

Space, Time, and Quantum Uncertainty Under an Immutable Past Framework

Introduction

What if the **Past** is not a hazy backdrop that can be reshaped by new events, but an **immutable singularity** – a fixed record where change is impossible? In the framework proposed (axiomatically declaring “*the past is immutable*”), once an event happens and slips behind the “**event horizon**” of the **present**, it becomes *permanent*. This notion implies a state of **perfect stasis** for anything in the past: no motion (momentum effectively zero), no kinetic energy (temperature zero), and no entropy increase ¹. In other words, all dynamical evolution halts once an event is consigned to history. The “**Eternal Now**” – the moving present moment – then plays the role of a surface of transition: on this surface, quantum uncertainty reigns, but once an outcome is registered (observed), it is irreversibly “inscribed” into the past. Below, we explore how core physical concepts can be reinterpreted through this lens, and compare it with established physics and interpretations of quantum theory.

Redefining Space and Time under an Immutable Past

In this view, **time** is no longer a flowing river but a layering of fixed events. The past exists as a *static* record – much like the frames of a film that have already been recorded, with no possibility of alteration. This idea closely parallels the **block universe** of relativity (the philosophical doctrine of **eternalism**), which holds that past, present, and future events all exist in a four-dimensional spacetime “block” ². In standard eternalism, every event from the Big Bang to the distant future is equally real, and the flow of time is an illusion – all moments co-exist in a static 4D structure ². If one adopts this block-time perspective, the *immutability of the past* is essentially built in: all past events are embedded in spacetime and cannot change or be “rewritten.”

However, our everyday experience suggests that the future is open and only the past is fixed. A closer philosophical fit to the Immutable Past framework might be the **growing block universe** (also known as no-futurism or possibilism). In the growing block view, the past and present **exist** while the future does not yet exist ³. The present is the moving edge where new events are added to the ever-accumulating past. This is analogous to the “event horizon” of **Now** – as the present moment passes, events get *locked in* behind it. Crucially, both eternalism and growing-block theories agree that once an event lies in the past, it *cannot be altered* ³ ⁴. The Immutable Past axiom enshrines this: time is **orderly** only on the forward progression, while behind the present everything is frozen in a definitive order (even if different observers may slice spacetime into “past” and “present” differently due to relativity).

What about **space** in this framework? If nothing in the past can move or change, one can imagine that all past objects and particles are fixed at particular spatial coordinates in the record of spacetime. Space, as part of the 4D continuum, becomes the stage on which each past event has a permanent address. In a sense, space and time coalesce into an unchanging grid of events in the past. (This resonates with Minkowski’s famous notion that space and time “together” form a single four-dimensional reality, wherein

all events just *are* ².) From the perspective of the present, dynamic spatial relationships (motions, fields evolving, etc.) only exist on the **now-horizon**. Once those relationships are recorded in the past, they assume a fixed configuration.

There is an evocative analogy here to a **black hole's event horizon**. In the Immutable Past model, the present is like an event horizon: crossing it (i.e. an event becoming past) is like a point of no return – beyond it, change ceases. In fact, one proponent of this theory suggests that crossing the event horizon of a black hole could be interpreted as the object becoming part of the immutable past (no motion, no new entropy) ⁵. While standard physics would describe the infalling object as still existing (just unobservable beyond the horizon) and ultimately reaching a singularity, the immutable past view metaphorically identifies the horizon crossing with **instant “freezing”** of the object's history. The object would, in this picture, join the past in a state of changelessness (hence the idea that black holes are “black” because nothing, not even light or information, *changes* or escapes once inside ⁶). This is a speculative interpretation, but it aligns with the core idea: beyond the now-horizon, all processes grind to a halt.

In summary, redefining space-time under an immutable past means treating the past as a *completed, unchangeable spacetime structure*. Time's flow is just our local experience of new slices being added to this structure at the now-horizon. Space and time, in the past, become an eternal archive of “everything that has happened.” This is strongly reminiscent of block-universe eternalism ², except that it leaves open the status of the not-yet-realized future (much as the growing block idea does ³). The **Eternal Now** is then the only place where quantum indeterminacy and change exist – the transient, ever-updating interface between an undefined future and an unchangeable past.

Momentum and Position: Conjugate Observables at the Past Horizon

A striking implication of this framework is a new intuition for the **Heisenberg uncertainty principle** – particularly the conjugate pair of **position and momentum**. In quantum mechanics, one cannot precisely know a particle's position and momentum simultaneously; more formally, a state with a very well-defined position must have an ill-defined momentum, and vice versa ⁷. The Immutable Past interpretation gives this a temporal twist: once a particle's position becomes definitely known (i.e. the particle is localized as part of the recorded past), the particle *no longer has momentum* in any meaningful sense, because it is no longer “in flight” – it's frozen in the past. Conversely, if a particle is in motion (has momentum), it hasn't yet surrendered to the past – it does not have a single fixed position in the record until it is observed. In the words of the theory: **“Position without momentum; momentum without position.”** The moment an uncertain position *collapses* to a definite location (joining the immutable past), the momentum drops out (effectively $p = 0$ for that event) ⁸. If the particle is still moving with definite momentum, then it's in the process of becoming part of the past but not there yet – it lacks a determined position ⁹.

This qualitative picture is fully consistent with standard quantum mechanics. Upon measurement of a particle's position, the quantum state is projected onto a position eigenstate. Such a state is *not* an eigenstate of momentum – in fact it is a superposition of infinitely many momentum states ¹⁰. In physical terms, when you pin down an electron's position almost exactly (say by detecting it at a point on a screen), you have maximally disturbed its momentum. Immediately after that position measurement, the electron's momentum is completely uncertain – it no longer has a single well-defined value. This is often expressed by saying that a position measurement “randomizes” the momentum. As Heisenberg wrote, any use of the

concept of position and velocity beyond the uncertainty limit is meaningless ¹¹ . Our framework recasts this as: *the Past provides definite positions, but at the cost of momentum; the Future (or the process heading toward the past) provides definite momentum, but at the cost of a defined position.* At the exact **surface of Now**, conjugate variables trade off – one can either remain free (momentum, motion) or be captured (position, at rest), but not both at the same time ⁷ .

To illustrate: imagine an electron in a double-slit experiment (which we will discuss more later). As it flies through the apparatus, it has a well-defined momentum (roughly, it moves in a straight line of a certain velocity), and thus its position is not definite – it could be going through either slit or indeed has a delocalized wavefunction covering both. At that point it is still part of the **quantum present/future**. But when it hits the screen and creates a dot, that position becomes absolutely defined (we see the dot “here, not there”). That event – electron hit at this spot – is now an immutable part of the past record. And accordingly, the electron is no longer moving at all; its journey is finished (momentum effectively zero, at least from the perspective of any continued motion). The **uncertainty principle** in the conventional sense quantitatively backs this up: the narrower the localization Δx , the larger the spread Δp must be (in fact an idealized exact position corresponds to $\Delta p \rightarrow \infty$) ⁷ ¹⁰ . In the extreme limit of “position is fully fixed in the past,” momentum becomes totally undefined – which one may poetically describe as “vanished.” On the flip side, a free particle with a very well-defined momentum has a delocalized, spread-out position (perhaps spanning both slits as a wave); it has **not yet** generated a single localized past event. This matches the concept that it’s still in the process of *becoming* part of the past, carrying momentum but no fixed position ⁹ .

In summary, **position vs. momentum** can be reinterpreted as a dichotomy between being *anchored in the past* versus *moving through the present*. The past-record (when viewed as the classical world) contains objects with definite locations but – once recorded – they have no “motion” (their momentum information is lost to uncertainty or literally zero relative to that frozen frame) ⁸ . The unfolding quantum realm, on the other hand, can have particles in motion (momentum states) but until they are observed, they don’t have a single definite position in any record. This view doesn’t change any physics, but it provides a vivid metaphysical narrative for Heisenberg’s principle.

Energy and Temporal Uncertainty: The Role of Time’s Thickness

Another pair of conjugate quantities in quantum theory is **energy and time**. Although time isn’t an operator in the same way position is, there is an analogous uncertainty relation: $\Delta E \Delta t \gtrsim \frac{\hbar}{2}$ (in a heuristic sense for the lifetime of states). The **shorter** the time interval in which a process occurs, the more *uncertain* or spread-out the energy can be. In our framework, as an event approaches the boundary of the **Now** (the moment it becomes past), the time interval associated with it *shrinks* (think of $\Delta t \rightarrow 0$ at the instant an event is finalized into the past). That suggests, by the uncertainty relation, a blow-up in energy uncertainty ΔE . In plainer terms, if something “exists” only very briefly, it cannot have a sharply defined energy ¹² . The Immutable Past view identifies the past with $\Delta t = 0$ (time has essentially no duration in the frozen past), so one might say that any given *event* recorded in the past could in principle have come from a range of energy possibilities. This sounds abstract, but it connects to known quantum phenomena.

For example, consider an unstable excited atom: it has a certain lifetime Δt before it decays and emits a photon. Because that excited state only “exists” for a short time, the energy of that state (and thus the emitted photon) cannot be perfectly definite – there is a natural spectral *width* to the photon’s

frequency. A very short-lived state (lifetime on the order of 10^{-8} seconds) yields a broadened range of photon energies, whereas a long-lived state yields a very sharp energy (narrow spectral line) ¹³. This is an experimental reality explained by the energy-time uncertainty principle. In our terms: when an atom's decay transitions from present to past (the emission happens and becomes a recorded event), the more abrupt that transition, the more "fuzzy" the energy bookkeeping can be. **Energy fluctuations** are thus tied to temporal uncertainty. If the "Now" is an extremely thin slice (approaching $\Delta t \rightarrow 0$), then energy can fluctuate wildly in that tiny window (since nature doesn't have time to "decide" on a precise value) ¹².

This idea can be extended to the concept of **vacuum fluctuations**: in quantum field theory, for example, the vacuum is teeming with ephemeral particle-antiparticle pairs that pop in and out of existence. They can "borrow" energy ΔE as long as they annihilate within a short time Δt , roughly obeying $\Delta E \Delta t \sim \hbar/2$. From the Immutable Past perspective, one could say these fluctuations never last long enough to be memorialized in the past – they are strictly temporary, and hence their energies are uncertain by exactly the amount allowed by their fleeting existence. Only when a fluctuation becomes an actual particle (say, promoted by some measurement to a real particle) and persists does it become part of the stable past, with a definite energy. If time as we experience it is an emergent, relational concept (as some physicists like David Bohm or Carlo Rovelli have suggested, time might not be fundamental at all ¹⁴), then energy-time uncertainty hints that **what we call energy** might be a property that is only well-defined *relative to the duration of observation*. At the instant of "joining the past," a system's energy may take on a definite value (like a measured value), but if the time window is vanishingly small, the concept of energy loses its sharp meaning.

In short, **energy** and **time** in this framework reinforce the idea of the **Now as an active zone**: if the Now is broad, energies can be well-behaved; if the Now is extremely thin, energy can be almost anything (consistent with conservation only in a statistical or expected sense). The past, having no duration, could be seen as containing events of indeterminate energy – yet in practice, when we say something *is* in the past, we usually mean it had some definite energy outcome recorded (like a particle's rest mass energy, a photon's detected frequency, etc.). Thus, more precisely, the act of measurement or decay that fixes an event in the past also tends to give the system a definite energy **at that moment**, but a very short event implies a wide spread of possible energies that could have been realized ¹². This perspective resonates with the famous notion that **"a quantum state that exists for only a short time cannot have a definite energy."** ¹² The immutable past is where time's flow halts, so any uncertainty in time translates to an uncertainty in energy that must be resolved by the moment of recording.

Measurement as Irreversible Inscription (Double-Slit and Stern-Gerlach)

Quantum measurement has long been understood as an **irreversible** process – once a quantum system's state is observed (an outcome obtained), the superposition of possibilities appears to "collapse" to that one result and cannot be un-collapsed. In this framework, that irreversible **collapse** is identified with **inscription into the Past**. The **surface of Now** is where the infamous Schrödinger's cat can be alive and dead, or an electron can go through both slits; but as soon as a measurement occurs – as soon as an outcome is registered – that outcome becomes an unchangeable part of history. The past is essentially **the collection of all measurement outcomes (or decoherence outcomes) that have happened**.

Double-Slit Experiment: The two-slit interference experiment epitomizes the role of measurement. If electrons (or photons) pass through a double slit with **no which-path observation**, they produce an interference pattern on the screen – a wavelike phenomenon that implies each particle took a superposition of both paths. In our terms, until the electron **hits the screen**, it has not been definitively recorded in the past; it retains a sort of *momentum without a single position* and thus can exhibit interference. The screen itself (or a detector) plays the role of the measuring device: when an electron is detected at a particular spot, that is a **permanent record** of “it arrived here.” This act is one of *irreversible magnification*: a microscopic uncertainty is amplified into a macroscopic event (a visible dot, or an ionization in a detector) that leaves a mark ¹⁵. At that moment, the electron’s path “chooses” a definite slit in retrospect. If, alternatively, one places a detector at the slits to see which one the electron goes through, the mere act of obtaining that information will destroy the interference pattern. Why? Because a **which-way detector** creates an **irreversible record of the path** – effectively tagging the electron with a piece of information that gets lodged in the environment (and hence in the past). As a Physics Forum mentor succinctly put it: “the crucial part is that an irreversible record is made of which slit the electron went through (by measuring its spin, for example)” ¹⁶. Once such a record exists, the electron can no longer interfere with itself; it behaves like it went through one definite slit (particle-like behavior).

From the Immutable Past viewpoint, we’d say that when no record is made, the electron’s **path is not a settled part of the past** – it remains an open possibility until it finally hits the screen. But when a record is made (either at a slit detector or at the screen), the electron’s journey acquires a concrete story: “it went through slit A and hit *here*.” That story is now written into the past and cannot be altered (you can’t undo the measurement and make the electron “un-hit” the screen or go back and form an interference pattern). In fact, John Archibald **Wheeler** emphasized this in his famous **delayed-choice** version of the experiment. He argued that “**the past has no existence except as it is recorded in the present**”, meaning it’s wrong to think of the photon as having *definitely* gone through one path or the other (or both) prior to measurement – only when a measurement in the present is made can we say anything about its past trajectory ¹⁷ ¹⁸. Wheeler’s delayed-choice experiments (later actually performed) show that whether we see wave-like interference or particle-like behavior can be decided *after* the photon has entered the apparatus, as if our present choice of measurement setup determines the photon’s past behavior ¹⁷. In Wheeler’s words: “*It is wrong to think of that past ... as ‘already existing’ in all detail. The past is all theory. The past has no existence except as it is recorded in the present.*” ¹⁸. This striking statement aligns perfectly with the Immutable Past interpretation: until an event is registered, what we call “the past” of that particle is not an objective fact – it’s a haze of possibilities. Once registered, it becomes an immutable fact. We **participate** in creating the past by the very act of observation ¹⁸.

Stern–Gerlach Experiment: In the Stern–Gerlach setup, a beam of (for example) silver atoms with spin- $\frac{1}{2}$ is passed through a non-uniform magnetic field, separating the beam according to spin-up vs spin-down along a certain axis. If no further measurement occurs, one could in principle recombine the beams or perform other operations (analogous to keeping quantum coherence between the spin states). But if one places detectors to catch the atoms in the separated paths (or blocks one path, etc.), that constitutes a measurement of spin. Each atom’s spin state *collapses* to either up or down, and a definite outcome is recorded (like a dot on a detector corresponding to “spin up outcome”). Once this happens, that atom’s spin is *in the past* with a particular value. If you take that same atom and run it through another Stern–Gerlach apparatus aligned the same way, you will get the **same result** every time – the atom now behaves as a spin-up atom consistently, because its spin state was irreversibly set in the first measurement ¹⁹. This is an illustration of the **projection postulate**: after measurement, the system is in the eigenstate corresponding

to the observed eigenvalue ²⁰. In other words, the act of measurement has created a new fact about that atom (spin up) which will persist.

The irreversible aspect comes from the fact that many different prior states (any superposition of up/down) could lead to the same recorded outcome, so knowing the outcome, you cannot retrodict the exact prior state – information has been lost ²¹. The “function” mapping pre-measurement states to post-measurement states is many-to-one and thus not invertible ²². Thermodynamically, the measurement dissipates entropy (or rather, produces entropy in the measuring device) and is practically irreversible. In the Past-as-Immutable view, we say: *the atom’s spin becoming known is the moment its spin enters the past*. Before measurement, “spin up or down” wasn’t a concrete reality; after, it is a fixed historical fact for that atom. You can’t un-measure it. You can, of course, prepare new superpositions by further manipulations, but that entails additional interactions and doesn’t erase the original outcome – it just creates new states moving forward.

Both double-slit and Stern–Gerlach scenarios highlight the role of **measurement as the creator of reality’s records**. It’s reminiscent of a quote often attributed to Niels Bohr: *a measurement is an “irreversible amplification”* – a quantum event is amplified into a macroscopic outcome, and that outcome, once registered, cannot be undone ¹⁵. In our context, that amplification is the point at which the quantum system transitions from the realm of possibility to a definite entry in the logbook of the universe. That logbook **is** the immutable past. Notice that this does not necessarily require a conscious observer; what’s required is that the information gets **irreversibly imprinted** into some degree of freedom (be it a piece of photographic film, a detector’s memory, or even the scattered environmental particles like air molecules or photons that carry away the which-path info). Decoherence theory (next section) emphasizes that *any* interaction with a large environment can serve to create an effectively irreversible mark (for all practical purposes), even if no human is watching. Thus, when we say “observation” or “measurement” here, it could be a detector or environment – not strictly a person.

In summary, the Immutable Past interpretation of quantum measurement says that every measurement outcome is like a bit chiseled into stone: it *happens* at the Now interface and then resides permanently in the Past. The double-slit experiment shows that if you don’t chisel anything (no which-path info), the quantum system remains in limbo and can exhibit interference; once you do make a mark (detect a path), the ambiguity is gone and one reality is selected. The Stern–Gerlach experiment shows that once a particle’s property is measured, it behaves henceforth *as if* that property is an objective fact (because it is now a fact of its history). These are entirely standard quantum behaviors – what the Immutable Past framework adds is a colorful but arguably insightful way to think about it: **measurement is the process of writing the present into the past**.

Links to Quantum Interpretations: Decoherence, QBism, Relational QM, etc.

How does this metaphysical storytelling align or conflict with mainstream interpretations of quantum mechanics? We examine a few prominent views:

Decoherence and Objective Records

Decoherence is not so much an “interpretation” as a mechanism that any interpretation must contend with. It explains how quantum superpositions interacting with the environment “dephase” and *einselect* a set of stable outcomes (pointer states) that *persist*. Decoherence theory, pioneered by Wojciech Zurek and others, essentially supports the idea that once information about a quantum system leaks into a large environment, the superposition is **irreversibly** degraded into an apparent mixture – the possible outcomes **decohere** into distinct, non-interfering branches ²³ ²⁴. In Zurek’s formulation of **Quantum Darwinism**, the environment doesn’t just passively cause decoherence; it actively **records** copies of the system’s state. The environment becomes a **witness** to the event ²⁴. For example, when a photon from a measurement scatters into the room, many air molecules or other photons can carry the information of that event. Soon, that information is replicated in countless degrees of freedom. Any would-be observer can intercept some fragment of the environment (a photon, a sound, etc.) and learn what happened. As Zurek puts it, these redundant imprints in the environment are why we get an objective classical reality – many observers can **agree on the outcomes** because the environment broadcast them ²⁴.

This aligns perfectly with the Immutable Past idea: decoherence describes *how* quantum possibilities turn into classical certainties by **entrenching information in the world**. Once the information is widely distributed in the environment, it becomes virtually impossible to erase – practically irreversible. The “past” in physics is often identified with the information content of the universe (records, memory, thermodynamic entropy increase, etc.). Decoherence provides the micro-physical explanation for why **quantum events acquire an arrow of time**: the entanglement with environment is effectively one-way (since reversing it would require improbable reassembly of scattered degrees of freedom). Thus, decoherence *bridges* the gap between a quantum superposition and a single classical outcome without needing to invoke a mysterious wavefunction collapse postulate – the outcome **appears** when enough information has flowed to the environment. The **environment-as-witness** paradigm even says explicitly that the environment’s records are what give us the classical sense of an objective past ²⁵ ²⁴.

One way to view this: the **Immutable Past** axiom gets its physical grounding from decoherence. The past is immutable because, once information has spread into a macroscopic number of particles, no feasible process can recombine them to “undo” the measurement. The quantum uncertainty at the now-surface (say, which slit the electron will go through) *solidifies* into an eigenstate in the past because decoherence has effectively **measured** it. In fact, **Quantum Darwinism** takes it further, pointing out that the environment will selectively favor stable states (pointer states) that can survive and proliferate – in essence, the outcomes we see as “real” are those that have left many copies of themselves lying about ²³ ²⁴. Those copies *are* the records that constitute reality’s history. This is very much in harmony with the information-centric view of the past: only what is recorded is real. As Wheeler eloquently said, “By deciding what questions our quantum equipment asks now, we have an undeniable choice in what we have the right to say about the past.” ¹⁸ – our measurements (or environmental interactions) choose which bits of information become the story of the past, out of the prior quantum possibilities.

It’s worth noting a subtle divergence: Standard decoherence (especially in a **Many-Worlds** type picture) would say that the *process* is fundamentally unitary and reversible in principle – it’s only because the environment has so many degrees of freedom that reversal is infeasible. In principle, if one had Laplace’s demon control of every particle, one could *re-phase* the environment and restore a superposition. The **Immutable Past** idea might lean a bit more into saying “No, fundamentally the past cannot change,” which might imply an additional assumption that even in principle the past is not reversible. However, many

physicists would agree that *for all practical purposes* the past is immutable due to thermodynamic irreversibility (which decoherence is consistent with) ¹⁶ . So decoherence strongly **aligns** with this model on the practical level: it provides the mechanism by which quantum ambiguity is irreversibly resolved into classical reality (i.e. into facts in the past).

QBism (Quantum Bayesianism) and Participatory Reality

QBism – Quantum Bayesianism – is an interpretation that places the **agent** (observer) at the center. In QBism, the quantum state (wavefunction) does not represent an objective physical reality, but rather an agent's **subjective knowledge**, or belief, about the world ²⁶ . A quantum measurement, then, is not some physical collapse of a wavefunction out there; it is simply the updating of the agent's information when they experience an outcome ²⁷ ²⁸ . Each observer has their own personal wavefunction that they use to assign probabilities to possible experiences, and when an observation happens, that observer's wavefunction *collapses* only in the sense that they update their bets. Chris Fuchs, a founder of QBism, famously says "**Quantum mechanics is a law of thought**" ²⁶ – meaning it's a tool for how an agent should set expectations and revise them, rather than a law about wavefunctions floating in space.

At first glance, QBism diverges from the Immutable Past framework, because QBism downplays any *objective* "written in stone" history. For a QBist, what is immutable is *my past experiences*. Once I (the agent) have seen a result, I cannot un-see it; I update my catalogue of experiences and that's that. But QBism would hesitate to say that measurement *creates* an objective fact for all of reality – it creates a fact **for the agent**. Other agents might have different information and thus different "pasts" in their own sense. There is no single global wavefunction or single objective collapse in QBism – each observer's reality is somewhat personal until they communicate. However, the spirit of "*the past is immutable*" can be translated into QBism as: *once an experience happens to me, it is a definitive part of my internal reality*. I cannot reverse time and change that record in my memory (this links to the idea of **consciousness and the arrow of time**, sometimes expressed by saying we remember the past but not the future, and we can't "un-remember" things). In fact, in a Physics StackExchange comment, one John (possibly echoing a QBist-like view) argued that **consciousness is what enforces the arrow of time: "past is what you know already and future is what you are yet to know"**, and that un-knowing something would "break the distinction between past and future" ²⁹ . This is not a strict scientific argument, but it resonates with the QBist ethos that the **knowing** of an outcome is the fundamental event.

According to QBism, the wavefunction collapse is "**simply the observer updating his or her beliefs after making a measurement.**" ²⁷ There's nothing mystical – the observer's information has changed, that's all. How does this map to our framework? We could say: the Immutable Past is basically the collection of all **observational facts** (for each observer). Once the observer has the answer, that answer becomes part of their personal past and is unchangeable for them – which is tautologically true. But QBism would caution that saying "the past is immutable" outside of an agent's perspective might be meaningless: whose past? In QBism each agent might even disagree on past events if they haven't compared notes, until they do and standard quantum rules ensure consistency when they do compare.

Where QBism diverges clearly is in the role of an objective history. The Immutable Past framework, as we've described, tends to imply a single classical history that *everyone* shares once things are recorded (we talk about "the universe's record"). QBism would say there is no God's-eye view of the universe's record – only the records each agent has. Fortunately, once agents exchange information with each other (a kind of measurement between them), they will find that their accounts of any shared events agree. QBism is

constructed such that it is *fully compatible with all quantum predictions*, so it won't lead to actual contradictions about history between observers. It just emphasizes that quantum theory is an **user's manual** for updating personal knowledge. In that sense, QBism echoes a key part of this framework: **the act of measurement (observation) is primary**. It's the moment where knowledge (information) jumps and the world for the agent takes on a concrete aspect. As Wheeler said, *"no phenomenon is a real phenomenon until it is an observed phenomenon."* ³⁰ ³¹ QBism agrees, but adds "...and it's real only for the observer who observed it."

In summary, **QBism aligns** with the notion that measurement is an **irreversible update** – once you know something, you can't *un-know* it (the arrow of time in knowledge). It **diverges** on whether the measurement's result is an element of an objective "past." QBism would say that's an unnecessary extra – only the **agent's past** (their experiences) is well-defined and immutable. However, since we do find consensus reality in practice, a QBist would acknowledge that when many agents have interacted and compared notes, we effectively have a stable common past (hence why physics works at all). They just interpret the process of reaching that consensus differently (as communicating experiences and updating beliefs rather than "accessing a shared record"). The Immutable Past model, by contrast, is more realist – it imagines a sort of cosmic ledger being written.

Relational Quantum Mechanics (RQM) – Facts Are Relative

Relational Quantum Mechanics, proposed by Carlo Rovelli ³² ³³, has a motto: *"quantum states (and events) are relative to observers."* It asserts that there is no absolute state of a system – any state or value of a physical quantity is only defined **relative to some other system that has interacted with it**. In RQM, a "measurement" is just an interaction between two physical systems, and that interaction establishes a fact (a value) *between those two systems* ³⁴. But another system that wasn't involved in that interaction might not attribute the same fact. A classic RQM scenario: Wigner's friend measures a spin inside a lab (for the friend, the spin now has a definite value – a fact). Wigner, who hasn't looked, might still describe the entire lab+spin as in a superposition from his external perspective. There's no contradiction because *facts are relational*. When Wigner eventually interacts (opens the box), new facts relating Wigner and the lab are created, and consistency is restored (the friend's record now also becomes a fact for Wigner) ³⁵.

This is somewhat like a cross between QBism and objective collapse: it doesn't require conscious observers (any system can play "observer" to another upon interaction) ³⁶, but it denies a single global collapse. It says each interaction's outcome is a fact only for the systems involved. Now, how does this relate to an immutable past? RQM would agree that once two systems interact and record a result, that result is an incontrovertible fact – **for them**. It cannot be changed (unless another interaction happens that changes the property, but that would be a new event). However, RQM also implies that **different observers may have different accounts of the order or outcome of events** until they communicate. There is no **"God's-eye view"** where we can say "this happened" independently of a reference frame; we can only say "System \$A\$ has property \$X\$ relative to system \$B\$ after their interaction" ³⁴ ³⁷.

If we interpret the Past in a relational way, we'd say: *the past is a set of facts, but each fact is tagged by the systems that share it*. My past and your past might not line up on some quantum event if we didn't both witness it or have it in common in our causal past. Only when we eventually interact (e.g., I ask you what you saw) do our records become correlated and we arrive at a mutual agreed past. This sounds exotic, but RQM insists it avoids paradoxes and fits quantum experiments. It also naturally accommodates the idea

that nothing is objectively “decided” until an interaction – very much in line with “*the past has no existence except as recorded*”, except RQM would add “...recorded **by some system.**”

For example, if an electron went through a Stern–Gerlach magnet, the magnet’s atoms might get correlated with the electron spin – thus in the electron+magnet’s relational world, a particular spin value is now a fact (the magnet’s internal state encodes it). But for an external observer who hasn’t checked the magnet, there’s no fact yet about spin – the electron+magnet could be still in a superposition relative to that observer. This is essentially a reinterpretation of quantum mechanics’ usual story without a collapse, just making collapse “relative”. RQM thus **aligns** with the notion that outcomes are only concrete once they are **recorded by something** (which could be a measuring apparatus, an observer, etc.), and that once recorded, that result is fixed (for those who have that record) ³⁴ ³⁷ . It also aligns with the idea that time’s order can be frame-dependent – recall that relativity already says two observers might disagree on the order of spacelike separated events. RQM extends the relativity of “when events happen” into the quantum domain for perhaps all events, to ensure consistency.

Where RQM might **diverge** from a naive Immutable Past picture is in the idea of a singular, universal past. Immutable Past as described in earlier sections sounds like there is one classical history that everyone shares. RQM would say “which past?” – each interaction defines some piece of history, and there isn’t a single narrative until you consider all relevant interactions. However, practically, once we limit to observers that all are in contact (like humans on Earth sharing experiments), RQM would reduce to an ordinary classical shared past (because we constantly interact and exchange information, syncing our records). RQM also implies that facts (like the outcome of a measurement) **lack any meaning in between interactions** – they only “exist” at the moment of interaction and then as a relation. Between events, variables may not have values at all ³⁷ . This resonates with the earlier statement: in the past (between events) time is “unordered” or meaninglessly stands still. RQM would say a particle’s spin, for instance, has no value until measured; after measuring device interaction, it has a value relative to that device, but we shouldn’t speak of an absolute value at all. This is quite compatible with the idea that *until something becomes past (via measurement) it isn’t well-defined*. And once it is past (measured), it’s stuck with that value relative to whomever measured it.

In summary, **Relational QM** strongly resonates with the notion that “*facts are created by interactions*” and that these facts are then fixed (relative to those systems). It provides a concrete interpretative framework where *the past is a sparse set of relational events* – very much an information-based historical record, just one that’s partitioned by reference frame. If one is comfortable with that, RQM and the Immutable Past axiom are allies. They both reject an independent, observer-free reality of “the electron went through this slit at time t ” unless something recorded that. They differ in that RQM is explicit about the relativity of those records, whereas the Immutable Past as originally stated might be imagined as an absolute record. But we can incorporate relativity by recognizing that different observers slice the spacetime (and thus the division of past/present) differently – what one frame considers past, another considers still now or future. Only interactions create invariant facts. Thus, RQM’s stance could enrich the Immutable Past view by clarifying that **immutability is always of the relationships forged in interactions**.

Other Interpretations: Many-Worlds, Objective Collapse, etc.

Though not asked explicitly, it’s worth touching on other interpretations briefly. **Everett’s Many-Worlds (MWI)** would say that the wavefunction never collapses at all; instead, all possible outcomes *actually occur* but in non-communicating branches of the universe. At face value, this seems at odds with a single

immutable past – because in MWI, the question “what is the past outcome of this experiment?” has many valid answers (one per branch). However, within any given branch (the world an observer finds themselves in), the past *is* definite and immutable. The difference is that MWI’s “global past” would be a superposition of many inconsistent histories, which is not an issue because no single observer ever sees that global superposition – each one sees a definite history. In a sense, Everett accepts immutability but pluralizes the past: each branch’s past is fixed, but the universe as a whole contains many alternative pasts corresponding to different outcomes. This interpretation might diverge philosophically (since it posits a kind of block universe but with a vast branching structure), yet for an observer within it, things look as if wavefunctions collapsed and the past took one course. So an Everettian could still speak the language of “once an outcome happens, that branch’s history is fixed.” They just caution that what “happened” might depend on which copy of you we follow.

Objective collapse theories (like GRW or Penrose’s ideas) modify quantum mechanics so that wavefunctions *stochastically collapse* on their own (or due to gravity) with some probability. These theories explicitly introduce irreversibility at a fundamental level – wavefunction collapse is one-way and objective. They do this to avoid the measurement problem by ensuring that large systems don’t stay in superposition for long. In an objective collapse worldview, the **past** is generated by these spontaneous collapses (or collapse upon certain interactions) and once collapsed, that outcome is “truly” what happened, end of story. In fact, proponents like GRW give a mathematical framework for why superpositions of macroscopic states will almost surely collapse into one outcome in extremely short times. This strongly enforces an arrow of time and a definitive history. If one embraces such a theory, the Immutable Past idea is almost built-in: collapses create facts and those facts propagate forward, never to be reversed (since the theory explicitly breaks time-reversal symmetry by the collapse mechanism) ³⁸.

Consistent histories and the **histories interpretation** (Griffiths, Omnès, Gell-Mann & Hartle) view the universe’s evolution in terms of many possible consistent narratives (histories) that one can choose a decoherent set of. Within one consistent history, you have a sequence of definite events (like a quasi-classical trajectory); the theory says one cannot combine incompatible histories, but within one history you can talk about “the past” meaningfully. This framework might say: the Past is immutable *within a given consistent history*, but there are many potential histories until one “set” is realized (this gets technical and overlaps with decoherence ideas). It’s another way to think of quantum events becoming fixed along one storyline, which is analogous to the idea that an outcome picks one path out of many.

In summary, virtually all interpretations agree that once a measurement outcome is obtained, observers will not see that outcome spontaneously change later – that is the effective immutability of recorded history. They only differ in what they think *happens to the other possibilities*. Everett keeps them in other branches, objective collapse says they genuinely disappear, Copenhagen-ish views say “don’t even talk about them, they weren’t real,” QBism says “they were just my imagination anyway,” RQM says “they weren’t facts relative to me,” etc. But the *fact that our experience yields a consistent, stable past* is common ground. The “Immutable Past” axiom is really highlighting that as a first principle and coloring the narrative around it (by saying, for instance, momentum and entropy “vanish” in the past).

Philosophical Parallels and Deeper Insights

The metaphysical stance of an immutable past has interesting echoes in philosophy of time and reality:

- **Eternalism / Block Universe:** We discussed this under space-time, but philosophically eternalism is the view that *all moments of time are equally real*. It implies that the flow of time or the coming-into-being of events is an illusion of our perspective – in truth, the universe is a static 4D block ². An eternalist would indeed say the past is fixed and exists “out there” just as the present does. In fact, so is the future (which would go beyond our framework if we only assert past immutability). The Immutable Past model is like a *weakened* eternalism: it agrees the past is fixed, but maybe not the future. It’s closer to the **Growing Block** theory (past and present exist, future doesn’t yet) ³. In both cases, once an event *becomes* part of reality, it doesn’t change or go away. The idea that “*only the present is real*” (presentism) is at odds with an immutable past, because presentism says past things literally **no longer exist** (except perhaps as influences or records). If one is strict about immutability, one might lean more to the block view where past events are still “there” in spacetime, just not accessible. The block universe has the past and future set like a landscape – nothing “flows”; change is perspectival. This rather deterministic vision might conflict with the quantum notion of an open future, but it’s worth noting that some physicists (like Huw Price, mentioned in the retrocausality context ³⁹) consider time-symmetric or block universe approaches even to quantum phenomena.
- **Arrow of Time and Thermodynamics:** The second law of thermodynamics (entropy tends to increase in a closed system) provides a physical underpinning for why the past is different from the future. The past has lower entropy and more order; the future has higher entropy and more disorder. In an immutable past framework, one could say: at the exact moment an event happens, you can consider it “frozen” with a certain entropy. As time moves forward, entropy in the world increases, but that event’s record (a snapshot of lower entropy) remains embedded. We don’t literally set entropy to zero in the past (despite the framework’s $\Delta S=0$ slogan ¹ – that $\Delta S=0$ should be taken to mean *no change in entropy*, not that the universe’s entropy is zero after every event). However, it is true that the **entropy of an isolated historical record doesn’t spontaneously decrease or undo itself**. If you have a photograph, it tends to fade (increasing entropy); you can’t expect a blurry photo to sharpen itself or a broken egg to un-break. This “no going back” is essentially the second law. So the idea “entropy vanishes in the past” ¹ can be interpreted as: *the past no longer participates in the entropy-increasing processes*. Those processes happen in the now, adding new entropy. Once it’s in the past, entropy is a number associated with that state and it’s not evolving. In that sense, yes, the past has “zero entropy change” – which is the hallmark of equilibrium or stasis.
- **Eternal Now (Mystical and Philosophical concept):** Some philosophical and spiritual traditions talk about an “Eternal Now” – the idea that only the present truly exists, or that a divine perspective sees all of time at once. The usage here, calling the present the “*Eternal Now*” as the surface of experience, is interesting. It suggests that from our perspective, the Now is *always* what is happening – it’s the only time we directly experience. But it is “eternal” in the sense that whenever you consider it, it’s always now. Meanwhile, the past could be seen as “eternally past” – fixed forever. This resonates with Augustine’s musings on time, or with certain interpretations of relativistic time where one might say that in a higher reality, everything is now. The event horizon analogy even evokes **Hermann Weyl’s** statement after Minkowski introduced the block universe: “*The objective world simply is, it does not*

happen." Each now is like a cross-section, and nothing objectively "happens," it just is – which is a radical view but that's block universe thinking.

- **Information Realism / It from Bit:** John Wheeler's phrase "*It from Bit*" encapsulates the idea that physical things ("its") fundamentally derive from **information** ("bits") ⁴⁰ . The universe is seen as a kind of information processing or information storage device, and reality is made of yes/no answers (bits of observation) ⁴⁰ ⁴¹ . This view is sometimes called **information realism** – the belief that information is as real as (or more real than) matter and energy. In Wheeler's participatory universe, every observation is like a binary answer that **creates reality** ⁴⁰ . Our framework aligns strongly with this: the Past is essentially the **information content** of all events that have happened. Matter and energy themselves could be seen as just carriers of that info (Wheeler: "the photon's potential paths are just an accounting of information, until observed"). If the past is immutable, that's akin to saying information, once created, is never destroyed – an interesting parallel to certain interpretations of quantum theory that argue information is fundamentally conserved (like in black hole information paradox discussions, many believe information cannot be destroyed even by black holes). Indeed, our linking of the black hole event horizon to the past horizon has a kinship with the **holographic principle**, where all information that falls into a black hole is thought to be encoded on the horizon surface (so the information is not lost) ⁴² ⁴³ .

In broader terms, **information realism** suggests that perhaps space and time themselves are emergent from information. Some theorists (e.g. in quantum gravity or digital physics) speculate that spacetime might be like a code or a network of quantum information ⁴² ⁴⁴ . **If so, what we call the "past" is basically a vast, distributed database of all the bits that have been established. Our present observations are transactions writing new bits. This is a highly modern way to conceive of reality, but it dovetails nicely: rather than thinking of the past as a "place" or "time," think of it as an ever-growing collection of facts (a ledger, if you will). This ledger is appended with each measurement/interaction (much like how a blockchain ledger gets new blocks that cannot be altered). We as observers are like users of this cosmic database – we can read records (memory, history) and we can write new records (by our free actions/measurements). But we cannot alter the old records. This analogy might be stretched, but it's quite apt to an immutable past and is in line with Wheeler's participatory universe remark that we shape the past by the questions we ask of Nature** ¹⁸ .

- **Modal realism or Multiverse:** If one goes the route of Many-Worlds or even philosophical modal realism (all possible events exist in some branch or universe), then the idea of an immutable past gets an interesting twist: each branch's past is immutable, but there are many pasts. Philosophically, one could recall Leibniz's idea that we live in one "branch" (the actual world) among many possible ones. Only one path is taken in our reality, so that path's past is fixed, but other paths exist in a platonic sense. Many-Worlds is like that but says all branches are equally real. However, since we only ever experience one branch (the one we're on), for experiential purposes the past we know is fixed.
- **Eternal Return or Cyclic time:** This is opposed to immutable past, but interestingly, some ancient philosophies (and even some modern cosmological models) consider that time might be cyclical or the universe could reboot (big crunch, bounce, etc.). In a strict eternal recurrence, one might say the past *will happen again* in the future exactly as before – which is a very different metaphysics (and arguably conflicts with any standard physics without exotic conditions). The immutable past concept decidedly does not entertain that; it's one-and-done. If one included retrocausality (mentioned in the Medium article ⁴⁵ ¹⁷), one might wonder if the future can affect the past (but even those

interpretations don't allow *changing* an existing past, they just say future boundary conditions help determine the present *consistently* with the past).

- **Presentism vs. Block:** One could ask, if only the past is real and fixed and the future not, what is the ontological status of present? In growing block, the present is just the edge – sometimes considered a special ontological status but often not given independent existence except as a demarcation. The Eternal Now concept might try to elevate the present to something fundamental (as some “moving spotlight” theories do, where now is a special spotlight moving along the block ⁴⁶). However, physics hasn't been kind to an absolute present. Relativity merges space and time and denies a universal now. So any “present” is observer-dependent. That might either cause trouble for an Immutable Past notion (since whose past is immutable?), or it might indicate that each observer's past is immutable in their frame and that's all one can say. But usually, in relativity, all observers eventually agree on causal sequence for events that are timelike or lightlike separated (and disagree only on simultaneity for those spacelike separated). So one might refine: the *causal past* (the past light cone for an observer) is immutable for that observer. And if we consider the entire causal past of the universe (like the backward light cone from now out to the entire cosmos), that's fixed for our current now. As time moves, that past cone grows.

In concluding this philosophical reflection, one sees that the **“Past is Immutable”** axiom dovetails with a view of the universe as an information-preserving, record-accumulating system. It leans into a **realist, classical worldview** applied to outcomes (once things happen, they assume the solidity of classical facts). Yet it is fully aware of the **quantum foreshadowing** of those facts in the form of uncertainties and superpositions at the edge of now. It has sympathy with **interpretations that emphasize information and observation** (Wheeler's participatory universe, Zeilinger's information principle, Zurek's environment as witness) and with **philosophies that treat time as a dimension** (block universe) or at least treat *becoming* as something not altering what has become. The novelty is in how it packages these ideas into a single intuitive principle and traces out consequences like $p=0$ (no motion) in the past, or “measurement = inscription.”

To be sure, this is a kind of **metaphysical overlay** on physics – the physics itself hasn't been changed by these interpretations. But such frameworks can help guide thinking or suggest new analogies (as with the black hole event horizon example). Whether one finds it compelling or not may come down to taste: do we gain insight by calling the past a “singularity” of no entropy and unordered time? Perhaps it reminds us that **all we ever have access to empirically are records here-and-now** – and physics, at its core, is about correlating those records. As Wheeler quipped, “*The past is theory.*” ¹⁸ We infer the past from what is recorded in the present. In that sense, *immutability of the past* is almost tautological – once a record exists, it exists. The real mystery is how the indeterminacy of the unrecorded world resolves into the determinate records we see. On that, this framework doesn't provide a new equation, but it gives a storytelling device that is intriguingly compatible with many threads in modern physics: from quantum information to relativity's block time, from decoherence to the existential “now.” It encourages us to think of physics not as evolving a universe *forward*, but as steadily **accreting an unchangeable history** – one quantum event at a time.

References: The ideas discussed draw upon quantum physics fundamentals and interpretations (Heisenberg uncertainty ⁷ ¹⁰, quantum measurement theory ²⁰ ¹⁶), relativity and philosophy of time (eternalism and growing block universe ² ³), and modern quantum interpretation frameworks like decoherence and Quantum Darwinism ²³ ²⁴, QBism ²⁶ ²⁷, and RQM ³⁴ ³⁷. John Wheeler's quotations

on the nature of quantum reality and the role of observation have been cited to highlight the information-centric view adopted here ¹⁷ ¹⁸ . These sources provide a grounding in reputable physics literature and thought for the claims made. The framework itself is a synthetic interpretation, knitting together these ideas into the single axiom of an immutable past and exploring its consequences. It serves as a conceptual bridge between hard physics and a philosophical understanding of reality, one in which what *happens* truly becomes an everlasting fixture of the world.

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