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(Dis)entangling Barad: Materialisms and ethics

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Abstract

In the wake of the widespread uptake of and debate surrounding the work of Karen Barad, this article revisits her core conceptual contributions. We offer descriptions, elaborations, problematizations and provocations for those intrigued by or invested in this body of work. We examine Barad's use of quantum physics, which underpins her conception of the material world. We discuss the political strengths of this position but also note tensions associated with applying quantum physics to phenomena at macro-scales. We identify both frictions and unacknowledged affinities with science and technology studies in Barad's critique of reflexivity and her concept of diffraction. We flesh out Barad's overarching position of 'agential realism', which contains a revised understanding of scientific apparatuses. Building upon these discussions, we argue that inherent in agential realism is both an ethics of inclusion and an ethics of exclusion. Existing research has, however, frequently emphasized entanglement and inclusion to the detriment of foreclosure and exclusion. Nonetheless, we contend that it is in the potential for an ethics of exclusion that Barad's work could be of greatest utility within science and technology studies and beyond.

Keywords

New Materialism; Karen Barad; Cultural Theory; Ethics; Ontology; More-than-Human; Quantum Physics

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Introduction

In *Artful*, her collection of critical essays, Smith (2013: 41) reminds us of a childhood game designed to break the boredom of long car journeys – 'Ten points to the person who can see the Forth Road bridge' – and points to its direct suitability to the situation of the academic conference: 'Ten points to the first person who hears someone say the words Walter Benjamin.' In recent years, it has been possible to play a version of this game substituting 'Karen Barad' for 'Walter Benjamin'. If we add in bonus points for a cluster of terms taken from her book *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (2007) – especially 'entanglement', 'diffraction', 'intra-action' and 'agential realism' – then a fine game of 'Barad Bingo' can be had far and wide across the humanities and social sciences: from conferences on ruins, animal ethics and informational infrastructures to journal articles on lifelong learning (Edwards, 2010), bullying in schools (Søndergaarda, 2012) and feminist theories of fashion (Parkins, 2008).

It is striking that a book dealing with quantum mechanics, double-slit experiments, wave-particle duality, and Bohrian notions of complementarity has been engaged with so readily across fields such as cultural theory (Haraway, 2008), economics (Carlile et al., 2013), media (Parikka, 2011), social movement studies (Feigenbaum, 2014), theoretical psychology (Shotter, 2014), and even Hegelian philosophy (Žižek, 2012). It is perhaps equally striking that this work has received a more ambivalent response from what Barad calls 'mainstream' (Barad, 2007: 36) and Haraway calls 'canonized' (Haraway, 2004: 339) science and technology studies (Lynch, 2014; Pinch, 2011; Woolgar and Lezaun, 2013), a discipline that might be imagined to be particularly receptive to a book concerned with such topics.

We proceed with caution when drawing upon this distinction between mainstream/canonical and feminist science and technology studies (STS), given that the distinction threatens to marginalize feminist scholarship. In an extensive discussion of the topic, Haraway (2004: 338-341), describes feminist technoscience as 'both inside and outside' (p. 340) 'canonical' STS. The relationship is described as problematic, not least when researchers like Harding and Fox Keller are written out

of the discipline's genealogy. Accordingly, we urge a consideration of the ethics associated with 'cutting' away (in Baradian vocabulary) feminist technoscience from another portion of the discipline. Nonetheless, Haraway does note differences (including the political visions of feminist technoscience – p. 341) and, as noted in the body of our text, Barad discusses meaningful distinctions between 'mainstream' and 'feminist' STS at various points (e.g Barad, 2007: 29, 36, 56-57, 87).

In this article, we examine Barad's work and her framework of 'agential realism' in order to interrogate some apparent theoretical resonances and tensions with the rest of STS. We flesh out the implications of Barad's work for STS, explore its broader implications, highlight key problems, and offer theoretical, methodological and particularly ethical provocations for future work.

Both theory and physics

Barad currently holds the title of Professor of Feminist Studies, Philosophy, and History of Consciousness at the University of California at Santa Cruz. Barad's background is, however, in physics, completing a PhD within the field (Barad, 1984a) and publishing several, related, articles in the discipline (Barad, 1984b, 1988; Barad et al., 1984). Yet, as is evident from the above discussion it is since changing disciplines that Barad's work has taken off, and she is now described as 'one of the most influential and important representatives of contemporary materialist scholarship' (Lemke, 2015: 5).

Interestingly, Barad's significance arises from a comparatively small output. Two articles published in the 1990s have received several hundred citations (Barad, 1996, 1998) but it is an article of 2003 (Barad, 2003; 3000 citations) and the aforementioned book, *Meeting the Universe Halfway* (Barad, 2007; 4400 citations) that have really captured the imagination. In the words of reviewer Hird (2009: 338): 'to say that this book crosses disciplines is an understatement'. What is more, and as evidenced below (Figure 1), the influence of Barad's work continues to grow, with the above outputs receiving significant year-on-year increases in citation counts. And this brings us to an important point: While Barad's project spans twenty years, it is evidently of *this* moment.

Certainly, Barad's work offers elaborations and nuances to hybridity studies, mobility studies, actor-network theory and a host of other projects being undertaken within the social sciences

and humanities. Importantly, however, Barad seeks influence beyond social theory, stating that her

> project departs from mainstream and feminist science studies in that it does not merely offer insights about the nature of scientific practices but also makes a constructive contribution to the field of science being studied. (Barad, 2007: 36)

Barad's work, then, aspires toward a substantial contribution *to* the natural sciences and, undeniably, it is also remarkably of its time in this domain. First, Barad has been used by social scientists to understand contemporary scientific concepts such as the Anthropocene (e.g. Haraway, 2015: 159), epigenetics (e.g. Papadopoulos, 2011: 434), and neuroplasticity (e.g. Schmitz and Höppner, 2014: 5) wherein nature and culture are self-evidently collapse into one another. Second, Barad's project has supported forms of inter- or trans-disciplinary work (e.g. Fitzgerald and Callard, 2014; Science and Justice Research Centre, 2013) that tally with recent 'legislative calls for the integration of social sciences and humanities in publicly funded research and development initiatives' (Viseu, 2015: 643). Yet while this emphasis on entanglement (of both matter and disciplines) is precisely what lends Barad's work purchase within a broad interdisciplinary arena, it may also account for a certain ambivalence within strands of STS that have emphasized critical distance and reflexivity.

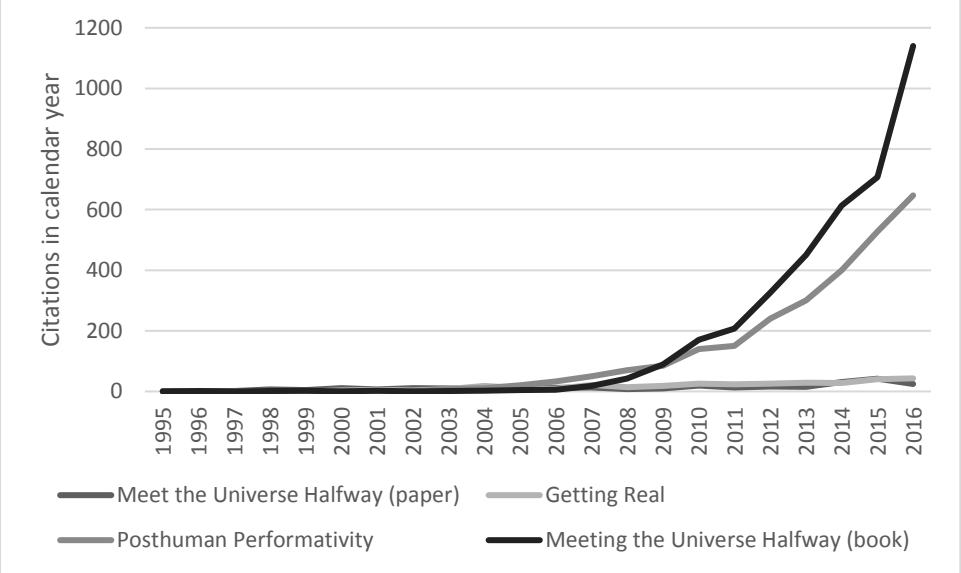

Figure 1: Citations counts for Barad's key works. Information from Google Scholar and accurate as of 21st June, 2017

Approaching Barad

In response to the widespread interest – positive and otherwise – in Barad's work, and at the ten-year anniversary of *Meeting the Universe*'s initial publication, here we return to the source material in order to offer an exploration and assessment of Barad's work, clarifying its significance and implications. To do this, we engage with some of the diverse contexts in which Barad's work has resonance, teasing out the ethical, methodological and conceptual significance of her work in relation to some of the core concerns of STS, whilst foregrounding her interdisciplinary significance along the way.

As described above, Barad suggests that she is not only 'doing STS' but also 'doing science'. We begin, therefore, by delineating the role of quantum physics in Barad's work. We highlight that physics is not a metaphorical resource for Barad but, rather, underpins agential realism's articulation of how the material world is brought into being. This realist, materialist basis offers agential realism a stability that is argued to be of political utility in avoiding dangers associated with both social constructivism and relativism. Questions are raised, however, about the applicability of concepts originating in the quantum realm and what is lost when they 'jump scales' and are used in order to grasp macro-sociological concerns.

The implications of Barad's relationship with science is then discussed in the context of STS, with a focus on tensions that have emerged in relation to Barad's critique of reflexivity in favour of diffraction. While diffraction productively lends itself to an interdisciplinary agenda, we suggest that Barad's reading of reflexivity does not do justice to the heterogeneous understandings of the concept within STS and that there is an unacknowledged possibility of rapprochement.

In the next section, we introduce Barad's theory of agential realism. Agential realism contends that wide-ranging apparatuses do not measure but, rather, produce material realities. Furthermore, Barad argues that the instantiation of one reality necessarily excludes another, equally feasible, possibility. These 'agential cuts' are exclusions that arise when a particular reality is brought into being. There is, thus, both an ethics of inclusion and an ethics of exclusion inherent in Barad's work. We conclude the article by arguing that in much of the literature drawing upon Barad there is a focus upon diffraction and entanglement and that this has come at the expense of considerations of complementarity and necessary exclusion. We suggest, however, that it is the radical potential of an ethics of exclusion which is perhaps most vital to those continuing to use Barad's work.

We are *not* putting forward a singular way in which in which Barad 'should' be read. Instead of a definitive reading we have three aims, the first of which is to simply provide a 'way in', to describe Barad's key concepts. Our second aim is to elaborate, to detail some of the existing, interdisciplinary, literature that furthers, problematizes or speaks to Barad, to place it within a broader context. Finally, and perhaps most importantly, in undertaking the above, we are also offering a series of provocations, suggesting possible alliances and directions for future study.

Making matter matter, or, in search of lost realness

Rather than speculate as to what might be fuelling the surge of interest in Barad, it might be better to begin by pressing hard upon the physics of *Meeting the Universe Halfway* and, in particular, the role of physics within Barad's more general social theory. It is important to ask whether the guarantees that seem to be offered by a quantum take on the relationship between matter and meaning are as secure as they might appear. Does the process by which 'matter comes to matter' in Barad's thesis *matter*? When we call upon Barad to help secure an argument, how can we be sure that we are not suffering from a new case of physics envy – of the quantum variety?

Psychologists, ecologists, economists, geographers, geologists, geneticists and political and social scientists, have all, at one time or another, been accused of suffering from 'physics envy' (Clarke and Primo, 2012; Egler, 1986; Massey, 1999, 2005). Depending upon the company they keep, researchers can be seen to be more or less hard in their relation to the hard sciences (Massey, 1999). Physics – with its abstractions and detachments – is said to be 'ontologically hard' as well as methodologically, epistemologically and emotionally challenging (Traweek, 2009: 74-105), contributing to the received idea that physics simply *is* hard (McAlpine, 2012).

The 'hardness' of physics assumes a distinct form in Barad's work. Avoiding naïve positivism, Barad argues that her engagement with quantum theory offers the humanities and social sciences a way of undoing 'the pairing of constructivism with some form of antirealism' (Barad, 2007: 43) and a potential resolution to the essentialism/social constructivism, postivism/postmodernism debates of the 1990s where 'language has been granted too much power' (Barad, 2007: 132). In what follows we detail Barad's specific conception of matter and how it has offered a means of plotting a path through these longstanding debates. We also, however, suggest that further attention needs to be paid to the politics of scale, and whether insights from quantum mechanics should be smoothly related to phenomena that occur at the macro-scales that are more often of concern to social and cultural theorists.

A philosophy-physics

The hardness that is offered by Barad's thesis is comprised of different properties than that which attracted, for instance, neoclassical economists (Mirowski, 1992, 2008) or the positivists and behaviourists that Foucault warns against in *The Order of Things* (2001[1970]). A mildly apologetic realist, Barad 'own[s] up' and 'confess[es]' her commitment to a rehabilitated objectivity: an objectivity resting, oddly, upon principles of uncertainty, paradox and 'quantum weirdness' (Barad, 2007: 83).

This rehabilitated objectivity draws significant inspiration from Niels Bohr's 'philosophy-physics', which utterly rejects Newtonian mechanics, with its positivist certainties, discrete objects and measurable forces. Instead, Bohr's thought pursues its case via principles of uncertainty and indeterminacy. Here, the classical version of physics gives way to an entangled universe governed by subatomic particles and, moreover, where measuring instruments become inextricably snagged in the scenes of their experiments, softening and fraying science at the edges. The sensorium of the laboratory – the feeling of doing science – serves to blur the boundaries still further as Barad insists upon the presence of the scientist as a productive force in her experiments.

We pursue these topics at greater length in subsequent sections. For the moment, however, the most important point is that, despite all this blurring and indeterminacy, quantum measurements are still *objective* insofar as they are reproducible and communicable with 'permanent marks ... left on bodies which define the experimental conditions' (Barad, 2007: 119). The predictable outcome of quantum experiments – for Bohr, their reproducibility and communicability – adds a strange stability to the world. For those frustrated by the rhetorical spinning associated with deconstruction and, with this, the social constructivist overestimation of discourse (a markedly feminist concern see Zalewski, 2003), Barad's 'ontoepistemological' account of nature sets out to show that 'direct engagement with the ontology of our world is possible' (Barad, 2007: 44), all without reinforcing a naïve positivism.

By way of comparison, Kellert (2005, 2008) has discussed the use of chaos theory within the social and human sciences. He explores chaos theory as a form of 'borrowed knowledge' within social science and suggests that physics here serves a 'rhetorical function', used to establish prestige, additional understanding, or methodological innovation and which may be both fruitful and dangerous (Kellert, 2005: 240). This is resolutely not what Barad intends in *Meeting the Universe Halfway*. Barad's agential realism is strongly premised upon the continuity – or

entanglement – between the results of quantum theory and the macro-realms with which social scientists are generally concerned. Quantum physics is not a metaphor, but is instead an instance of matter with which Barad is working.

Barad (2007: 279) asserts that the same rules apply in the microscopic and macroscopic domains and that conclusions reached from studying experimental physics apply to a legion of other domains. Both Pinch (2011) and Morton (2012) have questioned this approach, throwing down the gauntlet when it comes to the quantum entanglement experiments that lend empirical support to agential realism and asking the question: To what extent does this thesis, together with its attendant conceptual apparatuses, rest upon its physics? Again, Barad, in her reply to Pinch, is unequivocal:

> I propose an agential realist interpretation of quantum physics …. This agential realist interpretation is vulnerable to empirical results, as it should be. It has to cohere with what we know. And, likewise, yes, scandalous as it may be to some, agential realism could ultimately be proven wrong …. (Barad, 2011: 446)

There are two entirely concordant consequences to this continuity between physics and social theory. First, Barad's realism promises to firm up the 'beneath', to put it in Foucauldian terms, of knowledge (Lather, 2010) by offering 'the weight of realism' as 'ballast' against too much postmodernism (Barad, 2007: 43). Barad's thesis, thus, can be pressed into service as support for an array of political projects, ranging from the practice of cultural geography (Whatmore, 2002) to a socially sensitive science (Harding, 2004) to the proposition of new (Dolphijn and Van der Tuin, 2012) and materialist feminisms (Alaimo, 2008): 'Material feminists want to know how we can define the "real" in science and how we can describe nonhuman agency in a scientific context' (Alaimo, 2008: 7). Baradian onto-epistemology, with its notions of agential realism and intra-action, works hard, then, to establish a lively and worldly substratum, which, despite its mysterious nature, is testable and trustworthy. Objects, entities and phenomena are demonstrably instantiated in and by material practices, produced performatively in concrete situations and thus – crucially – can anchor political actions. This approach carries distinct ethical implications, on which we focus shortly.

The second issue concerns whether we can assume that rules that govern the quantum sphere also govern macro-scales. That macroscopic objects (like Schrodinger's cat) don't appear to follow quantum rules is of course widely known, discussed, and a variety of diverse explanations have been offered over the decades (e.g. Jammer, 1974). Again, Barad discusses these topics at

length, drawing upon Bohr and arguing that the micro- and macro- worlds are entangled with one another, that there is no clean break between the two, and that the same rules apply in both domains (Barad, 2007: 279). It is not for us to decide if Barad's particular take on this issue is more or less robust than Everett's many worlds hypothesis, or Bohm's hidden-variables interpretation (discussed in Pinch, 2011), or any one of the other interpretations offered and discussed within the physics community (Barad, 2007: 287). It does, however, mean that the issue of *scale* is particularly pertinent for those seeking to draw upon Barad's work, and worth dwelling on.

Jumping scales

In a discussion on the topic, Barad strongly resists 'geometric readings of the notion of scale' (Barad, 2007: 245) wherein the micro- or quantum-scale can always be assumed to be unproblematically 'smaller' than the macro-realm, the local always be assumed to be unproblematically smaller than the global, and so forth. Scale is, instead, an *outcome* of on-going worldly processes of production, contestation, and reproduction (Barad, 2007: 245). In making this point, Barad draws heavily upon the work of geographer Neil Smith, which is a pertinent touchstone here for at least two reasons: First, Smith's work is attuned to debates within the history of physics (e.g. Smith, 2008: 94-107). Second, and more important, Smith questions the givenness of scale, arguing instead that 'the construction of scale is a social process, i.e., scale is produced in and through societal activity which in turn produces and is produced by geographical structures of social interaction' (Smith, 1992: 62). This second point in particular is very obviously in keeping with Barad's work.

For Barad and Smith to argue that scale is produced is not for them to assert that diverse scales are not real. Rather, the argument is that 'nested' scales (Smith, 1992: 66) emerge as exteriorities-within-phenomena. Attention is thus shifted away from '[q]uestions of size and shape (geometrical concerns),' and is instead reoriented to 'questions of boundary, connectivity, interiority, and exteriority (topological concerns)' (Barad, 2007: 244).

There is an additional important point here. For Smith, the 'deliberate confusion and abrogation' of diverse scales, the deliberate 'jumping' of scales is an activity with profound radical, political potential (Smith, 1992: 66). Barad explicitly endorses this proposal to jump scales (Barad, 2007: 245) and 'jumps' repeatedly in *Meeting the Universe Halfway*, taking agential realism and Bohr's philosophy-physics from the quantum realm to pregnant bodies (pp. 215-222), factories (pp. 226-230, undersea creatures (pp. 377-380), and any other number of spaces. Furthermore, and

just as importantly, Barad's project self-evidently lends itself to the jumping of scales. Agential realism is deployed across a range of scales, in an array of different spaces, and it has jumped these scales rather smoothly.

The capacity to 'jump scales' is problematized not only by those physicists who question the relationship between micro- and macro-scopic realms but also by Tsing, with whom Barad also shares a great deal. In her recent book *The Mushroom at the End of the World* (2015), Tsing argues that '[t]he ability to make one's research framework apply to greater scales, without changing the research questions, has become a hallmark of modern knowledge' (p. 38). Tsing is careful not to refer to scalable projects as 'bad' and non-scalable projects as 'good', but the reference to a 'plantation' mentality among those who 'change scales smoothly without any change in project frames' has obvious negative connotations. Instead, Tsing draws attention to 'scales [that] do not nest neatly' (p. 37), the frictions experienced when moving between scales, and encourages pause over what is *lost* in the transition between scales; those specific qualities which are valuable precisely because they are not scalable.

We introduce Tsing here not to demonstrate that those who take up agential realism are 'wrong' to apply philosophy-physics so widely; besides being a purposive political strategy it also worth noting that a capacity to jump scales is probably a necessary quality of any theory which has gained the purchase that Barad's work has. We do, however, seek to dwell upon the frictions experienced when jumping scale and urge a consideration of what is lost during the jump. In following sections, we will argue that, in the widespread uptake of Barad's work, political and ethical potential is one such lost quality and that these themes need to be revisited in order for the more profound implications of her approach to be developed. In the following section, we will begin to lay the groundwork for this focus on ethics by examining the knowledge-politics of agential realism more closely focusing upon one transition where considerable friction has been evident: the use of agential realism within STS.

Reflection and diffraction

Concerns about new materialist appeals to an ontology grounded in physics have been brought to the fore in debates surrounding Barad's work within STS. Interestingly, and despite aligning with STS (Barad, 2007: 58), Barad's uptake within this community has been patchy and, outside of the feminist technoscience perspective to which Barad is most obviously connected, responses from leading figures within 'mainstream' (see above) STS have been, fairly consistently, disparaging (e.g. Lynch, 2014; Pinch, 2011). Why might this be the case?

Barad disavows the separation and reflection which she sees as typical in STS and states instead that 'the crucial point is not mirroring but its creative undoing, not sameness reproduced without end but attentiveness to differences that matter' (Barad, 2007: 382). As others have suggested (Pinch, 2011: 439-440; also Fitzgerald, 2012: 107-110), Barad's stance on this matter is surely one of the core reasons why she has found ambivalent response from much of the STS community. In this section, we explore Barad's critique of reflexivity and her alternative, diffraction. Despite the obvious utility of diffraction, the section concludes with some thoughts on the possible merits of rescuing reflection.

Barad's critique of reflexivity

Barad's critique of reflexivity is well captured in the following quote:

> Reflexivity, like reflection, still holds the world at a distance. It cannot provide a way across the social constructivist's allegedly unbridgeable epistemological gap between knower and known, for reflexivity is nothing more than iterative mimesis: even in its attempts to put the investigative subject back in the picture, reflexivity does nothing more than mirror mirroring. Representation raised to the nth power does not disrupt the geometry that holds object and subject at a distance as the very condition for knowledge's possibility. Mirrors upon mirrors, reflexivity entails the same old geometrical optics of reflections. (Barad, 2007: 87-88)

The key points for Barad, then, are that reflexivity emphasises *sameness* and *separateness*. Perhaps, we might argue, this is an unfair representation of constructivist views (Lynch, 2014: 142) or that reflexivity retains methodological utility in encouraging us to dwell upon the influence of our own activity? Barad rejects this methodological suggestion with a wonderful line: 'Turning the mirror around, as it were, is a bad method for trying to get the mirror in the picture' (Barad, 2007: 418).

Diffraction as an alternative

So Barad is unimpressed with reflexivity. In its place, she, via Haraway, suggests *diffraction* as both a methodology and a way of viewing the world. In order to understand Barad's use of diffraction it is helpful to return to the physical basis of the phenomena from which she draws conceptual inspiration. When two particles encounter each other they are not able to occupy the same space; they retain their own distinct properties and bounce off in different directions, as in a game of snooker. Waves, however, are quite different. When two waves encounter one another they *are*

able to occupy the same point in space and time – this is called superposition – and the new emergent wave has properties that result from the combination of the two (Barad, 2007: 76). Barad uses the example of two stones being dropped into a calm pool of water to illustrate this point; the waves spread out, ultimately overlap, and form new patterns. This is the process that gives rise to Barad's terminology: The coming together of two waves is called *diffraction*, the resulting pattern of new waves is called a *diffraction pattern*, and the thing which makes the two waves come together in the first place (the dropping stones) is called the *diffraction apparatus*. Importantly, by studying the diffraction pattern it is possible to learn about the nature of the diffraction apparatus so, for example, we can learn something about the dropping of the stones by examining the ripples in the pool (Barad, 2007: 83). As noted above, studying the effects of a mirror is much harder and, thus, focusing on diffraction is seen as a much more useful way of bringing the method, the apparatus, in to focus.

So whereas reflection focuses upon sameness and separateness, diffraction is about '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 focus on coming together, entanglement and emergent difference stands not only for physics but also for analyses in STS, cultural studies and a range of other disciplines. The founding error of STS for Barad, then, is evident in title of Bloor's book; he should be concerned not with a Sociology *of* Scientific Knowledge but rather a Sociology *through* Scientific Knowledge and he should be aware that, following this disciplinary diffraction, the emergent object of investigation will look like neither sociology nor science but will be quite different with its own, unique, properties.

There is much to admire about Barad's vocabulary. It is well suited, deliberately so (Barad, 2011: 444), to a transdisciplinary research agenda and it is no surprise that Barad has been taken up favourably by those striving for such collaboration (e.g. Fitzgerald and Callard, 2014).

Reflecting on reflexivity

Perhaps ironically, Barad does not seem be to attentive to difference where reflexivity is concerned; both Ashmore (1989) and Lynch (2000) have conducted extensive analyses of reflexivity and identified numerous categories, each with sub-categories that often have very little in common with one another (Lynch, 2000: 27). Furthermore, not all of these categories are based upon optical metaphors or mirroring. Slavoj Žižek makes this point while discussing

Hegelian notions of reflexivity in relation to Barad's work (2013: 931), but similar arguments have also been made within STS. Ashmore (1989: 31), for example, notes that optics is just one element of a diverse and complex etymological background where reflexivity is concerned. Indeed, Ashmore notes the concept of 'essential reflexivity' within ethnomethodology refers to 'the mutually constitutive nature of accounts and reality' (p. 32). This is the form of reflexivity taken forward by Woolgar (1986) and others (e.g. Lynch, 2000) under the moniker 'constitutive reflexivity'. According to Woolgar, constitutive reflexivity:

> '…offers us a way of seeing these distinctions [between 'a thing and what is said about a thing'] as actively created achievements rather than as pre-given features of our world. In particular, the distinction between talk and the objects-of-talk is seen from the constitutive perspective as the upshot, rather than the condition, of discursive work.' (Woolgar, 1986: 314)

Woolgar's account shares a great deal with Barad's. It encourages us to believe that any discussion of '*the* methodology of reflexivity' (Barad, 2007: 72, our emphasis) is misguided, but also that there exists significant possibility for rapprochement between many reflexive and diffractive accounts in STS.

A second issue concerns what we learn from Barad about physics. It is beyond dispute that a great deal has been learnt about physics by '*playing* the stranger' as Shapin and Schaffer (1985: 6, our emphasis) have it. It is also true that existing studies of the physics community (see, for example, the classic studies by Collins [1975], Knorr Cetina [1999], and Pinch [1981]) are far more sceptical about the 'reproducibility and unambiguous communication of laboratory results' (Barad, 2007: 340) upon which an objective philosophy-physics (e.g. p. 174) is founded.

In a recent article, Paxson and Helmreich (2013: 169) argued that:

> '[New materialism] is productive because it can shake thinking away from the certainties of social determinism, as exampled, canonically, in the Strong Programme in the Sociology of Knowledge – and because it can show that phenomena emerge in practice. But it is also risky, because new materialist tactics often veer towards universalizing metaphysical claims about the nature of 'matter' as such and also, at times, take scientific truth claims about the world at face value – a move that we consider a step backwards for STS.'

There are instances where these 'promises and perils' are played out in *Meeting the Universe Halfway* for alongside its distinctive contribution it is easy to argue that the text is less critical about contemporary physics, nanoscience, and genetic modification than we expect from STS. The reading of synthetic biotechnology (p. 365-367), for example, arguably trades in the 'speculative scenarios' (Jefferson et al., 2014) and myths of biotechnical revolution (Nightingale and Martin, 2004) that research informed by STS has long queried. Nonetheless, the aforementioned affinities with constitutive reflexivity suggest no fundamental incompatibility between diffractive approaches and much of the research in STS that preceded them. Rather, and as Paxson and Helmreich argue, the on-going challenge is to produce analyses able to incorporate insights from both reflexive and diffractive approaches, including agential realism. One potential area of investigation in this regard is the nature of scientific apparatuses, given that determining what is included in the apparatus is a significant question for various strands of STS.

Agential realism and the nature of the apparatus

In the previous sections, we made the following arguments: First, Barad is a self-consciously realist scholar who attests that matter really does matter. Second, Barad is dismissive of reflexivity and, more generally, of any research endeavour – including much of STS – suggestive of an 'optics of reflection' (Barad, 2007: 135) preferring instead to rely upon notions of 'diffraction'. While highlighting the very obvious strengths of these positions, we have not treated these assertions unproblematically and have questioned these claims on several grounds. In this section, we show how these two themes come together in the notion of 'agential realism' and demonstrate that at the heart of this concept is a reworking of what constitutes a scientific apparatus. This reworking is an important move in going beyond a critique of reflection, in order to craft alternative approaches to knowledge politics and, by extension, ethics.

Barad strongly resists any metaphysics that insists that things-in-themselves stand separate from representations of those things. For Barad, both naïve scientific realism and social constructivism are equally guilty 'concordant epistemologies' (p. 135) in this regard. For naïve realists, tools of measurement are entirely separate from the thing being measured. So, for example, a ruler does not affect that nature of the item being measured and is instead a neutral conveyer of information. Social constructivists, meanwhile, give language a primacy and distance from the world to the extent that matter is inaccessible and inquiry is limited to discourse. These differences may be profound enough to have ushered in the science wars but, for Barad, there is a deep unity; a dependence upon representation. In many ways this approach echoes Haraway's earlier criticisms of a Kantian metaphysics that 'set[s] off at extreme poles Things-in-Themselves

from the Transcendental Ego … with escalating and dire consequences for the repertoire of explanatory possibilities' (1992: 329). And, as with Haraway, the shift from reflection to diffraction, highlighted in the previous section, provides a way out of representation. Within diffractive approaches there is no pre-given distinction between worlds and words. Instead measuring devices, words, and things are thoroughly entangled and *co-constitute* one another; the way Barad figures this entanglement, however, offers distinct conceptual trajectories.

From uncertainty to indeterminancy

In elucidating the co-constitutive nature of matter and discourse, Barad once again draws heavily upon the 'philosophy-physics' of Niels Bohr and, in particular, his solution to Werner Heisenberg's uncertainty principle. The uncertainty principle states that it is impossible to measure all the properties of a given particle accurately – most famously it is possible to measure a particle's momentum *or* its position, but not both. This problem is frequently read as an epistemic problem – the act of measuring trait *a* (e.g. position) disturbs the particle to the extent that it is impossible to measure trait *b* (e.g. momentum) accurately. This is precisely the form of representationalist position that Barad disputes, for it suggests there are things-in-the-world (particles with position and momentum) that pre-exist attempts to measure or represent them.

The alternative offered by Barad closely follows that provided by Bohr. Bohr argued that the uncertainty principle is not one of epistemic uncertainty but, rather, of ontic *indeterminacy*. Prior to the measurement attempts, Bohr and Barad suggest, the particle simply did not exist in any fixed state. In other words,

> there aren't little things wandering aimlessly in the void that possess the complete set of properties that Newtonian physics assumes (e.g., position and momentum); rather, there is something fundamental about the nature of measurement interactions that, given a particular measuring apparatus, certain properties *become determinate*, while others are specifically excluded. (Barad, 2007: 19, italics in original)

For Bohr and Barad, therefore, it is following specific *intra-actions*, such as attempts at measurement, that objects like particles take on the properties they do. Particles do not pre-exist interactions but instead emerge from them, taking on particular properties (like position) while others properties (like momentum) are excluded. Position and momentum, in other words, are complementary states. This principle of complementarity ensures that the existence of one property necessarily excludes the other.

> Relata do not preexist relations; rather, relata-within-phenomena emerge through specific intra-actions. Crucially, then, intra-actions enact *agential separability* – the condition of *exteriority-within-phenomena*. (Barad, 2007: 140, italics in original).

The key terms within this passage – intra-action, agential separability, exteriority-within – all indicate that for Barad the separations between words, things, and knowers are real enough but these separations are *effects* of particular engagements with the world (p. 138). This is the crux of Barad's agential realism.

Agential realism thus insists that key elements involved in experimentation – the particle, the measuring apparatus, the conceptual frameworks and the scientist recording the measurements (p. 138) – all emerge from the experimental entanglement and do not pre-exist them. This performativity does not lead to anarchy, however, for, as noted above, the same particular diffraction apparatus will always produce the same diffraction pattern and, thus, scientific experiments that take a particular apparatus to the world are reproducible: same matter, same apparatus, same outcome.

Agential realism and the apparatus

As detailed thus far, Barad's concept of agential realism largely reframes the work of Niels Bohr for a new audience. Barad argues that this in itself is an important activity: by reading the humanities, in particular Michel Foucault and Judith Butler, against Bohr, Barad seeks to show that these thinkers accept and uphold a nature-culture binary while under-appreciating the role of matter and treating agency as something that resides solely within a pre-existing, rather than emergent, human subject (see Lemke [2015] for a riposte and Hollin (2017) for an elucidation). Nonetheless, Barad also seeks to trouble and further Bohr's work.

Barad first extends Bohr by questioning his reading of the apparatus as 'mere laboratory set-up' (Barad, 2007: 141), those elements safely contained within the methods section of a scientific report. For Barad, Bohr underappreciates the range and extent of material-discursive factors that (re)produce and maintain apparatuses. Barad demonstrates this point with reference to a further example from physics known as the Stern-Gerlach experiment (p. 161). While the particulars of this experiment are not important in the current context, what is important is that experimental results were only evident because one of the experimenters smoked cheap cigars, the sulphuric fumes from which were required to make experimental effects visible. On the basis of this finding, Barad concludes that:

> Apparatuses are not static laboratory setups but a dynamic set of open-ended practices, iteratively refined and reconfigured. [In the Stern-Gerlach experiment] … a cigar is among the significant materials that are relevant to the operation and success of the experiment …. Not any cigar will do. Indeed, the cigar is a 'condensation' – a 'nodal point', as it were – of the workings of other apparatuses, including class, nationalism, economics, and gender, all of which are a part of this Stern-Gerlach apparatus. (p. 167)

There is thus, and contra Bohr, no intrinsic outside to the apparatus; it extends far beyond the laboratory and methods section.

Barad's understanding of the apparatus, then, is more expansive than in a 'typical' methods section, more-than-human in its composition, and emergent through practice. There are clear affinities here with actor-network theory (e.g. Latour, 1987: 162) as well as with existing research in other fields attending to materiality (Kirsch, 2012), more-than-representation (Lorimer, 2005) and the more-than-human (Whatmore, 2004). It is perhaps interesting to note in this regard, that in areas where it may seem obvious that Barad's work would be utilised – such as more-than-human geographies – her work is conspicuous by its absence or minimal presence. These fields have already made valuable engagements with non-representational theories and methodologies; in particular the work of Whatmore (1997; 2002; 2004; 2006) has been hugely influential, as has that undertaken by Latour and Haraway. Perhaps, we might speculate, for theorists whose bread and butter it is to consider the nonhuman and their relations with humans and other nonhumans, Barad's considerations are neither seismic nor entirely novel. Such a response would be understandable given the aforementioned affinities with a range of theorists that are consistently underplayed within *Meeting the Universe Halfway*. Nonetheless, such straightforward dismissals miss an important emphasis in Barad's work which moves it beyond the diagnoses of hybridity found, for instance, in *We Have Never Been Modern* (Latour, 1993)

The ethics of the outside

A key point in Barad's work is that just because apparatuses have no *intrinsic* outside does not mean there is no outside. Barad discusses this point with reference to another of Bohr's cases, the example of a person using a stick to navigate a dark room. When the stick is held tightly the stick is part of the measuring apparatus used to observe and feel the room. When the stick is held loosely, however, the stick is an object, touched and experienced as part of the room, an object of investigation that is cut away from the measuring apparatus. This is an example of an *agential cut*, a moment where exteriorities-within emerge into the world.

> The stick cannot usefully serve as an instrument of observation if one is intent on observing it. The line between subject and object is not fixed, but once a cut is made (i.e., a particular practice is being enacted), the identification is not arbitrary but in fact materially specified and determined (Barad, 2007: 154-155).

Beyond those features identified by Barad in this quote, this example makes another facet of agential realism apparent: Not only is cutting a boundary-making practice (p. 148), it is a process over which there is a degree of control. Thus, for Barad, boundaries are not only real but there is a degree of responsibility for their creation, the worlds that are made, and those that are excluded (p. 243). Barad states that there is a lesson for STS here. In a passage that resonates with Haraway's (2004: 226) earlier critique of *Leviathan and the Airpump*, Barad states that

> [t]he point is this: one can't simply bracket out (or ignore) certain issues without taking responsibility and being accountable for the constitutive effects of these exclusions. Since science studies needs to take account of gender and other crucial social variables …, and since it no doubt wants to avoid reinstalling the metaphysics of individualism or other representationalist remnants into its theories, its methods, and its results, turning to performative accounts of gender to find out what they have to offer at least seems like a good starting point. (Barad, 2007: 58)

This emphasis on separability, exteriority and constitutive exclusion is a significant part of what makes Barad's work distinct and important. It is also the part of Barad's scholarship that is most frequently lost in the re-telling. We conclude this paper by discussing the decisive ethical contribution that we believe Barad is able to make, which builds on her specific conception of matter, commitment to diffraction and reworking of the apparatus (with its attendant implications for knowledge-politics).

Crafting an ethics of exclusion

We have argued that, while Barad does indeed foreground the entanglement of matter and meaning (most notably in a preference for diffraction over reflexivity) agential realism is also about absence. The concept of complementarity makes clear that, for Barad, when one apparatus instantiates a particular world another is necessarily excluded. It is in these cuts and through these boundary-making practices that Barad's ethical contribution is to be found. The significance of Barad's focus upon cuts and exclusions is precisely what has been most frequently lost as agential realism's vocabulary has jumped scales. In this final section, we discuss this loss

by considering research that has engaged with Barad via the situated, relational ethics articulated by Haraway. Haraway is one of Barad's most significant interlocutors and the engagement with Barad in and through *When Species Meet* (2008) offers a striking illustration of how concepts associated with agential realism travel.

Following the uptake of the term 'intra-action' by Haraway (2008: 17, with the concept underpinning her account of companion species) the term has obtained widespread currency in perspectives influenced by feminist STS (e.g. Latimer and Miele, 2013; Puig de la Bellacasa, 2011). Yet, as Haraway herself suggests, use of Barad's terminology does not necessarily mean an ethical engagement with the 'radical change Barad's analysis demands' (2015: 162, n.1). In response to Haraway's provocation, in this section we draw together our previous themes. On the one hand, we return to Barad's work to interrogate what the 'radical change' that Haraway evokes entails ethically; on the other hand, through the ethics of agential realism we also complicate some of the ways that Barad has been taken up, including by Haraway. We argue that the ways with which Barad's approach has been engaged have resulted in an over-emphasis on questions of entanglement. In contrast, we suggest that the 'radical potential' of agential realism is in drawing attention to what is excluded from particular entanglements.

Situating materialist ethics

Barad's intra-active conception of the world offers a specific understanding of relationality that goes beyond earlier conceptualizations of hybridity (Haraway, 1992; Latour, 1993), a term which suggests relations shape pre-existing entities (Lorimer, 2015: 24). Yet, aside from offering a neat neologism that makes its difference from interaction explicit, on a superficial level, intra-active conceptions of the world do not appear to be wholly novel. Approaches that have considered the 'mangle of practice' (Pickering, 2010) such as posthumanism (Castree and Nash, 2004; Hayles, 1999; Wolfe, 2010), actor-network theory (Latour, 2005; Mol, 2003), non-representational theory (Anderson and Harrison, 2010), vital-materialist approaches (Bennett, 2009), engagements with cosmopolitics (Stengers, 1997, 2010, 2011; also Hinchcliffe et al., 2003), or object-oriented ontology (Bogost, 2011; Harman, 2012), all stress the agency of more-than-human entities and make clear that the human is shaped through encounters with other agencies. Barad's understanding of reality as enacted rather than pre-given similarly troubles pre-defined ethical hierarchies such as human/animal, subject/object, and nature/culture, as a way of thinking about the world.

In a sense, then, agential realism's specific contribution to STS could, as Woolgar and Lezaun note, be situated as part of a broader 'turn to ontology in STS' that 'can be better understood as another attempt to apply its longstanding core slogan – "it could be otherwise" – this time to the realm of the ontological' (Woolgar and Lezaun, 2013: 322) or as intensifying the provocative power of STS perspectives rather than revolutionizing them (p. 336). Barad could thus be situated as part of a longer lineage of work that has collapsed the ontological and epistemological and turned attention to the performative composition of reality (e.g. Mol, 2002; Star, 1992). Yet, whilst Woolgar and Lezaun's framing is helpful in drawing attention to conceptual lineages that are understated in Barad's own work, it is agential realism's emphasis on ethics that demands the most sustained 'radical change' in approach, and make it more than another – differently modulated – articulation of hybridity or constitutive reflexivity.

Barad's emphasis is not on the possibility of multiple ontologies, but on the relative stability afforded to matter after it has intra-actively emerged, due to the same apparatuses producing the same outcome. The ethical significance of agential realism, therefore, is not just in extending the idea that things 'could have been otherwise' to the ontological realm but in conceptualizing the precise moments at which things congeal 'as they are', by understanding the processes through which particular material properties emerge and other realities are excluded from being. Any given phenomenon, for Barad, is understood as being composed of specific intra-actions, with discreet identities (such as 'subject' and object') only emerging after an agential cut has taken place. As with the example of the dark room, the stick can be part of the measuring apparatus (or subject) exploring the room, or experienced as an object within the room, but it cannot be both for these are complementary states. The stick's affordances, and the distribution of agency in this arrangement, are determined by whichever cut is made. A focus on agential cuts is, therefore, generative of particular sets of ethical responsibilities; though matter itself has stability, it is still necessary to be accountable for the cuts that created this stability and grapple not just with the ethical consequences of these cuts, but with the constitutive exclusions that underpin them. It is this emphasis on cuts, we argue, that holds particular ethical significance, as becomes apparent when reading Barad against some of the most influential work which has engaged with her approach.

Embodied ethics and exclusions

As mentioned above, much of Barad's influence has been obtained through Haraway. This influence is made explicit in Haraway's articulation of situated, relational ethics in the animal laboratory, a case that offers a useful example for elucidating and interrogating the ethical

significance of agential realism. In a series of critical moves, Haraway first decentres the human, by foregrounding the entanglement of humans with other actors, and then uses this foundation to problematize the use of humanist ethics to adjudicate what course of action should be taken. Entanglements between species mean that predetermined humanist frameworks such as 'human good is more important' and appeals to 'inviolable animal rights' are both unworkable and undesirable (Haraway, 2008: 87). This then lays the foundation for Haraway's core argument about what should replace longstanding ethical frameworks: care generated from entangled and embodied encounters. Through an openness to learning from encounters (rather than interpreting the behaviour of nonhuman actors in line with predetermined assumptions), Haraway argues (following Despret, 2004) that new forms of interest can emerge and space can be created to understand how nonhuman needs are articulated. This recognition of multispecies entanglement, coupled with an insistence on the intra-active aspect of encounters, therefore, is key to Haraway's realization of a cosmopolitical ethics that creates room for nonhumans to impose their own 'requirements' on humans (Stengers, 1997, 2015).

Grounding the ethics of companion species in Barad's language of intra-action and agential cuts, Haraway is able to cement her argument that mutually transformative encounters can redistribute agency in ethically significant ways, depending on how things are cut. Yet while Haraway's work has proven influential across a range of disciplinary contexts (e.g. DeKoven and Lundblad, 2011; Hinchliffe, 2010) its Baradian underpinnings are seldom engaged with in a sustained way. We suggest, however, that considering Barad's work on its own terms can serve to enrich, complicate and re-orient accounts of situated, relational ethics.

The importance of re-orienting ethical questions away from valorizing entanglement and towards the ethical implications of cuts can be elucidated through drawing on a series of debates that have emerged in relation to ethology, specifically the act of allowing birds to imprint upon humans. Despret's re-reading of the work of ethologist Konrad Lorenz, for instance, details how he regularly caused goslings to imprint on him in order to acquire new knowledge about goose behaviour. Despret argues, moreover, that these intimate entanglements between bodies were also generative of new forms of ethics, as Lorenz

> involves his own responsibility because he will have to fulfil the goose's needs, to be a 'good mother' for it, to care for it, to walk like it, to talk like it, to answer its calls, to understand when it is scared. Lorenz and his goose, in a relation of taming, in a relation that changes both identities, have domesticated one another. (Despret, 2004: 130)

Van Dooren (2014) offers an alternative analysis of this case, however, focusing upon the (sometimes violent) exclusions that are inherent to particular cuts. He foregrounds how imprinting: 'produces a relationship with humans at the expense of a whole set of other ways of being, often severing the possibility for a bird's relating with others of its own species, and so profoundly altering its chances for social and procreative relations' (p. 103). In this analysis, therefore, van Dooren is able to re-orient things away from a straight-forward valorization of what is generated by entangled relations themselves, and towards the realities that are excluded as cuts emerge through these relations. In doing so, he creates space to ask about the obligations that are created when things are cut in a particular way at the expense of other ways of being.

While Haraway refers to the importance of agential cuts, they are predominantly foregrounded in order to denaturalize discreet distinctions between humans and other entities and, thus, emphasize the entangled composition of reality (an argument offered further support through her engagement with Despret). Indeed, these thinkers' shared emphasis upon the transformative capacity of bodily entanglements has been a central theme in work that has sought to re-conceptualize ethics as something borne of situated, relational engagements both within the laboratory (e.g. Davies, 2013; Greenhough and Roe, 2011; Latimer and Miele, 2013) and beyond (Lorimer, 2015). Revisiting Barad's work, however, offers a reminder of an equally important dimension of agential cuts and one that is often underplayed when her work is used to underpin straightforwardly hybrid or more-than-human accounts of the world. Questions of the obligations opened up when certain realities are excluded are pushed to the forefront of *Meeting the Universe Halfway*, and offer an important reminder that the consequences of particular cuts are often difficult to reverse, especially if they are instantiated through vast socio-technical networks. Indeed, recent work ranging from the standardization of laboratory beagles (Giraud and Hollin, 2016) to links between laboratories and military apparatuses (Johnson, 2015), more-than-human battle-scapes (Forsyth, 2017), industrial agriculture (Puig de la Bellacasa, 2017) and disability politics (Hollin, 2017) foreground the dangers associated with an ethics borne of situated entanglements. These studies all illustrate that certain responsibilities and manifestations of agency could have already been foreclosed by a succession of cuts.

Conclusion

In this paper we have reviewed the conceptual implications of agential realism in the light of Barad's work having gained momentum and purchase across the social sciences and humanities. We do not propose how Barad 'should' be read or used but, instead, offer descriptions,

elaborations, problematizations, and provocations, attempting to trace affinities and potential directions of future travel. In particular, we have sought to detail the following arguments.

First, we provide an overview of some of the key elements of Barad's work: entanglement, intra-action, diffraction and agential realism. Several of these concepts travel with Barad from physics. Quantum physics, for Barad, is resolutely *not* a metaphor but, rather, underpins agential realism's articulation of how the material world is brought into being. The material grounding in physics is significant because it promises a stability and reality that can be pressed into service as support for an array of political projects. A corollary of this assertion, however, is that the rules that govern quantum realms must also be deemed applicable in macro contexts, and socio-cultural contexts in particular. We question the ease with which Barad's work has 'jumped' between diverse scales and urged that attention be paid to frictions between scales, and what may be lost precisely because it is not scalable.

We articulate Barad's concept of diffraction and discussed the attempt to circumnavigate persisting critiques of reflexivity in STS. Barad argues that while reflection maintains and emphasizes sameness and separateness, diffraction focuses on entanglement, coming together and emergent difference. We argue here that diffractive approaches have demonstrable utility, but that they are closer to work grounded in 'constitutive reflexivity' than is often recognized. There is, thus, significant scope for rapprochement between Barad's work and that in other strands of STS.

Third, we turn to the core concept of agential realism and Barad's reworking of apparatuses in order to further elucidate how matter is stabilized and can be taken seriously. Barad's apparatuses are not neutral measuring devices but, rather, are directly implicated in the production of the real, material world. While Barad stresses that apparatuses do not have an *intrinsic* outside – apparatuses include not only scientific instruments but also any number of socio-cultural factors – this is not to say that there is *no* outside. Apparatuses are boundary-making practices, cutting up the world in particular ways that necessarily and inevitably exclude possible alternatives. This focus upon exclusion and exteriority, we argue, is often lost as agential realism travels between sites and needs to be revisited in order for the ethical potential of Barad's work to be realized.

We make this argument through a reading of literatures that have approached Barad through Haraway's work. We argue that there is a tendency in much of this work to ground a situated, relational ethics upon concepts of entanglement and intra-action without a consideration of issues of complementarity and necessary exclusion. Such approaches, we suggest, may

uncritically celebrate relationality and hybridity without a consideration of alternative worlds lost at the moment of emergence. Reorienting matters towards questions of exclusion, we suggest, may offer the sort of 'radical change' that could be provoked by Barad's work, hinted at by Haraway.

Despite seeing a number of potentials in agential realism, however, it is important to caution against uncritically extolling the value of this approach. As Willey (2016: 993) powerfully argues, it is dangerous to position new materialism as a radical break from feminist, postcolonial STS (see also Sundberg, 2014), and uncritically valorizing agential realism can lend strength to this trap. It is instead important to pay careful attention to lineages with longstanding work within STS, which are often neglected or understated in 'disciplinary stories' that insist on the outright novelty of new materialism.

In a manner similar to that of Barad, Rose (1995: 779) attempts to break with 'the phallocentric mirror' of critical-theoretical practice in an effort to expose the fragilities of power and to theorize other spaces of self/knowledge that shatter 'the singular reflection of the same'. Yet she continues to work with the shards of that mirror to produce partial, plural and attentive research. Perhaps this provides a means for how Barad's work can be more effectively read and employed. It can become a tool that interrogates, explores and builds upon pre-existing – but nonetheless vital – conceptual developments. Such an engagement with Barad positions *Meeting the Universe Halfway* as part of the on-going apparatus that seeks to produce research that is attentive, plural, partial and politically ambitious. In his reading of Foucault, Agamben (2009: 13) states that 'there comes a moment when we are aware of our inability to proceed any further without contravening the most elementary of hermeneutics. This means the development of the text in question has reached a point of undecidability where it becomes impossible to distinguish between the author and the interpreter. Although this is a particularly happy moment for the interpreter, he [sic] knows that it is now time to abandon the text that he is analysing and to proceed on his own.' Let *Meeting the University Halfway*, likewise, not become a tome to cling to but a tool to synthesis.

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