Possibly Even Right

Noncommutative Geometry and the Real World

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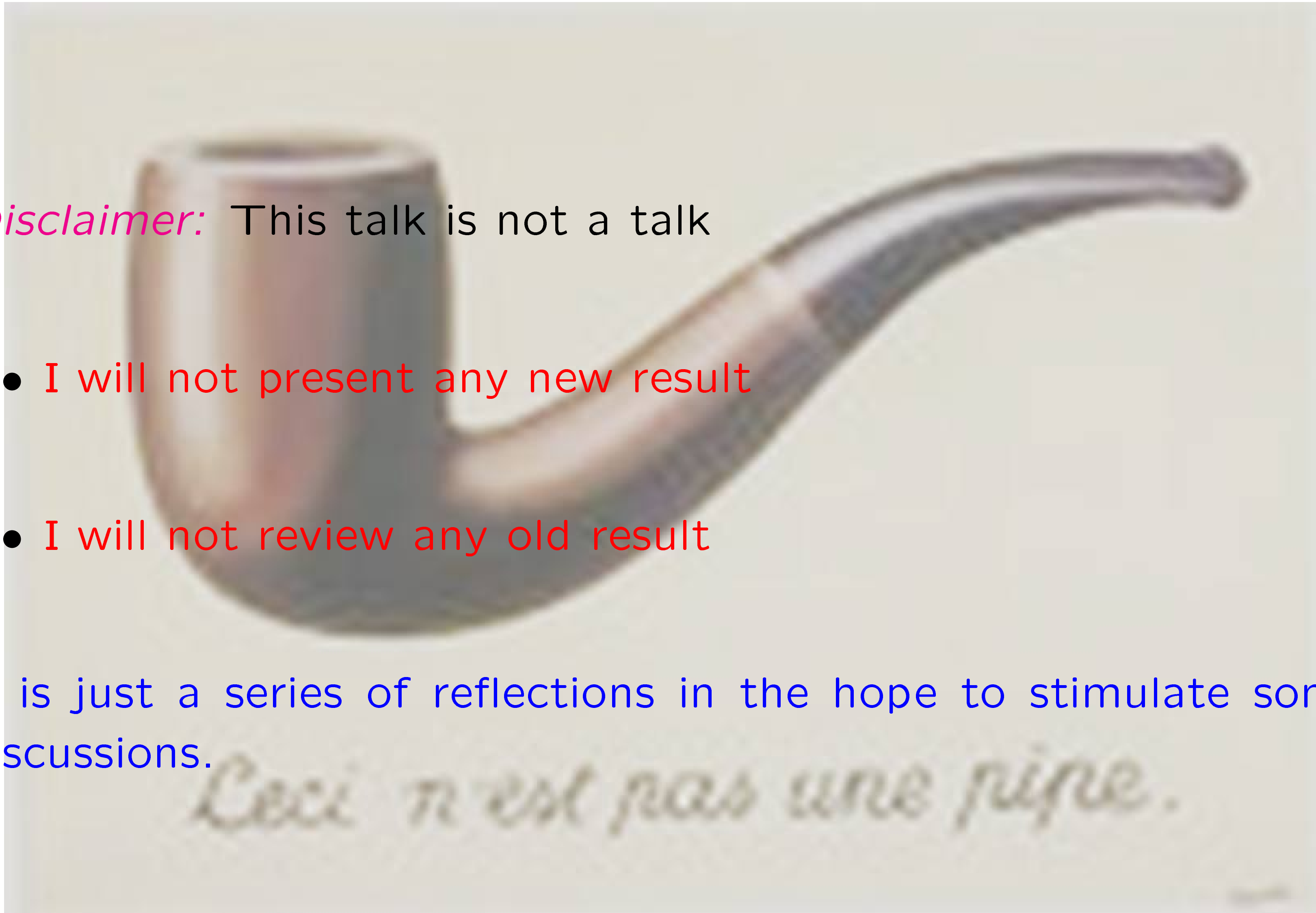
Disclaimer: This talk is not a talk

- I will not present any new result
- I will not review any old result



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It is just a series of reflections in the hope to stimulate some discussions.

Why this non talk

It all started with a discussion session on Noncommutative Geometry, strings and cosmology at the NCG07 conference in Alessandria.

Paolo Aschieri asked me to co-chair the session, and the discussion went well, in the direction of the connections of Noncommutative Geometry and phenomenology, and at the end Julius Wess asked me to talk on this topic in a conference he was organizing in Bayrischzell with Harold Steinhacker, Josip Trampetic and Michael Michael Wohlgenannt the following spring.

In Bayrischzell I prepared an after dinner talk, the discussion went well again, despite the late hour, and then Josip and Julius asked me again to repeat this talk in Zagreb.

I was resisting a little the idea to become a "physics critic", but did not have the courage to say no to Julius then, and sadly I could not do it later. So I talked in Zagreb. Harald was there, and he suggested I make again the review. In the meantime the talk has grown a little, but it remains a collection of personal thoughts without any pretense of completeness, or even fairness. The hope is again just to stimulate discussions and reflexions.

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NOW I PROMISE: THIS IS THE LAST TIME I GIVE A NON-TALK FOR A LONG PERIOD!

Why this title

The story goes as follows: apparently Pauli in Zürich used to interrupt seminars jumping out and saying: "This is wrong!". Once there was a particularly bad seminar, during which Pauli did not say anything. At then someone asked him why he had been silent. The answer was "Is not even wrong!"

Recently the accusation of being *not even wrong* has been levelled to string theory is a couple of books

In a nutshell the criticism is that string theory is not a theory, but a collection of mathematical results without any possible verifiable connection with the real world.

Independently of your opinion of these books and of their authors, and independently of your opinion of string theory, I think we would all agree that:

Physical theories need the confront with experiments. They set up the priorities, decide what are the important results, and give a definition of wrong which is different from the one of mathematics.

Unfortunately now we are confronting issues of the structures of spacetime for which experiments (and observations) are not easily feasible.

Can the accusation of not even being wrong be used also against noncommutative geometry as a part of theoretical and mathematical physics?

Or can we be right?

Can we (noncommutative geometers) give an input towards a physically testable theory, which can then give rise to a feasible experiment or observation?

To set the scenario we have to first define two entities:

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Who are we?

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What is Noncommutative Geometry?

Where do we come from?

Quantum Mechanics

Heisenberg, Dirac, Weyl, Von Neumann, Moyal. . .

Quantum mechanics is the original Noncommutative Geometry, and to some extent still the less understood.

Seeing quantum mechanics as a deformation of classical mechanics, and in particular the fact that for both theories the observables are states of an algebra, is certainly one of the best way to understand the relation between the two theories

Mathematics

Weyl, Von Neumann, Gel'fand, Naijmark, Connes, Drinfeld, Woronowicz, Kontsevich. . .

he study of noncommutative C^*-algebras as a generalization of ordinary space started already in the forties. Today noncommutative geometry is a very active field in pure mathematics, cutting across several areas

Quantum groups is in this way a filiation of noncommutative geometry, they are in a sense the symmetries of noncommutative spaces.

Connes' version of the standard model

Connes, Lott, Kastler, Iochum, Schucker, Chamseddine, Vàrilly, Gracia-Bondìa, Barrett...

The standard model is seen as the "electrodynamics" of a particularly simple noncommutative geometry. The construction is very rigid and points to some peculiarities of the standard model.

Connes-Lott model, its variants, and the programme of the spectral action is fascinating, and it definitely makes prediction (Higgs mass etc.) It does have problems, it uses classical (nondeformed) field theory, to be able to explain fermion doubling and neutrino masses the theory becomes enormously complicated.

Strings

Fröhlich, Schomerus, Gawedski, Seiberg, Witten, ...

Strings are a theory in which the structure of space time is not the arena in which everything happens as usual. In string theory the coordinates of spacetime become *Fields*

It is natural that the space time of an interaction string theory, described by a vertex operator algebra, be noncommutative. What is perhaps surprising is the fact that a theory which uses such modern physics, in its main structure still uses nineteenth century mathematics (with some exceptions, notably K-theory)

Quantum Field Theory- Structure of space time at Planck length

Doplicher, Fredhenagen, Madore, Seiberg, Witten, Wess, Grosse, Wulkenhaar, Balachandran, Rivasseau,. . .

Quantum gravity has a natural scale (Planck's length), and at that scale most likely some sort of noncommutative geometry has to be used. For the moment mainly the Moyal product has been investigated. Attention has to be given to symmetries (mainly Poincaré)

The original hope of an improved renormalizability of a noncommutative field theory (with the Moyal product) were not borne out, but noncommutative quantum field theory has still a strong potentiality, and the inclusion of gravity seems possible.

Where can we go?

Mathematics

The importance of Noncommutative Geometry in mathematics seems is well established, and it has lead to several important successes. The structure of noncommutative spaces and their quantum symmetries is very active and very exciting.

This is a noble activity, and apart that it may create problems with funding agencies I see nothing wrong in doing it.

Or we may do physics . . .

Connes' standard model

Recently a series of articles by Barret and Connes, Chamseddine and Marcolli, and a book by Connes and Marcolli, have revived the model, with a new version that solves some problems in the older models, such as neutrino masses and fermion doubling.

Reading Connes-Marcolli's book, or listening to Connes, shows incredible connections at a very high level from particle physics to the purest number theory. What is better is the fact that the models is very close to phenomenology at all time. It makes predictions testable at LHC

There are of course problems. The model is at is stands enormously complicated. This may be inherent, or it may be that a process of *translation and vulgarization* by physicist will improve things. At any rate the geometry (structure of spacetime) is still commutative, and therefore the model is at best an effective theory.

κ-Minkowski

It is an Hopf Algebra with a rich structure. The commutation relations in spacetime are such that the space is the homogeneous space of the deformed Lie algebra.

It has non trivial dispersion relations, and there have been physical prediction, expecially regarding γ ray bursts, but these are dependent on the basis (once the commutation relations are non linear it is possible to have nonlinear basis change).

Refer To Freidel talk for the kind of way forward to the construction of a physically unambiguous approach

Fuzzy Physics

There can be situation in which the drastic reduction of degrees of freedom,keeping the symmetries, operated by fuzzyfication, can have an important physical meaning.

This apart form the intrinsic interest of fuzzyfication as an approximation for the calculations.(O'Connor, Biethenolz talks)

Here the problem is that at present only very particular spaces have been successfully fuzzyfied. We may use these techniques to approximate noncommutative spaces

Quantum Field Theory on the Moyal Plane

Here recently there have many very interesting results in the renormalization of this theory (Grosse-Wulkhenaar, Rivasseau)

The main issue is related to symmetries. If one considers θ a background tensor then there is a breaking of Lorentz invariance.

Most of the effects are a consequence of Lorentz non invariance, and this certainly has experimental consequences, depending on course on scales and energies.

The calculations on a realistic noncommutative field theory are not easy, especially because of course one has to perform them in a noncommutative gauge theory. Here an useful tool is the Seiberg-Witten map.

This is of course a very good time to look at consequences for accelerator experiments (Trampetic, Ohl). The fact that the background field is not fixed with respect to the laboratory due to the rotation of the earth washes out some effects. Best look for effects which would be absent in the commutative case

Very promising is the study of a noncommutative field theory in the early universe (Chu Greene Shiu, Brandemberger, Napoli). In this case the primordial breaking on Lorentz invariance is amplified by inflation and show us as a quadrupole correlation for the cosmic microwave background. This may be detected in some future observation (Planck could go to $10^{13} GeV$).

θ-Poincaré

In this case We still have a (deformed) Lorentz invariance based on a Hopf algebra in which only the coalgebra structure is deformed, while the algebra structure remains the same (Wess, Chaichian et al., Aschieri et al.)

This is a general framework in which one can study gravity, or classical mechanics, or quantum field theory, in a canonical way, with a procedure which permits a consistent definition of all products.

There have been already some predictions based on θ-Poincaré (Balachandran et al.), as opposed to predictions of noncommutative geometry based on a Lorentz violating geometry. Spin statistics, decays $Z_0 \to \gamma\gamma$ and recently also cosmic microwave background.

This framework, and its predictions, however have caused some controversies. What is probably lacking is a θ-deformed measurement theory. If one deforms coherently all symmetries and all products, it is then necessary to understand well all of the tensor products “hidden" in the measurement process (interaction with the detector, products between the observable and the density matrix. . .). There may be a similarity with κ-Minkowski.

Do we stand right or wrong?

Do we stand right or wrong? Or neither?

Do we stand right or wrong? Or neither?

In my opinion the community is still healthy, in the sense that we are trying to produce physical theories, with a connection with the real world

We aspect we certainly have to improve is the fact that we are using too simple a noncommutativity. There is no compelling reason for which the spacetime should have the same structure of the phase space.

The natural scale of noncommutativity is the Planck scale, and there direct experiments are impossible, and even indirect ones are very difficult.

Unfortunately it seems that all experiments keep confirming the various standard models

Therefore for the moment we set upper limits. How nice would it be if we were doing calculations attempting to fit data different from zero!

We can hope in LHC. Will they find Supersymmetry? Which kind?

Also surprises can come from gravitational wave detections, and expecially neutrinos and high energy cosmic rays

One worry. A noncommutative structure is too generic a concept. Can we make predictions which are unambiguously generic to noncommutative geometry?

More probably we should wait for a general theory based on noncommutative geometry with testable predictions. Something like gauge theory and the standard model

Will it be alternative or a refinement of existent theories?

Which kind of noncommutativity?

Which sort of symmetries (quantum groups)?

Which symmetry? Classical or quantum?

How many degrees of freedom at Planck length?

How many degree of freedom?

Still the old field theory?

There is no way we are going to give an answer to this sort of questions if we do not anchor ourselves to measurements, observations, gedanken experiments, physics in one word.

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One thing is for sure:

We have physics to do. Possibly even the right one!