# Bending Spacetime Via Entanglement Collapse (Small Lab Compatible)

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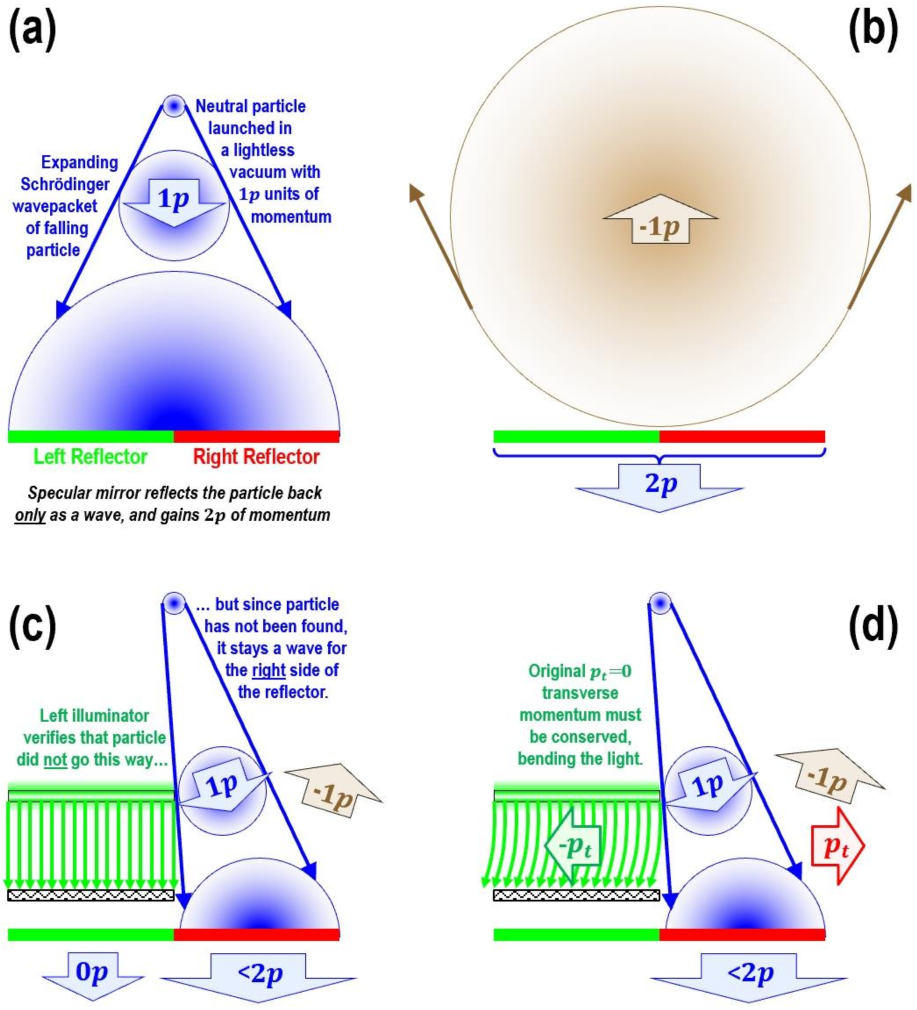

*When particle packets partially collapse, they transfer momentum to light, modifying spacetime geodesics.*

***Abstract:*** The popular idea that quantum wave functions lack physical properties is incompatible with the ability of well-confined pulses of fermions and bosons to impart momentum to a target through specular (mirror-like) reflection. However, since one can control the shape and direction of this momentum pulse by doing nothing more than verifying that the particle does *not* reside in some part of the overall wave function, conservation of linear momentum requires the act of testing an empty region of space to impart canceling momentum into one of the entities in the nominally empty region. This paper proposes that the light pulse used to verify the empty region is the best candidate for receiving the canceling transverse momentum, causing the light pulse to curve slightly outward. Furthermore, since this region lacks conventional potential fields, the simplest interpretation for the curved light path is that the entangled collapse of the wave function created a minute transient curvature of spacetime in the empty region, one just strong enough to transfer the needed momentum. This transient quantum bending of spacetime may be testable using little more than high-quality optical equipment and a reference beam. If validated experimentally, quantum bending would suggest space is a quantum phenomenon and gravity as a fabric of momentum transfers orchestrated by quantum "non-observation" of matter concentrated in an adjacent region. In that case, dark matter may be nothing more than unresolved momentum energy located far away from galactic-scale regions of high matter density.

## Basics of Specular Quantum Reflection

Fig. 1 shows a thought problem inspired by one on Dr. Sabine Hossenfelder's YouTube channel [1] and first presented as a comment on that video [2].

The critical premise of the thought problem is that wave functions are physical phenomena that carry momentum and that rescaling (collapse) of these wave functions is real and does *not* necessarily involve collapsing the wave function to atomic or particle scales. Since all experimentally accessible wave functions have classical origins in space and time and thus are finite in size, "wave packet" is a better description. I avoid the Hilbert state space model intentionally since the goal is to uncover the detectable behavior of the Schrödinger 3D wave function.

The alternative to a full wave function collapse is a specular (mirror-like) reflection of the wave from a potential barrier. While such reflections do not destroy the coherence of the quantum wave, they can easily severely reduce its size by guaranteeing that the particle can be found only in the much smaller specularly reflected wave function. The ability of specular reflections to impart momentum without destroying the quantum interpretation of a particle shows up most vividly in Maxwell's light pressure, which is used to propel some satellites and is a major force in shaping cosmic dust clouds [3].

The concept of specular reflection of wave packets is important because it provides a way to define and test their geometry and properties without necessarily destroying them in the same fashion as particle-like detection. The top two boxes of Fig. 1 show this effect by pointing out that units of momentum (here $p$ as the momentum of one particle, regardless of its specific mass or energy) distribute smoothly across the reflecting surface and can, if desired, be focused again after reflection to prove that. The well-established fact that individual particles and photons respond to reflection and diffraction identically to enormous numbers of the same particles, such as in conventional optics, is critical to understanding how such arrangements work. No matter how non-intuitive the idea of a single particle, such as a neutron, acting as a human-scale wave when specularly reflecting from a dense surface, this is the only method by which accurate predictions of travel and momentum transfers are possible.

## The Curious Case of Reading Empty Space

Once a particle with reflectors is set up and working reliably, an interesting experiment is possible, one first suggested by Dr. Hossenfelder in her video.

The problem is simple enough: If one *knows* that the particle does not reside in a particular region of spacetime, then wave function for that particle can exist there either. This tight relationship is the basis of the Copenhagen interpretation that wave functions are "pure information" about the particle's location, with all of the testable properties of that particle remaining with the particle.

As already noted, the extremely well-proved phenomenon of specular reflection makes this assertion difficult to reconcile with the point that such reflections distribute momentum *evenly* across the entire reflecting medium. If it does not, the wave function ceases to exist because the *specific* location of the particle on the specular reflection surface is not known, "collapsing" the wave function. Feynman was fascinated by this distinction, pointing out that as long as a particle did not leave a "spin signature" on a single atom of a reflector, the particle reflects in a way that allows it to continue interfering like a wave [4].

Thus, if you use photons to scan half of a large, expanding wave function and see no particle there, you ensure that no wave function exists on that half of the wave packet, but *without* removing wave-like behavior and momentum transfers from the other half of the wave function. As shown in the bottom left example in Fig. 1, the net result of the photon scan is that a formerly testable symmetric wave function now becomes a highly asymmetric wave function that deposits no momentum on the left but almost a full two units of momentum on the right. Reflection doubles momentum by creating a new pair of positive and negative parts, while the now off-angle reflection reduces the total momentum transfer to less than the maximum possible two momentum units. This reduction makes sense since a glancing impact transfers less momentum in everyday life than a straight-on, full-contact impact.

The final point to notice in this new setup is that the new offset of the wave function adds *transverse* (sideways) momentum to the system. The new momentum comes from the altered trajectory of the wave function, which continues to move to the right even after reflecting. Adding a small amount of transverse momentum is critical to understanding the nature of the problem since linear momentum is an absolutely conserved quantity in physics.

## Expanded Thought Experiment Description

As first described in a comment [5], the overall experimental procedure goes like this:

Launch a neutral, low-momentum particle or molecule toward a circular momentum detector split into two semicircular parts. The momentum detector operates not by absorbing the molecule but by reflecting it. For a real experiment, you would likely want to use low-angle impacts to ensure specular (mirror-like) particle reflection, but for this thought experiment, we can assume simple vertical reflection.

Note that all forms of specular reflection, including everyday reflection of light in a mirror, are unavoidably quantum phenomena since any particle vastly smaller than the flat surface must somehow “see” the larger surface to know the proper angle of reflection. In the Schrödinger wave interpretation, the probability wave function gathers this information.

Note also that momentum is vector-conserved, which sharply contrasts with scalar-conserved energy. That means you can create any number of opposing action-reaction momentum pairs from a potentially tiny amount of energy. All you need is for the total set of vectors to cancel to zero.

This idea of reflection without atomic absorption sounds strange, but it is how NASA light sails use the sun for propulsion without absorbing photons in the black-surface sense. That kind of absorption would result in a very different effect of heating. Also, specular reflection is not just a photon effect since low-momentum neutrons, for example, reflect specularly.

What happens in specular reflection is the creation of a new momentum pair that did not exist before. Counterintuitively, this doubles the momentum the momentum detector gains compared to simply absorbing the particle. The detector receives not just the original momentum of the particle but a second, same-direction unit of momentum from the newly created momentum pair. Specular reflection conserves overall momentum by reversing the momentum of the particle’s probability wave, sending it back in the direction from which it came and giving a total momentum identical to that of the original particle.

Above and to the side of each semicircular detector is a low-intensity laser pulse generator with optics that spread the directed beam across the volume just above each detector. Each can generate pulses synchronized with particle launches, with each pulse having barely enough coverage, energy, and frequency to ensure the particle did not cross that region of space on its way to the reflector.

Why use “barely enough” light to view the region above the detector with photons?

This thought experiment has one more twist: A detector opposite each laser pulse generator that is sensitive enough to detect whether the laser pulse acquired any lateral momentum while traversing the empty region of space above the detector. If you think about it, for laser pulses, that is equivalent to this question: Does the laser pulse bend ever so slightly as it traverses the empty region of space just above the detector? The best way to detect such an optical distortion would be interferometry, which can be exquisitely sensitive to such minute path distortions.

## Experiments and Predictions

It's time to run some experiments.

First, launch particles with both lasers off. The prediction is this: Each semicircular detector receives one unit of momentum as long as the particle reflects specularly. There are no surprises here, as this is standard quantum mechanics. Both semicircular detectors report no deviations in the path of the particle. Note, however, that both also equally report the reflection of the particle. That's a neat trick if only particles impart momentum.

Second, launch a series of particles accompanied by the low-level laser flashes on one semicircle detector side, say the left side. The question is this: What do the various lateral motion sensors for both particles and laser pulses see in this case?

Copenhagen does not handle this question easily because it explicitly assumes probability waves cannot carry momentum, only particles. Most quantum interpretations, even ones that try to be different from Copenhagen, continue to assume this duality of information-only waves and property-only particles.

But why not just follow what we know from experiments happens in specular reflection, and assume that momentum conservation holds? That analysis gives this set of predictions:

For every detection where the laser pulse sees only empty, particle-free space over the left detector, the right detector receives twice as much specular reflection momentum as before. Why? Because the laser pulse has reshaped the total particle wave and now falls only on the right detector. Moreover, since the light pulse breaks the symmetry of the wave, the lateral momentum detectors of the right side suddenly kick in and report a slight bending of the particle path to the right.

What about the left laser receivers that detected only empty space? Conservation of momentum requires that if the particle path bends toward the right, the light paths in the detector must bend toward the left as if the empty space had become a weak lens.

## Implications for Quantum and Gravity Theories

If all of this proves true experimentally, what are the implications?

The first implication is that the infinite duality of the Copenhagen translation — the attempt to translate quantum theory into a pair of "perfect" waves and "perfect" particles — is incorrect. Until they are detected, probability waves contain momentum, and that momentum is completely and experimentally real.

When the left laser "proved" no particles went that way, it also interacted with that region of the very-much-real wave function and captured its load of momentum. It was never "empty" space, and the absence of a particle there does not disconnect its presence from experimental reality. On the contrary, that empty space with a wave function behaves like a one-use-only lens that bends the light interacting with it.

I proposed a space-mediate momentum transfer in comments in Sabine Hossenfelder's Backreaction blogs from 2020 and 2024 [6] [7]. At that time, I called this idea of momentum transfers in "empty" branches of an experiment *vacuum photons*, *space phonons*, or *sonons*, since they involve situations in which space behaves like a momentum transfer mechanism. I now lean away from that terminology since what is going on works more at the specular reflection level and involves changing geodesic ("gravity") light paths in empty space. It is more akin to probing the deeper nature of what we mean by local, single-inertial-frame space and time. If validated experimentally, quantum bending suggests space is a quantum phenomenon, and gravity is a fabric of momentum transfers orchestrated by quantum "non-observation" of entangled matter concentrated nearby. In that case, dark matter may be nothing more than unresolved momentum located far away from regions of high matter density.

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