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I N T E R V I S T E

Conversation with Tim Maudlin

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Tim Maudlin is one of the most important philosophers of physics around. Professor of philosophy at NYU, he is the founder and director of the John Bell Institute for the Foundations of Physics. He is a member of the Academie Internationale de Philosophie des Sciences and of the Foundations Questions Institute (FQXi). He is also a referee for prestigious publishing houses and journals including Cambridge University Press, Oxford University Press and Foundations of Physics. Specialized mainly on the metaphysical foundations of physics, he is the author of several articles and four books: Quantum Non-Locality and Relativity: Metaphysical Intimations of Modern Physics *(1994, 2002, 2011);* The Metaphysics Within Physics *(2007);* Philosophy of Physics: Space and Time *(2012); and* Philosophy of

Physics: Quantum Theory *(2019). In this interview, Professor Maudlin talks about the concept of time between physics and metaphysics.*

1. Professor Maudlin, thank you very much for accepting our invitation for this interview. I'd like to start with your first approach to philosophy. You studied at Yale University and you earned your Ph.D. in 1986 from the University of Pittsburgh. How has philosophy influenced your studies?

TM: There are several characteristics of a philosophical training that one tends not to get anywhere else. The most important is strict attention to the precise meanings of terms and to the conceptual resources being used. Since philosophy often has nothing to rely on except abstract argumentation, one becomes sensitive to both fine gradations in meaning and to hidden premises (or outright invalidities) of arguments. Another aspect of philosophy that is useful for foundational work in physics is the skill of close reading and the habit of going back to original sources. Physicists often do not know the historical origins of the theories they learn from textbooks and are even positively misinformed about them. They often also pick up the habit of just attending to the equations in papers and skipping the prose, whereas the prose is where the exact significance of the equations is addressed. Finally, philosophy is the search for foundational principles, and always tries to look deeper into things if possible. It is not satisfied with mere pragmatic success unaccompanied by understanding. Physicists are often trained to be satisfied with that, hence the slogan "Shut up and calculate".

2. What led you to focus your interests on philosophy and physics? Which philosophers or physicist have influenced your attitude the most?

TM: The pairing of philosophy and physics is quite a natural one. In one sense, philosophers are always trying to "get to the bottom" of things. That incessant desire to probe the foundations of beliefs that are generally taken for granted is what got Socrates in the position of having to drink the hemlock. There is a related sense in which of all the empirical sciences physics "lies at the bottom". It is glibly said that biology is just applied chemistry and chemistry is just applied physics. That misses the structure and importance of the special sciences, but there is still a grain of truth in it. Every biological system and every chemical system are also a physical system that can in principle be subjected to physical analysis, but not every physical system is either biological or chemical. Physics aspires to a universality

unique among the empirical sciences. So the same impulse to "get to the bottom of things" leads naturally to both physics and philosophy. On the philosophy side, I have probably been most influenced by Plato, Hume and Lakatos. On the physics side, by Einstein and John Bell.

3. What contribution can philosophy bring to physics?

TM: What a philosophical disposition can bring to physics is, mostly, a demand for conceptual clarity and precision of argumentation and expression. Einstein famously read Hume as a young man, and it shows.

4. You certainly know that Stephen Hawking declared that philosophy is dead since the main issues philosophy has struggled with for centuries have now entered the domain of physics. What is your opinion about this claim?

TM: I'm sure that Hawking read little to no actual contemporary philosophy, including philosophy of physics. Reading must have been difficult for him, and he had other things to spend his time on. Since he himself seemed have no coherent exact understanding of quantum theory (at least, he never exposits or defends one), he would not be in a position to explain how physics really resolves most physical problems, much less philosophical ones. He did not seem to appreciate what well-executed philosophy is like, and admittedly much of it is not well-executed. But I see no reason at all to regard him as well informed about philosophy.

5. Do you think that philosophy has a specific method of inquiry which distinguishes it from other kinds of research?

TM: No: what makes philosophy special is not what it has but what it mostly lacks: direct empirical testing. Philosophical disputes can generally not be resolved by experiment or in a lab. Since all you have to rely on is argumentation, philosophy demands that one be meticulous about arguments, both in articulating the premises and attending to the inferences. A philosophical ear is closely attuned to pick up ambiguities and the fallacies that ambiguity allows. It also notices the gaps or elisions or plain errors in argumentative structure. One sees a similar situation with regard to different basic approaches to understanding quantum theory, or about the fundamental nature of space and time. These are clearly physical questions, but they

generally cannot be resolved in any straightforward way by observation or experiment. So, they are the sorts of questions philosophers are better trained to address than are physicists.

6. Let's now move on to the concept of time and in particular on the arrow of time. I will start with a very "simple" question: What is time?

TM: Time is a fundamental aspect of physical reality. Exactly because it is fundamental, and not derived or constructed from anything else, one cannot answer the "what it is?" question by providing an analysis or definition. It is rather in terms of temporal structure that other things get explained or defined. Since the Theory of Relativity, we have become used to thinking of time as an aspect of a larger spatio-temporal structure, which has "time-like", "space-like" and "light-like" characteristics. The time-like and light-like characteristics have a directionality to them: unlike the space-like aspect, each of these divides into a future-directed and past-directed part relative to any event. So, I could say that time is an intrinsically directed aspect of the fundamental geometrical structure of the universe. But in the most immediate sense we all know what time is, and something about the role it plays in the world, by every aspect of our everyday experience. If someone had no temporal experience (which is impossible, but still…), no one could possible convey to them what time is.

7. Well, Julian Barbour (1999) states that time does not exist. In case you agree with him, what is the main argument in support of this view? In case you disagree, what is the main argument which justifies your disagreement?

TM: The main argument against Barbour is that 1) temporal structure is a fundamental aspect of every experience we have and every verb we use to describe the physical world 2) we have a quite successful account of temporal structure in the General Theory of relativity and 3) there is no "analysis" or "account" or "reduction" of time to non-temporal items that can provide an explanation of the world as we understand it. Barbour, for example, wants to try to "reduce" time to an infinite set of non-ordered purely spatial objects he calls "time capsules". According to him, the ordering of these time capsules into a temporal sequence is not an objective physical fact but rather an act of "closest matching" that is somehow done by the mind to create a sense of temporal flow. But 1) no mind has access to even one of these "time capsules" since they include the spatial structure of the entire

universe 2) even if a mind had access to them, the computational job of ordering them by closest matching would be beyond anyone's computational abilities 3) it makes no sense to even talk about the mind "ordering" or "computing" anything if the mind is not already something that operates in time, so the whole account is question-begging and 4) even if we ignore all that, there is no explanation of why the set of "time-capsules" that exist should even have the right structure to be matched up in sequences at all. A random collection would not have that structure. The obvious explanation for why the universal states of the universe form a smooth sequence from the Big Bang to the present day (and beyond) is that they are sequentially generated by a process that takes place in time. Positing the collection with its special features without the generation of them in time leaves you with no explanatory resources to account for the obvious fact that they fit together so well.

8. With regard to the same issue, in the chapter "On the Passing of Time" of your famous book The Metaphysics within Physics *you argue that time really passes. Can you explain what you mean in simple words?*

TM: The fact that time passes — i.e. that it has the fundamental asymmetry we express in everyday words like "there's no use crying over spilt milk" (but there is a use in trying to prevent milk from being split in the future!), or that we express by saying that time "goes by", or "flows", or "passes" (concepts that have no spatial analogs)—is a fundamental fact about the nature of time that cannot be "explained" by appeal to anything more basic or more familiar. Every physical account of the world must end somewhere, with the basic structures that account for everything else, and temporal structure is one of those. That does not, of course, make the passage of time somehow mysterious or obscure. We all know, in an intuitive way from every experience we ever have, what it is for time to pass. If someone honestly claimed to have no idea what I was talking about, I would not know where to begin, not least because if such a person were serious they would not understand the concept "begin". Arguments and explanations *start* from premises and *result* in theorems or conclusions, and the grasping of them is a temporal process. Everyone knows what the direction of time is, and we cannot even imagine a conscious creature with no time sense. Understanding the precise geometrical details of temporal structure may well require understanding the General Theory of Relativity and Lorentzian manifolds and so on, which can't be explained in simple terms. But

if one did not already understand the immediate directional flow of time, one would have no idea what that theory was even in the business of accounting for.

9. It seems that the arrow of time represents a topic where physics and philosophy meet each other. How do you think it originated? What can physics and philosophy tell us about this arrow?

TM: Since I take time to be an intrinsically directed aspect of the geometry of the world, I do not think that the directionality (the "arrow") can be reduced to or explained by or accounted for by anything non-directional and more basic. In that sense, the "arrow of time" did not *originate* in anything else. It is not, for example, the direction of the gradient of entropy. If it were, then it would be analytically impossible for entropy to decrease, since "decreasing" is "becoming lower as time goes forward to the future". But every understanding of entropy we have allows it to decrease and even predicts that, given enough time, it will decrease. So, the proposed analysis of the direction of time in terms of entropy fails. The interesting question that needs to be answered is rather why the entropy of the early universe (where "early" is explained *in terms* of the direction of time!) was as low as it was, which allowed plenty of room for it to monotonically increase before approaching anything like equilibrium. That is one aspect of the cosmological question of whether the universe had an "original state", and if so, what characteristics it had, or if it had no "original state" at all. If it did have one, there is the question of what would even count as "explaining" or "accounting for" it, since such an explanation could not be causal. If there was no beginning (as in the theory of "eternal inflation") then we are left with the puzzle of how an infinite amount of time could have elapsed to bring us to the present. But these questions about the origin—if there is any—of the universe do not appear to be ripe for solution yet.

10. In addition, this debate involves metaphysical reflections concerning the concept of "primitive." Indeed, you claim that the flow of time is primitive. What does "primitive" mean to you?

TM: As mentioned above, any account of the universe must ultimately depend on some primitive postulated entities or structures or laws: the fundamental things from which everything else is constructed and explained. There is nothing at all special in postulating primitives. Every theory does

that. I think that the directionality of temporal structure is primitive because it seems like the sort of simple, basic property that is a natural stopping point of analysis and because I don't even understand what a purported "explanation" or "reduction" of it could look like, for the reasons given above. Physical explanations presuppose temporal order, which underlies causal order and explanation.

11. In your book you suggest that the laws of nature and directed time are assumed as primitive in the so-called «anti-Humean metaphysical package». What do you mean by «anti-Humean metaphysical package»?

TM: A "metaphysical package" is just a collection of postulated metaphysical primitives or fundamental items in terms of which everything else is to be explained. They form a "package" in virtue of how they interact with and are presupposed by each other. For example, the Schrödinger equation, which is postulated as a fundamental physical law not reduced to or accounted for by anything else, is stated in terms of both a time parameter and a wavefunction. So, to take that law seriously as an expression of a fundamental physical (and hence metaphysical) fact requires also accepting as physically fundamental a real temporal structure of the universe and something physically real that is represented by the mathematical wavefunction. Further, since it is presented as the articulation of a physical law, one needs to take the status of lawhood seriously. I take all these things—temporal structure, quantum states (represented by wave functions), and laws—seriously as ontological primitives. A Humean does not accept lawhood as a physical primitive, but tries (unsuccessfully, in my view) to reduce it to something else. A Humean could take the direction of time as primitive, but for some reason actual Humeans tend not to and try to reduce *that* to something else. And there are Humeans who also do not want to accept quantum states as primitive, since they are non-local items and the "Humean mosaic" is supposed to be a local sort of thing: just local items juxtaposed spatiotemporally, and hence a "mosaic". So, there is almost no overlap between a "Humean metaphysics" and mine.

12. Another issue is the relation between the arrow of time and other arrows, such as the cosmological and the causal ones. Do you think that the arrow of time is reducible to any other arrow?

TM: Causes precede their effects, so the causal arrow is ontologically parasitic on the temporal one. The cosmological and thermodynamic arrows are just temporal asymmetries in the universe that are accounted for by the laws of physics generating later states from earlier ones. The asymmetries arise due to the special nature of the initial or earlier states. Whether that in turn can be somehow explained or accounted for is a hard question, addressed a bit above.

13. At the end of the chapter «On the Passage of Time» you defend your view from a number of arguments according to which the flow of time is only «an illusion or merely the product of our viewpoint, or an appearance due to our special mode of perception». With that, you claim that the passage of time is not a "myth". Which is the argument that you have found the strongest one to oppose?

TM: Perhaps the most entrenched argument is one that takes the fact that the laws of classical physics—and maybe quantum physics—have a technical feature misleadingly called "time-reversal symmetry", to suggest or imply that there is no direction of time. This is just a confusion caused by bad terminology. I might remark that a physical equation has a formal feature called "symmetry under parity", and explain that it implies that if one does an experiment and its mirror-image—reversing the "handedness" of all the apparatuses, as in a mirror—then the results will similarly be mirror images. That is the sort of thing I can actually check (and it turns out not to be true). But what could it possibly mean to compare an experiment with another that is just like it but "run backward in time"? No experimentalist, or anyone else, would have a clue how to do that, since time direction itself can't be reversed. What is meant, of course, is something much simpler and obvious: not *time* reversal but *velocity* reversal. If in one experiment, for example, some particles are moving east-to-west, I know perfectly well what the velocity-reversed experiment looks like: particles would run west-to-east. (Indeed, there is an obvious relation here between velocity reversal and reversal of parity.) The "time reverse" of a bottle falling to the ground and smashing is a bunch of shards of glass on of the ground gathering together, forming into a bottle and rise into the air. That, of course, is not something I can arrange for in the lab even though the laws of physics imply it is physically possible. But note: in the description of the "time reversed" event *I did not change the direction of time*. It is the direction of time itself that distinguishes a bottle falling down from a bottle jumping up. So, the idea that ve-

locity-reversal symmetry suggests that time has no direction is just a conceptual error promoted by a bad terminology. But it seems hard to eradicate.

14. Let's conclude by talking about some very general issue. At the end of the same chapter you explain the way you conceive metaphysics and ontology. Basically, you do not draw any distinction between them, so that they reduce to the same thing. Can you try to clarify this view?

TM: I'm not sure how to make that clearer. We inherited the term "metaphysics" from some later editor of Aristotle's works, who slapped that name on some of Aristotle's writings that never, ever use it. What Aristotle does in those works he gives three names to. One is "theology", but that is clearly too narrow for the extent of what he discusses. One is "first philosophy", which tells you that the subject matter is somehow absolutely basic and fundamental (primitive) but does not tell you exactly what the subject matter is. Since physics is called "second philosophy", it does locate this subject matter in relation to physics, and from that we get "metaphysics". But what is physics? Physics is the study of things that exist *insofar as they have an internal principle of motion and rest*. So, numbers, for example, do not fall within the purview of physics even if they exist. Rocks do, because rocks have a natural motion: they fall. Aristotle's third characterization of the subject matter of the Metaphysics is "the theory of being *qua* being", or in other words the study of things that exist *simply insofar as they exist and nothing else*. It is the theory of what exist and the different manners or types of existence. So, whether numbers exist, and if so, what they are, is a topic for metaphysics even if not for physics. But "ontology" just is the direct Greek word for the theory of existence, the account of what exists. So etymologically, "ontology" and "metaphysics" are just different ways to refer to the very same thing. Anyone who thinks otherwise does not understand the origins of those terms.

15. Finally, what are the current research perspectives which aim at solving the dilemma of time? Do you have any future research project related to the issues of time?

TM: Since I don't think there is a "dilemma" of time to be solved, I don't think there is any research to be done on that. Time is an intrinsic and intrinsically directed aspect of the fundamental geometry of the universe. There is an interesting question of what exactly that geometrical structure is. For ex-

ample, there is the question of whether it is intrinsically a continuous structure which contains an infinitude of "points" or "events" with zero magnitude, or whether it is a fundamentally discrete structure that is inherently finite. Most of modern mathematical physics is predicated on the former assumption, although everyone acknowledges it might just be a useful approximation (as representing water as a continuous medium is useful for many purposes but breaks down at a fine enough scale). At present, I am working on a mathematical account of discrete geometry, including discrete spacetime geometry with a temporal aspect. That would be important for a fine-grained account of the structure of time, although not for the direction of time, which is taken as primitive.

References

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