A Brief History of Dual Universes

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A Comment on the The Institute of Art and Ideas (YouTube) post:
The reality behind spacetime | *Donald Hoffman* (Aug 19, 2023)
https://youtu.be/t_ZrwdSYu-A

@NotNecessarily-ip4vc, thanks. If you think mirror universes — the phrase "dual universes" may be more common — are relevant to how space and time emerge, yes, I could not agree more. However, I'm unaware of Professor Hoffman mentioning mirror universes in his Fusion [1] or other papers.

I've never encountered the idea that CPT symmetry [Wikipedia has a nice intro] violations were the source of dual-universe theories, nor have I encountered any mention of CPT symmetry violations in the earliest papers. The earliest, somewhat oblique variant of the idea seems to have been the oddly intermixed universes proposed in a remarkable and difficult-to-classify 1925 short book by William Sidis [2].

The first unambiguous invocation of dual universes I've ever found is a remarkable 2004 paper by Jennifer Chen and Sean Carroll [3]. I don't recall that one mentioning the parity violations issue. Checking now… That is correct: The Chen-Carroll paper does not mention parity or chirality. That paper is, in fact, notable for *ignoring* CPT violations in matter and antimatter and instead assuming they form a "perfect" time symmetry (they do not).

The second proposal of virtual-pair universes was mine in 2007 [4]. My approach was based entirely on CPT arguments using quaternions interpreted as pairs of independent four-dimensional rotations. Once interpreted as dual 4D spins, all sorts of simple but intriguing symmetries pop out of quaternions. Such symmetries fit with how Maxwell developed his electromagnetic equations solely using quaternions. (Heaviside's more compact vector equations, the ones we know, came much later. Remarkably, Heaviside gave full credit to Maxwell [5].) Fig. 1 shows a more recent (2022) elaboration of my 2007 dual universe concept, replacing Sir Roger Penrose's idea of Conformal Cyclic Cosmology scale loss of structure with a more virtual-particle-like return to null.

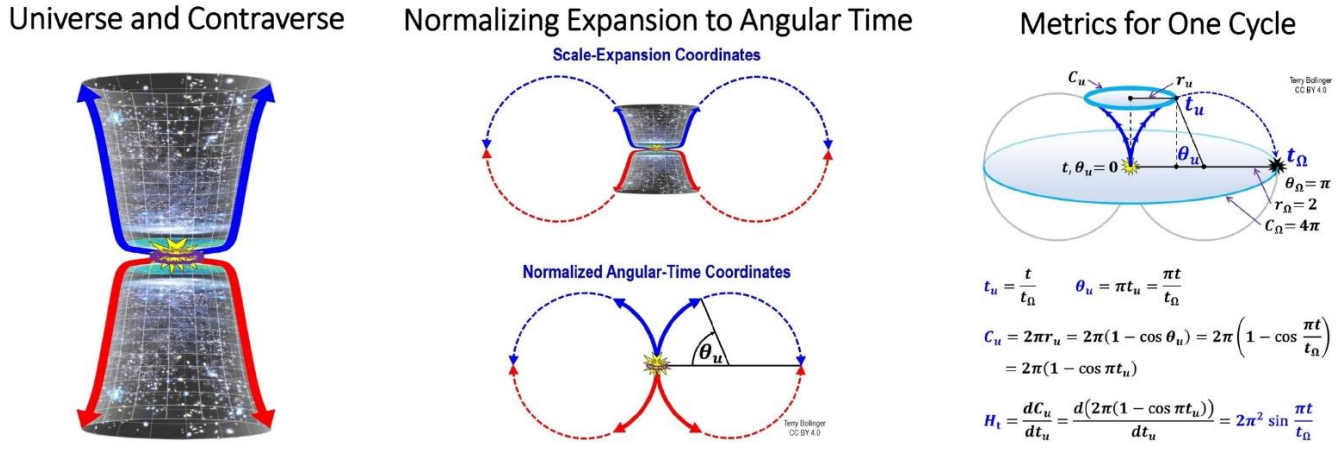

FIG. 1. Dual universes using a modified Penrose Conformal Cyclic Cosmology (CCC).

Despite the simplicity of the quaternion derivation, I recall how sharply the possibility of two time-symmetric universes traveling in opposite directions hit me as I sat in the bleachers at a local high school Friday American football game. What struck me then was not just how easily dual universes take care of the missing antimatter problem but how much cleaner and more symmetric it made the Big Bang, in multiple ways and at various scales. The not-quite symmetry of matter and antimatter no longer matters because what's in the other universe only *resembles* what we think of as antimatter. You wind up needing four kinds of matter, not just two, and the chirality you mentioned is the additional variable required to resolve this issue. I'll say more about the critical role of chirality at the end of this comment.

The next dual universe idea to pop up was Julian Barbour's 2014 argument [6] that such universe pairs arise from nothing more complicated than Newtonian N-body gravity dynamics constrained by a small set of "vanishing" (net zero) conserved quantities. Barbour references Gibbons and Ellis [7] for these constraints, including vanishing linear and angular momentum. These two are rock-solid and well-described by Gibbons and Ellis's work. Unfortunately, the third Barbour constraint, "vanishing energy," is *not* in the Gibbons and Ellis work. Vanishing energy violates all known physics at classical scales since our universe requires the total mass and energy in any non-quantum-scale region of space to be *positive,* not zero.

This constraint subtly creates a universe in which the particles have negative mass and the other half positive mass. What is happening is that the two universes are sorting themselves out gravitationally based on whether a given Newtonian particle has a positive or negative mass. For this reason, I usually don't mention the Barbour 2014 idea. It's too confusing to readers when the paper introduces the critical concept of negative energy as if it were a standard constraint of Newtonian dynamics instead of clearly stating that vanishing energy is not part of any standard physics textbook.

However, I have no problem with Barbour introducing negative energy as an *explicit* hypothesis. It turns out that creating symmetric entities that cancel to null rather than to positive energy is required to develop a CPT-symmetric universe pair. Virtual particle pairs also collapse to null energy. One way to understand CPT-symmetric universe pairs thus is as virtual particle pairs on a delightfully cosmic scale, stabilized into long-term persistence by the widespread emergence of the strikingly complicated three-part wave operator we so casually call "time."

The next flurry of dual universe papers began in 2018 [8] with an excellent and ongoing [9] set of CPT-focused dual-universe papers by Perimeter Institute physicists Latham Boyle and Neil Turok. Their close attention to the CPT symmetry issue is why I steer interested folks toward these much later papers. However, CPT-aware or not, the 2004 Chen and Carroll paper first captured the need for a "virtual pair" concept of dual universes arising in the location we now consider the "Big Bang."

My only fault with these papers is that they must address the negative energy issue squarely. They also try a bit too hard to make the sterile neutrino — the ordinary neutrino of our partner universe — into an explanation for dark matter. Maybe there's a way to do it, but I haven't found that part particularly persuasive. They need to address the negative energy issue first.

Even more importantly — and quite counterintuitively, including for me in 2007 — there's a strong argument that all dual-universe approaches need to recognize negative energy fermions as *intrinsic parts of our universe,* not just the constituents of our contraverse.

But that seems inherently preposterous! Wouldn't the existence of large quantities of negative-mass antimatter in our universe be even worse than antimatter? Contact between matter and contra-matter within our universe would not just convert both to energy but return that region to empty space. Moreover, it would make the net gravitational curvature of our universe flat if the two are in equal portions — although, as in inflationary models, achieving almost flat space is not such a bad thing overall. (And for those aware of the model: I am not using Dirac's powerful but ratty infinitely-filled sea-of-states model. Again, think of virtual particles returning to null. It's a cleaner symmetry.)

So, what are these negative-mass particles hiding in plain sight in our universe? They are the weak-blind chiralities of matter and antimatter, the right-handed matter fermions, and the left-handed antimatter fermions, which cannot see the weak force. And yes, I just said that every particle accelerator has been working directly or indirectly with negative-mass particles without realizing it. These weak-force-blind versions of fermions cannot precisely see the weak force because they are too busy traveling backward to devour the past in a fashion delightfully reminiscent of (and just as thorough as) Stephen King's Langoliers.

But if both chiralities are abundant in both universes — with the conspicuous exception of neutrinos, which are universe-specific — then what is the difference between us and our contraverse partner? (I should mention that I prefer my own constructed and collision-checked word "contraverse" over antiverse, which makes folks think it's full of antimatter when it's full instead of the negative-mass almost-equivalent of antimatter.)

The difference is that our universe has tiny excesses of the positive-mass chiralities, while our contraverse contains slight excesses of the negative-mass chiralities. The interactions of these minute excesses with their opposite chiralities become the foundation for classical time and mass, the latter being because the Higgs boson "commutes" between the two chiralities. You can find some colorful figures on these and related ideas here [10], but I've still not gotten around to writing the surrounding text. You can read more about the fascinating relationship between the color force and time here [11].

But how does all of this fit with Professor Hoffman's emergent space and time goals?

I would have started with something other than duality. The bigger problem is the deeply entrenched mathematical belief that the world is a superposition of infinitely precise universes, as captured in its most extreme form by the Everett many-worlds. What's going on is that the universe must work *hard* to create local rough approximations of infinitely precise xyzt coordinates. We call those entities "inertial frames," and that's the real reason they all have identical xyzt physics: They are creating their own. That's also the deeper source of twin paradoxes since you cannot just jump willy-nilly from one local frame to another without paying a gate cost.

References

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