Professor Aharonov receiving the degree of Doctor of Science from the Vice-Chancellor

PROFESSOR Y. AHARONOV

PUBLIC ORATOR:
PROFESSOR M. V. BERRY

Mr Vice-Chancellor, when Yakir Aharonov began studying physics in the 1950s at the Technion in Haifa, Israel, one of his teachers was Nathan Rosen. Twenty years earlier, Rosen had made an important contribution to the interpretation of the (then rather new) quantum mechanics. But by the time the young Aharonov became entranced by the fundamentals of that theory, its study was unfashionable, and Rosen advised him to concentrate on applications.

This fatherly advice was sabotaged by the arrival in Haifa of David Bohm. At that time Bohm was on an odyssey forced by political persecution in the USA, which was then in the grip of anti-communist hysteria. With Bohm, he began to delve into the forbidden subject and they wrote several papers together. One was about quantum uncertainty; another was about the meaning of the equation for the electron devised by that great Bristolian physicist Paul Dirac. It was natural that when Cecil Powell offered Bohm intellectual refuge and a lectureship in Bristol, Aharonov would accompany him, and register here for a PhD as Bohm's student.

Imagine Aharonov arriving in the Bristol of 1957—not the most exciting city at that time, I am informed—on his first trip abroad. According to rumour, he was embarrassed by his Israeli accent, and thought it would be a handicap in pursuing the natural enthusiasms of a young man, so he took elocution lessons out his new voice, the person he addressed replied in Hebrew.

Back to physics, then, and a spectacular discovery with Bohm, in 1959, that now bears their name. It concerns an aspect of the microscopic behaviour of quantum particles that contrasts dramatically with that of the same particles in the 'classical' mechanics of Newton (which applies on larger scales). The Aharonov–Bohm effect is the ability of charged quantum particles, for example, electrons, to respond to electric and magnetic fields remote from them; classical particles can respond only to fields where they are. Dr (later Professor) Bob Chambers, then himself recently arrived in Bristol, carried out an elegant experiment, helped by a suggestion by Professor (now Sir) Charles Frank, and the Aharonov–Bohm effect was observed, as a shift in the pattern of fringes of interfering electron waves.

Their discovery caused an immediate sensation in the world of physics, as an apparently paradoxical but experimentally confirmed prediction of quantum theory. Over the years its importance has grown as its ramifications have emerged in one area of physics after another: molecules, atoms, solids and, most fundamentally, as a cornerstone of the 'gauge theories' that now dominate the physics of elementary particles.

After leaving Bristol with his PhD, Aharonov held several temporary appointments in the USA before accepting a chair at the University of South Carolina in 1966 and a chair at the University of Tel Aviv in 1967. Two chairs? Only a quantum mechanic could occupy two

Aharonov's contributions to physics did not end with the Aharonov–Bohm effect. That was followed by many further brilliant discoveries, of which I will describe two. An object in space, unconnected to any other, looks the same after one complete turn. If the object is tethered by a rope, its turn is registered as a twist in the rope. The surprise comes after two turns: then the rope can be untwisted, and again the tethered object looks the same as before. You can perform this trick with your own hands (I learned recently that it is now accepted as a t'ai chi exercise). In 1967, Aharonov (with Leonard Susskind) took seriously a fact that had been noted before but dismissed as insignificant, that the distinction between tethered and untethered rotations persists into the microscopic world. In particular, some quantum particles behave as though they are linked to the rest of the world by ghostly strings, and look different after one complete turn: their waves change sign, and return to their original state only after two turns. They suggested an experiment with neutrons to detect this bizarre effect, and in 1975 it was seen by two groups of investigators.

The second discovery concerned the 'geometric phase'. This occurs in quantum systems that undergo a sequence of changes in a cycle, so as to return to their original state. After the cycle, the waves that describe the system exhibit a shift that depends on the geometry of the cycle. This shift is the geometric phase. Its existence as a general phenomenon—with the Aharonov–Bohm and Aharonov–Susskind effects as special cases—had been demonstrated already, but only under the restriction that the cycle be performed slowly. In 1987, Aharonov (working with Jeeva Anandan) removed this restriction, and gave a more general, and rather simple, reformulation of the geometric phase.

I mention a curious historical fact. In 1959, when Aharonov and Bohm were discovering their effect here, the Head of Department was Professor Maurice Pryce. At that time, he was studying the quantum mechanics of molecules, with Longuet-Higgins, Öpik and Sack: specifically, the interaction between the motion of the nuclei wave describing the electron changes sign, and this gets reflected in the spectrum of the molecule. Now, it turns out (with the benefit of hindsight) that this too is a geometric phase, mathematically similar to the Aharonov–Susskind effect for neutrons. So, two geometric phases were discovered in Bristol at the same time (two out of seven over the years, actually). There is no evidence that the connection was appreciated then.

Theoretical physics is a strange calling. You dream and scribble and, if you are lucky, the world conforms. Popperists would argue that if the world does not conform you are luckier, because then you are surprised and so learn more. I am sure, however, that most of us would be more than happy to be lucky as often as Aharonov has been, rather than luckier.

Mr Vice-Chancellor, I present to you Yakir Aharonov as eminently worthy of the degree of Doctor of Science, *honoris causa.*

PROFESSOR P. W. HIGGS

PUBLIC ORATOR:
PROFESSOR M. SPRINGFORD

Mr Vice-Chancellor, 50 years ago, Professor Cecil Powell, working in Bristol at the H. H. Wills Physics Laboratory, discovered the pi-meson in interactions of cosmic rays in photographic emulsions exposed on the peaks of high mountains. As we celebrate the anniversary of this great discovery, for which Powell was awarded the Nobel Prize, it is especially appropriate that the University should be honouring Professor Peter Higgs. .

Peter Higgs is a theoretical physicist whose work is related to one of the most baffling but fundamental of all questions: why is there something rather than nothing? In a remarkable series of papers, published between 1964 and 1966, he was able to demonstrate a mechanism which accounted for the existence of particles with mass; that is to say, how it is that matter can exist in the universe. The Higgs mechanism, as it came universally to be known, confounded the then orthodox view that certain particles, the so-called gauge particles or bosons, had to be massless. There is no doubt that this discovery laid the proponents, Glashow, Salam and Weinberg.

The key idea is that empty space, that is a vacuum, is not as simple as it seems. Rather it is everywhere permeated by a field, (the Higgs field), a kind of modern-day version of the aether so beloved of scientists in the 19th century. It is through their interactions with this all-pervasive field that fundamental particles acquire their mass (via the Higgs mechanism). Furthermore, as with any field, there exist quanta or particles (the elusive Higgs bosons) whose detection is one of the central goals of present day elementary particle physics.

Mr Vice-Chancellor, this beautiful and elegant theory leads to what some have referred to as 'the unbearable heaviness of being'. It is clear too that one of the penalties that must be paid by such pioneers as Peter Higgs, is that their name becomes public property.

Like many of the most influential ideas in science, Peter Higgs' idea was distilled from an intellectual environment in which similar speculations existed in other fields of physics. His achievement was to develop the underlying principle in such a lucid way that its importance in the area of elementary particle physics became obvious. The impact of Professor Higgs' work has been enormous and has had repercussions well beyond particle physics. Indeed it has attracted the attention of Cabinet ministers, one of whom donated free bottles of champagne to physicists bold enough to explain the idea to the non-scientist on one side of A4. Letters from the Cabinet Office on the subject sometimes referred to the 'Higgs Bosun', spelt b-o-s-u-n, leaving physicists to speculate on the possibility that Whitehall believed that particle physics could be applied to the European Common Fisheries Policy.

Mr Vice-Chancellor, there are some remarkable parallels between the situation in elementary particle physics now and 50 years ago. Then, Professor Yukawa had predicted the existence of a new particle, a boson which would mediate the strong nuclear force. Despite many years of searching for such a particle, and several false trails and misidentification, no-one had then discovered Yukawa's