

1 **A CPT Model with Implications for Causality in the Setting of Maxwell’s Equations and**
2 **for Uniting Quantum Mechanics and General Relativity**

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8 Lamont Williams
9 williams_lamont@outlook.com

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13 **Abstract**

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15 **A CPT Model with Implications for Causality in the Setting of Maxwell’s Equations and**
16 **for Uniting Quantum Mechanics and General Relativity**

17
18 A model is presented that unifies the core principles of the Charge Conjugation, Parity, and
19 Time-Reversal (CPT) theorem within a single conceptual framework. Additionally, the
20 model integrates the time-symmetric structure of CPT invariance with the asymmetric
21 thermodynamic arrow of time. It emphasizes that the time component of CPT encodes
22 formal symmetry operations and not causal mechanisms at macroscopic scales.
23 Concepts from the model are extended to the retarded (forward-in-time) and advanced
24 (backward-in-time) wave solutions of Maxwell’s equations for electromagnetism. They
25 show that the temporal symmetry between these waves reflects the time-symmetric
26 structure of CPT invariance. And as such, it is likely that the wave solutions do not directly
27 encode macroscopic causal activity. This aligns with Maxwell’s equations, which are not
28 inherently causal, but which are typically interpreted in causal terms in established
29 practice. This also has direct implications regarding the ontological status of advanced
30 waves. The CPT model is further extended to the settings of quantum mechanics and
31 general relativity, where it appears to offer a small advance toward their integration.

32
33 **Keywords:** Charge Conjugation, Parity, Time Reversal; CPT; Maxwell’s equations;
34 electromagnetism; quantum mechanics; general relativity

35
36 **Introduction**

37 Time symmetry is an important concept in physics, where some fundamental physical laws
38 are invariant under time-reversal conditions. However, discussions about time symmetry

39 are often adjusted to be consistent with matters of causality—in which *cause* always
40 precedes *effect*. In classical electrodynamics, Maxwell’s equations involve wave solutions
41 in which half propagate forward in time (retarded waves) and half propagate backward in
42 time (advanced waves). Although both types of solutions are mathematically valid,
43 conventional practice typically privileges retarded waves, as they are considered to be
44 consistent with matters of causality. Advanced wave solutions, which imply retrocausal
45 activity, are often dismissed as unphysical.

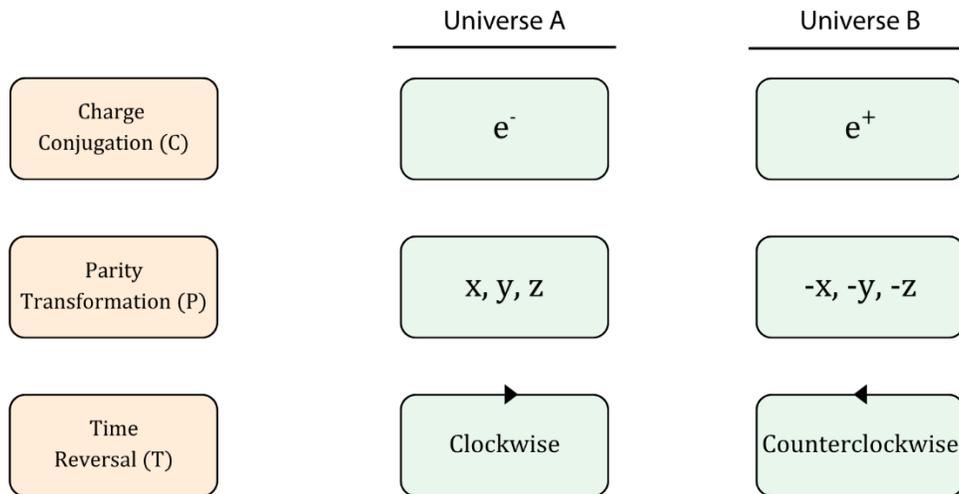
46 Presented below is a model that unifies the key symmetry principles of the Charge
47 Conjugation, Parity, and Time-Reversal (CPT) theorem within a single conceptual
48 framework. The model also integrates the time-symmetric structure of CPT invariance with
49 the asymmetric entropy-driven arrow of time. Concepts from the framework are extended
50 to the retarded and advanced wave solutions of Maxwell’s equations, drawing a connection
51 between the temporal symmetry of the waves and the time-symmetric structure of CPT
52 invariance, and emphasizing that the temporal aspects of the wave solutions likely do not
53 encode macroscopic causal outcomes directly. This has a critical impact on the
54 ontological status of advanced waves.

55 The model is further extended to concepts concerning the union of quantum mechanics
56 and general relativity. It appears to offer a degree of advancement toward their integration.

57 **The CPT Model**

58 The psychological and thermodynamic arrow of time is rooted in the concept of entropy,
59 linked to such one-way phenomena as the metabolism of food and fading of paint. These
60 processes disrupt time symmetry, giving rise to the sense of cause preceding effect.
61 However, viewing the electron in a point-like state, consider one alone, frozen motionless in
62 space with no other matter or radiation around it. Even in this state, the particle is moving
63 through time, despite no thermodynamic events associated with it.

64 According to the CPT theorem, time can be reversed in this scenario (e.g., from clockwise
65 or forward running to counterclockwise or backward running) and the universe would
66 operate the same way, as long as the particle is subjected to charge conjugation (i.e.,
67 transforming it to its antiparticle, the positron), and the spatial dimensions undergo a
68 reflection transformation (Figure 1) [1-5]:

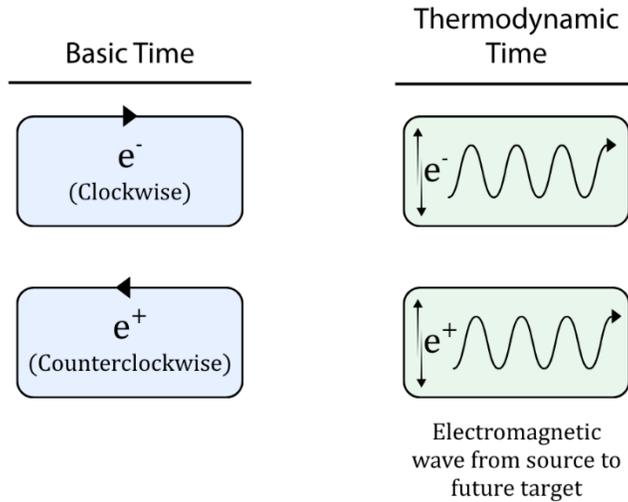


69

70 **Figure 1. In the CPT theorem, a universe based on positrons will work the same way as**
 71 **one based on electrons as long as the spatial dimensions undergo a reflection**
 72 **transformation and time is reversed.**

73

74 The time experienced by the electron and positron in the CPT context— here called “basic
 75 time”—is unrelated to the time of our experience (i.e., entropy-driven thermodynamic
 76 time).[6] However, if the electron in universe A and the positron in universe B in Figure 1
 77 were to oscillate, each would send an electromagnetic wave (e.g., a radio signal) that
 78 would travel away from the emitting particle to some future target, never to reverse its
 79 course. Here, the particles lose energy. Some future target gains energy. And each system
 80 moves toward higher entropy. This emission is related to thermodynamic time, providing a
 81 one-way transmission of energy. It reflects a causal asymmetry in energy transfer despite
 82 the underlying time-reversal symmetry of the CPT framework. As such, both the electron
 83 and positron can behave as a unidirectional, forward-running clock, despite their basic
 84 time running in opposite directions (Figure 2).

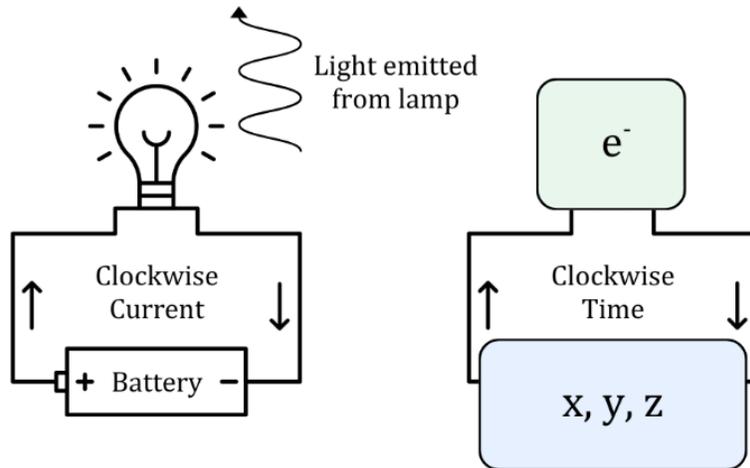


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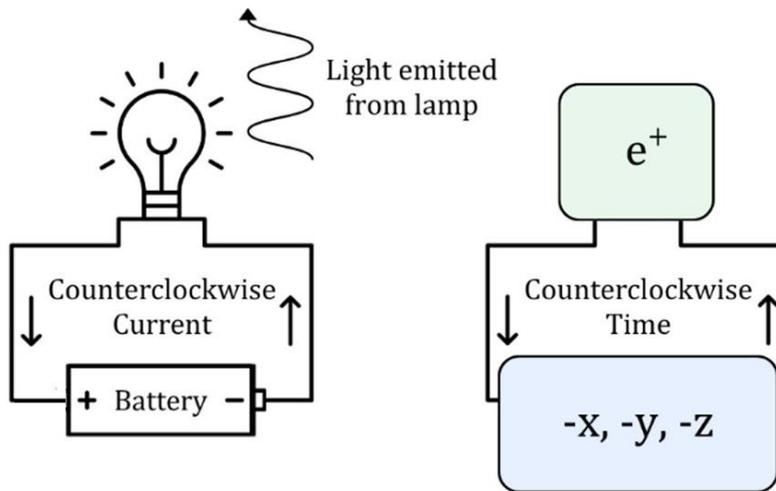
86 **Figure 2. The basic, CPT-related time of an electron runs oppositely to that of a**
 87 **positron, and each version of time exists despite no thermodynamic events (left). If**
 88 **the electron and positron were to oscillate, each would emit an electromagnetic wave**
 89 **in a direction away from the particle to some future target, with the wave transmitting**
 90 **energy and never reversing its course. In this sense, both the electron and positron**
 91 **can behave as a unidirectional, forward-running clock.**

92 Modeling concepts from CPT like an electrical circuit involving a battery can help to
 93 visualize these various conditions. In the electrical circuit, electrons flow from the negative
 94 terminal to the positive terminal (oppositely of a conventional current diagram), allowing
 95 the device to emit a signal (e.g., a lamp emitting a burst of light). If positive charges were
 96 instead mobile and flowed from the positive terminal to the negative terminal in the circuit,
 97 the fundamental behavior of electricity would remain the same, such that a signal would
 98 still be sent outward. In modeling CPT like an electrical circuit, space would be in the
 99 battery position, the electron and positron in the position of the device, and time in the
 100 position of the flow of electricity, where time runs clockwise, or forward, for the electron,
 101 and counterclockwise, or backward, for the positron (Figure 3).

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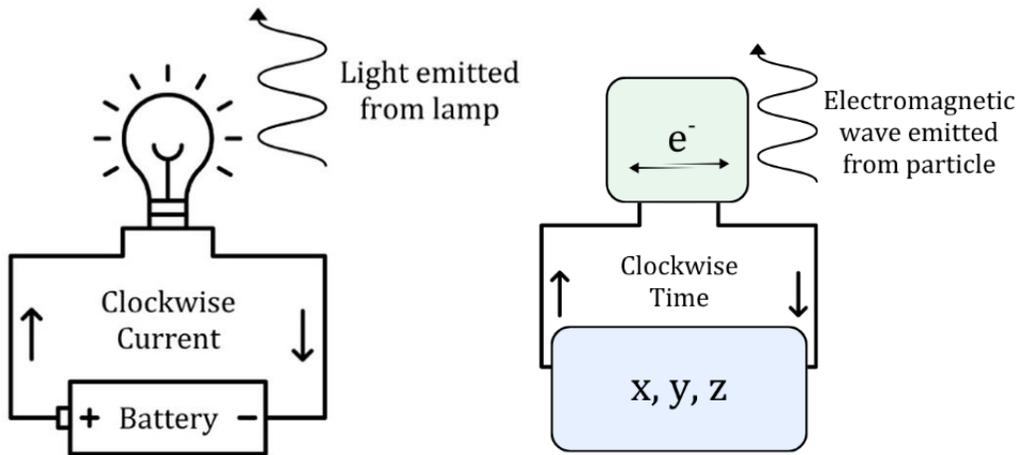
105

106 **Figure 3. CPT can be modeled like an electrical circuit involving a battery, with space**
 107 **in the position of the battery, the electron and positron in the position of the device,**
 108 **and the flow of time in the position of the electrical current. The fundamental nature**
 109 **of electricity would work the same if positive charges were mobile and electrical**
 110 **current flowed in the opposite direction. Similarly, a universe based on the positron**
 111 **system, with its counterclockwise-running time, will work just as well as one based on**
 112 **the electron system, with its clockwise-running time, given the reflection**
 113 **transformation of space as well.**

114

115 Figure 4 shows the same as above but with the electron and positron oscillating, sending
 116 an electromagnetic wave outward. A benefit of modeling CPT in this manner is that it
 117 unifies the time-reversal symmetry of CPT invariance and the asymmetric thermodynamic
 118 arrow of time in one fairly intuitive schematic.

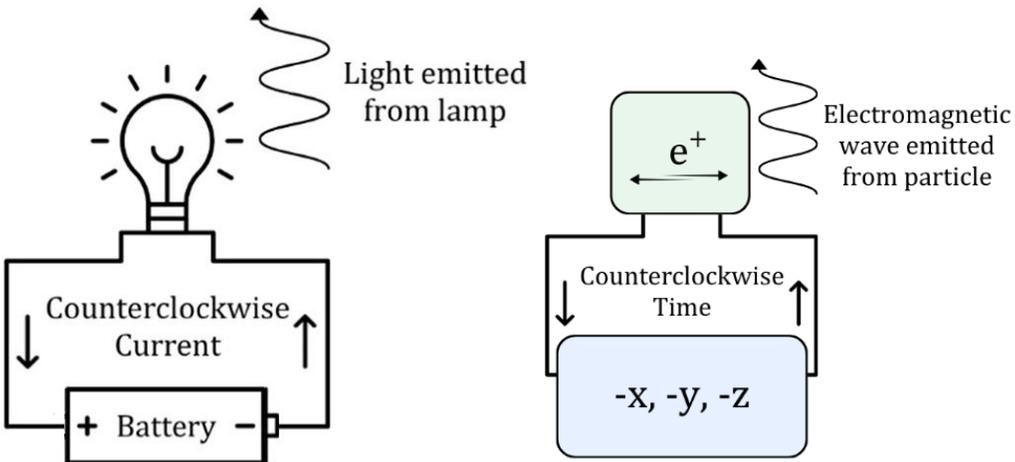
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125 **Figure 4. CPT symmetry and thermodynamic temporal asymmetry are co-represented**
126 **within a unified model, preserving CPT invariance while also showing entropy-driven**
127 **temporal directionality by way of an electromagnetic wave being emitted from the**
128 **electron and positron. In the electrical circuit, reversing the direction of the current**
129 **from clockwise to counterclockwise would not lead to a burst of light from some**
130 **future target traveling backward to the lamp. Similarly, reversing the direction of basic**
131 **time for the positron does not lead to the retrocausal outcome of an electromagnetic**
132 **wave traveling from some future target back to the emitting particle.**

133

134 In the electrical circuit, reversing the direction of the current from clockwise to
135 counterclockwise does not lead to a burst of light from some future target traveling
136 backward to the lamp—understandably a difficult concept to even contemplate. Whether

137 electricity flows from the negative terminal to the positive terminal or vice versa, the same
138 signal is produced and travels in one direction—away from the light source.

139

140 Similarly, reversing the flow of time for the positron does not lead to the retrocausal
141 outcome of an electromagnetic wave traveling from some future target back to the emitting
142 particle. Whether time flows forward for the electron or backward for the positron, a signal
143 is produced and travels in one direction—away from the particle source. The basic time
144 experienced by the particles has no direct relationship with physical events and therefore
145 cannot effectuate any physical outcomes—that is, it has no direct impact on causality,
146 which will continue to occur in accordance with thermodynamic principles, regardless of
147 which way the basic time flows.

148

149 As discussed below, advanced electromagnetic waves, which like positrons also travel
150 backward through time, are however thought to have retrocausal influences, and thus
151 advanced wave solutions are typically discarded in analyses as unphysical. This is despite
152 the fact that causality is not a fundamental aspect of Maxwell's equations for
153 electromagnetism. This and other physical phenomena are discussed from the standpoint
154 of the CPT model, which may provide important insight.

155

156 **Discussion**

157 The CPT model presented above is in line with established physical principles, including
158 CPT symmetry and causality, and exhibits no internal contradictions. The model is also
159 simple and self-contained, with no free-floating parameters. Despite its simplicity, it may
160 have utility in helping to advance progress in several areas where there are some ongoing
161 challenges, namely involving advanced waves in electromagnetism and the union of
162 quantum mechanics and general relativity.

163

164 ***Time in Electromagnetic Fields***

165 As highlighted above, the basic time experienced by electrons and positrons in the context
166 of CPT has no direct impact on causality. In Maxwell's equations for electromagnetism,
167 which are fundamentally time-symmetric, retarded waves and advanced waves also have
168 no direct impact on causality. Currently, causality is imposed upon the equations by the
169 usual choice in standard practice to privilege retarded wave solutions and discard
170 advanced ones as unphysical, as they seem to be associated with retrocausal influences.

171 The retarded (*ret*) wave solutions (privileged) for the scalar and vector potentials using
172 Green's functions are:

173
$$\varphi_{ret}(r, t) = \frac{1}{4\pi\epsilon_0} \int \frac{\rho(r', t_r)}{|r-r'|} d^3r' \quad (1)$$

174 (retarded scalar potential)

175

176
$$A_{ret}(r, t) = \frac{\mu_0}{4\pi} \int \frac{J(r', t_r)}{|r-r'|} d^3r' \quad (2)$$

177 (retarded vector potential)

178

179 where the retarded time is

180

181
$$t_r = t - \frac{|r-r'|}{c} \quad (3)$$

182

183 where,

184 $\rho(r', t_r)$ is the charge density evaluated at the retarded time

185 $J(r', t_r)$ is the current density evaluated at the retarded time

186 t is the observation time

187 t_r marks the moment when the retarded field began to propagate forward in time

188 $r - r'$ is the distance between observation point r and source point r'

189 d^3r' is the volume element

190 ϵ_0 is the vacuum permittivity

191 μ_0 is the vacuum permeability

192 c is the speed of light in a vacuum.

193

194 The advanced (*adv*) wave solutions (typically disregarded) for the scalar and vector
195 potentials using Green's functions are:

196
$$\varphi_{adv}(r, t) = \frac{1}{4\pi\epsilon_0} \int \frac{\rho(r', t_a)}{|r-r'|} d^3r' \quad (4)$$

197 (advanced scalar potential)

198

199
$$A_{adv}(r, t) = \frac{\mu_0}{4\pi} \int \frac{J(r', t_a)}{|r-r'|} d^3r' \quad (5)$$

200 (advanced vector potential)

201

202 where the advanced time is

203
$$t_a = t + \frac{|r-r'|}{c} \quad (6)$$

204

205 where,

206 $\rho(r', t_a)$ is the charge density evaluated at the advanced time

207 $J(r', t_a)$ is the current density evaluated at the advanced time

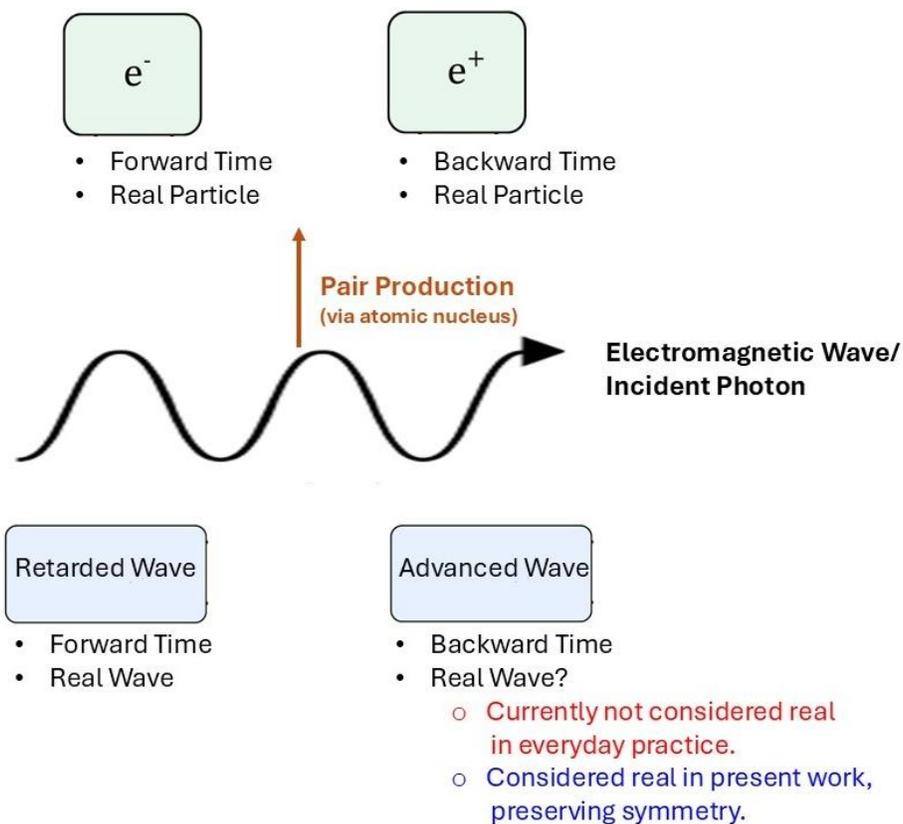
208 t_a marks the moment when the advanced field began to propagate backward in time.

209

210 Given that an electromagnetic field can give rise to an electron-positron pair through the
211 process of pair production, and that Maxwell's equations for electromagnetism admit both
212 retarded and advanced wave solutions, it is reasonable to consider that the electron is
213 connected to the retarded wave component—with each moving forward in time—and that
214 the positron is connected to the advanced wave component—with each moving backward
215 in time. That is, the temporal orientation of the particles and the temporal orientation of the
216 retarded and advanced wave components of the electromagnetic wave that gave rise to the
217 particles are likely two layers of the same reality (Figure 5).

218

219



220
221

222 **Figure 5. Simplified depiction of an electron and positron being produced from an**
 223 **electromagnetic wave/incident photon through the pair production process. The time**
 224 **of the particles and the time of the components of the electromagnetic wave that gave**
 225 **rise to the particles are likely two layers of the same reality. Like the electron, the**
 226 **retarded wave has forward-running time. Like the positron, the advanced wave has**
 227 **backward-running time. All elements are considered real in current practice except**
 228 **the advanced wave, which is assumed to lead to retrocausal activity, and is thus**
 229 **typically disregarded. The current work suggests that 1) none of the particle or wave**
 230 **times has causal agency, 2) advanced waves are real, and 3) the symmetry between**
 231 **the particle pair and wave pair is maintained in nature.**

232

233 In this sense, as electrons and positrons are both real particles with a basic form of time
 234 that has no direct link to causality, retarded and advanced waves are likely both real waves
 235 with a basic form of time that has no direct link to causality. Again, causality is not a
 236 fundamental feature of Maxwell's wave solutions. The asymmetry between the particles
 237 and waves in Figure 5 is due only to the human practice of discarding advanced waves as
 238 unphysical because of their apparent connection to retrocausality.

265 To assist in this effort, equations (3) and (6) are rearranged as follows:

266

$$267 \quad t = t_r + \frac{|r-r'|}{c} \quad (7)$$

268

269 observation of retarded wave

270

$$271 \quad t = t_a - \frac{|r-r'|}{c}. \quad (8)$$

272

observation of advanced wave

273 With the emission point (causal event) held fixed, and both t_r and t_a representing the
274 source time (as opposed to the observation time of t), then $t_r = t_a$, with both having a value
275 of zero in the reframing. In this context, the retarded wave reaches earth at $t = +8$ minutes,
276 representing movement forward in time, while the advanced wave reaches earth at $t = -8$
277 minutes, representing movement backward in time. Both are legitimate for telling time and
278 for putting appropriate timestamps on the events, as long as the direction of the time's flow
279 for each case is understood.

280 This is reflective of the time-reversal transformation within the CPT symmetry framework,
281 where $\frac{|r-r'|}{c}$, the light-travel time, is symbolized as τ , and where $|r - r'|$, the spatial interval,
282 is symbolized as R and remains unchanged under time reversal:

283

$$284 \quad T_{CPT\ Time}: (R, t) \rightarrow (R, -t) \quad (9)$$

285

$$286 \quad T_{Light-Travel\ Time}: (R, \tau) \rightarrow (R, -\tau) \quad (10)$$

287

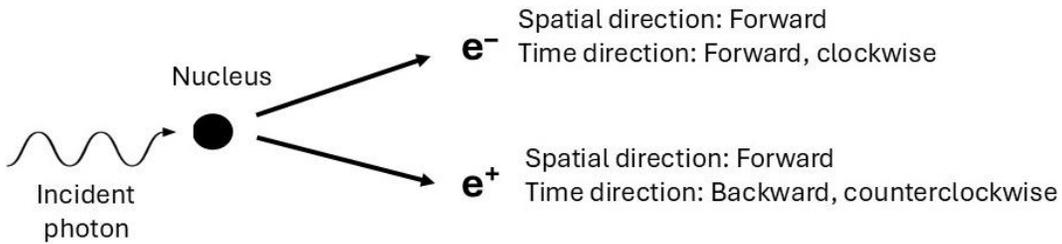
288 As there are mirror-image flows of time across the CPT framework, there are mirror-image
289 flows of time across the electromagnetic field.

290

291 Viewing the advanced wave's time as 11:52 a.m., before the 12:00 p.m. emission, is to view
292 the wave's time by using a retarded-time bias. The 11:52 a.m. time is not reflecting
293 retrocausality, just the fact that the clock of the advanced wave is simply rotating
294 counterclockwise compared to the clock of the retarded wave. The retarded time and
295 advanced time are each appropriately measuring the intervals between events in their
296 particular time direction. Thus, for both the retarded and advanced waves, cause precedes
297 effect.

298 As already suggested, while the retarded and advanced waves move oppositely through
 299 time, they would move in the same spatial direction, from the sun toward the earth. This is
 300 also similar to the electron and positron during pair production. During this process, the
 301 particles appear as two tracks diverging from a point, but with both generally moving in the
 302 same direction, despite moving oppositely through time (Figure 7).

303
304



305
306

307 **Figure 7. The electron and positron produced through pair production both move**
 308 **forward in space, with the electron moving forward or clockwise in time, and the**
 309 **positron moving backward or counterclockwise in time.**

310

311 Table 1 lists several ways in which the CPT and retarded–advanced wave symmetries
 312 appear to be manifestations of the same deeper symmetry (Table 1).

313 **Table 1. CPT Symmetry Compared with Retarded–Advanced Wave Symmetry**

Feature	CPT Symmetry	Retarded – Advanced Wave Symmetry	Equivalence
Time	Forward-flowing or backward-flowing time	Continuous bidirectional propagation via Green’s functions	Both involve oppositely running clocks within the system
Causality	Acausal	Causality not a fundamental aspect of wave solutions	Neither encodes causal outcomes
Particle/Wave Counterparts	Particles interpreted as traveling forward in time; antiparticles interpreted as	Retarded waves interpreted as traveling forward in time; advanced waves interpreted as	Both involve a balance between paired-elements: particle-antiparticle,

	traveling backward in time	traveling backward in time	retarded wave– advanced wave
Lorentz Invariance	Foundational to CPT [7]	Preserved by symmetric Green’s function and wave equation [8]	Both are Lorentz invariant

314

315 All of the above suggests that like the electron and positron are both real, the retarded and
316 advanced waves are both real. It further suggests that the temporal symmetry between the
317 waves reflects the time-reversal symmetry of CPT invariance, with the time of the waves, as
318 with the time of the electron and positron, having no direct impact on causality. As such,
319 advanced waves would not produce retrocausal outcomes. And this is consistent with
320 Maxwell’s wave solutions, given that they do not fundamentally involve matters of causality
321 as well. Thus, the CPT model–inspired treatment of the time of retarded and advanced
322 waves preserves the symmetry that naturally occurs within Maxwell’s equations and sets
323 the stage for a more coherent account of electromagnetic interactions within a time-
324 symmetric framework, which could have important implications for future studies of
325 electrodynamics.

326

327 Motivated in part to better align descriptions of electromagnetic phenomena with
328 Maxwell’s work, several prior studies, often collectively referred to as direct-action
329 theories, have sought to place retarded and advanced waves on equal footing to describe
330 an electromagnetic interaction.[9–12] However, they have various problems and conditions
331 that make the frameworks largely untenable. The root cause of these issues is likely the
332 implicit assumption within the studies that retarded and advanced waves have causal
333 significance individually. This would lead to the development of an array of measures for
334 addressing non-existing causality-related problems, particularly retrocausality from
335 advanced waves. This issue and how a time symmetric approach that is still tied to
336 causality might work in the setting of an electromagnetic interaction are briefly explored in
337 the appendix.

338

339 Privileging retarded waves and disregarding advanced waves, while perhaps generally
340 useful for some computational purposes, appears to not be the most appropriate
341 approach at least from a theoretical perspective. And doing so leads to an unusual, and
342 quite unnatural, asymmetry as shown in Figure 5. Advanced waves likely have just as

343 important a role in electromagnetic interactions as retarded waves and are likely just as
344 real.

345 The practice of disregarding advanced waves as unphysical is very reminiscent of the
346 practice of disregarding positrons as unphysical in the early 1900s, following Dirac's
347 prediction of their existence.[13] Blackett and Occhialini definitively identified the positron
348 through electron-positron pair creation from gamma rays—in accordance with Dirac's
349 theory.[14,15] Ernst Stueckelberg and Richard Feynman later interpreted the particle as
350 moving backward in time at the particle level helping to lay for foundation for the CPT
351 theorem.[16,17] Much critical information about how the physical universe works would be
352 currently unknown if positrons were still considered to be unreal and their associated
353 mathematics disregarded. As such, it is plausible that by treating advanced waves as
354 unreal now, equally critical information about physical phenomena is being missed today.

355 ***Uniting Quantum Mechanics and General Relativity***

356 The information above could also have important implications in efforts to bridge the divide
357 between quantum mechanics (with the term used here for all quantum theories) and
358 general relativity. As one example, the propagation of advanced waves through curved
359 spacetime might not be as challenging as it would be if the waves were causally active
360 individually. Curved spacetime affects how light and signals travel and would further
361 complicate matters of causality if advanced waves had causal significance. If individual
362 advanced waves do not behave as causal agents, this opens the door to further exploration
363 of the transmission of such waves through curved spacetime.

364
365 The information above also has implications for the Wheeler–DeWitt equation, which
366 emerges within the canonical quantization of general relativity, specifically through the
367 ADM (Arnowitt–Deser–Misner) formalism. In the ADM approach, the machinery of quantum
368 mechanics is applied to the classical gravitational field, with the ultimate goal of
369 constructing a quantum theory of gravity. The Wheeler-DeWitt equation, shown below in
370 simplified form, eliminates the external time parameter from the quantum description of
371 spacetime, challenging the conventional notion of temporal evolution in quantum theory
372 [18,19,20]:

373

$$374 \quad \hat{H}(x) | \psi \rangle = 0 \quad (11)$$

375

376 The tension between this timeless structure and our experience of temporal evolution is
377 known as the “problem of time.” To restore time, it must be reconstructed internally from

378 within the framework—but it is not immediately clear how this reconstruction should
379 proceed.

380 One way to begin evaluating this situation from the standpoint of the CPT model is to
381 consider the time emerging from space in the model involving the electron as carrying
382 vacuum energy toward the particle, to be borrowed by it to create a field of virtual photons,
383 which allows the particle to engage in an electromagnetic interaction. The time leading
384 back to space carries energy away from the electron, in essence paying the energy back to
385 the vacuum. Time is being viewed here as a parameter—in this instance, as a variable that
386 indexes the evolution of energy flow.

387 This borrowing and paying back of energy in relation to time evolution is a kind of
388 visualization of the Heisenberg uncertainty principle, which permits transient, but
389 unobservable, deviations from energy conservation. The concept of “borrowing energy”
390 reflects a virtual energy contribution to the system, instantiating no observable excitation
391 or change in the electron’s properties. The rapid “payback” reflects the energy conservation
392 that must ultimately be obeyed in any observation (Figure 8) [21]:

393

$$394 \quad \Delta E \Delta t \gtrsim \frac{\hbar}{2} \quad (12)$$

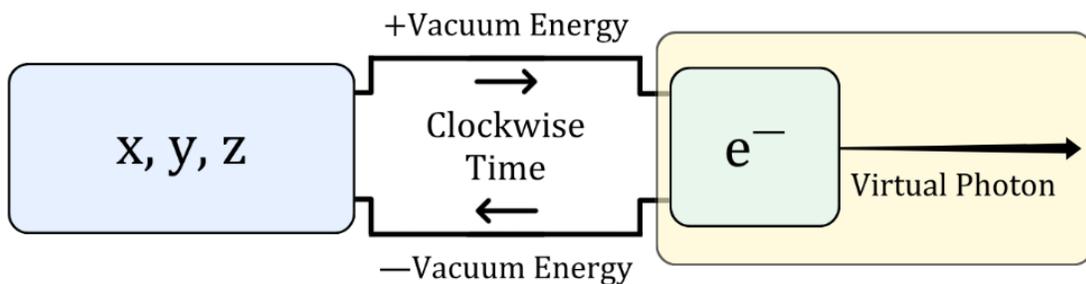
395 Heisenberg Uncertainty Principle

396 where,

397 ΔE is the range of possible energy values

398 Δt is the duration over which the energy is defined or measured

399 \hbar is the reduced Planck’s constant.



400
401 **Figure 8. A depiction of the Heisenberg uncertainty principle in the setting of an**
402 **extended version of the CPT model, here incorporating a virtual photon. Vacuum**

403 **energy is borrowed by the electron to create a field of virtual photons to drive an**
404 **electromagnetic interaction. Simultaneously, energy is paid back to the vacuum, with**
405 **both activities occurring through the progression of time—in the figure, the borrowing**
406 **and repayment is considered to be occurring by way of time’s fundamental flow. The**
407 **borrowed energy never manifests as an observable change in the electron’s state and**
408 **the virtual photons themselves have no measurable properties, representing merely a**
409 **“priming” of the vacuum (by way of the energy exchange) to activate its capacity to**
410 **mediate an electromagnetic interaction between two electrically charged particles.**

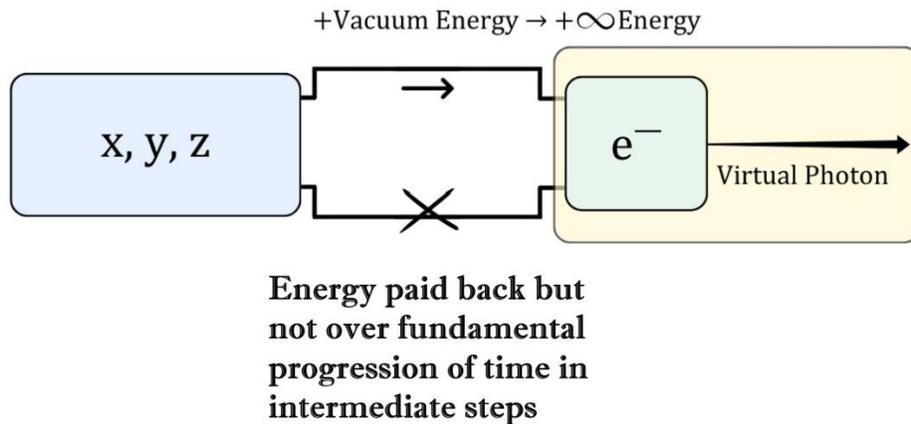
411 Notably, the units of energy borrowed and paid back as depicted in Figure 8 are not one and
412 the same—rather, as one unit of energy is extracted from the vacuum by the particle, a
413 different unit of energy is lost to the vacuum. Also in the figure, all of the activity is
414 occurring through the fundamental flow of time—that is, over smaller intervals than the
415 Planck time of about 10^{-44} s, which marks a theoretical limit below which current physical
416 models lose predictive power. Intervals smaller than this are still within the bounds of the
417 Heisenberg uncertainty principle, as it does not forbid arbitrarily small Δt values.

418 The virtual photons carry no detectable mass or energy and are not really particles. They
419 are more like a non-substantive “priming” of the vacuum to activate its capacity to mediate
420 an electromagnetic interaction between two electrically charged particles—to awaken the
421 latent connectivity between the particles through the vacuum. Not being real particles,
422 they do not require a source of energy the way real particles do, and they do not need to
423 obey energy conservation laws locally, as long as energy is conserved globally in all
424 observable interactions they mediate.

425 Despite being unobservable, the energy borrowed and paid back to the vacuum in relation
426 to this activity is nonetheless consequential. If the energy flow ceased or did not exist,
427 there would be no virtual photons, no priming of the vacuum between electrically charged
428 particles to allow them to engage in an electromagnetic interaction. Such interactions
429 would fundamentally break down. Thus, the presence of the energy, even if not detectable
430 physically, is particularly impactful, leading to real, measurable effects.

431 One problem in quantum mechanics is that despite initial and final states of an interaction
432 obeying conservation laws, the electron takes on infinite mass in intermediates steps
433 mathematically, which interferes with quantum mechanics’ predictive power. The infinite
434 mass arises from the electron constantly emitting and reabsorbing arbitrarily high-energy
435 virtual photons from its own electromagnetic field.

436 From the standpoint of the CPT model, the infinite mass is occurring because, while energy
 437 is borrowed and paid back quickly, it is not being done so through the fundamental
 438 progression of time in some intermediate steps of quantum mechanics. That is, for virtual
 439 photons to linger long enough to be emitted and reabsorbed, the borrowed energy that led
 440 to the photons' activation would also have to linger for a while. This lingering introduces an
 441 excess energy footprint beyond the idealized borrowing–repayment cycle. Any interval of
 442 time longer than a fundamental moment to pay energy back to the vacuum will ultimately
 443 result in the buildup of infinite energy (Figure 9).
 444



445
 446 **Figure 9. From the standpoint of the CPT model, the energy borrowed from the vacuum**
 447 **during intermediate steps in quantum mechanics is paid back quickly, but not by way**
 448 **of the fundamental progression of time. For virtual photons to linger long enough to be**
 449 **emitted and reabsorbed in quantum mechanics, the borrowed energy that led to the**
 450 **photons' activation would also have to linger for a while. This results in the electron**
 451 **eventually taking on infinite energy or mass, as energy is not returned to the vacuum**
 452 **as quickly as it is taken on.**

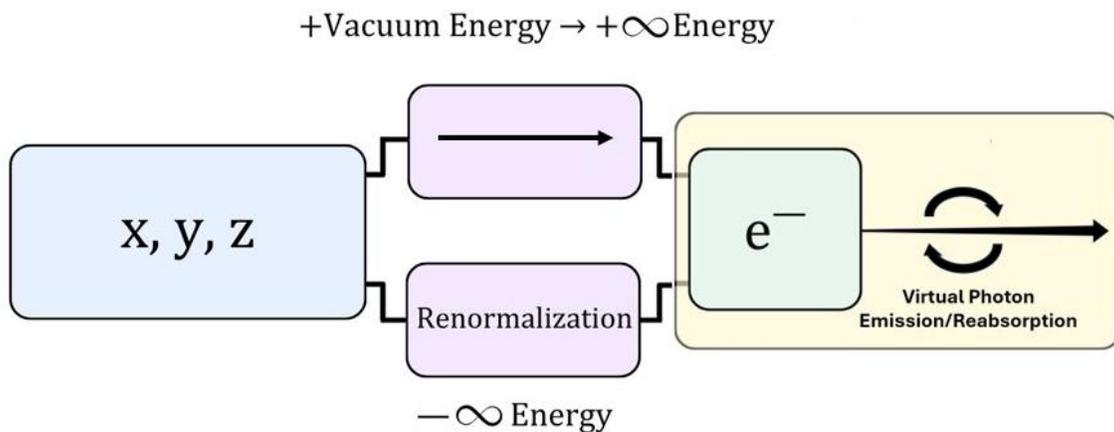
453 Leaving the top half of the model in Figure 9—the borrowing of vacuum energy through the
 454 fundamental progression of time—intact but removing the timeliness of the bottom half is
 455 like turning on the faucet of a tub filled with water but partially closing the tub's drain. While
 456 some water still exits the system (i.e., “is paid back”), the sheer volume of water flowing
 457 from the faucet eventually overwhelms the partially closed drain, leading to flooding, or in
 458 this case, an infinite energy result for the electron.

459 As long as the drain remains fully open and functional, and the rate by which water enters
 460 the tub matches the rate by which it exits, an infinite amount of water could theoretically
 461 flow through the tub of water without any water ever spilling over the top. All that would
 462 remain from moment to moment is a constant volume of water in the vessel. Similarly, an

463 infinite amount of energy could theoretically flow through the electron without issue, as
464 long as the energy is returned in the same timely manner, leaving nothing but a constant
465 energy level (i.e., rest mass) from moment to moment.

466 In quantum mechanics, the process of renormalization is needed to mathematically,
467 eliminate the infinite energy problem—depicted in Figure 10 in relation to the model.[22–
468 24] It involves the use of negative counterterms to remove the infinities, restoring the
469 predictive power of quantum mechanics.

470

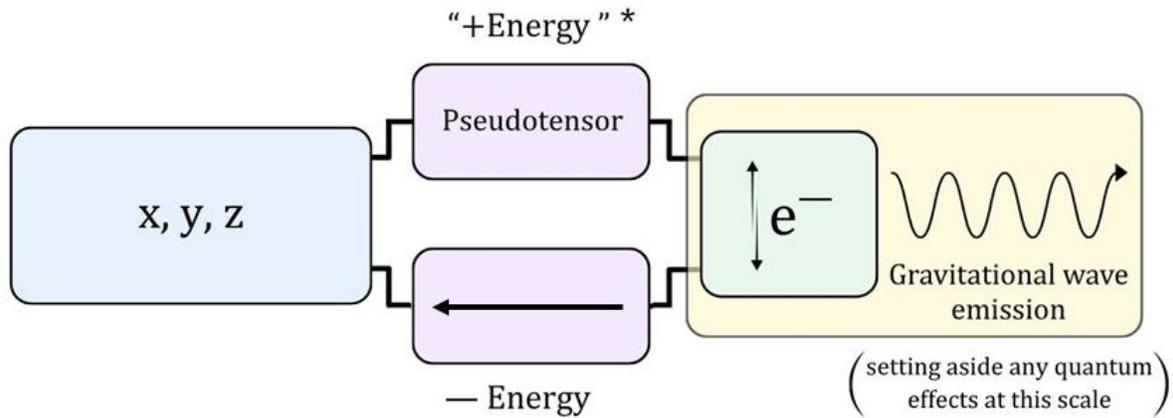


471

472 **Figure 10. Addition of the renormalization process to the CPT model to eliminate the**
473 **infinite energy problem.**

474 In contrast to the increase in energy over time in quantum mechanics, general relativity
475 predicts energy loss in systems such as binary stars through gravitational wave emission
476 and orbital decay. Such loss reflects the dynamic curvature of spacetime, where energy is
477 radiated away via changes in the spacetime curvature, which can be interpreted as a form
478 of vacuum energy. The loss of energy is accounted for in a time-dependent manner. Thus,
479 as in quantum mechanics, time here behaves like a parameter.[25–29] In this
480 circumstance, it could be said that general relativity focuses on the bottom half of the time
481 cycle in the CPT model. The stress-energy-momentum pseudotensor allows, at least
482 mathematically, for the conservation of the combined energy-momentum of matter,
483 radiation, and gravity (Figure 11).

484



* More of an accounting of the lost energy than an addition per se.

485
486

487 **Figure 11. In general relativity, gravitational wave emission and orbital decay reflect a**
 488 **decrease in system energy over time, as energy is radiated away through dynamic**
 489 **changes in spacetime geometry. In this setting, general relativity focuses on the**
 490 **bottom half of the time cycle in the CPT model. The loss of energy is accounted for by**
 491 **the stress-energy-momentum pseudotensor—a mathematical tool that makes the**
 492 **conservation of the combined energy-momentum of matter, radiation, and gravity**
 493 **expressible.**

494

495 Without a pseudotensor, there would be no way to formally account for the energy loss.
 496 Revisiting the tub analogy, it is like the drain being fully open, but the faucet turned off. If
 497 the system is left alone, the water would gradually vanish, but without a way to measure
 498 the outflow. Similarly, with no pseudotensor, energy would appear to dissipate without a
 499 measurable flux. The pseudotensor behaves like a “catch basin” beneath the drain. The
 500 catch basin does not block the drain, but collects the water as it exits, allowing for the
 501 quantification of its outflow over time. That is, the pseudotensor operates as a
 502 mathematical retention scaffold—a way to retain and integrate energy flux across
 503 spacetime. Thus, in a sense, the pseudotensor collects the energy that vanished and adds
 504 it back to the system, but only for accounting purposes.

505

506 As suggested in the model, the gravitational dynamics are driven by negative energy (energy
 507 being returned to the vacuum). Gravitational field energy is typically considered to be
 508 negative; it takes positive energy to separate masses. As two bodies approach one another
 509 under mutual gravitational attraction, the system’s total energy decreases — that is, the net
 510 energy becomes more negative. This decrease reflects a redistribution of energy into the
 511 spacetime curvature. This redistribution in the setting of two bodies gravitating is also

512 tracked using an energy–momentum pseudotensor, again operating as a mathematical
513 retention scaffold for energy-accounting purposes.

514

515 From the standpoint of parallelism in the setting of the tub analogy, it is as if quantum
516 mechanics has the faucet *open* and the drain “effectively” *closed*, leading to flooding.
517 “Effectively” is used here because water (energy) is technically being drained away (paid
518 back), but given the flooding that results (infinite energy), the drain might as well have been
519 fully closed. There is no appreciable difference in the flooding/infinite energy outcome.
520 Conversely, general relativity has the faucet *closed* and the drain fully *open*, leading to the
521 draining away or vanishing of the water/energy.

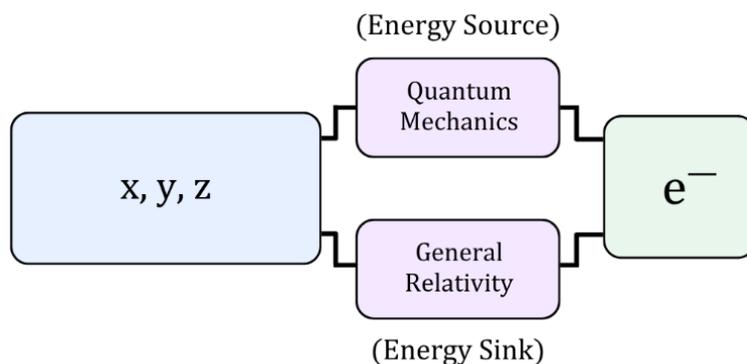
522

523 In neither case is energy cycling through the system as one continuous loop through the
524 fundamental progression of time. Quantum mechanics and general relativity both force the
525 mathematical usage of energy outside of time’s fundamental flow in the description of their
526 dynamics. Doing so has the benefit of making the energy visible long enough within the
527 theories to be used mathematically to create an effect or to take account of dynamics.

528

529 When the theories are united within the CPT model, the structural presence of general
530 relativity obviates the need for renormalization in quantum mechanics, while the structural
531 presence of quantum mechanics obviates the need for a pseudotensor in general
532 relativity—reflecting the exclusion of these adjustment mechanisms in the ADM formalism
533 of canonical quantization, which yields the Wheeler–DeWitt equation (Figure12). (Note that
534 this is not suggesting an overlap of the specific examples provided in Figures 10 and 11,
535 namely virtual photon activation and gravitational wave emission, but rather a general
536 overlap of the associated flows of energy in each case.)

537



Total net vacuum energy = 0

538

539 **Figure 12. In a unified framework, the structural presence of general relativity**
540 **suppresses the need for renormalization in quantum mechanics, while the structural**
541 **presence of quantum mechanics suppresses the need for a pseudotensor in general**
542 **relativity. The total net energy of the vacuum from the union of quantum mechanics**
543 **and general relativity becomes zero, as the positive energy of quantum systems**
544 **(energy source) is balanced by the negative gravitational field energy (energy sink).**
545 **This balanced-energy state gives the appearance of no external time parameter being**
546 **possible within the combined framework.**

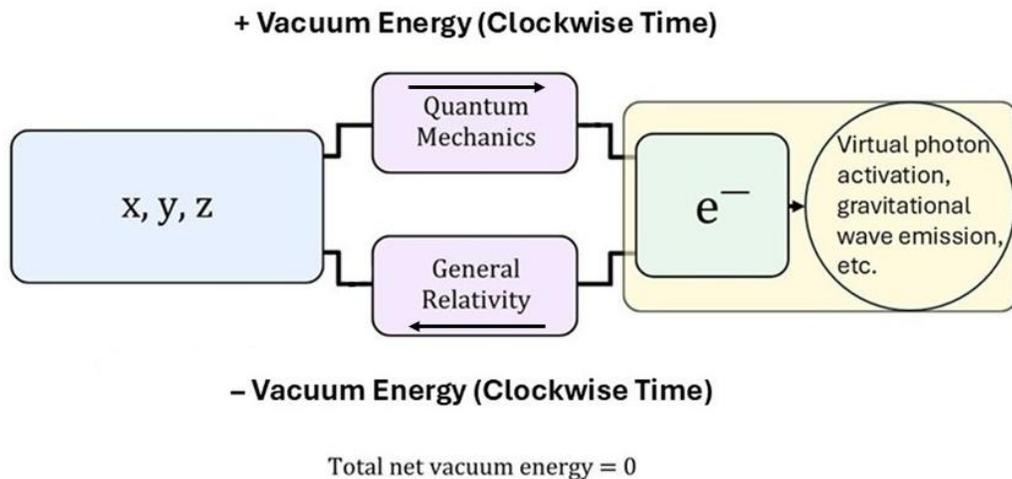
547
548 In this setting, the positive energy of quantum fields is balanced by the negative energy of
549 the gravitational field. Quantum mechanics becomes an “energy source,” and general
550 relativity becomes an “energy sink,” leaving a net-zero value for the total energy in the
551 vacuum—there appears to be no net change in energy from moment to moment. In this
552 state, their energy flows are forced back into alignment with the fundamental flow of time.
553 Within the bounds of time’s fundamental flow, no amount of energy is existing over any
554 perceptible or mathematically resolvable interval within the Planck-scale limits.

555
556 As time as an external parameter is tied to such energy changes, with no discernible
557 changes, it vanishes from the mathematics of the combined quantum mechanics–general
558 relativity framework, leading to the Wheeler-DeWitt equation and a seemingly frozen or
559 static condition for the universe. With the external parameter sidelined, the question then
560 becomes whether or not the flow of time is recoverable internally.

561
562 Here, the CPT model offers an advantage by permitting the visualization of internal
563 dynamics diagrammatically, describing energy changes that do not currently manifest
564 mathematically. The model not only helps to show why a static appearance to the universe
565 would arise from the combination of quantum mechanics and general relativity, as
566 described above, but in so doing, also emphasizes that the dynamic processes underlying
567 the seemingly static state condition continue to occur in the background, sustaining that
568 state. There exists no conceptual, mathematical, or physical mechanism by which the flow
569 in either quantum mechanics or general relativity would be nullified or arrested. The energy
570 flow consistently upheld in the theories (continuing to lead to the causal outcomes to
571 which it is tied) mandates its continuity in any coherent synthesis of the two frameworks.

572
573 Within the unified system, the energy flow itself then serves to signify the passage of time.
574 Although a necessity, the shift in focus from an external time parameter to this internal
575 energy flow as representative of time’s progression also offers a more accurate
576 representation of reality. Whereas time as an external parameter lacks physical

577 instantiation, the energy flow within quantum mechanics and general relativity provides a
 578 physically grounded correlate of time evolution. This is because the flow exhibits
 579 directional structure and causal efficacy (e.g., resulting in electromagnetic interactions).
 580 As such, it acquires ontological status, not as a detectable, measurable entity, but as an
 581 independent, causally efficacious, structural property of the vacuum. Thus, even with the
 582 lack of an external time parameter, time continues to evolve internally in relation to this
 583 energy flow, and this activity is able to be captured within the CPT model (Figure 13).
 584



585

586 **Figure 13. The CPT model suggests that time is flowing in the background of a**
 587 **combined quantum mechanics–general relativity system, despite no external time**
 588 **parameter. Here, the flow of time stems from the continued energetic activity within**
 589 **quantum mechanics and general relativity, given the ontological status of the energy**
 590 **flow in each of them.**

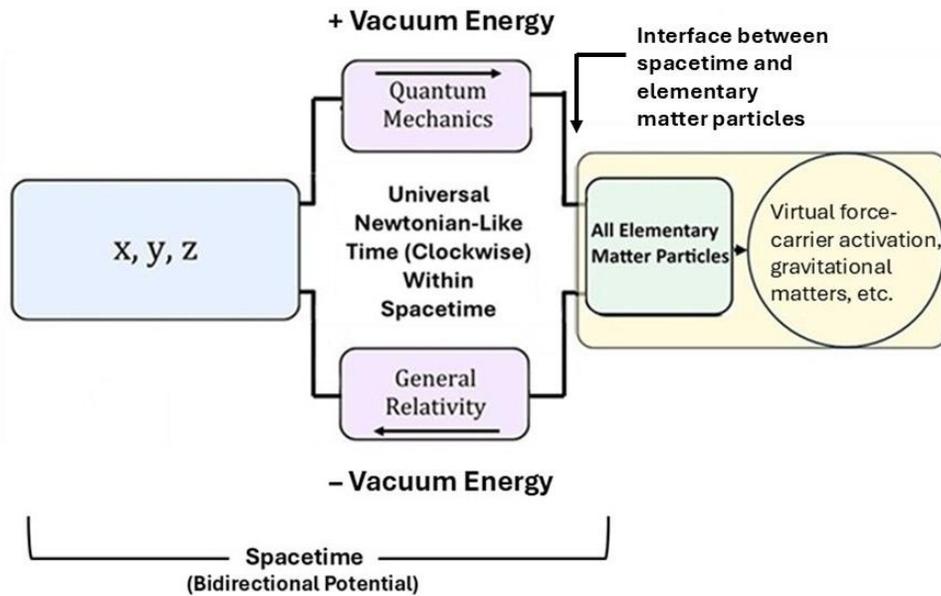
591

592 Thus, the CPT model enables a visual reconstruction of temporal flow within the ostensibly
 593 timeless Wheeler–DeWitt structure, tracing its emergence to ontological internal energy
 594 dynamics that, while conceptually defined, currently lack formal mathematical expression
 595 as a manifestation of time’s fundamental flow. By illuminating how time can arise within
 596 the timeless universal state, the model addresses a central challenge in canonical
 597 quantum gravity. That is, for nearly 60 years, the Wheeler–DeWitt equation has posed a
 598 formidable obstacle to unifying quantum mechanics and general relativity. The model
 599 offers the first meaningful step beyond this mathematical impasse, potentially opening
 600 new pathways for theoretical progress.

601

602 Interestingly, taking the ontological status of the energy flow in quantum mechanics and
 603 general relativity as foundational, this flow in relation to the full set of elementary matter
 604 particles throughout the universe necessarily induces a directional bias for time across the
 605 global spacetime field—as another manifestation of the reconstruction of time within the
 606 seemingly timeless universe of the Wheeler-DeWitt equation. This flow becomes a
 607 universal time parameter—like phenomenon operating in the background of all of
 608 spacetime—a Newtonian-like time. Arguably, this is the true replacement of the defunct
 609 external time parameter, as it spans all of spacetime as a statistical effect from the
 610 ensemble of elementary particles (Figure 14).

611



612
 613

614 **Figure 14. A Newtonian-like time in the setting of spacetime in the CPT model. While**
 615 **the time of spacetime continues to have the potential to flow in either direction**
 616 **(clockwise, counterclockwise), the overall energetic flow from the combined activities**
 617 **of quantum mechanics and general relativity in relation to all elementary matter**
 618 **particles throughout the universe creates a global directional bias for time,**
 619 **manifesting as a universal Newtonian-like time (clockwise), flowing underneath the**
 620 **smooth “surface” of spacetime.**

621 However, despite its universal nature, the true value of this global time parameter in any
 622 given moment is unknowable. For any one person to know it, the individual would need to
 623 know the state of every particle throughout spacetime at once, which is an impossible task,
 624 particularly given states of probability concerning position and momentum, as well as

625 issues associated with relativity. There is no universal “now” that all could agree on.
626 However, the phenomenon can be regarded as the default time parameter for the universe.

627 In this view, Newton’s and Einstein’s versions of time do not appear to be incompatible;
628 they appear to be complementary. This union too might assist in efforts to unite quantum
629 mechanics and general relativity.

630 **Conclusion**

631 A model of CPT is presented above that may have utility in various contexts involving
632 physical phenomena. As one example, the model helps to show how the time of retarded
633 and advanced waves is likely the same kind of basic time experienced by electrons and
634 positrons in the context of CPT. The basic time of these particles has no direct influence on
635 causality—and thus similarly, the basic time of retarded and advanced waves also would
636 have no direct effect on causality. This is consistent with the fact that causality is not a
637 fundamental aspect of Maxwell’s wave equations—causality is only imposed upon the
638 equations. This ultimately leads to the possibility that both retarded waves and advanced
639 waves are real. The current practice of discarding advanced wave solutions as unreal—as
640 was done with positrons in the past—may not be the most appropriate approach, at least
641 in theoretical studies, as it could be masking critical information.

642 Although electrons and positrons provide the clearest, unadulterated view of basic time,
643 other particles, including composite particles, likely experience this form of time as well—if
644 only in combination with thermodynamic time. As such, it might be of benefit to reevaluate
645 some equations or systems describing physical phenomena to ensure that the “kind of
646 time” involved is clear. That is, they might be connected to thermodynamic time, basic
647 time, or some combination of the two. Thermodynamic time should not necessarily be
648 assumed to be involved in a given case, with basic time appearing to be in effect in some
649 aspects of CPT, Maxwell’s equations, and the Wheeler-DeWitt equation. Indeed, viewing
650 the combination of quantum mechanics and general relativity through the lens of an
651 electron’s basic time assists in seeing the flow of time or the evolution of the universe even
652 with no external time parameter and the overall appearance of timelessness. It also
653 appears to help in understanding how Einstein’s spacetime and Newton’s time, or a
654 Newtonian-like time, overlap.

655 While the presented model may help to clarify and unify different time concepts, more
656 study is needed to understand the physical interface between the vacuum and elementary
657 particles such as an electron. At issue is what actual physical effect is the vacuum having
658 on the electron that influences the particle’s experience with time, and what does it mean

659 for a given elementary particle to have an internal clock? The answers to these questions
660 will be important for understanding quantum gravity.

661

662 **Appendix: Exploring Time-Symmetry and Causality in Electromagnetism**

663 A critical limitation among several direct-action theories—which aim to describe
664 electromagnetic interactions in a time-symmetric way—is their implicit assumption that
665 retarded and advanced waves can exert causal influence independently. This not only
666 leads to the possibility of retrocausality, but also to an emitter’s field having the potential to
667 act back on itself, resulting for example in an infinite energy state within the theories.[9–12]
668 One of the principal solutions has been to treat the universe as a “perfect absorber.” Here,
669 the collective set of charged particles throughout the universe co-generate a time-
670 symmetric field through mutual interaction with an emitter’s time-symmetric field. An
671 advanced wave from the universe cancels the advanced wave at the emitter’s location. A
672 retarded wave from the universe reinforces the emitter’s retarded wave at a distant point,
673 suppressing self-action. This one-to-one, perfect absorber operation removes the
674 possibility of retrocausality and ensures that there is no radiation available for self-action.
675 If the global absorber activity is not exactly tuned, the direct-action framework would break
676 down. The existence of such fine-tuning on a cosmic scale, to the point of perfect absorber
677 activity, seems doubtful in nature.

678

679 However, as discussed in the sections above, retarded and advanced waves likely have no
680 direct effect on causality—and causality is not fundamentally built into Maxwell’s
681 equations. As such, a more appropriate course for describing an electromagnetic
682 interaction by way of a time-symmetric exchange would be to separate causal efficacy
683 from mere wave existence and instead link it to interaction dynamics. In this framework,
684 retarded and advanced waves are real and carry causal information (e.g., energy,
685 momentum), but neither carries any causal agency by itself. They become causally
686 meaningful only when both emitter and absorber contribute in both time directions—in a
687 sort of “lock and key” dynamic. That is, the full causal loop—involving emission,
688 propagation, absorption, and response—would only emerge when both the emitter and
689 absorber fields are present and symmetrically paired.

690

691 In one such scenario, an emitter sends a retarded wave and an advanced wave toward an
692 absorber. The absorber sends an advanced wave and a retarded wave back. The fields are
693 independent. The emitter does not require the absorber to radiate, nor does the absorber
694 require the emitter to respond. The fields carry causal information but lack causal agency
695 unless matched. Equation (A1) expresses a decomposition of the total field into its

696 constituent retarded and advanced components associated with the emitter and the
697 absorber:

698
699 where,

- 700 • $F_{ret}^{(E)}$ is the retarded field from the emitter
- 701 • $F_{adv}^{(E)}$ is the advanced field from the emitter
- 702 • $F_{ret}^{(A)}$ is the retarded field from the absorber
- 703 • $F_{adv}^{(A)}$ is the advanced field from the absorber

$$704$$
$$705 \quad F(x) = \frac{1}{2} \left[F_{ret}^{(E)}(x) + F_{adv}^{(E)}(x) + F_{ret}^{(A)}(x) + F_{adv}^{(A)}(x) \right] \quad (A1)$$
$$706$$

707 where, $F(x)$ is the total field at spacetime point x . This is a time-symmetric superposition,
708 where each source contributes both wave types, and the physical field is the sum of all
709 paired contributions. The factor of one-half ensures that no single field component is
710 causally adequate on its own. Causality occurs through matched pair interactions as
711 follows:

$$712$$
$$713 \quad F_{pair}(x) = \frac{1}{2} \left[F_{ret}^{(E)}(x) + F_{adv}^{(A)}(x) \right] + \frac{1}{2} \left[F_{ret}^{(A)}(x) + F_{adv}^{(E)}(x) \right] \quad (A2)$$
$$714$$

715 This formulation preserves time symmetry, ensures field independence, and enforces
716 causality locally by way of the constructive interference of retarded and advanced wave
717 pairs from the emitter and absorber. It represents the smallest unit of causal closure (a
718 minimum emitter-absorber loop), but is generalizable to a multi-pair array, and can support
719 partial coherence (i.e., causal activation conditions), and probabilistic absorption.

720 In this context, the emitter's field does not act back on itself when simply propagating
721 through spacetime because engagement with an absorber's field is required to effectuate
722 any physical outcome. That is, causality arises only from retarded-advanced matched
723 pairs, thereby suppressing self-action and avoiding infinities. Only upon pairing is the
724 causal information encoded within the retarded and advanced waves unlocked to produce
725 physical effects (e.g., energy transfer), with the effects occurring in accordance with the
726 thermodynamic arrow of time. Here, the time symmetry between the retarded and
727 advanced waves gives rise to an asymmetrical, causal outcome.

728

729 In some cases, there is no overt absorber to complete the emitter-absorber interaction.
730 However, the absorber in question could be the vacuum generally, by way of field
731 fluctuations, virtual particle-antiparticle pairs, and/or a statistical effect from an ensemble
732 of possible states (i.e., a collection of many potential absorbers such as particles, atoms,
733 or molecules spread out over spacetime). This pairwise, causal activation can generally be
734 expressed as follows:

$$737 \quad F_{pair}(x) = \frac{1}{2} \left[F_{ret}^{(E)}(x) + F_{adv}^{(V)}(x) \right] + \frac{1}{2} \left[F_{ret}^{(V)}(x) + F_{adv}^{(E)}(x) \right] \quad (A3)$$

738
739 Here, $F^{(E)}$ denotes the emitter's field and $F^{(V)}$ the vacuum's conditional response. Thus,
740 what appears to be self-action in quantum mechanics, leading to such effects as the Lamb
741 shift and anomalous magnetic moment, which require renormalization, is here, emergent
742 effects from near-field interactions with vacuum modes acting as statistical absorbers.
743 Rather than invoking an electron acting upon itself, these corrections arise from a
744 balanced, bidirectional structure reflective of Maxwell's wave solutions. From this
745 perspective, it would be impossible for an electron to reabsorb its own photons because
746 the electron cannot act as both the emitter and absorber at the same time. Ironically, from
747 this view, while the universal absorber is used to avoid electron self-action in the direct-
748 action theories, the vacuum absorber here helps to create the effect attributed to self-
749 action.

750 More study is needed regarding time-symmetric approaches to describing an
751 electromagnetic interaction, the Lamb shift, the anomalous magnetic moment, and
752 related phenomena. What is clear now, however, is that, in accordance with Maxwell's
753 equations, both retarded and advanced waves are real and carry no causal significance by
754 themselves.

755 The practice of disregarding advanced waves as unreal is similar to the former practice of
756 disregarding positrons as unreal, until experimental confirmation of the existence of the
757 particles. Much information about how the physical universe works would be currently
758 unknown if positrons were still considered to be unreal. Likewise, critical information about
759 the universe could be missing today by considering advanced waves to be unreal.

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813 **Author Contribution Statement**

814 Lamont Williams wrote the content of the article and conceptualized all artwork.

815 **Data Availability**

816 All data from this study are publicly available.

817 **Additional Information**

818 The author declares no competing interests.

819 The author declares a potential financial interest: I am the author of a commercially
820 available book published in 2010 that addresses themes related to the paper:

821 www.greatestsourceofenergy.com

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