

# Imagining the Shape of Space

Huseyin Ozel  
number.theory.paper@gmail.com

**Abstract.** This work comprises an effort to develop a framework to construct various space geometries in 3 and higher dimensions, and also in flat and curved settings. Such construction is based on scientific knowledge, existing approaches, and own approach and imagination. Higher dimensional geometries are presented in forms of 2 and 3 dimensional projections. Curvature settings are considered along regular object bending and also gravitational space warping, however the exact space curvature is rendered according to a proposed methodology that makes use of glissette geometric formation to resolve the shape of space under expansion and contraction conditions. The resulting geometric forms point to potential various physical shapes of the universe and possibly offer an opportunity to help expand our imagination and understanding of the universe.

**Keywords:** Space, dimension, spatial, curvature, visualization, imagination

## Index

	Introduction	2
	Understanding Space	3
	Background on the Ideas of the Shape of Space	6
	Approach & Methodology	11
Modelling the Space Forms under Various Distortion Settings		20
	Process	36
	Findings	39
	Conclusions	40
	Bibliography	42
	Appendix 1	44
	Appendix 2	46

## 1. Introduction

In this work, I try to construct a framework for imagining and visually representing the shape of space under various curvature settings and in ordinary and higher spatial dimensions.

With a keen interest in physics, mathematics and cosmology, space has always been a fascinating subject for me to learn more about. An online video that I had watched where a boy was explaining how he perceives spatial dimensional curvature gave me the initial inspiration that led to conducting this work. In addition to researching existing knowledge and philosophical background, I mainly relied on my imagination and logical justification to produce the arguments and geometric forms. The fact that this work is not within the pure domains of physics or mathematics gave me the freedom to focus on imagination and visualization. A quote by Einstein that I often find encouraging and guiding seemed very relevant through this work: "Imagination is more important than knowledge. For knowledge is limited to all we know and understand, while imagination embraces the entire world, and all there ever will be to know and understand." [1]

It will be useful note that the emphasis in deriving the arguments in this work is through logical articulation and visual modelling, rather than physical and mathematical formulation, since the main domain of this work is design.

The figures reflecting visual modelling in 2- and 3-dimensional forms were generated using a few computer software, that are detailed in Section 6: Process, in combination.

Representing the shape of space with more than 3 dimensions requires some explanation. Imagining and representing dimensions beyond 3 might be possible by applying certain optical techniques but they fall outside the scope of this paper. In this work, I provide projections for those dimensional space forms into our naturally accessible 3-dimensional realm. Yet, they are also re-projections into 2-dimensional space since they are presented here flat on screen or paper. Using lighting (and in some cases multiple light sources) and consequent shades in objects in the presented images helped project 3-dimensional forms onto the 2-dimensional media.

## 2. Understanding Space

The fundamental nature of space, its very fabric, its dimensions and its relations to time, consciousness, and reality have been subjects of philosophical and scientific debates, especially within the domains of metaphysics, classical mechanics, relativity, quantum mechanics, string theory, topology, and geometry.

The nature of space, that obviously is the medium things exist within and move through, has been approached primarily by the substantivalist and relationalist definitions.

The substantivalist approach argues that space is a container that is fundamentally independent of the things that are contained. Sklar proposes that space exists with its specified features independently of the existence of matter. [2]

The relationalist definition, on the other hand, such as the one offered by Leibniz, views space not as a fundamental entity, but rather one that is constituted by the spatial and temporal relations between physical entities and events. [3] [4] [5]

Newtonian physics is based on the substantivalist definition of space and the absolute space theory which proposes that space is a fixed, pre-existing entity, independent of any matter or physical events. [6]

As opposed to the absolute space theory, the relative space theory, which forms the foundation for Einstein's theory of relativity, suggests that space is not an absolute entity, but rather its properties are relative to the observer's frame of reference. [7]

Einstein's theory of relativity is composed of two major layers. Special Relativity demonstrates that space and time are not absolute, but they are relative to the motion of the observer. General Relativity builds upon Special Relativity and introduces the concept of matter mass warping the spacetime hence causing curvatures that determine motion paths for objects, and such motion is experienced as gravity. Space and time together form spacetime which is based on perceiving 3-dimensional space as an entity that floats along

the timeline. Such continuum of 3-dimensional space along the axis of time constitutes the 4-dimensional spacetime.

Newtonian physics, in contrast defines gravity as a force that is exerted on matter masses as an interaction that occurs by default.

There is further work to define and explain the nature of space beyond the two main approaches of substantivalism and relationalism, such as the structural spacetime realism, suggested by Dorato that takes elements from both approaches. [8]

In addition to the physical discussions, the nature of space has also been debated within the domain of human perception in relation to how we sense and construct reality. Some arguments state that space is a product of our minds, rather than a material entity.

Kant argues that space is not an empirical concept derived from experience, but rather a fundamental priori form of intuition. [9] Similarly, Hegel viewed space as a priori form of sensible experience, fundamental to both consciousness and the objective world. [10]

Unified consciousness, arising from the interplay between the brain and the body, rather than being solely brain-based, emphasized by the Default Space Theory (DST) proposes that the brain and body together create a three-dimensional, internally generated simulation of reality, called the "default space". [11]

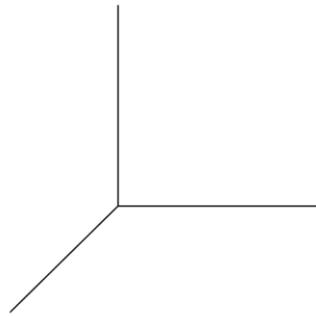
Regardless of the discussions on whether space was a real entity that exists independent of our perception or if it was constructed by the perceptions and input interpretations of our minds, the most suitable and proven way to universally navigate and quantify it is by modelling a metric space. [12]

Following the definitions and axioms offered by the concept of metric space, the foundational elements of space are dimensionless points, as depicted in Figure 1.



*Figure 1- Dimensionless points are the elements that constitute all dimensions, hence space*

Space, as we perceive and interact with dwells on 3 distinct dimensions, as familiarly depicted in Figure 2.



*Figure 2 - A simple representation of 3 spatial dimensions that we naturally sense and interact with*

Having referred to some of the fundamental premises, I shall briefly discuss some common questions in relation to space.

One common question is around why we perceive and deal with only 3 spatial dimensions. Could there be more than 3 and what would they be like if there were?

Another common question is whether space extends out flat, or if it is curved in some way. What would be the shape of space and the universe if it were curved?

### 3. Background on the Ideas of the Shape of Space

Revisiting the common questions will be helpful to gain an understanding of the existing philosophies and approaches.

The existence of spatial dimensions further than the first 3, also referred to as higher dimensions, is a subject of debate. While dimensions of any number are mathematically possible to formulate, physically proving, detecting, and representing them has mostly been a challenge since it is most likely that we evolved to sense and interact with only 3 spatial dimensions.

There are methods being employed to make it easier to visualize higher dimensions, for instance by using colour-coded geometric representations [13] and by using projections onto 2 and 3 dimensions with the aid of electronic displays. [14]

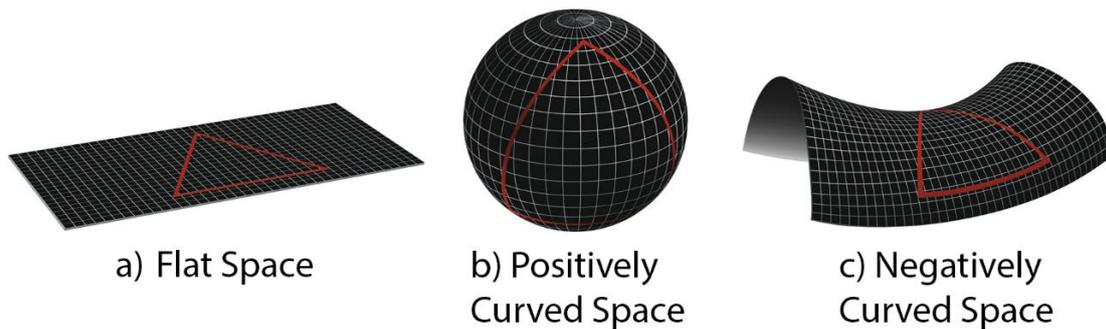
Hyperspace that is the space of higher dimensions, has been often posited as the base for explaining various phenomena such as the behaviour and interaction of subatomic particles, gravity itself, and the behaviour of blackholes.

String theory proposes that the fundamental constituents of the universe are not point-like particles, but rather tiny, vibrating strings. [15] The theory, in fact, requires hyperspace in order to maintain its integrity and mathematical consistency. [16]

String theory also posits dimensional curvature, at scales that are too small to be discernible, as the rationale for suggested string vibration that underpins the behaviour of fundamental particles and forces in nature. [17]

While space and time are inseparable entities according to the theory of relativity, explicit analysis can be conducted on space warping by isolating space from time. Space curvature posited by General Relativity and formulated by Einstein Field Equations (more specifically in Ricci Curvature), are often rendered under 3 possible curvature settings as presented in Figure 3: flat, convexly curved and concavely curved. [18] [19]

These renderings also implicate geometries for single dimensional paths: flat paths in flat space, closed loop paths in convex space, and parabolic paths in concave space.



*Figure 3 – Depiction of shape of the universe under various assumed curvature settings, according to general relativity*

*Figure adapted from <https://imagine.gsfc.nasa.gov/observatories/satellite/wmap/shape.html>*

While the spacetime warping suggested by general relativity seems to explain many physical phenomena successfully, including gravity, physical observations of the universe have yet to prove any evidence of overall curvature in the observable universe as far as can be detected to an error margin of 0.2%. [20]

Cosmic microwave background (CMB), the ‘universal background radiation’, also known as the ‘light left over from Big Bang’, is often considered a useful tool for gaining a better insight into the shape of universe, however more detailed maps of CMB are required for meaningful correlations to be made. [21]

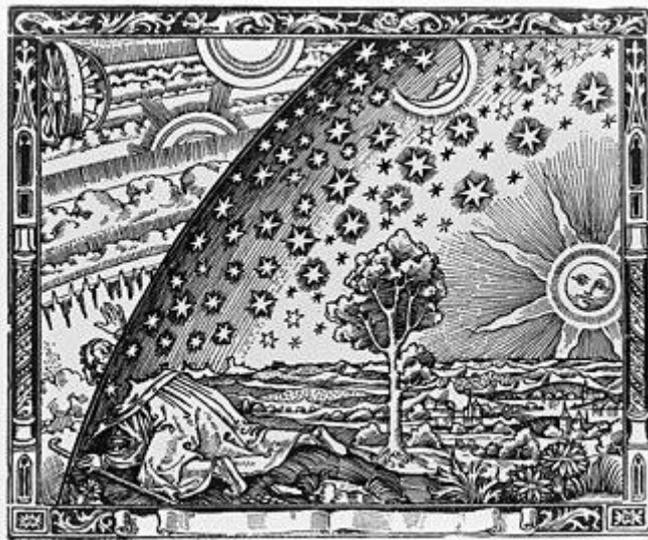
Some scientists also believe that the collection of inputs from CMB, the expansion rate of the universe and the overall matter density only indicate that universe actually is flat, rather than curved in some way. [22]

There is, however, ongoing work for new interpretations of CMB to find patterns, such as some circular structures, that were previously not identified. [23]

Of course, speculating on the shape of the universe has not been limited to scientific studies only. It has also been an intriguing subject for artists and thinkers alike.

Almost any civilization that developed an interest in astronomy and cosmology, including Mesopotamian, ancient Egyptian, Hindu, Norse, Mesoamerican civilizations, developed their own renderings for the shapes of Earth and the cosmos. Some of such work seem secular in nature while some reflect religious beliefs and mythology.

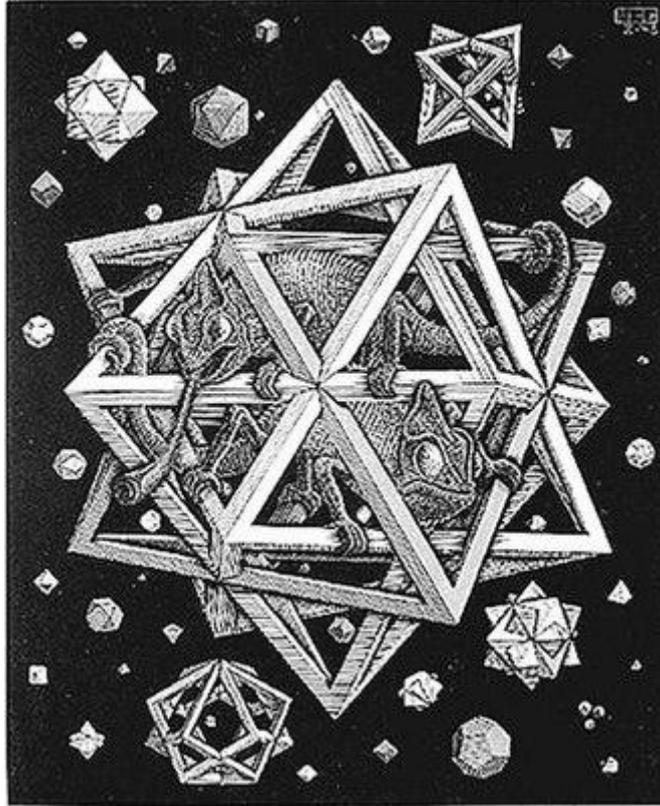
The Flammarion engraving, a wood engraving by an unknown artist, as presented in Figure 4, is one of the earlier examples for such artistic speculation. [24]



*Figure 4 – Flammarion engraving that offers a depiction on Earth and its place in the universe.*

*Figure taken from [https://en.wikipedia.org/wiki/Flammarion\\_engraving](https://en.wikipedia.org/wiki/Flammarion_engraving)*

Another interesting wood engraving, by Escher, depicted a creative imagination for how complex the dimensional settings and the universal geometry could get, as presented in Figure 5. [25]



*Figure 5 – Stars, by M.C. Escher that offers an imaginative view on dimensional and consequent geometric complexity.*

*Figure taken from [https://en.wikipedia.org/wiki/Stars\\_\(M.\\_C.\\_Escher\)](https://en.wikipedia.org/wiki/Stars_(M._C._Escher))*

The contemporary artist Yayoi Kusama's installation 'Infinity Mirror Rooms' offer immersive and kaleidoscopic settings that make use of mirrors and light to generate the illusion of space infinity, as depicted in Figure 6. [26]



*Figure 6 – The immersive installation by Kusama, setting an environment that feels infinite in dimensions*

*Figure taken from <https://hirshhorn.si.edu/kusama/infinity-rooms/>*

Arguably, even purely scientific approaches into the imagination of the shape of space and the universe include an element of artistic approach, since researchers need to rely on their imagination to fill in the gaps in our current body of knowledge about physics and the universe.

## 4. Approach & Methodology

The approach and methodology employed in this work to imagine, visualize, and speculate on the geometry of space is based on 6 main arguments:

1) Focusing on space rather than spacetime:

For the scope of the work here, similar to the space distortion resolutions conducted according to General Relativity, I have chosen isolating space from time and focusing on imagining space geometries. This simplifies the analysis by taking the time element out and provides an intermediary step should further holistic analysis including time wanted to be conducted.

I shall also make a reference to the common understanding that time might be the fourth dimension. There are two points that are worthwhile noting in this context: First, it is a subject of debate whether time really is a dimension or a series of dimensions. While I also have certain personal philosophy on this, the subject is outside the scope of the work here. The second point is that time, even if it were a dimension, would not necessarily be the fourth dimension. For instance, if we had evolved to sense and interact with a universe of 2 spatial dimensions, we could as well argue that time was the third dimension. It seems that time could be applied at any relevant point.

2) Endeavouring to construct the spatial geometry dimension by dimension, rather than building a specific shape in its entirety:

Given the fact that we don't know the exact extent of space in terms of the number of its dimensions, any attempt to formulate the shape of space as a whole within any given number of dimensions is likely to be incomplete. Hence, deriving the envisioned shape for each dimension in turn to subsequently build up the resulting space geometry gradually has been the preferred approach in this work.

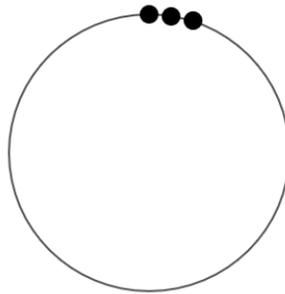
Starting with a single point, the form of zero spatial dimension, the method is to construct the shape of space as the number of dimensions increases, step by step.

Let us imagine the form of 1 spatial dimension. In the standard setting with perfectly flat dimensions, this geometric form will be a straight line, produced by infinite dimensionless points, as presented in Figure 7.



*Figure 7 – The space form of 1 flat spatial dimension*

What if that one dimension had a constant positive curvature, what form would it take then? The instinctive answer to this question could be that the form would be a circle, produced by infinite dimensionless points aligned around a new axis that has a convex constant curvature, as presented in Figure 8.



*Figure 8 – The space form of 1 spatial dimension with constant convex curvature*

It is needed to formulate a generic method that could be applied to derive dimensional hence spatial forms under various curvature settings. The construct employed needs to tackle the geometric formation of space as moving from a certain number of total dimensions ( $n$ ) to the next level ( $n+1$ ).

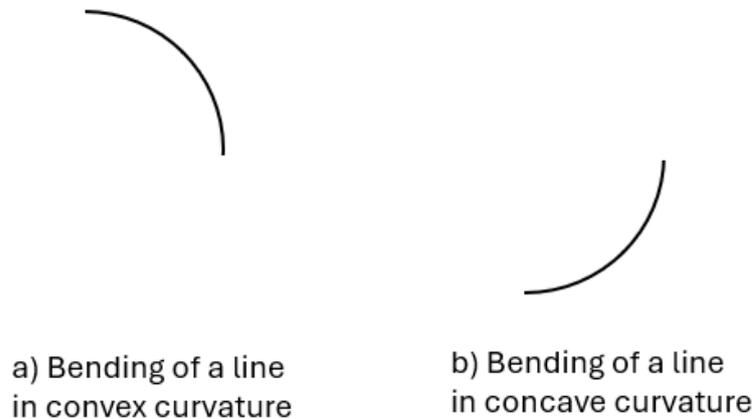
This construct is to be devised as an axiom stating that a level of spatial dimensional formation needs to extend into its next level of spatial dimensional axis to conclude its curvature. In other words, while moving from a certain number dimensional space ( $n$ ), to the next one ( $n + 1$ ) to form the geometry of space, the constitutional elements of dimension  $n$  get aligned along an axis in dimension  $n + 1$ , following its given curvature setting.

While this presents a sensible basis to derive the curved forms of dimensions, it still needed to determine the exact geometry that shall be employed, as will be discussed henceforth.

- 3) Treating space and spatial dimensions as distinct types of entities, rather than as objects or fields:

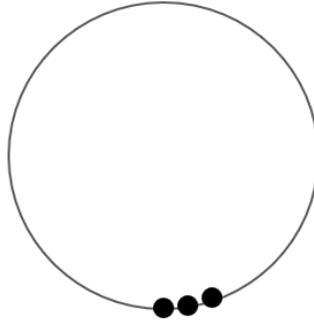
Leaving aside the discussions on whether space is independent of matter and energy and whether it is absolute or relative, space is a fundamental construct and a distinct entity that things, such as objects and fields, exist within and interact with. To this end, it is a very specific entity of its own kind.

A potential way to construct the form for the space of 1 spatial dimension with a constant curvature, could be to follow simple object bending as presented in Figure 9.



*Figure 9 – A line would curve up to become a circle under constant curvature*

This rendering based on object bending would suggest a circle form for the space of 1 spatial dimension with constant concave curvature as presented in Figure 10.



*Figure 10 – The space form of 1 spatial dimension with constant concave curvature, according to object bending geometry*

Since the approach is based on treating spatial dimensions not as objects, bending them in the way that objects would do by default is not the direction chosen in this work. Hence, this geometric form could not be concluded for the concave curvature of spatial dimensions.

- 4) Attempting to apply an even more generic mechanism, rather than limiting the understanding of spatial distortion to the effect of mass and energy density formulated by General Relativity:
  - i. Current human knowledge for the effects of mass and energy, and their interactions with space might be incomplete. For instance, there are still ongoing efforts to explain gravity better.
  - ii. There might be further physical effects, forces, and phenomena that we haven't yet discovered. For instance, anti-matter, dark matter and dark energy might be interacting with each other and with space in completely new ways.

Let us reconsider the form for space of 1 spatial dimension with concave curvature. Following the space curvature geometry suggested by General Relativity, a parabolic form as presented in Figure 11, could be suggested.

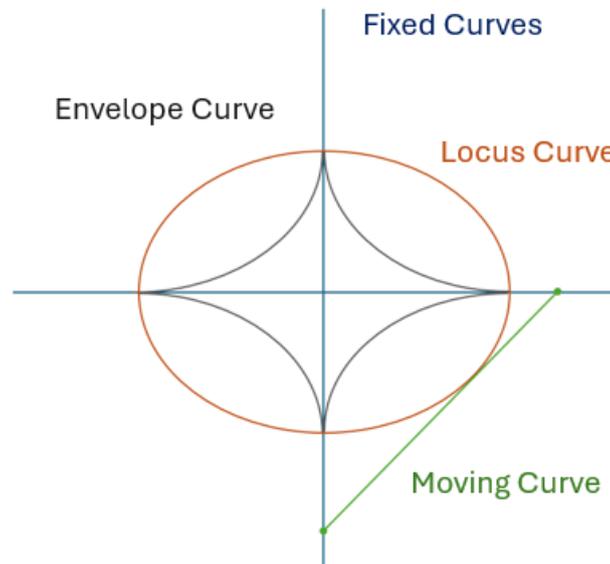


*Figure 11 – The space form of 1 concavely curved spatial dimension, according to the curved path proposed by General Relativity*

Since I suggest that General Relativity might not be the conclusive holistic explanation for space distortion, this geometric form could not be concluded for the concave curvature of spatial dimensions, either.

- 5) Seeking a spatial distortion mechanism that is geometrically generic, universal (multi-versal) and multi-dimensional (higher-dimensional):

Along with this work, I propose that the spatial dimensional paths take the form of glissettes under space distortion effects. A glissette is the curve traced by a point that moves under certain sliding constraints, such as a point on a segment (line or curve) that slides with one end on one fixed curve and the other on another fixed curve. The traced curve can be the locus (path) taken by the tracing point or it can be the envelope (the curve tangent to every position of the moving generating curve). Figure 12 exemplifies the elements of a glissette. [27]



*Figure 12 – Elements of a glissette*

Offering a complete rationale for the glissettes to be the default curvature paths for spatial dimensions could be impossible without the holistic knowledge into the collection of all universal effects and mechanisms for space distortion. However, by observing some properties of the glissette, following reasons could be presented as notable for such speculation to be relevant:

- i. Glissettes are motion-based, and this is the exact nature one would expect from space itself since it contains things for existence and movement.
- ii. By setting the two fixed curves as the standard perpendicular lines (such as x and y axis), it is possible to take the non-curved, standard dimensional setting as the base and apply the curvature on top naturally.
- iii. Setting the two fixed curves as the standard perpendicular lines (such as x and y axis), fits well with the dimensional curvature methodology suggested in argument (2) since the curvature can be extended into the next level of dimensional axis.

Using the standard perpendicular two axis as the fixed curves, and by making a generalization, the locus curve reflects the outward movement with accumulative motion, and the envelope curve reflects the inward

movement with restrictive motion. [27] Hence, I speculate that the locus curve presents the dimensional curvature of space expansion, and the envelope curve reflects dimensional curvature of space contraction.

- 6) Considering dimensional geometry beyond merely 3 space distortion and curvature options of flat, convex and concave:

According to General Relativity, local space contraction could generally be associated with positive curvature and local space expansion could generally be associated with negative curvature, while on the cosmological scale these effects can be more complicated.

Spatial contraction and expansion and the corresponding curvature settings referred to in this work might seem to differ from those of General Relativity, but these definitions merely depend on the point of reference and observance.

Instead of 3 standard space distortion and curvature outcomes that are often rendered following General Relativity, the more complicated case of a mixture of the expansion and contraction effects, shall also be included. Also, for the sake of simplicity of the arguments in this work, expansion and contraction cases shall be considered in symmetrical settings. Table 1 summarizes these dimensional settings that are taken into account in this work.

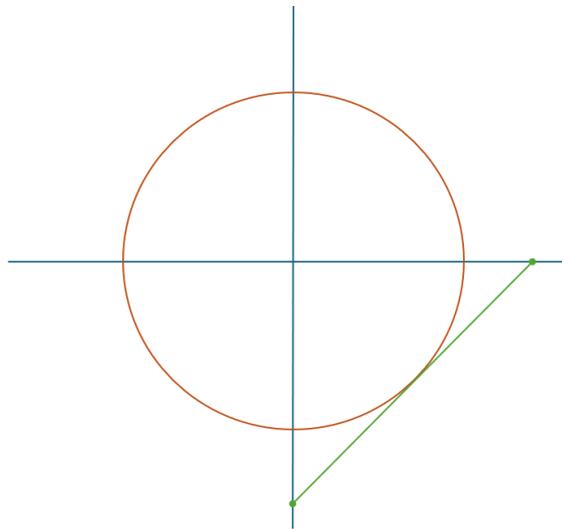
<b>Distortion</b>	<b>Case</b>
None	Case 1
Symmetrically Expanded	Case 2
Symmetrically Contracted	Case 3
Irregularly Mixed Distortion	Case 4

*Table 1 – Various cases of dimensional settings used to render space geometries in this work*

I should note that I get to imagine further and more complex cases for dimensional settings but prefer keeping them outside the scope of this work for the sake of simplicity. I consider the four cases listed in Table 1 as the fundamental ones that help drive and elaborate this work. Appendix 1 offers information about what further dimensional settings could be

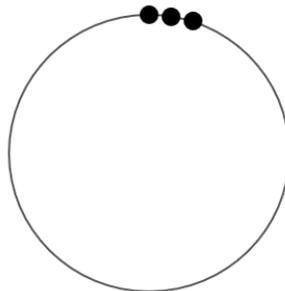
observed at this point. Such settings could lay the foundation for more detailed work beyond this one.

Following the argument (5), by setting a straight-line segment as the sliding curve with its endpoints moving along two perpendicular lines (x and y axis) and tracing the locus of the midpoint the sliding line, leads to obtain the geometry for a symmetrically expanded spatial dimension, that is in the form of a circle, as presented in Figure 13.



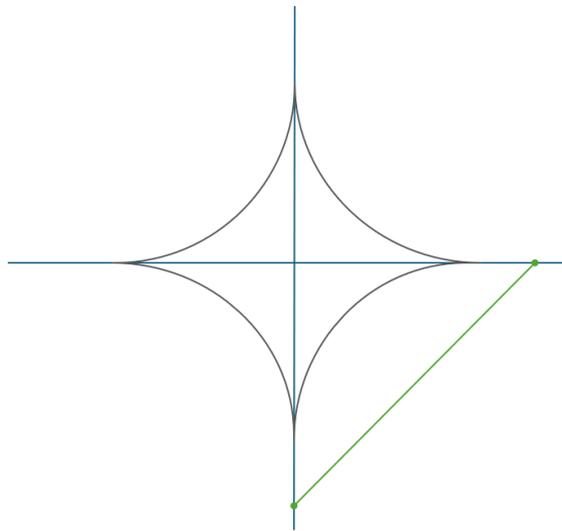
*Figure 13 – The locus curve of the glissette with a moving straight line with the mid-point as the tracing point and fixed curves of perpendicular straight lines*

Hence, based on the proposed arguments, the circle form for the space of 1 spatial dimension under symmetrical expansion could be concluded, as presented in Figure 14.



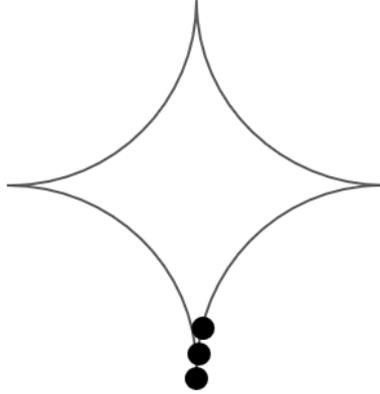
*Figure 14 – The space form of 1 symmetrically expanded dimension*

Similarly, by setting a straight-line segment as the sliding curve with its endpoints moving along two perpendicular lines and tracing the envelope of the sliding line, leads to obtain the geometry for asymmetrically contracted spatial dimension, that is in the form of a tetracuspid (the mathematical term for the closed regular curve form with 4 pointy ends – cusps, also referred to as astroid), as presented in Figure 15.



*Figure 15 – The envelope curve of the glissette with a moving straight line with the mid-point as the tracing point and fixed curves of perpendicular straight lines*

It follows, along with the proposed arguments, that the tetracuspid form for the space of 1 spatial dimension under symmetrical contraction could be concluded, as presented in Figure 16.



*Figure 16 - The space form of 1 dimension under symmetrical contraction*

An obvious observation at this point is the fact that tetracuspid form has a variable curvature, for instance infinite curvature at its cusps. The suggested methodology in this work does not provide a one-to-one match between space contraction and expansion conditions and uniformly convex and concave curvatures at the dimensional geometry. Hence, dimensional settings in this work get classified based on the distortion effect rather than the curvature settings, as presented in Table 1.

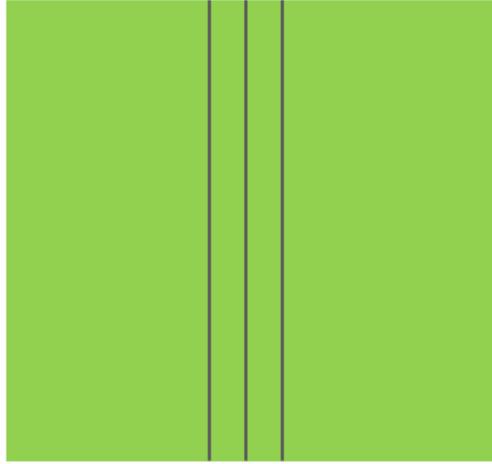
This overall methodology provides the basis to construct the shape of space in many numbers of dimensions, also beyond 3, and in various distortion settings as laid out in Table 1.

## **5. Modelling the Space Forms under Various Distortion Settings**

The geometric space forms corresponding to various spatial distortions are to be derived, by applying the elaborated methodology.

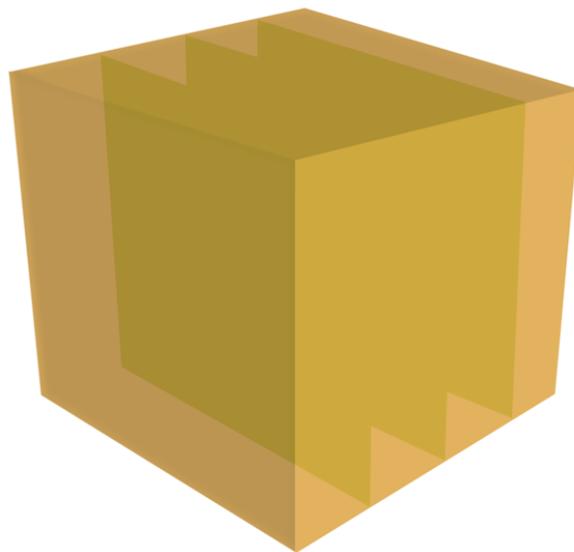
### **5.1 Space with No Distortion**

The form of space with 1 flat spatial dimension as already established and depicted in Figure 7, presents the space form of 1 undistorted dimension. I shall move onto the form of 2 undistorted spatial dimensions. This form will be a flat plane, made up of infinite 1-dimensional straight lines aligned along a new flat axis, as presented in Figure 17.



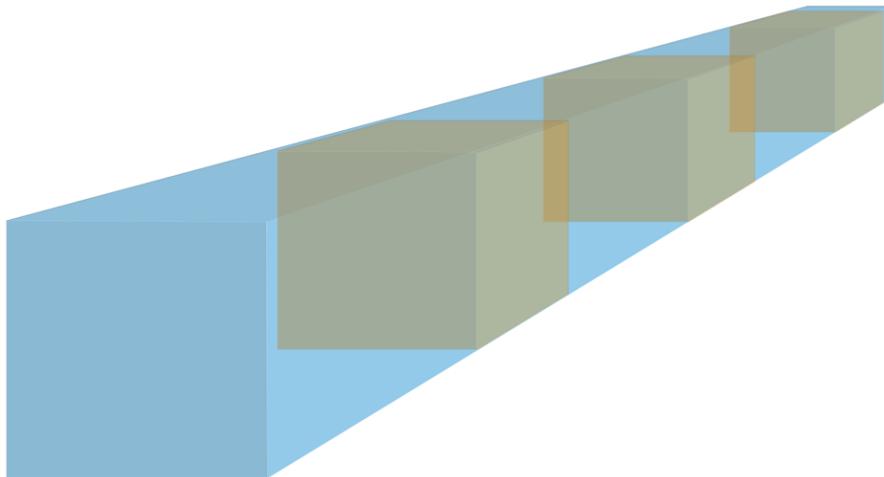
*Figure 17 – The space form of 2 undistorted dimensions*

I shall next move on to the form of space with 3 undistorted spatial dimensions. This form will be a block volume, made up of infinite 2-dimensional flat planes aligned along a new flat axis, as presented in Figure 18.



*Figure 18 – The space form of 3 undistorted dimensions*

The next one in turn to imagine is the space form of 4 undistorted spatial dimensions. As noted, higher dimensional forms will be presented as projections into 3 dimensions. The projected form for 4 spatial dimensions is a block volume made up of infinite 3-dimensional block volumes aligned along a new flat axis, as presented in Figure 19.



*Figure 19 – The projected space form of 4 undistorted dimensions*

This form is produced by infinite 3 flat dimensional blocks aligned along a new axis. However, it is important to note that the blocks should not be imagined as set side by side, like objects, but rather stacked where each point in a block corresponds to another in the adjacent one. This is best depicted as in Figure 20.



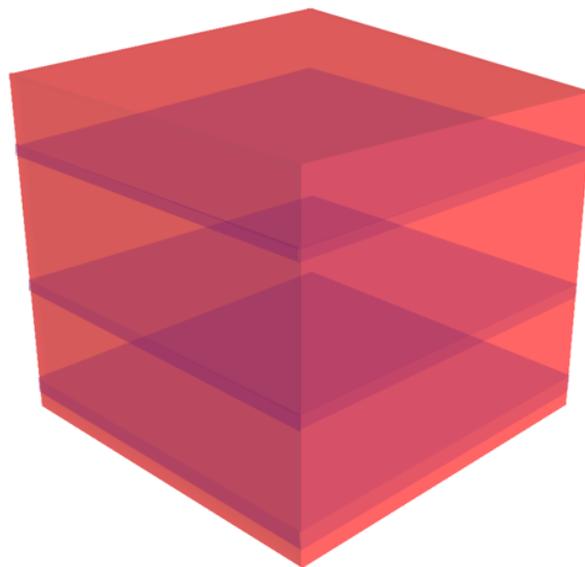
*Figure 20 – Space blocks with points corresponding, not set side by side like objects*

The next one in turn to imagine is the form of space with 5 undistorted spatial dimensions. This projected form is a block volume made up of infinite 4-dimensional blocks aligned along a new flat axis, as presented in Figure 21.



*Figure 21 – The projected space form of 5 undistorted dimensions*

Similarly, the projected space form of 6 undistorted spatial dimensions is a block volume made up of infinite 5-dimensional blocks aligned along a new flat axis. So, my imagination for the projected form of 6 spatial dimensions is presented in Figure 22.

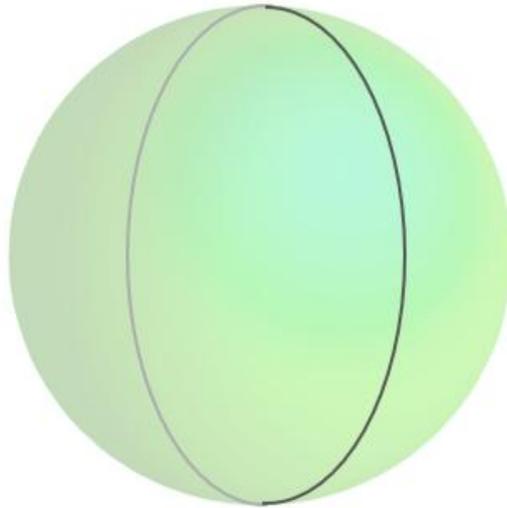


*Figure 22 – The projected space form of 6 undistorted dimensions*

Observing the space forms through spatial dimensions 1-3 and 4-6, it will be obvious that there is a cyclic pattern in the geometric formations. This is because the forms are projected into what we seem to have evolved to imagine: 3-dimensions. Projected forms of further dimensions will follow the same 3-span cyclic pattern based on the way as imagined and projected.

## 5.2 Space with Symmetrical Expansion

Having already established the space form of 1 symmetrically expanded dimension as presented in Figure 8, I shall move onto the space form of 2 symmetrically expanded dimensions. This form will be a hollow sphere, made up of infinite 1-dimensional circles aligned around a new circular axis, as presented in Figure 23.



*Figure 23 – The space form of 2 symmetrically expanded dimensions*

Following the methodology, the space form of 3 symmetrically expanded dimensions is a filled ring torus, made up of infinite 2-dimensional hollow spheres convexly aligned around a new circular axis, as presented in Figure 24.



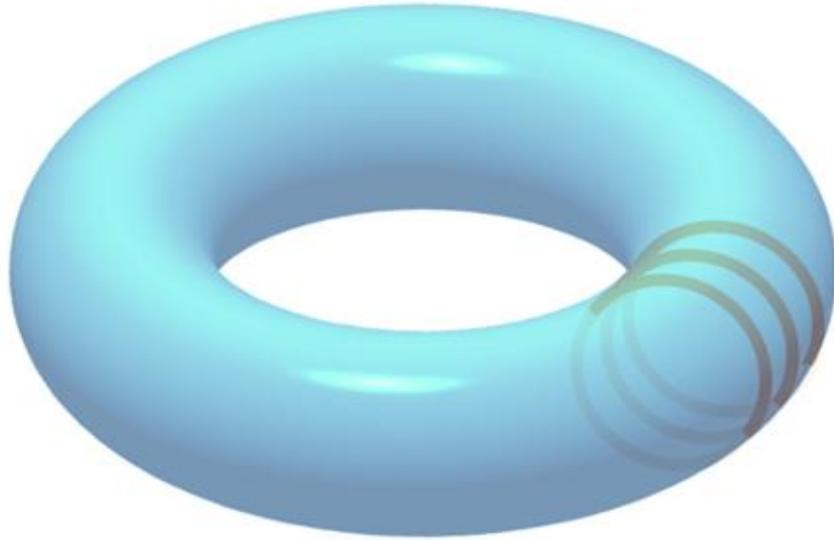
*Figure 24 - The space form of 3 symmetrically expanded dimensions*

It is important to note that the spheres forming the ring torus are not set against each other as standard object thinking would suggest, but are stacked as space volumes as depicted in Figure 25.



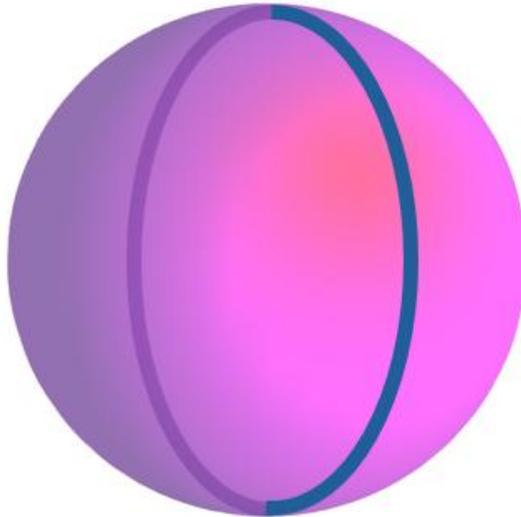
*Figure 25 – Spheres accumulate as space volumes, not set side-by-side like objects*

Similarly, projected space form of 4 symmetrically expanded dimensions is a hollow ring torus made up of infinite 3-dimensional ring tori aligned around a new circular axis, as presented in Figure 26.



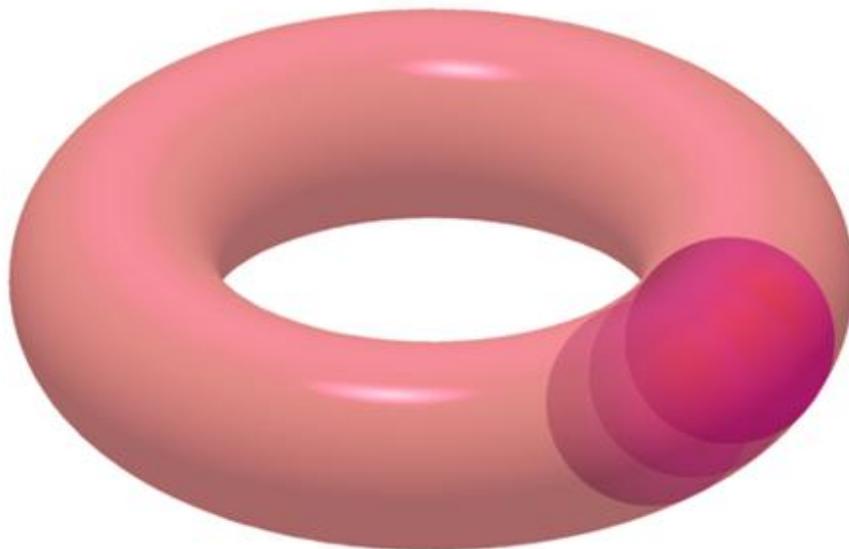
*Figure 26 – The projected space form of 4 symmetrically expanded dimensions*

Next is to render the projected space form of 5 symmetrically expanded dimensions as a hollow sphere made up of infinite 4-dimensional ring tori aligned around a new circular axis, as presented in Figure 27.



*Figure 27 – The projected space form of 5 symmetrically expanded dimensions*

And next step is the projected space form of 6 symmetrically expanded dimensions that is a ring torus made up of infinite 5-dimensional hollow spheres aligned around a new circular axis, as presented in Figure 28.

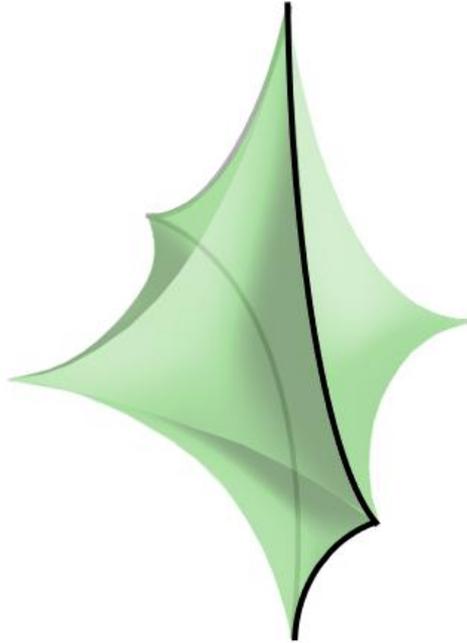


*Figure 28 – The projected space form of 6 symmetrically expanded dimensions*

Again, the 3-span cyclic pattern in the constructed forms is noticeable. Forms in further dimensions will follow the same pattern.

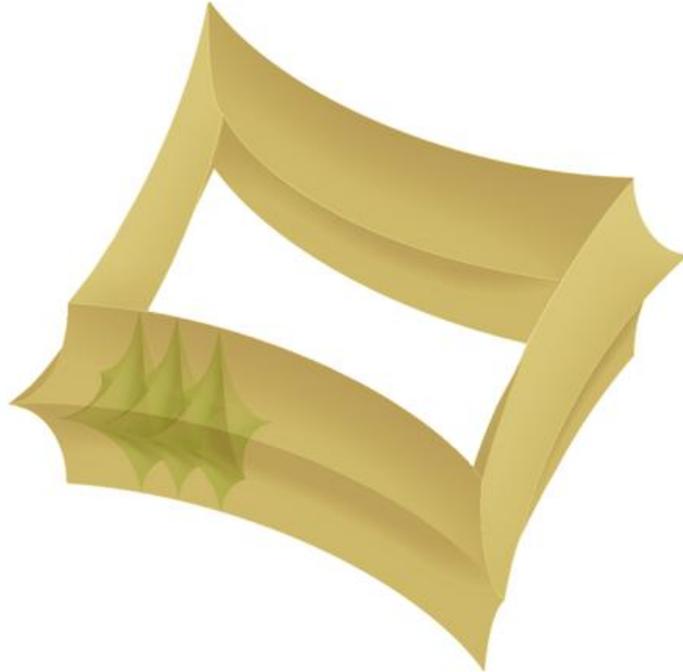
### **5.3 Space with Symmetrical Contraction**

Having already established the space form of 1 symmetrically contracted dimension, as presented in Figure 16, I shall move onto the space form of 2 symmetrically contracted dimensions. Following the methodology, this form is a hollow 6-pointed star structure (an imploded sphere), made up of infinite 1-dimensional tetracuspids aligned around a new tetracuspoid axis, as presented in Figure 29.



*Figure 29 - The space form of 2 symmetrically contracted dimensions*

Similarly, the space form of 3 symmetrically contracted dimensions is a filled imploded torus, made up of infinite 2-dimensional hollow stars aligned around a new tetracusp axis, as presented in Figure 30.



*Figure 30 - The space form of 3 symmetrically contracted dimensions*

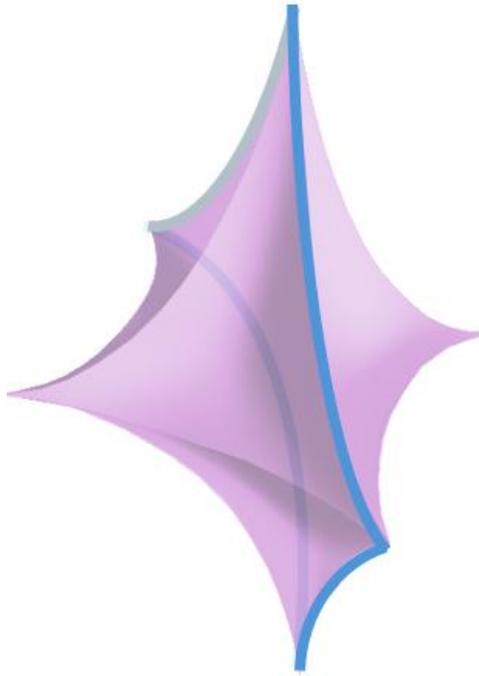
Additional views of the tetracuspid and imploded torus forms are presented in Appendix 2 to clarify the geometry.

Further, the projected space form of 4 symmetrically contracted dimensions is a hollow imploded torus, made up of infinite 3-dimensional imploded tori aligned around a new tetracuspid axis, as presented in Figure 31.



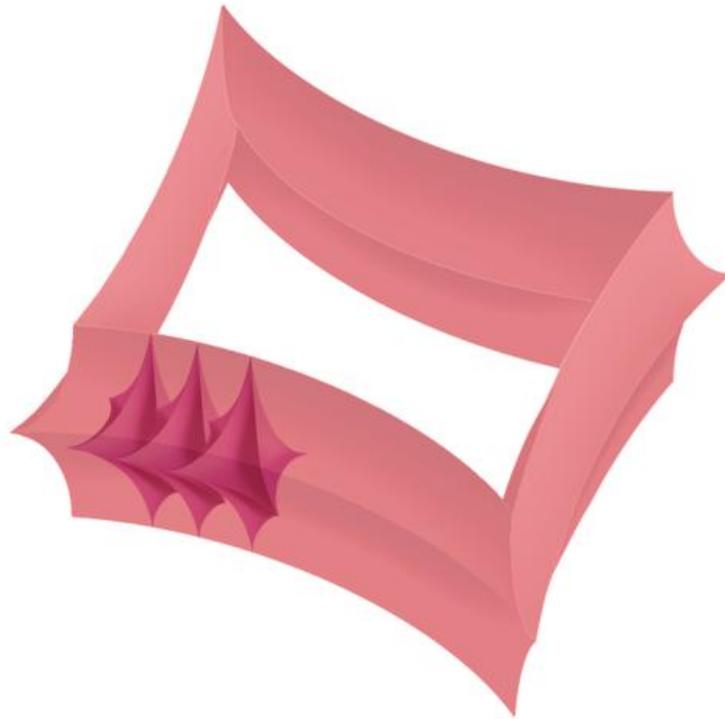
*Figure 31 - The projected space form of 4 symmetrically contracted dimensions*

Similarly, the projected space form of 5 symmetrically contracted dimensions is a 6-pointed hollow star, made up of infinite 4-dimensional imploded tori aligned around a new tetracusp axis, as presented in Figure 32.



*Figure 32 – The projected space form of 5 symmetrically contracted dimensions*

Further, the projected space form of 6 symmetrically contracted dimensions is a filled, imploded torus, made up of infinite 5-dimensional hollow stars aligned around a new tetracuspid axis, as presented in Figure 33.



*Figure 33 - The projected space form of 6 symmetrically contracted dimensions*

Again, it is noted that there is the 3-span dimensional cyclic pattern to render the forms of further dimensions.

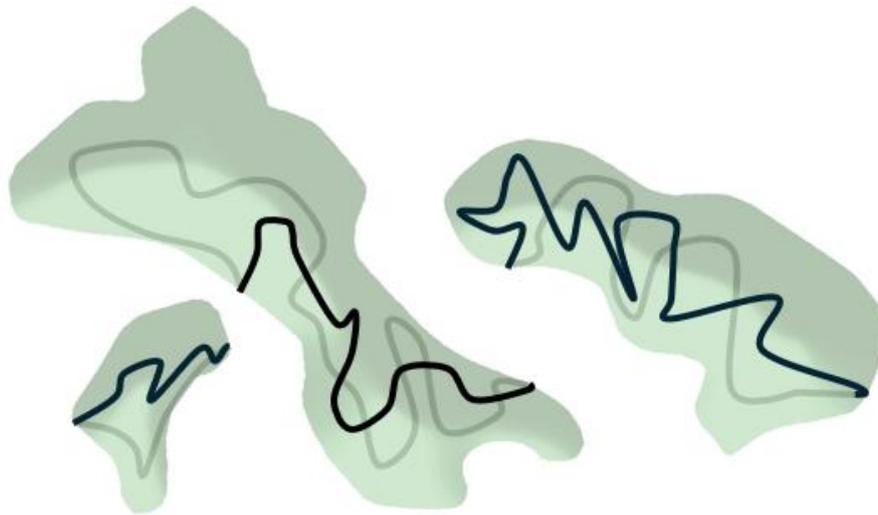
#### **5.4 Space with Irregularly Mixed Distortion**

To depict the geometry of space with irregularly mixed distortion, I shall start by rendering the first dimension, as zero-dimensional points grow into an irregular path, aligned in a mix of curvature settings as presented in Figure 34.



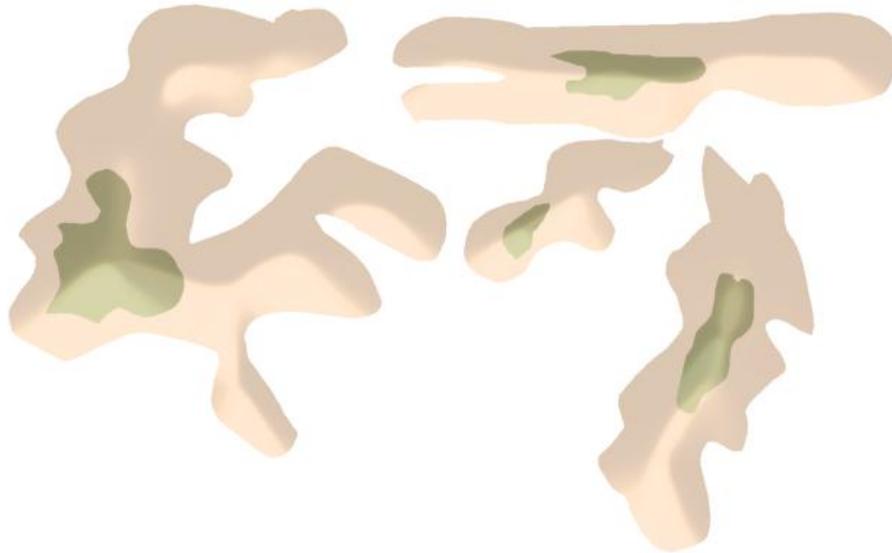
*Figure 34 - The space form of 1 irregularly mixed distorted dimension*

Following the methodology, the space form of 2 irregularly mixed distorted dimensions is hollow amorphous shapes, made up of infinite 1-dimensional irregular lines aligned around a new axis that is also in an irregular form, as presented in Figure 35. The resulting shape might include multiple spaces, some inter-connected and some isolated and it is the result of the fact that the axis that the elements align along is not a straight line but an irregular curve that causes fragmentation of the resulting form.



*Figure 35 - The space form of 2 irregularly mixed distorted dimensions*

Similarly, the space form of 3 irregularly mixed distorted dimensions as filled amorphous shapes, made up of infinite 2-dimensional hollow amorphous spaces aligned around a new axis that is also in an irregular form, as presented in Figure 36.



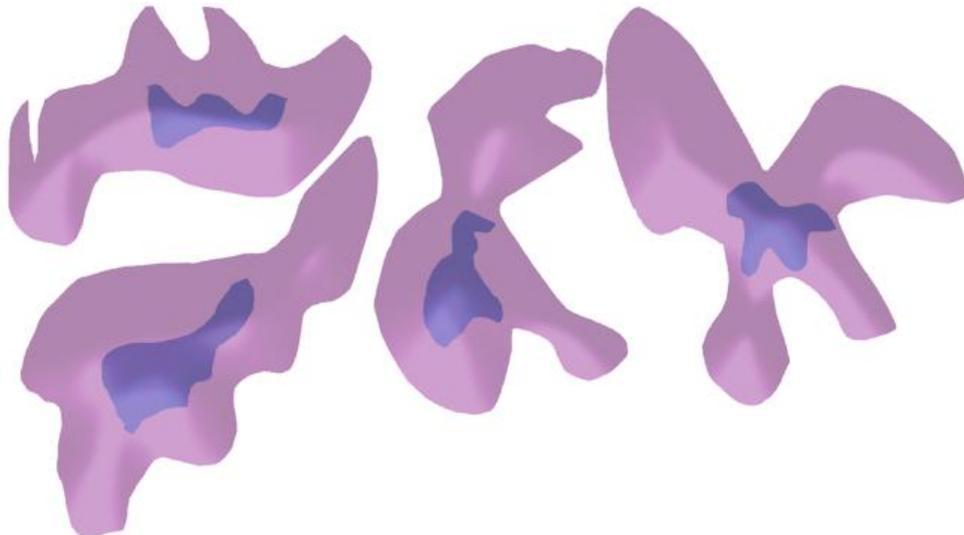
*Figure 36 - The space form of 3 irregularly mixed distorted dimensions*

Further, the space form of 4 irregularly mixed distorted dimensions is filled amorphous shapes, made up of infinite 3-dimensional hollow amorphous spaces aligned around a new axis that is also in an irregular form, as presented in Figure 37.



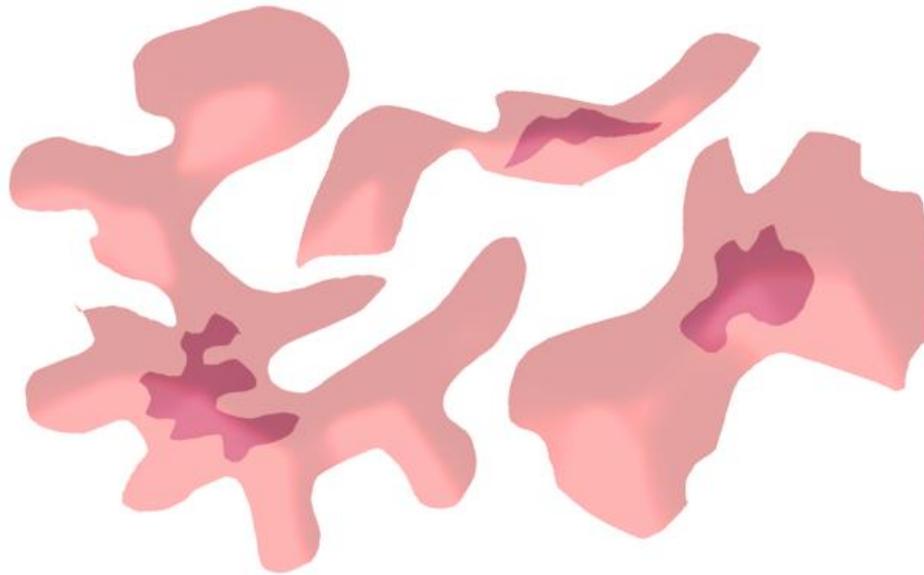
*Figure 37 - The projected space form of 4 irregularly mixed distorted dimensions*

Similarly, the space form of 5 irregularly mixed distorted dimensions is filled amorphous shapes, made up of infinite 4-dimensional hollow amorphous spaces aligned around a new axis that is also in an irregular form, as presented in Figure 38.



*Figure 38 - The projected space form of 5 irregularly mixed distorted dimensions*

Further, the space form of 6 irregularly mixed distorted dimensions is filled amorphous shapes, made up of infinite 5-dimensional hollow amorphous spaces aligned around a new axis that is also in an irregular form, as presented in Figure 39.



*Figure 39 – The projected space form of 6 irregularly mixed distorted dimensions*

The noted repetitive pattern where forms in further dimensions will follow suit.

## **6. Process**

I shall provide some insights into the process followed in this work, within the domain of design.

Once inspired by some opinions on potential spatial curvature, my initial geometric imagination was intuitive and instinctive rather than based on research and analysis. At this phase, I tried to model my visual models with pen and paper.

This intuition was mostly based on observing the historical human experience where Earth itself felt almost like a 2-dimensional plane but in fact it was discovered that Earth was closer in shape to a 3-dimensional sphere. The curvature of the sphere was so small to be discerned; hence it was experienced almost like a 2-dimensional object.

Similar thinking has been the guiding principle in suggesting the curvature of space. It could have been that the universe was so slightly curved that we

couldn't notice such curvature until we expand our capabilities of detecting its form at a larger scale.

As my ideas on the geometric forms were still settling, I had the opportunity to experiment with 3D-printing an object of a related form and also to make a physical model of the form using poliuretano material. This provided a hands-on experience with geometric intricacies.

A large part of the work was to research existing knowledge and ideas on space, shape of space, and spatial curvature, especially within the branches of theoretical physics and topology. I approached the research findings with critical thinking. Unsuitability of object approach to model space occurred as an obvious argument in this process, along with the potential incompleteness of General Relativity on the universal scale given the unknowns in our current body of knowledge.

Another major part of the process was to seek and find sensible, consistent arguments for the geometric forms that I was suggesting. Modal thinking provided a structure into assessing and testing various options. For instance, cycloidal curves, instead of glissettes, were the geometric formation I had considered at one point.

As I concluded on the geometric formations, I moved onto developing a narrative to elaborate my work in stages with relevant justification at each point. The drawings were the ideal tools in such elaboration.

Many of the 3-dimensional forms were generated using the desktop version of the software SketchUp. Some image adjustments and finishes were done using Adobe Photoshop. Microsoft PowerPoint also proved useful to generate many simple images and apply minor manipulations.

Since the drawings were presented in stages as a part of an overall narrative, there were logical links between drawings from one stage to another. Colour-coding the drawings helped distinctly identify such stages in the narrative. I tried to choose colours with adequate contrast in adjacent stages so that visual identification could be maintained.

In addition to colour-coding of the geometric forms, I also used transparency so that internal structures of them could be revealed in order to expose the constituting elements from a lower dimension.

Overall, design proved to be the ideal language for me to develop and express my ideas and visualizations in this work.

While I followed a scientific structure and justification to set the basis for my arguments and methodology in this work, building the right story narrative to express the ideas and generating the right images to express imagined forms required significant design & artistic approach.

The figures compiled as a part of this constitute a holistic story rather than being very meaningful independently. The narrative takes us from a dimensionless point all the way to multiverses in spatial fragmentation through high dimensions.

## 7. Findings

Based on various dimensional settings as listed in Table 1, many potential geometric space formations were rendered as listed in Table 2.

Case	D1	D2	D3	D4	D5	D6	D+
Case 1							Cyclic Pattern D1-3 & 4-6
Case 2							Cyclic Pattern D1-3 & 4-6
Case 3							Cyclic Pattern D1-3 & 4-6
Case 4							Continuous Cyclic Pattern

*Table 2 – A summarized view of geometric space forms rendered per various dimensional setting*

Through the formations, dimensions get to overlap and intersect in some cases, since they do not behave like objects or fields, but rather special entities.

Given that the amount of knowledge available on whether the universe is flat, positively curved, negatively curved, or mixed irregularly curved is limited, it is not exactly possible to suggest which resulting geometric form is the shape of the universe.

## 8. Conclusions

Scientific studies based on the analysis of potential repetition or significant patterns in the background radiation of the universe [28], show that there is no specific, definitive form of the universe. This makes the amorphous shape the most likely candidate for the exact shape of the space, hence makes the irregularly mixed distortion of space the most likely case to be real within our current framework of knowledge, and along with my proposed methodology.

As understood from the geometric renderings, the forms of irregularly mixed spatial distortion have certain implications: They contain multiple, isolated spaces that are disconnected from each other. This represents a universe with multiple islands or a multiverse with many universes, depending on how they get labelled.

The fact that space forms get fragmented and merged again repeatedly while going higher in the number of dimensions under irregularly mixed distortion, also have many consequences: Physical entities (even as small as subatomic particles) might get placed at the same and different universes with each other as the number of dimensions changes. This might help explain the observed behaviour of some subatomic particles.

The possibility of space distortion and consequent formation of space geometry according to the arguments and constructs employed in this work, points to various specific consequences among many:

- i. A knowledge framework beyond our current understanding of interaction of space, time, mass and energy, is needed to establish the 'default relativity' principles for more detailed and advanced modelling of space.
- ii. Figuring out how spatial distortion affects the shape of space will expand our understanding of the universe or at least make us question how we have been educated to envisage space. Such understanding can also be useful in developing models for the lowest and highest number of dimensions that are physically feasible to sustain existence or maintain unfragmented physical entities.

- iii. An exact understanding of space curvature can help map out space across higher dimensions which is a prerequisite to navigate hyperspace and other use-cases such as to catch returning light to observe the past.

The methodology employed in this work yields straight-forward results that are justified by pure means of geometrical formation, while there are speculated premises underlying the methodology such as space distortion in forms of glissette curves. It seems that space-related proposals, including those of Einstein, historically have been mere speculations in their early days, until there were growing means to test such speculations. To this end, this work seems to be stand adequate ground to be relevant.

The process employed and the results obtained in this work bring together the concepts of the nature of space, hyperspace, space distortion in an integral manner. This helps provide holistic answers to interrelated common questions relating to space and the universe.

The design process provided an efficient mechanism to translate imagination into visual elements that help convey the ideas and present the logical narrative.

## **Bibliography**

- [1] Einstein, Albert. "What Life Means to Einstein." Interview by George Sylvester Viereck, *The Saturday Evening Post*, October 26, 1929.
- [2] Sklar, Lawrence. *Space, Time, and Spacetime*. University of California Press, 1974.
- [3] Leibniz, Gottfried Wilhelm. "Third Letter to Clarke." In *The Leibniz-Clarke Correspondence*, edited by H. G. Alexander, 34–50. New York: Philosophical Library, 1956.
- [4] Leibniz, Gottfried Wilhelm. "Fourth Letter to Samuel Clarke." In *The Leibniz-Clarke Correspondence*, edited by Samuel Clarke, Section 41. New York: Philosophical Library, 1956.
- [5] Leibniz, Gottfried Wilhelm. *The Labyrinth of the Continuum: Writings on the Continuum Problem, 1672–1686*. Edited by R. T. W. Arthur. New Haven: Yale University Press, 2001.
- [6] DiSalle, Robert. "Newton's Philosophical Analysis of Space and Time." In *The Cambridge Companion to Newton*, edited by Rob Iliffe and George E. Smith. Cambridge: Cambridge University Press, 2016.
- [7] Einstein, Albert. *Relativity: The Special and the General Theory*. Crown Trade Paperbacks, 1995.
- [8] Dorato, M. "Substantivalism, Relationism, and Structural Spacetime Realism". *Foundations of Physics* 30 (2000): 1605–1628. <https://doi.org/10.1023/A:1026442015519>
- [9] Kant, Immanuel. *Critique of Pure Reason*. Edited and translated by Paul Guyer and Allen W. Wood. Cambridge Edition of the Works of Immanuel Kant. Cambridge: Cambridge University Press, 1998.
- [10] Hegel, G.W.F. *Phenomenology of Spirit*. Translated by A.V. Miller, Oxford University Press, 1979.
- [11] Jerath, Ravinder, Beveridge, Connor, and Jensen, Michael. "The Default Space Theory of Consciousness: Phenomenological Support from Personal Observations and Clinical Deficits." *World Journal of Neuroscience* 9 (2019): 1-21. doi: 10.4236/wjns.2019.91001
- [12] Ishiki, Yoshito & Koshino, Katsuhisa. "On isometric universality of spaces of metrics." (2024). <https://arxiv.org/abs/2409.17701>
- [13] Weeks, J.R. *The Shape of Space*. 3rd ed. New York: Chapman and Hall/CRC, 2020.
- [14] Cavallo, Marco. "Higher Dimensional Graphics: Conceiving Worlds in Four Spatial Dimensions and Beyond." (2021). <https://doi.org/10.48550/arXiv.2103.14627>

- [15] Green, Michael B., John H. Schwarz, and Edward Witten. *Superstring Theory*. 2 vols. Cambridge: Cambridge University Press, 1987
- [16] Polchinski, Joseph. *String Theory*. Volume 2: *Superstring theory and beyond*. Cambridge: Cambridge University Press, 1998.
- [17] Candelas, P., Horowitz, G. T., Strominger, A., and Witten, E. "Vacuum configurations for superstrings." *Nuclear Physics B* 258 (1985): 46–74.
- [18] Einstein, Albert. "The Field Equations of Gravitation." In *The Berlin Years: Writings, 1914-1917 (English Translation Supplement)*, 117-123. Translated by Anna F. Beck and Robert E. Ryan. Princeton: Princeton University Press, 1990.
- [19] NASA. "The Shape of the universe." Archived July 2001. <https://imagine.gsfc.nasa.gov/observatories/satellite/wmap/shape.html>
- [20] Chudaykin, A., K. Dolgikh, and M. M. Ivanov. "Constraints on the curvature of the Universe and dynamical dark energy from the full-shape and BAO data." *Physical Review D* 103, no. 2 (2021): 023517.
- [21] Shapiro, Joey. "The Shape of the Universe: Ten Possibilities." *American Scientist* 89, no: 5 (2001): 443. <https://www.americanscientist.org/article/the-shape-of-the-universe-ten-possibilities>
- [22] Rayne, Elizabeth. "What is the shape of the universe?" *LiveScience.com* (November 13, 2022). <https://www.livescience.com/what-is-shape-of-universe>
- [23] Nadis, Steve. "Cosmologists Try a New Way to Measure the Shape of the Universe." *QuantaMagazine*, 2025. <https://www.quantamagazine.org/cosmologists-try-a-new-way-to-measure-the-shape-of-the-universe-20250127/>
- [24] Wikimedia Foundation. "Wikipedia: Flammarion Engraving." Last modified 10 August 2025, at 22:19 (UTC). [https://en.wikipedia.org/wiki/Flammarion\\_engraving](https://en.wikipedia.org/wiki/Flammarion_engraving)
- [25] Wikimedia Foundation. "Wikipedia: Flammarion Engraving." Last modified 26 August 2024, at 00:42 (UTC). [https://en.wikipedia.org/wiki/Stars\\_\(M.\\_C.\\_Escher\)](https://en.wikipedia.org/wiki/Stars_(M._C._Escher))
- [26] Hirshhorn Museum. "Infinity Mirror Rooms" 1965. <https://www.yale.edu/about-yale/yale-facts>.
- [27] Lockwood, E.H. *A Book of Curves*. Cambridge: Cambridge University Press, 1961.
- [28] Ade, P. A. R. and Aghanim, N. and Arnaud, M. et al. "Planck2015 results: XVIII. Background geometry and topology of the Universe." *Astronomy & Astrophysics* 594 (2016). <http://dx.doi.org/10.1051/0004-6361/201525829>

## Appendix 1

There are numerous potential varieties for dimensional settings, once one starts considering further distortion options and further parameters beyond just distortion direction and symmetry.

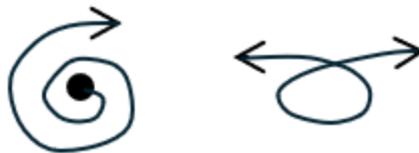
Distortion, to start off with, could be asymmetrical. Additionally, open-ended dimensional paths could extend to infinity, or they could be terminating. Based on these options, I extend the list of dimensional settings as presented in Table A1.

Of course, there are many more potential varieties than the example catalogue provided in Table A, when further parameters are considered, such as set continuity, set openness (open, closed, clopen, neither), ray openness (open, closed, half-open), one-sided infinity. Figure A1.1 depicts the symbolic representations for a few such variations of undistorted paths as an example, while they could also be applied in distorted paths.



*Figure A1.1 – A few potential varieties for the flat path dimensional settings*

Further variations could be considered on path continuity, and various loop and knot structures. For instance, spiral paths and slip knots, as presented with symbolic representations in Figure A1.2, could be evaluated for feasibility and consequences.



*Figure A1.2 – Spiral path and slip knot as some potential dimensional settings*

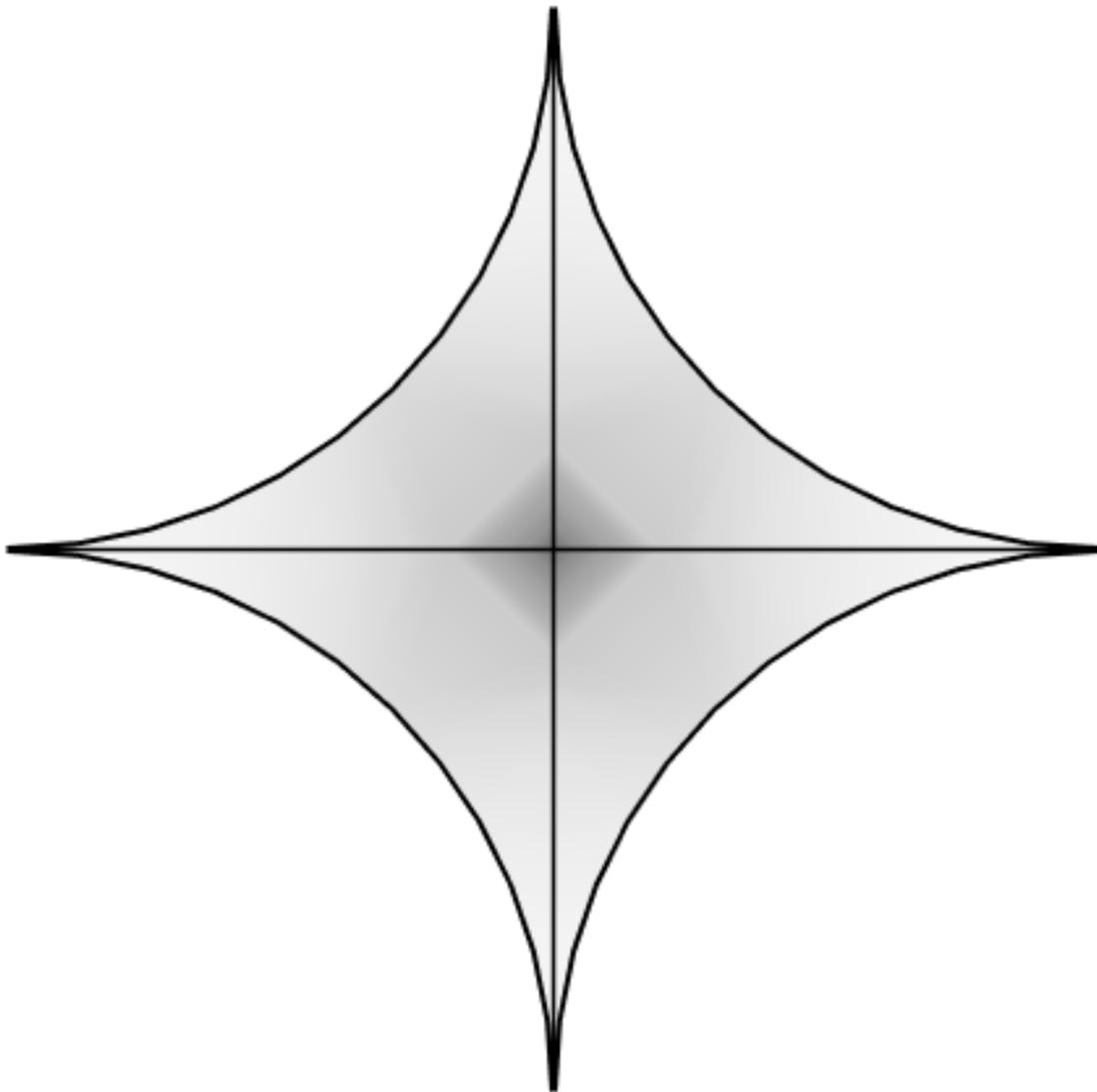
Feasibility and suitability of such and further variations are subject to further evaluation.

Various Cases for Dimensional Settings						
Distortion	Distortion Symmetry	Boundary	Extent	Ends	Symbolic Representation	#
No (Flat)	N/A	Bounded	Finite	Terminating ends		1
		Unbounded	Two-sided Infinite	Extending infinitely		2
Expanded	Symmetrical	Bounded	Finite	Looped ends		3
		Bounded	Finite	Terminating ends		4
	Asymmetrical	Bounded	Finite	Looped ends		5
		Bounded	Finite	Terminating ends		6
		Unbounded	Two-sided Infinite	Extending infinitely		7
Contracted	Symmetrical	Bounded	Finite	Looped ends		8
		Bounded	Finite	Terminating ends		9
	Asymmetrical	Bounded	Finite	Looped ends		10
		Bounded	Finite	Terminating ends		11
		Unbounded	Two-sided Infinite	Extending infinitely		12
Mixed	Asymmetrical	Bounded	Finite	Looped ends		13
		Bounded	Finite	Terminating ends		14
		Unbounded	Two-sided Infinite	Extending infinitely		15

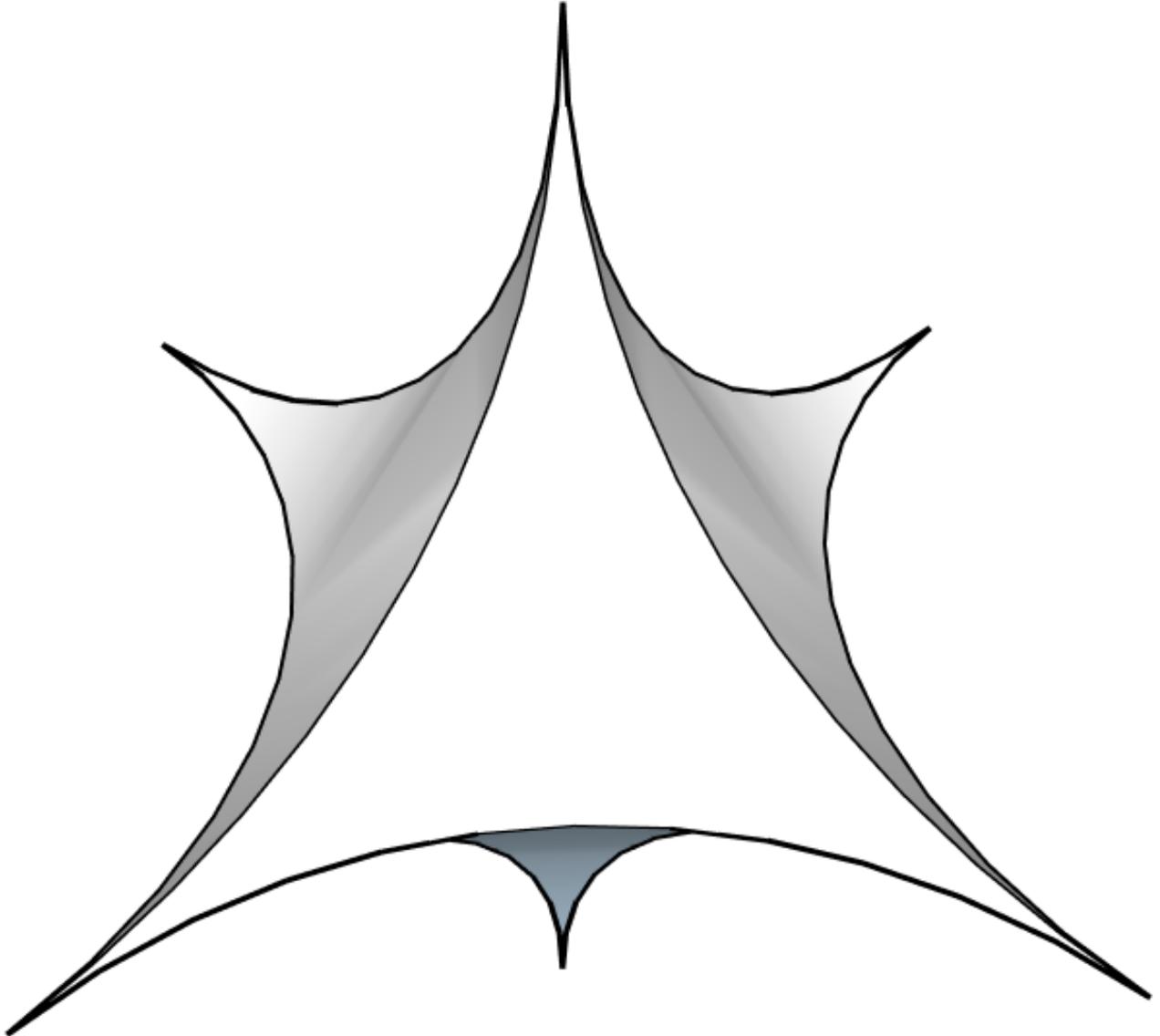
Table A1 – An example for an expanded catalogue of dimensional settings

## Appendix 2

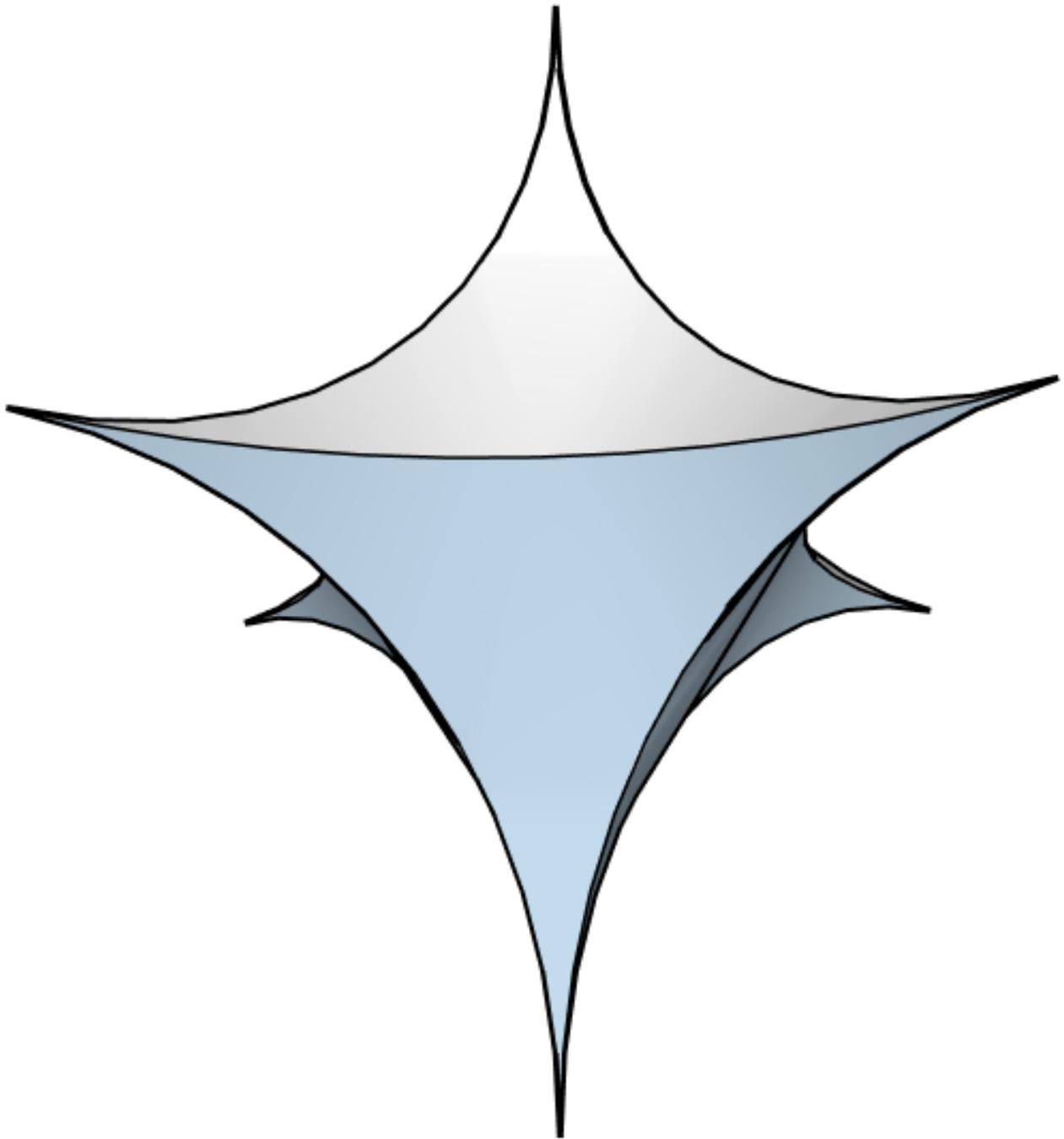
Views of the imploded sphere and imploded torus forms from various angles are presented in Figures A2.1-A2.3 and Figures A2.4-A2.6 respectively.



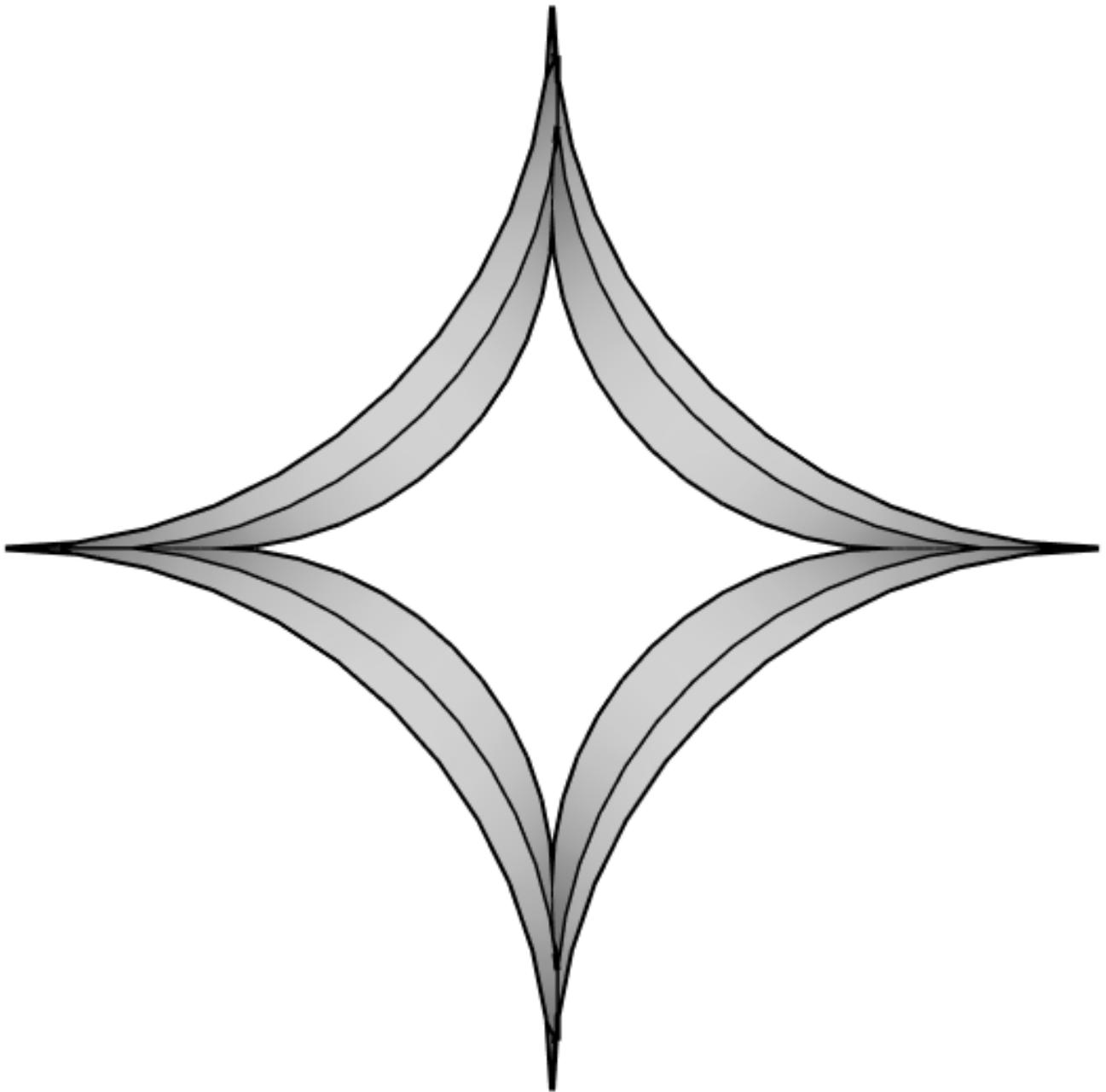
*Figure A2.1 – A view of the imploded sphere*



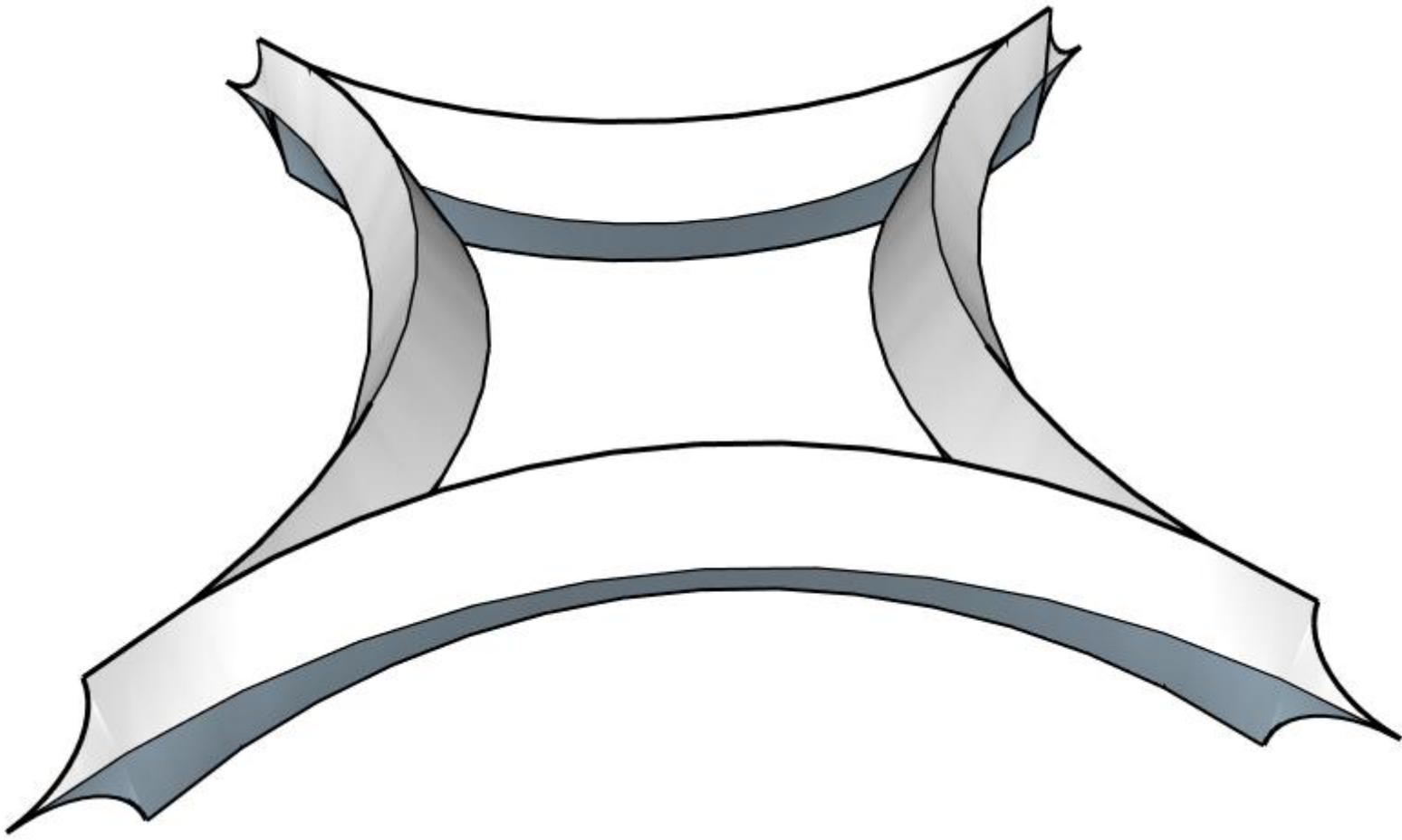
*Figure A2.2 – A view of the imploded sphere*



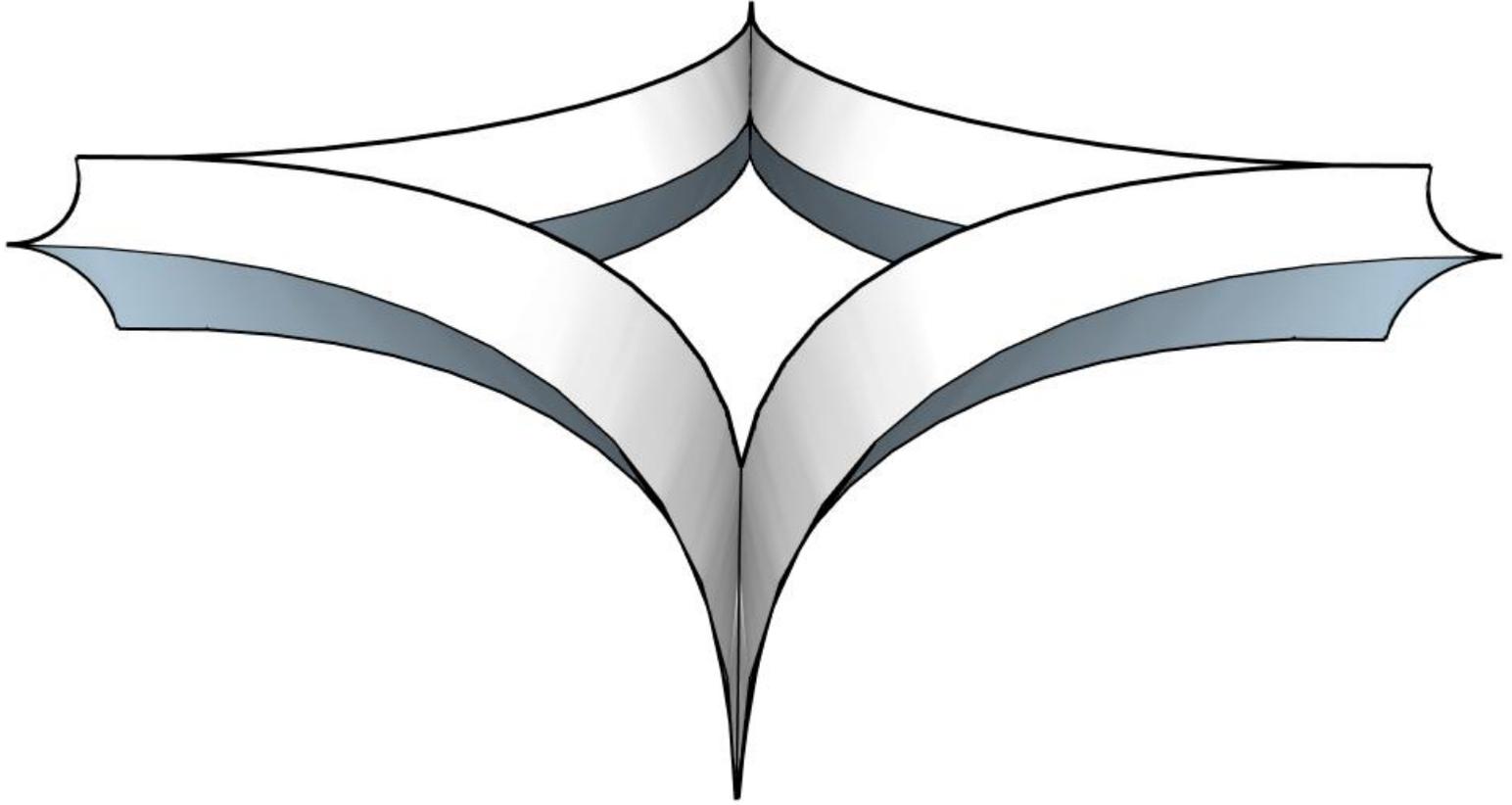
*Figure A2.3 – A view of the imploded sphere*



*Figure A2.4 – A view of the imploded torus*



*Figure A2.5 – A view of the imploded torus*



*Figure A2.6 – A view of the imploded torus*