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Noēsis

METAPHYSICS, QUANTUM MECHANICS, AND THE PHILOSOPHY OF PHYSICS

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in conversation with Michael Miller[1]

Ng: Can you tell us a bit about your training as a philosopher and how you got involved with the topics that you study?

Miller: I started out my undergraduate studies mostly focused on physics and was enrolled in the intensive physics major at the university I attended. They had what was called a core-curriculum where there were certain core paths that you could take for the first and second-year humanities and social science courses. I took the philosophy option which was an introduction to some episodes in the history of philosophy. This led to an interest in logic which eventually became an interest in computability theory. But all along, I was mostly focused on physics until towards the end of my undergraduate studies, at which point I started to get more interested in questions in philosophy of science and philosophy of physics.

So, I guess I came to univeristy already interested in philosophy but I got interested in philosophy of physics in particular when I started learning quantum mechanics. I could understand quantum mechanics as a computational algorithm, but I couldn't understand it as a physical theory — as a description of how the world really is. And so that became something that I was intensely focused on. But I was also still interested in doing physics, and so I went and worked on the ATLAS experiment at CERN. During that year working on ATLAS, my more foundational interests expanded beyond quantum mechanics to include quantum field theory. I applied to do a masters in the foundations of physics. During the masters, I was able to continue studying physics at the graduate level but also to spend a lot of time with David Albert. He had an enormous influence on me and through my interactions with him I became confident that philosophy of physics was the right path for me to pursue. I did my PhD at the University of Pittsburgh in the History and Philosophy of Science and I arrived there knowing that I wanted to work on the foundations of quantum field theory. Pittsburgh was just a great place to be working on those problems and that is where I developed my interests in the history of physics as well.

1. Michael Miller is an assistant professor in the philosophy department at the University of Toronto. He works primarily on the philosophy of physics and is interested in how mathematics functions as a language used to describe empirical phenomena.

Ng: It sounds like your introduction to Quantum Mechanics, as well as working with David Albert, facilitated your transition towards the philosophy of physics, even though you started out as a physics student. Can you think of a specific moment, event, or even problem where after tackling it or trying to solve it, you thought "okay, it's time to change gears and do philosophy of physics for real now"?

Miller: I remember when I was an undergraduate, I took the graduate quantum mechanics courses and in one of them we discussed non-locality and the EPR argument. I read that paper for the first time - that short little four-page paper - and I just couldn't shake it. The argument seemed airtight, but the conclusion turns out to be wrong, and the reason it is wrong is that the world exhibits this incredible phenomenon of non-locality. My first exposure to that paper was certainly one of the moments that pushed me in the direction of the foundations of physics.

Pandey: Your academic background is both in physics and philosophy and you've mentioned that you worked at CERN on ATLAS and now you're doing philosophy of physics. Do you consider yourself more of a physicist or a philosopher?

Miller: I'm a philosopher. You know, I studied lots of physics and math and did some physics research early in my studies, but my PhD training was in the philosophy of science. I'm employed in a philosophy department, all of my colleagues are philosophers, I publish in philosophy journals and things like that. So, by all the standard metrics, I am a philosopher and the kinds of research inputs that I have to contribute are primarily philosophical in nature. They're concerned with conceptual issues in quantum field theory, not with the development of new theories or new calculations. That said, a lot of my work involves engaging pretty closely with the physics literature and with physicists, so I think of myself as a philosopher who is very deeply engaged with physics, but what I have to contribute is very much philosophical in nature.

Ng: Continuing that line of thought, I think most people outside of the philosophy of physics, or even more generally the philosophy of science, are perplexed when they hear of the combination "Physics and Philosophy". To you, what is the nature of the relationship between Physics and Philosophy?

Miller: I think the fact that we think of these as totally disparate fields is a relatively recent phenomenon. You don't have to go that far back in history in order to arrive at a time when what people would call "physics" now and what people would call "philosophy" were very tightly integrated with one another and no firm distinction would really be drawn all the time between all parts of them.

There's certain ways of doing physics where you don't really need to work in a particularly philosophical mode: there's important physics to be done where the conceptual framework of the theory that you're using doesn't really enter into the question under discussion. Lots of important physics work gets done that way. But there are parts of physics where what you're doing is questioning the kinds of basic conceptual aspects of the theory and that is exactly the sort of thing that philosophers are interested in. In the foundations of quantum mechanics you find lots of this kind of work, but it's starting to expand throughout physics now. Then, from the philosophy side, you can do lots of interesting philosophy without worrying about physics, obviously. But, if you're interested in a certain kind of metaphysical project, the project of understanding what reality is fundamentally like, then it seems to me that one really requires input from physics. Philosophy of physics is that space where you can really interrogate to what extent the image of the world that physics delivers can be filled out into an answer to that sort of metaphysical question.

Pandey: You mentioned that some physics can be done without philosophy and that a lot of philosophy is not relevant to physics-related questions, but there's much debate about whether physics needs philosophy and a lot of people have talked about this: Einstein, Rovelli, Feynman, Hawking. Where do you fall in this debate?

Miller: I find it hard to imagine what physics done in an entirely philosophically neutral mode would even look like. The closest thing I can imagine is something like instrumentalism, though even that isn't really philosophically neutral. There are certain sorts of projects that you can get up and running if you adopt a thoroughgoing instrumentalism about a theory, and I can imagine certain kinds of purposes somebody might have that would make that a fruitful approach to doing physics. But, if you're interested in what the success of our theories tells us about the nature of physical reality, then it seems to me like there just is no way to do physics in a philosophically-neutral mode. You need to specify some kind of commitment about the nature of the connection between the formal manipulations you're doing with whatever theory you're working with, and the aspects of physical reality that you take that theory to be about. So my view is that there's lots of productive physics work that can be done without philosophy - or at least, without careful philosophical reflection - but it's hard to understand the project of physics without philosophy in anything but a fully instrumentalist mode. To just bracket out the connection between your theory and the world and to make your theory into a mere tool for prediction, is to render the project of physics less interesting. It takes out exactly the ingredient that makes physics one of the most fascinating things that there is to study.

Ng: So, we've talked about both metaphysics and philosophy of physics without actually drawing a stark line between them. Do you think analytic metaphysics needs science, specifically physics? Or is it possible to do good metaphysics without being informed by natural science?

Miller: Again, I think this is one of these questions where it just depends on what kinds of metaphysical questions you're interested in. There's lots of philosophy you can do well without input from physics and part of that is metaphysics. There's parts of metaphysics where it seems to me like the questions under discussion just don't really require input from the sciences. However, there certainly are metaphysical questions where the only way to build a theory that does justice to the kinds of reasons that we have for believing that we've got a grip on reality really requires appealing to things that we know from the practice of doing physics. So, if the question under discussion is about the ultimate nature of microphysical reality, then I think that the best way to approach the question is to avail oneself to the resources of our best physical theories. Of course, just because one is reasoning from the best physical theories that we've got doesn't mean that what you get is a fully settled picture of the question, because our theories as we have them now aren't the end of the story. We know that things are very likely to change, and probably fundamentally so, but I think it's hard to make progress on questions about the fundamental nature of the microphysical realm without input from physics. That said, I think trying to just read off the answer to that question about what reality is fundamentally like at the microphysical level, directly off the physics, is also a non-starter because the physics itself doesn't come with a full-blown metaphysical interpretation in the way that it's presented in the physics literature. So, there I think the tools coming from metaphysics can be really useful for clarifying what the space of options looks like in terms of how to fill out the picture that physics affords us.

Pandey: Physics shares a deep connection with mathematics and has for a while, yet they're very different fields. UofT has the physics and philosophy program, and also the math and philosophy program. How do you see the relationship between mathematics and philosophy differing from the relationship between physics and philosophy?

Miller: That's a good question. For whatever reason, thinking historically, early in the 20th century there's debates going on in the foundations of mathematics, which turn on questions about logic and how mathematics is connected to logic. So, at least in the last century or so, the connection between mathematics and philosophy has been less fraught, let's say, than the relationship between physics and philosophy. But, for me at least, the conceptual boundaries seem similar in terms of what kinds of productive back-and-forth one can expect, bringing tools from one side to bear on issues from the other.

Ng: Quantum Mechanics is obviously a hot topic in the philosophy of physics, although it is not the only one. And within Quantum Mechanics, interpretation is hotly debated. Do you have a favourite interpretation of Quantum Mechanics?

Miller: What I usually say about this question is that I'm not fully satisfied with any of them. There's a certain subset of interpretations of Quantum Mechanics that philosophers of physics seem to take seriously and those are: Bohmian Mechanics, Everettian Quantum Mechanics, and then varieties of spontaneous localization theories, realistic collapse theories. They all have various virtues, but they all face challenges and I guess for me, because of my interest in quantum field theory in particular, one of my central worries has always been that a lot of the focus on interpretations of quantum mechanics focuses exclusively on interpretations of quantum mechanics in the non-relativistic regime. That's problematic because when we move to a relativistic spacetime, some of the things that you do to solve the measurement problem in the non-relativistic regime work against the relativistic invariance of the theory. On that front Everett seems to do better than the other interpretations that people take seriously.

There is a problem in Everettian quantum mechanics however, which concerns where the probabilities of quantum mechanics come from. One thing I've never felt entirely settled about concerning Everett is the account that we have available for explaining why it looks to individual observers on individual branches like the world is probabilistic. People have offered arguments for why you should expect things to look that way for individual observers on individual branches, but I've never been fully satisfied with those explanations. And hence, while Everett gives you the tools to have a realistic theory of quantum mechanics, and one which can enjoy relativistic invariance of the sort that one wants in quantum field theory, I still feel unsettled about the nature of probability on the Everettian approach and for that reason, I don't feel fully satisfied with any of the realistic interpretations.

What I've become interested in recently are efforts to understand what's distinctly quantum mechanical about quantum mechanics. Recent work on this question goes beyond the standard debate about interpretations. The idea of this more recent work is to try to explain certain features of quantum mechanics, and in particular why nature exhibits the kind of departure from classicality that quantum mechanics amounts to, and not some distinct departure from classicality. Quantum mechanics is just one particular way that the world can fail to be classical, but it's not the only such way, and one question you might have is just "why that one?". Is there something about the way that quantum mechanics fails to be classical, which gives us some hint on what could be going on behind quantum mechanics.

Philosophers are just starting to get interested in these things, but for me that's a promising new way to come at questions about the nature of quantum mechanics which don't directly attack the measurement problem, and in that sense don't provide one with a new kind of interpretation of quantum mechanics. This strikes me as a productive new way to unpack what it is about the quantum realm that we find so mysterious or unsettling, or just wanting of explanation. My hope is that we might get some insight about quantum mechanics coming from this program which will eventually make the puzzles about quantum mechanics look different and somehow more natural.

Pandey: There's definitely areas of philosophy that are often criticized for their lack of applicability to real life. Do you believe philosophers have a responsibility to produce work that has real world applications?

Miller: I think I'm just going to say no, at least as the question is standardly understood. There are certainly people who have, in recent years, turned their attention to making their philosophical work applicable to more everyday concerns and I am fully in support of those efforts. But I think there's an important role for the kind of theoretical investigation that goes on in philosophy that doesn't have that immediate character of being applicable to what people think of as ordinary, everyday concerns. Ultimately, these questions about what reality is fundamentally like are centrally important for understanding who we are and what our place is in this universe. I guess there might be some sense in which worrying about such things is impractical, but I think that facing up to these questions is a fundamental aspect of being human and feeling as though one understands their place in the world to the extent that they can. To me, that is an everyday concern about real life.

Ng: Do you have a piece of work that you're most proud of? And what about it is meaningful to you?

Miller: The central problem that most of my work has been concerned with is how it can be that quantum field theory exhibits so many different mathematical pathologies, and despite that, still is the most empirically successful physical theory that we've ever had. I've tried to help make some progress with that question, and I think in the last 10 years or so, a small group of philosophers have started to really get into the details of how quantm field theory works and which parts of it are genuinely conceptually puzzling and which parts are only apparently so. So, I guess one thing I'm proud of is the progress that we've made in pushing the boundaries of our conceptual understanding of quantum field theory. This theory was often treated as a purely computational algorithm, because the mathematical problems in the theory were so bad. People just thought, keep your head down, use it as a formalism for extracting predictions and don't worry about what is going on conceptually in the background. I'm most proud of contributing to the project of trying to say something more about how to understand the theory realistically.

Pandey: Speaking of interpreting quantum mechanics realistically, Ian Hacking, who was also a philosopher of physics at UofT, famously said "if you can spray them, then they're real" about particles. What do you think of that quote?

Miller: I think Hacking was onto something. That quote is a slogan intended to capture his form of entity realism. That view has not been, by any means, a dominant view in philosophy of physics, at least. People tend much more often to subscribe to some form of what's called structural realism instead which is directly in tension with entity realism. But I think the kinds of considerations that Hacking made in arguing for his entity realism are quite compelling. What he is after in that quote is the suggestion that the kinds of causal control that we're able to establish over a given regime, or a given collection of phenomena, is the kind of evidence that functions as conclusive proof that there is some new kind of entity there in the world for you to engage with. As a prescription about how we come to have enough evidence to make that sort of conclusion, I think he was onto something. Something like causal control does seem to me to play a really important role in how we come to think that we've got enough reason to believe in the existence of some new particle. I think the challenge that Hacking ran into is just that it's not clear how seriously we need to take the slogan. It's not clear how much causal control over some new range of phenomena is sufficient for saying that we've really identified some new item in the ontology of the world. So, there's challenges in applying the view to particular cases and I think to fully fill out the program, more would need to be said about that but in general I'm quite sympathetic to his picture. I don't favour structural realist views because of the kind of commitments about the connection between mathematics and reality that they involve.

Ng: I just have a short, fun question, do you have a favourite particle?

Miller: Favourite particle?

Ng: Or maybe, if it's easier, do you have a favourite field?

Miller: I guess I'd say I think photons are interesting for a number of reasons and they cause conceptual trouble in quantum field theory. That trouble comes from the fact that they are massless, or at least they appear to be massless, as far as we can tell. But massless particles, because you're working in a theory with relativity, have a funny feature. In quantum field theory, particle number is not conserved, so you can have processes that create particles out of the vacuum and because photons are massless, creating very low momentum photons costs almost no energy. Because of this, we think that the idea of a bare electron propagating through space turns out to be not what electrons really are like, precisely because they're constantly radiating clouds of low momentum photons and this actually causes a particular kind of difficulty in quantum field theory called infrared divergences. I've spent a fair amount of time thinking about those divergences and what they mean about the physical nature of physical electrons propagating through space. To the extent that I've thought about individual particles, I guess I've been interested in the massless ones. There's other massless particles too — gravitons and gluons are also massless. They also give rise to the same kind of difficulties.

Pandey: Can you tell us about the work you did on the ATLAS project.

Miller: I did a couple things. A lot of the work I did was concerned with writing monitoring software for what's called the hadronic calorimeter. Basically, you've got a very complicated machine with like a million read-out channels — don't quote me on that number — but with a very large number of read-out channels and in order to understand how the detector is functioning, and to ensure that you're collecting reliable data, you need a way to gather information about detector performance in real time. That requires elaborate software to be able to generate plots about detector efficiencies and things like that. The way those big experiments are divided up is that you have groups from different universities, and those groups tend to focus on one detector subsystem. The part of the physics analysis that each group works on is often linked to the natural kind of process for the detector component that they're working on at the machine level. For the hadronic calorimeter, the physics questions tended to circle around the reconstruction of hadronic jets. When you have particles that go through a process called hadronization, you can get jets of particles after a scattering event at the LHC. The group I was working in was developing that kind of jet reconstruction software and testing its performance. That was the physics part of the analysis that was going on when I was there.

Pandey: The last question we have for you is: what advice do you have for young philosophers of physics and science?

Miller: Young philosophers of physics and science ... I guess my advice is that it's easy to feel like you're getting pulled in too many different directions. Focus on the questions that you find most interesting and if that leads you into the physics for a while, then follow your nose that way. And if you're getting drawn back to the philosophy, then follow your nose that way. At the end of the day, to do philosophy of science at the highest level, you've got to have good familiarity with the relevant science, but you also have to be a philosopher, and you have to have a reasonable command over all parts of philosophy, not just philosophy of the particular science that you're interested in. The philosophy of science and philosophy of the particular sciences are challenging parts of philosophy to work in, precisely because you have to do two things at once. You've got to be doing the science, and doing the philosophy. As a discipline, it's sometimes thought of as siloed, in that the philosophers of science do their own thing. I think that that's a trend to be resisted. Philosophy of science is done at its best when it's treated continuously with other parts of philosophy — metaphysics, epistemology, language and so on. So the advice is: you eventually have to arrive at a place where you've got full command over the science, and over the philosophy. But, the way that you get there doesn't matter so much. There's not one unique path into philosophy of science, there's lots of different ways to get there in the end. And if you're just following what you're interested in all along the way and that's where you end up, then that's great. It's not the kind of thing that you can really force.