A Tale of Two Theories

Our universe is currently explained using two contradicting theories: general relativity and quantum mechanics. The quest for one unified theory has gripped the world of physics into frenzy.

PRACTICAL SCIENCE WITH PHIL FREDA

Our universe is split into two different worlds; the world of the very big and the world of the very small.

Einstein's theory of general relativity elegantly and effectively explains the world of the large, including things like stars, planets, galaxies and even black holes to an extent.
However, when zooming into the atomic realm of electrons and photons, general relativity starts to unwind and break down.

The core issue when analyzing very small particles is that gravity, the weakest of the forces and a major component of general relativity, seems to have no effect.
Let's explore the two theories and their importance to our everyday lives with help from PBS, Stanford University and Infoplease.

General relativity

The theories of general relativity and special relativity explain everything from the orbits of planetary bodies to the relativity of time.
The key aspect we will focus on is the relation of mass and its effect on the fabric of space-time.

In general relativity, an absence of mass on a piece of space equates to a smooth flat surface.

Imagine your bed just after it has been made. The sheets are flat and smooth.

When your body is added to your bed, however, the sheets buckle and warp.

This is what essentially happens to space-time upon the addition of a massive body like a star or planet.

With general relativity and its equations, we have a level of certainty that can be measured with expected results.

We use Einstein's equations to this day to send shuttles and satellites into orbit. Also, the GPS system in your car operates using direct manifestation of Einstein's equations.

The motions of planets through our solar system are regular and defined without deviation.

We measure our years and days with a level of certainty.

When looking at the world of the very small, specifically the atom and the electron, things begin to get a bit hazy, even downright weird.
The application of general relativity with particles and waves yields extremely improbable and mathematically irrational results.

Quantum mechanics

Quantum mechanics and quantum field theory deal with lengths that may seem unimaginable to us.
Quantum theorists deal with lengths so small that the standard model of gravity proposed by general relativity really makes no sense whatsoever.

The Planck length, which is equal to approximately 1.6×10^{-35} meters, is the point where our classical ideas of mass and gravity cease to be valid.
In case you were wondering, the size of a single proton, usually found in the nucleus of an atom, is approximately 10^{20} times larger than this length!
At this very small scale, it is theorized that space acts very weird.

In the absence of mass, fluctuations in space-time are observed, meaning that with no apparent mass and gravity act upon it, space is not static, but constantly in flux.

This is in direct contradiction to general relativity where space is smooth in the absence of a massive body.

Some call this fuzziness in space the quantum foam.
In the quantum world, particles literally come in and out of existence and appear to be located in more than one place in any given time.

To better "understand" the quantum world, let's look at the electron.

Electrons orbit the positively charged nucleus of an atom and they carry a negative charge.

The classical model of the atom usually depicts the electron orbiting nicely around the nucleus of an atom like the Earth orbits around the Sun.
Quantum mechanics, however, paints a much more interesting picture.

Niels Bohr was the first to create a working model of the hydrogen atom.
Using the work of Max Planck, he noticed that electrons have distinct values of momentum and can occupy orbits only at certain distances.
Imagine atomic orbitals as railroad tracks. Some are close to the nucleus, some are farther away, and some form extreme shapes.

Research began to understand where the electrons orbited and how fast they were moving.

To the dismay of the researchers, they soon found that it was impossible to determine both of these results.

This led to the Heisenberg uncertainty principle.
The uncertainty principle states that you cannot specify both the location and the speed of an electron at any one point in time.

In other words, if you pinpoint the exact speed of the electron, you will not be able to determine the location of it with any certainty.

It seemed that electrons acted like classical particles at some points, and as waves at other points.
It even became acceptable to call the electron both a wave and a particle at the same time.

The electron went from a standard elementary particle, to more of an idea. One could estimate where the electron was only with some probability.

Moreover, it seemed possible that things like electrons and photons could theoretically be in two different places at one time.
This led to theoretical physicist Erwin Schrodinger to create wave function equations to at least attempt to explain where and how electrons orbit the nucleus of an atom.
His work has given us a better understanding of the electron and its orbital pattern into a model of a cloud rather than that of a planet.
Around the nucleus of an atom is a cloud of probability where the electron may be located.

In addition, the level of energy the electron is carrying determines the shape of the orbital cloud and which way the electron in spinning.

The quantum world may be extremely strange but unexpectedly, the equations used in quantum mechanics work very well.

Hungry for one grand unified theory that explains all of nature, physicists began a quest to find one elegant theory to meld the worlds of the large and the small.

String theory

Currently, theoretical physicists around the world are working on a new model called string theory in which tiny 10-dimenional strings make up all of the elementary particles in the universe.

Remember, we humans experience three spatial dimensions (length, width and height) and one temporal dimension we call time.

String theory calls for additional dimensions beyond our capability of observance.

The elementary particles discussed in string theory make up atoms themselves, which in turn make complex molecules found in all things from a human to a star.

The goal of string theory is to incorporate gravity into the standard model of quantum mechanics.

By doing this, physicists will have effectively bridged the gap between general relativity and quantum field theory.

I know that the topics discussed here may seem strange, but the more we find out about the world we live in, the more we realize that the universe we know with our senses is far from the whole picture.

Think about it!

If you are interested in reading about more about string theory, check out the Official String Theory Website!