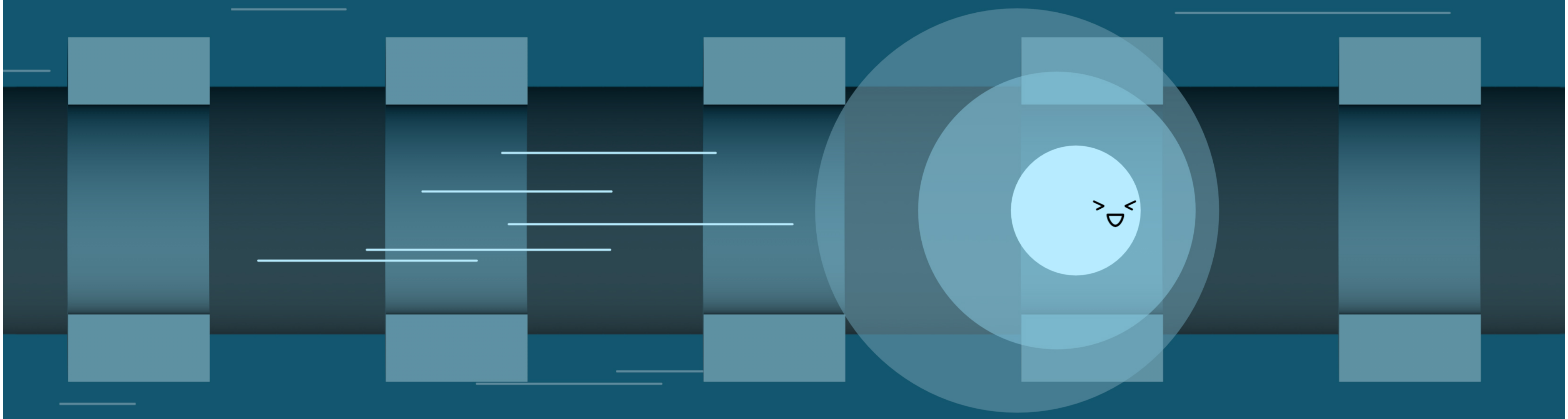
symmetry's

ABCs

of

particle physics

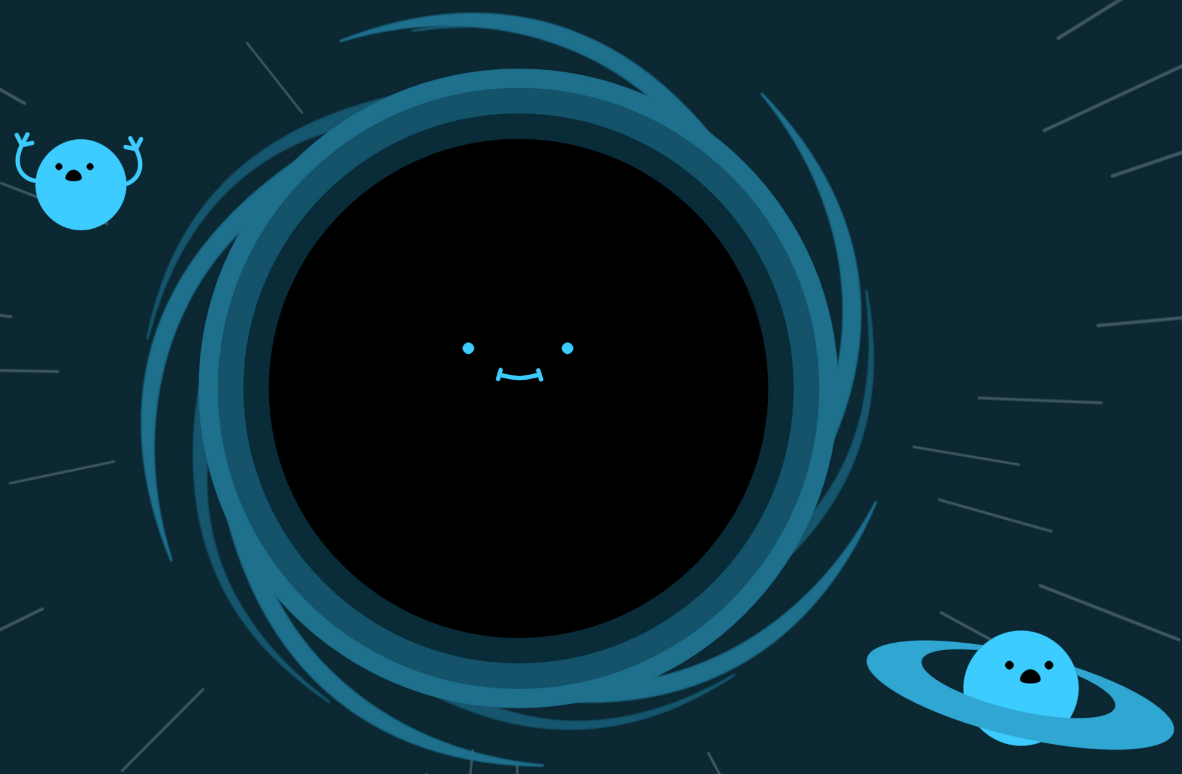
A



is for accelerator, which makes things move fast.

Accelerators take tiny particles and speed them up. They can smash particles into a piece of matter or make two particles collide head on. They are in operation around the world, serving medicine, industry, energy, the environment, national security, and discovery science. In particle physics research, scientists use accelerators to discover new particles and explore how the universe works.

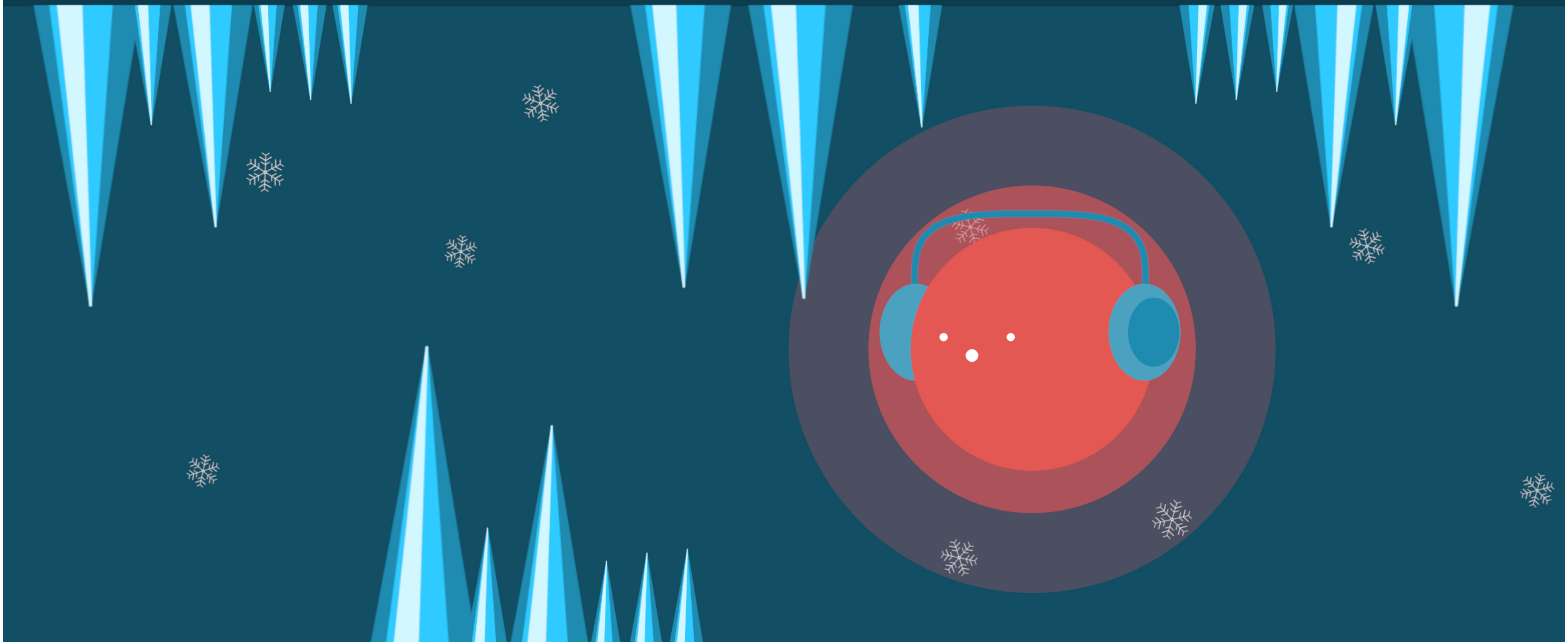
B



is for black holes, which have lots of mass.

Black holes are extremely dense, with so much gravity that even light cannot escape them. Within a black hole, the known laws of physics go out the window. Scientists think there could be around 100 million black holes within the Milky Way galaxy and estimate billions upon billions more in the universe.

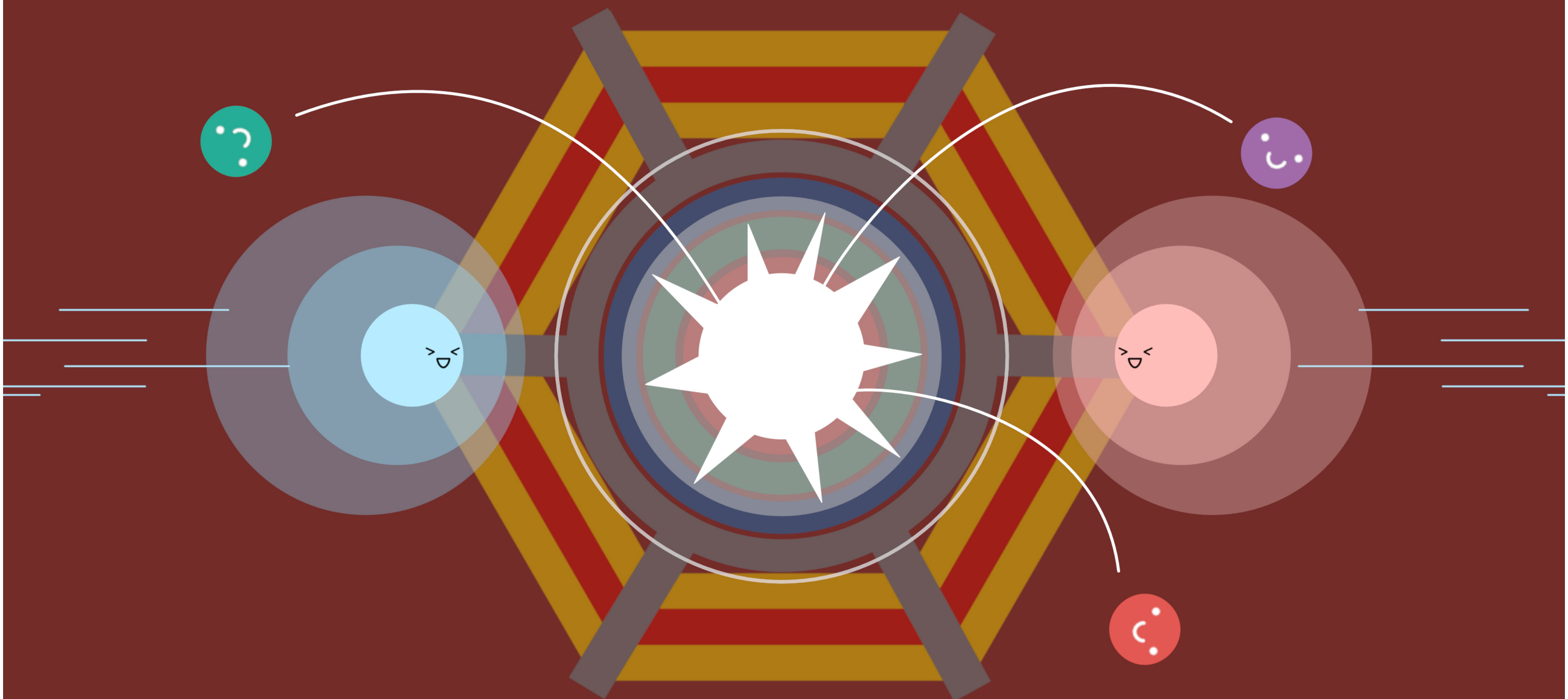
C



is for cryostat, so icy and cold!

A cryostat is an apparatus that keeps things very cold. Many pieces of particle physics experiments work only when they're chilled to very low temperatures, as little as a few degrees above absolute zero. Cryostats keep superconducting materials cold enough to conduct electricity without resistance, and they can keep particle detectors cold enough to register even the most miniscule deposits of energy from particles such as dark matter.

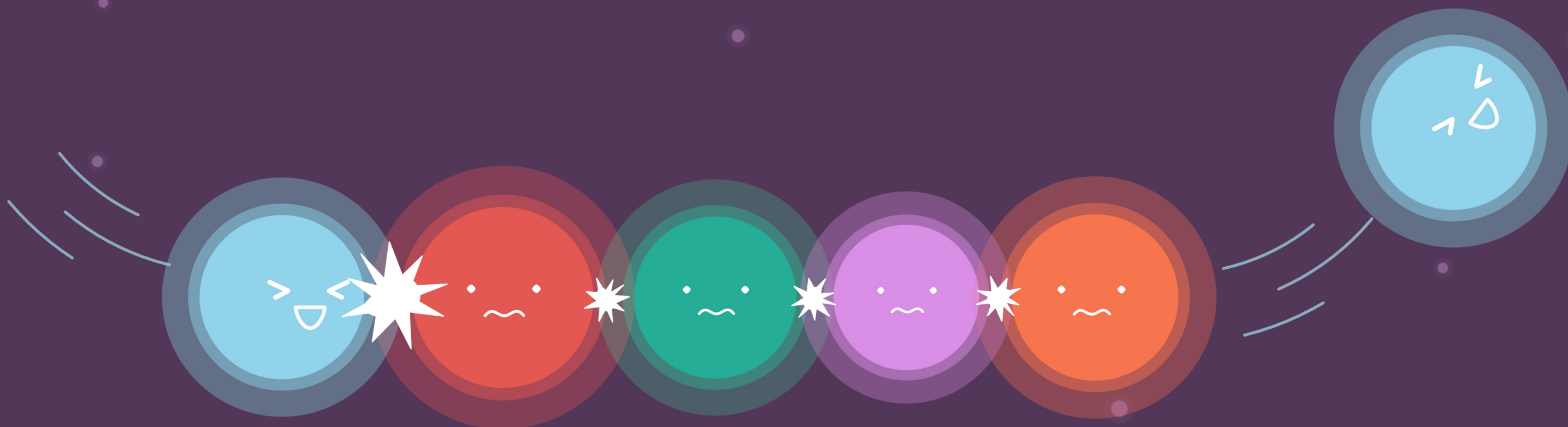
D



is for detector, where collisions unfold.

Particle detectors are scientists' windows to the subatomic world. When a particle hits a detector, it gives up information such as its energy, direction, speed and electric charge. Detectors are often made up of multiple layers and devices to measure these different aspects of the particles they study and to figure out the identity of the particles they detect.

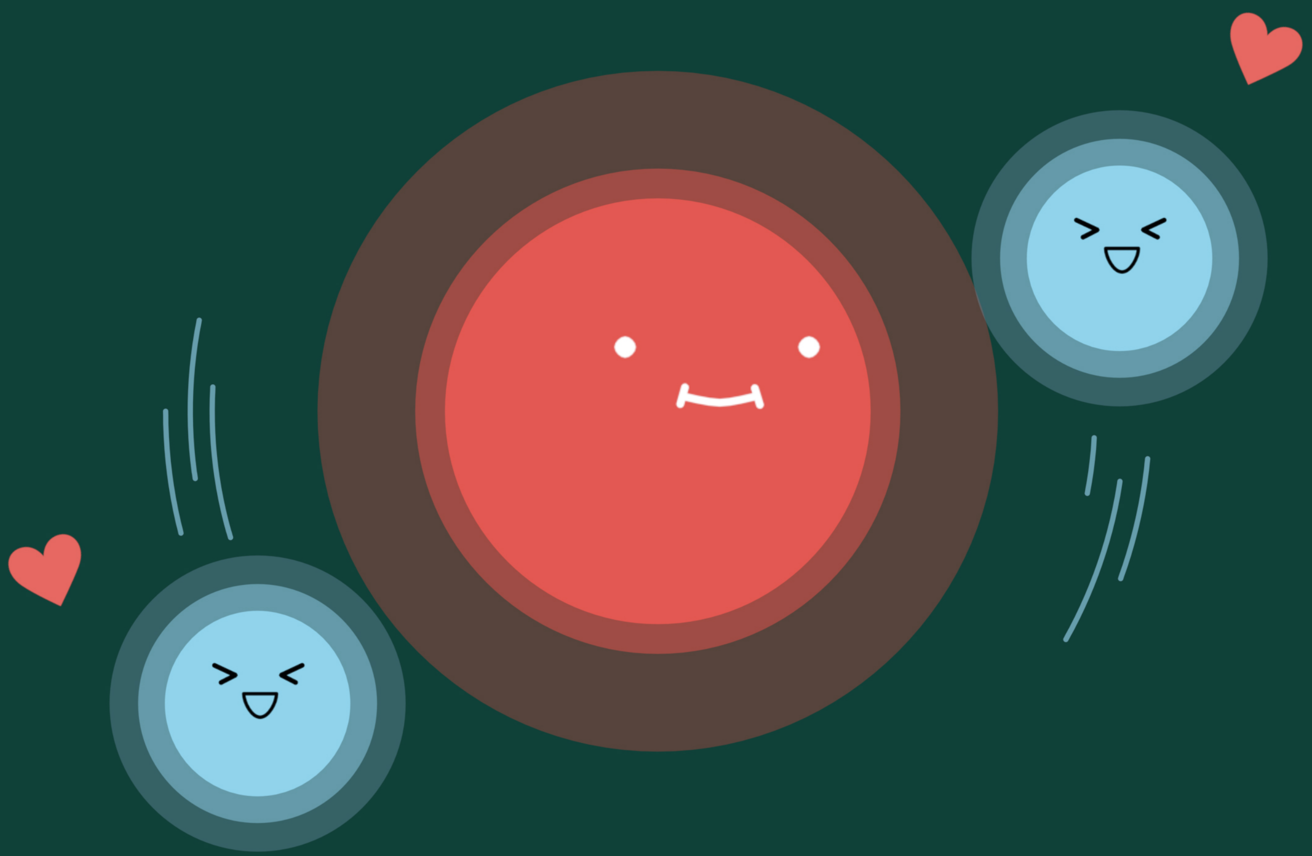
E



is for energy, which must be conserved.

Energy comes in many forms, and the total amount of energy in a reaction is always conserved–which is great news for particle physicists. By measuring the energy that comes out of particle collisions, scientists can determine whether it is equal to the energy that went into them. If it's not, some of that energy might have been carried away by something hard to detect, such as a neutrino.

F



is for forces, making particles swerve!

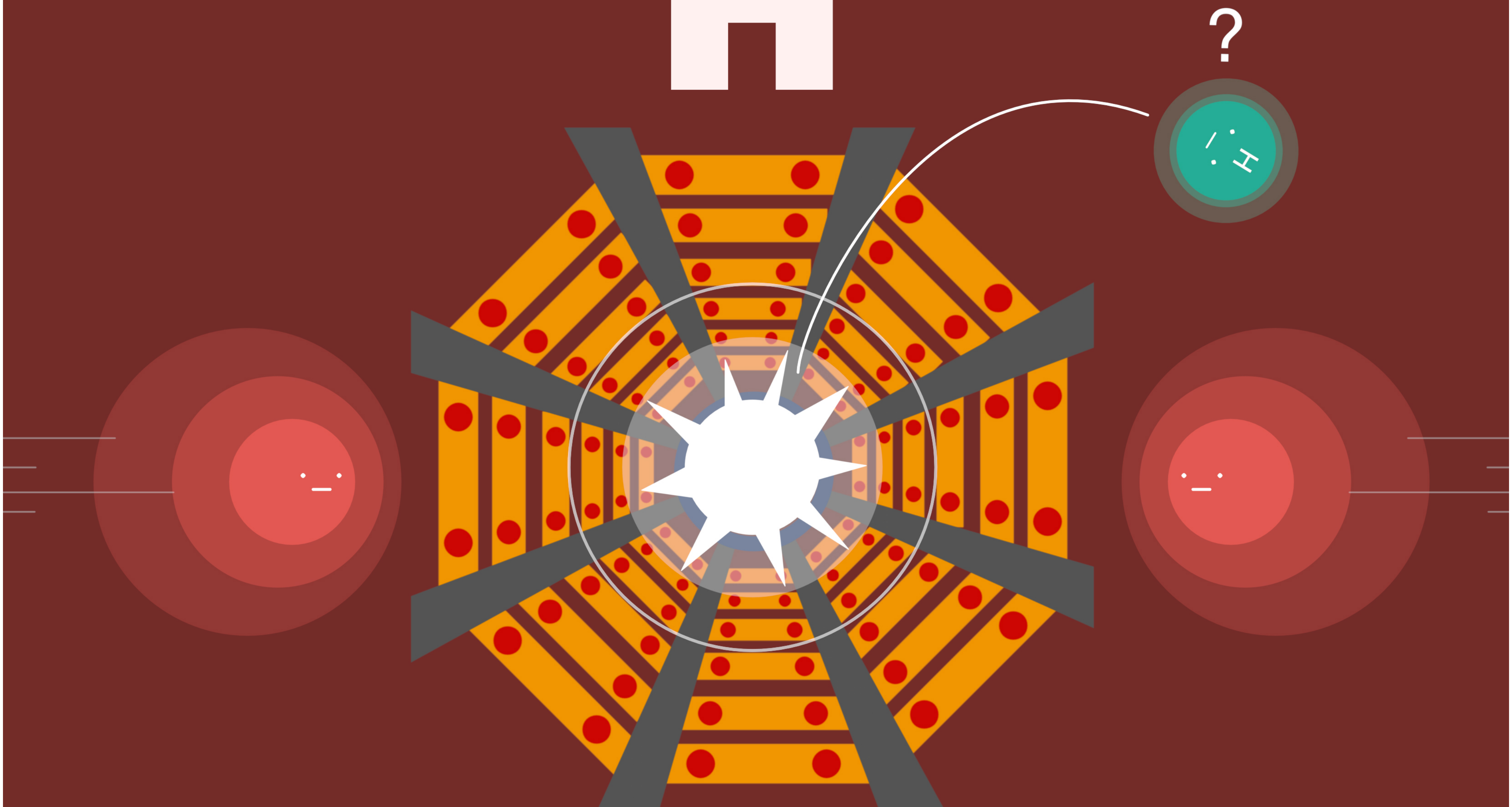
We're most familiar with the force of gravity, which holds us on the Earth and makes us circle the sun. But at the smallest scales gravity is weak, and particles interact with much stronger forces. There is the strong nuclear force, which holds the nucleus of atoms together; the weak nuclear force, which allows particles to decay; and the electromagnetic force, which holds atoms and molecules together.

G

is for galaxies—see how they turn!

Galaxies are huge collections of stars, all held together by gravity. By some estimates, the Milky Way galaxy contains up to 400 billion stars, and scientists estimate that our universe holds at least 100 billion galaxies. Researchers study the behavior of galaxies to learn more about the invisible things that influence them, such as dark matter and dark energy.

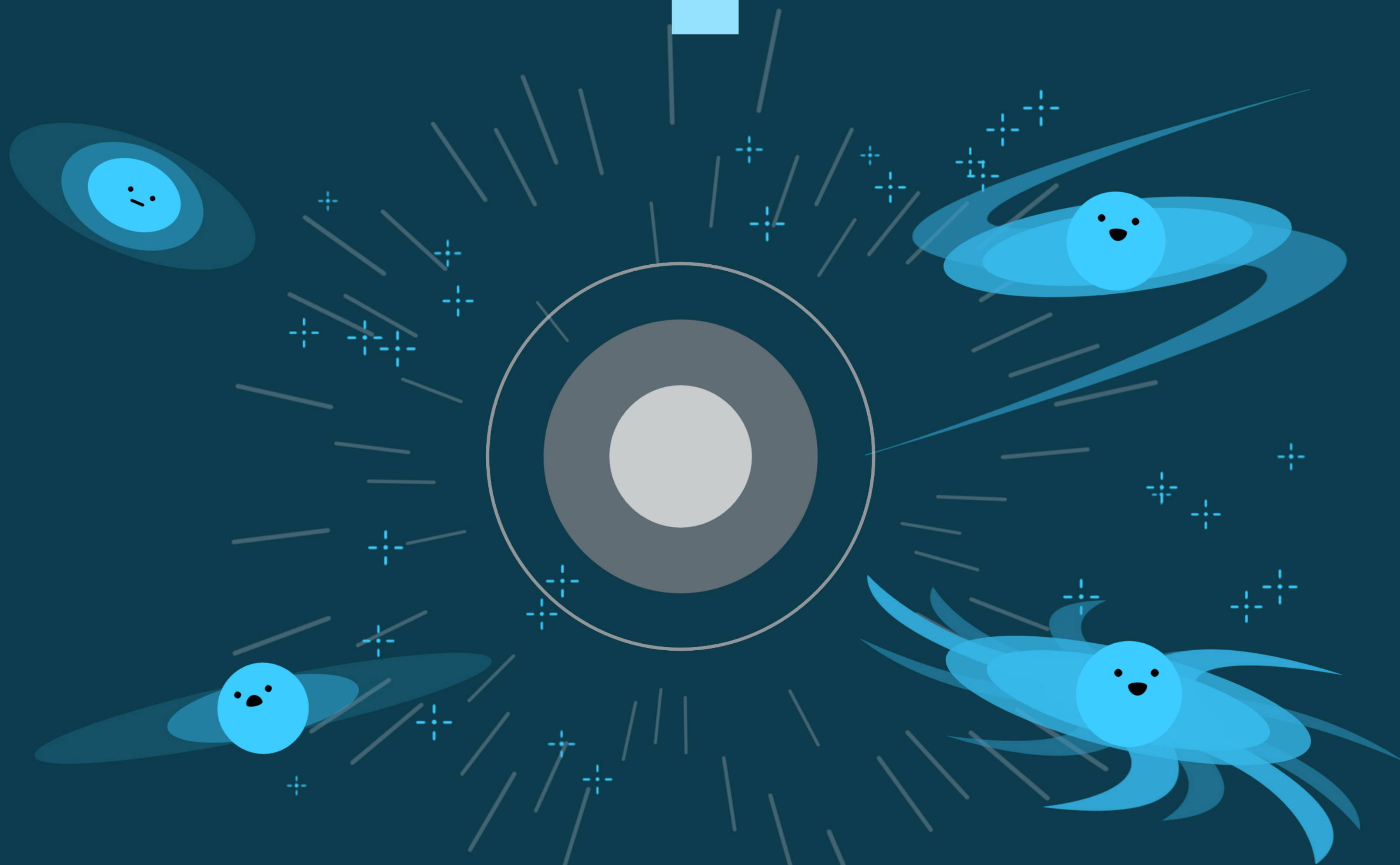
H



is for Higgs, discovered at CERN.

The Higgs field gives many fundamental particles their mass. Theorists predicted the existence of the Higgs boson in the 1960s, but they didn't know what mass the Higgs boson itself might have, making it very difficult to find. After five decades of searching, experimentalists finally discovered the Higgs boson at the Large Hadron Collider in 2012.

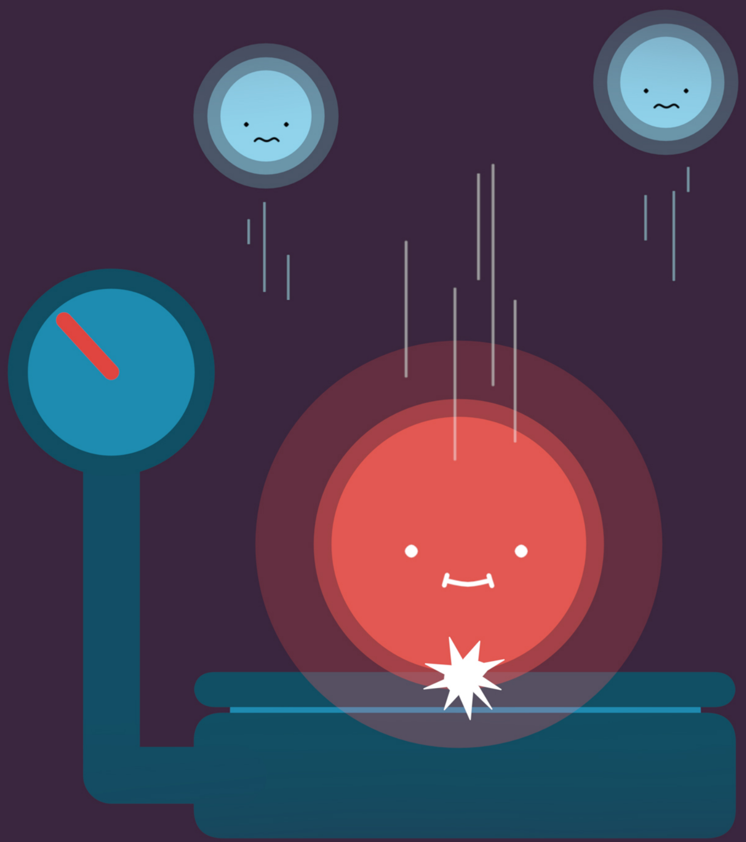
I



is for inflation that made the universe expand.

Imagine if things the size of an atom suddenly expanded to the size of a grapefruit. That’s what scientists believe happened during inflation, a short but violent period early in the universe’s history. The universe grew, stretching minor quantum variations into larger patterns that can still be read in the sky in light left over from just after the big bang.

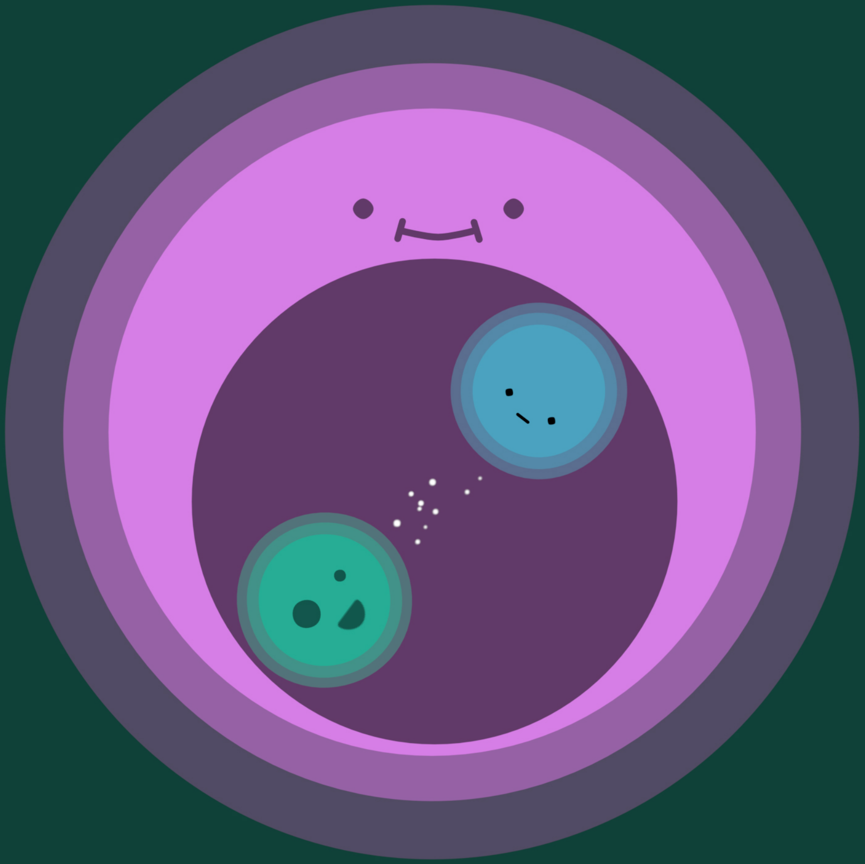
J



is for Joule, a measurement of energy on hand.

A joule is the name for a certain amount of energy. It's roughly equivalent to you lifting a small apple a meter in the air. One of the most energetic cosmic ray particles ever detected clocked in around 50 joules, which might seem unimpressive—until you compare the size of your arm to the size of a subatomic particle! This cosmic ray, propelled by an unknown source in space, was millions of times as energetic as the particles accelerated at the Large Hadron Collider, the most powerful accelerator ever built.

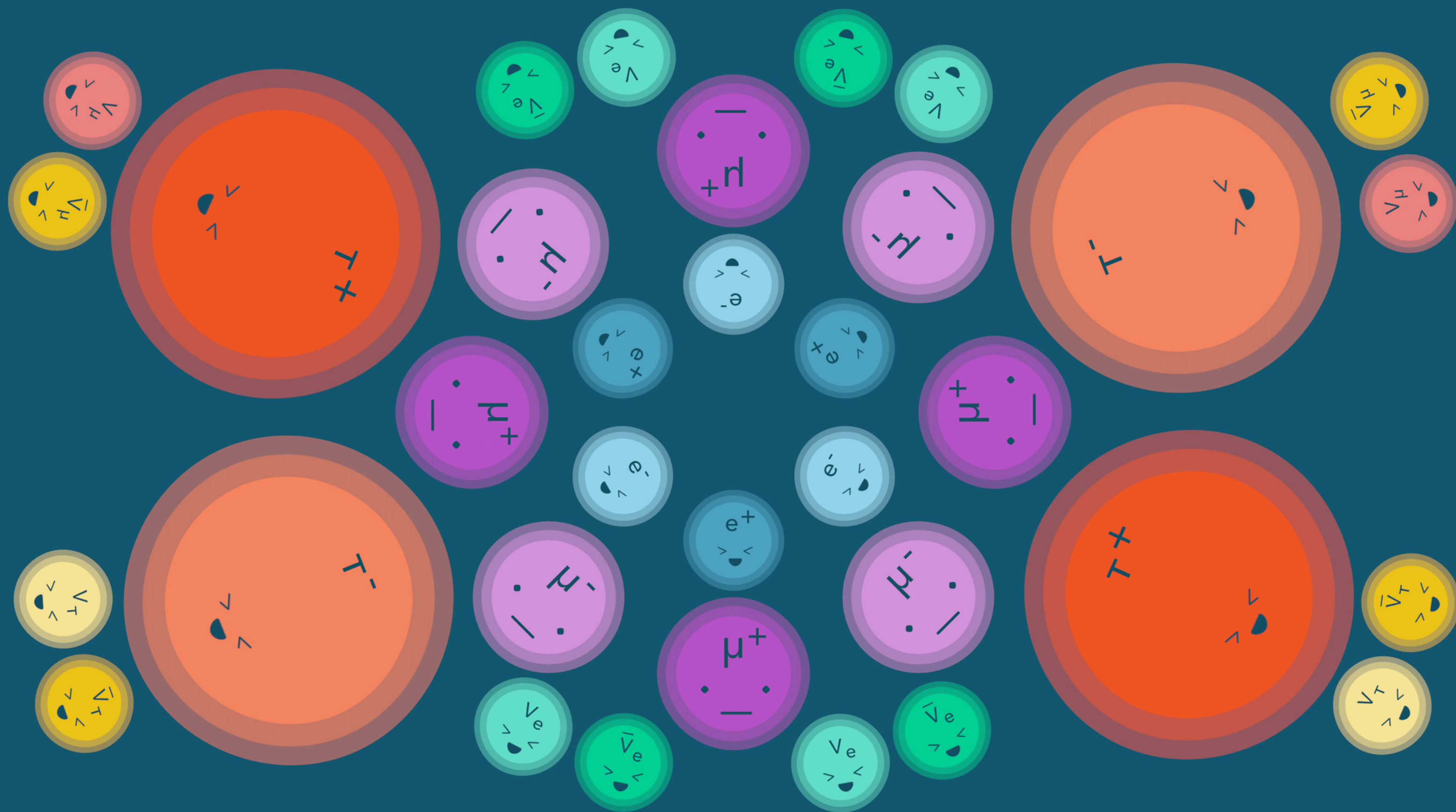
K



is for kaons, with quarks that are strange.

Many subatomic particles are made of building blocks called quarks, which come in six different types. Kaons are particles that contain a quark called a strange quark. Kaons are important because scientists used them to find clues as to why our universe is made of more matter than antimatter. They discovered that kaons and their antimatter partners decay in different ways, contributing to the imbalance.

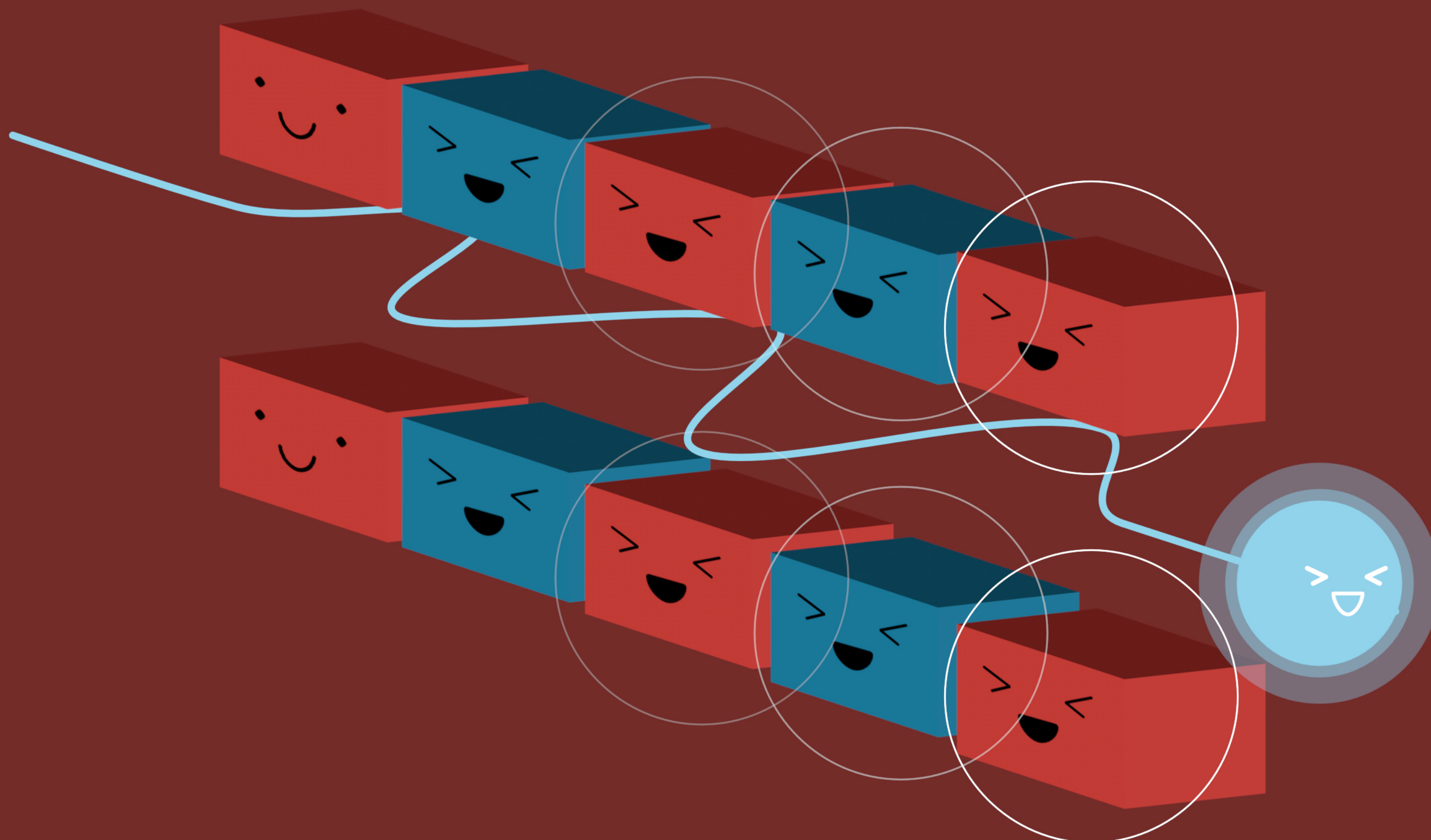
L



is for leptons, which have a wide range.

The leptons are a family of subatomic particles. The best-known lepton is the electron. Other leptons include heavier versions of the electron called muon and tau particles, and a group of three almost massless particles called neutrinos. Unlike some other particles, leptons don’t combine with one another; they like their personal space.

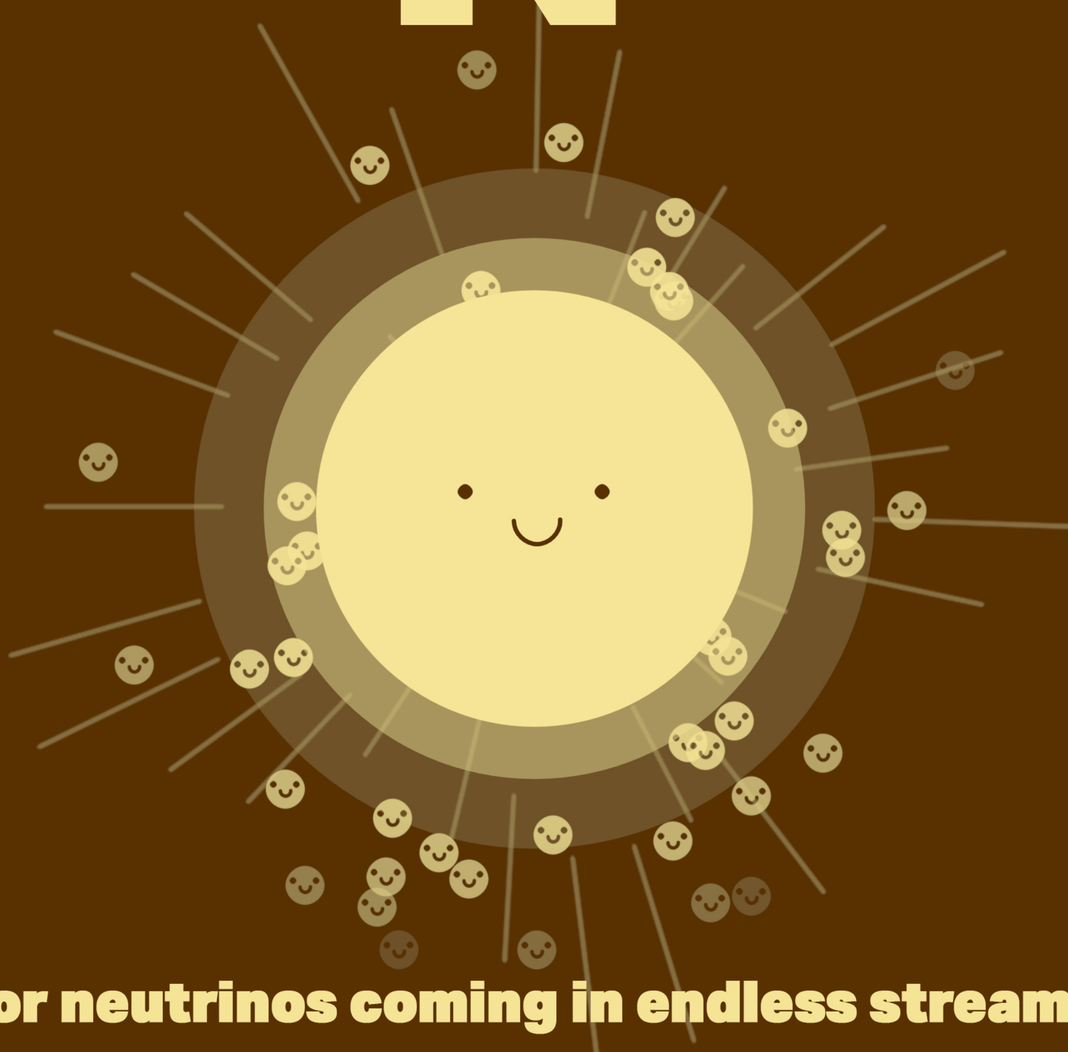
M



is for magnets, directing particle beams.

Magnets are essential for particle physics. Scientists use magnets to steer charged particles through particle accelerators. They also use them to squeeze particles into beams. The largest accelerator in the world, the Large Hadron Collider, is 17 miles long and uses more than 9000 magnets.

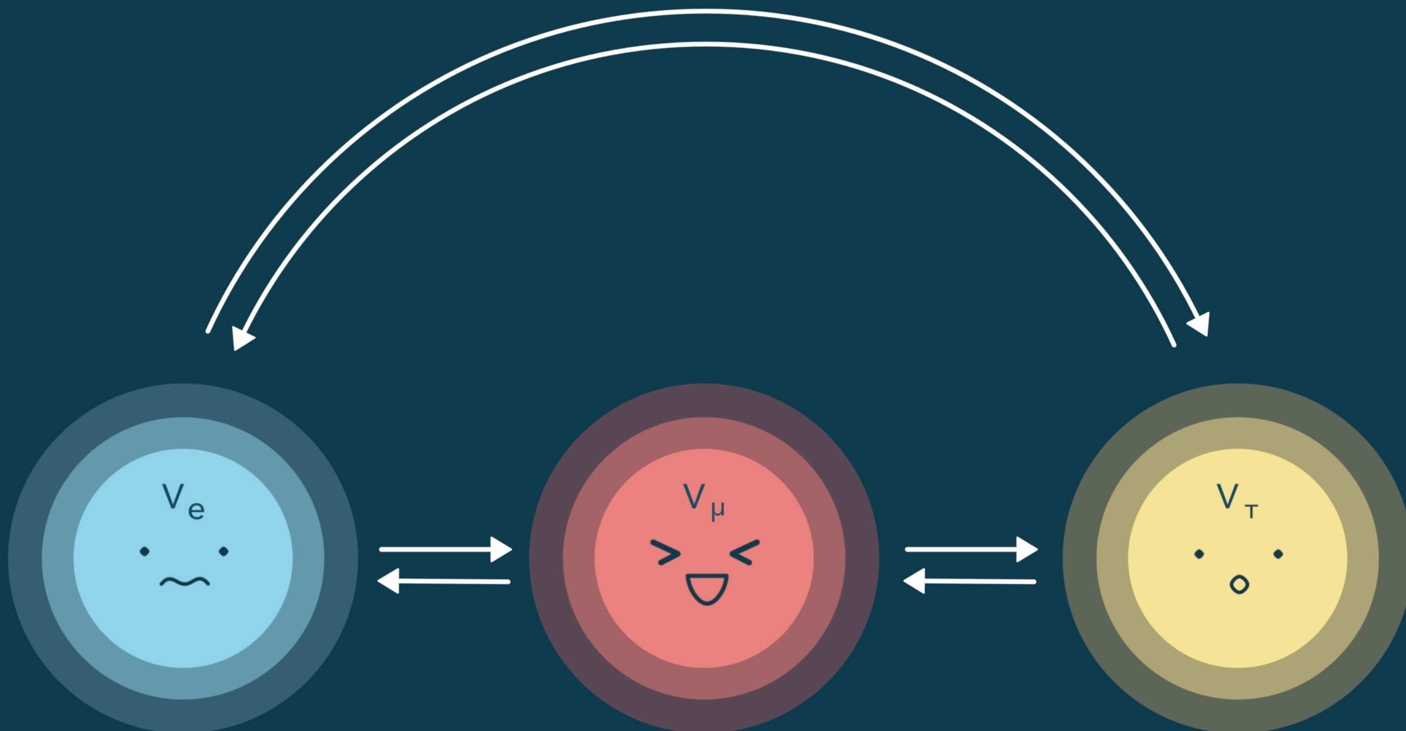
N



is for neutrinos coming in endless streams.

Neutrinos are all around you. They are extremely light, electrically neutral particles that only rarely interact with other matter. They are made in a variety of processes in space and on Earth. Even though they are constantly streaming through us billions at a time, we never feel a thing. Yet neutrinos seem to play a crucial role in our universe and might even hold the key to explaining why matter exists.

O



is for oscillation, when neutrinos change type.

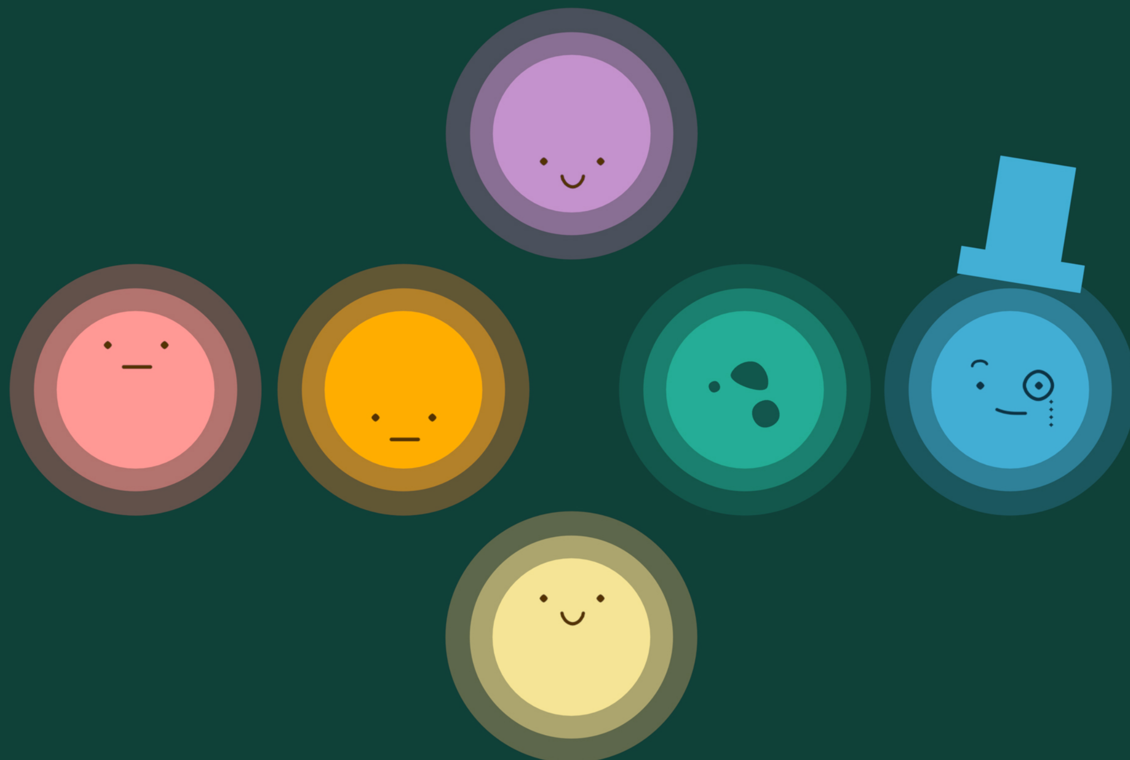
Neutrinos come in three types. As they travel, they transform from one type to another. This is called oscillation. When scientists first discovered neutrinos, they noticed they were catching fewer than they expected. They found out later that the neutrinos they were looking for had simply changed into another type that they needed to detect in a different way.

P

is for photons, which brighten the night.

Photons are particles of light. They are the fundamental particles that carry the force of electromagnetism. And they're the most abundant particles in the universe. Photons are important in particle physics experiments; scientists can detect many types of particles by the trail of light that they leave in a detector.

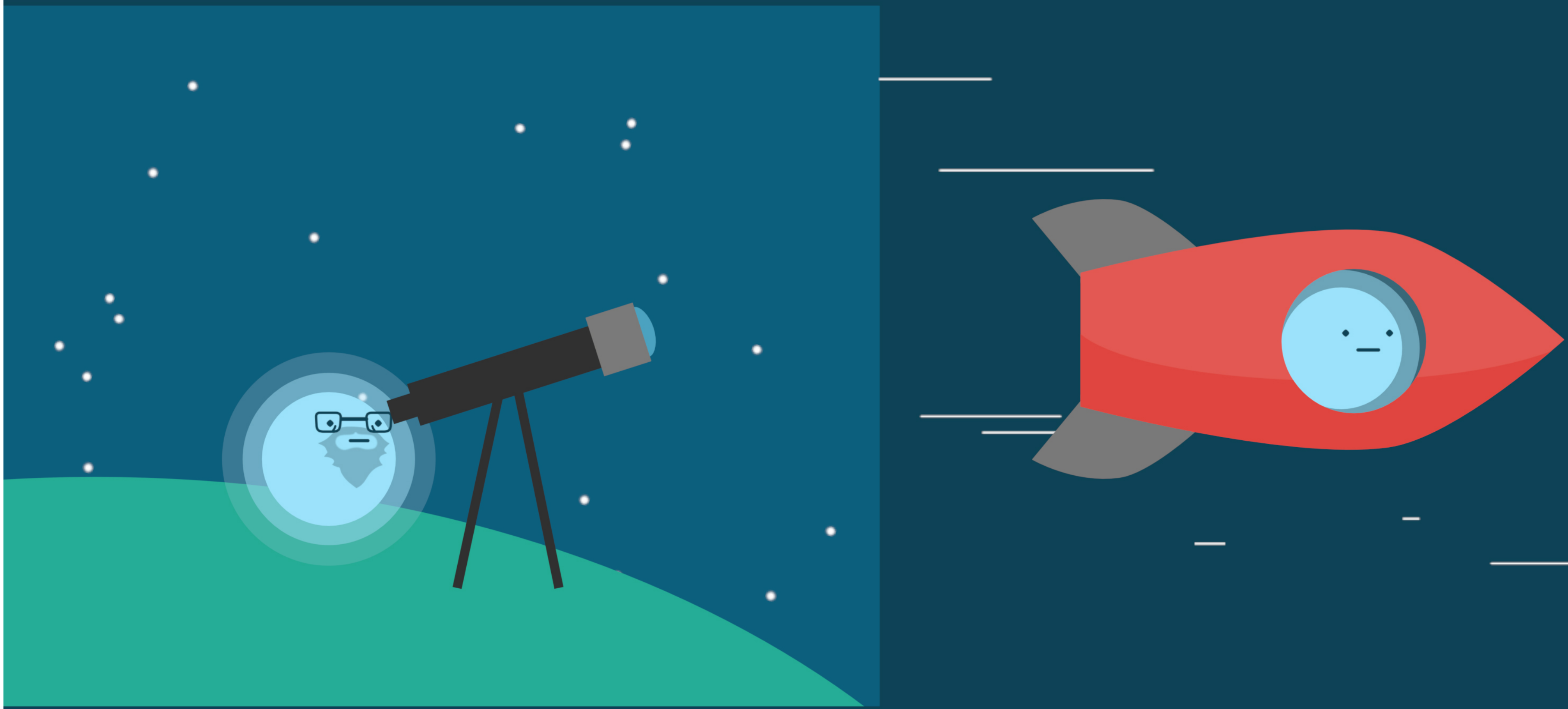
Q



is for quarks—they come in six kinds.

Quarks are among the smallest building blocks of matter. They come in six types: up, down, charm, strange, top and bottom. Up and down quarks bind together via the strong nuclear force to form the protons and neutrons in atomic nuclei. The top quark is the heaviest elementary particle ever discovered. It weighs as much as an entire gold atom.

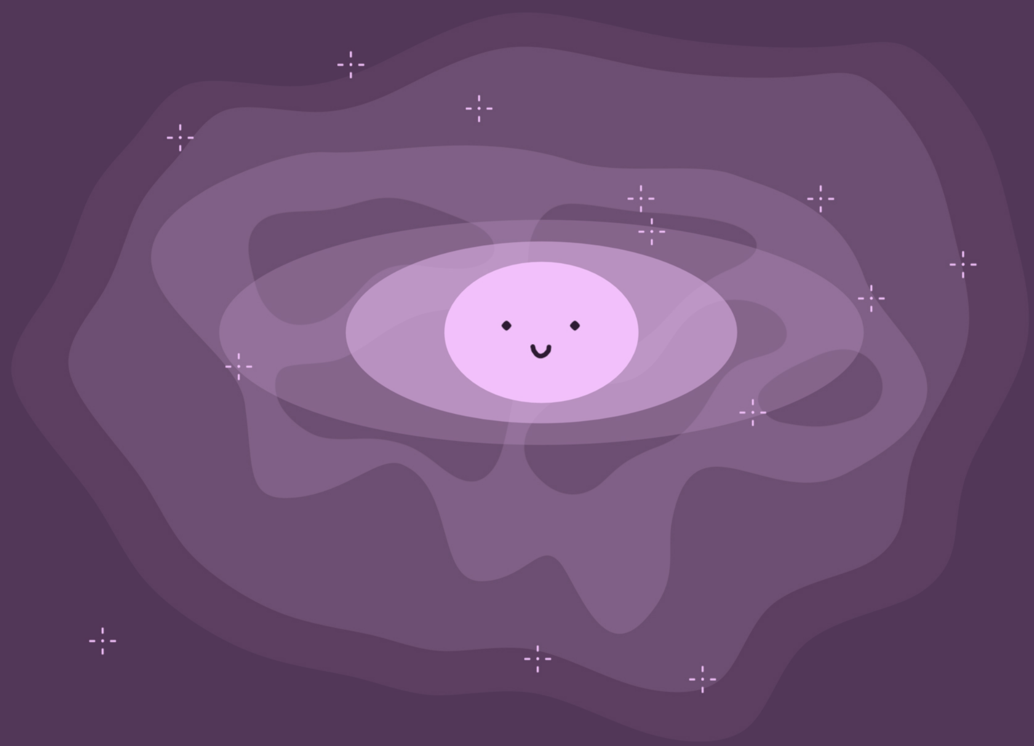
R



is for relativity—how Einstein blew minds.

According to Albert Einstein's theory of relativity, the passage of time depends on your frame of reference. Time passes differently for someone in motion than it does for a stationary observer. So someone on a rocket ship traveling near the speed of light will age more slowly than someone observing the ship from Earth.

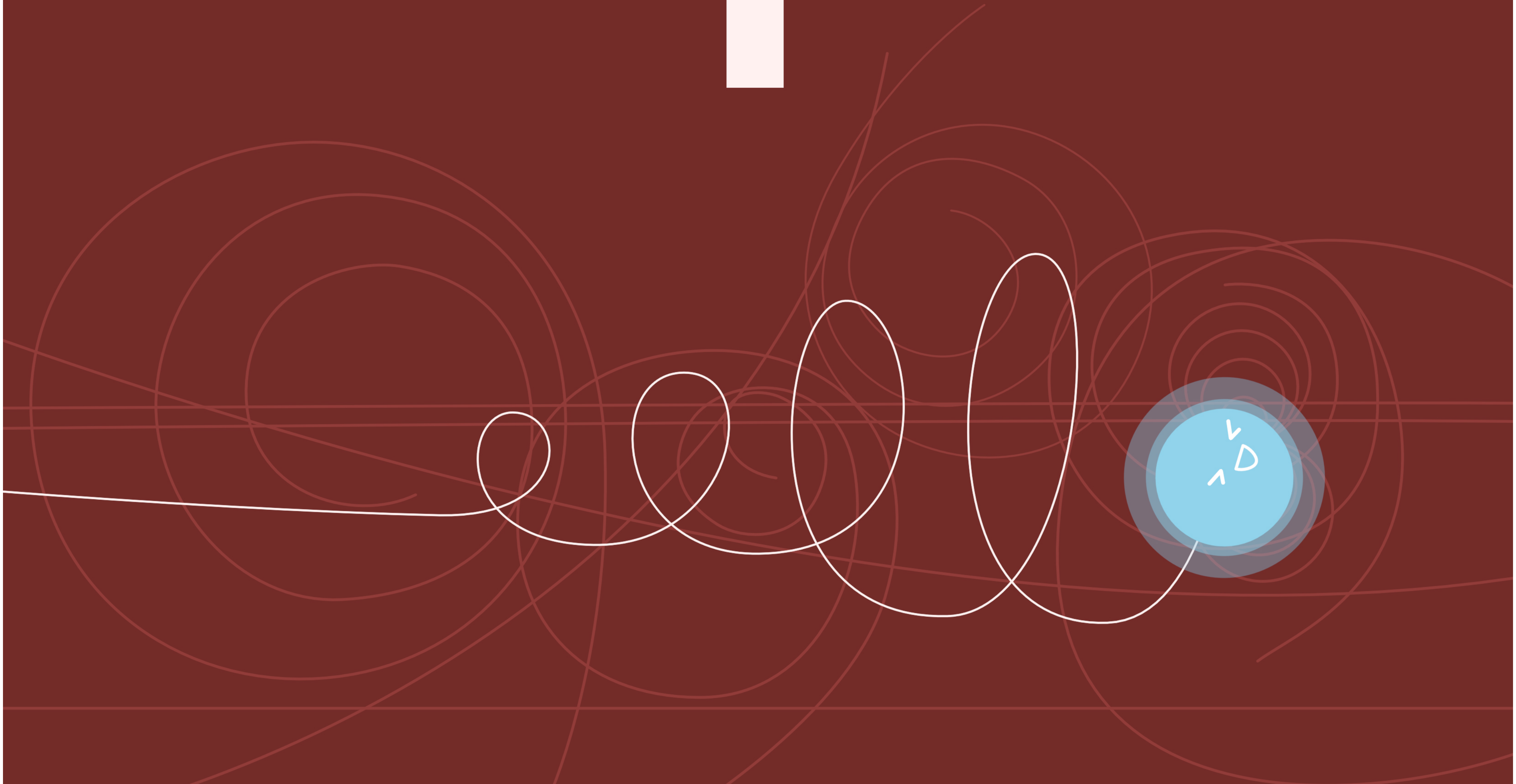
S



is for supernova, making galaxies pale.

Supernovae are exploding stars. They emit much of their energy in invisible neutrinos, but they still shine brightly enough to temporarily eclipse entire galaxies in the sky. Certain types of supernovae explode with a predictable level of brightness. Scientists have used these types of supernovae to figure out how quickly the universe is expanding.

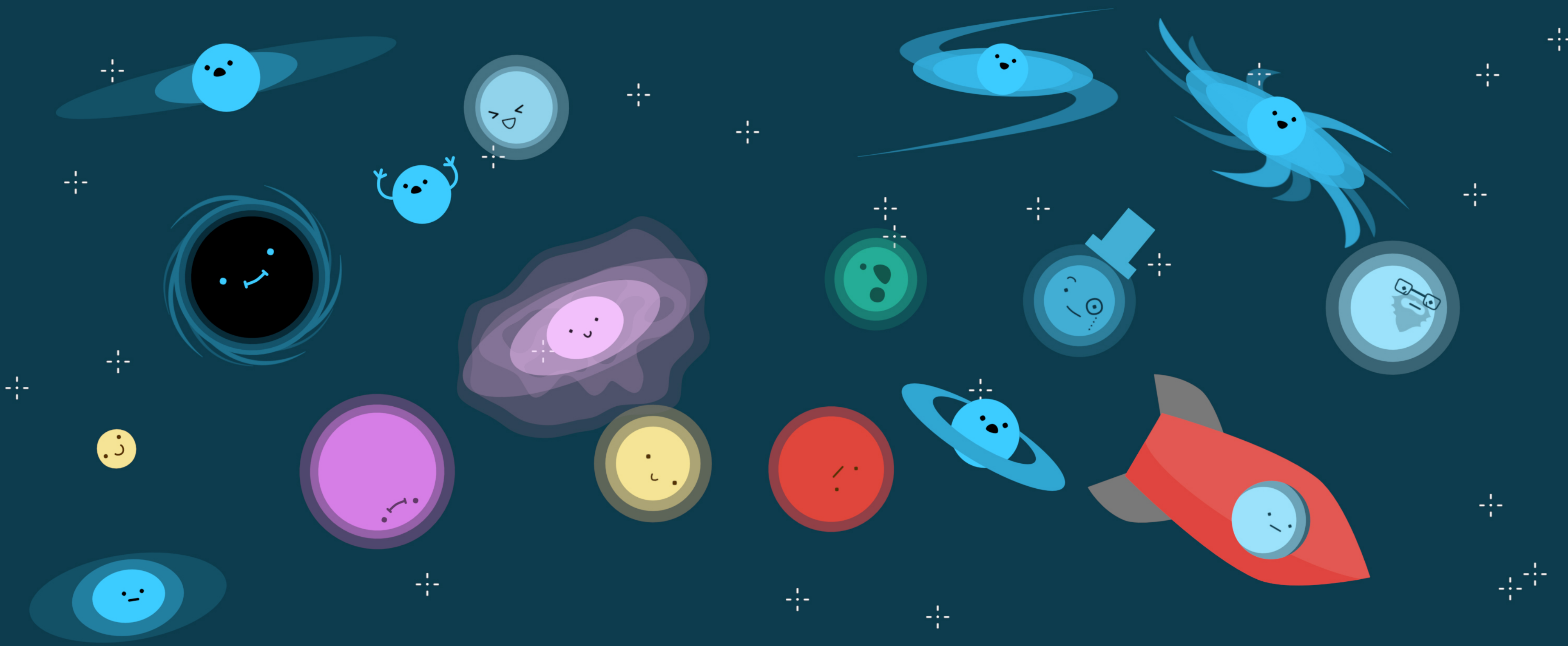
T



is for tracks particles leave as a trail.

Physicists learn about invisible particles by studying the tracks that they leave in detectors. The shape of a track can tell a scientist about a particle’s energy, direction, speed or electric charge. You can see particle tracks on your own if you build your own cloud chamber!

U



is for universe, where all this stuff lives.

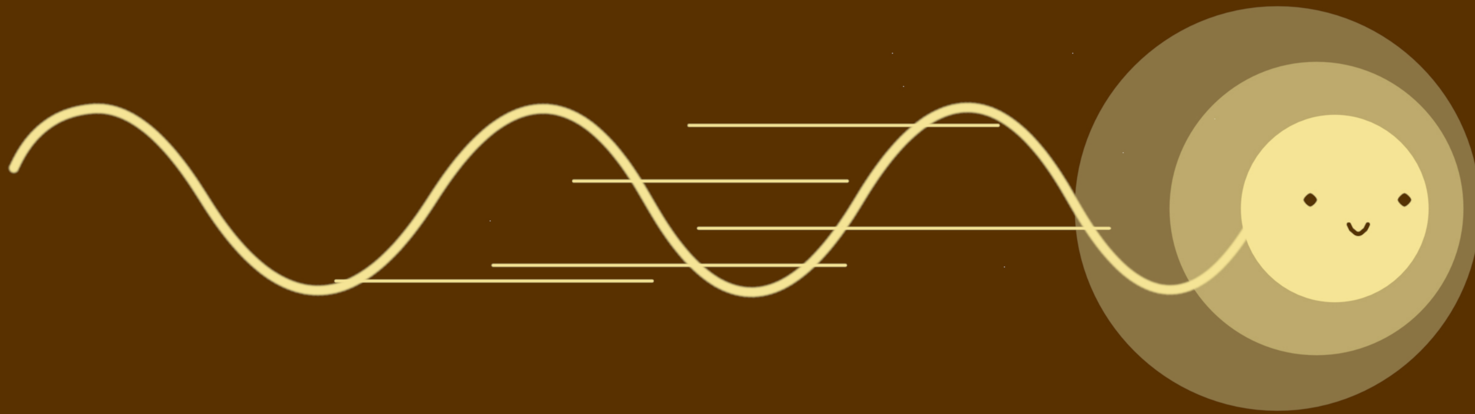
The universe is everything we know. Scientists estimate the observable universe is about 91 billion light-years across. They think it is roughly 14 billion years old. The universe appears to be very flat and uniform, with no center and no edge. It is expanding at an accelerating rate, something scientists attribute to dark energy.

V

is for vacuum, space where nothing is.

In the purest sense, a vacuum is empty space. But no vacuum is purely empty. Even in the vacuum of space, lonely particles float by, and virtual particles pop in and out of existence. More practically, a vacuum made by a machine on Earth is an area with less pressure than normal. Many particle physics machines create vacuums to remove gas molecules that might interfere with experiments.

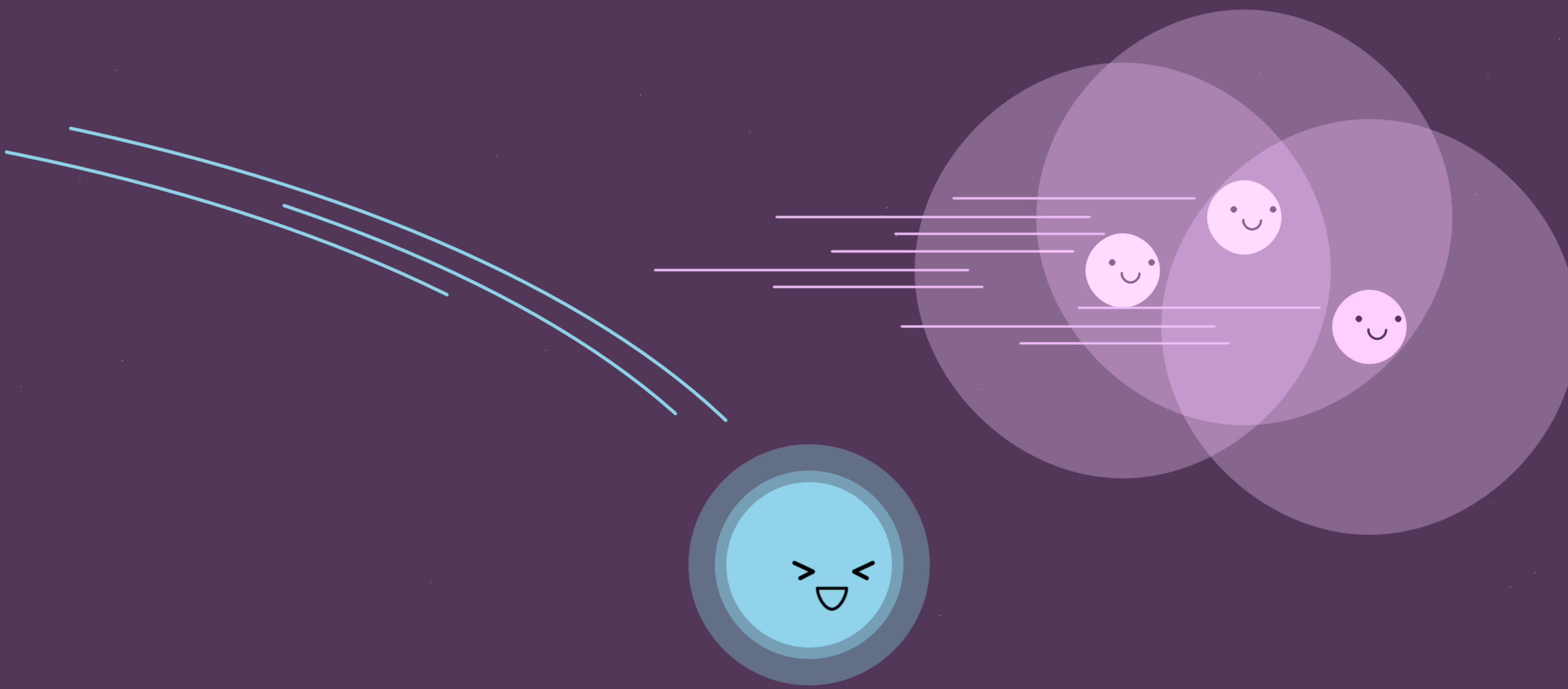
W



is for wave, a property of light.

Elementary particles seem to obey a different set of rules than we do. One perplexing thing about them is that particles also act like waves. This is called wave-particle duality. Scientists discovered the double nature of the quantum world in experiments with light, which displays both particle- and wave-like behavior.

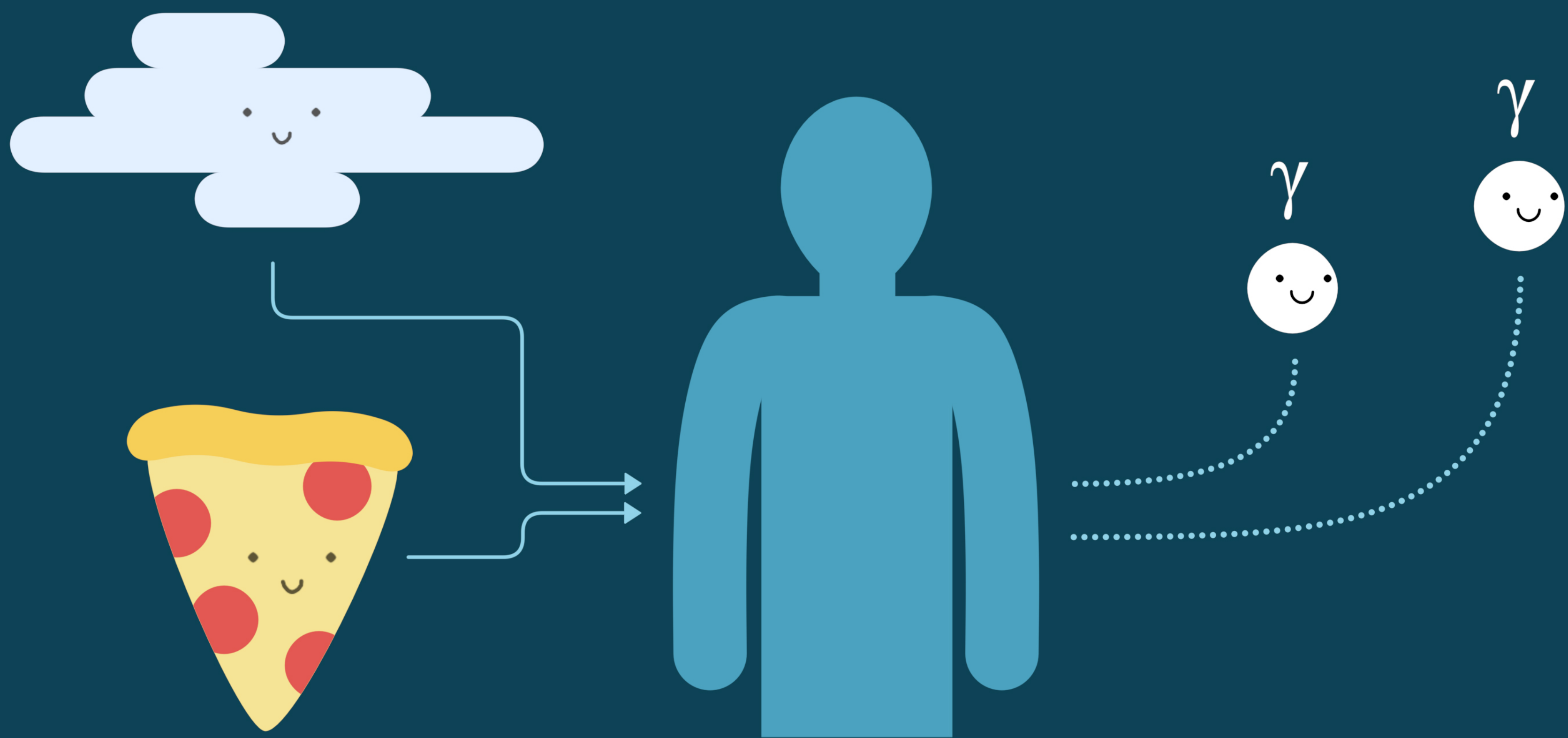
X



is for X-rays, which are really bright!

An X-ray is a very high-energy form of light. When scientists bend the path of particles in an accelerator, the particles emit energy in the form of X-rays. Scientists used to find this annoying, but over time, they realized they could harness these X-rays to take extremely detailed images of atoms and molecules and even chemical reactions.

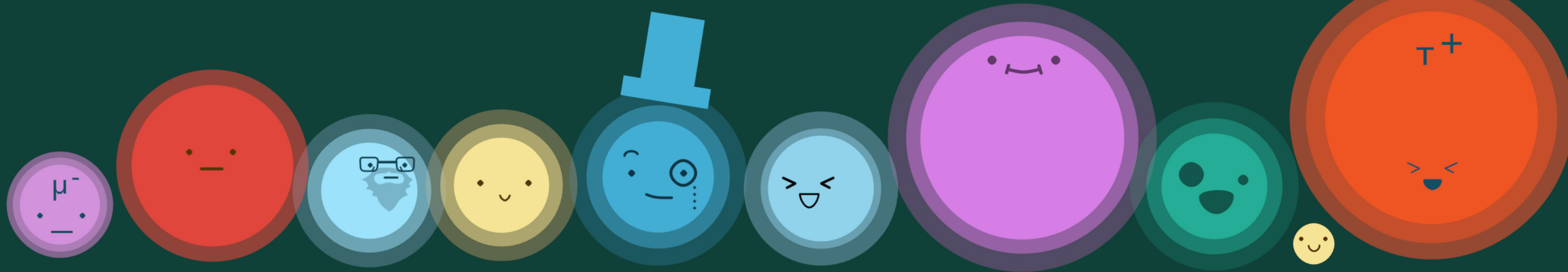
Y



is for you, with a radioactive core.

You are a giant made of tiny particles. And you are a source of them! The food you consume and the air you breathe have small amounts of naturally occurring radioactive materials that become incorporated into your molecules and later decay. Each year, your body emits an amount of radiation roughly equivalent to four chest X-rays.

Z



is for the particle zoo that scientists explore!

In the 1950s and 1960s, scientists discovered hundreds of particles that they thought were fundamental—unable to be broken into any smaller bits. They called this unruly collection the particle zoo. Later, they discovered that many of these particles are made of smaller pieces. Today, the known particle zoo can be explained with just 17 fundamental particles: six types of quarks, six types of leptons, four force-carrying particles and the Higgs boson. But we don't know yet what types of particles make up dark matter.

Learn more about particle physics at
symmetrymagazine.org

Support provided by the US Department of Energy’s Office of Science

U.S. DEPARTMENT OF ENERGY | Office of Science