Utrecht University

MATERIALIST SUBJECTIVITY

From quantum mechanics to the space of subjectivity

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Index

Acknowledgements

Before I started with my thesis, I had *a thousand little ideas* which were all loosely connected to each other. Or: I had a strong feeling that they were connected to each other. I talked with a couple of potential supervisors about these ideas, who all highlighted one of these ideas and encouraged me to thoroughly investigate it. These conversations were certainly helpful to order my thoughts. Only when I spoke with Iris, though, did I have the feeling that I could start the project of writing a thesis. She was enthusiastic about the big picture I wanted to work on. As a supervisor, she gave me the confidence to develop a not yet very well formed philosophical system, bringing together different thinkers which are not often directly associated with each other. That is because *affirmation* and *diffraction* are at the core of Iris' academic approach.[1] The conversations we had were fruitful, reassuring and most of all very enjoyable. She encouraged me to visit the institute for architecture theory and philosophy of technology (ATTP) at TU Wien, headed by her friend Vera Bühlmann. That was a wonderful experience of a completely different perspective on the philosophy of science than the analytical perspective of the master here in Utrecht. I want to thank Iris for her affirmation in all of her activities, illustrated by all of the above.

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Obviously, there are many others who have—either directly or indirectly—influenced and supported my research. Thanks to all of those teachers, friends, family and study buddies for their moral support, and conversations about my inquiry and the process of writing a thesis.

[1] These terms are explained at the end of the first chapter.

Introduction

How do scientists view the world around them? They see stars and galaxies, atoms and molecules, foetuses and trees. They see *material things*. Admittedly, scientists also talk about processes in which these things participate: they flutter and flash, they build and bend. But at the bottom of these processes are the things. These things form nature. And the scientist stands before nature to behold her.

Scientists are materialists. But what have they forgotten? And what about us, who live in a scientific world, what have we forgotten? We have forgotten that we *are* nature, that we are a part of what we are trying to understand, rule and exploit. Scientific inquiry is thus self-referential, it is nature-investigating-nature. Now, this is the exact character of subjectivity. And we have forgotten the subject.

The reason for our ignorance is twofold. Firstly, thanks to the amazing scientific progress of the last couple of centuries, we have become too arrogant towards Nature. Secondly, due to science's explanatory success, we have become scared of contradiction and incompleteness. Scientists fear the self-referentiality of subjectivity, because they view it as a logical contradiction.

Hence, can we come up with a materialist theory of subjectivity? At first sight it seems impossible to faithfully account for subjectivity in a materialist framework. Therefore, our first task is to map the problematic points. From there, we can adjust our ideas of the nature of matter and the nature of subjectivity such that they become consistent. All along the way we have to preserve our respect for nature, for the accomplishments of science and for subjective first person experience.

This thesis consists of three parts. In the first, I sketch the context of the problem and review different ideas concerning the relation between subjectivity and reality. This will be the necessary foundation for a fruitful further discussion. Here I follow the ideas of Jenann Ismael, Bruno Latour and Donna Haraway.

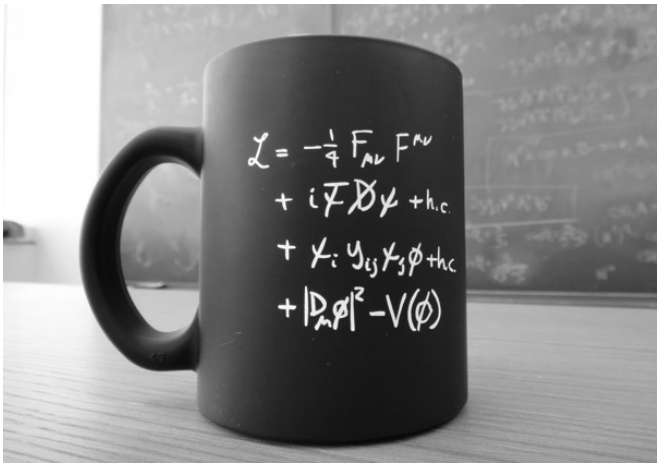
In the second part, I discuss a materialist theory in which the subject plays an important role: quantum mechanics. We look at this theory for inspiration to reconceptualise matter. The thinkers central in this part are Nils Bohr, Karen Barad and Hugh Everett.

The third and final part is more abstract. I will turn to the genesis of the subject as a material entity and role of subject in the genesis of matter. Here, again, we encounter the indispensable self-referentiality of subjectivity and matter. The inspirations for this new model for the simultaneous genesis of matter and subject are Henri Bergson, Gilles Deleuze and Manuel DeLanda. I will connect the concept of the virtual to that of chaos, in order to speculate about a space of subjectivity which provides the canvas for reality.

Part 1:
The necessity of subjectivity for reality

One of the reasons people start a degree in the natural sciences is to discover the truth about the world we live in. From personal experience, I know that physics students oftentimes have the desire to learn what the fundament of reality, the elementary structure of the universe, is like.

However, as the psychoanalysts teach us, desires will never be fulfilled.[2] Every child discovers the perpetual power of the question "why?" After being answered, the question can be asked again—"but why?" Just like this, the physics student will never be satisfied. Would we be happy, once we reduce the universe to a simple equation? CERN sells mugs with this (supposedly) fundamental equation, the so-called standard model.[3] Besides the fact that an audacious student could ask the mug "why?", they might also sip some coffee from it and wonder how on earth the simple equation relates to the complex esthetic experience of flavour and emotion.



These two questions, the first about absolutism and the second about subjective experience, are intimately related and will be central to this thesis. Briefly, subjectivity unveils the difficulties of absolutism. And every absolutist will sooner or later bump into the limitations set by their own subjectivity.

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[2] For example, Jacques Lacan writes "desire is situated in dependence on demand—which, by being articulated in signifiers, leaves a metonymic remainder that runs under it, an element that is not indeterminate, which is a condition both, absolute and unapprehensible, an element necessarily lacking, unsatisfied, impossible, misconstrued (*méconnu*), an element that is called desire." (*The Four Fundamental Concepts of Psycho-Analysis* (2004), page 154)

[3] https://visit.cern/content/standard-model-mug

Illusion

For me as a physicist, this realisation arose by reading about the subjective experience of time. Philosopher of physics and metaphysician Jenann Ismael describes the difference and relation between time in experience and time in physics. She writes:

> We are temporal beings. We have histories, we experience those histories in stages, we keep a running record of our histories as they unfold, and we act with an eye to the future. Time as we encounter it in experience is very different from time as conceived by physics. Time as conceived by physics is very simple. There is no intrinsic difference between past and future. Change and movement are represented as static relations between different parts of time. All of the parts of time exist in a fixed set of relations to one another. As we encounter it in experience, by contrast, time is intrinsically directed and in continuous flux. There are differences between past and future in how much we know about them, in whether we can affect them, and other ways that have come under examination in this volume. The past seems fixed, but there is a sense of openness about the future.[4]

When one illuminates a concept from different perspectives (like Ismael does with time), a tension between difference and similarity automatically arises. There is a connection between physical and experiential time, but the one perspective is not exhaustive of the other.

Someone else who attempts to build bridges between the experiential and the physical reality of time, is chemical engineer and scientific philosopher Kenneth Denbigh, who argues that human time perception is based on thermodynamic processes in our body, in particular the brain.[5] Instead of the conventional second law of thermodynamics (entropy never decreases with time), Denbigh *defines* time as entropy increase. Because the brain and the world are in interaction, their entropies increase in the same direction. In this way, the "arrow of time" is relative to the human subject carrying the brain.

Denbigh thus shows that the fact that we are macroscopic beings influences our perception. The branch of physics concerned with macroscopic objects is statistical mechanics, which uses probability theory to connect macroscopic phenomena to its microscopic parts. There are many mathematicians and philosophers who consider probability to be dependent on subjective knowledge.[6] If we accept that, we could argue that macroscopic phenomena are subjective too.

In the same way that Ismael advocates the reality of temporal experience, she upholds the reality of free will, in response to thinkers who have rejected free will on the grounds that it cannot be explained by physics. One of them is neuroscientist and public intellectual Sam

[4] Jenann Ismael, "Temporal experience" (2011)
[5] Kenneth G. Denbigh, "Thermodynamics and the subjective sense of time" (1953)
[6] Jos Uffink, "Subjective Probability and Statistical Physics" (2011)

Harris.[7] He explains that, first, deterministic classical physics rules out freedom, because it can exactly predict the future and retrieve the past from the current state of a system. Second, indeterministic quantum mechanics postulates that nature is fundamentally stochastic and therefore unpredictable. This excludes agency, i.e. influence over future events, from human capability. Therefore, free will must be an illusion, Harris concludes. Ismael agrees that free will is indeed not a fact of fundamental physics.[8] However, we can understand it as a feature of consciousness, if we let go of the naturalist essentialism which Harris preaches.[9] Nevertheless, she contends that there is a relation between physics and consciousness, which she rigorously supports with philosophical and scientific arguments. For example, she presents the mechanical description of an IGUS (information gathering and utilising system) to bridge the gap between time symmetry in physics and the difference between past and present in the phenomenological experience of time.[10]

What I want to illustrate with the above is how naturalist, scientist or physicalist essentialism can lead to absurd designations of phenomena as illusory. Time is an illusion because there is a block universe, free will is an illusion because it is neither deterministic nor indeterministic. In line with these examples, we could call *any* emergent or subjective phenomenon an illusion: temperature, emotions, life, the economy, the individual. Just like that, we could theoretically reject any concept using the trickery of scientific abstraction. Nevertheless, no one on earth would ever change their *intuition* about time, free will or any of the phenomena mentioned above. Intuition is the direct and singular perception, or a common sense understanding of a phenomenon. This is opposed to a reductive, "objective" understanding. For the very reason that these intuitions are so native to our perception, people will hardly be inclined to change their *behaviour* connected to these intuitions. For instance, we still make food preserves for the future and not for the past, even if physics tells us that time is symmetric. The ability of intuitions to influence our behaviour is, in a literal sense, the only thing that *matters*: they have a material impact on our lives. Then, are we really prepared to call intuitions and subjective phenomena alike illusory?

If we perceive something which we cannot explain we have two options. We could reject the reality of the phenomenon and call it illusory. Doing so based on its theoretical definition or explanation is like putting the cart before the horse. Instead, the second option is to change our explanation of the phenomenon. Thinkers like Ismael and Denbigh do exactly that. They show that it is possible to believe in the broad applicability of science, all the while avoiding using it dogmatically. They add concepts to science such that it can account for phenomena it could not account for before.

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[7] Sam Harris, *Free Will* (2012)

[8] Jenann Ismael, *How Physics Makes Us Free* (2016)

[9] I used the word "preach" on purpose, because Harris presents himself as atheist, using capital-S Science to prove the non-existence of God. That is obviously hypocritical.

[10] Jenann Ismael, "From physical time to human time" (2016), page 116-117

I alluded to two sources of illusion: either a phenomenon is emergent, or it is subjective. If we take probability theory as a theory of our subjective ignorance, then emergence is a specific case of subjectivity. For now, let us take a look at subjectivity.

Subjectivity: from rigid to fluid

Just like the term illusory, the term subjective is often used to discredit a phenomenon. The dichotomy objective versus subjective corresponds to good versus bad in many narratives, both scholarly and societal. Subjectivity deserves to be emancipated, especially by the scientist, as, ultimately, the subject is the only source of knowledge. Because of the presence of the subject in all knowledge, I claim that there is no such thing as objective knowledge. Things are always perceived or thought *by someone*.

Many historiographies of the philosophy of subjectivity start with René Descartes.[11] He split the world in mind and body in his *Meditations*, where he writes:

> I possess a body with which I am very intimately conjoined, yet because, on the one side, I have a clear and distinct idea of myself inasmuch as I am only a thinking and unextended thing, and as, on the other, I possess a distinct idea of body, inasmuch as it is only an extended and unthinking thing, it is certain that this I [that is to say, my soul by which I am what I am], is entirely and absolutely distinct from my body, and can exist without it.[12]

Some 140 years later, Immanuel Kant discussed the condition and the limits of the subject in the *Critique of Pure Reason*. He claims that we perceive the world within certain *a priori* categories of the mind, the most infamous of which cause and effect. With this, he creates an even starker division between subject and object, or, in his own words, *Vorstellung* (representation) and *Ding an sich* (thing-in-itself). Those *Dinge an sich* will always remain out of reach. The term *Ding an sich* insinuates that there are individual entities behind the representation, that there are Platonic Ideas which we cannot know. In how far are entities already formed before being observed by a subject? Maybe Kant just meant the *Ding an sich* as a metaphor of pure chaos. In order to argue for the pre-observational as chaos, we need to reconceptualise the subject.

For Kant, the categories of the mind are universal and fundamental for all perception. All sensations and thoughts are poured in this rigid mould. The phenomenologists, however, have argued that these categories are not so rigid after all. They depend on our material perceptual apparatus, that is, our body. Maurice Merleau-Ponty, a major phenomenologist, declares:

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[11] For example: Diana Coole and Samantha Frost, "Introducing the New Materialisms" in *New Materialisms* (2010), page 7-8

[12] René Descartes, "Meditations On First Philosophy" (1641/1911)

> [W]e shall need to reawaken our experience of the world as it appears to us in so far as we are in the world through our body, and in so far as we perceive the world with our body. But by thus remaking contact with the body and with the world, we shall also rediscover ourself, since, perceiving as we do with our body, the body is a natural self and, as it were, the subject of perception.[13]

By embodying perception like this, the phenomenologists took the *a priori* concepts off of their metaphysical pedestal. Some might argue that this naturalisation of the concepts also makes them *a posteriori*. But that is not the case, they are still prior to perception. We can explain some aspects of a perception by considering the perceptual apparatus, but we can never recreate the experience using theoretical methods. As we have seen, this is how Ismael and Denbigh handle these issues. Although we can never fully convey direct perceptual experience, there is a relation between perception and perceptual apparatus nevertheless.

Descartes and Kant broke up the world into subject and object. They made the world dualistic. The phenomenologists began a journey towards a new reconciliation between the two. Merleau-Ponty took it to another level. He explained how objects can be assimilated into the perceptual apparatus that is the body:

> The blind man's stick has ceased to be an object for him, and is no longer perceived for itself; its point has become an area of sensitivity, extending the scope and active radius of touch, and providing a parallel to sight. […] If I want to get used to a stick, I try it by touching a few things with it, and eventually I have it 'well in hand', I can see what things are 'within reach' or out of reach of my stick. […] To get used to a hat, a car or a stick is to be transplanted into them, or conversely, to incorporate them into the bulk of our own body.[14]

The baton was taken up by the post-phenomenologists, who expanded upon the idea that embodiment is not only biological, but can also come from technology.[15] The telescope and microscope, for example, have transformed our perception and ontology of the universe.

Around the same time in the late 20th century, feminist philosopher of science Donna Haraway coined the term "situated knowledges" which accounts not only for biological and technological embodiment, but also for its sociocultural aspect.[16] She analyses subjectivity with questions about knowledge creation. Where was a piece of knowledge created? What did the lab look like? Which instruments did the experimenters use? Who were in the lab? What was their sociocultural background? Once again we conclude that there is no such thing as absolutely objective knowledge. She writes:

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[13] Maurice Merleau-Ponty, *Phenomenology of Perception* (1962), page 239

[14] Ibid., page 164-165

[15] This school of thought is represented mostly by Don Ihde, who has written many books about technological embodiment. For example, *Bodies in Technology* (2001) and *Postphenomenology and Technoscience* (2009).

[16] Donna Haraway, "Situated Knowledges" (1988)

> The only way to find a larger vision is to be somewhere in particular. The science question in feminism is about objectivity as positioned rationality. Its images are not the products of escape and transcendence of limits, i.e., the view from above, but the joining of partial views and halting voices into a collective subject position that promises a vision of the means of ongoing finite embodiment, of living within limits and contradictions, i.e., of views from somewhere.[17]

Subjectivity is all around us, and it takes many forms. Being able to look at the subject's embodiment, its material or "objective" aspects, blurs the border between object and subject.

This fluidisation of subjectivity leads to the breaking down of many artificial dichotomies which have dominated philosophical debate since the 15th century. French philosopher of science Bruno Latour describes how the dichotomy of subject versus object is related to that of nature versus culture.[18] The Kantian subject pertains to the human, arguably the white male.[19] This creates a class of non-subjects, i.e. objects, which are all non-human. We end up with the human being outside and above all other entities in the universe. Those other entities pertain to nature. Latour goes on to argue that this dichotomy has enabled humankind to exploit nature, leading to climate and biodiversity crises.

The dichotomy of subject versus object has ramifications in all of philosophy. Schools of thought are divided into idealists and materialists, realists and constructionists. Common sense thinking illustrates the inapplicability of the exclusionary pairs. We experience mental ideas *and* material objects, our economy is socially constructed *and* it has real implications on our lives.

Another related opposition is Descartes' mind versus matter. As Denbigh, Ismael and Haraway all illustrate, the two are intimately entangled. The mind takes cues from the sense organs, and scientific tools. Conversely, these tools are created in order to serve certain ideas of the mind. Philosophy-physicist and feminist theorist Karen Barad, who we will discuss below in more detail, also opposes this strict exclusionary separation of word versus world, meaning versus matter.[20] Conventionally, the philosophy of matter and world has been ontology, answering the question "what is out there?" Similarly, epistemology could be described as the philosophy of word and meaning, asking "how is the world represented?" Recognising the entanglement of matter and meaning, Barad shows the mutual dependence of the typically separate fields of ontology and epistemology. That is, what exists always already depends on interaction with its environment. They explain it as follows:

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[17] Donna Haraway, *Simians, Cyborgs, and Women* (1990), page 196

[18] Bruno Latour, *We have never been modern* (1993)

[19] Pauline Kleingeld, "Kant's Second Thoughts on Race" (2007); "On Dealing with Kant's Sexism and Racism" (2019)

[20] Karen Barad, *Meeting the Universe Halfway* (2007)

> There is an important sense in which practices of knowing cannot fully be claimed as human practices, not simply because we use nonhuman elements in our practices but because knowing is a matter of part of the world making itself intelligible to another part. Practices of knowing and being are not isolable; they are mutually implicated. We don't obtain knowledge by standing outside the world; we know because we are of the world. We are part of the world in its differential becoming. The separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse. *Onto-epistem-ology*—the study of practices of knowing in being—is probably a better way to think about the kind of understandings that we need to come to terms with how specific intra-actions matter.[21]

Here we encounter another key concept in Barad's work: *intra-action*. Let me point out two of its aspects. First, it is opposed to *interaction*, in which two entities, *relata*, exist independently of each other and establish a *relation*. Intra-action, on the contrary, prioritises the relation over relata in what we would normally call interaction. In other words, the relata owe their existence to their relation. Second, Barad emphasises that object-subject intra-actions are equal to all other (physical, social, etc.) intra-actions. They push this non-separation to the extreme on all levels of analysis.

Against the absolute

Now, one might ask whether the connection between ontology and epistemology is not just another relativism. Admittedly, this *onto-epistemology* does have radically relativist aspects. But before we dive into those, let me set up the stage on which the discussion takes place. When answering questions about the fundamental nature of reality, one will eventually be confronted with the choice between absolutism and relativism. Either there are some absolute truths, initial conditions or laws from which everything else arises, or things can only exist insofar as they are in relation to something else. Examples of absolutisms are Plato's eternal Ideas from which all objects in the world originate, a religious god as the creator of everything and scientific laws that can predict any phenomena. Latour recognises this as *reduction* and he finds it in many places:

> A Christian loves a God who is capable of reducing the world to himself because he created it. A Catholic confines the world to the history of the Roman salvation. An astronomer looks for the origins of the universe by deducing its evolution from the Big Bang. A mathematician seeks axioms that imply all the others as corrolaries and consequences. A philosopher hopes to find the radical foundation which makes all the rest epiphenomenal.[22]

[21] Karen Barad, *Meeting the Universe Halfway* (2007), page 185
[22] Bruno Latour, *The Pasteurization of France* (1993), page 162

The main problem here is the problem of first cause: what is the origin of the absolute? Absolutists would consider this to be a nonsensical question, because the absolute does not have a cause per definition. Others see the very question as an argument against absolutism, because something without a cause cannot exist.

Today's relativism has its roots in at the end of the 19th century and reached its peak with poststructuralism. In the 1990s, this philosophical position caused the conflicts which came to be known as the "science-wars" between scientist absolutists and the poststructuralists.[23] The main criticism of relativism is that we are not able to hold on to absolute truths or morality anymore. Then, how are groups in society ever supposed to agree on anything? The general answer is: by negotiation, power plays, dialogue.

The question arises: where do these interactions take place? And: between which entities? The questions make sense for us, as these are the terms in which we are programmed to think, in terms of a space containing objects. But if someone were to provide us with such a fundamental space, we would end up with some absolutism again.

This never-ending search for a first cause or principle might be the one true statement we can make about reality. It is central to subjectivity, the framework in which entities can observe (and act) in the world. Subjects can never fully understand the relation between the reality they perceive and the embodiment and situatedness of their perception. A (set of) first principles, *a priori* categories or axioms must always be assumed. And once one starts to investigate one's first principles, those principles change. For, to examine one's embodied modes of perception, one has to go as far as physically taking them apart. To understand a telescope, I might want to disassemble it. But by doing so, I cannot use the instrument for observation anymore. We should regard neurological research in relation to consciousness in a similar fashion. That is, we will be able to say something about the relationship between neural structure and the way we perceive things, but we will never be able to have an experience of consciousness "through" neurons by studying them.

The act of investigating first principles is comparable to the two-dimensional mapping of the Earth. It will never be complete; there will always be infinities or singularities at which the planar coordinates do not correspond to spherical coordinates one-to-one. Hegelian-Lacanian philosopher Slavoj Žižek uses the metaphor of a Möbius strip.[24] Locally we can find a flat area of the strip. That corresponds to the fact that if we consider an incomplete part of reality, it can be consistent. But if we try to consider reality (the whole Möbius strip) in its totality, it will always be twisted. This twist represents the incompleteness of any totality. In the case of subjectivity, perception is incomplete by its very nature. Investigating this twist is again to localise our attention to a subsection of reality—we iron out the twist. For the totality of the Möbius strip, this means that the twist just shifts to another location currently

[23] For an overview, see Nick Jardine and Marina Frasca-Spada, "Splendours and Miseries of the Science Wars" (1997).

[24] Slavoj Žižek, *Sex and the Failed Absolute* (2019), page 244

not under investigation—the a priori concepts, embodiment and/or situatedness of the subject changes.

It is tempting to view these topological metaphors of spheres and Möbius strips as our new fundament of reality. But we should, above all else, avoid such absolutisation. In fact, these metaphors should be tools for us to stay away from any absolutisms.

A radical relativism: networks of relations

Now, let us approach the topic of subjectivity and reality a bit more constructively. If we cannot hold on to an absolute, why do we experience anything in the world at all? I propose a radical relativism. That might seem counterintuitive. After all, does relativism not remove the backbone of reality, on which all meaning, being and truth depends?

Latour has been critical of relativism as well, demonstrating that "our" critical methods have been hijacked and perverted by our enemies.[25] The fluidity of truth has led to a general suspicion towards science. Of course, Latour would not pretend science has always been a purely ethical or innocent practice. This should not, however, lead to a complete nihilism.

In short, we are at a quandary: there are problems with absolutism and with relativism. While some contend that sociocultural relativism is too extreme, I argue it is not extreme enough. As I said, the way forward is a radical relativism. I understand that "radical relativism" might not be the most practical term to use, because of its theoretical and political charge, but please do not be scared because of those reasons. In fact, the absolute has been quite frightening all along. The likes of God, elementary particles and cosmologies can be quite overwhelming.

Relativism does not necessarily have to refer to the instability of everything we take for granted, which critics of relativism would be more than happy to point out. Etymologically, the word "relativism" shares its origin with "relation", almost needless to point out.[26] So relativism can be about relations instead of perspectives, and relations can be sturdy instead of precarious. Entities have actual influence on each other, and that is how those entities assert their existence, by interaction. We, as humans, have only limited power over the relations between other entities. To reduce all of reality to sociocultural narratives is anthropocentric and flat-out fallacious. We should somehow expand sociocultural relativism to also include physicochemical relativism. A human should be in the same category as a fly, an ice cube and a

[25] Bruno Latour, "Why has critique run out of steam?" (2004)

[26] Douglas Harper, "Etymology of relative" and "Etymology of relation"

carbon dioxide molecule, namely the category of every possible being.[27] To distinguish postmodern relativism from this radical relativism, it might be better to call the latter *relationism*. I did not do so before, because I wanted to emphasise its radical opposition to any absolutism.

Relationism is, unsurprisingly, about relations, interactions. There are interactions between hydrogen atoms and photons, between trees and chainsaws, between economies and volcanic eruptions, between objects and subjects. Why would we assume the relation between object and subject to be completely representational, i.e. reflexive, while we treat most interactions as having a changing impact on their relata.

Taking into account a multiplicity of interactions, we find that they form sprawling networks of relations. James Ladyman's ontic structural realism takes the relation as its fundamental constituent of reality.[28] But what are the related objects of these fundamental relations? And why do we not call these related objects our elementary entities? To resolve this problem, one has to postulate relations without relata. This discussion, however, is beyond the point. It is predicated upon the assumption of a hierarchical structure of reality. Contrarily, we should regard reality as a cloud of interactions, all interdependent. In this system, Ladyman conceptualises objects as tangled knots of interactions. These knots, in turn, interact with other knots, and in this way an intricate web forms itself. Objects are but an emergent entity and their borders are blurred. I like to think of it as similar to the cosmic web.[29]

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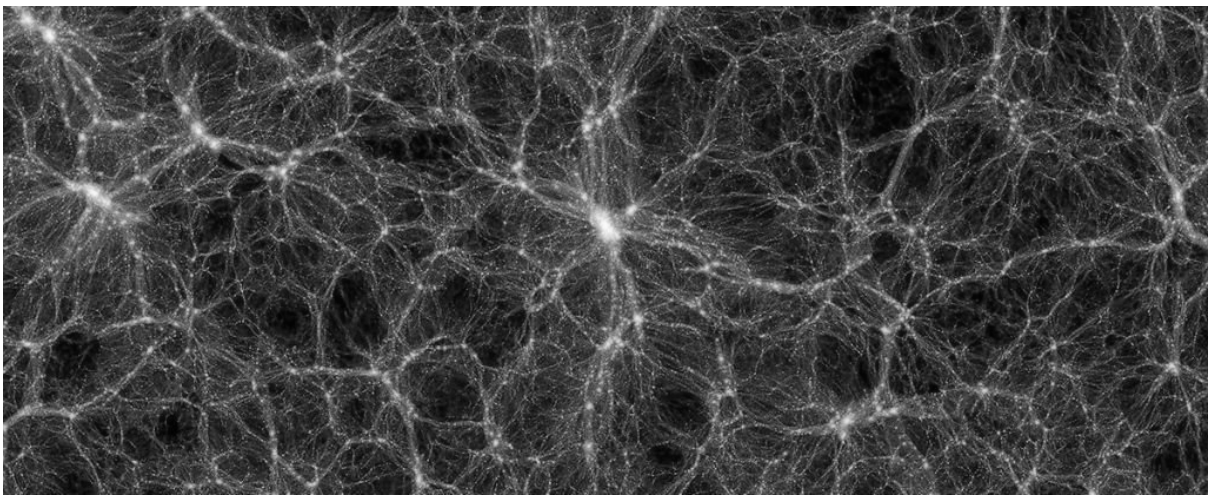
[27] Object oriented ontology (ooo; Levi Bryant, *The Democracy of Objects* (2011); Graham Harman, *Object-Oriented Ontology* (2018)) expands on this idea of equality of all objects. It starts from the absurdity in dualistic philosophy that the world is divided into human subjects and everything else. Despite the noble intentions of ooo, we should be cautious that is does not "[provide] for the capital-S Subject to come back with a vengeance" (Iris van der Tuin, "Diffraction as a Methodology in Feminist Onto-Epistemology" (2014), page 233), a God's eye point of view if you will. The risk of such a perspective is that it is rarely explicitly declared. It is viewed as apolitical and universal, while in reality it might exclude certain groups of beings.

[28] James Ladyman, "Structural Realism" (2018); Steven French and James Ladyman, "Remodelling Structural Realism" (2003)

[29] Simulated by Volker Springel et al., "Simulations of the formation, evolution and clustering of galaxies and quasars" (2005); and observed by Roland Bacon et al., "The MUSE Extremely Deep Field: The cosmic web in emission at high redshift" (2021).



In this web, the interactions can be characterised as actions, observations or communications.[30] Which one of those we are talking about corresponds to the entities involved in these interactions. Are they passive stones or active humans? Haraway's posthumanism blurs the border between these categories by showing how material embodiment and social situatedness both contribute to the subjectivity and agency of an entity. In particular, she demonstrates how (scientific) knowledge is dependent on one's specific context.[31] Latour also does this, by exploring what agency means.[32] Agency is a quality which pertains to many more objects than just humans. Haraway warns us for making the same mistake as the absolutists did:

> Relativism is the perfect mirror twin of totalization in the ideologies of objectivity; both deny the stakes in location, embodiment, and partial perspective; both make it impossible to see well. Relativism and totalization are both 'god-tricks' promising vision from everywhere and nowhere equally and fully, common myths in rhetorics surrounding Science. But it is precisely in the politics and epistemology of partial perspectives that the possibility of sustained, rational, objective enquiry rests.[33]

Therefore, we need a radical, inclusive relativism. And because it is so radical, there is room for a soft kind of absolutes. Relations imply dependence. Once one relation is

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[30] Each of these terms is used in different contexts or fields of study. They are all activities which generally involve multiple entities. For example, "observation" is used in many of the natural sciences and "communication" is more common in public relations. These two seemingly distinct activities can be commonly grounded. That is, they share a fundamentally similar structure. Because common grounding reduces a phenomenon to its parts, I view the method as a purely epistemic tool. In general, phenomena in reality are more than the sum of their parts. For more on common grounding, see Jenann Ismael and Jonathan Shaffer, "Quantum holism: nonseparability as common ground" (2020).

[31] Donna Haraway, "Situated Knowledges" (1988)

[32] Bruno Latour talks about "The Parliament of Things," in which natural entities like oceans and forests are granted political agency. In 2020 he gave a lecture about this at Radboud University Nijmegen: https://www.youtube.com/watch?v=zZF9gbQ7iCs.

[33] Donna Haraway, *Simians, Cyborgs, and Women* (1990), page 191

determined, other ones will be influenced because of their dependence. Entities, events and phenomena are mutually connected to each other in this great web of interaction, and they fold into one another. Even though there are no ultimate capital-A Absolutes in such a web, processes of emergence and subjective context give coherence, codependence and rigidity to objects. Very ridgid (although not untouchable) entities might look like absolutes. That simply means that they are very well connected to all parts of the network through interaction. Latour expresses a similar idea:

> An entity gains in reality if it is associated with many others that are viewed as collaborating with it. It loses in reality if, on the contrary, it has to shed associates or collaborators (human and nonhuman).[34]

From chaos to being: the virtual, the actual and subjectivity

If there is no one or no thing observing (i.e. interacting with) the network, it will not be interpreted and therefore be completely meaningless. It will be a soup of everything relating to everything: that is chaos. For some this is a scary word. After all, does it not lead to nihilism? Nevertheless, it is a concept with a long history, from ancient cultures to contemporary information science.[35] The ancients view chaos as the primordial substance from which all being arises. Modern scientists are concerned with chaotic *processes*. Chaos theories study the emergence of structure in systems with a lot of uncertainty, complexity and large numbers of constituents. The ancients might have interpreted this emergence as the path from the primordial substance to particular beings.

The path from chaos to being is called actualisation. It can be viewed from (at least) two perspectives: from within an interaction, or from a network of interactions. Of course these perspectives are not really distinct. Nevertheless, they highlight different aspects of actualisation. The first emphasises subjectivity in the broadest sense: the subjectivity of a human, a tree, a protein. The second emphasises emergence in complex systems: consciousness from neurons, living cells from inorganic matter, an economy from human agents and goods.

Barad describes this actualization in terms of intra-action. Intra-action results in two (or more) relata, like subject and object, or fish and river. They co-constitute each other. That is, the being of the two entities is guaranteed by this intra-action. Without it, there would be no entities; there would only be pre-onto-epistemological chaos. The relation between subject and object has been described by philosophers from Descartes onward. And many of them

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[34] Bruno Latour, *Pandora's Hope* (1999), page 158

[35] Two good historical overviews of the term chaos are Güngör Gündüz, "Ancient and Modern Chaos Theories" (2006) and Stefan Lobenhofer, "Chaos" (2020).

have been obsessed with their self-referentiality or circularity: *the subject is the being that gives rise to being*. This circularity, which is characteristic of intra-action, should not be used as an argument against the concepts, though, but as a genuine feature of how reality works.

The realisation that subject and object are not *a priori* entities yields an equivalence between *observation* and *interaction*. Here is a naturalist example from astronomy. When one looks at a star through a telescope, there is a co-constitution of the person looking through the telescope and the star. We should not forget, however, that this *observation* is also a cascade of physical *interactions*. Hydrogen fuses to helium inside of the star, photons scatter around before they escape the star into space, a tiny fraction of those photons enters the telescope and is diffracted by its lenses, they crash on a retina where their momentum is transferred to electrical signals in the nerves leading to the brain. This is not to say that the brain is the central point of perception. In fact, the opposite is true: every link in the chain of events described above is equally responsible for the phenomenon of observation. Accordingly perception is not of the mind, but of the body. That is, it is affective.

It is not very controversial to say that observation is an interaction, but people would get confused if you tell them that all interaction is observation. Take heliotropism. Some flowers, daisies for example, track the sun as it moves across the sky during the day. What prevents us from claiming that daisies *see* the sun? Certainly not the fact that we can explain heliotropism in biological, chemical and physical terms. That would not be an appropriate reason to reject human subjectivity either. Rather, we deny subjectivity to plants because it is difficult to imagine an inner world of an entity so different from us. I am not necessarily arguing for consciousness in plants (or stones and atoms for that matter), but I think it is counterproductive to do the opposite. To better understand nature, it might be helpful sometimes to assume plants *want*, *experience* and *act*.[36] The objects a subject perceives, that is, a subject's ontology, depends on its material embodiment, its needs and its previous interactions.

In chaos nothing is subject nor object. In fact, there are no entities in chaos. Those form by interaction, interaction between parts of chaos. These parts are not defined until they interact. The process from the meaningless soup of chaos can be interpreted in terms of (thermodynamic) emergence, the spontaneous creation of order. Modern chaos theories differentiate between many modes of emergence: evolution, self-assembly, morphogenesis, phase transitions, self-similarity, et cetera. In the last chapter I will discuss Manuel DeLanda, who discusses emergence as immanent becoming, inspired by Gilles Deleuze.

Important to note is that the structures dependent on underlying interactions need to be observed as a whole in order to be considered as an object. That is, they are only reified by intra-action with an entity which benefits by being able to know and interact with the structure in question. In other words, networks of interactions need to intra-act with other networks of interactions to exist as an objective entity. For example, the human body is an

[36] For more on the agency of plants, see for example Jeffrey Nealon, *Plant Theory* (2015).

emergent object: emergent because it is a structure that arose out of a chaos of molecules, cells and organs, object because it intra-acts with other humans, animals and computers.

Intra-action depends on underlying *virtual* emergent stability. It is the stability of the cascade of events which constitute intra-action. We do not (and in principle cannot) directly perceive the processes of our own perception. But the virtual (composed of pre-observational events, perceptual apparatus, subjective predispositions, etc.) is required for experience and actual being.

As we saw above, this reification or actualisation of objects can be explained in evolutionary terms, a survival of the fittest. An object is "fit" if it is ontologically stable. That is, if it features in ontologies of other entities, which happens upon intra-action. The intra-actions between objects are viewed by Latour as power relations in a broad sense, which transcends the everyday usage of political power but does give an interesting intuition to being.[37] Objects, then, can ascertain their being by establishing their power in relation to other objects.

Quantum mechanics as a showcase of subjective nature of reality

Since my background is in physics and its foundations, when I read and think about subjectivity and reality, I do so through a physicist's lense. I realised there is a clear correspondence between the ideas above and certain interpretations of quantum mechanics. Moreover, thinkers such as Barad and Žižek have used quantum mechanics as an example to support their philosophical theories. Barad doubled down and generalised the lessons quantum mechanics teaches us about reality such that these lessons also apply to the macroscopic world including living organisms and societies. In general these two thinkers inspired me to think about reality in a different way as well. How do subjectivity and being relate in quantum mechanics?

One of the biggest influences for this thesis is Karen Barad. They are inspired by Niels Bohr, who is one of the founding fathers of quantum mechanics. Barad investigates his so-called "philosophy-physics" and sets out to extract its lessons for reality and perception in general. Bohr argues that the agencies of observation should be central to quantum theory, because they partially determine observed properties of objects. I want to stress what a radical divergence from (classical) physics this is. Classical objects and their properties are

[37] "Power" is a word used mostly in a social context, so it might be confusing to use it as an attribute to dead objects. In "The Importance of Bruno Latour for Philosophy" (2007, page 41), Graham Harman expresses cracks down on these worries: "We can call [Latour's actor-network] 'the social construction of science' if we want, but only if our society includes atoms, blood cells, sunlight, gravity, and lab equipment no less than Victorian notaries and other power-hungry imperialists of academic nightmare."

independent of observation. In fact, one could argue that it is the goal of physics to find out what the independent things out there are.

Bohr shows that, at a fundamental level, the means of observation should be taken into account. He mainly focuses on experimental setups as being part and parcel of physical systems. Barad, however, generalises the agencies of observation to include perception of the subject. This idea establishes a view of reality which is usually not associated with science: "*we are a part of that nature that we seek to understand.*"[38]

Bohr takes measurement to be central to reality. And, according to Barad, this is exactly how measurement, or observation if you will, should be seen: as a necessary and influential requirement for the construction of reality. In measurement, matter and meaning meet. Ontology and epistemology become synchronised. Regarding measurement as a quantum mechanical interaction, Barad proclaims the observer and the observed to become *entangled*. As, in quantum mechanics, a measurement result cannot in general be predicted in advance, the measurement process itself results in a reification of a definite measurement outcome and corresponding quantum state. More briefly, quantum measurement influences reality. In this sense, the observer and observed co-constitute reality. This is what Barad calls *intra-action*:

> The neologism "intra-action" *signifies the mutual constitution of entangled agencies*. That is, in contrast to the usual "interaction," which assumes that there are separate individual agencies that precede their interaction, the notion of intra-action recognizes that distinct agencies do not precede, but rather emerge through, their intra-action. It is important to note that the "distinct" agencies are only distinct in a relational, not an absolute, sense, that is, *agencies are only distinct in relation to their mutual entanglement; they don't exist as individual elements*.[39]

These ideas about the nature of reality lead Barad to their philosophical framework of *agential reality*. In it, co-constitution is central. Reality is not built up by individual entities, but by *phenomena*,[40] which epitomise "the *ontological* inseparability of agentially intra-acting

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[38] In *Meeting the Universe Halfway* (2007, page 67), Barad ascribes this lesson to Bohr, but I think it is better described as Barad's generalisation or extension of Bohr's thought.

[39] Karen Barad, *Meeting the Universe Halfway* (2007), page 33

[40] Ibid., page 412: "For some readers, the term "phenomenon" will no doubt carry what for my purposes are unwanted phenomenological connotations. Crucially, the agential realist notion of *phenomenon* is not that of philosophical phenomenologists. In particular, phenomena should not be understood as the way things-in-themselves *appear*: that is, what is at issue is not Kant's notion of phenomena as distinguished from noumena. Rather, as will be explained in later chapters, my notion of phenomenon is an elaboration of Bohr's notion of phenomenon. I preserve the term not merely to honor Bohr but to underline the important shift that an agential realist understanding of phenomena plays in reconsidering the foundational or interpretative issues in quantum mechanics. […] And last but not least, I preserve the term "phenomenon" because of its common usage, especially in the scientific realm, to refer to that which is observed, what we take to be real. This is useful because when the term is invoked an opportunity presents itself for the possibility of getting the objective referent right-that

components."[41] The separation between entities like object and subject, or measuring device and physical system, only results from intra-action. They write:

> Intra-actions include the larger material arrangement (i.e., set of material practices) that effects an *agential cut* between "subject" and "object" (in contrast to the more familiar Cartesian cut which takes this distinction for granted). That is, the agential cut enacts a resolution *within* the phenomenon of the inherent ontological (and semantic) indeterminacy. In other words, relata do not preexist relations; rather, relata-within-phenomena emerge through specific intra-actions.[42]

> Agential realism offers the following elaboration of [Ian] Hacking's critique of representationalism: *experimenting and theorizing are dynamic practices that play a constitutive role in the production of objects and subjects and matter and meaning*. [T]heorizing and experimenting are not about intervening (from outside) but about intra-acting from within, and as part of, the phenomena produced.[43]

According to agential realism, reality is not *outside of us*, as a conventional realist or materialist would argue. Neither is reality only *inside of us*, which the idealist contends. Rather, it is *in between*.

For another metaphysical lesson from quantum mechanics we return to Slavoj Žižek. He only has a small deliberation on the relation between quantum mechanics and reality—he did not study the philosophy of quantum mechanics nearly as much as Barad did.[44] Nevertheless, the lesson he takes away from quantum mechanics is instructive and fits Barad's account very well.[45] He frames the measurement problem as a problem of incompleteness. Before measurement there is incomplete information about what the future is going to look like. He calls this an "open ontology". He compares it with a virtual reality such as a first-person computer game. In such a simulation, reality does not have to be recreated in its totality. But,

> we just have to reproduce features which make the image realistic from the spectator's point of view. For example, if there is a house in the background, we do not have to construct a program of the house's entire interior, since we expect that the participant will not want to enter the house; or, the construction of a virtual person in this space can be limited to his exterior – no need to bother with inner organs, bones, etc. We just need to install a program that will promptly fill in this gap if the participant's activity necessitates it (for example, if he cuts deep into the virtual

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is, of associating the term with the full complexity that is a "phenomenon" in the agential realist sense."

[41] Ibid., page 33

[42] Ibid., page 139-140

[43] Ibid., page 56

[44] Slavoj Žižek, "Towards a materialist theology" (2007), page 22-23; "Preface: Bloch's ontology of not-yet-being" (2014), page xvii

[45] Nevertheless, he has not always been respectful towards Barad. See: Evelien Geerts and Iris van der Tuin, "The Feminist Futures of Reading Diffractively" (2016).

> person's body with a knife). It is like when we scroll down a long piece of text on a computer screen: earlier and later pages do not pre-exist our viewing them; in the same way, when we simulate a virtual universe, the microscopic structure of objects can be left blank, and if stars on the horizon appear hazy we need not bother to construct the way they would appear on closer inspection, since no one will go up there to take such a look at them.[46]

The installation of a program to fill in a gap in the virtual space corresponds to the measurement in quantum mechanics. Reality is only formed insofar as we observe it. In this account it also becomes clear that reality is only formed in how precisely we observe it, with how much resolution we look at an object. We see the house in the distance only insofar as we are *able* to see it. Žižek concludes that either our ability to grasp reality for what it is, is deficient (epistemic incompleteness), or reality itself is fundamentally flawed (ontological incompleteness).

If we follow Barad in blurring the line between ontology and epistemology, the conclusion reduces to: onto-epistemology is incomplete. This relates to incomplete knowledge in stochastic processes, the incompleteness of flat maps of the Earth and our inability to perceive an object and the perceptual apparatus at once.

Now, even though Barad is inspired by Bohr, I contend that Hugh Everett's interpretation of quantum mechanics is much more appropriate to account for the nature of subjectivity.[47] In particular it gives a framework which has the ability to embed multiple subjects of different types, whereas Bohr's framework is more Kantian: there is, ultimately, one reality experienced by and communicated between the subjects of the same kind. Just like Haraway and Latour generalise Kant's transcendental subject to a more inclusive subjectivity, Everett generalises Bohr's singular reality to a more relativist approach to reality. All this is, in fact, what my thesis is about.

A contentious part of Everett's interpretation of quantum mechanics is his concept of the universal wave function, which represents the complete state of the universe.[48] He claims that this entity is what is ultimately real. He clearly adheres to the notion of reality as (mind) independent existence. We should forgive him for that. What is problematic, though, is the elevation of the concept to absolutism. I believe it is a lot more valuable to use the concept as an intellectual tool to make sense of the many possible realities. From this angle, the universal wave function corresponds to chaos, the meaningless possibility for being.

Although he does not mention Everett in this context, Arkady Plotnitsky wrote about the relation between quantum theory and Gilles Deleuze and Félix Guattari's concepts of chaos and the virtual. Plotnitsky shows how even physical reality is more like a realm of constant creation than an eternal solid block.

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[46] Slavoj Žižek, "Towards a materialist theology" (2007), page 22-23; "Preface: Bloch's ontology of not-yet-being" (2014), page xvii

[47] Hugh Everett III, "'Relative state' formulation of quantum mechanics" (1957)

[48] Hugh Everett III, "The theory of the universal wave function" (1973)

Diffraction

Let me elucidate my method of inquiry. The philosophy of science contains the concept of theory-ladenness, which comes down to the fact that our observations of the natural world and society are influenced by our theoretical presuppositions. I would like to broaden this concept a little bit. Not only the things we encounter in nature and society, but also our perception of ideas are theory-laden. When reading philosophical texts, we interpret new ideas in terms of our existing conceptual framework. We associate new ideas with old ones. That is, our memory intra-acts with new ideas presented.

Even though this observation of the theory-ladenness of acquiring new ideas is quite evident for anyone who has ever read a philosophical text or even a novel, in Western academia we are taught to read reflexively. Reflexivity is an optical metaphor, which is fitting because perception is often associated with (optical) vision. A mirror reflects, because it represents a part of the visual world one-to-one. The assumption that we can read or think reflexively presupposes that human understanding works representational, like a mirror. But as we saw, memory constantly interferes with incoming perceptions and ideas.

In appreciation of the intra-action between memory and ideas, Donna Haraway introduced *diffractive reading*, which she explains as reading through one another. Just like reflection, diffraction is an optical metaphor:

> My invented category of semantics, *diffractions*, takes advantage of the optical metaphors and instruments that are so common in Western philosophy and science. Reflexivity has been much recommended as a critical practice, but my suspicion is that reflexivity, like reflection, only displaces the same elsewhere, setting up the worries about copy and original and the search for the authentic and really real. Reflexivity is a bad trope for escaping the false choice between realism and relativism in thinking about strong objectivity and situated knowledges in technoscientific knowledge. What we need is to make a difference in material-semiotic apparatuses, to diffract the rays of technoscience so that we get more promising interference patterns on the recording films of our lives and bodies. Diffraction is an optical metaphor for the effort to make a difference in the world.[49]

Let me discuss three points of difference between reflection and diffraction. First, while the former concerns similarity, the latter reveals difference. Diffraction is the result of intra-action between light and a surface of incidence, which is in general not as perfectly smooth as a mirror. Diffraction exposes the intricacies and details of objects. Just like that, diffractive reading brings to the surface certain aspects of ideas which would have remained obscure in a reflective reading.

Second, where reflection is passive, diffraction is active. Diffractive reading requires engagement with the material. Readers are encouraged to read the text through different

[49] Donna Haraway, *Modest_Witness@Second_Millennium. FemaleMan_Meets_OncoMouse* (1997), page 16

philosophical and cultural frameworks, and to embrace the intra-action between themselves and the text. Because each reader is different, each reading (i.e. the intra-action between reader and text) will be different. In this regard diffraction is creative; it produces new ideas. This is exactly how Deleuze and Guatarri characterised philosophy: as a creative practice.

A critic might ask what happens to objectivity. Is there still an objective reading of a text? Unfortunately, we have passed that station. We cannot pretend that every reader is the same. However, there is a way to reconceptualise objectivity such that we are able to account for the conclusions we draw from a text. Objectivity is not so much about representing a text (or any other object for that matter) accurately, but it is about understanding the materiality of the intra-action which constitutes the reading.[50]

A method closely related to diffraction is affirmative reading.[51] It is not a critical method, which merely negates or vilifies a text. Nor is it a simple celebratory method. In fact, these are two sides of the same coin. A criticism of an idea necessarily asserts that idea. The affirmative method aims to move beyond such dialectics. It, once again, prioritises engagement with ideas. An apt example is John Wheeler's (Everett's supervisor) attitude towards different interpretations of quantum mechanics. He did not regard different theories as competitive, but as synergistic.

Now, how does this apply to my research project? Having studied the philosophy of quantum physics and some "pure" philosophy simultaneously, I recognised many parallel aspects between the two. This only happened because there was a specific contingent material arrangement of my academic context which involved teachers, courses, fellow students and buildings. It would be fair to ask if the parallels between these disconnected fields of thought would be acknowledged by the physicists and philosophers in question. But, in the spirit of diffraction, philosophy is a creative practice. Bringing (maybe slightly different) ideas together and showing how they interact can be a way for new ideas to come to fruition. In this thesis, I read Everett's universal wavefunction through the concept of chaos, and I read quantum state relativity through subjectivity. In every text I read, I engage with its writer, and associate its ideas with the full body of literature in my memory.

[50] Karen Barad, *Meeting the Universe Halfway* (2007), page 91

[51] Iris van der Tuin, "'A different starting point, a different metaphysics': Reading Bergson and Barad diffractively" (2011)

Part 2:
Bohr, Barad and Everett

Bohr's philosophy-physics offers some interesting insights into first person experience of reality. These lessons are expanded upon by Karen Barad. They take the lessons from ideas about measurement of quantum mechanical systems to metaphysical conceptions of the relation between the subject and reality.

In the previous chapter, we discussed the many forms this first person perspective can take, by changing its material embodiment. This allows for a world with a variety of subjects. And in fact, our intuition tells us this is the case: there are thousands of people around us, all slightly different. Also, it is hard to deny that animals have an inner world. To argue for the subjectivity of plants is a bit more tricky, but, as we saw in the previous chapter, not impossible. Therefore, we are looking for a theory involving *multiple* first persons. In such a theory, a particular perspective would simply be a special case. That is, the theory should be able to account for all of the subjective experiences out there. We are looking to generalise the Bohr-Barad interpretation. In the philosophy of quantum mechanics, Hugh Everett's relative state interpretation is a fitting candidate for that generalisation.

In the following, I will first give a quick overview of Bohr's thought, so that we have a basis to think about Barad's ideas. In the sections about Barad, I will emphasise their ideas on subjectivity and their departure from aspects of Bohr. Then, I will introduce Everett's interpretation of quantum mechanics in contrast with and as a generalisation of Bohr's. Finally, just like Barad distilled philosophical ideas from Bohr, I will do the same for Everett. In the same manner that Everett generalises Bohr, I want to generalise Barad.

Bohr's interpretation of quantum mechanics

Barad's philosophy is inspired by Bohr's interpretation of quantum mechanics and Everett's interpretation is a response to the Copenhagen interpretation. We should keep in mind that there were points of disagreement within the Copenhagen group, because of which the Copenhagen interpretation is not a very well-defined set of claims about quantum mechanics.[52] But because of Bohr's authority in the group and for the sake of argumentative clarity, I will present the Copenhagen interpretation as identical to Bohr's thought.

As a foundation for the discussion of Bohr, let me briefly present the supposedly interpretationless version of quantum mechanics which is taught to physics students: the

[52] Don Howard, "Who invented the 'Copenhagen Interpretation'? A study in mythology" (2004); Jan Faye, "Copenhagen Interpretation of Quantum Mechanics" (2019)

textbook interpretation. In the textbook interpretation, the state of a quantum system evolves linearly, according to Schrödinger's equation, unless the system is observed, i.e. measured. In the case of observation there is an abrupt projection of the state onto one of the eigenstates defined by the measurement apparatus. If we conceptualise the quantum state in terms of a wave function, we call this abrupt projection the collapse of the wave function.

This dual dynamics (sometimes linear, sometimes instantaneous change) solves the measurement problem insofar that it explains how we can get determinate measurement results from indeterminate states, or, in more technical parlance, how a superposition of eigenstates collapses into one eigenstate.

Bohr's interpretation is more rigorous than the sparse textbook interpretation. I distil two main aspects from his thought: complementarity and experiment.

The idea of complementarity takes many forms in Bohr's work. The general idea is that there are some concepts which always come in pairs but which are mutually exclusive. The best known example in quantum mechanics would be the complementarity of the wave and particle behaviour of light. Both concepts are necessary to describe the phenomenon of light in its totality, but logically they are inconsistent with each other. That is, one has to choose which description to use, depending on context.

The idea of complementarity is mathematically formalised in Heisenberg's uncertainty relations—which we will shortly discuss more critically. They state that there are pairs of properties which cannot both be observed precisely at the same time. For instance, when a particle's position is very accurately observed, its momentum will be highly uncertain.

Bohr has also written about the complementarity of concepts which are not necessarily quantum mechanical. For example, he wrote about the complementarity between observer and observed object.[53] In the previous chapter, I explained this in the telescope example: one cannot observe the telescope *and* use it to observe simultaneously. In terms of quantum mechanics, this is the arbitrary but necessary divide between microscopic quantum system and macroscopic classical experimental setup.

Experiment is the other central aspect of Bohr's thought. It is his starting point for explaining what (physical) reality consists of, and how quantum theory corresponds to reality. He writes:

> While, within the scope of classical physics, the interaction between object and apparatus can be neglected or, if necessary, compensated for, in quantum physics this interaction thus forms an inseparable part of the phenomenon. Accordingly, the unambiguous account of proper quantum phenomena must, in principle, include a description of all relevant features of the experimental arrangement.[54]

[53] Niels Bohr, "The Quantum of Action and the Description of Nature" (1929/1985), page 96/[212]
[54] Niels Bohr, "Quantum Physics and Philosophy" (1958/1996), page 311/[391]

Bohr's ideas are geared towards solving problems in the theory of physics, not to explain the fundamental nature of reality. Nonetheless, we can deduce from Bohr's approach to physical problems his *meta*-physical ideas. First of all, he attaches a lot of importance to experimental context. Quantum theory only has meaning insofar as it pertains to experiment, to measurement. Concretely, Bohr argues that there are entities, say, atoms, which can be known through measurement done by experimental devices. Properties and phenomena of those atoms, thus, owe their reality to the experiment.

Even more enlightening is an entity Bohr does *not* deem real. That is the quantum state. For him, the state vector of wave function is simply an instrument for calculating probabilities of measurement outcomes. It is an epistemic construct, relative to an experimental context and dependent on the previous interactions of the system under investigation.[55]

Taken together, regarding his ontological views, Bohr is, on the one hand, an unconventional physicist, as he does not believe one of the basic concepts in quantum theory—the quantum state—to be a fundamental building block of physical reality. On the other hand, he fits quite neatly in the stereotype of the conventional physicist for the sake of his firm emphasis on experimental context. For Bohr, we cannot say much about quantum mechanical reality, as experiment does not simply reveal that pre-existing reality. Because, our macroscopic experimental setups only engender classical properties and phenomena. The philosophical reason for this, according to Bohr, is that measurement outcomes must be *communicable* and *classicality* (i.e. determinacy) is a prerequisite for communication.

Barad's agential realism

Now, let us turn to Barad, who was inspired by Bohr's ideas and drew out their philosophical implications. In their magnum opus *Meeting the Universe Halfway*, they write:

> The starting point for this transdisciplinary engagement is the philosophically rich epistemological framework proposed by the physicist Niels Bohr. […] Bohr's philosophy-physics is a particularly apt starting point for thinking the natural and social worlds together and gaining some important clues about how to theorize the nature of the relationship between them, since his investigations of quantum physics open up questions not only about the nature of nature but also about the nature of scientific and other social practices. In particular, Bohr's naturalist commitment to understanding both the nature of nature and the nature of science according to what our best scientific theories tell us led him to what he took to be the heart of the lesson of quantum physics: *we are a part of that nature that we seek to understand.*[56]

[55] Jan Faye, "Complementarity and Human Nature" (2017); Dugald R. Murdoch, *Niels Bohr's Philosophy of Physics* (1987)

[56] Karen Barad, *Meeting the Universe Halfway* (2007), page 26

In what follows I want to explain Barad's philosophy, with a particular focus on subjectivity. We will be investigating the tension between the wholeness of the world on the one hand, and the necessity of (subject-object) dualisms on the other. So let me run through Barad's construction of their so-called "agential realism" focussing on the subject-object divide.

One of the most outstanding non-classical aspects of quantum mechanics is what physicist Werner Heisenberg coined the *uncertainty principle*. It asserts that certain pairs of properties, e.g. position and momentum, cannot simultaneously be determined with arbitrary accuracy. Heisenberg explained this quantum behaviour as the result of microscopic disturbances in the process of measurement. So, according to him, both of the properties, like position and momentum, have definite values, independent of measurement; it is just that any measurement interaction will disturb the system such that we cannot know both values with arbitrary precision. In other words, we are *uncertain* about one of the quantities.[57]

Bohr did not agree with this explanation. According to him, as we saw, it is not that the measurement disturbs either position or momentum, but that the two are not even there in the first place. That is, one of the two only comes into being through measurement. The other one remains *indeterminate*, not just unknown. For, the two measurement devices associated with each physical quantity are mutually exclusionary. Therefore, a better term is the *indeterminacy principle*.

From this, Barad concludes:

> Bohr argues that the indeterminacy of the measurement interaction is of profound consequence. […] [T]he question of what constitutes the object of measurement is not fixed: as Bohr says, there is no inherently determinate Cartesian cut. *The boundary between the "object of observation" and the "agencies of observation" is indeterminate in the absence of a specific physical arrangement of the apparatus.* What constitutes the object of observation and what constitutes the agencies of observation are determinable only on the condition that the measurement apparatus is specified. *The apparatus enacts a cut delineating the object from the agencies of observation.* Clearly, then, as we have noted, *observations do not refer to properties of observation-independent objects (since they don't preexist as such).*[58]

Let me break this down. The metaphysical lesson Barad takes from Bohr is that there is no such thing as a measurement-independent property of an object. And, as such, there is not even an independent object to begin with. A natural question to ask, then, is "why do we perceive all these objects with their determinate properties?"—the measurement problem.

As explained above, Bohr resolves the measurement problem by granting the experimental arrangement an important role in his theory. He takes into account the measuring apparatus as a device which contributes to the properties which it measures. Hence, these properties are measurement-dependent.

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[57] Heisenberg's explanation could be seen as a hidden variable interpretation avant la lettre.

[58] Karen Barad, *Meeting the Universe Halfway* (2007), page 114

This dependency between object and agencies of observation goes straight against Descartes' idea that a subject (*cogito*) has the power to know independent objects as they really are. As we saw, at least in quantum mechanics, there is no such neat Cartesian cut between object and subject. As much as we like to think that we can retrieve independent properties from objects, they will always be dependent on the experimental setup as well. Therefore, physical quantities, like position, momentum and energy, do not refer to measurement-independent objects, but to the object and measurement agency as a whole. This whole is what Barad calls a phenomenon. They explain:

> Bohr resolved the wave-particle duality paradox as follows: "wave" and "particle" are classical descriptive concepts that refer to different mutually exclusive *phenomena*, not to independent physical objects. He emphasized that this saved quantum theory from inconsistencies, since it is impossible to observe particle and wave behaviors simultaneously because mutually exclusive experimental arrangements are required. To put the point in a more modern context, according to Bohr's general epistemological framework, referentiality must be reconceptualized: the referent is not an observation-independent object but a phenomenon. This shift in referentiality is a condition for the possibility of objective knowledge. That is, *a condition for objective knowledge is that the referent is a phenomenon* (and not an observation-independent object).[59]

Barad borrows the term "phenomenon" from Bohr, who uses it in a very particular way, according to Barad. He asserts that the experimental setup is part of the physical phenomenon. Recall that physical quantities refer to phenomena, which consist of object *and* measurement apparatus, not just an object by itself. This characterisation of "phenomenon" is quite similar to Kant's usage. He uses it as a designation for how an object is constituted by the subject, as opposed to the noumenal *Ding an sich*. Barad writes:

> Phenomena are constitutive of reality. Reality is composed not of things-in-themselves or things-behind-phenomena but of things-in-phenomena.[60]

Moreover, Barad describes phenomena as a special kind of *intra-action*. Intra-action is opposed to conventional belief that two objects, the *relata*, bring about an interaction, the *relation*. Rather, they argue, it is the other way around: the relation is prior to the relata. That is, the relata co-constitute each other. The phenomenon, then, is an intra-action in which an object and an agency of observation are co-constituted. In quantum mechanical terms, the measurement process reifies the physical system under investigation *and* the measurement device.

Intra-action in general results in a cut between two co-constituted entities. A phenomenon in particular results in a cut between object and subject. Nevertheless, it is not

[59] Ibid., page 198
[60] Ibid., page 140

obvious at all where to locate that cut, where to draw the line. To illustrate this point, let us recall Merleau-Ponty's example:

> The blind man's stick has ceased to be an object for him, and is no longer perceived for itself; its point has become an area of sensitivity, extending the scope and active radius of touch, and providing a parallel to sight.[61]

The stick has to be considered either as an object or as part of the subject—it cannot be both at the same time. If one decides to view it as an object, the cut will be between hand and stick. If one chooses the stick to be part of the subject, the cut is located at the end of the stick. In physics, the cut between experimental setup and observed system is only determined by the theory, by experimenters. In fact, Bohr presented a similar example decades before Merleau-Ponty did:

> One need only remember here the sensation, often cited by psychologists, which every one has experienced when attempting to orient himself in a dark room by feeling with a stick. When the stick is held loosely, it appears to the sense of touch to be an object. When, however, it is held firmly, we lose the sensation that it is a foreign body, and the impression of touch becomes immediately localized at the point where the stick is touching the body under investigation.[62]

In short: you can treat subject as object and the other way around, but you *have* to make a choice. The result of such a shift of the object-subject cut can be dramatic, as it influences how reality is perceived—it influences reality.

But, if reality is contingent on this arbitrary cut, can we still talk about an objective world? At least not in the conventional sense: we already established that there are no measurement-independent properties of the world out there. Instead of rejecting objectivity altogether, Bohr insists on amending our conception of it. According to him, objectivity should be defined as a property's possibility for unambiguous communication. For example, if I measure the spin of an electron to be up, then I can communicate that with my colleagues. The whole scientific community will agree on this outcome.

Albeit empirically evident that scientists do not disagree about the outcomes of measurement, why would it be true in principle? In other words, why would human communication be such a physically unique activity? Barad accuses Bohr of being anthropocentric on this issue. Bohr ultimately places the observational cut between humans and the world. When Bohr says "phenomenon", he means the combination of object of interest and measurement device. The human scientist then observes the measurement outcome of that phenomenon.

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[61] Maurice Merleau-Ponty, *Phenomenology of Perception* (1962), page 164-165

[62] Niels Bohr, "The Quantum of Action and the Description of Nature" (1929/1985), page 99/[215]

As Barad contends that Bohr's phenomenon is anthropocentric, they reconceptualise it as the combination of object and subject. More precisely, the Baradian phenomenon is the intra-action between object and subject. This subject does not necessarily have to be a human. Or, it can be a human—but what *is* this human in the first place? Where does one's body begin and end? Is the measurement device part of the physical system or is it part of our perceptual apparatus? And what about our arms? And the blind man's stick? With these questions, Barad exposes the subject for what it is: embodied and situated. In doing so, they do not only reconceptualise the human body but also the nature of reality:

> I use Bohr's crucial insight about the production of bodily boundaries to argue that his liberal humanist conception of human bodies and subjects is in fact untenable, and I propose instead a posthumanist understanding of the "human." Crucially, I will argue that the nature of the production of bodily boundaries is not merely experiential, or merely epistemological, but ontological—what is at issue and at stake is a matter of the nature of reality, not merely a matter of human experience or human understandings of the world. Beyond the issue of how the body is positioned and situated in the world is the matter of how bodies are constituted along with the world, or rather, as "part" of the world (i.e., "being-of-the-world," not "being-in-the-world"). That is, the central issue for my purposes concerns the nature of the body's materiality.[63]

Barad's divergence from Bohr

In a recent paper, Danish philosophers of science Jan Faye and Rasmus Jaksland criticise Barad for misrepresenting Bohr's philosophy-physics. They argue that, even though Barad allegedly bases their interpretation on that of Bohr, it turns out to be quite distinct on closer inspection. They discuss four aspects: dualism, influence of the observer, phenomena and realism. Let me explain them and discuss whether the critique is justified. I agree that Barad's interpretation of quantum mechanics is not entirely equal to Bohr's, but that they are completely aware of this. In fact, this divergence opens the door towards a generalisation of Barad's agential realism à la Everett.

First, Faye and Jaksland maintain that Bohr thinks of the object-subject dualism as essential, whereas Barad straight-out rejects it. Faye and Jaksland write:

> [W]e must, according to Bohr, speak as though there is a sharp separation between the object of study and the subject studying it; the latter including both measuring device and experimenter.[64]

I do not think Barad would disagree with that. For Barad, there is no inherent cut between object and subject, but an arbitrary cut is needed nonetheless for meaning and being to arise. What is true, though, is that for Bohr, this cut is either located between quantum system and

[63] Karen Barad, *Meeting the Universe Halfway* (2007), page 159-160

[64] Jan Faye, Rasmus Jaksland, "Barad, Bohr, and quantum mechanics," page 14/8244

measurement device or measurement device and human. And this is something Barad explicitly and consciously disagrees with.

Then, the two critics argue that Barad gives much more agency to the observer than Bohr would allow for. Barad allegedly insinuates that the observer has influence on the observed object. In my opinion Faye and Jaksland strawman Barad here. Barad does not argue that people can influence reality by their free will. It is just that reality is (also) dependent on the embodied subject. Bohr would agree with that at least insofar as embodied subject means experimental setup.

Next, in contrast to Barad, Faye and Jaksland claim that Bohr's phenomenon is quite close to the phenomenological or Kantian concept, that is, "how the quantum object appears during the interaction with a particular measuring instrument."[65] As discussed before, Barad represents Bohr's phenomenon as the combined system of physical system and agencies of observation. This is what Bohr writes about phenomena:

> [The interaction] between the object and the measuring instruments will have an essential influence on the phenomenon itself.[66]

> [I]n quantum phenomena, no sharp separation can be made between an independent behaviour of the objects and their interaction with the measuring instruments.[67]

> The essential lesson of the analysis of measurements in quantum theory is thus the emphasis on the necessity, in the account of the phenomena, of taking the whole experimental arrangement into consideration.[68]

> It is certainly far more in accordance with the structure and interpretation of the quantum mechanical symbolism, as well as with elementary epistemological principles, to reserve the word « phenomenon » for the comprehension of the effects observed under given experimental conditions.[69]

> [A]ll ultimate measuring instruments [...] define the external conditions of the phenomenon.[70]

From these quotes, it becomes clear that, for Bohr, the experimental setup should be taken into consideration in order to determine the phenomenon. To Faye and Jaksland's credit, it seems like Bohr thought of the experimental setup as determining but not included in the phenomenon. For Barad, on the other hand, the agencies of observation are part of the

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[65] Ibid., page 10/8240
[66] Niels Bohr, "The Causality Problem in Atomic Physics" (1939/1996), page 19/[311]
[67] Ibid., page 19/[311]
[68] Ibid., page 20/[312]
[69] Ibid., page 24/[316]
[70] Ibid., page 28/[320]

phenomenon. However, it should be noted that this distinction is very small and does not lead to conceptual problems. Moreover, Bohr often uses the term in combination with the claim that there is no sharp separation between objects and experimental arrangement. Therefore, it does make sense for Barad to define phenomenon as the intra-action of object and experimental arrangement.

Finally, the most pertinent criticism of Faye and Jaksland deals with Barad's realism. There are not many Bohr scholars who describe him as a realist, not because he is a definite anti-realist, but mainly because his interpretation of quantum mechanics is mainly epistemological as opposed to ontological. Some of those who do call Bohr a realist, argue that he is an "entity realist", which means that he believed in measurement-independent entities behind their measurement-dependent properties. So, an atom for example is real, that is, it exists independently, but its properties of e.g. position and momentum are measurement-dependent. Barad's "agential realism" is completely different. It incorporates the idea that, ultimately, every entity and its properties are dependent on other entities—namely, they are intra-actively co-constituted. For Barad, there are no pre-existing entities. Faye and Jaksland correctly note that entity realism and agential realism are different, but that is hardly an attack on Barad's philosophy. Barad is fully aware that any realist interpretation of Bohr is an extrapolation from his epistemology, because he has never made any ontological commitments. On this, they write:

> Bohr's writings on complementarity focus on the inherent semantic indeterminacy and the profound epistemological implications of the lack of inherent separation between knower and known, but I propose that it is not a stretch to understand the indeterminacies to be at once semantic *and* ontic (not merely epistemic). Indeed, although Bohr does not make such an explicit claim, as I've indicated in my explication of his views, there is justifiable reason to do so (including, notably, his rejection of the metaphysical presupposition, embraced by Heisenberg, that objects have preexisting properties that are disturbed by the measurement process). Making the ontological nature of this indeterminacy explicit entails a rejection of the*classical metaphysical assumption that there are determinate objects with determinate properties and corresponding determinate concepts with determinate meanings independent of the necessary conditions needed to resolve the inherent indeterminacies*.[71]

All in all, it does make sense to position Barad's interpretation of quantum physics in the tradition and show what makes their interpretation unique. For, many readers of their work are not familiar with the field of philosophy of quantum mechanics and might mistake Barad's interpretation as the only possible and true interpretation. However, it is not the case that Barad is not aware of the field and their place in it. In particular, contrary to what Faye and Jaksland insinuate, apart from some minor aspects, Barad is very conscious of diverging from Bohr's interpretation.

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[71] Karen Barad, *Meeting the Universe Halfway* (2007), page 127

Barad was influenced and inspired by Bohr's interpretation of quantum mechanics to revise our ideas about reality. However, they make a posthumanist step and an ontological step away from Bohr's ideas, which sparked the criticism of Faye and Jaksland.

Although Bohr was on the right path in explaining quantum indeterminacy by taking into account the measurement apparatus, he did not dare to go as far as to include the human experimenter into physical reality as well. Barad eliminated the human as a metaphysically separate entity, by incorporating it in the phenomenon.

I argue that precisely this divergence of Bohr should be a reason for us (including Barad) to move on to another interpretation of quantum physics. Namely, there is still a subject-object cut, which we all experience as a necessary part of perception. Barad acknowledges this problem themself:

> In Bohr's account, one is not entitled to presume that an object has determinate boundaries and properties in the absence of their specification through the larger material arrangement. The boundaries and properties of an "object" are determinate only within and as part of a particular phenomenon. Therefore, by the logic of Bohr's own analysis, the boundaries and properties of an apparatus are not well defined outside its determination within a larger phenomenon.
> [...]
> In other words, to measure [the characteristics of a measurement apparatus] (as part of a larger phenomenon), the original apparatus in question would have to become the "object" of investigation in its intra-action with an auxiliary apparatus, thereby involving it in some larger phenomenon. Since it is not possible for the apparatus to simultaneously be both measured object and measuring instrument, the apparatus cannot be fully characterized and function according to its ("original") purpose simultaneously. Or to put it another way, any attempt to measure the "original" apparatus's characteristics will require its involvement within a larger phenomenon whereby it is positioned as the object of investigation, thereby excluding its role as an agency of observation. The measurement of the apparatus entails a different phenomenon from the original one, and the connection of the two different phenomena would require a third, yet larger phenomenon entailing these.[72]

Here, they frame the indispensable subject-object cut as a problem of Bohr's thought, but Barad does not solve the problem either. A disclaimer to this thesis: nor am I going to do so. In fact, I think it is a problem we fundamentally cannot resolve. What is possible, though, is to describe the cut, the subject and (material) reality in different ways. As I discussed in the previous chapter, different philosophers have addressed this problem with different stories. I want to contribute such a story, a new philosophical tool if you will. To get a better intuition of the arbitrariness of the object-subject cut and its implications, I believe it makes sense to involve Everett's interpretation of quantum mechanics, being a generalisation of Bohr's. Therefore, let us turn to Everett now.

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[72] Ibid., page 160-161

Everett's objections to Bohr

All criticism Everett has on the Copenhagen interpretation in general and on Bohr's interpretation in particular, emanates from just one objection: they are artificially dualist. That is, they make an ontological distinction between quantum system and measurement apparatus, between knower and known, between macroscopic and microscopic. Everett calls the approach to make such distinctions the "external observation formulation", as those interpretations assume an external observer which is not subject to the same laws as the system under investigation.[73] This is the same as Barad's criticism, when they accuse Bohr of being anthropocentric. In what follows, I will discuss three aspects of Everett's criticism of the dualism of the textbook interpretation (first two) and Bohr's complementarity (last):

- The projection postulate or the collapse of the wave function
- The objectivity of quantum probabilities
- The priority of classical physics

First, as discussed before, according to the textbook interpretation, there are two modes of evolution for the quantum state. On one hand, there is linear evolution according to Schrödinger's equation and, on the other hand, there is abrupt collapse of the wave function. Linear evolution is how quantum systems behave when we just leave them for what they are. But as soon as we observe the system, i.e. make a measurement of a property of the system, the quantum state instantaneously assumes one of the eigenstates. According to such a description, measurement is a process fundamentally different from any other in nature.[74]

To introduce Everett's second criticism, let us appreciate something that the two physicists agreed on. According to both Everett and Bohr, quantum systems do not possess absolute properties.[75] For Bohr, those properties are relative to the experimental setup. Therefore, anybody with knowledge about the quantum system *and* the experiment would agree on the probabilities of each measurement outcome. In that sense, probabilities, and thus the quantum state of a system, are objective for Bohr. Everett would disagree. For him, as well as for Barad, probabilities are relative to the observer. That is, probabilities are subjective.[76] Here, again we see how Bohr treats the experiment or measuring apparatus as a special entity. It makes the microscopic quantum system knowledgeable for all macroscopic observers. According to Everett, that distinction should be removed to the effect that separate observers deduce different probability distributions, wave functions, for the same quantum system.

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[73] Hugh Everett III, "'Relative State' Formulation of Quantum Mechanics" (1957);
Hugh Everett III, "Objective vs Subjective Probability" (1955/2012), page 59;
Letter from Everett to Petersen (1957/2012), page 239-240;
Letter from Everett to DeWitt (1957/2012), page 255

[74] Hugh Everett III, "'Relative State' Formulation of Quantum Mechanics" (1957), page 454-455

[75] Stefano Osnaghi, Fábio Freitas and Olival Freire Jr., "The Origin of the Everettian Heresy" (2009), page 114

[76] Hugh Everett III, "Objective vs Subjective Probability" (1955/2012)

Third, Everett holds that Bohr cannot faithfully deduce classical phenomena from quantum ones. For, Bohr already presupposes a classical measurement apparatus which is prior to any quantum probabilities or wave function. Subsequently, one might be able to derive classical behaviour from quantum mechanical principles. But that would simply be circular reasoning. "[In the Copenhagen interpretation] the deduction of classical phenomena from quantum theory is impossible simply because no meaningful statements can be made without pre-existing classical apparatus to serve as a reference frame."[77] To this, Bohr would probably have responded that no meaningful statements can be made without presupposing classical concepts in the first place. But it is not obvious that this is true. Can we not devise a quantum language?[78]

The relative state interpretation

Everett claimed that theories are scientific constructs, which by itself do not have any relation to reality. For that reason, every theory needs an interpretive part.[79] And in quantum mechanics, that interpretive part was unsatisfactory. So, to resolve these issues discussed above, Everett developed his relative state interpretation. I want to describe Everett's interpretation according to two aspects: the relativity of the quantum state and the reality of the wave function.[80]

Unsurprisingly, the central concept in Everett's relative state interpretation is the relativity of the quantum state. As discussed before, state relativity just played a secondary role for Bohr, as a consequence of the fundamental relativity with respect to the measurement arrangement. Everett wanted to make this concept fundamental. The state of a system should always be relative to another system.[81] If this system happens to have the typical properties of an observer, then states relative to this system behave like the quantum states of the textbook interpretation.

This is best explained using some formal notation. Say, there is an experimenter, O, who wants to investigate the spin of an electron, e. Because Everett does not want to split physical reality into partly quantum mechanical and partly classical, he treats everything as a quantum mechanical object. That is, not only the electron is described by a quantum state, but the

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[77] Hugh Everett III, "The Theory of the Universal Wave Function" (written 1955-1965, published 1973), page 111

[78] Vera Bühlmann, Felicity Colman and Iris van der Tuin allude to such a language in "Introduction to New Materialist Genealogies" (2017).

[79] Ibid., page 133

[80] Although quantum state and wave function are almost synonyms, I did not choose to only use one of the two, because Everett writes about the "relative *state* interpretation" and the "universal *wave function*."

[81] Hugh Everett III, "'Relative State' Formulation of Quantum Mechanics" (1957); Hugh Everett III, "The Theory of the Universal Wave Function" (1973), page 43

experimenter as well. Barad would certainly approve of this posthumanism.[82] Before measurement the experimenter is in state $|\text{“?”}\rangle_O$ denoting her curiosity as to what the spin (for instance, in the z-direction) of the electron is. Omitting normalisation, the electron state is $|\uparrow\rangle_e + |\downarrow\rangle_e$. As the question of the experimenter is answered upon measurement, her state changes into $|\text{“spin-up”}\rangle_O$ if she were to interact with $|\uparrow\rangle_e$ and into $|\text{“spin-down”}\rangle_O$ in case she were to interact with $|\downarrow\rangle_e$. From our third-person perspective, then, the evolution of the combined experimenter-electron system would be

$$|\text{“?”}\rangle_O \otimes (|\uparrow\rangle_e + |\downarrow\rangle_e) = |\text{“?”}\rangle_O \otimes |\uparrow\rangle_e + |\text{“?”}\rangle_O \otimes |\downarrow\rangle_e \rightarrow |\text{“spin-up”}\rangle_O \otimes |\uparrow\rangle_e + |\text{“spin-down”}\rangle_O \otimes |\downarrow\rangle_e.$$

Here we see how the experimenter became entangled with the electron. We ended up with a superposition of the experimenter having measured an electron with spin-up and her having found the electron with spin-down.

Note that in this spin measurement process there has been no projection of the state onto one of the eigenstates. But still it can be explained why the experimenter *experiences* only one of the eigenstates after measurement. That is because, being a quantum system herself, she got entangled with the electron. In other words, the state of the electron and the state of the experimenter are relative to each other. Moreover, the state of the electron is dependent on the observer as well. The experimenter will have measured a determinate spin-up or spin-down state, but from our third-person perspective, we still experience the electron as being in a superposition.

Everett phrases beautifully the principle of relativity for non-discrete measurement parameters, like position and momentum:

> The observer will not become aware of the fact that the state does not correspond to definite positions and momenta (i.e., he will not see the objects as “smeared out” over large regions of space) but will himself simply become correlated with the system—after the observation the composite system of objects+observer will be in a superposition of states, each element of which describes an observer who has perceived that the objects have nearly definite positions and momenta, and for whom the relative system state is a quasi-classical state [...], and furthermore to whom the system will appear to behave according to classical mechanics if his observation is continued.[83]

Now, let us move on to the second aspect of Everett’s interpretation, the one considering reality. Everett set out to break away from the artificial dichotomy between the classical and the quantum mechanical, between the macroscopic and the microscopic. Therefore, he chose just one fundamental theoretical structure of physical reality: the wave function.[84] That is, he

[82] Obviously, Everett did not use this term himself.
[83] Hugh Everett III, “The Theory of the Universal Wave Function” (1973), page 90
[84] Hugh Everett III, “Probability in Wave Mechanics” (1955/2012), page 70

chose the quantum mechanical description to be the true language of nature, whereas classical phenomena are merely emergent from the quantum realm.

But what does it mean for all of physical reality to be represented by a wave function? In the case of the electron which is in a superposition of spin-up and spin-down, that superposition is, according to Everett, real. Similarly, the superposition is real of the experimenter who thinks "up" and she who thinks "down". So are neither or both of the opposing states real? We can simply circumvent this question by saying that they are *equally real*. Reality thus becomes a sliding scale rather than a binary variable.

Everett calls the particular components of a quantum state its branches, and affirms that every branch is equally real.[85] Our perspective of the world, just like the perspective of the experimenter, or the perspective of the electron, is always within a branch of a more general wave function. Therefore, if we continue to conceptually zoom out from our particular branch, we will ultimately end up with a wavefunction encompassing all possible substates of the universe. This is what Everett calls the universal wave function, the ultimate description of reality.

Flaws in Everett's thought

Historians of science have suggested to divide the development of interpretations regarding quantum mechanics into three periods.[86] The first one, running from 1925 to the early 1950s, was named the "monocracy of the Copenhagen interpretation" by Max Jammer,[87] to identify the period in which almost no-one would risk undermining the titans, Heisenberg and Bohr. In the third one, starting in the 1970s, the controversy about quantum interpretations became institutionalised with seminars about and investigations into the foundations of quantum mechanics. The historically most interesting period is the intermediary transition period in which some courageous academics started to question the orthodox version of quantum mechanics.

Everett was one of these outsiders. And he was met with a lot of resistance. His mentor, John Wheeler, had worked with and became friends with Bohr in the past. As Wheeler had a lot of faith in Everett's ideas, he thought it would be interesting for Everett to visit Bohr. This encounter eventually happened, but was a total disaster. The two were not able to find common ground. Accompanying this conversation were letters and discussions with other physicists within the orthodox Copenhagen group (which does not necessarily mean that they were all situated in Copenhagen, but simply that their ideas on quantum mechanics were aligned with Bohr's). By reviewing these interactions, historians demonstrated how much

[85] Hugh Everett III, "'Relative State' Formulation of Quantum Mechanics" (1957), page 459
[86] Olival Freire Jr., "A Story Without an Ending" (2003), page 573-574
[87] Max Jammer, *The Philosophy of Quantum Mechanics* (1974), page 250

power the Copenhagen group had and how difficult they made it for diverging ideas to establish themselves within the scientific discourse.[88]

To illustrate their closed-mindedness towards Everett's relative state interpretation, let me exhibit an excerpt of a letter from one of his toughest critics, Léon Rosenfeld.

> With regard to Everett neither I nor even Niels Bohr could have any patience with him, when he visited us in Copenhagen more than 12 years ago in order to sell the hopelessly wrong ideas he had been encouraged, most unwisely, by Wheeler to develop. He was undescribably stupid and could not understand the simplest things in quantum mechanics.[89]

Rosenfeld rejected Everett's notion that the experimental apparatus should be described according to the laws of quantum mechanics just like any other physical system, by arguing that the one *necessitates* classical concepts in the formulation of quantum theory. He puts it as follows:

> To try (as Everett does) to include the experimental arrangement into theoretical formalism is perfectly hopeless, since this can only shift, but never remove, this essential use of unanalysed concepts which alone makes the theory intelligible and communicable.[90]

Aage Petersen, another Copenhagen associate, argued that it is "silly to say [that the measuring] apparatus has [a] Ψ-function."[91] And that

> Obviously, one can treat any interaction quantum-mechanically, including the interaction between an electron and a photographic plate, but when utilized as an "observer" the definition of the "state" (position) of the plate excludes considerations of quantum effects.[92]

In between the lines of this objection to Everett, I find two contentions. First, Rosenfeld and Petersen argue that the measurement should not be treated on equal footing with the object of observation, the physical world. Second, Petersen questions the universality of the wave function.

Of course, these two matters are related, but they are not inseparable, i.e. they are not mutually dependent. The first should be rejected for the reason that experiments are clearly just things-in-the-world like any other. Although Petersen explicitly agrees with this in the quote above, he does not act accordingly. That is, he still grants the agencies of observation a special conceptual category.

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[88] Fábio Freitas, Olival Freire Jr. and Iolanda Faria, "Power Relations in Science" (2020)
[89] Quote in Stefano Osnaghi, Fábio Freitas and Olival Freire Jr., "The Origin of the Everettian Heresy" (2009), page 113
[90] Quote in ibid., page 117
[91] Quote in ibid., page 118
[92] Letter from Petersen to Everett (1957/2012), page 237

The latter criticism, on the other hand, is better-founded. Historically the wave function was constructed as a theoretical device. It is a big leap to say it directly corresponds to everything in reality. In particular the claim that any other branch of a more-encompassing wave function is as real as the branch which I inhabit, seems implausible. It is difficult to accept things as real, if they are fundamentally inaccessible. This is the case for parallel branches, but most significantly for the universal wave function. For the reason that the referent of the universal wave function is inaccessible, Peterson concludes it is a bad theoretical concept. From a physicist's point of view that makes sense. From a *meta*physical perspective, though, the universal wave function might prove to be an excellent concept.

Metaphysical lessons from Everett

Although Bohr and Everett never showed any sign of agreement, Wheeler, being a friend of Bohr and a mentor to Everett, thought that the quantum interpretations of both rivals could coexist.[93] For, the relative state interpretation could be viewed as a generalisation of the Copenhagen interpretation. I admire Wheeler's attitude of cooperation over competition. In general, I think that academics would benefit from acting similarly. Different views are not necessarily contradictory.

Now, just like Barad extracted lessons about reality from Bohr's interpretation of quantum mechanics, I want to extract the lessons from the *generalised* interpretation by Everett. But before we bring these new ideas to the table, I want to emphasise an aspect in which Everett and Barad already agree, and in which they oppose Bohr: their posthumanism. For both, the observer or subject is a quantum mechanical system, just like the object it is observing. This is not where the correspondence has to end, though. Therefore, let us generalise Barad's agential reality.

With this term for their philosophy—agential reality—Barad already insinuates a kind of relativity. Namely, that reality is relative to the agent. In Everettian terms: the quantum state of the observed world is relative to the quantum state of the observer. Note that this observer need not be a human. Relative states are well-defined for any system, human or not. The ingredient Everett adds, then, is a philosophical tool to imagine the world from other relative states. In particular, he talks about the state of the universal wave function. This is the most general state, encapsulating all of reality. He therefore insinuates a possibility to move between more and less particular versions of reality, if only conceptually. The ultimate reality of the universal wave function is different from Barad's agential reality, but Barad does implicitly acknowledge transcendental subjectivities by talking about entanglement even in a first person description. This is striking, because entanglement can never be observed when one is part of it. For this very reason, Bohr would never allow for that.

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[93] Letter from Wheeler to Stern (1956/2012), page 219;
Everett agrees in "'Relative State' Formulation of Quantum Mechanics" (1957), page 454

Now, we can take Everett's idea about relative states to a lesson about subjectivity. It allows us to move our subjectivity, between more "universal" and more particular. This movement can only very limitedly be done in reality. That is, we can change our material embodiment and situatedness slightly. We can, for instance, use glasses, or take a train. But we cannot radically change; we are quite stuck to our body. However, our imagination might help us to conceptualise radically different subjectivities without materially changing. And for this purpose I want to construct a philosophical tool.

In the next chapter, I will attempt to build this tool, which I tentatively call *the space of subjectivity*. In this space, we can imaginarily walk around, and zoom in and out. The first movement, of walking around "horizontally," corresponds to changing our embodiment and situatedness. The second movement, of zooming in and out, corresponds to moving between more universal, general, "objective" subjectivities and more particular, "subjective" subjectivities. An important point here is that by zooming out to a more universal picture of reality, we lose information, finally to the point of total unintelligibility, complete chaos. Therefore, we need particular subjects to say something about the world. Moreover, science needs particular subjects to have a purpose. The creation of matter and meaning from chaos will be the topic of the next chapter.

Part 3:
The space of subjectivity

This last part of my thesis will be more exploratory than the others. Because, I want to construct a philosophical framework that accounts for subjects in the material world, without totalising this world. I tentatively called this framework "the space of subjectivity," but that term might itself prove to be problematic, so please do not attach too much importance to it.

This part is separated in two. First, I'm going to explore the concept of the virtual, which, I believe, should be a central element in any theory of subjectivity. Here, I mainly focus on the role the virtual plays in the object of observation. In part 3.2, though, I will lay out how the subject itself is (partially) virtual as well. For that, I introduce the concept of singularity, which also pertains to subjects *and* objects. For an understanding of the relation between objectivity and reality, we should constantly oscillate between these two perspectives on the virtual and singularities. This complementarity is crucial if we want to account for the self-referentiality of reality and subjectivity.

Part 3.1:
On virtuality

I believe that the explanation for subjective experience, i.e. determinate measurement outcomes, in Everett's relative state interpretation is instructive to how we should approach reality and ontology. To bridge the gap between Everett's interpretation and metaphysics, we need conceptual tools. We need words. For that, I turn to Gilles Deleuze's concept of the virtual.

To introduce the virtual, I will contrast it with Aristotle's concept of potentiality. Then, I will sketch the concept in the abstract, after which I will discuss it more concretely, in the context of quantum mechanics. I will then critically consider whether the application of the virtual to quantum mechanics is legitimate and show that Henri Bergson, an important inspiration for Deleuze, did a similar thing in his theory of time. Finally, I will spend some words on the function of the virtual in the relation between subjectivity and ontology.

Potentiality and actuality in Aristotle

In his metaphysics, Aristotle presents the dichotomy of *δύναμις* on the one hand, and *ενέργεια* or *ἐντελέχεια* on the other.[94] The first term is often translated by potentiality or possibility, the latter two are translated by actuality. So we have one Greek term which is translated by two different English words and two Greek terms which are translated by one English word. For the sake of conceptual simplicity, I will treat the double terms as interchangeable, which is reasonable since their differences are, indeed, minor.

For Aristotle, we can regard potentiality in a weaker and stronger form. In its weaker version, potentiality is the power of something to cause change or movement (*κίνησις*). This is the more mechanical idea of potentiality and actuality, formalised in physics by the corresponding notions of potential and kinetic energy. In its stronger form, it is the capacity to thrive, that is, to reach one's *τέλος*. This is the spirited—vitalist if you will—version. It describes the way a rose bud becomes a rose, and also human flourishing, in terms of tendency towards an end (a *τέλος*).

Actuality, then, is a result of this tendency of everything to its*τέλος*. Moreover, actuality is prior to potentiality for Aristotle. First of all, because the potential presupposes the actual in order to be explained. A block of clay has the potentiality to become a vase, and the potentiality to become a sculpture.[95] We *have* to refer to the actualities of vase and sculpture in

[94] S. Marc Cohen and C. D. C. Reeve, "Aristotle's Metaphysics," 2020, section 12

[95] In "Reflections on Etienne Souriau's 'Les différents modes d'existence,'" Bruno Latour borrows Étienne Souriau's concept of *instauration* to indicate the two-way interaction between agent and object.

order to express the potentiality of the clay. Second, because the potential is always caused by the actual state of a system. An acorn might be a potential oak, but it still needs to be produced by an oak. And third, because *τέλος* and eternity are prior to anything else, and they are always actual.

Virtuality

Now, Deleuze (inspired by Bergson) argues that the potential-actual dichotomy is unhelpful in addressing metaphysical questions, because potentiality describes something imaginary, what the world *could have been* like.[96] In this dichotomy, only the actual is associated with reality. Therefore, the more accurate opposite of potentiality would be reality.

Following this logic, actuality would be better served with another opposite. For this purpose, Deleuze used virtuality.[97] Both actuality and virtuality are real, and as such more appropriate topics of philosophical discussion. In this regard Deleuze is in agreement with Aristotle: potentiality is subordinate to reality, including actuality. However, Deleuze would prefer Aristotle's notion of *κίνησις* over his notions of *τέλος* and eternity as fundamental to reality, because Deleuze is a philosopher of movement and change, not of eternity and absolutism.

In order to understand what virtuality is, we have to take a look at actualisation (the process from virtuality to actuality) and how it relates to realisation (the process from potentiality to reality). According to Deleuze, realisation is a *restrictive* process.[98] An acorn has the potential to become different oak trees, with different arrangements of branches and leaves. But in the end only one of these trees is *realised*, because of certain limitations like the amount of water available to its roots, how hard the wind blows, and how much the sun shines. Actualisation, on the other hand, is *creative*. It creates difference, new stuff.

So far we have mainly explained virtuality from the perspective of potentiality, but we also have to differentiate it from actuality. What is this thing that is real but not actual? Deleuze describes this in temporal terms. The virtual occurs "in a period of time shorter than the shortest continuous period imaginable", such that it is subject to indetermination and the unconscious.[99] Where the actual is accessible to direct experience, the virtual is too fleeting to be noticed. Not only fleeting in time, but also in space and other perceptual dimensions. It is too small, too light, too fast, too quiet. Bergson stresses that many scientists make the mistake

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Sculptors, for example, mould their clay according to their creative ideas. The clay, however, *talks back* by purprising the artist with its final form. Likewise, facts are not just presented to passive subjects; apart from their origins in the object, they are actively constructed, interpreted and represented.

[96] Matt Bluemink, "On Virtuality: Deleuze, Bergson, Simondon" (2020)

[97] Ibid.

[98] Ibid.

[99] Gilles Deleuze and Claire Parnet, "The Actual and the Virtual" (2007), page 48

to look for virtual matters (like form, meaning, value, the ego) in the "intervals" between actual matters (the things we directly perceive).[100]

However, all actual stuff, i.e. the things we take for objects, are always surrounded by a "fog of virtual images".[101] The virtual is always there, and it can be actualised by something else: an agent, a subject, an observer. From fleeting chaos new objects can be created.

This concludes the abstract discussion of the virtual. Before we move on to see how the virtual manifests in quantum mechanics, let me attempt to succinctly grasp the concept of virtuality by three main features: as I have argued, the virtual is real, creative and fleeting.

The virtual in quantum physics

In the original, French version of *The Actual and the Virtual*, Deleuze states that: "*Tout actuel s'entoure d'un brouillard d'images virtuelles. [...] C'est ainsi qu'une particule actuelle émet et absorbe des virtuels plus ou moins proches, de différents ordres.*"[102] I use this French original, because the English translation leaves much to be desired. My own, more literal translation is: "Everything actual is surrounded by a fog of virtual images. [...] This is how an actual particle emits and absorbs more or less close virtual ones, of different orders." The particular wording here insinuates a relation to quantum (field) theory. First, the phrase "*un brouillard d'images virtuelles*" is reminiscent of the electron cloud in an atom. In the second part of the quotation, the metaphors are even more suggestive. Quantum field theory employs the concept of virtual particles to explain the fundamental interactions of nature: a *particule actuelle* emits a *particule virtuel* which is then absorbed by another *particule actuelle*.

Now, what is the character of this relation between the virtual and quantum physics? In this explanation of Deleuze, particles and clouds are mostly used as a metaphor. The idea of fog captures the ungraspable nature of the virtual quite well and emission of particles is a creative process, just like actualisation is. But metaphors are also quite close to examples, instances in which the to-be-explained idea is at work. One of novelist Haruki Murakami's characters even proclaims that "everything in life is metaphor."[103] And Philosopher Hannah Arendt writes:

> What connects thinking and poetry is the metaphor. In philosophy one calls concept what in poetry is called metaphor. Thinking draws its "concepts" from the visible in order to designate the invisible. In Hans Blumenberg, *Paradigms for a Metaphorology* (Bonn 1960), the metaphor plays the role of the model, the "orienting support" for speculation about unanswerable questions.[104]

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[100] Henri Bergson, *An Introduction to Metaphysics* (1912), page 32-36

[101] Ibid., page 48

[102] Gilles Deleuze and Claire Parnet, "L'actuel et le virtuel" (1997), page 179. I write "Deleuze states that" because this book is written based on Claire Parnet's interviews with Gilles Deleuze.

[103] Haruki Murakami, *Kafka on the Shore* (2005), page 187

[104] Hannah Arendt, *Denktagebuch* (1969), page 728, my translation

For apparently there is a metaphorical connection between quantum physics and the virtual, I would like to exploit the example of quantum mechanics to get a grasp of virtuality in physics.

In order to do so, let us consider the hydrogen atom. I chose this object, because Everett already proved it to be a good example in order to explain his relative state interpretation.[105] What is a hydrogen atom? It consists of an electron and a proton. But those constituent parts are not enough. They are in a specific dynamic configuration in order to really *be* a hydrogen atom. For, if I were to place an electron and a proton three metres apart, I would not have a hydrogen atom. But, conversely, there are multiple configurations under which the particles would form a hydrogen atom. And, typically of quantum physics, the hydrogen atom will be in a superposition of all these configurations. If we were to observe the hydrogen atom,[106] we would only observe it as such, not as a sum of its parts. That is, we would only measure features of the hydrogen atom as an autonomous object. For instance, we would measure the mass or energy of the hydrogen atom, not of the electron and the proton. However, we know, at least conceptually, that the underlying particles are there to comprise the atom. They are just not directly perceived. They are virtual. Nevertheless, the emergent hydrogen atom is actual. Deleuze acknowledges this by stating that "purely actual objects do not exist."[107] He explains that the virtual and the actual are not always easily distinguished,[108] just like the hydrogen atom and its constituting subatomic particles cannot be separated.

Now that we have somewhat of an intuition of the virtuality of the hydrogen atom, we can search for its aspects which connect to creativity, fleetingness and reality. I will discuss them in that order.

The virtual is creative insofar as it has the capacity to reify an object through the process of actualisation. Deleuze puts it poetically: "The actual falls from the plane [of immanence] like a fruit, whilst the actualization relates it back to the plane as if to that which turns the object back into a subject."[109] Let me take this apart. The "plane of immanence" is the space of the virtual, from where things can actualise. One can think of it as a replacement of *the fabric of reality*. From this plane, the actual arises. That is, it presents objects. The process of actualisation, then, links an entity's objectivity to its subjectivity. In other words, the subject and the object in the process of observation are symmetrically intra-acting entities.

In quantum physics, measurement represents the process of actualisation. The act of observation actualised the hydrogen atom. But, since the subatomic particles are not measured individually, they remain virtual. If we were to measure one of them, it would mean to destroy the hydrogen atom and actualise the subatomic particle.

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[105] Hugh Everett III, "The Theory of the Universal Wave Function," 1973, page 86

[106] This is a thought experiment. It is very difficult to isolate a single atom, let alone measure its weight or vibration.

[107] Gilles Deleuze and Claire Parnet, "The Actual and the Virtual" (2007), page 148

[108] Ibid., page 150

[109] Ibid., page 150

Virtual particles are more widely discussed in quantum field theory, where they perform the role of mediator in interactions between actual (i.e. observed) particles. The lifetime of such a virtual particle is extremely brief. Virtual particles are fleeting.

Lastly, Deleuze contends that the virtual is real. Even though it cannot be observed directly. In quantum mechanics, we cannot observe one of the elements of a superposition without actualising that element, that is, find the element as a measurement result. To say that the virtual in quantum mechanics is real, is to say that the wave function and the eigenstates corresponding to all possible measurement quantities are real. This is the exact realism we find in Everett: there is an all-encompassing universal wave function, of which all the elements are real as relative states.

What is actual and what is virtual depends on observer-subjects and on the measurements they perform. The actual, then, is what they directly observe. The virtual can be split up in two: the sub-observational and the super-observational. The myriad state components of the subatomic particles in the hydrogen atom are sub-observational. But an observer could be part of a superposition as well. This superposition state transcending the observer state is super-observational. The ultimate super-observational state is represented by the universal wave function.

Difficulties of the virtual in quantum mechanics

In the above, I simply took Deleuze's concept of the virtual and parsed it onto quantum theory, that is, reading quantum theory through Deleuze. Now, we should take a more critical approach and ask the question whether Deleuze would agree with my usage of the virtual. Did I do my philosophy correctly? What better place to look for answers than in the book asking exactly that question, Deleuze and Guattari's *What is Philosophy?*[110]

According to Deleuze and Guattari, most philosophers in history have been pursuing a capital-T Truth. The postmodern tradition has in many ways argued that such absolutism is untenable. The impossibility of finding the fundamental ontology of the world we live in challenges the relevance of philosophy. If its goal is not to discover the nature of reality, what is it supposed to do? That is, Deleuze and Guattari contend, concept creation. Philosophy is a creative enterprise in that it constructs concepts, just like the arts which creates affects. Philosophy does not discover an ontology, it creates an ontology for us to navigate the world.

The virtual features in this description of what philosophy is, or ought to be. It is not a part of an ontology, but it is part of the explanation that there is no such thing as a true ontology of our world. Therefore, we should be careful to employ the virtual within an ontology. And this is what I did by applying the virtual to quantum mechanics. Quantum

[110] Gilles Deleuze and Félix Guattari, *What is Philosophy?* (1994)

mechanics is a *theory*, an ontology created by scientists, for their particular purposes and interests. We must not recklessly glorify it as the fundament of everything.

But did Deleuze not think of the virtual as real? And is an ontology not everything in reality? We could view an ontology as just a layer of reality, the layer that categorises objects under concepts. The virtual is pre-ontological[111] but still part of reality. It is the chaos we cannot understand or experience before we endow it with an ontology. Reality is always there as virtual and can be actualised by an ontology. Constructing an ontology is, then, to make choices about what is there to be perceived, not what is real.

The virtual is a concept in concept creation. It features in a theory about theory making. Like any theory, this one cannot be grounded and will ultimately contain self-referential parts. And that does not have to be problematic. In fact, this self-reference is characteristic to reality. So if the theory of concept creation can use the virtual, why would quantum theory be excluded from doing so? Deleuze's virtual pertains to all of reality, without a specific ontology. Quantum mechanics, like any scientific theory, comes with a certain ontology indicating different kinds of beings with different relations to reality and knowledge. There are wave functions, particles, measuring devices, entangled systems, interference patterns, et cetera. This is a specific ontology, and therefore the virtual should not be exclusive to it.

Nevertheless quantum theory bears strong parallels with Deleuze's theory of philosophy and ontology. At the very least there is a *resemblance* between observation in Everett's quantum mechanics and actualisation in Deleuze. Moreover, both theories force us to rethink the nature of reality (and if there even is such a thing) in a similar way: there is a reality, but the beings of reality only emerge by way of actualisation, measurement, observation. Above all, Deleuze used quantum mechanical language himself when he explained the virtual. In conclusion, I think it can be useful to examine the virtual in Deleuze and in quantum mechanics diffractively through one another, but it would be a bridge too far to equate the two. We have to be vigilant in order to notice where the resemblance ends.

The virtual in Bergson's theory of time

As a last argument for the use of the virtual *within* a theory, instead of only as an explanation for theory creation, I want to present Bergson's theory of time from which Deleuze originally appropriated the virtual.

Around half a century before Deleuze, Bergson already criticised the static immobility of philosophy and science.[112] It is assumed that the most fundamental concepts would be eternal, unchanging, absolute. This tradition arguably begins with Plato's Ideas. And still in modern science we find static fundamental concepts such as elementary particles in physics and personality traits in psychology. It is surprising how accepting we are of understanding

[111] Ibid., page 40-41

[112] Henri Bergson, *An Introduction to Metaphysics* (1912)

the world in static terms, if our experience of that world is much more characterised by change: every tree, sip of coffee, street, face is different. And they do not only differ from each other; they themselves are also changing from moment to moment. It is in fact very difficult to pinpoint something in the world as a static object. Nevertheless, science and philosophy have tried to do this tirelessly.

One of the concepts that has been, so to speak, frozen[113] by philosophers and scientists alike, is time. The irony could not be more striking, as our experience of time is all about change. Nevertheless, physicists set out to tame time. In 1905, Einstein presented his theory of special relativity.[114] One of the consequences of thetheory was that space and time are not independent, which led to the concept of Minkowski space, a static framework in which space and time can both be represented.

Bergson, as a philosopher of change over immobility, had another theory of time. Of course, he had not been the first philosopher to think about time and change, but what made his attempt interesting is his emphasis on science. There needed to be a *naturalist* response to the scientific freezing of time. And that is what he did.

Bergson notes that, although science and the understanding have a preference for static concepts, consciousness is always in movement.[115] In our experience no one moment is the same. That is because we have a memory which registers what we perceive and experience now, and influences the next instance of experience. So even if we try to concentrate on one supposedly constant sensation, it will change because in the next moment that sensation will be influenced by the memorised sensation of the previous moment. Static consciousness is consciousness without memory. And, since we do have memory, there is perpetual change, which Bergon calls flux.

The consequence of this theory is that time becomes less linear. The past influences my direct experience as much as the present does, through memory. Bergson describes this element from the past, this memory, as virtual. And it is clear that the virtual heavily influenced our present experience, our direct, *actual*, perception. Once again, the virtual is completely tangled up in the actual. It is very difficult, if not impossible, to say which parts of our experience are influenced by previous experience and which parts are new or pure. Moreover, the virtual is not only found in memory of the past, but it also contains traces of the future. In his own words: "Every feeling, however simple it may be, contains virtually within it the whole past and present of the being experiencing it, and, consequently, can only be separated and constituted into a 'state' by an effort of abstraction or of analysis."[116]

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[113] In *What is Philosophy?* (1994), Deleuze and Guattari write "[A scientific plane of reference] is like a freeze-frame. It is a fantastic *slowing down*, and it is by slowing down that matter, as well as the scientific thought able to penetrate it with propositions, is actualized."

[114] Albert Einstein, *Zur Elektrodynamik bewegter Körper* (1905). Bergson has been critical about the interpretation of this theory in his book *Durée et simultanéité. À propos de la théorie d'Einstein* (1922).

[115] Henri Bergson, *An Introduction to Metaphysics* (1912), page 11-14

[116] Ibid., page 25

Again, we could ask the question whether we are not ontologising the virtual. We are indeed calling a form of being, namely memory, virtual. But that does not mean that the virtual and memory are the same thing. Calling an apple red does not equate red to apple. In Bergson's theory of time, memory is simply an instance in which the virtual is at work as an indirect influence on perception. And the virtual can take many other forms as well.

The function of the virtual in subjectivity, ontology and reality

When we experience a certain sensation, we do not only experience the "pure" perceptual data, but also what could be happening around (in space and in time) the experienced event. That is the virtual, it represents the possibilities for being, which are deduced from the pure perceptual data.

The virtual is what creates the possibility for an ontology, for a collection of beings. What is the material origin of that? That is *embodiment*. An ontology is thought or experienced. Experienced by a body. For Bergson, this body is not an apparatus for representation, but a "centre of action."[117] It intra-actively constructs the world in its materiality. This materiality of the body has many different parts. There is a perceptual apparatus, comprising the senses and observational instruments. There might be a theory which links sensations to concepts. Then there are mental processes which are able to do all kinds of prediction and reconstruction. During the process of actualisation, or concept creation, or ontology constructing, all these parts are at word, unconscious or unobserved. That is, they process the virtual. And, as we have seen, the virtual can come in many forms. We have seen it in the form of elements of quantum states and memory. Specific to perception we can also find the virtual as probability and prediction. As our tools for perception are not sufficiently high in resolution, our brain constantly makes predictions about reality. It interpolates and extrapolates. As these are not directly observed they are virtual. However, once again they are enmeshed into direct perception, indistinguishable from the actual.

[117] Iris van der Tuin, "'A Different Starting Point, a Different Metaphysics': Reading Bergson and Barad Diffractively" (2011), page 34

Part 3.2:
The becoming of the subject

In the previous chapters we have looked at different aspects of how scientific reality and subjective reality come together. That laid the groundwork for a theory of subjectivity in the materialist world. In this chapter I want to speculate about a materialist model of subjectivity. Since I believe the subject is material as much as material is a subject, I think it is helpful to look at the genesis of subjectivity just like we look at the genesis of other, supposedly non-sentient, things around us. For that reason, I want to model this tentative theory of subjectivity after morphogenesis from chaos.

Chaos

According to Barad, reality consists of constantly appearing, persisting and disappearing intra-actions. From there, we could wonder what the pre-intra-active world would look like. It would be a world without structure or meaning, because those (entities in relation, words in meaningful strings, etc.) only arise through intra-action. Barad does not really consider the question as to what this structureless world without being would look like, perhaps because they think the question is meaningless or too metaphysical. I agree that we should be cautious here and have just very minimalist ideas about such a pre-intra-active world. We could start by simply defining it negatively: meaningless, structureless, without being.

There is a conceptual parallel between chaos and Everett's universal wave function. Because, every time we "zoom out" towards a more universal wave function, we end up with less information about reality, or, more accurately, reality itself becomes less determinate. In other words, a more objective view (i.e. a perspective less bound by subjective embodiment) will result in a less abundant reality. As such, I think we could use Everett's model of inferring the universal wave function which consists of *making-indeterminate* or *making-meaningless* for investigating what chaos really is (or is not).

We are not the first, however, to think about what comes before being: *chaos*. This term has a long history from cosmologies of ancient civilisations to modern studies of complex systems. In what follows I will cherry pick some of the ideas about chaos from throughout history, using overview articles by philosopher of statistical physics Güngör Gündüz and philosopher Stefan Lobenhofer. I have selected the ideas which are most straightforwardly compared to chaos in contemporary materialist philosophy and I believe they can be helpful in constructing our own idea of chaos.

In many Mesopotamian cosmogonies, water was seen as a material facilitating the creation of gods, the Earth, stars and life. Likewise, the ancient Egyptians believed water was

the essence of the universe and the Quran states the same. The Egyptians were the first to introduce chaos as a philosophical concept, denoting the primordial state before genesis.

The ancient Greek poet Hesiod wrote about the origins of the world and the gods in his *Theogony*.[118] He mentions chaos before the earth and the gods are formed. So chaos is some kind of undifferentiated matter, which allows for the becoming of an ordered cosmos.

The three philosophers of the ancient Greek city of Miletus came up with many different descriptions of chaos as a primordial material.[119] Thales supported the water doctrine that I mentioned above. After him, Anaximander replaced it with a more abstract material: *ἄπειρον*, that which is unlimited. Anaximenes did not approve of such an uncertain concept (in modern language: *ἄπειρον* is too metaphysical). He proposed air to be the essential material.

Despite their differences, these primitive materials shared some defining characteristics. Namely, everything rests on and can be reduced to the primitive material. In particular, it is both the stuff that moves and what is moved, what forms and what is formed.[120] In other words, at the same time as being a fundamental element to which everything can be reduced, it is a fundamental principle or law which describes its dynamics. This allows for *immanent becoming*, that is, a becoming without from within, instead of form being imposed from outside. This fits perfectly into Barad's agential reality, in which dynamic intra-action is the nature of being. The agent and its environment are part of the same chaos, before being reified in their intra-action.

In spite of the fact that chaos as a primitive material can be a source of immanent becoming, it still has an air of essentialism or absolutism, which we wanted to avoid. It is wrong, however, to think that this supposed essentialism is only a delusion of antiquity. In the 19th century, physicist James Clerk Maxwell assumed a medium for the electromagnetic waves of his theory, the aether.[121] We can directly trace that back to the Aristotelian concept of *αἰθήρ*, referring to primaeval matter. To stay true to our anti-essentialist, anti-absolutist intentions, we must think of chaos only in negative terms: disorder, non-being, unintelligible, indeterminate.

Although the ancients already viewed chaos as a source of becoming, they were not explicit about (and maybe not interested in) what that becoming would look like. How does order arise from the structureless soup that is chaos? As we discussed above, people have been thinking about this question for millenia. But only in the second half of the 20th century, the efforts were consolidated into the somewhat unified field of complex systems and chaos theory, most certainly because of developments in computer science.[122]

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[118] Stefan Lobenhofer, "Chaos" (2020)

[119] Ibid.

[120] Güngör Gündüz, "Ancient and Modern Chaos Theories" (2006), page 2-3

[121] James Clerk Maxwell, "Ether" (1878)

[122] For example, in *The Chaos Avant-Garde* (2001) Yoshisuke Ueda writes: "[T]he data I was collecting with my analog computer on the 27th of November, 1961, is the oldest example of chaos discovered in a second-order non-autonomous periodic system" (page 23).

So, instead of indulging in the metaphysical exercise of understanding chaos, modern scientists have investigated the becoming of structures and entities from chaos. Not all of science explicitly formulates their practice as such, but arguably all sciences ask questions of the form "how did this or that come to be?" Accordingly, if science indeed studies particular becomings, then the philosophy of science, as meta-science, studies the mechanisms of becoming. Let us discuss a couple of concepts in that field.

First of all, as chaos is devoid of structure, it is completely random. How could things emerge from randomness? If this randomness is nonetheless dynamic, like a gas in equilibrium inside of which the molecules still bounce around, then it becomes possible for a persistent microstructure to emerge.[123] These little disturbances, then, provide the possibility for the growth of a larger, even macroscopic, structure. Lower level structures coding for higher level phenomena could be regarded as proof for this theory of becoming from dynamic randomness. For instance, DNA codes for organisms and unit cells in a crystal code for the macroscopic shape of that crystal.

Now, what makes a structure persistent, or rigid? One of the characteristics of persistent entities is that they consist of, or are part in *autocatalysis*.[124] Autocatalysis is a process of self-multiplication. We encounter it in organisms at different levels, in human culture, in chemical reactions. Beings that try to make more of themselves are self-evidently more inclined to persist. A thing can make more of itself by turning other things into itself: a plant turns carbon dioxide into plant, a fox turns rabbit into fox. Autocatalysis results in growth. However, we must not forget the other side: decay and decomposition. In fact, growth and decline often happen simultaneously.[125]

But even when something is able to self-multiply, it is able to change through evolutionary principles. On this, Gündüz writes: "Whatever descends from the precursor serves as memory to the new system. […] Every chaotic or nonlinearly growing process has its own history."[126] Self-similarity is expressed between members of a species, but also between precursor and successor in the form of *memory* or *records*. As similarity decreases, the memory of the far predecessor will decrease simultaneously.

Because chaos is characterised by randomness, it is impossible to predict which structures, things and phenomena are going to arise from it. This unpredictability allows for the creation of true novelty. Here are some examples I dwell upon when I think about true novelty. We encounter it, for instance, when we switch between magnitudes of scale: a water

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[123] Güngör Gündüz, "Ancient and Modern Chaos Theories" (2006), page 6-8

[124] Güngör Gündüz, "Ancient and Modern Chaos Theories" (2006), page 8-11

[125] The interplay between growth and decay is studied by the emerging field of ecological philosophy in which Timothy Morton is a central figure. Specific philosophical inquiry into decay and circularity is scarce. Interesting research themes include funghi, compost, humus, waste, etc. Moreover, these specific topics provide an entry into circular ontology, which I discuss in this thesis from a more abstract point of view.

[126] Güngör Gündüz, "Ancient and Modern Chaos Theories" (2006), page 11

molecule is something totally different from an ocean. Then, when we travel to the North Pole, we see that the ocean starts freezing. Such phase change is yet another expression of novelty. A last example we find in self-assembly. Some proteins spontaneously fold themselves in the correct way to facilitate a metabolic process.

Someone who offers a thorough philosophical system to account for how being arises from chaos is philosopher Manuel DeLanda. Even though he does not like the term "chaos theory," he uses the findings of this modern scientific field for inspiration for and support of his system. In the following I will present that system.

A non-essentialist model of morphogenesis

In several papers, DeLanda distributes ontologies over three broad categories.[127] Firstly, idealist philosophers argue that there is no mind-independent reality. Then, positivists or empiricists claim that direct perceptions are independent, but their theoretical, unobservable entities are not. Electrons, for example, are considered outside of reality, as we cannot observe them without a whole theory about particles and electromagnetism. Finally, there are realists, who hold that there are entities out there, completely separate from the human mind. For, according to them, the distinction between observable and unobservable is anthropocentric.

DeLanda joins the realists, but points out that there are, once again, many philosophical flavours within this category, depending on how those realists answer the question of how things in independent reality arise. Most realists from the past necessitate essences to underpin their ontology. The realist ontology of the standard model, for example, presupposes essences of elementary particles. Just like that, any scientific theory could be regarded as being essentialist. To avoid falling into a renewed essentialism, DeLanda advocates for a philosophy of *becoming*, inspired by Deleuze, whose *morphogenesis* is opposed to the so-called *hylomorphic model*. DeLanda calls this non-essentialist, non-rationalist philosophy "neo-realism."

Being can be described as a combination of matter and form. Now, DeLanda is not necessarily opposed to this division, but he is interested in the causal relation between the two. In the hylomorphic model form is imposed on matter,[128] just like molten plastic is poured into a mould in order to create a toy. Here, plastic is an instance of matter and the mould is what represents form. Since the mould is not a part of the final *being*, the toy, it is clear that form is imposed *from the outside*. According to DeLanda, this kind of becoming cannot be how the world works, because these external forms are essences. In other words, the hylomorphic model begs the question: "what or who determines the form of the totality of the world?",

[127] Manuel DeLanda, "Deleuze and the Open-Ended Becoming of the World" (1998), page 3;
"Emergence, Causality and Realism" (2012), page 6;
"Ecology and Realist Ontology" (2009), page 24-25

[128] Manuel DeLanda, "Ecology and Realist Ontology" (2009), page 31

which is an inherently *absolutist* question, that is, it asks for an absolute such as god or scientific law.

To avoid this essentialism—because we can never be sure of the validity of the essences we choose, by their very nature—, DeLanda contends that entities arise from within. Instead of the idea that dead matter follows the blueprint of form, form emerges from living matter.[129] That is, DeLanda reverses the causal direction. To describe this idea, he borrows a term from Deleuze: *immanence*.

Many scientists today agree with DeLanda that there is no ultimate authority above us directing matter into their essential forms. Moreover, most scientists are materialists and believe that matter creates form. However, they tend to fall into the trap of determinism. Namely, they think that we could, in principle, explain everything in nature from a couple of fundamental laws. Hence, they are implicitly essentialist. DeLanda's (and Deleuze's) immanence, on the contrary, is creative. It accounts for nature's capacity to generate truly novel phenomena and properties.

The nice thing about DeLanda's work, is that he compliments Deleuze's immanence with concrete arguments from the scientific realm itself. He explains why physics has been obsessed with linear theories to represent nature. Historically this makes sense, because linear differential equations are analytically solvable.[130] However, most systems we encounter around us are not linear. For a rubber band, for instance, deformation and force are not linearly proportional. In fact, the band even breaks if a large force is applied—an irreversible change. Nevertheless, physicists still use Hooke's law of elasticity, which is linear. The problem with these all too simple equations is that they do not account for unexpected or non-equilibrium behaviour.

Nonlinear equations, on the other hand, often require numerical methods, which are cumbersome to solve by hand. However, recent developments in nonlinear mathematics and far-from-equilibrium thermodynamics, and the advancement of the computer have brought about the possibility to approximate solutions to nonlinear problems much more precisely.[131] For this reason, computer models and simulations open the door for a theoretical inquiry into the creativity of nature. DeLanda gives another example to showcase this true creativity, this time from biology: "[Genes] cannot be seen as defining a blueprint of the final product (and hence its essence) but only as a program to guide self-organising embryological processes towards a given final state."[132] How do we account for this creativity without relapsing into essentialism again? For that, DeLanda devised his philosophy of intensive becoming.

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[129] Manuel DeLanda, "Ecology and Realist Ontology" (2009), page 27
[130] Manuel DeLanda, "Emergence, Causality and Realism" (2012), page 4
[131] Manuel DeLanda, "Material Complexity" (2004), page 17
[132] Manuel DeLanda, "Ecology and Realist Ontology" (2009), page 40

Intensive becoming

From his criticisms on the hylomorphic model and linear science, Delanda changes to a positive approach, to answer the question of being or, rather, becoming:

> The view of the material world that emerges from these considerations [i.e. the criticisms of the hylomorphic model, essentialism and linearity] is not one of matter as an inert receptacle for forms that come from the outside, a matter so limited in its causal powers that we must view the plurality of forms that it sustains as an unexplainable miracle. It is not either an obedient matter that follows general laws and that owes all its powers to those laws. It is rather an active matter endowed with its own tendencies and capacities, engaged in its own divergent, open-ended evolution, animated from within by immanent patterns of being and becoming. This other material world can certainly inspire awe in us but does not demand from us to be accepted with pious resignation. This is the kind of reality worthwhile being a realist about.[133]

To specify this philosophy of morphogenesis, he discusses two complementary conditions which create the possibility for creative becoming: tendencies and capacities. We need both in order to fully describe natural phenomena.[134] Here is an overview of the several terms DeLanda uses, which we will encounter below:

INTENSIVE PROCESSES

DeLanda's terms	Tendencies	Capacities
Deleuze's terms	Singularities	Affects
Source	Endogenous	Exogenous
Associated concepts	Immanence Emergence	Heterogeneity Consistency

Tendencies are the source of becoming from within a system. The particular properties of the vibrant matter[135] that constitute a system gives rise to novelty by *tending* towards certain *singularities*. In slightly more technical terms, one can define a probability distribution over the phase space of a physical system, which might contain one or more singularities (DeLanda dubs these *endogenous points*).[136] These singularities represent optima (i.e. minima and maxima) of variables. This variable could be energy, path length, and arguably even quantities which are more difficult to measure, like happiness and wealth.

[133] Manuel DeLanda, "Emergence, Causality and Realism" (2012), page 16
[134] Manuel DeLanda, "The New Materiality" (2015), page 20
[135] This term I borrow from Jane Bennett's *Vibrant Matter* (2010).
[136] Manuel DeLanda, "Deleuze and the Open-Ended Becoming of the World" (1998), page 7; "Emergence, Causality and Realism" (2012), page 11

DeLanda presents the example of a soap bubble.[137] The spherical form is not imposed from an outside authority, but is immanent. The behaviour of the soap and water molecules underlying the bubble define a probability space in which the singularities (points of least potential energy) correspond to the shape of a sphere: a bubble!

Capacities are the other kind of intensive processes. They do not pertain to underlying components of a system, but to interaction with external factors. A knife, for example, has the capacity to cut. But, this is only true in relation to, for instance, an apple, which has the capacity to be cut. Capacities are, thus, relational. However, the relation does not have to be actual. A knife has the capacity to cut even without an apple being present. All of this must sound rather obvious. The point is that the idea of a capacity replaces that of a property. The latter, namely refers to essences of an entity.[138] Moreover, the phenomenon of cutting is intensive, novel. It transcends the knife, the apple, and even their sum. Cutting is emergent from their combination. In Deleuzian terms, cutting is the locus of consistency between apple and knife. And in Baradian terms, cutting is an intra-action in which knife and apple are co-constituted.

So, tendencies and capacities (or singularities and affects, in Deleuze) constitute the abstract structure of intensive processes.[139] But they are two sides of the same coin. That is best explained with an example. Blackbirds like to eat berries and, luckily, they have the *capacity* to do so. From the perspective of a tree it is advantageous to carry berries, so that blackbirds can spread their seeds over large areas. To frame it in DeLanda's model, the tree has the capacity to transfer its seeds to birds. The tree and the bird become consistent. The symbiosis between the two is, again, different from the sum of its parts. Now, we can look at the same material on another scale, the scale of the forest. This ecosystem has certain tendencies, depending on its internal processes, like the symbiosis just discussed. These tendencies immanently give the forest its form. That is, without its hidden microprocesses the forest would not be what it is. Now, we can acknowledge that all intensive processes can be explained as tendencies *and* as capacities, depending on the scale at which we consider them.

An aspect that stands out in DeLanda's explanation of morphogenesis, is his emphasis on space. He discusses both types of intensive processes, tendency and capacity, in spatial terms. First, tendencies are consequences of the topology of possibility space. This space is completely virtual, with the exception of one point, the point of actuality which is the state of

[137] Manuel DeLanda, "Deleuze and the Open-Ended Becoming of the World" (1998), page 6-7
[138] Manuel DeLanda, "Emergence, Causality and Realism" (2012), page 7
[139] Manuel DeLanda, "Ecology and Realist Ontology" (2009), page 31

the system.[140] Interestingly, the singularities in such a space will never be actualised.[141] This becomes clear when we consider an analogy from general relativity. Celestial bodies in curved space will never reach a minimum of potential energy. Because, when the celestial body tends towards that singularity, its kinetic energy will become so great that it swings away. In such a manner, the body keeps circling around the singularity, constituting an orbit. In other words, while the actuality of the celestial body's orbit is dependent on this singularity, that singularity itself will never be actualised.

A fair question to pose is: what or who imposes these singularities in possibility space? We need to be careful not to invite an absolute law to define the shape of these spaces. Fortunately, as I mentioned before, these singularities are immanent, that is, they are determined by the optima of variables describing the system itself.

The other driver of intensive processes, capacity, relates to space as well. However this is not a possibility space, but the so-called space of consistency (this term comes from Deleuze, who writes *plane* of consistency). The space of consistencyis the canvas for things to intra-act with each other and, as such, co-constitute each other. In other words it is the space in which very different things come together and become consistent with each other. Once again most of this space is virtual. For example, the knife has the capacity to cut an apple even without the apple being present. Therefore the capacity to cut is virtual and only actualises if an apple comes close.

By combining possibility space and the space of consistency, orthogonally into one space, we end up with a space which can account for all immanent becoming. The topology of this space depends on the entities, or rather becomings, one encounters in that space. In turn, the entities depend on the topology of the space of becoming. The same self-referentiality applies to general relativity: energy densities curve space, curved space determines the kinetics of energy densities.

Genesis of subjectivity

In his philosophical framework, DeLanda does not touch on (the problem of) subjectivity. Then why did I discuss his work? We wanted to know how a materialist theory could account for subjects. And I think that DeLanda's materialism without essences is suitable for that. I think it is able to keep the materialist embodiment of the subject intact, while not compromising on the first person experience of that subject. DeLanda's model of becoming applies to subjects as much as it does to a tree or a tornado.

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[140] This statement is not true for a quantum mechanical description of reality as the quantum state is not represented by a point, but a distribution. As a consequence even the actual is not to be grasped as a singular point which can be unambiguously referred to. Rather, things must always be observed from a distance. In their paper "On Touching" (2012), Karen Barad explains that even the closest intra-action is never a classical touch of thing-on-thing at the same point.

[141] Manuel DeLanda, "Emergence, Causality and Realism" (2012), page 13

First, we turn to this duality of the subject between its material embodiment and its first person perspective. As we have seen in previous chapters, these are intimately connected and interdependent. But subjects are not unique in this duality, every entity or phenomenon has it, at least in DeLanda's materialism: every entity has extensity and intensity. In the subject they correspond to embodiment and first person perspective, respectively. This makes our materialist theory of subjectivity posthumanist. For, either subjectivity is just the name for intensity of a human being, or we broaden the definition of subjectivity and also apply it to other entities. In other words, subjectivity thus becomes a fluid term.

To ground this abstract parlance somewhat, let me give a couple of dualities which should be viewed in the same way: a song and its sound frequencies; today's temperature and the molecules in the air; looking through a microscope and the microscope itself.

The subject is a result of the *tendency* of physical material to arrange itself into a perceiving being. Deleuze would say that the physical material tends to a *singularity*, a point which can never be reached but is the defining piece of the subject. We constantly fall towards but fail to hit the singularity. We approach the singularity of the subject by inquiring into its material embodiment; it brings us near, but not into the first person experience. Moreover, intensive subjectivity is experienced as something indivisible—a singularity.

Apart from that, we constantly use our subjectivity to perceive the world. In this way we reify ourselves and what we are perceiving. In DeLanda's terms, perception is a *capacity* of the subject. In Deleuze's Spinozist terms, it is the ability to *affect* and be *affected*.[142] Capacities are about virtual and actual intra-action. In the case of subjectivity it is the intra-action between subject and object, the phenomenon.

Again, the above is very abstract, diffractively reading terms from different thinkers through one another. Now, let me phrase it a bit more intuitively. Our common sense tells us that there is more than just one (our own) subject in the world. That is, we see people around us of which we intuitively assume subjectivity. These subjects all reify each other by their capacity to perceive each other. They constantly intra-act. As such, this is not so different from the intra-actions we encounter between non-sentient things. If an entity can respond to certain stimuli, why do we not call it a subject? After all, we do the same thing to our fellow humans. DeLanda adopts Deleuze's posthumanism to explain truly creative becoming:

> Deleuze achieves openness by making the world into a creative, complexifying and problematizing cauldron of becoming. [He] plunges ahead into a post-humanist future, in which the world has been enriched by a multiplicity of non-human agencies. […] [T]he key non-human agency in Deleuzian philosophy has nothing to do with the negative, with oppositions or contradictions, but with pure, productive, positive difference. It is ultimately this positive difference, and its affirmation in thought, that insures the openness of the world.[143]

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[142] Gilles Deleuze, *Spinoza: Practical Philosophy* (1988)

[143] Manuel DeLanda, "Deleuze and the Open-Ended Becoming of the World" (1998), page 16

Treating subjects as matter (or matter as always subjective) forces us to reassess the term realism. Realism used to mean subject-independent existence. But if all of reality has a pinch of subjectivity to it, if all interaction is observation, then is there a reality? Should we be anti-realists? Barad would answer resolutely: "no!" Reality is in between entities, objects and subjects alike. Reality without subjectivity is simply untenable. What I attempted with the above is to blend Barad's agential realism with DeLanda's neo-realism. Captured in one sentence: *intra-action is an immanent process*.

Conclusion

We set ourselves the task to account for subjectivity in a materialist framework. In order to do so we turned to quantum mechanics as an example of a materialist theory in which the subject plays a substantive role, discussing the interpretations of Karen Barad and Hugh Everett. With their ideas in mind, we looked for leads in 20th and 21th century materialist philosophies. We touched on different aspects of subjectivity such as intra-action, virtuality, intensive becoming. In this manner we have been circling around the problem, just like a comet orbiting a singularity. This might be an argument for why I did not succeed in providing a rigorous materialist theory of subjectivity. And indeed I have not provided that. But exactly this circling movement is typical of subjectivity: first you get closer to a framework and then everything dissolves in front of your eyes. It is the movement between subject and object, intensity and extensity, meaning and matter. These dualisms seem to imply a dualist metaphysics, but they are intimately entangled. Our capacity to see both sides of these complementary pairs makes them one. Subjects constantly move around their singularities, always failing to coincide with their identity, their *self*.

From our investigations into quantum mechanics we found that matter is not as solid as conventional materialists once thought. Matter coheres in a web of intra-actions. This web is never fully visible, though. Namely, it is mostly virtual and just a little bit actual, just like Everett's universal wave function is mostly virtual. The actual is always incomplete, and that incompleteness is the exact condition of the subject. The fleetingness of the virtual is usually not associated with matter, but Manuel DeLanda shows how we should conceive the virtual as material.

So, we had to redefine materiality so that it can accomodate subjectivity in an acceptable way. As I mentioned, I did not offer a strict system for material subjectivity. In fact, we should be wary to pretend that we did find such a system, resulting in a dogmatic metaphysics. Still, we have to keep experimenting with ideas like the space of subjectivity and material virtuality. Maybe we will never find the correct conceptual system. What is more important is the lessons we learn during this quest. We have to keep inquiring into the nature of subjectivity. Now, what is the best way to go about that? I think we should set up research programs into particular material subjectivities, under the umbrella of subject studies. Admittedly, there already exist fields of study that (unintentionally) research subjectivity in its materiality. For instance, biology and medicine study the physiology of the eye, the organ endowing us with vision. Neurologists study the nervous system which on the one hand allows us to perceive the things nearest to us by touch, and on the other hand gives us the agency to move our body and our surroundings. Not to mention that neurologists study the brain which is capable of creating imaginary worlds and abstract analysis. Then there are historians who try to convey how people in another context and time experienced reality. They look at material artefacts such as scientific instruments to get a sense of our ancestors' worldview. In short, there are

many inquiries into subjectivity, but they are implicit and dispersed. By implicit I mean that the goal of the research into eyes and nerves, for example, is not to understand material subjectivity, but to create new medical technologies. The dispersion of these studies shows that, if we were to establish an institute for subject sciences, it should be necessarily interdisciplinary, because each discipline perceives different things in the world, with different senses.

The subject, as a material apparatus of observation and locus of co-constitution, shows us that we are not detached from reality or nature. Intra-action is a symmetric process which involves synchronisation. Our experience of time, for example, is a synchronisation of our bodily processes with the processes of our environment. We as a society are at a quandary: we have to evaluate our active role in our synchronisation with nature. Do we synchronise with it or let it synchronise with us?

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