Fudan-Zhongzhi Science Award Acceptance Speech

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With great pleasure, I accept this Fudan-Zhongzhi award for developing the *geometric phase*. Today is not the occasion for a technical explanation, so I will say just three things about it.

• It is a way in which the *phase* of a vibration, such as a quantum wave, hides a memory of what has been done to it.

• It is an application to quantum physics of the same *geometry* that helps a cat land safely on her feet when dropped upside-down, and helps us reverse-park a car into a narrow space.

• It is a *connecting idea*, linking phenomena in different areas: energies of molecules, quantum materials, optical microscopy, swimming of tiny organisms, even the peristalsis of our stomach as we digest food. Connections are important. As my late colleague Sir Charles Frank said: *Physics is not just Concerning the Nature of Things, but Concerning the Interconnectedness of all the Natures of Things.*

Let me tell you a little about theoretical physics. It is a strange activity: we dream, gazing at equations on our computer screens or scribbling our calculations; yet our craft describes aspects of the physical world outside ourselves. This has been called *The unreasonable effectiveness of mathematics in the natural sciences*. I don't think it is unreasonable. Our brain-power is limited, so it is reasonable that as humanity evolves our latest theoretical discoveries should involve our most advanced mathematics. Not unreasonable, but wonderful!

We receive this award as three individuals. But it recognises research by many. In every case, our discoveries, in direct collaboration or alone, originate with, are inspired by, or develop, insights by others. I am often sole author of my papers, yet all of them were stimulated by something I read, a lecture I heard, a remark by a colleague, or a chance encounter at a meeting. This direct

or implicit interaction is what has made science so successful: in a sense, it is a product of humanity's group mind.

In the case of geometric phases, there was a complicated prehistory, involving many people, traceable back to 1830; I was ignorant of it when I found the phase in 1983. My insight was prompted by a question following a lecture. At that time, there was much interest in chaos theory. In my lecture, about a technical aspect of *quantum* chaology, I mentioned that it applies only when there is no magnetic field. The question, by Ronald Fox, was: "*But what happens if there is a magnetic field?*" The answer, after several weeks' hard thinking, was the geometric phase. Its origin was a question, but I needed the scientific background. As Pascal wrote: *Chance favours the prepared mind*.

Also important is our research environment. For me, over more than half a century, this has been the support provided by the University of Bristol, and especially our physics department and my colleagues. Another important part of our 'environment' is travel – in my case to many countries, including, increasingly and with much pleasure, China. International contacts have always been part of intellectual and commercial life. As with international trade, our common scientific standards and practices encourage peace between peoples with different governments and ways of living.

Interaction is essential, but not enough. To understand, we need long periods of intense quiet concentration: dreaming time, to enable the elements of an idea to collide and combine and settle into their final form at the moment of insight. This 'elementary particle of sudden understanding', I call the *clariton*. It describes the magic moment when what has been obscure appears in clear light. But particles have their antiparticles, and there are unwelcome *anticlaritons*: disappointments that arrive today and annihilate yesterday's clariton.

In pandemic times, the internet, and Zoom, help us interact remotely (as now), but it's not the same as face-to-face. However, there is a compensation: during the pandemic, we enjoy much solitary creative thinking time. So did William Shakespeare, who wrote some of his greatest plays during a twenty-year series of plagues, when theatres in England were closed for 78 months; so did Isaac Newton, who made his seminal discoveries in physics and

mathematics during the plague of 1665, while self-isolating at home, away from Cambridge.

Receiving this recognition from Fudan University and the Zhongzhi Enterprise Group, and sharing it with two such distinguished scientists, is an honour and a delight, and I thank you.