws, and they affirmed that a similar device was never realized. Moreover, they affirmed that the machines of Alberto Magno and the Egyptians were counterfeit, or at least built with the help of evil spirits, as well as divinities that gave responses through speaking oracles and statues.

Other people, instead, considered feasible a statue with the capacity to pronounce some articulated sounds: following the examples in nature, it is possible to build a larynx, a tongue, and other phonetic organs, capable of producing the clear effect of an articulate voice, when animated with the wind.

However, Kircher didn't want to argue about the famous head of Alberto Magno or ancient Egyptian devices, because he thought they were impossible in themselves. Therefore he provided an alternative construction method for a similar statue, able not only to pronounce articulate sounds, but even to sing, reply to any solicitations, and to reproduce animal cries.

The text of *Phonurgia* relevant to figure 1(above) says:

«Inside a room ABCD, where a spiral-shaped tube (*cocleato*) was put and moved in E or in the vertical conduit S, lies a statue having moving mouth and eyes and having breathing life through the entire mass of the body. This statue must be located in a given place, in order to allow the end section of the spiral-shaped tube to precisely correspond to the opening of the mouth. In this manner it will be perfect, and capable to emit clearly any kind of sound: in fact the statue will be able to speak continuously, uttering in either a human or animal voice: it will laugh or sneer; it will seem to really cry or moan; sometimes with great astonishment it will strongly blow. If the opening of the spiral-shaped tube is located in correspondence to an open public space, all human words pronounced, focused in the conduit, would be replayed through the mouth of the statue: if it is a dogs bark, the statue will bark, if someone sings, the statue will answer with singing and so on. If the wind blows, this will be taken into the spiral-shaped tube; therefore the statue will be forced to emit very strong breaths. Applying the breath to a pipe, it will play. Bringing the trumpet near to mouth of the statue, the musical instrument will play and it will make innumerable fun effects of this kind, provided that the spiral-shaped tube is disposed with the greatest of attention».

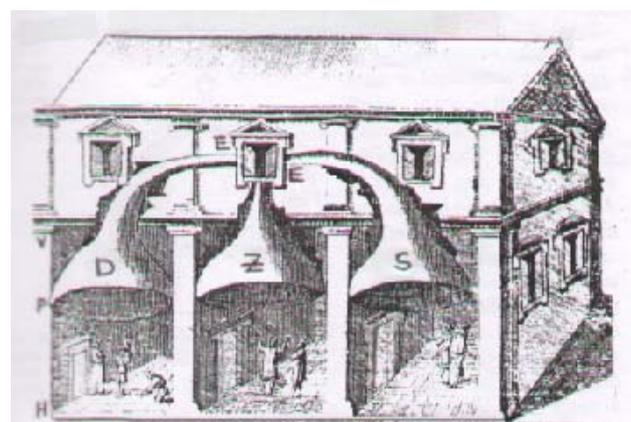
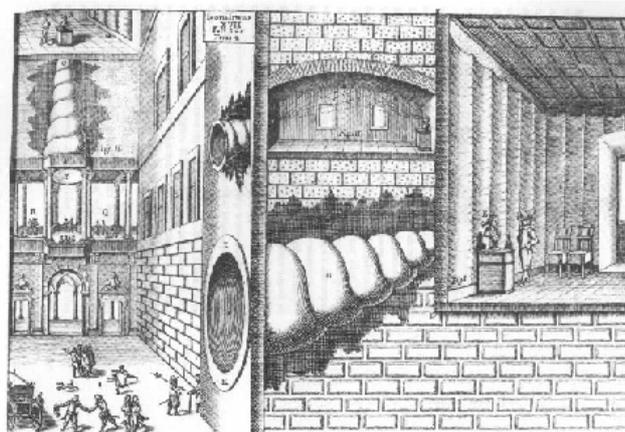


Fig.1 The talking statue and the spiral-shaped tube (*cocleato*) towards the square (above). A device to

Analysing figure 1, the section of the conduit becomes narrower from the outside towards the inside, and therefore the air velocity increases to a considerable degree from left to right, inducing the talking effect in the statue. The acoustic mechanism which made the statue talk is substantially a microphone, which Kircher designed

as a huge spiral-shaped tube, having the inner surface perfectly dressed to reflect the waveforms. It was therefore able to convey the sound from outside into the room.

In the vertical version, it seems to recall Borromini's lantern of S. Ivo to the Sapienza, even if the inspiration for Kircher were in the "Grotta di Dionigi" in Syracuse. Giorgio de Sepi [4], who wrote the first catalogue of Kircher's museum, described this talking statue. «Kircher, in the laboratory of his room, has realized such a tube that the concierges can call him at the entrance, avoiding to go to his far apartment, but they can stop and call him with a usual voice from the garden».

### 3.2 "Sonorous voyeurism"

Kircher reserved a whole chapter of his *Phonurgia Nova* to describe many gorgeous architectonic devices, appositely developed for worthy nobles, who should have read, or heard, about his work. All these devices are fully illustrated and described. Moreover, Kircher provided a lot of technical information about their realisation.

The *delectationes* were developed particularly to amplify the voices inside places, to call at a distance, to send music to different rooms, to eavesdrop. Kircher's first described invention is regarding the singular location of certain palatial royal chambers, where every word, also whisper, could be heard distinctly, not only in the same space, but also in other rooms. Kircher, after having underlined that the conduits had a tubular or lengthened shape, which were inserted into walls as suitable for directing sound, gave an indication about how to realize the building (Fig. 1, below). Three receivers D, Z, S, have exactly the same common origin E, corresponding to the window on the floor above (see the drawing in section). Inside the room, where the tube (D) captured and channelled the conversation, (i.e. the "D room"), there was a short and narrow door, which, in case of necessity, had to be closed hermetically, in addition to a window with glasses of a crystalline thickness. The same tricks had to characterize the Z and S rooms. In this way, the sound emitted in one of the rooms, being not able to come out either by the door nor by the window, which were accurately closed, had necessarily to go toward DE, ZE, SE conducts and, through secret conduits, until reaching the people who were on the floor above. This device, if realised inside a huge building, following the indications of Kircher, could be feasible and functional.

### 3.3 Heidelberg's echo

In Section IV of the first Book of the *Phonurgia nova*, Kircher described the interior structure of the Palace of the powerful Elector of Heidelberg, which he personally visited.

Inside the palace, there was a particular room characterized by an extraordinary echo: with reference to figure 2 (up), inside the circumference CEF, nothing could be pronounced in a low voice that could be perceived by any other person, who was at positions F or

G. The same phenomenon, besides, can be compared with the cupola of the Basilica of S. Peter in Rome.

This room in the palace of Heidelberg, due to its circular shape, possessed a remarkable capacity to amplify sounds, especially due to the vaulted ceiling, which contributed to the surprising acoustic effect. However, Kircher analysed in particular the floor of the room, and he presumed that the type of material utilised could contribute to the special acoustic effect. At that time, the so-called "pavement in Venetian style" became very fashionable and extensively used in many palaces. This pavement, still existing in ancient palaces, is a mixture of mortar and stones; the pavement, besides pleasant aesthetic effect, once trampled, produces a singular sonorous effect that Kircher emphatically compared to a thundering crowd in threatening pursuit.

### 3.4 The elliptical room

Kircher demonstrated his knowledge that the geometric shape of the room would influence acoustic behaviour. One of Kircher's most interesting studies regarded the elliptical shape of ceilings and the capability of this peculiar geometric shape to reinforce the voices better than any other. Kircher understood that the ellipse, which is provided with two focuses, could be used for the construction of a room with an ellipsoidal vault, where it was possible to use the focus of the ellipse to set two people who could communicate with each other (Fig. 2, below).

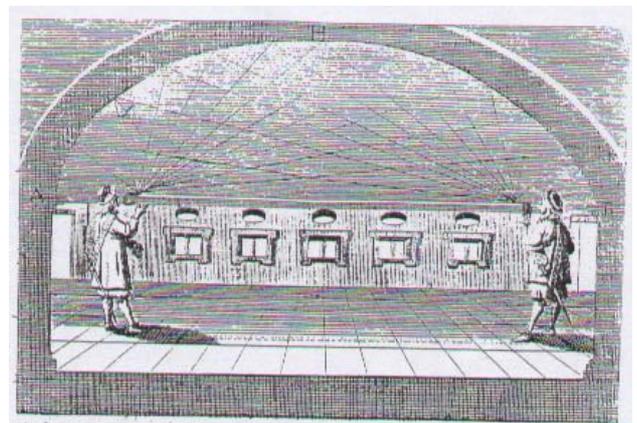
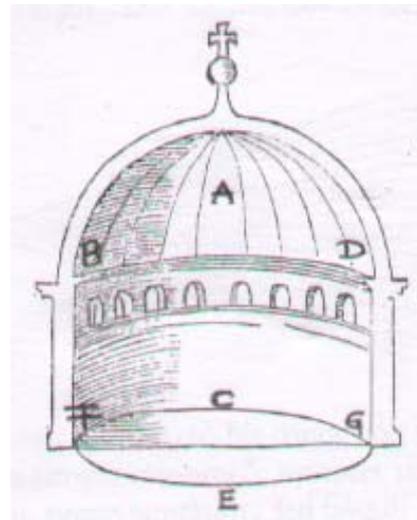


Fig.2 Heidelberg's echo (above) and the elliptical room (below).

Kircher's intuition and his consequent observations were, of course, correct. In the ellipse every straight line outgoing from a focus will be directed to the other focus, and this concentration of sounds at a point is as greater as the surfaces of the room are reflecting. [Consider rewording, the sense is lost here] In such case the property of restitution of the sound are effectively surprising.

In order to strengthen his observation, Kircher also suggested the surfaces of the inner walls of the ellipsoidal vault should be rendered clean with a mixture of water and Arabic rubber to optimize the acoustic effect.

## 4 Sound Architecture

Section IV of the first Book of the *Phonurgia nova* also illustrates typologies and modalities of realizing buildings together with sound architecture, and the description of particularly interesting places, according to Kircher, from the point of view of their acoustic potentialities. Some of these places still exist today, and they have been famous since antiquity. In these cases, Kircher tried to comprehend the recondite modality of the production of particular sonorous effects or to explain their inner architecture. However, there are a few places with detailed descriptions and the modalities of their realisation that are pure inventions of the Jesuit, meant to entertain, delight and provoke the curiosity of the contemporary wealthy nobility.

### 4.1 Villa Simonetta

The description of Villa Simonetta, "just outside the Door of the gardeners" to Milan, was of particular interest. The Governor of the city at that time, Ferdinando Gonzaga, built the villa. It is more famous, says the Jesuit, for its echoes, rather than for the extraordinary and admirable architectonic symmetry of the complex, which characterized the villa. On the first floor of the building there is a window (Fig. 3, up) where every word pronounced there projects reinvigorated in intensity and echoed four-fold. Moreover, if the words are pronounced with a stentorian voice, they are multiplied so many times they can be heard almost infinitely. Kircher, having heard from many people about the singular acoustic phenomenon in the villa, decided to find the reasons, and therefore satisfy his own desire. He declared that P. Matteo Storr, a faithful and erudite clergyman of the Company of Jesus, already observed and diligently annotated the dimensions of the building and its architectural details.

The complex of Villa Simonetta consists of three parts, which spread on three sides around a great courtyard opened on the back towards a luxuriant garden. The façade is made of two porticoes supplied with ten columns on each floor.

The building has two floors, which are separated by an ambulatory. On the ground floor, stones pave the zone indicated with the letter K, in figure 3. Laterally and parallel, are the other two blocks named XMVN and GFHL respectively. After having accurately described the measurements (height, length and width), of the three

zones where the dwelling is divided, Kircher then moves his attention to the window where the famous echo is produced.

Some witnesses reported to Kircher that in this location the voice emitted is multiplied by 24 or even 30 times, according to its pitch. The Jesuit identified the cause of this as due to the proportional distance between the two parallel areas of the building, and in their perfect equality and absence of roughness, on each surface; Furthermore, he demonstrates, with the help of a drawing, this thesis (Fig. 4). Let us consider the walls AC and BD, which correspond to the two parallels zones of Villa Simonetta; they are placed at a distance where it is possible to perceive, by means of the echo, two-syllables word.

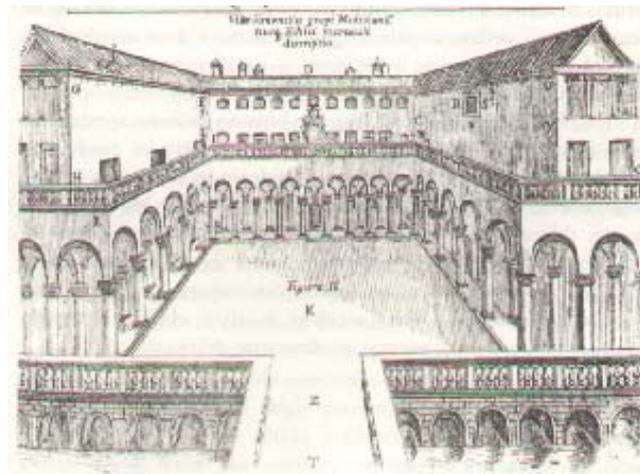


Fig.3 The Villa Simonetta in Milan.

Pronouncing a generic word from the window (E), it will be reflected, due to the echo, from E to I, from I to E, and again from E to I for an almost infinite time, until it will be extinguished, once its intensity has finished. The sound behaves similarly to a ball, if launched between two walls, bounces from one wall to the other, and, after more or less six bounces, it stops. This happens when the angle of incidence is equal to the angle of reflection. The same phenomenon occurs when the voice comes from a cistern or well. As shown in figure 5, considering that ABCD is a well and DEB the water contained inside, I the opening made on the cover and CA the top of the well, it is possible to verify that a sound emitted at the position I turns down with a singular harmony.

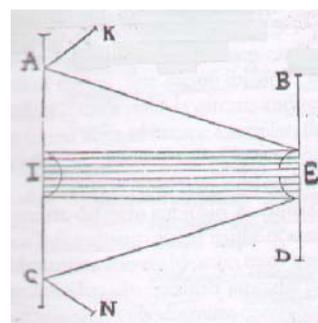


Fig.4 Demonstration of echoes in Villa Simonetta

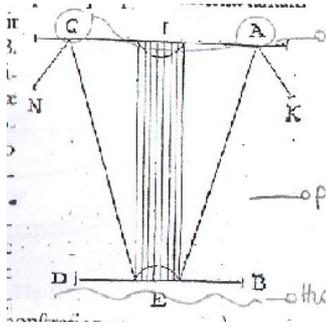


Fig.5 Demonstration of echoes in a well

With the treatment of echo in the *Phonurgia*, Kircher made a remarkable contribution in feeding the curiosity and interest surrounding the Villa Simonetta, the history of which is long and troubled. Some people prefer evocatively to call it the "Villa of the echo", following a popular tradition, that Kircher has certainly contributed to establish.

Nowadays Villa Simonetta is an important cultural centre, which organises concerts and courses.

## 5 Conclusions

The complex symbolic universe of Kircher most expressly emerges in his machines. By appearance alone, they are easy games, but they open the mind to questions, and create surprises out of their simplicity.

It is a continuous playing, in the *Phonurgia*, among several planes: playful, religious, mystical, esoteric and scientific. Every theorem is described with the rigor of a geometric demonstration - hypothesis, corollary, explanatory images, solutions - but Kircher does not wish simply to extract data, but focuses on an element to formulate a law, transcribed with mathematical and geometric certainty the repeatability of a phenomenon.

The illusions induced from Kircherian devices provide evidence of the inadequacy of the human mind compared with the mysteries of nature. But still they give a great vision of the recent world that is far away from our 21<sup>st</sup> Century.

## Acknowledgments

The authors express their acknowledgment to Galia Mastromatteo, who considerably contributed to the translation from Latin of the *Phonurgia nova*, to Paolo Gozza who gave precious suggestion about Kircher, and to David J. Knight, who carefully gave his help during English proof.

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