DOES THE UNIVERSE HAVE A MEMORY?

SOME SPECULATIONS ON QUANTUM MECHANICS

[CRAZY THOUGHTS OF AN OLD MAN]

EINSTEIN

1. DID NOT ACCEPT QM AS FINAL THEORY
2. SEARCHED FOR A UNIFIED (GEOMETRIC THEORY)

STANDARD MODEL OF ELEMENTARY PARTICLES
(GAUGE THEORY)

ATTEMPT TO COMBINE QM + GR
(STRING THEORY, M-THEORY ....)

MODIFY GR TO QM FRAMEWORK? [ORTHODOX]

OR " QM " GR " ? [MAVERICK]
PENROSE

STRING THEORY

AS MATHEMATICS

NOT YET FULLY RIGOROUS BUT HAS LED TO
REMARKABLE MATHEMATICAL RESULTS FIELDS MEDALS
BEAUTIFUL, POWERFUL
MATHEMATICS OF 21ST CENTURY (WITTEN)

DUALITIES NON-LINEAR FOURIER TRANSFORM?

AS PHYSICS

IS IT THE PHYSICS OF 21ST CENTURY?
HOW MUCH FURTHER NEEDS TO BE DONE?
WHAT WILL ULTIMATE THEORY LOOK LIKE?
USES VAST MATHEMATICAL STRUCTURE

IS THIS THE WAY GOD CREATED THE UNIVERSE ??

PERHAPS THERE IS A SIMPLER WAY OF LOOKING AT THINGS?

PERHAPS M-THEORY IS SO COMPLEX BECAUSE WE JUST USE ALL TOOLS AT OUR DISPOSAL

CONSIDER PTOLEMY EPICYCLES

KEPLER PLATONIC SOLIDS

REPLACED BY NEWTON INVERSE SQUARE LAW + CALCULUS

CAN WE TAKE A STEP BACK & DISCARD SOME BASIC ASSUMPTION?

(LIKE EINSTEIN DID WITH SPACE & TIME)

PERHAPS WE CAN FIND "SIMPLE" GEOMETRIC THEORY (INCORPORATING GR) WHICH IS VERY DIFFICULT TO SOLVE AND M-THEORY ARISES FROM OUR BEST ATTEMPTS ??

PERHAPS QM EMERGES FROM SUCH A THEORY (PERHAPS IN SOME APPROXIMATION)

(COMPARE WITH NEWTONIAN GRAVITY AS AN APPROX OF EINSTEIN GR)

1) ANY SUCH THEORY HAS TO AGREE WITH EXPERIMENTS

2) SHOULD BE AS "SIMPLE" AS POSSIBLE [OCCAM'S RAZOR]

3) SHOULD (EVENTUALLY) SEEM "NATURAL"

4) WOULD HAVE BEEN APPROVED OF BY EINSTEIN

A UNIVERSE WITH MEMORY

WHAT BASIC ASSUMPTION SHOULD WE DISCARD ?

CONTINUITY OF SPACE-TIME ?

DISCRETE MODEL ? [VERY DRASTIC CALCULUS TOO USEFUL]

CAUSALITY ?

STRONG FORM : PRESENT DETERMINES FUTURE

BASIC ASSUMPTION

CLASSICAL MECHANICS — POSITION + VELOCITY ? → DYNAMICS

QUANTUM MECHANICS — STATE IN HILBERT SPACE → EVOLUTION

RELATION TO EXPERIMENT SOURCE OF PHILOSOPHICAL DIFFICULTIES

WEAK FORM OF CAUSALITY

PAST + PRESENT DETERMINE FUTURE

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MEMORY

1. CAN WE DEVELOP PHYSICAL THEORY ON THIS BASIS ?
2. WHAT KIND OF MATHEMATICS WOULD WE NEED ?
3. HOW WOULD IT RELATE TO STANDARD PHYSICS (CLASSICAL + QUANTUM) ?
4. IS THIS MUCH TOO DRASTIC - HOPELESS?

CLEARLY "MEMORY" MUST BE VERY SHORT TERM

ON SCALE RELEVANT TO QM

(PERHAPS THIS "SCALE" IS RELATED TO PLANCK'S CONSTANT ?)

TC

PERHAPS IGNORANCE OF OUR PAST EXPLAINS HEISENBERG UNCERTAINTY ?

WHAT WILL REPLACE DIFFERENTIAL EQUATIONS?

CONSIDER SIMPLE EXAMPLE OF DYNAMICS

PATH $x(t)$ IN R^3 EVOLVING IN TIME

ORDINARY DIFF. EQN $\frac{dx}{dt} = F(x,t)$

GENERALIZE TO

RETARDED DIFF. EQN IN WHICH

$\frac{dx}{dt}$ DEPENDS NOT JUST ON x (AT TIME t) BUT ON $x(s)$ FOR ALL $s \leq t$

SUCH THEORY EXISTS

BUT VERY DIFFICULT EVEN FOR "SIMPLE EQUATIONS"

J. HALE FUNCTIONAL DIFFERENTIAL EQUATIONS SPRINGER 1971

MANY POSSIBILITIES FOR TYPE OF DEPENDENCE ON PAST

THESE HAVE ARISEN IN MANY APPLIED PROBLEMS (EX. CONTROL THEORY)

SIMPLEST EXAMPLE

$$\frac{dx}{dt} = F(t, x(t), x(t-\tau))$$

FOR SOME FIXED CONSTANT $\tau > 0$

DIFFERENTIAL - DIFFERENCE EQNS

IF TAKEN SERIOUSLY AS MODEL FOR PHYSICS

INCORPORATES A FUNDAMENTAL LENGTH SCALE γ (GOOD PHYSICS)

[SHARED IDEA WITH DISCRETE MODELS BUT PRESERVES CONTINUITY + CALCULUS]

MATH. THEORY . EXISTENCE + UNIQUENESS OF SOLUTION PROVED UNDER SUITABLE TECHNICAL RESTRICTIONS

EVEN SIMPLER MODEL

DIFFERENCE EQUATIONS WITH PARAMETERS

$$F(x(t), x(t-\gamma)) = 0$$

FAMILY OF DIFFERENCE EQNS

PARAMETER (INITIAL CONDNS) CHOICE OF FUNCTION $x(t)$ IN INTERVAL $0 \le t \le \gamma$

BUT MATCHING AT ENDS

"QUANTIZATION"

IF WE REPLACE DERIVATIVES $\frac{dx}{dt}$

BY FINITE DIFFERENCES $\frac{x(t) - x(t-\gamma)}{\gamma}$

WE HAVE "UNIVERSAL" WAY TO DISCRETIZE EQNS OF CLASSICAL PHYSICS AND

AS $\gamma \to 0$ WE RECOVER CLASSICAL LIMIT

(FEATURE OF QM WITH $\gamma = \hbar$)

RELATION TO WORK OF CONNES ?

CONNES SHOWED STANDARD MODEL COMES OUT VERY SIMPLY USING A SIMPLE NON-COMMUTATIVE GEOMETRY

INVOLVING 2 COPIES OF SPACE-TIME

ONE WITH USUAL ALGEBRA OF C-VALUED FNS

THE OTHER HAVING ALGEBRA OF QUATERNION-VALUED FNS

EQN INVOLVING $x(t)$ AND $x(t-\nu)$

$\Rightarrow$ 2 COPIES

WITH DIFFERENT ROLES

INVOLVE SPINORS AT $x(t)$

SCALARS AT $x(t-\nu)$?

RELATION TO QM

CAN WE ASSOCIATE TO PAST HISTORY OF PARTICLE $x(s)$ FOR $s \leq t$ A VECTOR $u(t)$ IN HILBERT SPACE THAT EVOLVES (PERHAPS APPROX) ACCORDING TO SCHRÖDINGER EQN AS TIME MOVES ?

IF SO THEN WE HAVE

MEMORY $\longrightarrow$ QUANTUM STATE

AND IGNORANCE OF PAST

$=$ " " QUANTUM STATE

$\Rightarrow$ UNCERTAINTY

INABILITY TO PERFORM RETROSPECTIVE EXPERIMENTS

SUCH A THEORY DOES NOT

INVOLVE LINEAR SUPERPOSITION

PRINCIPLE [EXCEPT AS APPROXN]

"DISPOSES" OF SCHRÖDINGER'S CAT!

RAISES QUESTION.

HOW MUCH CAN WE PREDICT IF WE

KNOW A LITTLE OF OUR PAST?

PROVIDES A MORE SATISFACTORY

EXPLANATION OF QUANTUM

UNCERTAINTY

A POSSIBLE WAY FOR PASSAGE

PAST → STATE

GIVEN TRAJECTORY $x(t)$ IN

CURVED SPACE-TIME

CONSIDER IT AS MOVING "STAR" LIGHT-SOURCE

AND TAKE PROPAGATION OF LIGHT

GIVES SOLUTION OF WAVE-EQUATION

BUT LOTS OF PROBLEMS TO "NATURAL"

INVESTIGATE INCLUDING

1). RELATION OF HAMILTONIAN TO

EQN OF MOTION OF $x(t)$

2) WAVE EQN. → SCHRÖDINGER EQN

(DIRAC EQN)

3) DIVERGENCIES

ULTIMATE PICTURE

BASIC EQNS NON-LINEAR RETARDED

FIELD EQNS ON CURVED SPACE-TIME

WHAT EINSTEIN WAS SEARCHING FOR

A PRECISE PRESCRIPTION OF THE

PASSAGE TO QFT [PERHAPS WITH

SOME APPROXN] • PROPAGATION OF GRAVITATIONAL FIELD

SOPHISTICATED MATHS OF M-THEORY

EMERGING FROM SOME USE OF

" NON-LINEAR FOURIER MODES " TO

ANALYZE THE BASIC EQNS ⟹

DUALITIES

HIGHER DIMENSIONAL STORY EMERGING FROM

4-DIMENSIONS AS WAY TO TREAT THE

WHAT WOULD BE GAINED?

IS THIS JUST A FANCY WAY TO

DRESS UP QM + QFT?

1) PHILOSOPHICAL SIMPLIFICATION AND

BETTER UNDERSTANDING OF THE RELATION

OF THEORY TO EXPERIMENT

2) SIMPLER + MORE RIGOROUS

MATHEMATICAL FOUNDATION

3) UNDERSTANDING OF WHAT

M-THEORY REALLY IS

4) POSSIBILITY OF SOME SMALL DEVIATION

FROM QM CAPABLE OF EXPERIMENTAL

VERIFICATION

5) STIMULUS TO BETTER MATHEMATICAL

UNDERSTANDING OF THE BASIC EQNS

PROBLEMS AHEAD

1) EXPLORE VARIOUS FORMS OF RETARDED DIFF. EQNS IN PHYSICAL CONTEXT

3) EXAMINE VARIOUS ARGUMENTS & EXPERIMENTS USED TO SUPPORT QM

a) TWO SLIT EXPERIMENT

b) BELL'S INEQUALITY

c) EPR EXPERIMENT (QUANTUM ENTANGLEMENT)

4) UNDERSTAND ROLE OF COMPLEX NUMBERS IN Q.M [PENROSE]

2) EXTEND TO FIELD THEORY (PARTIAL DIFFERENTIAL - DIFFERENCE EQNS)

PRINCIPLES DISCARDED

[AT FUNDAMENTAL LEVEL]

1. TIME REVERSIBILITY
2. DUALITY BETWEEN POSITION & MOMENTUM

PRINCIPLES PRESERVED

1 GEOMETRICAL DESCRIPTION
2. USE OF CALCULUS

} OK BY EINSTEIN!