

Solving the Quantum Mystery with the Arrow of Time

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1 The Quantum Mystery

What is the wave function?

- All of our best quantum theories require the wave function.
- It is still there after we clean up the “measurement problem!”

The wave function: $\psi : \mathbb{R}^{3N} \rightarrow \mathbb{C}$, where $N \approx 10^{80}$.

- High-dimensional.
- Complex numbers.
- Defined with arbitrary conventions.
- Quite unlike the local ontology of particles and fields.

Moreover, since it is high-dimensional and non-separable, it is a problem for:

3D-ism: The fundamental space is (more or less) 3-dimensional.

Humeanism: The fundamental ontology is a Humean mosaic of local matters of particular facts, and everything else supervenes on that.

Quantum Mystery: what is the wave function?

2 The Arrow of Time

What explains the arrow of time?

- Can physics explain the arrow of time?
- Obstacle: fundamental physics is time-reversal invariant. (Some caveats)
- A theory T is time-reversal invariant (TRI) $\stackrel{\text{def}}{=}$ for any sequence of events, it is possible in T if and only if its time reversal is possible in T .
- The standard solution: add a new law of nature called the “Past Hypothesis”—the universe started in a low-entropy state.

- Macrostate vs. Microstate.
- Entropy measures “how many” microstates are compatible with a given macrostate.

The Past Hypothesis (PH): standard quantum version

- The initial quantum state of the universe is a low-entropy wave function Ψ_0 .

(For the experts: at t_0 , the universe is described by a wave function chosen at random from the set of wave functions in the low-dimensional subspace.)

Statistical Postulate: a uniform probability distribution over the wave functions compatible with PH.

3 A Unified Theory

Proposal: we can solve the quantum mystery with the arrow of time.

Step 1. Coarse-Graining.

- Epistemic vs. Ontic.
- Ontic: the subspace S is the complete description of the universe’s quantum state at t_0 .
- Mathematically: density matrix $a\mathbb{I}_S$, where $a = 1/\text{dimension}(S)$ and \mathbb{I}_S is the identity matrix restricted to S .

Step 2. A New Postulate.

The Initial Projection Hypothesis

- The initial quantum state of the universe is $W_0 = a\mathbb{I}_S$.

(For the experts: at t_0 , the universe is described by the unique normalized projection on the low-dimensional subspace S .)

- W_0 : macrostate of the universe at t_0 .
- It encodes the low-entropy information of the Past Hypothesis.
- It is simple and unique.
- We no longer need the wave function or the Statistical Postulate.

Step 3. The Nomological Thesis.

The Nomological Thesis: The Initial Projection Hypothesis is a law of nature.

The New Theory Q :

1. Local ontology: particles or fields.
2. Dynamical Law: the von Neumann equation.
3. Initial Condition Law: the Initial Projection Hypothesis.

Theory Q explains both the quantum mystery and the arrow of time. Also, 3D-ism and Humeanism are triumphant.