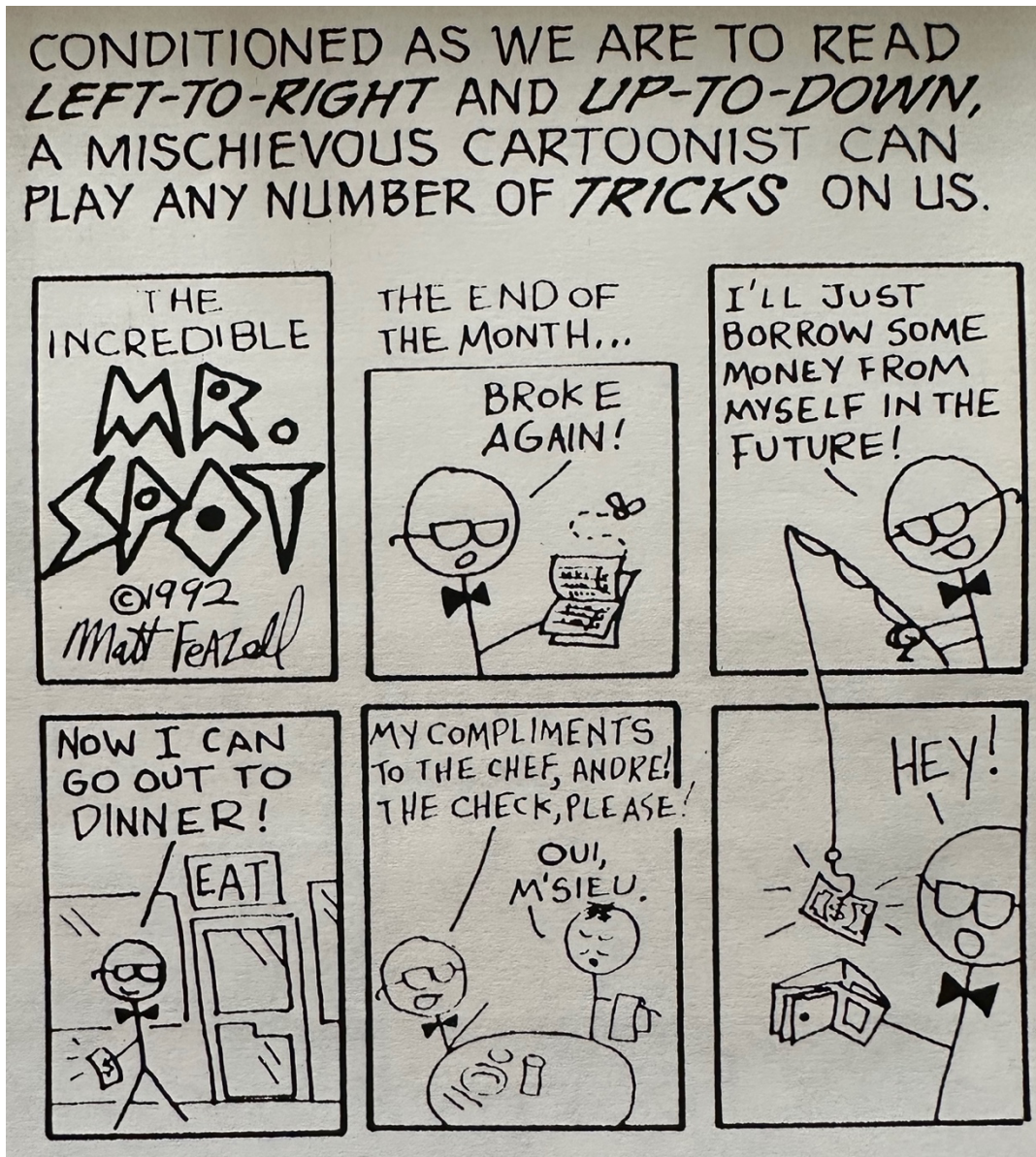


Chapter 22

“Quantum Temporal Indeterminacy”



Credit – Mr. Spot: “Borrow from the Future” (need permission)

Evidence for a Solution

The evidence that self-reference is the key to the quantum measurement problem will be organized into three categories. Separating facts from developments and creative speculation is essential for scientific rigor.

Facts

In times of normal science paradigms are efficient, reliable guides to truth, interesting problems, strategies for solutions, and confirming what constitutes success. However, during times of crisis, they are extraordinarily constraining, erecting conceptual boxes whose sides consist of hidden, sometimes impenetrable assumptions.

The quantum measurement problem has gone unsolved for a hundred years. Perhaps a solution will be found within the current framework, but history suggests that progress has often been thwarted by the strength of prevailing paradigms and, unless overturned, they may continue to keep potential solutions out of reach. Its lack of resolution suggests that this is a time of crisis for physics.

There is a cosmic speed limit, the speed of light, which looks like a truly hard limit. While it has the units of speed, it is more than just a velocity, it is the thread that weaves space and time together. Yet nature allows nonlocal correlations, not signals exactly, which imply that something superluminal is happening behind the scenes. Nature jealously guards this shortcut, keeping it exclusively for herself, and blocks our every attempt to wrest it from her.

Randomness is a pervasive feature of quantum reality. The classical view of causality does not permit randomness, it is exclusively an epiphenomenon due to ignorance about the state of a system, rather than something fundamental. In the quantum view, randomness is fundamental and irreducible.

The quantum formalism is linear, built into the math, which admits solutions in closed form, but only applies to the *evolution* of the wave function. Its *reduction*, the collapse to classical values due to a measurement, is inherently nonlinear.

Relativity treats space and time on an equal footing yet prohibits spacelike causality.

Self-reference is ubiquitous, inherently nonlinear, generally rejected, ignored, or deliberately prohibited, yet continues to find creative ways to insert itself into formal systems. It won't go away.

Developments

Many of the following developments are not new, just not well known. They provide conceptual tools that emerge naturally once the above facts are taken seriously.

The concept of world lines was never generalized from the classical case to the quantum case. World ribbons gives them thickness, which makes the collapse question particularly poignant – what does the top edge of a world ribbon look like upon a measurement? It is obviously spacelike.

Formal self-reference presents two deep fundamental conceptual challenges: paradox, self-denying contradictions, and indeterminacies, the self-affirming creation of information.

Quantum games reveal just how deep some of our classical prejudices extend. Adding nothing more than superposition, with the simplest possible weights, yields a troubling view of causality and time. In a classical system, the present is an infinitely thin line between past and future. In a chronoblock, the present has a thickness, and within this window around now, the very concepts

of past, present, and future become ambiguous. Talking about causality within this window requires the use of jargon normally associated with the science fiction depiction of time travel.

The introduction of imaginary truthvalues as the solution to logical self-reference portend a coupling between representational bases and the twin evils of paradox and indeterminacies. Each makes the other more palatable.

Nature provides a natural asymmetry in time, past and future, that make timelike causality unambiguous. She has left figuring out an equivalent asymmetry in space to us, but the symmetric spacetime interval is a candidate that allows us to tell left from right and thus provides a situationally dependent way to make spacelike causality as unambiguous as timelike causality. It's a start.

Self-reference can be inserted into physics given spacelike causality. At first blush it looks like a death blow to physics, paradox and indeterminacy, but it invites a much needed humility into the scientific enterprise – perhaps what we don't understand is self-reference.

Speculation

The QTP/QTI hypothesis is that self-reference can be introduced into physics in a natural way if some kind of spacelike causality is allowed. The above tensions suggest that the conventional objections to this are not as strong as traditionally assumed. It suggests that the measurement process actually *depends* on temporal paradox. There is a certain beauty in this speculation, and beauty has, historically, been an unreasonably effective guide in developing sound and far reaching theories.

A Checklist

This is a lot of hints to try to keep in mind at once, particularly given their unfamiliar status. The following checklist summarizes the preceding discussion; items are grouped by epistemic status, not by independence.

Facts

- **Paradigms** are a dual edged tool, normally efficient, but extremely constraining.
- The **quantum measurement problem** is harder than it looks.
- The **speed of light** is absolute.
- Reality is **nonlocal**.
- **Randomness** is fundamental.
- QM and QFT (evolution of the wave function) are **linear**.
- Collapse (reduction of the wave function) must be **nonlinear**.
- **Relativity** places space and time on equal footing, yet causality treats time preferentially.
- Spacelike causality allows **closed causal loops** in spacetime.

Developments

- **World ribbons** generalize worldlines to the quantum case.
- Seen from conjugate bases, **paradox** and **indeterminacy** are two sides of the same coin.
- **Quantum games** are effective challengers to classical paradigms.
- **Chronoblocks** offer a framework for discussing nonlocal causality.
- **Imaginary truthvalues** suggest that conjugate bases are foundational.
- **SSI** shows that introducing asymmetry into space might level space and time in relativity.
- **Self-reference** naturally introduces nonlinearity yet remains poorly formalized.

Speculation

- The **QTP/QTI** hypothesis offers a framework for integrating these once unrelated concepts into a unifying whole, a new paradigm of physics.

This is a daunting list of concepts. Whether or not there is a solution hiding inside, begging to be freed from paradigm bondage, is uncertain, but the very effort, the quest if you will, to uncover a testable, falsifiable theory is going to lead to interesting places, destinations with their own inherent scientific validity.

There is a lot to like about this speculative idea, but liking is not enough. The pros are enticing, but the demands of rigor remain; while the motivation is in the pros, the science is in the cons. We turn now to the cons.