4.2 VISUALISATION AS A POLITICAL ACT

Peter Galison in Conversation With Moritz Neumüller

MORITZ NEUMÜLLER: Peter, you have been working for many years in and between the domains of art, physics, science theory, epistemology, and image theory, to name a few, in a transdisciplinary, interdisciplinary, integrative way. With the growing specialisation in all of these fields, this must be becoming a difficult task. Which are the questions that have driven your work and how did you start to look across disciplines?

PETER GALISON: I began this work with an interest in the way that concrete actions, procedures, instruments, and image-making devices work, how they help us understand the most abstract concepts that are given to us. For many reasons, I like the sudden juxtaposition of the very abstract and the very concrete. The first book that I wrote was about how experiments end (Galison 1987). I was interested in a fundamentally epistemological question, which was that, given the nature of experimentation, you always come to a point where you have to say: *ceteris paribus*, all things being equal, we've demonstrated the existence of this particle, or that effect, or this process. That result can never be given to us by logic alone. I was interested in how, in the laboratory, in the actual doing of experiments, people come to the conviction that they have shown that something exists, or that a process takes place in nature. This is epistemology not in a universal set of rules, but instead incorporated into objects and images – for example, in the photographs that so often issue from laboratory work.

Building on *How Experiments End*, I wanted to dig deeper into this process in *Image and Logic* (Galison 1997). I had seen that there were different tendencies in science to document and calculate findings, on the one hand to make images, and on the other to use statistics and counts. This drove me even further into the material infrastructure, down a level, if you will, from experimentation, into the instruments themselves, such as a cloud chamber or a bubble chamber, or the direct use of film on which particles leave their tracks – visualization in general and photography in particular were altogether central (Figure 4.6). It took me as well to an alternative tradition, driven by instruments such as Geiger counters, spark chambers and wire chambers that functioned largely (or in some cases entirely) *without* images. I became interested in how these two traditions clashed in the first instance and eventually found a way of working together. Why was one or the other instrument used, and what does it mean, at the level of demonstration? What is it that is handed down, pedagogically, technically, epistemically, as you went from one generation of scientists to the next? For example, the cloud chamber physicists of one generation went on to do bubble chamber work; the experts in counter experiments of one generation handed down their skills to the spark chamber experts of the next, and wire chambers after that.

My work continued in this vein of material epistemology. I became interested in the way Albert Einstein and Henri Poincaré formulated what for the time was the most abstract theory of physics that had ever been accomplished. Around the turn of the century, Einstein was a patent officer in Bern, Switzerland, and Poincaré, among his many other academic positions as a mathematician-physicist-philosopher, was also in charge of the Paris-based Bureau of Longitude. In a philosophical piece that he wrote towards the turn of the 19th to the 20th century, Poincaré said that, in order to understand time, we have to imagine the coordination of clocks between two telegraph operators trying to exchange signals to coordinate the hour in Brazil and the hour in Paris, or Paris and London (Galison 2003).

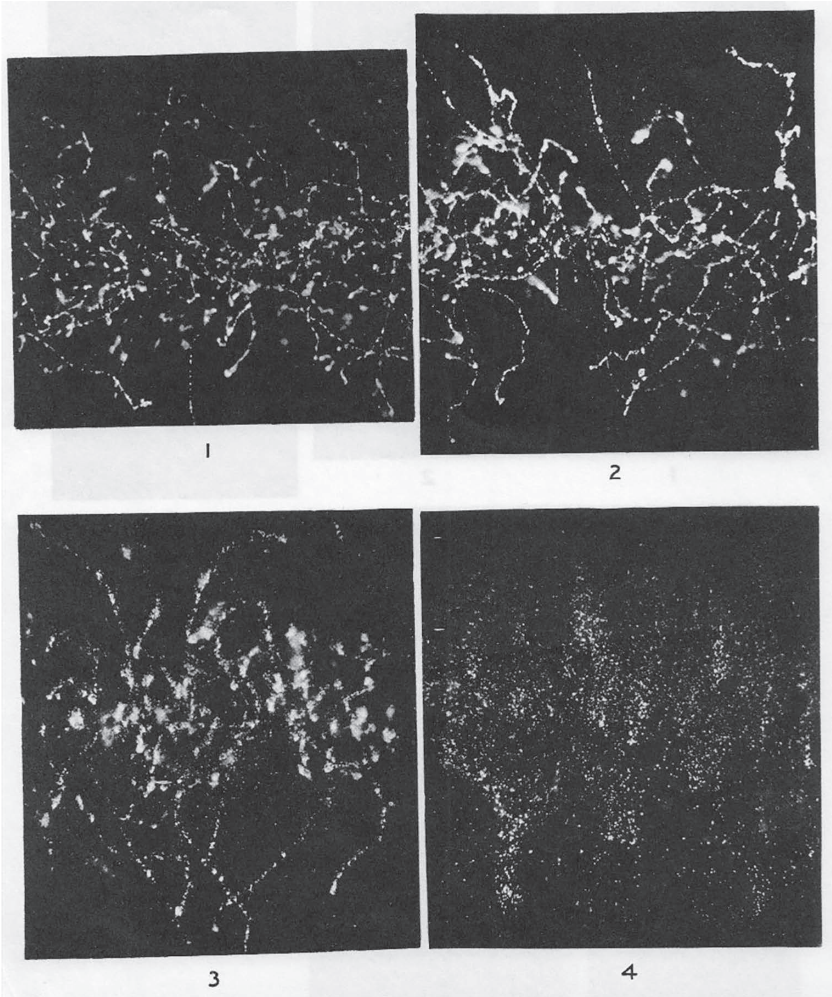

Figure 4.6 The imaging tradition in microphysics gets its launch with C.T.R. Wilson in the early years of the 20th century. For the first time, individual atomic-scale events could be seen – leading to a host of other technologies, from nuclear emulsions (recording particles skittering on the plane of the film itself) and the industrial-scale bubble chambers in which particle physics flourished in the 1950s to 1970s. This image is from Wilson, 1912.

Source: https://commons.wikimedia.org/wiki/File:Cloud_chamber_1912_X-ray.jpg.

What struck me is that, at that time, he was directly involved with coordinating clocks in South America and Paris, and Paris and London. It's this kind of question that really interested me, and continues to inspire my work: How did the material circumstances of actions in the laboratory in science interweave with the demonstration of very abstract concepts?

MN: Poincaré was a polymath whose work has influenced many artists, namely Marcel Duchamp. In a certain sense, this connection between the arts and science is also in the focus of the book *Objectivity*, which you co-authored with Lorraine Daston (Galison and Daston 2007): specifically the way that visual artists helped to shape the image of scientific findings, in illustrations and atlases, and then were excluded from these tasks, so that photography could take their place, as a presumably objectifying medium that is able to document reality without human intervention.

PG: The book takes the very abstract notion of scientific objectivity, and gives it flesh and bones by tying broad epistemic claims to the techniques of making photographs, lithographs, tracings, and other procedures deployed to move images from nature to the page. This theme of the criss-crossing of abstraction and concreteness has threaded my work from the very beginning. As I continued in my work in physics, I became interested in black holes, perhaps the most abstruse, mysterious objects in the universe.

The Black Hole Initiative began in 2015, opening formally in 2016, with a physicist, a mathematician, an observational astronomer, two theoretical astrophysicists, and myself. (In fact, I'm currently in the office at the Black Hole Initiative, at Harvard.) Our foundational idea was that black holes are riveting objects to all these different fields, that a deeper understanding of them required a concerted effort that would involve these different specialties. Having history and philosophy in conversation with the physics, mathematics, and theoretical astrophysics was very intentionally part of the design. Through the BHI, I got involved in the Event Horizon Telescope led by one of the other co-founders of the BHI, Shep Doeleman. Across some 20 countries with more than 200 collaborators, the EHT is an effort that has been going on for some fifteen years to take the first picture of a black hole, to bring to the visual what had been the most abstract kind of object imaginable.

MN: Indeed, it seems that your scholarship has orbited around the combination of abstraction and materialism, the visualisation and epistemology of scientific findings. Before diving into the issue of the black hole, allow me to share an insight that I got from an interview with the virologist Florian Krammer of Mount Sinai hospital, an expert in avian flu and Covid, who also stressed the distinction between visualisation aspects and quantitative data. He recognised the importance of visualisations for dissemination purposes, but insisted that in his field, it was the quantitative data that makes the difference, and something I found very interesting – that the use of colours was something of very little importance in his field. In their academic journals, according to Krammer, virologists mainly use black and white illustrations, while colours are reserved for non-scientific dissemination, that is, for us, we who see the Coronavirus in popular magazines, on TV, in the newspapers, on the Internet, etc. Therefore, when I found out from Maciej Wielgus' talk (Wielgus 2020) that the decision to visualise the black hole in orange was not a scientific decision but a sort of aesthetic, nearly emotional decision, I became very interested in that. I understand that you were involved in this decision, to make the orange donut image of the black hole, am I correct?

PG: Yes. In the black hole image, there is no intrinsic colour: the radiation that gets to us from around the black hole is not in the visible domain. So, while the image faithfully reflects the intensity of the signal and its spatial distribution, we could have made it black and white, we could have made it purple, we could have made it blue. . . . I was involved with those discussions. In fact, there were some colleagues who said, roughly, 'Maybe we should make it blue, because the blue part of a flame is hotter than the red part of a flame. The colour should reflect the fact that this is 10 billion degrees Kelvin, this is incredibly hot plasma gas that surrounds the black hole, these particles are being pulled around violently by the black hole.' However, I thought that a red orange would be a better colour because, in fact, people in their daily lives think that red is hot; we don't say, "Don't touch that, it's blue hot." We wanted to use colour in this image to convey something beyond the data themselves, we wanted to convey the extreme temperature (hundreds of billions of degrees

Kelvin), and we concluded that this red-orange colour would be the best way of conveying it (Galison and Kessler 2019).

MN: So there was a deliberate decision on the colour, and thus the "look" of this image, which made it to the front pages of nearly all major newspapers around the world. And in contrast to what I heard about the practice concerning the Coronavirus and virology in general, you did not distinguish between a black and white picture for the scientific community, and a colour image for general dissemination.

PG: Now that you point it out, it does seem interesting that in the fields that I'm involved with, in physics and in astrophysics, we use colour all the time in scientific journals. Yes, in fact this first picture of a black hole was precisely the same colour map published in *The Astrophysical Journal* and for the newspapers and other mass and social media where about a billion people saw the image of M87* within a day of its publication. It is the same colour of the print we made for the permanent collection of photography at the Museum of Modern Art in New York.

The sky is full of fascinating objects, neutron stars, quasars, all sorts of things, yet the black hole has a singular hold on our imagination. It's a very interesting object for mathematicians, as it raises questions about fundamental aspects of differential equations. It's fascinating to physicists because it fosters foundational questions of the nature of spacetime. It grabs the attention of astronomers because it participates in the formation of galaxies and the regions of space where stars form. It's interesting to philosophers because it questions ideas of causality and time-reversibility, about determinism and the limits of knowledge. The black hole just seems endlessly generative, in and at the boundaries of these different fields.

The EHT Imaging Working Group, in which I have been most involved, was only one part of the overall effort, as there were people working on the telescopes and people working on data collection, modelling, simulation and theory. In any case, in this imaging working group we used some of the ideas from the *Objectivity* book that you mentioned earlier, to frame how we would make the case for the existence of the image. The argument that Lorraine Daston and I made was that the idea of the best representation of nature began with a certain commitment to idealization, in Goethe, Albinus, and others in the 18th century, who thought that you needed to idealize because no one would or should care whether the particular flower outside your office was sun-burned or was half-eaten by a caterpillar. They wanted to know what the underlying form was, not the particular specimen. Around the first third of the 19th century, scientists became fascinated with the idea that you should in fact do the opposite. That is, their goal shifted toward the ambition to transfer an object from nature to the page – be it a skull, hand, cloud, flower, or blood crystal – with a minimum of interference and idealization. Finally, in the more recent period, scientists and medics across the disciplinary map began to be interested in using the judgment that they had acquired as experts to assess, and sometimes to adjust, the image. Each of these epistemic ideals layers on top of the previous one – mechanical objectivity begins in the mid-19th century but adds to (does not displace) the older, will to idealize. The judgment objectivity gathers strength in the first third of the 20th century – it too rides on top of the two earlier layers. We saw no reason to think of these shifts as abrupt ruptures à la Foucault or Kuhn. Instead, we saw innovation – dramatic, even radical change – supplementing the earlier aims.

More specifically: In our work on the image of the black hole, we began by distributing the data to four different groups who were forbidden from speaking to one another. Each of them had to use their expertise to elicit an image, first on test images, then on real observational data taken by the array of telescopes in April 2017. By 5 June 2018, some of the groups had begun to see a bright ring around a dark centre – the black hole. On 24 July the four groups got together and, for the first time, to a hail of cheers, saw that their images looked very much alike – highly correlated pixel by pixel, yielding similar-sized dark disks in the centre, and qualitatively much alike (bright crescent in the south). A new fear set in: what if *all* of us were somehow expecting and guiding our images toward a ring?

We decided that we did not want to rely entirely on expert judgment, that we wanted to make something procedural-algorithmic; we wanted a form of mechanical objectivity. So we wrote code so that the computer would do a survey of many – millions – of different settings, analogous (roughly) to making a machine that would systematically vary shutter speed, aperture opening, and ISO equivalent in a hand-held camera. We next asked the computer to compare test images with this panoply of mechanically-generated settings and to choose the best settings, the settings that gave the highest pixel-by-pixel similarity with the test pattern. We used that "top set" of settings to reconstruct real data from M87* – and still got a bright ring around a dark disk, bright crescent in the south.

Finally, we chose one observation day – a day of particularly good observing conditions and telescope readiness – and created an image that was an average of three different image reconstruction methods. We used that average, that idealization as it were, as a way of finding something we could present. By averaging, we minimized quirks of any one or even two methods, and visually underscored those features that were in common.

Interestingly enough, what we ended up doing in the Event Horizon Telescope, was tracking the three great epistemic forms, but, in our own work, inverting their historical arc. Historically, we see a move from idealization to mechanical objectivity to judgment objectivity. In the EHT, we went from expert judgment to mechanical objectivity, to idealization: a kind of *backwards* play through the history of objectivity! Perhaps this underscores the idea that the forms of visual ambition in the hunt for objectivity do not die, they remain resources for subsequent periods. Those old epistemic virtues were helpful in thinking through these new forms of highly computed images (see also Galison 2019). Finally, on 10 April 2019, we released the image to the world – almost ten hard-driven months after we glimpsed that first image (Figure 4.7).

MN: It seems that your collaborations at the interface of different disciplines, including image theory and photographic studies is very dynamic and rewarding for you, also in a personal sense.

PG: I enjoy working with other people, whether it's on a film or on a scientific project, or something philosophical. I think that these questions of images, materialism, abstraction, are so interesting across these different domains that it's productive, and completely riveting for me to think about them as they cross the boundaries of disciplines traditionally conceived.

MN: Absolutely. Coming back to the *Objectivity* book for a last time, I would like to ask you about the question of Fear that, as you say, "drives epistemology." What is this fear about? Could you speak a bit about how anxiety and fear drive the way we conceive science and epistemology?

PG: I strongly believe that epistemology, the study of how we gain and secure knowledge is evolving, that it is not a fixed domain. Our standards and ambitions for establishing and securing knowledge change, and that's a good thing. Think about the discovery of the microscope, the telescope, diagrams, or statistics. Those are moments in the history of epistemology when we could suddenly ask questions in different ways. Every form of epistemology, every organized approach to gaining and securing knowledge, is always arguing *against* something,

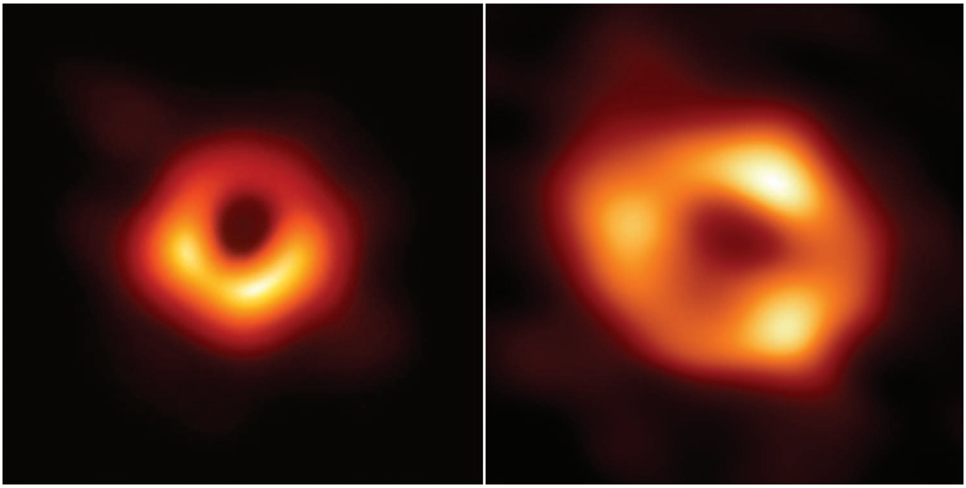

Figure 4.7 Black hole portraits. (a) Image of M87* which the EHT released on 10 April 2019. (b) Image of the supermassive black hole Sgr A*, which lies the centre of the Milky Way. I and all of us on the EHT were still sworn to secrecy about SgrA* at the time of this interview – the EHT issued this picture on 12 May 2022.

Source: Credit: https://eventhorizontelescope.org/.

there's always a fear against which the establishment of knowledge is being positioned. For Goethe, the fear was that we would lose our grip on understanding were we to be distracted by studying this plant over here, and that plant over there. We would never come to any understanding of nature, we would never learn anything, if the objects of our inquiry were hyper-individualized in this way. The cure, the form of idealization that he embraced, was in response to a specific fear: the fear of a fragmentation of the objects of nature. In the 19th century, a different fear arose and a different cure was developed: in a proliferating scientific community, with everybody claiming to be able to see the true ideal beneath the particulars, there was chaos! If you had an idea of what the form of the skull was, and I had another idea, and 20 other people in our scientific community each had different ways of idealizing the skull, a flower, a plant or a crystal, we would never advance. As a result, the governing fear was different: It was that idealization could get so proliferate in the face of different desires, different ambitions, different hopes, different pet theories. They came to the conviction that we needed something that was grounded in a procedure, in which, at least in principle, all of us would aspire to a mechanical, procedural transfer from the objects of the world to the page – from this skull to that page in a scientific atlas.

I think that the broader claim is that every epistemological setup, every apparatus in the broadest sense, is always juxtaposed against a fear of the loss of knowledge or our incapacity to grasp the world around us. In the case of the Event Horizon Telescope, we were worried that we already had theoretical ideas about what the image should look like. We were concerned that we would succumb to confirming what we suspected, and that one group might, even unconsciously, tune their settings in a way to conform to what they had seen next door. This idea of blind comparison was a response to that particular kind of a fear. Each of four independent groups practiced making an image form various artificial data sets, not knowing what the data set originally depicted *and* not knowing what the other groups were recovering.

MN: Anxiety and fear have become an important factor in our societies in the last few years, especially in relation to science and progress, and some political tendencies on the rise in the last few years. Where does this anti-progressive or anti-epistemological fear in our society come from, and why are conspiracy theories so much more successful than scientific research, in some parts of our Western societies?

PG: That is a vital and difficult question. It might seem like a paradox on the surface, that on the one hand people are very broadly and deeply interested in science, they do want to know what the world is like around them, yet, on the other, there's a suspicion of scientists, or rather, experts. I think that a lot of what may seem to be anti-*science* is, in fact, in part the project of a concerted effort to mislead, and in part a revolt against the imposition of authority of a certain type, an anti-elitist populism. Of course this has been exploited by politicians, and by industry, to advance their own narrow aims. Tobacco companies, for example, long encouraged doubt about the medical, public health, and epidemiological conclusions about the catastrophic dangers of smoking. "Doubt is our product," one infamous industry memo read. And so the tobacco shills cultivated doubt about the danger of cigarettes, as they claimed that scientists disagreed, and statistics were not to be trusted.

MN: A kind of doubt that has been reused directly in the climate change debate . . .

PG: It has. My colleague, Naomi Oreskes, has written (with Erik Conway) a book called *Merchants of Doubt* (2010) precisely about the connection between the people arguing that tobacco was not really dangerous, and people arguing that climate change had not been established as real. In both cases, they were exploiting the idea of doubt as a wedge, trying to disable regulation or control that might help us, on the one side, free ourselves from addiction to tobacco smoking, or on the other side, to take measures that would constrain fossil fuel production and use, as a way of slowing global warming. At the same time, politicians encouraged a populist anger at people they consider to be elites, or experts – saying that they, the politicians, stand for your interests, casting doubt that wearing a mask or social distancing could reduce the probability of getting Coronavirus, or that getting vaccinated against the virus could impede transmission or accelerate recovery.

These doubts then became part of a broader political movement that united many different forces (ideological, economic, political) with an interest in disabling our faith in specific programs of action grounded in scientific and medical argumentation. This populist movement has been allied with big forces of industry with major amounts of money behind it: fossil fuels, toxic chemicals, tobacco products.

So, again, the problem of doubt toward science is deep and complicated, but most people actually are interested in science. I've never met somebody who said, 'I'm not interested in the black hole.' Never. People enjoy learning and being able to share in the excitement of new discoveries: they want to know how viruses function, how bees communicate, and how weather systems form. Children love science, and it's only because we teach them badly that some of them end up later not being interested in science, but everybody's interested in it to begin with!

MN: Talking about fear, politics, history and science, I find it fascinating that the phenomenon received its name, the Black Hole, via Colonial history. It seems that we still have so much to discuss about how colonialism, industrialization and capitalism have shaped science, and how enlightenment and progress in our latitudes went hand in hand with, or were actually based on, the exploitation of the other part of the world.

PG: I completely agree that much of the wealth and culture of what people often call the West is predicated on the extraction of resources, the trafficking in human beings. It is part of our past that we must confront. As you say, long before anyone had thought about swirls in spacetime, the name black hole was given to a suffocating dungeon (the "Black Hole of Calcutta") in 18th century colonial India: the very name evoked terror and horror. Black holes (astrophysical ones) are fearsome objects to us, and at the same time fascinating. They are most elusive of things, in all sorts of different ways; objects into which you can pass but from which you cannot return with their one-way membrane separating our part of the universe from a part that's inaccessible to it. This no-return portal inevitably is redolent of death, we all will fall from life to death, but it is not given to us to travel backwards from death to life. Black holes have this compelling significance that even the most hard-boiled scientist cannot escape, because they are utterly unlike anything else that we know.

MN: Let's come back to the great concerns about our planet and the way we relate to our environment. You have written about and made movies about oil spills, nuclear waste and other examples of manmade disasters, and on how to make them visible for the human eye, so we can grasp and understand them, which is the first step in the direction of acting against them.

PG: I have been interested in images more broadly, partly as a way of materializing things that are given to us as abstract, hidden, inaccessible. I made a film with Robb Moss, *Secrecy* (2008) about the procedures and impact of national security secrecy. The aim was to capture the struggle over the necessity and danger of state secrets – how it shapes our understanding of the world around us, impinges on democratic deliberation, and alters the lives of secret holders. We made another film together, *Containment* (2015) about the attempt to contain nuclear waste that was produced in making weapons and making power (Figure 4.8). Nuclear waste remains dangerous for thousands, sometimes millions of years, presenting a problem of containment that is unlike anything we've ever experienced. When nuclear weapons waste was to be buried in a site outside Carlsbad, New Mexico, it was demanded by the Congress of the United States that the site should be marked as "dangerous" for a period not less than 10,000 years. Suddenly, people had to imagine what the future would be 400 generations from now. It became an extravagant attempt at futurology, incomparably more difficult than anything that had ever been done. At the time, futurists were trying to predict industry, military, and social movements 5 or 10 or maybe 20 years down the road, not 10,000.

Figure 4.8 Filmwork. (a) From Galison and Moss, *Secrecy* (2008). (b) Mrs. S. had to evacuate after the failure of containment at the Fukushima nuclear power plant, during the triple disaster of March 2011. She came back every few weeks to tend to her home in the hope that she and her family would eventually be able to return. Galison and Moss, *Containment* (2015).

Source: Credit: secrecymovie.net and containmentmovie.com.

I thought that it was important to visualize the concept of nuclear waste: What does it look like? – After dissolution in an acid bath, one form of liquid waste is a flow of material with the consistency of peanut butter stored in million-gallon tanks. Other waste, nuclear weapons waste destined for the New Mexico site, takes the form of the everyday detritus of the weapons work – plutonium-infested smocks and glove boxes, instruments and rags, moved by trucks carrying these barrels of waste which are being emplaced half a mile underground. The drive to image these things for me has a political aspect. But by political I do not mean, whether you vote for this political party or that political party. I mean that we must deal with nuclear waste, we need to dispose of it. So how are we going to do that – in terms of policy, infrastructure? What is our responsibility towards the future? Astonishingly, while making that film, the Fukushima disaster happened, so Robb Moss and I went to Fukushima prefecture and filmed houses that were contaminated with nuclear waste, and how people were handling it. What does it look like to be there? Who lives near the site? What are the sounds of the installations, the abandoned restaurants and churches, the river? Similarly, in my film about black holes, *The Edge of All We Know* (2020) I wanted to show what scientific theoretical and observational practice looks like, to track science-in-process, full of the ups and downs of collaborative work, rather than explaining completed science. And I wanted to bring together the work and images all aimed at making specific and concrete the black hole: simulations, tanks of swirling water, equations, animations, and of course, the making of the first picture. Sometimes that meant filming in a room full of computers, handling images and data, at other times with teams at telescopes set at the oxygen-poor redoubts 15,000 feet above sea-level.

Finally, in the case of the oil spills, in a collaborative work with the art historian Caroline Jones, we wanted to say that when you see pictures of an oil spill, what are you seeing are the choices that have been made (Galison and Jones 2010). There's a traditional set of pictures of that almost every oil spill generates: a young child holding a bird that's been covered with oil and wiping it off. And that tells you something, yet there's a lot that you're *not* seeing. This is why Caroline Jones and I are taking this further in our book, *Invisibilities: Seeing and unseeing the Anthropocene*. Our interest is in understanding what images reveal and what they conceal about the great carbon spew into water, land and air that is warming the earth's climate. What other kinds of images, photographs and non-photographs, might make it possible to envision the processes underlying our anthropocentric times?

MN: So, could we say that images are an active part of our grasp of the material conditions of the world we live in, and therefore a condition of possible political action?

PG: Absolutely.

MN: And how does photography fit into all this? You have made films, written books, participated in scientific projects, yet it seems to me that the photographic medium has always played a key role in your thinking, and in your methodology, right?

PG: Photography crosses many of the different domains that have interested me, bringing into the material world environmental imagery, astrophysics, epistemology, particle physics, filmmaking. . . . Photography is an infinitely protean and dynamic form! It has changed so much and continues to change. There's photography without cameras, photography without film, digital and analogue photography, infra-red (thermal) imaging, x-ray and gamma ray photography. There's photography that requires massive computation to make an image – like those of the black holes M87⋆ and Sgr A⋆ (Galison 2022). The lesson of photography and photographic history for me, is that its relationship to politics, to epistemology, to scientific knowledge is ever-evolving, and that's a good thing! It reflects the fact that photography is constantly on the hoof, expanding and developing in new ways. I think that's part of its promise, whether it's for documentation, aesthetics, social justice, or for photographing black holes.

MN: Thank you very much for this inspiring conversation.

PG: Thank you.

This conversation was held online on March 30, 2022.

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4.3 HOW TO PHOTOGRAPH A VIRUS

Florian Krammer in Conversation With Moritz Neumüller

MORITZ NEUMÜLLER: Good morning, Florian, and thank you for your time. You are one of the top researchers in microbiology and virology, and this conversation is for a book whose readership has a special interest in photography, visual culture, representation and technology. As an art historian and curator, I work with visual information mostly as a means of artistic expression, which is very different from the scientific use of images in your field. This shapes the way how we look at them, how we analyze, employ and trust, or distrust imagery. However, I am convinced that these kind of cross-discipline conversations can help to broaden our horizons, if we manage to talk about pictures in a way that will take both of us out of our comfort zones, and require to think beyond the schemes we usually apply. Let's give it a try. My first, and very simple, maybe innocent question is: We have seen so many images of the coronavirus in the last year and a half, mostly 3D models in vivid colors, but also some black and white images that resemble photographs. Is that true? Is it possible to photograph a virus?

FLORIAN KRAMMER: Yes, it's similar to taking a picture, and it's always black and white. There are many different methods, for example the electron microscopy. In this case it's similar to taking photographic images, only that instead of photons, here, it is electrons that "make" the picture. But there are many other techniques, and they allow us not only to