Ontological Opportunism
Reanimating the Inanimate in Physics and Science Communication at CERN

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Abstract

Understanding inanimate 'nature-as-such' is traditionally considered the object of physics in Europe. The discipline acts as exemplary discursive practice of scientific knowledge production. However, as my ethnographic investigation of doing and communicating high-energy physics demonstrates, animist conceptions seep into the ontological understanding of physics' 'objects', resonating with contemporary concepts of new materialism, new animism and feminist science and technology studies, signifying an atmospheric shift in the understanding of 'nature'. Drawing on my fieldwork at CERN, I argue that scientists take an opportunist stance to animate concepts of 'nature', depending on whom they're talking to. I am showing how the inanimate in physics is reanimated especially in scientific outreach activities and how the universalist scientific cosmology overlaps with indigenous cosmologies, as for example the Lakota ones.

Keywords

CERN, digital media, nature cultures, new animism, new materialism, outreach practice and public science

We Are All Made out of Stardust

'Mostly void – partially stars', reads the quip on John's t-shirt. In its ironic innocence, it seems to make a bold statement for physics, especially when worn on the chest of a physicist based at the European Organisation for Nuclear Research (CERN).[1] In this specific context, those four short words are more than a witty slogan. As a physicist's object of fashion, they turn into a totemist embodiment of a cosmopolitical worldview (Stengers 2010), a bold statement of what humans are in times of the Anthropocene. Carrying it, the wearer disseminates a statement about physics contemporary understanding of matter. The meaning refers to the composition of atoms, being mostly void composites of elements created in a stellar explosion. When studied, their properties seem to be either particle-like or wave-like, depending

on the conditions of observation. Moreover, these words open the door to a complex and contradictory technoscientific cosmology. Worn by a living being, the t-shirt is, on the one hand, challenging and defending at the same time the contradictory concept of modern natural science, founded on a clear separation of the inanimate from the animate. On the other hand, the animist conceptions underline ontological understanding of science at its most fundamental level.

The claim that science is infused with magical thought, animist concepts and has 'never been modern' (Latour 1993) has been a long-standing given in anthropology as well as science and technology studies (Jones 2017; Latour 1993, 2017; Nader 1996; Stengers 2012). However, this claim has not been empirically analysed. Specifically, how and why concepts of animatedness seem so important to many physicists at the psychological level, pervading everyday communication among physicists and taking a vital role in the culture of communicating science, has not received much attention. In this article, I aim to investigate this phenomenon, bringing to the fore the complexity of internal debates about and attitudes towards studying nature in a scientific institution. Consequently, this text is not a piece of systematic ethnography but rather an account that tries to understand – based on ethnographic and historiographic episodes I gathered over seven years of intense field work in CERN's research collaborations and other physical institutions between 2013 and 2020 – how scientists, indigenous cosmologists, and philosophers engage with the world in an animist fashion, and illustrating an atmospheric shift of how humans understand nature in the Anthropocene.

Based on ethnographic fieldwork, I am arguing that animist conceptions are reinforced by digital media technologies (Ong 1992), causing a 'virtualisation of cosmology'. While 'demons' are inhabiting physics for a long time (Canales 2020), I show in the ethnographic vignette 'the tale of two Johns' that animist understandings of nature are reinforced through digital media representations of particle interactions. These images are important actors in a syncretistic narrative that allows scientists to talk about physics or communicate with those outside of the physics community. I argue that physical scientists take an ontological and opportunist stance when communicating and claiming to have the final say about the cosmos. They justify this based on their perceived superiority of reasoning, coding, measurement, and mathematics of 'pristine' nature (Law and Lien 2018: 135). By weaving ironic (Rorty 1989: 73) (self-)reflections into the narrative, I furthermore elaborate how the disciplinary knowledge of anthropology

interferes with physical knowledge. Anthropologists are using science as contrasting dominant and capital 'Other' to theorise about seemingly partial perspectives of non-Western, indigenous cosmologies, while the actual scene of empirical observations is not that Janus-faced at all. I will delineate how these interferences resonate with the anthropological and STS approaches of new materialism (Barad 2007; Bennet 2009; Kirby 2011) and new animism (Bird-David 1999; Espírito Santo et al. 2013; Harvey 2005; Voss 2014) that, in turn, allow understanding of how things and their meaning are made at CERN and hence situate the shift within Western cosmology in times of the Anthropocene from a modernist rationale towards an inclusive, manifold and relational understanding of the world we are living in.

The Master Narrative Told by a Master of Narration

Although over fifty, John still airs the aura of a physicist in his twenties. It is late summer in 2017. The grand scenery of Mont Blanc, stretching behind his back and prolonging the cafeteria patio, accentuates his self-confident manner, especially here on his territory. He is one of the gatekeepers of the ATLAS project, responsible for outreach activities, an evangelist for rationality among the greater population. 'I come from a third world country, you know, where people still question evolutionary theory', he declares ironically. Most of the time, especially when it comes to high energies, the US-American who found his home between France and Switzerland looks at me with a dose of scepticism that tends to accompany a natural scientist in the 'Mecca' of European high-end research in physics, whose daily task is to repeatedly explain the most complicated phenomena in the simplest of ways.

Since I encountered him for the first time in 2014, I have never managed to rid myself of the divided feeling that he has for me: on the one hand, he tries to control my presence in his function as a member of the science communication team that manages the public image of one of the detectors at CERN; on the other hand, he sees me as one of the humanities acolytes who will potentially pass on his outreach theories. He also cares so much about science as a matter of fact, that everything that happens here is turning into a matter of concern to him (Latour 2005; Puig de la Bellacasa 2017). If he could, he would rather do physics. Trained in rhetoric and stage experience, from guided CERN tours to TED Talks, John now sets out to explain

the Big Bang Theory to me, which seems to be at the same time a traumatic and a dream-like narrative of physicists. This is the place where collective symbols are woven into semantics in order for them to be translated for a broader public, attesting to the material-semiotic entanglements (Barad 2007) of knowledge created in physics.

This is the narrative I have been told since starting my research in 2013 and have been retold by John today: according to physics, cosmos emerged out of a singularity, a mathematical point of no dimension, no space and no time; a point of decision, an elusive entity of energy, which exploded and expanded with the speed of light about thirteen billion light-years ago. The Large Hadron Collider (LHC) was built precisely to help us understand the matter emerging from this energetic intensity. 'From the point we call the singularity, everything emerges – space, time, and light.

According to the theory of matter and antimatter, there must have been an asymmetry in the beginning. But where did mass form in the first place?' He pauses for a while, building up the narrative tension: 'Now, the Higgs field explains this as a theory. It explains these phenomena. It tells us how matter came to be'. While he continues to clarify, a thought flashes through my mind: isn't the Higgs field the cause of mass and the physical placeholder for animatedness, something that permeates all and accounts for matter in the first place (Barad 2007; Bennet 2009; Ingold 2006; Kirby 2011)? I ponder whether I should share these thoughts with my conversation partner but decide to keep them to myself. I do not feel intimate enough to expose the concepts of my discipline. Besides, John is not tuned to dialogue at the moment; he is on a mission to *send* information, not receive it. Science communication reminds me sometimes of a secular form of missionary engagement with those outside of the realms of physics.

Unfortunately, I cannot record this conversation. It is too loud in the cafeteria, during the well-deserved lunch break filled with the murmur of chitchat and the humming that arrives on a summer breeze. It is quite windy today. I turn to a more classic ethnographical toolset and start to take notes in my field diary instead. After what seems an endless pause, during which John chews on a piece of meat while his eyes express doubt in my capacity to understand what he has just explained, he continues enthusiastically, elaborating on how the LHC discovery of the Higgs particle proves the theory experimental physics betted on when building the ATLAS detector.

Some physicists draw a sharp line between those who understand physics because they studied physics and lay people who understand

best through analogies and metaphors. As a professional educator, he makes another pause in search of signs of understanding, even enchantment on my face, or any potential sign of astonishment – perhaps a 'gradient' of understanding. But my poker face says nothing – blank and unmoved it mirrors his, like that of a psychoanalyst. It seems to me as if he expects admiration for the story of physics he is telling me. He, an expert, the chair of the ATLAS particle physics outreach group, the grail keeper of positivism. He, who knows measurement and mathematics, standing firmly on the fundament of falsification and reproduction. Gatekeeper of the one truth, not many; and a truth based on measurement and metrics, numbers, mathematics, obtained by theoretical and experimental engagement with the world. 'Popper is built into us', John says, insisting on the scientific concept of testing the truth by discarding invalid theories and proving things *ex negativo* through exclusion.'I like your t-shirt', I say before we part. John replies, 'Yes, isn't it fascinating? We are all made out of particles older than our solar system'. Science communication is an impersonated form of totemism, I think, in order to gain some distance from my interlocutor and the situation.

It is somewhat ironic and promising at the same time to see a living physicist proudly admitting to being made out of inanimate stardust, all the while representing a discipline thought of as the epitome of hard science, looking exclusively into the non-living matter. Usually, physics is considered as a discipline defining the realm of inanimate matter, generating the tools to master "things" and exercising the control about the division of modernist knowledge, thus being in the vanguard of extractivist and colonial ideologies. During my participant observations I observed instead, how physicists as gatekeepers of scientific reason engage in a paradoxical practice. Even if the particles themselves are taught and thought of as inanimate, they are practically turned into and semiotically treated as animated matter by those who investigate their behaviour within strictly confined experimental settings, depending on computer simulations. As I stroll back to my guest desk at one of the main office buildings, passing by the statue of Shiva performing a cosmic dance of creation (Dippel 2017), I think of how enchanted and religious science is. Claude Lévi-Strauss's (1962) words resound in my head; religion must be considered as the humanisation of natural laws, and magic the naturalisation of human action (Styers 2004: 7). I wonder whether physics' animatedness is somehow related with a certain Freudian 'fort/da' – presence of physics' objects – reinforced by digital media (Ong 1992), that creates the virtual realm of their measurable

performances. As I observed in many situations, stretching from the participant observations in experimental control rooms to dialogues within chat groups and to attended public presentations, the everyday language of physicists turns matter, and more specifically objects, into living beings, regardless of whether they are codes, particles, or experimental setups. Is this a sign of humanness or does this signify an atmospheric shift within scientific cosmology in the 21st century?

Although physics is by definition of its subject devoted to inanimate nature, it seems humans, including physicists, cannot resist the temptation to bring inanimate nature alive. In the past few years of this research, I have regularly encountered rhetorics of animatedness in the everyday use of media technologies and physical concepts, starting with the common phrase, that particles 'behave' in a certain manner when observed in a detector. Despite that, I put aside a heap of data collected on the topic, marking it as 'not significant enough'. Recently, I decided to reconsider my initial approach with the philosopher Hans-Georg Gadamer, who states that the differentiation between the symbolic and the actual use of a language must be considered obsolete, as language is a human mode of experiencing the world (Gadamer 1990: 108). We live by metaphors (Lakoff and Johnson 1980). Rhetorics, narratives, and language shape our world and generate different frames and shades of truth. In times when truth is simulated and mediated through computers, the insight into how we symbolise the world becomes even more crucial.

Nature on the quantum level should make it reasonable enough to rethink the idea of physics as the practice of studying inanimate 'objects-as-such', turning it into a science concerned with objects that 'come-into-being' (Ingold 2006: 10). Leaving aside the esoteric literature accompanying quantum mechanics since its emergence at the end of the nineteenth century – even the most rational physicists such as Erwin Schrödinger and Robert Oppenheimer found comfort in reading the Bhagavad Gita – questions still resounds: Why do physicists as gatekeepers of rational science based on falsification often seem to find psychological comfort in esotericism, animism, and transcendental justification of their work? And why do they especially do so in light of not being condemned to 'shut up and calculate', as the physicist David Mermin once summarised postwar physics practice with the aim to end speculative thoughts emerging out of quantum mechanics? Can physics be solely understood as a 'culture of no culture' (Traweek 1988: 179), the high temple of objectivity that does not know any other objects than those 'as such'?

Based on the above assumptions, the answer to this last question of course is no – especially when physics is engaging with 'others' in a 'more-than-human' (De la Cadena 2015, Kohn 2013, Tsing et al. 2021) world, 'objects-as-such' are turning into 'relational objects' with agency, decentralizing human's position on the whole. As animate beings, humans mirror not only their environment but also themselves in everything surrounding them. Semantics and metaphors create meaning, especially when it comes to communicating science. Still, modern dualisms are often anchored in the contemporary culture of physics, and some of the stereotypes about physicists' reductional positivism are used by anthropologists and scholars of science and technology to promote their visions of the world as complexity in the making. This comes as no surprise, given the structural similarities between physics and anthropology: both are disciplines that can easily be described as interfering knowledge systems, in which objects, concepts, and ideas are brought to harmonious resonance. In what follows, I seek to probe the assumptions that reanimation of the inanimate must be read as a contemporary phenomenon in physics practice and communication, rooting in a globalised science and localised truths mediated by digitality.

Science as a Counterpart to Animistic Concepts of Nature

The anthropological debate on how to situate scientific cosmological understandings is complicated even more when reflected upon by means of empirical data gathered within a scientific subculture, for example within physics. Many researchers have emphasised the relational constellation between science and animism, but few have empirically analysed science itself (for an exception see Borck 2014). As French sociologist Bruno Latour pointed out, above all science has never been modern (1993). It has tried to veil its origin, emerging within a three-cornered constellation alongside magic and religion (Nader 1996; see also Jones 2017; Pels 2003). Instead of understanding science as evolutionary success evolving out of magic, witchcraft, and religion (Frazer 1900; Malinowski 1954; Mauss 1972; Tylor 1873), it must be seen as part of a triangle that frames humankind's desire to master nature while also acknowledging its indispensable mastery over all of us. Although Latour takes on board inherent animisms in science, he never probes deeper into the matter and does not investigate his field in an empirical case study. Instead, he incorporates

within his neoliberal theory of actor-networks cryptoanimisms that enable hierarchies to function, while levelling the value of actors disregarding responsibilities and embedding discursive powers in things and beings alike (Lossin 2019).

In contrast to Latour, British anthropologist Tim Ingold argues in his famous article 'Re-thinking the Animate, Re-animating Thought',

> We know it from ethnography, that people do not universally discriminate between the categories of living and non-living things. This is because, for many people, life is not an attribute of things at all. That is to say, it does not emanate from a world that already exists, populated by objects-as-such, but is rather immanent in the very process of that world's continual generation or coming-into-being. (Ingold 2006:10)

An intriguing and convincing argument, exemplified by many ethnographies of non-Western societies and lately meticulously elaborated for example in such different approaches at the one of Brazilian anthropologist Eduardo Viveiros de Castro's *Cannibal Metaphysics* (2014) or the one of Philippe Descola in *Beyond Nature and Culture* (2013). It rests on the construction of a stable exception to the rule of animacy in humankind's manifold visions of cosmology: science must be seen as the Other, the stronghold of inanimateness, the dark lord of natural control without a reason but reason as such. Similarly to other critical thinkers decentring Western cosmology of science and reason, Ingold holds on to the trick, first installed by science itself. He is making his case about 'gerundive' and intra-active cosmologies (Barad 2007; Haraway 2013) by referring implicitly to science as an unmarked Other, solidifying science's naivety and blindness towards its animate relativities within its cosmology. Even Isabelle Stengers' concept of animism, although aware of its colonial pasts, still resounds to the rules of this heuristic gameplay (Stengers 2018) in order to establish a cosmopolitical vision of science that understands nature in the tradition of Giordano Bruno. In that way, science seems to be the only cosmology populated with objects-as-such that stay inanimate, although they continuously come into being based on expansion and evolution of matter or through the act of human will in experiments such as those situated at the LHC.

I want to understand how the categories of the inanimate and animate come together in physics practice and science communication, and how physicists turn their mundane objects into animated tools (Lemonnier 2012). Investigating these questions ethnographically helps to understand the atmospheric shift of how humans understand naturecultures today. It sheds light on the rise of new materialism and

new animism in the humanities and social sciences as well: While new materialism emphasises the agential qualities of matter itself (Barad 2007), new animism sheds light on the common practice of animating the inanimate (Bird-David 1999; Espírito Santo et al. 2013; Harvey 2005; Voss 2014). Both include nonhuman actors and forces of all kinds in the equation trying to explain how humans make sense of their worlds.

I am stating that the animate in Western science and cosmology is intricately intertwined with digital media technologies and production of material-semiotic naturecultures. Although the ubiquity of digital media in experimental physics is highly significant to the above argument, it needs to be put into the background in this article. In a nutshell: while photography turned life into objects of death (Barthes 1980), digitality is electrifying things, turning objects into animated creatures, neither dead nor alive, as if each one of us were holding a Frankenstein-device (Ong 1992; Shelley 2017 [1818]).

Fundamental Ambiguities

The ontology of modern physics is based on fundamental ambiguities. Physicists try to understand particles that otherwise behave as waves. Matter, at the basis of its smallest constituents, might be seen as the 'bricks of the cosmos', as one informant explains, while for others these constituents are considered as 'wave packages'. Since the formulation of quantum mechanics to explain the behaviour of these entities, physical sciences have to deal with an ambiguous concept of particles (Falkenburg 2007). This ambiguity of 'nature' is mastered through more than just empirical observations and repetitive measurements. After all, 'nature does not care whether it is named wave or particle. These are human words', as Mia, a PhD student, says when I ask her about the ideological connotations of seeing the elementary entities either as a wave or as a particle. As we are living in this world by and through metaphors, the question of master narratives and how we are building analogies (Jones 2017) based on and with collective symbols is of utmost importance. For example, Georg, a PhD student explains,

> In IT [information technology] terms, nature is the framework that allows us to study particles and interactions. Interactions can be described as relations that can change over time. Particles act upon each other – without an electron, you would not have an electromagnetic

> field. In this case, the actor is connected with the framework. But here metaphors reach an end. An electron has no hand and no intention.

We lead this discussion in a chat group, an organisation that actually serves lunch. Georg's colleague Rob intervenes: 'I find "acting upon" too "active". Particles carry forces, and particles are exposed to forces and force fields. In this case, an interaction happens'. Mia, founder of the lunch chat group, sums up: 'You could also say that CERN researchers ask the following questions: Where are we coming from? What are we made of? And where are we going?' How do you communicate scientific uncertainties in your community – and how do you translate these uncertainties to 'laypeople' all over the world? Scientists, it turns out, approach the world with ontological opportunism. Words matter, but what wording matters the subject of physics is related to those who are talking with each other. Depending on whom they communicate with, they draw their conclusions from the respective mind set of their interlocutors on how to relate to their interaction partners, and how to engage with nature.

Natural language, used to explain the entanglement of particles, introduces animating qualities. In their everyday talk, physicists and laypeople alike attribute agency, intentional behaviour, or a sensual apparatus to potentially inanimate entities, be it for outreach purposes or in everyday exchanges about the detector, sometimes jokingly described as a 'living being'. Physicists engage with their detectors, calling them 'baby', placing little 'helpers' and 'luck bringers' to ensure positive outcomes of their experiments. They talk about their tools, and even about the objects they are dealing with, as if they were animated, considering them as vital actors. This opens an ontological Pandora's box. Does our animated perspectivism fail to understand what is going on, or does 'Western science' fail to acknowledge in its very conception the animism of all things, while humans unconsciously tend to treat things as animated objects? Yet again we end up entangled in scholastic confusions, in which 'nature' is on the side of Averroes, Giordano Bruno, and Baruch Spinoza – as well as Karen Barad, Donna Haraway and Isabelle Stengers. Humans are concerning this topic on a philosophical betting ground, and any position always reminds us of the existential gamble humans engage in when opting for cosmological visions of a world they are part of. The whole setup of science as such with an undisputable, intangible observer, participating and engaging or not, is highly suspect, but it grants knowledge beyond the scholastic triangle of axioms, correlations and subjective authorities. Physics and anthropology (as well

as most magical cosmologies) share a common understanding that observation affects the observed. Both disciplines have to deal with a 'world' (or a nature-culture) that 'kicks back' (Barad 2007: 112), in the first case by behaving (pseudo)randomly, in the latter by objecting any definitions of what objectivity is. Why, I wonder, did Bronisław Malinowski, a trained physicist, not take the findings of quantum mechanics into account in his theoretical reflections?

The Tale of Two Johns

In this section, I will delineate how physicists engage with their field and relate to each other by leading the reader through the CERN site based on ethnographic entries in my field diary. I am weaving an epistemological story, a fictitious stream of ethnographic experiences (Dippel 2015), for example I am recalling another meeting with the science communication expert and physicist, John. The section shows the complexity of everyday practice in physics and ironic engagement with this field I gradually learned to understand – and which in turn taught me so much (about also anthropological self-confidence). Some physicists deal with their topic from an experimental point of view, while others engage with physics theoretically or by coding. Depending on the respective frame of what doing physics entails when talking about physics, physicists shift their mode of engagement, adapting to the situation and their interlocutors. No matter what professional talents CERN physicists contribute to understanding physics at the research site, the engagement with physics through humour and play can be observed as an everyday practice, no matter whom they are interacting with (Dippel 2017, 2019).

I decided to see John again during my latest research trip in early March 2018. It is always good to find out what is going on. I walk down the grey linoleum corridors, passing Prussian blue painted doors. Pipes are transporting gas in the pipeline. I am not sure whether they are currently filled with anything. At least, in theory, it's the fuel running the experiments flowing through them, and in practice I'm given the feeling of being caught in a gigantic experimental system, or the digestive tract of a cyborg creature out of E. M. Forster's novel *The Machine Stops* (2013 [1909]), as if the most ancient part of CERN would be the ur-mother of European laboratories. Today the offices are mostly stuffed with desks and humans behind computers. Back in the day, it is said that it even gave a home to more experimental

systems. Physicists are nostalgic about the fact that Albert Einstein walked down these halls. Maybe that is why no one tried to renovate the building. It feels as if the magic touch of geniuses and Nobel laureates of all tempers and temperaments enlightened all of those who are working here today; as if the ghost of Enrico Fermi strolled along the pathways of knowledge, finding no rest in these technoscientific environments, a steady reminder of the atomic factory he built around the transuranic element Pu-239, the matter of bombs.

I pass the big common room, a place where the members sometimes meet as if it were a 'church', as several interlocutors told me as we walked along the corridor. It was here that Fabiola Gianotti, the current director-general, back then spokesperson of the ATLAS detector group, announced the detection of the Higgs boson in front of her most important colleagues, including Peter Higgs and François Englert, after the end of run 1 of the LHC in 2012. I recall again what I learned in the narratives of last years, words collected in the field: the inner fabric of the cosmos remains a conundrum. Although four forces have been located, and a fifth is currently presumed through recent findings at Fermilab's Muon g-2 experiment, they cannot be described according to one coherent model. The current standard model is the closest approximation to nature that we have and stands on the stage of the LHC to be tested. As in other cosmologies, humans do not invent what is to be observed. Nature, according to physics, can be described as a relationship of space, time, and matter, as well as forces that connect or disrupt what materially exists. Based on mathematically formulated models, a condensed symbolic notation helps to explain nature, and itself produces assumptions about the very nature tested in experiments. At the heart of this conception of nature lives symmetry, although it gets broken often enough. When physicists started to work on the standard model, the physical calculations needed a field that gives matter mass.

The Higgs field produces exactly this kind of mass, transforming energy into mass and therefore creating matter in the first place, and us in the end. I think of the t-shirt John was wearing last summer during our meeting ('Mostly void – partially stars'). The particle itself has never been seen, but patterns of other particles decaying have been observed, which must be considered the signature of the Higgs particle (Cohen-Tanoudji and Spiro 2013). The Higgs particle can be imagined as a sign of the presence of the Higgs field. Its presence, appearing at very high energies that can only be produced in the proton–proton collisions of the LHC, is consolidating the hypothesis of

the existence of the field. It takes millions of repetitions to get the coveted '5 sigma', the gold standard of statistical proof in high-energy physics. After the 'God particle', as Leon Lederman (1993) called the boson, had been found, the existence of the multibillion-euro-project LHC could finally be justified.

The Higgs particle has taken a special position in the standard model of elementary particles. When we met in 2016, I asked John, 'Are these particles synthetic particles?' He gave me that specific look, then relaxed, harking back on his job to do outreach properly. 'I mean, aren't there natural counterparts in the cosmos to those you produce "artificial"?' He nods and elaborates: 'Astrophysics observes similar particles to our own. To us, there is no difference between these produced and the "natural" ones. Both behave similarly, whether here in the lab or up in the sky'. Particles of physics are the epitome of nature as 'one' for physicists, they are independent of us. Culture is pushing these pristine concepts, conjected through maths and proven through measurements, into the grey zone of cultural ambiguity.

Sign interpretations are ontologically dirty, writes Donna Haraway, the feminist philosopher of science, referring to the physiology of semiotics (1997: 127). So are proton–proton collision experiments with their ontological dependency on computer-simulated processes of purification; taming the random through probability calculations. Despite this, for physicists, there is little dirtiness or ambiguity about their particles once they acquired the coveted 5 sigma, which means that there is a 1 in 3,5 million chance that the measurements are a statistical fluctuation. They are proven through decades of experimental work. So has been the Higgs boson. As a scalar boson, the Higgs is not only part of the particle scale – a potent taxonomic device of material origins – but it also 'embodies' a trans-atomic and trans-cosmic aspect of matter. The Higgs boson, currently not an autochthonous inhabitant of our solar system, must therefore be considered neither artificial nor natural. It is naturally 'akin to PU239, to transgenic, transpacific, and transported creatures of all kinds' (Haraway 1997: 62). Pointing toward the Higgs field that permeates all things like an invisible ether, it is a signifier of the connectedness and interrelatedness of all matter and being in what we call cosmos.

Most office doors are adorned with funny comics or sayings, embodiments of the ludic culture of physics. One poster states, 'Without engineers, physics is just philosophy'. Another one shows a man shovelling snow, encapsulated in a crystal snowball, ranting in French, 'For God's sake, I would really like to know what kind of an

idiot is shaking this ball'. After another labyrinth-like narrow gangway, I leave the building and cross the backyard. I am quite proud to be able to finally find my way through all the corridor mazes. In a small building, the size of a container rather than a house, the outreach office gives home to John and his two colleagues. I am greeting John, having knocked at his door. He is delighted to see me. Again, I feel a sense of control as soon as we engage in a discussion about my current research stay. John, who once said to me, 'We are physicists. We can do anything', is preparing a STEM outreach conference talk, in which he is about to share his magical experience of doing physics education on sacred ground, working together with the Lakota-Sioux cosmologists at Standing Rock. This collaboration emerged following a virtual visit John made to a physics class at Taos Pueblo High School, and it has been a fruitful ongoing mission for John to spread the knowledge of high-energy physics among people from his home.

John explains quickly in an excited manner how he engaged in interdisciplinary collaboration, bridging art, science, and education to bring Native American culture and Western physics together. Still enchanted by the sacred indigenous lands of Standing Rock, he tells me about his visit over the summer, how he met a Lakota cosmologist, 'the other John', and how this affected his vision on physics and indigenous science itself. 'Let me share the slides with you'. He refers to Gregory Cajete, who wrote a book on native science, explaining the natural laws of interdependence in Lakota cosmology (2000). 'The other John and I have learned so much from each other during the workshop. First, we discussed the Lakota cosmology. On another day, I explained the basics of particle physics and Western cosmology. The students learned to build a tipi, and we shared our thoughts'. On his slides, I read that science is dependent on the 'culture/worldview/paradigm' of the definer. We see the world through particular 'human goggles'. Is this still the same Popperian John I met last summer, I wonder?

John continues: 'So, I explained the Feynman diagrams;[2] how we visualise particles through images instead of long formulas'. John tells me how he showed photographs from the quark-gluon plasma in the bubble chambers of the Gargamelle experiment to illustrate his point. He also explains how he raised the interest of the 'other John' – that's what they called each other. Lakota John got very excited as he looked at the Feynman diagrams of the Physics John. He studied them for some time and then recognised the 'spider-god' in the trickster particles appearing as exchange particles in the old bubble chamber

images. 'Then, he started to draw Lakota symbols, comparing our two diagrams'. For Lakota John, the elusive particles were manifestations of Iktomi, the spider-trickster god of Sioux cosmology, belonging to the category of the creator gods. According to the Lakota cosmology, John explains, Iktomi is represented as a spider-god weaving his worldwide web around the globe. The internet represents the return of Iktomi, the god of technology, to the earth. I can hardly believe my eyes and ears as I listen to John. I was puzzled, but I did not say a word. There he was, the falsification John who explained to me with nuisance, back in 2014 when we first met, the logic of physics, and lectured me on objectivity. John, who used to elaborate on how imprecise hermeneutic sciences are because they lack mathematics and are bound to words instead. Now, that very same John equates particles with tricksters. After all, their appearance is unforeseen and they can just be understood as signs of something else. I tend to think of particles as forces of *différance*. I ask myself ironically whether John indeed did physics while in the Lakota land or perhaps had a meeting with a Peyote cactus instead? [3] If only Donna Haraway could be here right now to witness this. In John's eyes, particles turn into tricksters, even if only for outreach communication. I agree, that's how you could describe them, as tricksters, I am telling him, 'I would have never dared, considering it as an imposition of my dearest concepts of thought onto a field, just because I can'. I ask him, 'Have you ever heard of the philosophy of Donna Haraway?' John shakes his head. I continue:

> The concept of the trickster has been one of the most important outcomes of science and technology studies in the last decades, alongside her idea of cyborgs and simians. It describes ambiguous entities, oscillating between two states – such as organism and machine, or – in this case – one could say wave and particle. Initially, I thought of the particles as tricksters, but I would have never considered that a physicist would acknowledge those similarities.

John's interest in feminist philosophy of science stays rather modest. He continues to talk about outreach possibilities and further objectivities. Then, he declares that there is a difference, of course, between native science and Western science, guiding me through his PowerPoint presentation.

John elaborates that indigenous science rests on subjective observation but centres around the natural and human relevance, considering cultural implications and thus having a subjective element. Western science, on the other hand, is based on measurement, theoretical

prediction, methodology, and objectivity. Sure, he sees some common threads, such as the drive to understand and communicate nature to future generations, or the understanding that observation affects that which is observed, or even the appreciation of data. At the end, 'what else is the daily observation of nature, but passing on empirical knowledge from generation to generation? Still, there is a difference', says John. 'Western science is objective, and native science is, due to its embeddedness in a religious worldview, subjective'. I am a bit calmer now. I almost believed that John had been convinced to drop his Western conception of science as the holy grail of objectivity thanks to Lakota John, just like Carlos Castaneda did in his narrative of the Yaqui sorcerer Don Juan (Castaneda 1968). Back home on the CERN site, he fits his experience into the perspective of his job. As a gifted science communicator, he is practising ontological opportunism every day when it comes to spreading the word of high-energy physics.

Ambiguous Entities

Ambiguous particles, neither seen nor unseen, proven, and methodologically predicted through theoretical reasoning, emerge out of the daily business of the LHC. When two cosmological worldviews come together, the spider-god Iktomi jumps from one cosmological system into another, turning into a particle, animating the inanimate, back and forth. He is a shapeshifter just like the entities of the quantum world. Both can be seen as tricksters, proving the sharp analyses of Donna Haraway's work on ambiguous entities in the technoscientific world, from cyborgs over coyote tricksters to coevolved dogs and all kind of creatures from the Anthropocene to the Chthulucene (1991, 2016). It resonates strongly with Isabelle Stengers' latest works on animism and Eduardo Viveiros de Castro's and Déborah Danowski's call for arms in the Gaia war between 'terrans' and humans (Stengers 2018; Viveiros de Castro/Danowski 2018). How come these entanglements between feminist STS, physics communication, and Lakota cosmology become visible these days? Are all three symptoms of cosmological virtualisation?

New materialism follows these readings of material-semiotic objects, first explored by Donna Haraway, herself a white Western scientist born in the USA. It situates objects in a defined chronotopos, focuses on partial connections, and unblinds diffractions instead of fabricating shiny representation of what Western science calls nature. Of course, given the language of agency attributed to creatures of all

kinds questioning fundamentally that 'objects-as-such' even exist, the concepts of technoscientific ambiguity put forward by Donna Haraway embrace a conscious concept of animism critically aware of the entailed post-colonial and settler colonialist background noise, fitting it into monistic philosophies (Braidotti 2013). While the wall between object and subject is being torn down in a world of agential realism, the material animism of high-energy physics still lives in denial. Or, physicists exercise in ontological opportunism to have the final say on how to make sense of nature.

The ambiguity of entities is a lesson emerging not just out of the subatomic world investigated at CERN. Ambiguity is the core aspect of an animist worldview (Ingold 2006). Also in our Newtonian reality embedded in processualism and based on sociocultural conventions, seeing objects is an uncertain enterprise. We can never be sure of what we see. Without referring to the hidden cultural variables of seeing things as such, leaving aside our physiological apparatus, we are always prone to animate whatever we see. This problem has been most famously illustrated by Wittgenstein through the ambiguous image of the rabbit-duck, thinking about the difference between 'seeing as' and 'seeing that' (2009).

Physicists always critically and carefully study their data, making sure that nothing is missed out or read into it (Dorigo 2011). In the story of the two Johns, those reproducible practices of dealing with experiments are related to the transgenerational observation of Iktomi, an ambiguous god, neither good nor bad. Even if the measurement gives a promise of certainty as to what is seen, physicists cannot be entirely sure of what they are looking at, because 'in our gravitational world', the observed can appear either as a wave – if decelerated – or as a particle, in the moment of acceleration.

Nature needs to be conjured up – either from within the cave below the Jura Mountains or in the visions of Lakota and their natural observations of the Dakota prairie. Even if Western physics consciously refuses to be associated with pagan animism, the many cosmological overlaps place it closer to animism than ever before. Maybe the entanglements allow translations beyond the ruins of colonialism and extractivism. Physics John and Lakota John experienced many intersections between their usually very remote cosmological views based on very different teleologies and rationales. While Lakota John sees the manifestation of Iktomi, the spider-god, in the world of physics, Physics John perceives natural science as the next evolutionary step of natural observation, thus reinstalling his superiority upon his return

at CERN.The particle imagery on the detector visualisations and the Feynman diagrams, symbolizing particle decays, seem to closely resemble Lakota diagrams and their cosmological concepts. These pictographic symbols both fall into the same media category. The images allow us to describe dynamic processes or abstract representations of objects that are not existing 'as such' but concerning other objects fitted into a hierarchy. Pictographic diagrams from both cosmologies share a basic commonality, both being media of condensed information storage, decipherable only in relation to the greater cosmological system. Both must be seen in alliance with Donna Haraway's reasoning about semiotics as a trope and a model at the same time (1997). In this tale of complexity and contradictions, science as a universal practice and Lakota indigenous science approach each other, both trying to keep up their distinction, while at the same time paradoxically trying to show that their methods and their goals are essentially identical in that they relate to their respective concepts of truth. While the physical scientist clings to ideals of objectivist modes of falsifying hypotheses, the native science generates tropes and stories, ironic narratives, and jokey 'über-readings' of techno-scientific knowledge productions, marking the unmarked epistemological system of objectivity and incorporating it into Lakota Sioux cosmology. This moment should highlight and can be understood beyond standard narratives of colonial and decolonial communications of science as a universal practice, since both Johns are communicating on an equal footing, and I, as an anthropologist who recounts this episode with a sense of self-reflexive irony, become part of the story, since I am 'inventing' (Wagner 1975) it in this ethnographic piece by writing about experiences I gathered during my field work.

In comparing the diagrammatic visions of both cultures as a form of abstracting notations of natural observation, Lakota John and Physics John managed to symmetrise the two cosmologies during a workshop with children, easily connecting both visions. Both – not only Western physics – encompass subjectivities, both can relate to the figure of Iktomi, the shape-shifting trickster god spinning his worldwide web. It does not seem to be a coincidence for Lakota John that the www protocol has been invented at CERN to understand the trickster behaviour of particles. And on sacred land, all this makes total sense for Physics John. The worldwide web and the particles are manifestations of the same god, who controls human visions of the cosmos and is seen as the creator and master of contemporary communication technologies by Lakota John. The worldwide web is seen as a gift by

many native cultures, allowing them to connect for political causes, to voice their concerns, and to disseminate ideas like never before. And just as Iktomi, ambiguous at heart (Melody 1977), media technology such as the internet is representing the good and the bad in humankind. The worldwide web may be seen as a gift and a curse at the same time. It makes perfect sense for a particle to be ambiguous and elusive, deluding the observational traps set up by human observers.

Technology, according to British anthropologist Alfred Gell, must be understood within the framework of magical ideas, 'in providing the orienting framework within which technical activity takes place. Technical innovations occur, not as the result of attempts to supply wants, but in the course of attempts to realise technical feats heretofore considered "magical"' (Gell 1988: 8). For Lakota John, high-energy physics shows Iktomi's work: the trickster god weaves humans into his magic web of perception. With a feminist STS framework, this all makes perfect sense. The two Johns form a dialectical synthesis, proving higher-order concepts of trickster ontologies and natural scientific epistemology at the lower level of empirical, technoscientific observations of 'nature', though using divergent filters of different cultural imaginaries and modes of reasoning. Digital times reverse long-standing dichotomies of the West and the rest, at least when it comes to the cosmology of matter: be it within anthropological debates or within the practices of physics, dichotomies dissolve into ultimately relational dynamics.

Conclusion

Pondering on the tale of two Johns, I have concluded that physical particles can be situated at the core of the technoscientific body, exemplifying that Western science must be treated as a located practice with universalist appeal producing material-semiotic objects, animating and sorting things into powerful taxonomies. Western science is superseding the dialectics of object and subject. It turns the equality of actors into a universe of animated creatures that might be seen as offspring of technoscientific capitalism (Haraway 1997), but which have a life of their own (Tsing et al. 2021). Particles are changing the 'culture of no culture', of 'extreme objectivity' (Traweek 1988: 162). They turn the unmarked modality of knowledge called science into a marked chronotopos, where women, cosmopolitans, and nerds find refuge side by side, fleeing from the world of self-made entrepreneurs by engaging in a collaborative enterprise. By describing this

ephemeral moment in history, I have become myself part of the story, half inevitably acting out the 'god-trick' of science, by simply writing this ethnographic piece, half taking this moment beyond its (post)-colonial, anthropocentric entanglements through ironic reflection.

I learned that particles can be considered tricksters even by physicists. Furthermore, these entities can be considered as 'stem cells of the techno-scientific body' (Haraway 1997: 129). Humans today are made out of stardust of the cosmic system, their world being animated by invisible fields. Turning the time-bound entity of a *Homo sapiens* mammal into a cosmic body, scientists morph the origin of space, time, and matter with the ephemeral complex being that we are. The deadly entity of life and the infinity of subatomic matter form relationalities that need to be carefully analysed to understand the current shift in Western scientific cosmology. While acknowledging the technical constructions behind it, science searches for connections to the Big Bang totem that has resulted in the world as we know it today. This ominous concept of singularity is the riddle that physicists turned into the answer in their master narrative of Western cosmology. Despite the constant acts of purification, scientific knowledge is contradictory. Truth is coloured by storytelling frames (Mol 2002), it involves human and nonhuman actors, and it depends on media technology. Physicists, engaging with many worlds within different cultural contexts, adapt their narratives as a function of these worlds and contexts, a phenomenon I call 'ontological opportunism'. Whether or not they are conscious of their narrative ingratiation when upgrading technical conversations within their community or when downgrading them outside of this community in discussion with laypeople. The line between animism and realism slowly dissolves in the digital era of the pluriversal Anthropocene.

Many physicists continue to adhere to a worldview in which they are more than modest witnesses to phenomena they refer to as 'one' nature – but these are rioting, untamed objects technoscientific agents of nature-cultures. In the world of the late twentieth century, ethnographically accompanied by Sharon Traweek (1988) and Karin Knorr-Cetina (1999), these objects were tamed, and physics seemed to be the epitome of a 'culture of no culture'. But in the digital era of the LHC, the virtuality of particles unravel their ambiguous ontological state. Due to the central epistemological status of computer simulations in contemporary science, particles today have been transformed into material-semiotic phenomena, easily recognisable as tricksters in Iktomi's realm for Lakota Sioux cosmologists and feminist anthropologists of STS alike.

Western science has come a long way from its origins in attempting to understand divine rivers, nymphae, and music that is the witness to godliness, harmonious mathematical patterns detected from philosophers in Asia Minor, from Pythagoras to Leibniz and beyond. It has subjected nature to arithmetic, geometry, statistics calculating correlations, computers modelling simulations and detecting the imaginary within the reality of physics. Secular physics does not need to consider any gods and spirits anymore. It is the mathematical formulae that mediate and translate nature into an abstract system of signs. Whether mathematics must be considered as transcendental, obfuscating, or clarifying nature remains yet another puzzle in the ambiguous concept of the scientific cosmos.

This process brought about a change in the self-representation of physicists. Robert Boyle (Shapin and Shaffer 1985), the seventeenth-century experimental physicist, has little in common with the twenty-first-century sorcerers of the code collaborating in their experimental control rooms. Despite the clear difference, they share a similar dream of objectivity. Enchanted technology and animated matter have had a major impact on physics, turning the 'culture of no culture', with its ideal of a world where nation, race, class, and gender do not matter, into a nerd culture of cosmopolitans, with diversity departments and discussions on race, gender, and sexuality. Above all it is transforming the researchers themselves into an endangered species of rational universalist cosmopolitans in a world of renationalisation and fragmentarianist identity politics.Who else tames nature and claims to be able to do anything but a Promethean tribe of natural philosophers turned into science through the use of technologies and the deployment of mathematics? At the same time, as I have witnessed, the adherents of rational science imagine a world in which dry science is comparable to the enchanted world of witches and magicians, as in Harry Potter novels, or gods and monsters, as in science fiction. In the computer age, the god(s) seem to manifest themselves in the technical images and mathematically predicted signatures of physical experiments. Physicists' digital tools seem to augment ambiguity – a topic that still needs to be further explored.

Acknowledgements

This research has been conducted while working at University of Jena, as well as the Cluster of Excellence 'Image Knowledge Gestalt'

of Humboldt-University of Berlin. I gained profound inspiration while being visiting assistant professor in the Department of Science, Technology and Society at the Massachusetts Institute of Technology and during several fellowships at the Institute for the Advanced Study of Media Cultures of Computer Simulation. For the purpose of my current research I have been an associated member of ATLAS collaboration at the European Centre for Nuclear Research (CERN) from 2015 to 2017. The research has been additionally funded by the Humboldt Graduate School and the Jena Graduate Academy. I want to thank Diana Espírito Santo, Sonia Fizek, Tania Hron, Hanna Nieber, Ursula Rao, Karl-Andrew Woltin, David Yellin, and Cornelius Borck for commenting on earlier drafts of this article. Borck aptly coined the phrase 'virtualisation of cosmology' to reflect part of the findings I present in this final version.

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Notes

1. This article will be also part of the collected volume *Mattering the Invisible. Technologies, Bodies, and the Realm of the Spectral.* Edited by Diana Espírito Santo and Jack Hunter, published in 2021 by Berghahn Books.
2. Representations of mathematical descriptions of subatomic particles in pictorial form.
3. This is a self-reflexive passage based on my field diary and shows, also, how I sometimes mix things up while being in the research context. I had just read Castaneda's work for teaching purposes again. The tradition of Peyote does not belong to Lakota Sioux, but is part of Navajo culture.

References

Barthes, R. (1980), *Le chambre claire: Note sur la photographie* (Paris: Gallimard, Le Seuil).

Barad, K. (2007), *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham, NC: Duke University Press).

Bennet, J. (2009), *Vibrant Matter: A Political Ecology of Things* (Durham, NC: Duke University Press).

Bird-David, N. (1999), ''Animism' Revisited: Personhood, Environment, and Relational Epistemology', *Current Anthropology* 40, no. 1: 567–591.
Borck, C. (2014), 'How to Do Voodoo with Functional Neuroimaging', *EspacesTemps.net*, 9 December, www.espacestemps.net/en/articles/neuroimaging/ (accessed 15 February 2021).
Braidotti, R. (2013), *The Posthuman* (Cambridge: Polity Press).
Cajete, G. (2000), *Native Science: Natural Laws of Interdependence.* Foreword by Leroy Little Bear (Santa Fe, CA: Clear Light Books).
Canales, J. (2020), *Bedeviled. A Shadow History of Demons in Science* (Princeton, NJ: Princeton University Press).
Castaneda, C. (1968), *The Teachings of Don Juan: A Yaqui Way of Knowledge* (Berkeley: University of California Press).
Cohen-Tannoudji, G. and M. Spiro (2013), *Le boson et le chapeau mexicain* (Paris: Folio).
De la Cadena, M. (2015), *Earth Beings: Ecologies of Practice Across Andean Worlds* (Durham, NC: Duke University Press).
Descola, P. (2013), *Beyond Nature and Culture* (Chicago: University of Chicago Press).
Dippel, A. (2015). Dippel, A. (2015). 'Der Erlebnisstrom. Ein Werkzeug ethnographischen Schreibens'. In: *Berliner Blätter* 1/2015: 72-83.
Dippel, A. (2017), 'Das Big Data Game: Zur spielerischen Konstitution kollaborativer Wissensproduktion in der Hochenergiephysik am CERN', *NTM, Journal of the History of Science, Technology and Medicine* 4: 485–517.
Dippel, A. (2019), 'Ludopian Visions: On the Speculative Potential of Games in Times of Algorithmic Work and Play', in B. Beil, G.S. Freyermuth and H. C. Schmidt, *Playing Utopia. Futures in Digital Games* (Bielefeld: Transcript), 235–252.
Dorigo, T. (2011), 'Should You Get Excited by Your Data? Let the Look-Elsewhere Effect Decide', Compact Muon Solenoid, http://cms.web.cern.ch/news/should-you-get-excited-your-data-let-look-elsewhere-effect-decide (accessed 15 February 2021).
Espírito Santo, D., K. Kerestetzi, and A. Panagiotopoulos (2013), 'Human Substances and Ontological Transformations in the African-Inspired Ritual Complex of Palo Monte in Cuba', *Critical African Studies* 5, no. 3: 195–219.
Falkenburg, B. (2007), *Particle Metaphysics: A Critical Account of Subatomic Reality* (Berlin: Springer).
Forster, E. M. [1909] (2013), *The Machine Stops* (New York: FKM Books).
Frazer, J. G. (1900), *The Golden Bough: A Study in Magic and Religion.* 2nd ed. (London: Macmillan).
Gadamer, H.-G. (1990), *Gesammelte Werke. Bd. 1 (Hermeneutik I. Wahrheit und Methode. Grundzüge einer philosophischen Hermeneutik)* (Tübingen: Mohr Siebeck).
Gell, A. (1988), 'Technology and Magic', *Anthropology Today* 4, no. 2: 6–9.
Haraway, D. J. (1991), *Simians, Cyborgs and Women: The Reinvention of Nature* (New York: Routledge).
Haraway, D. J. (1997), *Modest_Witnness@Second_Millennium. FemaleMan©Meets_OncoMouse™: Feminism and Technoscience* (New York: Routledge).
Haraway, D. J. (2013), 'SF: Science Fiction, Speculative Fabulation, String Figures, So Far', *Ada: A Journal of Gender, New Media & Technology* , 3, https://adanewmedia.org/2013/11/issue3-haraway/ (accessed 15 February 2021).

Haraway, D. J. (2016), *Staying with the Trouble: Making Kin in the Chthulucene* (Durham, NC: Duke University Press).
Harvey, G. (2005), *Animism: Respecting the Living World* (London: Hurst & Co).
Ingold, T. (2006), 'Rethinking the Animate, Re-animating Thought', *Ethnos: Journal of Anthropology* 71, no. 1: 9–20.
Jones, G. (2017), *Magic's Reason: An Anthropology of Analogy* (Chicago: University of Chicago Press).
Kirby, V. (2011), *Quantum Anthropologies: Life at Large* (Durham, NC: Duke University Press).
Knorr-Cetina, K. (1999), *Epistemic Cultures: How the Sciences Make Knowledge.* (Cambridge, MA: Harvard University Press).
Kohn, E, (2013), *How Forests Think* (Berkeley: University of California Press).
Lakoff, G., and M. Johnson (1980), *Metaphors We Live By* (Chicago: University of Chicago Press).
Latour, B. (1993), *We Have Never Been Modern* (Cambridge, MA: Harvard University Press).
Latour, B. (2005), 'What is the Style of Matters of Concern? Two Lectures in Empirical Philosophy'. April–May 2005.
Law, J. and M. Lien (2018), 'Denaturalizing Nature', in M. De La Cadena and M. Blaser (eds), *A World of Many Worlds* (Durham, NC: Duke University Press), 131–171.
Lederman, L. (1993), *The God Particle: If the Universe Is the Answer, What Is the Question?* (New York: Dell Publishing).
Lemonnier, P, (2012), *Mundane Objects: Materiality and Non-verbal Communication* (San Francisco: Left Coast Press).
Lévi-Strauss, C. (1963), *Structural Anthropology.* Translated by Claire Jacobson and Brooke Grundfest Schoepf [in French] (New York: Basic Books).
Lossin, R. H (2019), 'Neoliberalism for Polite Company: Bruno Latour's Pseudo-Materialist Coup', *Salvage* 7: 131–155.
Malinowski, B (1954), *Magic, Science and Religion; And Other Essays* (Garden City, NY: Doubleday Anchor Books).
Melody, M. E. (1977) 'Maka's Story: A Study of Lakota Cosmogony', *Journal of American Folklore* 90, no. 356: 149–167.
Mauss, M. (1972), *A General Theory of Magic* (London: Routledge).
Mol, A. (2002), *The Body Multiple: Ontology in Medical Practice* (Durham, NC: Duke University Press).
Nader, L. (1996), *Naked Science: Anthropological Inquiry into Boundaries, Power, and Knowledge* (New York: Routledge).
Ong, W. J. (1992), *Orality and Literacy: The Technologizing of the Word* (New York: Routledge).
Pels, P. (2003), 'Introduction: Magic and Modernity', in B. Meyer and P. Pels (eds), *Magic and Modernity: Interfaces of Revelation and Concealment* (Stanford, CA: Stanford University Press), 241–271.
Puig de la Bellacasa, M. (2017), *Matters of Care: Speculative Ethics in a More than Human World.* (Minneapolis: University of Minnesota Press).
Rorty, R. (1989), *Contingency, Irony, and Solidarity* (Cambridge: Cambridge University Press).

Shapin, J. and S. Schaffer (1985), *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, NJ: Princeton University Press).
Shelley, M. J. [1818] (2017), *Frankenstein, or the Modern Prometheus. Annotated for Scientists, Engineers and Creators of all Kind* (Cambridge, MA: MIT Press).
Stengers, I. (2010), *Cosmopolitics I* (Minneapolis: University of Minnesota Press).
Stengers, I. (2012) 'Reclaiming Animism', *E-flux Journal* 36, www.e-flux.com/journal/36/61245/reclaiming-animism/ (accessed 15 February 2021).
Stengers, I. (2018) 'The Challenge of Ontological Politics', in M. De La Cadena and M. Blaser (eds), *A World of Many Worlds* (Durham, NC: Duke University Press), 83–111.
Styers, R. (2004), *Making Magic: Religion, Magic, and Science in the Modern World* (Oxford: Oxford University Press).
Tsing, A. L., J. Deger, A. K. Saxena and F. Zhou (2021), *Feral Atlas: The More-Than-Human Anthropocene,* http://feralatlas.org (accessed 15 February 2021).
Traweek, S. (1988), *Beamtimes and Lifetimes: The World of High-Energy Physics* (Cambridge, MA: Harvard University Press).
Tylor, E. B. (1873), *Primitive Culture: Researches into the Development of Mythology, Philosophy, Religion, Language, Art and Custom.* 2nd ed. Vol. 1 (London: Murray).
Viveiros de Castro, E. (2014), *Cannibal Metaphysics: For a Post-structural Anthropology* (Minneapolis: Univocal).
Viveiros de Castro, E. and D. Danowski (2018), 'Humans and Terrans in the Gaia War', in M. De La Cadena and M. Blaser (eds), *A World of Many Worlds* (Durham, NC: Duke University Press), 131–171.
Voss, Ehler (2014), 'A Sprout of Doubt: The Debate on the Mediums' Agency in Mediumism, Media Studies, and Anthropology', in J. Schlehe and E. Sandkühler (eds), *Religion, Tradition and the Popular: Transcultural Views from Asia and Europe* (Bielefeld: transcript), 205–224.
Wagner, R. (1975), *The Invention of Culture* (Chicago: University of Chicago Press).
Wittgenstein, L. [1953] (2009), *Philosophical Investigations* (London: Wiley-Blackwell).