Dream Journey into the Atom

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

PPARC
Particle Physics and Astronomy Research Council
the physics of the universe
www.pparc.ac.uk

It takes sixty MILLION, 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

brrrrrrrrrrgg brrrrrrrrrrgg

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

particle	mass	electric charge	where it's found
proton	1	+1	in the nucleus
neutron	1	0	in the nucleus
electron	1/1840	-1	outside the nucleus

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.

Atoms and molecules are TINY particles.

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!

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.

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 ...

... the bigger the microscope you need.

Electrons and quarks are TINY, 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.

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.

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.

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.

We're on TV!

Oooee! Hello Mum!

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.

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.

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.

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

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!

We're not sinking but SHRINKING.

OW! Stop pushing

It wasn't me!

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

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.

These 'somethings' must be invisible.

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

BROWNIAN MOTION of microscopic grains

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.

ATOMS & MOLECULES

Molecules are tiny but they can move fast.

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

The substances of our own bodies are made of atoms.

What's an atom?

A molecule is a cluster of atoms.

What's a molecule?

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

What's an electron?

OW! Another molecule just hit me!

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

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

The light at the end of the tunnel

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

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

Electrons are much lighter than atoms...

J.J. Thomson discovered electrons in 1897. He made a BEAM of them (like a beam of light) in a VACUUM TUBE.

Cambridge, 1897

Vacuum

Help! I can't breathe in here!

Invisible beam of electrons

Hot metal

A modern vacuum tube

Visible spot of light

Electrons come out of a hot piece of metal.

Glass tube

The screen glows when the fast electrons hit it.

Screen

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

ELECTRONS

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.

Jo Cole
Bristol University

...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.

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

Yeuch!

Yeuch!

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.

This was J.J. Thomson's idea of what an atom MIGHT be like. The electrons are embedded in a ball which has a positive electric charge. It was called the PLUM PUDDING model of the atom.

Currants: electrons with negative charge.

Pudding dough: a sphere with positive charge.

Perhaps the tiny electrons are EMBEDDED in the positive part like currants in a sponge pudding?

When electrons flow, do they make a CURRANT CURRENT?

Dough!

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

Oooh! This looks nice.

Yeuch, let's get away from here.

What's going on here?

The positive end of a battery is ATTRACTIVE to electrons.

The negative end of a battery is REPULSIVE to electrons.

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

But what's happening INSIDE the wires?

LOTS of electrons are on the move.

Inside the wire.

Electric Cell

An imaginary 'close-up' view of a nucleus shows that it is made of PROTONS and NEUTRONS.

Nucleus 'close-up'

Protons

Neutrons

Electrons in orbit (negative electrical charge)

Nucleus at centre (positive electrical charge)

An atom with nucleus and electrons

By firing fast particles at neutrons and protons we find that they are not simple spheres but have EVEN SMALLER particles inside. These particles are QUARKS.

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.

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

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

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 NOT what I predicted.

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

Thin gold foil made of gold atoms

Alpha particles

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.

Ow!

Manchester, 1910

Radioactive source of alpha particles

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.

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