Newsletter No. 3

- for the Indiegogo crowdfunding campaign

A THEORY OF EVERYTHING

Cadiz, Spain 24.12.2017

Hi everyone,

merry christmas!

A few days ago Johannes and I posted a new preprint on the archive. In this preprint we analyse the question, which I also discussed in my last newsletter to you, namely whether our quantum theory has a connection to the quantum theory of fields (perturbative quantum field theory) that has been used by physicists for decades. We find that this is indeed the case. In this newsletter I will try to explain to you what we have found and what I believe it means.

Let us begin with the most tasty parts and leave the potatoes for later. I believe that our results imply:

1. that a theory of quantum gravity may not exist. Einsteins theory of relativity could be a purely classical (non-quantum) theory.

2. that quantum field theory exist because points don't.

3. that Einsteins theory of relativity may be an output of our theory.

4. that there was no big bang and that black holes are not infinitely deep.

I will try to make my explanations as simple and non-technical as possible, but if you should get stuck somewhere I suggest that you just jump ahead a sentence or a paragraph.

1. Once upon a time at Penn State

Around 2009 Johannes and myself visited Penn State University to see Professor Abhay Ashtekar, who is one of the founders of loop quantum gravity. During our stay at Penn State we also visited the mathematician Nigel Higson, whom I had previously met at various conferences. Higson asked us to come by his office one afternoon, where he told us that he had read our papers and that he liked our ideas but believed that the 'measure' we were using was not the right one (the 'measure' is a key mathematical ingredient in a quantum theory).

Higson was right, both Johannes and I knew that, but at that point we did not know what other measure we could use. Not until 8 years later, in september 2017, when we published our preprints with the result that we have a theory, that exist in a rigorous sense.

During those years I had kept Higsons words in the back of my mind and thus I was keen to write to him once more to let him know that we now believed that we had found the answer to his question. And so I did, I sent my email to him one sunday morning in early October and Higson replied just 6 hours later.

In his reply he told me that the answer we had found reminded him very much of a mathematical construction he had made with the mathematician Gennadi Kasparov in 2001 — and sure enough, when I checked his paper I found it to be the case. One of the key ingredients in our theory (the Hilbert space) had the same structure as Higson and Kasparov had used 16 years earlier.

But there was something more. One of the central pieces in their construction looked different from the one we were using. It had an extra little 'thingy' attached to it, a mathematical nicety, which made a lot of sense from a mathematical point of view but whose physical meaning was not clear to us.

So we began to toss this little extra thingy around. Play with it. I kept it in my mental pocket when I went walking in the forest and I fiddled around with it in my evenings as I sat in front of the fire. And then one day we realised that this 'thing' was in fact a *key* and that this key opens the door to quantum field theory. Once we put it the right place and turned it around everything opened up in front of us.

2. Turning the key

What is a quantum theory? Well, as I have written about previously a quantum theory consist of two basic ingredients: operators and a Hilbert space. These two components form the backbone of any quantum theory, where the operators encode the physical degrees of freedom of the system at hand and where the Hilbert space is the place where we get the numbers, which we need for our experiments.

Remember my metaphor with actors and theatre stages: the operators are the actors and the Hilbert space is the stage where our actors *play*.

But there is a third ingredient, which is what is called a Hamilton operator. This is what makes time tick. The Hamilton operator is — in my theatre metaphor — the *play* that the actors perform. The Hamilton operator defines precisely what theory we are dealing with.

Now, when Johannes and I started to look more closely at the construction that Higson and Kasparov were using we realised that their little extra thingy — and from now on I shall call it by its propper name which is a Bott-Dirac operator (yes, in math and physics we know how to pick cool names!) — we realised that it gives us the Hamilton operator for the theory that we are looking at.

And what theory is that? Well, perhaps you remember that of all the forces in Nature — the electro-magnetic, the strong and the weak nuclear forces and gravity — the first three can be described as what is called a Yang-Mills theory. Gravity is slightly different, it can be formulated in a very similar manner, but the Hamiltonian has a different structure. Now, it turned out that the Bott-Dirac operator, which Higson and Kasparov used, gives us the Hamiltonian of a Yang-Mills theory.

Wow, this is kind of nice. But hang on, it gets even nicer.

Because Johannes and I then became curious and decided to try to formulate a different theory within this setup. Instead of the operators, that we had previously used, we decided to construct a new set of operators, that match what is called a scalar theory (this is the type of field theory that describes the famous Higgs particle) and to put it into our machinery.

And what did we find? We found that the Bott-Dirac operator gives us the correct Hamiltonian also in this case.

Nice! So no matter what theory we feed into this machinery this magical Bott-Dirac operator will give us the correct Hamiltonian? Well, it looks that way. And in fact, there is more.

Because the way that this Bott-Dirac operator works it naturally includes an additional sector of what is called fermions.

Fermions? Lets pause for a second to explain this. In nature there are two basic kinds of particles. Bosons and fermions. The bosons are what constitute the forces in Nature and the fermions are the 'stuff'. An electron is a fermion and a photon is a boson.

Now, the quantum field theories of bosons and fermions look fundamentally different and what Johannes and I found is that our construction naturally includes fermions too and that the Bott-Dirac operator gives the correct Hamiltonian also for the fermions!

Sweet!

Now, as with all stories there are also boring details, which one should really leave out because nobody wants to know precisely how the hero swam across that ocean or what the dragon actually did during all those years in the cave. But, I can't write this without adding some of these details, so here goes.

The Bott-Dirac operator does not give the *full* Hamiltonian but only the one that corresponds to the theory without interactions. The full Hamiltonian also exist but here the story is a little more complicated. And the fermions, which we find, are not just any type of fermions but are sort of tailored against the bosons. Nevertheless, to have a well-defined quantum field theory of the kind we find is a very big deal — to this date there are no other examples of physically realistic theories that exist non-perturbatively.

But let us now discuss what this business with the Bott-Dirac operator really means.

3. What this business with the Bott-Dirac operator really means

Einsteins theory of relativity tells us that gravity should really be understood in terms of curvature of space and time. The reality, that we live in, has a complicated geometry, which is formed by the *stuff* in it.

What Johannes and I have found is very similar to what Einstein found — and yet radically different.

Think about your living room. You have your sofa standing against the kitchen wall and the table in front of it. Or you have the sofa standing behind the table. Or you may even have your sofa standing on top of the table (why not?). There are very many ways that you can organise your living room. Now, let us imagine the abstract space, where each *point* is one particular configuration of your living room. This is a huge space, even infinite dimensional. And imagine if *this* space has a geometry.

That sounds crazy, I know, but that is in a way precisely what Johannes and I have found. Our 'living room' is the fields that we work with. Take for instance electro-magnetism. Here we have the electro-magnetic fields and thus we can think of the huge space where each point is one particular configuration of the electro-magnetic fields.

That means that one point in this space is the configuration where the sun is shining (electro-magnetic waves) and another point is the configuration where it does not. One point in this space is a configuration with radio waves and wifi, another point in this space is a configuration without all that.

And what we have found is that a quantum field theory can be understood as a geometry on this infinite-dimensional space of all possible field configurations. We have built an 'Einstein theory of relativity' *over* the space of all possible scenarios.

(Note: a geometry means to have *distances* between points. Once you have that you also have the possibility of curvature etc.)

And the magical thing about this is that it is the same geometry — the same Bott-Dirac operator — no matter what quantum field theory we deal with. There seems to be a universal mathematical structure behind it all.

If you think this is a bit mind-blowing then I actually agree with you. I find this mind-blowing. But one thing I can tell you with complete certainty: the mathematics is solid. This makes perfect sense from a mathematical point of view. And one more thing: we do find ordinary quantum field theory within our construction. That is truly there, so as sci-fi-ish as my explanation might sound, it does look like we are describing something about reality.

What we have found is a very elegant mathematical construction. It is beautiful and very simple. I am deeply fascinated by it and intrigued by the question whether it does in fact tell us something deep about reality.

What about quantum gravity?

One of the central assumptions in theoretical physics today is that we need to find a theory of quantum gravity. We need a theory that brings together Einsteins theory of relativity and quantum mechanics. This problem is old and it is very hard.

But what Johannes and I have found puts, in my opinion, into question whether such a theory of quantum gravity is really needed and if it even exist.

Let me explain this. The domain, where quantum gravity will dominate is at a scale below what is called the Planck scale. We are talking about distances that are insanely short. This is also what makes this problem so hard because we cannot access this domain experimentally.

A central consequence of the framework of quantum field theory, that Johannes and I have found, is that things cannot be localised arbitrarily. Points do not exist in this framework, nothing can be localised indefinitely. And what this means is that the domain of quantum gravity can actually never be probed. Not even theoretically. This puts into question, however, whether we really need a theory that deals with gravity and quantum theory together — if the domain where such a theory should reign does not exist (if it cannot be probed it does not really exist) then why bother? And why should Nature have bothered if it does not need it? And perhaps this is a good explanation for why we have had such a hard time finding this theory of quantum gravity? That it does not exist?

A theory of quantum gravity is meant to deal with the space-time singularities that supposedly exist within black holes and with the initial big bang singularity — the mother of all singularities, where the entire Universe is collapsed to a single point. But within the framework that Johannes and I have found such singularities do not seem possible. And if there are no such singularities then we don’t need a theory of quantum gravity to explain to us what happens within them.

We are still not sure about this, but in my opinion it is questionable whether a theory of quantum gravity is needed at all.

What about relativity?

There is one neat detail about our work, which I would also like to mention, and that is about *time*. Einsteins theory of relativity treats space and time as a whole, but it does so in a very particular way. I am thinking about Einsteins *special theory of relativity*.

Now, all you need to know here is that the way Einsteins theory of relativity deals with time is in fact encoded into the Hamilton operator. The Hamilton operator is what makes time go by, it is the mathematical entity that describes the passing of time. But if our Hamilton operator is given by the Bott-Dirac operator, that Higson and Kasparov first constructed, then what does that tell us about time?

Well, this is a good question. It tells us that we do in fact not seem to have a choice with respect to how time should be dealt with. And it also seems to tell us that the time, which these theories have, is precisely the time one finds in Einsteins special theory of relativity (the technical term is the *Minkowski signature*).

So, it seems that Einsteins theory of relativity — or at least the part of it called special relativity — is an output of our theory.

About my crowdfunding

Back on earth let me finally tell you a little about my Indiegogo crowdfunding campaign.

You may have noticed that I sent you monthly updates for a while and then stopped. The reason is that Indiegogo keep changing their terms of use — and now they seem to have dropped the requirement of monthly updates.

But my campaign is still open and you are more than welcome to invite friends and acquaintances to join us. I am still living from the funding from the 2016 campaign but these funds will soon run out. So if you know anyone who would like to order a book about theoretical physics and about whitewater kayaking and about hitchhiking illegally through Tibet and many other weird things, then please invite them!

Merry christmas and happy new year

I wish you all a merry christmas and a happy new year. I'll write the next newsletter sometime in the summer of 2018 — or perhaps sooner if something cool happens.

Take good care, may the bosons be with you all.

Jesper

ps: you can find all my newsletters on my homepage.