Photons as Observers and the Emergence of Scale

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A Comment on the Closer To Truth post:
Thomas Hertog on the Origin of Time | Closer To Truth Chats (Apr 14, 2023)
https://youtu.be/XXxcjJHqDOg?t=1h9s

1:00:09 Thomas Hertog *"… observation is … always done … at the quantum level … by one … photon or an interaction between fields. So we are not saying that human observations today fix the entire history of the universe."* More precisely, and as Feynman aptly noted in his Lectures about electron slit self-interference, the observation done by such a photon never rescales the wave function to a size any smaller than the momentum wavelength of the photon [1]. That's no surprise since reducing the momentum wavelength of probe particles is as much a reason for building particle accelerators as reaching higher energies and temperatures.

What is perplexing is how little attention the critical role of dumb, simple linear momentum gets in most discussions of the nature of observation.

Outside of Feynman's Lectures, statements like the above are surprisingly rare, with most discussions preferring to go in the opposite direction of making observation one of the most mystical processes in all of physics. Moreover, even in this quick mention, the focus is not clearly on the role of linear momentum since Thomas Hertog mentions *both* photons and field interactions. Linear momentum wavelength is the deeper thread that connects both examples and, for that matter, any other experimentally meaningful example of rescaling a wave function.

(Notice that I intentionally avoid using the term "particle" since the history of experimental physics contains precisely zero examples in which the rescaling gives anything other than a smaller wave function within the finite, speed-of-light limited boundary of the earlier wave function. The *size* of the wave function rescaling can be cosmic, e.g., an ancient photon wave function can rescale, with absorption, to the atomic scale on a detector in a telescope on earth and do so in an utterly timeless fashion. While such enormous timeless rescalings asymptotically give the impression of a "point-like" rescaling, it's all a bit of a charade since it's only the upper end of the wave function that can grow without limit, and even then, only at a considerable cost in terms of how much time, travel, and isolation it requires to creates such vast photon wave function examples.)

One reason folks neglect the essential mathematical role of linear momentum in wave function rescaling is that a tiny amount of momentum energy goes an incredibly long way when rescaling wave functions. Classical physics trains us to believe that the proper way to isolate an experiment from an observer is to reduce the ratio of energy used to observe compared to the mass and energy of the experiment itself. Quantum mechanics, however, informs us that, at least in the case of linear momentum, this is a false limit. What counts is *not* how small the energy is but how short the momentum *wavelength* is, even if that wavelength is associated with almost no energy compared to the target.

Feynman uses an electron wave function as the target of his photon probes. That sounds like a small amount of mass, but compared to the modest photon wavelengths of his thought experiment, an electron is a stupendously large object to have its wave rescaled by the puny energy of the photon. Yet, as Feynman notes, this puny level of momentum energy becomes *the* determining factor in whether the electron wave rescales to the point that it can no longer see both holes. Light intensity increases the odds of observing the electron but has no impact on the rescaling of the electrons observed.

What about a larger wave function target, however? What if the target is, say, 46 million times heavier than an electron, roughly the mass of a 2000-carbon-atom organic molecule? Surely more than the linear momentum of one puny photon is needed to rescale that wave function?

Nope. Successful quantum interference experiments with just such molecules [2] demonstrate the *same* extreme rescaling sensitivity to single-photon impacts as electrons. Once again, only the momentum *wavelength* counts for determining the rescaled size of the wave function, *not* the ratio of probe energy to target mass and energy. Whether it's an electron, a macromolecule, or — and please note this point carefully — an *entire universe,* as Thomas Hertog somewhat indirectly proposes here, the rescaling power of that single photon remains invariant. Compared to that level of energy-vs-impact, any level of computational energy efficiency hypothesized in current quantum computing technologies pales.

There is another name for the forms of linear momentum whose rescaling power is unlimited but whose total energy is trivial compared to the target wave function. We call it information.

The connection between linear momentum and information is vital since overlooking it risks losing grasp of experimentally meaningful physics and drifting off into untestable mysticism. All quantum observation involves a transfer of linear momentum. It's just that when classical systems exist at one or both ends of the transfers, the momentum transfer can be vanishingly small compared to one photon's energy, and the transfer's energy is far less than that. Unlike angular momentum, linear momentum is not measured in units of action and thus does not need to abide by the assumption that only *quantized* units of energy give experimentally detectable outcomes. Furthermore, there's no simple answer to how much rescale-capable momentum even one photon can generate, given the proper ratios of masses [3]. A single photon in a house of mirrors can do a *lot* of observation, with every observation capable of rescaling an arbitrarily large mass's wave function.

Another implication of information being the low-energy limit of linear momentum is that quantum experiments that *claim* never to see anything happen in an always-empty branch of an experiment are not quite telling the truth. That's because there should always be a tiny bit of momentum deposited in the supposedly empty branch, even as the primary energy of the photon lands on some other branch [4]. Careful examination of such experiments should verify this effect. One well-known, well-verified example of how linear momentum remains conserved even when added in vanishingly small quantities is the double momentum imparted by a photon reflected from a deep-space solar sail [5]. So little of the photon's total energy is lost in these transfers that there is no easily perceptible change in its frequency. Nonetheless, the total momentum transfer of many photons is high enough to, in principle, accelerate such sails to near-light speed.

So, Thomas Hertog, what might this mean for your no-boundaries theory?

A subtle implication of mass-indifferent wave function rescaling — the ability of, e.g., the momentum in one photon to rescale and relocate the wave function of an object as small as an electron or, potentially, as large as the entire universe — is that this rescaling necessarily crosses the usual boundaries of space and time. The more profound suggestion is that our classically-biased thinking is upside down. Causality is *not* the norm; the norm is a chaos of indefinitely low-energy, indefinitely-variable, boundary-free rescaling outside our local definitions of space and time. Our inertial-frame-based impositions of agreed-to xyzt scales — a marvelous little trick enabled by not-quite-xyzt half-spin — are the exception. A collection of almost continual rescalings via local momentum exchanges (who'd of thunk it: dumb little low-energy phonons as fundamental to spacetime emergence) allow atoms to agree on what is and is not a good size to be.

Recognizing that one photon can act as an observer is a more powerful tool for understanding many surprisingly deep problems in physics than one might expect. I strongly suspect these insights include how an otherwise scaleless and (in our perception) timeless universe can nonetheless wrap around itself to create "interesting" physics *without* invoking arbitrary boundary conditions or infinitely distant and infinitely powerful observers. Nor is this some remote, unfathomable, untestable process since you are using small-scale examples of it at this very moment when single photons perceive and transform the vastly larger shapes of your eye corneas and lenses into directions for how to form an image on your retina. That small QED example of an integral-of-histories performance defies classical definitions of space and time as profoundly as the broader and deeper case of $\approx 10^{81}$ xyz images (credit: R. L. Kuhn) of a *single* universe-spanning electron pattern.

References

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