John Hasted, *The Metal-Benders*. Routledge & Kegan Paul, 1981.

Chapter 25
The many-universes interpretation of quantum theory and its implications

It is true that only a minority of physicists are dissatisfied with the usual interpretation (by Niels Bohr of Copenhagen) of the quantum theory of measurement, but at least it can be said that members of this minority have made various proposals aimed at overcoming our mental distaste for a completely random universe that is comprehensible only through statistical laws.
Let us consider a stream of electrons being diffracted by a pair of slits. The familiar wave diffraction pattern will appear on a fluorescent screen. If one of the slits were blocked up, there would be no interference between the two waves, and only a single smudge would appear on the screen. If instead the other slit were blocked up, again only one smudge would appear. But if both slits were opened again, a complete set of fringes would build up as more and more electrons reached the screen.

What about the first electron to pass through the pair of slits? To which fringe does it contribute? Can quantum theory tell us where it will go? At present it cannot, and most physicists would give the opinion that we can never know the answer. The point of arrival of the first electron is random and that of the second electron is still random, and so on. But as an increasing number pass through, the fringe pattern gradually appears. This experiment could in principle be carried out very slowly, maybe one electron per year; the same principle would apply, each electron path being unpredictable. In this extreme example, quantum theory does not seem to be very powerful. The system also seems to have non-locality in time. But for predicting the most probable results of a large number of electrons, quantum theory is extremely powerful; it has developed to the extent when it can be included as part of engineering. With the aid of solutions of the Schrodinger wave equation, the probabilities of events happening can be calculated with precision. These are expressed as the square of 'probability amplitudes', which are represented by means of the bra-ket notation:
<electron arrives at y |electron leaves x> or <y|x>.

Within the limits of uncertainty determined by the Heisenberg Principle, and within the limits imposed by sheer mathematical difficulty, the most probable behaviour of a system can be calculated. One can extend the calculation to that of the probability amplitude of the electron leaving x for y. and leaving y for x (two slits one after the other); this would be represented as the product <x|y> <y|x>.

Now consider again the question of which of two interference slits a single electron passes through. Since the electron has the properties of a particle, the question is not meaningless; but quantum theory gives no answer, unless there is some method of detecting the passage of the electron. For example, a photon might be arranged to pass behind one of the slits; when it is scattered by the passing electron, detection of the electron is possible. But this introduces an *observer* or *apparatus* into the system, and the probability $|A\rangle$ of the apparatus being in a certain state A must be taken into account, as well as the probability $|s\rangle$ of the system being in a state s. The combined probability is

$$|s,A\rangle = |s\rangle|A\rangle$$

The observer is an integral part of the description of the event, and without the observer there can be no description and no complete understanding of reality. A similar difficulty about unpredictability is encountered in the phenomenon of radioactive decay. Most people will be familiar with the behaviour of a 'radioactive source', which is a sample consisting of a species of radioactive atom. When these atoms decay, each one emits (often by a tunneling process) a highly penetrating particle, which is a form of nuclear radiation. These particles can be detected by a suitable type of detector such as the Geiger counter used in the Uri Geller experiment of chapter 15. The average time taken for a radioactive atom to decay can be measured if sufficient atoms are available. But the exact moment of decay of an individual atom can in no way be predicted by quantum theory. The moments at which the Geiger counter clicks are random within the bounds set by a probability distribution. The quantum mechanical description of the system is a linear combination of the wave functions not only of the undecayed atom but also of the decayed atom. The wave function is the mathematical expression of the form of the wave for the system, and it must satisfy the wave equation. Schrodinger went further than demanding this inclusion of both wave functions; he insisted that the consequential wave functions must also be included.

He illustrated this requirement with a dramatic example of a cat enclosed in a chamber with a sealed flask of cyanide poison, which can be broken by a hammer which is released by a relay activated only by the radiation pulses from a radioactive source. This source is very weak, so that there is a chance that there will be a pulse within the natural lifetime of the cat, and a chance that there will be none. Since the cat is provided with adequate food, drink and air, the question of whether the cat will live out its natural life or be prematurely poisoned by cyanide vapour cannot be answered with any certainty; only the probability could be calculated. Schrodinger insisted that a complete description of the system must include both the wave function of the living cat and that of the dead cat.

Since no physical condition exists to determine causally the state of a particular system at the moment of measurement, it follows that until a measurement is carried out, a system is properly described by what is known as a state vector, which is the linear combination of all possible states of the system. Only after a measurement is performed can we affirm with confidence that the system, let us say an atom, is in a certain state. Before the measurement, the atom is collectively in all the states.

The problem of the quantum theory of measurement was formulated mathematically by von Neumann(75) and the short account given by de Witt(76) will be repeated here. The world is considered to be composed of two dynamical variables, a system *s* and an apparatus *A*. A combined state vector is expanded in terms of an orthonormal set of basis vectors:

|s,*A*>= |s>|*A*>

where *s* is an eigenvalue of some system observable and *A* is an eigenvalue of some apparatus observable. The state of the world at an initial moment is represented by:

|psi0>= |psi>|phi>,

which is a combined state vector with |psi> referring to the system and |phi> to the apparatus. The learning of the apparatus about the system requires a coupling between the two; the result of this is described by a unitary operator *U*:

|psi>= *U*|phi0>

U acts as follows:
U|*s,A*>= |*s,A* +*gs*>= |s>|*A* +*gs*>

where *g* is an adjustable coupling constant, which is said to result in an observation, the information from which is stored in the apparatus memory by virtue of its irreversible change from |*A*> to |*A* + gs>. Using the orthonormality and assumed completeness of the basis vectors, the initial state vector is found to become:

|psi1>= sum over s Cs|s>|phi[s]>
where
Cs=<s|psi>
|phi[s] >=integral |*A* +*gs*>*phi(A)dA*
phi(A) = <*A*|*phi*>

This final state vector is a linear superposition of vectors |*s*>phi[s]>, each of which represents a possible value assumed by the system observable, the value which has been observed by the apparatus. The observation is capable of distinguishing adjacent values of *s* (spaced by delta *s*) provided that *A* << g delta s where delta *A* is the variance in *A* about its mean value relative to the distribution function |phi(A)|^2. Under these conditions,

<phi[s] | phi[s']> = delta function of s,s'

where delta function is the Dirac delta function. The wave function of the apparatus is initially single, but splits into a great number of mutually orthogonal packets, one for each value of s (i.e. s, s', s'' etc.).

The apparatus cannot decide which is the correct value of the system observable, and would have to be supplemented by a second apparatus to observe the first one; but the second one also cannot decide, and so must be supplemented by a third; and so on. This 'catastrophe of infinite regression' requires resolution by a fresh approach, otherwise the whole quantum theory of measurement remains inadequate. One cannot make predictions about the whole universe, because the universe must contain all the observers. This infinite regression has an affinity with Russell's paradox and with Godel's theorem in mathematics.

To recapitulate; in the absence of any observation, matter is in continual fluctuation. When an observation is made, a single value of the energy is observed, and the physical observables instantaneously take on certain single values. Until the observation is made, at a time which is determined by a mental decision of the observer, no certainty about the physical reality is possible. To a second observer this system of 'wave function and first observer' appears to be in continual fluctuation, even when the first observer makes his observation. The second observer believes that the first observer is in continual fluctuation, and is split into many copies of himself, even though he is making an observation. But he must again become singular when the second observer performs.
The conventional escape from infinite regression is that proposed by the Copenhagen school,(77) which states that as soon as the state vector attains the form of the equation above it collapses into a single wave packet, so that the vector | psi> is reduced to an element |*s* >|phi[s]> of the superposition. We cannot predict which element will be formed, but there is a probability distribution of possible outcomes. This assumption is not a corollary of the Schrodinger equation, and it leaves the world in an essentially unpredictable state.

A different proposal was made by David Bohm(78) with his introduction into quantum theory of 'hidden variables', which determine the indeterminable quantities but at the same time conform to the probability distribution. For many years the search for these hidden variables has continued, but up to the present none has been found. We are now coming increasingly to believe that the mind is the only remaining undiscovered hidden variable.

A proposal was in fact made by the theoretical physicist, Eugene Wigner,(79) that the infinite regression could be arrested by the intervention of mind. This was almost the first appearance of mind in modern physics; it was accompanied by a mathematical description of the conversion from a pure to a mixed state arising from possible nonlinear departures from the Schrodinger equation when consciousness intervenes. Wigner also proposed that an experimental search be made for unusual effects of consciousness acting on matter. It is my own conviction that the clue to paranormal phenomena lies embedded in quantum theory.

An important formulation was made nearly twenty years ago by Everett, Wheeler and Graham.(80) They attempted to deny the collapse of the state vector, and take the full mathematical formalism of quantum mechanics as it was originally

presented. The world could be represented by a vector in Hilbert space, a set of dynamical equations for a set of operators that act on the Hilbert space, and a set of commutation relations for the operators; always provided that it were possible to decompose the world into systems and apparatus. Hilbert space is the complex analogue of Euclidean space, namely a space in which a system of orthogonal straight line coordinates is possible. Complex vectors epsilon(i) satisfying orthogonality relations (epsilon(i), epsilon(k)) = delta function of *i,k* are employed. Every vector psi is a linear function of the unit vectors:
psi=sum over k of psi k * epsilon (k)
and
psi k = (psi, epsilon(k))

This proposal forces us to believe in the reality of all the simultaneous universes represented in the superposition described by the above equations. These universes cannot communicate physically with each other, because the vectors are mutually orthogonal. In three-dimensional space it would be possible to have only three mutually orthogonal sets of vectors, but in a many-dimensional Hilbert space many such vectors could simultaneously exist, so that there is here the basis for simultaneously existing universes which cannot communicate physically with each other. Simultaneous universes have always been a subject which has fired the highest flights of human imagination. One has only to think of Milton, Dante, or in recent times of Jean Cocteau's *Orphée.*

It is not the existence of many simultaneous universes that is the most difficult concept to believe, but the continual splitting of one universe into an infinite (or very large) number each time an observed quantum transition occurs. We can hardly conceive of how many simultaneous universes there must be if this can really happen. For this reason Schrodinger refused to accept the consequences of the fully formal quantum mechanics.

I will repeat the proposal in the words of de Witt:(81)

The universe is constantly splitting into a stupendous number of branches, all resulting from the measurement-like interactions between its myriads of components. Moreover, every quantum transition taking place on every star, in every galaxy, in every remote corner of the universe is splitting our local world on earth into myriads of copies of itself.

What is really uncomfortable about this formulation is the invasion of our privacy. We do not like the idea of countless ($>10^{100}$) doppelgangers of ourselves, increasing in number all the time, even if they can never communicate physically. Perhaps they could communicate telepathically. But at least a proof can be given, in quantum mechanical terms, of the fact that we cannot feel the splits in physical terms.

Some comfort can be taken from the experience of physics, that it is only in microscopic, atomic, terms that quantum theory gives different results from classical mechanics. In the limit of large numbers of energy quanta within one system - that is in the limit of large quantum numbers there is correspondence between quantum and classical mechanics. In classical, macroscopic, surroundings the universes all look the same, and this is surely less uncomfortable. Nevertheless there are quantum-determined events, such as the mysterious death of Schrodinger's cat in the chamber, which differ from one universe to another.

If macroscopic objects were able to make quantum transitions, then the situation would be very much more precarious. There is a whole field of physics in which macroscopic quantum effects occur - namely the physics of very low temperatures, close to absolute zero, where superfluids and superconductors exhibit their extraordinary properties. Theorists who have worked in that field, such as Frohlich,(82) are alive to the possibility that quantum theory may apply macroscopically even at room temperature. If we can describe a macroscopic object by a single mathematical expression, a wave function, when its temperature is close to absolute zero, then for very short periods of time macroscopic wave functions might have significance at higher temperatures, where the movements of the atoms obscure the regularity of the system.

David Bohm and his colleagues(83) have proposed that there is a characteristic time t ~= *h/kT* for which a macroscopic wave function has reality. Here *h* is the Planck constant, *k* the Boltzmann constant, and *T* the temperature. This time will be appreciable at very low temperatures, but very short, 2 * l0^-13 sec, at room temperature. Only certain types of atomic and nuclear transition can take place in such a short time, but the remote possibility of macroscopic quantum phenomena in solids at room temperature remains. Normally within a solid object the localized wave functions may not be considered as assembling coherently into a single macroscopic wave function; but local coherence domains might develop, the boundaries changing with time and with the characteristic time t determining the rate of the process. This concept has as yet no experimental basis in solid state physics, but it opens up many possibilities. What is proposed is a continual fission-fusion process; the fission of macroscopic wave functions into microscopic ones, and their subsequent fusion into other macroscopic ones. But it is not clear that the temperature *T* is the thermodynamic temperature.

What has prompted such interest in macroscopic wave functions has been the realization by many physicists of the non-locality of quantum theory, of both photons and particles possessing rest-mass. The Einstein-Rosen-Podolsky paradox is at last coming to receive the attention due to it. The situation envisaged, and now confirmed experimentally, is that in the dissociation of a two-particle system into single particles, with the latter travelling in space, the relative polarizations of the particles become determined and related only at the instant of measurement at two remote locations. This instant can be made sufficiently short for no communication between the two particles by (virtual) photons to be possible; therefore the quantum description of the situation is non-local over the space of the experiment.

The extreme position which it would be possible to adopt is that of considering the whole universe to be described by one single wave function; there would be myriads of stationary states, and until an observation was made, the universe could be written as a linear combination of all of them. This is equivalent to the statement that the universe contains only a single electron, and it provides some justification for the experimentally observed constancy of electronic charge and rest-mass.

In Copenhagen quantum theory, using the wave equation, we can predict the passage of a system of unique energy Eo into a mixture of states, each with its own unique energy E*abc,* but each possessing a certain calculable probability of being the state to which the first state has been changed; at any instant the energy is equal to Eo = a*Eb + b*Eb + . . . But at the instant of observation a discontinuous change occurs in the system by which it collapses from a mixture of states into one state only.

But in the many-universe formulation, the wave function does not collapse at the moment of an atomic transition; rather, it splits into an infinite number of wave functions, each in its own set of Hilbert space co-ordinates, and each differing from the others in its energy, *Ea, Eb,* etc. The observer, in his particular universe, is capable of measuring this energy, but another observer, in a different but physically incommunicable universe, would measure a different energy. Since it is purely a matter of chance which universe the observer is in, the particular result he obtains appears to him random. But if he repeats a similar observation a sufficient number of times, then his result is predictable by the wave-equation (from which the forementioned a, b, c, etc. are derived), because all sets of co-ordinates are equally probable. The collapse of the state vector is avoided by postulating that within a single universe only the initial and final states are real, the mixture having no reality unless an infinity of universes is taken into account.

The proposal inherent in the many-universe theory, that each atomic transition in our own insignificant bodies causes the remotest galaxies to split into an infinite number, has resulted in the theory having only a very limited acceptance among physicists. Perhaps it would be more satisfactory if bounds were placed upon the local universes. But such bounds would introduce physical effects akin to surface phenomena, and normal effects of this type are as yet unknown to physics. The original Everett-Wheeler-Graham theory assumed that there was one observer in one universe, the same universe which contains the observed phenomenon.

But if we were to allow ourselves the luxury of a dualistic system, with non-material, or at least trans-spatial minds, then there would be powerful possibilities for the interpretation of physical psychic phenomena.

For example, we might speculate that the unconscious mind possesses the facility of receiving 'trans-spatial' information from the corresponding minds in other 'universes'. Since, because of the orthogonality, physical signals cannot pass from one universe to another, we would be forced to assume that the unconscious mind has trans-spatial properties and is able to communicate with physical reality in other universes only through other unconscious minds.

On the parallel universe model, millions of copies of each individual have parallel existences, but are entirely isolated physically from each other by the orthogonality, which prevents the passage of physical signals between universes. Let us propose that each one of these individuals possesses his own mind, and that communication between these corresponding minds is sometimes possible. No individual knows of the existence of his many *alter egos.* But if he were able to adopt the mind of one of these *alter egos,* he would then take the other universe to be his reality, without knowing that any change had occurred. Moreover, at the moment he successfully does this, one might suppose that his neighbours' minds (the observers' minds) could also come to be dominated by those of their own *alter egos,* so that they would also take the other universe to be their reality. All observers could now notice whatever physical differences there might be between the two universes. The differences could be that psychic phenomena, metal-bending, psychokinesis or teleportations have taken place. This principle could be extended in complication in two ways. First, there is no reason to limit the number of universes to two only, one before the mental change and one after. The only situation in which we know the universe to be singular (locally) is at the moment at which datum of an atomic physics experiment is recorded. This is a comparatively rare moment, so why should we not propose that we all pass through life in a continual state of subtending many universes at the same moment of time? Since these universes are in nearly all respects identical, we have hitherto imagined them to be a single universe. Sometimes a unique universe forces us to notice it, and it is then that we say that an atomic physical phenomenon has occurred.

Second, it might be that some of the universes are partially incomplete in the sense that the mind only knows of their existence locally. the mind might actually impose spatial boundaries on some or all of its local universes. These boundaries could be the 'surfaces of action' at which we have observed metal-bending action to take place. Outside the boundaries, that universe would not exist. If the boundary were made to move through space by the action of the psychic's unconscious mind, with which the observers' minds concur, then one universe will actually grow, contract or change shape; and the surface effects continually resulting from such changes would make up the metal-bending structural and quasi-force action. The change of shape is not noticed in other ways, because so many universes are superposed that no mind regards any one of them as incomplete. If the observers' minds do not concur, then no physical changes can be measured, and the event is hallucinatory. The fusion and fission of wave functions(83) into macroscopic size would also be necessary to this interpretation of physical psychic phenomena.

I include these speculations in order to show the extent to which it would be necessary to go in order to explain physical psychic phenomena with the aid of quantum physics.(84) I have in fact carried the speculations a good deal further, but I will not indulge myself at this stage, other than in a summary:

1 Teleportations could be interpreted using the hyperdimensional character of the many-universes model. It may be that such hyperdimensionality is strongly indicated by the discovery in the 1960s of the non-conservation of parity.

2 Metal-bending and structural change could be interpreted in terms of the reorganization forces which must occur in the creation or annihilation of atoms at the inter-universe boundaries or 'surfaces of action'. The configurations of these surfaces would have to be very complicated, showing turbulence perhaps down to atomic dimensions.

3 Quasi-forces would have to be interpreted in terms of a rapid series of local transformations into universes, each one with its own individual momentum, each slightly greater than the last. The rate of change of momentum would then have the appearance of a force acting on the transformed object.

4 For psychic acoustic phenomena,(85) psychometry, optical and electromagnetic phenomena and even the insensitivity of the human body to great heat, similar interpretations could be considered.

But if we allow ourselves the luxury of such speculations, then we must be prepared to accept the nightmare universes that could have evolved in continually increasing numbers since the 'big bang'. Precisely how many degrees of orthogonality different from our own these would have to be is difficult even to conjecture.

Since most people (including, probably, the proponents of the original many-universe quantum theory) would stop short of this, they find themselves drawn inevitably to the denial that physical psychic phenomena exist at all. That is why the spearhead of research must be not in theoretical formulations but in physical observations.

My purpose in including this chapter has been to show just how difficult it is for a physicist to incorporate physical psychic phenomena within existing physical theory. Once the difficulties are faced, however, a wide variety of alternative hypotheses about the nature of what we have called 'primary events' can readily be envisaged.