

# A Beautiful Question

Finding Nature's Deep Design

Does the world embody beautiful ideas?

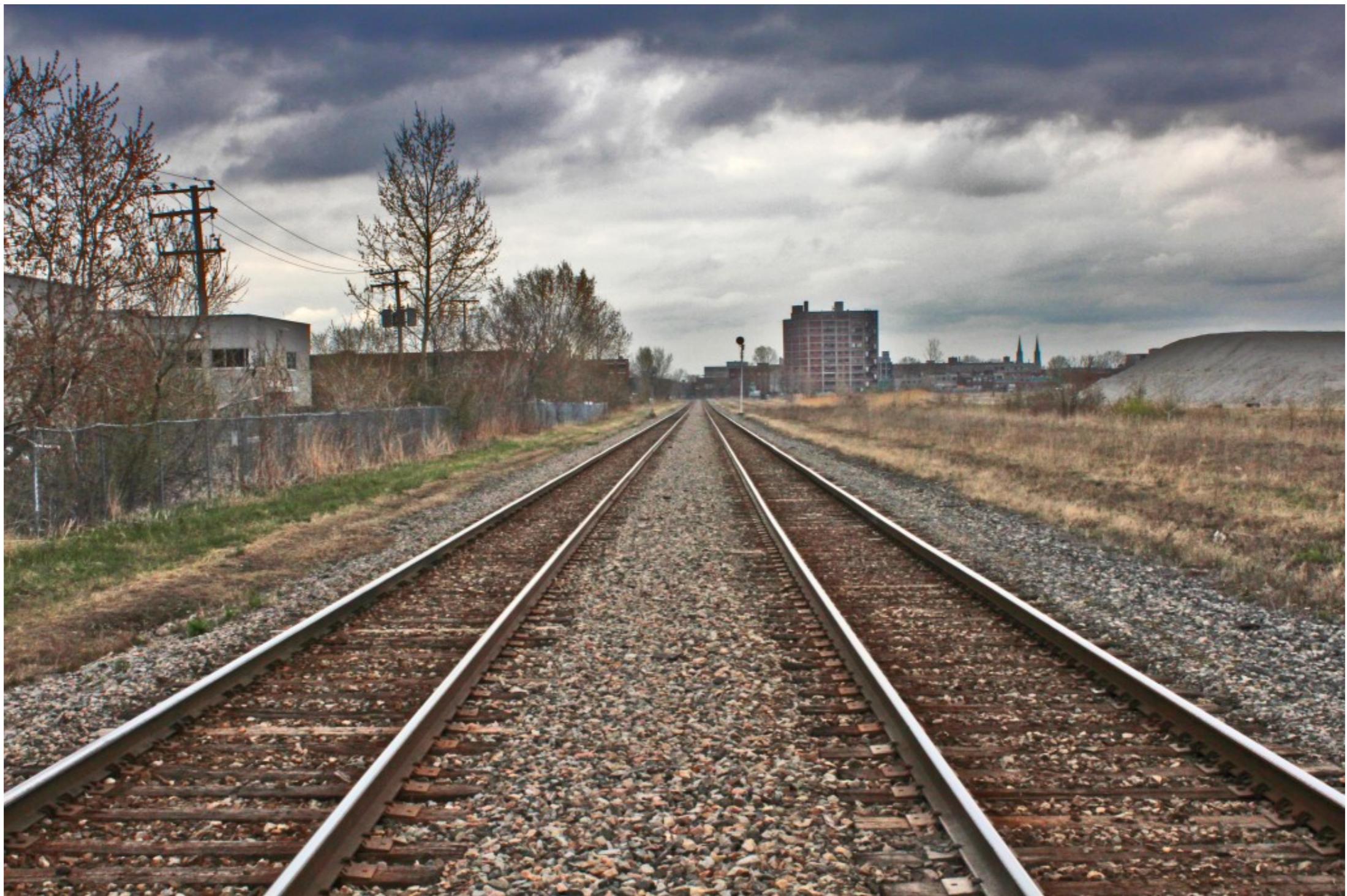
Another formulation: Is the world a work of art?

# Perspective and Symmetry

A Crossroads of Art and Science

Viewed from above and afar, train tracks run in  
parallels, and they never meet.

But there are other valid perspectives ...



What transformations can one make on an image, while representing the same object (seen from different places)?

That question leads to the subject known as perspective in art, and as projective geometry in mathematics.

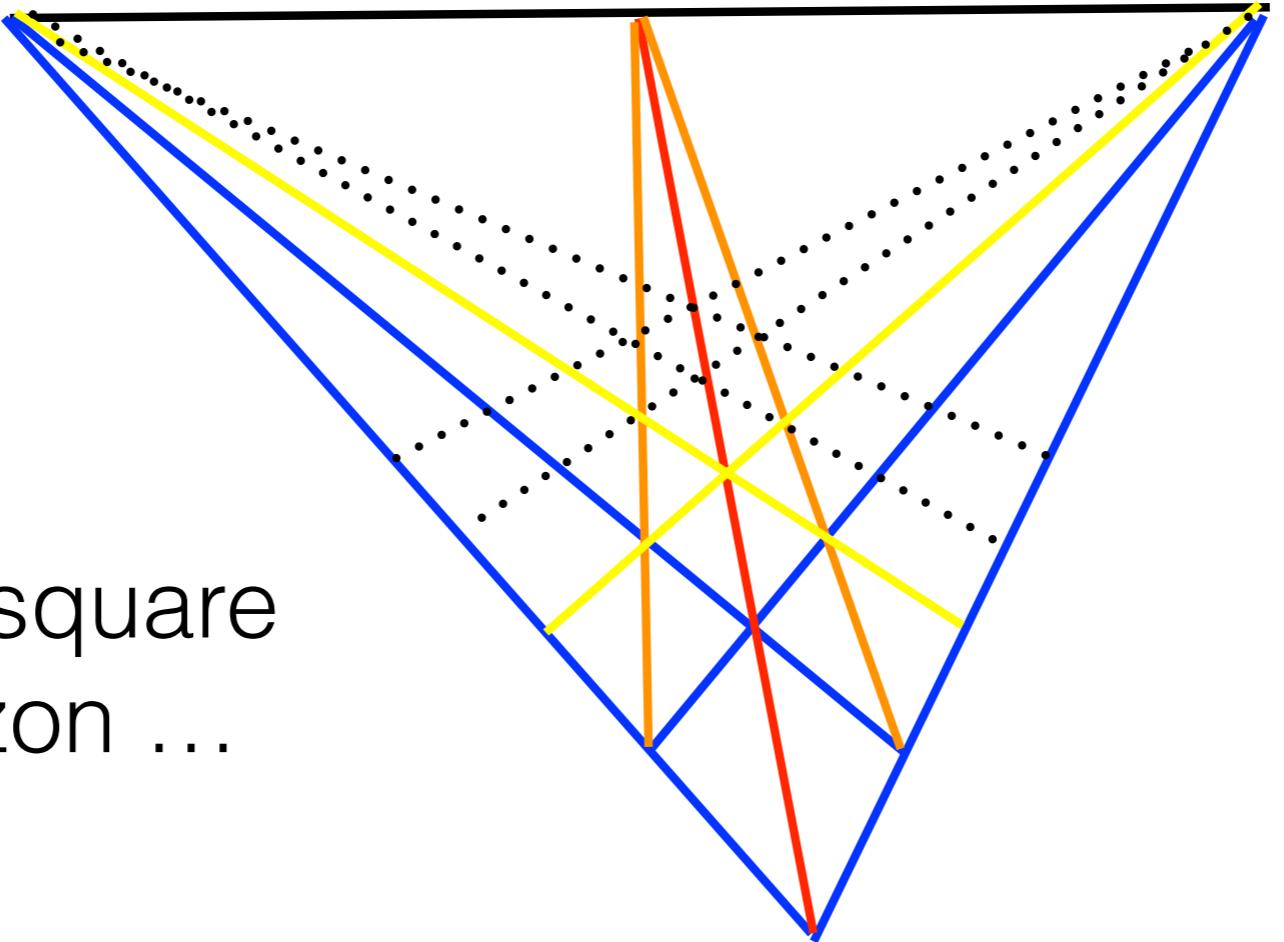
We can *change* the image, *without change* in what it represents.

Conversely, many *changes* in the object will *not change* the **totality** of its valid images.

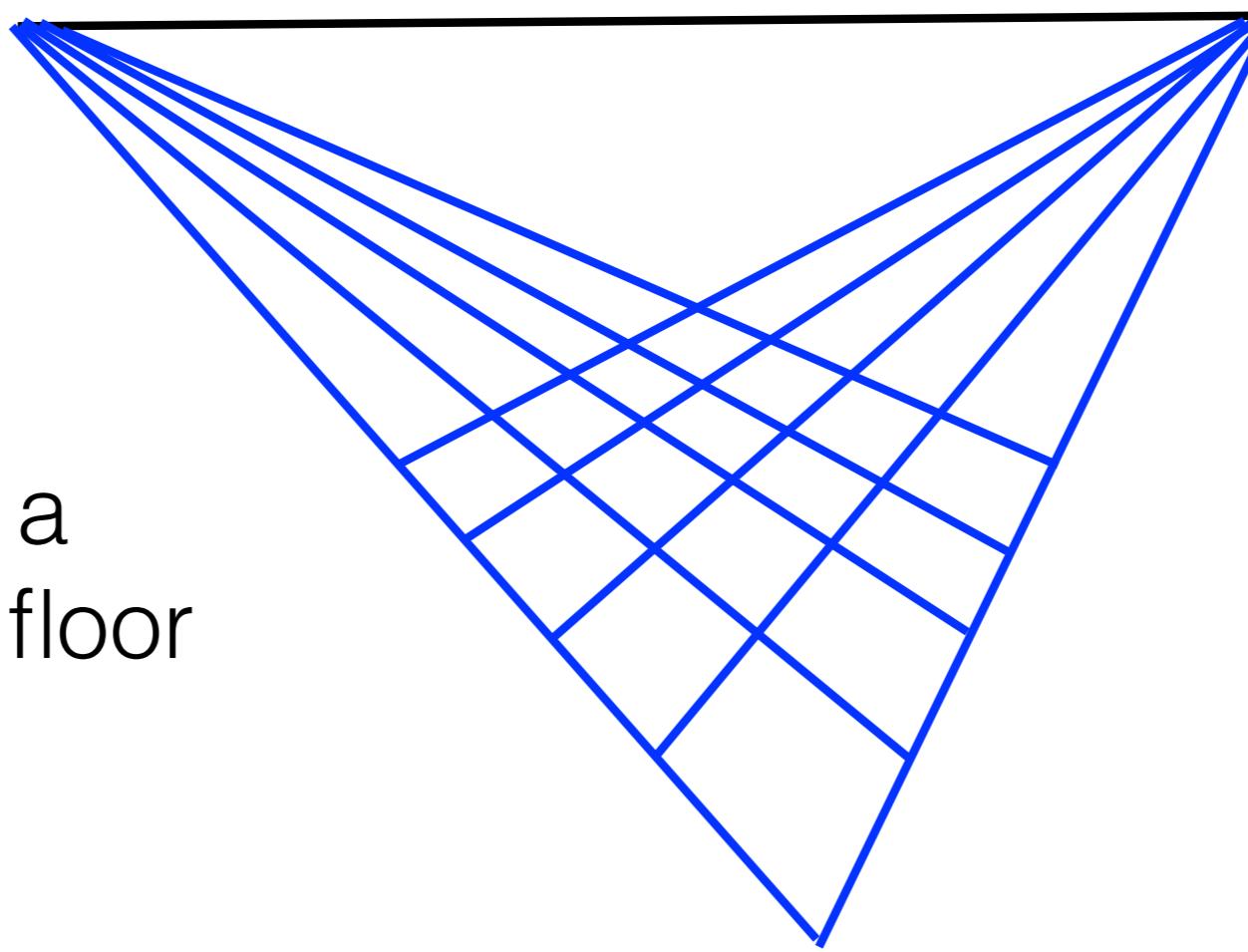
“Change without change” is the essence of *symmetry*.

People find Symmetry beautiful, both intellectually and artistically -

start with a square  
and a horizon ...



... create a  
square-tiled floor





# Anamorphia

Perspective Goes Local

A vastly expanded concept of transformation is the essence of anamorphic art ...



... and also of the of the general theory of relativity.

To enable such generalized perspectives, in both cases, we must introduce image-changing media.

In art, the media are curved mirrors, or lenses.

In general relativity, the medium is called the metric fluid. It encodes distortions - *curvature* - of space-time.

The Yoga of general relativity, according to John Wheeler:

Space-time tells matter how to move\*.

Matter tells space-time how to curve\*\*.

\* Move as straight as you can!

\*\* Let's be *anamorphic*!

Our theory-construction involves choosing:

the objects that transform (~ substances)

the sorts of transformations we'll allow (~ symmetry)

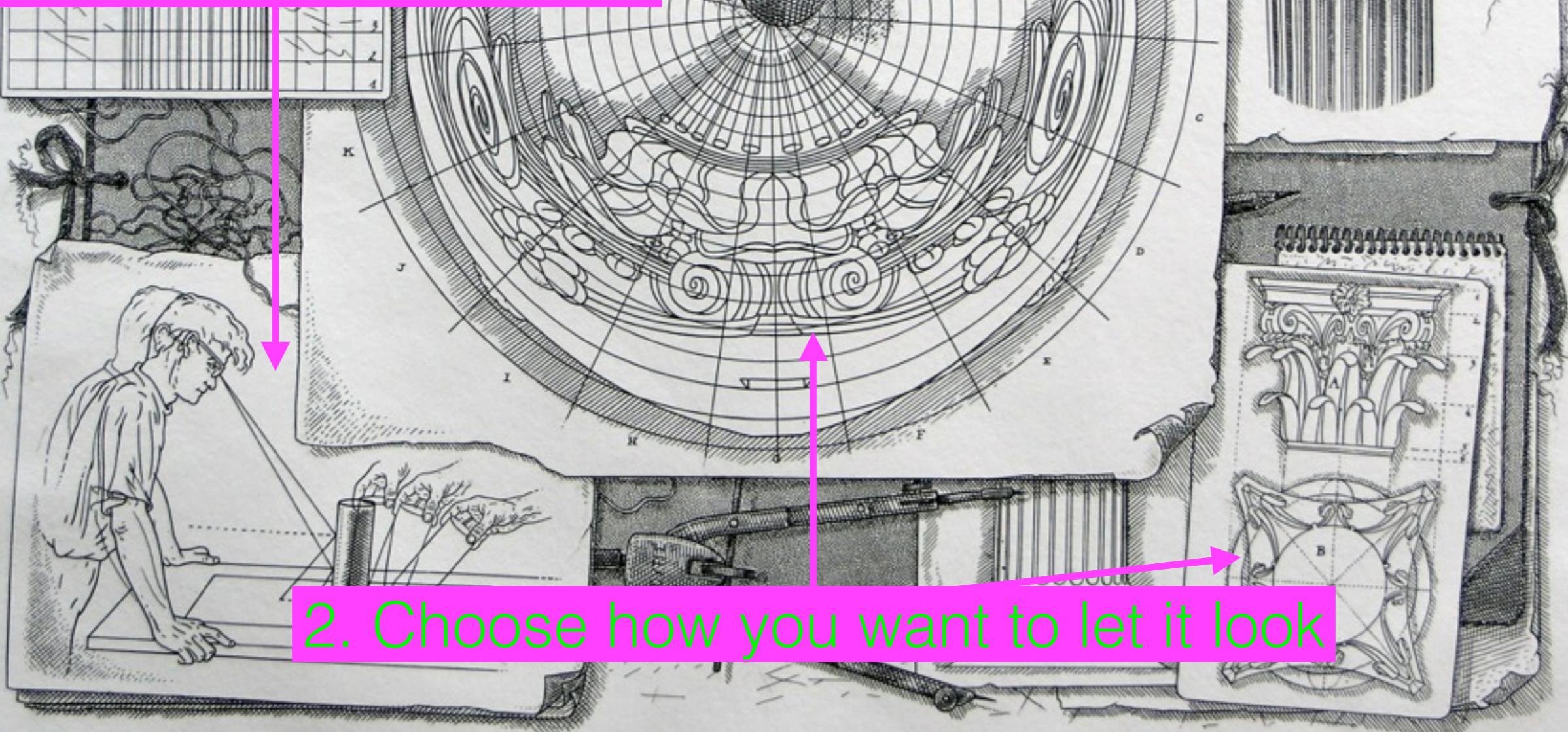
the enabling media (~ fluids, or force-fields).

Our art of theory-construction deeply resembles the art of artistic creation:

1. Specify the substance



3. Design the enabling material



2. Choose how you want to let it look

A more refined version, for wider use:

The metric fluid tells energy-momentum how to flow.

Energy-momentum tells the metric fluid how to flow.

# Symmetry of Physical Law

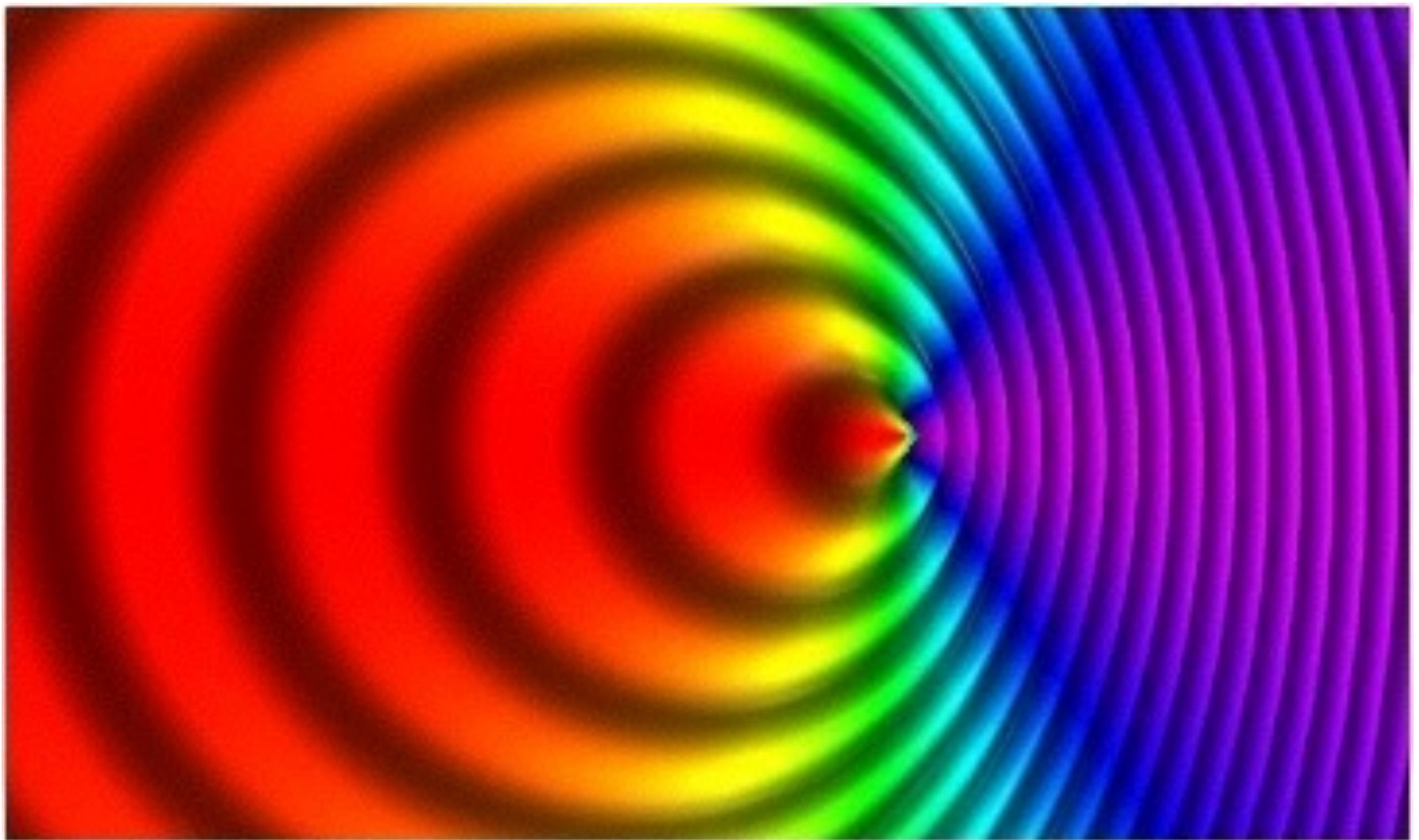
The Example of Relativity

Cruising with Galileo:

With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distances being equal ...

... Have the ship proceed with any speed you like, so long as the motion is uniform and not fluctuating this way and that. You will discover not the least change in all the effects named, nor could you tell from any of them whether the ship was moving or standing still.

In his special theory of relativity, Einstein combined this Galilean *symmetry* with the *invariance* of the speed of light, and got wonderful consequences.



# Symmetry of Equations

Inspired by that example, physicists learned to focus on equations (i.e., precise laws) that can be transformed in many ways.

The transformed versions generally *look drastically different*, but for special equations, or systems of equations, they *lead to the same consequences*.

Example:

$x = y$  is symmetric under the transformation  $x \rightarrow y$  ,  $y \rightarrow x$

$x = y + 2$  is not

If we assume that our equations will allow a wide variety of transformations, we get led to very specific equations!

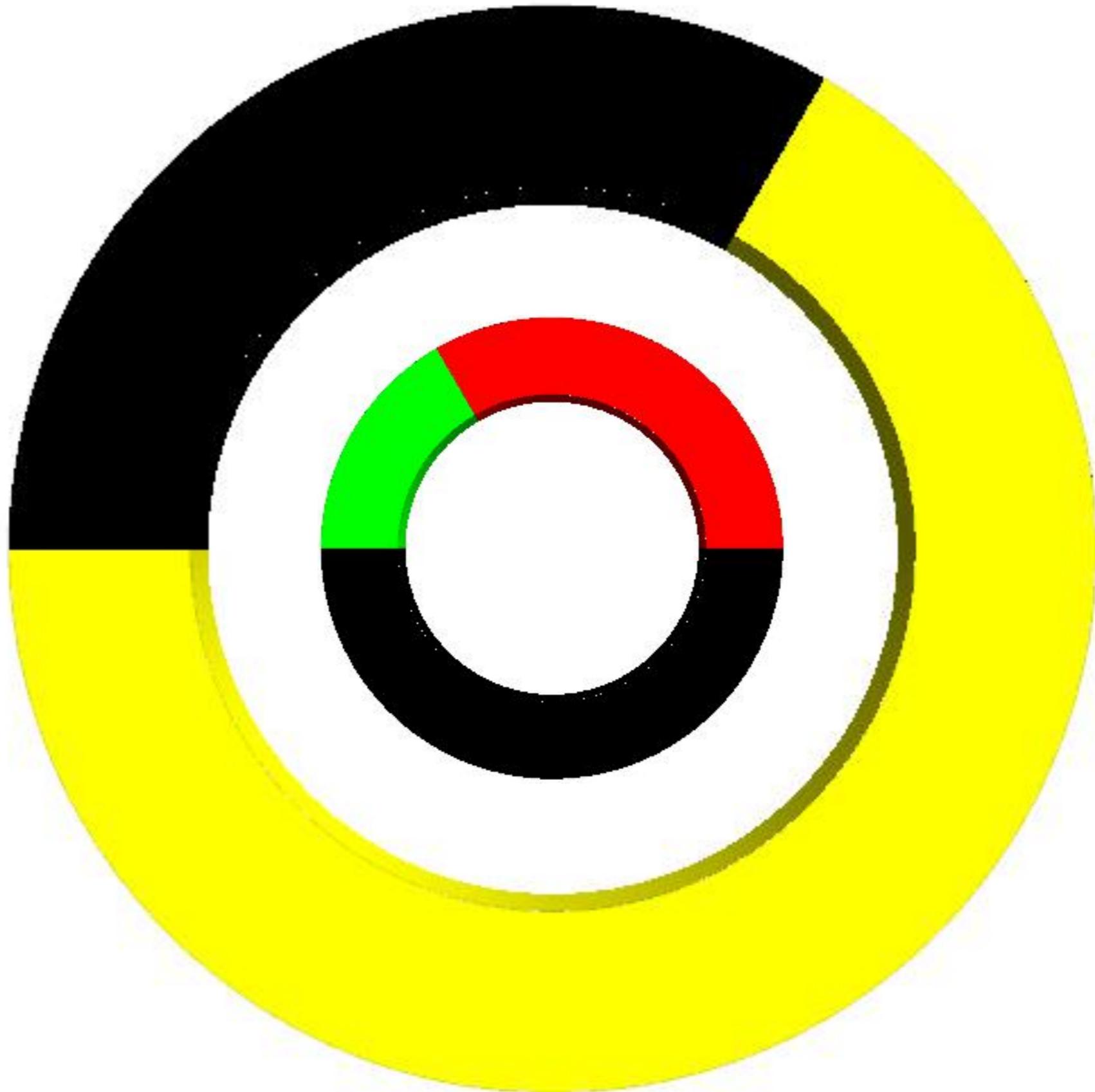
*Symmetry of equations* is the essence of our deepest understanding of Nature: our Core theories.

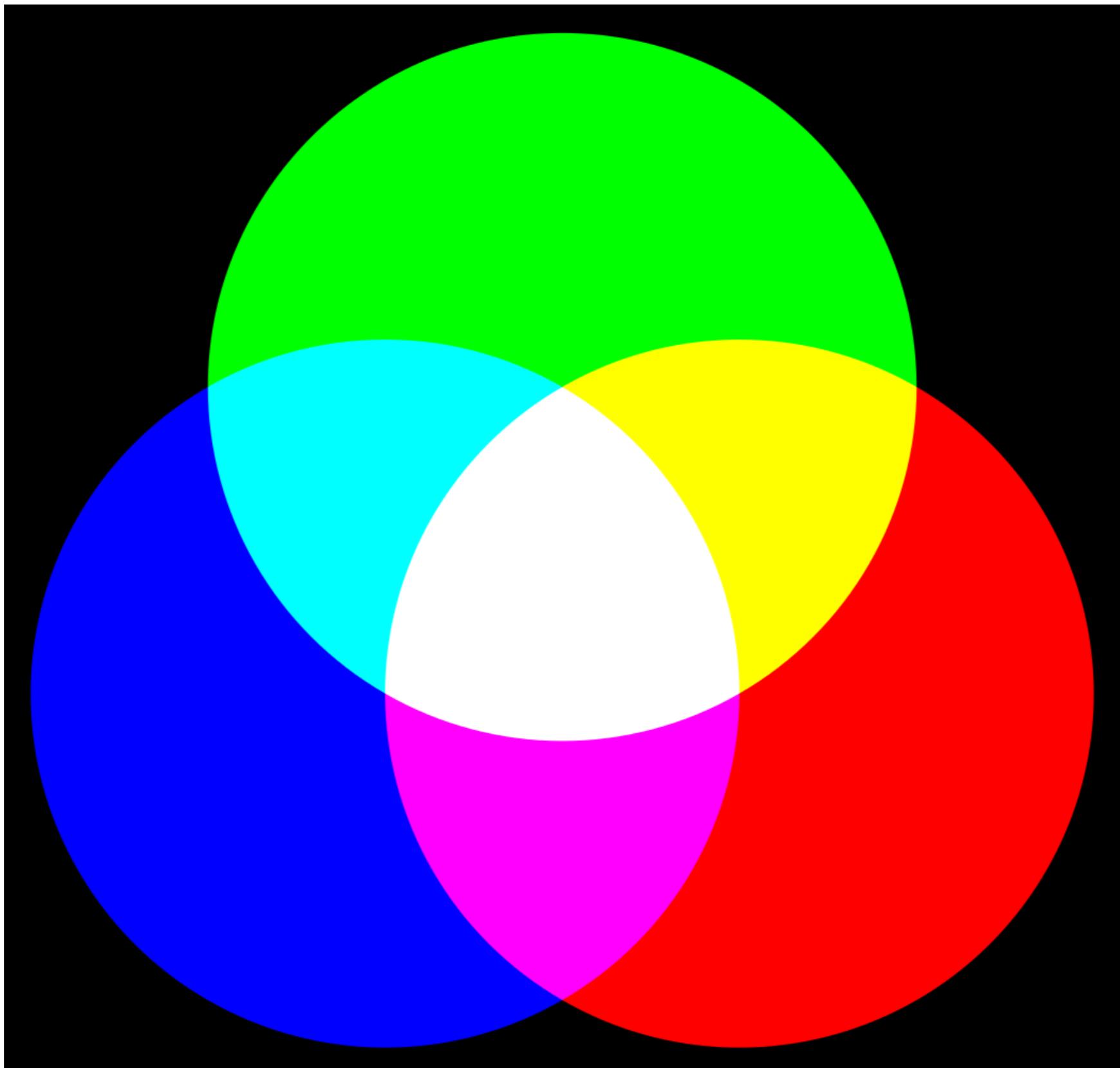
**From Color to  
Extra Dimensions**

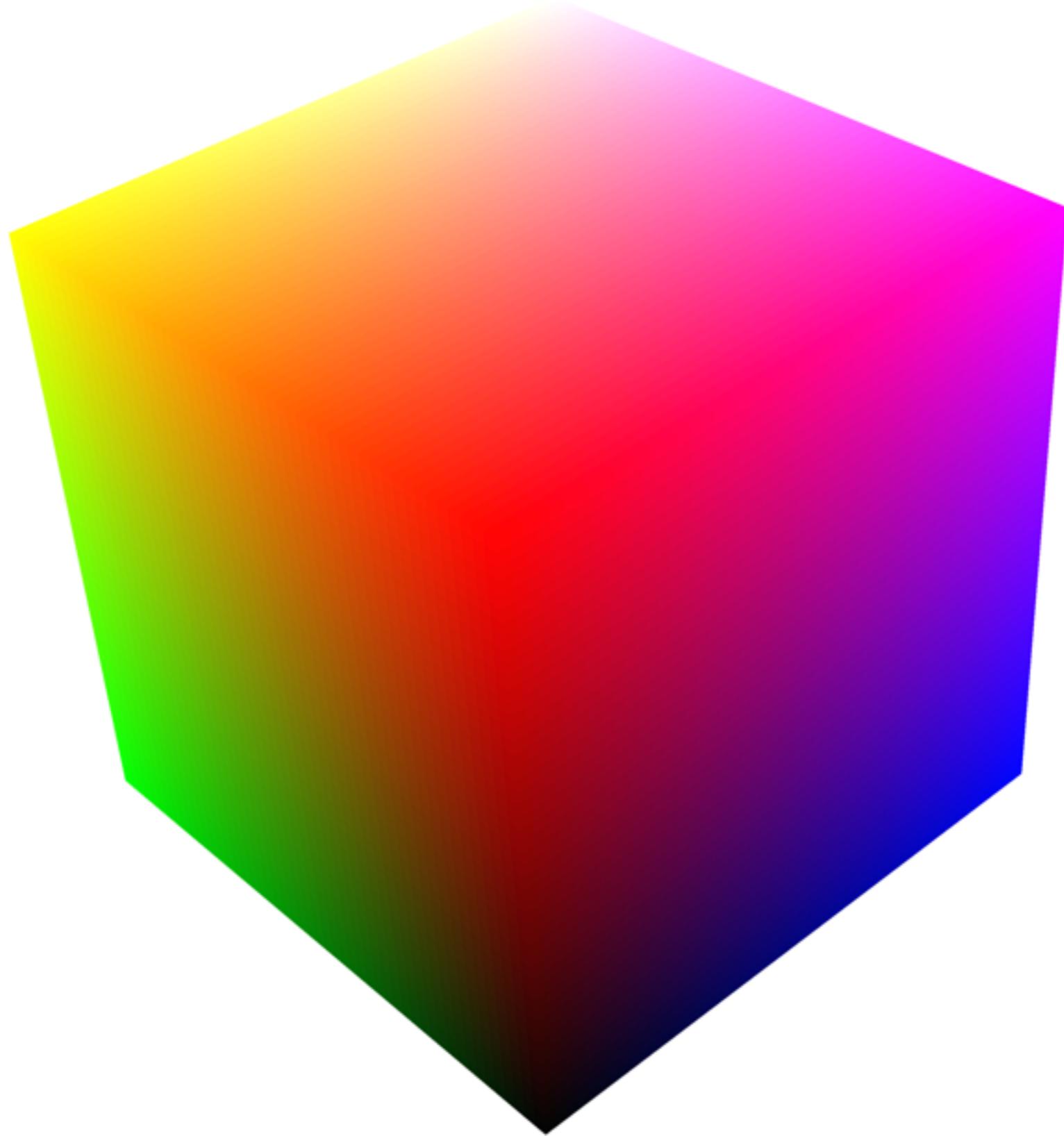
To understand the other (non-gravitational) forces, we need to introduce a new idea: “property spaces”.

Fortunately, that is an idea we meet in everyday life - when we see the world in color!

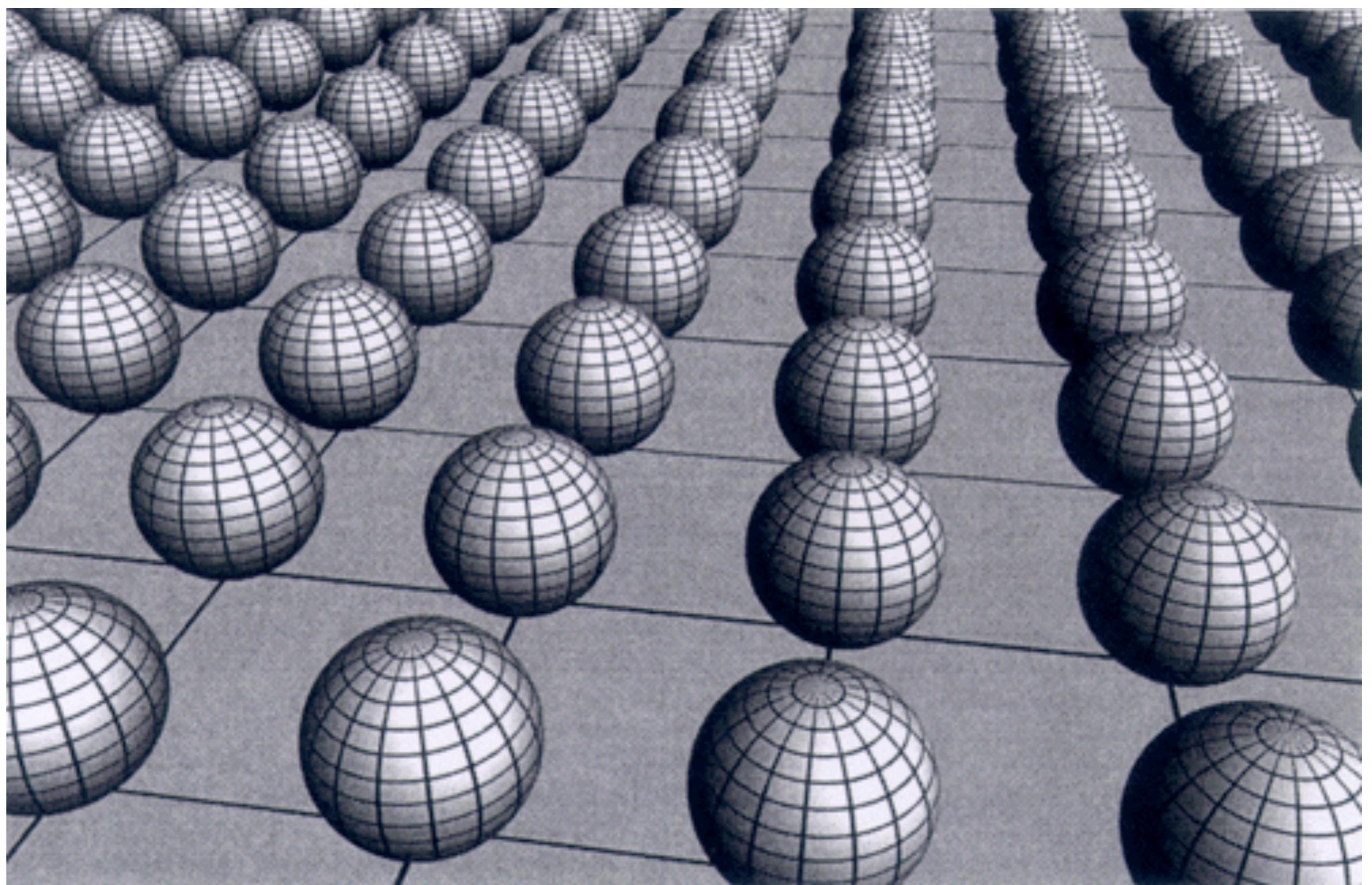






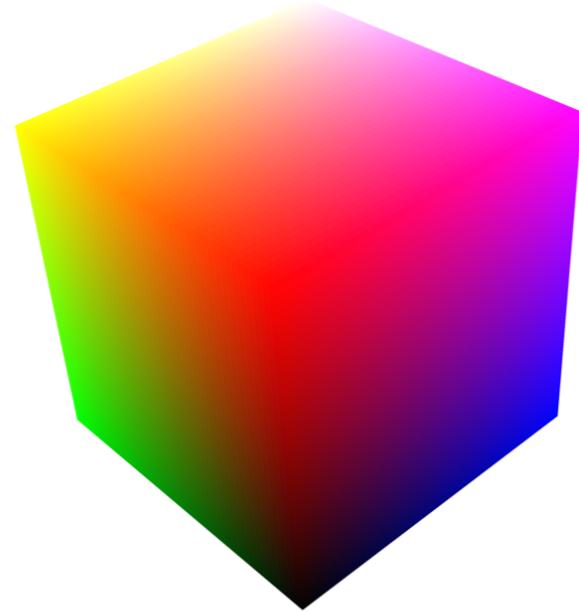


There's no denying the mystical appeal of the concept of extra dimensions:



If only we could *experience* them!!

Well we can, and we do.



(t, x, y, r, g, b)

Q: What do extra dimensions look like?

A: You're looking at them!

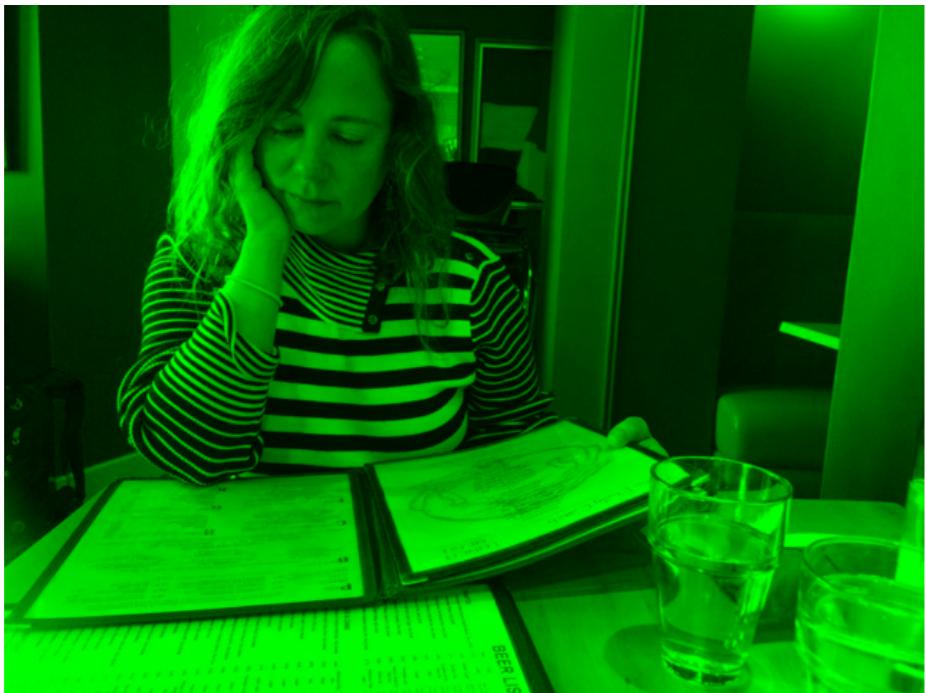
# Anachromia

(= Anamorphia of Color Spaces)

Property spaces of “color” charges are the essence of our Core theories of the electromagnetic, weak, and strong forces.

The density of electric charge is described by one number, i.e. a space of one dimension.

The weak and strong color spaces are two and three dimensional.



electromagnetic

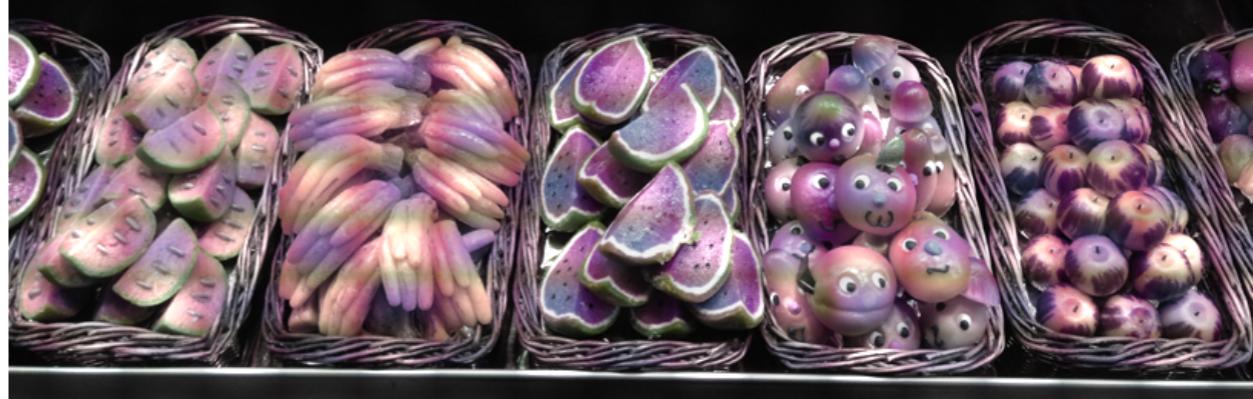


weak



strong

Equations that allow anachromic (or “local”) rotations in color spaces are the basis of our Core theories of the electromagnetic, weak, and strong forces.



As in general relativity, we find that if we want to enable those sorts of distorted representations (without changing what we're representing) we must introduce image-changing media, with very specific properties.

For electromagnetism - one dimension - we get the electromagnetic fluid, and Maxwell equations.

The Yoga of QED:

The photon fluid (electromagnetic field) tells electric charge how to flow.

Electric charge tells the photon fluid how to flow.

For more dimensions, we get more complex fluids, and the Yang-Mills equations.

These are like the electromagnetic (photon) fluid and Maxwell's equations *on steroids*.

The Yoga of QCD:

The gluon fluid tells strong color charge how to flow.

Color charge tells the gluon fluid how to flow.

In this way, we discover a common, dualistic conception from which all the known fundamental interactions flow.

People found such dualistic understanding beautiful long before anyone knew that it governs the fundamental laws of physics.



Yin is substance, Yang is force.

Each responds to, and is shaped by, the other.

Each contains an aspect of the other.

A Beautiful  
Answer

Seeking to embody divine beauty, artistic creators anticipated the spirit of anamorphic and anachromic creativity long before anyone knew that it runs the world.

For example, this magnificent intuition of the divine embodies both:



So: *Does the World embody beautiful ideas?*

Clearly, “by experiment”: Yes!

Exuberance of form.

Exuberance of color.

Beauty of concepts:

symmetry

taiji

In Beauty We  
Trust

*One **substance** plus one **force** would still be two **things**.*

Can we transcend that duality?



太極渙魚乃中華  
文化之精髓今以空為琴

寫照

甲午冬初何北

汰山我識



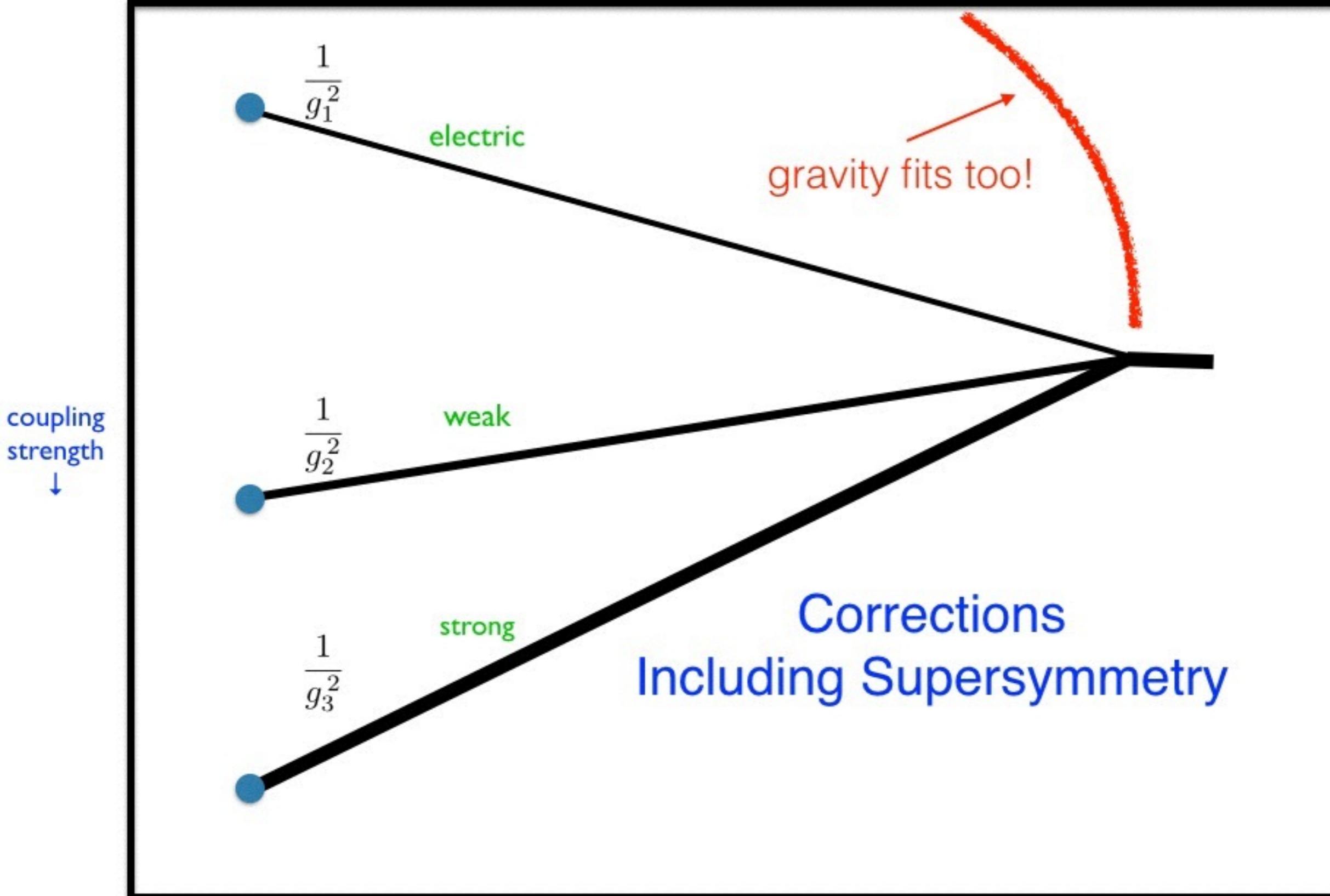
To accomplish that trick we must extend Galilean symmetry, allowing motion into new *quantum* dimensions (superspace).

It's not for the faint of heart ...

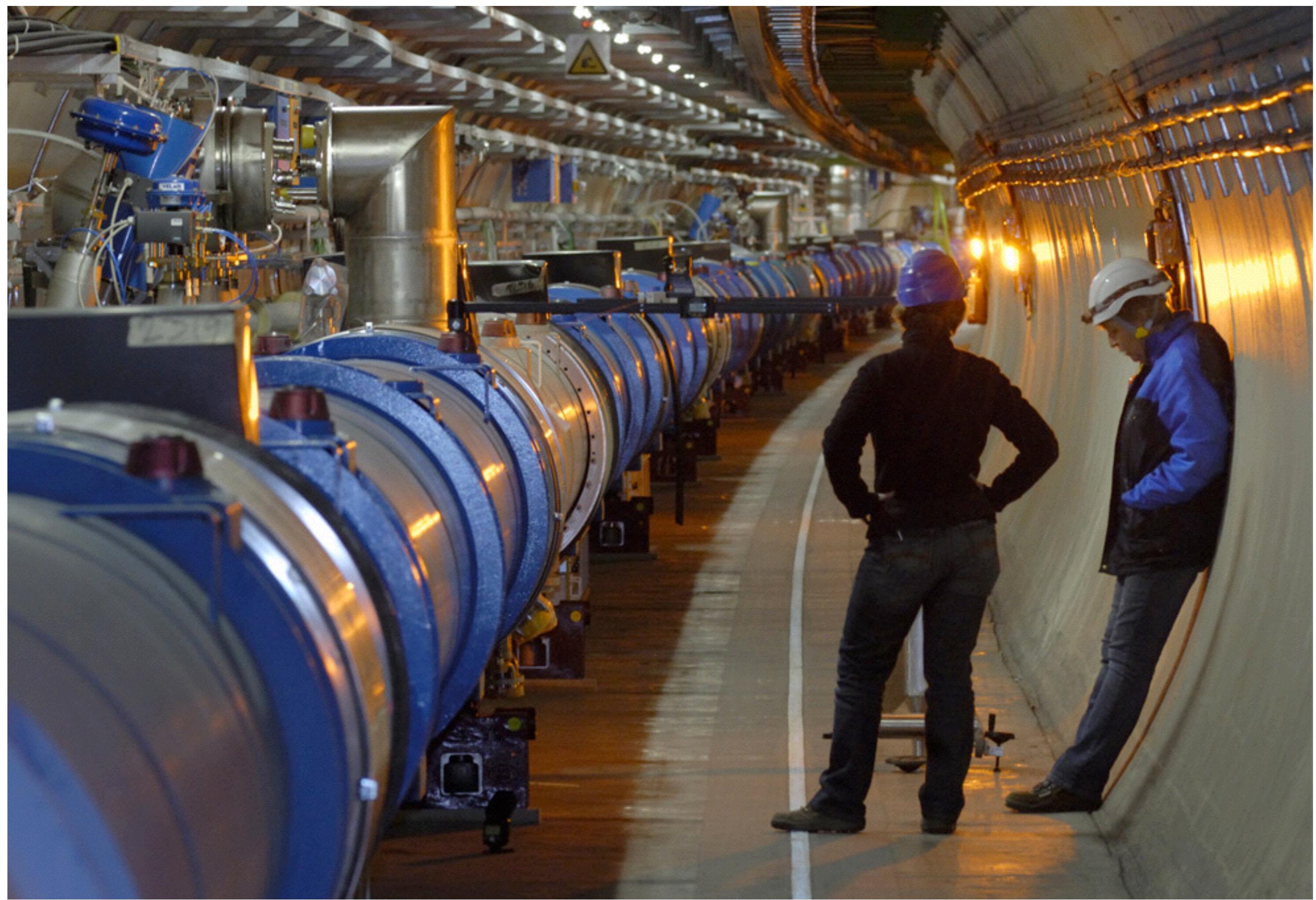


.. but it's an eye-opening experience:

# Why I ❤️ SUSY

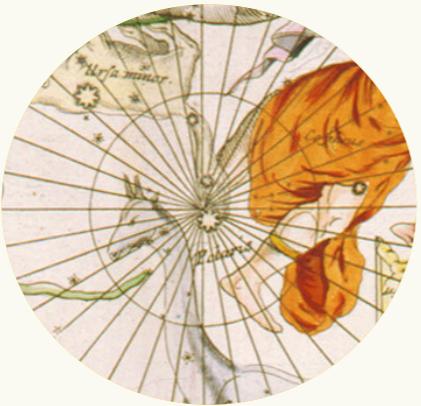


Revelation, or Illusion?



For All This In Depth,  
and Much More:

# A BEAUTIFUL QUESTION



through the  
peephole →

FINDING NATURE'S DEEP DESIGN

FRANK  
WILCZEK

WINNER OF THE NOBEL PRIZE IN PHYSICS

