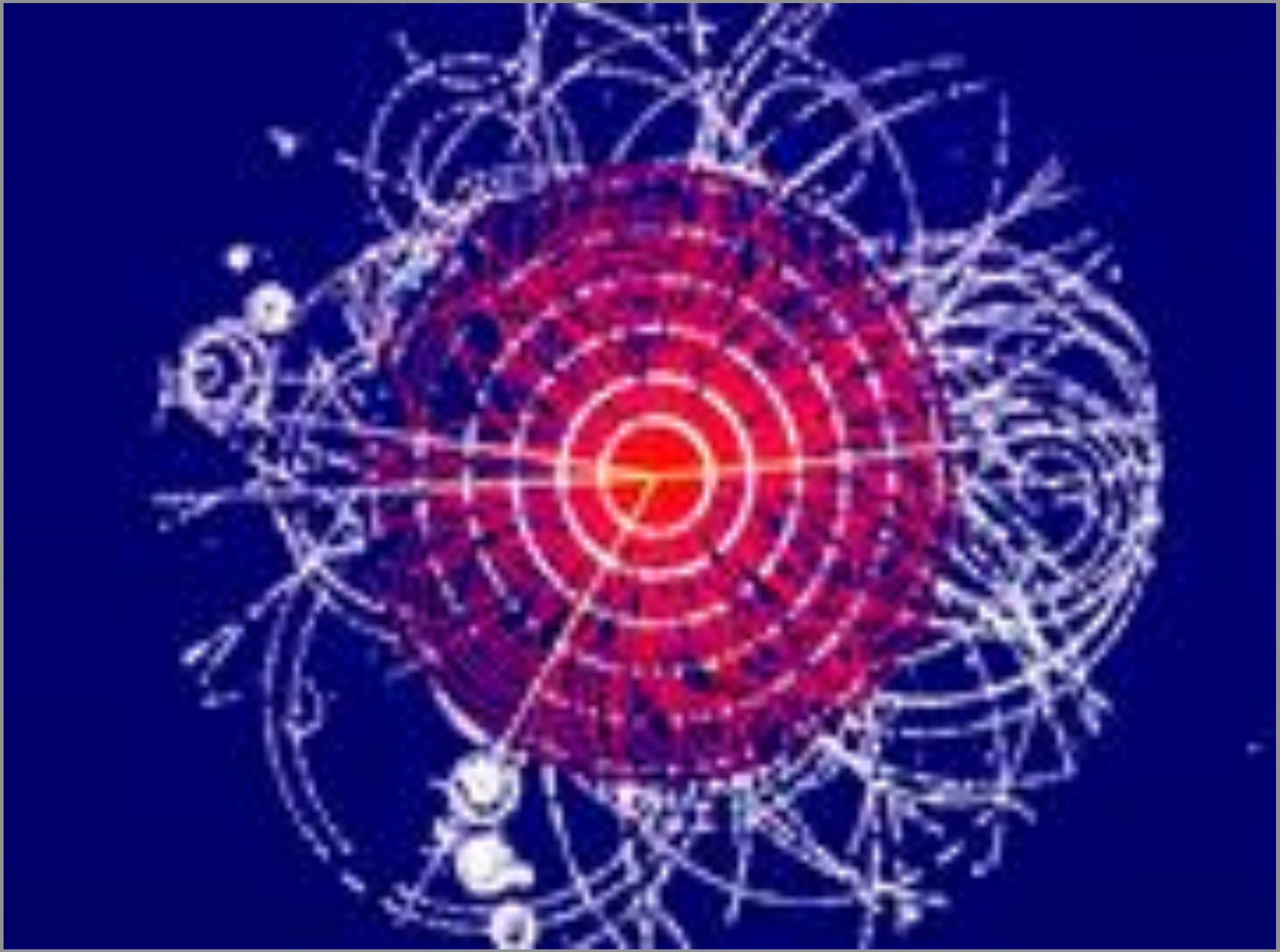
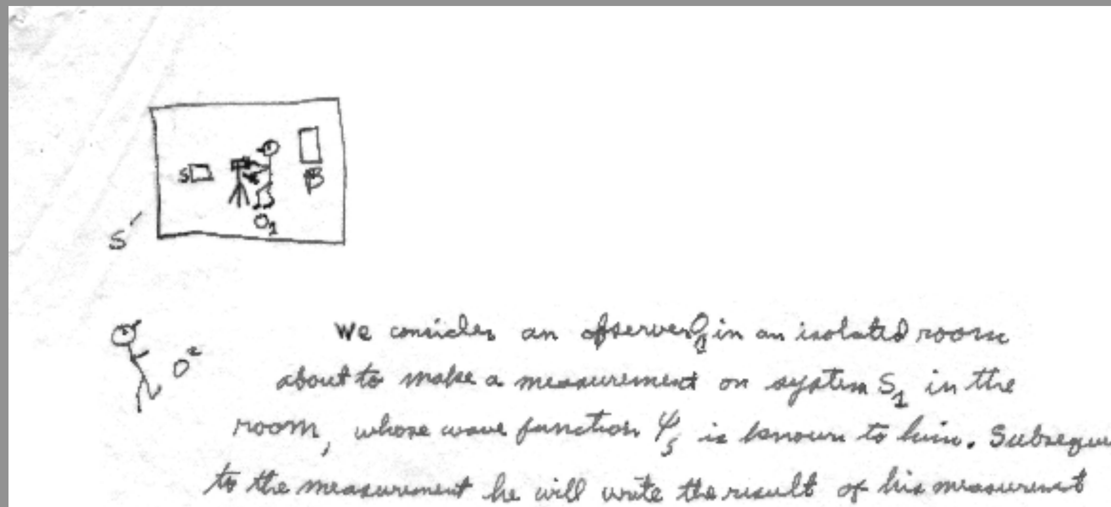
Hugh Everett III
All photos are courtesy of Mark Everett unless otherwise credited

Everett at Princeton University, 1953



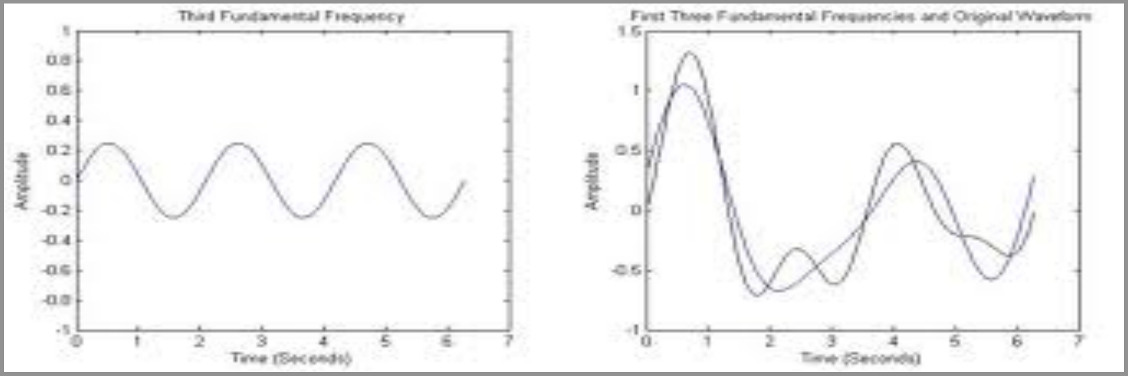
Higgs boson decay in a universe far, far, far away

Image courtesy of CERN



- Everett’s crude drawing of a Wigner’s Friend experiment setting up the Measurement Problem in an early draft of his thesis (1954).

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$



Third Fundamental Frequency
Amplitude
Time (Seconds)
First Three Fundamental Frequencies and Original Waveform
Amplitude
Time (Seconds)

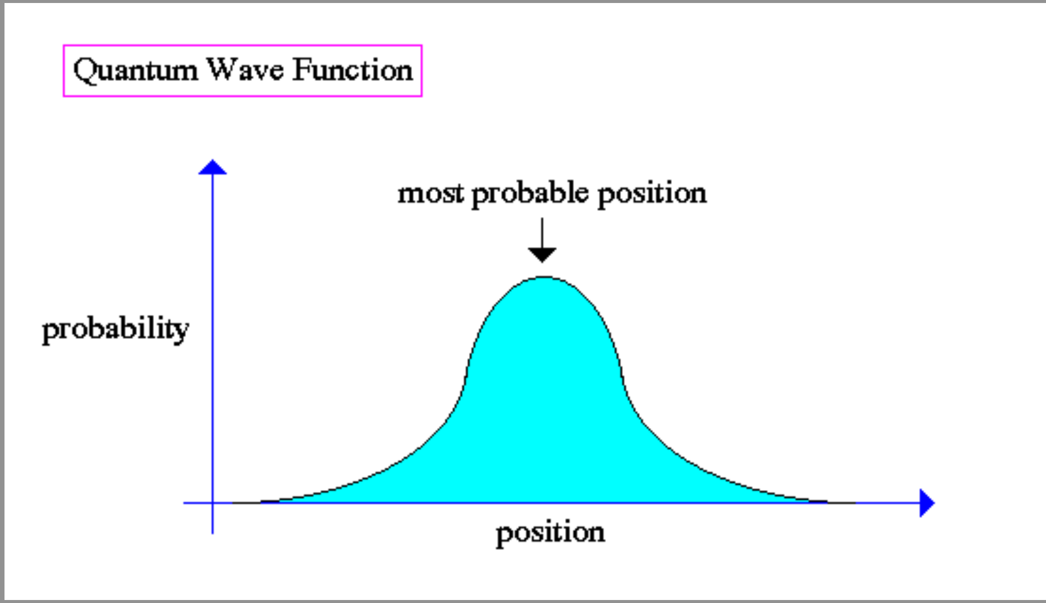


Image: courtesy of Tyson Koska

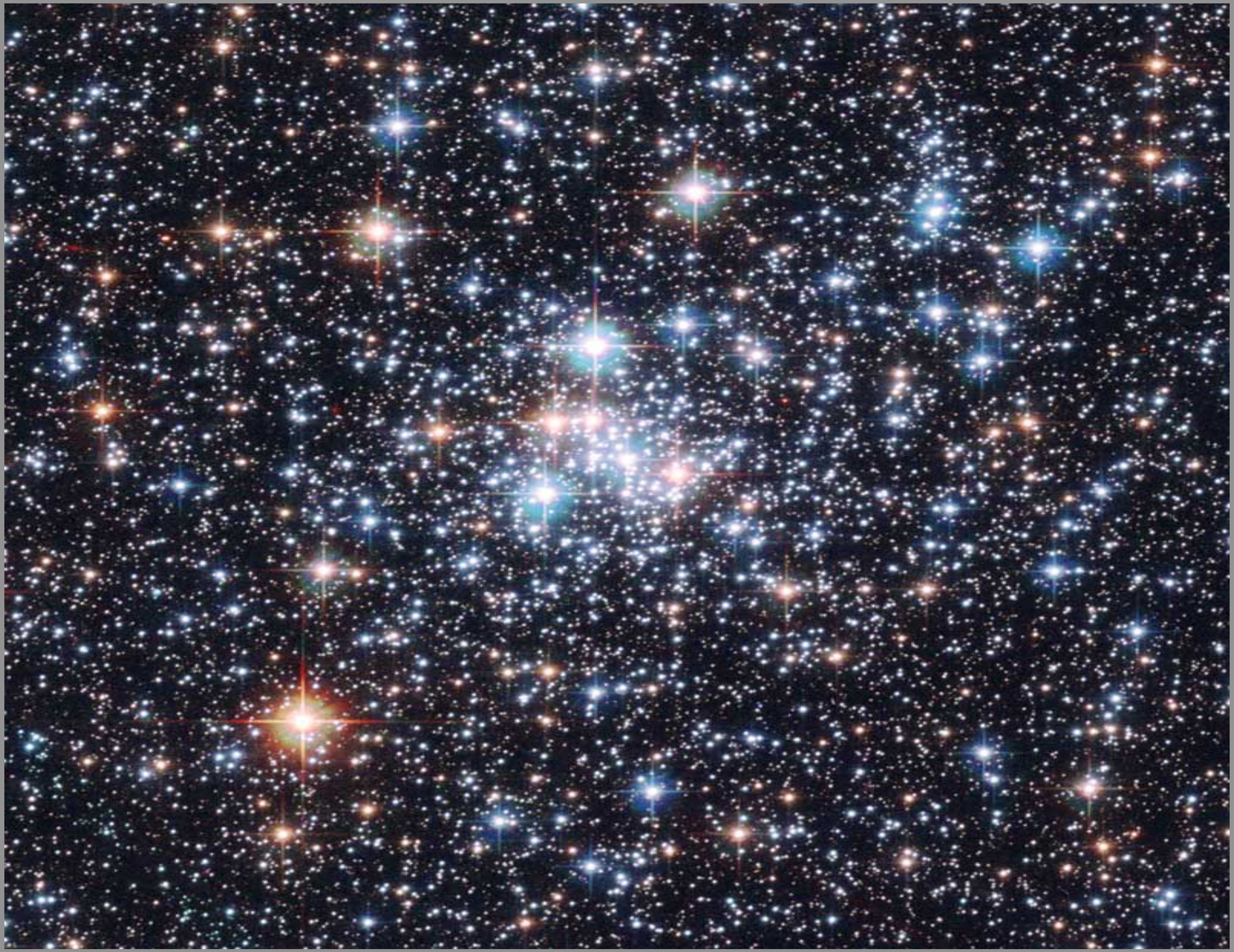
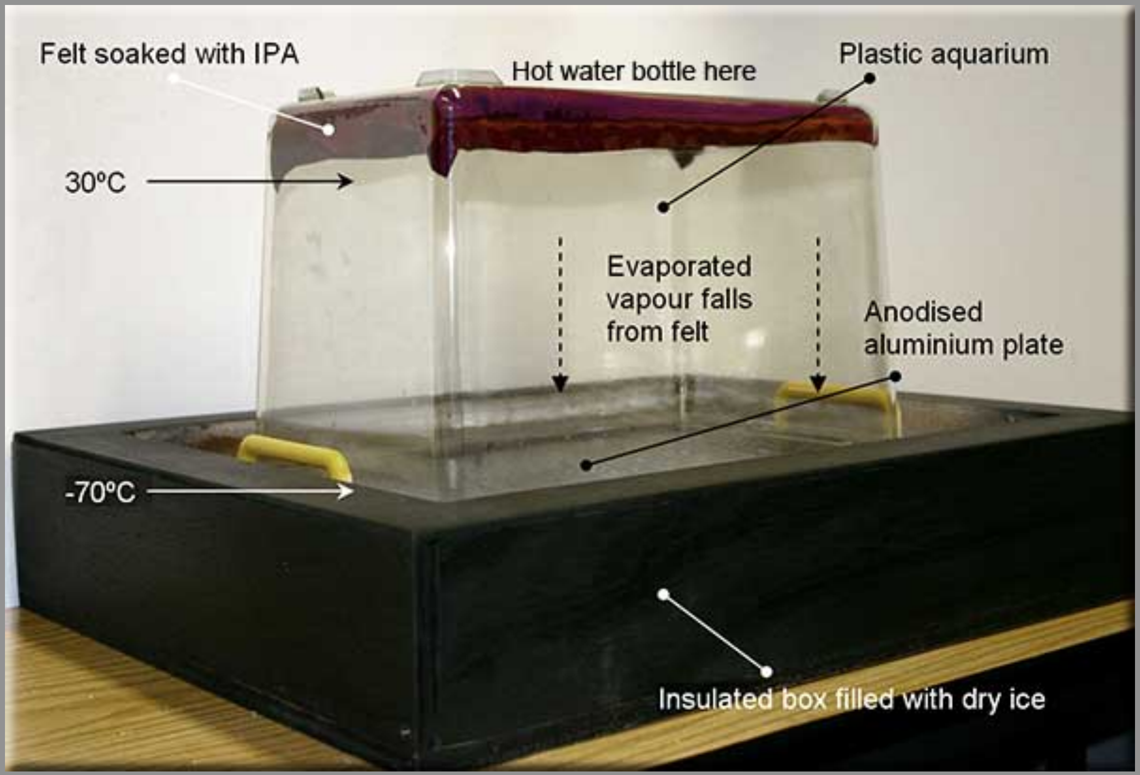


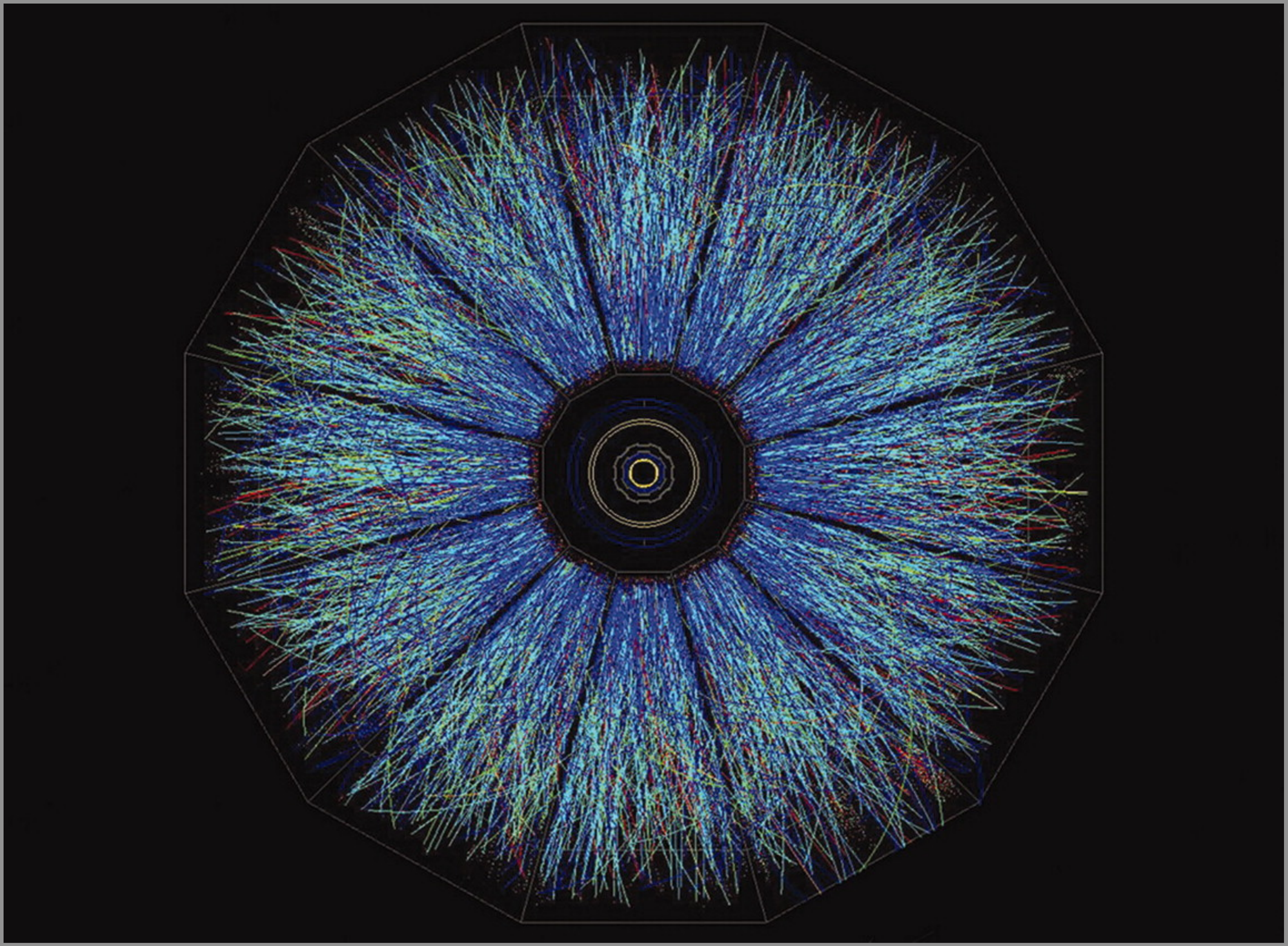
Image credit: European Space Agency & NASA



Felt soaked with IPA
Hot water bottle here
Plastic aquarium
30ºC
Evaporated
vapour falls
from felt
Anodised
aluminium plate
-70ºC
Insulated box filled with dry ice

Large Hadron Collider

Courtesy of CERN



Colliding gold ions: courtesy CERN

O_1 can of course continue to repeat the determination, obtaining the same result each time.

We now suppose that O_2 determines β in S_2, which results in

$$\psi'' = \sum_{i,j} a_i(\eta_j^2, \phi_i^2)\phi_i^1\eta_j^2\psi^{O_1}_{i[\ldots,\alpha_i]}\psi^{O_2}_{j[\ldots,\beta_j]}. \tag{3.11}$$

However, in this case, as distinct from *Case* 2, we see that the intervention of O_2 in no way affects O_1's determinations, since O_1 is still perfectly correlated to the states $\phi_i^{S_1}$ of S_1, and any further observations by O_1 will lead to the same results as the earlier observations. Thus each memory sequence for O_1 continues without change due to O_2's observation, and such a scheme could not be used to send any signals.

Furthermore, we see that the result (3.11) is arrived at even in the case that O_2

“Many Worlds” painting by Warren Bellows (2011)

Parallel Remix Show
Yuko Shiraishi, Curator
Leonard Hutton Galleries
New York City, 2010

$$i\hbar \frac{\partial \Psi}{\partial} = H\Psi(r,t)$$

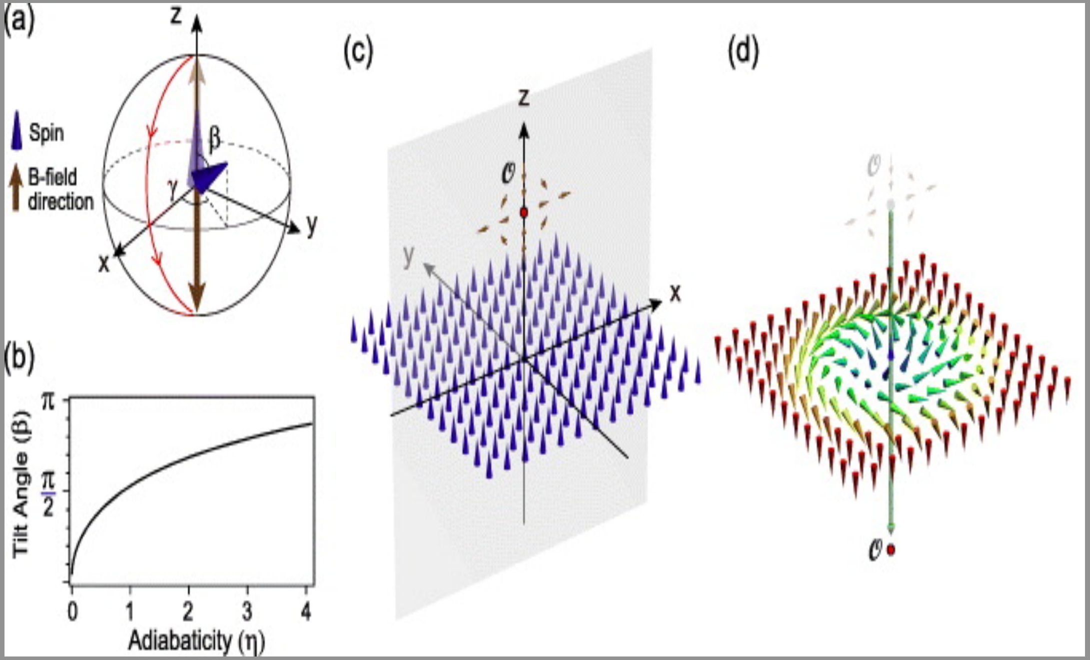
Schrodinger wave equation

Max Born

$$P = |C_1|^2$$

Born rule

Max Born photo courtesy Emilio Segre Visual Archives



(a)
z
Spin
B-field
direction
β
γ
y
x
(b)
π
Tilt Angle (β)
π/2
0
1
2
3
4
Adiabaticity (η)
(c)
z
𝒪
y
x
(d)
𝒪
𝒪

$$i\hbar\frac{\partial}{\partial t}\Psi = \hat{H}\Psi$$

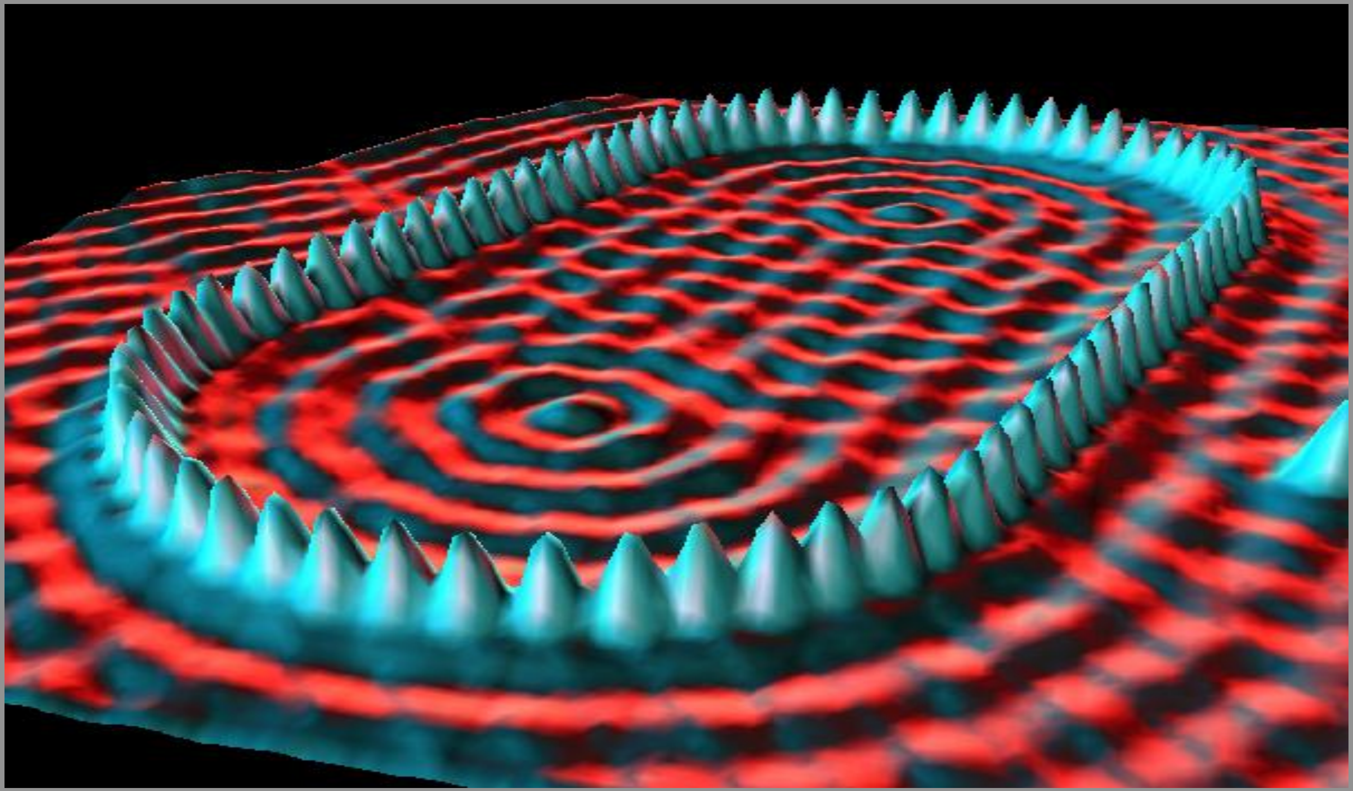
$$P = |C_1|^2$$

Tools

Paul Dirac

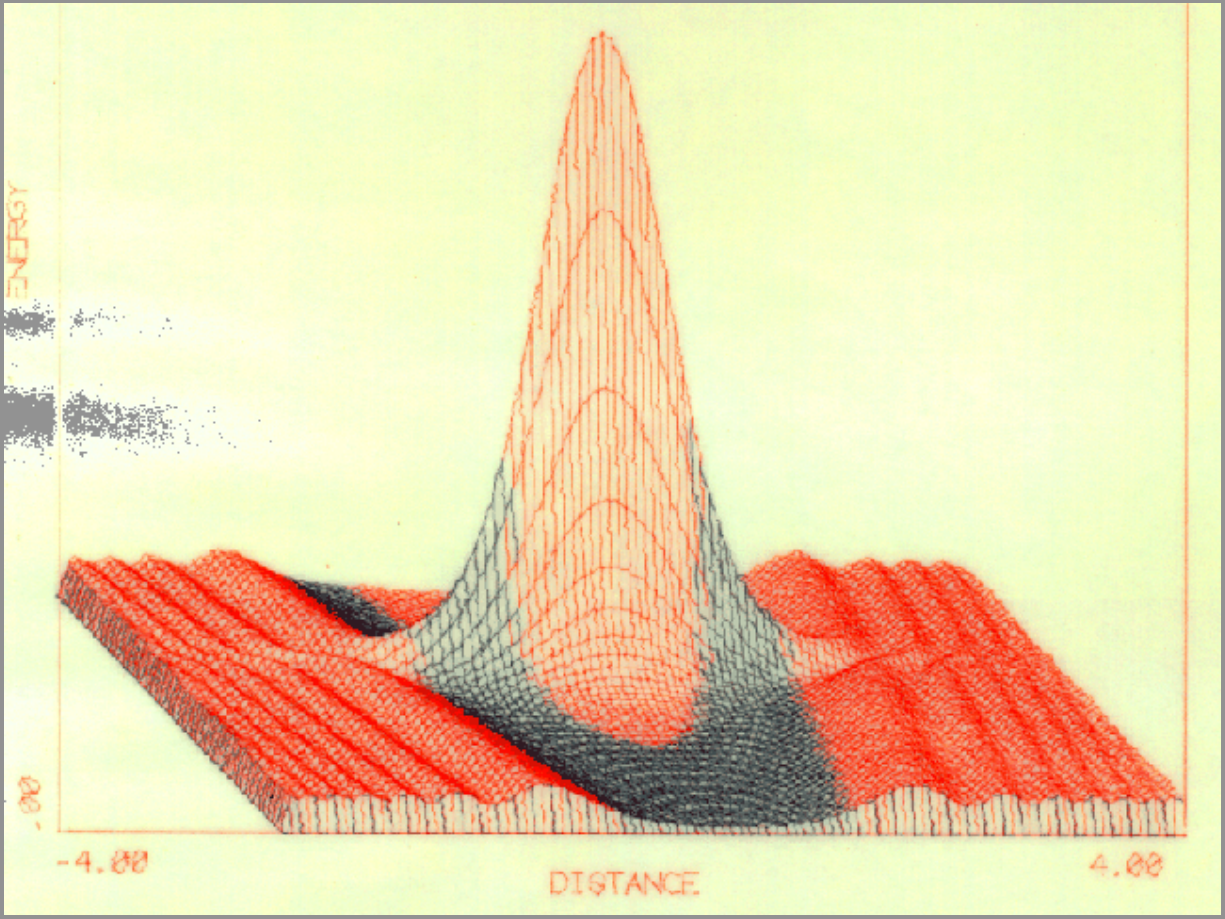
John von Neumann

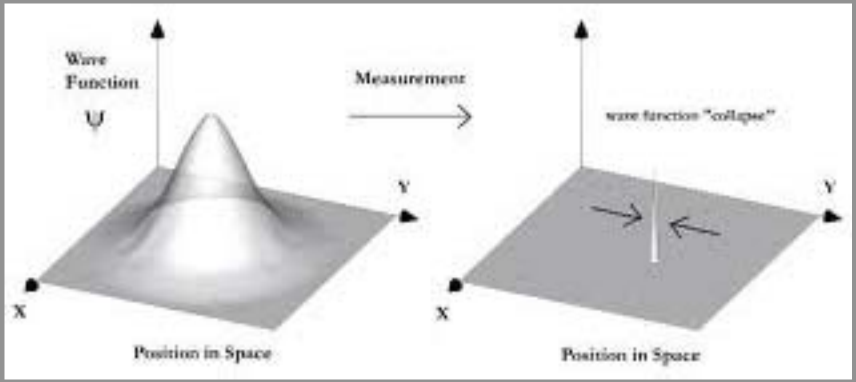
Photos courtesy Emilio Segre Visual Archives

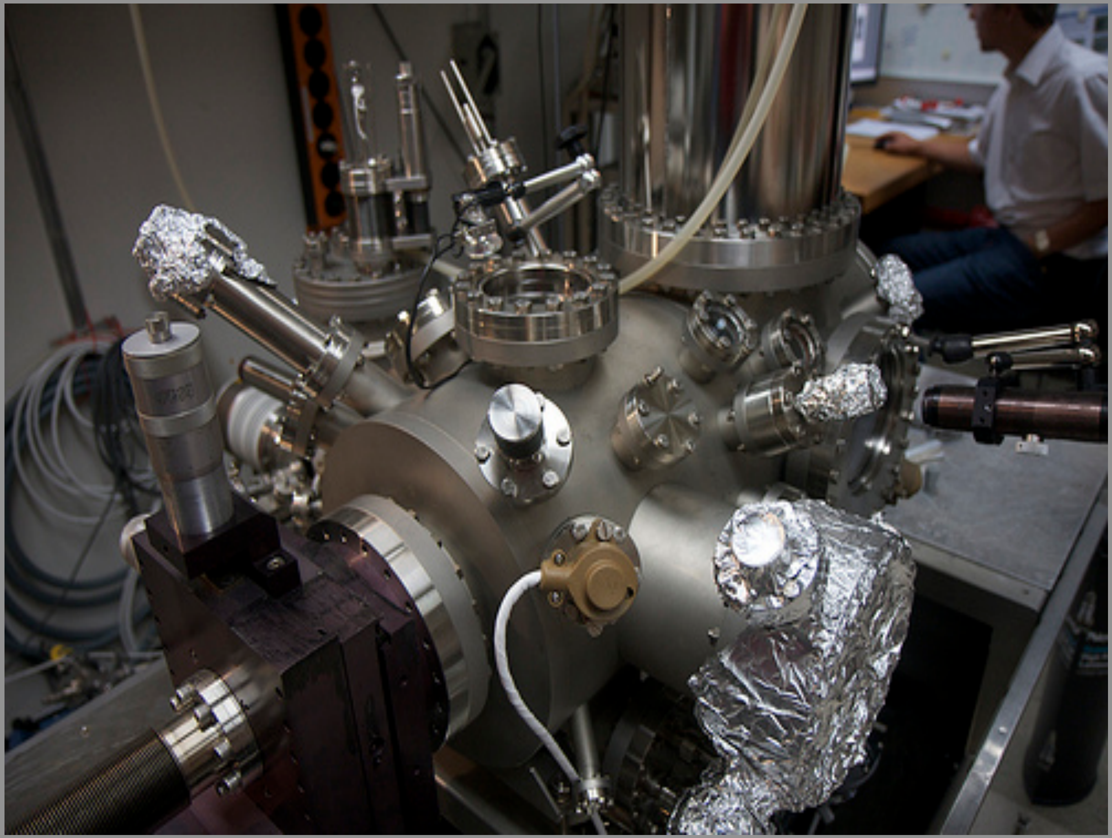


Iron on copper quantum corral

Image originally created by IBM Corporation


ENERGY
.00
-4.00
DISTANCE
4.00


Wave
Function
ψ
Measurement
wave function "collapse"
Y
X
Position in Space
Y
X
Position in Space

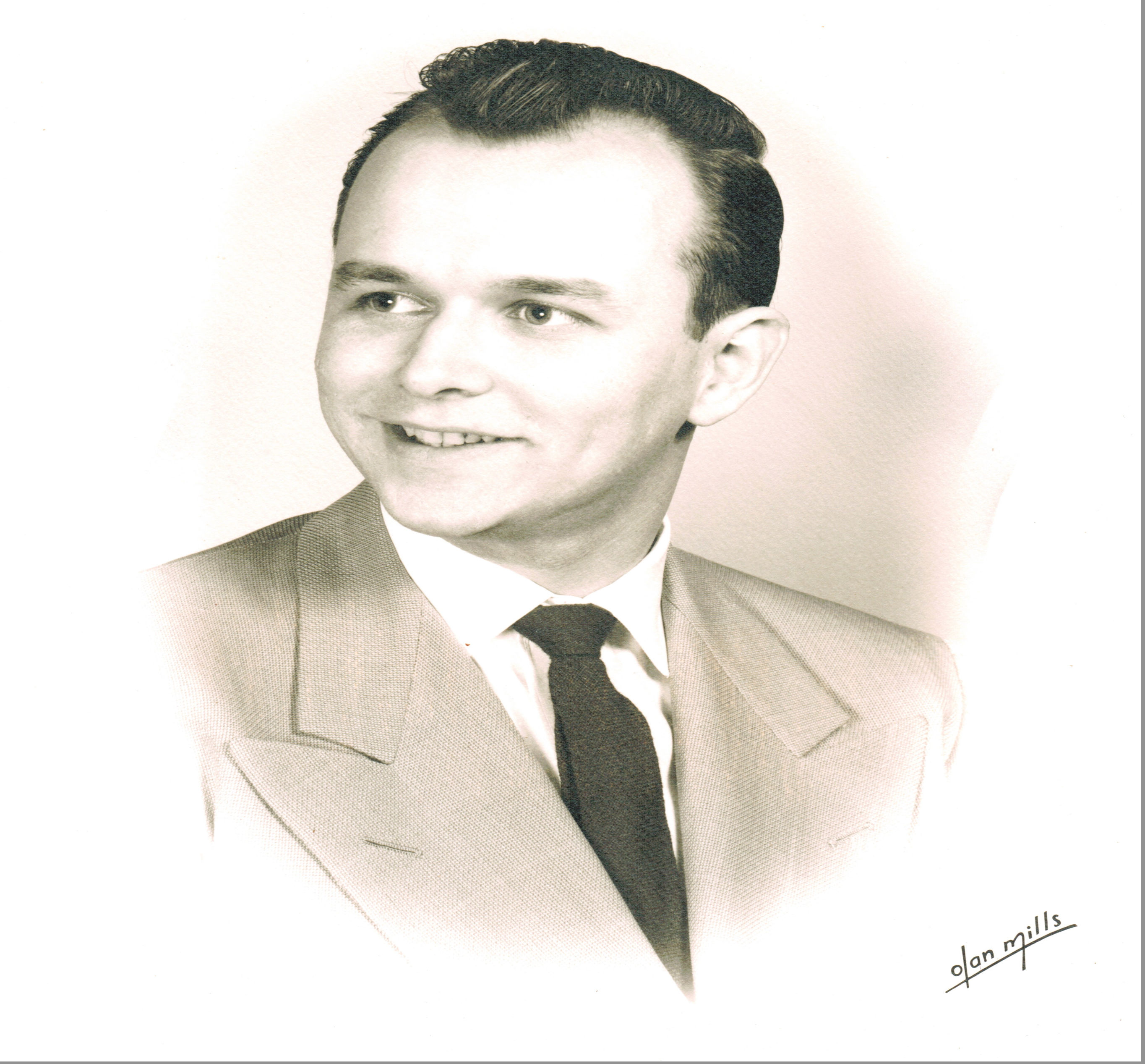


Scanning tunneling microscope

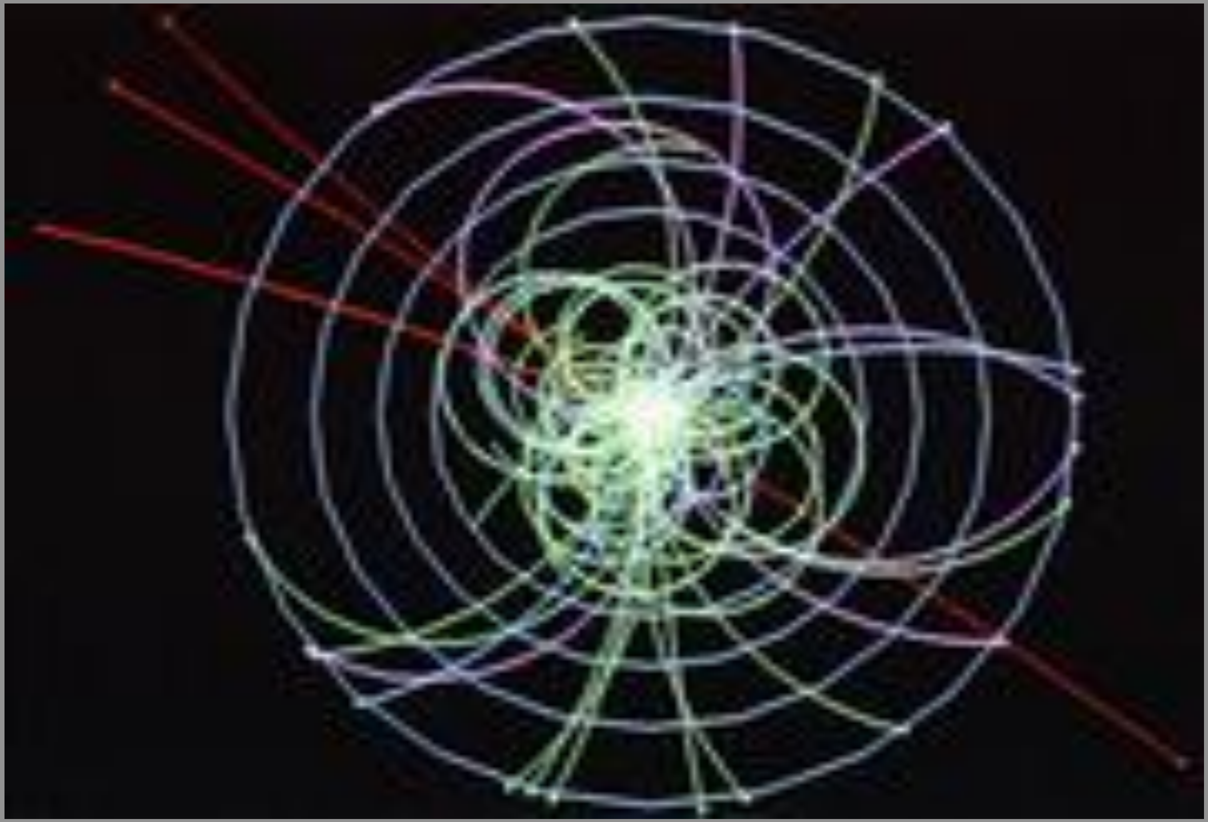
Erwin Schrodinger

Niels Bohr

Photos courtesy Emilio Segre Visual Archives



Everett in 1957



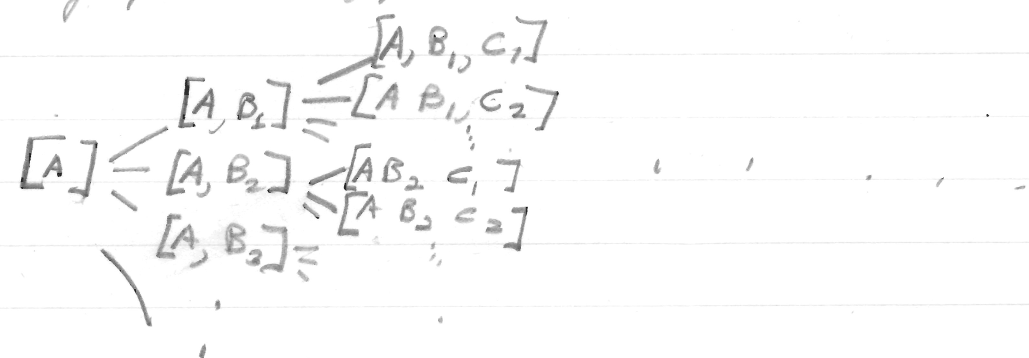
Simulated Higgs event: CERN




Thus, if we wish, we can regard observation as a process which converts a single observer with memory sequence [A, B, ... C] into a number of observers with memory sequences [A, B, ... C, D_i]

There is no question about which of the final observers corresponds to the initial one, since each of them posses the total memory of the first.
(which amoeba is the original one?)

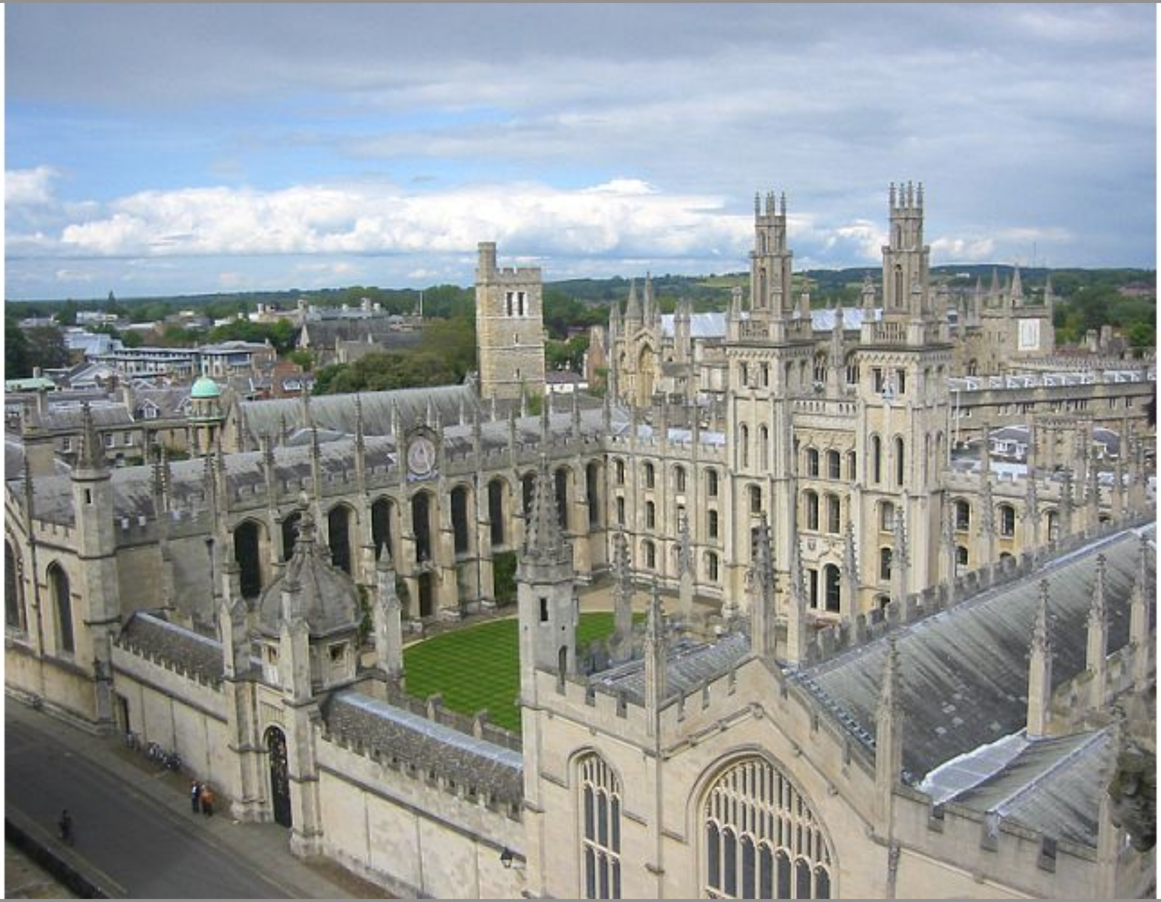
The successive memory sequences of an observer then do not form a linear array, but a planar graph (tree):



That is, "the trajectory" of an observer forms not a line but such a tree.

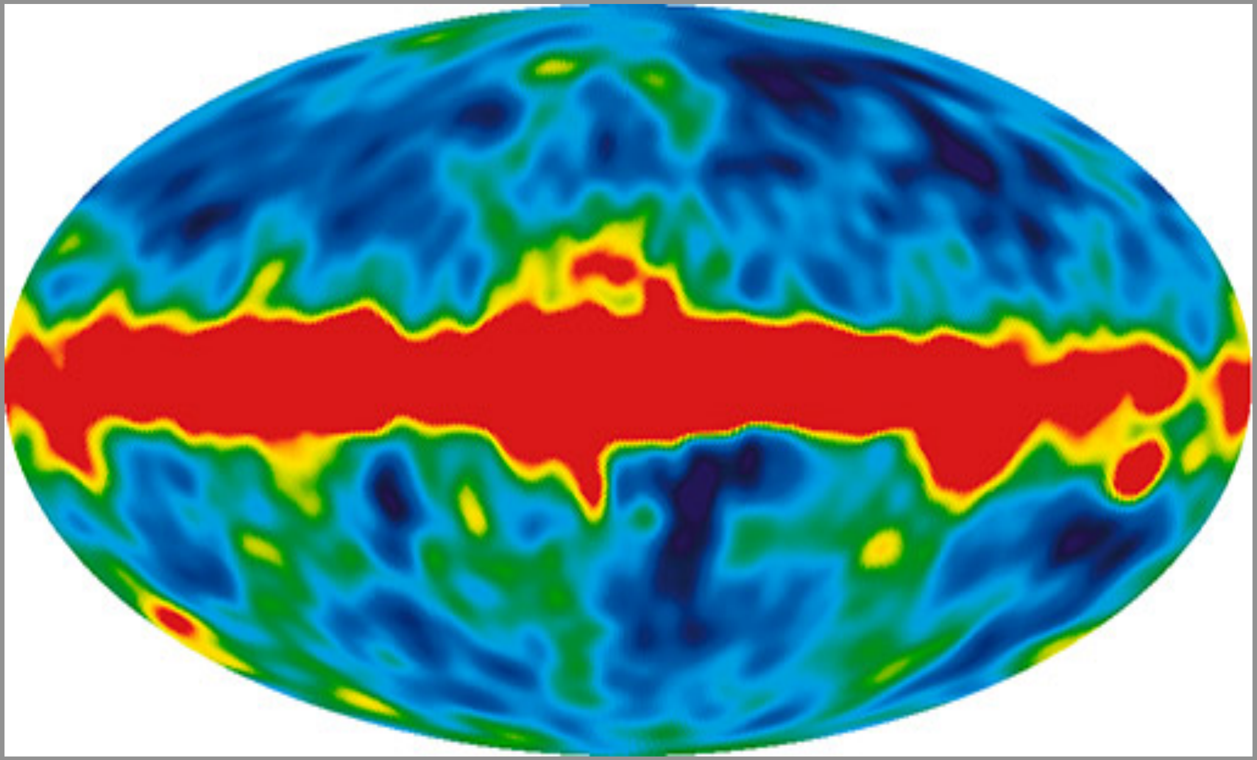
Bryce DeWitt

Photo courtesy Emilio Segre Visual Archives



University of Oxford

Photo credit: Byrne



Cosmic microwave background

Image credit: NASA

Image courtesy: Nature Publishing Group

H. Dieter Zeh

Photo courtesy D. Zeh

H. D. Zeh

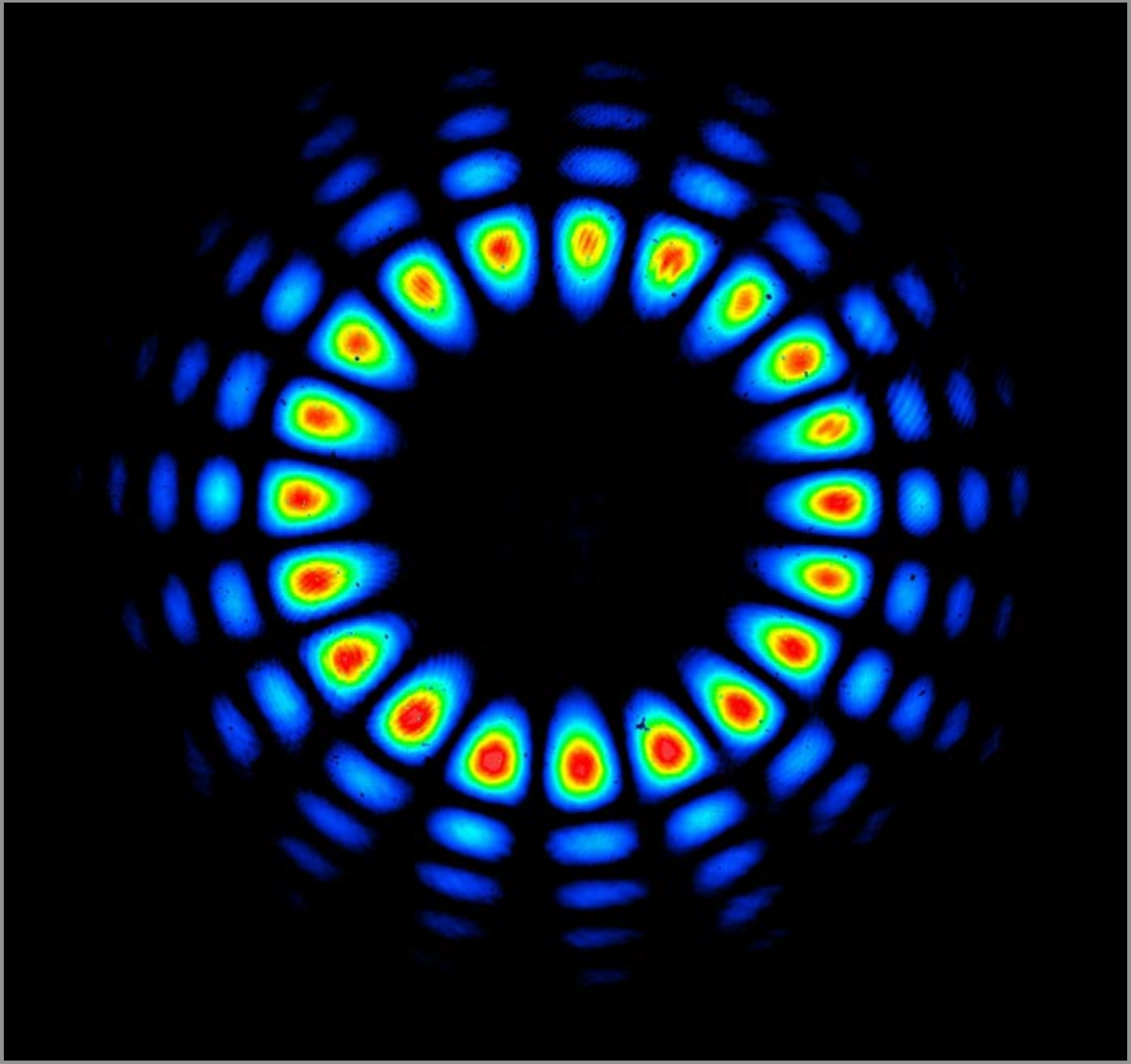
W. H. Zurek

Zurek photo courtesy LANL

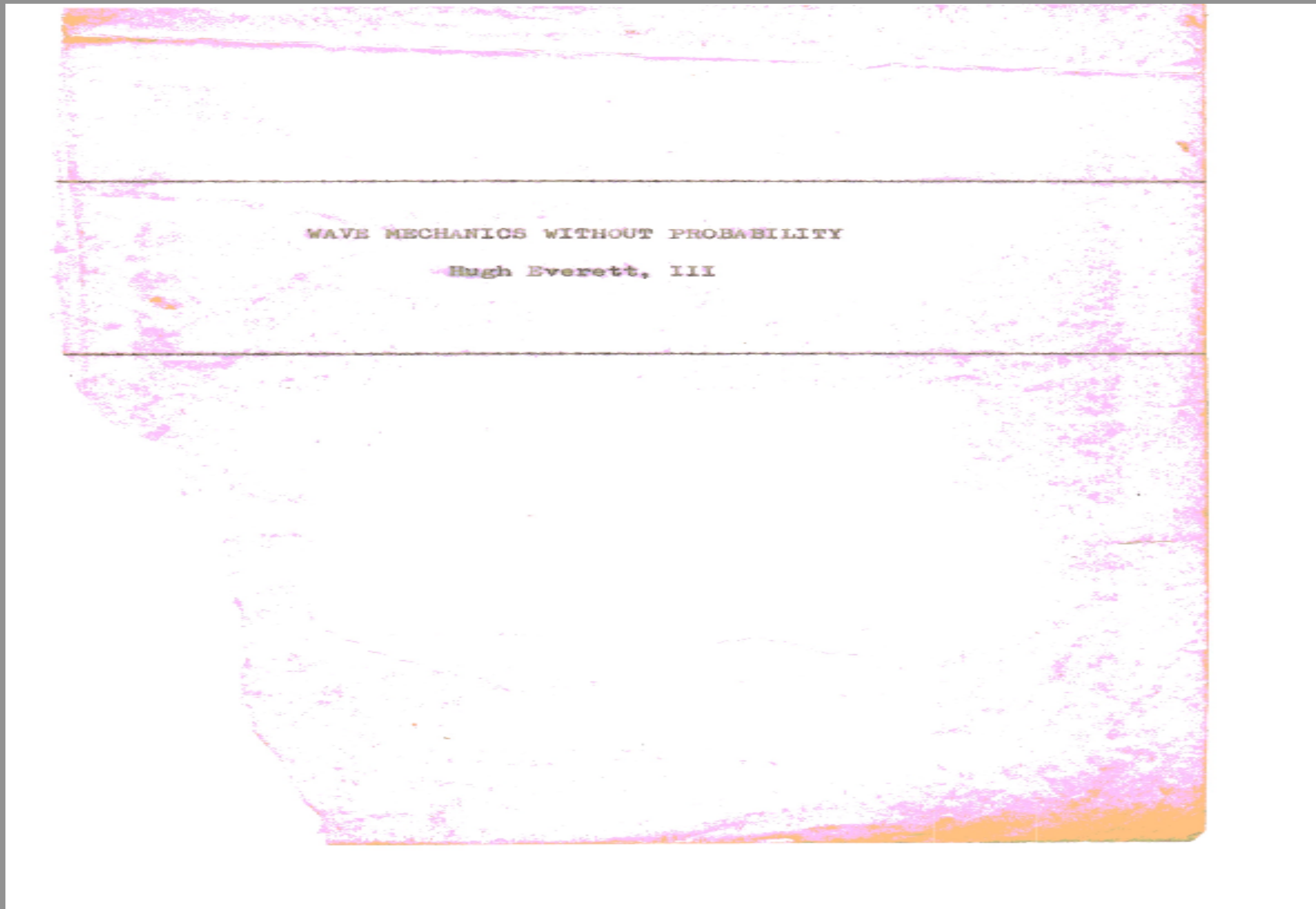
Niels

Hugh

Bohr photo courtesy Emilo Segre Visual Archives



Courtesy: Robert Fickler, University of Vienna


WAVE MECHANICS WITHOUT PROBABILITY

Hugh Everett, III

1956: Thesis title page from basement archive

Reprinted from REVIEWS OF MODERN PHYSICS, Vol. 29, No. 3, 454–462, July, 1957
Printed in U. S. A

"Relative State" Formulation of Quantum Mechanics*

HUGH EVERETT, III†

Palmer Physical Laboratory, Princeton University, Princeton, New Jersey

1. INTRODUCTION

THE task of quantizing general relativity raises serious questions about the meaning of the present formulation and interpretation of quantum mechanics when applied to so fundamental a structure as the space-time geometry itself. This paper seeks to clarify the foundations of quantum mechanics. It presents a reformulation of quantum theory in a form believed suitable for application to general relativity.

The aim is not to deny or contradict the conventional formulation of quantum theory, which has demonstrated its usefulness in an overwhelming variety of problems, but rather to supply a new, more general and complete formulation, from which the conventional interpretation can be *deduced.*

The relationship of this new formulation to the older formulation is therefore that of a metatheory to a theory, that is, it is an underlying theory in which the nature and consistency, as well as the realm of applicability, of the older theory can be investigated and clarified.

The new theory is not based on any radical departure from the conventional one. The special postulates in the old theory which deal with observation are omitted in the new theory. The altered theory thereby acquires a new character. It has to be analyzed in and for itself before any identification becomes possible between the quantities of the theory and the properties of the world of experience. The identification, when made, leads back to the omitted postulates of the conventional theory that deal with observation, but in a manner which clarifies their role and logical position.

We begin with a brief discussion of the conventional formulation, and some of the reasons which motivate one to seek a modification.

2. REALM OF APPLICABILITY OF THE CONVENTIONAL OR "EXTERNAL OBSERVATION" FORMULATION OF QUANTUM MECHANICS

We take the conventional or "external observation" formulation of quantum mechanics to be essentially the following[1]: A physical system is completely described by a state function ψ, which is an element of a Hilbert space, and which furthermore gives information only to the extent of specifying the probabilities of the results of various observations which can be made *on* the system *by* external observers. There are two fundamentally different ways in which the state function can change:

Process 1: The discontinuous change brought about by the observation of a quantity with eigenstates $\phi_1, \phi_2, \cdots$, in which the state ψ will be changed to the state ϕ_j with probability $|(\psi,\phi_j)|^2$.

Process 2: The continuous, deterministic change of state of an isolated system with time according to a wave equation $\partial\psi/\partial t = A\psi$, where A is a linear operator.

This formulation describes a wealth of experience. No experimental evidence is known which contradicts it.

Not all conceivable situations fit the framework of this mathematical formulation. Consider for example an isolated system consisting of an observer or measuring apparatus, plus an object system. Can the change with time of the state of the *total* system be described by Process 2? If so, then it would appear that no discontinuous probabilistic process like Process 1 can take place. If not, we are forced to admit that systems which contain observers are not subject to the same kind of quantum-mechanical description as we admit for all other physical systems. The question cannot be ruled out as lying in the domain of psychology. Much of the discussion of "observers" in quantum mechanics has to do with photoelectric cells, photographic plates, and similar devices where a mechanistic attitude can hardly be contested. For the following one can *limit himself to this class of problems,* if he is unwilling to consider observers in the more familiar sense on the same mechanistic level of analysis.

What mixture of Processes 1 and 2 of the conventional formulation is to be applied to the case where only an approximate measurement is effected; that is, where an apparatus or observer interacts only weakly and for a limited time with an object system? In this case of an

---

* Thesis submitted to Princeton University March 1, 1957 in partial fulfillment of the requirements for the Ph.D. degree. An earlier draft dated January, 1956 was circulated to several physicists whose comments were helpful. Professor Niels Bohr, Dr. H. J. Groenewald, Dr. Aage Peterson, Dr. A. Stern, and Professor L. Rosenfeld are free of any responsibility, but they are warmly thanked for the useful objections that they raised. Most particular thanks are due to Professor John A. Wheeler for his continued guidance and encouragement. Appreciation is also expressed to the National Science Foundation for fellowship support.

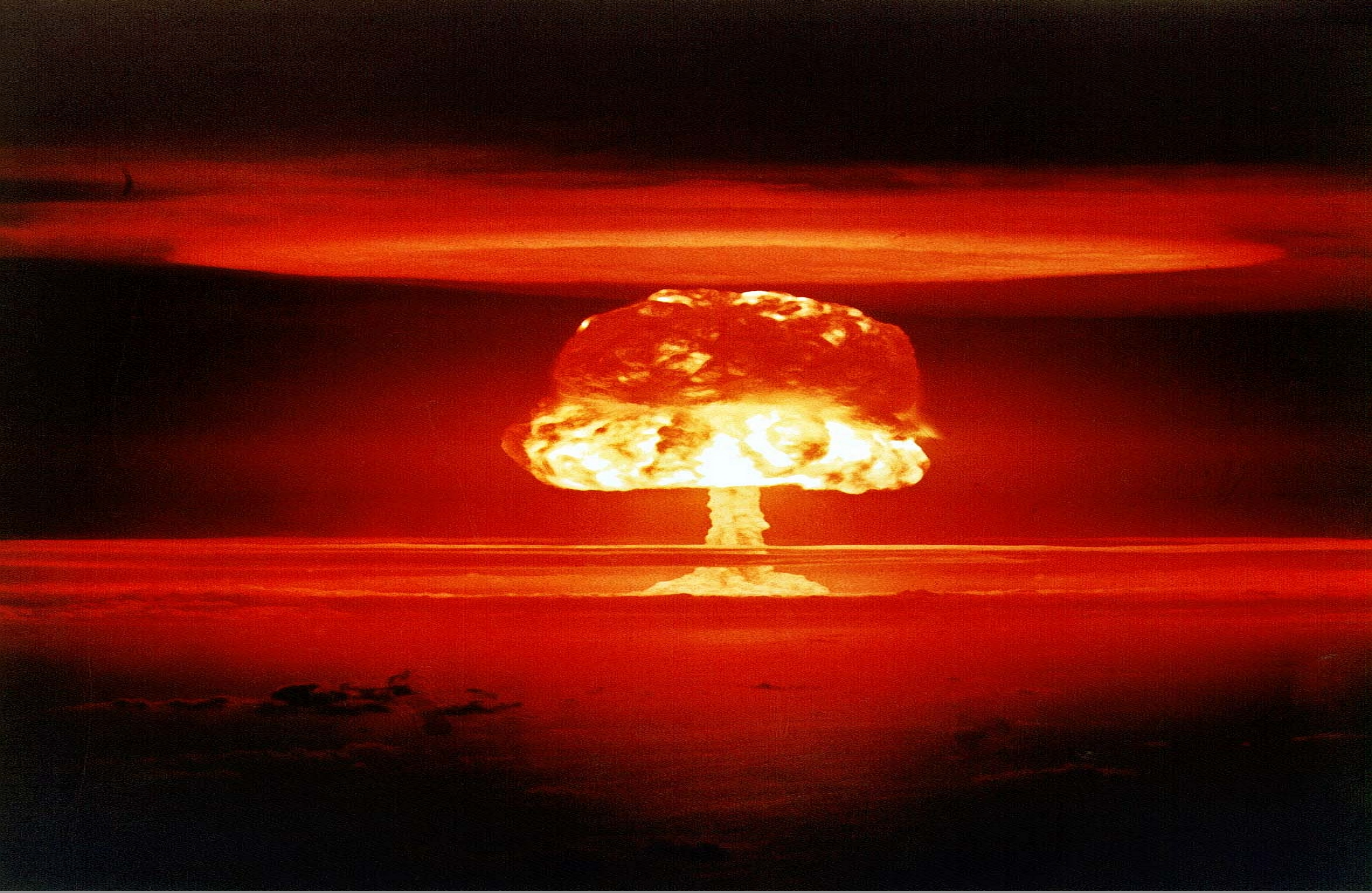
† Present address: Weapons Systems Evaluation Group, The Pentagon, Washington, D. C.

[1] We use the terminology and notation of J. von Neumann, *Mathematical Foundations of Quantum Mechanics,* translated by R. T. Beyer (Princeton University Press, Princeton, 1955).

John Wheeler, 1934

John Wheeler, 2003

Photos courtesy Emelio Segre Visual Archives



Bikini Atoll hydrogen bomb test, April 1954

Photo courtesy: LLNL

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HEADQUARTERS FIELD COMMAND

Sandia Base

NEW MEXICO

This is to certify that MR

HUGH EVERETT III

has received orientation in special weapons

by

attending

Weapons Orientation Advanced Class No. 113

23 October - 26 October 1956

Frank O'Beirne

FRANK O'BEIRNE
REAR ADMIRAL, U.S. NAVY
COMMANDER

Everett subscribed to Missiles and Rockets

Courtesy of American Aviation

HOTEL ØSTERPORT

(3)

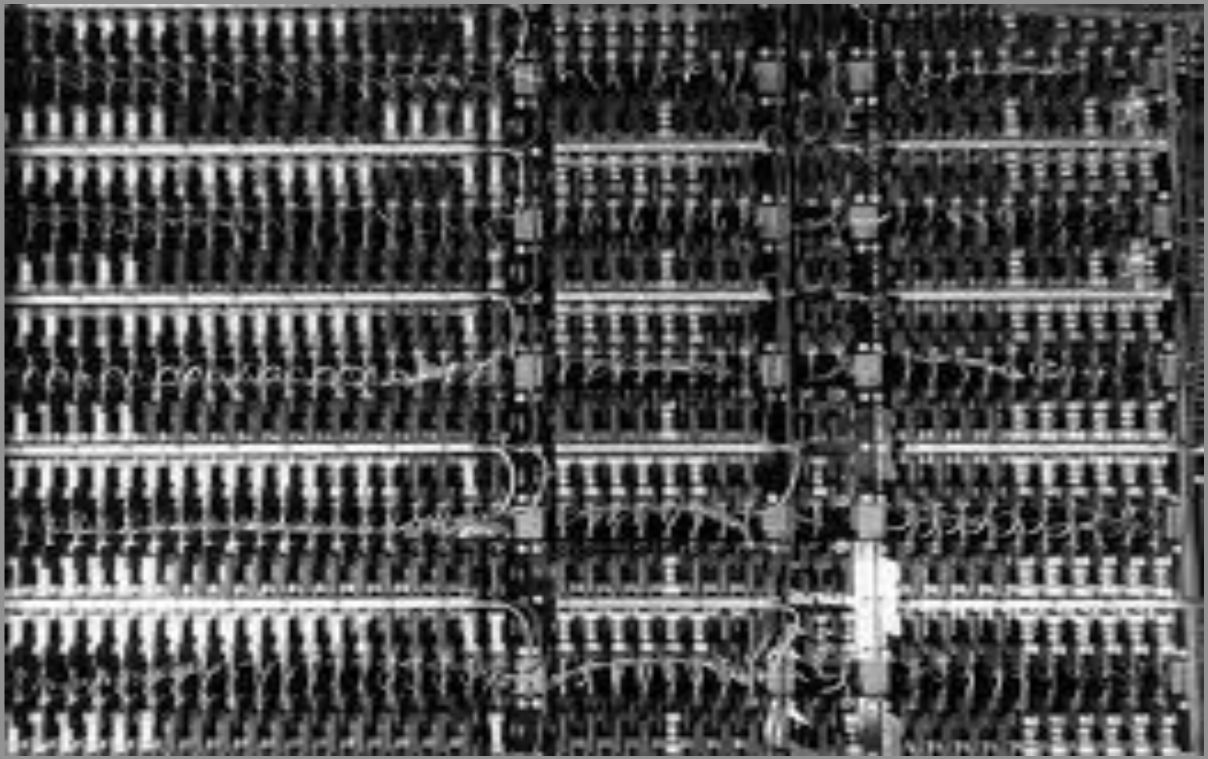
COPENHAGEN, DENMARK

So much for the theory of Lagrange multipliers. The main point for us is that the magic is not in the derivatives but simply in the maximization. Player 2 is merely interested in minimizing

$H = \sum_i \frac{1}{i}(1-e^{-A_i n_i}) - \lambda \sum n_i + u \sum j_i$, which (an important point) amounts to independently minimizing each

$H_i = \frac{1}{i}(1-e^{-A_i n_i}) - \lambda n_i + u\, j_i$ -- and the problem really separates to independent consideration for each i!

To select among the 3 roots when they all exist, simply plug them in (H_i) and see which is [illegible] smallest! (n_i is known function of A_i from its own maximization -- $n_i = \ln(A_i/\lambda_i)/A_i$ or something like that and j_i is also known function $j_i = \ln((1-e^{-A_i})/P_i)$. Also, at the same time the other two possibilities should be tried, namely $A_i =$ UPLMA and $A_i = \lambda i$ since they represent boundaries on the region and might be the minima. So there is a fairly simple selection criterion.



IBM Univac, 1957

Photo courtesy LLNL

They Tackle Tangled Mess, World Of The Aton

P. A. M. Dirac
. . . all the way from England

Nathan Rosen
. . . from Israel

Yakir Aharonov
. . . Yeshiva's young man

Wendell H. Furry
. . . from Indiana to Harvard

Eugene P. Wigner
. . . Princeton via Hungary

Boris Podolsky
. . . cause of it all

6 Noted Physicists Here To Scan Quantum Theory

The world of the atom is a mess, P.A.M. Dirac said yesterday.

He and five other renowned physicists are in Cincinnati to help straighten it out.

But they didn't hold out much hope yesterday that the tangles of quantum theory and reality could be

of the German scientist, Max Planck.

He realized that a beam of light—or any similar activity is not a continuous action but billions of bits of energy or quanta.

An atom can't let go of a piece of light or a quantum of gamma or X ray unless it is stimulated enough so that it has a

some other nation did. He also won the Atomic Energy Commission's Enrico Fermi Award in 1958 for his contributions to the design and theory of atomic reactors.

Dr. Dirac is professor of physics at Cambridge University, England, and won the 1933 Nobel Prize in Physics with the late Er-

THE CINCINNATI ENQUIRER

5 STAR ★★★★★ PAGE

Page 34 Tuesday, Oct. 2, 1962

Milk Processors

Ohio Dentists Hear Talk On Making Dentistry Pay

BY JACK SMITH
Of The Enquirer Staff

How to succeed in dentistry without being trying was the theme of a talk yesterday at the 96th annual meeting of the Ohio State Dental Association.

Dr. John H. Mosteller, Mobile, Ala., told an audi-

amount we ever disc with a patient is th amount needed to put the mouth back into go health."

The policy of insisting c doing only the best wo will mean losing some p tential patients more inte ested in saving money tha their teeth, Dr. Mostell said.

Xavier University Panel, 1962

Courtesy Cincinnati Enquirer

observers fit in together.

Everett replies: Well, again, all of the consistency of ordinary physics is preserved by the correlation structure of this state. You'll always find that an observer who repeats

the same measurement will always get the same answer, and ~~be~~ even more well always agree when interacting with another observer measuring the same system. This consistency can be deduced from the structure of wave mechanics

Podolsky speaks: It looks like we would have a non-denumerable infinity of worlds.

Everett: Yes.

Podolsky continues: Each proceeding with its own set of choices that have been made.

Furry says: To me, the hard thing about it is that one must picture the world, oneself, and everybody else as consisting not in just a countable number of copies but somehow or another in an undenumerable number of copies, and at this my imagination balks. I can think of various alternative Furrys doing different things, but I cannot think of a non-denumerable number of alternative Furrys.

(Podolsky chuckles)

Everett says: I'd like to make one final remark here. ~~The~~

Wendell Furry

The Many-Worlds Interpretation of Quantum Mechanics

edited by
Bryce S. DeWitt and Neill Graham

with papers by
Hugh Everett, III, J. A. Wheeler,
B. S. DeWitt, L. N. Cooper
and D. van Vechten, and N. Graham

Princeton Series in Physics


TO THE CHEF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Improvement on
Ontological proof:

Tautology:

$$(x)P(x) \vee \exists x\ \overline{P(x)}$$

Let P(x) stand for "x exists." Then it is manifestly false that ∃ an x ∋: x does not exist and we have established:

Theorem: (x) x exists.

Let x = God.

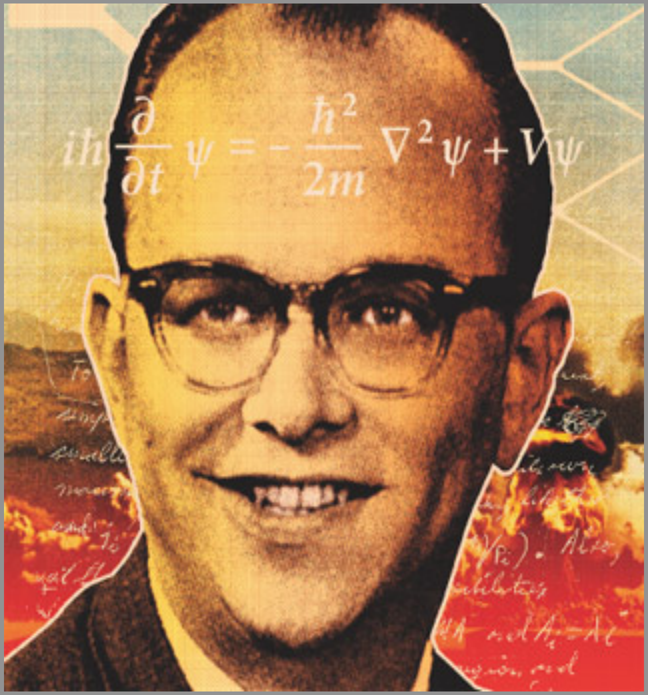


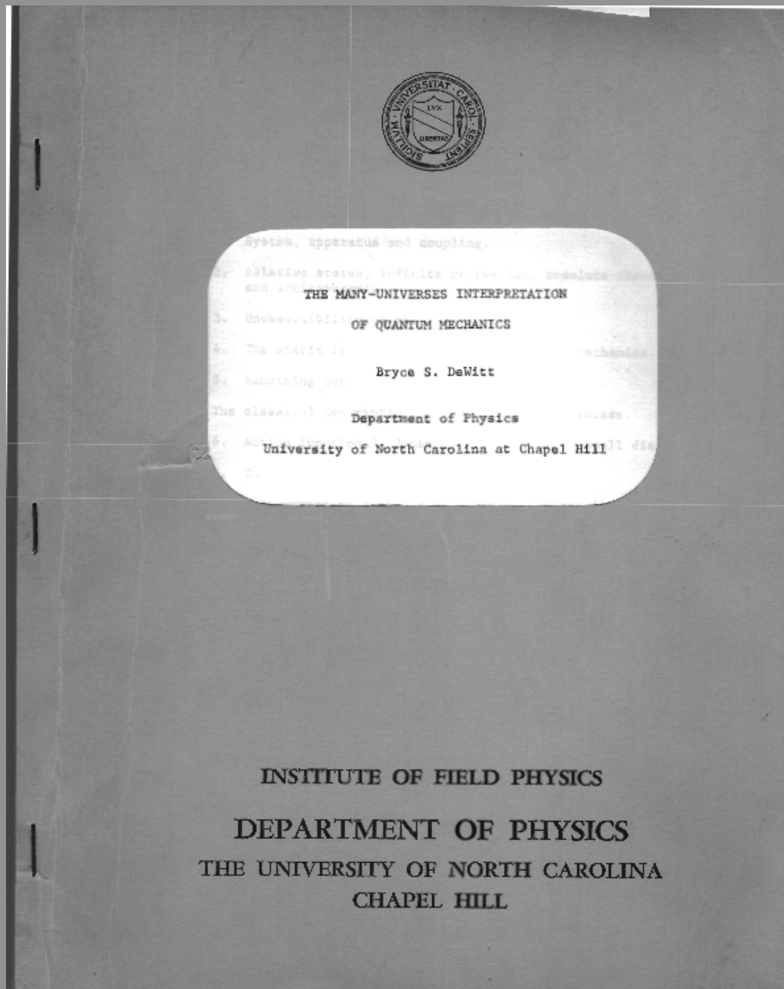
Image courtesy Scientific American

explaining the appearance of the macroscopic world. The price, however, is the abandonment of the concept of the uniqueness of the observer, with its somewhat disconcerting philosophical implications.

As an analogy one can imagine an intelligent amoeba with a good memory. As time progresses the amoeba is constantly splitting, each time the resulting amoebas having the same memories as the parent. Our amoeba hence does not have a life line, but a life tree. The question of the identity or non identity of two amoebas at a later time is somewhat vague. At any time we can consider two of them, and they will possess common memories up to a point (common parent) after which they will diverge according to their separate lives thereafter.

We can get a closer analogy if we were to take one of these

Excerpt from draft paper “Probability in Wave Mechanics”, Sept. 1955



THE MANY-UNIVERSES INTERPRETATION

OF QUANTUM MECHANICS

Bryce S. DeWitt

Department of Physics

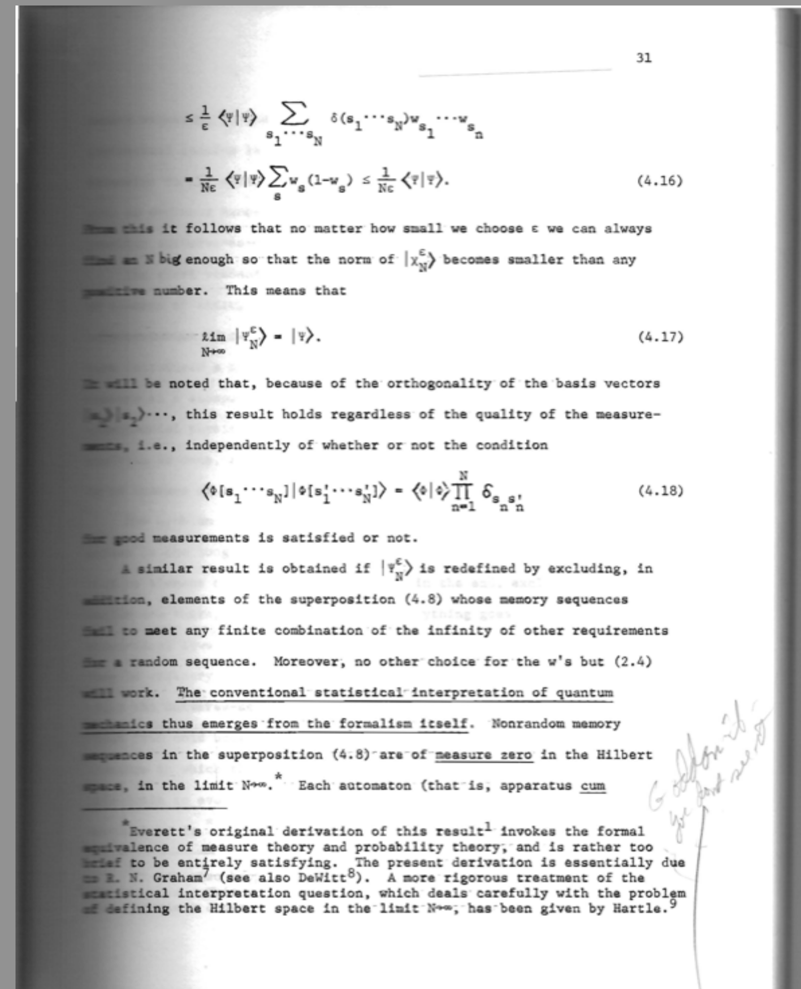
University of North Carolina at Chapel Hill

INSTITUTE OF FIELD PHYSICS

DEPARTMENT OF PHYSICS

THE UNIVERSITY OF NORTH CAROLINA

CHAPEL HILL



31

$$\le \frac{1}{\varepsilon} \langle \Psi | \Psi \rangle \sum_{s_1 \cdots s_N} \delta(s_1 \cdots s_N) w_{s_1} \cdots w_{s_n}$$

$$= \frac{1}{N\varepsilon} \langle \Psi | \Psi \rangle \sum_s w_s (1 - w_s) \le \frac{1}{N\varepsilon} \langle \Psi | \Psi \rangle. \qquad (4.16)$$

From this it follows that no matter how small we choose ε we can always find an N big enough so that the norm of $|\chi_N^\varepsilon\rangle$ becomes smaller than any positive number. This means that

$$\lim_{N\to\infty} |\Psi_N^\varepsilon\rangle = |\Psi\rangle. \qquad (4.17)$$

It will be noted that, because of the orthogonality of the basis vectors $|s_1\rangle|s_2\rangle\cdots$, this result holds regardless of the quality of the measurements, i.e., independently of whether or not the condition

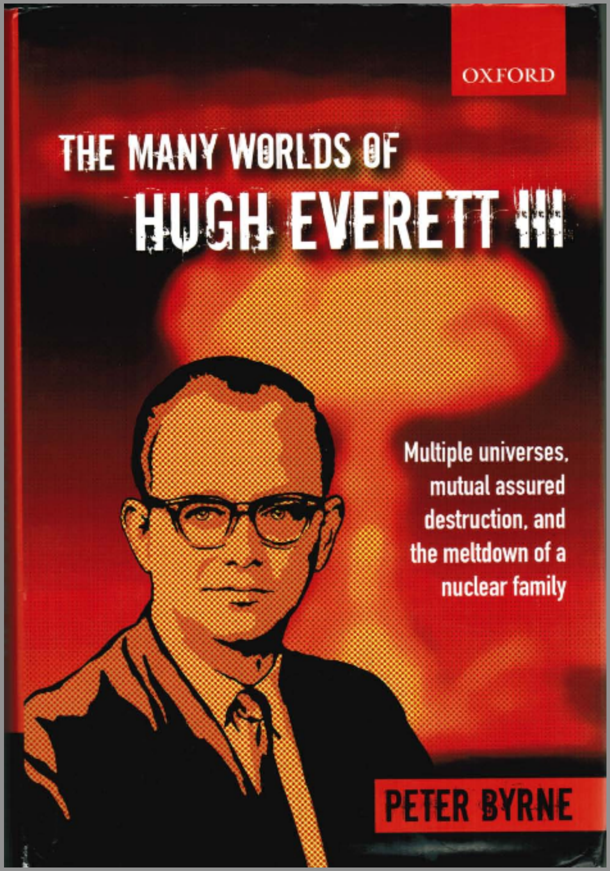
$$\langle \Phi[s_1 \cdots s_N] | \Phi[s_1' \cdots s_N'] \rangle = \langle \Phi | \Phi \rangle \prod_{n=1}^{N} \delta_{s_n s_n'} \qquad (4.18)$$

for good measurements is satisfied or not.

A similar result is obtained if $|\Psi_N^\varepsilon\rangle$ is redefined by excluding, in addition, elements of the superposition (4.8) whose memory sequences fail to meet any finite combination of the infinity of other requirements for a random sequence. Moreover, no other choice for the w's but (2.4) will work. The conventional statistical interpretation of quantum mechanics thus emerges from the formalism itself. Nonrandom memory sequences in the superposition (4.8) are of measure zero in the Hilbert space, in the limit $N\to\infty$.* Each automaton (that is, apparatus cum

*Everett's original derivation of this result[1] invokes the formal equivalence of measure theory and probability theory, and is rather too brief to be entirely satisfying. The present derivation is essentially due to R. N. Graham[7] (see also DeWitt[8]). A more rigorous treatment of the statistical interpretation question, which deals carefully with the problem of defining the Hilbert space in the limit $N\to\infty$, has been given by Hartle.[9]

"Goddamn it you don't see it"


OXFORD
THE MANY WORLDS OF
HUGH EVERETT III
Multiple universes, mutual assured destruction, and the meltdown of a nuclear family
PETER BYRNE

The Everett Interpretation of Quantum Mechanics

Collected Works 1955–1980 with Commentary

Hugh Everett III

Edited by
Jeffrey A. Barrett
& Peter Byrne

Hugh Everett III Manuscripts

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Description

Permanent url: http://hdl.handle.net/10575/1060

This archive contains a collection of scanned original documents and audio recordings related to Hugh Everett III (November 11, 1930 – July 19, 1982), the American physicist who first proposed what has come to be known as the many-worlds interpretation (MWI) of quantum physics.

These documents include draft and final versions of Everett's long and short Ph.D. theses and the early notes that led to these published works, Everett's correspondence regarding his relative state formulation of pure wave mechanics, and miscellaneous biographical material. Most of these documents were discovered in the basement of Mark Everett, Hugh Everett III's son, in Los Feliz, California by Peter Byrne in 2007 and are published here for the first time.

First published in *Reviews of Modern Physics* in 1957 as "The 'Relative State' Formulation of Quantum Mechanics,"

Peter Byrne

Spektrum Sachbuch

Viele Welten

Hugh Everett III – ein Familiendrama zwischen Kaltem Krieg und Quantenphysik