In the

UNIVERSE

{ Christina Cahalane }

In the

UNIVERSE

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Contents

"Somewhere, something incredible is waiting to be known."

{ Carl Sagan }

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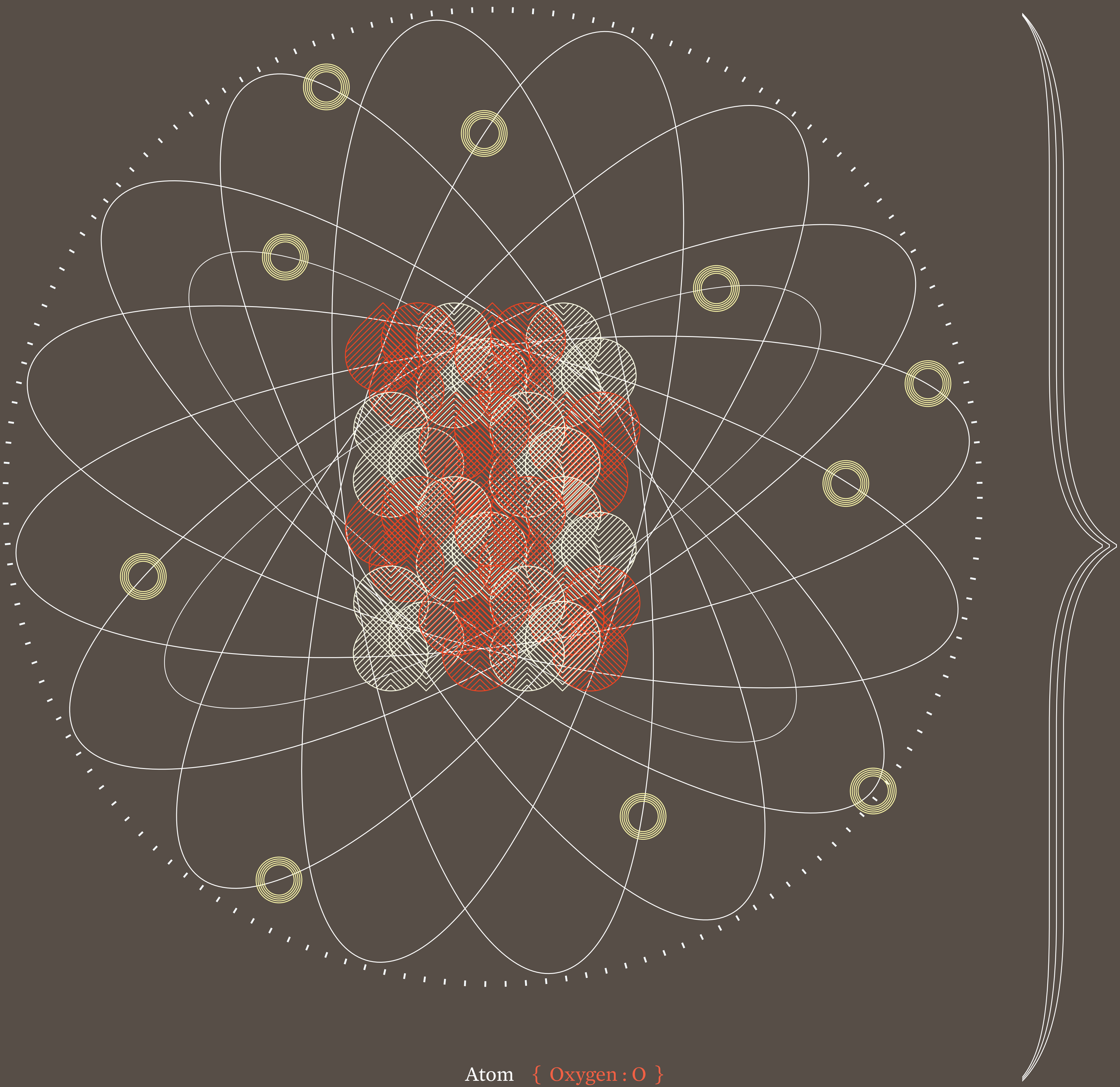
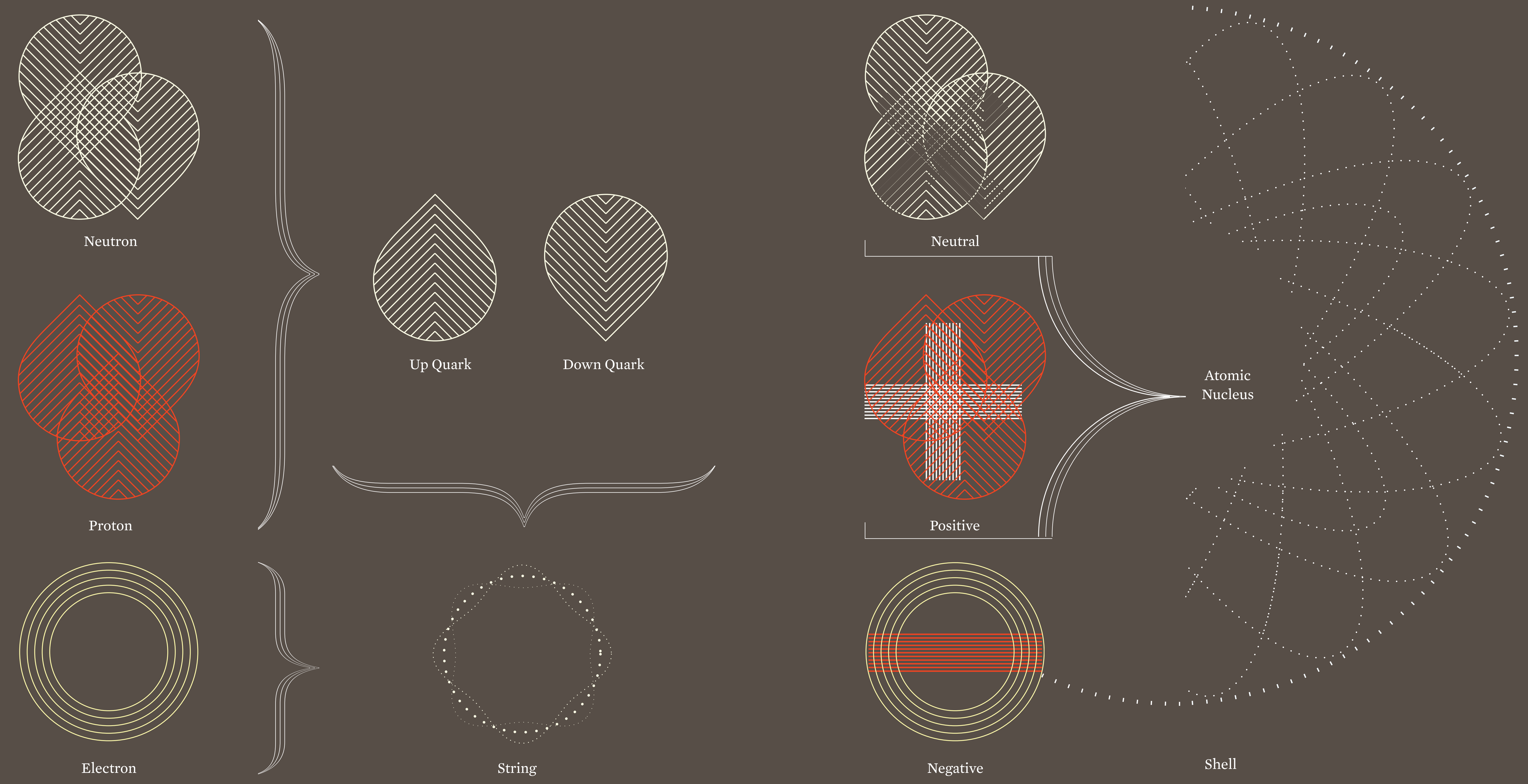
In Matter

{ Water }

Molecule { Water : H_2O }



Atom { Oxygen : O }


Neutron
Proton
Electron
Up Quark
Down Quark
String
Neutral
Positive
Negative
Atomic
Nucleus
Shell

In an Atom

The first concept of the atom emerged in the 6th century BC in India. 100 years later, ancient Greeks coined the term *atom*, meaning *indivisible*. Atoms were once thought to be the basic building blocks of matter, but it is now known that they are made up of even smaller components—*subatomic particles*.

Atoms are built of *protons, neutrons* and *electrons*, and these consist of even smaller pieces, that are called *fundamental particles*.

Atoms that contain an equal number of protons and electrons are *neutral*, but if the balance is uneven (meaning that the particle has a positive or negative charge), the atom is known as an *ion*.

Electrons

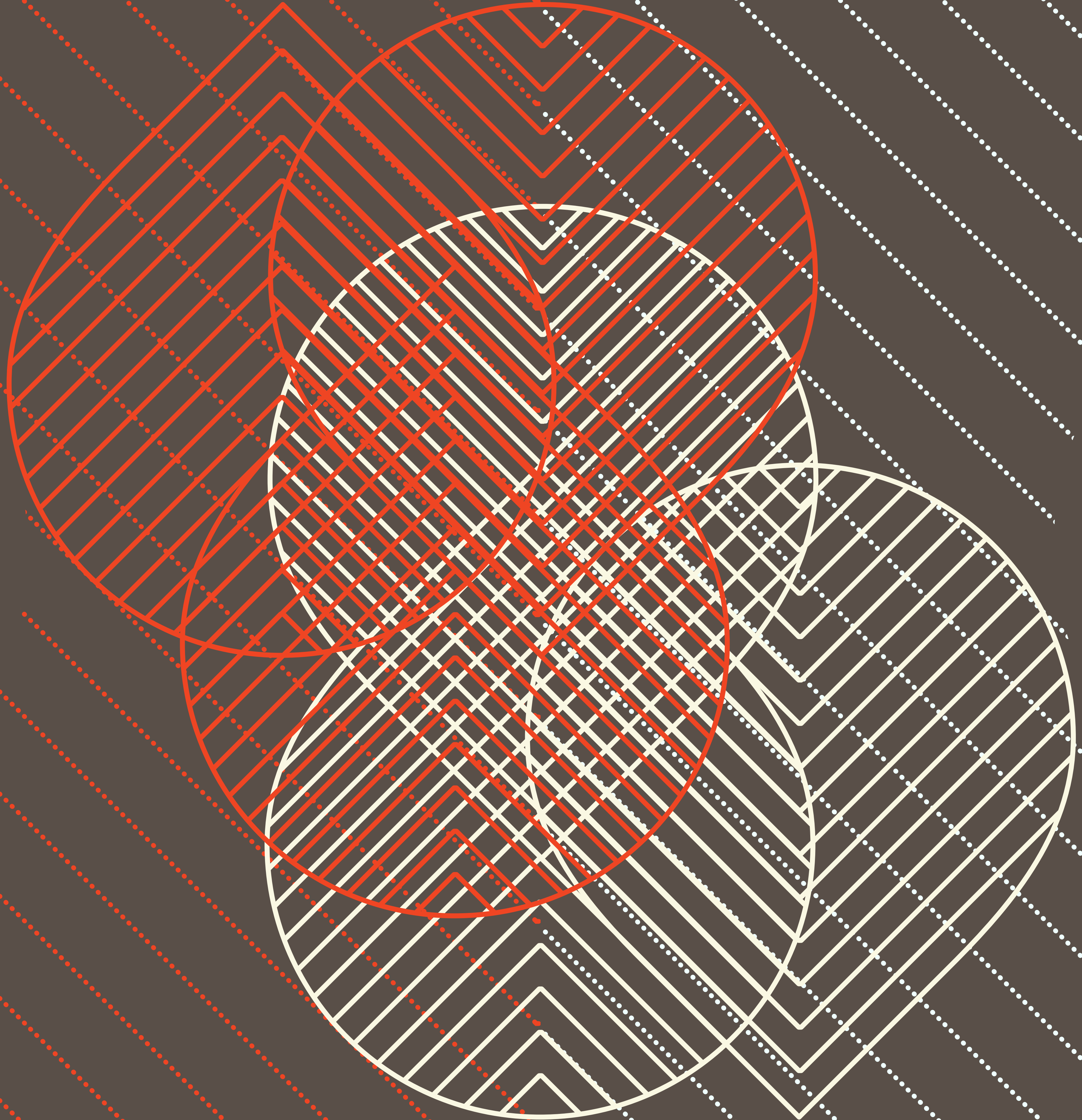
These negatively charged subatomic particles orbit the nucleus of the atom, which has a positive charge.

Molecules are ordinarily held together by *bonds* that are formed by electrons shared between two atoms.

Electrons are essential to many things including electricity, lasers, magnetism, and heat conduction.

Protons

Each proton consists of two *up quarks* and one *down quark*. Every atom has at least one proton. In the periodic table, elements are numbered according to their proton count. Protons can also be found solo, as the *hydrogen ion*.



Neutrons

The neutron is made of two *down quarks* and one *up quark*. About the size of a proton, the neutron is approximately 1,839 times the size of an electron.

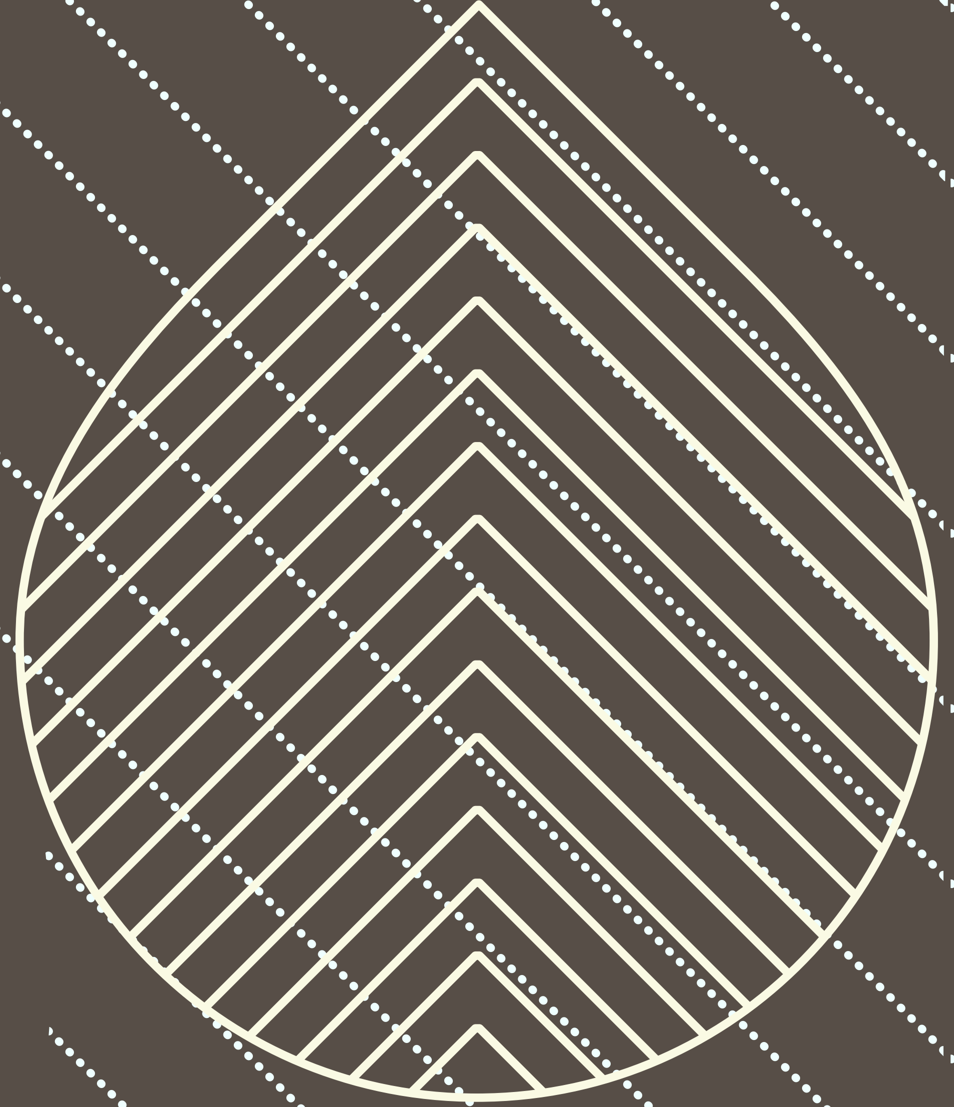
The only atom that does not have a neutron is *hydrogen*. Unlike protons, neutrons are unstable on their own.

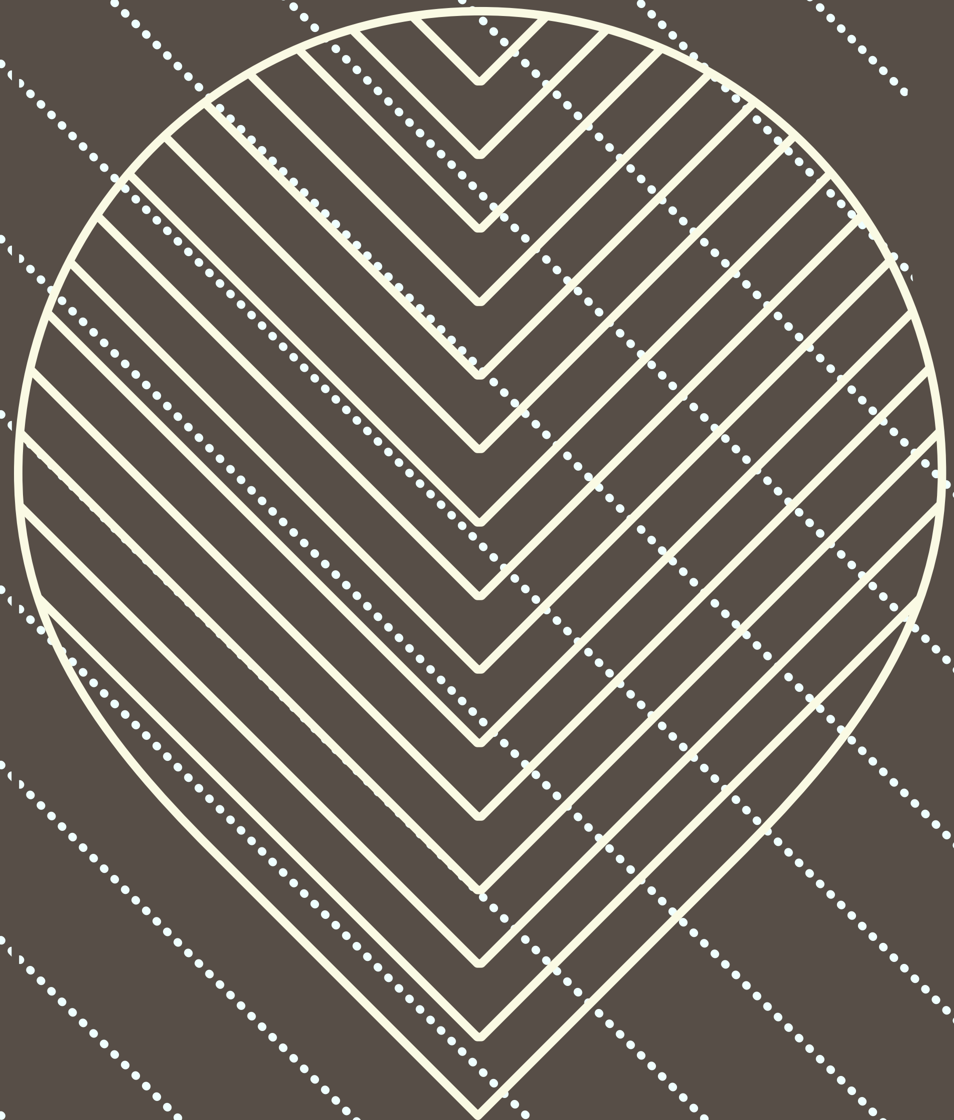
Quarks

The unusual name *quark* is meant to mimic the sound of a duck, and its spelling is derived from a James Joyce novel.

Quarks are elementary particles that can only be found within *hadrons*, which are composite particles (like protons and neutrons).

There are six types or *flavors* of quarks. *Up* and *down quarks* are the most common. As of 1995, every flavor of quark has been observed.





Up { u }
2/3 || 2.4 MeV

Charm { c }
2/3 || 1.27 GeV

Top Quark { t }
2/3 || 171.2 GeV

Flavors of Quarks

There are six types of quarks, which are known as *flavors*.
All quarks have a *spin* of 1/2.

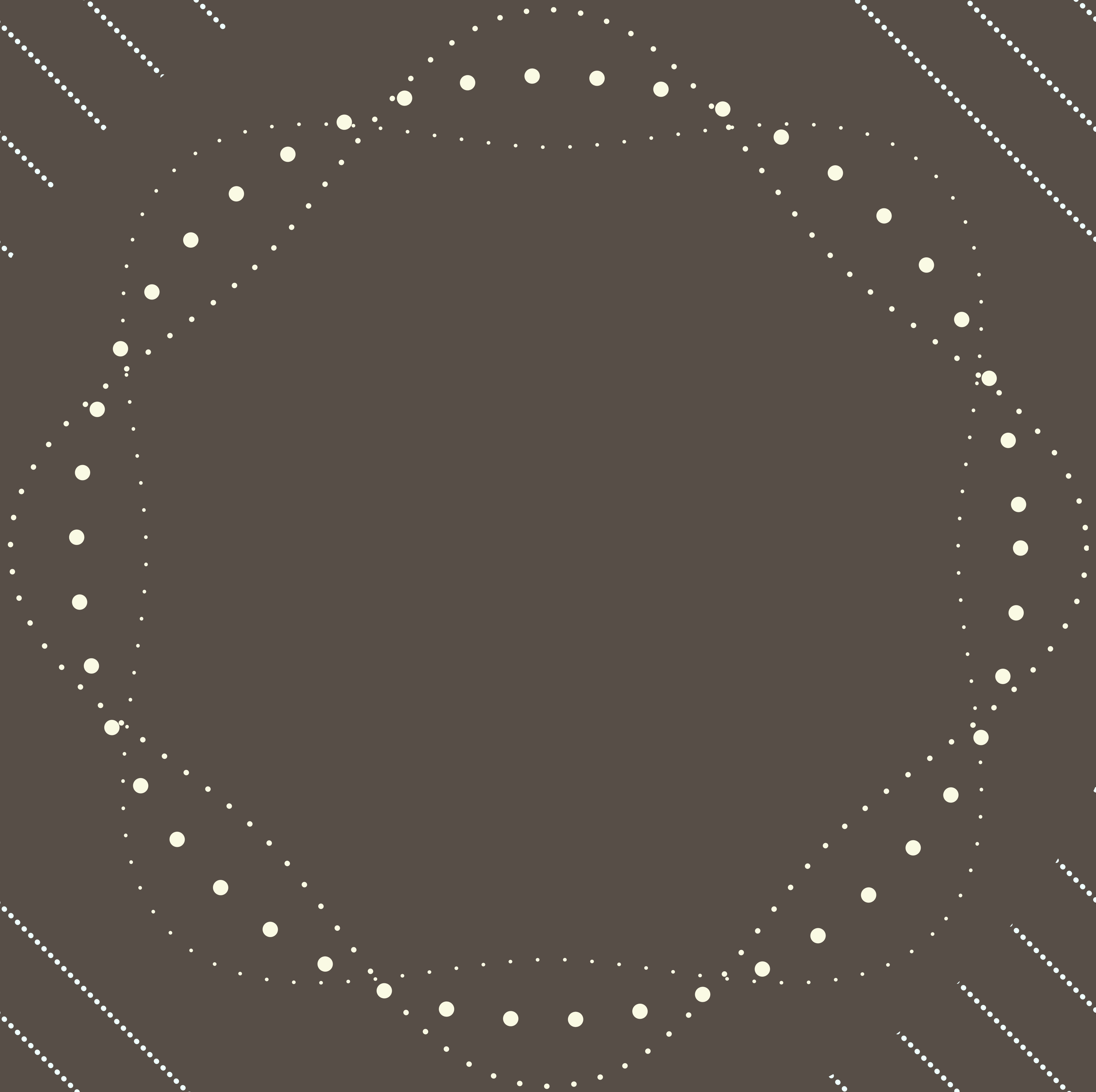
Symbol

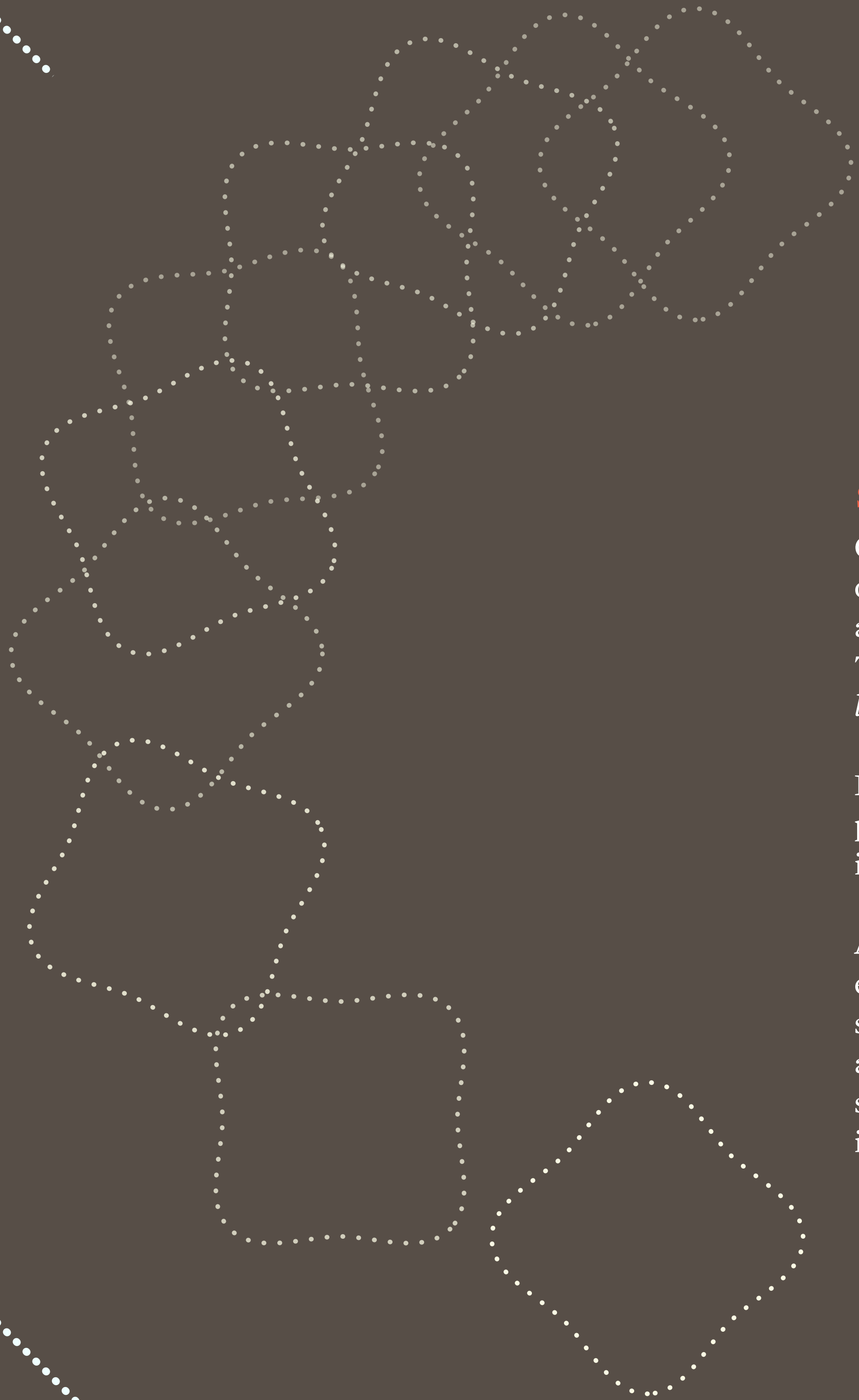
Quark's Name { Symbol }
Charge || Mass

Down { d }
– 1/3 || 4.8 MeV

Strange { s }
– 1/3 || 104 MeV

Bottom { b }
– 1/3 || 4.2 GeV





Strings

Quarks, electrons, protons, and the other particles in the standard model are all theorized to consist of strings. These strings are *one dimensional loops* that vibrate rapidly.

Differences between string vibration patterns may explain why variations in particle properties exist.

Although physicists are able to explore mathematical models of string theories, they currently face a major obstacle. The incredibly small scale of strings makes them impossible to observe.

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In the Standard Model

Bosons

Bosons are fundamental particles that are generally thought of as *force carriers*, or the messengers for the fundamental forces of nature.

Particles exert forces upon one another through the exchange of bosons. For example, the two *weak force* bosons *mediate* (enable) particle interactions involving the *weak force*.

Some bosons have an *intrinsic mass* of zero, or no inherent mass.

Fermions

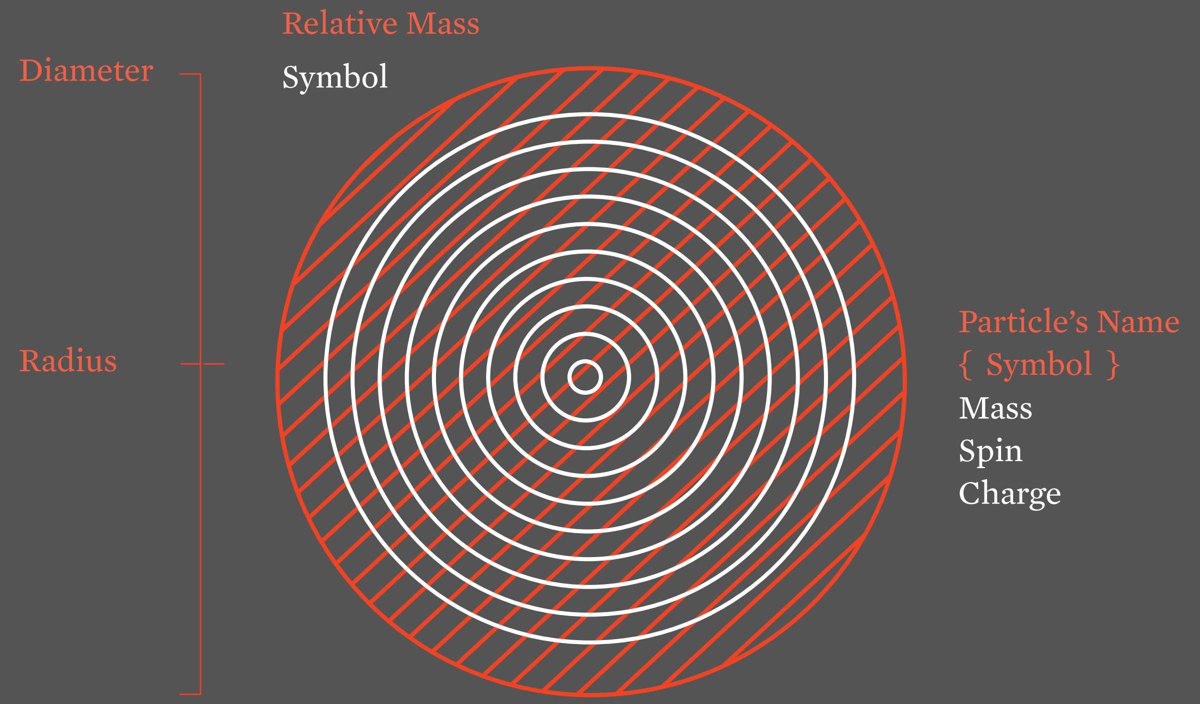
There are two types of fermions, known as *leptons* and *quarks*.

In contrast to bosons, fermions are generally associated with matter.

Atoms are built of fermions but are held together and affected by forces which are mediated by bosons.

Elementary Particles

{ By Mass }



Elementary Bosons

{ Force Particles }

Weak Force
{ w }
80.4
+/– 1
1

Weak Force
{ z }
91.2 GeV
0
1

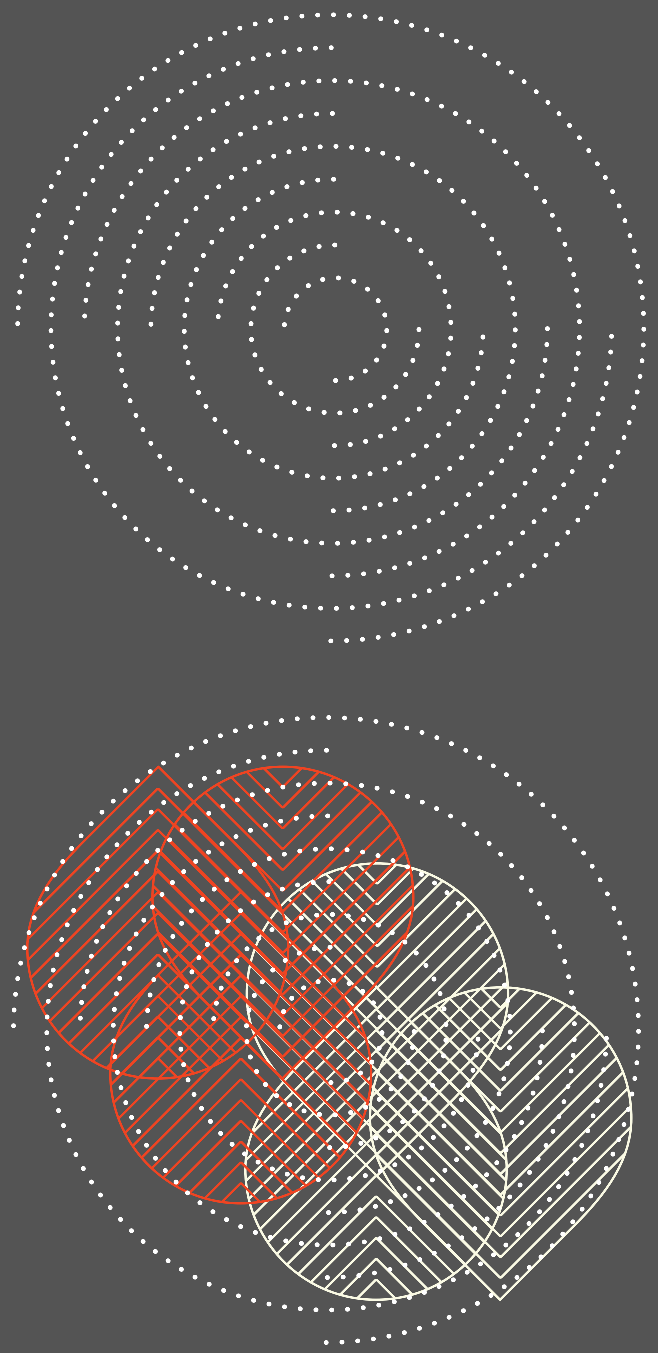
Gluon
{ g }
0
0
1

Photon
{ Y }
0
0
1

Massless Bosons

Gluons

Gluons play an indirect role in the *binding* of protons and neutrons in the nucleus of the atom by mediating *strong force* interactions that occur between quarks.



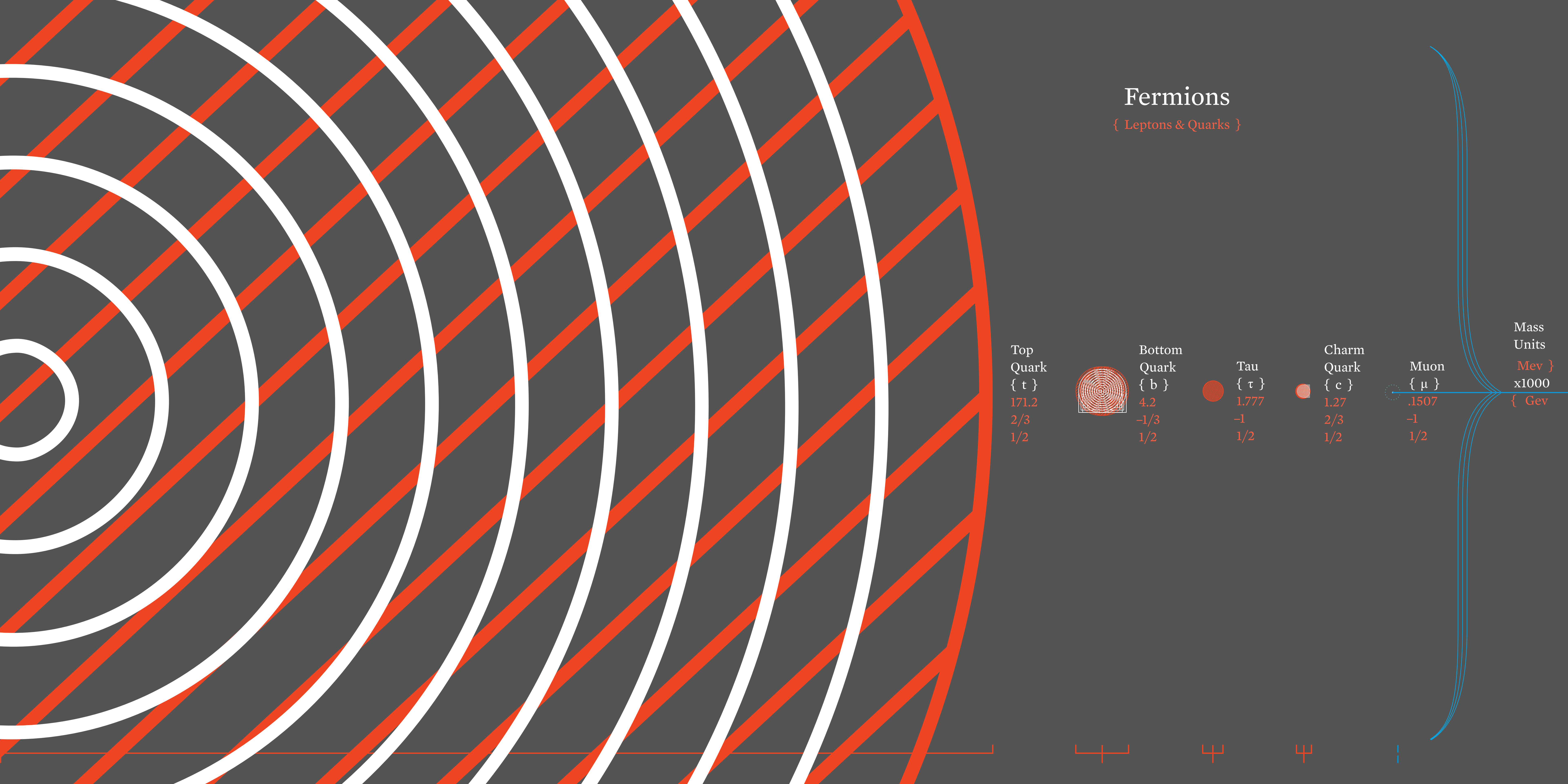
Photons

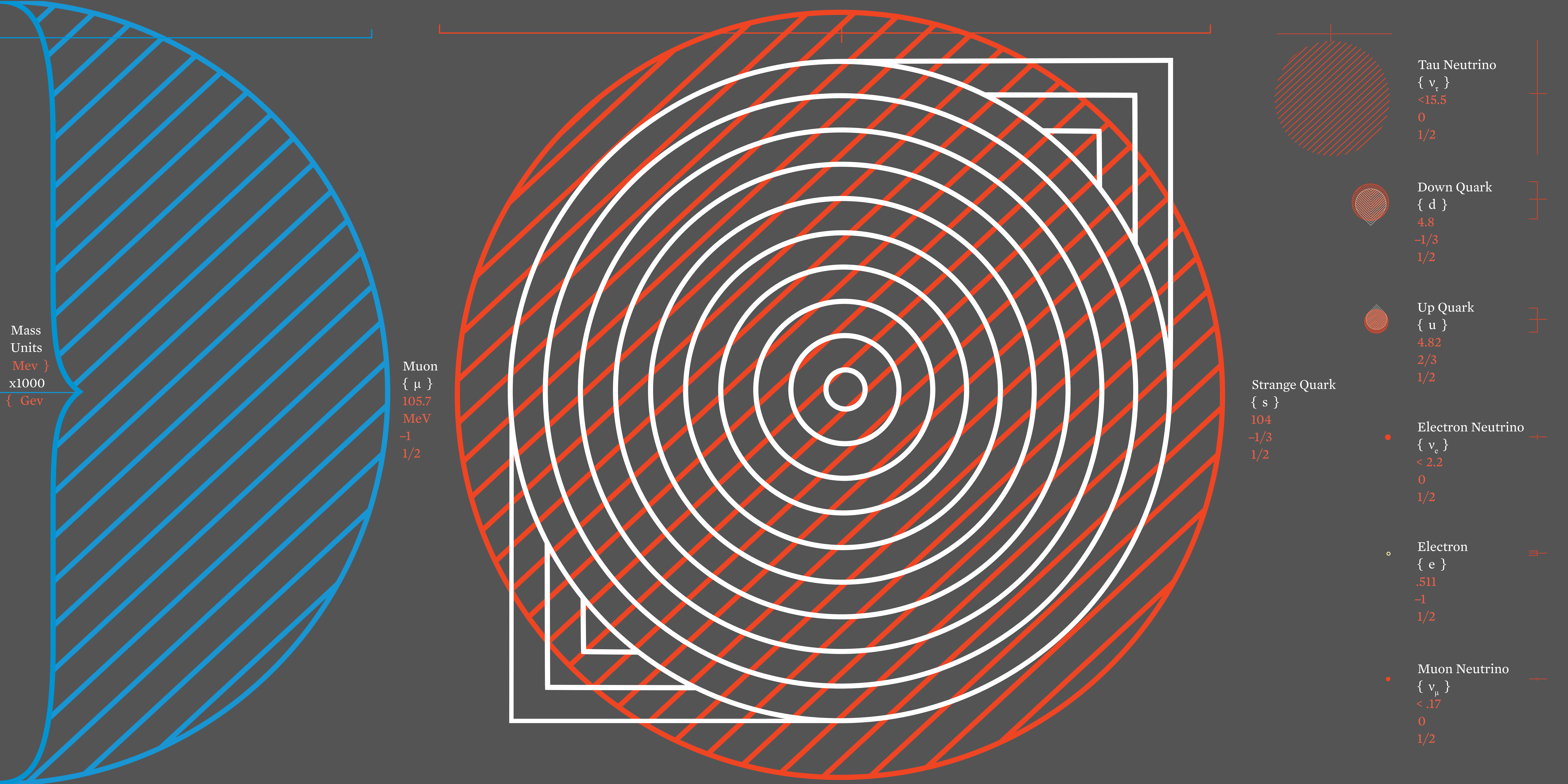
Photon literally means *light unit*. In our eyes, photons are read as light while different *wavelengths* are detected as different colors.

Photons are massless particles and have no electric charge. They exhibit *wave-particle* properties and travel through space at the *speed of light*.

Fermions

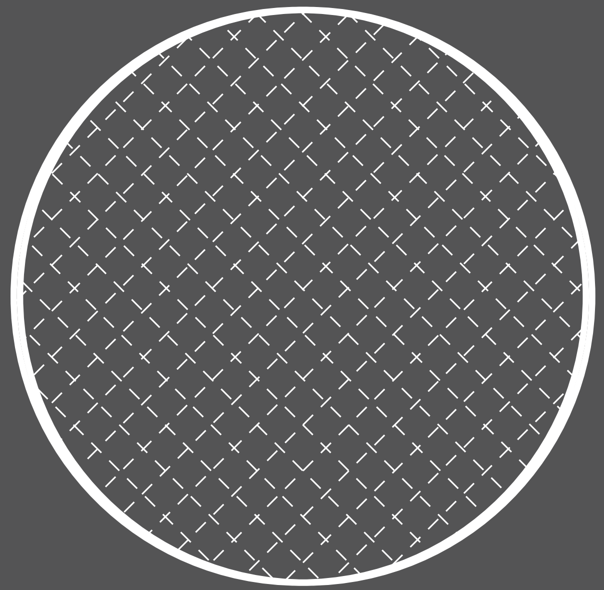
{ Leptons & Quarks }




Mass
Units
Mev }
x1000
{ Gev
Muon
{ μ }
105.7
MeV
–1
1/2
Strange Quark
{ s }
104
–1/3
1/2
Tau Neutrino
{ ν_τ }
<15.5
0
1/2
Down Quark
{ d }
4.8
–1/3
1/2
Up Quark
{ u }
4.82
2/3
1/2
Electron Neutrino
{ ν_e }
< 2.2
0
1/2
Electron
{ e }
.511
–1
1/2
Muon Neutrino
{ ν_μ }
< .17
0
1/2

Theoretical Particles

{ Unobserved }

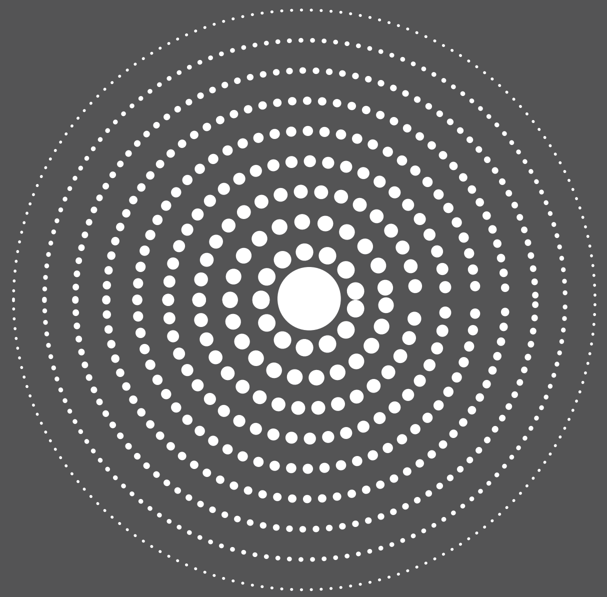


The Graviton

The graviton is a theorized massless particle that mediates the force of *gravity* in the same way that other particles mediate other forces.

Individual gravitons are impossible to observe, but the presence of *gravitational waves* would imply the particle's existence.

Modifications to the standard model that include the graviton encounter difficulty in high energy situations. It is possible that these issues may be related to the larger problem of the disparity between quantum physics and general relativity.



The Higgs Boson

It's often called *The God Particle*. Although it would be a significant discovery, many physicists feel the name is overly grandiose given the particle's actual significance.

The existence of a *higgs field* would provide an explanation for why particles have mass. This is an exciting prospect, which is why the detection of this theoretical particle is at the center of modern experimentation.

Concluding whether this particle exists is essential to developing modern theories. As it is possible there may be no higgs boson, *higgs-less models* that do not include the particle also exist. Some extensions of *supersymmetry*, on the other hand, suggest that several types of higgs particles may exist, perhaps an entire family.

Are We in a Higgs Field?

It is theorized that a higgs field permeates all of space, and that we are effectively immersed in a vast ocean of *higgs particles*.

As a particle moves through space, the field *clusters* around it, giving the the particle its mass. This *higgs mechanism* is often compared to a celebrity moving through a party; as they walk by, people gather, but once they're gone, the crowd vanishes.

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In a Lab

Antimatter

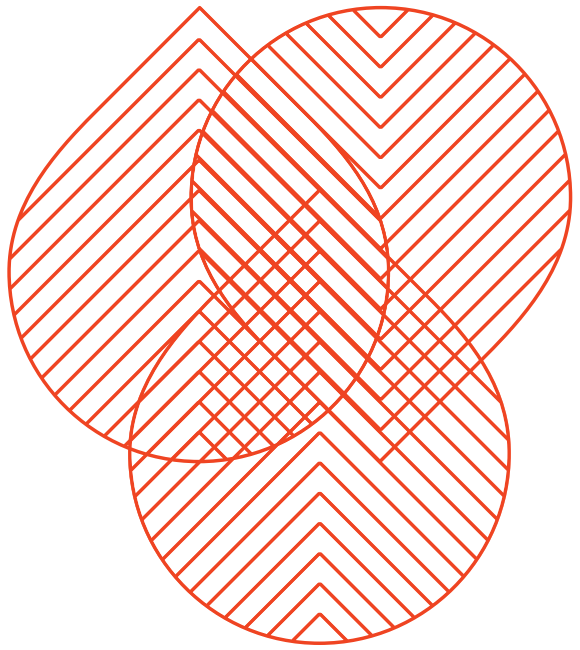
Practically all observable matter appears to be *ordinary matter* rather than antimatter. The cause of this *asymmetry* between the two is still undetermined, and remains a major question in physics.

Antimatter, as the name suggests, is the *antiparticle* of matter. It is produced artificially so that its properties and behaviors can be studied in hopes of uncovering nature's fundamental laws.

Antimatter also has a practical application in medical imaging. PET scans are made possible by the electron's antiparticle, the *positron*.

Currently, antimatter production is very expensive, and we have no way of collecting the antimatter that occurs naturally in space. At a cost ranging from $25 billion to $62.5 trillion per gram, it's been said that antimatter is the most expensive substance on the planet.

Proton



Consists of
2 Up Quarks
1 Down Quark

Antiproton

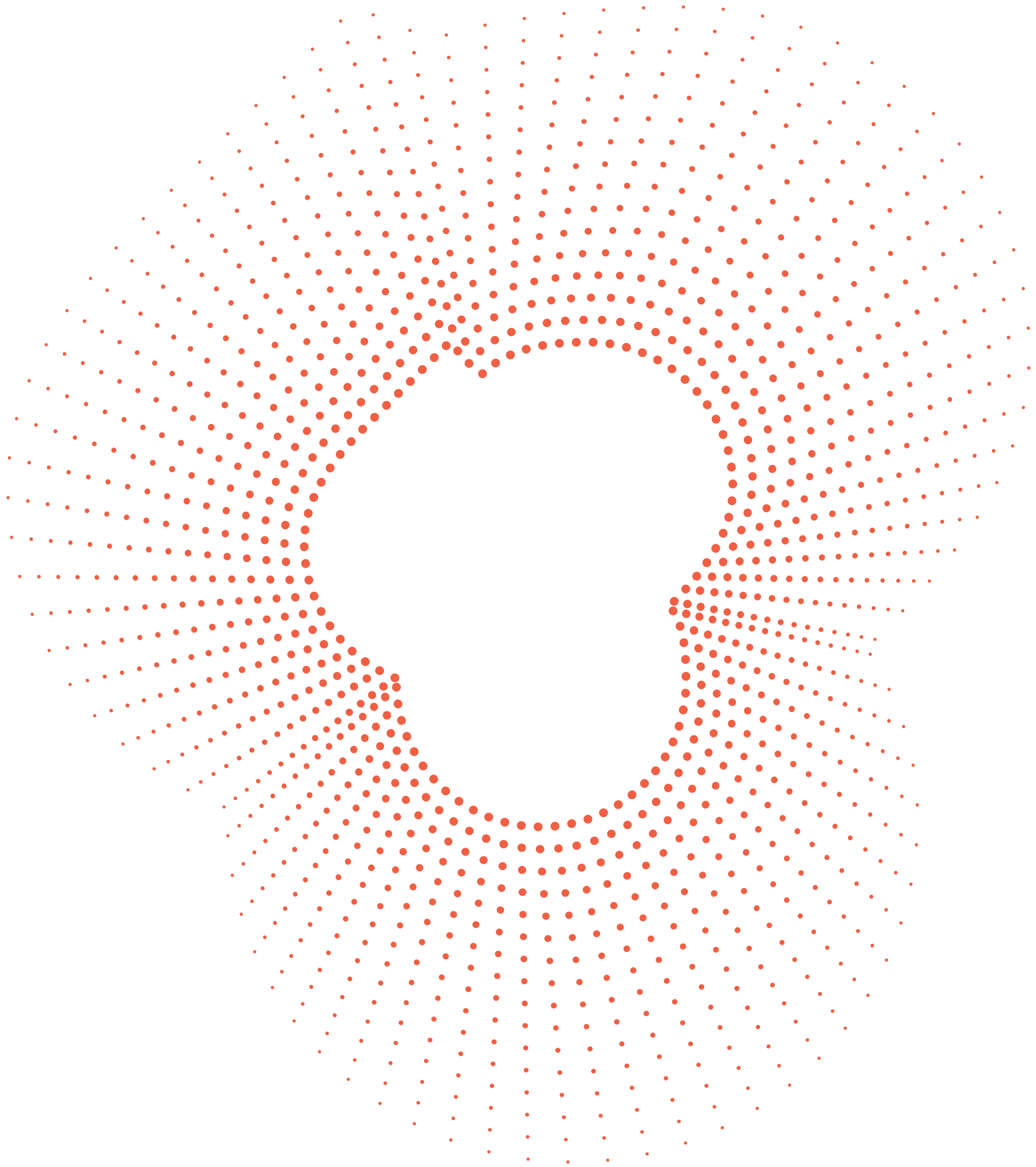
Consists of
2 Anti Up Quarks
1 Anti Down Quark

Annihilation

When matter and antimatter come into contact, both are *annihilated*. The mass of the particles is released as kinetic energy, gamma rays, or pairs of loose particles and antiparticles.

Although annihilation produces energy, antimatter has no potential as a fuel source due to its scarcity. All of the antimatter ever produced would only be enough to keep a single light bulb illuminated for mere minutes.

The short supply of antimatter also eliminates the possibility of its use as a weapon. Although the substance is potentially dangerous, it would take billions of years to produce enough antimatter to pose a threat.



The Large Hadron Collider

{ In Use Since 2008 }

Atom Smashers

To learn about particles, we study their collisions. By colliding particles at high speeds, the large hadron collider will create conditions similar to those just after the *big bang*. This provides a way of studying what the first seconds of the universe may have been like.

There are several experiments set to run in the collider, and many problems in modern physics will receive clarification.

Controversy

The collider gained media attention when it was postulated that the machine's potential to form *microscopic black holes* could destroy the world. However, any black holes that could form would be harmless, destined to disintegrate instantaneously.

Claims have also been made that the collider's many setbacks could have been caused by time traveling saboteurs in hopes of preventing a dangerous discovery.

Purposes

The collider will search for evidence of the *higgs boson* and *higgs fields*. These could provide insight into the nature of mass.

By studying the differences in the behavior of matter and *antimatter*, we hope to understand the apparent imbalance between the two.

The collider will also mimic and study conditions of matter in the very early universe.

It will search for signs of *dark matter* and *dark energy*, which are predicted to make up 96% of the universe.

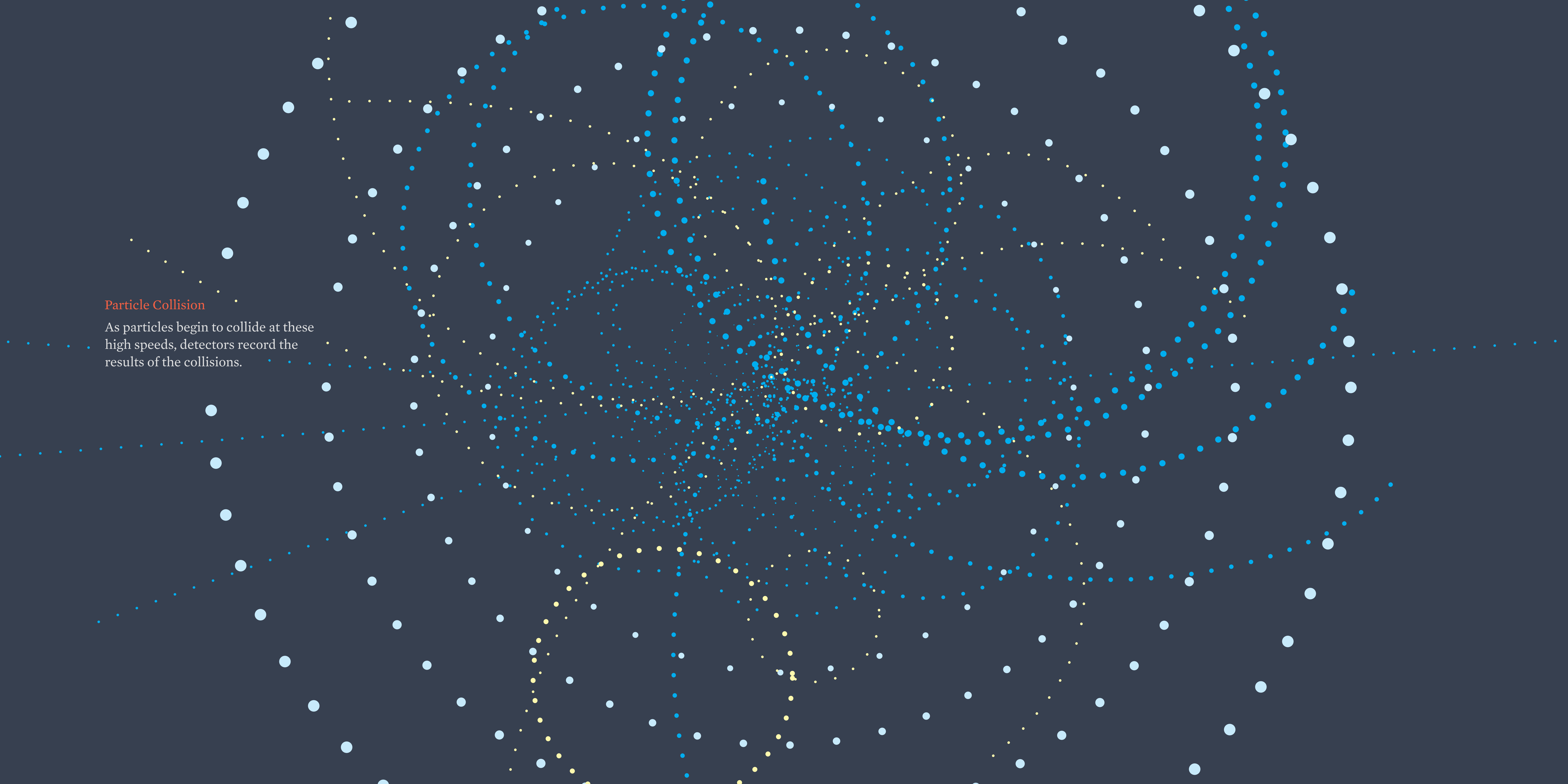
Should they exist, it may be possible to detect *extra dimensions* of space.

In the Collider

Controlled beams of particles are streamed through the accelerator in opposite directions, gaining speed as they travel. The Large Hadron Collider can accelerate particles to a speed of only 3 meters per second less than the *speed of light*. Most experiments in this collider will be conducted using streams of photons.

Particle Collision

As particles begin to collide at these high speeds, detectors record the results of the collisions.



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In Space

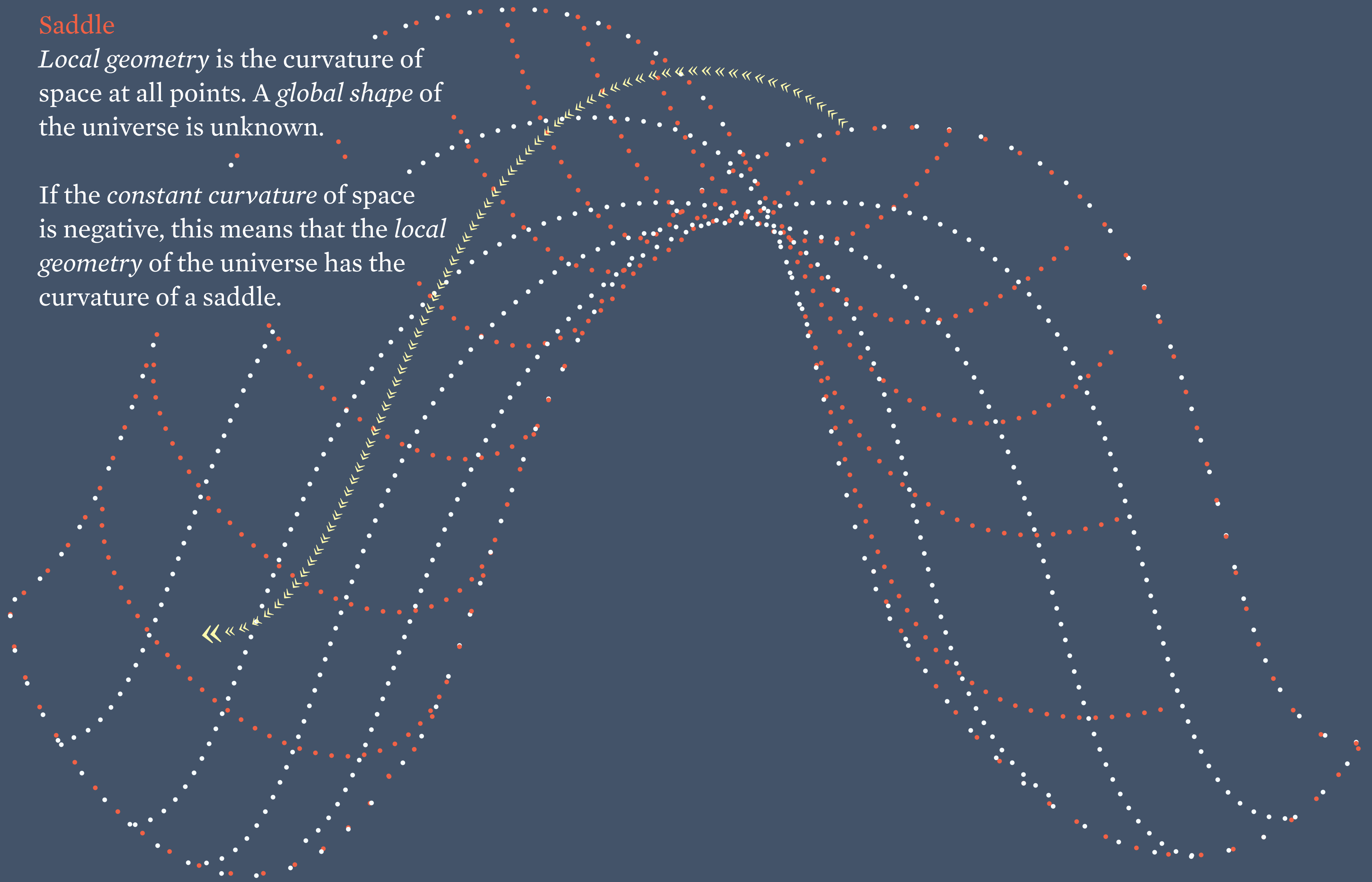
Geometry of Space

{ Three Possible Shapes }

Saddle

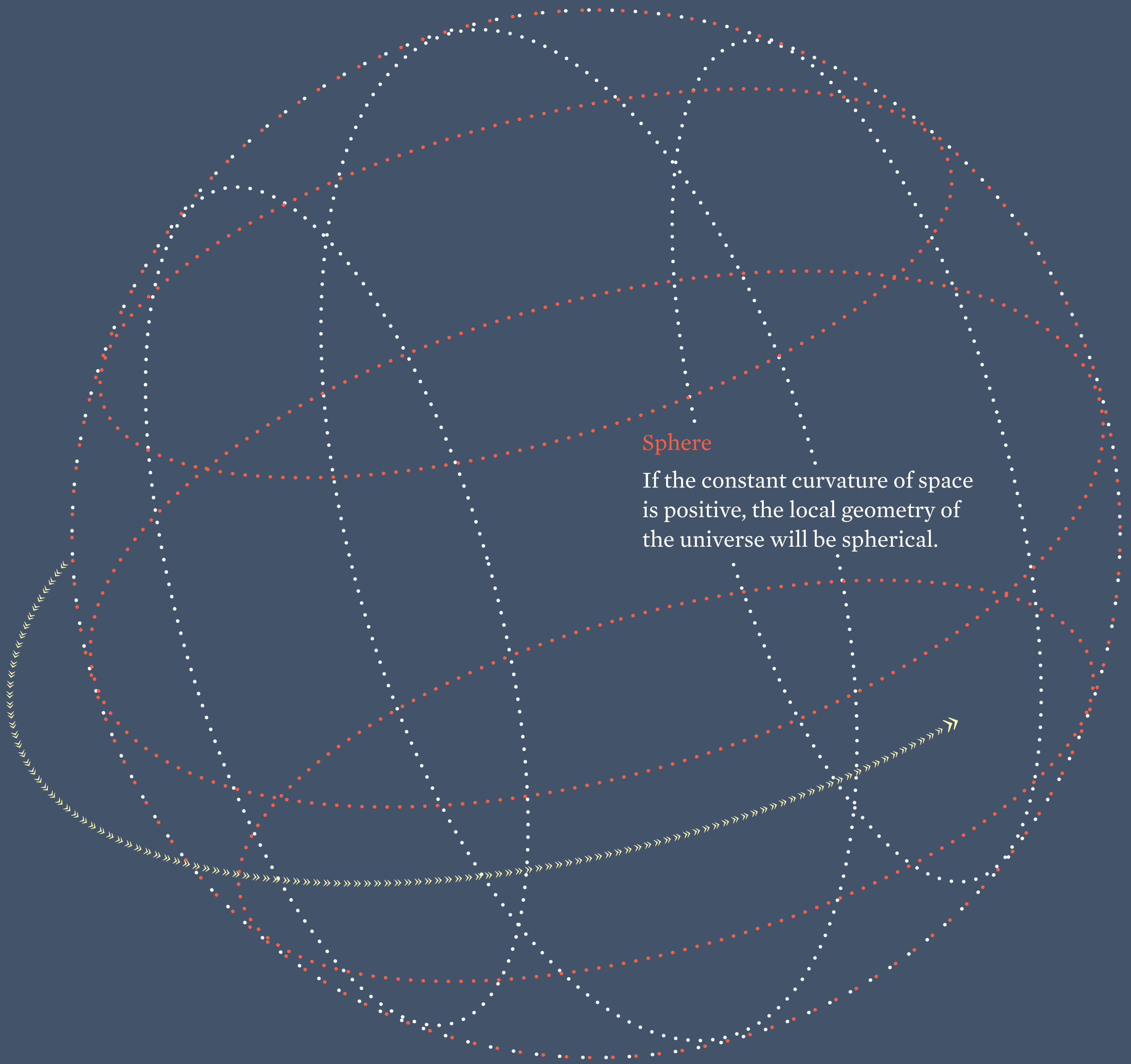
Local geometry is the curvature of space at all points. A *global shape* of the universe is unknown.

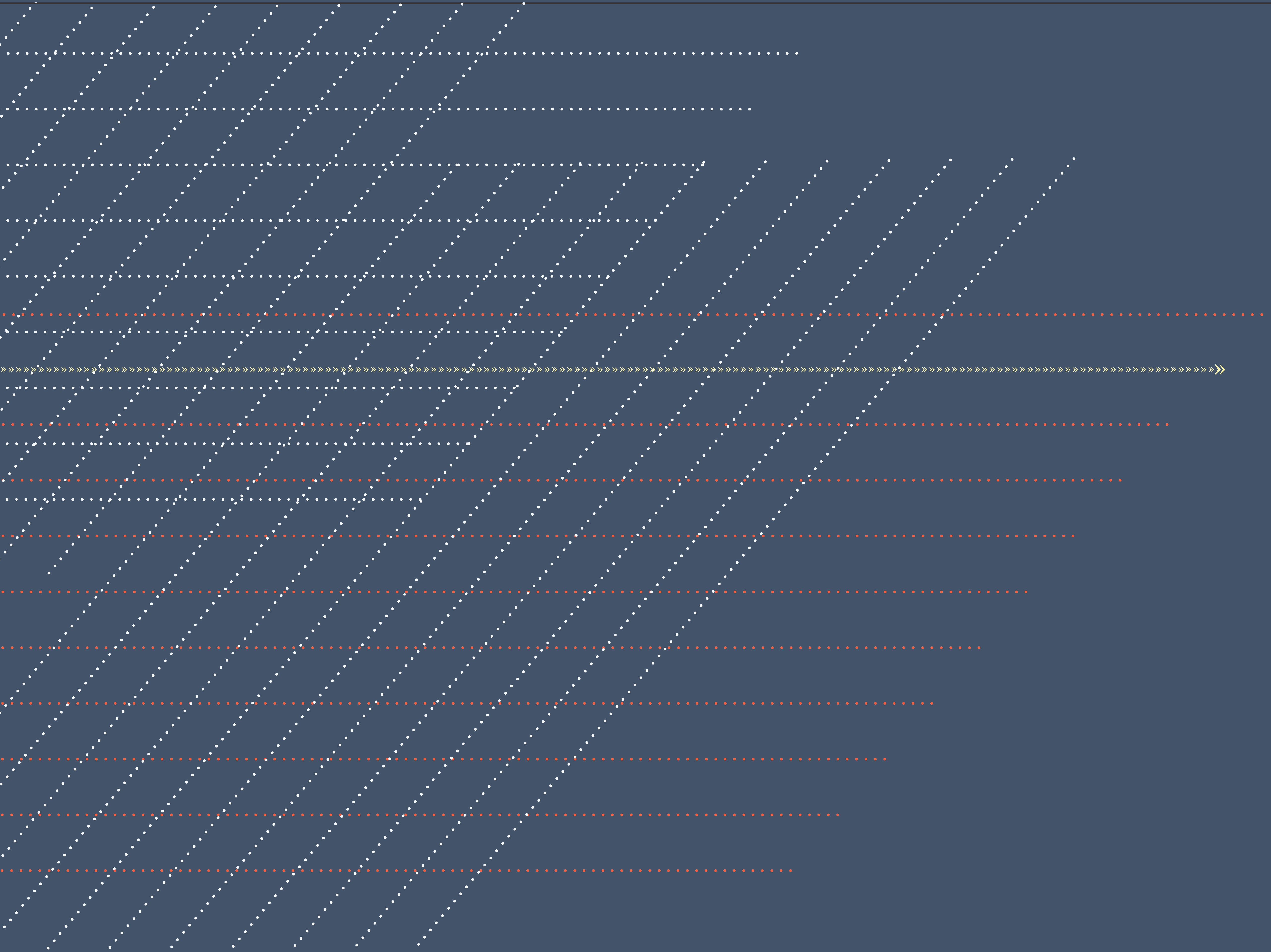
If the *constant curvature* of space is negative, this means that the *local geometry* of the universe has the curvature of a saddle.



Sphere

If the constant curvature of space is positive, the local geometry of the universe will be spherical.



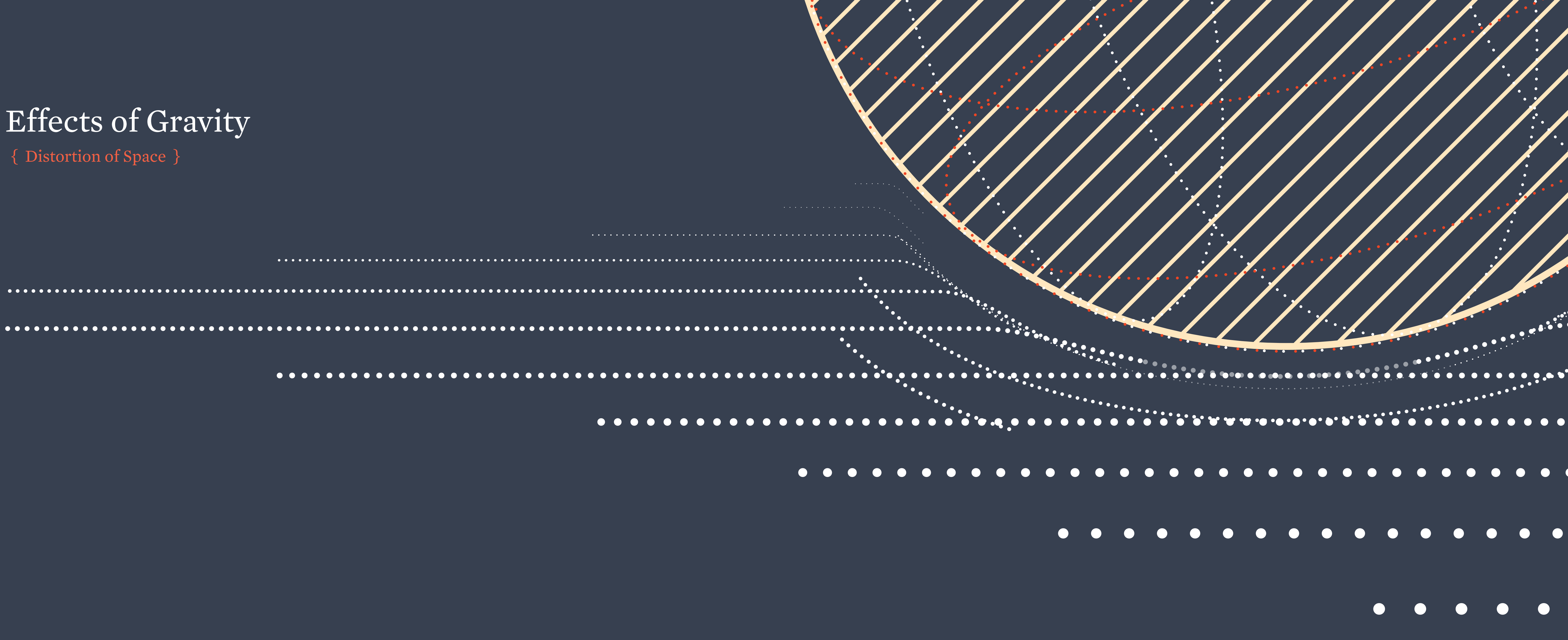


Flat

If the universe has no curvature, then its shape is *spatially flat*. Recent data (with a 2% margin of error) suggests this is the case.

The Effects of Gravity

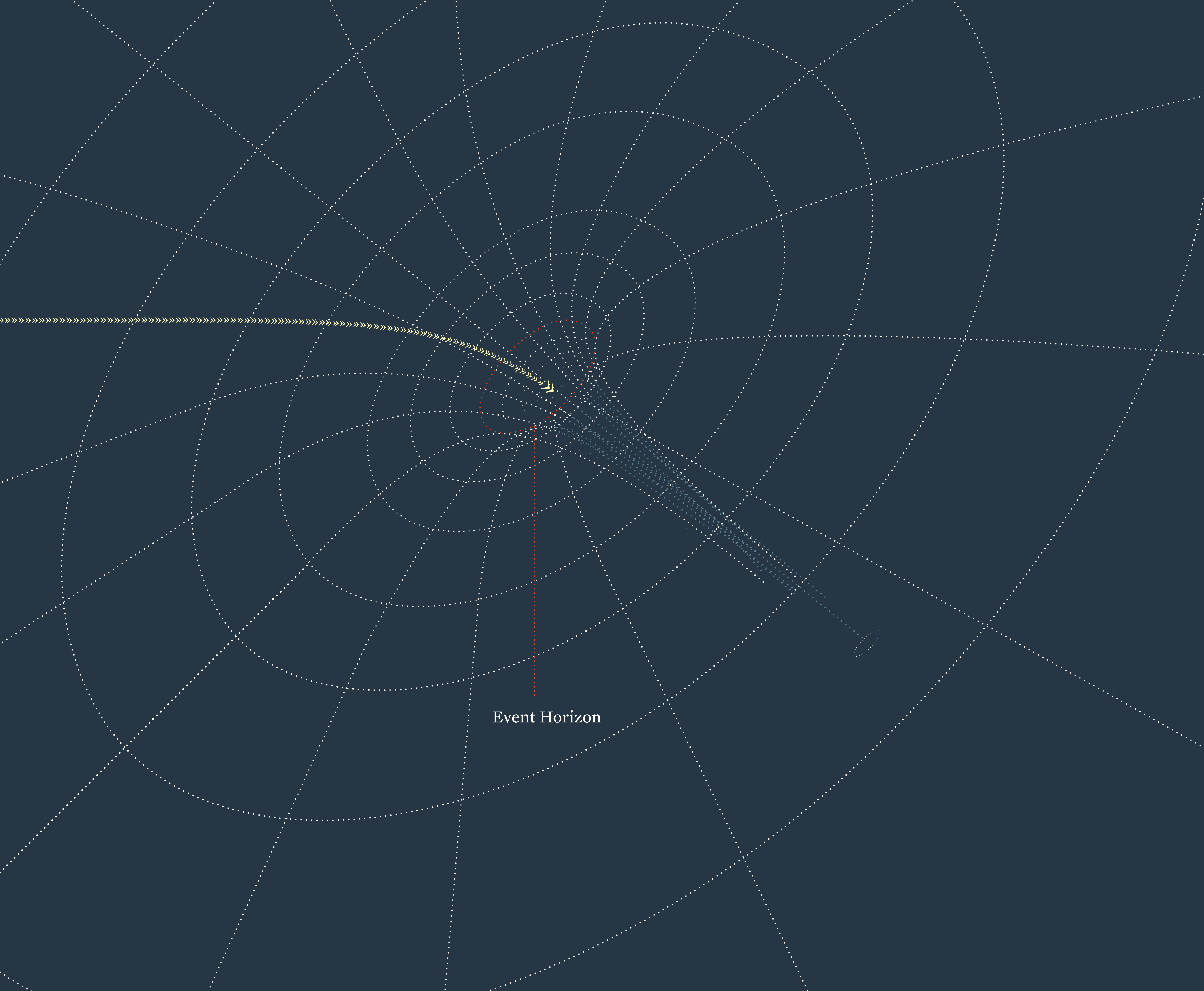
{ Distortion of Space }



Gravity and Space

The geometry of space is subject to the struggle between the universe's outward expansion and the inward pull of *gravity*. The influence of gravity varies depending on the density and mass of matter.

The gravity of large objects has an effect on the space surrounding them. When the object is high in mass and density, these effects are greater. The alteration of space by gravity has a visible effect in the light that moves past the object.



Black Holes

Black holes are regions in space that show extreme *gravitational effects*. They are caused by an object with a very dense mass.

At the mouth of the black hole lies an invisible point known as the *event horizon*. This is the point of no return. Beyond the event horizon, nothing escapes a black hole, including light. Thus, it's impossible to see what the center of a black hole actually looks like.

Although the interior of a black hole has extreme properties, outside of the event horizon its effects are ordinary. In fact, there is evidence that at the heart of our galaxy lies a *super massive black hole* that's 4 million times the size of our sun.

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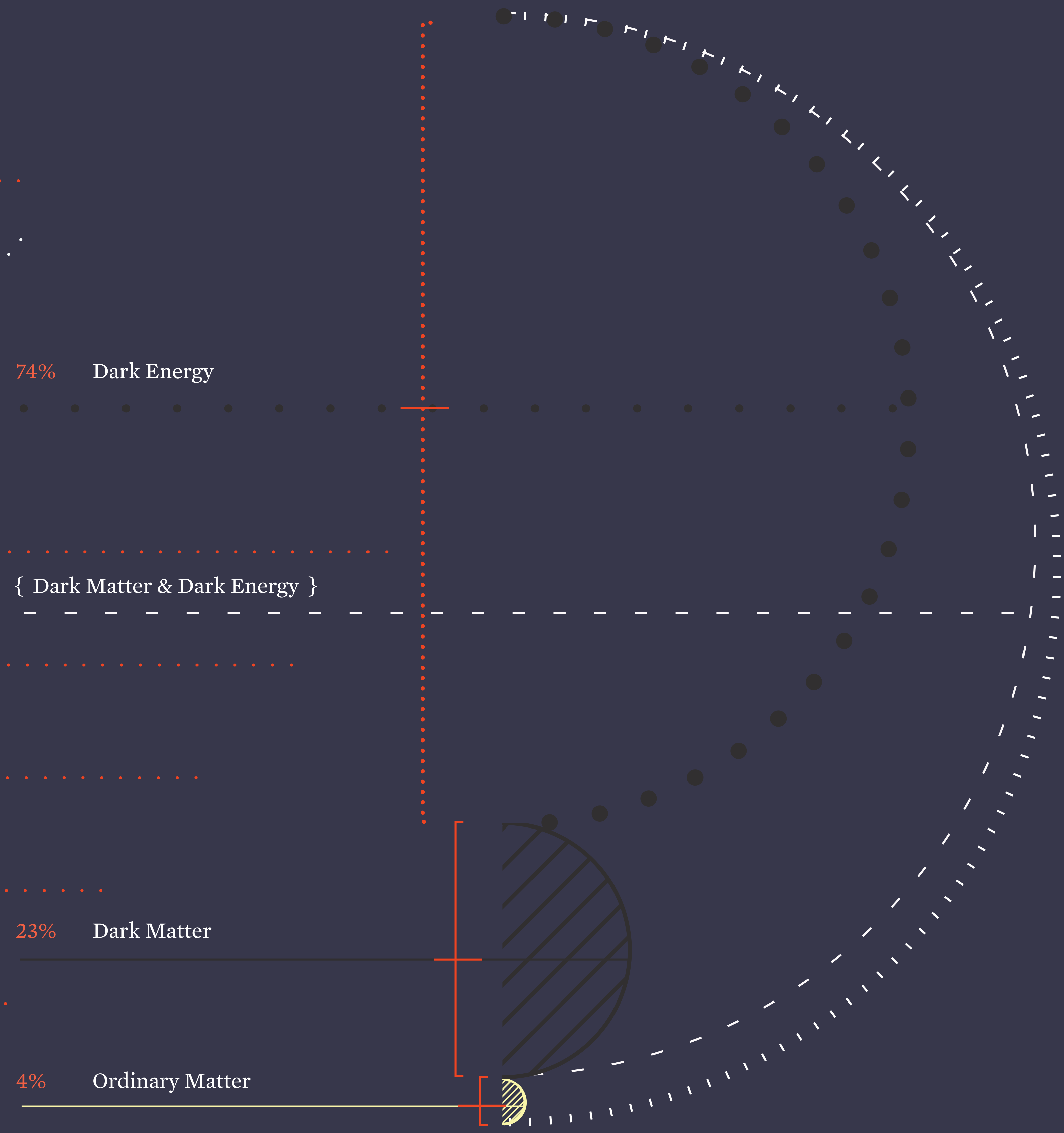
In Proportion

Matter in Space

In addition to ordinary matter, *dark matter* and *dark energy* exist in theory. Their existence is implied mathematically and evidence of each has been detected. Although neither has been directly observed, together they are thought to make up the large majority of the universe.



96% consists of dark matter and dark energy.

4% of the universe is composed of ordinary matter.

Dark Energy

Dark energy is speculated to exist throughout space. It's believed to account for nearly 2/3 of the universe's mass-energy, but it has not yet been directly detected.

It is evident through observational data that the universe is in fact *expanding,* as objects in space in every direction appear to be moving away from us at an increasing rate.

Dark energy is often cited as a possible cause for the acceleration of the universe's expansion.

Dark Matter

Unlike ordinary matter, it is believed that dark matter is not *luminous*, and does not reflect light. This could be one reason why dark matter has never been directly observed.

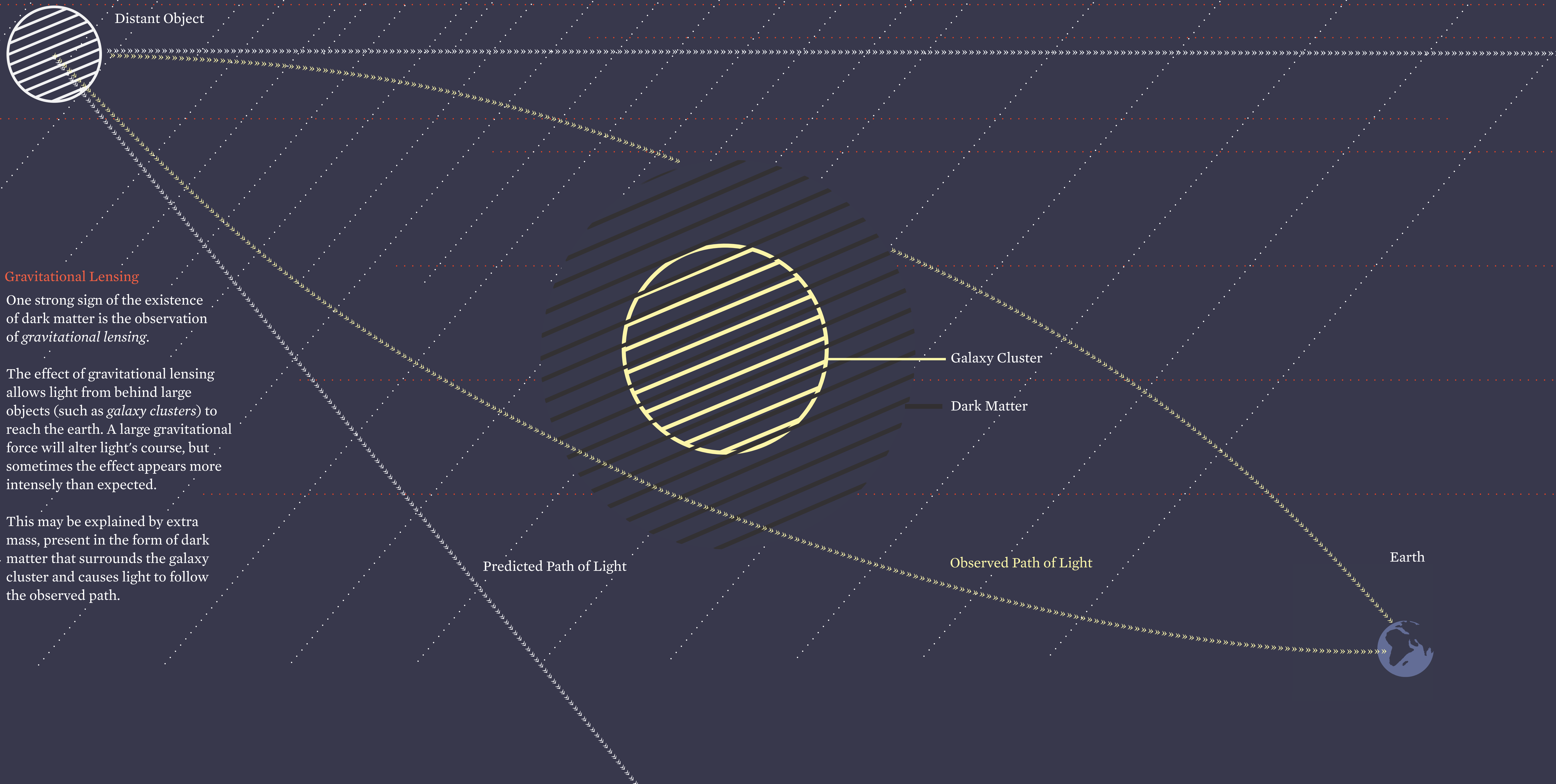
Little is known about dark matter and its nature.

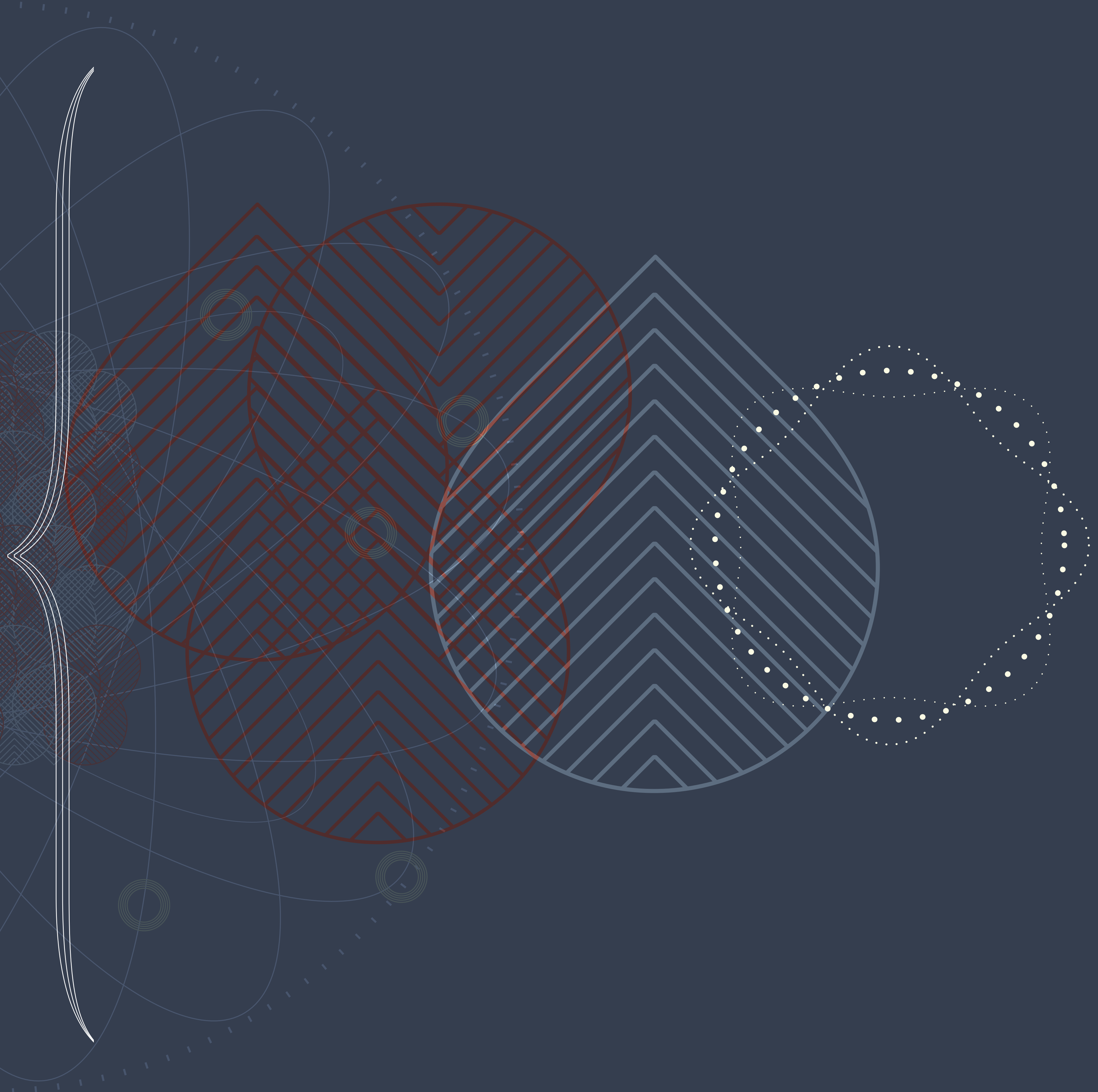
Gravitational Lensing

One strong sign of the existence of dark matter is the observation of *gravitational lensing.*

The effect of gravitational lensing allows light from behind large objects (such as *galaxy clusters*) to reach the earth. A large gravitational force will alter light's course, but sometimes the effect appears more intensely than expected.

This may be explained by extra mass, present in the form of dark matter that surrounds the galaxy cluster and causes light to follow the observed path.





"The universe is full of magical things patiently waiting for our wits to grow sharper."

{ Eden Phillpotts }