

ATHANASII KIRCHERI
E SOC. JESU.

PHONURGIA NOVA

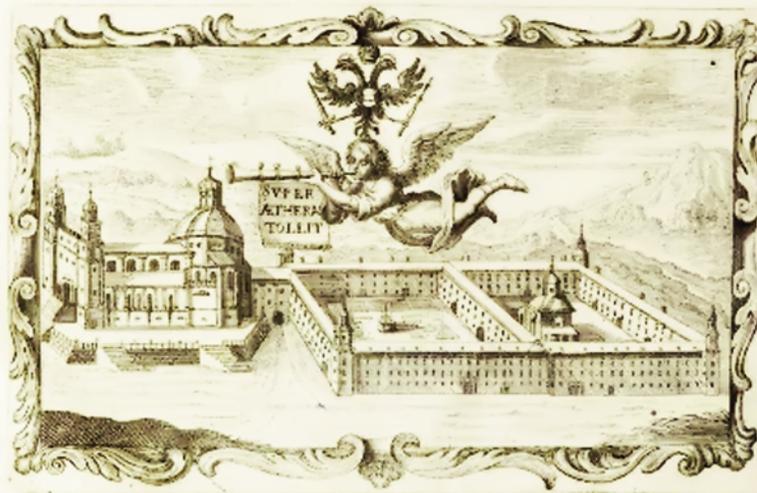
SIVE

Conjugium Mechanico-physicum
ARTIS & NATURÆ
PARANYMPHA PHONOSOPHIA

Concinnatum;

quâ

*UNIVERSA SONORUM NATURA, PROPRIETAS, VIRES
effectuumq; prodigiosorum Cause, novâ & multiplici experimentorum exhibitione enu-
cleantur; Instrumentorum Acusticorum, Machinarumq; ad Naturæ prototypum
adaptandarum, tum ad sonos ad remotissima spatia propagandos, tum in abditis domo-
rum recessibus per occultioris ingenii machinamenta clam palamve sermo-
cinandi modus & ratio traditur, tum denique in Bellorum tumul-
tibus singularis hujusmodi Organorum Usus, & praxis
per novam Phonologiam describitur.*



CAMPIDONÆ

Per RUDOLPHUM DREHERR. ANNO M. DC. LXXIII.

ATHANASIUS KIRCHER'S *PHONURGIA NOVA*: THE MARVELOUS WORLD OF SOUND DURING THE 17TH CENTURY

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Athanasius Kircher

Athanasius Kircher (Geisa, Germany; 2 May 1602– Rome, Italy; 27 November 1680) became a Jesuit in 1628 in Mainz, Germany (Fig. 1). He taught in Würzburg, Germany in 1629 and in Avignon, France in 1631. Afterwards, in 1633, he was invited to Vienna, Austria to take up Kepler's former post as Mathematician at the Court of Ferdinand II. However, during his journey across Northern Italy, Pope Urbano VIII (Barberini) called Kircher to Rome, where he moved and is known to have taught Mathematics and Hebrew at the Collegium Romanum (Fig. 2). After eight years, he was released from teaching, and he

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focused exclusively on studying hieroglyphs. At this time he began to collect many items from all over the world, and in 1651 founded his Kircherian Museum.

At his time he was considered a *homo universalis*, since he studied many different topics starting from a single point of view. He studied geology (volcanoes), medicine (he understood that plague is caused by germs and he was the first to use the microscope), history (he invented a theory for translating the Egyptian hieroglyphs using Coptic manuscripts) anthro-

pology, astronomy, mathematics, magnetism, optics, mineralogy, exploration, archaeology and many other various topics.



Fig. 1. Athanasius Kircher in 1664, at the age of 62.



Fig. 2. The Roman College in the 17th Century.

As a typical Baroque academic, Kircher used astrology and trusted the existence of griffins and sirens while at the same time debating against the followers of Christian Rosenkreutz (1378–1484), the Rosicrucians. Kircher's intellectual contemporaries such as Boyle and Newton likewise trusted in alchemy, but whereas these names are celebrated in the history of science, Athanasius Kircher's name is not. His works were considered too much a patchwork of both fantastical and scientific worlds, and despite writing to more than 760 people, including two Emperors of the Holy Roman Empire and scientists such as Leibniz, Torricelli, and Gassendi. Kircher, *doctor centium atrium*, was completely ignored in



Fig. 3. The Kircherian Museum.

the *Dictionnaire historique et critique* of Pierre Bayle (1647–1706) and the *Encyclopédie* of Diderot and D’Alembert and in all the other encyclopedic works written during the Enlightenment.

Kircher’s *Phonurgia nova*

The literary production of Athanasius Kircher is vast, spanning almost every branch of knowledge, including the theory of music. The title of the literary work analyzed in this article contains the neologism, *Phonurgia*,¹ a compound of the Greek words *φωνή* (sound) and *ἔργον* (work, energy). The Latin word *nova* (the entire book was written in Latin) is added, and the title translates as *New Modality of Sound Production*. In the *Explicatio terminorum* (explanatory words) on the last page of the *Phonurgia nova*, Kircher himself defines “*Phonurgia* as *Facultas mirabilium per sonos operatrix*,” meaning “capability to provoke the marvelous by means of sounds.”

This treatise was written during the dispute with the contemporary English engineer Samuel Morland,² who claimed responsibility for the invention of the tuba stentoronica, 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 and provided the evidence for this claim in his *Musurgia*

Universalis,³ written twenty years previously. In this work he had already described the “tuba.” Besides, the polemical intention of Kircher’s *Phonurgia nova* expresses a wish to enrich and widen already existing knowledge in the field of room and musical acoustics. The *Phonurgia nova* is an original mixture of Baroque aesthetics and sonic enquiry that could be called in Italian, “meraviglia,” or in English, “wonder,” and yet only a few studies of this fascinating work exist.

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

The Venetian Ettore Ausonio began the geometric 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), focusing on sound and modifying the musical scale. The first mathematic development along such lines was due to Bonaventura Cavalieri (*De speculo uestorio*, 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, interested a large section of eighteenth-century science and culture. Kircher, for his part, revealed a logical, 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 that is perceived by hearing. It is a movement of bodies that 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 Boethius. Aristotle defined sound as “a determined movement from two bodies that crash one against the other” (*Musurgia Universalis*); Boethius, similarly, believed that the sound was a movement that broke the air up and afterwards reached the ear.

For Kircher, however, 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* is the more anthropological: in which Kircher analysed the influences of music on the human mind, inclined towards various types of “affections.” He also developed the concept that the art of sound making can be used effectively for therapeutic purposes. A remarkable example of this is the “tarantolati,” people who were bitten by

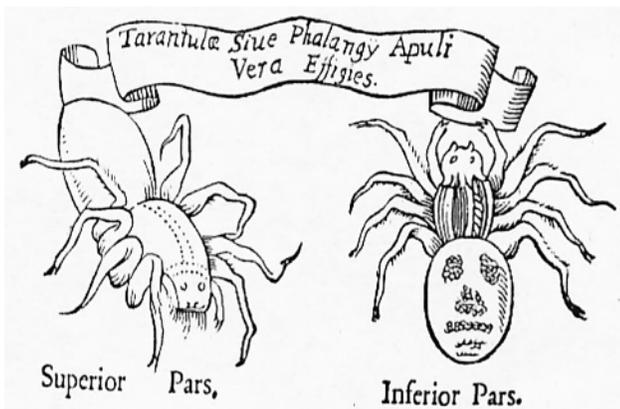


Fig. 4. The tarantula (*Lycosa tarentula*).

the tarantula (Fig. 4), a poisonous spider native to the Apulia Region in Italy (*Aranea Apula...arachneum animal nocentissimum*) that during 17th Century was considered very dangerous. The “tarantolati” (Fig. 5) were considered to be insane because they danced continuously without stopping, and looked like people dancing on a fire, jumping continuously, nervously. They could apparently be healed, thanks to the performance of a particular type of melody and rhythm (*antidotum tarantulae*).

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

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

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 hermeticism and exact science. From the point of view of the traditional history of science, the inventions of this German Jesuit remained a provocative source of perplexity. Such inventions could hardly be included into “experimental science.” Nevertheless, at that time, the Kircherian Museum (see Fig. 3) was renowned for its great splendour. The Kircherian inventions and other items collected in his museum reveal his audience to be specifically selected. The marvellous exhibits that he conserved and displayed belonged to a large variety of branches of learning, from mechanics to metallurgy, distillation to cosmetics, and magnetism to aerology.



Fig. 5. The “tarantolati.”

Sound entertainment for the aristocracy

The talking statue. Kircher’s talking statue caused a great amount of discussion: some people, following the principles of the occult sciences, believed the statue could have been constructed. They declared that Alberto Magnus built a man’s head that could perfectly pronounce articulate sounds. Moreover, Kircher declared that he had already fully demonstrated in his work, *Oedipus Aegyptiacus*, that the Egyptians had built some statues that were able to speak. Nevertheless, many people asserted this idea was in contrast with natural laws, and they argued that such a device had never been constructed. They declared that the machines of Alberto Magnus and the Egyptians were either fake or built with the help of evil spirits and divinities that gave responses through speaking oracles and statues. Others considered it feasible that a statue could be built with the capacity to pronounce some articulated sounds: following the examples in nature, it would be possible for the wind to animate a mechanical larynx, tongue, and other phonetic organs capable of producing the clear effect of an articulate voice.

However, Kircher did not wish to enter the argument over the famous head of Alberto Magnus 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 nova* relevant to Fig. 6 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 of clearly emitting 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

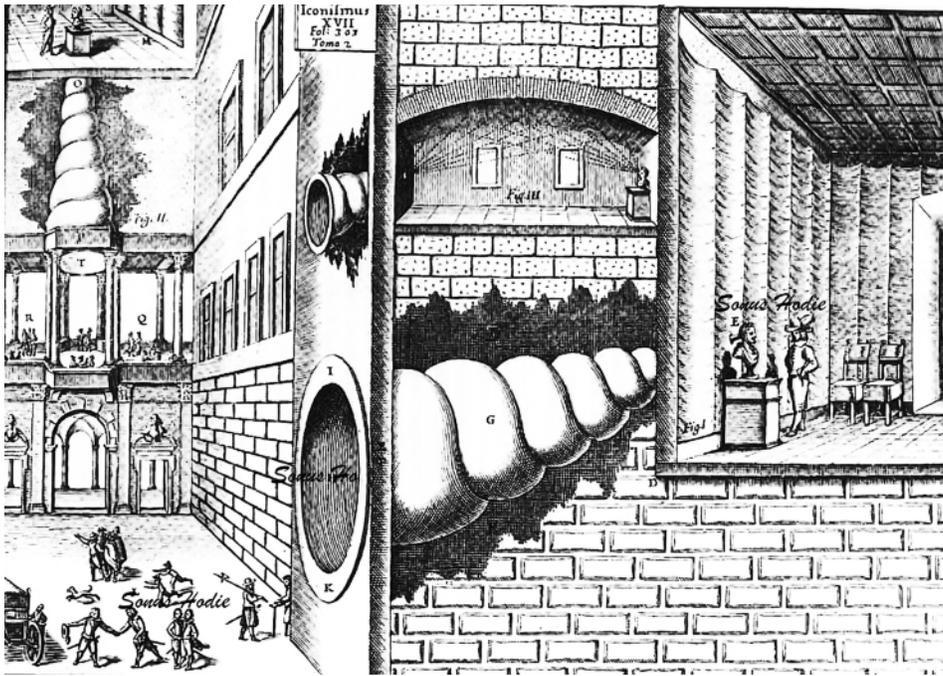


Fig. 6. The talking statues. They would be able to reproduce whispers from the square.

through the mouth of the statue: if it is a dog's 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 and the statue will be forced to emit very strong breaths. Applying the breath to a pipe, it will play. Bringing a trumpet near to the 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."

Analyzing Fig. 6, the section of the conduit becomes narrower from the outside towards the interior, 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 polished to reflect the waveforms. It was therefore able to convey the sound from outside into the room.

In the vertical version, (left side of Fig. 6 and in the back of the square) it seems to recall Borromini's lantern of St. Ivo to the Sapienza, even if the inspiration for Kircher was 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 constructed 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."

Sonorous voyeurism. Kircher devoted an entire chapter of his *Phonurgia nova* to the description of many gorgeous architectonic devices developed for worthy nobles, many of whom would have read, or heard, of his work. All these devices are fully illustrated and provided with extensive technical information about their construction.

The *delectationes* were specifically developed to amplify the voice, to communicate at a distance, to send music to dif-

ferent rooms, and even to eavesdrop. Kircher's first described the invention regarding the singular location of certain palatial royal chambers, in which every spoken or whispered word could be heard distinctly, not only in the same space, but also in other rooms. Having explained that conduits suitable for directing sound and inserted into the walls should have a tubular or lengthened shape, Kircher indicated how to construct the building (Fig. 7).

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 low narrow door, which, in case of

necessity, could be hermetically sealed. In addition there was a window with glass of a crystalline thickness. The same characteristics had to be shared by the rooms Z and S. Sound emitted in one of the rooms, not able to exit by the sealed door nor by the window, was directed toward DE, ZE, SE and conducted through secret conduits, reaching the people on the floor above."

Following Kircher's detailed description, such a device could be feasibly installed and function in a large building.

The "science of the echo"

The first book of the *Phonurgia nova* is called *Phonosophia anacamptica*, i.e., "the science of sound from the perspective of the echo." Performing many experiments, Kircher studied the phenomenon of echo, beginning with its definition given by the Frenchman Marin Mersenne (1588-1648) in his *Harmonie Universelle*. Echo has two different meanings—in the first case *echo* is *imago vocis*—reflected (or repeated) voice. In the second meaning as expressed in Latin is resonance, from the Greek verb *ἤχέω*, (resound). This second meaning of echo is intended as the air in the cavities of a body, as within the Vitruvian vases, or in sound-chests.

The second section of the *Phonosophia anacamptica* is entitled *Architectura echonica*, and describes many experiments Kircher conducted with the phenomenon of echo (see Fig. 8). One of the more interesting experiments is regarding the *obiectum phonocampticum*, which refers to all the objects where the sound or the voice could be reflected, not only from walls and buildings, but also including trees, rivers, and metallic surfaces. During the explanation of his *Echosophia* (the "science of echoes"), Kircher found that air movement causes sound propagation, and wind propagation can influence echo effects as well as weather conditions. This could be considered as one of the most relevant results Kircher achieved in the field of acoustics.

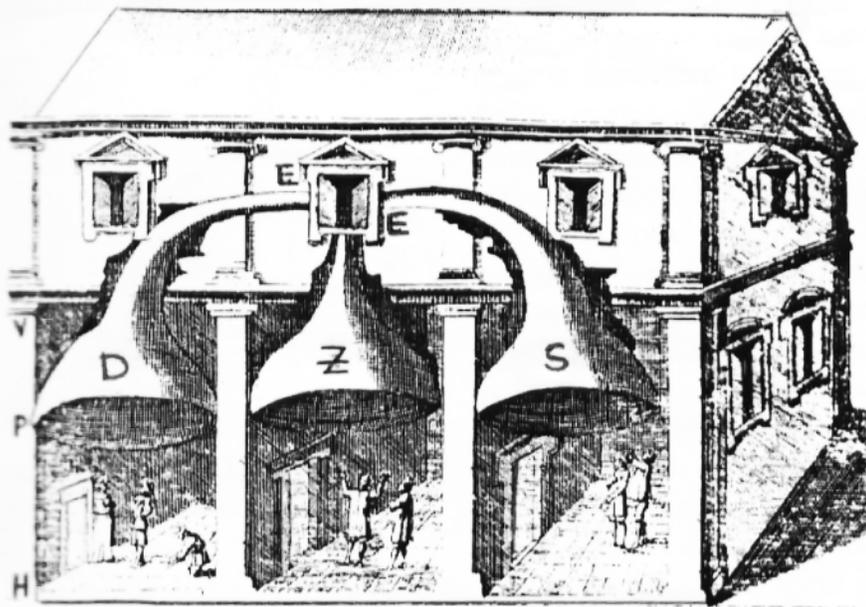


Fig. 7. Amplifiers and conductors of sound.

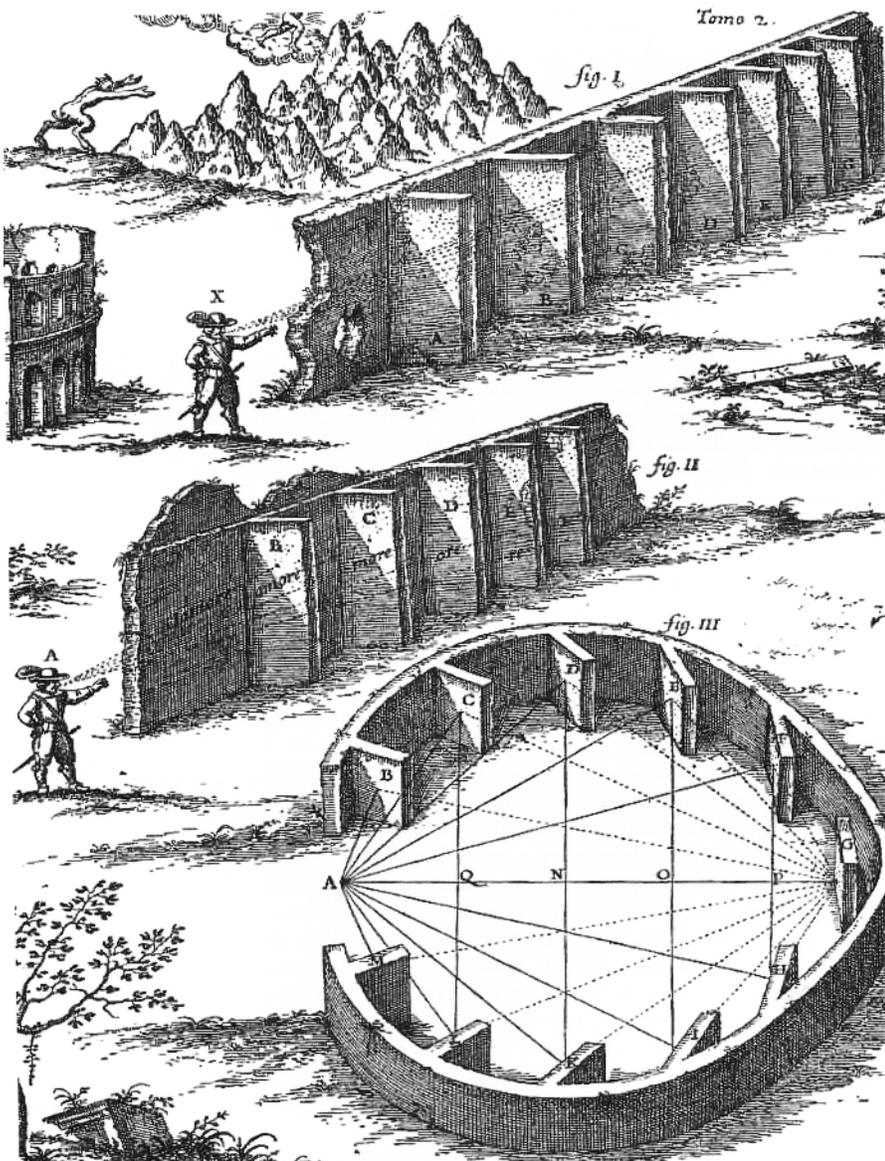


Fig. 8. Experiments with echoes.

Architectural acoustics. Section IV of the first Book of the *Phonurgia nova* also illustrates typologies and modalities of constructing buildings together with architectural acoustics, 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 he describes in detail which are actually pure Kircher inventions, intended to give entertainment, delight and provoke the curiosity of the contemporary wealthy nobility.

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 that he personally visited. Inside the palace, there was a particular room characterized by an extraordinary echo. Within the circumference CGEF (Fig. 9), words spoken in a soft voice at C could be perceived by another person at positions C, G, or F. The same phenomenon is present within the cupola of the Basilica of St. Peter in Rome (the whispering gallery). This room in the palace of Heidelberg possessed a remarkable capacity to amplify sounds, due especially to its circular shape and the vaulted ceiling, which contributed to a surprising acoustic effect. However, Kircher

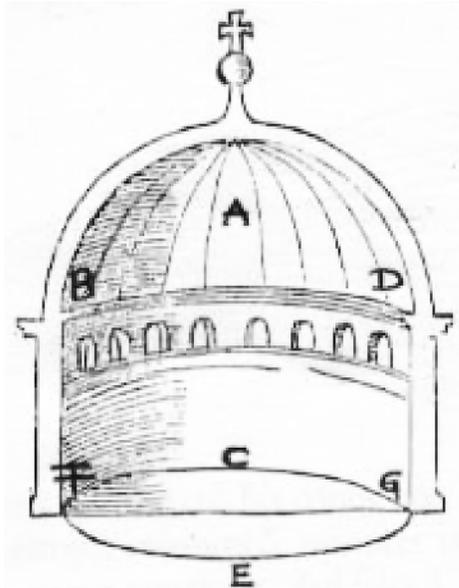


Fig. 9. Heidelberg's echo.

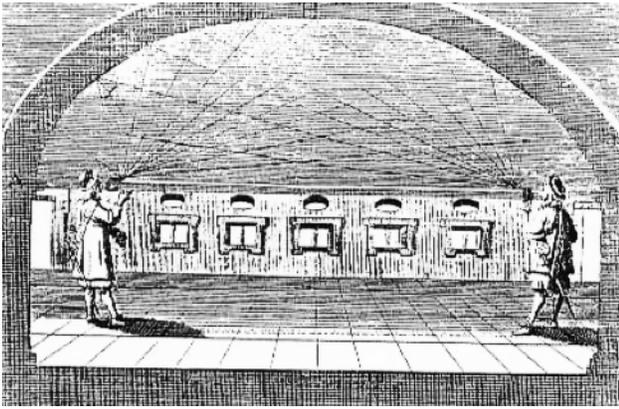


Fig. 10. The elliptical room. As with Heidelberg's echo, Kircher studied the effect of the ceiling shape.

analysed in particular the floor of the room, presuming the material used could contribute to the special acoustic effect. At that time, pavement in the so-called "Venetian style" became fashionable and extensively used in many palaces. This type of pavement, which still exists in several ancient palaces, is a mixture of mortar and stones; besides giving a pleasant aesthetic effect, once trampled, produces a singular sonorous effect Kircher emphatically compared to a thundering crowd rushing in threatening pursuit.

The elliptical room. Kircher demonstrated his knowledge that the geometric shape of rooms would influence acoustic behavior. One of his most interesting studies is regarding the capability of elliptically shaped ceilings to transmit and reinforce the voice better than any other shape. Kircher understood that the ellipse, which has two foci, could be used for the construction of a room. With an ellipsoidal vault it would be possible to use these two foci for two people to communicate easily with each other at a distance (Fig. 10). Kircher's intuition and consequent observations were of course correct. In the ellipse every outgoing straight line from a focus will be directed to the other focus. Moreover, the more reflective the surfaces, the more concentrated are the sounds. In such a case the property of restitution of the sound is effective and surprising. In order to strengthen his observation, Kircher also suggested the surfaces of the inner walls of the ellipsoidal vault should be cleaned with a mixture of water and Arabic rubber to optimise the acoustic effect.

Villa Simonetta. The description of the Villa Simonetta, "just outside the Door of the Gardeners" in Milan, was of particular interest. Ferdinando Gonzaga, the Governor of the city at that time, built the villa and, as Kircher relates, it became more famous for its echoes than for its extraordinary and admirable

architectural symmetry. On the first floor there is a window (Fig. 11) where every word that is uttered projects reinforced in intensity and echoed four-fold. Moreover, if the words are projected 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 discover what caused it, and therefore satisfy his own curiosity. 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 Villa Simonetta complex consists of three parts around a great courtyard opening at the back towards a luxuriant garden. The façade is comprised of two porticoes with ten columns on each floor. The building has two floors separated by an ambulatory. On the ground floor, paving stones comprise the zone indicated by the letter K in Fig. 11. Laterally and parallel to this are the other two blocks, labeled XMVN and GFHL respectively. After having accurately described the measurements (height, length and width) of the three zones divided into dwellings, Kircher then moved his attention to the window where the famous echo is produced.

Some witnesses reported to Kircher that at this location the voice was multiplied 24 to 30 times according to its pitch. Kircher identified the cause of this as the proportional distance between the two parallel areas of the building, and in their perfect equality and absence of surface roughness. Furthermore, he demonstrated this thesis with the aid of a drawing (Fig. 12). Let us consider the walls AC and BD, which correspond to the two parallel zones of the Villa Simonetta; they are placed at a distance where it is possible to perceive, by means of the echo, words with two-syllables.

With the treatment of echo in the *Phonurgia nova*, Kircher made a remarkable contribution to feeding the

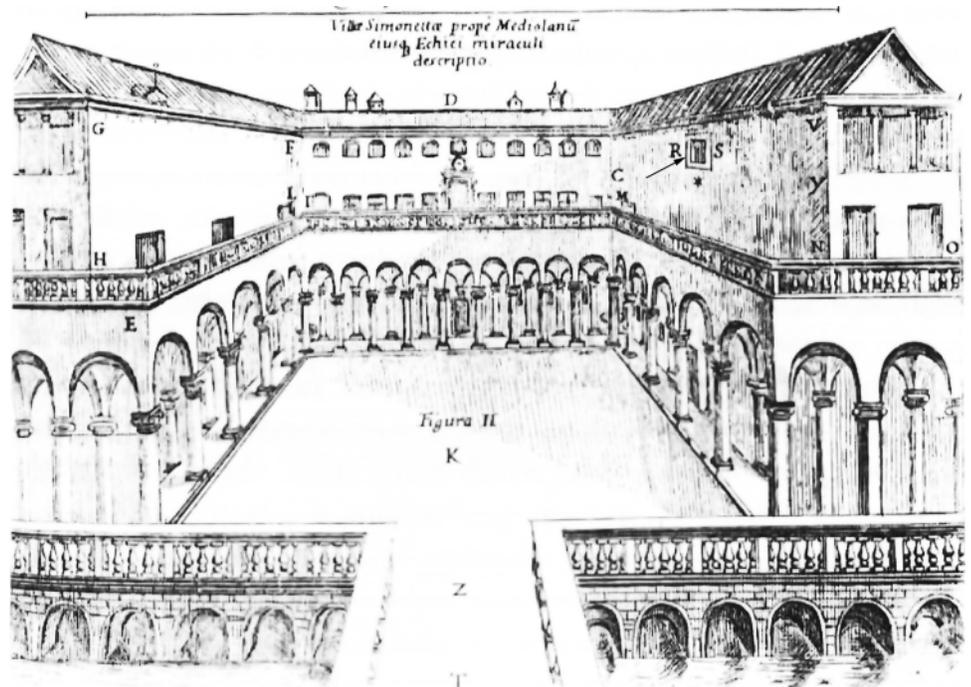


Fig. 11. Villa Simonetta.

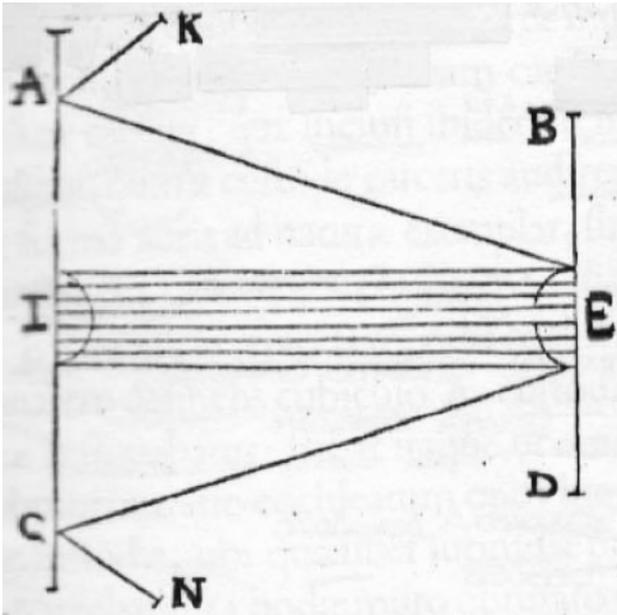


Fig. 12. Demonstration of echoes in the Villa Simonetta.

curiosity and interest surrounding the Villa Simonetta, the history of which is long and troubled. Some people prefer to call it evocatively the “Villa of the Echo,” following a popular tradition that Kircher helped establish. Today the Villa Simonetta is an important cultural centre that organizes concerts and courses.

Conclusions

Kircher’s complex symbolic universe is most expressly revealed in his machines. From appearance alone, they seem to be mere simple games, but by creating unexpected connections he surprises and invites the enquiring mind to question and investigate further.

The *Phonurgia nova* exhibits a rich and consistent playfulness that works on several levels—the religious, mystical, esoteric and scientific. Every theorem is described with the



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rigor of a geometric demonstration—hypothesis, corollary, explanatory images, solutions—but Kircher does not wish simply to extract data, but focuses on a particular element in order to formulate a law, transcribed with mathematical and geometric certainty that a particular phenomenon can be experimentally repeated.

The illusions induced by Kircherian devices are intended to provide evidence of the inadequacy of the human mind compared with the mysteries of Nature. Nevertheless, they do give us an intriguing vision of 17th century scientific concerns.

Acknowledgments

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References and further reading:

- 1 A. Kircher, “*Phonurgia nova sive conjugium mechanico-physicum artis & naturae paranympa phonosophia concinnatum*” (Kempten, R. Dreherr, 1673).
- 2 S. Morland, “An account of the speaking trumpet, as it hath been contrived and published by Sir Samuel Morland, Knight and Baronet,” London, an. 1673.
- 3 A. Kircher, “*Musurgia Universalis, sive ars magna consoni et dissoni*” (2 volumes) (Roma, Francesco Corbelletti, 1650).
- 4 G. De Sepi, “*Musaeum kircherianum*,” ex officina Janssonio-Waesbergieriana, Amsterdam, 1678.
- 5 J. S. Kestler, “*Physiologia kircheriana experimentalis*,” Amsterdam, 1680.
- 6 P. Findlen, Athanasius Kircher, *The last man who knew everything* (Routledge, New York, 2004).
- 7 L. Tronchin and G. Mastromatteo, “Il meraviglioso sonoro nella *Phonurgia Nova* (1673) di Athanasius Kircher” (“The fantastic sound world of the *Phonurgia Nova*”), 34th National Congress of AIA, Florence, 2007.

in Japan, a visiting professor at the University of Graz in Austria, Special honored International Guest at the International Workshop, “Analysis, Synthesis and Perception of Music Signals,” at Jadavpur University of Kolkata, India in 2005, at La Trobe University in Mildura (Australia) and at the International Musical Festival of Ballarat (Australia) in 2009. Dr. Tronchin is a pianist and earned a diploma in piano from the Conservatory of Reggio Emilia. He is the author of more than 140 papers and is Chair of the Musical Acoustics group of the Italian Association of Acoustics. He is a member of the Scientific Committee of the Inter-University Centre of Acoustics and Musical Research, has chaired sessions on architectural and musical acoustics during several international symposiums, and has been a referee for a number of international journals. He is the Chair of organizing and scientific committees of the International Advanced Course on Musical Acoustics.