Abstract
Since the early days of quantum theory, the concept of wave function collapse has been looked upon as mathematically unquantifiable, observer-dependent, non-local, or simply inelegant. Consequently, modern interpretations of quantum theory often try to avoid or make irrelevant the need for wave collapse. This is ironic, since experimental quantum physics requires some variant of wave collapse wherever quantum phenomena interact with the classical universe of the observer. This paper proposes a pragmatic view in which wave function collapses are treated as real phenomena that occur in pairs. Paired collapses occur when two wave packets exchange real (vs. virtual) momentum-carrying force particles such as photons. To minimize reversibility, such pairs must be separated by a relativistically time-like interval. The resulting model resembles a network of future-predictive simulations (wave packets) linked together by occasional exchanges of data (force particles). Each data exchange “updates” the wave packets by eliminating the need for them to “consider” some range of possible futures. The rest of the paper explores the information processing implications of this idea of networked wave packets. It is postulated that similar networks of simulations in classical computers could provide faster, more efficient ways to process sensor data.

Introduction
The main objective of this paper is to propose a quantum-inspired approach to extracting the maximum possible semantic value from sensor data, even when the quality and level of detail of that data varies widely. The approach has broader cognitive implications as well [1].

The approach is based on a pragmatic view of naturally occurring quantum systems, referred to in this paper as Wave Packet Network (WPN) theory. This pragmatic view of quantum mechanics interprets large classical systems as multi-scale networks of wave packets. Exchanges of information between pairs of WPN packets cause both packets to restructure (“collapse”) in ways that restrict the sets of possible futures associated with each wave packet.

The premise of this paper is that well-designed emulations of WPN using modern simulation hardware could lead to a general model for exploiting sensor data. Available sensor data would “collapse” a set of simulated wave packets that represent the best current interpretation of the external world. It is postulated that WPN emulation will enable sensor processing that is more top-down, more linear in time, and more compatible with control systems due to its use of object-like packets to represent the world.

If a general theory of sensors can be developed using WPN analogies, and if the resulting analogies can be implemented efficiently on modern simulation hardware, the implications for designing intelligent and autonomous systems could be profound. For example, a general theory of sensors would enable more systematic and energy efficient design of sensors and processing for small robots. Efficient sensors would aid in the design of autonomous vehicles to support a wide range of human activities. A general theory of how to maximize semantic value from sparse or variable-quality data would cut costs and make autonomous systems more robust, especially if it enables sensor processing that can adapt dynamically to changes in environment or sensor quality. Such capabilities would enable designs that rely on less costly sensors, and make it easier to function with degraded or damaged sensors.

WPN was developed by the author as a pragmatic way to map quantum concepts into the world of classical-time-based information processing [2]. However, WPN qualifies as a physical theory in its own right, one that suggests alternative views of how quantum mechanics relates to classical physics. For example, WPN packets with high rates of data exchange (collapses) approximate classical thermodynamic particles, and high levels of WPN data exchanges approximate thermodynamic heat. Appendix A discusses several other WPN implications for physics.
As exemplified in particular by Nobel Laureate Richard Feynman’s formulation of the theory of quantum electrodynamics (QED) [3], the most mathematically precise way to interpret any quantum experiment is as an integral of all of the possible histories by which a specified final outcome could have occurred. QED itself is a static theory that only calculates probabilities between specified preconditions and outcomes, but even before finishing it Feynman recognized the need for a more dynamic version that, like Schrödinger’s non-relativistic wave equation, would enable wave functions to evolve over time [4].

Feynman’s final QED theory accommodates such approximations of wave evolution through calculation of individual points in a cone-like four-dimensional spacetime volume. This cone can be interpreted from any observer frame as a series of three-dimensional slices that show the evolution of a wave function over time [5]. This approach provides a precise and relativistically accurate way to interpret Schrödinger’s earlier concept of an evolving wave packet, that is, of a physically compact but expanding wave form. A QED wave packet then can be interpreted as an evolving representation of all the possible histories that could have arisen in classical space as outcomes of the original set of preconditions and their dynamics. In a QED wave packet the emphasis shifts subtly from the probability of a specific outcome occurring (the Schrödinger wave packet) to the probability of a specific spacetime history (or more precisely, a reduced set of histories) occurring.

A QED wave packet is reduced into a classical history if it is paired with information that ties it irreversibly to an outcome recorded somewhere in the classical world. While this “observer paradox” is the root of much philosophical speculation [6] [7] [8], Feynman observed that the only precondition that must be met for a particle to cease to behave under quantum rules is for it to leave this type of historical trace anywhere within the classical universe. The trace may be as small as a change in the state of a single atom or particle [9] [10], a view that if applied consistently makes the need for a conscious observer irrelevant.

The combination of QED wave packets and reduction via information recording provides a more uniform way to view the evolution of quantum and classical systems. Both resolve into bundles (wave packets) of potential histories that expand under quantum rules until recording events occur. Wave packets then “reset,” generating both specific histories and preconditions for launching new packets. If wave packet collapse and information recording are accepted as physical events, the result is a discontinuous view of time in which the smoothness of QED applies only to the cone-like four dimensional spacetime regions that exist between collapse events. Classical history in this view becomes an interlinked network of smaller history units that emerge every time a wave packet collapses. Such collapse events can occur on nearly any scale, giving time a fractal structure. For example, intergalactic photons may remain quantum—go unrecorded in any historical record—for billions of years [11], while photons in a room usually rejoin classical history within nanoseconds. Molecules in solids are nearly classical, with very short rejoin half-lives.

In this pragmatic view, quantum physics becomes the subset of physics for which information recording events occur only occasionally. Classical physics represents the other extreme, that of systems for which recording events occur rapidly and at near-atomic levels of detail. Between these two extremes are the physics of everyday existence, which counterintuitively include many intermediate scales of data recording. Such everyday intermediate situations include photons delocalized over large areas, and reflective effects in metal that are caused by delocalized electrons with high but classically unavailable thermal energies.

The relevance of the above summary of quantum theory to sensor interpretation is that these naturally occurring, multi-scale networks of quantum wave packets exploit available status information with remarkable (and likely maximal) efficiency to “decide” both what has happened in the past and what could happen in the future. Both of these results—knowledge of the past and estimation of the near future—are fundamental to the design of efficient systems for gathering and interpreting sensor data. The premise of this paper is that quantum wave-packet networks are the most fundamental example of a general class of algorithms in which networks of evolving state packets provide an optimal overall structure for capturing, reconciling, and interpreting both the past history of dynamic systems, and the future paths down which they are most likely to evolve.

When applied to sensor networks, this premise becomes an assertion that if the predictive abilities of quantum wave packets can be emulated well by using modern simulation hardware, new algorithms for maximizing the extraction of semantic value from sensor data may become possible. The emulations would both track past status information and use this information to estimate likely future events.

When emulated in hardware, wave packets would be replaced by simulation packets that model the evolution of external objects. Just as quantum packet evolution is guided by the conservation laws of physics, simulation packets would focus on various “conserved properties” of external world objects, such as their tendency to persist as units and to behave in certain predictable ways. As a scene is analyzed, higher-level packets that predict the behavior of entire suites of pixels would replace simpler pixel-level packets, a process that corresponds to the simplification of using rigid classical objects to stand in for many bundled quantum objects. Quantum collapse becomes simulation collapse, in which ranges of uncertainty in the predictions of a simulation packet are reduced by applying new sensor data. Even quantum entanglement [12] has an analog in packet correlations, where data that updates one packet must also update a “distant” packet with a shared history. Packet correlations need to be minimized, since there is no efficient way to emulate them in classical computers [13].

This overall strategy of quantum-inspired simulative data interpretation analyzes sensor data not by attempting to interpret it only in its raw form—which can be very costly computationally—but by looking at how sensed data
matches internal estimates of how the external system is most likely to have evolved. Closely matching data can be reduced quickly into simple updates of parameters such as position and velocity, with no need for full image analysis.

The ability to match sensor inputs based on predictions of behavior derived from past data makes it easier to match partial images to known simulation packets, which in turn enables use of this data to update simulation status. In fact, a single-pixel “hit” can in certain cases be used reliably to perform major updates to a packet, since that single pixel may have very high semantic value if it falls in a well-defined estimate of a likely future. This feature of simulative data interpretation has intriguing similarities to the mathematical field of compressive sensing [14], in which under the right conditions of prior knowledge it becomes possible to extract very high levels of “meaning” from individual pixels. This may indicate an underlying mathematical connection. For example, simulative data interpretation may provide a way by which the basis sets of compressive sensing can be updated dynamically.

**Risks and Challenges**

The fundamental premise of using networks of simulation packets to capture and evolve predictions about sensor data seems strong enough from an algorithmic and information theory perspective to keep overall risks fairly low. The highest risks instead emerge from two premises implied by this framework.

The first major risk is whether sufficiently detailed and efficient simulations can be performed in real-time on cost-effective computer or simulation hardware. Most forms of simulation are computationally expensive, so a poor choice of platforms or algorithms could easily erase any overall benefits from using predictive simulations. A factor that helps offset this risk is the emergence in recent years of powerful low-cost simulation platforms in response to a strong global market for online immersive gaming.

The second major risk is whether the right mathematical algorithms can be found for implementing fast, easy-to-update simulation packets. These algorithms would need to calculate collections of future histories that are in some sense “sums” of all possible future histories. They would also need to “reset” easily based on new data. Both of these goals are very different from those typically imposed on simulation systems. Quantum theory should provide some insights on how to implement the required algorithms, but additional cross-disciplinary insights may also be needed from topics such as neurology.

Both risks are non-trivial, but likely not insurmountable.

**Topics for Expansion and Exploration**

The theme of this initial paper is that the pragmatic quantum theory of Wave Packet Networks also suggests viable paths by which modern computer and simulation hardware could be used to support faster, more efficient, and more robust sensors and sensor algorithms. The full development of such simulative approaches would require exploration and development far beyond the scope of this initial paper. Examples of possible candidate topics for future expansion and exploration of WPN ideas include:

- **Assessment of the limits of the WPN analogy.** The use of an analogy to quantum mechanics immediately suggests there could be limits to its applicability to any general theory of sensors. In particular, the existence of objects and conserved quantities is fundamental to how quantum wave packets evolve, so similar constraints should apply to simulative data interpretation. This aspect of the analogy may prove to be more a useful design guide than a limitation, however, since it suggests that the most vital feature of a good simulation packet will be its ability to capture those properties of an external entity that are most likely to remain invariant as future data arrives. Entanglements (packet correlations) are more clearly an example of a limit, since entanglement cannot be simulated efficiently in classical computers.

- **Assessment of broader information theory implications of Wave Packet Network concepts.** If Wave Packet Networks do exist in phenomena as fundamental as the quantum evolution of systems over time, it implies that the mathematical roots of the pragmatically inspired WPN approach may run deeper than they might seem, given such mundane origins. Possible links to the mathematics of compressed sensing have already been mentioned. More broadly, since WPN deals with issues of how to extract maximum semantic content from complex networks, even when those data exchanges vary widely in quality and level of detail, it is possible that a networked simulation framework could support development of a network-level superset of information theory. Such a network-level information theory would focus more on maximizing and validating the extraction of semantic content than on the transfer of messages per se, and would replace passive data storage concepts with active simulations of how past events lead to future predictions. Static data would simply become the simplest possible form of such a past-future simulation.

- **Development of a general theory of how to maximize extraction of semantic value from sensor data.** Based on insights from both WPN and information theory, it should be possible to develop a general theory of how to maximize extraction of semantic content from sensor data in any given situation. The result would be a General Sensor Theory that could be used to guide and optimize the design of cost-effective sensor systems.

- **Application of General Sensor Theory to available hardware.** Given its WPN origins, a careful assessment of relevant off-the-shelf capabilities could prove vital for applying a new theory of sensors effectively. Examples of products likely to be relevant when applying sensor theory to sensor design include simulation hardware, software, algorithms, and new generations of fast, powerful Field Programmable Gate Arrays (FPGAs).
Multi-Disciplinary Aspects of WPN

Any future work on WPN will unavoidably need to be multi-disciplinary. Quantum theory must be understood not just in terms of equations and applications, but also at the deeper level of how it applies to the evolution of systems over time. Aspects of fractal geometries emerge from the spectrum of frequencies at which packets are updated. This is true not just in WPN, but also in networks of simulation packets for which some bits of sensor data will have far broader impacts than others. Mathematical considerations must include assessments of whether and how quantum frameworks apply to classical simulations. The possibility that simultaneous data interpretation could have relevance to dynamic updating of the basis sets used in compressive sensing has already been mentioned.

Biological considerations include assessing whether constructs comparable to WPN packets and data exchanges exist within neurological systems. If they do, a general theory of sensing derived from WPN might provide new insights or interpretations of structures within advanced neurological systems. Conversely, if WPN-like structures can be identified in biology or neurology, such examples might well provide insights on how to make computer-based sensors more efficient.

Finally, the inherently classification-focused use of wave packets very likely can be generalized upwards to the broader topic of how to construct highly intelligent systems that can interpret and manipulate the external world.

Conclusions

The potential of Wave Packet Networks as an inspiration for constructing new types of simulation-based sensors and processing systems appears solid. The WPN approach simultaneously both preserves data and keeps that data structured in ways that makes it more immediately useful for interpreting new data. It is robust in handling incomplete data, and automatically provides intelligent classifications of that data. The WPN model also has potential as a unifying model that may apply across a diverse range of disciplines. It is a model worth examining.

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Appendix A. Wave Packet Network Theory

While constructed around theories such as Feynman’s path integral formulation of Quantum Electrodynamics, the Wave Packet Network (WPN) theory upon which the ideas of this paper depend is original. WPN differs in a number of non-trivial ways from most interpretations of quantum theory. This appendix overviews the main assumptions of WPN, describes how they differ from other interpretations, and suggests several interesting physical implications.

Fundamental Precepts of WPN Theory

The precepts of Wave Packet Network (WPN) theory are:

Wave packets are real. It is impossible to set up an experiment that looks at quantum behaviors without in some way forcing quantum wave functions to interact with classical machinery and observers. For example, creating an electron source for a double-slit diffraction experiment first requires that the electrons be confined to and emitted from a classical source. Such manipulations place time-dependent constraints on the physical sizes of real wave functions, since the wave function can in general expand only within the limits of the future light cone emanating from the classical source. This allows such wave functions to become very large very quickly, but it also prevents them from ever reaching the levels of mathematical state perfection used in quantum theory. For a universe with a finite duration, classically originated quantum waves thus cannot behave as pure wave states, but must instead behave as spatially limited packets that can only approach pure wave states over time. Similar arguments can be made for other quantum properties. In short, the classical origins of quantum systems force them to be expressed as wave packets, not as pure states.

Wave collapse is real. Quantum systems cannot interact with classical systems without undergoing some form of reduction of the complexity of their wave functions, a fact that is most vividly represented by the wave-like diffraction and particle-like detection of photons, electrons, and other low-mass particles. Most quantum interpretations that disdain wave collapse neglect to notice that without it, quantum experimentation becomes literally impossible. It is not in general a good idea to ignore concepts that are intrinsic to all known experimental results, no matter how distasteful those concepts may seem from a mathematical or philosophical perspective.

The real issue with wave collapse is that it needs to be taken far more seriously from a theoretical perspective. A serious theory of wave collapse must deal meaningfully with its highly non-local (or “superluminal”) component.

In WPN, the superluminal aspect of wave collapse is handled in part by asserting that an entire self-consistent classical history is selected whenever a collapse occurs. It is almost as if an entire cone-shaped wave packet “bead” in spacetime is collapsed into one classical history thread. While time-path collapse is in some ways more radical than “superluminal” interactions, it also avoids the various
causal ambiguities of spatial entanglement by generating an entire self-consistent history “all at once.”

When combined with the observation that all quantum phenomena are based on (possibly very large) wave packets, the reality of wave collapse means that quantum phenomena are in general cyclic or “ratchet like” in how they are expressed over time. That is, each time a new particle-like wave packet forms, it begins to spread again until another collapse event occurs, at which point its indeterminate history is replaced by a more definite classical one. For ordinary thermally-dominated classical systems, these beads of wave packet expansion and collapse will be so closely spaced that the particles involved can be said to remain “classical” for the duration.

Quantum systems collapse each other. One of the most common ways of explaining how a quantum system loses its special or wave-like features is to say that it is “disturbed” by the arrival of another particle that disrupts its quantum state. While crude, this explanation captures an essential feature of all forms of quantum collapse: Collapses are induced by “unplanned” interactions with other particles or systems of particles.

A more specific version of this idea is to say that the interaction changes the state of the particle, which in turn means the interaction “adds information” that guarantees the distinctiveness of the particle in the future.

WPN uses this concept of information identification to provide a surprisingly simple approach to wave packet collapse: Wave packets collapse each other, without any requirement for more complex systems or for abstract ideas such as observer consciousness. Packets collapse each other simply by exchanging “disturbing” (momentum-carrying) force particles such as photons or phonons, which may in turn be carried by larger non-force particles (e.g., atoms). The result is dual collapse, since momentum is both removed from one particle and added to another. Both actions add information to wave functions. The implication in WPN is that such exchanges collapse both wave functions and reduce both into “classical” histories.

The idea of dual wave function collapse fits surprisingly well with results from quantum experiments, and also with the readily apparent lack of quantum behavior in most large objects. As noted by Richard Feynman [10], any system for which it becomes possible to distinguish “how it happened” will cease to interfere—that is, it will stop being quantum in its behavior. In everyday life, the potential for exchange of phonons and photons within any room temperature object is so enormously high that the vast majority of large-scale (atomic and above) behaviors in such an object will necessarily be classical. Quantum effects will continue to hold sway for special cases in which the exchange of momentum-changing force particles is forbidden, such as in the state-filling Fermi seas of delocalized metallic electrons. As a general rule, the dual collapse idea also fits well with the general observation that quantum effects increase as temperature are reduced. Such reductions drastically reduce the numbers of phonons in such systems, and so reduce the odds of wave collapses.

It should be noted that the idea of dual wave collapse also provides a different way to look at and understand the concept of information erasure. Reversing an exchange of momentum, if done precisely and without any losses in magnitude or changes in orientation, and before any other exchange can alter the state of either system, becomes the mechanism by which quantum behavior is restored in both the sending and receiving wave packets. This in general can occur only on a very small scale, but for entities such as electrons in orbitals, “constant erasure” can become the default rather than the exception.

Erasure is in general strongly discouraged when one of the two wave packets is delayed in time, since a delay long enough to resemble classical time will nearly guarantee that one of the other of the two systems will be disturbed by a third system before the reverse exchange can be made.

In WPN, information is in effect a version of ordinary momentum. However, in terms of its ability to induce wave packet collapse, the information interpretation of momentum imparts to it a highly disproportionate impact. For example, while a photon-sized packet of momentum typically would have no detectable impact on a large classical object, that same packet when interpreted as information has the potential to obliterate a large-object wave function. It is this extreme asymmetry of effect that makes large-object wave packets so difficult to maintain.

A final observation on dual wave collapse is that it appears to have an interesting relationship or interpretation in terms of the electromagnetic solutions of Wheeler-Feynman theory [4]. In this theory, which formed the core of Feynman’s PhD thesis, the momentum impact of two particles separated by time is mediated by two different solutions to Maxwell’s Equations: a “retarded” solution that sends momentum in the usual direction from the past into the future, and an “advanced” solution that somewhat paradoxically sends momentum from the future particle back to the particle in the past. While Feynman eventually lost interest in these solutions, it is possible they could provide a very interesting asymmetric way of interpreting how information is exchanged during the passing of time.

Wave packets are bundles of possible histories. One of the most fascinating and insightful features of Feynman’s version of Quantum Electrodynamics is its abandonment of the requirement to use a rigidly ordered time sequence when dealing with quantum systems [4]. By instead looking end-to-end from a point in the past to a point in the future, Feynman was able to show that the most accurate way to calculate the probabilities surrounding the arrival of a particle at that future point is to derive every possible way in which the event could occur, including paths that travel backwards in time in ways that a rigidly moment-by-moment approach would never even consider.

It is important to note that Feynman was not an advocate of using wave packets. For example, he once referred to them dismissively as “magic” while explaining QED. The irony of his view of wave packets is that by the very act of setting up his path integrals between distinct points in the past and the future, he made identifiable wave collapses...
unavoidable at both ends of any physical realization of his
calculations. The initial point cannot be created without
using classical equipment that constrains wave functions.
The final spacetime point implies collapse by its very
probabilistic nature, since experimental implementations of
it necessarily must create a broader wave packet to ensure
conservation of the particle if it does not arrive in the
calculated target area. That packet must then “collapse.”

Viewing Feynman’s QED structures as maps of how a
wave packet could play out over time helps emphasize that
wave function collapse selects entire histories, and not just
individual outcomes. For every point that is selected by
experiment at the end of a Feynman structure, there is also
an implied set of “most likely” paths that can be
determined by tracing back from that final result. These
implied histories can range from very general (e.g., one or
the other side of a sphere) down to very specific (e.g., one
path down a maze of partially reflective mirrors), but in all
cases they involve discarding previously possible histories.

Conversely, when viewed from the originating point in
the past, a Feynman structure unavoidably describes which
paths are the most likely to occur in the future. It thus
summarizes what is most likely to occur later given what is
known from past information.

It is this combination of knowledge of the past combined
with probabilistic models of future behaviors, all linked by
exchanges of data, that makes WPN a promising model for
how to build more quantum-like networks that may in turn
be capable of handling sensor information more efficiently.

Other Implications of WPN

The main focus of WPN is to provide a pragmatic model of
quantum behavior that can inspire new approaches to
information processing. However, the details of WPN are
different enough and specific enough that they also have a
number of interesting physics implications. A few of the
more interesting examples of this are described below.

State-Machine Universe (SMU). WPN interprets the
universe as a state machine, one whose storage capacity is
literally astronomically large, but finite. More specifically,
SMU disallows the idea of a past or future that exists
independently of the present. The deep symmetries of time
that seem to imply the reality of the past and future are
reinterpret in SMU as consequences of conservation
laws that preserve certain state configurations strongly
over the evolution of the state machine. The multiplicity of
worlds that seem to be implied by some quantum behaviors
is similarly reduced to a resource-limited virtual effect in
which the intrusion of classical time—the collapse of wave
functions—will in the long run always force “atemporal”
quantum regions to re-integrate back into the SMU in the
form of specific historical results.

SMU disallows both relativistic world-line and quantum
many-world views, since both imply limitless information
storage capacities. Classical relativity interprets the world
as a fixed collection of world-lines extending indefinitely
far into the past and future, which in turn implies infinite
state capacity. Many-worlds interpretations of quantum
mechanics imply limitless expansion of information
storage as new universes branch off from current states.

In contrast, any level of complexity that exceeds the
total capacity of the SMU will simply be lost, in the sense
of being unrecoverable by any manipulation of the current
state of the universe. This is a fairly heretical idea, since
conservation of information is assumed in most theories of
the universe. It is possible to create a version of SMU that
retains all information by expanding capacity over time,
but this approach is comparable to increasing mass without
limit over time. A large but finite set of states is simpler.

SMU provides a simple answer to many questions about
time travel. Time travel into the past, with all of its many
quandaries of how to prevent temporal paradoxes, becomes
a non sequitur. There is no past into which to travel, only
variants of the current state of the SMU. Time travel into
the future, which of course is possible via relativistic time
dilation, becomes little more than freezing a local pattern
and reactivating it within a future SMU configuration.

In SMU, “now” is defined by the network of wave
packets that represent conserved quantities and their
possible histories. Time itself becomes granular, with the
various sizes of uncollapsed wave packets representing
regions in which the specifics of the past and future have
not yet been fully decided. Classical systems represent one
extreme of very finely-grained definition of the flow of
time, with the constant phonon interactions of Boltzmann
thermodynamics ensuring very limited growth of quantum
wave packets and their uncertain time relationships. At the
other extreme are small, isolated systems such as photons
traveling through intergalactic space. These represent the
other extreme of events whose final histories remain
indeterminate over very large volumes of space and time.

Absolute reality of “classical now.” As described above,
WPN assumes that if an object or particle is observed
continuously and in sufficient detail to keep it from
becoming significantly quantum in behavior, the concept
of “now” for that object or particle becomes an invariant
that remains valid and unchanged regardless of the
relativistic frame of reference from which the object or
particle is observed.

That is, the proper time of a classically observed particle
or object cannot be reversed or altered by any manipulation
of relativistic physics, although its history may remain
nominally reversible via certain very low probability
quantum events.

While the idea that a continuously observed event
cannot “change its history” is in many ways nothing more
than an affirmation of the principle of temporal causality,
and thus hardly radical, the idea that a local procedure can
create a universal invariant has broader implications than it
might seem. One such implication is that solutions to the
equations of general relativity that allow constructs such as
wormholes must be incorrect, for reasons unknown but
presumably related to some misinterpretation of how
mathematically valid solutions to those equations apply to
the physically observable universe.
Implications for relativistic time dilation. A more subtle implication of time being determined locally is that it removes an important degree of latitude that has been used in special relativity since its earliest days [15]. Specifically, the concept of absolute local time seems to imply a need for reinterpretation of the well-known time dilation effect.

The problem is straightforward: If the concept of “now” is determined solely by observations taking place locally within classical systems, then the first derivative of “now”—that is, the rate at which time flows—must also be determined by local observation. This can cause problems.

Assume you are within such a locally-determined time flow and wish to observe time flow in another frame. To avoid ambiguities caused by the delay of light, you arrange for a stream of small, point-like clocks in the other frame to flow continuously and without acceleration through your measuring apparatus, which relies on similarly point-like clocks. The arbitrarily close mixing of the point-like clocks from the two frames avoids the ambiguity of light delays between distant frames (e.g., spaceships).

In the standard SR interpretation of time dilation, no frame is privileged. This leads to an interesting question: In the direct-frame-contact experiment, will the two sets of point-like clocks (those flowing past and those in the observer frame) exhibit the same or a different time flows? Minkowski [15] supported the view that time must remain indeterminate as long as there is no acceleration of a frame. The ambiguity introduced by the delays of light travel would then cover up this ambiguity of time dilation until the two systems are reunited into a single frame.

In the direct-frame-contact thought experiment, both the measurement ambiguity of distance and the distinction of frame acceleration are absent. Observers in both frames can make unambiguous measurements of the time rates of the others by comparing two point-like clocks as they pass closely by each other. Direct-frame-contact thus captures the essence of the WPN idea that time rates are determined by local observation, not deferred until a later resolution.

Stated another way, observers within each frame should be able to calculate and agree upon a single absolute time dilation ratio that exists between their two frames.

If full frame equivalence (a type of symmetry) is to be maintained, only one result is possible: Both frames in the direct-frame-contact experiment must see a time dilation ratio that exists between their two frames.

Unfortunately, this prediction violates very well-known physics. Any particle with a known half-life, such as muon, can be used as a point-like clock. Furthermore, it is not difficult to find or arrange scenarios in which such particles travel unaccelerated, at high velocity, and in intimate contact with similar clocks in other frames. Muons generated by cosmic rays striking the top of earth’s atmosphere are a good example. Such muons undergo major accelerations only at the starts and ends of their journeys, while for the rest of their trips through the atmosphere they maintain unaccelerated velocities very close to c. In the absence of acceleration, full frame equivalence demands that the observed time dilation ratio between the muons and earth’s atmosphere be exactly one. In reality, the unaccelerated muons exhibit an externally observable Lorentz factor (time dilation ratio) of roughly 5. This enables a huge increase (about five orders of magnitude) in the number of muons that strike the earth’s surface, and creates a commensurate reduction in the decay (“clock speed”) of the muons as they pass through the atmosphere.

Other examples of asymmetric Lorentz factors during unaccelerated phases in the travel of point-like clocks are easy to find, since modern particle physics depends upon this property to observe rare and highly unstable particles. Even an experiment as simple as an old-fashioned cloud chamber science kit is fully capable of exhibiting particle time dilations that, strictly speaking, violate the assumption that time dilation remains indeterminate until some final acceleration event reconciles the two frames into one. In contrast, the WPN view that time is locally determined and invariant regardless of frame is entirely compatible with all of these everyday examples of particle-level time dilation.

There is more. If any two unaccelerated frames have an absolute, calculable Lorentz factor that fully characterizes their relative rates of time flow, an unavoidable implication is that by comparing all possible pairs of relativistic frames one would eventually uncover at least one frame for which time dilation reaches an absolute and literally universal minimum. That is, it implies that there exists a fastest time frame (FTF) in which time passes at a faster rate than for any other frame of reference possible in the universe.

Using energy conservation arguments beyond the scope of this appendix, the FTF can be identified as the “center of all mass” of the universe. The concept of a universal center of mass is tricky in an expanding universe. However, there is a well-known distinguished frame that arguably defines just such a center of mass: the Cosmic Microwave Background (CMB). Thus a plausible route for attempting to access the FTF experimentally would be to cancel out all motion relative to the CMB frame. This could be done by traveling at 369.0 km/s (relative to the sun) towards the celestial coordinate (α, δ) = (23h11m57s, +7.22), which is about one-third of the way along a line from Gamma Piscium (in Pisces) to Alpha Pegasi (in Pegasus) [16]. If the concept of locally determined time is valid, a speedup in time of somewhat less than one part per million (~0.7575 x 10⁻⁶) should be seen. The simplest test would be to inject and maintain muons at 0.001231 c (369 km/s) in a roughly oval loop whose long axis points at the above coordinate, ideally corrected for earth orbit and rotation vectors at the time of the experiment. Measuring relative decay rates on either side of the loop axis should exhibit a muon decay rate delta of up to about 1.5 parts per million.

Notably, such a setup resembles Michelson-Morley [17]. This makes a final crucial point: Michelson-Morley proved frame invariance for massless photons, but it did not prove invariance for the case of traveling particles with mass. The generalization of Michelson-Morley to particles with mass was assumed, but does not appear ever to have been tested. Muon loops would provide one way to do so.
Finally, partial alignments of earth orbital velocities with the CMB frame vector could provide smaller time dilation deltas in the range of a few parts per billion. Low-earth satellites with seasonal corrections could show alignment deltas with magnitudes less than one part per billion. High precision systems such as Gravity Probes A and B could be rich data sources in searching for such lesser effects.

Any result verifying the existence of an FTF would of course have many interesting implications for astrophysics.

**References**


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10. Feynman, R.P.: The Feynman Lectures on Physics. Addison Wesley (1964). See: Vol. III Ch 3-4, Identical particles, near start of recorded version (not in printed version). Key quote: “... if there is a physical situation in which it is impossible to tell which way it happened, it always interferes; it never fails.” (Feynman’s emphasis). See discussion at: http://en.wikipedia.org/wiki/Symmetry#Consequences_of_quantum_symmetry


12. Bell, J.S.: Speakable and Unspeakable in Quantum Mechanics, 2nd ed. Cambridge University Press (2004). See especially: Paper 16, Bertlmann’s socks and the nature of reality, 139-158. This is a readable explanation of Bell’s discovery that “spooky action at a distance,” or entanglement, has measurable experimental implications.


