# Why Is Space 3D?

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## Introduction

Our perception of the world is that it has three-dimensional (3D) space. This highly speculative article will suggest a reason for this using an anthropic argument.

The article supports an ensemble view of reality in which many space-times exist and considers the type of space-time in which most observers will find themselves. It is suggested that such a space-time is the type in which we should most likely expect to find ourselves.

Two main influences are suggested on the frequency distribution of observers over space-times with different numbers of spatial dimensions:

1. the proportion of space-times which have a given number of spatial dimensions.
2. the average population of observers expected in each space-time with a given number of spatial dimensions.

## Assumptions

1. There are many space-times.
2. The proportion of space-times with a given characteristic depends on the proportion of the different ways in which a space-time can exist that involve it existing with that characteristic.
3. Each different way of describing a space-time corresponds to a different way in which it can exist.
4. The probability of an observer finding him/her/itself in a given situation depends on the proportion of all observers who are in that situation.

## The Argument

### Part 1: General Consideration of Space-Time

1. From the assumptions, it follows that the proportion of space-times with a particular characteristic depends on the proportion of different ways of describing space-times for which the space-time has that characteristic.
2. The number of spatial dimensions $d$ of a space-time is a characteristic of that space-time.
3. Therefore, the proportion of space-times with d dimensions is dependent on the proportion of different ways of describing space-times for which the space-time has d dimensions.
4. The proportion of ways of describing space-times with d dimensions will be lower when d is higher.

5. Therefore, the proportion of space-times that exist with d dimensions will be lower when d is higher.
6. If we assume that each space-time contains the same number of observers then it follows that the proportion of observers finding themselves in a space-time with d dimensions is higher when d is lower. (*Is this a reasonable assumption, though?*)
7. Therefore the proportion of observers should be higher in space-times with the lowest possible number of dimensions; that is to say with 1 spatial dimension.
8. Therefore, any randomly selected observer should most likely find him/her/itself in a space-time with 1 spatial dimension. *If we are typical observers this disagrees with our experience of living in a 3D world*.

**Part 2: Consideration of Observers**

1. Observers are complex systems made of interacting parts.
2. Interaction between the parts of an observer relies on communication of matter, energy or various effects – in general, transmission of information – between different parts of an observer. An obvious example of this is in the human brain in which electrical signals are communicated along different pathways.
3. Such communication relies on pathways not interfering with each other.
4. With 1 spatial dimension the issue of preventing pathways from interfering with each other introduces a lot of complexity. There is only one available path between any two points, which must be shared, partially or totally, for communication between other points. Communication is possible between any two points – signals could be made to carry combined information and various forms of time sharing could be used – but it is complex. Imagine the problem of getting a 1 dimensional, Turing equivalent cellular automaton to do any useful computation.
5. With 2 spatial dimensions getting pathways around each other without interference is easier, but significant complications are still introduced. It is still inevitable that paths between points will still cross, even if the different parts of a system are confined to a 1 dimensional line and the 2 dimensional plane is just used for the paths between them.
6. With 3 spatial dimensions the seriousness of the issue of paths crossing is dramatically reduced, no longer being much of an issue.
7. With 4 spatial dimensions the issue of paths crossing is less important still as the number of spatial dimensions is increased, however with more than 3 dimensions this does not matter much: going from 2 to 3 dimensions removed it as a significant issue.
8. The expected population of observers in a given space-time is likely to be depend on the number of ways in which observers can result from processes in that space-time. When observers are required to be more complex in a space-time then it should be expected that the expected number of processes that can cause them is reduced. An example of this is if we consider the process of Darwinian evolution, probably the main process that causes observers to exist. The more complex an observer needs to be then the less often Darwinian evolution will generate observers.

9. Therefore, all else being equal, the expected population of observers in a space-time should depend on the number of spatial dimensions of that space-time. The greater the number of spatial dimensions then the greater should be the population of observers, on average.
10. This effect, however, is most pronounced going from 1 to 2, and finally from 2 to 3 dimensions. A space-time with 2 spatial dimensions should contain, on average, many more observers than a space-time with only 1 spatial dimension and a space-time with 3 spatial dimensions should contain, on average, many more observers than a space-time with only 2 spatial dimensions. The effect when going from 3 to 4 dimensions, etc is one of diminishing returns for adding dimensions.

**Part 3: Combination of the Considerations of Space-Time and Observers**

1. In considering space-time in general we established that the proportion of space-times that exist with d spatial dimensions will be lower when d is higher, so that any randomly selected observer should most likely find himself in a space-time with the lowest possible number of dimensions. If we are typical observers this disagrees with our experience of living in a 3D world.
2. In considering observers themselves we established that the average population of observers in a space-time with d spatial dimensions should increase as d increases. It should be much higher when d=2 than when d=1 and much higher when d=3 than when d=2. Beyond d=3 there are diminishing returns for adding further dimensions.
3. Therefore, we should expect the number of observers to be much higher in space-times where d=3 than in other space-times. Although space-times where d=2 are more common than space-times where d=3, the complications in connecting different parts of an observer together mean that, on average, there is a much smaller population of observers in each such space-time – it may even be the case that many more such space-times are uninhabited – more than negating any effect due to the larger number of space-times. Although a space-time where d=4 contains, on average, more observers, than a space-time where d=3, due to the increased ease of connecting different parts of an observer together, this effect is not major, as there is little complication in connecting parts of systems where d=3 anyway and the fact that the proportion of space-times where d=4 is lower more than offsets any increase in the number of observers in each space-time.
4. Therefore, space-times where d=3 should contain a greater proportion of observers than space-times with other numbers of dimensions. If we assume that the effects discussed so far are very significant, rather than just having a minor effect on the distribution of observers, we can say that almost all of the observers who exist are in space-times where d=3.
5. Therefore, any randomly selected observer should almost certainly find that he/she/it lives in a space-time with 3 spatial dimensions.
6. This is why we find ourselves in a space-time with 3 spatial dimensions.

## What about the extra dimensions?

An obvious objection to all this is that space is not truly 3D. Some scientific theories predict higher dimensions; for example, at the time of writing, there are two theories, *string theory* and *M-theory*, predicting 10 and 11 spatial dimensions respectively, though neither is universally accepted yet.

Am I saying that these higher dimensions cannot exist? No, we should actually be surprised if they did not. If they do exist then the size of our space in these dimensions is considered to be very small, so that humans cannot directly perceive them. Any anthropic argument like this should result in clustering of observers in particular types of space-times, but we should hardly expect this to be perfect. While there may be many ways of describing space-times with simple numbers of dimensions, there may be more ways of describing space-times with “almost” a certain number of dimensions, so that the points in space connect together in such a way as to form, for example a 3D space but with some much smaller amount of connectivity between points still occuring to allow “smaller”, much less significant, higher dimensions. In a way, a space-time with three “obvious” spatial dimensions and some other microscopic ones can be considered a “3 point something” dimensional space, if not in a technically correct mathematical sense, and can be considered to be an instance of the kind of clustering very close to 3D space suggested by the argument.

## Relationship to Scientific Models

None of this is suggested as a replacement for any particular scientific theory. Various theories describe our space-time as one of many existing in some more expansive, higher dimensional structure and propose various reasons for its apparently 3D nature; for example, a particular kind of scientific model may only allow certain space-times to be stable. Such a model may *appear* to explain why space is 3D, but does not really do this as it is not clear why such a model has to apply in the first place. This article takes a more general view by considering a more expansive set of space-times: rather than looking at the set of space-times allowed in a particular model we are taking the set of all space-times described by all possible scientific theories as a reference class, so that none of this is specific to any particular physics model, neither supporting nor refuting it.

## The Ultimate Ensemble

This article fits particularly well with ensemble views, which are mathematical and physical models of reality having some relationship to *model realism* proposed by David Lewis **[1]**, which suggests that “all possible worlds exist”. Various physical and mathematical ensemble models have been proposed which resemble modal realism to various degrees.

One such ensemble model is the “ultimate ensemble” suggested by Max Tegmark **[2,3]**. Tegmark’s proposal is that every mathematically describable structure exists in reality and the suggestion in this article fits well with such a view.

The reasoning in this article would suggest that some of these structures describe space-times with varying numbers of spatial dimensions, that some of them may indirectly describe space-times by describing structures of which space-times are a part (from our point of view such a structure would appear to be a scientific theory accommodating many space-times), and that the distribution of all these space-times and the populations of observers in them is the basis for the reasoning in this article.

## Conclusion

Using an anthropic argument, a reason has been suggested for space being 3D, at least as far as human perception is concerned.

Two main influences are suggested on the frequency distribution of observers over space-times with different numbers of dimensions:

1. the proportion of space-times which have a given number of spatial dimensions.
2. the average population of observers expected in each space-time with a given number of spatial dimensions.

The first effect, by itself, makes space-times with fewer dimensions more common. The second effect, by itself, tends to make the population of observers in space-times greater for space-times with more dimensions, because of the complexity in connecting parts of complex systems together to make observers when there are issues with paths crossing in space-times with small numbers of dimensions. This effect becomes very significant as the number of dimensions is increased to three, but beyond this there are diminishing returns. The result is that space-times with three spatial dimensions are the ones containing most observers. Observers should therefore expect to find themselves in space-times with three spatial dimensions.

The suggestion in this article fits well with modal realism views of reality and in particular with the Tegmark ultimate ensemble in which all mathematical structures exist.

## References

**[1]** Lewis, D. K. (1986). *On the Plurality of Worlds*. Oxford: Basil Blackwell.

**[2]** Tegmark, M. (1998). Is the theory of everything merely the ultimate ensemble theory? gr-qc/9704009. *Annals of Physics 270*, 1-51. (Received November 19, 1996).

**[3]** Web Reference: Tegmark, M. (?). *Which mathematical structure is isomorphic to our Universe?* Retrieved 13 January 2007 from http://space.mit.edu/home/tegmark/toe.html. (An online version Tegmark's paper from reference **[2]**).