

QUANTUM COSMOLOGY

- IF THE UNIVERSE IS A QUANTUM MECHANICAL SYSTEM.
- THEN IT HAS A QUANTUM STATE.



- WHAT IS IT ?
- THAT IS THE CENTRAL PROBLEM OF QUANTUM COSMOLOGY.

IGNORANCE IS NOT BLISS.

IGNORANCE OF THE INITIAL STATE

$$S = \frac{I}{\text{Tr}(I)}$$

~~X~~ INFINITE TEMPERATURE

$$\rho = \frac{e^{-\beta H}}{\text{Tr}(e^{-\beta H})} \Big|_{\beta=0}$$

~~X~~ EQUILIBRIUM

$$[H, \rho] = 0$$

~~X~~ NO SECOND LAW

~~X~~ NO QUASICLASSICAL REALM

$$\langle \phi(R) \rangle = 0, \quad \langle \phi^2(R) \rangle = \infty$$

THEN

NOW

WHAT IS Ψ ?

WHAT IS THE VACUUM?

DOES Ψ EXPLAIN CLASSICAL SPACETIME?

ASSUMED

ALL PROBABILITIES FOR OBSERVATION DETERMINED BY H & Ψ + CONDITIONS

WHAT IS THE MEASURE DEFINING THE DISTRIBUTION OF OBSERVERS?

WHAT IS THE ORIGIN OF THE ARROWS OF TIME (INCLUDING QM ONE

ASSUMED?

FINAL THEORY
 $\Psi + I(\phi(x), g(x))$

STRING, M, ...
+ ?

LOCALITY & QM

- QM ALLOWS NON-LOCALITY TO BE TRANSFERRED FROM DYNAMICS TO STATE (NA-H.)
 - EPR CORRELATIONS
 - AHARANOV-BOHM
- A UNIFIED THEORY OF DYNAMICS & STATE MIGHT BE A NATURAL WAY OF INCORPORATING NECESSARILY NON-LOCALITY.

IS THERE A
NON-TRIVIAL
FINAL CONDITION
FOR THE UNIVERSE?

WHY QUANTUM MECHANICS?

HOW COME THE QUANTUM?

JOHN WHEELER

- THE FOUNDERS OF QUANTUM THEORY THOUGHT THAT INDETERMINACY "REFLECTED THE UNAVOIDABLE INTERFERENCE IN MEASUREMENT DICTATED BY THE MAGNITUDE OF THE QUANTUM OF ACTION." (BOHR)
- WHY A QUANTUM UNIVERSE THAT IS NEVER MEASURED?
- WHY A SUPERPOSITION PRINCIPLE WHEN THERE IS NOTHING TO SUPERPOSE?

WHY IS THERE A DIVISION INTO
REGULARITIES OF DYNAMICS
AND REGULARITIES
OF THE INITIAL CONDITION?

THEY ARE CONNECTED IN
HAWKING'S NO-BOUNDARY
WAVE FUNCTION

$$\Psi = \int \delta g \delta \phi e^{-I[g, \phi]}$$

COULD THERE BE
ONE PRINCIPLE
THAT DETERMINES BOTH?

WHAT IS THE STRUCTURE OF THE FINAL THEORY?

- WILL THERE BE A CLEAN SEPARATION INTO DYNAMICS AND STATE?
- WHAT REGULARITIES WILL BE PREDICTED FROM THE THEORY ALONE AND WHAT WILL REQUIRE CONDITIONS?
- WILL A SEPARATE MEASURE BE NEEDED?

WILL THERE BE A
FINAL THEORY OR
WILL PARTICLE PHYSICS
BECOME AN
ENVIRONMENTAL SCIENCE?