Quantum Entanglements and Hauntological Relations of Inheritance: Dis/continuities, SpaceTime Enfoldings, and Justice-to-Come

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Abstract

How much of philosophical, scientific, and political thought is caught up with the idea of continuity? What if it were otherwise? This paper experiments with the disruption of continuity. The reader is invited to participate in a performance of spacetime (re)configurings that are more akin to how electrons experience the world than any journey narrated though rhetorical forms that presume actors move along trajectories across a stage of spacetime (often called history). The electron is here invoked as our host, an interesting body to inhabit (not in order to inspire contemplation of flat-footed analogies between 'macro' and 'micro' worlds, concepts that already presume a given spatial scale), but a way of thinking with and through dis/continuity – a dis/orienting experience of the dis/jointedness of time and space, entanglements of here and there, now and then, that is, a ghostly sense of dis/continuity, a *quantum dis/continuity*. There is no overarching sense of temporality, of continuity, in place. Each scene diffracts various temporalities within and across the field of spacetimemattering. Scenes never rest, but are reconfigured within, dispersed across, and threaded through one another. The hope is that what comes across in this dis/jointed movement is a felt sense of différance, of *intra-activity*, of

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agential separability – differentiatings that cut together/apart – that is the hauntological nature of quantum entanglements.

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> If I am getting ready to speak at length about ghosts,
> inheritance, and generations, generations of ghosts,
> which is to say about certain *others* who are not present,
> nor presently living, either to us, in us, or outside us,
> it is in the name of *justice* . . . . It is necessary
> to speak *of the* ghost, indeed *to the* ghost and *with* it.
>
> —Derrida (1994, xix)

> As in *Hamlet*, the Prince of a rotten State, everything
> begins by the apparition of a specter.
>
> —Derrida (1994, 4)

Act 1. Scene 1. *Visitations: Elsinore by Way of Copenhagen*

SpaceTime Coordinates: Elsinore, by way of Copenhagen. 1941 [a mysterious and risky visit by German physicist Werner Heisenberg (Nobel laureate, inventor of quantum uncertainty, head of the German bomb project under the Nazis) to Danish physicist Niels Bohr (Nobel laureate, inventor of quantum indeterminacy, founder and director of the famous physics institute in Copenhagen, Jewish by ancestry) in Nazi-occupied Denmark at the height of Nazi domination during WWII]/ diffracted through 1998 [Michael Frayn's Tony Award-winning play *Copenhagen;* a ghostly play about science, politics, ethics, responsibility, and uncertainty]/ diffracted through 1927 [key year in the development of quantum physics]/ diffracted through 1945 [August 6: U.S. drops atom bomb on Hiroshima; August 9: U.S. drops atom bomb on Nagasaki]/ the darkness inside the human soul . . .

> On the dark stage, under a very dim light, the ghosts, dressed in grey, business-like attire, keep playing out the events of one night in 1941 when Heisenberg, then working for his home country of Germany, visited Niels Bohr, who was living in occupied Denmark . . . . Like the ghost, foretold by the opening question of *Hamlet*, [the ghostly reiterative (re)enactments of] Heisenberg's visit [mark] the spectral voice of justice. (Hennessey 2008)

Margrethe. But why?

Bohr. You're still thinking about it?

Margarethe. Why did he come to Copenhagen?

Bohr. Does it matter, my love, now we're all three of us dead and gone?

Margrethe. Some questions remain long after their owners have died. Lingering like ghosts. Looking for the answers they never found in life.

. . .

Heisenberg You remember Elsinore? The darkness inside the human soul . . . ?

Bohr. And out we go. Out under the autumn trees. Through the blacked out streets.

Heisenberg. Now there's no one in the world except Bohr and the invisible other. Who is he, this all-enveloping presence in the darkness?

Margrethe. The flying particle wanders the darkness, no one knows where. It's here, it's there, it's everywhere and nowhere.

Bohr. With careful casualness he begins to ask the question he's prepared.

Heisenberg. Does one as a physicist have the moral right to work on the practical exploitation of atomic energy?

Margrethe. The great collision.

(Frayn 2000, 3; 87–88)

An explosive end to the great friendship of two of the twentieth-century's greatest scientists, Werner Heisenberg and Niels Bohr, authors of the 'Copenhagen interpretation' of quantum physics. Why did Heisenberg go to Copenhagen, in the midst of the war to see his old friend Niels Bohr? Did Heisenberg hope to find out what Bohr knew about the Allied bomb project? Did he come to warn Bohr about the German bomb project to reassure him that he was doing everything in his power to stall it? Did he want to see if he could persuade Bohr to take advantage of their status as authorities on atomic physics to convince the Axis and Allied powers to abandon their efforts to build atomic weapons? Did he hope to gain some important insight from his mentor about physics, or ethics, or the relationship between the two?

Speculation. Specularity. Spectrality.

Science and justice, matter and meaning are not separate elements that intersect now and again. They are inextricably fused together, and no event, no matter how energetic, can tear them asunder. They cannot be dissociated, not by chemical processing, or centrifuge, or nuclear blast.

'Does one as a physicist have the moral right to work on the practical exploitation of atomic energy?' Heisenberg's haunting question to Bohr

hangs in the air throughout *Copenhagen* (Frayn 2000), enfolded into the making of spacetime, its reverberations returning again, for the first time.

Act 1. Scene 1. *Diffracting Events, Entanglements, Ghostly Matters*

SpaceTime Coordinates: Reiteration/ Reconfiguration/ Returning for the first time, again / 1941 [Copenhagen] / diffracted through 1998 [*Copenhagen*] / diffracted through 1927 [Copenhagen, Niels Bohr Institute: a monumental year in the development of quantum physics; major disagreements emerge between Bohr and Heisenberg concerning the interpretation of quantum physics] / diffracted through 1990's [diffraction experiments – *gedanken* experiments (thought experiments, laboratories of the mind) made flesh – quantum erasers, quantum entanglements, and possibilities for changing the past] / diffracted through 2007 [*Meeting the Universe Halfway*: meditation on quantum physics; entanglements of matter and meaning; diffraction as synecdoche of entangled phenomenon, intra-active meta/physics, différance; diffraction as methodology: reading texts intra-actively through one another, enacting new patterns of engagement, attending to how exclusions matter] / diffracted through 1994 [*Specters of Marx*] / diffracted through 1600 [*Hamlet*] / diffracted through 1848 [*Communist Manifesto*, materialism] / diffracted through 1687 [Newton's *Principia,* classical understandings of matter and the void, Aethers, Spirits] / diffracted through 2060 [Newton's prediction for the end of time, derived not from his deterministic laws of physics, but from biblical prophesising, calculation, anti-speculative speculating, a speculation to end all speculations] / diffracted through 1703 [Newton's *Opticks*, spectrality] / diffracted through 1912 [Bohr's Nobel Prize winning explanation of atomic spectra, origins undone, queer causality, spectrality] / diffracted through 1935 [Schrödinger's cat – a feline entangled with a radioactive atom is in a superposition state of alive and dead . . . still?] / diffracted through 1945 [dropping of atomic bombs on Hiroshima and Nagasaki; cities populated with the living dead; a ghostly/ghastly scene; hauntings] / . . . / war time / science time / spacetime / imaginary time / mythic time / story time / inherited time / a time to be born / a time to die / out of time / short on time / experimental time / now / before / to-come / . . . threaded through one another, knotted, spliced, fractured, each moment a hologram, but never whole . . . Time is out of joint, off its hinges, spooked.

This 'beginning', like all beginnings, is always already threaded through with anticipation of where it is going but will never simply reach and of a past that has yet to come. It is not merely that the future and the past are not 'there' and never sit still, but that the present is not simply here-now. Multiply heterogeneous iterations all: past, present, and future, not in a relation of linear unfolding, but threaded through one another in a nonlinear enfolding of spacetimemattering, a topology that defies any suggestion of a smooth continuous manifold.

Time is out of joint. Dispersed. Diffracted. Time is diffracted through itself.

It is not only the nature of time in its disjointedness that is at stake, but also *disjointedness itself*. Indeed, the nature of 'dis' and 'jointedness', of discontinuity and continuity, of difference and entanglement, and their im/possible interrelationships are at issue.

This paper is about joins and disjoins – cutting together/apart – not separate consecutive activities, but a single event that is not one. *Intra-action*, not interaction.[1]

Center stage: the relationship of continuity and discontinuity, not one of negative opposition, but of im/possibilities.

An experiment. I've attempted to write this paper in a way that disrupts the conventions of historical narrative forms that underlie stories of scientific progress: tales of the continuous accretion and refinement of scientific knowledge over the course of history, sagas of progress from an earlier time period to a later one punctuated with discoveries that lead the way out of the swamp of ignorance and uncertainty to the bedrock of solid and certain knowledge. In an effort to disrupt this kind of narrative (and not only this), I aim to provide the reader with an opportunity to engage in an imaginative journey that is akin to how electrons experience the world: that is, a dis/orienting experience of the dis/jointedness of time and space, entanglements of here and there, now and then, a ghostly sense of dis/continuity, a *quantum dis/continuity*, which is neither fully discontinuous with continuity or even fully continuous with discontinuity, and in any case, surely not one with itself. There is no overarching sense of temporality, of continuity, in place. The position and time of the reader is not assumed to be contemporaneous with here-now. The scenes are neither discontinuous nor continuous with one another (or themselves). (They are not wholly separate, nor parts of a whole.) There is no smooth temporal (or spatial) topology connecting beginning and end. Each scene diffracts various temporalities, iteratively differentiating and entangling, within and across, the field of spacetimemattering. Scenes never rest but

are reconfigured within and are dispersed across and threaded through one another. Multiple entanglements, differences cutting through and re-splicing one another. The reader should feel free to jump from any scene to another (is there any other way to proceed?) and still have a sense of connectivity through the traces of variously entangled threads and of the (re)workings of mutual constitution and unending iterative reconfigurings (of sections, reader, writer, ideas, . . .). My hope is that what comes across in this dis/jointed movement is a felt sense of différance, of *intra-activity*, of *agential separability – differentiatings that cut together/apart – that is the hauntological nature of quantum entanglements*.[2]

Act E_{nlm}. Scene $E_{n'l'm'}$. Quantum Spectrality: 'Fits, Passions and Paroxysms'

SpaceTime Coordinates: indeterminate, untimely.

Center stage: change, movement, causal forces, fits, paroxysms, and paradoxes.

> Enter the ghost, exit the ghost, re-enter the ghost. (From *Hamlet*, quoted in Derrida 1994, xx)
>
> I find the idea quite intolerable that an electron exposed to radiation should choose of its own free will, not only its moment to jump off, but also its direction. In that case, I would rather be a cobbler, or even an employee in a gaming house, than a physicist. (Albert Einstein, quoted in Shapiro and Epstein 2006, 228)

Particles are given to fits, to paroxysms, to spasmodic bouts of e-motion or activity. According to classical physics, mechanical forces alone move particles, or so it has been said.[3] What queer quantum attribution, what strange agency, do we have here? What is this talk of fits, passions, and paroxysms of inanimate entities? Passion-at-a-distance no less?[4]

There seemed to be something queer about the quantum from the beginning. Or rather, it became evident from the start that the quantum causes trouble for the very notion of 'from the beginning'.

1912: Niels Bohr proposes the first quantum model of matter (i.e, the atom).

Bohr's inheritance: The planetary model of the model of the atom – electrons orbiting the nucleus like planets orbit the sun. A debt he owes to his teacher Ernst Rutherford. The planetary model has drawbacks: an orbiting electron would continuously radiate away its

energy, giving off a continuous spectrum of light while it quickly spirals into the nucleus. Atoms wouldn't be stable. No small matter.

Other inheritances: In 1900, Planck proposes the quantisation of energy. Energy is exchanged in discrete packets, not continuously. In 1905, Einstein proposes that light itself is quantised. He wins the Nobel Prize for his 'crazy idea' of the photon (light quantum), not for relativity.

Bohr's idea: The nucleus remains at the atom's center, but electrons don't *orbit* the nucleus (*pace* Rutherford). Rather, each electron *resides* in one of a finite set of discrete/quantised energy levels, and atoms only emit photons when their electrons 'jump' from one level to another. In particular, when an electron jumps from a higher energy state to a lower one it emits a photon whose colour/frequency is determined by the size of the jump, i.e., the change in energy. In this way, there is no continuous draining away of the electron's energy and no continuous spectrum of light emitted. Hence, atoms are stable and each kind of atom (of the more than 100 kinds listed in the periodic table) emits a unique discrete 'line spectrum'. The hydrogen atom, for example, emits only four primary lines: red, light blue, dark blue, and violet.

The model's predictions match the experimental results for hydrogen! The calculation works. A Nobel Prize is awarded to Bohr. Atoms – the uncuttable ones – have parts after all (*pace* Democritus), but at least now matter is stable, again.

A tidy little mechanism? A simple causal explanation for the existence of matter that accounts for its spectral qualities. Nice. But not so fast . . .

Specters abound. The very process by which a single line in the atomic spectrum is produced is spooked. Each spectral line is the result of an electron making a *quantum leap* from a higher energy level to a lower energy level. But what precisely is the nature of this 'leap'?

Quantum signifies the 'smallest possible, and therefore indivisible, unit of a given quantity or quantifiable phenomenon' (*Wiktionary*). It is a measure of *the discreteness of nature*. Unlike any ordinary experience of jumping or leaping, when an electron makes a quantum leap it does so in a discontinuous fashion (belying the very notion of a 'leap', classically and colloquially speaking). In particular, the electron is initially at one energy level and then it is at another *without having been anywhere in between*. Talk about ghostly matters! A quantum leap is a dis/continuous movement, and not just any discontinuous movement, but a particularly queer kind that troubles the very dichotomy between discontinuity and continuity. Indeed, *quantum dis/continuity* troubles the very notion of *dicho-tomy* – the cutting into two – itself (including the notion of 'itself'!). All this 'quantum weirdness' (the display of an increasing

array of uncanny phenomena) is actually 'quantum *queerness*,' and I don't mean simply strange. Q is for queer – the un/doing of identity. *Quantum dis/continuity* is at the crux of this im/possible, im/passible, trans/formation.

A closer examination brings the spectral quality of this process to light. Initially, the electron is in some higher energy state E_2, and then in some lower energy state E_1. At what point is the photon emitted? On Rutherford's classical physics account, an atomic electron can have a continuous range of energy values, changing its orbit continuously in time: as the electron circles around the nucleus it continuously loses energy as it spirals inwards all the while continuously emitting light. (The colour or frequency of the light changes with changes in electron energy). By contrast, on Bohr's quantum account, an atomic electron can only occupy a discrete set of energy levels, and light is emitted in a small packet, that is, *all at once as a photon* of the appropriate colour/frequency to match the energy change. That is, the leap of the electron and the corresponding emission of the photon must happen *at some moment in time* (in order for energy to be conserved at all times). But there's the rub! On close examination one sees that the situation is quite spectacular. When the electron is in a given energy state, either E_1 or E_2, it can't emit a photon because there is no energy change involved and so there is no energy to make a photon. The photon is a result of the leap itself. But at what point during this leap is the photon emitted? Well, the emission of the photon can't take place when the electron is on its way from E_2 to E_1 because *it is never anywhere in between.* And furthermore, something is deeply remiss about the nature of causality, for if the atom were to emit a photon of a given colour as the electron leaves E_2 *it will have had to already wind up where it was going (i.e., E_1) before it left* so that a photon that has the proper colour/frequency (needed to conserve energy) would be emitted. A queer causality indeed! As we can now see, *the paradoxical nature of quantum causality derives from the very existence of a quantum dis/continuity in the cutting together/apart that is the nature of all intra-actions.*

Let's pause to consider the quantum dis/continuity further. This discontinuity that queers our presumptions of continuity is neither the opposite of the continuous, nor continuous with it. Quantum 'leaps' are not mere displacements in space through time, not from here-now to there-then, not when it is the rupture itself that helps constitute the here's and now's, and not once and for all. The point is not merely that something is here-now and there-then without every having been anywhere in between, it's that here-now, there-then have become

unmoored – there's no given place or time for them to be. Where and when do quantum leaps happen? Furthermore, if the nature of causality is troubled to such a degree that effect does not simply follow cause end-over-end in an unfolding of existence through time, if there is in fact no before and after by which to order cause and effect, has causality been arrested in its tracks?

This strange quantum causality entails the disruption of discontinuity/continuity, a disruption so destabilising, so downright dizzying, that it is difficult to believe that it is that which makes for the stability of existence itself. Or rather, to put it a bit more precisely, if the indeterminate nature of existence by its nature teeters on the cusp of stability and instability, of possibility and impossibility, then the dynamic relationality between continuity and discontinuity is crucial to the open ended becoming of the world which resists acausality as much as determinism.

I don't want to make too much of a little thing, but the quantum, this tiny disjuncture that exists in neither space nor time, torques the very nature of the relation between continuity and discontinuity to such a degree that the nature of change changes with each *intra-action*. Change, to the extent that any general characterisation can be given, is a dynamism that operates at an entirely different level of existence from that of postulated brute matter situated in space and time (e.g., existence is not simply a manifold of being that evolves in space and time); rather, what comes to be and is immediately reconfigured entails an iterative intra-active becoming of spacetimemattering.

Quantum dis/continuity is the un/doing. (Even un/doing itself, as well as the notion of itself.) Even its appellation is at once redundant and contradictory: a smallest unit, *a discontinuous bit . . . of discontinuity*. 'Quantum', 'discontinuity' – each designation marking a disruption, bringing us up short, disrupting us, disrupting itself, stopping short before getting to the next one. A rupture of the discontinuous? A disrupted disruption? A stutter? A repetition not of what comes before, or after, but a disruption of before/after. A cut that is itself cross-cut. A cut raised to a higher power forever repeating. A passable impassability. (An irresolvable internal contradiction, a logical disjunction, an im-passe (from the Latin *a-poria*), but one that can't contain that which it would hold back. Porosity is not necessary for quantum tunneling – a specifically quantum event, a means of getting through, without getting over, without burrowing through. Tunneling makes mincemeat of closure, no w/holes are needed.) A possible impossibility, an impossible possibility. An ontological im/probability. Identity undone by a discontinuity at

the heart of matter itself. What spooky matter is this, this *quantum discontinuity*?

Act t_0. Scene t_∞. *Newtonian Inheritance*

SpaceTime coordinates: Universal time. No time. 1687 [Newton's *Principia*] diffracted through 1814 [Laplace's demon – the hero of a thought experiment, a clever chap who stops time, gathers information about the whereabouts and instantaneous movements of every particle, making for a complete data set which when plugged into Newton's equation gives Man his ultimate wish of complete knowability]. All time is calculable, laid out, the entirety of the past, of all that lays behind us, and the entirety of the future, of all that is before us, starting with but one moment, any moment, all moments made equal . . . All time in no time at all.

How much of our understanding of the nature of change has been and continues to be caught up in the notion of continuity? For Newton, physicist extraordinaire, inventor of the calculus, author of biblical prophesies, uniter of heaven and earth, continuity was everything.

It gave him the calculus. And the calculus gave voice to his vision of a deterministic world: placing knowledge of the future and past, in its entirety, at Man's feet. Prediction, retrodiction. Time reversal, time universal. Man's for the asking. The price but a slim investment in what is happening in an instant, any instant. Determinism rules. Nature is a clockwork, a machine, a windup toy the Omniscient One started up at time $t = 0$ and then even He lost interest in and abandoned, or perhaps remembers now and again and drops in to do a little tuning up. The universe is a tidy affair.

The presumed radical disjuncture between continuity and discontinuity is the gateway to Man's stewardship, giving him full knowability and control over nature. Calculus is revealed as the escape hatch through which Man can take flight from his own finitude. Man's reward: a God's eye view of the universe, the universal viewpoint, the escape from perspective, with all the rights and privileges accorded therein. Vision that goes right to the heart of matter, unmediated sight, knowledge without end, without responsibility. Individuals with inherent properties there for the knowing, there for the taking. Matter is discrete, time is continuous. Place knows its place. Time too has its place. Nature and culture are split by this continuity, and objectivity is secured as externality. We know this story well, its written into our bones, in many ways we inhabit it and it inhabits us.

And yet, Newtonian inheritance is not one but many. No unity can hold, not from within or without, when restless spirits walk the night.

Act $\int$ Scene Ψ. *Learning Spirits: Indeterminacy, Quantum Superpositions, Quantum Entanglements*

SpaceTime Coordinates: undecidable spacetimes, superposition of here/there-now/then, 1935 [Erwin Schrödinger's paper on quantum measurement, almost no one remembers any of it except for the one paragraph on the cat] diffracted through, entangled with . . . times past and times to come.

> If it – learning to live – remains to be done, it can happen only between life and death. Neither in life nor in death *alone*. What happens between the two, and between all the 'two's' one likes, such as between life and death, can only *maintain itself* with some ghosts, can only *talk with or about* some ghost. So it would be necessary to learn spirits. (Derrida 1994, xviii)

A cat caught in a superposition of alive and dead. An awkward affair. A ghostly/ghastly position. Its fate entangled with an atomic critter – a radioactive atom, a small bit of matter ruled by probabilities (forget about the impossibility of the metaphor). The famous Schrödinger's cat experiment: a Rube Goldberg-style machine, coupling a radioactive atom to a Geiger counter to a hammer to a bottle of poison to the fate of the cat.

What has driven Schrödinger to such perverse lengths? He's trying to make a point about measurement and he understands that the kind of sympathy we muster for cats, we don't seem to have for electrons or photons, or any of the critters that populate the world of the nonliving. A world perhaps more densely populated than on first thought, if one includes the undead, that is, all matter of spooks. Although it's worth noting that the line between the living and that which has never lived is, after all, one of the most hardfast, most sacrosanct disjunctures of them all.

What does it mean for the cat's fate to be entangled with that of an atom? If the atom decays, the cat dies; if the atom doesn't decay, the cat lives. But the atom's fate is indeterminate, in 'a superposition of having decayed and having not decayed'. Correspondingly, due to their entanglement, the cat is 'in a superposition of alive and dead'! Our sympathy clicks in! Outrageous! What? How can this be? It's one thing for an atom to be in a superposition of decayed and not decayed, but cats are either alive or dead – period. And Schrödinger would be the first to

agree, but only after the state of the cat is observed. Before it is observed, *there is no determinate fact of the matter* about its condition.

Once more, a bit more slowly. What is meant by 'superposition'? A *quantum superposition* is a nonclassical relation among different possibilities. In this case, the superposition of 'alive' and 'dead' entails the following: it is not the case that the cat is either alive or dead and that we simply do not know which; nor that the cat is both alive and dead simultaneously (this possibility is logically excluded since 'alive' and 'dead' are understood to be mutually exclusive states); nor that the cat is partly alive and partly dead (presumably 'dead' and 'alive' are understood to be all or nothing states of affair); nor that the cat is in a definitive state of being not alive and not dead (in which case it presumably wouldn't qualify as a (once) living being). Quantum superpositions radically undo classical notions of identity and being (which ground the various incorrect interpretative options just considered). Quantum superpositions (at least on Bohr's account) tell us that being/becoming is an indeterminate matter: there simply *is not a determinate fact of the matter* concerning the cat's state of being alive or dead. It is a ghostly matter! But the really spooky issue is what happens to a quantum superposition when a measurement is made and we find the cat definitively alive or dead, one or the other. By what law of the universe does such an occurrence happen? How can we understand this 'collapse'–or rather, resolution–of an ontological/hauntological indeterminacy into a determinate state? Not by following Schrödinger's equation. Perhaps not by any calculable means whatsoever.

Quantum entanglements are generalised quantum superpositions, more than one, no more than one, impossible to count. They are far more ghostly than the colloquial sense of 'entanglement' suggests. *Quantum entanglements* are not the intertwining of two (or more) states/entities/events, but a calling into question of the very nature of two-ness, and ultimately of one-ness as well. Duality, unity, multiplicity, being are undone. 'Between' will never be the same. One is too few, two is too many. No wonder quantum entanglements defy commonsense notions of communication 'between' entities 'separated' by arbitrarily large spaces and times. Quantum entanglements require/inspire a new sense of a-count-ability, a new arithmetic, a new calculus of response-ability.

> 'Spooky action at a distance' is how Albert Einstein famously derided the concept of quantum entanglement–where objects [in such a state] instantaneously influence one another regardless of distance. Now researchers

> suggest that this spooky action in a way might work even beyond the grave, with its effects felt after the link between objects is broken . . . memories of entanglements can survive its destruction. (Choi 2009, 24)

Entanglements of here, there, now, then. Entanglements between one side of the Danube and the other, and between La Palma and Tenerife in the Canary Islands.[5] Between Elsinore and Copenhagen. Between Newton's time and the twenty-first century. Between life and death.

Act p. Scene q. *Bohr's Hauntology*

SpaceTime Coordinates: Copenhagen, between war times, ghostly times.

> To haunt does not mean to be present, and it is necessary to introduce haunting into the very construction of a concept. Of every concept, beginning with the concepts of being and time. That is what we would be calling here a hauntology. Ontology opposes it only in a movement of exorcism. Ontology is a conjuration. (Derrida 1994, 161)
>
> *This condition of possibility of the event is also its condition of impossibility* . . . without this experience of the impossible, one might as well give up on both justice and the event. (Derrida 1994, 65)

It's quite uncanny. During the early years of the twentieth century evidence came to light that light is . . . well, it behaves like a particle (after all – the position Newton advocated) . . . except when it behaves like a wave (as James Clerk Maxwell, Thomas Young, and others helped to demonstrate convincingly in the nineteenth century). And matter, it most definitely behaves like a particle, . . . well, except when it behaves like a wave. What nonsense is this? Has science lost its mind, gone mad? Waves and particles are ontologically distinct kinds: waves are extended disturbances that can overlap and move through one another; particles are localised entities that singly occupy a given position in space one moment at a time. Light can't simply just *be* a wave *and* a particle, extended *and* localised.

So much for the solid confidence, the assured certainty, the bedrock consistency of science, at the brink of a new century. It was not merely that new empirical evidence concerning the nature of light seemed to contradict the established view, but during the first quarter of the twentieth century, it became increasingly difficult to understand how *any* consistent understanding of the nature of light could be possible.

Desperate to make sense of all this, Bohr makes one of the strangest moves in the history of physics: he turns his attention to the question of . . . *language*! (A respectable move for a scholar in the humanities,

but what on earth is a physicist doing examining the nature of concept use and meaning making?!) Entertaining questions that most physicists wouldn't even see as questions Bohr asks: What do we *mean* by 'particle' or 'wave'? What are the conditions for the possibility for the meaningful use of these concepts? What is the nature of scientific concepts? What role do they play? How do they matter?

Bohr's unique contribution is this: he proposes that we understand *concepts* to *be specific material arrangements* of experimental apparatuses. (For example, an apparatus with fixed parts is needed to make the notion of 'position' intelligible; whereas an apparatus with moveable parts is needed for 'momentum' to be intelligible). Concepts are indeterminate outside of the appropriate material conditions needed to make them intelligible. Any particular experimental arrangement, which gives determinate meaning to a particular concept (for example, 'position') will, by necessity, always produce its constitutive exclusion (for example, 'momentum'), that is, an equally necessary, 'complementary' concept which is thereby left outside of the domain of intelligibility. That is, the contingent determination of the meaning of any concept necessarily entails constitutive exclusions. Every concept is haunted by its mutually constituted excluded other. This is what Bohr means by *Complementarity*.

On Bohr's account then, there is an intimate relationship between discourse and materiality that goes beyond the frequently repeated refrain that writing and speaking are material practices. Bohr argues that this materialist understanding of concepts, in combination with the empirical finding that there is a quantum discontinuity, undermines the notion of an inherent fixed (apparatus-independent, Cartesian) subject-object distinction. But this does not mean that there are no such distinctions. Rather, the material-discursive apparatus, in addition to giving meaning to specific concepts to the exclusion of others, also enacts a specific cut between 'observed' and 'agencies of observation'. There are no separately determinate individual entities that *interact* with one another; rather, the co-constitution of determinately bounded and propertied entities results from specific *intra-actions* (see endnote 1). That is, not only concepts but also boundaries and properties of objects become determinate, not forevermore, but rather, as an inseparable part of, what Bohr calls a *phenomenon – the inseparability (differentiated indivisibility) of 'object' and 'agencies of observation'*.

Concepts do not refer to the object of investigation. Rather, concepts in their material intra-activity enact the differentiated inseparability that *is* a phenomenon. In the absence of the intra-action there is no

determinate fact of the matter or any determinate way to describe it. Being is not simply present, there to be found, already given. There is no fixed essence or substance simply there for the measuring. Particles aren't inherently bounded and propertied entities running in the void. Mattering is about the (contingent and temporary) becoming-determinate (and becoming-indeterminate) of *matter and meaning*, without fixity, without closure. The conditions of possibility of mattering are also conditions of impossibility: intra-actions necessarily entail constitutive exclusions, which constitute an irreducible openness. Intra-actions are a highly non-classical causality, breaking open the binary of stale choices between determinism and free will, past and future.

Act x. Scene λ. *Diffractive Imaginings and Double Slit Experiments*

SpaceTime Coordinates: diffracted spatialities and diffracted temporalities, entangled 'across' space and time; past, present, future threaded through one another.

> To think the 'holding together' of the *disparate* itself. Not to maintain together the disparate, but to put ourselves there where the disparate itself holds together, without wounding the dis-jointure, the dispersion, or the difference, without effacing the heterogeneity of the other. (Derrida 1994, 29)
>
> Diffraction patterns record the history of interaction, interference, reinforcement, difference. Diffraction is about heterogeneous history, not about originals. Unlike reflections, diffractions do not displace the same elsewhere, in more or less distorted form, thereby giving rise to industries of metaphysics . . . Diffraction is a narrative, graphic, psychological, spiritual, and political technology for making consequential meanings. (Haraway 1997, 273)

Stage Left:

A ghost of Thomas Young and his famous two-slit experiment. The two-slit experiment – the grand identity filter, the perfect litmus test of the character of being, the greatest ontological sorting machine of all time. Thomas Young is lecturing. Sound waves from the two speakers set up at the front of the lecture hall form a sonic diffraction pattern so that alternately spaced conic sections of the audience can hear Young's voice with clarity while the others sit with quizzical looks not hearing a word and still others have their ears plugged because the sound is so loud as to be unbearable. The words come clearly to those who are well-placed:

> This can be demonstrated using a simple instrument which I call a *two-slit apparatus*. It's very simple really. It has just three parts: a device that is the source of the entity being tested, a barrier with two holes in it, and a screen placed some distance further back. Now, if you want to know if an entity is a wave or a particle you simply fire a bunch of them at the barrier with the two open slits. One of two patterns will appear on the screen. If most of the entities hitting the screen collect directly across from the slits the entity in question is a particle. On the other hand, if a distinctive pattern with alternating bands of intensity appears on the screen, the entity in question is a wave. Note that the pattern of alternating bands, or *diffraction pattern*, is similar to the wave pattern formed by overlapping disturbances when two stones are dropped simultaneously into a pond at a small distance from one another. In summary, my device – the two-slit apparatus – gives a sure-fire method of distinguishing waves from particles. In this way, it is possible to categorise all of nature as one kind or the other.

Some audience members clap when Mr. Young has finished. Others have already left in frustration and have asked for a refund of the ticket price. Someone notices that the remaining audience members form a pattern of bands radiating outwards from the stage. Interested in this phenomenon, she raises her hand, but Mr. Young has already disappeared.

Stage Right:

The lights go up on the house and reveal the ghosts of Einstein and Bohr pushing away from the craps table, where Einstein, with unchecked disdain in his voice, reports that some physicists claim they saw God playing there. Einstein has had enough. They mosey on over to another table and quickly fall into the groove of an old conversation.

The table in front of them sports a two-slit apparatus at the very center of their imaginations. They are performing *gedanken* or thought experiments with the two-slit apparatus. The stakes: nothing less than the nature of reality. Einstein is getting irate. Bohr insists that using a two-slit apparatus he can show that with one arrangement of the two-slit apparatus light behaves as a wave, and with a complementary arrangement light behaves as a particle. He explains that entities are not inherently 'wave' or 'particle', and that it is possible to produce wave and particle phenomena/behaviours/performances when the entity in question 'intra-acts' with the appropriate apparatus. Einstein picks up a large stack of chips, neatly arranges them in his hand, and confidently places them on the table. Bohr says he will bet against Einstein, but he keeps talking without laying down any determinate number of chips in any particular spot.

Both Bohr and Einstein agree that entities, like photons, atoms, and electrons, exhibit a diffraction pattern, characteristic of waves, when sent through a two-slit apparatus. What they disagree about is what would happen if the apparatus is modified in such a way that it would be possible to detect which slit a given entity had gone through on its way to the screen. Einstein, who rejects quantum theory and is committed to holding onto a classical ontology, argues that this experiment would catch the entity in the act of behaving like a particle at the slits and behaving like a wave at the screen – exposing the deficiencies of the quantum theory. Bohr adamantly disagrees. He argues that with the which-slit apparatus in place the entity would no longer behave as a wave – that there would no longer be a diffraction pattern on the screen. Bohr's exuberance is hard to contain as he explains that Einstein's which-slit experiment beautifully demonstrated his Principle of Complementarity according to which an entity *either* behaves like a wave *or* a particle *depending on how it is measured*. Einstein is losing his patience.

Heisenberg, seeming to come out of nowhere, slips in between them and remarks that he agrees with Bohr that the moment you try to reconfigure the apparatus to detect which slit it goes through you will disrupt the entity whose characteristics you set out to measure. The result will be that light will no longer behave as a wave, but rather a particle. Heisenberg sets off in another direction once he finishes. As he leaves Bohr shakes his head insisting that he and Heisenberg actually don't agreed at all. Bohr mumbles something about Heisenberg believing that the pattern changes because in the act of determining which slit it goes through the which-slit apparatus *disturbs* what would have happened in the absence of such a measurement. Einstein long ago stopped listening, but Bohr forges on. The point, he argues, is not that measurements disturb what is being measured but rather what is at issue is the very nature of the apparatus which enacts a cut between 'object' and 'agencies of observation', which does not exist prior to their intra-action – no such determinate features or boundaries are simply given. What results is an entanglement – a *phenomenon*. The performance of the measurement with an unmodified two-slit apparatus results in *a wave phenomenon*, while the measurement with a modified two-slit apparatus (with a which-slit detector) results in *a particle phenomenon*. There is no contradiction, Bohr insists. Classical metaphysics has misled us. Entities do not have an inherent fixed nature.

Einstein's reverie is broken by this last comment. Exasperated he asks, 'So what you are saying is that the very nature of the entity – its

ontology – changes with the experimental apparatus used to determine its nature? Or worse, that nothing is there before it is measured, as if measurements conjure things into existence?'

Act A. Scene Ω. *Inheriting the Future: Newton's End of Time*

SpaceTime Coordinates: The Apocalypse ≥ AD2060 (AD2060, or thereafter) [Newton's prediction for the end of time] diffracted through 2003 [discovery of Newton's seventeenth-century prediction/prophesy] diffracted through 17th century [Newton – the prophet, the seer of the future, the inventor of the calculus, the great calculator, the seer of the laws of nature that determine every event for all time – kills time for a second time].

> What does it mean to follow a ghost? And what if this came down to being followed by it, always, persecuted perhaps by the very chase we are leading? Here again what seems to be out in front, the future, comes back in advance from the past, from the back. (Derrida 1994, 10)
>
> Plus d'un [More than one/ No more one]: this can mean a crowd, . . . but also the less than one of pure and simple dispersion. (Derrida 1994, 3)

The end of time. We've heard this before, we hear it all the time. We inherit the future, not just the past.

Newton, the natural philosopher, had already done in time. His laws of physics always already make this pronouncement: in a deterministic universe there is no time – all events have already happened, time doesn't exist. The future has already happened. And yet, the Great Calculator makes a prediction to end all predictions. Newton, the theologian, the scholar of biblical prophesy, calculates the end of time. His prediction hidden away for a time not his own.

Biblical prophesy and natural philosophy, each engages in predictions. One prediction for the end of time is uncertain ('It may end later'), the other leaving absolutely no room for uncertainty, not a hair's breadth.

Biblical prophesy was surely more than an avocation for Newton; it was an invocation of spirits dis/continuous with his natural philosophy. Spirits took center stage in his natural philosophy, but not his theology. For Newton they were everything and nothing. Filling all space, then banished. Appearing and disappearing. They have a peculiar presence/absence throughout his work. A vanishing presence. A reappearing absence. Forever returning. Coming from the future as well as the past.

Newton the great natural philosopher, the first modern scientist, the greatest scientist of all time, the inventor of the calculus. Newton the

theologian, the devoted student of biblical prophesy, a devout non-trinitarian Christian. Newton, the Chosen One, the reader of the Great Clockwork, the one who could take one moment in time, any moment, and use his calculus to spread before the world the entire future and past. The prophet who could see the end of time. Newton the great empiricist, the great positivist, the great determinist, the great mechanist. All these honourifics left hanging as questions. All co-existing along with other ghosts of Newton that speak of the undoings of mechanism, determinism, positivism, scientism.

Superpositions, not oppositions. Physics has always been spooked.

Act ~~tr(A)~~. Scene tr(A). *Quantum 'Erasers': Thought Experiments Made Flesh, but Spooky Nonetheless*

SpaceTime Coordinates: untimely, no given space, no given time.

> The concern is 'not with horizons of modified – past or future – presents, but with a "past" that has never been present, and which never will be, whose future to come will never be a production or a reproduction in the form of presence'. (Derrida 1982, 21)
> *Phenomena* are never one, never merely situated in the present, here and now. Phenomena are quantum entanglements of intra-acting agencies. Crucially, intra-actions cut things together and apart – Barad.

Physicists now claim to have empirical evidence that it is possible not only to change the past, but to change the very nature of being itself . . . in the past.

Tunneling from the realm of imagination to the empirical world, from the laboratory of the mind to the laboratory of hard facts, from the 1930s to the 1990s, the two-slit apparatus at the center of the Bohr-Einstein debate is made flesh. New technological advances make it possible to actually do this great *thought* experiment *in the lab*. But much more than technological innovation is at issue. The way in which this experiment is designed is remarkable for its imaginative ingenuity as well, for this experiment is engineered to empirically test a difference in the *metaphysical* views of Bohr and Heisenberg. Experimental meta/physics! Empirical marks from the world beyond. A ghostly matter. The line between physics and metaphysics is undecidable/indeterminate.

Heisenberg understands measurements as disturbances that place a limit on knowability – that is, measurements entail epistemic uncertainties. Whereas, for Bohr, measurement is about the conditions for possibility of semantic and ontic determination – that is, indeterminacy.

So the disagreement between Bohr and Heisenberg has to do with what exists in the *absence* of a measurement. But how can one even begin to contemplate an experiment that tests what exists *before* a measurement takes place when the very act of experimenting always already entails measurement?

It turns out that there *is* a way to determine *empirically* which, if either, of the 'metaphysical' views of Bohr and Heisenberg has empirical support. The basic idea behind this ingeniously designed experiment is the following.[6] The key is to use the inner workings of the atom (that is, its 'internal degrees of freedom') to leave behind a telltale sign of which slit the atom passes through in a way that does not disturb its forward momentum (that is, its 'external degrees of freedom'). In particular, the experiment is designed in just such a way that an atomic *electron* is made to jump from a higher energy level to a lower energy level at just the right moment (thereby tinkering only with the atom's internal degrees of freedom) such that it leaves a telltale photon behind in one of the two containers placed adjacent to each of the two slits, while the atom continues on its way unaffected by this event.

The result? Unambiguous confirmation of Bohr's point of view: when a which-slit detector is introduced, the pattern does indeed change from a diffraction pattern to a scatter pattern, from wave behaviour to particle behaviour, and, crucially, this shift, *by design*, is *not* a result of a disturbance. This finding goes against both Heisenberg and Einstein's understandings, and strongly confirms Bohr's point of view, for it can be shown that the shift in pattern is the result of the *entanglement* of the 'object' and the 'agencies of observation'. That is, there is empirical evidence for Bohr's performative understanding of identity: Identity is not inherent (e.g., entities are not inherently either a wave or a particle), but rather 'it' is performed differently given different experimental circumstances.

Now, given the performative nature of identity, things get even more interesting, for if Bohr's hypothesis that phenomena are quantum entanglements (of 'objects' and 'agencies of observation') holds, then some (other) clearly impossible things become possible. Suppose that the which-slit detector is modified in such a way that the evidence of which slit the atom goes through (the existence of the tell-tale photon in one container or the other) can be erased *after* the atom has already gone through one of the slits. It turns out that if the which-slit information is 'erased' (that is, if any trace of which slit information is destroyed and the question of which-slit is once again undecidable), then a diffraction pattern characteristic of waves is once again in evidence (as in the case

without a which-slit detector)! This result is remarkable, but there's more. It turns out that it doesn't matter at what point the information is 'erased'—in particular, it could be erased *after* any given atom has already gone through the entire apparatus and made its mark on the screen, thereby contributing to the formation of the overall pattern!

This result is nothing less than astonishing. What this experiment tells us is that whether or not an entity goes through the apparatus as a wave or a particle can be determined *after* it has already gone through the apparatus, that is, *after it has already gone through as either a wave (through both slits at once) or a particle (through one slit or the other)*! In other words, it is not merely that the past behaviour of some given entity has been changed, as it were, but that the entities' very identity has been changed! *Its past identity, its ontology, is never fixed, it is always open to future reworkings!*

The physicists who proposed the quantum eraser experiment interpret these results as the possibility of 'changing the past'; they speak of the diffraction pattern as having been 'recovered' (as if the original pattern has returned) and the which-slit information having been 'erased'. But this interpretation is based upon assumptions that are being called into question by this very experiment, assumptions concerning the nature of being and time.

If one assumes a metaphysics of presence, that the pattern obtained results from the behaviour of a group of individually determinate objects, then it seems inexplicable that the erasure of information of which slit each individual entity went through, *after* the individuals have gone through the slits, could have any effect. Otherwise, what notion of causality could account for such a strange occurrence? What could be the source of such instantaneous communication, a kind of global conspiracy of individual actors acting in concert? What kind of spooky-action-at-a-distance causality is this?! The difficulty here is the mistaken assumptions of a classical ontology based on the belief that individual determinately bounded and propertied objects are the actors on this stage, and the stage itself is the givenness of a container called space and a linear sequence of moments called time. But the evidence indicates that the world does not operate according to any such classical ontology, an ontology exorcised of ghosts. On the contrary, *this is empirical evidence for a hauntology*!

It's not that (in erasing the information after the fact that) the experimenter changes a past that had already been present. Rather, the point is that the past was never simply there to begin with and the future is not simply what will unfold; the 'past' and the 'future' are iteratively reworked and enfolded through the iterative practices

of spacetimemattering – including the which-slit measurement and the subsequent erasure of which-slit information – all are one phenomenon. There is no conspiracy at work among individual particles separated in space or individual events separated in time. Space and time are phenomenal, that is, they are intra-actively produced in the making of phenomena; neither space nor time exist as determinate givens, as universals, outside of phenomena.

Furthermore, the evidence is against the claim made by some physicists that all trace of the event is 'erased' when the which-slit information is destroyed and that the previous diffraction pattern is 'recovered'. On the contrary, the diffraction pattern produced is not the same (as the original). Unlike the 'original', the new diffraction pattern is not plainly evident without explicitly tracing the (extant) entanglements. That is, the trace of all measurements remain even when information is erased; it takes work to make the ghostly entanglements visible. The past is not closed (it never was), but erasure (of all traces) is not what is at issue. The past is not present. 'Past' and 'future' are iteratively reconfigured and enfolded through the world's ongoing intra-activity. There is no inherently determinate relationship between past and future. Phenomena are not located in space and time; rather, *phenomena are material entanglements enfolded and threaded through the spacetimemattering of the universe*. Even the return of a diffraction pattern does not signal a going back, an erasure of memory, a restoration of a present past. *Memory – the pattern of sedimented enfoldings of iterative intra-activity – is written into the fabric of the world*. The world 'holds' the memory of all traces; or rather, the world *is* its memory (enfolded materialisation).

~~Act Ψ~~. ~~Scene ℵ~~. *Science & Justice*

SpaceTime Coordinates: diffracted spacetimes; time of inheritance, time-to-come; whither?

> There is no inheritance without a call to responsibility (Derrida 1994, 91).
>
> No justice . . . seems possible or thinkable without the principle of some *responsibility*, beyond all living present, within that which disjoins the living present, before the ghosts of those who are not yet born or who are already dead, . . . Without this *non-contemporaneity with itself of the living present*, . . . without this responsibility and this respect for justice concerning those who *are not there*, of those who are no longer or who are not yet *present and living*, what sense would there be to ask the question 'where?' 'where tomorrow?' 'whither?'. (Derrida 1994, xix)

Copenhagen is densely populated with ghosts. Every being made killable on a mass-scale by twentieth-century technologies, whether victims of Auschwitz, or hibakusha of the atomic bombs dropped on Hiroshima and Nagasaki, or the victims of the Dresden firestorm, or the many other victims (some of whom lived as ghosts even before they died), and not only those deaths related to WWII but also other entangled high-tech massacres of populations made killable, or at least dispensable, whether at Bhopal, Chernobyl, Bikini Atoll, or elsewhere. And not only human ghosts, but all manner of ghostly beings (including the millions sacrificed each year by the killing machines of industrial meat production). Atomic ghosts. Copenhagen lives in the shadow of bombs dropped and bombs not dropped (Schrödinger's cat again. Ghostly entanglements).

And yet, if Elsinore is the darkness inside the human soul, Copenhagen is not a place, internal or external to the eternal referent of all – to Man as the measure of all things – but rather a nonplace, and nontime, a dislocation of referent, a fracture, a rupture, a disjuncture, an opening. The ethical questions concerning the making of the atomic bomb are not about rights or calculation or blame, and surely not about innocence – the themes that swirl around the ghosts of Bohr and Heisenberg in Frayn's *Copenhagen* (2000).

Copenhagen is haunted by disjunctures. It is a play that knows more than its author (as do all our works). Traces of the undecidability/indeterminacy of knowing-not knowing, being-not being. Dispersions. Aspersions. Frayn is undone by what he sees as an injustice to Heisenberg, that history has unfairly judged him and soiled his reputation, that he was in any case doing the best he could living under a totalitarian regime. In marked contrast, Frayn makes it clear that he believes that Bohr and the scientists who worked to build the atomic bomb at Los Alamos are far more culpable than their German counterparts (due to the 'success' of the U.S. efforts) and yet not held accountable (by whom?). On Frayn's account(ing), it is in fact the very fact that we'll never know Heisenberg's intentions – the existence of that 'final core of uncertainty at the heart of things' (Frayn 2000, 94) – that saves humanity not only from judging each other inappropriately, but ultimately, from destroying itself. Apocalypse again, even in its absence. Once again, Man is the measure of all things, the beginning and the end, the alpha and the omega. Evidently, uncertainty is too dull a blade to cut through or disrupt the usual stories of certainty and the end of the time. And no wonder, uncertainty's fate is in any case no better than humanity's, since uncertainty lives inside the human mind ('When no more decisions, great or small are ever made again. When

there's no more uncertainty, because there's no more knowledge' (Frayn 2000, 94)).

Heisenberg is all but certain about his uncertainty paper. Throughout the paper (proper), which lays out his argument for the inevitability of uncertainty in measurement interactions, a certain confidence abides. But then after the fact, after the argument is given, an afterthought – a thought that arrives almost too late on the scene (in any case after the particles have already gone through the slits and hit the screen) – a tempered nod to his mentor sending a tremor through the paper that shakes the foundations of his analysis. In a little known postscript to his famous uncertainty paper, Heisenberg's certainty/uncertainty falters. A confession at the end throws the whole analysis into crisis: Heisenberg admits that Bohr is indeed correct ('In this connection Bohr has brought to my attention that I have overlooked essential points in the course of several discussions in this paper'), that Bohr's point about Complementarity – that is, the play of indeterminacy/determinacy – is vital to the analysis of measurement interactions.

A fascinating irony haunts *Copenhagen*. Frayn picks up on this little known postscript – Heisenberg's unwitting ode to Bohr – and places it at the center of the key scene in the play, and yet completely misses its importance: the profound meta/physical disagreement between the two primary founders of the Copenhagen interpretation of quantum physics, and how it matters. The co-existence of these two irreconcilable viewpoints fractures the presumed unity of the so-called Copenhagen interpretation of quantum mechanics (allegedly a seamless suturing of the views of Bohr and Heisenberg and other important contributors). Ironically then, despite Frayn's rather surprising acknowledgement of Heisenberg's acquiescence to Bohr's point of view, which marks indeterminacy as the primary philosophical point, Frayn, nonetheless, places uncertainty (à la Heisenberg) at the center of his play.

Copenhagen/Copenhagen is haunted by its own internal fracturings/disjunctures that belie the presumed unity of places, spaces, times, and beings. A ghost that is the very specter of multiplicity itself haunts the play and the interpretation (of quantum physics that goes by the same name). What if this ghost were taken seriously? That is, what if it were understood that the point is not uncertainty after all – not man's knowledge measured against some present presence that is or some past-present that was – but rather, *indeterminacy – hauntological multiplicity* – which, crucially, is not about Man once again, not about origins finally, nor the end of time?

What if one torqued Frayn's clever use of the theme of uncertainty, of the playing out of various possible scenarios of what might have occurred during Heisenberg's visit to Bohr in 1941, and instead took the ghosts at their word?[7] What if the revisitings (the restagings of the fateful visit) were read not as epistemological possibilities, but as the hauntological im/possibilities? That is, what if they were taken to be matters of indeterminacy in the nature of being/becoming, not uncertainties in human understanding? How would it matter to have them speak to us as *co-existing multiplicities of entangled relations of past-present-future-here-there* that constitute the worldly phenomena we too often mistake as things existing here-now? What if the ghosts were encountered in the flesh, as iterative materialisations, contingent and specific (agential) reconfigurings of spacetimematterings, spectral (re)workings without the presumption of erasure, the 'past' repeatedly reconfigured not in the name of setting things right once and for all (what possible calculation could give us that?), but in *the continual reopening and unsettling of what might yet be, of what was, and what comes to be*?[8]

Along with Derrida we might ask, 'Does [justice] come simply to repair injustice or more precisely to rearticulate *as must be* the disjointure of the present time? ... Does not justice as relation to the other suppose ... the irreducible excess of a disjointure or an anachrony, ... some "out of joint" dislocation in Being and in time itself ...?' (Derrida 1994, 25; 27). Only by facing the ghosts, in their materiality, and acknowledging injustice without the empty promise of complete repair (of making amends finally) can we come close to taking them at their word. The past is never closed, never finished once and for all, but there is no taking it back, setting time aright, putting the world back on its axis. There is no erasure finally. The trace of all reconfigurings are written into the enfolded materialisations of what was/ is/ to-come. Time can't be fixed. To address the past (and future), to speak with ghosts, is not to entertain or reconstruct some narrative of the way it was, but to respond, to be responsible, to take responsibility for that which we inherit (from the past and the future), for the entangled relationalities of inheritance that 'we' *are*, to acknowledge and be responsive to the noncontemporaneity of the present, to put oneself at risk, to risk oneself (which is never one or self), to open oneself up to indeterminacy in moving towards what is to-come. Responsibility is by necessity an asymmetrical relation/doing, an enactment, a matter of différance, of *intra-action*, in which no one/ no thing is given in advance or ever remains the same. Only in this ongoing

responsibility to the entangled other, without dismissal (without 'enough already!'), is there the possibility of justice-to-come.

Entanglements are not intertwinings of separate entities, but rather irreducible relations of responsibility. There is no fixed dividing line between 'self' and 'other', 'past' and 'present' and 'future', 'here' and 'now', 'cause' and 'effect'. Quantum discontinuity is no ordinary disjunction. Cartesian cuts are undone. *Agential cuts*, by contrast, do not mark some absolute separation but a cutting together/apart – a 'holding together' of the *disparate* itself, ... without wounding the dis-jointure, the dispersion, or the difference, without effacing the heterogeneity of the other ... without or before the synthetic junction of the conjunction and the disjunction' (Derrida 1994, 29). *Agential cuts – intra-actions* – don't produce (absolute) separation, they engage in *agential separability* – differentiating and entangling (that's one move, not successive processes). *Agential cuts radically rework relations of joining and disjoining*.[9] Separability in this sense, *agential separability*, is a matter of irreducible heterogeneity that is not undermined by the relations of inheritance that hold together the disparate without reducing difference to sameness. Entanglements are not a name for the interconnectedness of all being as one, but rather specific material relations of the ongoing differentiating of the world. Entanglements are relations of obligation – being bound to the other – enfolded traces of othering. Othering, the constitution of an 'Other', entails an indebtedness to the 'Other', who is irreducibly and materially bound to, threaded through, the 'self' – a diffraction/dispersion of identity. 'Otherness' is an entangled relation of difference (*différance*). Ethicality entails noncoincidence with oneself.

Crucially, there is no getting away from ethics on this account of mattering. Ethics is an integral part of the diffraction (ongoing differentiating) patterns of worlding, not a superimposing of human values onto the ontology of the world (as if 'fact' and 'value' were radically other).[10] The very nature of matter entails an exposure to the Other.[11] Responsibility is not an obligation that the subject chooses but rather an incarnate relation that precedes the intentionality of consciousness. Responsibility is not a calculation to be performed. It is a relation always already integral to the world's ongoing intra-active becoming and not-becoming. It is an iterative (re)opening up to, an enabling of responsiveness. Not through the realisation of some existing possibility, but through the iterative reworking of im/possibility, an ongoing rupturing, a cross-cutting of topological reconfiguring of the space of responsi-bility.[12] 'Inheritance is never a given', Derrida reminds

us, 'it is always a task. It remains before us... To be... means... to inherit. All the questions of the subject of being or of what is to be (or not to be) are questions of inheritance.... the being of what we are *is* first of all inheritance' (Derrida 1994, 54).

An ethics of entanglement entails possibilities and obligations for reworking the material effects of the past and the future. As the quantum eraser experiment shows, it is not the case that *the* past (a past that is given) can be changed (contrary to what some physicists have said), or that the effects of past actions can be fully mended, but rather that the 'past' is always already open to change. There can never be complete redemption, but spacetimematter can be productively reconfigured, as im/possibilities are reworked. Reconfigurings don't erase marks on bodies – the sedimenting material effects of these very reconfigurings – memories/re-member-ings – are written into the flesh of the world. Our debt to those who are already dead and those not yet born cannot be disentangled from who we are. What if we were to recognise that differentiating is a material act that is not about radical separation, but on the contrary, about making connections and commitments?

*

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Notes

1. *Intra-action* is a key concept of *agential realism* (Barad 2007). In contrast to the usual 'interaction', the notion of *intra-action* recognises that distinct entities, agencies, events do not precede, but rather emerge from/through their intra-action. 'Distinct' agencies are only distinct in a relational, not an absolute sense, that is, agencies are only distinct in relation to their mutual entanglement; they don't exist as individual elements. Importantly, intra-action constitutes a radical reworking of the traditional notion of causality.
2. This paper is diffracted through Barad (2007). The reader should keep in mind that there are multiple interpretations of quantum physics. This paper makes use of my own reading and interpretation of quantum physics given in my book. For other readings of quantum physics and deconstruction see works by Arkady Plotnitsky, Christopher Norris, and John Protevi, among others. For more on the method of reading insights diffractively through one another, see especially Chapter 2 of Barad (2007). Due to space limitations and the minimalist approach to footnotes by this journal many footnotes were deleted. I refer the reader to Barad (2007) for further details and more complete references. This paper highlights material covered especially in Chapter 7. This paper is an excerpt of a longer work in progress.

3. ' "Fits", "passions", and "paroxysms" are all legitimate Newtonian terms for easy reflection and transmission of light' (Shapiro 1993, xii). Newton argued that light is a particle.
4. David Mermin (1985) suggests that spooky-action-at-a-distance be understood as passion-at-a-distance.
5. Quantum entanglements between La Palma and Tenerife in the Canary Islands (a distance of 144 kilometers) have been experimentally confirmed. See Choi for references.
6. For more details see Barad (2007) Ch. 7.
7. 'HAMLET: Speak; I am bound to hear.' Taking someone/something at its word entails material obligations, being bound by responsibility. Making sense is after all a material matter, especially if materiality isn't the closed and limited set Newton, or even Marx, had imagined, and meaning isn't taken to be merely a matter of language, but rather of a general textuality (see esp. Kirby forthcoming). See Barad (2007) for performative (intra-active) reworkings of *materiality* and *discursivity*. These rearticulations are assumed in this article.
8. In particular, contra Frayn, the point is not about discovering a past that has already happened, but rather about the entanglement of past-present-future here-there, that is, about responsibility and justice-to-come. So for example, the point is not that Heisenberg's motives were not merely unknown to him, but that they were multiple, indeterminate, spooked, not his alone.
9. Agential cuts never sit still; they are iteratively reworked. Inside/outside is undone. Constitutive exclusions are both the conditions of possibility for openness, for reworking im/possiblities, and are themselves always being reworked as part of this reiterative dynamics. An uncanny topology: no smooth surfaces, willies everywhere. Differences percolate through every 'thing', reworking and being reworked through reiterative reconfigurings of spacetimematterings – the ongoing rematerialisings of relationalities, not among pre-existing bits of matter in a pre-existing space and time, but in the ongoing reworkings of 'moments', 'places', and 'things' – each being (re)threaded through the other. Differences are always shifting within. Intra-actions don't occur between presences. Intra-actions are a ghostly causality, of a very different order.
10. Levinas's point that 'ethics . . . does not supplement a preceding existential base; the very node of the subjective is knotted in ethics understood as responsibility' (Levinas 1985, 95) is pertinent here. See Barad (2007) for an elaboration of this Levinasian intervention without the humanist foundations that have been an integral part of Levinas's philosophy.
11. The very dynamism of matter (unto 'itself', as it were, without the need for some supplement like culture or history to motor it), its agential and affirmative capacity for change with every doing, is its regenerative un/doing. Matter is always already open, heterogeneous, noncontemporaneous with itself. Matter is always shifting, reconfiguring, re-differentiating itself. Deconstruction is not what Man does (it is not a method), it is what the text does, what matter does, how mattering performs itself. Matter is never settled but is agentive and continually opens itself up to a variety of possible and impossible reconfigurings. Matter is ongoing hauntological transformation. Nature is not mute, and culture the articulate one. Nature writes, scribbles, experiments, calculates, thinks, breathes, and laughs (see esp. Kirby forthcoming and this volume).
12. Possibilities aren't narrowed down to one in the realisation of some possibility as an actuality. Rather, im/possibilities are reconfigured and reconfiguring with each intra-action.