

## Article

# Rediscovering the Intangible Heritage of Past Performative Spaces: Interaction between Acoustics, Performance, and Architecture

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**Abstract:** The relationship between the shape and social use of Greek and Roman theatres has always been overshadowed by the technical and acoustic analyses of these performance spaces. Relevant ruins illustrate the relationship between performance typology, acoustics, and construction development of ancient theatres, which were mainly determined by the requirements of artistic venues. The music in tragedies and comedies, the dances, and the public speeches performed in the same places helped to shape the constructions according to the requirements of the events. In addition to the need to satisfy social and political interactions, the functions of musical performances and public speeches in theatres were maintained across generations so that they organically coexisted in both Greek and Roman times. This paper presents new insights into the relationships between sound and architecture, focusing on the case study of the Greek–Roman theatre of Katane and its evolution through the centuries. Architectural features have been described in terms of the social functions of the theatre rather than as mere results of geometric rules. A brief comparison with the neighboring *odeion* of Katane and other Greek–Roman theatres has been made regarding destination use.

**Keywords:** Intangible Heritage; Roman theatre; Greek theatre; historical acoustics; performative spaces



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## 1. Introduction

The ancient Greeks were probably aware of how the artistic performances and the acoustics of the spaces were connected. Although the acoustic description of performance spaces is rarely mentioned in written sources [1], it can be assumed that the Greeks attached an important value to sound, which applied to social and political events [2]. This supports the thesis of the unclear function attributed to these public buildings since many functions coexisted in the same place.

Archaeological evidence provides useful information about the relationship between the design and social use of ancient theatres, as it helps to reconstruct the context of the origin of the activities [2,3]. All performances (e.g., music, dance, drama, poetry, sacred acts) were interrelated and contributed to creating a unique listening experience for the audience [4].

The Greek theatres that spread in Sicily and throughout the Magna Graecia were built in areas with mild climates and were generally located on cliffs, taking advantage of the natural slope of the hills. The hard material used for the finishes and the geometric features of the open-air theatres determined the optimal acoustic conditions of the live experiences [5]. Consequently, the acoustic characteristics of this type of construction could ensure a high level of speech intelligibility and optimal results in terms of acoustic parameters related to musical (vocal and instrumental) activities, covering even the last rows of seats [6].

It cannot be excluded that the development of the spatial configuration of these performative spaces contributed to the modeling of their intangible aspects. This paper raises some questions regarding the hypothesis that social meetings could take place in these spaces in addition to artistic performances. However, some theories also put forward an idea about the architectural changes of these constructions that could be related to the evolution of musical culture and performances, although the requirement of space for a larger number of spectators could be crucial [7].

A case study analyzing the characteristics of a Greek–Roman theatre has been considered, and the theatre of Katane (the ancient name of modern Catania) has been chosen for this purpose because it represents one of the few ancient theatres that encompasses the evolution of the configuration as much as possible.

## 2. Overview of Greek and Roman Theatre Architecture

### 2.1. Combination of Construction and Performance

It is unclear where the word “theatre” was first used in history, but ancient Greek architects and designers were the first to create new forms of architecture based on the practical needs of plays, music, and dance performances. Over the centuries, this practice led to constructions with the features we identify today with Greek theatres and, later, Roman theatres [8].

Originally, the seats, called *ikria*, the arrangement of which is unclear, were made of wood. According to graphic representations, in the 5th century BC, they were placed in the *orchestra*, a flattened terrace dedicated to dancing. Despite the characteristics of the *orchestra*, the spectators had the habit of sitting on the natural slope of the hill (*theatron*), which was called “the viewing area” [9]. The change from wooden to stone seats seems to have taken place in the 4th century BC, when the front seats (*proedria*), dedicated to eminent figures of the society, were placed closer to the performance, followed by more stone steps erected to cover the natural slope, called *koilon* (literally, “hollow”), for the rest of the audience [2].

It should be remembered that the plan layout of the first *koilon* had a slingshot shape, which was not based on any particular geometry since the stone steps took the natural shape of the hill. An example of this is the ancient theatre of Thorikos (now Lavrio), the world’s oldest Greek stone theatre (6th century BC). Because of the mining of silver-bearing lead, the population of this small town was largely made up of miners [10]. No document proves whether the shape of the theatre was unfinished; however, the northern extension and the entrances on the west and east, which took place in the 4th century BC, may indicate that the shape was slowly taking place in accordance with the needs of social events. Figure 1 shows how the configuration of the stone rows mimicked the geomorphological profile of the hill. A similar case would be the theatre of Aitolian Makynaia, where the existing remains of 14 rows of seats, showing a so-called curvilinear arrangement, cannot confirm the geometrical structure of the *koilon* since some blocks have shifted over the centuries [11].

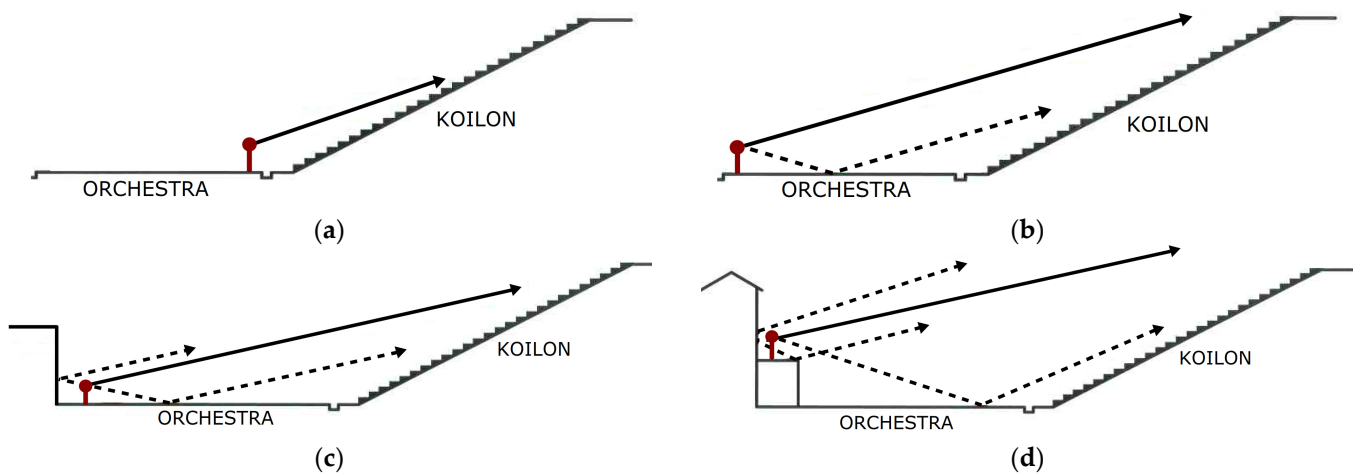
The adaptation of the other elements was gradually developed, based on the requirements of the performance [2]. The emergence of the vertical surface behind the action was represented by a wooden panel, which was changed to a cloth curtain (*skene*) in 465 BC to hide changing of costumes and masks from view [1]. The change between wooden and cloth backdrop is not clear: with the development of Sophocles’ tragedies, the *skene* was a rigid wooden panel, which was subsequently transformed into a solid roofed building because of its sound-reflecting properties [9]. For social purposes, the roof was also used as a podium for public speeches, reminiscent of the ancient podium (*bema*) of the Pnyx in Athens, where political speeches were delivered to very large audiences [2].



**Figure 1.** Overhead view of the Greek theatre in Thorikos.

Theatrical performances and music festivals were divided into different categories, such as the scenic festivals (dramatic, from *drama*), to include the theatrical performances and the thymelic (from *thymele*, as the altar of Dionysus was called) events, characterized by the use of aulos and kithara, which mainly represent the religious aspect of the spectacles. On this basis, each specific performance required a particular organization of the space in which the action took place: when the *thymele* was in the center of the *orchestra*, the actors were in a different part of the theatre [1]. In 425 BC, the extension of the skene on the two side walls (*paraskenia*) was realized and provided the doorways to allow the actors' entrances (*parodoi*) and exits (*eisodoi*) [2]. The auxiliary doors behind the stage were useful to allow movements, especially when the drama required closing the central door, as was the case in several tragedies by Sophocles and Euripides.

The arrangement of the steps in the *koilon* was such that each spectator could perceive the direct and reflected sound, depending on the position of the sound source, as shown in Figure 2. It should be reminded that the raised stage was closely related to the innovation of dramaturgy [2], in particular to the introduction of a third actor in the tragedies, which resulted in the shift of the acting center from the *orchestra* to the *proskenenion*. This phenomenon occurred mainly in the Hellenistic period.



**Figure 2.** Schematic representation of ray tracing during the evolution of the Greek theatre. Direct and reflected sound waves based on the position of the sound source: closer to the audience (a), far from the audience (b), closer to the *skene* (c), and on the raised stage (d).

The Romans adopted the theatrical culture when the tragedies had almost reached the end of their splendor, although they were still part of the artistic program. New types of entertainment were developed in Roman theatres, including comedies and satyr plays, as well as dances and songs [12]. Regarding the elements of theatre staging and architectural references, Vitruvius, in his *De Architectura* (Book 5, paragraph 6, line 8), recommends that each type of performance requires specific decorations, which are summarized below:

- Tragedy was distinguished by a setting consisting of columns, statues, and other similar elements;
- Comedy was characterized by images and forms of private houses with balconies and windows;
- Satire was characterized by floral decorations and the depiction of mountains and caves typical of rural areas.

Despite the diversity of stage dressing, the Romans gave the theatre a uniform shape based on geometric and structural rules [13]. Vitruvius (1st century BC), in his treatise on architecture, discussed in detail the rules for improving the acoustics of the theatre [14]. According to these rules, the *cavea* should be semicircular, and the total height of the steps should be equal to the height of the scenic building; the length of the scenic building should be twice the diameter of the *orchestra*; the height of the podium should be 1/12 of the diameter of the *orchestra*; the *velarium* was important for shading the seating area during the day [15]. As he points out in Book 5 of his treatise, his approach is rooted in a long tradition that goes back to the “ancients,” including the mathematical theorists. He explains the following:

*«Hence, following the example of nature, the ancient architects perfected the gradual ascent of theatrical seats by studying the path of the ascending voice; and with the aid of the canon theory of mathematicians and the ratio of music, they sought to bring each voice uttered on the stage to the ears of the spectators with greater clarity and sweetness. For just as musical instruments (organa) reach perfection in the clarity of the sound of their notes by means of bronze cases or sound boxes made of horn, so also the theoretical principles (ratiocinationes) of theatrical buildings were developed according to the science of harmonics in order to increase the power of the voice» [15].*

## 2.2. Some Considerations on the Acoustics Features of Greek and Roman Theatres

The Romans changed the layout of the theatres built by the Greeks. This phenomenon is especially interesting in Sicily. The theatre in Tyndaris, built around the 4th century BC [16], is considered an example. The need for sporting competitions, which consisted of fights between gladiators and wild animals, was the main reason for lowering the level of the Greek *orchestra* by 0.9 m [17], as shown in Figure 3. In addition, the need to build a podium 2.5 m high contributed to the destruction of the first four rows of steps.



**Figure 3.** A perspective view of the theatre in Tyndaris.

Another Greek theatre in Sicily, modified by Romans, was built in the city of Syracuse in the 5th century BC. The archaic configuration from the 6th century BC, which was trapezoidal and shaped the natural slope of the hill, was transformed into a semicircular layout in the 3rd century BC [18]. For the performance of the farses, a wooden stage was erected, supported by six short two-sided columns, on which the actors appeared wearing grotesque masks that ridiculed the characters they played. Since the curtains were to be moved from below, an empty box 3.0 m deep was hewn into the rock below the *orchestra* floor [19], as shown in Figure 4.



**Figure 4.** Aerial view of the theatre in Syracuse.

The theatre in Syracuse was widened by the tyrant Hieron II, who enlarged the *cavea* to accommodate up to 15,000 spectators, while the Romans built a scenic building according to the rules of Vitruvius, which was to be equipped with three doors (a so-called *regia* in the center, and two lateral *hospitalia*) [20].

While many other Roman theatres in southern Italy were built on Greek models, the structure of the theatre was developed by the Romans and replicated in other cities of the imperial territory. The present conditions of the Roman and Greek theatres are comparable in acoustic response, being in a ruinous state determined by the absence of architectural constructions, such as the scenic building, the ambulatory, and the upper *cavea* [21]. However, comparisons between the existing conditions and the original forms of the theatres have already been evaluated by researchers based on numerical simulations created using digital models [22,23].

As the examples show, the Roman theatre of Verona, shown in Figure 5 and considered one of the most representative in northern Italy, and the Greek theatre of Tyndaris, have already been introduced. In the literature [22,23], similar results are attributed to the deterioration of the constructions and their damaged state, which significantly worsens the optimal conditions for live performances. The acoustics of Roman theatres were more reverberant due to the closed configuration of the volumes, characterized by the ambulatory crowning of the outer perimeter, than the multiple orders of the scenic building reaching the total height of the *cavea* [24].



Figure 5. Aerial view of the Roman theatre of Verona.

### 3. A Case Study in Sicily: The Sonic Heritage of the Greek–Roman Theatre and the Odeion in Katane

In Sicily, as well as throughout the Mediterranean, theatres became one of the preferred expressions of monumental architecture during the late Classical and Hellenistic periods, with many open-air theatres such as Taormina, Segesta, Syracuse, and Katane considered the most representative [25]. Written sources indicate the existence of theatres in Katane from the 5th century BC [26]. Specifically, Frontinus [27] refers to a speech by Alcibiades in the theatre of Akragas on the occasion of the Athenian expedition in 415. However, the same episode is also reported by Thucydides [28], who instead refers to how Alcibiades tried to persuade his soldiers in the theatre of Katane [29,30] to fight against Syracuse [31]. This episode could be reliable since it was common in Sicily to hold assemblies in such public places, and there is evidence that a separate place was used for public speeches in Katane in the 5th century BC. The existence of a theatre in Katane is also attested by a straight wall and the monogram KATA(NA) on various limestone blocks representing the trapezoidal *koilon* of an original 5th-century BC Greek enclosure [32].

#### 3.1. The Theatrical Structure and Its Development

The theatre structure in Katane underwent significant changes during the imperial period, as local elites wanted to invest in a structure for spectacles. Archaeological evidence suggests that the Roman rulers, particularly in Katane, significantly remodeled the former theatre building, removing the blocks of the earlier structure and building a more functional space specifically designed for musical performances [33].

The *odeion* was a smaller building, called by Romans a *theatrum tectum*, because it had a roofed structure [33] that provided better physical conditions for singing. Considering the widespread use of this structure throughout the Mediterranean, the *odeion* built in the Roman period in Katane could show (Figure 6) that the acoustic features of the Greek theatre could not meet the requirements of musical culture. Scholars, such as Izenour [34], stated that from an acoustic perspective, the *odeia* in their original form were more suitable than theatres for listening to solo or chamber music performances. Although it is difficult to define due to the lack of evidence, it can be assumed that ancient architects designed the *odeia* to meet the innovative requirements of increasing the sound level of musical instruments, especially in the Roman period. Although the reason that led to the roofing of the *odeia* is unclear, it cannot be excluded that the design of these small, roofed buildings evolved from larger Greek open-air theatres to create more suitable conditions for speech and music events [35].



**Figure 6.** View of the *odeion* of Catania.

The morphological evolution of the earlier theatre in Katane can be traced, as can the concomitant evolution of its use and functions. The theatre built by the Greeks was a south-facing construction of limestone, with the *koilon* resting on the slope of the Acropolis [33]. Other Greek ruins were found under the *parodoi*, in the *orchestra*, and near the ambulatories below the Roman theatre. Moreover, the blocks of the first step of the *ima cavea*, made of white marble, also date from the Greek period [33].

As for form, the *koilon* (the auditorium) in the theatre of Katane consisted of a horseshoe-shaped floor plan composed of steps on which the spectators could sit. All the wedged-shaped sectors were called *kerkides* and were separated by radial stairs (*klimakes*). The steps sectors were interrupted by horizontal corridors (*diazomata*) that divided the *koilon* into three areas: low, middle, and high. There are nine wedged-shaped sectors of the *koilon*, divided by eight stairs. The first rows of seats, represented by marble thrones (*proedria*), were occupied by magistrates, ambassadors, and aristocrats [30].

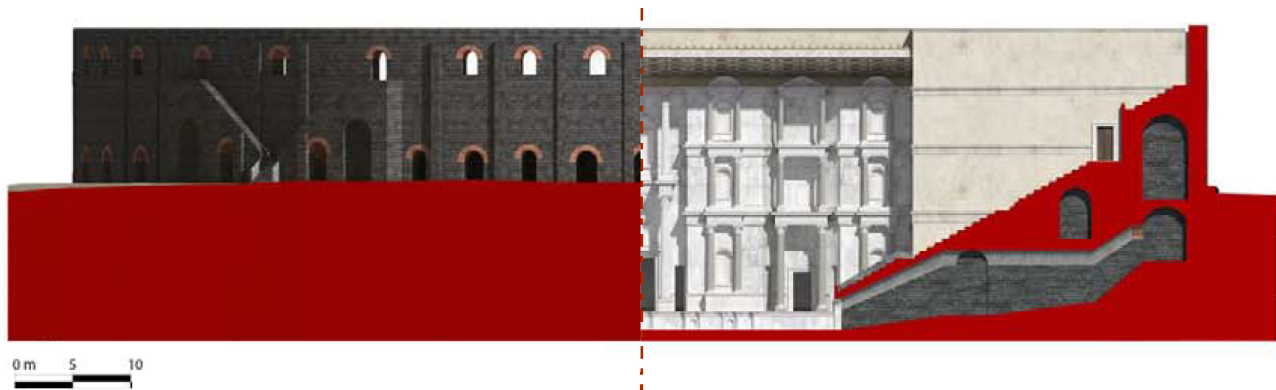
The actors entered the *orchestra* through uncovered corridors (*parodoi*). The first stage set consisted of a curtain (*skene*), while the first design of a scenic building was a cubic room with a flat roof, used by the actors for changing costumes. Later, the scenic building design was extended by two rooms on the sides; the structural walls were made of bricks and covered with marble sheets. Moreover, the facade of the scenic building was decorated with granite columns of the first order, 5.1 m high. The two uppermost orders are characterized by columns on tall pedestals decorated with dolphins and other animal motifs [36]. With the development of the scenic building, the stage also changed. At first, the actors performed in the *orchestra*, a space with a 29 m diameter. Later, when the scenic building was provided with lateral constructions (*paraskene*), they performed on a raised stage (*logheion*).

On this basis, the architectural development of the theatre of Katane could be redefined depending on the need to optimize the seating capacity and the visual experience, but also with better acoustics in accordance with the arrival of new theatrical performances [25]. The development of form and function followed the need for spatial separation between performers and spectators, as well as the requirements for visibility and intelligibility of speeches and music. The function of Katane theatre was so important that it was a major gathering place for public and civic purposes, as well as for athletic competitions. It cannot be ruled out that the theatre of Katane was used only for meetings and theatrical performances during the Roman period since an appropriate building for listening to music had been erected in the immediate vicinity of the theatre. The *odeion* was primarily suitable for musical performances and song recitals, which were mainly aimed at a select audience consisting mainly of aristocrats [34].

### 3.2. Architectural Elements Added by the Romans to Improve the Reverberation

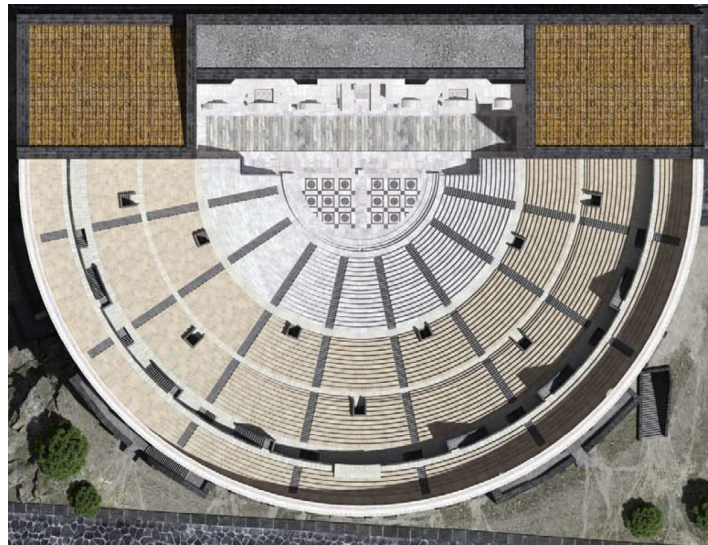
Katane became part of the Roman territory in 263 BC. The Romans changed the city centre, erecting new public buildings and changing the theatre based on Greek foundations. For this reason, it is difficult to determine the dimensions of the original ground plan, although research studies on theatres built in the same period in Greece and Sicily can help to reconstruct some hypotheses [30]. After the Romans took over the Greek theatre, it was adapted to Roman needs, keeping its original use as a public and sacred place. A new construction phase dates back to the 1st century BC when Augustus appointed the citizens of Katane as Roman *cives* as part of the Roman Empire [33].

The Romans used *opus cementicium* as a construction technique to erect tall buildings with different levels. In Katane, three ambulatories (*ambulacra*) are connected by stairs and provided with accesses (*vomitoria*) to the different sectors of the *cavea*. While the first two ambulatories are underground, the third has windows that filter natural light and provide spectacular effects, as shown in the reconstructed section in Figure 7. The openings of the third *ambulacrum* are framed by squared columns supporting semi-circular arches that support the vault at the intersection with corridors [33]. The use of the arch allowed the Romans to realize agile structures. On this basis, the external façade was decorated by different orders of columns.



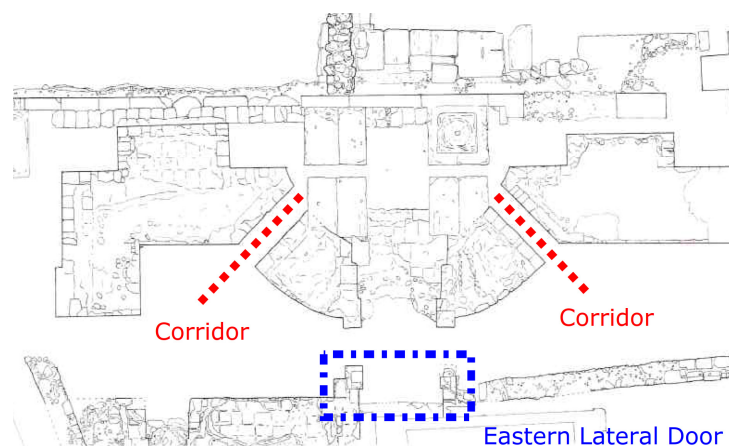
**Figure 7.** The digitally reconstructed elevation of the Roman theatre of Catania. Credit to D. Malfitana et al., 2016 [34].

The new stage (*pulpitum*) was raised more than 1 m from the *orchestra* level in the 4th century AD and built on the old stage from the 1st century AD, as revealed by a 1991 archaeological excavation [37]. The construction of the *pulpitum* corresponds to the last phase of the theatre's life and consists of square and circular niches. In the same period, the *parodoi* were covered and connected to the scenic building, where the balconies of the aristocrats (*tribunalia*) were constructed above these corridors [37]. The *koilon* was called *cavea* by the Romans and was divided into horizontal strips by semi-circular corridors (*praeinunctiones*). In particular, the *ima cavea* consisted of 21 steps, while the *summa cavea* of 12 steps, as shown in Figure 8, with a total capacity of about 7000 spectators. The architectural structure at the top level (*porticus in summa gradatione*), which crowns the *summa cavea*, was to be supported by columns and consisted of doors and windows placed alternatively. The *cavea* with these additional constructions had an external diameter of 98 m and was divided into sectors by semicircular structural walls (*maeniana*) built under the steps.



**Figure 8.** The digitally reconstructed plan layout of the Roman theatre of Catania. Credit to D. Malfitana et al., 2016 [36].

The scenic building was modified in the Roman period by shaping the stones of the doors and creating two diagonal corridors, as shown in Figure 9.



**Figure 9.** Lateral door of the scenic building modified by the Romans (1st c. AC).

The horizontal decoration of the beams belonging to the scenic building was characterized by floral motifs. The floor of the *orchestra* was covered by the Romans with multi-coloured marble sheets made with the construction technique called *opus sectile*. The design of the floor consisted of circles of granite inscribed in squares and executed with precious marble. During the restoration works, some marble tiles were replaced with white ones without respecting the original geometry and design [38].

Along the first step of the *cavea* in the theatre of Katane, there is the *euripo*, a semi-circular ring lowered from the *orchestra* level and used to collect rainwater [6]. Near the *euripo*, vertical sheets of precious marble served as a parapet (*balteum*) of the seats for the aristocracy (*proedria*). The development of the theatre of Katane as a solid stone-clad structure may have allowed the architects to focus their studies on acoustics so that sound and voice should reach the last rows of seats. A balance between reverberation and speech intelligibility is the core of the acoustics developed by the Greeks and deepened a few centuries later by Vitruvius [14].

The details laid down by Vitruvius also concerned the characteristics of the *orchestra*, which was to be flat and covered with hard material instead of grass [39] to improve reverberation in all parts of the *koilon* [40], although dancing on the tiled floor of the

*orchestra* was not easy. The *skene*, as a solid structure behind the actors, increased the sound envelopment due to the strong reflections coming from the vertical surfaces. A good example of this is the theatre of Epidauros, part of the sanctuary of Asclepius. With a *cavea*, which should be equal to the height of the scenic building, Vitruvius' architectural rules seem to apply to Katane's theatre building as well. The addition of a porch to the *summa cavea* also had the function of increasing reverberation [14]. According to the literature [41], the resonance system described by Vitruvius agrees with the distribution of tones attested in the musical documents of the imperial age. It is possible that the architects and designers in the theatre of Katane applied the principles of mathematical architecture of musical and sound proportions described by Vitruvius to achieve a perfect correspondence between theoretical principles (*ratiocinationes*) and practical expertise (*fabrica*) [14], as discussed in the previous section.

#### 4. Soundscape Archaeology of the Performative Spaces in Katane

Special attention can be paid to the development of the theatrical structure in Katane and its places of performance. A connection can also include acoustic evolution and its role in the transformation process. Based on current discoveries, it is difficult to understand whether the acoustic features were part of an advanced architectural design that responded to the needs of accommodating a larger number of spectators.

In the 6th and 5th centuries BC, the theatre spaces in Sicily were mainly associated with sacred cults and ritual performances [42]. Theatrical spaces were suitable for both musical events performed in sacred contexts by poets and musicians, such as Stesichoros (7th–6th century BC) [43], and for dancers, such as the Sicilian aulete Andron of Katane (5th century BC), who began to use body movements to give expressiveness to their performances. Theophrastus [44] reports that Andron first set rhythmic movements of the human body to pipe music. As a result, the verb *sikelizein* was synonymous with dance (*orcheisthai*). This connection must have had some plausibility, confirming the link between Sicily and dance [32].

Very interesting is the finding of bone fragments from *auloi* in the theatre of Katane [45]. Similar to other archaeological findings in Sicily [46], this wind instrument may have helped to “mark” the soundscape of the performative space in the performative spaces of the ancient city. Despite its relevance to soundscape archaeology, no study has focused on the physical and acoustic properties of musical instruments in a theatrical space. International research studies that have attempted to investigate the organological [47] and technological [48] properties of *auloi* still lack an adequate connection between the sound perception of these instruments and the acoustic features of theatrical structures.

This analysis could contribute to understanding how musical instruments were shaped based on the listeners' sound experiences in a performative space [49]. In addition, clay figurines of female *aulos* players and dancers depicted on vases<sup>1</sup> from the Classical and Hellenistic periods were found in the theatrical area of Katane. This provides further evidence that musical events and dances associated with sacred activities were performed in the theatre [50]. However, the development of the theatre and the *odeion* in Katane during the Roman period reveals that architectural design can influence the acoustics of a space intended for specific performances [51].

#### 5. Historical Acoustics of Ancient Performative Spaces

Sounds are not often considered in archaeology because they leave no trace. However, sound represents an important aspect of ancient life. It can be investigated using a new approach to archaeological methodology [51] since acoustic aspects are detectable in the archaeological records [52]. It seems surprising that important public spaces of antiquity, such as performative spaces or theatrical structures, have so far been studied almost exclusively with a focus on their visual function. Since antiquity, the combination of space, dance, and sound has been characteristic of performative practices, emphasizing the role of acoustics in shaping the volume. The setting of theatrical structures was created for

performative and multisensory activities in which music, dance, and other sonic events played an important role [53].

Structures, decorations, and the surrounding landscape of the theatre buildings were the best ingredients for creating specific acoustic characteristics that influenced the perception of the performances. The soundscapes of these places were composed of songs, music, recitations, and vocal utterances. Based on archaeological findings in Katane, the architectural components were adapted depending on the evolution of music, including song and dance practices.

Nowadays, it is common practice to recognize ancient theatres as embodied spaces based on the way sound physically responds to these architectural structures [54], but the discussion on the correlation between acoustics and architectural shape is still open, including any association with performance, social and sensory interactions [55]. In addition, research on the social utility of ancient spaces would address acoustics to provide new insights into the connection between sound and architecture. On this basis, exploring the fundamental properties of sound in the context of performing arts spaces allows acoustics to gain new insights into the social utility of sound in these spaces. Furthermore, exploring the relationship between acoustic and auditory (intangible) aspects could have a positive impact on a deeper understanding of these tangible constructions.

## 6. Discussions

Current research on archaeo-acoustics, soundscape, and archaeo-musicology poses numerous hypotheses about the historical acoustics of ancient theaters. Because of its multidisciplinary nature, the study of sound in theatrical contexts should encompass many disciplines ranging from auditory to archaeology to physics and acoustics.

Each of these areas presents numerous challenges in terms of the choice of the methodology and the approach since, in archaeo-acoustics, the variation in results depends on the methodology used for data collection. Archaeo-acoustics has always been characterized by computational approaches and modeling. However, from a soundscape perspective, it *«can be considered as a contextual experience of spaces, and auditory perception as one of the ways in which people made sense of their world»* [56]. As Shannon Mattern has argued, *«opening the ears during archaeological investigation allows us to recognize that human experience is, and always has been, multisensory and that ancient spaces have long functioned, either accidentally or intentionally, as resonant chambers and transmission media for sonic activity—for public address, interpersonal communication, ritual or musical performance»* [57].

Although soundscapes have been discussed extensively at the theoretical level and form a basis for many archaeo-acoustical studies, historical acoustics has received little attention in archaeological research. This is due to the conceptualization of soundscapes, which is understood differently by each field and even by archaeology and acoustical science.

While acoustic research methods usually focus on physical aspects of sound, cultural and performative contexts should also be explored, which are crucial to an anthropological approach to studying sound in archaeology. The soundscape is influenced by a combination of anthropological data located in an audible and an acoustic space. It is important to keep in mind that sounds, performances, and music were more than mere channels of communication: they contributed to the education of individuals, as they represented constructive activities and sacred practices.

Sounds and auditory experiences have been ubiquitous throughout time and in all cultures. Therefore, when archaeology deals with historical acoustics, it is possible to use sensory methodologies to answer anthropological questions in the context of cultural heritage [58].

A common methodological feature of most research studies dealing with historical acoustics is the presence of acoustic measurements and acoustic simulations in the cases studied. As far as measurements are concerned, the work of researchers should be appreciated, as the implementation of standardized measurement protocols in sites that are often difficult to access and present problems of operability is a major challenge. By applying

qualitative and quantitative methods to studying ancient performative spaces, it is possible to investigate both the past and present soundscapes of sites using binaural recordings that reflect the original performance.

Historical acoustic approaches can link technical concerns with heritage conservation and management and provide new insights into understanding the past [59]. This would be a valuable benchmark for looking at the subject from different perspectives and highlighting the connection between the sound that permeates the spaces and their social functions.

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## Notes

- <sup>1</sup> Museo Archeologico Regionale of Gela. Inv. 20966. Bellia 2009: 49, n. 57.

## References

1. Perrot, S. Ancient Musical Performance in Context: Places, Settings, and Occasions. In *A Comparison to Ancient Greek and Roman Music*; Lynch, T.A.C., Rocconi, E., Eds.; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2020; pp. 92–96.
2. Frederiksen, R.; Gebhard, E.R.; Sokolinek, A. The architecture of the ancient Greek theatre. In Proceedings of the Act of an International Conference at the Danish Institute, Athens, Greece, 27–30 January 2012; Aarhus University Press: Aarhus, Denmark, 2015; Volume 17.
3. Beckers, B.; Borgia, N. The acoustic model of the Greek theatre. In Proceedings of the International Conference on Protection of Historical Buildings (PROHITECH 09), Rome, Italy, 21–24 June 2009; Volume 2.
4. Blauert, J. Conceptual aspects regarding the qualification of spaces for aural performances. *Acta Acust. United Acust.* **2013**, *99*, 1–13. [\[CrossRef\]](#)
5. Barba-Sevillano, A.; Lacatis, R.; Giménez, A.; Romero, J. Acoustics vases in ancient theatres: Disposition, analysis from the ancient tetracordal musical system. In Proceedings of the Euronoise, Paris, France, 29 June–4 July 2008.
6. Canac, F. *The Acoustics of Ancient Theatres: Their Teaching*; CNRS: Paris, France, 1967.
7. Chourmouziadou, K.; Kang, J. Acoustic evolution of ancient Greek and Roman theatres. *Appl. Acoust.* **2008**, *69*, 514–529. [\[CrossRef\]](#)
8. Izenour, G.C. *Theater Design*, 2nd ed.; Yale University Press: New Haven, CT, USA, 1996.
9. Barkas, N. The contribution of the stage design to the acoustics of Ancient Greek theatres. *Acoustics* **2019**, *1*, 337–353. [\[CrossRef\]](#)
10. Wordsworth, C. *Athens and Attica*; Wentworth Press: London, UK, 2016.
11. Stiros, S.; Psimoulis, P.; Kolonas, C. The theatre of Aitolian Makynia. In *The Annual of the British School at Athens*; Cambridge University Press: Cambridge, UK, 2005.
12. Wiles, D. Theatre in Roman and Christian Europe. In *The Oxford Illustrated History of Theatre*; Brown, J.R., Ed.; Oxford University Press: Oxford, UK, 1995; pp. 49–92.
13. Cocchi, A. Theatre design in ancient times: Science or opportunity. *Acta Acust. United Acust.* **2013**, *99*, 14–20. [\[CrossRef\]](#)
14. Vitruvius, M.P.; Morgan, M.H. *Vitruvius: The Ten Books on Architecture*, 1st ed.; Dover Publications Inc.: Dover, UK, 1998.
15. Alfano, F.R.; Iannace, G.; Ianniello, C.; Ianniello, E. “Velaria” in ancient Roman theatres: Can they have an acoustic role? *Energy Build.* **2015**, *95*, 98–105. [\[CrossRef\]](#)
16. Bo, E.; Konstantinou, E.; Lepore, F.; Shtrepi, L.; Puglisi, G.; Mangano, B.; Mangano, F.; Barkas, N.; Astolfi, A. Acoustic characterization of the ancient theatre of Tyndaris: Evaluation and proposals for its reuse. In Proceedings of the ICSV 2016, Athens, Greece, 10–14 July 2016.
17. Bernabò Brea, L. Due secoli di studi, scavi e restauri del teatro greco di Tindari. *Riv. Dell'istituto Naz. D'archeologia Stor. Dell'arte Nuova Ser.* **1964**, *13–14*, 99–144.
18. Bo, E.; Shtrepi, L.; Pelegrín-García, D.; Barbato, G.; Aletta, F.; Astolfi, A. The accuracy of predicted acoustical parameters in Ancient Open-Air Theatres: A case study in Syracusae. *Appl. Sci.* **2018**, *8*, 1393. [\[CrossRef\]](#)
19. Syracuse Charter, for the conservation, the fruition and management of the ancient theatrical architecture. In Proceedings of the II International Conference Ancient Theatres in the Mediterranean Area, Verona, Italy, 13–17 October 2004.
20. Gullo, M.; La Pica, A.; Rodono, G.; Vinci, V. Acoustic characterization of the ancient theatre at Syracuse. In Proceedings of the Euronoise 2008, Paris, France, 29 June–4 July 2008; pp. 4143–4147.

21. Gugliermetti, F.; Bisegna, F.; Monaco, A. Acoustical Evolution of the Roman Theatre of Ostia. *Build. Acoust.* **2008**, *15*, 153–168. [CrossRef]
22. Tronchin, L.; Bevilacqua, A. Historically informed digital reconstruction of the Roman theatre of Verona. Unveiling the acoustics of the original shape. *Appl. Acoust.* **2022**, *185*, 108409. [CrossRef]
23. Benvenuto, G. Il teatro antico di Tindari: Ricostruzione Virtuale Dell'evoluzione Acustica. Master's Thesis, Politecnico di Torino, Turin, Italy, 2020.
24. Rindel, J.H. Roman theatres and revival of their acoustics in the ERATO Project. *Acta Acust. United Acust.* **2013**, *99*, 21–29. [CrossRef]
25. Caminneci, V.; Parello, M.C.; Rizzo, M.S. *Theaomai—Teatro e Società In Età Ellenistica*; All'Insegna del Giglio: Florence, Italy, 2019.
26. Nicoletti, F. *Catania Antica—Nuove Prospettive Di Ricerca*; Grafica Sturnia: Siracusa, Italy, 2015.
27. Frontinus, S.J.; Fitzpatrick, R.E.J.; Bennett, C.E. *The Strategemata: The Stratagems*; Book 3, Chapter 6; Heinemann: London, UK; Harvard University Press: Cambridge, MA, USA, 2020.
28. Thucydides; Bottino, P. *History of the Peloponnesian War*; Book 1, Chapter 6; Dent & Dutton: London, UK, 1910.
29. Diodorus, S.; Oldfather, C.H. *Diodorus Siculus: Library of History*; Book 13, Chapter 4; Harvard University Press: London, UK; Harvard University Press: Cambridge, MA, USA, 1946.
30. Krentz, P. *Polyaenus: Stratagems of War*; Book 1, Chapter 40; Ares Pub: Chicago, IL, USA, 1994.
31. Morgan, K.A. A prolegomenon to performance in the West. In *Theater Outside Athens: Drama in Greek Sicily and South Italy*; Bosher, K.G., Ed.; Cambridge University Press: Cambridge, UK, 2012; pp. 35–55.
32. Bosher, K.G.; Marconi, C.; Hall, E. *Greek Theater in Ancient Sicily*; Cambridge University Press: Cambridge, UK, 2021.
33. Branciforti, M.G.; Pagnano, G. *Il Complesso Archeologico del Teatro e dell'Odeon di Catania*; Area Soprintendenza Per I Beni Culturali ed Ambientali di Catania: Palermo, Italy, 2008.
34. Izenour, G.C. *Roofed Theaters of Classical Antiquity*; Yale University Press: New Haven, CT, USA; Yale University Press: London, UK, 1992.
35. Merli, F.; Bevilacqua, A.; Tronchin, L. The sound of the cultural heritage: A case study on the Odeon of Pompei. In Proceedings of the Immersive and 3D Audio: From Architecture to Automotive (I3DA), Bologna, Italy, 5–7 September 2021. [CrossRef]
36. Malfitana, D.; Gabellone, F.; Cacciaguerra, G.; Ferrari, I.; Giuri, F.; Pantellaro, C. Critical reading of surviving structures starting from old studies for new reconstructive proposal of the Roman theatre of Catania. In Proceedings of the 8th International Congress on Archaeology, Computer Graphics, Cultural Heritage and Innovation, Valencia, Spain, 5–7 September 2016. [CrossRef]
37. Pensabene, P. La decorazione architettonica del teatro di Catania. In *Megalai Nēsoi: Studi dedicati a Giovanni Rizza per il suo Ottantesimo Compleanno*; Gigli, R., Ed.; Studi e Materiali di Archeologia Mediterranea 3; Consiglio Nazionale delle Ricerche I.B.A.M.: Catane, Italy, 2005; Volume 2, pp. 187–212.
38. Paga, J. The Greek Theater. In *A Companion to Greek Architecture*; Miles, M.M., Ed.; Wiley Blackwell: Chichester, UK, 2016; pp. 360–373.
39. Mayhew, R. *Aristotle. Problems, Volume 1: Books 1–19*; Harvard University Press: Cambridge, MA, USA, 2011.
40. Jones, W.H.S. *Pliny, Natural History, Volume 3: Books 8–11*; Harvard University Press: Cambridge, MA, USA, 1963.
41. Lynch, T.A.C. Unlocking the Riddles of Imperial Greek Melodies I: The 'Lydian' Metamorphosis of the Classical Harmonic System. Available online: <https://zenodo.org/record/6927929> (accessed on 28 October 2022).
42. Bellia, A. Musica, spazio e rito nelle città cerimoniali dell'Occidente greco. Il caso di Selinunte. In *Theatroeideis. L'immagine della Città, La Città Delle Immagini*; Livadiotti, M., Belli Pasqua, R., Calì, L.M., Martines, G., Eds.; Thiasos Monografie 11; Quasar: Rome, Italy, 2018; pp. 329–342.
43. Branciforti, M.G. *Il Teatro Greco Romano di Catania e Gli Spettacoli Nell'antichità: Progetto Scuola Museo*; Regione Siciliana, Assessorato dei Beni Culturali E Dell'identità Siciliana; Dipartimento dei Beni Culturali E Dell'identità Siciliana: Palermo, Italy, 2013.
44. Raffa, M. *Theophrastus of Eresus: Commentary Volume 9.1*; Brill: Leiden, The Netherlands, 2018.
45. Bellia, A.; Pavone, D.P. Computed tomography and handcrafting processes of an ancient musical instrument: The aulos from Poseidonia. In *From Digitalisation and Virtual Reconstruction of Ancient Musical Instruments to Sound Heritage Simulation and Preservation*; Bellia, A., Ed.; Archeologia & Calcolatori 32.1; All'Insegna del Giglio: Florence, Italy, 2021; pp. 421–447. [CrossRef]
46. Kolltveit, G. Classification of Sound, Sound Tools, and Soundscapes. In *Sounds Like Theory, Proceedings of the XII Nordic Theoretical Archaeology Group Meeting, Oulu 25–28 April 2012*; Ikäheimo, J., Salmi, A.-K., Äikäs, T., Eds.; Monographs of the Archaeological Society 2; Archaeological Society of Finland: Helsinki, Finland, 2014; pp. 73–84.
47. Bellia, A. Introduction: An overview of how virtual reconstructions and sound simulations can improve our knowledge on ancient musical instruments and sound heritage. In *From Digitalisation and Virtual Reconstruction of Ancient Musical Instruments to Sound Heritage Simulation and Preservation*; Bellia, A., Ed.; Archeologia & Calcolatori 32.1; All'Insegna del Giglio: Florence, Italy, 2021; pp. 351–357. [CrossRef]
48. Vincent, A. Tuning into the past: Methodological perspectives in the contextualised study of the sounds of Roman antiquity. In *Senses of the Empire: Multisensory Approaches to the Roman Culture*; Betts, E., Ed.; Routledge: London, UK; Routledge: New York, NY, USA, 2017; pp. 147–158.
49. Bellia, A. Danza nell'Occidente greco: Un approccio all'archeologia della performance nel contesto sacro. In *Studi Miscellanei di Ceramografia Greca 7*; Giudice, E., Giudice, G., Eds.; Monografie dell'archivio ceramografico dell'Università di Catania; EDIARCH, Edizioni Scientifiche: Catane, Italy, 2021; pp. 31–54.

50. Camp, J.M., II. Bouleuteria and Odeia. In *A Companion to Greek Architecture*; Miles, M.M., Ed.; Wiley Blackwell: Chichester, UK, 2016; pp. 342–359.
51. Mills, S. *Auditory Archeology. Understanding Sound and Hearing in the Past*; Routledge: Walnut Creek, CA, USA, 2014; pp. 53–74.
52. Kolltveit, G.; Rainio, R. *The Archaeology of Sound, Acoustics & Music: Studies in Honour of Cajsa S. Lund*; Ekho Verlag: Berlin, Germany, 2020.
53. Bellia, A. Afterwords: Towards a Soundscape Archaeology. In *Soundscape and Landscape at Panhellenic Greek Sanctuaries*; Angliker, E., Bellia, A., Eds.; TELESTES, Studi e Ricerche di Archeologia musicale nel Mediterraneo 6; Istituti Editoriali e Poligrafici Internazionali: Pisa, Italy; Istituti Editoriali e Poligrafici Internazionali: Rome, Italy, 2021; pp. 101–106.
54. Blesser, B.; Salter, L.-R. *Spaces Speak, Are You Listening? Experiencing Aural Architecture*; MIT Press: Cambridge, MA, USA, 2007.
55. Holter, E.; Muth, S.; Schwesinger, S. Sounding Out Public Space in Late Republican Rome. In *Sound and the Ancient Senses*; Butler, S., Nooter, S., Eds.; Routledge: London, UK; Routledge: New York, NY, USA, 2019; pp. 44–60.
56. Pasalados, R.J. A “Phenomenology of Soundscape”: Archaeoacoustics, Landscape and Environment in Music Archaeology. In *Actas das IV Jornadas de Jovens em Investigação Arqueológica I*; Cascalheira, J., Gonçalves, C., Eds.; Promotora Monografica 16; Universidade do Algarve: Faro, Portugal, 2011; pp. 443–446.
57. Mattern, S. Sonic Archaeologies. In *The Routledge Companion to Sound Studies*; Bull, M., Ed.; Routledge: London, UK; Routledge: New York, NY, USA, 2019; pp. 222–230.
58. Blake, E.C.; Cross, I. The Acoustic and Auditory Contexts of Human Behavior. *Curr. Anthropol.* **2015**, *56*, 81–103. [[CrossRef](#)]
59. Aletta, F.; Kang, J. Historical Acoustics: Relationships between People and Sound over Time. *Acoustics* **2020**, *2*, 128–130. [[CrossRef](#)]

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