String theory deconstructed

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Abstract

The method of deconstruction is used to identify and analyse metaphors of string theory.

1 The aim

...The history concludes with an unexpected and glorious success: the so-called standard model. The way in which this structural classification fell into place, and the great leaps of imagination involved, justifies a degree of hubris among the few dozens truly extraordinary individuals who discovered it. However both this hubris, and the complexity of the result, fed the temptation to go on leaping, and to forget that this earlier leaps, without exception, had taken off from some feature of the solid experimental facts laboriously gathered over the years....

Phil Anderson, in "Loose ends and Gordian knots of the string cult"

Since the string theory community has liberated itself from the toil of experimental verifiability by linking the fate of particle physics to that of the still elusive quantum gravity, it has been each time more difficult to criticize them on the ground of their distance from observation; in fact they have developed a certain immunity against such criticism. Therefore I will try to show in detail that the post SM hubris, which according to Phil Anderson is the cause of the present situation, has led to the amazing situation where all the arguments and results of ST can be subjected to deconstruction by a combination of historical and factual knowledge about particle physics. Conjectures based on ST have a certain metaphoric charm which is partially supported by conceptually uncontrolled free-wheeling selective[1] computations, but that charm crumbles under closer conceptual scrutiny. The problem is exacerbated by the growing loss of critical knowledge after this metaphoric approach was actively endorsed by two Nobel laureate and one Field medallist; as a consequence, starting already in

[1] If a calculation does not comply with the metaphoric expectations it is replaced by an excuse.

the 80s, most of the economic support in particle theory went into ST related research. There is no doubt that this mass cult (following Phil Andersons critical remarks) will continue. It would be dewy-eyed to expect that new experimental data from LHC could stop it; like most sociopolitical movements it has to play itself out. But this should not prevent critical minds from taking issue, even if it would only be for the historical record.

In the following I will list some ST claims which afterwards will be shown to be fundamentally flawed:

1. The Kaluza-Klein argument can be used in QFT (or ST) to encode compactified spatial coordinates into inner symmetries
2. Holography is a construct which needs quantum gravity as a prerequisite
3. The Maldacena conjecture is about a AdS—CFT holography
4. The counting zero mode degree of freedom estimate about the cosmological constant is consistent with the principle of QFT in CST
5. String theory solves the "information paradox"
6. Strings are quantum objects with a localization in spacetime which is string- instead of point-like
7. It has been shown that ST contains QFT in the limit of low energies.
8. The S-matrix of ST has the properties of a particle physics S-matrix

2 Kaluza-Klein compactification only exists as a metaphoric idea

For discussing the quantum aspects of KK it is necessary to first get a very good understanding about the origin of inner symmetries. Let us agree to exclude "local gauge symmetries" (and deal with those separately) because they are not physical (Wigner) symmetries.

The concept of internal symmetries was since its inception (the SU(2) isospin of nuclear physics introduced by Heisenberg in the 30s) one of the most mysterious proposals. Whereas it is natural to accept spacetime symmetries since they accompanied us in the classical setting since the time of Newton, the understanding of internal symmetries is a somewhat metaphoric concept in QT. In classical physics one can only get inner symmetries by reading QT concepts back into classical physics (as e.g. classical Fermions as Grassmann variables) i.e. they are classically unnatural.

A profound understanding in the setting of local quantum physics was finally solved in the work of Doplicher, Haag and Roberts during 1970-1990 [1]. Their ground-breaking idea was to abstract internal symmetries by taking a dichotomist view about QFT: local observable algebra (bosonic and neutral) which carry all the intuitive physical properties as the basic structural input, and the field algebra (the name for the algebra generated by charge-carrying operators which contains the observable algebra as the fix-point algebra under the action of some compact group) about which such an immediate knowledge is not available but whose structure is preempted in the structure of the local observable net of algebras indexed by spacetime regions. By a sequence of conceptually extremely interesting and profound steps this unique field algebra (including the concrete inner symmetry group which acts on it) can be constructed. This is similar in spirit but much more subtle in detail than Marc Kac's "how to hear the shape of a drum".

The first step is to classify all "representation of physical interest" (local representations) and construct their intrinsically defined statistics. In this way one obtains (for spacetime dimensions ≥ 4) a unitary representation of the infinite symmetric group which belongs to parastatistics[2] of height d (where d is determined by the structure of the observable algebra). The second step is to realize that these data can be encoded into a better description which trades parastatistics with the Fermi/Bose alternative plus the symmetry group by extending the observable algebra the *field algebra.* The latter is uniquely determined (after fixing some normalization conventions); the so constructed compact symmetry group acts on the field algebra in such a way that precisely the observable subalgebra is left pointwise invariant. This required the elaboration of a completely new duality theory for groups because the old Tanaka-Krein duality theory was not appropriate for this field theoretic problem. The elaboration of the details of this marvelous mathematical construction took Doplicher and Roberts many years; it constitutes a magnificent mathematical achievement (highly praised by those mathematicians who studied it as e.g. the mathematician Marc Rieffel) which does not have to hide itself behind Witten's mathematical achievements.

The representation structure of physical interests coming from the DHR theory in lower than 4 spacetime dimensions is richer, in this case the observable structure leads to representation sectors which carry a representation of the braid group [1] (a generalization of the symmetric group) and instead of the field algebra you find something which does not permit a clear-cut separation into inner and outer (spacetime) symmetries.

The first step is explained in Haag's book and the second in the reference to the original D-R work cited therein. The DHR theory therefore resolves the mystery of the Heisenberg isospin and its generalization in the modern notion of internal symmetries in terms of the spacetime structure of representation theory of observables. Having explained something in terms of spacetime localization makes it more palatable i.e. less mysterious. The transmutation of compactified spacetime coordinates into something like "Casimir invariants" of group representation symmetries is a far-fetched metaphoric idea which is contradicted by the intrinsic meaning of inner symmetries in QT.

There is the additional problem of not being able to make mathematical

[2] This is what is measured directly in scattering data; the encoding into internal symmetries on Fermions/Bosons is a simplifying theoretical encoding.

sense of ”curling up” compactified spatial dimensions. The correlation functions of QFT have no controllable limit under such a manipulation since violent vacuum fluctuations will prevent any convergence. This is seen as follows. Imagine that you have a higher dimensional QFT and convert one of the spatial coordinates into a circle (impose periodicity). Then, as a consequence of the Nelson-Symanzik duality [2], you can change that particular spatial coordinate with time and obtain a spatially infinitely extended system in a thermal state whose temperature depends on the radius of the circle[3]. The KK limit (decreasing the circle) corresponds then to the divergent situation of infinite temperature. The reason is clear, the vacuum fluctuations in the original spatial interpretation become uncontrollably large a property which becomes more exposed after the N-S duality converts this into the thermal interpretation. Even if the process would not be divergent (such a case presumably does not exist in QFT), there is still the previous structural argument that spatial extension can never be converted into internal symmetries. One has the suspicion that ST misses out on vacuum fluctuation because as a first quantized theory it only contains the vacuum fluctuations of the auxiliary conformal chiral theory but misses the intrinsic spacetime vacuum polarization (in target space) which are characteristic for QFT and (in contrast to ST) are responsible for the thermal aspects of localization.

Aficionados of KK apparently never look at such problems. What they actually do is to manipulate the classical action (having a functional integral representation in mind) by retaining only the lowest Fourier-component in the classical Lagrangian before they quantize i.e. before they do the functional integration and compute correlation functions. But that is not identical with what they say when they claim that the curling up is something which has an intrinsic meaning within the theory (and not just in its nomological presentation before its actual construction). In other words their implementation of KK is not more than a mnemonic device to produce certain Lagrangians by manipulating a higher-dimensional Lagrangian; it has nothing to do with taking a limit in the actual correlation functions where they would encounter all the mentioned problems.

The classical example is that of a 5-dim. curved spacetime metric splitting according to the KK prescription into a 4-dim. metric and a vectorpotential. Again the statement is not the a solution of the 5-dim. Einstein-Hilbert equation of motion with one compactified spatial coordinate of variable sized splits into the solution of the 4-dim. solution of E-H and a gauge field. It would be very surprising if any 5-dim solution has this property since the interpretation of gauge transformation (purely passive) is very different from the active interpretation of local diffeomorphisms[4]. I recently red that already Pauli had shown

[3]Using the (artistic, not mathematical, but as such useful) Feynman-Kac functional integral representation, this duality is evident; the more rigorous use of the Osterwalder-Schrader Euclideanisation gives rise to a more demanding mathematical problem [2].

[4]The local covariance principle for classical solution says that if two solutions share an isometric submanifold (easily achievable for a given solution), an observer whose measurements are restricted to that submanifold can not know in which global spacetime he lives or in a

that this is impossible, but there was no reference given.

3 Holography on null-surfaces exists in Minkowski- and curved- spacetime

I think that anybody who knows the framework of particle physics (say beyond the level of recent QFT texts which where written by string theorists) would agree that holography from d+1 to d dimension and its possible inversion cannot be anything else than a radical change of the spatial encoding of a specified algebraic substrate; using this word for anything else would be a misuse and lead to misunderstandings. If such a substrate was given say in the natural spacetime labeling of a d+1 spacetime in form of a d+1 dimensional QFT and one would like to analyze this data from the viewpoint of a radically different localization concept which is naturally associated with its causal- or event- horizon (in the highly symmetric case of AdS one takes a brane at infinity) one has to find ways to implement such a change. Of course physics depends not only on the substrate, but also on its spacetime organization. It is a bit like stem cells which by enzymes can be forced to organize in different ways (organs). Localization in QFT, independent of whether nature realizes it (as in case of black holes, at least according to everybody's expectation) or just as an imagined process in the form of a Gedankenexperiment (e.g. Localization in Minkowski spacetime a la Unruh), leads to thermal manifestations which are caused by vacuum polarization near the causal (or event) horizon. The Hawking effect is fully accounted for by quantum matter in a Schwartzschild spacetime (one does not need QG which is very helpful since there is no agreement what QG is and how one should describe it). Any state which extends from the outside into the black hole without developing a singularity on the horizon will lead to Hawking radiation at the Hawking temperature (in particular the unique state which is invariant under the Killing motion). Nowhere in the existing derivation are gravitons or QG entering. Since the state is thermal, it has also an associated entropy. To compute that localization entropy, I have developed a formalism of holography on null-surfaces (which led to extended chiral QFT) which explains why the entropy follows an area law. This area behavior is totally generic and has apriority nothing to do with Bekenstein's classical differential geometric area law. In fact one obtains a one-parametric family of entropies depending on the chosen thickness epsilon of the vacuum polarization "atmosphere". This family corresponds to the family of boxed Gibbs systems which one introduces to define the thermodynamic limit. Of course one can use Bekenstein's classical formula and equate it with this microscopically computed entropy to determine epsilon (I have not done this, but there can be no doubt that at this point the Planck length enters and determines the size of the vacuum polarization cloud). The calculations are in two papers (the first one is published in CQG and the second has been submitted there) [4][5]

more spectacular sounding terminology, he is part of several worlds.

The reason I did the computation in Minkowski spacetime and not in curved space time directly for the Schwarzschild model is very simple. On the one hand I wanted to show that null-surface holography is independent of whether the surface originates as a causal horizon in Minkowski spacetime or as an event horizon in the presence of curvature. On the other hand given the ideological prejudice of a possible string referee against any work which does not invoke the metaphor of QG in connection with black hole physics (and in particular with black hole entropy) would run a high chance of rejection; but even a hard core string theorist would probably not mind something in Minkowski spacetime which in his mind would be a part of not very relevant mathematical physics.

4 The interpretation of the Maldacena conjecture as a AdS–CFT holography is a QG illusion

As the null-surface holography is a change in the spacetime encoding of an algebraic substrate which is originally given in bulk form, so is the AdS—CFT correspondence . In that case the change of the spacetime ordering-device is more gentle and has a unique inverse (without necessitating additional assumptions). This has been elaborated with great clarity by Rehren in a series of papers [3][6], including the demonstration that the change of spacetime encoding point of view agrees formally with Witten's dual version of a prescribed conformal source in a functional integral representation[7][8]. I do not know any competent quantum field theorist who does not accept Rehren's work as the correct formulation of AdS—CFT holography (Hollands, Wald, Brunetti, Fredenhagen, Verch, Buchholz,. . . .).

On the other hand the Maldacena conjecture also alleges to address the AdS—CFT correspondence, but it burdens the AdS side with a metaphoric idea for which one knows no argument (probably dating back to a conjecture of 't Hooft) which says that the holomorphic encoding of a QFT into a lower dimensional QT needs the intervention of the hitherto elusive QG. Given the speculative nature of QG which prevents a clear picture on what one has to expect on the AdS side, it is not clear what one wants to prove. For psychologically understandable reasons it was this metaphoric QG connection which attracted the attention of string theorists (QG is the raison d'etre for string theory) and which led Maldacena idea of formulating a conjecture involving a vague idea of supersymmetric form of QG in case one starts from a supersymmetric conformal field theory[5]. The only computational support came from some numerics of a double limit (large numbers of colors N$\rightarrow \infty$ limit as well as large 't Hooft coupling) in lowest order. Since the status of conformality for SUYM

[5]In order to avoid any freakishness, the conjecture about conformal QFT having a gravitational AdS duals has been extended later to all conformal QFT (except for free fields where the explicit computation confirms Rehren's version). Originally it was made for a special supersymmetric Yang-Mills theory which is believed to be conformally invariant.

finite N is totally unclear (the only thing which seems to have been established is the vanishing of the beta function in lowest order), the N$\rightarrow \infty$ limit of a QFT is not itself QFT and thirdly the computation is by no means a straightforward perturbative calculation but rather involves additional "massaging" the meaning of the conjecture remains ambiguous. If there is a structural property behind these very incomplete calculations then the conjecture has received the wrong interpretation; to think that a conformal QFT has two correspondences on AdS, one as described above and another one through QG is fantastic. *It could be an interesting nonperturbative aspect of QCD discovered by chance, so saying that the Maldacena conjecture is not the AdS–CFT holography does not diminish the alleged possible value of the associated computational observation about non-perturbative QCD.* A few interesting findings have been accidental, and their chance inceases naturally with the number of people working in an area.

As argued above a connection with QG is not what holography in the obvious sense of a radical change of the spacetime encoding of a quantum matter substrate[6] can deliver. Despite the more than 4000 (inconclusive) papers on the Maldacena conjecture, it is better to move ahead and leave the explanation of this strange sociological phenomenon to future historians and sociologists of science. It shows the depth of the crisis particle physics has entered. An interesting and to me very convincing interpretation has been given by Philip Anderson (see beginning) who blame the hubris of the protagonists (combined with the new age receptiveness of their foot soldiers) in the aftermath of the relatively easy but nevertheless impressive discovery of the SM for the present self-delusions. I would be reasonable to assume that the Maldacena conjecture will never be proved, it will just fade away with string theory and join other ideologically motivated conjectures which appeared with a lot of noise but evaporated quietly into the dustbin of history.

It is interesting to observe how the described situation plays out in discussions between string ideologues and the protagonist of the structural proof of the AdS–CFT correspondence. With all reservations which one may have about weblogs, I think that the opinion in [9][10], as strange as it appears to quantum field theorists, represents a majority belief in ST. There is no way to get beyond the faith-based QG mantra on the AdS side, so finally Rehren (who tries to explain his proof in those weblogs) has to give up.

The metaphoric approach to particle physics will certainly continue. In very recent continuations of QG metaphors the Maldacena conjecture is already accepted as a consumed fact and the excursion continues into a meta-metaphoric conceptual blue yonder. There is nothing which seems to be able to stop this sociologically interesting phenomenon in the midst of particle theory; similar to present events in the political arena hubris has to play out all the way (fortunately only lost careers and not lifes).

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[6] According to Leibniz and to AQFT spacetime is an ordering device for an abstract matter substrate.

5 The QM level counting approach to vacuum energy is inconsistent with the local covariance principle of QFT in CST

Most of the quantum entropy calculations are in fact based on a counting picture where energy levels are populated and the occupied levels are counted. The same adding up procedure is used to compute the energy density (the vacuum energy problem). This kind of quantum mechanical picture of entropy is at odds with the recently discovered principle of quantum local covariance of QFT in curved spacetime (in particular in Minkowski spacetime) which is also related to the background independence [16]. Such level-counting calculations of energy and entropy have been used in the calculation of the cosmological constant as well as in string theory based microscopic calculations of entropy of certain limiting cases of black holes. According to a recent paper by Hollands and Wald [17] entitled: "*Quantum Field Theory is not merely Quantum Mechanics applied to low energy effective degrees of freedom*" such level occupation type computations should be looked upon with suspicion because they violate one of the most cherished principles underlying general relativity. Since both classical relativity and local quantum physics should come together in a future theory of QG, the unknown principles of QG should constitute a synthesis and not a negation of the known principles. The problem is intimately related to Wald's old problem of defining the correct energy momentum tensor. His proposed solution was the start of the modern theory of QFT in CST in which the Lagrangian formalism is abandoned in favor of the adoption of the dichotomy of AQFT between the algebraic structure of QFT and the admissible states on such algebras. The message for the construction of the correct energy-momentum tensor (in case of free quantum fields) is as follows. Pick a state from a natural family of states to which (in case of Minkowski spacetime) the vacuum state belongs; the natural family turns out to be given by the so-called quasifree Hadamard states. Compute the energy momentum tensor via a spacetime limit just as you do it for the vacuum case (i.e. subtract the expectation value in the quasi-free Hadamard state before taking the limit of coalescing points). This so defined e-m tensor is finite in all quasifree Hadamard states but it does not yet fulfill the principle of local covariance under the action of diffeomorphism (under such transformations the e-m tensor mixes with other operators). The most elegant way of finding the algebraically correct e-m tensor which transforms correctly is to solve a well-defined cohomology problem. This works for all Wick products [13]; there is a new basis, call it a locally covariant Wick basis (which reduces for the Minkowski vacuum to the standard Wick products), which transform correctly (locally covariant i.e. independent of states) [14].

The existing estimates about CC ignore this basic message (see the otherwise nice review [18]). A realistic calculation based on a quasifree Hadamard state (often misleadingly called vacuum states) associated with one of the popular cosmological metrics (e.g. Robertson-Walker) would probably give a reasonable value but this has not yet been done. With interaction-free normal quantum matter the density in the cosmological state the only mechanism for obtaining a nonzero value would be a nonvanishing curvature and/or nontrivial boundary conditions.

6 There was never any *information paradox* associated with the physics of causal- or event-horizons

It is well-known that localization in a spacetime region $\mathcal{O}$ causes vacuum polarization at the horizon (see the previous discussion) which in turn leads to the thermal manifestations. The nature of the localized subalgebra on one side of the horizon (e.g. the interior of a black hole) and that on the other side of the causal divide $\mathcal{O}'$ (the causal disjoint), which under natural circumstances is equal to the commutant $\mathcal{A}(\mathcal{O}') = \mathcal{A}(\mathcal{O})'$, is such that despite their commutativity and the fact that $\mathcal{A}(\mathcal{O})$ and $\mathcal{A}(\mathcal{O})'$ together span the full algebra $B(H)$ (all bounded operators in Hilbert space), the latter is not a tensor product of the former two algebras. This is related to a peculiarity of sharply localized algebras in QFT; they are very different from the type of algebra one meets in QM where subdivision into an algebra localized at a given time and its commutant localized in the complement region leads to tensor factorization and is not accompanied by thermal manifestations (absence of vacuum polarization). Mathematically the localized operator algebras in QFT are of the unique hyperfinite type III_1(called *the monade* in [19]). In QFT models which have a reasonable phase space degree of freedom structure one can show that the tensor factorization can be achieved if one creates an arbitrary small "collar" region around the sharp localization boundary (the *split-property*) [1]. In this case the operator algebra $A(O)$ and that enlarged by the collar of size $\varepsilon : \mathcal{A}(\mathcal{O}_\varepsilon) \supset \mathcal{A}(\mathcal{O})$ admit an intermediate quantum mechanical operator algebra

$$\mathcal{A}(\mathcal{O}) \subset \mathcal{N} \subset \mathcal{A}(\mathcal{O}_\varepsilon)$$

In terms of and its commutant $\mathcal{N}'$ the total algebra factorizes

$$B(H) = \mathcal{N} \otimes \mathcal{N}' \supset \mathcal{A}(\mathcal{O}) \otimes \mathcal{A}(\mathcal{O}_\varepsilon)'$$

but the vacuum restricted to $\mathcal{N}$ or its commutant $\mathcal{N}'$ remains a thermal KMS state at the Hawking temperature. It is a pure state for the tensor product algebra which does not factor and hence a mixed state (in fact a KMS state) upon restriction. In particular the restriction to $\mathcal{A}(\mathcal{O})$ or $\mathcal{A}(\mathcal{O}_\varepsilon)'$ are not pure neither is the restriction to $\mathcal{A}(\mathcal{O}) \otimes \mathcal{A}(\mathcal{O}_\varepsilon)'$ since the collar is spacelike to both regions. All of these statements are perfectly in agreement with QT which has no information loss. What would cause an apparent paradoxical situation is the non-observance of the radically different nature of the sharply localized algebras whose uncommon (from the QM point of view) appearance is inexorably linked with the ubiquitous vacuum polarization and the associated thermal nature which is absent in QM; but this has nothing to to with information loss. Hence there is no role to play for string theory in explaining a presumed information loss in black hole physics.

7 The quantum objects of ST are not string-localized

It is quite interesting to start a critique of string theory concerning its apparently incurable metaphoric nature by asking whether the word "string" in its name has any intrinsic meaning in the quantum theoretical realm. In the setting of the quantization of the 10 dimensional supersymmetric version of the classical Nambu-Goto string, this would amount to ask whether the localization, which is intrinsically related to the interaction free one-string state-space (the state space after the BRST descend from pseudo-unitary to unitary), can be viewed as being generated by pointlike fields or whether one needs stringlike generators. Since the representation is one of a tower of massive particle in which no zero-mass infinite spin Wigner representations occur (which are the only ones which would destroy the pointlike generating property of the representation [11]), the canonical quantization of the classical N-G string is a theory with pointlike localized generators. In fact since the c-number character of the graded (supersymmetric) commutator of the Nambu-Goto operator is a c-number, the autonomous content of the associate field theory is a *graded generalized free field*. Generalized free fields did not find any constructive physical use in QFT; to the contrary they served as illustrative objects showing that Einstein causality does insure the causal shadow property (the time-slice property) and that a reasonable statistical mechanics behavior requires a reasonable control of phase space properties (the nuclearity condition).

Both structural arguments are quite straightforward. The anomaly-freeness depends on whether the anomaly-free super Poincaré Lie algebra (after the cohomological removal of the ghosts) of the 10-dimensional canonically quantized supersymmetric Nambu-Goto model (extended by the covariant BRST ghosts formalism) can be integrated up to a unitary representation of the Poincaré group. For this one would have to check certain joint domain properties (the Nelson criterion for the exponentiation of Lie algebras of unbounded operators) of the unbounded operators which represent the Lie algebra. This has apparently not been done, so we will cross our fingers and assume that it leads to a strongly continuous unitary representation to which the decomposition theory into irreducibles is applicable. Then the (test function-smeared [12]) N-G "string field" generated a one-field Poincaré invariant state space whose decomposition into irreducibles leads to the unitary equivalence with a direct sum of irreducible "mass-tower" contributions. The fact that the (graded) commutator of the non-interacting N-G string is a c-number and the determination of this c-number in terms of the particle tower representation yields the desired result that the N-G field is (unitarily equivalent to) a generalized free field. Like the infinite component fields studied during the 60s the localization is pointlike. With other words the equality of the classical pointlike localization with its quantum counterpart which was the basis of Jordan's quantization approach to QFT (afterwards universally adopted) does not extend to classical N-G strings. A quantum string should show its intrinsic localization if in a commutator of two alleged quantum strings one is entering the causal dependency region of the other. But the result is negative, the intrinsic localization concept which is associated with the unitary representation of the Poincaré group is pointlike and not stringlike as the classical picture would suggest.

In some sense string theorists are aware of this phenomenon but that has not led to a change of terminology. In earlier times talks on string theory often started with the mantra " whereas field theory is based on pointlike-localized objects, the fundamental objects of string theory are string-like localized". Recently such statements have been less frequent. If one would say that strings are pointlike-localized quantum objects which result from the quantization of relativistic classical Nambu-Goto strings, the description would be less elegant but at least correct.

Returning to the string theoretic selection of (in the supersymmetric case) of 10 spacetime dimensions it should be notes that from the viewpoint of the Veneziano duality this selection property appears physically suspicious. The dual model exists of course (as any S-matrix with crossing) in every spacetime dimension and it is not clear why one chooses a multi-particle extension which only appears to exist in 10 dimension if there would be others which do not show this strange selective behavior. Presumably the ST will have vanished from the scene before there is sufficient interest in investigating such fundamental questions.

8 The inclusion of QFT as a low energy inclusion into ST is far from clear

Another metaphoric claim of string theorist which goes beyond terminology is the statement that ST contains QFT in a large distance (low energy) limit. For a rigorous proof one would have to solve string theory and show that is contains objects which asymptotically for large distances approach the correlation functions a task which even in case of the relativistic QFT→nonrelativistic QM relation would be asking the impossible. The message from this last case that metaphoric arguments (e.g. looking at functional representations without actually doing the functional integrals) may turn out to lead to wrong results. Take for example the case of 2+1 dimensional QFT which have braid-group statistics. If the spin is anyonic (i.e. not semi-integer) the statistics is plektonic and the upholding of the spin-statistics theorem in such a case prevents the nonrelativistic limit to be a (second quantized) QM; it remains a nonrelativistic QFT. Only if one relinquishes the plektonic commutation relations, but preserves the anyonic spin one finds Wilczek's anyons in the form of quantum mechanical Aharonov-

Bohm dyons[7]. The theoretical reason why QM is physically relevant is that its more fundamental QFT counterpart has the same Fock-space structure or to but it more bluntly: without the existence of relativistic local bosonic and fermionic free fields there would be no QM. There are simply no free (on-shell) plektons and consequently also no plektonic QM. Only after having indications about a structural compatibility "scale sliding arguments" on classical actions in functional representations become trustworthy. The message from this illustration is that one theory can only be asymptotically (e.g. for long distances) contained in a more fundamental one if the structures harmonize. Whereas one has convincing knowledge about the intrinsic structure of QFT, the metaphoric state of ST prevents such comparison and the claim that it contains QFT becomes dubious.

All important properties of particle physics (starting from the Lamb shift up to black hole entropy) which cannot be explained in terms of QM have their origin in vacuum polarization. ST is an S-matrix theory and it would be crucial to study off-shell objects associated with this S-matrix in order to see whether there is any vacuum polarization in the target space of string theory. The vacuum polarization in spacetime (target space) as a result of localization and the ensuing dynamical (local covariant) of vacuum energy and entropy is the Achilles heel of ST. This is a structural question which cannot be answered by manipulations in functional representations. It seems that the answer is not known.

9 None of the properties which an S-matrix of particle physics must satisfy has been checked in ST

String theory started with the proposal of an elastic scattering amplitude by Veneziano. There is of course no method in particle physics which permits to complete such a tiny bit of specified information to a full scattering matrix. One (certainly highly non-unique) proposal was based on the similarity of infinite mass tower with the spectrum expected of an extended quantum object. Indeed the canonical quantization of the relativistic Nambu-Goto string reproduces the mass tower spectrum. However for the construction of S-matrix elements the operator approach was not useful; one rather had to return to the first quantized string wave functions in order to formulate those splitting and fusing multi-particle S-matrix rules which go with those well-known Euclidean tube pictures.

But the use of momentum space in particle physics is not a fast selling item; it results from more basic localization structures in spacetime under special circumstances (which were carefully checked in the case of Feynman rules and are completely violated for QFT in CST). Only in pointlike local QFT the

[7] This is a n-particle QM which satisfies clustering but permits no second quantized represenration in terms of field operators.

Fourier transform of the generator of translations has anything to do with the localization of an event. Therefore it would have been one of the most important safety measures to check at least those properties which are even indispensable in more general theories of particle physics than local QFT. One such property is the cluster factorization which is part (the spacelike part) of macro-causality[8]. These properties are extremely subtle and it is almost impossible to implement them by hand without an additional physical idea [20]. According to my best knowledge the cluster factorization has never been checked and it would be a matter of incredible luck if this property holds for the string theory prescription. But without this the physical name S-matrix is completely misleading. and the terminology is nothing else but false labeling.

10 Epilog

Since there is no indication for contemporary particle physicists being less intelligent and sophisticated than their predecessors (one may in fact argue that the opposite is true), one has to look for sociological explanation for the popularity of a theory which is metaphoric on all the ideas which went into it as well as in all the results which are alleged to follow from it. I know of no better explanation than that by Phil Anderson above. But of course it is not sufficient to have a couple of seducers who are driven by hubris, one also needs a group of physicists who like to be seduced. Here the explanation is more sociological. The new age Zeitgeist has made metaphoric arguments more acceptable and eradicated already some of the autonomous knowledge about QFT. Most textbooks on QFT written within the last two decades suffer from a stringy metaphoric presentation even if the issue is QFT. The latter is presented in such a way as if the generalization to ST would appear natural. Meanwhile several critical articles about ST from a historical and sociological viewpoint have recently appeared [21][22].

In its monomaniac pursuit of quantum gravity ST has seriously paralyzed the post SM research which is aimed at an understanding of the many conceptual questions which the SM is able to raise but unable to answer. All indications from more realistic approaches as QFT in CST (which is in the middle of sorting out some deep problems as local covariance and diffeomorphism covariance) as well as from spectacular experimental astrophysical discoveries point towards one conclusion: it is much too early to seriously take up QG, especially if it leads to the post SM research getting into an oblique position.

As it happened several times in the past, a single-minded pursuit of a problem by an entire community turns out to be detrimental. The solution often comes from individuals who follow a conservative path, but using a higher penetrating conceptual depth of focus combined with a more appropriate mathematical formalism. The best known illustration of this was the end of wild

[8]The timelike part is a certain one-particle factorization structure (which goes with a timelike iε-prescription) which was first recognized by Stuekelnberg.

speculations about how to overcome ultraviolet divergencies through the work of those individuals who discovered renormalization theory.

Presently there is a similar situation with respect to gravity and QT. Here the big recent breakthrough came from individuals in particle physics who showed that as a result of the newly discovered principle of local covariance (diffeomorphism covariance) there is much more substance in QFT in CST then hitherto expected; in fact their paradigmatic change of the whole framework of QFT[9] [14] reaches deeply into that area which was reserved for QG[10]. With their new concept of a relative evolution operator they were able to show that the step from diffeomorphism covariance to diffeomorphism invariance follows for any operator Einstein-Hilbert like theory which links the change of the metric to the energy-momentum tensor [16]. The theorem also applies to the standard perturbative formulation of quantum gravity which leads to infinitely many parameters (nonrenormalizable); but even though it cannot be taken seriously for distances down to the Planck length (no predictive power), the implementation of the operator E-H equation guaranties the diffeomorphism invariance. The state of QG is more or less like that of the weak interaction at the time of Fermi; the serious problem of getting a finite parametric theory still lies ahead, but not one which merits to be called a conceptual clash between gravity and quantum theory (ST has to stick to this terminology in order to justify itself). The discovery of the new framework of QFT which allows to incorporate the classical covariance principle of Einstein into the quantum setting is the third big conceptual step (after the theoretical discovery of black holes and Hawking radiation) in gravity. The fact that (in contrast to past paradigmatic discoveries) it was hardly noticed, testifies to the depth of the present crisis in which all the attention is sucked up by ST conference hype and the beginning of a futile Amargeddon between ST and LQG. The respect for individual achievements seems to remains a propagandistic lip service.

Another single-directed structural approach to gravity is LQG. Every expert agrees that the essential step from QFT in CST to QG is the conversion of diffeomorphism covariance into diffeomorphism invariance, in that respect the LQG approach runs into open doors. Local covariance is the essential step of considering isometries (diffeomorphism which preserve the metric) as mentally identifying isometric causally complete submanifolds inside (globally non-isometric) different larger manifolds as being observational indistinguishable whereas diffeomorphism invariance in the sense as explained before lumps such isometric manifolds into one single quantum object. But I think that there are myriads of theories which are diffeomorphism invariant and the generic interpretation of the so-called LOST uniqueness theorem appears to me very suspicious. It is an interesting question whether diffeomorphism invariant subalgebras retain still some autonomous localizability properties; the LQP model would exclude such a situation.

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[9]The first observations in this direction date back to Wald's investigation of the correct (locally covariant) energy momentum tensor.

[10]In view of the new situation it seems to be appropriate to re-investigate the reasons for the alleged conceptual necessity of QG.

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