C T R Wilson and the discovery of Cosmic Rays

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September, 1994 wasn't very different from any other September on the summit of Ben Nevis. Winds blew, rain fell, sun shone and people went up and down Britain's highest mountain. Nothing unusual happened from the mountain's point of view. But that month should have been special for those who climb Ben Nevis, because it marked the centenary of C T R Wilson's stay there, in the old Ben Nevis Observatory. His name is hardly a household one, but as the only Scot ever to be awarded the Nobel Prize for Physics, perhaps he deserves a few minutes of our time. His Nobel-winning work stemmed directly from his time on Ben Nevis; many who might otherwise be unimpressed by his achievements will sympathise with his finding inspiration in such a place.

Charles Wilson was born on 14 February, 1869, at Crosshouse farm in the Pentland Hills. His father, a sheep farmer, died when he was four and the family moved to Manchester, where his maternal grandparents then lived. At the age of fifteen, a family holiday at North High Corrie on Arran filled young Charles with awe at the beauty of nature, and he resolved to study the natural world in all its aspects. On his return to Manchester he commenced studying widely in the natural sciences, in particular spending hours peering down a microscope at tiny pond creatures. By the time he went to Cambridge in 1888, however, he had decided to study Physics, the science which tries to get to the bottom of all things.

His own recollections of his early years, published in the *Notes and Records of the Royal Society* are quite charming. He recalls his anxiety for the future, in terms that might interest present-day Physics students: 'I could not imagine what career I was fitting myself for as there were remarkably few openings for trained physicists. I felt I might be of use as an explorer as I had some knowledge of a wide range of sciences and powers of endurance tested on the Scottish hills. The prospects of gaining admission into an electrical engineering works seemed rather remote'. He also felt a worrying responsibility to provide for his family. However, he was persuaded to settle down to hard work, and in 1892 completed his degree. A couple of rather unsettled years, including a spell as a grammar school teacher, followed, and it was during this period that he spent his fateful sojourn on Ben Nevis' summit.

The Ben Nevis Observatory had a short but remarkable life. The path to the summit (still used as the most popular, 'tourist' route) and the Observatory itself were constructed in 1883 by the Scottish Meteorological Society. This body had no funds for such a venture, but the idea caught the popular imagination and a public appeal raised over £4,000. The founders hoped that the usefulness of the Observatory would persuade the Government of the day to assume responsibility for its upkeep, but these hopes proved forlorn. The financial burden of the Observatory eventually became intolerable, and it closed down on 1st October, 1904. Only ruins and the commemorative plaque now remain. During its operational life, however, meteorological observations were made every hour, sometimes in life-threatening conditions, and it must count as one of Scotland's boldest and most colourful scientific endeavours. Its tale is well told in the little booklet, 'Ben Nevis Observatory 1883 - 1904', published by the Royal Meteorological Society.

Young physicists were sometimes employed to relieve permanent Observatory staff for a couple of weeks during the summer. The combination of scientific work and the remarkable setting must have appealed greatly to Wilson, and he was duly accepted in this role for a two-week period in September, 1894. This fortnight was to prove fateful - just as mountainous Arran had given him direction, so mountainous Lochaber led to the great achievements of his scientific career. This statement is no self-indulgent romance on my part; he himself later wrote, 'the whole of my scientific work undoubtedly developed from the experiments I was led to make by what I saw during my fortnight on Ben Nevis in September 1894.' So (without getting too technical), what did he see on Ben Nevis, and where did it lead?

A few years ago, a friend and I spent a Sunday afternoon on Beinn an Lochain, the grand, craggy hill that looms above the top of the Rest and Be Thankful road. Thick cloud surrounded us for much of the ascent, but it thinned around our heads as we neared the summit, and sunlight began to filter through. Our shadows were visible on the cloud beneath us. All of a sudden the cloud thinned just a little bit more, and we saw something strange. A bright 'halo' began to form around the shadow of my head, with the colours separated out similarly to the rainbow. It brightened and faded as the cloud came and went, eventually disappearing altogether. My friend saw the same thing around the shadow of his head. This was the 'Brocken Spectre', a beautiful and eerie optical phenomenon seen under exactly these conditions: sunlight from behind, cloud and a steep drop in front. The multi-coloured halo has another, technical name: a 'glory'. Unlike the rainbow, whose size and form can be understood fairly simply, there seems to be no simple explanation of the Brocken Spectre (although a detailed, mathematical one does exist). Of course this only adds to its air of mystery. It is certainly a very beautiful sight, and a little bit out of the ordinary. Apart from mountaineers, aircraft passengers sometimes see glories surrounding the shadow of the 'plane, when this is formed on cloud beneath them.

On Ben Nevis' cloudy summit in September, Wilson saw the Brocken Spectre in the great northern corrie several times. He was also treated to other, remarkable glories at sunrise, formed as the mountain's shadow sped eastwards across lower cloud layers towards him. The appearance of these various glories captivated him, and he decided to understand how they are formed. This rapidly led him to something only incidentally connected with glories, but of much more fundamental significance.

Nowadays we are surrounded by all sorts of ingenious electrical devices that make our lives easier. These work on (fairly) well-understood principles, one of which is the idea that all matter is made up of tiny particles called atoms, and that these in turn are made up of smaller particles, called electrons and protons, which carry electrical charge. By making these charged particles move in wires we can persuade them to do all sorts of things, to heat and light our homes, to carry information (such as sound or images) very long distances, and to 'shuffle' information in calculators and computers. Making the silicon chips perform their commonplace miracles rests on this way of looking at the world (if you choose to deny the reality of electrons and protons, please don't use a word processor to say so). Children are all told this in school, and we take the fruits of these ideas so much for granted that it is easy to forget how new they are, as ideas go. One hundred years ago, when Wilson started his experiments on glories, X-rays and radioactivity were new, exciting discoveries, and ideas of the atom and its constituents were only just starting to emerge.

By 1895 Wilson had a bit more security, in the form of work demonstrating to physics students at Cambridge. He also had ideas, and access to the facilities of Cambridge's famous Cavendish Laboratory. In the spring of that year, he began experiments to start understanding the glories, constructing a device that rapidly expanded moist air so that little clouds were formed in a controlled way. In this he was following John Aitken, another remarkable Scottish scientist. In his home in Falkirk, Aitken discovered in 1888 that the water droplets of cloud or mist start forming around tiny particles of dust. These particles are still called Aitken nuclei in his honour. In the process of starting to investigate glories, Wilson found that moist air from which all the Aitken nuclei had been removed could still be made to produce a small quantity of water droplets. These droplets had to start forming around atoms which were distinct in some way from the bulk of the atoms in the moist air, but in what way? The idea of *ions* (atoms which have a net electrical charge, produced from normal atoms by adding or removing one or more electrons) had just become current, and Wilson was excited by the notion that his water droplets might mark the places that ions were being formed in the moist air. X-rays were known to produce lots of ions, and, sure enough, lots more droplets were produced in his apparatus if he exposed it to X-rays. Wilson had shown that droplets of water could be made to form around ions in expanded moist air; the poor old glories paled into unimportance beside this discovery.

Many ideas followed, the most momentous (and Nobel Prize-winning) being the device known as the Wilson Cloud Chamber. Many of us have heard the term 'ionising radiation', which refers to the invisible radiation, generated by radioactive material, that damages the cells of our bodies. The name 'ionising radiation' comes from one of the effects of this radiation - it removes electrons from ordinary atoms, turning them into ions. When referred to in this way it is rather mysterious, but much 'ionising radiation' is made up of exactly the same particles that make up atoms, except moving very fast, so that they do some damage when they collide with normal atoms. In particular, fast-moving atoms of the gas helium with all their electrons removed are called 'alpha-rays', and fast-moving electrons are called 'beta-rays'. The nature of the alpha- and beta-rays was indirectly suspected by about 1910, but Wilson eventually provided the most dramatic demonstration imaginable.

As alpha- or beta-rays pass through matter, they leave a trail of ions behind them. This is just as true in moist air as anywhere else. So, if a device could be constructed which would expand moist air by just the correct amount, quickly enough (before the droplets had time to move from where they were formed), the paths of the ionising particles would be visible as a trail of water droplets. In 1911 Wilson managed to perfect such a device, and he used it to produce photographs of the trails of individual ions and electrons. These sub-microscopic phantoms were then known only indirectly from ingenious argument. In the cloud chamber they burst into vivid, visible reality. They behaved exactly as they should have, and much that was new was subsequently learnt by examining their trails.

Deserved celebrity followed for Wilson. The device for rapidly expanding moist air is known as the Wilson Cloud Chamber, and its development led to the award of the Nobel Prize in 1927. It was a vital tool for the exploration of the microscopic world, and was not superseded until the 1950s.

J J Thomson, the discoverer of the electron, was head of the Cavendish Laboratory in Cambridge when Wilson first worked there. He made some interesting remarks on the development of the cloud chamber, which also give us a little glimpse of Wilson's character: 'This work of C T R Wilson, proceeding without haste and without rest since 1895, has rarely been equalled as an example of ingenuity, insight, skill in manipulation, unfailing patience and dogged determination. Those who were not working at the Cavendish Laboratory during its progress can hardly realise the amount of work it entailed. For many years he did all the glass-blowing himself, and only those who have tried it know how exasperating glass-blowing can be, and how often when the apparatus is all but finished it breaks and the work has to be begun again. This never seemed to disconcert Wilson; he would take up a fresh piece of glass, perhaps say, "Dear, dear", but never anything stronger, and begin again............It is to him that we owe the development of a method that has been of inestimable value to the progress of science.' Didn't scientists write beautifully in those days?

Many other lines of work, to do particularly with atmospheric electricity, followed from Wilson's early experiments on producing clouds. Let me mention one other idea which emerged.

X-rays produce lots of ions from ordinary atoms in the cloud chamber. But even in the absence of an X-ray source, a small number of ions are continually produced (they are made 'visible' in the cloud chamber, but of course they are always being produced in normal air). What makes them? Wilson made a bold, imaginative suggestion: perhaps enormously powerful penetrating radiation, arriving at the top of the Earth's atmosphere from somewhere else in the cosmos, might do the job. He devised an experiment to test this idea, which involved going into the tunnel of the Caledonian Railway near Peebles ('at night, after the traffic had ceased'!), where one might expect to be shielded from this continual cosmic bombardment. But the rate of production of ions there was the same as normal, so it seemed that there was no such cosmic radiation. Some other mechanism had to be producing ions in normal air, and Wilson turned away from this idea.

However the cosmic radiation does exist, and goes under the name 'cosmic rays'. It is produced by far-off, celestial events of extreme violence and uncertain nature. By the time it has passed through our atmosphere it is greatly reduced in strength, and it is responsible for only 5 - 10% of all the ions produced in normal air, at ground level (small quantities of radioactive material that are everywhere around us make the rest). Historically, then, it took a little time and care (and some dangerous balloon ascents) to establish whether it was real or not. Although he incorrectly ruled out its existence, Wilson rightly gets the credit for having first suggested that there might be such radiation.

Wilson died on 15th November, 1959, at the age of 90. He remained healthy and active all his life and climbed on Casteil Abhail on Arran when he was 82 years old. His last scientific publication, the result of a lifetime's ruminations on thunderstorm electricity, was published in his 88th year, by which time he was the oldest living Fellow of the Royal Society. He was survived by his wife, Jessie and three children.

The words of J J Thomson, quoted above, gave us a glimpse of Wilson's character. Other glimpses are found in his own published reminiscences, which have great dignity as well as gentle humour, and also in his Royal Society obituary notice. There P M S Blackett, himself a Nobel Prize winner, wrote, 'Of the great scientists of this age he was perhaps the most gentle and serene, and the most indifferent to prestige and honour; his absorption in his work arose from his intense love of the natural world and from his delight in its beauties.' In an age when science is often seen as the enemy of nature, his life and work remind us that the natural world becomes no less beautiful because we understand it better.