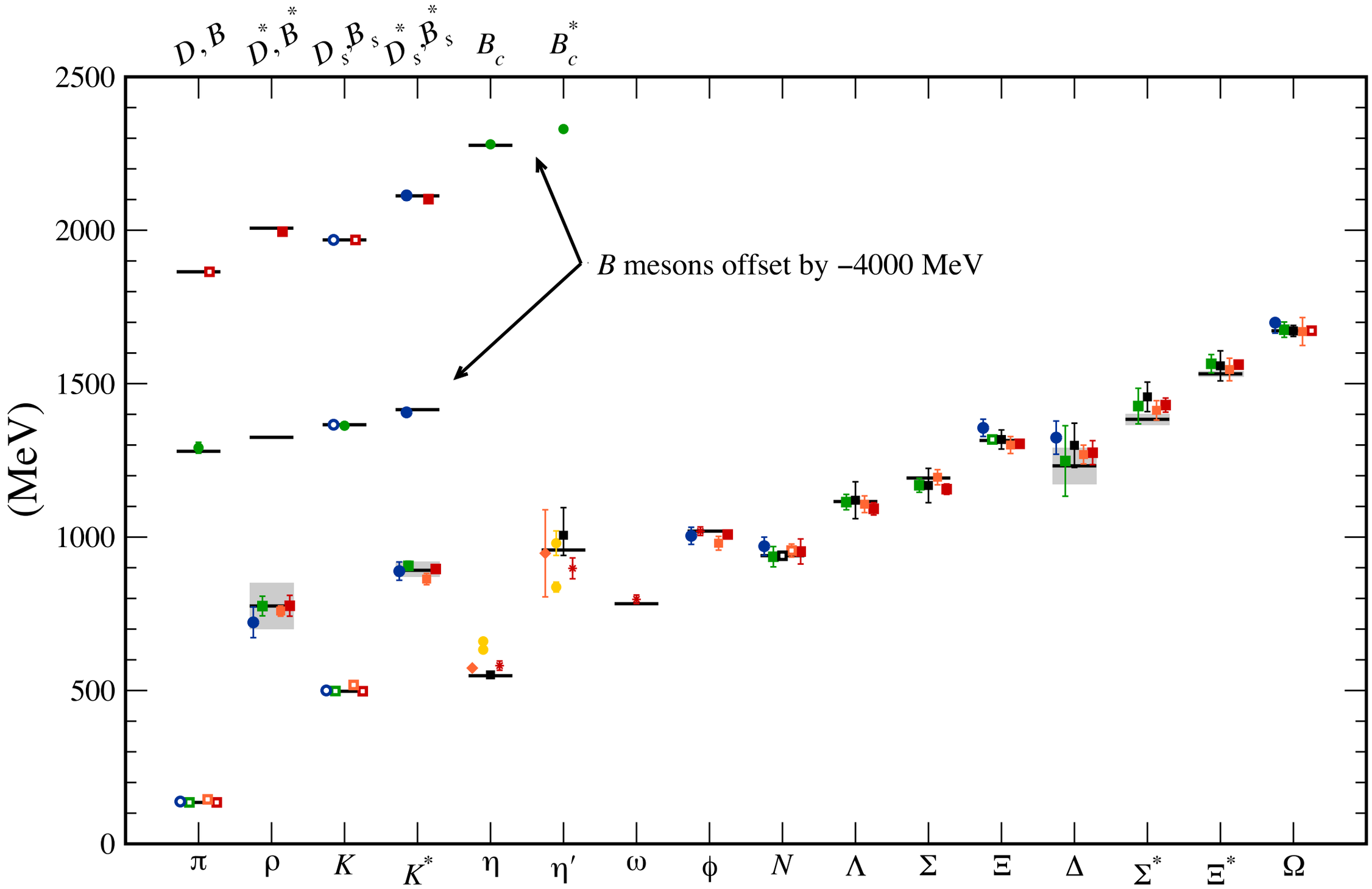
Aspects of Quantum Epistemology

Five Highlights

Reality as a Guide to Reality

World ↔ Concepts (? ↔? Computation)

Physical reality embodies equations that can be stated purely conceptually, and programmed on a computer: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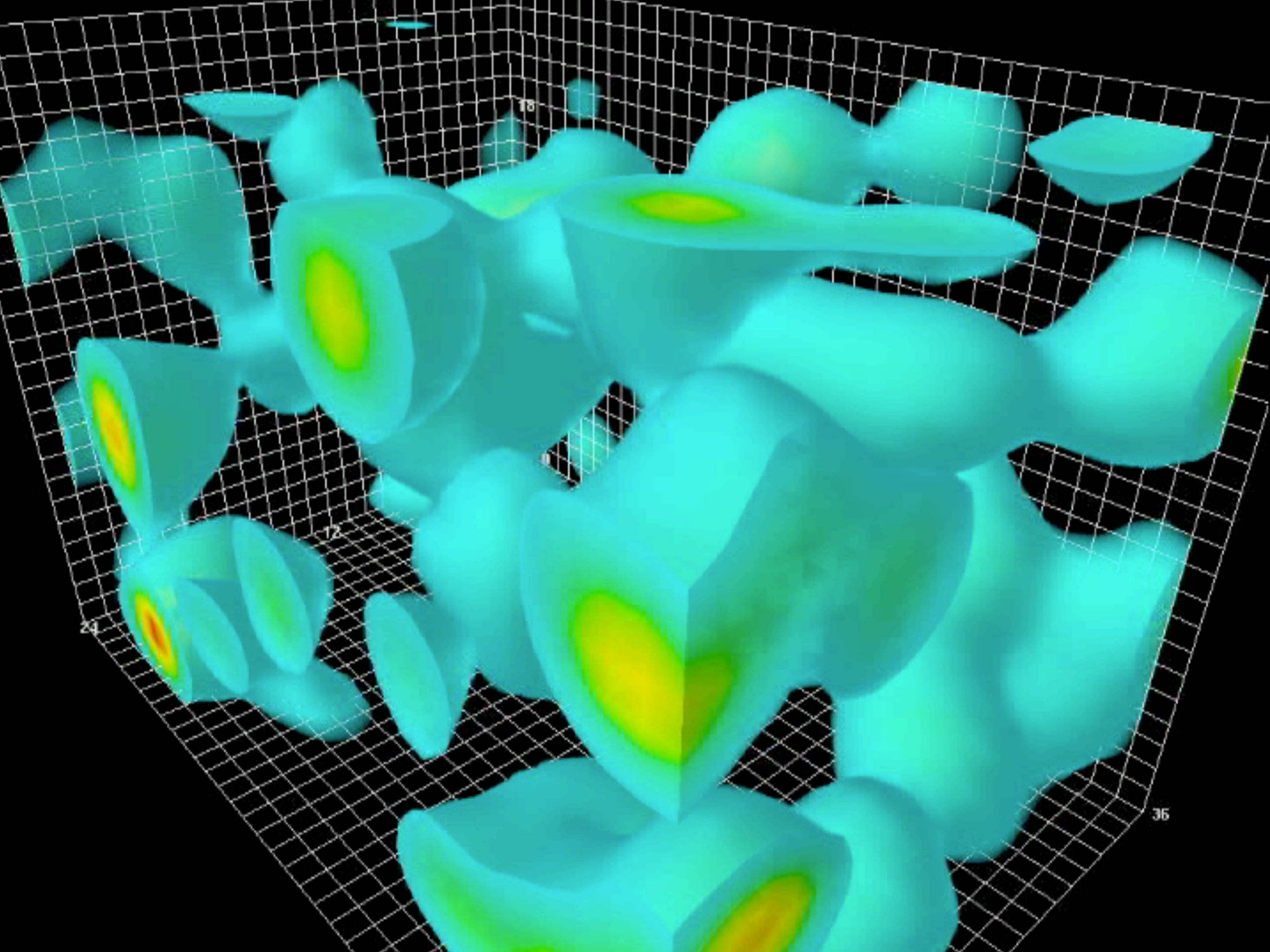
Empty space is not Void.

It is the seat of ceaseless, spontaneous activity.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The Virtue of (Selective) Ignorance

From the perspective of quantum theory, *interference* arises from the possibility of getting from the same initial state to the same final state through several distinct paths.

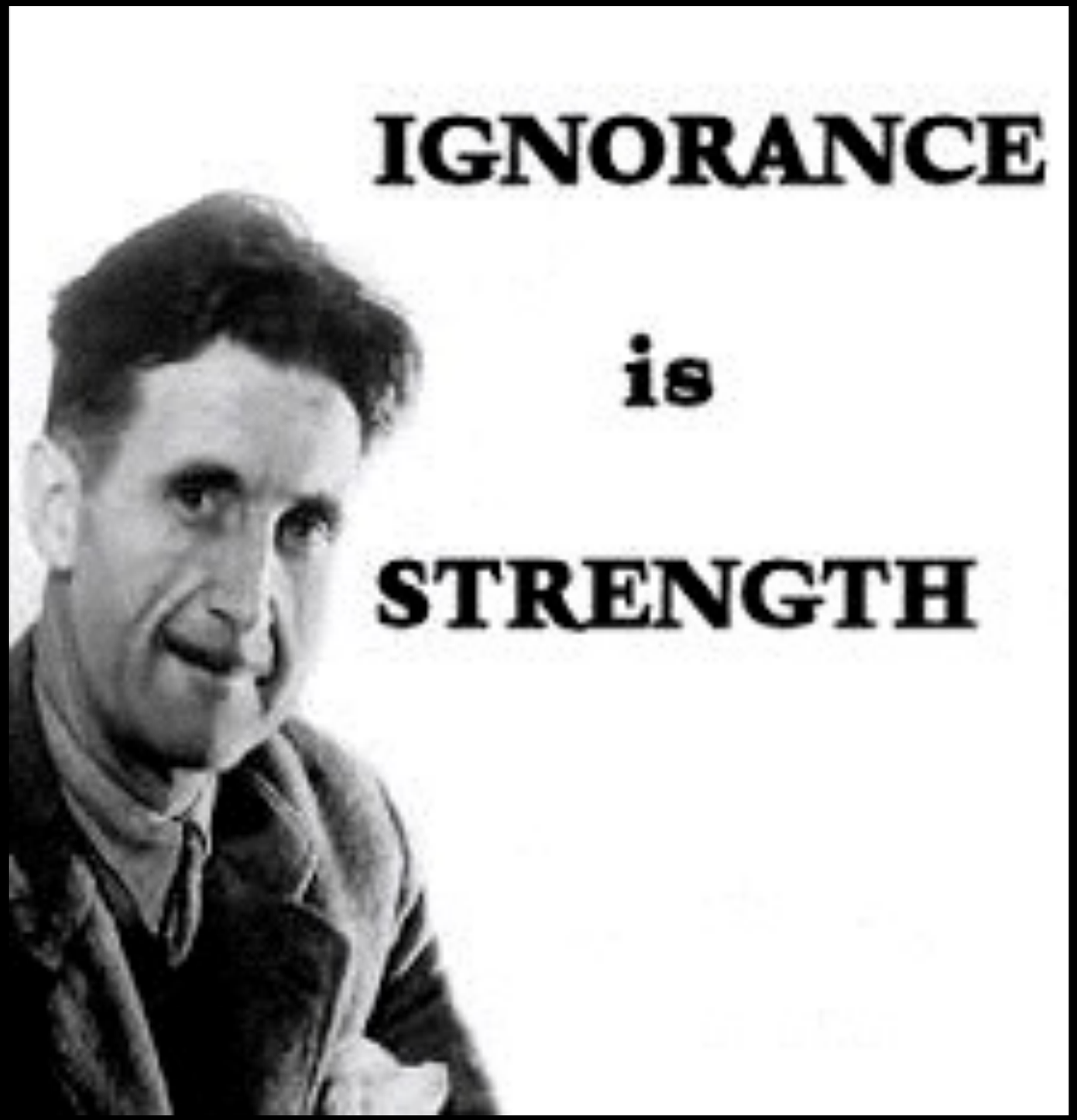
The probability for the overall process is then the square of the sum of amplitudes, which differs from the sum of the squares.

$$|A+B|^2 = |A|^2 + |B|^2 + (AB^* + A^*B)$$

interference term

Access to interference terms gives new information, that is quite useful in many applications.

This inspires the promising idea of strategically *erasing* information that would otherwise distinguish different final states, in order to allow them to interfere.


IGNORANCE
is
STRENGTH

Quantum History

The conventional formulation of quantum observables emphasizes operators acting on states.

Yet many important quantities, which one would like to regard as observables, depend not only upon the state of a system but also on its history.

Examples: proper time, Wilson line integrals

When we make a conventional observation, we learn about the location of our system in Hilbert space. (We project on an eigenspace.)

What do we learn, when we measure the value of “historical” observables?

One can introduce a history Hilbert space, with an appropriate inner product, to address such questions.

Compensated measurements are described by a generalized Born rule, using that inner product.

The eigenspaces of history operators typically involve *entangled histories*.

Entangled histories can violate Bell-like inequalities that are satisfied by all pure histories.

Information and Action

In the current formulation of physics, the foundational concept is *action*.

Action is what appears in path integrals, as the measure.

Action is implicit in Hamiltonian mechanics, which quantum theory relies on.

Action is what is *invariant* under fundamental symmetry transformations.

(Physics progresses by integration …)

Given Planck's constant as a unit, action becomes a purely numerical (dimensionless) quantity. The world-action is therefore a specific *numerical* quantity that governs the basic operation of the physical world.

One would like for such a basic quantity to have profound independent meaning.

Information is another dimensionless quantity that plays a large and increasing role in our description of the world.

Can one identify action with information?

Nowadays many treatments of the microphysical origin of entropy, and of foundations of statistical mechanics in general, begin with discussions of information and ignorance.

A strong formal connection between entropy and action arises through the Euclidean, imaginary-time path integral formulation of partition functions.

It would be wonderful to motivate that imaginary-time path integral directly and insightfully, rather than indirectly through the apparatus of energy eigenvalues, Boltzmann factors, and so forth.

Complementarity

In quantum theory, the primary representation of reality is the wave function.

But to relate the wave function to reality as observed, we must do some processing.

The kind of processing we should do, depends on the question we want to address.

Different forms of processing may be mutually incompatible.

Reality is complicated.

To parse it in ways we can understand, we must process it.

The kind of processing we should do, depends on the question we want to address.

Different forms of processing may be mutually incompatible.

There can be several valid, though mutually exclusive, perspectives on the same thing.

That general insight, which I find quite liberating, is Bohr's *complementarity*.

Examples, I suspect, of complementary perspectives:

Free will and determinism

Person and object

Purpose and causality

Duck and rabbit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