An alternative to string theory

Roland E Allen
Department of Physics and Astronomy, Texas A&M University, College Station, Texas
77843-4242
E-mail: allen@tamu.edu

Abstract. String theory has many compelling features, including higher dimensions, supersymmetry, and topological defects of central importance. Here we describe a theory which also contains these features, but which is much more ambitious than string theory and also much closer to experiment. Since the mathematical details are given in a much longer paper, we summarize only the most important results, which include $SO(N)$ gauge unification, vanishing of the usual cosmological constant, and a credible dark matter candidate.

1. Introduction
Although string theory is now half a century old [1], it has not yet been successful in confronting experiment or naturally resolving problems like an enormous cosmological constant. Here we argue that a likely reason is its conservatism: It is basically an extension of field theory from world lines to world sheets, with (higher-dimensional) spacetime, Lorentz invariance etc. assumed from the beginning.

In a longer paper [2], a theory is offered with a radically different starting point – in fact, the simplest imaginable starting point. Spacetime, Lorentz invariance, etc. then emerge at a later stage, rather than being put in by hand at the beginning.

Some successes of the theory will be enumerated below and emphasized with bullets. It is the author’s experience that essentially everyone finds Ref. [2] difficult to read, because of the density of new ideas and level of abstraction (and perhaps also the many mathematical details). The present paper therefore represents the opposite extreme, with only a summary of the most central conclusions and almost no mathematics.

John Wheeler conjectured that physics is fundamentally based on bits and the act of observation: “It from bit” [3]. The theory of Ref. [2] differs by starting with dits, which can assume any of $d$ states, and which have physical reality apart from any observer. Giving rise to all of Nature, there is a fundamental system which consists of an arbitrary number of dits, with each dit in any of the many states available to it. $D$ of the states correspond to coordinates $x^M$ and the rest to fields.

• The fact that fields and coordinates have essentially the same fundamental status then finds a natural explanation. (String theory, for example, shows this when coordinates are interpreted as fields on a 2-dimensional manifold.)

• A point that may seem trivial but is not: Since the theory is initially based on counting arguments involving only integers (with the continuum defined merely as an approximation), it is manifestly mathematically consistent.
As described in detail in Ref. [2], one can then proceed through a set of arguments to define an entropy $S$ which ultimately becomes the familiar Lorentzian action for bosonic and fermionic fields in a path integral description.

- There is then a natural explanation of the similarity of statistical partition functions and quantum path integrals.

The following aspects of nature emerge automatically:

- bosonic fields
- fermionic fields
- path-integral quantization (which can then be converted to canonical quantization)
- 4-dimensional spacetime
- a metric tensor with one time coordinate
- Lorentz invariance
- the vierbein of general relativity
- correct coupling of the bosonic and fermionic fields to the vierbein
- supersymmetry (without which the theory cannot even be formulated).

The most natural cosmological model involves a vortex-like topological singularity in 4-dimensional spacetime, corresponding to the Big Bang.

There is also an internal space with $D - 4$ dimensions, again containing a vortex-like topological singularity, and from this the following features emerge:

- gauge fields
- correct coupling of the original bosonic and fermionic fields to the gauge fields
- an unavoidable $SO(N)$ symmetry for the gauge fields, with $SO(10)$ being an excellent candidate for grand unification of gauge fields (and $N > 10$ possibly yielding family structure).

Except for one term which is relevant only at high energy, the theory is both Lorentz invariant and supersymmetric, with a Lagrangian density for fermions and scalar bosons of the form

$$\mathcal{L} = \psi_f^\dagger (x) i e_\alpha^\mu \sigma^\alpha D_\mu \psi_f (x) - g^{\mu\nu} (D_\mu \phi (x))\dagger D_\nu \phi (x) + F^\dagger (x) F (x)$$

(1)

where

$$g^{\mu\nu} = \eta^{\alpha\beta} e_\alpha^\mu e_\beta^\nu$$

(2)

and $F$ contains auxiliary fields which emerge automatically. The notation is standard and explained in Ref. [2]. The spin 1/2 fermion fields in $\psi_f$, the scalar boson fields in $\phi$, and the auxiliary fields in $F$ span the various physical representations of the fundamental gauge group, which must be $SO(D - 4)$ in the present theory (or more precisely $Spin(D - 4)$).

The fact that there is not a factor of $e = \sqrt{\det e_\alpha^\mu}$ in (1) is discussed at length in Ref. [2]. This is one of two features which, in conjunction, imply vanishing of the usual enormous cosmological constant. (The other feature is normal ordering of field operators in the quantized action for gauge fields.)

We conclude with three predictions discussed in recent papers:

- a dark matter particle with many favorable features, including well-defined couplings and a mass of $\leq 125$ GeV/$c^2$ [4–6]
- many other neutral and charged new particles at higher energy [4–6]
• a natural origin of the Bekenstein-Hawking entropy for all black holes, which is based on a remarkable result of Gibbons and Hawking [8].

The above claims may appear to be beyond outrageous, so we refer the reader to the arguments in Refs. [2, 4–7], and we also reiterate that many aspects – including the actions of the gauge and gravitational fields, and the topological defects accounting for curvature – are far from complete at this point and need further work. We also await experimental tests.

References
[1] Schwarz J H 1985 Superstrings: The First 15 Years of Superstring Theory, Volumes 1 & 2 (Singapore: World Scientific)
[2] Allen R E 2017 Predictions of a fundamental statistical picture (arXiv:1101.0586v9 [hep-th])
[3] Wheeler J A 1989 Information, physics, quantum: the search for links Proc. 3rd Int. Symp. Foundations of Quantum Mechanics (Tokyo: Physical Society of Japan) pp. 354-368
[4] Allen R E and Saha A 2017 Dark matter candidate with well-defined mass and couplings Mod. Phys. Lett. A 32 1730022 (arXiv:1706.00882 [hep-ph])
[5] Allen R E 2019 Saving supersymmetry and dark matter WIMPs – a new kind of dark matter candidate with well-defined mass and couplings Phys. Scr. 94 014010 (arXiv:1811.00670 [hep-ph])
[6] Throm M, Thornberry R, Killough J, Sun B, Abdulla G, and Allen R E 2019 Two natural scenarios for dark matter particles coexisting with supersymmetry Mod. Phys. Lett. A 34 1930001 (arXiv:1901.02781 [hep-ph])
[7] Allen R E 2019 Black hole entropy, the black hole information paradox, and time travel paradoxes from a new perspective J. Mod. Opt. in press (arXiv:1901.00906 [physics.gen-ph])
[8] Gibbons G W and Hawking S W 1977 Action integrals and partition functions in quantum gravity Phys. Rev. 15 2752