ORIGIN POINT
Harmonic echoes of a stone cosmology

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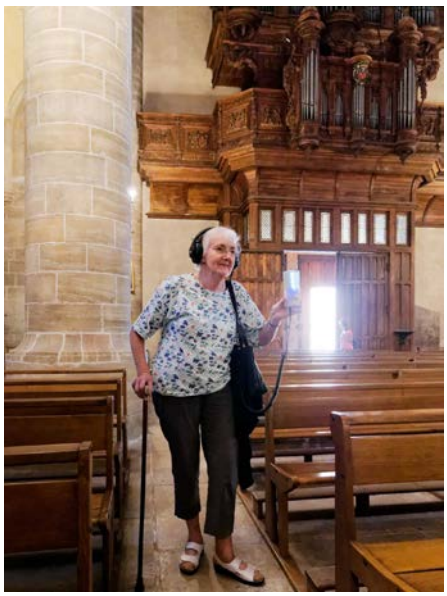
1 - Introduction



On these two photographs appear an old lady and an little girl. Both listen to music in a Gothic cathedral. The cathedral is located in the city of Mende, in Southern France, in the Department of Lozère. The object they hold in their hands is called a *harmonic lantern*. The harmonic lantern is a very simple device. Its only external features are an audio output, which can be connected to a headset, and a volume knob. They hold it vertically, like a candle. If they stand still, they hear nothing. When they walk the aisles of the cathedral, or when they move the lantern, they hear a music whose spectrum is very rich in harmonics that vary constantly according to their position. Each of their trajectories determines a different musical sequence. The harmonic lantern has a peculiar feature: at every moment, it stands at the centre of the world. In other words, each person carries a harmonic lantern carries the centre of the world with him.

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The lady and the girl are experimenting an *in situ* installation *called Mende Cathédrale*, developed from a research-creation program called *Origin Point*. It is designed to be very intuitive and extremely simple to use. It is meant for places accessible to all audiences. The photo above comes from the first presentation of this installation, which took place from July to October 2017. The device, as well as the music produced, represents both the conclusions and the results of several years of theoretical work, research and development spanning several disciplines. The purpose of the present paper is to summarize the main lines of this research, and to show how the final installation has become both the focal point and the synthesis of the conclusions of this work.

2. Architecture as a small cosmology

The starting point of the project, the one from which it emanates, is anchored in the following statement: any architecture, from the most miserable to the most sumptuous, is a small cosmology. This can be read through several elements, ranging from the symbolical to the analogical. Every building, even the most ordinary house, is loaded with a symbolic charge that connects its inhabitants to a set of questions for which there are no answers. The European suburban pavilion, the North American bungalow, are often presented as examples of the sheerest banality, or of the most saddening mediocrity. Yet, like any house, they shelter processes and actions that are essential for the perpetuation of life: to eat, to sleep, to reproduce, to excrete… Through this, they concretize in wood, brick or stone an assertion that is everything but obvious: human life, or the life of human beings, deserves to be perpetuated.

Very few people actually wake up in the morning wondering why they should stand up and start their day, rather than staying in bed, wondering why they should do anything at all and questioning the very necessity to do something, to conclude that life in general, and their life in particular, is useless and meaningless. In the same way, very few people would sit down to a meal, then get up and quit the room without eating because of similar concerns. People seldom question the need to start a family, less again the meaning of the chain of events that, from the birth of the Universe, generated this moment where they decide to have children and to perpetuate this very chain. To feed, to breathe, to wash, to talk with fellows or brethren, all these daily actions are suspended in a fragile balance above an abyss of vertiginous questions that are most of the time kept at a safe distance, in order for people to be able to live their daily life. This is where the role of the house becomes primordial: through its banality, through the everyday routines it induces, all its most ordinary aspects become safeguards that protect the reckless individual against the risk of endless questionings about origins, purpose, existence. Hovering between the biological materiality of the world and the vastness of the symbolic territories it dissimulates, even the most ordinary house can be said as talking with the gods.

The second cosmological connection of architecture appears through a set of analogical relations. In every historical period, it is possible to associate many, and sometimes most, elements of the building with the main elements of the cosmology

that prevails at the same time, and in the cultural area where it is located. Such associations can be sometimes subtle and sometimes obvious, but they appear at all scales, on all types of architecture, be they domestic, secular or religious, nomadic or sedentary. An eloquent example can be found in of the simplest houses of all, namely the Tuareg tent (fig.1). At a first glance, nothing seems to connect it to anything remotely or closely connected to the cosmos. A closer examination reveals that it maintains a constant dialogue with all scales of the world. A simple diagrammatic plan however shows that it is connected at several levels; for instance, it is oriented according to the four cardinal points. Despite the square shape of its structure, its name in Tuareg means "circle ", which makes no sense on a rational point of view, but illustrates the fact that the inside of the tent actually has the status of the centre of *something*. The areas facing the four sides of the tent have different significations. The western area, in front of the entrance, is open to the world and to encounters with other humans. It is the place for dining, for the tea ceremony, for receptions. In contrast, the eastern area, in front of the only blind side of the tent, is dedicated to contemplation and prayer. The northern area is seen as the evil one: supernatural beings gather there at dusk. They are called the *kel-esuf,* "those from the loneliness". On the contrary, the southern area is beneficial. It's the area of luck (*baraka*), and it is the place where woman give birth to their children.

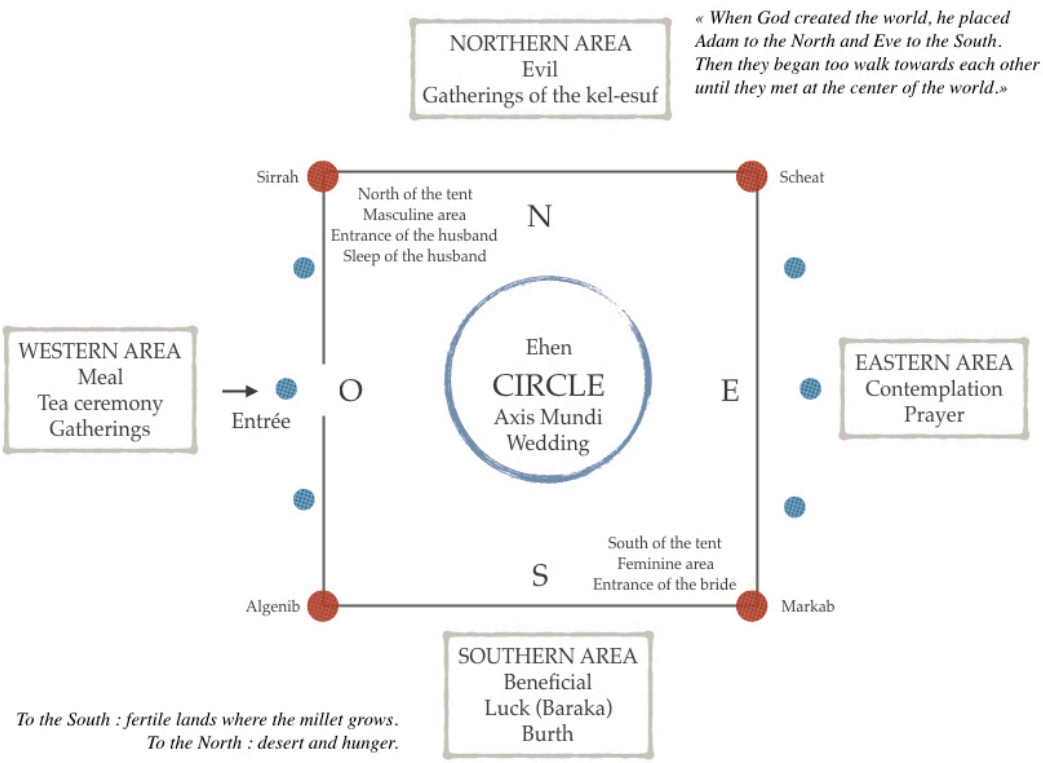

Fig. 1 – Symbolic Diagram of the Tuareg tent.

There is a first coincidence between this orientation and that of most Christian churches: the opening to the secular world, the reception, the meeting, is on the west side, in a kind of analogy with a church parvise. Prayer and contemplation,

corresponding to the dialogue with the divine beings of the religious cosmos of the tribe, take place against the eastern wall, which presents no opening, like the apse of a church. The beneficial and evil aspects of the northern and southern areas establish another connection with larger scale, namely that of the territory. They reflect the geographical situation of the Tuareg habitat: “The North is the kingdom of desert and hunger; in the South are fertile lands where the millet grows; inside the tent, the north side is the male area, that of the husband; this is where he sleeps; he enters the tent on that side, on the wedding day. The south side is the female area, the domain of the bride, through which she enters the tent on the wedding day.”

The plan thus determines not only the places of the spouses, but also the trajectory that leads to their encounter at the centre of the circle. This trajectory is also symbolical: “When God created the world, he placed Adam to the North and Eve to the South. They then began to walk towards each other until they met in the centre of the world”. The nuptial march of the spouses replays the meeting and mating of the original couple, from which all human life originates. The centre of the tent, whose Tuareg name, "ehen", means “wedding”, becomes at this very moment the symbolic centre of the world. The four pillars of the tent complete the cosmological connexion at an even larger scale: each of them bears the name of the main stars of the Pegasus constellation, Sirrah, Scheat, Algenib and Markab, which is approximately shaped as a square, and which is very obvious in the desert night sky. According to the Tuaregs, these stars were placed on the celestial vault by God to remind them that the whole sky is a gigantic tent, supported by four immense pillars placed very far away, out of human reach, on the four cardinal points.

To describe all the symbolic, poetic and analogical links that connect architecture to the cosmos and to the territory, we will use, for reasons that will be described in the following sections, the expression "harmonic connection". It is actually difficult to find a building that does not present a harmonic connection to some degree. If we decided to present the first installation from the Point Origin program in a cathedral, it is precisely because this building is a cosmological echo, by its symbolic load and through multiple analogies. To clarify this concept, we will look at a sequence that will take us back more than 2500 years in the past. It will allow us to recapitulate briefly the transformations that progressively led to the unique shape of the cathedral, and to see how it evolved afterwards. Then, thanks to a few selected examples, we will see how the successive changes in the cosmologies of different times have been reflected in the architecture of the corresponding periods.

3. Harmonic connections: the being and the world

The harmonic connection manifests itself by many different ways. It is not always obvious: it may imply permutations and substitutions between elements that could make it challenging to detect. An important point to consider is that it is not a scientific theory, not even a proven historical fact, but rather a poetic connection in the etymological sense of the term – a generator of *poiesis*, of creative possibilities. The history of architecture shows that architectural design in general does not bother with historical or scientific truths, except when it explicitly uses them as the basis for

a dedicated scenario: many major architectural pieces are based on myths, legends and fictions without any correspondence with history, nor with the reality of some ancient facts. The examples that follow are gathered only because they all present formal analogies with the cosmology of their times and places.

The following figure (fig. 2) illustrates different hypothesis about the structure of the cosmos at different times in history, from ancient Greece to today. The antique cosmos consists essentially in a planetary system, most of the time - but not always - centred on the Earth, or close to it. The sphere and the circle are common to all of them. As it is well known, in the cosmos that prevailed in Greece 2500 years ago, the planets circled the Earth in simple or complex orbits, depending on the models; but every orbit was always the result of combinations of circular motions. Beyond the farthest planets lied the sphere of fixed stars. These systems were invented in order to try to explain and predict the movements of the planets, especially those of the outer ones (Mars, Jupiter, Saturn), which at this time defied any attempt at prediction, hence their Greek name *planetai*, or wandering star.

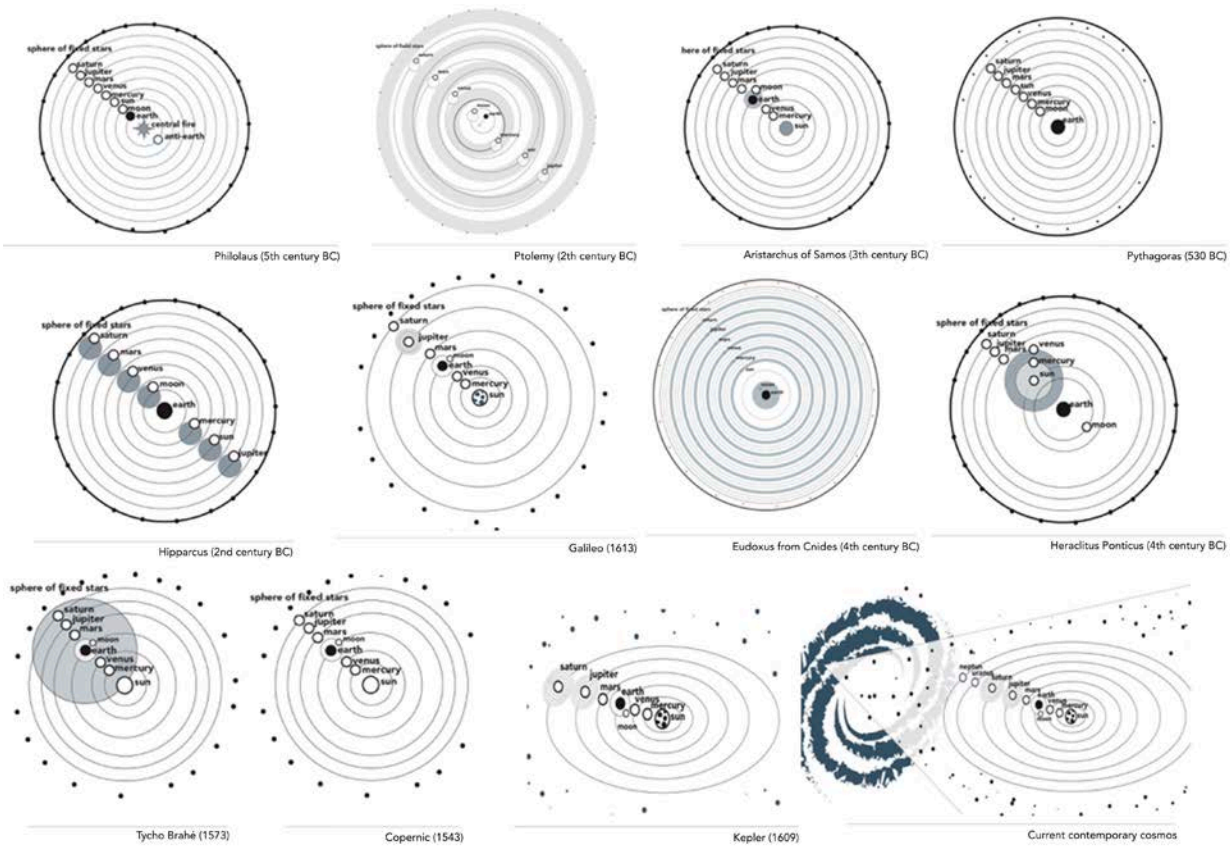

Fig. 2 – Schemas of planetary systems from the Antiquity to today.

In line with the writings of Anaximander of Miletus, whose explanations of natural phenomena are sometimes strikingly modern, Greek science has constantly sought to rid nature of any supernatural causality: the explanation of nature should be found in nature. The planetary movements had thus to be related to understandable geometric patterns that would allow to predict their trajectories with the best possible

precision. From this injunction were born a series of extraordinary models, all based on the notion of epicycle, in which the planets orbited around small circles whose centres revolved around the Earth along large circles called "deferent", and whose successive evolutions, which implied modifying or adding epicycles and circular movements to get closer to the observational data, served as a basis for Western cosmology for nearly 2000 years (fig.2). Although far from being free from all symbolic *a priori* - the obsession with the circular nature of celestial movements, and for the circle as a perfect form, brought the evolution of astronomy to a stall for centuries - the epicycles model is one of the first, if not the first model in history to use the notion of *harmonics*. Very different from that of *harmony*, it will not be properly formalized until the XVIIIth century through the work of French mathematician Joseph Fourier. As we will see later, it has become today a major principle for describing the physical reality.

As in the case of the Tuareg tent, the link between cosmos and architecture in ancient Greece unfolds on symbolical and analogical levels. The first one uses the notion of proportion, a very broad concept whose impact on the ancient world is impossible to overestimate. The second one associates elements of ancient buildings with elements of the celestial world.

The concept of proportion in this time was exclusively used to describe ratios of integer numbers. It was also impregnated with a symbolical load of mythical magnitude. Some special ratios, such as half or double, two thirds, nine eighths, were so important that they were given names, just like the numbers themselves: sesquialter, diatessaron, diapason... The origin of this status has been the object of innumerable publications. The most plausible hypothesis roots it directly in musical harmony. On the one hand, the divisions of the vibrating string of an ancient instrument, the monochord, produced sounds whose frequency was getting progressively higher when the length of the vibrating section of the string was decreased. The associations of the sounds produced by certain divisions produced timbres that were considered singular, either through their similarities, or just because they were pleasant to the ear ("harmonious"). The ratios of the corresponding lengths were therefore considered as having particular properties. On the other hand, the knowledge of the time imposed no theoretical limit to the number of divisions of a string. The frequency of the corresponding sounds could then rise indefinitely, giving the monochord the status of a messenger between the finite world of men and the infinite world of gods.

The gods themselves were morphologically similar to men, but the proportions of their bodies were, for the same mythical reasons, based on ratios of integers. As a result, the ideal body for a human being should show the same proportions: the body became the mean by which the gods revealed these proportions to men, in order for them to replicate them in all aspects of earthly life. It is from this hegemony of the concept that the injunction of harmony for all aspects of the world was born[1]. Harmonic proportions are found everywhere in the Antique world: law, economy, phases of pregnancy... and of course architecture and music, whose scales result - for obvious reasons - from these same proportions. The Greek temple, the very place where the supernatural world encounter the earthly one, is naturally based on

such proportions, constantly reminding to mankind the structure of the cosmos it inhabits. More than a simple state of things, harmony was an operator that actively ruled the world. Its power flowed along three lines: first, it was a descriptor, revealing to human beings how the Universe was made; second, it gave a list of instructions or injunctions about the actions to be taken to make the world harmonious – that is, to reach a satisfying arrangement of human affairs; third, it was a messenger between worlds, transmitting to mankind the information of the celestial realms that the gods wanted to communicate to them[2].

At the analogical level, the Greek temple can be seen as a topological inversion of the cosmos, through an antisymmetrical scheme that reveals both the connections and the differences between the two worlds. The plan of circular temples, or *tholos*, illustrates this fact better, because of the similarity between the circle of the plane and the celestial circles; but the overall topology remains the same even in the case of a rectangular plane (fig. 3). Greek cosmology places man and his world at its centre, surrounded by the spherical layers of the celestial world, where the planets reign. Each planet has its own layer. The last layer is the sphere of fixed stars, a celestial world through which the presence of the Gods can be felt and seen. The Greek temple echoes this sequence by reversing its order: human beings wander at its periphery; then comes the intermediate zone, made of progressively smaller circles delimitated by the colonnades and the walls; in the very centre lies the most sacred place, the *naos*, which is only accessible to the priests, and represents the passage through which the two worlds communicate. This tiny place is immense at the symbolical level: everything happens as if the whole sky was projected in it and engulfed into it, in the manner of a spherical mirror whose reflection includes all the points of the universe, even the most remotely located.

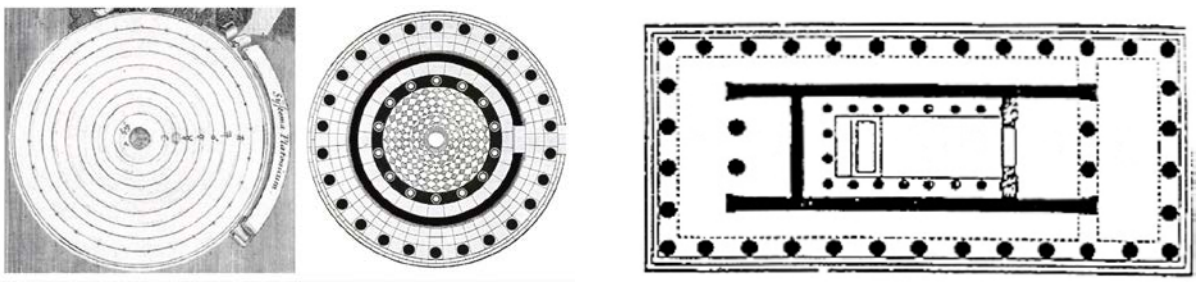

Fig. 3 – Left, tholos and planetary system; right, ground plan of the temple of Hephaestos (415 BC), by F. Hazan. The two buildings share the same topology.

Some 1500 years after the first Greek cosmologies, the Romanesque churches, as well as the abbeys of the same period, reflected the structure of an entirely different cosmos in a completely different way, corresponding to the radical transformations that affected the celestial worlds following the transition towards the Christian era. The example of the first Basilica of St. Peter in Rome illustrates these changes.

One of the main differences between the polytheistic skies of the Greeks and the monotheistic sky of the Christians is that the second is open and accessible to mankind: there are well established situations and circumstances by which humans

can become celestial beings, through beatification or canonization. These circumstances consist essentially in a life marked by ordeals, good actions and behaviours and initiatory phases, which will distinguish in the long run those who deserve to enter the celestial world. The righteous will go to heaven; the blessed and the holy will become celestial beings themselves. The drawings and photograph below illustrates two stages of Romanesque architecture that reflect this model (fig. 4). The two buildings are designed along a linear trajectory that leads towards a symbolic sky. In the left picture, the wanderer first crosses the westwork, a part of the building that is still connected to the terrestrial world, but gives access to the parvis (or paradise, the two terms being equivalent). The path then opens to the nave, whose spans reflect the initiatory stages, to reach the *saint des saints*, materialized by the tabernacle, the house of God at the heart of the building. It symbolizes, like the *naos*, the connection with the heavenly world. In the right picture, corresponding to a later scheme adopted by the vast majority of Romanesque and Gothic churches, the parvis is placed outside; the westwork is built directly against the nave. It is accessed through a porch that opens on the narthex, already inside the church, and then to the nave. The access to the paradise, or parvis, becomes far less restrictive and gets closer to the world of humans. The main threshold is shifted to correspond to the very moment when the path towards the heavens begins. The most essential point of this trajectory is that it is a two-way path: the Catholic religion states that anyone can speak to heavenly beings, asking for divine intervention, and that an answer will be provided. The nave of the church becomes the passage through which the world of men and the divine world communicate between each other and mutually infiltrate themselves, a situation that was not conceivable for the religion of ancient Greece.

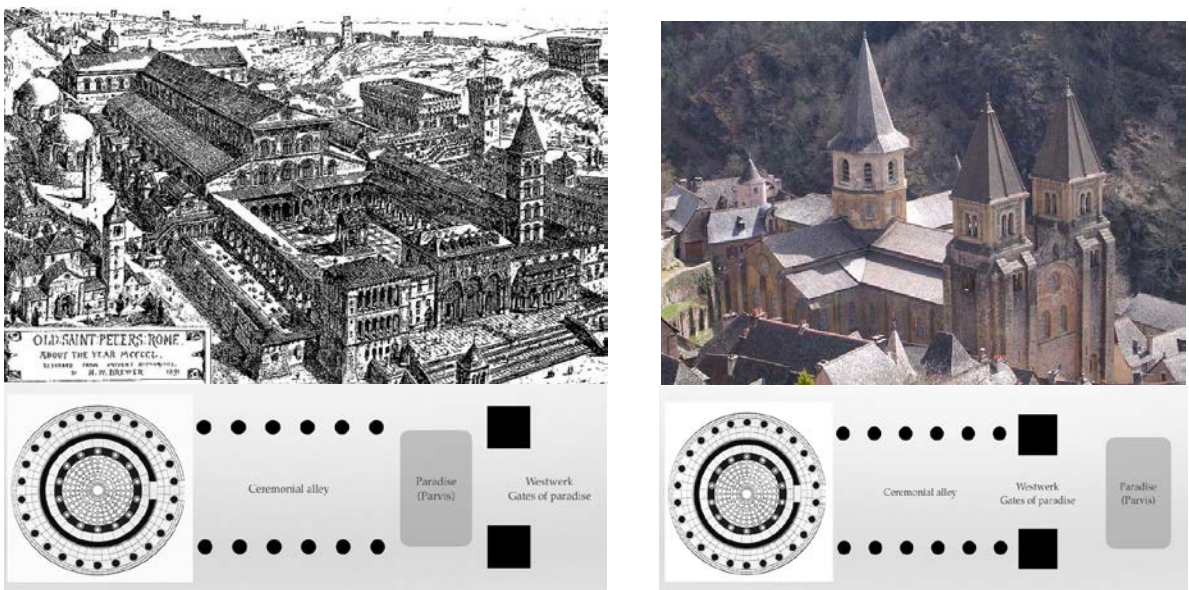

Fig. 4 – Two stages of the evolution of Romanesque churches, showing the displacement of the parvis out of the main body of the building.

The coincidence between the spatial orientations of the Christian church and the Tuareg tent described previously is worth noticing. In both cases, social events,

meetings and celebrations take place in front of the main entrance, located to the west. In both cases, the east side, which corresponds to the apse of most Christian churches, is blind. It corresponds the most sacred location: the space dedicated to the prayer in Tuareg tents; the choir that houses the relics, and where the ambulatory processions take place, in Christian churches. This is not a coincidence, since the tent described above comes from tribes who were converted to this same religion, but it shows that the harmonic connection can be found at all scales of architecture, in extremely different times, places and cultures.

Another similarity, perhaps more important, is present. It will be remembered that the centre of the Tuareg tent corresponds to the place where the wedding and sexual intercourse happen. It therefore symbolizes the origin and perpetuation of life. Christianity has constantly and stubbornly ignored the sexual symbolism of cathedrals, a symbolism which, in the light of psychoanalysis and early works on the unconscious, has become obvious. Just like the tale that rid the conception and birth of the Christ of any sexual connotation or desire, the symbolic centre of the cathedral represents the symbolic place where life perpetuates, but it hides in an obsessional and almost neurotic way any element pointing to the biological and corporeal aspects of human reproduction.

The architecture of the Renaissance marks another step in the harmonic connection sequence. The reinterpretation of Vitruvius by Alberti around 1440 is one of the most important events of Renaissance architecture. It chronologically corresponds to the introduction of new and specific elements both in architecture and in the arts, a discipline of which the same architect also treated a few years earlier in his treaty *De Pictura*, describing among many other things the proper method to create perspective drawings. It marks the beginning of a hybrid period that lasted several decades, where sciences and arts oscillated between an ancient world still dominated by divine forces and heavenly beings, and a new one during which, progressively, humans reconciled themselves, after a 2000-year eclipse, with the idea of a nature explainable by natural phenomena, themselves understandable by the power of rational thought.

Fig. 5 – Alberti's façade for Santa Maria Novella in Florence. The Renaissance façade was directly applied on an older Gothic nave.

Despite its coherence, the famous facade of Santa Maria Novella in Florence (fig. 5) is emblematic of such transitional architectures. Built in front of on a Gothic nave, it presents many elements still characteristic of this mediaeval style; but he skills of the architect allowed him to integrate them in a facade which, at first sight, fully corresponds to the canons of the new classical style, which derived directly from the writings of Vitruvius. The architect tamed the irregularities of the previous style to incorporate them in the clear, precise and austere style of the early Renaissance. Everything happens as if the cosmos could not be understood anymore by symbolic or mythological representations with ineffable causalities, but through the clear and transparent power of geometry, itself a product of humans'brains and reasoning.

The same duality appears, though on a slightly more blurred way, in a painting like the Wedding at Cana by Veronese (1563). This work is based on a double perspective that is not obvious at a first glance, and that determines two vanishing points (fig. 6): the first one stands in the face of Christ, the second one points towards an empty area of the cloudy sky. Neither of them corresponds to the centre of the painting. Veronese could not ignore the rules of perspective, precisely described in Alberti's *De Pictura*. They clearly state that the vanishing point of any perspective is the place where the infinite stands. The painting thus supposes the simultaneous existence of two infinities. The first corresponds to the Christ himself, which is in tune with the ancient cosmos. The second is in an early evocation of an infinite sky, a concept that was impossible even to imagine in the previous centuries. In the indeterminate zone that lies between the two points, precisely halfway, appears a dish in which a piece of lamb is sliced before being served to the guests. Exegetes of the work have been writing that it corresponds to the sacrificial lamb: it evokes the double nature of Christ and testifies for the necessity to join the most Earthly considerations - food - to celestial considerations - religion - to reach a full and complete description of the world.

Architectural echoes of the different stages that led to the contemporary cosmos can be similarly found during the following centuries. One of the main impacts of the Copernicus heliocentric model has been to dislodge the habitat of mankind, and consequently human beings themselves, from its singular and central (or nearly central) position in the universe, stripping them from a most privileged status. The dimensions of the sky, without becoming yet infinite, were multiplied by colossal factors in the new model. Along these transformations, the Earth was put into motion and became a *planetai* like the others seven, marking for humans the start of a perpetual wandering in a space which, over the centuries, was to become increasingly huge and elusive. The entire sky, rather than the Earth alone, has become the house of man and of his endless perambulations.

Published in 1543, the Copernican system was already circulating confidentially since 1513 and was rather known in educated circles. It preceded by a few years the completion of Palladio's Villa Almerico Capra, known as Rotonda (1566-1571). The architect explains the striking symmetry of the architecture by its location on the top

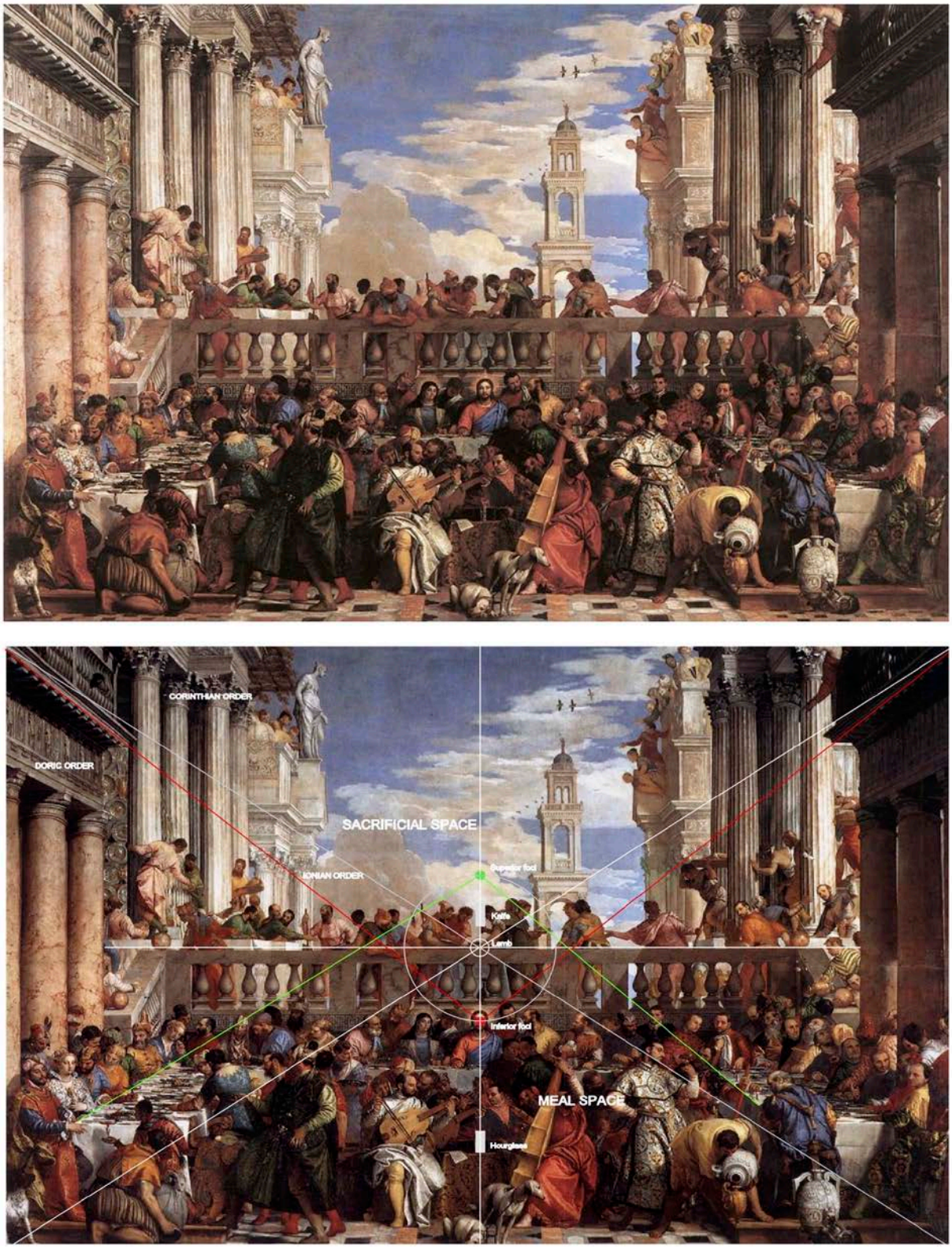

Fig. 6 – The Wedding at Cana (Veronese, 1563). The bottom picture shows the two vanishing points: the bottom one is on the Christ's face; the top one is in the sky. Midway between both is a piece of lamb, symbolizing the sacrificial meal.

of a hill: it enjoys a peripheral view that justifies the implementation of identical

façades, composed more or less like theatre stages, on its four sides, so as to contemplate the scenery of nature in all directions. Without refuting this interpretation, it is also possible to see in this centralized plan, one of the first to resurface since the Paleochristian and Byzantine eras, a first representation of the new cosmos on the surface of the Earth. For the first time, this representation is not proposed in a sacred building, but through a domestic one, which can be considered as the most profane type of architecture. The use of a dome on a house in the Western world, an element that was also found only on monuments, reinforces the image given of the new cosmos: instead of occurring at the very centre of the world, the wanderings of humans take place in the space unfolding beneath a stone sky. Several other elements concur to this cosmological interpretation: the architecture by itself evokes no domestic function, but is much closer, through its monumentality and morphology, to a mausoleum; the diagonal orientation with respect to the cardinal points determines a division of the world into four quarters on which the four façades open, a configuration that can also be found in the almost contemporaneous dungeon of the Chambord Castle in France (completed in 1547), partially attributed to Leonardo and also infused with a strong cosmic symbolism. From these clues, it is not unreasonable to suppose that here too, just like in the Touareg tent and the Medieval church, the building, through its architecture, anchors in the territory an echo and a model of the emerging cosmos.

We can find a similar chronological coincidence between the introduction of the ellipse as a celestial figure in Kepler's Astronomia Nova (1609) and the first uses of elliptic shapes in Western architecture. Among the main examples is the esplanade of Saint Peter’s Basilica in Rome, designed by Bernini (completed 1667). It is not unreasonable to suppose that Bernini, a highly educated man, was fully aware of Kepler's work. According to several authors, this may have faced him with a dilemma when designing this work, which can be seen as a symbolic evocation of a cosmos dominated and illuminated by the large basilica. He could either base his design on the old cosmology and use a circular plan, a position without risk for him. But if he did so, the architecture of this highly symbolic place would soon become obsolete to the light of the new knowledge. If, on the other hand, he designed it according to the new cosmology, he would deploy just in front of the basilica, and in front of the private apartments of the pope, vast geometrical figures that would remain heretical for decades, in a flagrant insult that could have led him directly to the stake. Bernini evaded the question by declaring that the colonnade represented two open arms, intended to welcome the crowd of the faithful. This assertion is refuted, and considered as an alibi, by most commentators of his work, on the basis of the drawings accompanying his texts, and of several other clues that point towards a cosmological meaning: the central Egyptian obelisk comes from Heliopolis, “the city of the Sun”; the opening of the colonnade and of the two trapezoidal arms define angles that correspond to the sunrise location on the solstices; the positioning of the fountains at the foci of the ellipse corresponds to possible positions of the Sun in the new system (fig. 7). The architect later used of the ellipse in the church of Saint-Andre-du-Quirinal (1661-1670), which served as a model for many churches of the Baroque and Mannerist periods, generalizing the use of this new cosmic figure to sacred architecture as a whole.

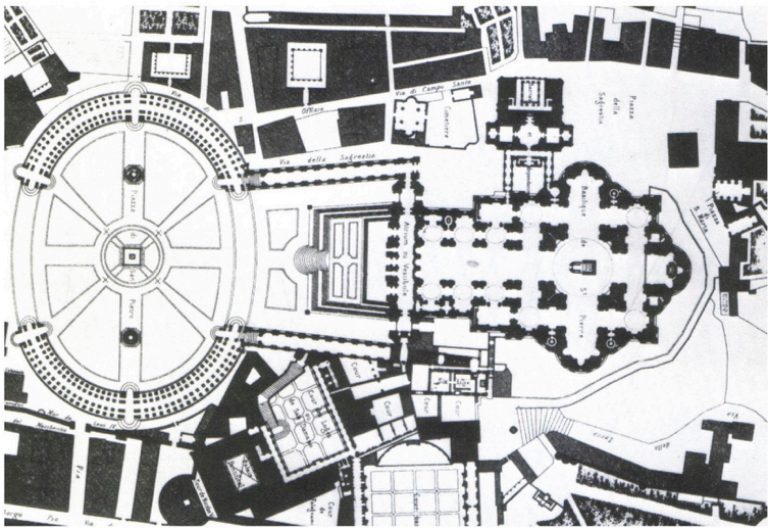

Fig. 7 – Plan of the elliptical esplanade in front of the St-Peter basilica in Rome, by Bernini (completed 1667).

The following centuries saw, in the same way, many formal correspondences between the cosmos and the architecture of a given time. After the publication of Newton's *Principia Mathematica* (1683), in which he formulates the law of gravity, a completely new image of the universe began to emerge. Huge celestial spheres, hovering in a space of gigantic proportions, were majestically revolving and orbiting without any support. During the following century, several architects, today known as “revolutionary”, but who would be more aptly called “newtonian”, published impressive drawings of buildings that were just as utopian as enormous: their size reached dimensions that were never seen before in the history of architecture (fig. 8).

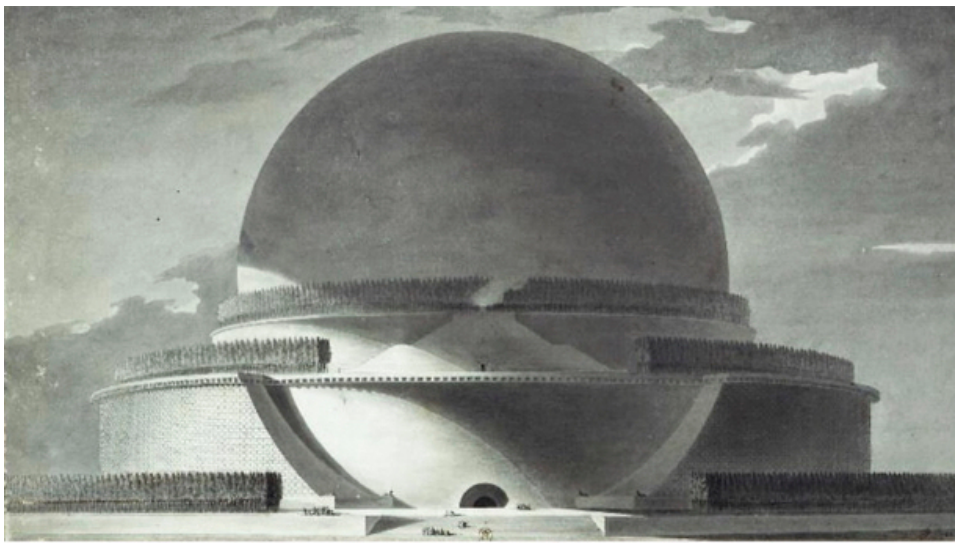

Fig. 8 – Newton’s cenotaph by Etienne-Louis Boullée (1784).

Also for the first time, several of these architects, Boullée and Ledoux among others, used a new architectural form, namely the complete sphere, rather than hemispheres, like in domes or cupolas, or quarter-spheres, like in *cul-de-four* vaultings.

In another historical premiere, Newton presented the hypothesis of an infinite space, a conclusion that logically derives from his theory: in a finite space, the stars would necessarily attract each other, to ultimately crash on each other. The huge size of some the revolutionary architects' buildings can be seen as figures of the potential architectures made possible within a universe of unlimited dimensions; but the first explicit architectural evocations of an infinite space are actually found in the architectural treaties published Jean-Nicolas-Louis Durand, then professor at the Ecole Polytechnique in Paris, published from 1800 on (fig. 9). Durand implicitly states through his drawings that the plans of remarkable buildings should be determined by the partitioning of a set of meshes chosen on a grid that extends well beyond the building, without apparent limits: the spaces were humans wander become closed cells, only differentiated from outer cells by the will of the architect, within a universe that extends far beyond any known frontier.

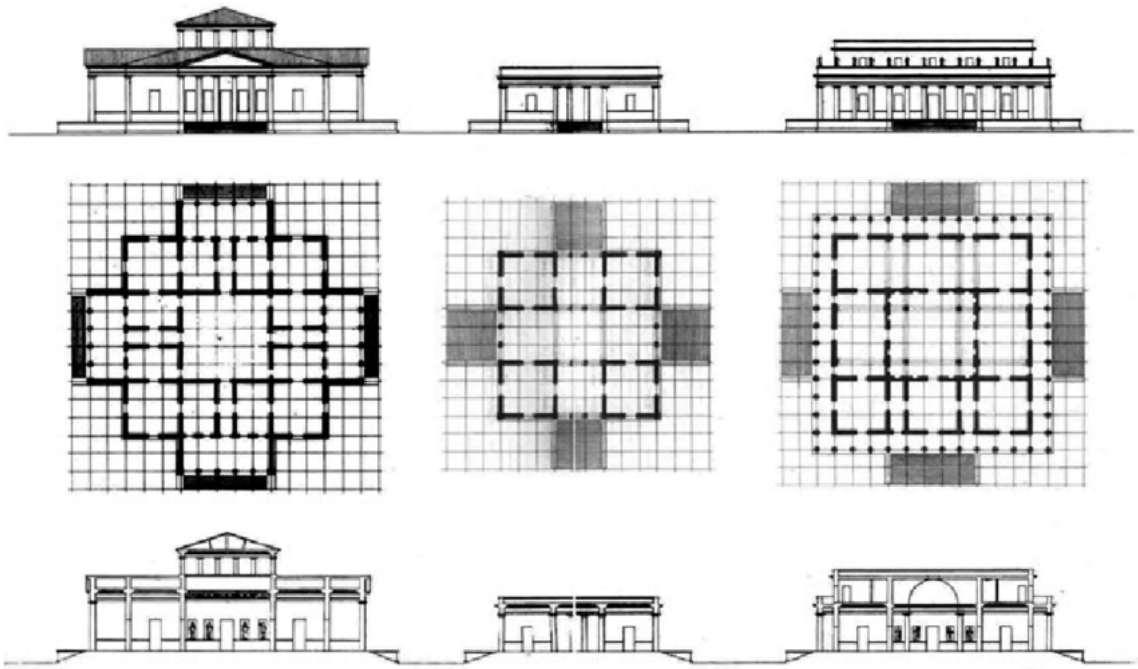

Fig. 9 – Building plans by J.N.L. Durand, plate No 2, Précis des Leçons d'Architecture Données à l'École Royale Polytechnique, 1825.

Despite its apparent neutrality, the grid itself is a powerful icon: it represents the Cartesian coordinate system, established decades earlier by Descartes. This conceptual tool, thanks to which Newton could derive its laws, is in fact a device for tracking precisely the behaviour of objects, events and phenomena. It assigns an address to each point in space, instantly determining the time and distance required for reaching it. It announces, also for the first time in history, the worrisome image of

a world in which getting lost becomes impossible. In the same way the new physical laws unify the description of apparently unrelated phenomena, and reduce the complexity of the world to a small set of simple principles, Durand's method of composition and analysis unifies all architectures by reducing them to the permutations and combinations of the cells of a perfect grid.

Throughout this cosmological sequence, the entire structure of the universe has evolved both geometrically and topologically. A pattern however seem to persist: the circle and its three-dimensional version, the sphere; but its status has undergone considerable changes. Like it is well known, for Greek geometers, the circle was a symbol of perfection and thereby had a privileged status among all other shapes; for modern science, its status depends on the way it is considered. It can be seen as a special case of the ellipse; or, since Desargues' projective geometry, all conical curves (circle, ellipse, parabola, hyperbola) can be seen as variations of a same curve seen from different angles and points of view; none of them can be seen anymore as special.

Compared to the circle, especially on the cosmological point of view, the ellipse poses a problem: it has three characteristic points - the centroid and the two foci. All of them could legitimately claim the status of centre, raising the crucial question to know what – and who- lies at the centre of a world of which the ellipse has become the main figure. By this, the very centre of the world ceased to be unique, and began to multiply. The history of cosmology, i.e. the history of the stories of the Universe, actually follows the history of the displacements of the centre of the world.

Fig. 10 – The perceptual sphere. The only acceptable centre in the contemporary cosmos is the point where I stand at any moment. All events, objects and phenomena of the world are projected on a virtual sphere whose centre is my position, and on which they draw constellations that constantly move and transform.

As we have seen, this highly symbolic point, whose existence has never been questioned for thousands of years, has long hovered very close to the Earth, shifting from the surface of a flat world to the middle of a spherical Earth, from empty points in space to the mythological inferno, before flying towards the Sun and to pulverize itself, from Galileo to Einstein, on every point of the Universe: the relativistic model implies that no place can claim to be at a privileged position anymore. There is still however a point that can be seen as being slightly different: it is the precise point where I stand at any given time. It might seem presumptuous to consider myself as the centre of the Universe, but it must be added immediately that the same can be said for every human being - and probably for every living organism. At every moment, I stand at the very centre of my own perceptual sphere, a virtual surface on which all objects, phenomena and events are projected in the manner of perpetually moving and transforming constellations. It is through it that I scan the world, in order to determine at every moment my next interactions with it (fig. 10). It moves constantly with me, opening in every direction various horizons that appear and disappear according to my displacements.

4 . From harmony to harmonics

During the Enlightenment, the birth of modern science brought an abrupt end to the ambitions of the harmonic connection to say anything sensible about the cosmos, and completely eliminated any human reference (foot, thumb…) from its new measurement system: starting closely after the French Revolution, every distance was determined in relation with the size of the Earth (the meter was initially defined as the 10 000 000th part of the quarter of the meridian). It may be time to remind that this connection, in the antique harmony of the spheres, implied another element, music, which we did not yet discuss. How did it evolve along this sequence of paradigmatic changes? It has actually not escaped them: the progressive ordering of the Universe and of architecture was accompanied by a similar rearrangement in all areas of music, including written text and musical notation, on which we will not elaborate here. We will only mention that the final standardization of the musical staff took place between in 1650 and 1750; and that the description of sounds in terms of frequencies, after the birth of acoustics, also followed a precise mathematical formulation, which was formalized in Helmholtz's treaty *On the Sensation of Tone as a Physiological Basis for a Theory of Music* (1863). From then, the score and the staff were based on a descriptive model that was, through several of its aspects, at least as accurate as the new scientific models of the cosmos. Each musical note of the classical score has a specific address in a time-frequency space in which durations are precisely determined. It is interesting to note that these "musical equations" appeared less than half a century after the publication of Newton's laws of gravity.

The great victim of this ordering is harmony itself, as well as the proportions system on which it was based. The virulence of the writings of some authors of the time, especially in England, with authors like Hogarth and Burke, leaves no doubt about the fierce determination of the new scientific establishment to exterminate all traces of what became to be seen as a set of obscurantist superstitions. Still, one of the

harmonious cosmos elements, directly derived form the notion of proportion, managed to get through these hard times to become today one of the key elements of the scientific model of the world. The name of this element, “harmonic”, echoes its musical origins. The notion of harmony has completely disappeared from all scientific models; it remains confined in the field of arts. The concept of harmonics on its side can be found in a tremendous number of fields. In science, it is now used to describe the basic components of a complex phenomenon. It is used to analyse, combine and reconstruct sounds, lights, images, shapes, signals. We owe the theory of harmonics to physicist and mathematician Joseph Fourier, who derived it from a research about heat propagation in solid bodies. As it is well known to all musicians and composers of electronic music, this theory postulates that all complex periodic timbres, such as the sound of a clarinet, a *grand orchestre* or a mechanical device, can be decomposed into a set of simple signals. In the case of sound waves, these elements are simple signals that correspond to basic trigonometric functions - sines and cosines; but the decomposition can be done on any basis of functions called "orthogonal", i.e. functions that, in a graphic representation, always intersect at right angles.

These simple signals correspond to the harmonics. To each sound corresponds a spectrum, which consists essentially in the list of harmonics required to create it. They are defined by their wavelength, amplitude and phase – this last term representing the amplitude of a given harmonic at the beginning of the sound. The epistemological importance of this discovery can not be overestimated: it proposes a unifying principle for all the sounds of the world, from the simplest to the most elaborated, which allows not only to compare them, but also to rebuild them using elementary signals, in an operation known as "additive synthesis”. It also allows the creation of brand new sounds by applying different operations on combinations of spectra coming from different sound samples.

Despite the importance of this theory, Fourier’s name fell into oblivion for a hundred years: his name does not even appear in the 1974 edition of the *Encyclopedia Universalis.* The last decades of the XXth century completely transformed this situation. The important developments in signal processing required by computer science, information technology and telecommunications have led to a massive revival of interest for this work, to the point that some authors do not hesitate to say that Fourier will soon join Newton, Maxwell and Einstein in the pantheon of the greatest theoretical scientists. His work extend far beyond music: applications are found in a wealth of disciplines - optics, image processing (the jpeg format is directly derived from it), pattern and shape analysis, cosmology, planetology, acoustics ... Far to be a local and anecdotal discovery, it offers a way to describe the physical reality with only one object, the wave, which has the unique and singular property of being able to describe simultaneously an element and its opposite: several wave trains meeting on a same area can create simultaneously, depending the additive or destructive nature of their interferences, sound and silence, light and darkness, matter and space, and so on.

Beautiful scientific instruments were created to analyse musical timbres according to

this new model, like an extraordinary tonometer with its 670 tuning forks, or a sound analyser with resonant spheres (fig. 11), both built by Rudolph Koenig in the XVIIIth century. The image of a timbre that can be decomposed into elementary sounds, just like white light can be decomposed into primary colours, became the preeminent model in acoustics and physics. It led in the following decades to a first unification of harmony, chord, timbre, and melody, which came to be considered as four aspects of the same phenomenon, mainly differentiated by their temporality. The idea to use spectral principles as a full basis for sound or musical composition came however much later, essentially because the required technology did not exist before. It find its premises in the mid-XXth century, with works by Xenakis, Ligeti, Stockhausen and several others; but the expression "spectral music" did not appear before 1979.

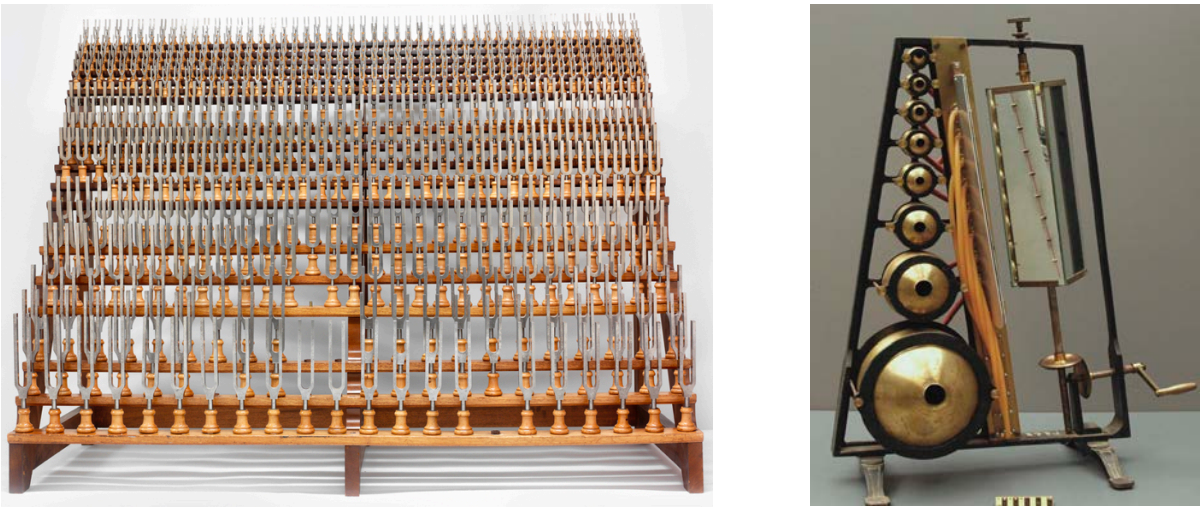

Fig. 11 – Left: tonometer with 670 tuning forks; right: frequencemeter with resonating spheres. Both instruments by Rudolph Kœnig, XVIIIth century.

The importance of Fourier's work and of spectral music theory, in the context of our discussion, lies in the fact that it leads to nothing less than a new version of the harmonic connection, reinterpreted and redefined in the light of contemporary science. It is precisely between 1960 and 1990 that Fourier's work was reconsidered to become a major cosmological principle; no rigorous demonstration could claim to give spectral music a cosmological status as such, like for the ancient music of the spheres, but the analogies it presents with the cosmological model of harmonics cannot be easily dismissed.

Such analogies are found in several places throughout the period leading up to the birth of modern science, whose beginning can be approximately dated at the time of the publication of Kepler's *Mysterium Cosmographicum* at the turn of the XVIIth century. Several authors could pretend to symbolize this transition, but Kepler occupies a special place: a hybrid character, rooted in the ancient cosmos and precursor of contemporary cosmology, he saw his career oscillating between astrology and astronomy. He was able to finalize the three laws that bear his name, and to describe the orbital features of any revolving object, by starting from a major feature of the ancient harmony of the spheres, namely the song of the planets: in the ancient cosmos, every planet was constantly singing. The farther it was from the

Sun, the lower was its voice. Men could not hear them since they were used to it; but new born babies were so terrified by these loud rumbling voices that they screamed and cried night and day - thus proving the theory. By trying to tune the song of the planets, Kepler derived one of its laws, namely the one that links their respective periods to their distance from the sun. The tuning of his new version of the ancient cosmos was obtained from the tone of the Earth: since its orbit is slightly elliptical, its plays a melody of only two notes, separated by a semi-tone interval. According to the astronomer, this semi-tone could only be the one that separates the notes E and F: in latin, these notes are called *Mi* and *Fa*. They perfectly represent the fate of mankind, summed up in two words, *MIsere* and *FAmes* – misery and hunger. Despite this optimistic origin, devoid of any scientific basis, Kepler's laws remain today as valid as they were at the time, and are expressed in the very same terms since then. They can be now directly and easily derived from Newton's laws, and they are used each time a satellite is launched into orbit.

Kepler is the first in a series of authors who have attempted, from the knowledge of their time, to develop new versions of the harmony of the spheres that became progressively more rigorous on the scientific point of view, and in which the concept of harmonics gradually became an essential element of the new cosmology. Everything happened like if, despite the relentless refutations of the old models by the new science, astronomers and astrophysicists could not bring themselves to imagine a universe without music at all scales and at all levels. This resilience of the model raises a number of questions, many of which being not fully understood, on the importance of musical analogies for the description of the world. In the next paragraphs, we will see two theories, one by Louis de Broglie and the other by Jean-Pierre Luminet, that will provide us with examples drawn from both ends of the cosmological scale.

At the level of the microcosm, in the early XXth century, Louis de Broglie, a French physicist, tried to find the laws that define the distances between the electron orbitals and the atomic nucleus, in the specific case of the hydrogen atom. He found the answer by using a direct musical analogy. By assuming, for theoretical reasons, a spherical shape for the orbitals, and by associating to each electron a spherical carrier wave of specified wavelength, he could find that the only allowed orbitals were those that corresponded to a whole number of wavelengths, just as for the frequencies emitted by the vibrating string of the monochord, or of any musical instrument. His theory allowed him to predict the radius of all orbitals with unprecedented accuracy. At the other end, at the macrocosm level, French astrophysicist Jean-Pierre Luminet recently proposed a new cosmological model that states that the Universe could be much smaller than what was previously calculated from the Big Bang theory. The Fourier analysis of the spatial distribution of the cosmic microwave background radiation, a remnant of the colossal radiations emitted shortly after the Big Bang, gives a spectrum in which the largest wavelength, or in other words the larger harmonics, are almost completely absent, when they should have been dominant. This suggested him an unexpected hypothesis according to which these wavelengths are missing because the universe is not big enough for them to travel. The dimensions of the cosmos must then be derived from the wavelengths of the largest present harmonics, which shrinks them by an order of

magnitude. If we see the Universe as big as it appears, it is because it is the object of multiple reflections on itself, like a room of mirrors whose shape would be dodecahedral. This model leads to a fascinating idea: looking in a particular direction, it should be possible, by using instruments considerably more powerful than our present telescopes, to contemplate our own Solar System - or rather, the place where our System stands - as it was billions of years ago, and even before his birth.
Besides these three examples, a wealth of books from all realms (science, architecture, poetry, arts, philosophy, esoterism, metaphysics…) uses direct and explicit reference to the music of the spheres. At the cosmological level, the mathematically redoubtable string theory, first enunciated in the 80's, postulates that the most fundamental particles of the universe should not be represented as punctual spheres, but as infinitesimal strings whose vibration modes in a 11-dimensional space generates all the particles we know. It is the first theory to propose a convincing unification of the four fundamental forces known today, but it is unfortunately unverifiable experimentally, and faces insurmountable mathematical obstacles that currently confine it to the status of mathematical speculation. The fact remains that despite its complexity, it presents several analogies with the ancient theories, and has occupied most of the research time of major physicists and astrophysicists during the last decades.

On its side, the field of architecture sees regularly, among students, researchers and practitioners, the emergence of projects based on a particular musical form, as if the link between both disciplines has remained privileged across the centuries. A common but approximate quote states that architecture is to time what music is to space. Countless authors, from Frank Lloyd Wright to Hassan Fathy, through Goethe, Paul Valery and Le Corbusier, associated in one way or another the too pairs space/architecture and time/music, either describing architecture as a frozen music, or an architectural promenade as a musical symphony, with its opening, its movements, its crescendi and its finale. Several of them, such as Valery or Le Corbusier, directly associate it to human body proportions. Their writings are mostly devoid of any cosmological reference, but they clearly suppose that any architectural or musical piece is a small cosmos, locally and temporally defined, in which all elements are organized according to a unique and particular arrangement: architecture installs and distributes matter in space, and space in matter, and works on the boundaries between them; music distributes and installs sounds in silence, silence in sounds, and works on the transitions between them.

Of course, things are not that simple: the relations of architecture to time, as well as the relations of space to music, are essential to fully appreciate these arts. What interests us here is that any known form of organization can be used to compose an architectural work or a musical piece; and that the discovery of new forms of organization is likely to trigger the appearance of new musical or architectural forms. This is for instance the case for fractal geometry. Introduced in the 70s, it helped to characterize shapes and configurations previously reluctant to any geometric reduction, such as clouds or mountains. It created a paradigmatic change when it managed to introduce these elements into the broad category of ordered objects: by doing so, it completely transformed the very meaning of words such as “order” and

"organization", and even added a new meaning to the word "harmonic". The repercussions of this shift were felt in all areas and at all levels, and triggered the emergence of architectural or musical works designed directly from fractal patterns or algorithms - cosmic echoes under which, even in the most modern world, still shine the faint glows of the principles into which the ancient universes were anchored.

4 . Mende Cathedral

Fig. 12 – Notre-Dame and Saint-Privat cathedral, Mende (France), completed 1512. The West and North portals were built during the XIXth century. Left: aerial view. Right: the westwork seen from the parvis.

As we have seen, the passage from the harmony of the spheres to the contemporary Universe as a model for describing the world was accompanied by the disappearance of the concept of harmony as a cosmological operator, in favour of harmonics. Nonetheless, the two concepts present important similarities in their respective roles. Just as harmony, harmonics are messengers who convey important information about the status of inaccessible worlds, such as atomic orbitals, or the most remote layers of the observable universe. Like it, they play an ordering role: all harmonics-based compositions show patterns or rhythm of various kinds that distinguishes them from random compositions; like it also, they allow a description of the world by abstract objects that are both simple and limited in number. Retrospectively, it is worth noticing that the epicycles of the Ptolemaian solar system and of many of its predecessors, just like the ones that Copernic used in a desperate attempt to preserve the circularity of his heliocentric orbits, correspond exactly to the contemporary definition of harmonics. Thus emerges a new connection between the ancient and modern theories, in which a deep equivalence is established between the concepts of orbit, wave and rhythm; and which states that any phenomenon that

can be described by one of these figures can also be described by the other two.

It is from these considerations that was born, several years ago, the Point of Origin research-creation program, from which the *Mende Cathédrale* project constitutes a first experimental installation. The basic idea underlying it was to explore the possibility of implementing, at least theoretically, the possibility to define a new method for transposing an architectural form into a musical form, in a contemporary version of the harmony of the spheres rethought in the light of the models proposed by modern science for music, acoustics and cosmology. In other words, the objective was to directly produce an architecture from a musical form, or the reverse, based on cosmological considerations, with a condition that was not met in any of the similar attempts that we studied, namely reversibility: the transition from one realm to another, just like the reverse transition, must be done without any loss of information, and must allow to fully restore the original form. This condition proved to be a very strong constraint. We quickly realized that it involved the use of strictly formal descriptions that should be reducible to numerical data and mathematical relationships. After several attempts, we developed a method that was based a particular mathematical object, called "spherical harmonics " – an object that is conceptually simple and fully in tune with our previous theoretical research, but whose handling requires a fairly advanced knowledge of mathematics.

The starting point of the installation is precisely the interpretation of any architecture as a small cosmology in which the visitor wanders without precise destination, like the human trajectories on Earth and in the Universe, constantly carrying with him his own centre of the world (Fig. 13). At every moment, the whole architecture of the cathedral is converted into a set of musical timbres; the conversion is made from the precise point where the visitor stands. Since each point determines a different transposition, the timbres and sounds constantly changes when the visitor travels the church. Any wandering in the nave of the cathedral becomes a musical trajectory among an architecture made of timbres and sounds, concretized by the specific frequencies of the waves, which by their interferences reconstitute the whole shape of the cathedral as accurately as the geometry of the stones. Any displacement in the cathedral determines a specific musical sequence; it is virtually impossible for two visitors to produce the same music.

To better understand the process by which the building is converted into sound waves, it might be useful to describe its different phases. The first phase consists in decomposing the building, or rather a digital model of it, into segments that can be individually analysed; these segments should ideally be topologically similar. The second phase consists in analysing each segment so as to convert its physical shape into a wave series. In the third phase, these waves are converted into sound harmonics. The fourth and final phase consist in combining these waves through a sound synthesis process, in order to produce the desired timbres.

The segments needed for the first step can be obtained by several different ways. For instance, it could be possible to split the cathedral into extremely thin slices like a cake, and to analyse them separately; or, to break it down into small cubes, similar to

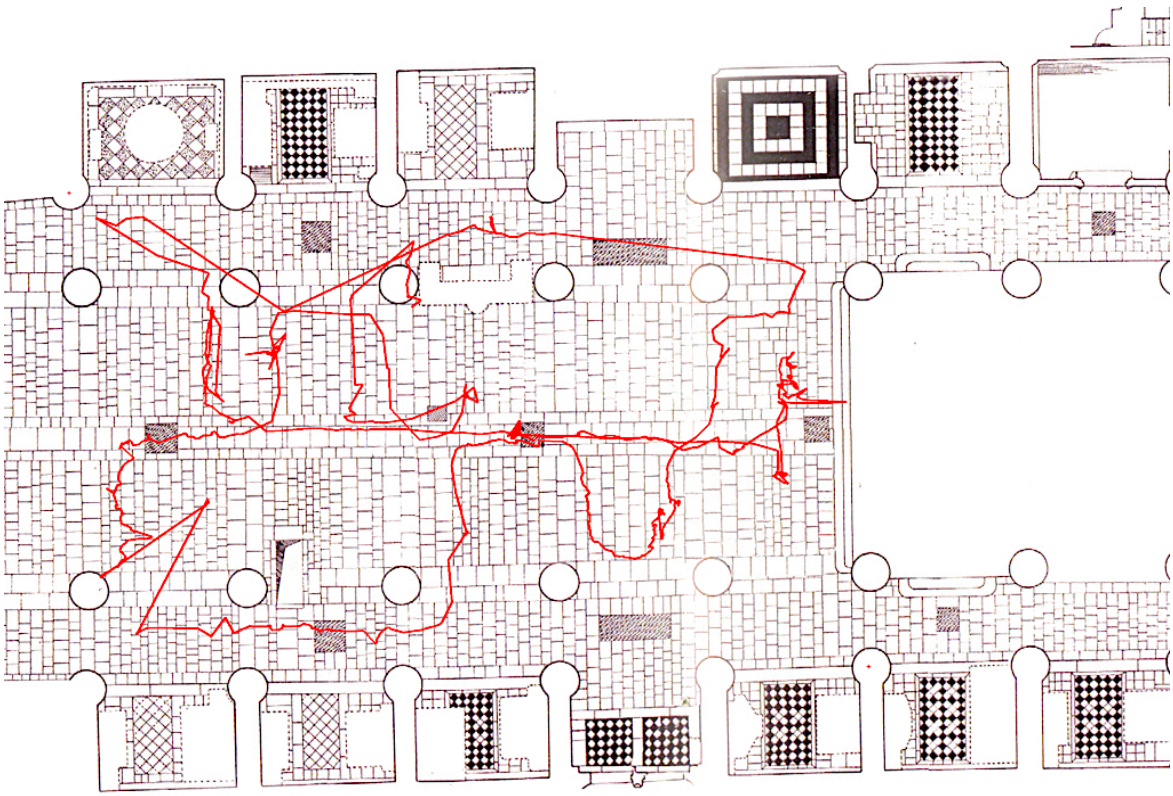

Fig. 13 – Wandering trajectory of a visitor in the installation space. Each point of the trajectory corresponds to a precise timbre. By walking the church, the visitor creates his own and unique musical sequence.

voxels, whose edge would be small enough to represent the smallest details one wishes to consider. The decomposition method that we used splits the cathedral into spherical shells. From each possible standing point for the visitor, a series of concentric spherical shells, separated by constant intervals, is generated. All shells have the same thickness; their radius increases up to the moment where they encompass the whole cathedral. For a visitor standing right in the middle of the nave, and for one-millimetre thick shells separated by null intervals, it would take about 8200 spherical shells to encompass the whole building. The radius of the smallest shell would be 20 centimetres, the radius of the largest about 84 meters. The crucial point here is that the intersection of each of these shells with the cathedral determines a unique pattern on its surface: a kind of spherical slice, whose precise pattern depends both on the position of the visitor in the nave and on the size of the shell. The combination of all spherical slices fully reconstructs the building, like a 3-D puzzle in three dimensions similar to a Russian Matryoshka (Fig. 14, 15).

The second step consists in considering individually each of the spherical slices (Fig. 16), and in analysing them in order to be able to produce a wave-based description for each of them. The waves that are used for this step, the spherical harmonics mentioned above, are not sound waves or light waves, but they behave in exactly the same way.

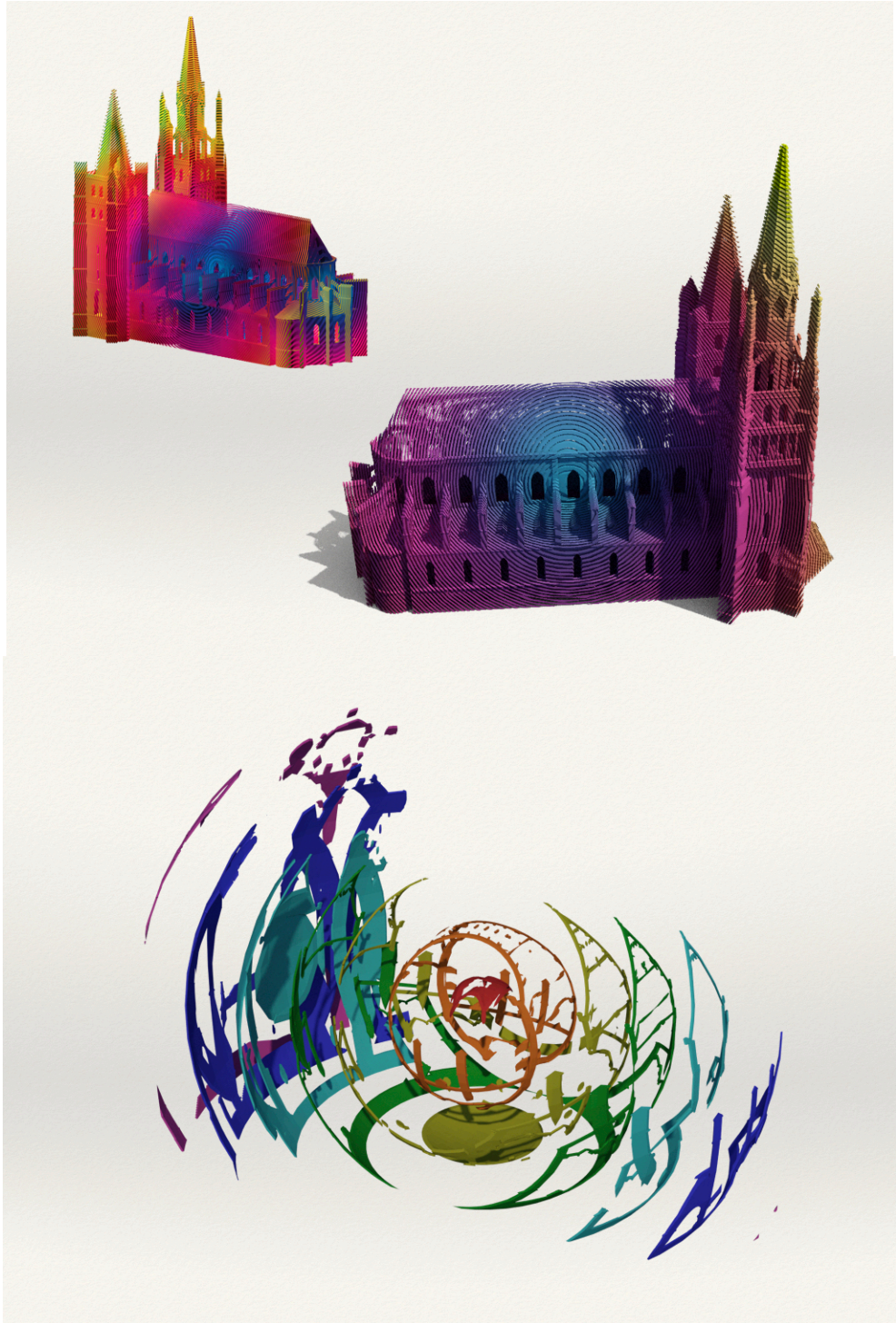

Fig. 14 - The first step for transposing the architecture of the cathedral into musical sequences consists in decomposing the building in series of concentric spherical shells. The two pictures on the top show the full decomposition; the colours indicate the radii of the shells. The smallest ones, in blue, are almost completely inside the church. The largest ones, in yellow, intersect only the top of the spires. The bottom picture shows a series of very thin shells, separated by large intervals. The patterns created by the intersections of the spheres with the building appear clearly.

In multiple domains of science, they are used, as their name suggests, to describe the modes of vibrations of spherical surfaces or objects (Fig. 15). They are based on elementary signals that are not trigonometric functions, like for the sound harmonics, but rather another family of orthogonal functions called "Legendre polynomials". Analysing each shell with the proper algorithm, it is possible to obtain at the output the whole spectrum of spherical harmonics required to produce each of the intersection patterns for all the spherical shells in which the church has been decomposed.

An aquatic analogy will help understand the unrolling of this abstract mathematical process. Let's imagine a perfectly spherical planet, entirely covered with water, crossed by two families of huge tsunamis. The first family travels parallel to the equator, the second from pole to pole. The two families intersect systematically at right angles when they meet, which gives a fairly good idea of the behaviour of orthogonal functions. It can be proven that by launching several of these tsunamis with appropriate wavelengths, amplitude and phase, interference patterns can be created that can draw anything on the surface of the planet, including irregular patterns without any symmetry. The only condition is that the wavelength of each tsunami must be a submultiple of its equator, a condition identical to the condition that De Broglie's imposed on the wavelengths of his electrons in order to find their distance to the nucleus. It should be mentioned here that the spherical harmonics used by De Broglie's are completely similar to the ones we use for our process.

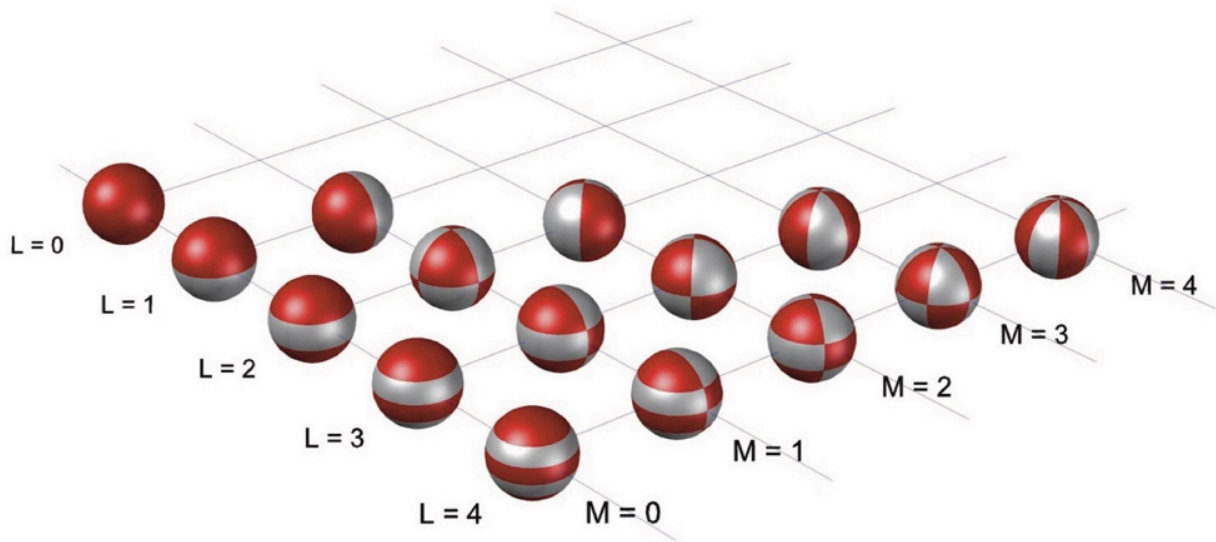

Fig. 15 – The first spherical harmonics. These mathematical objects correspond to the modes of vibrations of a sphere. The L series includes all vibrations parallel to the equator. For each L-order harmonic, there is a series of M-order sub-harmonics, corresponding to vibrations parallel to the meridian lines. By combining sets of spherical harmonics with specific amplitudes, frequencies and phases, it is possible to recreate any pattern at the surface of the sphere. They thus play for spherical vibrations the role than sound harmonics play for the analysis and reconstruction of complex sounds.

As a consequence, each pattern can be described by a list in three columns, giving the values of the abovementioned parameters for each of the spherical harmonics needed to recreate it - the equivalent of a sound spectrum applied on a spherical surface. The process yields a list of numbers that represents the geometry of the cathedral in a description that is as austere as it is accurate.

Several factors have led us to use spherical harmonics for this project, among all other options. The first one is the cosmological status of this mathematical object that is used today, as we have seen in De Broglie's and Luminet's case, but also in many others, to describe phenomena and objects of all scales, originating from all realms. The second is related to the very concept of centre of the world, of which we discussed in the first sections. Since the only valid centre today is the position from where I contemplate the world, any description of this world can be temporarily centred on me, and must move with me; the spherical shells are the mathematical equivalent of the perceptual sphere described in section 3 of the present paper, and any spherical pattern naturally suggests the use of spherical harmonics. The third comes from a concern directly linked to the fundamental principles of spectral (or Fourier) analysis. This process only works with objects that can be described by a periodic signal. This presents no difficulty while working with light or sound signals, which are periodic by essence. It is much less obvious in the case of a finite, material object. Working with linear harmonics would have required, in the case of the cathedral, a preliminary step consisting in repeating infinitely the cathedral in all directions, in order to artificially "periodize" its geometry. Moreover, in most cases, the signal must be modified by another mathematical object called a windowing function in order to smooth its ends - an operation that eases its analysis by limiting the computation time. These two operations modify the original object by introducing mathematical artefacts that change the harmonic structure of the spectrum. Spherical harmonics do not present these problems: since the pattern is drawn on a sphere, the spherical harmonics repeatedly scan it while travelling on the surface, which *de facto* creates the required periodicity.

The accuracy of the wave representation, corresponding to the needed resolution, depends on two factors: the thickness of each shell – the thinner the shell, the more it will be able to capture small details - and the frequency of the highest harmonic used for the analysis: here also, shorter wavelengths will capture finer details. These two parameters can be adjusted to become as small as desired. When they become small enough to capture the smallest details of the building, then the transformation becomes theoretically reversible. Since nothing is perfect, like in any situations of this kind, the amount of calculations needed increases very rapidly when harmonics of higher frequencies are added: they quickly become unmanageable. The *Mende Cathédrale* installation had to take these considerations in account.

Following our first tests, we limited the area of the installation to the nave and to the adjacent collaterals, excluding the choir and the ambulatory. In this area, whose dimensions are approximately 40 m x 20 m, we defined a square grid whose points were spaced 30 cm in all directions, up to a height of 2,30m. More than 60 000 points were thus generated; they cover all the possible positions for the visitors. For

each of these points, 20 concentric spherical shells, infinitely thin and separated by intervals of one meter, were selected among all the possible shells. The size of the smallest shell corresponds to one half the width of the nave. Each shell was decomposed in harmonics up to order 80.

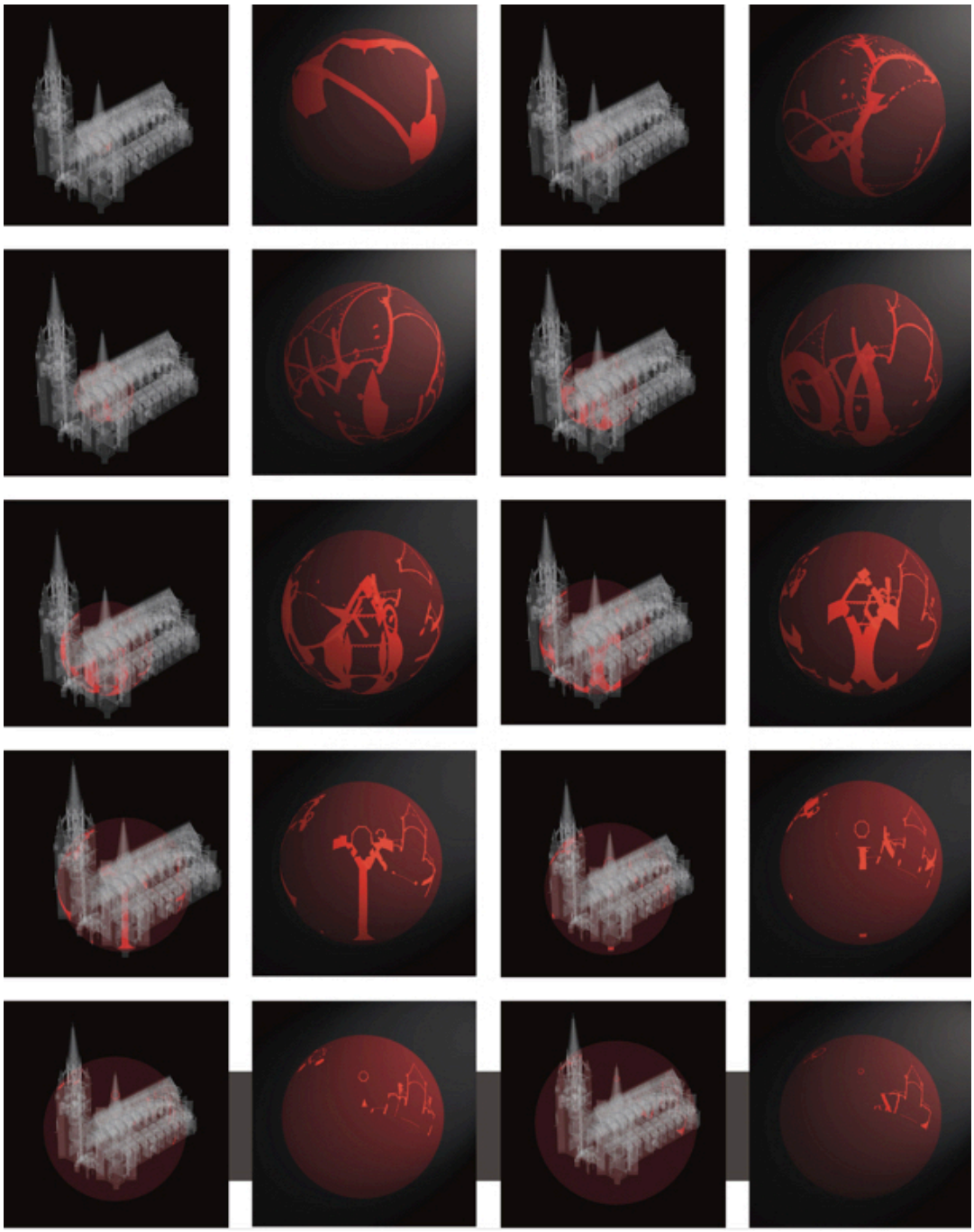

Fig. 16 – These pictures shows how the intersection patterns transform when the spherical shell grows. The pictures in the first and third columns show the sphere inflating in the cathedral, up to the point where it almost encompasses it. The pictures in the second and fourth columns show the resulting intersection spheres, with their unique patterns.

The third step is more systematic. It consists in converting as directly as possible the spherical harmonics into sound harmonics. It is conceptually very simple: each spherical harmonic is converted into a musical with the same amplitude, wavelength and phase. Two phenomena unfortunately combine to make this problem slightly more complex.

The first phenomenon is the number of spherical harmonics required to describe a spherical pattern. Since the surface is bi-dimensional, this number is much larger than for linear harmonics: each harmonic of order N is actually associated with 2N+1 sub-harmonics. Though half of them can be eliminated by symmetry, the harmonic of order 50, for instance, generates 51 sub-harmonics that must all be considered in the transposition. The resolution of order 80 that we used for our spheres generated, for all the points considered, a total of 3.4 billion harmonics and sub-harmonics, the combination of which, as can be expected, describing the architecture of the cathedral with a very good precision. We then had to find how to use each of these spherical harmonics while reducing the amount of data to be computed. We managed to develop a reversible and lossless process that allowed us to generate all the sound timbres without leaving any information behind.

Fig. 16 – Detail of an intersection shell. Like any pattern on a sphere, the one that appears in this picture can be decomposed into a sum of elementary spherical harmonics, which are then directly converted into sound harmonics.

Once this was done, we were still left with a huge set of sound harmonics, from which we had to produce identifiable timbres. In conventional models of composition, such as in classical music, the composer starts from a silent space in which he distributes and arranges musical notes. Here, the initial space can be seen as an extremely dense harmonic jungle, which, without processing, would produce a

constant homogeneous sound, similar to a white noise. The composition method then corresponds to the selective pruning of this the jungle, in order to generate simpler sounds that could be used use to create convincing musical sequences. The process we used is similar to certain methods of composition used in spectral music. It literally corresponds to a form of sound sculpture. It leaves a great freedom to the composer, and allows him to explore many different orchestrations while maintaining a precise correspondence with the architecture of the church.

The second phenomenon is caused by the fact that the frequency of sound harmonics increases rapidly, and quickly reaches the realm of ultrasounds, which, in addition to making them inaudible, is out of the frequency range of standard sound cards. We still decided to keep all harmonics up to the 80th order: on one hand the interferences of ultrasonic waves can produce sounds in the audible range; on the other hand, the addition of ultrasonic waves to audible waves can slightly shift the phase of the latter. The combined phase shifts from multiple high-frequency harmonics can modify the sound waves in a way that becomes perceptible. We also decided to keep standard sound cards for this step, considering that the deformation of ultrasonic waves potentially caused by the insufficient resolution of such cards was a characteristic of our devices. The instrumental artefacts thus created are considered as similar to those that appear in classical music, when a perfect sound wave is altered by the physical characteristics of a particular instrument.

Fig. 15 – The harmonic lanterns. These small modules are held like candles by the visitors when they travel the installation. They contain all the electronic equipment required for positioning, with a 10 cm precision, and for playing the different sounds. Each lantern possesses its own IP address for maintenance and updates.

In the Mende installation, the cathedral has been divided into thirty-five zones, each one corresponding to a different composition of harmonics. As mentioned in introduction, every visitor holds in his hand a harmonic lantern, a small and

approximately cylindrical module that contains both the positioning antenna, the timbres corresponding to the 60 000 positions, a controller that associates each position with a given timbre, a volume control, a miniature sound card, as well as several other components. A headset allows the visitor to listen to his own music at the desired volume, without ever disturbing the atmosphere of the cathedral. The areas close to the entrance have been orchestrated in order to produce more familiar timbres, evoking bells or organs. Towards the other end of the installation, the sounds become more contemporary. One for instance consists in a “harmonic rising fall”, in which thousands of harmonics are produced very quickly, separated by less than a millisecond. In areas where the visitors can walk, such as the aisle or the collaterals, the sounds are shorter, and become even percussive at times. In the sitting areas, they become much longer, generating a contemplative experience for the visitors who wish to sit and listen for more than a few minutes. Each point of space becomes a small drop of sound, hovering still in space, that the visitor triggers when his lantern passes through it. The lanterns are polyphonic, so that the precise sound heard in one spot depends not only on its location, but also on the direction from which the visitor approached it. In the middle of the nave, in the central aisle, lies a small island of silence. It allows the visitor to rest his ear before resuming his musical journey. If he stands within this island and turns on itself, holding the harmonic lantern at the end of his arm, it will hear sequentially the sounds from eight different zones, composing by this very simple movement a full timbral symphony.

5. Conclusion

Starting from a theoretical work on the ancient harmony of the spheres, the Origin Point research-creation program tries to explore the potential of new and poetic transpositions of this theory, based on the contemporary scientific knowledge about the cosmos, and of what science tells us today about acoustics and music. This massively interdisciplinary project has implied mathematicians, physicists, musicians, historians and architects. The *Mende Cathédrale* installation constitutes the first artwork generated by the program. It was simultaneously considered by our team as an art experiment, as a demonstration of our technological devices, and as an artwork meant for all audiences. The decision to present it in the cathedral of Mende, apart from the fact that any installation coming from the program should be presented in an architecture based on some cosmological scheme, was taken because of the particular atmosphere of the church. As opposed to most famous cathedrals such as Chartres or Paris, it is never filled with crowds of tourists. Quite the contrary: it is a living church, still used by the community. There are still lots of visitors from the outside – it is one of the main monuments of the region- especially during the summer, but the audience during the installation time was equally distributed between citizens and families from Mende, people from neighbouring provinces and tourists from farther regions. People from all ages came to experience it; a lot of people came several times. Through this project, we came to the conclusion that the presentation of digital art pieces in non-dedicated spaces such as galleries, museums or festivals has a tremendous potential for reaching the most diverse audiences, and thus to contribute more efficiently to the diffusion of less familiar forms of arts.

Obviously, the visitors in the church did not have to go through all these theoretical and technical explanations in order to appreciate the work: as it is said in introduction, experiencing the installation is extremely simple. For those who were interested in knowing more about its genesis, an exhibition was set up in a close-by gallery. It provided all the necessary explanations, in the form of posters and small bronze and polymer sculptures. By this, we tried to make another statement with a slightly cosmological overtone: reality implies every scales of the world. Just like a man or woman who appreciates a good meal does not have to know anything about the biology of the meat, the molecules and the atoms that compose them in order to appreciate it, the visitor of the installation does not need to know anything about its history and development in order to listen to the music. However, any information or knowledge about a given work can strongly modify his appreciation of it and considerably enrich his experience. The imaginary and the rational components of our minds are everything but independent: our artistic, poetic and scientific visions of the world constantly feed each other. They are strongly interrelated and can never be separated. One of our hopes is that the work we presented will be seen as an example and an illustration for these statements.

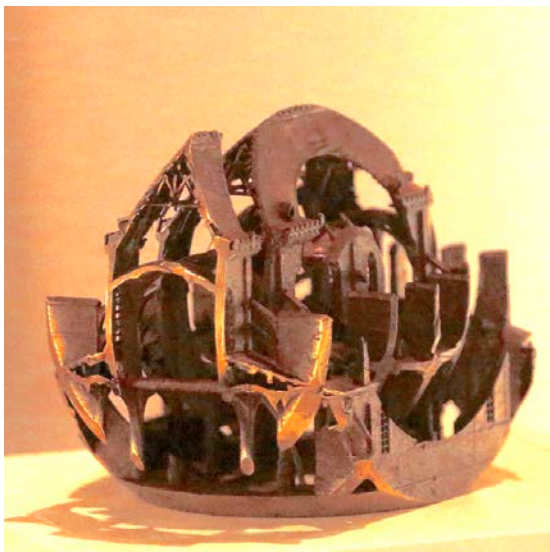

Fig. 16 – Two of the bronze sculptures that were shown in the exhibition presented along with the installation. They evoke the spherical decomposition process at the origin of the architecture-to-music transposition.

The reader who is interested in knowing more about the installation is invited to go to the internet address www.nxigestatio.org/NXI/MENDE-CATHEDRALE, in which he will find several pictures, sounds and documents about the work.

Notes

1 – It is worth noticing the etymological relations between the words "harmony" and “Olympus”. Both derive from a proto-Indo-European root indicating the concept of “rising above”. Mount Olympus was the residence of the gods. It was the place from where the harmony radiated towards the world, and imposed, through proportions, it reigns over it.

2 - The unit of measure used to implement these proportions, namely the ancient foot, is also drawn from the morphology of a supernatural being, namely the semi-god Hercules: the architecture of the time is both dimensioned and proportioned by elements of cosmic nature.

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