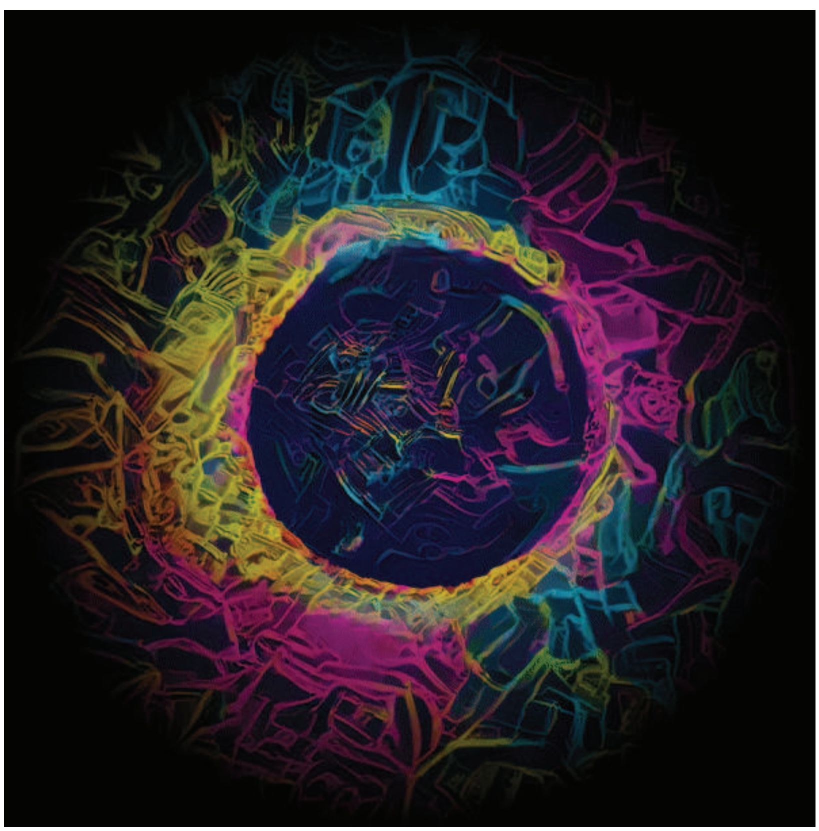
1. An Interconnected System of Energy

Husam Wadi

Overview

What is described in these articles is a framework of energy that I found interesting to think about, and perhaps you may find it interesting too. Equipped with a non-trivial amount of imagination, light mathematical intuition, and a testable hypothesis for validation, these woven models may help deepen our understanding of reality.

This series aims to form a foundation of exploration through successive thought experiments rather than being a set of detailed and rigorous proofs. I will be primarily using tools and methods found in robotic system development to explore reality, as that is what I am most familiar with. If this system points in the right direction, then there is tremendous opportunity to develop far beyond what is written here, bringing us to hopefully better perspectives in the future.



A neural-network-rendered black hole visualization I created

2. The Issues with Spacetime

Overview

While this isn't an exhaustive list of issues with our modern cosmological understanding, we have a sizable pool of evidence pointing to the incompletion of our currently accepted theories. Many theories provide solutions to these discrepancies: from *superstring theory* to *loop quantum gravity* and other *competing ideas*, each with their significant contributions to furthering our understanding of physics.

The models proposed in these articles attempt to complement the foundations of our knowledge in an intuitive and simple manner to solve some of the problems listed below.

The Hubble Constant Problem

This issue may point to a fundamental fracture in our assumptions about the universe and possibly spacetime itself. There appears to be a lack of congruency between the *cosmic distance ladder* and the *cosmic microwave background* methods of computing the *Hubble constant*. This lack of agreement could be errors in measurement, or perhaps it points to a more profound phenomenon within the cosmos.

PBS Space Time covers this topic extensively in their *New Crisis In Cosmology* episode:

Vacuum Energy Density

This discrepancy points to another possible hole in the assumptions underlying our theoretical frameworks. The vacuum energy predicted by *quantum field theory* is up to **10^{120}** times greater than the calculated *dark energy* values found in the observable universe today. The *Vacuum Catastrophy* episode expounds on the details of this issue:

Testable Theories

With our modern understanding of relativity, there isn't enough time for light to have interacted at the edges of the CMB to produce the measured level of uniformity in its temperature. To solve this issue, we apply *Inflation*: a seemingly well-fit but practically untestable theory. These articles will postulate a method to test how the expansion of the universe could have occurred through a different phenomenon.

This topic is covered extensively in the *What's Wrong With The Big Bang Theory* episode:

3. System Diagrams

Overview

Here, I'll introduce the idea of system diagrams and how to reduce any system into its core constituents to be precise about what we are defining. This step must come *before* any equations or formulations of physical phenomena.

What is a System

What differentiates a system with parts acting together from the things in your pocket? Also, how can we even qualify that our reality is a system?

Computer system vs. a collection of items: 1 2

Let's start with the pure definition of a system from the *Merriam-Webster* dictionary:

> *A regularly interacting or interdependent group of items forming a unified whole.*

Why wouldn't the *things in your pocket* be considered an interdependent unified whole? Couldn't I claim that together the pile is a pocket system? The easiest way to think about this is by going through the *Systems Checklist*:

1. Is it a collection of different elements?
2. Are the items together?
3. Can the items produce results not obtainable by the elements alone?

Do the *things in your pocket* pass the checklist?

1. Yes
2. Yes
3. No

A large pile of miscellaneous items does not produce any collective result that wasn't possible with a single item *on its own*. In other words, the items do not interact with each other systematically to produce a result. This idea seems trivial, but it's vital.

Can the known universe fit this definition?

1. Yes
2. Yes
3. **Yes**

If the last answer was no, then having laws, equations, and expecting results with *any* predictability in the universe wouldn't be possible. With that in mind, let's look at the scope of a system.

System Diagrams

There are three main aspects of a system:

1. Input(s)
2. The *Black Box*
3. Output(s)

A basic system

For now, we're not concerned with what's in the box. We are simply trying to define what goes in and what comes out. You may object and say, "How does the universe have inputs? It **is** the source of everything; there isn't anything we can define before the singularity since time doesn't exist, etc, etc..."

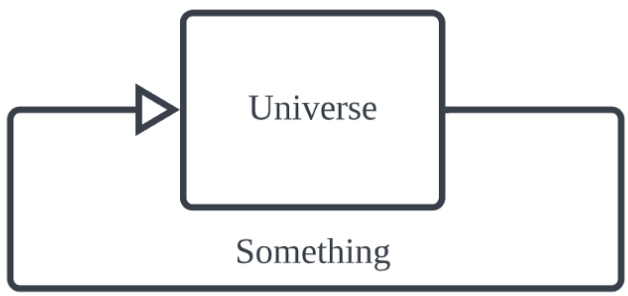
Let's allow something to exist outside our known universe (which may be a subset of a larger structure) and work purely through deduction first. Once we have deduced every abstract model possible, *then* we can look at the pieces of evidence we have to see which is most likely.

What realities are possible? There are potentially infinite input and output combinations that can form our reality, so how do we even begin? We can start by deriving four simple reality units. These reality units assume the standard definitions of the words being used.

The first type of universe we will define is the *nothing* paradigm. This is a universe where nothing goes in, and something comes out:

1: The nothing universe model

The second type is what I like to describe as the *infinite cycle*. This is where the output can create the input endlessly:



2: Cyclical something universe model

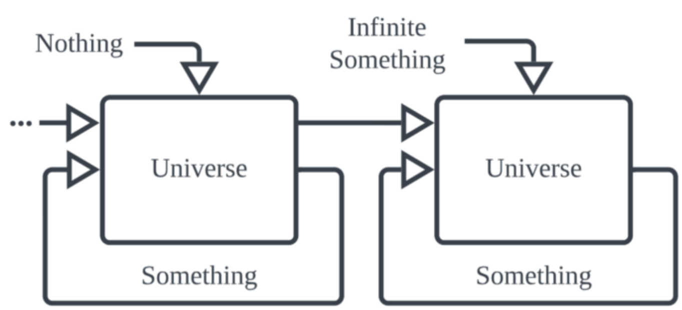
The third type is an *infinite regress* of finite systems. This is where the input is a finite directional universe that attaches to a prior finite universe back to an endless past:

3: Infinite regress of finite universes model

The fourth type is the *directional infinity*. This is where the input is infinite and not dependent on anything prior, and the output is something we experience:

4: Infinite something universe model

With these four basic universe types, we can create any arbitrary model to represent reality:



A possible model of reality

Note that anytime your *black box* expands to more than one element, you can always express it in terms of a greater black box that abstracts the details.

An infinite regress of finite universes dominates the complicated model above, so we can view it in terms of the third base model regardless of what's happening in every universe instance.

Which model could we exist in? What evidence can I directly observe to guide our selection? The answer may reside in entropy.

Entropy and Origin

What is entropy? Let's start with the pure definition from *Merriam-Webster*:

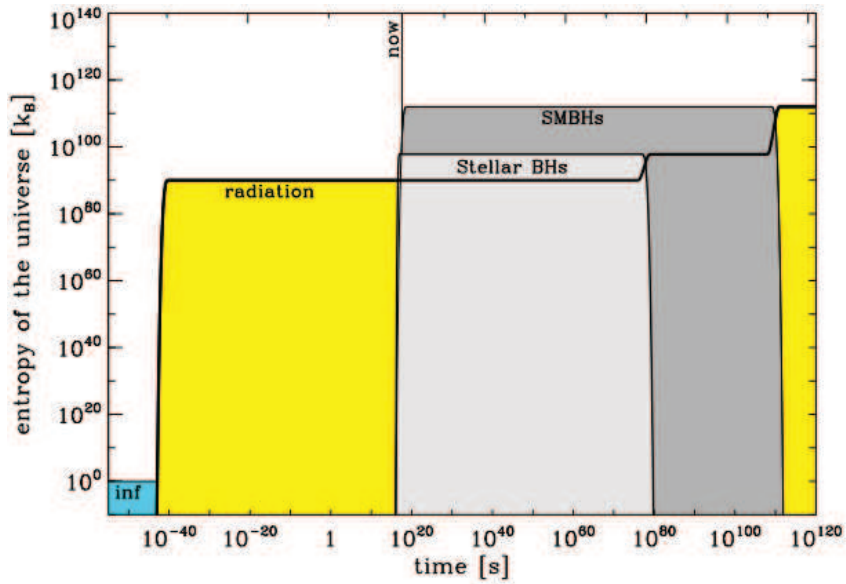
> *Thermodynamics: a measure of the unavailable energy in a closed thermodynamic system that is also usually considered to be a measure of the system's disorder, that is a property of the system's state, and that varies directly with any reversible change in heat in the system and inversely with the temperature of the system. Broadly: the degree of disorder or uncertainty in a system.*

While this definition is correct regarding thermodynamics, we also require the definition of entropy in terms of statistical mechanics and information. PBS Space Time covers this topic in depth in *The Misunderstood Nature of Entropy* episode:

An increase in entropy correlates with microstates that tend towards a macro-thermal-equilibrium arrangement (as these states are much more probable). Once at thermal equilibrium, the amount of new useful work is minimized.

In non-jargon, this means when you put an ice cube on a table, it's much more likely to melt to room temperature than stay frozen.

What is the state of entropy in our universe? We can refer to a paper by Chas. A. Egan about the estimated entropy of the universe:



Normalized entropy measurement vs. time: 1

This figure gives evidence of the increasing measured entropy in our known universe. For our system diagrams, it is imperative that we assume only what we can directly observe and have proof of.

Let's take a look at options **1** & **2** from above:

The infinite entropy and constant entropy universes

If I have nothing. Truly an unconscious nothing. *No-thing*. What information do I have about the system? **No** information: there is *no-thing* to describe. There exists a philosophical case to be made about what *nothingness* is, but for now, let's keep this real. I have yet to see any concrete evidence of something that is genuinely, unconsciously nothing into something. If we lived in a universe where orderly macroscopic candy appears on my desk randomly from nowhere, I would be less opposed to this idea. As this is not the case, and we do not have direct evidence of infinite entropy at the beginning of the universe, I will not be using the *nothing model* as a starting point.

What about a cyclical universe? Sir Roger Penrose proposed an intriguing idea of *Conformal Cyclic Cosmology (CCC)* that provides a framework for resetting entropy at the end of time. He may be onto something, but to stay consistent with observable evidence, I cannot postulate that we live in a purely infinite cyclical universe. For me to believe this, entropy in the known universe would have to be constant since the beginning, with no measurable increase. How otherwise could this universe recreate itself infinitely without perpetual motion or **100%** thermal efficiency?

That leaves us with two remaining base options to compare with our objective, measurable evidence. Let's start with the infinite recursion universe:

The frozen universe

Imagine I am writing a piece of code with an infinitely recursive function nested inside. What happens when I run the code? Does it ever move to the line after the infinite recursion?

Here I provide a simple example for you to run by clicking on the demo below:

Finite recursion to infinity: 1

The Python version runs to infinity: 1

A finite recursion that extends infinitely into the past freezes all motion in the present. Again, a philosophical argument can be made about the causal nature of an infinite regress, but here in engineering land, we must stay consistent with our direct observations of causality. Even if you decide to run that Python script until the end of time, the line following the infinite recursion never executes. For this reason, I am opposed to starting my system diagram with an infinite regress of finite prior universes.

That leaves us with one real option to work with:

The most likely candidate

Having something that by its own nature is entirely independent and has no prior, which by **definition** must extend infinity into the past, is the only real option I see to engineer a sound framework.

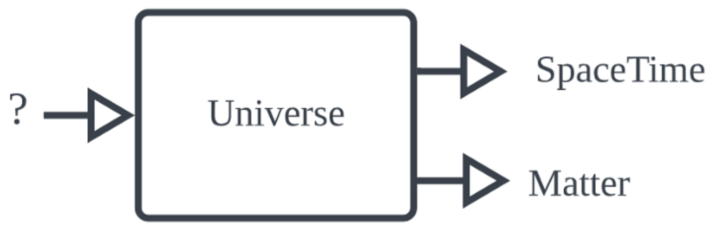
The question is, is there any way to rationalize what that infinite something could be? Or are we stuck in the land of philosophy? Maybe there's a way to find out.

Known Universe Outputs

Before we try to discover what goes into our universe system, let's tackle the low-hanging fruit of outputs. We will boil reality into the simplest terms possible, aiming only to output what we know to exist. Attributes or aspects of the output(s) will have to be eliminated for clarity.

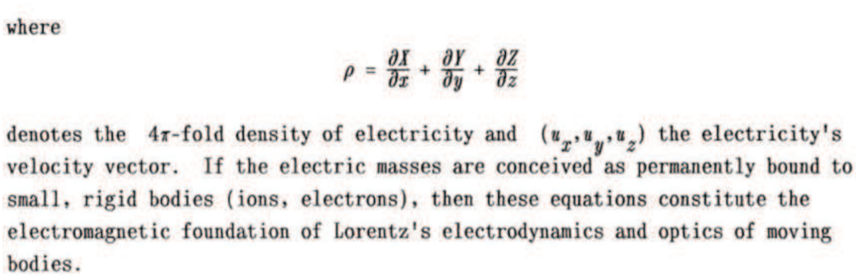
What do we currently know? The relativity principle from over **100** years ago holds incredibly well. Einstein derives *On the Electrodynamics of Moving Bodies* in 1905, also known as special relativity, which provides the physical interpretation to tie space and time together (merging them into one entity described as a four-dimensional Minkowski manifold) with respect to the speed of light.

Building upon the relativity principles, Einstein then formulates general relativity, which assumes that matter rests on the **4D** spacetime fabric (a Lorentzian manifold), bending and contorting it due to its mass. From a systems perspective, this is what the model looks like for relativity:



The relativity model

What could be off? Are there any assumptions made that do not match observed reality? Well, there is one foundational assumption that seems prominent:



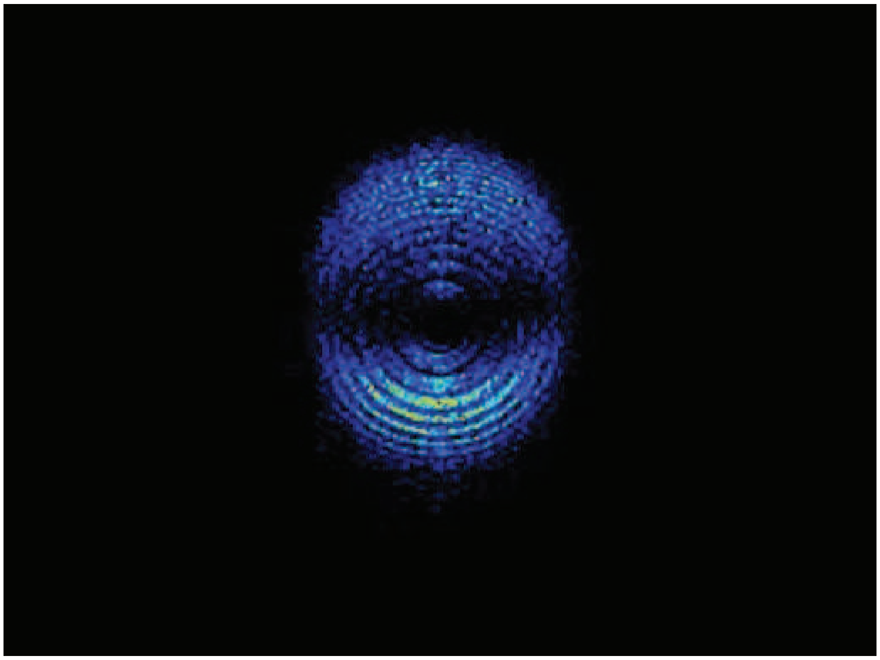
where

$$\rho = \frac{\partial X}{\partial x} + \frac{\partial Y}{\partial y} + \frac{\partial Z}{\partial z}$$

denotes the 4π-fold density of electricity and (u_x, u_y, u_z) the electricity's velocity vector. If the electric masses are conceived as permanently bound to small, rigid bodies (ions, electrons), then these equations constitute the electromagnetic foundation of Lorentz's electrodynamics and optics of moving bodies.

Special relativity rigid body assumption: 1

The physical interpretation of special relativity is derived from the assumption that electric masses are small, rigid bodies that can be ascribed to a fixed frame of reference. Are they genuinely rigid? This is a recording of an electron taken from a quantum stroboscope:



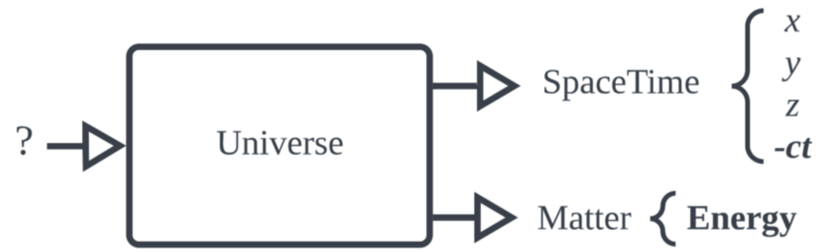
Quantum stroboscope electron imaging: 1

This doesn't appear rigid to me. It looks like it is in varying acceleration and wavelike rather than fixed and inflexible. Perhaps this would be an excellent place to start our exploration. Let's take a look at the classic relativistic equation that describes the total energy of a system:

$$E^2 = (pc)^2 + (m_0c^2)^2$$

In this equation, ***c*** = *speed of light,* ***p*** = *momentum,* and $\boldsymbol{m_0}$= *rest mass.* If I look at this equation and make no extraneous assumptions, it states that the total energy is related to the momentum of the speed of light plus a function of the rest mass multiplied by the speed of light. I'm curious how we defined the true speed of light through the interactions of that jello-like subatomic particle above.

Returning to our system diagram and adding one layer of detail to reflect the equation above, we find:



Einstein model level 2 breakout

Let's take a quick review of the general definition of energy. According to the *Encylopedia Britannica*:

> *Energy is the capacity for doing work… All forms of energy are associated with motion. For example, any given body has kinetic energy if it is in motion. A tensioned device such as a bow or spring, though at rest, has the potential for creating motion; it contains potential energy because of its configuration. Similarly, nuclear energy is potential energy because it results from the configuration of subatomic particles in the nucleus of an atom.*

Electrons appear as waves of probability, and their interaction with photons (energy carriers of the electromagnetic force) causes them to **change** energy states.

If electrons at a subatomic level appear to be in constantly changing motion/acceleration, and motion is associated with energy, then how is it possible to have any fixed inertial frame from which we can objectively measure time and thereby the speed of light? Also, how do we define time without the **transmission of energy**?

This video by PBS Space Time helps us understand what happens when we zoom in on the underlying fuzzy fabric of the universe:

It would not be precise to define time by the *absolute motion* of light since that definition crumbles when your motion (energy) interferes with the motion of light (energy transfer) and the motion of matter (also energy) which you are measuring. If you fire a laser from a *fixed frame,* the frame is neither fixed nor inertial if it is the collection of ~$\mathbf{10^{27}}$ sporadically accelerating subatomic *wave–particles*.

From this point forward, these are the definitions we will use to keep the aspects of this system clear in our minds:

1. **Energy:** The ability to change states, namely motion.
2. **Time:** The measurement of energy interactions, the difference of motion.
3. **Dimension:** The number of coordinates required to specify motion.
4. **Time-Energy Equivalence:** If the measurement of energy transfer (difference of motion) and matter (motion) cannot be distinctly separated, then they will be treated as equivalent properties.

Time-Energy equivalence can be represented by this seemingly simple formula:

$$\Delta t = \Delta E$$

I know you're probably having a severe guttural reaction to all this but bear with me until we've seen this through. Interestingly enough, Dr. Holger Müller's group from UC Berkeley created a mass clock not too long ago, so this idea couldn't be that far-fetched.

If this is the case, what does this difference in perspective do to the speed of light? Let's begin by defining a placeholder equation for time and energy:

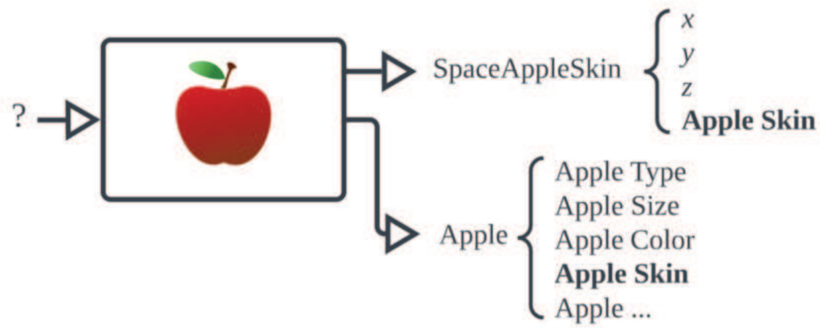
$$1s = 1e_u$$

1 second = **1** energy unit. Simple enough, if we factor that in for the speed of light, it appears in this form:

$$c = 3 \cdot 10^{\circ}\ m/e_u$$

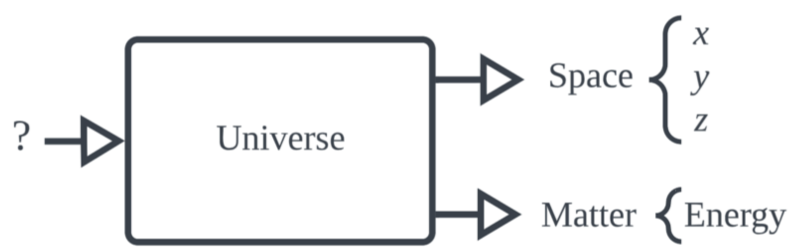
The speed of light is now defined as the *distance* traveled per energy unit. While this conversion isn't too relevant to the underlying mathematics we will perform, the conceptual idea behind this equation is **critical**.

I am not going to object to existing in three spatial dimensions yet, but the *time* and *matter* aspects of this system may require a deeper look. If ***-ct*** is simply an *aspect* of a unit of energy, this results in redundant information in our diagram. In layman's terms, imagine that we are trying to measure an apple and we make a system for it:



The fruit model of truth: 1

The **Apple Skin** is just a part of the definition of an **Apple**. Likewise, the **distance of energy (*-ct)*** is a subjective description of **energy itself.** Eliminating the **-*ct*** redundancy, our diagram takes this form:



System redundancy simplification

Taking this description at face value, let's combine terms and simplify them into a single definition:

Possible ground truth of reality

This finally seems like a real system. We know from experience that we live in three dimensions of space (unless you can genuinely perceive a tesseract in four spatial dimensions. If so, send me an email). However, we have no idea what type of space (open, flat, closed, etc.) these dimensions exist in, as we've reduced our diagram to absolute simplicity and are now rebuilding from the foundation.

Universe Inputs

That was quite a bit of work to define an output. What could the input be? We will make a simple assumption of the *law of conservation of energy* on the system we just created.

According to the *Encyclopedia Britannica*:

> *Conservation of energy implies that energy can be neither created nor destroyed, although it can be changed from one form (mechanical, kinetic, chemical, etc.) into another.*

Let's focus on *one* unit of energy, whatever it may be. The system we are forming cannot create or destroy this unit of energy; it can only modify it. This implies that the input (energy) is a modified version of the output (energy), which we can define using the same terminology:

The Simple Energy Model

What if everything around us is aspects of the same type of higher-dimensional energy? Is it possible that every fundamental force, every interaction, every atom, every molecule, and every medium is comprised of different facets of the same ultimate input constituent?

We still aren't exactly sure what the input is; however, we have some confidence that the output resides in three dimensions.

In the next section, we will use tools from linear algebra to bring clarity to our description of Dimensional-Energy.

. . .

4. Projections

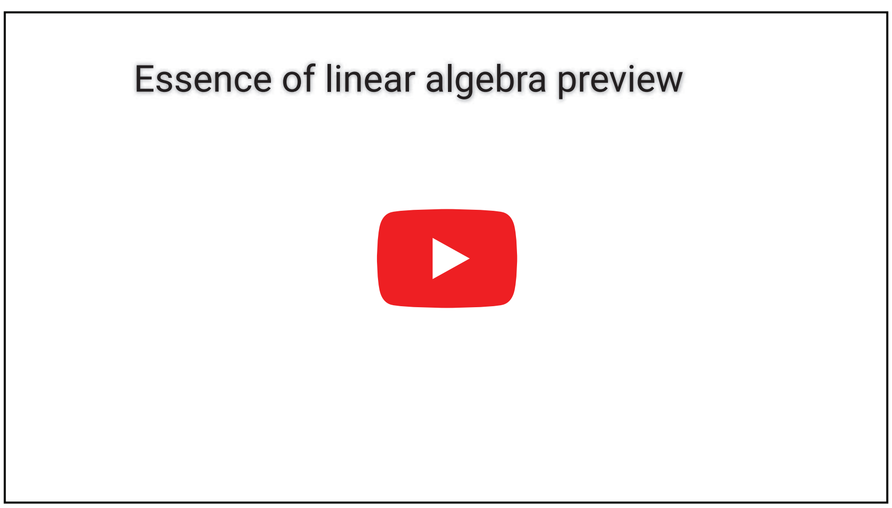
Overview

This section explores a method to create a representation of time that can be both seemingly *real* and *projected* onto our three dimensions of space. We'll then see how this framework can be scaled to match the geometry of other theories of reality, such as string theory.

Linear Algebra

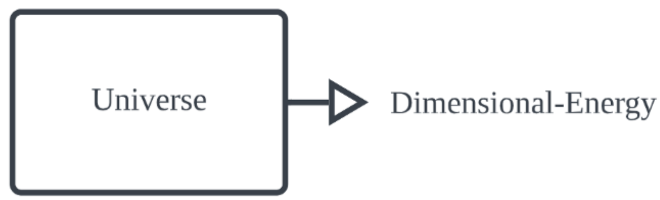
Linear Algebra is a mathematical framework that underpins many data science disciplines in the **21st** century. It is the branch of mathematics that codifies the manipulation of vectors, vector spaces, and linear transformations. Many of our computational simulations reside in matrices, and our modern-day macro physical understanding is embedded in tensors: a linear algebra concept. Linear algebra will be the basis for expressing homogeneous coordinates, which we will use to expand our system from the last chapter.

A conceptual overview of the essence of linear algebra can be found on Grant Sanderson's channel *3Blue1Brown*:



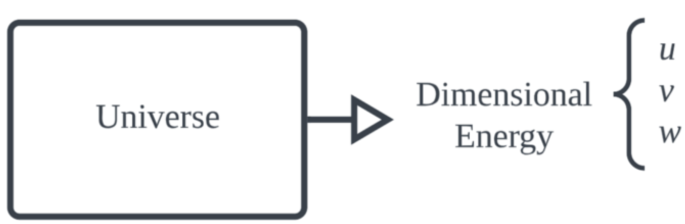
Homography and Time

Before we delve into this topic, let's try to understand why linear algebra, vectors, and homogeneous coordinates relate to the system we just developed in the previous section. Focusing on the output side, we have:



Universe output

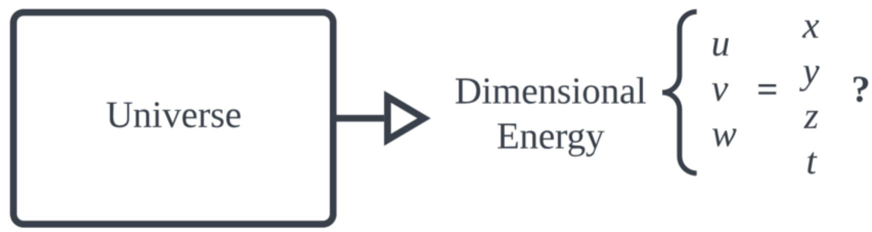
We defined something called *Dimensional-Energy* but are unsure of what it is. The first step in defining *Dimensional-Energy* is to break out the *Dimensional* portion into what we know to exist with certainty**, 3D** Space:



Universe dimensional output level 2 breakout

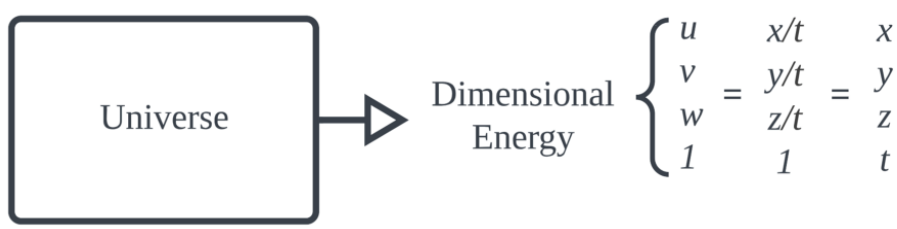
Since there are three independent coordinates in **3D**, I will represent this with three letters ***u**, **v**,* and ***w***. The question is, "How do ***u**, **v**,* & ***w*** relate at all to the spacetime framework we already have?"

Time can be represented independently but is fundamentally nested in *Dimensional-Energy*. Is there any mathematical tool that can represent time in this manner? We are going to factor out the ***-c*** (don't worry, it'll return eventually) and focus on the state-space definition of the universe we are in:



State space dimensional representation

The answer is yes. If we represent this in homogeneous coordinates, we can set time as a scale factor and swap back and forth between the two representations:



Homogeneous spatial transformation

This comes with the implicit cost that every measurement we have ever made using any type of energy has been an absement ($x = u \cdot t$) rather than an actual energy position (u) if it wasn't purely instantaneous. This may begin to explain some of the oddities of measurement at the quantum level. It always seems like trying to pin down the position of an electron is nearly impossible, and it's much better to regard its area of influence instead…

If you are new to homogeneous coordinates and want an in-depth introduction, this video by Dr. Cyrill Stachniss is a great reference:

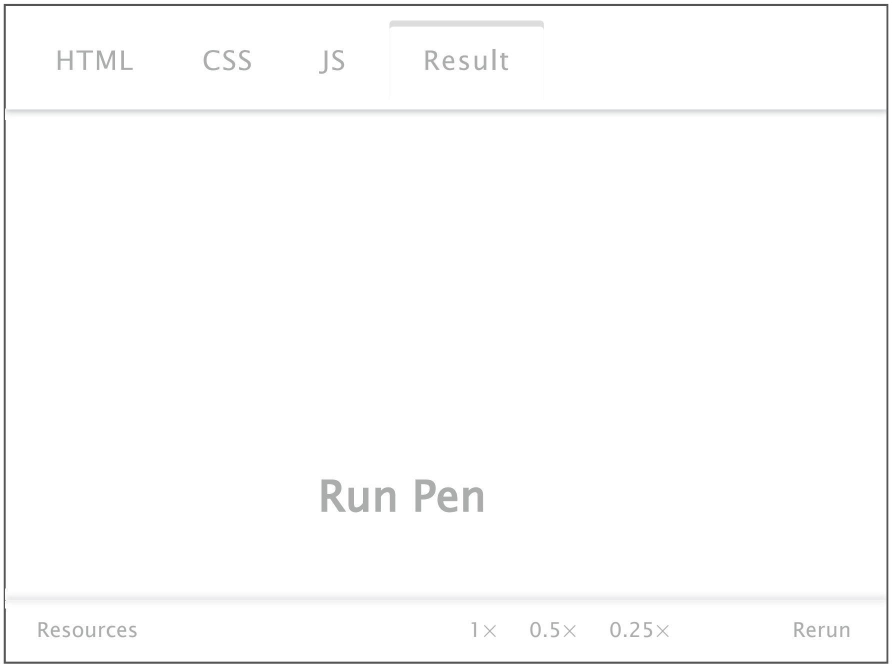
The difference between Euclidean and homogeneous coordinates is that in homogeneous coordinates objects are **equal** if a scale factor relates them:

$$x \neq \lambda x$$
$$Euclidean$$

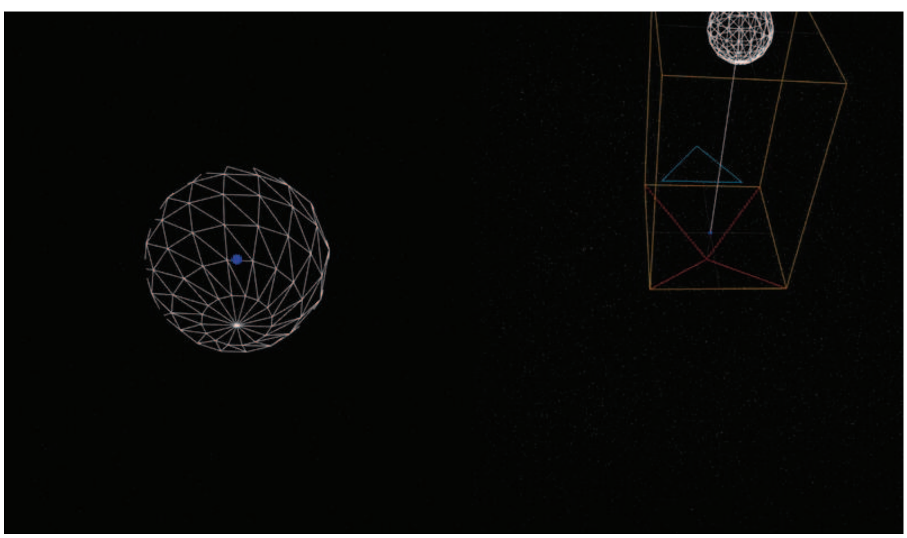
$$x = \lambda x$$
$$Homogeneous$$

This means that the space we measure (*x,y,z*) is a projection with time (*t*) determining the size of the projection. This is not the same as having a **3D** Euclidean space combined with one opposing dimension of time into a **4D** manifold.

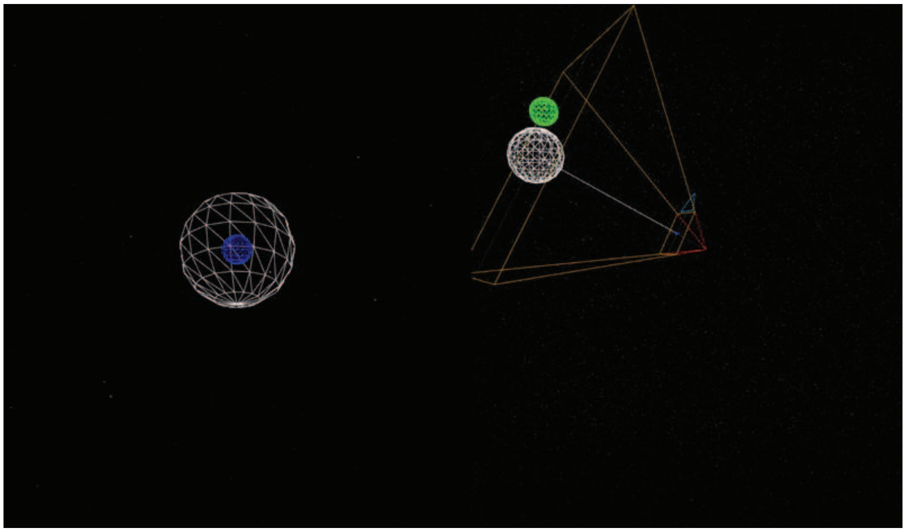
Below is an example from threejs.org of how perspective projection warps our view of size and scale. While **2D representations** of **3D** objects are not the same idea as changing coordinate systems from Euclidean to homogeneous, this is simply to illustrate the difference in concept between the two frameworks. In Euclidean coordinates, size and shape are objective properties of an object(represented by the orthographic projection), while in homogeneous coordinates, your perspective plane determines the size and shape of the object (represented by the perspective projection):



Orthographic vs perspective simulation: 1

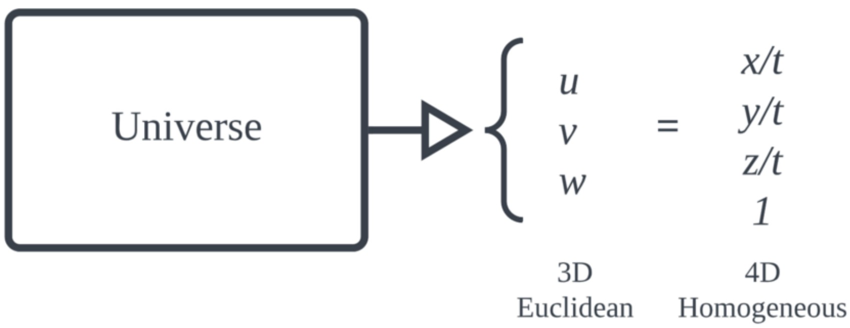


Euclidean: perspective doesn't affect objects



Homogeneous: perspective **really** matters

To recap, this is the view of the diagram that we are forming:



Transferring between Euclidean and homogeneous coordinate systems

No doubt this is quite a shift in thinking, but since we started with a sound foundation and a solid system representation, let's continue onward and see where this leads to.

Projections and Superstring Theory

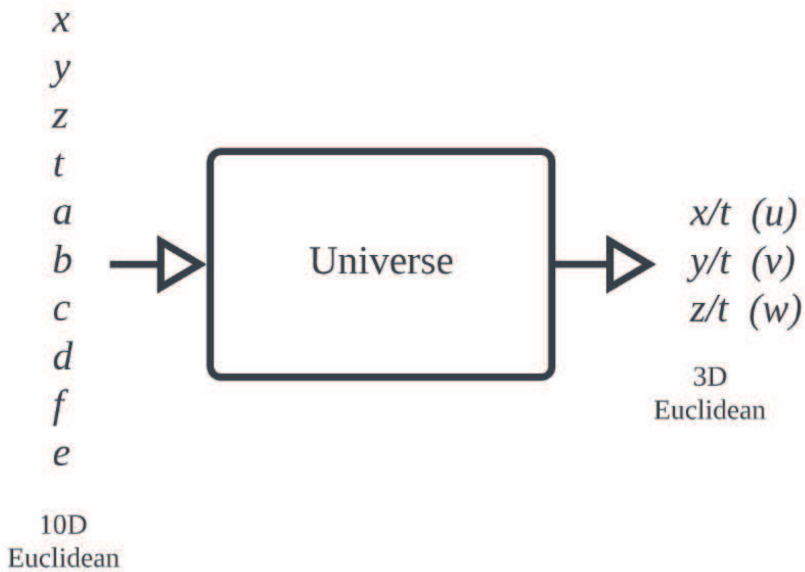
With a method to swap back and forth between our traditional spacetime representation and our new projective dimensional-energy representation, let's try to model the system input and, perhaps for the first time, the contents of the *black box*.

We have two clues at our disposal to tackle the system input; one comes directly from the combination of *string theory* and *supersymmetry* into *superstring theory*:

Type	Spacetime Dimensions
Bosonic (closed)	26
Bosonic (open)	26
I	**10**
IIA	**10**
IIB	**10**
HO	**10**
HE	**10**
M-theory	11

Superstring theories dimensional comparison: 1

Outside of the initial Bosonic and the meta-level M-theory, all modern superstring theories converge on **10** dimensions. This number of dimensions preserves quantum symmetry and serves as a good starting point. The other clue is an intuitive reason that guides to **10** dimensions and may be explored in the future. Let's try putting in **10** placeholder variables as a dimensional-energy input:



Input and output definition for dimensional-energy in spacetime variables

I've denoted the input side with ***x, y, z,*** & ***t*** for the dimensions we are familiar with and ***a, b, c, d, f,*** & ***e*** for the extra six we are unfamiliar with. I kept the last term as ***e*** arbitrarily to have it represent the full span of ***e***nergy.

How do we drop from **10** dimensions to **9** dimensions in homogeneous coordinates? Divide by the last element, the scale factor, ***e***:

$$\begin{bmatrix} z \\ t \\ a \\ b \\ c \\ d \\ f \\ e \end{bmatrix} \rightarrow \begin{bmatrix} z/e \\ t/e \\ a/e \\ b/e \\ c/e \\ d/e \\ f/e \\ 1 \end{bmatrix} \rightarrow \begin{bmatrix} y/e \\ z/e \\ t/e \\ a/e \\ b/e \\ c/e \\ d/e \\ f/e \end{bmatrix}$$

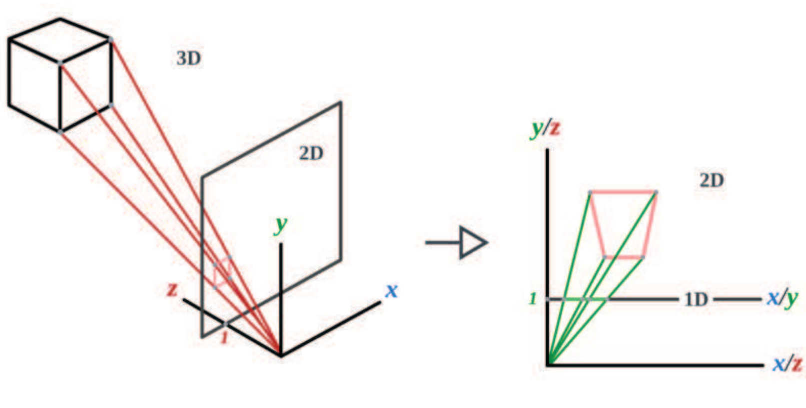
10 **9**

To shift from **9D** homogeneous representation to **9D** Euclidian we drop the underlying **1** which completes the conversion. What happens if we continue and divide again by the last term, ***f/e***?

$$\begin{bmatrix} z/e \\ t/e \\ a/e \\ b/e \\ c/e \\ d/e \\ f/e \end{bmatrix} \rightarrow \begin{bmatrix} \frac{z/e}{f/e} \\ \frac{t/e}{f/e} \\ \frac{a/e}{f/e} \\ \frac{b/e}{f/e} \\ \frac{c/e}{f/e} \\ \frac{d/e}{f/e} \\ 1 \end{bmatrix} \rightarrow \begin{bmatrix} y/f \\ z/f \\ t/f \\ a/f \\ b/f \\ c/f \\ d/f \end{bmatrix}$$

Interestingly enough, the original ***e*** term cancels out, and we are left with the scale factor of the last dimension, ***f,*** of the **9D** space. Perhaps this might be related to why we do not directly observe the other dimensions: they are embedded into the projective scale factor of our space, ***t***.

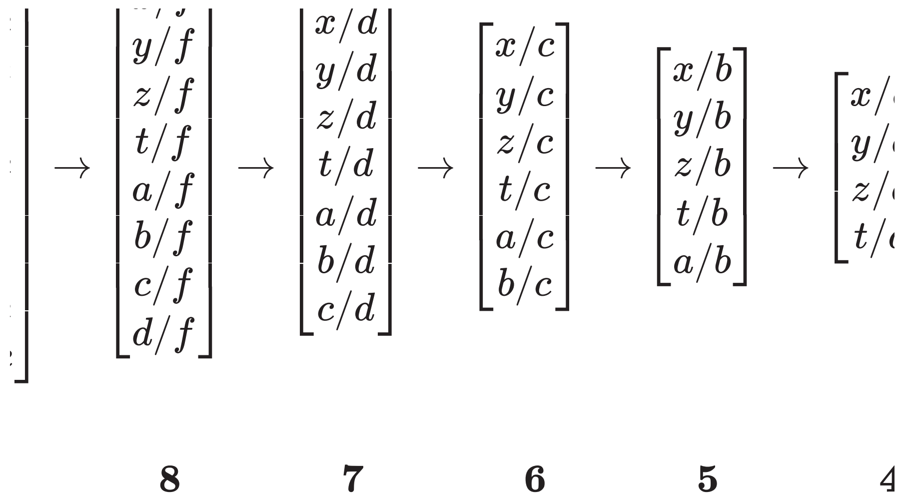
We can reason about what is happening visually. Imagine we are collapsing a **3D** object into a **2D** projection, then collapsing that **2D** projection down to a single dimension:



3D to 1D projection collapse

Once you reach down to **1D**, the *z-axis* is no longer relevant. However, it did play a significant role in forming the shape of the **2D** projection that resulted in the **1D** image.

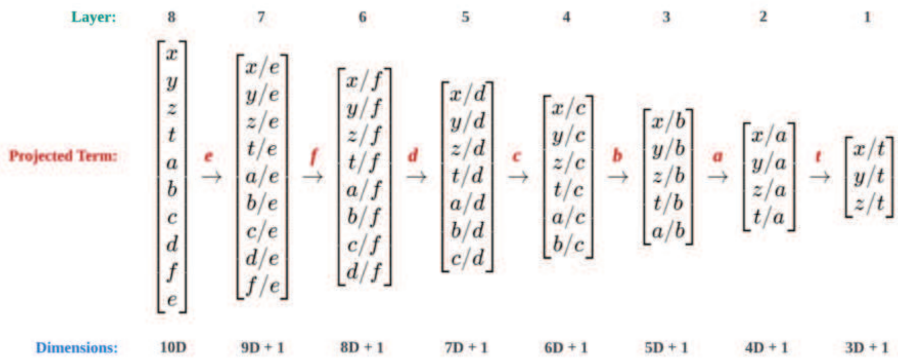
Completing our projection system, we find this arrangement:



This layout raises more questions than answers. What is going on with the **10th**-dimensional layer? If we count how many layers exist with a scale factor/projection, seven elements separate us from the last zone. Also, how do these seven elements combine into our familiar layer of spacetime? How does one shift between these layers if they do exist?

Testing the System

We've developed an elaborate diagram, but does it mean anything? Let's try inserting a test point and see if the system produces results. Here is how we will view our layered reality:

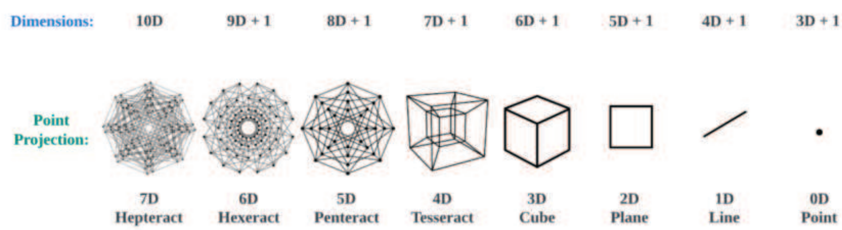


The Spatial Model of Dimensional-Energy in Spacetime Coordinates

For each layer above, we will count how many independent dimensions it has and whether it has a scale factor. We notice that we *lose* a term between layers, so we keep track of the lost term for later exploration. These dimensional definitions will be utilized to describe each layer:

1. A number followed by the letter **"D"** denotes spatial coordinates **only**. A **4D** space denotes a location where four-dimensional shapes are possible.
2. A spatial dimension followed by "**+1**" denotes the addition of a perceived projective **time** component. Our layer is **3D+1** as we have three spatial dimensions plus one of time. A **4D+1** layer denotes a location where four-dimensional shapes and time are reality.

If we focus on the spatial dimensions of the model, a point inserted into the **3D** space would appear as a line of possibilities in the **4D** space. A point is intrinsically zero-dimensional as it has no attributes (length, width, height, etc.) to define. Perhaps we can keep on going and see what the result is:



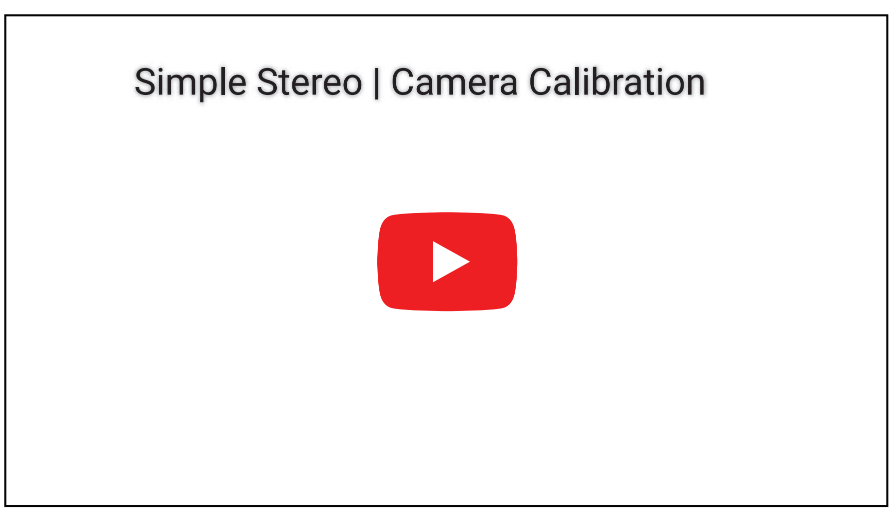
Point in 3D+1 space projected into 10D space: 1 2 3 4

We see that our **0D** point in **3D** space expands to a **7D** hypercube of possibilities in a **10D** Euclidean space. If we want to be more precise, these representations could be modeled as manifolds, with the highest dimension being **7D.**

Shifting our attention back to space and time, something extraordinary occurs when we remove our projective factor between the **9D+1** and the **10D** layer. There is no longer a projection factor in the **10D** layer, and time, in any meaningful manner, ceases to exist.

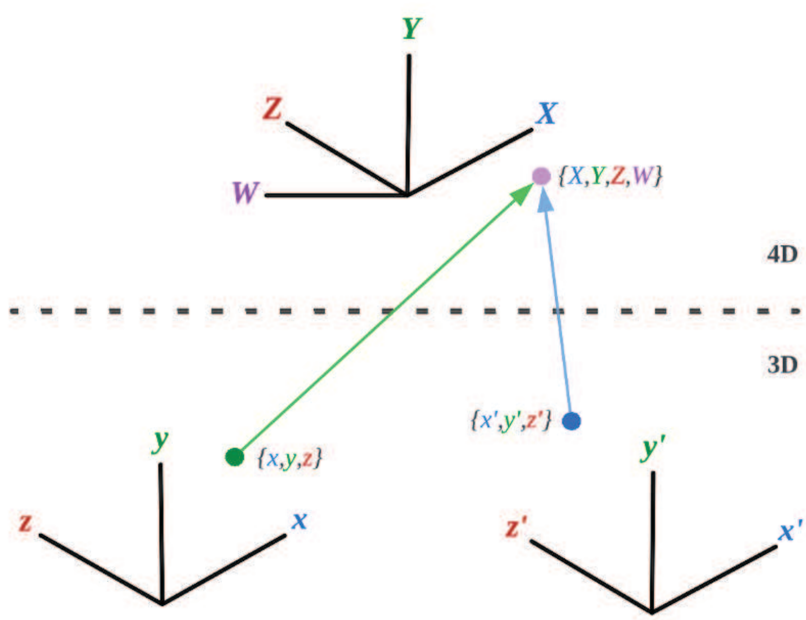
What happens if we try to go the other way? How can a higher-dimensional point be reconstructed from a lower-dimensional projected space?

This is a video demonstrating how to triangulate a **3D** point using two camera planes by Dr. Shree K. Nayar, who has a free series called *First Principles of Computer Vision* that I benefitted from considerably while studying computer vision:



There are more advanced techniques, such as epipolar geometry, that can be used to define point triangulation using uncalibrated cameras. These techniques can be extended to define **4D** points within a **3D** space, which has been explored in this paper by Dr. Jun Sato's group. Another paper by Dr. Gérard G. Medioni's group formulates a technique called *4D tensor voting*, which estimates epipolar geometry by applying local geometric smoothness constraints in **4D** joint image space.

To summarize in non-jargon, if you can compute the relation between two or more **3D** perspectives, you can localize a point in a higher-dimensional space:



2 x 3D = 1 x 4D

A projection of a **4D** point down to two discrete **3D** points could perhaps correlate to physical effects we perceive, such as *quantum entanglement*. Of course, this is purely speculation but something to keep in mind as we move forward.

In the next section, we will build more context into this homogeneous framework and observe how black holes relate to the projections of lower dimensions.

. . .

5. Black Holes & Light

Overview:

In this section, we will explore the meaning of a black hole in projective coordinates and how it modifies our understanding of reality on the macroscopic level. We will also delve into the basis for ***c***, the speed of light, and how we can perform an empirical test to validate our assumptions. We will lastly view some methods by which we can visualize cascading lenses and mirrored surfaces.

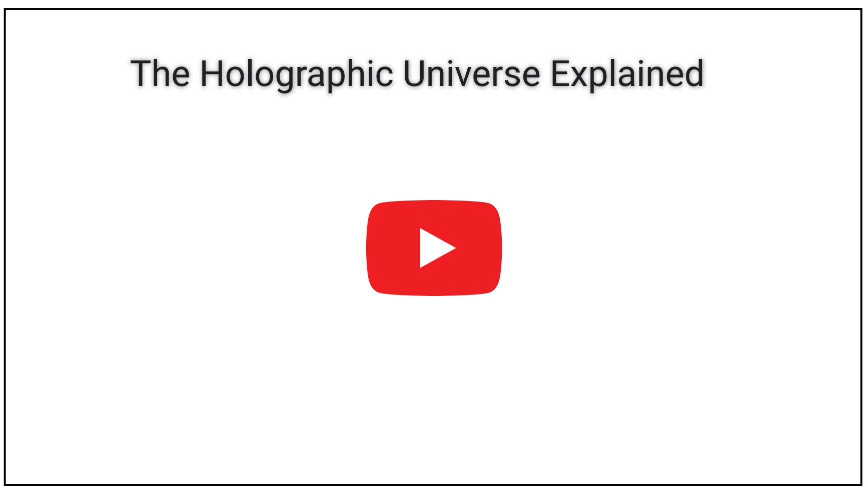
Black Holes & Singularities:

The traditional view of a black hole is a point in space with a gravitational pull so strong nothing, not even light, can escape it:

Spacetime black hole: 1

Black holes have been the crux of cosmological investigation for decades. Their elusive properties give clues to a deeper understanding of our universe. One such clue is the similarity between a black hole's and the big bang's singularity:

Another compelling clue, which we can utilize in relating black holes to homogeneous coordinates, is Dr. Leonard Susskind's string theory derivation of the holographic principle:



Perhaps we can construct a model that matches these observations. Let's gain inspiration from the holographic principle and imagine a black hole not as something that acts on spacetime but as a projector projecting an image on an infinite surface. We will assume that we are inside a higher-dimensional black hole, as there is prior literature by Dr. Niayesh Afshordi and colleagues and another paper by Dr. Jose B. Almeida to support this view. This black hole exists in the **4D+1** layer above us, projecting a **4D** spatial image of a **10D** form of energy on a **3D** surface in the **3D+1** layer we have currently named "the universe." The question is how we would formulate a system to reflect this.

Projections of Higher-Dimensional Light:

Taking a look at the homogeneous framework we previously created, let's imagine that each layer represents a sub-universe, each with its own speed of light:

Dimensions	Speed of Light
10D	$c_{10D} = \infty$
9D + 1	$c_{9D} = ?$
8D + 1	$c_{8D} = ?$
7D + 1	$c_{7D} = ?$
6D + 1	$c_{6D} = ?$
5D + 1	$c_{5D} = ?$
4D + 1	$c_{4D} = ?$
3D + 1	$c_{3D} = 3e8\ m/s$

The speeds of light

Since the **10D** layer exists outside of any time projection, I'm going to posit that it cannot be measured directly in any meaningful manner and set its light speed to infinity. However, all other layers are projections like our layer, can be measured, and are reachable by our faculties and instruments.

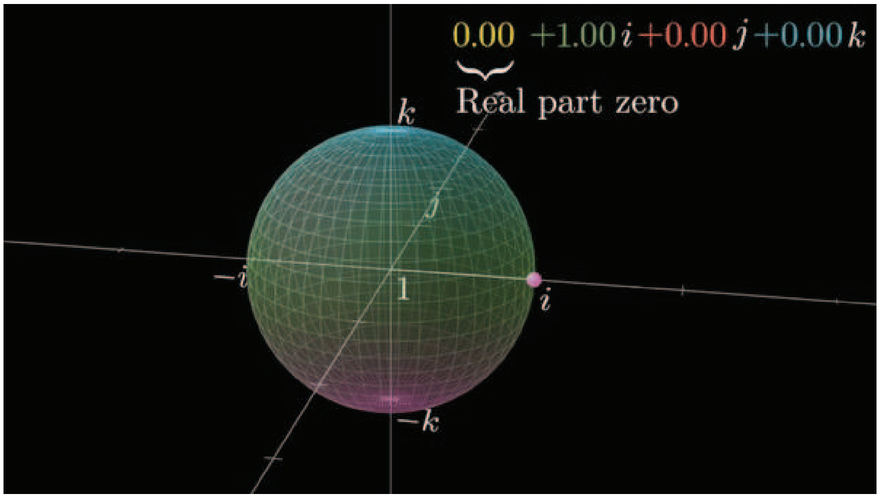
Figuring out the relationship between the layers of light speeds is a complex problem, so let's simplify it to two layers and assume that the "true constant speed" of light is the layer above us in the **4D+1** special relativity land. At some point in the ancient past, a **4D+1** star imploded into a black hole, creating our **3D+1** sub-universe. This would make our speed of light a function of the projected **4D+1** light coming into our **3D+1** layer:

Dimensions	Speed of Light
4D + 1	$c_{4D} = 1\ m/s^*$
3D + 1	$c_{3D} = f(c_{4D})$

1 m/s seems reasonable

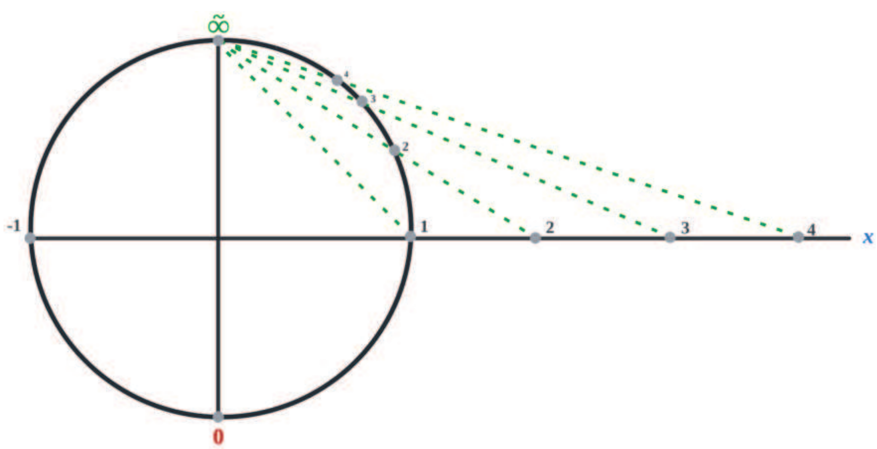
What we want to accomplish is to understand the relationship between a higher-dimensional black hole under the constraints of special relativity and its projective surface. This will reveal how maintaining the **4D+1** speed of light affects the projection of it in this **3D+1** layer.

Fixing the higher-dimensional speed of light to ***1 m/s*** will allow us to uncover how the core of this system operates. A form of projection that is relevant to this higher-dimensional black hole problem is stereographic projection. This is the same type of projection that describes the encoding of a **4D** quaternion in **3D** space. A resource that helps visualize this is Grant Sanderson's intuitive lesson on quaternion geometry:



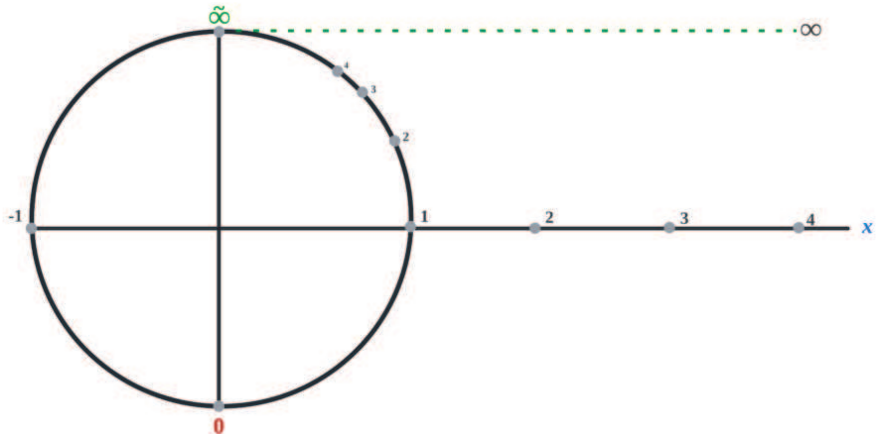
3-sphere stereographic surface projection in 3D Euclidean space: 1

We're looking for a tool that will allow us to encode an infinite surface embedded in a higher-dimensional space while also utilizing stereographic projection. A superb candidate for this task is Wheel Theory (which, in reality, is a disguised **1D** version of a Reimann Sphere). A wheel is an algebraic structure in which division by any element is possible. To perform this division, we first create a unit circle where the north pole is a complex infinity, and the south pole is zero. Then, any real number can be projected as an intersection on the circle's edge between the number line and the north pole:



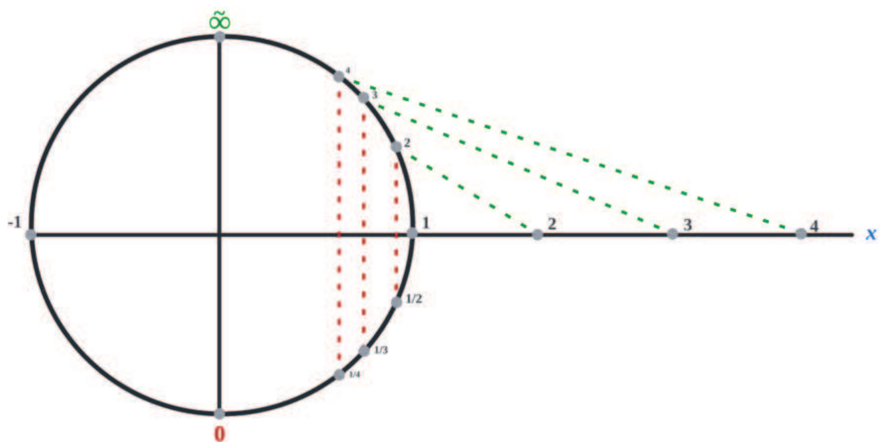
Projections on the wheel edge

Note that the line that crosses the complex infinity at the top is parallel to the *x-axis*:



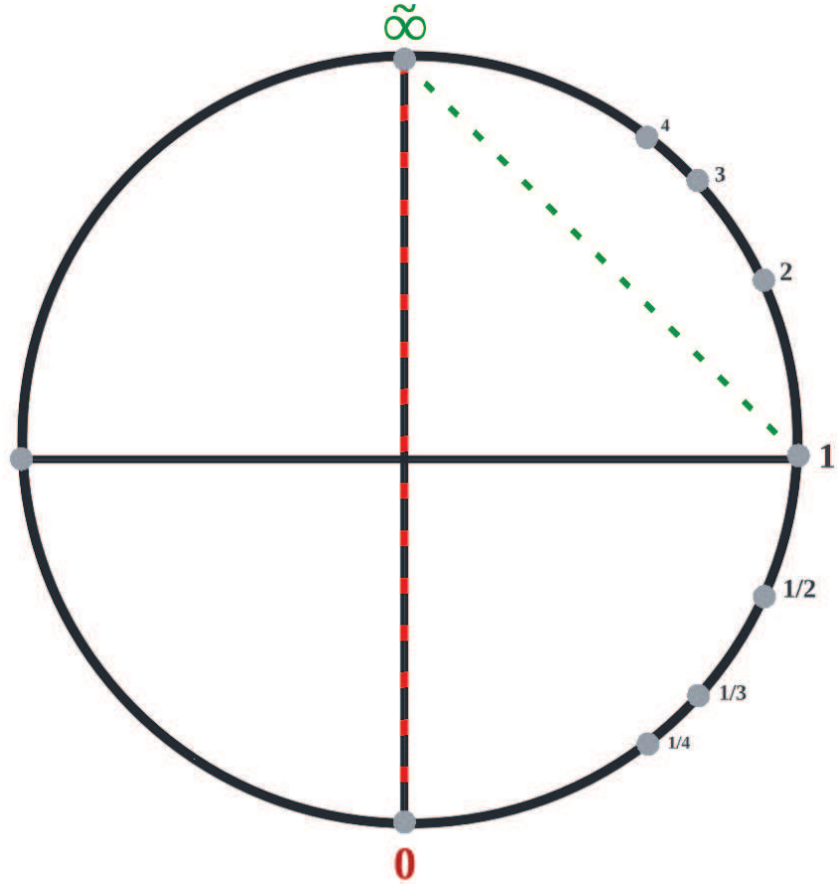
The parallel line of infinity

Division (as a reciprocal) is defined by a reflection about the *x-axis* on the unit circle:



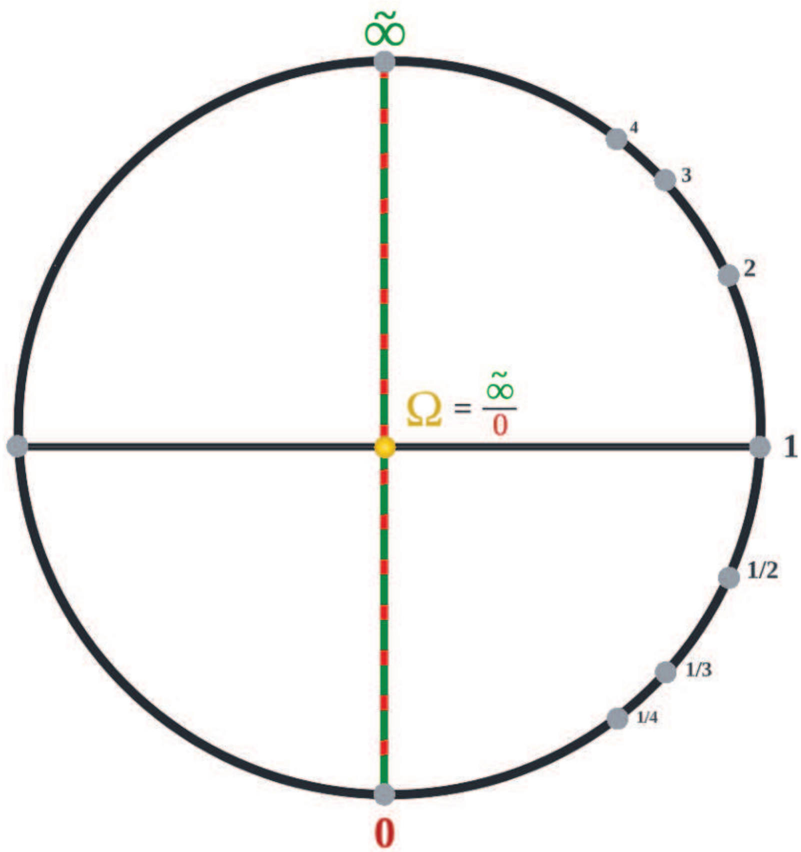
Division by reflection about the x-axis

By reinventing the wheel, we now have a structure where dividing by a complex infinity or zero is defined. All we have to do is project the number **1** to the north pole and reflect about the *x-axis*:



Example of 1/∞̃ = 0

A deeper dive into how wheel theory functions can be found at this link by Bill Shillito. Not only can we divide by zero, but we can also divide the complex infinity by zero which results in the center point of the unit circle, known as the *nullity*:



The indeterminate nullity point

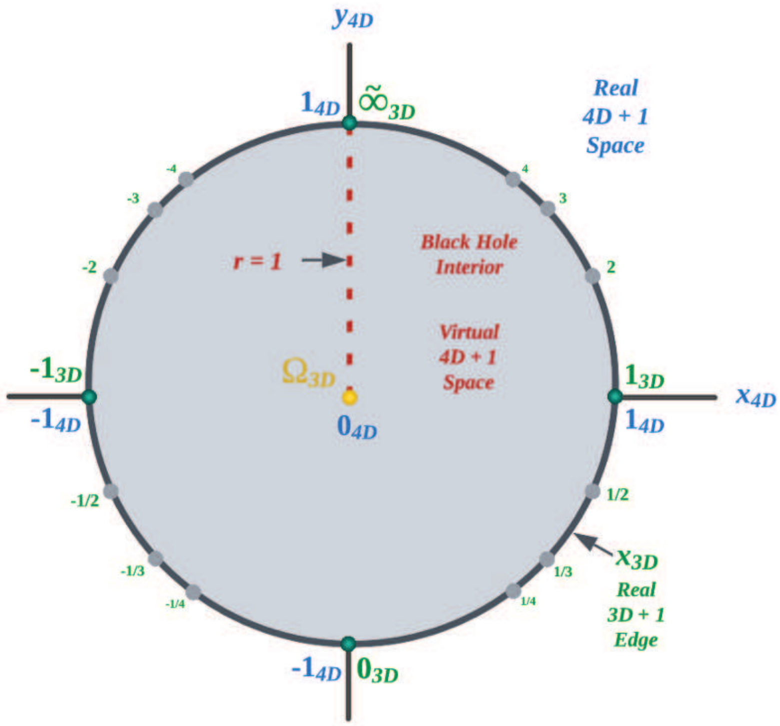
The nullity does not operate as a useable term, and any operation applied to the nullity results in nullity. We can probably think of at least one other entity that is similar to the nullity point:

Nullity	NaN
$\Omega + x = \Omega$	$\text{NaN} + x = \text{NaN}$
$\Omega \cdot x = \Omega$	$\text{NaN} \cdot x = \text{NaN}$
$0 / 0 = \Omega$	$0 / 0 = \text{NaN}$
$\infty \cdot 0 = \Omega$	$\infty \cdot 0 = \text{NaN}$

Calculators know the nullity as "Err: Domain"

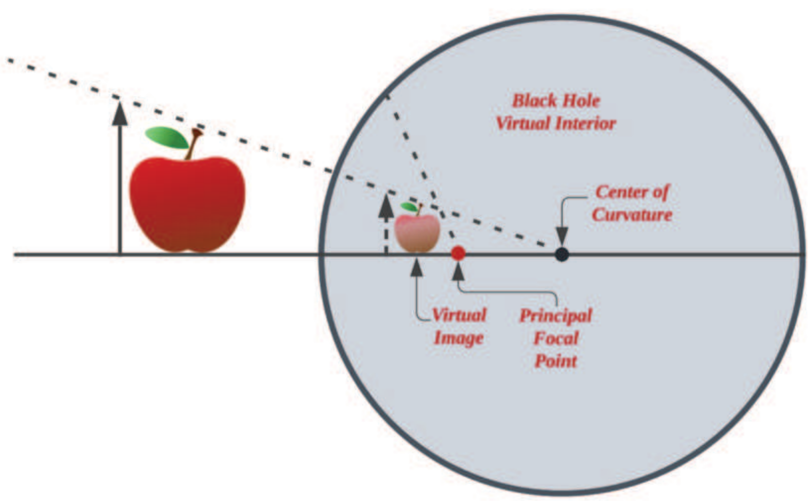
Perfect, we have a unit circle in which a complex infinity, zero, and "error, not defined" is defined.

Translating this model to represent the black hole we are in, the radius of the black hole will be defined as the radius ***r*** of the wheel. Since the black hole collapses a dimension from the upper **4D+1** layer, there **is no actual interior inside the wheel/black hole.** All that exists is the infinite edge which represents the **3D+1** universe:



The 4D+1 to 3D+1 projective black hole

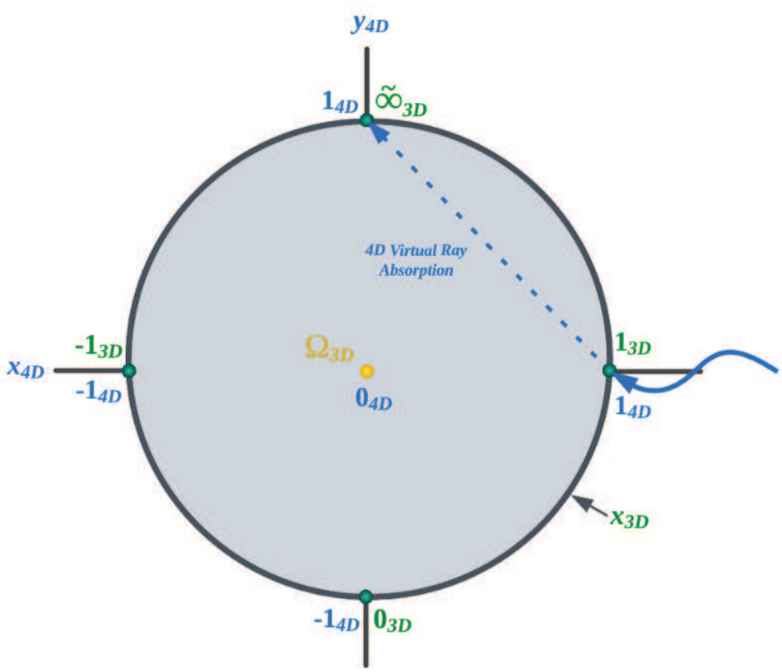
The manner in which we can reason about the bulk of the black hole is similar to how we reason about virtual images in a convex mirror. It would appear as though the light ray has traveled into the black hole, but in reality, it interacts **only** on the real surface, and its faint reflection creates the appearance of interior travel:



The black mirror: 1

The truth is that black holes do not seem to operate as mirrors on the macroscopic level. However, from this paper by Dr. Andrew N. Jordan's group, there may be motivation to interpret a black hole as a superconducting surface that facilitates Andreev reflections forming cooper pairs. This pairing property has also been recently explored for photons interacting with superconductors in this paper by Dr. Ado Jorio and colleagues. All the thought experiments in this section involve a single photon, so I will continue with the slightly correct but *currently* incorrect mirror analogy.

A physical definition of black hole light interactions is required to complete this model transfer. We will stipulate that any real **4D+1** light touching the black hole's event horizon becomes a *virtual* **4D+1** ray that is projected infinitely far away:



Black hole light capture

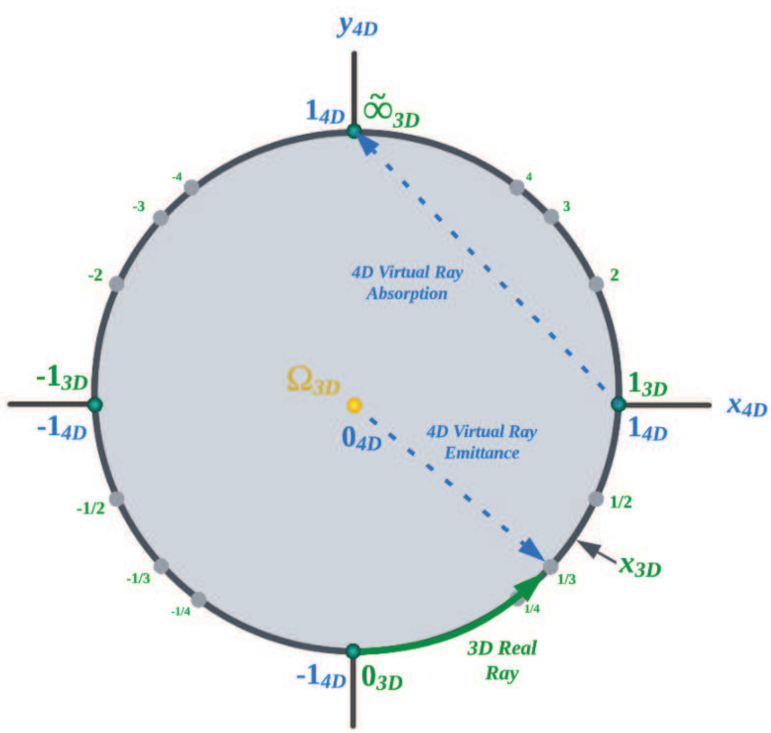
Once at the infinite point, the virtual light ray is emitted from the black hole's singularity and projected on the real **3D+1** surface. To find the singularity point, we can ask a simple question. Where did all the light originate from in this universe? From a central, undefinable point, correct?

What is a singularity other than:

- A point of infinite density, where mass is compressed into zero volume.
- A point in which none of our physics has any real definition.
- A point in which all paths going back in time inevitably leads to.

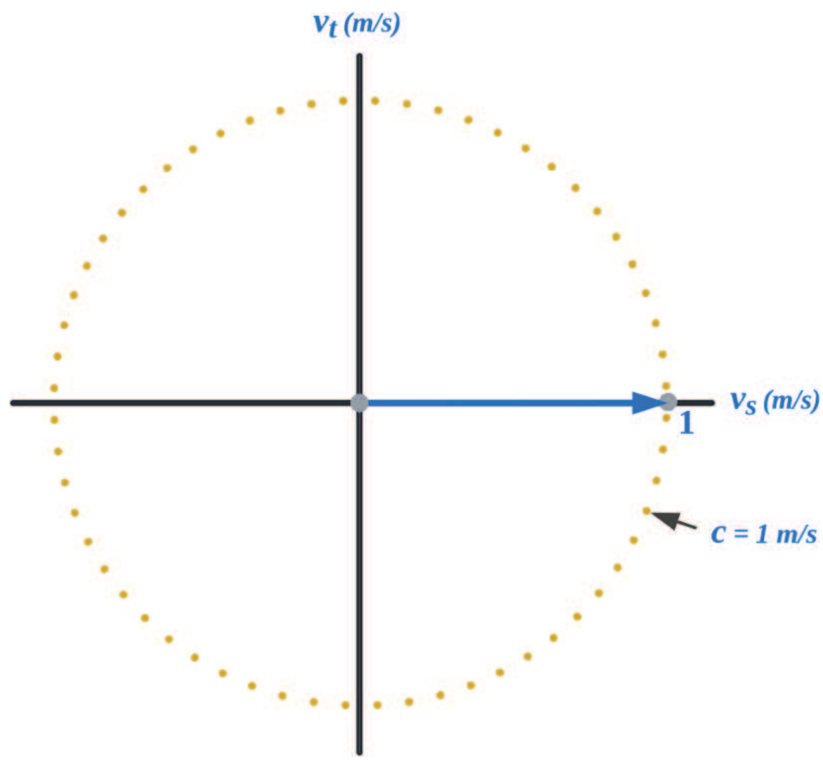
This, to me, is functionally equivalent to the nullity found at the center of the wheel. It is at this point that virtual 4D light rays are emitted.

Let's draw a virtual **4D+1** light ray emanating from that point to the real **3D+1** surface. The arc from **0** on the **3D+1** shell to where the **4D+1** virtual ray is pointing is the **3D+1** projection of that ray:



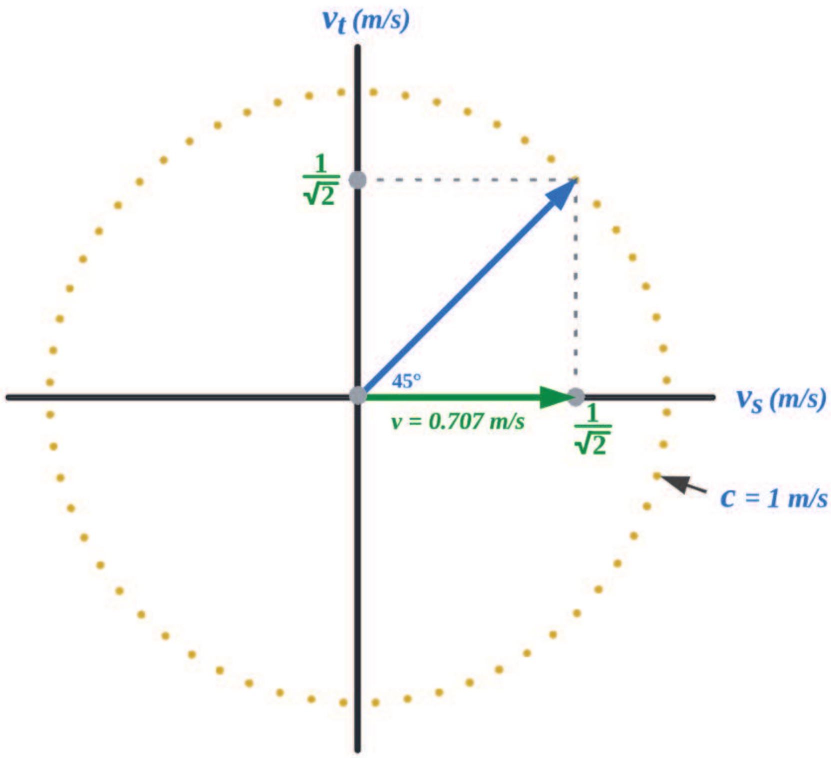
The Black Hole Projection Model

The next step is to create a spacetime velocity diagram that conforms to special relativity. This is not a typical spacetime diagram where the *y-axis* is ***ct*** denoting *meters*; instead, we want to focus on the tradeoff between temporal and spatial velocity (*meters/second*) with respect to the speed of light. We will represent the *y-axis* as the velocity of time v_t and the *x-axis* as the velocity of space v_s. A photon moving through this diagram will give **100%** of its velocity to space and **0%** to time:



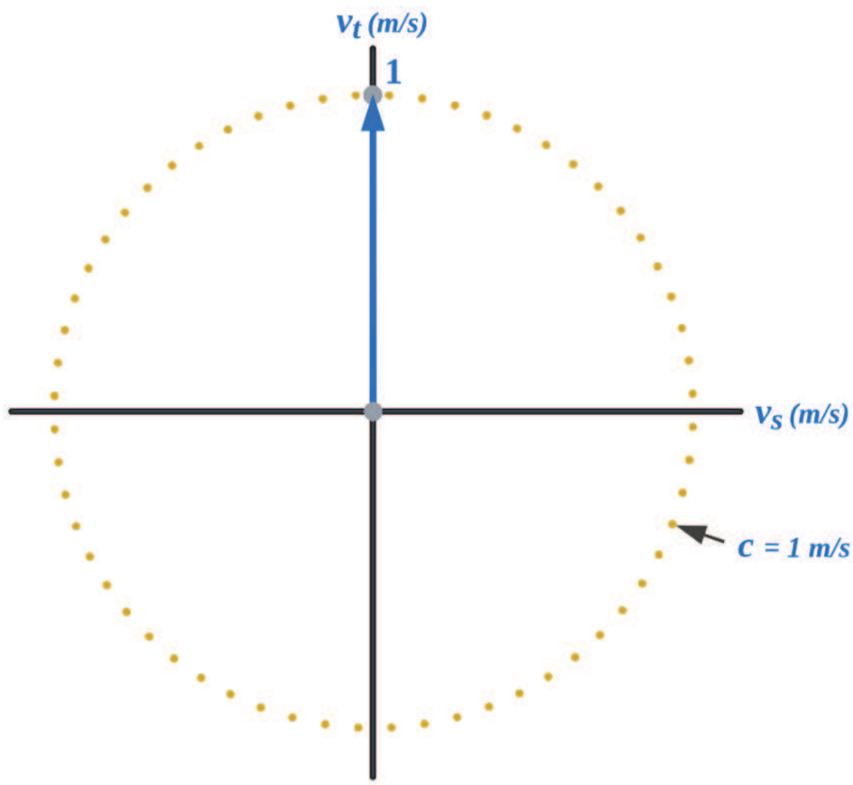
A photon's velocity through our hypothetical 4D+1 spacetime

From a photon's perspective, time is frozen in the diagram above. The next scenario is an object moving at ***0.707c,*** which will contribute equal velocities to space and time:



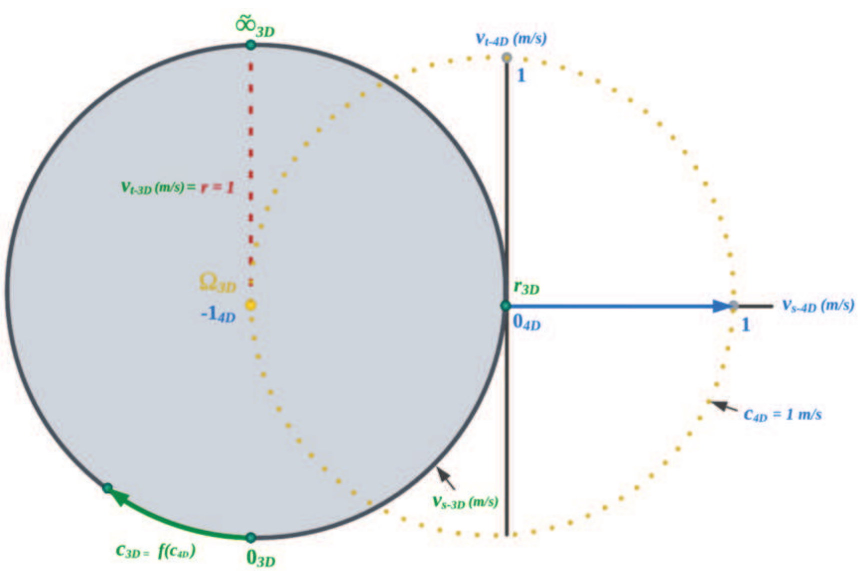
An object moving at 0.707c gives equal velocity to time and space

For the rest of us, we exist near rest relative to the speed of light, and the majority of our light-speed contribution is sent to the time axis:



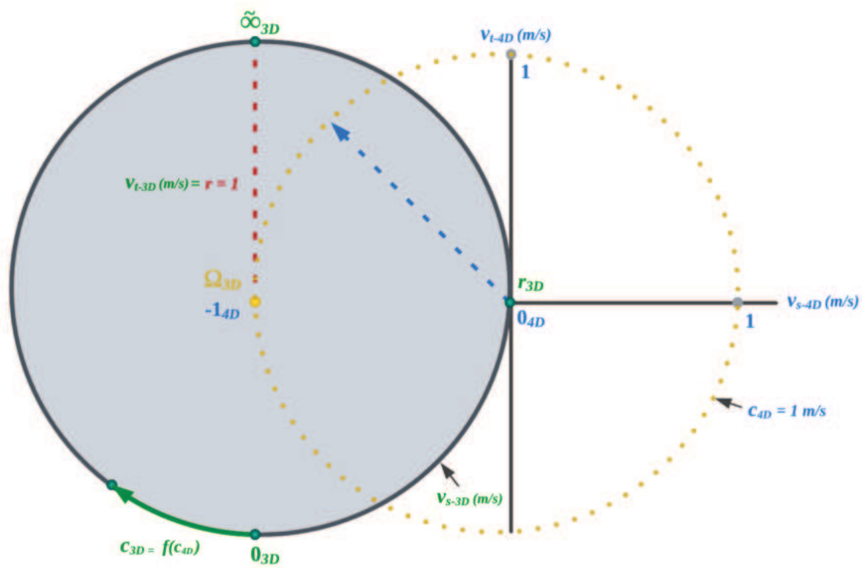
Mostly everything you interact with is around here

Let's combine this **2D** special relativity plane of the **4D+1** layer with the **1D** black hole's projective-wheel edge of our **3D+1** layer:



The 3D+1 projective black hole in a 4D+1 spacetime

We will center the graph on the **4D+1** special relativity coordinate frame and place the black hole projection to the left of the origin. Exploring what happens when we try to project the virtual speed of **4D+1** light into the black hole, we find:



The 4D speed of light cannot reach the infinite projection point

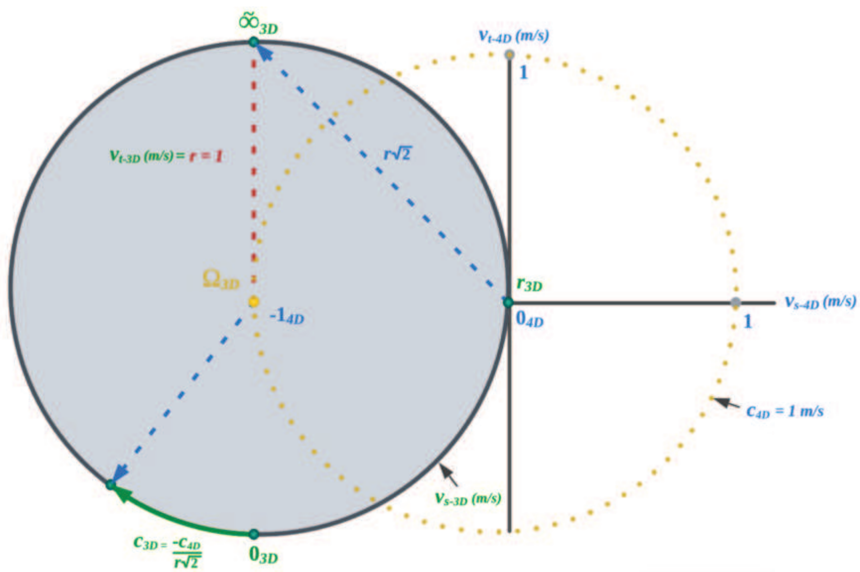
There are several intriguing notes from this image:

1. We cannot project a virtual photon to the complex infinity without inducing a time component, and thus some form of virtual mass.
2. The point at infinity is unreachable without the ability to scale the virtual **4D+1** speed of light.

We cannot violate special relativity and allow the virtual projection to exceed the **4D+1** speed of light without a tradeoff. What if we allow the absorbed virtual photon to go above the **4D+1** light speed; however, for the emitted virtual ray, we divide the external **4D+1** light speed by the excess absorption speed (hypotenuse) to balance out and preserve special relativity globally:

$$c_3 = \left| \frac{-c_4}{r\sqrt{2}} \right|$$

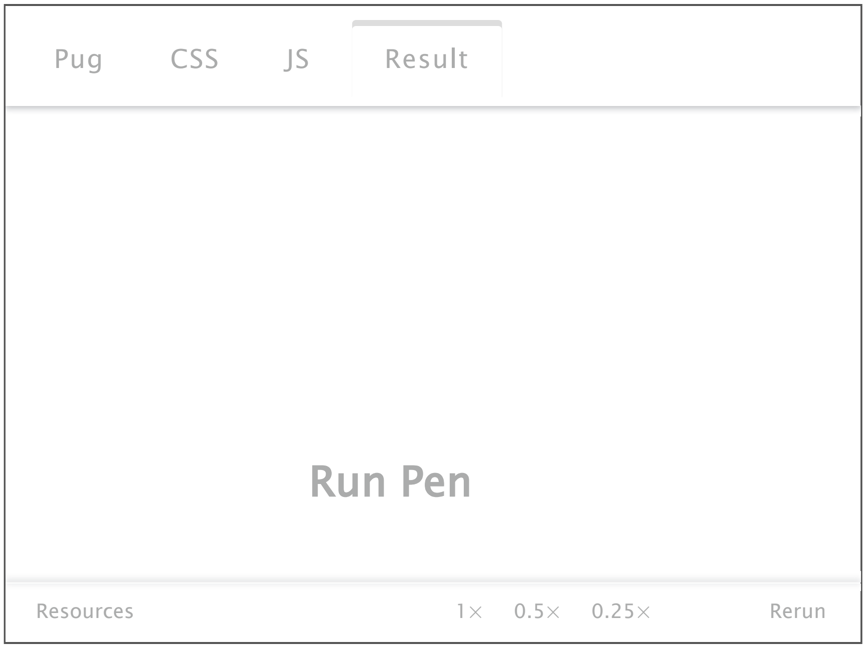
$$c_3 = \frac{c_4}{r \cdot \sqrt{2}}$$



The Projective Spacetime Diagram

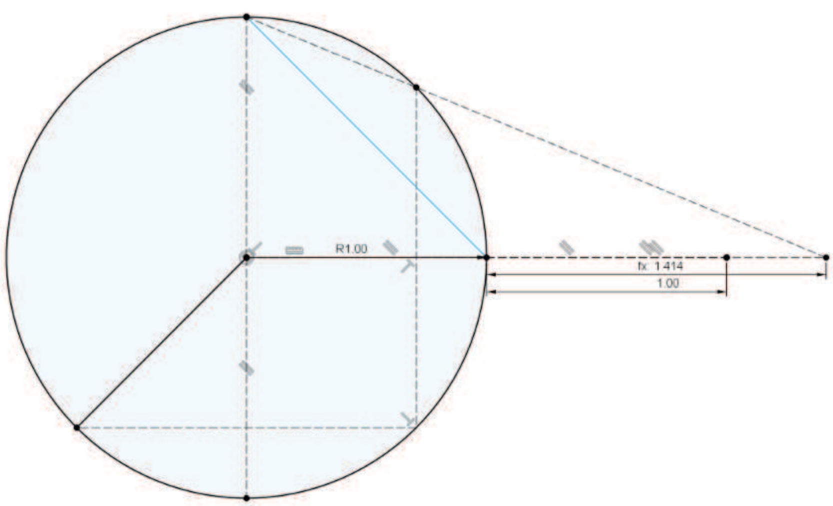
The negative sign in the numerator denotes that the virtual ray is pointing opposite to the original direction of the **4D+1** light. In the lower **3D+1** space, there may be no measurable way to tell that the speed is inverted, so the absolute value is what we would perceive.

We notice that the **3D+1** speed of light is inversely proportional to the size of the black hole's radius. As the black hole decreases in size in the higher-dimensional space, we would perceive an increase in light speed:



3D+1 projective speed in a 4D+1 spacetime: 1

Geometrically, we can find the **3D+1** point by taking the length of the infinite **4D+1** virtual projection (hypotenuse) and dividing it by the **4D+1** speed of light. This scaled length is then aligned with the *x-axis* and reprojected back onto the black hole's edge. Finally, we reflect the black-hole-intersection point about the *x* & *y-axis* of the circle. That's quite a bit to keep track of, so I created a CAD drawing with the relationships configured:



Geometric 4D+1 to 3D+1 light projection diagram: 1

By adjusting the radius of the black hole and the external speed of light, we see the virtual **4D+1** interior ray shift its position about the circle.

Running the c_3 formula we created through a spreadsheet, we will play with the numbers until we see values we are familiar with:

R	C4	C3	R*Sqrt(2)	C3*(R*Sqrt(2)) = C4
1	1	0.71	1.41	1.00
0.7071067812	1	1.00	1.00	1.00
0.5	1	1.41	0.71	1.00
0.25	1	2.83	0.35	1.00
0.005	1	141.42	0.01	1.00
0.00000000236	1	**3.00E+08**	3.34E-09	1.00
2	1	0.35	2.83	1.00
3	1	0.24	4.24	1.00
100	1	0.01	141.42	1.00
100000000	1	7.07E-09	1.41E+08	1.00

4D+1 black hole radius vs 3D+1 projected speed of light calculations: 1

If we think back to the homogeneous coordinates section, we find that spacetime velocities equate to dimensional-energy spatial distances in these models:

$$\begin{bmatrix} x/t \\ y/t \\ z/t \end{bmatrix} = \begin{matrix} m/s \\ m/s \\ m/s \end{matrix}$$

3D Euclidean
Spatial Coordinates

Velocities denote spatial distances from a photon's perspective

It is not an intuitive concept; however, we can view c_4 as equalling **1** *m* of distance per unit photon. To generate a familiar $3 \cdot 10^8$ *m* for c_3, we require a black hole with a radius ***r*** of **0.00000000236** *m*.

This seems to defy all logic: external **4D+1** light is essentially frozen on what could be a grain of **4D+1** quantum sand. Such is theoretical physics: one moment you think you're onto something, and the next, it becomes completely absurd.

In fact, that size is so tiny it begins to approach the plank scale. Here's an interesting thought: let's imagine that we are on the right track and that the higher-dimensional black hole **is** plank sized (or at least correlated in some manner to a plank length) from the exterior. Then, we could define our higher-dimensional black hole using a reconfigured Schwarzschild radius to solve for c_4, our external escape-velocity speed:

$$r_s = \frac{}{c_4^2}$$

$$c_4^2 = \frac{2GM}{r_s}$$

$$c_4 = \sqrt{\frac{2GM}{r_s}}$$

If we truly believe that the higher-dimensional black hole radius is plank sized and that it is governed by an external c_4, then we should be able to input plank units and solve for our own speed of light c_3:

$$c_4 = \sqrt{\frac{2GM}{r_s}} = \sqrt{\frac{2G\sqrt{\frac{\hbar c}{G}}}{\sqrt{\frac{\hbar G}{c^3}}}}$$

$$= \sqrt{2G\frac{\sqrt{\hbar}\sqrt{c}}{\sqrt{G}} \cdot \frac{\sqrt{c^3}}{\sqrt{\hbar}\sqrt{G}}} = \sqrt{2G\frac{\sqrt{\hbar}\sqrt{c}\,c\sqrt{c}}{\sqrt{G}\sqrt{\hbar}\sqrt{G}}}$$

$$= \sqrt{2G\frac{c^2}{G}} = \sqrt{2c^2} = c_3\sqrt{2}$$

$$c_3 = \frac{c_4}{}$$

Well, this is unexpected. We've created an equation almost identical to our projective spacetime derivation through a completely different method. If we take the implicit radius in this plank formulation to be **1**, then it is identical.

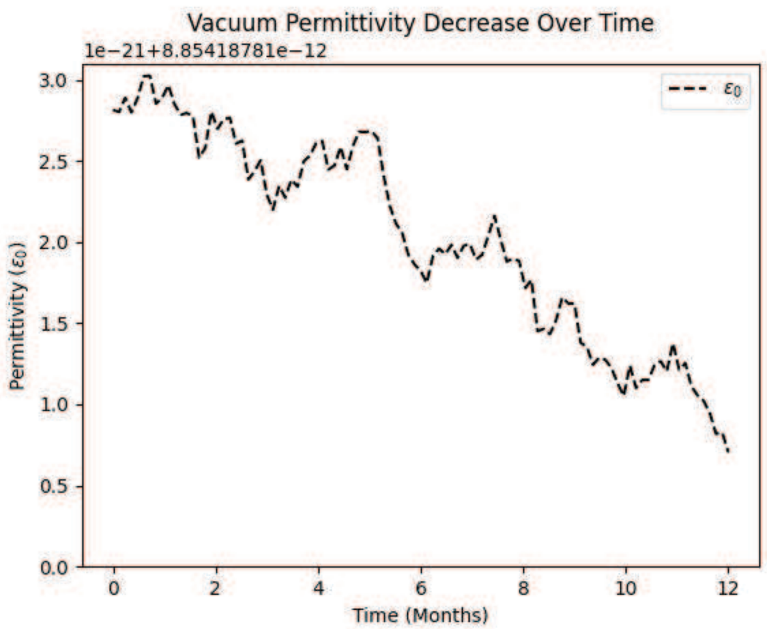
Empirical Test of Projected Light:

If we do exist in a **4D+1** black hole, then most likely, that black hole is releasing energy through relativistic quantum effects theorized by Hawking radiation. If that is the case, the **4D+1** black hole is shrinking over time. If the exterior radius is shrinking, then the projected speed of light on the **3D+1** surface is, by definition, increasing. There must be a method by which we can test if this is truly the case.

Here's my experiment proposal inspired by this paper from a lesser-known scientist, Morton F. Spears. His works give an alternative perspective of the cause of gravity and dark matter, one I find rather intriguing in concept. We know that the speed of light in a vacuum is related to permittivity, the interaction of a material by an external electric field, and permeability, the interaction of a material by an external magnetic field, through this relationship:

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

Select either of the two properties to measure. I recommend measuring the vacuum permittivity, **ε_0,** as dielectric capacitance sounds simpler to implement and verify. Fix the other variables to their currently accepted constant values to take a snapshot in time. Pull a maximally sensitive vacuum and measure the vacuum permittivity for half a year to a year. You should notice a drop at a rate of approximately **~1 part per 13–15 billion** (an almost imperceptible rate of change) in correlation to the period of a year and the approximate age of the universe. Note that the changing value of *c* may affect the anticipated ratio of the rate of change. Regardless, there should be a **clear**, **statistically significant** drop in the measured vacuum permittivity over time:



Sample graph of ∈0 decreasing over a year

Which would then correlate to an increasing value of *c*.

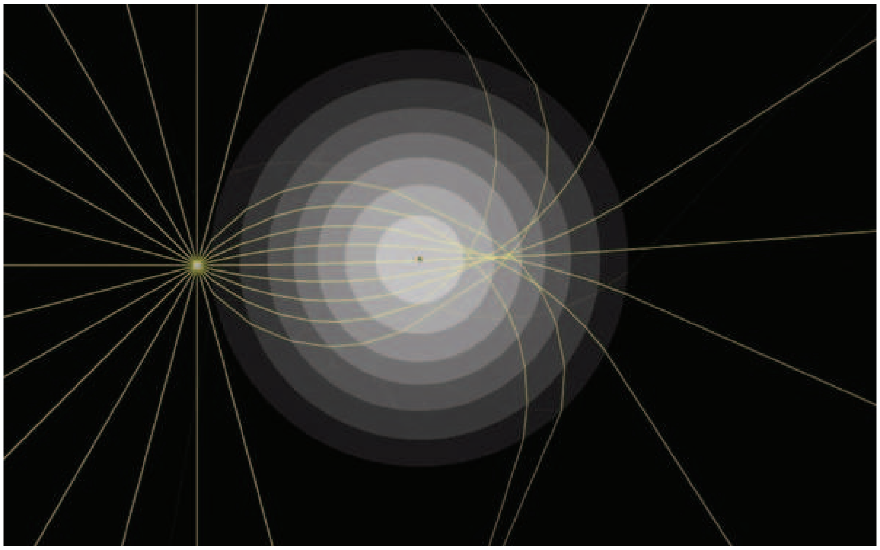
The Reflections of 10D Reality:

We haven't covered the **5D+1** to **9D+1** layers and their respective higher-dimensional black holes. This will have to await someone who is more sophisticated in their mathematical techniques, but generally speaking, the speed of light for each sublayer will be a function of the higher-dimensional light speed and the radius of the black hole it resides in:

Dimensions	Speed of Light
10D	$c_{10D} = \infty$
9D + 1	$c_{9D} = f(c_{10D}, r_{10D})$
8D + 1	$c_{8D} = f(c_{9D}, r_{9D})$
7D + 1	$c_{7D} = f(c_{8D}, r_{8D})$
6D + 1	$c_{6D} = f(c_{7D}, r_{7D})$
5D + 1	$c_{5D} = f(c_{6D}, r_{6D})$
4D + 1	$c_{4D} = f(c_{5D}, r_{5D})$
3D + 1	$c_{3D} = f(c_{4D}, r_{4D})$ $= 3e8\ m/s$

Functions of the speeds of light

The local changes of light speed in each layer may be insignificant enough to where it appears constant to a microscopic observer. A simple way to begin visualizing layered light projections is to create seven spherical lenses stacked on top of each other, then place a point light source just inside of the outermost shell. You can control the reflected patterns of the inner layers by changing the number of rays being projected from the outermost layer:



Layered Ray Optics Simulation: 1

I included the *.json file* of the simulation above in the appendix if you wish to try it on your own.

While researching spherical reflections, I discovered a video by Dr. James Orgill that includes almost everything required to conceptually understand how black holes and singularities operate in perfect spherical mirrors. If you pause and pay attention closely, you may notice some fascinating occurrences:

In the next section, we will apply knowledge from computer vision to the projection framework we created to define the layered interactions in an alternative manner.

. . .

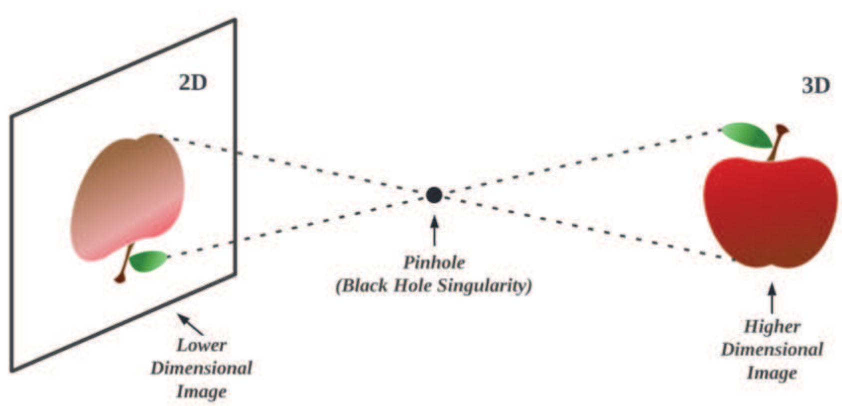
6. Camera Obscura

Overview

This section will delve further into the idea of a plank-sized black hole and how it manifests as a pinhole projection. From the pinhole projection model, we will derive the intrinsic camera properties required to facilitate a **4D** object on a **3D** screen. Then we will review the models we have created thus far to infer supplemental contextual meaning.

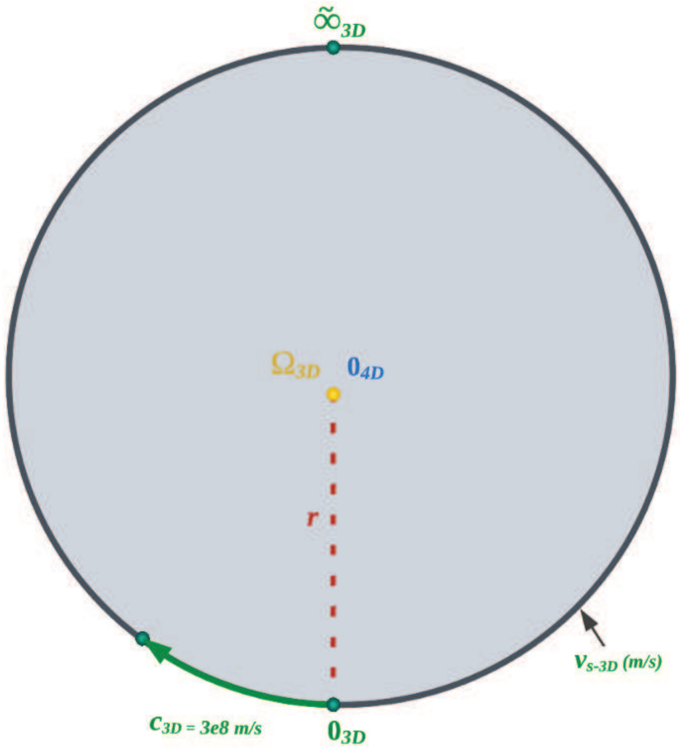
Black Pinholes—The Universal Dimension Reducer

I know precisely what you're thinking at this moment, "Husam, that black hole projection from the last section reminds me of a camera obscura. Higher-dimensional light is compressed through a pinhole and projects on a maximally distant surface." This is a great observation; an external (**4D+1** to **3D+1**) black hole singularity can, in essence, be modeled as a pinhole camera:



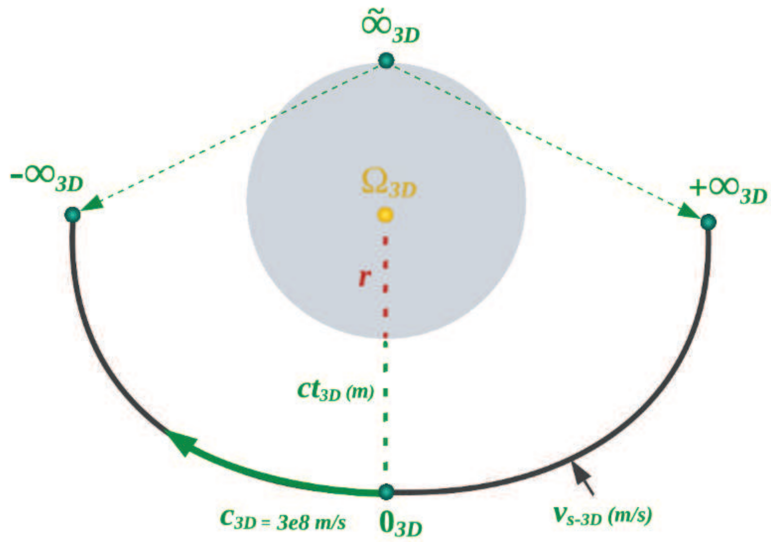
Singularity pinhole projector: 1

The way I imagine facilitating the conversion between the projective black hole diagram we created in the last section into a pinhole camera is as follows. First, we strip our projective black hole down to the bare minimum:

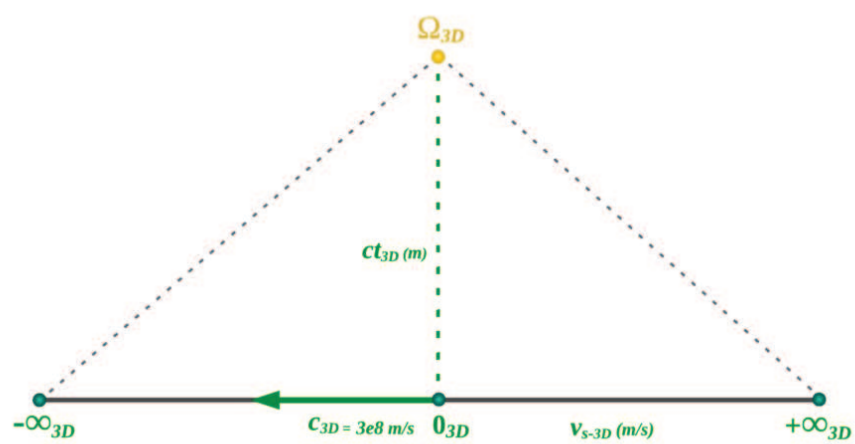


Bare minimum projective black hole model

The next step is to make a surgical cut at the top complex infinity point and begin flattening the projective edge into an infinite line. By doing this step, we are also shrinking (through stereographic projection) the **4D+1** black hole virtual space into the singularity point at the center while creating a projection distance equal to the age of the universe:

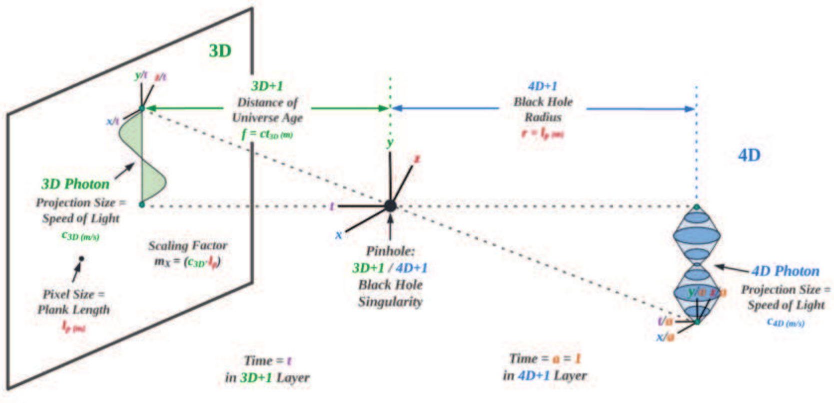


Cut at the top and flatten out the projective edge



Returning to a homogeneous coordinate frame

We will map this diagram as a homogeneous transform between **4D** camera Euclidian coordinates (***x/a, y/a, z/a, t/a***) and **3D** image Euclidean coordinates (***x/t, y/t, z/t***) through a singularity-sized pinhole. The focal length ***f*** is the distance passed since the initial singularity point, the screen's pixel size is the plank length l_p, the projection size is the speed of light ***c***, and the scaling factor is m_x:



The Singularity Pinhole Camera Model

Deriving only the intrinsic matrix required for this projection, we arrive at this formulation for a **4D** object to a **3D** image in **4D** camera coordinates:

$$= c_3 \begin{bmatrix} y \\ z \\ t \end{bmatrix} = \begin{bmatrix} 0 & f_y \cdot m_y & 0 & 0 & 0 \\ 0 & 0 & f_z \cdot m_z & 0 & 0 \\ 0 & 0 & 0 & r_4 & 0 \end{bmatrix}$$

$$\begin{bmatrix} f_x(c_{3x} \cdot l_p) & 0 & 0 & 0 & 0 \\ 0 & f_y(c_{3y} \cdot l_p) & 0 & 0 & 0 \\ 0 & 0 & f_z(c_{3z} \cdot l_p) & 0 & 0 \\ 0 & 0 & 0 & l_p & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ t \\ a \end{bmatrix}$$

If we plug in today's values (assuming they are correct) for the plank length, the age of the universe in meters, and the speed of light, the result is relatively close to our previous geometric and Schwarzschild escape velocity calculations:

$$c_3 = f(c_3 \cdot l_p)c_4$$

$$= 13.7 \cdot 10^9 \ y = 4.3 \cdot 10^{17} \ s \ (3 \cdot 10^8 m/s) = 1.3 \cdot 10^{26}$$

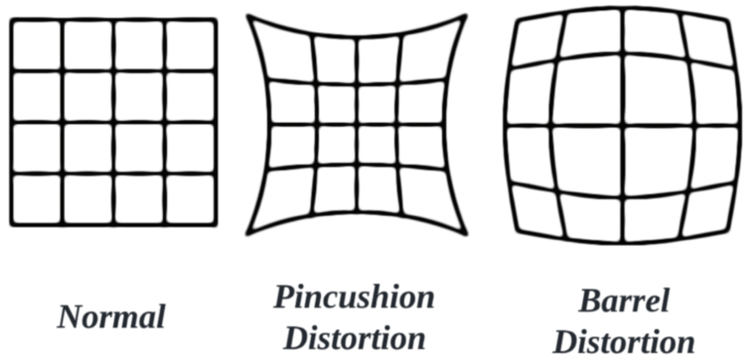
$$c_3 = 1.3 \cdot 10^{26}(3 \cdot 10^8 \cdot 1.6 \cdot 10^{-35})c_4$$

$$c_3 = 0.624 \cdot c_4$$

To create the full multi-layered equation for all ten dimensions, we have to take into account the intrinsic matrices from every layer:

$$\begin{bmatrix} \\ 4 \ X \ 5 \\ \\ \end{bmatrix} \begin{bmatrix} \\ 5 \ X \ 6 \\ \\ \end{bmatrix} \begin{bmatrix} \\ 6 \ X \ 7 \\ \\ \end{bmatrix} \begin{bmatrix} \\ 7 \ X \ 8 \\ \\ \end{bmatrix} \begin{bmatrix} \\ 8 \ X \ 9 \\ \\ \end{bmatrix} \begin{bmatrix} \\ 9 \ X \ 1 \\ \\ \end{bmatrix}$$

We also need to take into account the lens distortions that occur with time-scaled-spherical-light projections. This intuitively may explain cosmological redshift from a completely different perspective; however, finding evidence for this will require someone much brighter to create a more precise camera model:

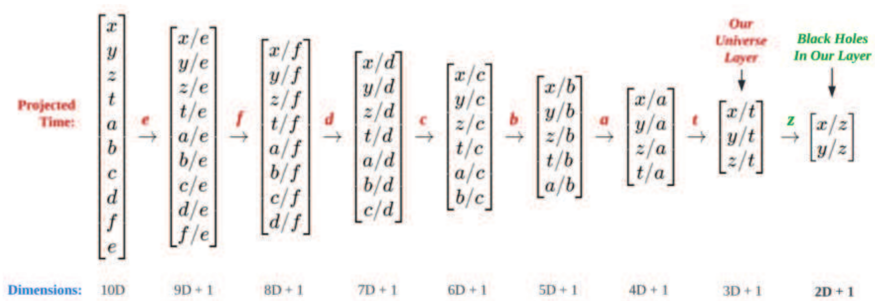


Various lens distortions: 1

The Shadows of 10D Reality

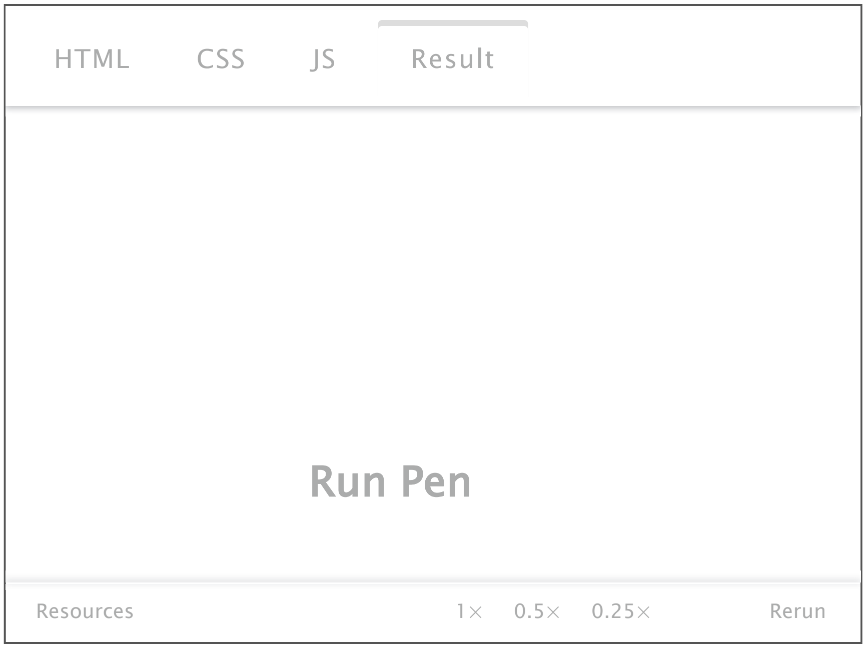
From the interconnected models we have created so far, here is what I observe.

The first observation is on the **2D+1** black holes from collapsed stars that we observe in this **3D+1** layer. Objects can never *fall* into a black hole; they flatten on the surface, lose a spatial dimension that becomes the new time projection (in this case: *z*), and gain a new "fundamental force" (which was the previous layer's time component, ***t***):



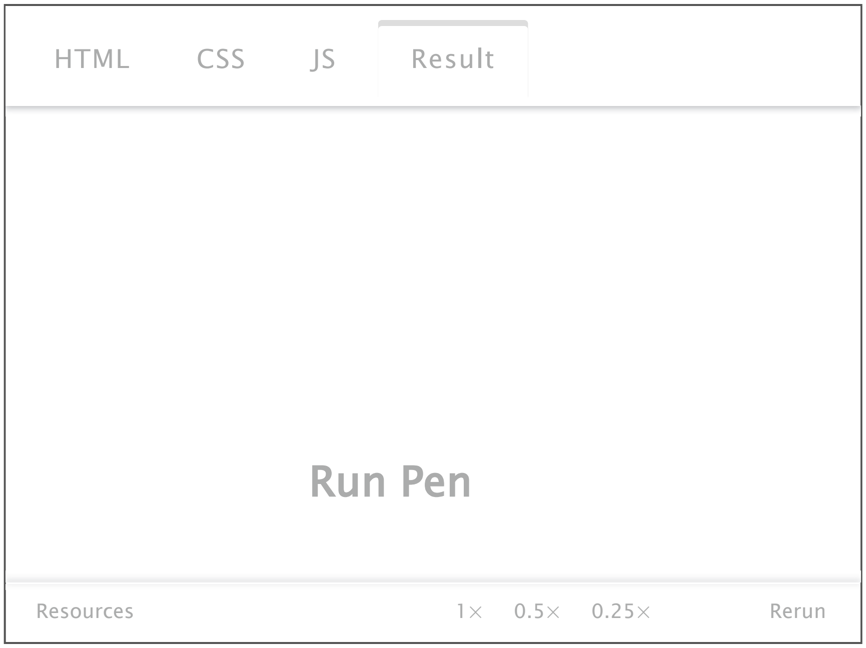
The "**z-axis**" is **z** time now. The previous time, **t**, in a black hole we see is a new…force.

Here is a visualization of this to drive this point home. Move your mouse across the screen to see the coordinates. The ***x,y*** & ***z*** **3D** coordinates we are familiar with become **2D** ***x*** & ***y*** on touching the event horizon. The new time component, which is tied to the radius of the black hole, is ***z***. The moment an object lands on the event horizon, it essentially gets teleported to a 2D Mario universe on the surface:



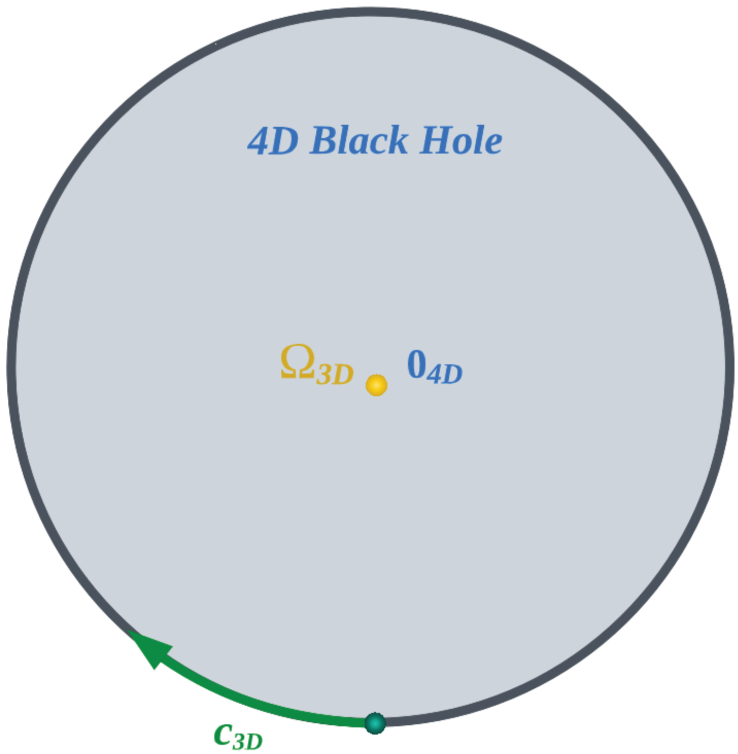
Dimension reduction: 1

Yet another way to visualize falling **on** a black hole is through this simulation. A person (made of pure energy, most likely) would feel that they are falling into a new universe as the space around them warps and bends, but in reality, they are flattening out on the surface. You can try this lovely experience by using your mouse wheel:



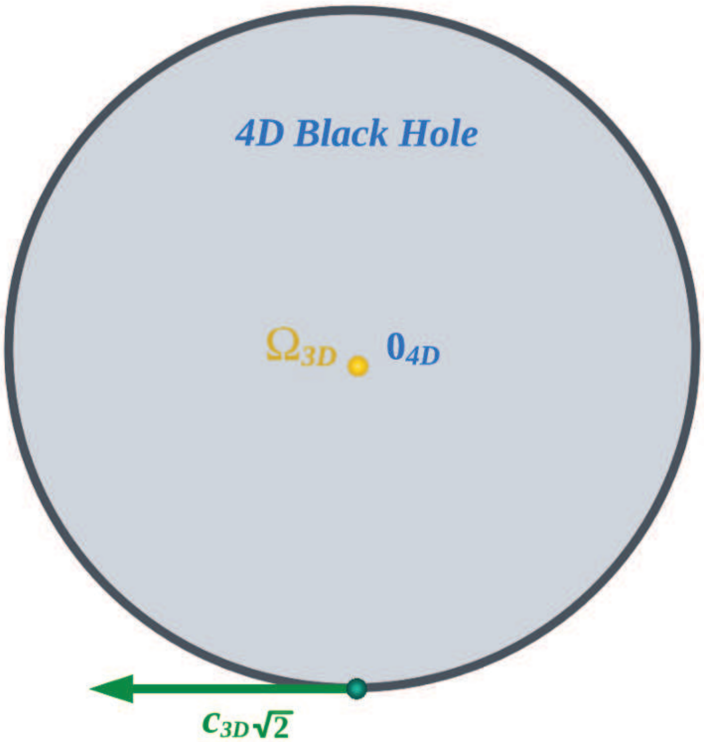
Projector 2D universe: 1

From our Schwarzschild radius interpretation, the speed of light here in **3D+1** land, c_3, acts as an orbit velocity for the **4D+1** black hole we are currently in:



Speed of light orbit velocity

Going ***sqrt(2)**** c_3 ejects you off the **3D** surface and into the **4D** space above:



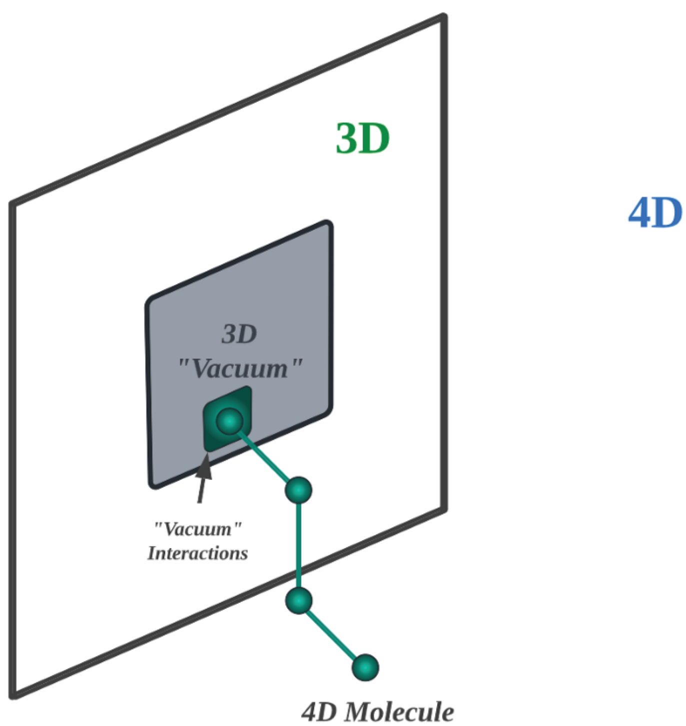
~1.41x the speed of light buys you a ticket out of the matrix

Imagining that you are a **10D** being looking from the outside, all the **black hole layers** combined would appear to be something like this:

The Jawbreaker candy had the right idea all along: 1

Note that this is a **3D** rendering of normal spheres on a **2D** screen. We do not have **10D** glasses yet, but when they are finally invented, I'll make sure to update the visualization above for precision.

One last point, I view the "vacuum" of **3D** space, in the sense that it is truly empty, as something that is not reflected in reality. If we think of our entire universe as the shell of a **4D** black hole and the **3D** speed of light here as a function of the radius of that **4D** black hole, then it only makes sense that there is a minimum energy level needed to maintain that projective radius. This minimum energy level will always appear as some sort of quantum soup in the "vacuum" of **3D** space. Geometrically, the argument I am making is that you cannot truly enclose a **3D** shape within a **4D** space in the same manner that a circle drawn on a piece of paper is exposed from the *z-axis* here:



By definition: **Not** a vacuum, **never** was empty space

In the next section, we will apply knowledge from artificial intelligence to the initial homogeneous model to define interactions at the sub-atomic level.

. . .

7. The Energy Network

Overview

This section expands on the previous homogeneous framework and draws upon the relationship between energy and information. By using tools commonly found in the study of information processing, we can advance our knowledge of the universe at the subatomic level.

Energy & Information

How much information is required to fully simulate the universe? Could a computer that exists within a universe precisely simulate the entire state of that universe?

PBS Space Time once again gives us relevant answers to these commonly asked questions:

Let’s assume there are $\mathbf{10^{180}}$ Planck cubes in the observable universe. Assuming on top of our assumption that each cube contains **1** bit of information, the Bekenstein bound can be used to determine the total Planck bits needed to encode the universe. The Bekenstein bound is the upper limit of thermodynamic entropy (and consequently informational entropy) of a finite area of space before collapsing into a black hole. Computing the spherical area of our Planck cubes, we find:

$$r \approx 10^{60}$$

$$A = 4\pi r^2, \quad A = 4\pi (10^{60})^2$$

$$A \approx 10^{120} \; bits$$

$$8 \cdot 10^{12} \; bits = 1 \; TB, \quad A \approx 1.25 \cdot 10^{107} \; TB$$

The upper limit is approximately **125** quattuortrignitillion terabytes of data before the entire known universe collapses into an opaque black hole.

A good question to ask is: why does this matter? The reason why this matter is due to how the information is encoded. Is all the data stored in a big memory bank of discrete bits as we assumed[2]? Maybe not; how quantum information is stored is through the entangled network of connections **between** quantum particles:

Quantum networks create entropy: 1

This idea of entangled networks storing information seems familiar to something I use every now and then.

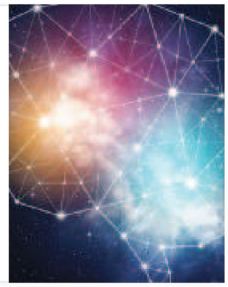
The Brain at Scale

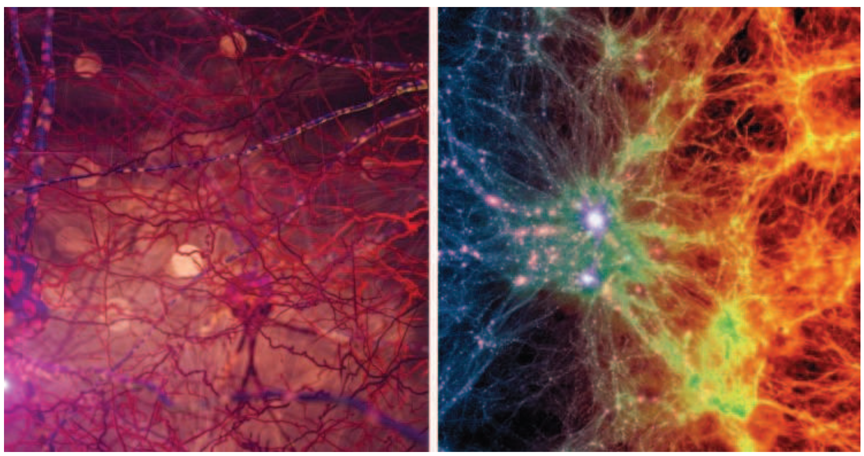
Looking at images of the large-scale structure of the universe and comparing it with sections of the human brain, Franco Vazza from the University of Bologna and neurosurgeon Alberto Feletti from the University of Verona have noticed something interesting:

The universe works like a huge human brain, discover scientists

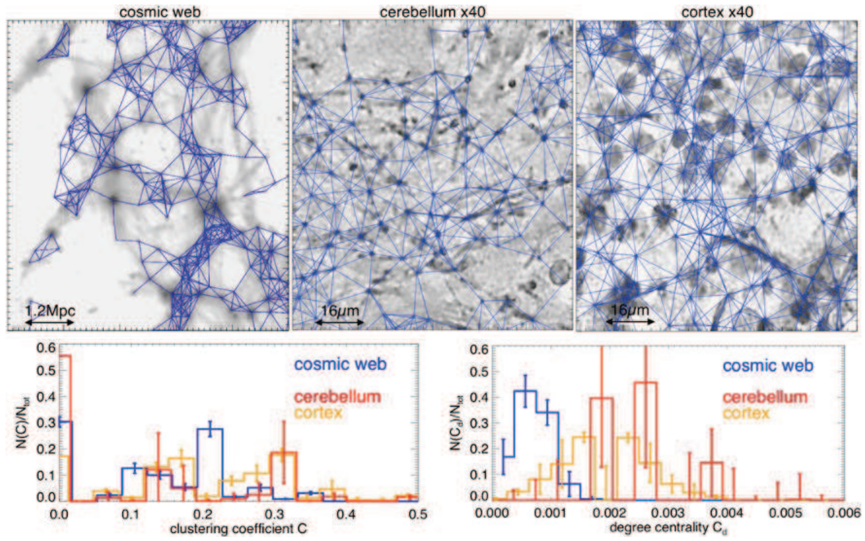
Scientists found similarities in the workings of two systems completely different in scale - the ...

bigthink.com





Neural networks vs. cosmic web: 1



Brain density vs. cosmic web: 1

They appear…similar.

According to the renowned *Husam Wadi School of Philosophy*:

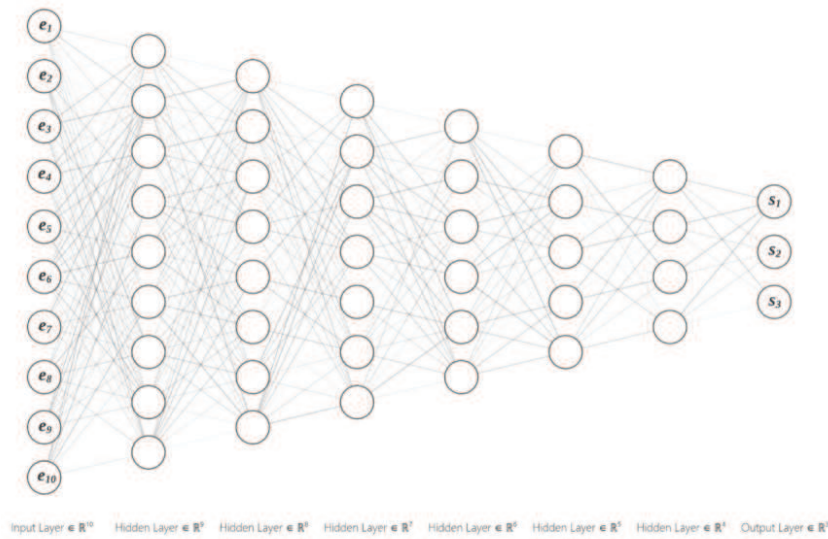
> *1. If it looks like a cat, acts like a cat, and says "meow": it's probably a cat.*

> *2. If it looks like a brain, has the density of a brain, and stores information like a brain: it's probably a brain.*

In the robotics toolkit, expansive tools exist to operate on artificial neural networks, which approximate brain activity. Perhaps we can use them to shed more light on this system.

Simple Feedforward Representation

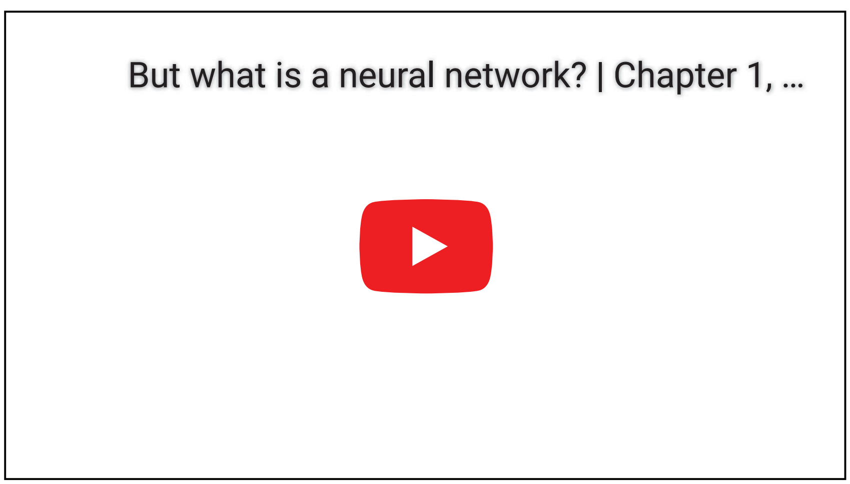
Instead of looking at this in terms of discrete spatial dimensions, what would happen if we treated this entire problem as a neural network?



The energy network: 1

There is quite a bit going on in this diagram, but essentially we are trying to filter down some **10D** form of energy into **3D** through a cascading network.

What do we know about neural networks, and how do they operate? Grant Sanderson has a steller overview of this topic, and Tensorflow has a visual neural network simulator to play with:



Tensorflow - Neural Network Playground

It's a technique for building a computer program that learns from data. It is based very loosely on ...

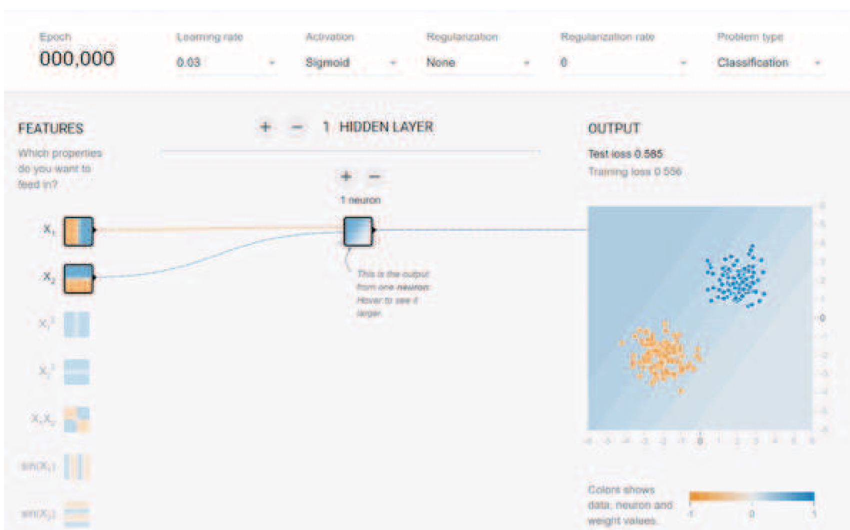
playground.tensorflow.org

From a broad overview, an Artificial Neural Network is a connectionist machine composed of perceptrons that can process information. In their raw form, these perceptrons are boundary lines that differentiate data:

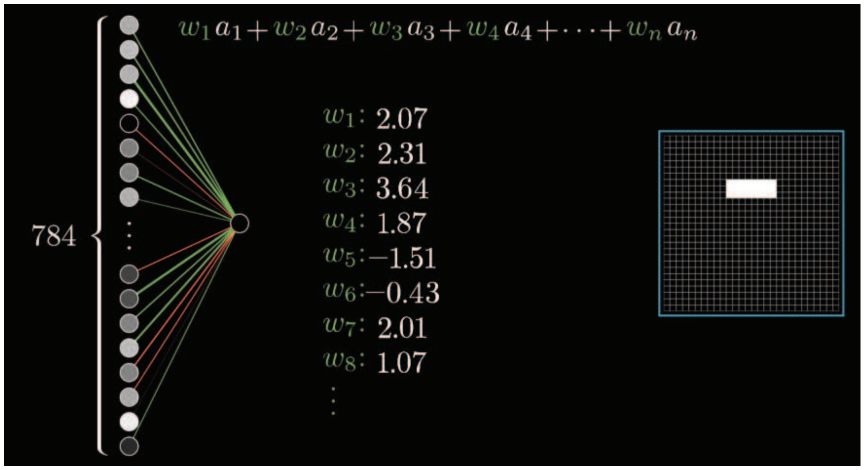
$$f(x) = \begin{cases} 1 & \text{if } \mathbf{w} \cdot \mathbf{x} + b > 0 \\ 0 & \text{otherwise} \end{cases}$$

$$\mathbf{w} \cdot \mathbf{x} = \sum_{i=1} w_i x_i$$

By stacking these boundary lines into networks and adding a non-linear activation function (such as a sigmoid curve), we can create powerful classification machines:



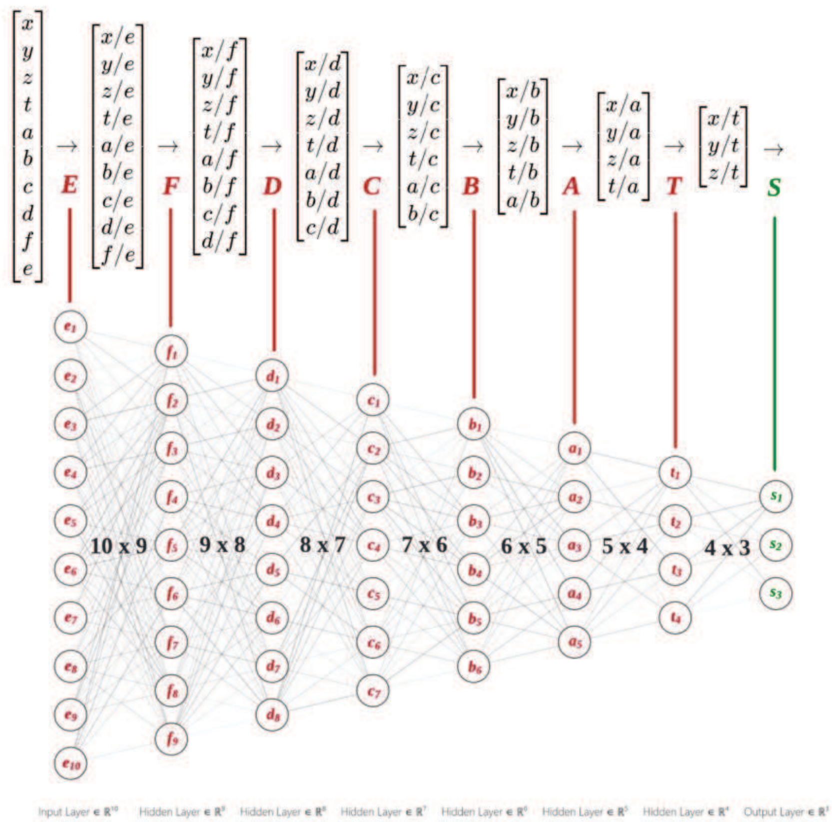
Simple multi-perceptron classifier with sigmoid activation: 1



The weight of connections determines subsequent node activation: 1

What do the connections represent in these higher-dimensional spaces? How do we think about the sum of connections for each layer?

Remember that we are switching from a spatial representation to an energy network. What this means is that we are interested in the projected energy terms between our spatial layers:



The Interconnected Model of Energy: 1

There are intriguing implications from modeling energy like this. Let's unpack them:

1. Time is a four-dimensional hidden layer that is formed from the combined interactions of six higher-dimensional layers (**E** + **F** + **D** + **C** + **B** + **A**).

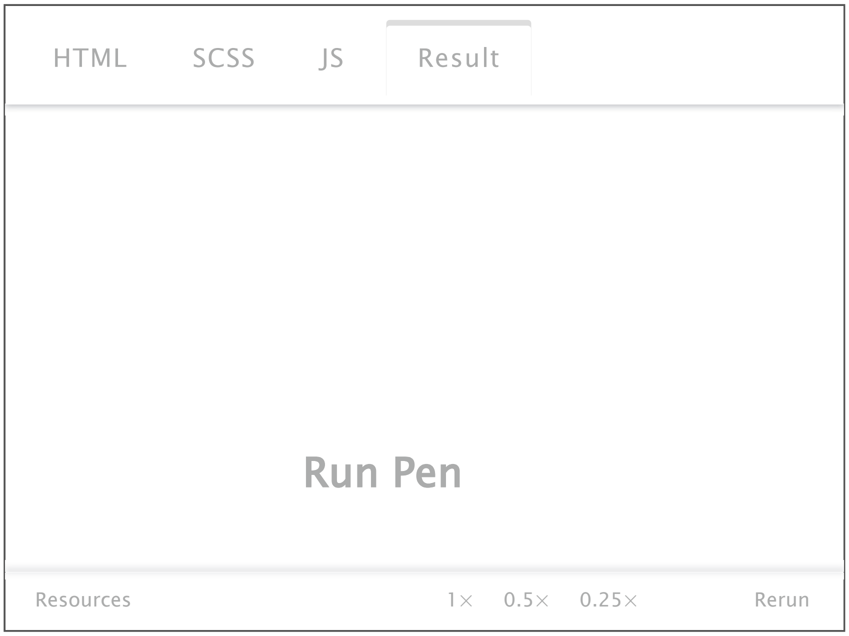
2. The effects of the hidden layers are perceived in the **3D** output layer **S**, space, through the compression of the **4D** hidden layer **T**, time.

3. **52** nodes and **322** separate connections with arbitrary weights exist.

The next question is, how does this artificial neural network relate to physics that we can interpret? Is there anything in the neural network space that can bridge the physical notions of energy and this abstract information representation?

Hopfield Networks

Fortunately for us, there is. A Hopfield network is a recurrent neural network in which the output from one neuron is fed to the input of another. This means there isn't a single direction of flow as with the feedforward network.



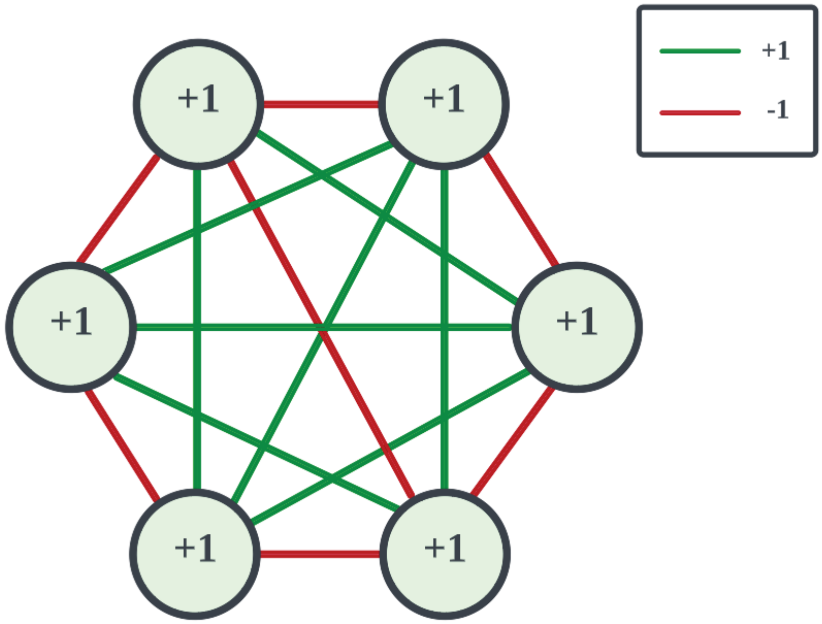
Hopfield Network: 1

One way to set up a Hopfield network is to have threshold neurons that output {**1**, **-1**} depending on the weighted sum of the other neuron's outputs. If the neuron has an opposite sign to the weighted sum, it flips to match the local *field* of influence:

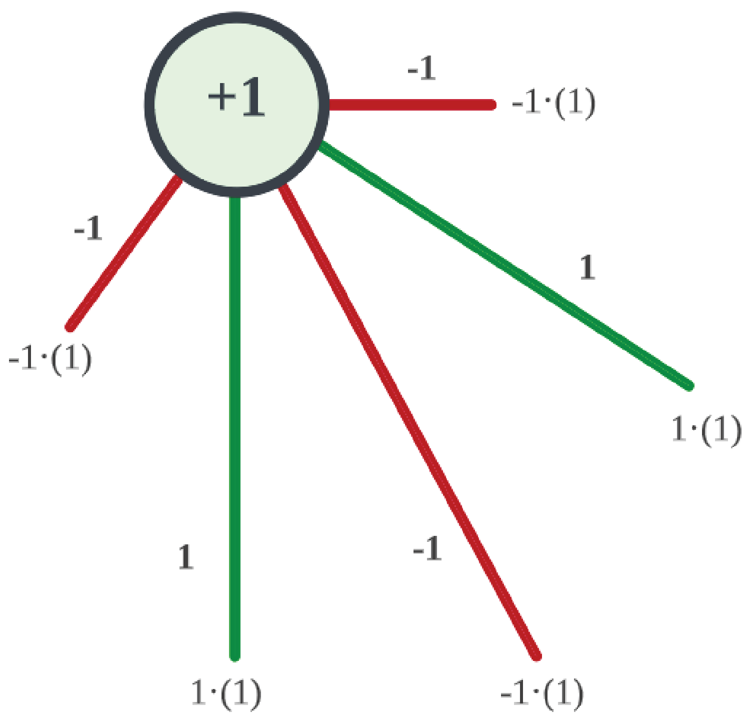
$$y_i = \Theta\Big(\sum_{j \neq i} w_{ji} y_j + b_i\Big)$$

$$\Theta(z) = \begin{cases} +1 & \text{if } z > 0 \\ -1 & \text{if } z \leq 0 \end{cases}$$

Let's see an example of this by initializing a Hopfield network with all neurons outputting **1s**. The connection weights between the neurons are randomly initialized, affecting the field of influence on the neurons. Updating one of the neurons by the field's influence, we find:



Initial hopfield network



Updating a neuron by computing the local field

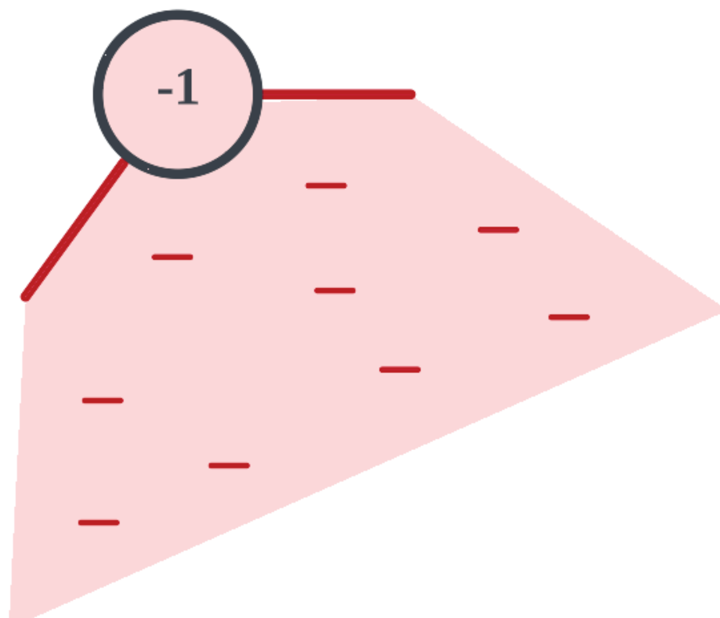
The overall contribution of the other neurons' weighted sum is negative, resulting in a local negative field of influence that flips this neuron's output to **-1**:

$$y_i = \Theta\Big(\sum_{j \neq i} w_{ji} y_j + b_i\Big)$$

$$y_i = \Theta\Big(-1 \cdot 1 - 1 \cdot 1 - 1 \cdot 1 + 1 \cdot 1 + 1 \cdot 1 + 0\Big)$$

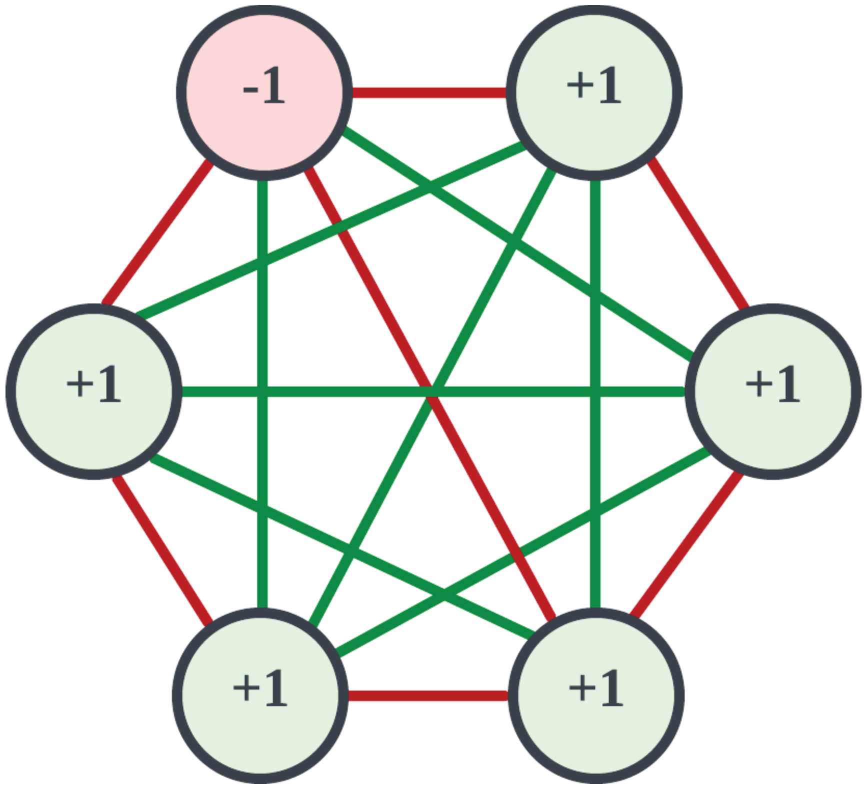
$$y_i = \Theta\Big(-1\Big), \quad \Theta(z) = \Big\{-1 \quad \text{if } z \leq 0$$

$$y_i = -1$$



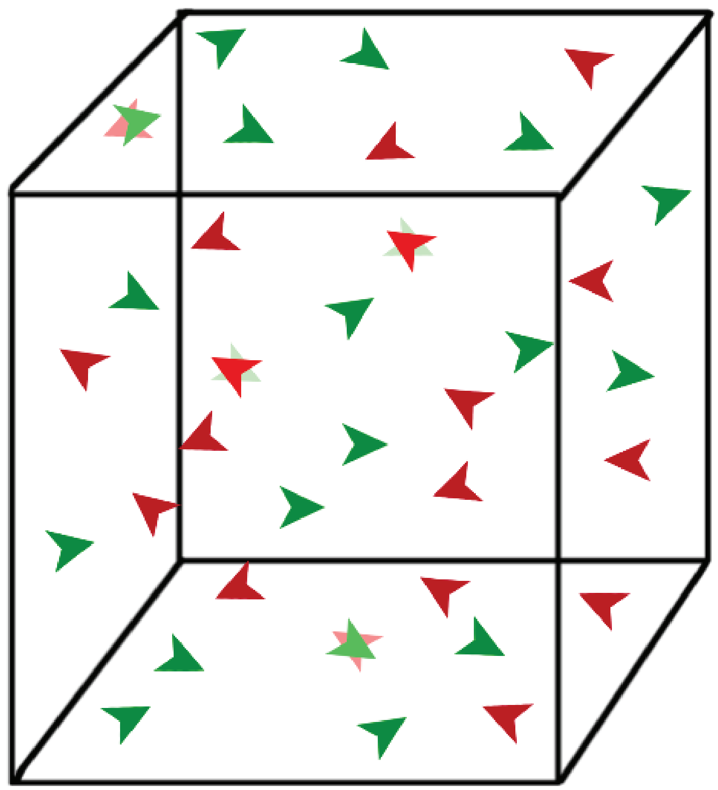
A negative local field flips the neuron

Since this neuron flipped, it will affect the local fields of the other neurons, which will flip those neurons, which in turn will change the fields at the same rate…forever:



Continuous neuron flipping

Or maybe not. Hopfield networks are analogous to a Spin Glass magnetic state in which dipoles try to align to a local field, causing a chain reaction in chaotic dipole evolution. The dipole flips stop when the system reaches a local minimum steady-state configuration:



Spin glass frustration

To model Spin Glass evolution, we can use Hamiltonian mechanics, which describes the total energy of a system by the sum of *kinetic* and *potential* energy formulated in terms of *momentum* and *position:*

$$\mathcal{H} = E_t$$
$$\mathcal{H} = KE \ + \ PE$$
$$\mathcal{H} = \frac{p^2}{2m} + V(x)$$

Hamiltonian Derivation of Newtonian Mechanics

The Hamiltonian has been instrumental in simplifying chaotic classical mechanical systems and foundational in quantum mechanics. In this case, an Ising model is used to describe the Spin Glass's Hamiltonian energy configuration, which we will now denote with the energy of the current configuration or state ***E(s)***:

$$\sum_{j \neq i}$$

$$x_i = \begin{cases} x_i & \text{if } sgn(x_i f(p_i)) = 1 \\ -x_i & \text{if } sgn(x_i f(p_i)) = -1 \end{cases}$$

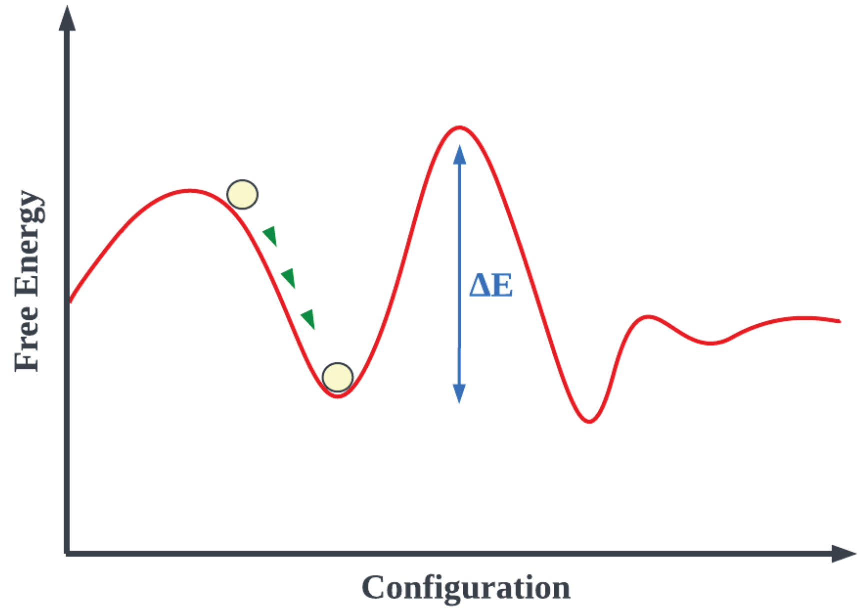
$$E(s) = -\frac{1}{2} \sum_i x_i f(p_i) = -\sum_i \sum_{i<j} J_{ji} x_j x_i - \sum_i b_i x$$

The total energy is described by the product of the dipole output and the local field generated by that dipole plus the contribution of the total external field on that dipole. Translating this framework to our Hopfield network results in this model:

$$y_i = \Theta\Big(\sum_{j \neq i} w_{ji} y_j + b_i \Big)$$

$$E(s) = -\sum_{i<j} w_{ij} y_i y_j - \sum_i b_i y_i$$

The takeaway from that equation is that the Hopfield network evolves to *minimize* free potential energy until it hits a local minimum. Once it finds a state where flipping any neuron increases free energy, the system becomes static. In reality, there are usually no absolutely stable minimal configurations, and thus the rate of flipping will decrease over time; however, neurons will still sporadically flip at the minimum:

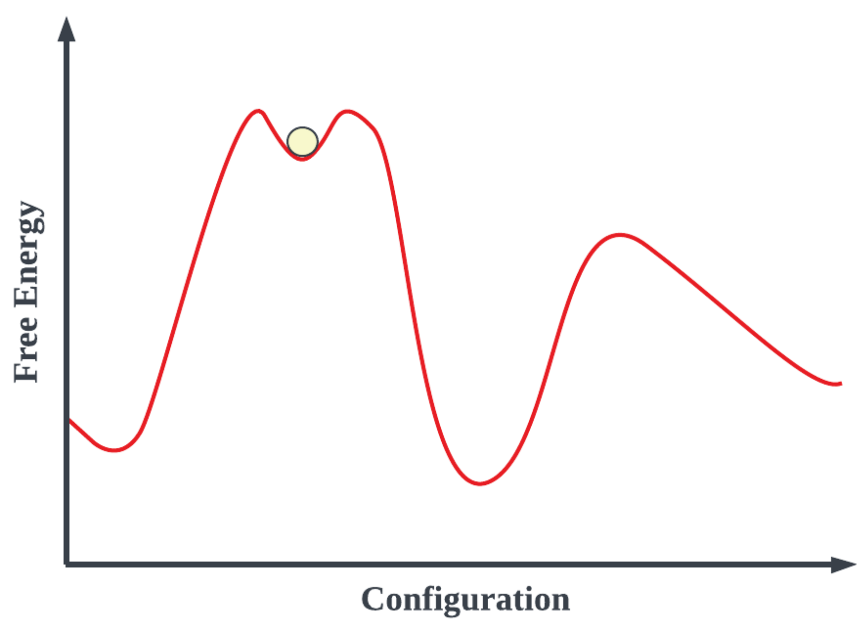


The state is driven to the lowest energy potential

This idea will help us understand how our universe potentially evolves when combined with *Deep Restricted Boltzmann Machines*.

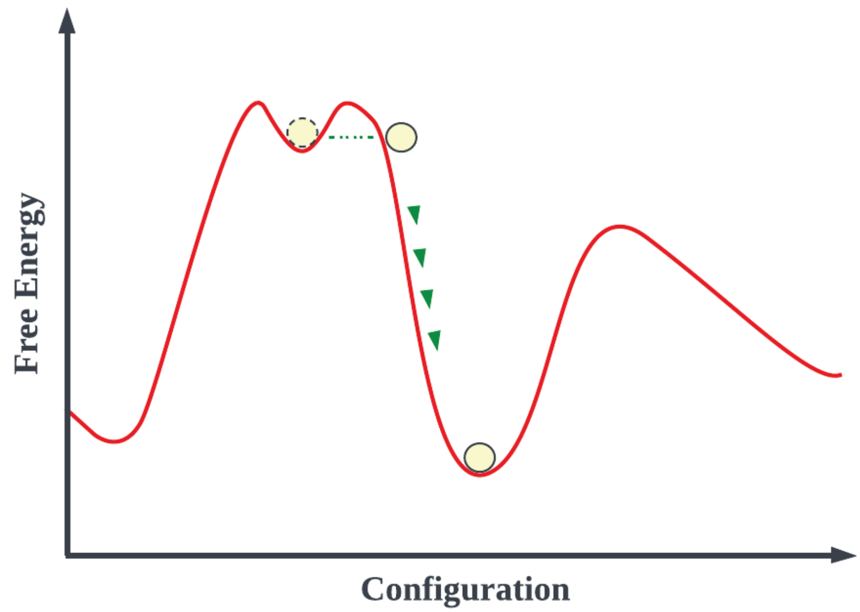
Stochastic Hopfield Networks

Imagine a scenario where a Hopfield network gets stuck in a small notch at the peak of an energy hill:



Stuck in a local minimum

To find the true optimal solution, we need a method to *tunnel* past the local peak. Under the deterministic rules we used prior, this would be impossible. However, if we allow the network to have stochastic properties, we can escape this local minimum and probabilistically traverse to the global minimum:



Tunneling through the local peak

A thermodynamic system can exist in infinitely many configurations at temperature ***T***. The probability of finding the system in configuration (state) ***s*** at temperature ***T*** is P_t with the associated potential energy of E_s. Combining all this, we find the *internal energy* of a system U_t as the average of the *potential* energy of all the probabilistic states:

$$U_T = \sum_s P_T(s) E_s$$

The internal energy potential is counteracted by the internal disorder of the system H_t, which is its *entropy*:

$$H_T = -\sum_s P_T(s) \log P_T(s)$$

The Helmholtz free energy F_t of a system measures the *useful* work of a system by evaluating the difference between the system's internal energy and entropy:

$$F_T = U_T + kTH_T$$

$$F_T = \sum_s P_T(s) E_s - kT \sum_s P_T(s) \log P_T(s)$$

The probability distribution of states visited changes to reduce the free energy in the system until a steady state minimum is achieved. Minimizing the equation above with respect to $P_t(s)$, we derive the Boltzmann (or Gibbs) distribution (**Z** normalizes all the probability to **1**):

$$P_T(s) = \frac{1}{Z} e^{(-E_s/kT)}$$

In a more generalized form, we can say that the probability of any state ***P(s)*** is inversely correlated to the *energy* and *temperature* of the state. The most likely states are those with the lowest energy:

$$P(s) \propto e^{(-E_s/kT)}$$

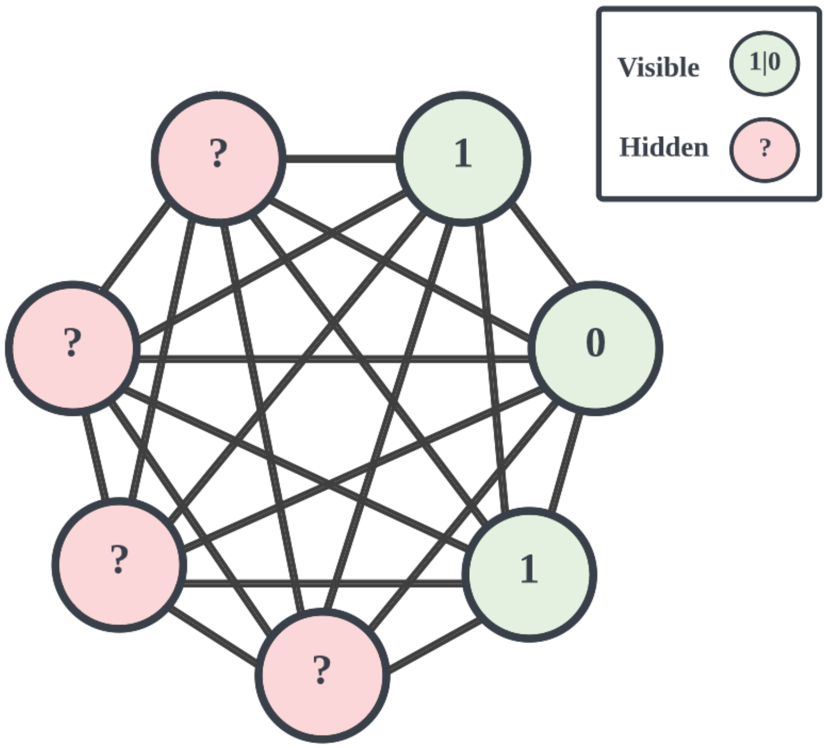
Now we will apply the probabilistic state above to our Hopfield energy equation (we're skipping the derivation for brevity). We will modify the output of the neurons from the Hopfield network's **{1,-1}** to **{1, 0}** to denote a binary state of **{on, off}**. The end result is a logistical equation of the probability of the y_i neuron outputting a **1**:

$$z_i = \frac{1}{T} \sum_{j \neq i} w_{ji} y_j + b_i$$

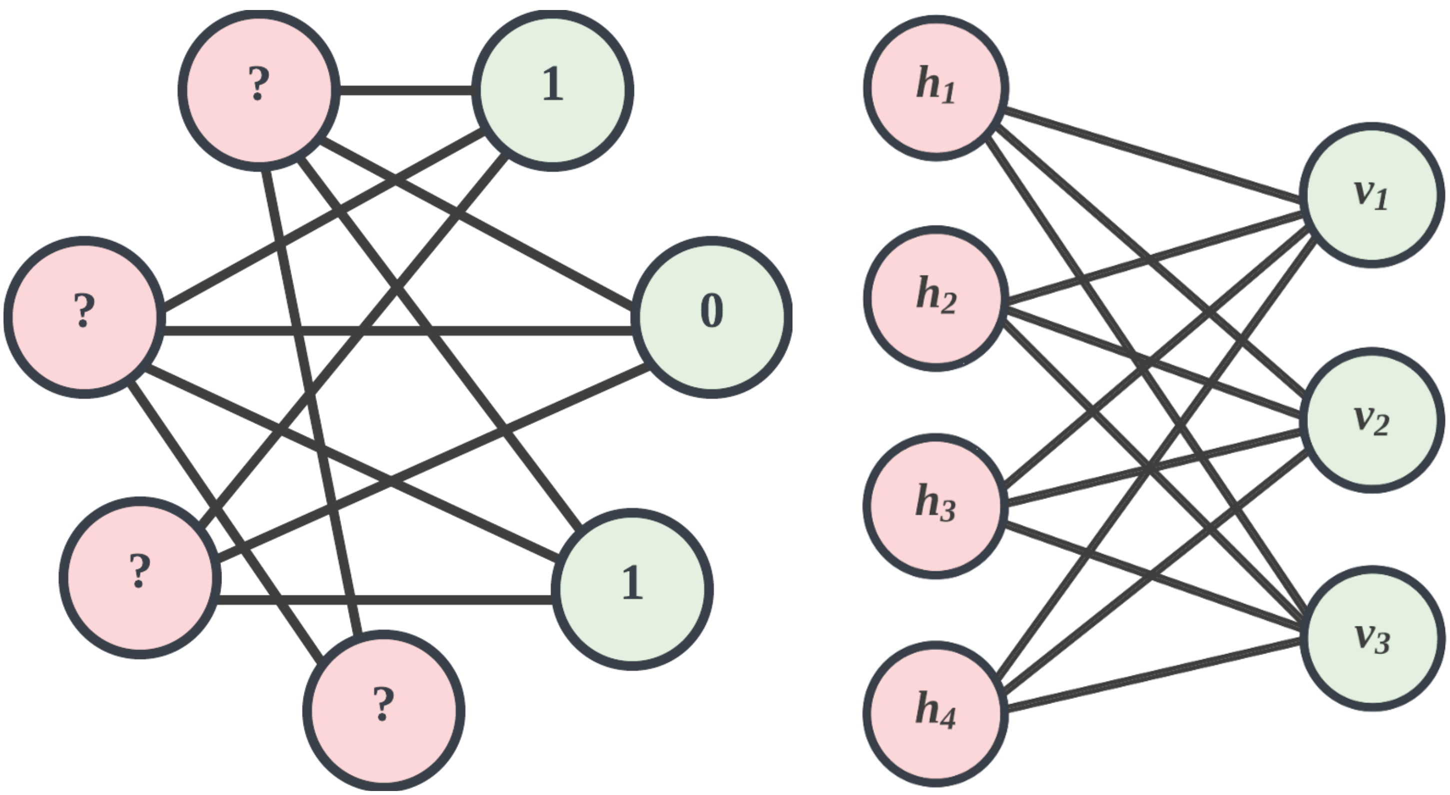
$$P(y_i = 1 | y_{j \neq i}) = \frac{1}{1 + e^{-z_i}}$$

Deep Restricted Boltzmann Machines (DRBM)

We're almost there. A Restricted Boltzmann Machine (RBM) is a Stochastic Hopfield Network in which the network is split up between visible (v_i) and hidden nodes (h_i), and no connections are made between the respective node types:



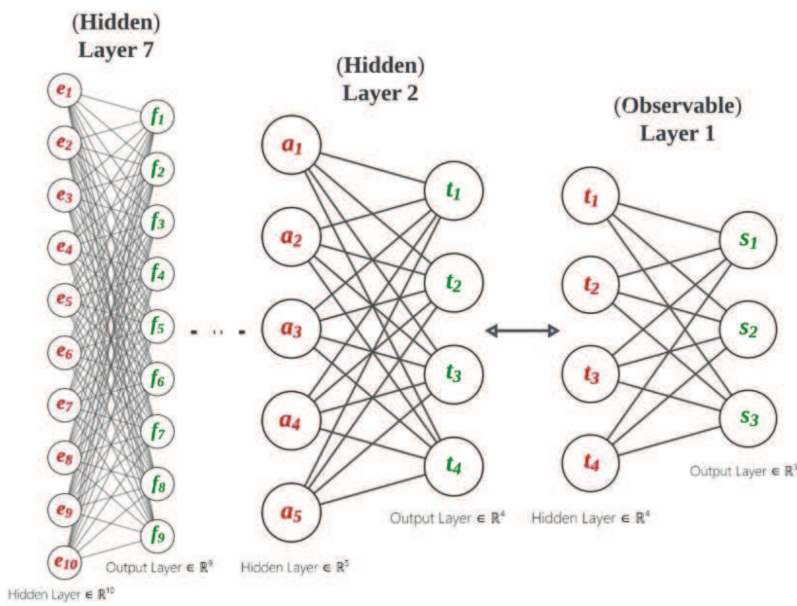
Normal Boltzmann machine



Restricted Boltzmann machine & alternate view

RBMs can be extended with complex number values as inputs and stacked to create a deep neural network. This structure has been used to describe the chiral boson CFT correlator wave function with **99.9%** accuracy up to **22** visible spins, as described in this paper.

Perhaps a single point in our observable layer can interact in the **3 x 4** RBM (space x time) but is influenced by the greater DRBM framework. The entire multi-layered structure operates by minimizing the free energy within every RBM as a collective, with the visible output of one layer becoming the hidden input of the next layer:



The Complete DRBM Universe Network: 1

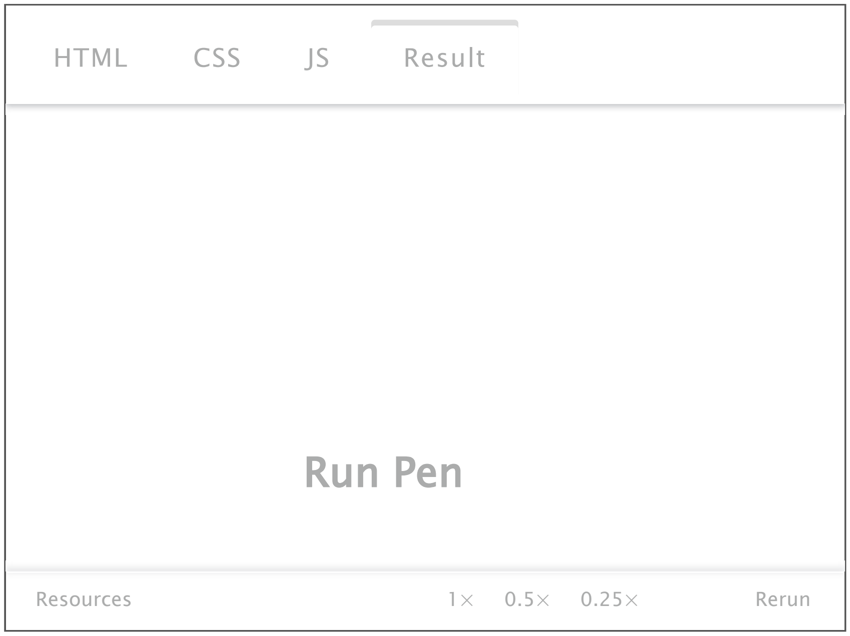
The generalized equation to describe this layout is found in the paper above and can be modified to fit the structure of our multi-layered reality (*3 x 4 x 5 x 6 x 7 x 8 x 9 x 10*):

$$h_1^1,\ldots,h_{m_1}^1 \quad h_1^1,\ldots,h_{m_1}^1 \quad h_1^k,\ldots,h_{m_k}^k \qquad p_0,p_1$$

$$\sum_{p_0} s_{p_0} a_{p_0} + \sum_{i=2}^{k} \sum_{p_{i-1},p_i} W^i_{p_{i-1},p_i} h^{i-1}_{p_{i-1}} h^i_{p_i} + \sum_{i=1}^{k} \sum_{p_i} h^i_{p_i} b^i_{p_i}$$

K-layer DRBM Equation: 1

The complete structure to describe a point would look like the network above; however, we would tie the ***u***, ***v***, and ***w*** outputs into a single node:



Visualization of a single-point neural network interaction: 1

If we visualize a single **3D** point expansion with the field interactions from seven stacked RBM layers, we would see a structure like this (except in **10D** instead of **3D**):

HTML CSS JS Result

Run Pen

Resources 1× 0.5× 0.25× Rerun

Visualization of a single-point field interaction: 1

The Route to Mathematical Rigor

I made quite a few simplifications and assumptions in these articles to cut straight to intuition. However, these simplifications must be addressed if an interconnected framework like this is to become mathematically rigorous and accurately reflect reality. The vision is to lay a conceptual foundation so that people far better than me in mathematics, physics, computer vision, and artificial intelligence can improve the meager diagrams and simple equations I am proposing.

I recently discovered Geometric Algebra when researching these models and am trying to deepen my knowledge of it. It is a powerful method to describe physics and can significantly simplify many of the complexities centered around nested dimensional projections. Geometric Algebra and mathematics at this level go well beyond my abilities as a systems developer, but I am confident that novel discoveries will be made by people who can develop equations at this level.

The concept that seems relevant to projective dimensional operations is Conformal Geometric Algebra. This will allow you to represent circle inversions and other transformations with relative ease: