

# Dream Journey into the Atom

with Proton Patsi and Ronnie & Charlie (the uncertain electrons)

**PPARC** the physics of the universe  
 Particle Physics and Astronomy Research Council  
[www.pparc.ac.uk](http://www.pparc.ac.uk)

It takes sixty MILLION, MILLION, MILLION, MILLION electrons to weigh as much as me.

We ain't heavy, us electrons.

But there's a lot of us around.

We're in EVERYTHING

Did you ever have a dream and wake up and realise it was based on the truth?

Proton Patsi: Come on, guys. That's the way we've got to go.

Charlie: Are you sure?

Ronnie: This gives me a SINKING feeling.

WEEEEHAAAA!

Did you ever get the feeling that you were being watched?

Things that are hard to see can be hard to understand. But even though we can't see them, we CAN see plenty of evidence that they're there.

We're not sinking but SHRINKING.

OW! Stop pushing.

It wasn't me!

Now that we're shrunk, something is pushing us around.

A modern electron microscope can show atoms on the surface of an object.

Jason Ward CERN (the European Laboratory for Particle Physics)

Here in Geneva, we build and run experiments on the world's biggest particle accelerator to answer profound questions like 'What gives heavy particles their mass? How this pursuit of pure knowledge will affect us is beyond our wildest dreams!

An ordinary microscope can let us see grains of dust or smoke being pushed around by MOLECULES of air.

What's a molecule?

OW! Another molecule just hit me!

These 'somethings' must be invisible.

And they must be moving fast to hit us so HARD.

The light at the end of the tunnel.

I've just discovered something new. I'm going to call it a HUMAN.

Electrons are much lighter than atoms...

If everything is made of atoms, then what are atoms like? And what have ELECTRONS got to do with them?

An ATOM is a PARTICLE. Everything around us is made of atoms.

The substances of our own bodies are made of atoms.

Atoms and molecules are tiny, but not as tiny as ELECTRONS

What's an atom?

We need to get out of this tunnel to answer that.

I think I can see a light at the end of the tunnel.

A molecule is a cluster of atoms.

Molecules are tiny but they can move fast.

A simple ball picture of an atom.

Nucleus

A picture of an atom showing the NUCLEUS in the centre and ELECTRONS in orbit.

We can draw different pictures of atoms, depending on how much detail we want.

It was particle physicists who first created the WORLD WIDE WEB.

An atom has a tiny nucleus made of neutrons and protons. Neutrons and protons are made of QUARKS. Atoms have ELECTRONS too. So I'M made of quarks and electrons!

Atoms and molecules are TINY particles.

Nuclei are TINY, TINY particles.

It takes a big team of people to build and operate a big detector.

Neutrons and protons are TINY, TINY, TINY particles.

Research scientists let fast particles collide with a target. That can produce a spray of different kinds of particles that the scientists can detect.

Electrons and quarks are TINY, TINY, TINY particles.

...the bigger the microscope you need.

Big accelerators are a bit like HUGE microscopes for looking at very tiny particles.

It seems that the smaller the particle you are looking for...

Accelerators

Mahfuzur Rahman Glasgow University

I use new semi-conductor detectors developed in large particle physics experiments to make better X-ray detectors. These detectors can be used to detect cavities in teeth more easily, and it is exciting to know that they could save lives by helping doctors to detect cancer earlier.

In modern accelerators, beams of particles travel close to the speed of light. Giant magnets can keep them travelling in huge circular tunnels.

J.J. Thomson's experiments showed how to control a beam of PARTICLES (electrons) using a magnetic field.

A TV works in the same way to make the pictures we see.

Oooee! Hello Mum!

We're on TV!

These days, scientists use giant ACCELERATORS to make beams of high energy particles.

Ernest Rutherford's experiment investigated the structure of atoms by firing fast particles at them.

People have learned how to control the movement of electrons, so we can make computer circuits.

A lightning flash is a huge electric current. Electrons move between the Earth and the thundercloud.

This hospital accelerator uses 10 million volts to accelerate electrons. It doesn't make light like a TV. It produces a beam of X-rays that can destroy cancer cells.

We're safe inside this metal cage. The current flows around the outside.

I'm scared.

Don't be so NEGATIVE.

I can't help it. It's my nature.

ACCELERATORS

Jo Cole Bristol University

All electrons are the same. They all have NEGATIVE electric charge and they all REPEL each other.

...but electrons come out of materials such as metals that are made out of atoms.

Perhaps an atom is made up of thousands of spinning electrons.

Hmm. But atoms must have some positive charge as well as negative electrons...

...or the electrons would all REPEL each other and fly apart...

...and the positive electric charge must balance the negative electrons to make an atom NEUTRAL.

When electrons flow, do they make a CURRENT?

Dough!

It's an interesting train of thought. But this isn't how we picture atoms these days.

These ideas were worth checking out. What was needed was a good EXPERIMENT.

ATOMS & MOLECULES

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What's going on here?

Oooh! This looks nice.

Yeuch, let's get away from here.

The battery is making an electric current in the wire. The ammeter measures the current.

The positive end of a battery is ATTRACTIVE to electrons.

The negative end of a battery is REPULSIVE to electrons.

But what's happening INSIDE the wires?

LOTS of electrons are on the move.

Inside the wire.

What's going on here?

Hot metal

A modern vacuum tube

Electrons come out of a hot piece of metal.

And they're ACCELERATED by electric force to make a high speed beam.

Help! I can't breathe in here!

Invisible beam of electrons

Visible spot of light

Screen

The screen glows when the fast electrons hit it.

I study collisions between electrons and protons at the HERA accelerator in Hamburg. As the electron is both simple and has no measurable size, it makes HERA a very powerful microscope which we can use to study what is inside the proton.

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ELECTRICITY & ELECTRONICS

Gavin McCance Glasgow University

The World Wide Web was invented by particle physicists. I am part of a team working on the Grid, the next-generation Web, which will link up computers like never before and allow us to examine the vast amounts of data produced by the experiments.

Other people have tried firing beams of electrons at metals. We could try ALPHA particles.

Around 1910, Ernest Rutherford decided to fire particles from a radioactive material at some gold foil.

Most of the alpha particles went straight through the gold foil just as Ernest predicted, BUT some were knocked off course. Some even went back the way they came.

That is NO! what I predicted.

I predict that the particles will pass through thin gold foil. The spongy atoms should have little effect on it.

Atoms couldn't be all soft and spongy. Ernest had to think of a NEW model of atoms.

Nucleus at centre (positive electrical charge)

An atom with nucleus and electrons

Electrons in orbit (negative electrical charge)

Thin gold foil made of gold atoms

Alpha particles

Radioactive source of alpha particles

Inside a proton or neutron.

So are us quarks.

Electrons are much smaller than protons or neutrons.

Ernest guessed that there must be something SMALL and POSITIVE but HEAVY inside atoms to knock the alpha particles off course. He called the small heavy part the NUCLEUS of the atom.

It's just as if you fired a bullet at tissue paper and it came right back and hit you.

NUCLEI

Jude Dann Rutherford Appleton Laboratory

I use beams of neutrons to probe new engineering materials. This helps us predict how these materials will behave. At the ISIS neutron and muon source, we are building a new machine to probe deeper and work faster.

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