Diffracting the 'quantum' and the 'social': *Meeting the Universe Halfway* in social science

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Abstract: The 'quantum' label has become a desirable brand in social studies, with notable prominence being given to Karen Barad's agential realism, as presented in her book *Meeting the Universe Halfway* (2007). This article provides an overview of the key ideas in the book, exemplifying the ways these ideas may help us 'do inquiry' in the social sciences. By drawing from Barad's writing and making comparisons with other social thinking with quantum elements (specifically Kirby, 2011 and Wendt, 2015), we can demonstrate the potential for productive and insightful avenues of investigation across interdisciplinary areas, particularly through a consideration of diffractive approaches to inquiry.

Introduction

The birth of quantum physics in the late 19th and early 20th centuries represented something of a turning point in the sciences, where previously well-established concepts were shown to be inadequate to describe new discoveries. More recently, in many areas of social and philosophical research the 'quantum' label has become extremely desirable, lending a contemporary and counterintuitive scientific gravitas to inquiry in much the same way as scientific positivism underpinned Durkhiem's sociology. Whilst many attempts to transfer concepts from quantum mechanics into broader social and philosophical areas fall flat, due to either a lack of understanding of the science, poorly constructed deductions, or spurious injections of 'spirituality', others weave together ideas far more effectively.

One such successful publication is Karen Barad's book *Meeting the Universe Halfway* (2007) which, in the eleven years since its publication, has been frequently cited in qualitative research. Described as "…unusually systematic, thorough, and clear" Barad's work "…may provide the foundation for a durable school of contemporary thought" (Harman, 2016: 1). With a PhD in theoretical physics Barad's understanding of the underlying science is obvious, and taking cues from the thinking of Niels Bohr and the Copenhagen interpretation of quantum mechanics, she presents a convincing series of "…constructive engagements across (and a reworking of) disciplinary boundaries" with a view to "…move conversations in science studies, feminist studies, and other (inter)disciplinary studies…" (Barad, 2007: 25) and perhaps outlines a "new kind of empiricism for the social sciences" (de Freitas, 2017: 741).

Unlike some of the other authors in this special edition I have the pleasure of exploring a work that has already been used in a variety of ways, cited in a range of fields, and reviewed by many others, so will be attempting to highlight the contributions made by the book. This article first looks at key ideas in Barad's 'agential realist' approach presented in *Meeting the Universe Halfway*, emerging within Science Studies, and considers the potential of these concepts to help us 'do inquiry' across the social sciences. Drawing on Barad's later writings and work of other authors, I will show that far from being a simple branding exercise, a 'quantum' understanding of the world provides productive and insightful avenues of investigation across interdisciplinary areas. The article then explores the particular case of diffraction as both a physical phenomenon and generative concept that can further understandings in social studies.

The 'quantum' and the 'social'

The first significant attempt at bringing concepts from quantum physics to work in understanding social settings came from Zohar and Marshall (1995), whose book *The Quantum Society* attempted to link New Age ideas of consciousness to the material world leading to the argument that "…the mind and the social life are macroscopic quantum mechanical phenomena." (Wendt, 2015: 2). Although Zohar and Marshall's work demonstrates a patchy understanding of quantum physics and is rife with speculation, it inspired a more structured work from Wendt, who in his 2015 book *Quantum Mind and Social Science* claims "That social life is not essentially different from that of subatomic particles" (p. 131). Interweaving several interpretations of quantum physics with Stapp's contentious ideas of 'quantum consciousness', Wendt argues for consciousness (and therefore life) as a quantum mechanical phenomenon. This causal closure is justified by the argument that

> …physics deals with the elementary constituents of reality, of which macroscopic phenomena are composed, everything in nature is ultimately just physics. This gives physics a foundational role with respect to other sciences... no entities, relationships, or processes posited in their inquiries should be inconsistent with the laws of physics.
>
> Wendt (2015: 7)

Although this somewhat reductionist strategy provides a suitable grounding for a philosophical introduction of quantum ideas into inquiry, the primacy Wendt gives to physics is by no means universally accepted. Balaban and Klein (2006), for example, present a hierarchy of science that echoes the title of Brown and LeMay's 1977 book in placing chemistry as *The Central Science*, as has the more recent work of Manuel Delanda (2015), whilst other authors have recognized the trend of increased interdisciplinarity in scientific fields in order to put the range of theories and specialisms to work "to solve complex problems such as climate change, sustainability and public-health issues" (Ledford, 2015: 309).

Rather than Wendt's fundamentalism regarding physics, Karen Barad revels in interdisciplinarity as *Meeting the Universe Halfway* takes ontological and epistemological suppositions from quantum physics, most notably the indeterministic 'philosophy-physics' of Niels Bohr (Barad, 2003: 813), and uses them to construct a philosophical framework by which to interrogate society. Rather than directly ascribing a quantum origin for social phenomena, Barad seems to ask 'What would the implications be for inquiries if they grew from a quantum ontology rather than that of classical physics?'. The resulting work is presented as 'agential realism' and demonstrates an intense coherency of thinking that traces transdisciplinary connections between science, science studies, and sociology more widely that marks it as unique and outstanding.

In the opening to *Meeting the Universe Halfway* Barad acknowledges "…electrifying conversations with my friend Vicki Kirby" (p. xii). It appears those conversations may have been mutually productive, as much of the thinking in Kirby's *Quantum Anthropologies* (2011) shares similarities with Barad's work. Bridging the gap between the quantum scientific influence of agential realism and more traditionally anthropological thought, Kirby revisits Derrida to extrapolate from the claim that 'there is no outside of text' arguing that if this is true then "…it is in 'the nature of Nature' to write, to read and to model" (Kirby, 2011: 84). This speaks to Barad's work, breaking

down the "…nature-culture dualism that feminists have actively contested." (Barad, 2007: 183).

Some of the uniqueness of Barad's work stems from her interweaving of science and science studies, and indeed in later work she states that "The nature of the relationship between science and science studies is an important issue that I care about a great deal" (Barad, 2011: 443). *Meeting the Universe Halfway* seeks to offer "…a posthumanist performative approach to understanding technoscientific and other naturalcultural practices" (p. 135). Recognizing a growing attention to ontology in science studies (p. 409 n.4), Barad interrogates "…the sense in which direct engagement with the ontology of the world is possible" (p. 44) through an application of scientific principles and a recognition of the interiority of all things and phenomena.

Central to Barad's 'agential realist' approach is the concept of entanglement; that the boundaries of 'subject' and 'object' are indistinct and delineations are momentary. In a scientific sense this is readily understood, as under close enough scrutiny physical boundaries begin to break down; the surface of my hands, for example, is predominantly composed of a cloud of electrons and a lot of empty space, so where does my touch begin and end? This point is addressed in detail by Barad in *On Touching – The Inhuman That Therefore I Am*, where she questions

> Whom and what do we touch when we touch electrons?... When electrons meet each other 'halfway,' when they intra-act with one another, when they touch one another, whom or what do they touch?
>
> Barad (2012b: 215)

This decentering and deconstructing of touching problematizes subject/object boundaries, and begins to tease out the ways that (sub-)microscopic quantum effects can be felt and rationalized in a macroscopic way. This represents a core difference between Barad's philosophy and that of others, in that the breaking of boundaries derives not from an appropriation of quantum ideas nor a social repurposing of subatomic effects, but a thoughtful expansion of ideas in a way that considers (but does not prioritize) lived experience of any kind. Where Wendt employs a philosophical extension of ideas from the "ever more micro" to the "macroscopic reality" (Wendt, 2015: 131) to develop a quantum coherent ontology that 'collapses' into consciousness, Barad's ontology is one of nebulous entanglement and materiality. In such a framework the differences of scale are not a simple matter of physical size, and Barad inherently rejects

> …geometric readings of the notion of scale, wherein the micro- or quantum-scale can always be assumed to be unproblematically 'smaller' than the macro-realm… and so forth. Scale is, instead, an outcome of on-going worldly processes of production, contestation, and reproduction
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> Hollin et al (2017: 924)

This performative understanding of scale demonstrates an entanglement in which "scale is also not a straightforward concept, and notions of 'macro' and 'micro', like 'past' and 'future', are not nested or ordered in simple ways" (Barad, 2012a: 51).

In addition to a blurring of subject/object boundaries, and a performative rather than geometric understanding of scale, Barad also challenges linear notions of time, as

seen in *Quantum Entanglements and Hauntological Relations of Inheritance* where Barad (2010) describes "…the 'past' repeatedly reconfigured… the continual reopening and unsettling of what might yet be, of what was, and what comes to be?" (Barad, 2010: 264). This queering of time allows for an embracing of potentiality and entangled future-histories, presenting a "…highly non-classical causality, breaking open the binary of stale choices between determinism and free will, past and future" (Barad, 2010: 254). Causally rethinking time resonates with Kirby's unpicking of nature and culture, such that "the entangled relatings of natureculture don't stop with the intra-action between Kirby and the biologist whose account precedes hers in a radical undoing of 'precedes'" (Barad, 2012a: 36), recognizing that 'precedes' cannot be sustained in a linear model of causal chains.

Wendt's consideration of time is both well-constructed and in general agreement with Barad and Kirby, in which he "…does not recognize a privileged moment called Now" (p. 199), a sentiment echoed in Barad's quotation "There is no inherently determinate relationship between past, present, and future." (Barad in Dolphijn and van der Tuin, 2013: 59). Wendt, like Barad, also acknowledges that time is "…constrained by material traces" (p. 199), drawing parallels with Barad's materialist ontology. With this rethinking and queering of time, Barad's quantum ontology points to the "irreducible relations of responsibility" (Barad, 2010: 265) that hold complex entangled networks together, underscoring the ways that agencies mobilized in phenomena produce a kind of heterogeneous but collective temporality.

In a practical sense the blurring of physical and temporal boundaries seen in an agential realist approach provides opportunities for new understandings in inquiry. Wide-ranging examples include Brøgger's work on higher education policy reform as a process that evokes "simultaneously existing worlds of practices propelled by the agency of the past troubling" (2014: 520), feminist materialist conceptions of disability formulated around "how the particularities of embodiment interact with the environment in its broadest sense, to include both its spatial and temporal aspects" (Garland-Thomson, 2011: 591), and a scientific/artistic consideration of slime mold through multi-modal apparatuses that are considered as "agential, intra-active entanglements of human, slime mould and environment." (Bates, 2015: 49). These papers serve to highlight the diversity and transdisciplinary nature of Barad's boundary-queering framework, and a rethinking of time has obvious implications for longitudinal studies, as seen in the methodological work of Mauthner (2015), who describes such studies as a "…constitutive part of the realities they help bring into being" (p. 321). This entanglement of method and reality will later be considered further.

An additional source of indeterminacy in Barad's philosophies stems from the probabilistic nature of phenomena. As with much of Barad's work this shares similarities with the Copenhagen interpretation of quantum physics, which asserts that when a particle is unobserved, it exists as a superposition of several states; a wavefunction of probabilities (Townsend, 2000: 151). When an observation is made, this wavefunction 'collapses' to a single, measurable state. That is, prior to measurement the matter only exists as a set of probabilities, and the very act of measurement or observation – of intra-action – causes a single specific probability to come about. Barad describes a situation where an observing apparatus "enacts an *agential cut* – a resolution of the ontological indeterminacy – within the phenomenon, and agential separability – the agentially enacted material condition of exteriority-within-phenomena – provides the condition for the possibility of objectivity" (Barad, 2007: 175 emphasis added). This probabilistic blurring of phenomena forces researchers to consider situations in less concrete ways,

embracing potentiality within systems and situations. This concept is put to good effect in O'Briens work on climate change (2016), that adopts strands from Barad's and Wendt's quantum approaches to social inquiry to draw attention to "people as the solution to climate change" by becoming "more aware of not only the role and significance of subjectivity, meaning, and collective human agency, but also the possibilities and potentials for transformative social change" (p. 625).

The discussion thus far has implicitly centered around a move away from representation towards a more indistinct understanding of the social world, but has not yet described the means by which distinctly recognizable objects come to be recognized. Rather than consider essentialist identifications, Barad draws on the work of Judith Butler and describes separations as occurring performatively, through repeated transient delineations enacted by people and/or things within a phenomena intra-acting. Such agential cuts iteratively allow perception of boundaries within entangled realities, where subject and object "emerge through intra-actions" (Barad, 2007: 89). Using the concept of agential cuts to inspect the varying perceptions of the world has been applied to the analysis of many social practices, including selfie-taking (Warfield, 2016), children's play (Änggård, 2016; Hultman and Lenz Taguchi, 2010), and a consideration of houses/homes (Mjaaland, 2017). Wendt offers a similar argument for temporary boundary making, recognizing that "…somewhere in the transition from quantum to classical a 'cut' gets made" (p. 68). Whilst this bears some similarity to Barad's performative agential cuts, the difference is that Wendt considers our observable social macro-reality to emerge into consciousness from a step-transition as 'fundamental' quantum effects collapse to larger scales. To Barad, the 'cut' is not a matter of transition or scale, but a matter of mattering and intra-action. Kirby's views have more in common with Barad, claiming that "…matter and its cognates are morphologically plastic and that these transubstantiations are myriad" (Kirby, 2017: 15). Barad's strongly 'mattered' ideas, calling boundaries into question ontologically and making distinctions on an ad hoc basis, as temporary differentiations in a wider interconnected world, sits comfortably with Kirby's vision of the world as "…a Whole, internally differentiated into an infinity of fragments" (Kirby, 2011: 38). She quotes Derrida as stating that the ongoing construction of this world is "…never exhausted by the work of objectification that proceeds with it" (Kirby, 2011: 85).

Although the importance of 'mattering' and the differentiating acts of agential cuts has been applied to much social research, including analyses of gender and embodied practices in the classroom (Taylor, 2013), racial biopolitics (Chen, 2012), and online constructions of sexuality (van Doorn, 2011), there has been some critique of the materiality presented by Barad. Woolgar and Lezaun (2013), for example, consider that "'materiality', just as 'context' and its cognate terms, needs to be understood as the contingent upshot of practices, rather than a bedrock reality to be illuminated by an ontological investigation." (p. 326). However, I consider this to be something of a misinterpretation of entanglement - without the 'matter' there is nothing to practice in/with/on, and without repeated performative practices of intra-action and delineation the matter has no meaning: "relata do not precede relations" (Barad, 2007: 334). The strength of an agential realist approach is an attention to entanglement, but it does present a philosophical redefining of 'realism'.

In considering Barad's agential realism, Harman (2016) finds an inconsistency in the use of 'atomism' as a shorthand for both a form of reductionism and a form of essentialism. Far from a pedantic triviality, Harman notes that "The rather glaring difference between these two positions, one object-oriented and the other very anti-

object-oriented, has strangely been converted into irrelevant nuance." (¶17). Harman goes on to accuse Barad of 'overmining', that is "…stripping individuals of all cryptic character, by making them nothing more than what they accessibly are here and now, [depriving] them of any unexpressed reservoir that might lead to future change" (¶22). This idea is challenged by de Freitas (2017), who draws on Barad's strong links to science and the idea of discontinuous 'quantum leaps' and the probabilistic nature of such formulations to conclude that "…individuation is achieved in terms of *degrees* of existence" (p. 747) and argues for a new kind of relationality.

Ideas of materiality are woven through quantum social interpretations, which consider the concurrency of matter and meaning. There is something of a bidirectionality to the way Barad and Kirby approach the idea of materiality. Kirby's thinking stems from a recognition of the objectivity of language, and the idea that scientific objects *become* language, that "…Nature is literate" (Kirby, 2002: 265). For Barad, meaning and matter are entangled in a way such that separation only becomes apparent through intra-action:

> Meaning is not an ideality; meaning is material. And matter isn't what exists separately from meaning. Mattering is a matter of what comes to matter and what doesn't. Difference isn't given. It isn't fixed. Subject and object, wave and particle, position and momentum do not exist outside of specific intra-actions that enact cuts that make separations – not absolute separations, but only contingent separations – within phenomena.
>
> Barad (2014: 175)

Although dense, this extended quotation expresses much of Barad's approach, which builds on earlier presented ideas of 'blurred' boundaries. We cannot consider clearly delineated systems of people and things interacting, since the meaning-making boundaries are not as constant as one might macroscopically assume. Even the boundaries of the 'system' under inspection are variable, porous, and tentative applications. The result is a framework that moves away from representation; since all people and things and systems are all entangled with one another, term intra-actions is employed to emphasize the ever-internal nature of mattering. Socially, such understandings are orientated towards "what things do, rather than what they 'are', towards processes and flows rather structures and stable forms" (Fox and Alldred, 2015: 407). This is deviation away from Butler's work on performativity and narrative conceptions of postmodern knowledge, placing focus on the more-than-human:

> …the productive, constraining, and exclusionary nature of naturalcultural practices, including their crucial role in the materialization of all bodies, agential realism goes beyond performativity theories that focus exclusively on the human/social realm.
>
> Barad (2007: 225)

This is a shift away from individual acts of cognition towards the co-constitutiveness of "bodies, things, spaces and cultural discourse" (Taylor and Ivinson, 2013: 665), and it is this co-constituent model that affords matter an element of agency,

since "matter does not refer to a fixed substance; rather, matter is substance in its intra-active becoming – not a thing, but a doing, a congealing of agency" (Barad, 2003: 822).

Whilst Wendt also recognizes the inherent materiality of a quantum consideration of the social world, he arrives at this concept by a somewhat different route. Insisting that "…life is a macroscopic instantiation of quantum coherence" (Wendt, 2015: 137), Wendt introduces an entanglement between matter and meaning via the idea of 'concept entanglement' (ibid.: 217), treating a categorization of meaning as an example of a quantum interference pattern. Barad's agential realist approach uses ideas from quantum physics to seek new interdisciplinary interpretations of social phenomena, where Wendt's arguments are driven to produce a theory of mind (he is a philosopher of mind) and come from an assumption that existence stems from inherently quantum effects. In the section below, I attempt to exemplify Barad's enfolding of scientific concepts (rather than a use of direct analogies), and I discuss optical metaphors that abound in social research, and how the quantum turn instills them with a renewed applicability.

Optical analogies and diffraction in social research

Although well-formulated, Barad's agential realist framework is difficult to put into action. Indeed, one of the weakest sections in *Meeting the Universe Halfway* is where she attempts to apply her ideas to the 'shop floor' of a Calcutta jute mill (p. 226-230), as the well-defined concepts from previous chapters prove difficult to apply. Nevertheless, the strength of her framework holds, and in an attempt to demonstrate its applicability to social research and reinforce the connections with physical science, I turn to the phenomenon of diffraction.

To Barad, the concept of diffraction is central in agential realism, so much so that in *Meeting the Universe Halfway* she considers diffraction "an overarching trope of this book" (2007: 71). In physics, the concept of diffraction is pervasive and can be used to draw understandings about the nature of matter and the universe. Much as the physical phenomena of diffraction, interference, and duality manifest themselves in different ways leading to a wide variety of applications, so too can these phenomena be employed to aid inquiry in the social sciences; if these effects occur in water, electromagnetic waves, and possibly even gravity, why not attempt an application to the ripples of the social world? In seeking to answer this question Barad's interpretation of diffraction in agential realism as a framework allows us to rethink the optics of social encounters. I apologise if what follows reads as a poor facsimile of a Physics 101 handout in parts, but even a brief understanding of optics and the physical principles of diffraction, interference, and duality can offer much insight into Barad's work.

In its simplest physical context diffraction occurs when any wave travels through a small gap. If the gap is large, the only impact is that the wave curves ever so slightly at each end. However, when the gap is roughly the same size as the wavelength of the wave, then the wave curves and spreads out. Figure 1 is an example of ocean waves diffracting between islands, showing constructive and destructive interference patterns of bending and overlapping that characterises diffraction. Diffraction is the reason that you can hear somebody in the kitchen when you are in the bedroom, as sound waves diffract around corner edges and through open doorways. It is also the reason that you can listen to the radio in a valley, as the radio waves diffract over the surrounding hilltops to be picked up by your receiver. With recent measurements of gravitational waves in the fundamental fabric of the universe (Abbott et al., 2016), ideas of diffraction may take on additional import on galactic scales.

Interference patterns are not confined to slits, as the effect is also seen in lenses. At increasing magnifications optical images begin to break down; the wavelength of the light is too long to resolve objects, and diffractive interference effects take over, such that "...the smaller the lens size the greater the blurring of the image by diffraction." (Hird and Giffney, 2016: 328). This is easily seen in images from optical telescopes, where the constructive and destructive interference of light waves from distant stars passing through a lens produces an artificial 'halo' artifact around the image, resulting in a minimum level of resolvable detail, as can be seen in Figure 2. These 'Airy disks' suggests a limit to the validity of increasingly close inspection, a concept that can be applied to social sciences.

It stands to reason that under sufficiently narrow scrutiny or an attempted application to a small enough sample population any model or theoretical approach may break down, or at best lead to artificial artefacts in the data. Whilst postmodernism effectively explored a blurring and breakdown of models, this diffractive approach recognizes the useful validity of such models provided they are not stretched beyond a minimum level of resolvable detail. Barad ties this diffractive blurring to observation, where "What often appears as separate entities (and separate sets of concerns) with sharp edges does not actually entail a relation of absolute exteriority at all." (p. 135). The implications for social research here are a caution around an overdependence on a particular approach, and an attention to areas when models and theories cease to be valid *or useful*. Whilst these awarenesses are not specific to agential realism, they arise out of its scientific connections.

Unlike diffraction, the phenomenon of specular reflection requires little additional introduction – anybody who has looked at themselves in a mirror can recognize both the effect and the synonymous use in social research. Reflection – often in combination with reflexivity, although it is beyond the scope of this article to unpick the differences – ostensibly provides an opportunity for a more objective consideration of the self, and allows for the creation of a synthetic space between the research and the subjects of their research. Haraway uses the reflective optical metaphor to suggest moving away from reflective "oppositional distinctions between the real and the figural" (Geerts and van der Tuin, 2016: online), and considering diffraction instead as an inspection of "the interference patterns on the recording films of our lives and bodies" (Haraway, 1997: 16). My interpretation here is that Haraway is referring to the unwanted patterns interference seen on old, improperly-tuned analog TVs and videotapes, recasting them as visible but disruptive lines from a researcher's life unavoidably imposed across data. In such a situation, the 'background image' of the data must be 'read through' the noisy interference. However, ideas of diffractively 'reading through' can be more powerful and generative than this.

In a physical sense the effect of diffractive interference patterns is compounded if, rather than two narrow slits, waves are passed through many uniform slits of equal spacing. Such uniform slits are called a diffraction grating, and the resulting diffraction pattern (see, for example, Figure 3) is much clearer and distinct than a two-slit pattern. This allows for detailed insight to be gained both about the waves themselves and the grating through which they are passing. The way this interlinked relationship between the grating and the waves can be leveraged to expand understanding can be seen in the contrasting examples of the analysis of the electromagnetic spectrum of stars, and x-ray crystallography. In the first case the light from distant stars is passed through a diffraction grating, and the resulting interference patterns allow physicists to identify the composition of the star and/or interstellar medium through which the light passed. To

learn anything about the star we must have a reasonable amount of detail about the grating. In the second case, x-rays are passed through a crystal, which causes them to interfere and diffract. Here the resulting patterns give an insight about the structure of the crystal that acts as a grating, but we can only make inferences about the crystal structure if we already know the specific properties of the x-rays used. This is a classical (rather than quantum) example of the connections between instruments of measurement and measured phenomena, but these are effective for understanding how diffraction and instrument are linked.

In social research the 'instrument of measurement' is frequently the researcher themselves, who seeks to codify qualitative data, prepare interview questions etc, and as such must recognise their strong impact upon observed phenomena. The idea that who we are as researchers, and the tools that we use in research, should impact upon observations is unsurprising and, as previously discussed, is more usually addressed in qualitative research through mimetic reflection or postmodern reflexivity. However, like Haraway (1997) before her, Barad eschews the metaphor of reflection in social research, instead embracing diffraction as a mode of inquiry that involves "reading insights through one another in attending to and responding to the details and specificities of relations of difference and how they matter" (Barad, 2007: 71). This approach involves a recognition of being within the world and part of it, rather than a "reflection of objects held at a distance" (Barad, 2007: 89). Recognizing the mutual interlinking of researcher and research in inquiry, diffractive approaches eschew the assumed objectivity of reflexivity. Much like the entanglement of waves and the material through which they are diffracting, when considering inquiry diffractively but it is essential to have an in-depth and tangible knowledge of at least one of the researcher and the research in order to learn anything valid. The reflexive approach demands that a researcher seeking to write an ethnography of an unfamiliar cultural group should know and state how their methods and background might affect the patterns of their representation of the group, where more autobiographical forms of research would require an existing understanding of the context in which the data is being collected, in order to focus on the personal journey occurring as a result of being in that situation and collecting that data. However, diffractive research goes further in attending to the quantum diffractive effects. Barad recognises this, and uses the difference between "the representationalist trap of geometrical optics" and "physical optics… like the diffraction patterns illuminating the indefinite nature of boundaries" (p. 135) not only as an introduction to blurred boundaries and entanglement, but further extends this with an introduction of quantum effects.

The interconnectivity between measuring object and measured phenomenon becomes increasingly heightened when quantum effects are taken into consideration. Classical diffraction as presented thus far was complicated in 1927 when Thomson and Davisson independently confirmed the de Broglie hypothesis and found that all matter, be that sub-atomic particles or macroscopic people, can also be diffracted. The most common example of this is electron diffraction, where these archetypical particles of matter can be shown to 'interfere' like waves. This is considered an example of wave-particle duality, and is a cornerstone concept of quantum mechanics. Barad uses the example of two-slit diffraction of electrons where

> …waves make diffraction patterns because they can go through both slits at once, particles don't. But in the early twentieth century electrons passing through a diffraction apparatus fail to behave like

> proper particles. Rather they behave like waves. Indeed, it seems that *each individual* electron is somehow going through *both slits* at once.
>
> Barad (2014: 173)

Of even more import is *the impact* (interference) of attempting to measure through which slit an electron is passing. When this is carried out we are able to observe an electron going through a single slit, but the interference pattern completely disappears; through measurement the electron ceases to behave as a wave and instead 'collapses' into particle behavior. The ontological conclusions of this are clear; the nature of measurements made at the slits not only impacts the resultant pattern displayed by the electrons afterwards, but has implications for the way that the electrons *are*. Observe which slit they pass through, and they are particles. Do not observe which slit they pass through, and they are waves. The 'reality' of the electrons alters according to the instrument of measurement employed, and the probabilistic wavefunction of their existence collapses to a definitive state. Barad recognizes this entanglement of apparatus and observation, or 'knower' and 'known', as an *onto-epistemology* – the term used to describe the inseparability of observation and existence, where "the nature of the observed phenomenon changes with corresponding changes in the apparatus" (Barad, 2007: 107).

Echoing ideas espoused by those advocating for reflexive practice in research, entanglement and diffraction can be used to challenge the mutual implication of practices of knowing and being; we do not know the world by studying it at a distance, we know because we are part of the world. And yet this alone does not fully demonstrate the impact of Barad's thinking in *Meeting the Universe Halfway*, where the entangled act of measurement produces a contingent separation, a definitive state that allows for the appearance (and possible putting to use) of temporary objectivity. Whilst such separations may be transient, they nevertheless provide a grounding for forms of research that are more accepting of measurement than prior postmodern turns, provided we accept that the trade-off for a contingent acceptance of measurement is a loss of potentiality; once the agential cut of measurement has been made, potential succumbs to realization.

Given the entangled separability of observer and observed, of subject and object, Barad proposes that knowing and being are similarly entwined, and that we must consider intra-actions as onto-epistemological. This calls into question the more 'classical' view of diffraction in social research (for example, in Haraway's work), since the entanglement of diffractive measuring apparatus and *reality* renders it impossible to separate out knowledge of the researcher and knowledge of the research situation - attempting to do so would constitute an agential cut and cause a collapsing into a different state from the original, and concrete observations would have lost the patterns of potentiality possibly made visible in diffractive methods.

Barad recognizes that the agential cut of passing one through another can produce new patterns and modes of understanding, and describes a diffractive approach as "…an intra-active phenomenon, and as such does not hold one set of concerns as pre-existing or stable or primary over another" (Barad, 2011: 449). It is with this quotation and an understanding of the physical principles of diffraction, interference, and duality that we can begin to distinguish what may constitute a diffractive analysis, and why diffraction is important in social research.

In some circumstances this diffractive work involves reading social theories through each other, as seen in Mazzei (2014) and van der Tuin (2011), or a diffractive reading of policy through theories and situations to provide insight (see Ulmer, 2016). In other cases diffraction is explored more methodologically, whereby the instrument of measurement affects not just the measured results but the *reality* of those results. This is seen in Mjaaland (2017), where the 'measuring agent' of the camera (and photographer) serves as a diffractive apparatus and captures the ambiguity of houses/homes in photographs. Here the combined agential cuts of the camera (framing, lighting, duration etc) construct a visual reality, and "are not mere observing instruments but boundary-drawing practices" (Barad, 2007: 206). The researcher has a key role to play here, as "to read these encounters diffractively is to see how 'you install yourself in an event of "becoming-with" the data'." (Fenwick and Edwards, 2013: 59).

In the applications of a diffraction presented so far, the approach has been generative, in that adopting a diffractive standpoint allows a different, newer understanding to be constructed. Taking a further prompt from physical science we may consider a criterion with which to identify diffractive methodologies.

Considering diffraction as seeking to understand social phenomena through observation of patterns and traces left in secondary data after 'passing though' an entangled instrument, then large scale quantitative studies may fall into this category; the operationalization of a situation to produce social statistics and subsequent numerical processing to seek patterns could be considered a 'diffraction' on a surface level. However, such positivist approaches to qualitative inquiry definitely hold one set of concerns (statistical validity and objectivity) as pre-existing, stable, and primary over the phenomena under investigation. To consider a converse approach, an autoethnographic study where understanding stems from an analysis of personal experience through observations and quotations recorded in a journal may not at first seem diffractive. However, an analytical reading of the situation *through* the journal (or reading the journal through another theoretical framework) whilst recognizing the co-constructive nature of the journal/events and the agential cuts made to document them is an example of Barad's 'condition for the possibility of objectivity' described earlier. Jackson and Mazzei explain it thus;

> A diffractive reading of data, then, is not an insertion into the context in an autoethnographic sense, nor is it a reflection that takes our own researcher subjectivity into account, but it is an installing of ourselves that attempts to make sense of the blurring and viscous interactions that Nancy Tuana names as a *viscous porosity*.
>
> Jackson and Mazzei (2011: 131)

As diffractive methodologies progress, increasingly insightful diffractive interpretations can be seen. One such example is van der Tuin's (2017) consideration of the website *brainpickings.org*, where author Maria Popova's daily writings connect many seemingly disparate sources in interesting ways. Each multimodal article suggests links to other material with which to 'complement' the current reading, offering insight but without formal categorization. Here a wide range of multimedia sources are diffracted through one another, with new interference patterns emerging over time and reshaping the import of previously written articles, with potentialities being realized in different ways. This example of temporally queer diffraction not only produces new

understandings from its eclectic archive, but is ultimately entangled with the author herself, who states that it is “really a record of my becoming who I am”. This example shows the generative potential of diffractive thought in social studies, and the impact of quantum thinking in inquiry.

Conclusions

Whilst the scientific connections of social research are well documented, the recent quantum turn is opening new avenues for inquiry that draw strongly on science and science studies. Barad’s agential realist approach goes beyond an appropriation of terms and presents a transdisciplinary framework that embeds ideas of entanglement, performative materiality, and blurred boundaries. Whilst similarities can be found with the work of Kirby and Wendt, Barad’s distinctiveness stems from a perpetual interiority of intra-action.

The ways in which diffraction figures in Barad’s work is both classical and quantum, and provides for the identification of bright spots of similarity in overlapping theories as well as more symmetrical and material alternatives to reflexivity when considering researcher influence on data. By seeking to iteratively identify “marks on bodies” (Barad, 2007: 90) over mimetic reflection without ascribing primacy or undue abstraction, there develops an ethical “responsibility and accountability for the lively relationalities of becoming of which we are a part.” (Barad, 2007: 393). While diffractive practice continues to develop, agential realism provides a structure and vocabulary with which to better understand contemporary issues.

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Figures

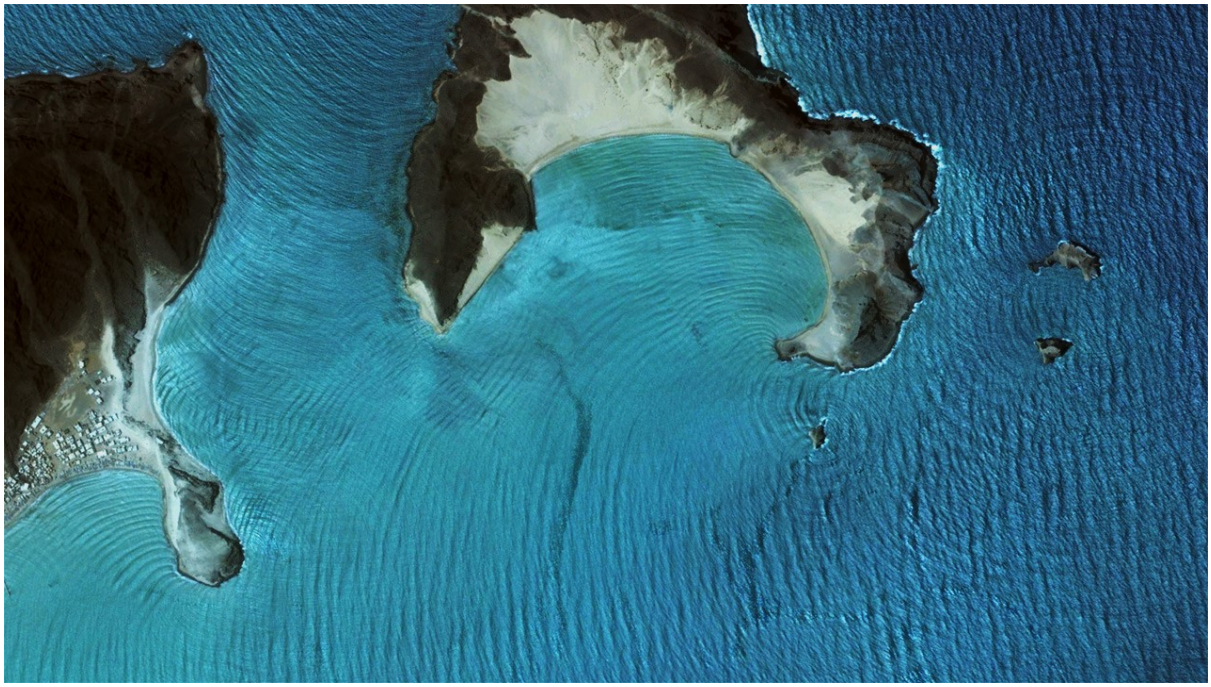

Figure 1: Diffraction of waves in the Arabian Sea (image courtesy of Google Earth)

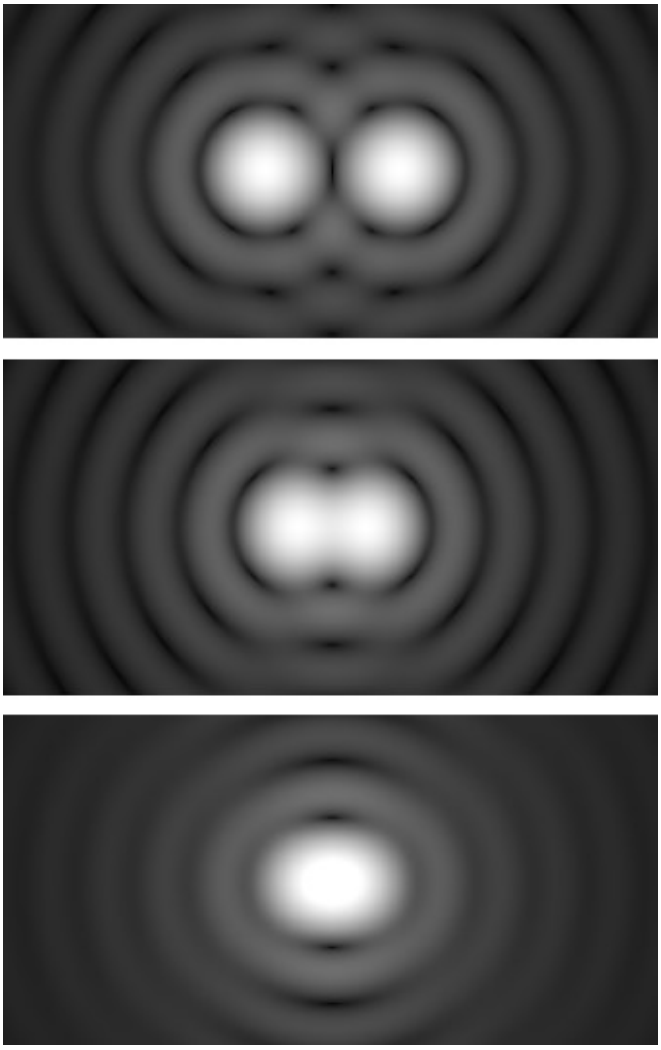

Figure 2: Airy disks around point light sources (public domain image)

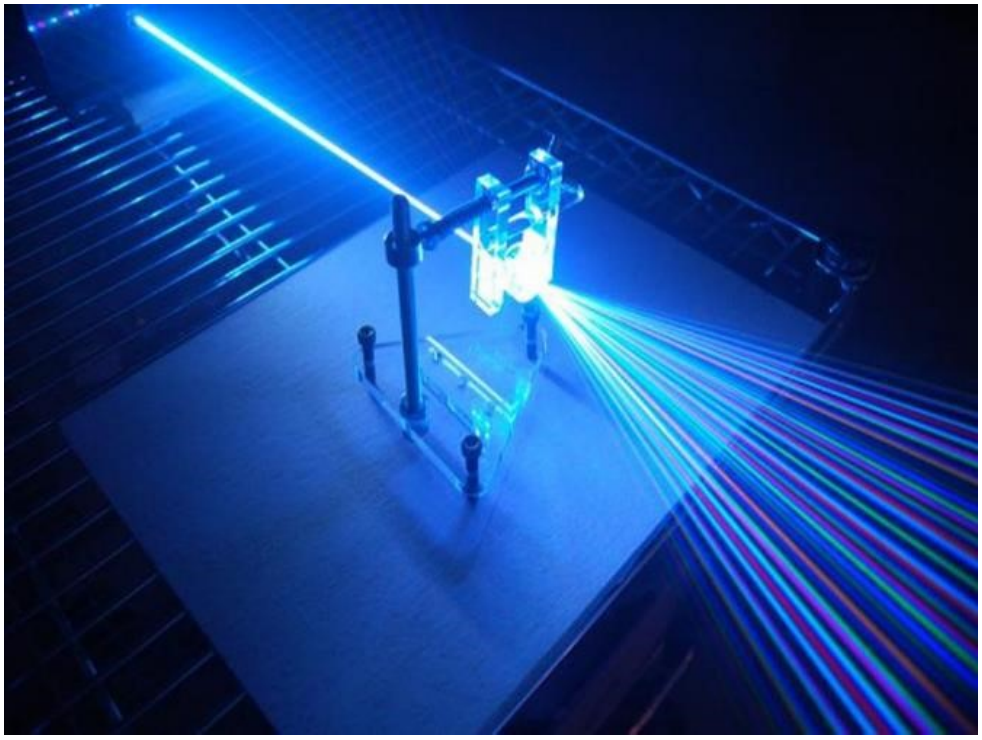

Figure 3: Light passing through a diffraction grating (image from physicsopenlab.org reproduced with permission)

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