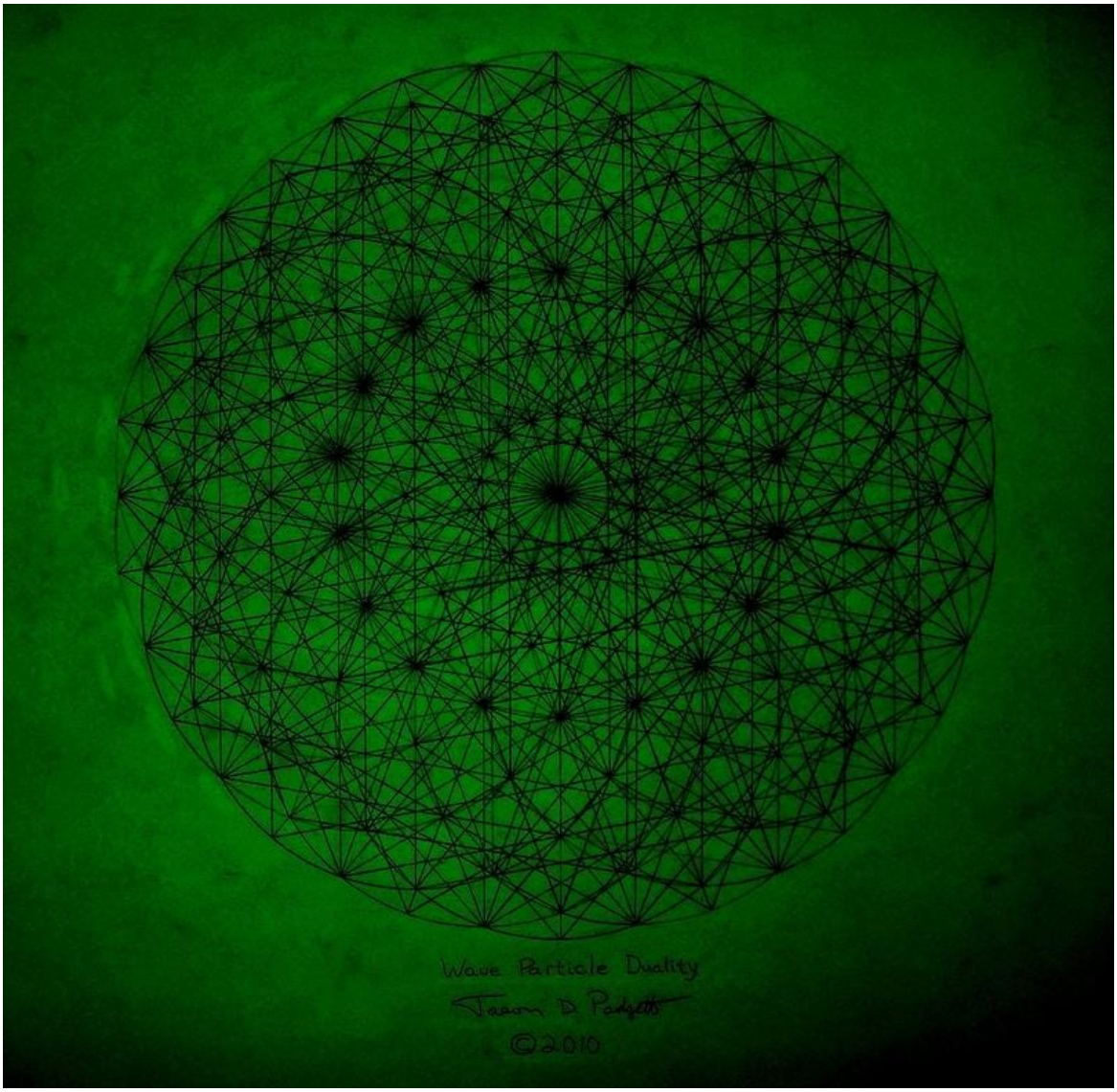
Wave-Particle Duality? What's the Big Deal?

by Lev Tsitrin (February 2025)



Wave Particle Duality II (Jason Padgett, 2010)

There are several ways in which certain scientific topics are beyond my mental grasp. A notion of field seems incomprehensible to my essentially mechanical way of thinking that comprehends action only as resulting from direct pushing

or pulling. When one magnet chases another one away without ever coming into contact with it or, when turned around, makes that other magnet rush towards it from a distance, it completely stumps me. The seeming magic of "action at a distance" paralyzes my ability to internalize the cause called a "field" (though interestingly, I noticed when reading Wikipedia's "field" article that even professional scientists find it hard to be just aloofly mathematical about it, declaring that in a physical sense a field is just what it is, and leaving it at that—instead, they come up with mechanical, contact-based visualizations like "virtual particles" that presumably push magnets apart, or "exchange particles" that bring them together. I am not alone feeling helpless without visualize-able mechanical props!)

The other kind of mental stupor results from not comprehending the seemingly-adequate scientific explanations—especially those based on the denial of causality, which by their very nature reject a notion of a "because." Much of subatomic, quantum physics that is statistics, rather than causality-based, falls under that category.

And finally, there is a type of incomprehension that could be labeled as "so what's the big deal?"

The discovery of a particle-wave duality, waves behaving like particles (like in the photoelectric effect, electromagnetic waves knocking electrons out of metal as if they were particles, or a jet of electrons shot through a slit winding up not just behind its openings, but veering off to the presumably shielded, side areas, exhibiting wave-like behavior called diffraction) falls under this category.

What I cannot understand is why this is being treated as some momentous, almost counterintuitive phenomenon. Aren't, in our macro, mechanical world, all waves really nothing more but moving particles which some triggering event—a rock thrown into a pond, or a picked string of a guitar—sets off into

wave-like motion? Water and air are composed of particles but—under triggering stimulus—behave like waves, producing widening circles on water, or music. Something as routine as speech, an activity in which we are near-constantly engaged, is triggered by the action of a tongue, and is detected by ear—and is conveyed by particles of air moving in wave pattern. And, of course, wave can act as a particle—producing, in a case of a tsunami, a devastating effect.

Examples can be multiplied, and extended to humans. A unit of soldiers goose-stepping at a parade behaves as a particle; yet the same unit ordered to charge an enemy position but encountering an obstacle—a trench, or barbed wire—will exhibit a wave-like behavior. Troops will concentrate in front of the obstacle as soldiers coming from behind start pressing upon those that were ahead, now stalled by the obstructing object, forming a wave's peak of density—to be followed by a valley when the obstacle gets cleared enabling the first line of soldiers to rush forward. It is not for nothing that military reporters talk in terms of "waves of attack." And having defeated the enemy, the unit will parade as a single particle, yet again—at least those in it who managed to survive the war.

Put simply, it is circumstances that determine the pattern of movement, be it particle-like or wave-like, rather than some ineluctable and puzzling fundamentals of nature. In the absence of a triggering event waves or particles will behave one way—but once triggered, in another; this is what we see every day (save for the tsunamis, thankfully). A rock thrown into a pond is a triggering event. Ditto a war. Ditto a metal plate obstructing the path of electromagnetic waves. Ditto a barrier with slits put in front of a stream of electrons. (In fact, I wonder whether the latter experiment has been tried in a macro world: put a barrier with a slit in front of a machine-gunner's target and shoot rounds of munitions across that barrier. Wouldn't a certain percentage of bullets ricochet off the edges of the slit, winding up in the

supposedly blind zone behind the barrier, thus displaying the diffraction effect—and proving that bullets can behave like waves, too? Or put very differently—does the electron diffraction experiment really prove that electrons behave like waves—or only that they do so when thusly experimented on? The latter would render the conclusion made by the experimenters at best moot, and at worst (i.e. if there are no natural circumstances that replicate the conditions of the experiment) wrong? It is of course impossible to give an answer one way or the other—but the question illustrates the fact that it is really a circumstance of the presence (or the absence) of a trigger that determines the mode of behavior of a particle or wave.)

This is the other way of saying that there really is no duality—it is either one pattern of behavior or the other, but not both at the same time—either particle or wave. A Dr. Jekill is never Mr. Hyde. A Mr. Hyde is never a Dr. Jekill. What is there to saw "wow!" to?

It is of course entirely possible that I entirely misunderstood the whole subject—thus creating the forth category of my incomprehension of science—i.e. thinking that I understand something when in fact I don't. That would perhaps be the most interesting category of all, because while Socrates observed that "I only know that I know nothing," I won't be able to make even that, seemingly absolutely minimalist statement. I guess he should have said "while I think that I know some things, that knowledge may not be correct." This is a much more satisfactory statement—and fully applies to my understanding of the wave-matter duality (and for that matter, to all other things I think I understand.) Well, getting Socrates corrected is not a bad outcome of a reflection on a physical phenomenon, whether understood adequately or not!

But as to my present state of understanding—admittedly potentially inadequate—my answer to the grand puzzle of the

wave-particle duality is—duh!

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