

A conversation on quantum gravity

What is quantum gravity? That is a question to which there is, as of yet, no decisive answer. The highly successful theories of quantum mechanics and general relativity do not match, and to reconcile them is an open problem. Over the years, many approaches have been developed in an attempt to harmonize the two in a single theory of quantum gravity, some of which I highlighted in a [recent article on the Quantum Universe website](#). To keep track of the developments in the different approaches is a Herculean task, even for the experts in the field. With this in mind, Jácome (Jay) Armas decided to interview the leading experts working on the different approaches, and collected these interviews in a book with the name 'Conversations on Quantum Gravity'. For the Quantum Universe website, the roles have been reversed, and it is now Jay who is interviewed. Spread out over two articles, Jay answers questions about his work, his own views on quantum gravity, his book, his outreach activities, and more.



Jay Armas with his book.

Note: the interview was conducted on the 10th of February 2025, in English. To keep the answers close to the original answers, we decided to keep the text in English rather than translate it to Dutch.

A conversation on ‘Conversations on Quantum Gravity’

Jay, in your own opinion, what are the main problems in theoretical physics at the moment?

(Laughs) I think my answer to this question will be very different from the answers given by the physicists I interviewed for the book. Overwhelmingly, in the book you will find that the

most interesting question is to understand how to combine [quantum field theory](#) with gravity, and once successful as in the case of [string theory](#), the most pressing questions deal with exploring the consequences of such a unified theory. This is a very interesting research direction but the questions that drive me personally, are those that can be addressed in other parts of physics using the lessons and methodologies that we learned from string theory.

For instance, I am particularly interested in understanding how to characterize the collective behaviour of different [phases of matter](#) across scales. Matter organises itself into various forms depending on the different arrangements of its microscopic constituents, and understanding the mechanisms/interactions that lead to those arrangements as well as the macroscopic description that emerges at large distances are for me the most exciting questions. I should clarify that, when I speak of “matter”, I do have a very broad understanding of the word, as “matter” can stand for phases and materials that we know of, such as superconductors, superfluids, plasmas, crystals, metals, spin ices, fractonic matter, etc, but also for black holes, and even gravity and the [D-branes](#) from string theory themselves.

For instance, I think that a very interesting question is suggested by string theory, namely, if gravity is an emergent effective description arising from the interactions of some kind of building blocks, then how can we characterise gravity as a phase of matter using generalised notions of [symmetry](#)? What about the [de Sitter](#) vacuum itself? String theory naturally harbors diverse notions of symmetry such as [higher-form and higher-group symmetries](#), which were shown in the past few years to be a more useful guiding principle for characterising even the most common phases such as plasmas and crystals. Perhaps even more surprising is that these notions of symmetry can also shine light on the description of living forms of matter that are inherently out-of-equilibrium, what physicists refer to as active matter. How to push the boundaries of physics dealing with inanimate matter in order to tackle the problem of describing animate matter for me is one of the most important questions at the moment, and one that methodologies from string theory can help with, in particular once living matter is viewed as a driven open system.

Questions such as ‘how does a generalised [second law of thermodynamics](#) emerge for such systems?’, or whether fluctuation-dissipation theorems are broken, are at the core of understanding the problem of the [arrow of time](#) that emerges at large scales. Interestingly,

while this seems to be a quite remote affair from the point of view of string theory, currently we see a push within string theory to understand [holography](#) of open systems, thermalisation and chaotic properties of strongly coupled field theories, out-of-equilibrium properties of de Sitter spacetime, etc, which can actually provide general lessons about how to tackle out-of-equilibrium systems in general. Understanding this more formally for me is a very important question and my preliminary guess is that patterns of symmetry breaking in which time translation symmetry is broken are key for making further progress. That was a big answer (Laughs).



An unbalanced scale. How to describe animate (out-of-equilibrium) matter is one of the most important questions for Jay. Credit: [winnifredxoxo](#), via Flickr.

That is already very much related to my second question, which is about your own work. You work on all these things, so, first of all, on string theory and black holes. But, if I understand correctly, you also work on hydrodynamics, and that's a buzzword that you did not yet mention.

Right. Let me give you a bit of context. One of the key concepts for describing phases of matter of either closed or open systems is symmetry. However, if you want to understand the collective behaviour of those phases of matter you need something else – in fact, you need hydrodynamics. For instance, how does this table respond if I hit it with a heavy object and kick it out of equilibrium? Such perturbations to the system (here, the table) will elicit a

response and that response is referred to as a type of “collective behaviour” in complex systems lingo, as it typically involves a non-trivial concerted effort of the microscopic constituents that make up the matter in question.

It has become clear in the past decade that [hydrodynamics](#) provides a universal language for describing collective behaviour across scales, applying to systems ranging from traffic jams (made out of cars as building blocks) to [black holes](#) (whose building blocks we are still searching for). Not surprisingly, it is precisely using the language of hydrodynamics that we describe elastic waves propagating in this table once I hit it with an object. In high-energy physics lingo, ‘hydrodynamics’ is just a stand-in word for ‘low energy non-equilibrium [effective field theory](#)’, which is what you expect that you should develop if you want to understand matter near equilibrium.

So, you apply ideas from hydrodynamics to string theory and black holes, but also the other way around

Indeed. The interest of many string theorists in hydrodynamics arose primarily when, in the context of the [AdS/CFT correspondence](#), it was realised that deformations of certain types of black holes in the bulk of an Anti-de Sitter spacetime are captured by a hydrodynamic expansion in the dual field theory living at the boundary. These black holes are special in the sense that they have planar [horizons](#), that is, certain directions of the horizon extend arbitrarily far. When these black holes are deformed, say by throwing a small rock into the black hole, they behave as if you had thrown a rock into the water, that is, they behave according to the rules of hydrodynamics. In fact, this is a special regime in which AdS/CFT can be shown to hold precisely and agrees with the expectation that every quantum field theory admits a hydrodynamic regime.

Interestingly, soon after, it was realised that the duality between black holes and hydrodynamics extends beyond AdS/CFT, hinting at the fact that black hole physics can provide a theoretical laboratory for testing and developing hydrodynamic theories – an example of this more general viewpoint is the so-called blackfold approach. Personally, I began thinking about fluid dynamics because I wanted to understand the behaviour of black holes in string theory, and then realised that you could make a black hole that mimics almost every phase of matter you would wish for, like a solid, a viscoelastic material, a piezoelectric

and plasmas around accretion disks. Thus, gravity can help you understand the low energy effective field theory of phases of matter and once you learn these lessons you can take a step back and say, let's just forget about the black hole and apply the effective field theory formalism to the phases of matter directly.

At the end of the day, you don't need the black hole anymore, however, I myself can never fully understand hydrodynamics of a given phase of matter if I don't really understand how I can make the corresponding black hole. That, you could argue, is just my problem, but making the corresponding black hole is just another way of asking for a microscopic example that realises the given hydrodynamic theory, very similar to requiring a specific kinetic theory example.



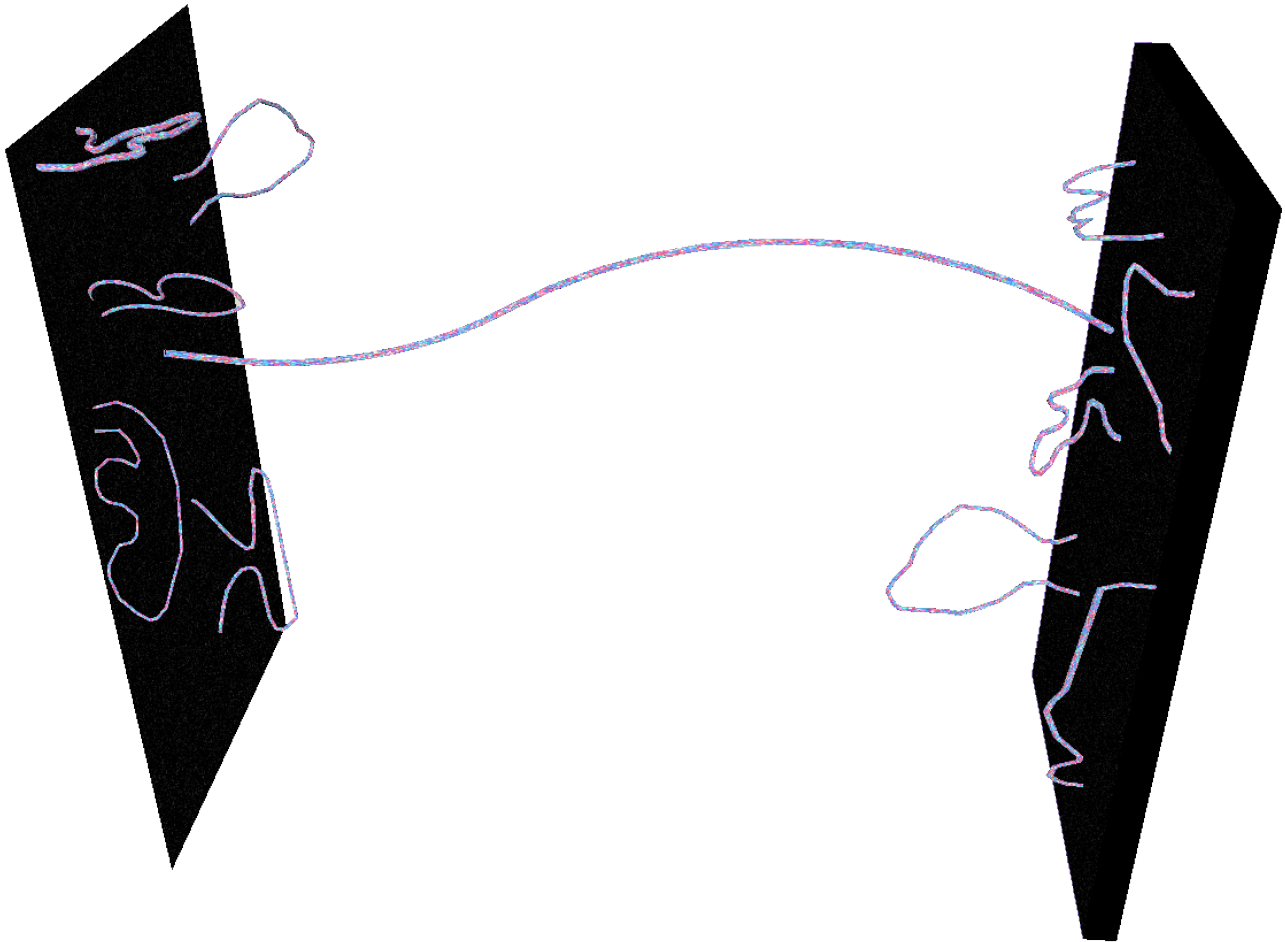
Artist impression of black hole. Black holes in string theory can mimic almost every phase of matter. Credit: [ESA/Hubble](#).

Next, a question about the book itself. What inspired you to write the book 'Conversations on Quantum Gravity'?

When I was a PhD student, I started a program of science lectures, called '[Science & Cocktails](#)', and I invited many people to speak in this program. One of the people I invited was the neuroscientist Susan Blackmore. She wrote the book 'Conversations on Consciousness', which I read and thought was an amazing book because it gave me an

overview of the field of consciousness. This book consisted of a collection of interviews with neuroscientists about their theory of consciousness, which was at the time, and as far as I understand still is today, a totally open problem. No one knows what is the right way to think about or describe consciousness. When I read that book, which is actually really accessible to anybody that doesn't know anything about neuroscience, I got an overview of what was happening in that field, and I thought that was amazing.

Just after having that thought, I also realized that, actually, the field that I am in is in a similar state. There are [many different proposals for a theory of quantum gravity](#) and there is no evidence for any of them. In other words, we don't know which one, if any, is the correct one. I wanted to know how much value one should assign to each of these proposals, what results each of them had accomplished and what the future could potentially bring. Each theory of quantum gravity has its own community of physicists that pursue it and as a PhD student I only had exposure to my own. So, I thought I would just do precisely the same thing that Susan Blackmore did: interview experts in quantum gravity and compile a book. Admittedly, originally, I wanted it to be as simple and accessible as the book by Susan so that everyone could pick up the book and get an overview of the problems in quantum gravity. It turned out, though, that the book became very technical due to the nature of the interviews and I wouldn't really recommend it to anyone without some basic training in physics.



Afbeelding 4: Open strings on a brane. There are multiple reasons that make string theory Jay's preferred approach. Credit: [Rogilbert](#).

What was your viewpoint on the different approaches to quantum gravity before writing the book, and did your opinion change after finishing the writing?

Yeah, sure it did. Before writing the book I admittedly did not have an opinion about which viewpoint was the best. I know for a fact that I didn't have such an opinion because every time, after interviewing someone, I was like, "wow, amazing". No matter who the interviewee was, every time I felt blessed by the enormous knowledge that each person had and the discoveries they had made. This "wow" effect changed over the years not only because I began collecting all these interviews and digesting them but also because it took about 10 years and I had evolved as a physicist since then.

Once the book was ready I did my own "meta analysis" of the interviews, bundled the interviews into different groups of "followers" and studied what each approach had accomplished and whether there were contradictory statements within the same community.

My end conclusion is that string theory is great and I was part of the right community. I do not wish to be part of other communities at least for now. However, I am very curious about the developments in other approaches and think that a volume 2 of the book would be useful to become updated with latest developments.

So string theory is your preferred approach?

I think that everyone has to decide for themselves and the book can help in reaching a conclusion. String theory is certainly my preferred approach, not only because of the many indisputable (and basic) results it has accomplished (e.g. [black hole microstate counting](#), recovering [Einstein's equations](#), dealing with divergences at high-energies, etc) which other approaches are still trying to show, but also because of the countless number of connections and bridges it has made with other fields including mathematics (e.g. [mirror symmetry](#)), astrophysics (e.g. [dark matter](#) candidates), quantum matter (e.g. holographic methods for strongly coupled systems), quantum information (e.g. complexity and [error correcting codes](#)), particle physics (e.g. gauge mediation and [supersymmetry](#)), heavy-ion collisions (e.g. the viscosity over entropy ratio), etc, to mention only a few.

I think it is in fact remarkable that such a small group of physicists worldwide (a community of about 500 to 1000 people) made a big stir in many adjacent fields by pursuing this thing we call string theory. At some point it would be great if a historian of physics would write an in-depth book on the history of string theory.

In part 2 of the interview, currently planned to appear on 9 January, we continue our conversation with Jay, and he discusses, among other things, his favourite interviews from the book, his outreach activities, and the role of a physicist in modern society.

Jay's book, [Conversations on Quantum Gravity](#), was published by Cambridge University Press and can be ordered both digitally and as a hard copy via [their website](#).