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Gravity Research Foundation,

Sir,

I enclose an essay to be entered into the 1986 competition.

Sincerely,

John B Davies

PARTICLES IN QUANTISED REGGE CALCULUS

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ABSTRACT

Regge calculus decomposes space-time into a net of simplexes with curvature residing on the 2-simplex, a triangle. This simplicial net can be quantised through its well-defined Action. Energy-momentum will be localised on the legs (4-vectors) of the 2-simplex. The 2-simplexes are shown to have the properties of fundamental particles which are shown to be inherent components of this quantised lattice.

INTRODUCTION

All presently viable models of particle structure, such as "quark", "string", "bag" etc., have been constructed to satisfy certain observed particle phenomena. We shall however reverse this process and examine a discrete space-time which will be shown to possess these particle, as well as other, properties of matter.

It has often been postulated that space-time may not be a continuum on the quantum level but rather a discrete lattice. A number of lattice structures are available and all are capable of removing the problems of infinities and unrenormalizability due to the continuum approach.

The quantum theory has, as its basic tenet, that Action is to be measured in units of "h", Planck´s constant. We must therefore look for Action to be well-behaved when space-time is discreted from the continuum into the quantum lattice. The lattice that naturally suggests itself is that of Regge calculus (1,2) as Regge calculus Action and the continuum Action are identical in their appropriate limits(3).

The Regge lattice is unique in that space-time is divided into a NET of simplicial cells, rather than filled with a grid of points. For a 2-dimensional surface such as a Fuller geodesic dome, which is built of planar triangles, the dome´s Curvature is localised on vertices that are 0-dimensional simplexes. For 4-dimensional spacetime, Curvature in this discrete lattice is localised on 2-simplexes, i.e. triangles.

These 2-simplexes will be shown to possess particle properties which the "quark" and "string" phenomenological models have classified. The inherent symmetries of the 2-simplex correlates identically with these models with the legs of the triangle mapping as confined quarks. Basic geometry of baryons, mesons and leptons will be seen to be governed by the elementary structures of this Regge calculus. With Regge lattices, gravity and the quantum world are intimately united.

REGGE CALCULUS

Rather than fill space-time with a grid of points, instead Regge calculus divides it into a NET of 0,1,2,3&4-simplexes. Fundamental quantities and operations of the continuum theory have their discrete simplectic analogues as singular instances of the continuum case(4).

In the Regge calculus of 4-dimensional space-time, Curvature resides on the 2-dimensional simplex, the triangle. The following are some of the more important and relevant properties of this 2-simplex :

1. The 2-simplex is a triangle whose 3 legs are 1-simplexes (vectors), whose lengths and directions determine its geometry(1)
2. The three vectors form a closed triangle, the vector addition of the component 1-simplexes being identically zero, hence confinement(4).
3. Energy-momentum is concentrated on the vector legs of the 2-simplex even though curvature is spread throughout the triangle.
4. Six fundamental invariants of the 2-simplex (4) are obtained when the inner-products are taken of the basis vectors and their duals in the "barycentric" coordinate system which reflects the 3-fold character of the vertices of the triangle.
5. Quantum numbers of the 2-simplex invariants are 2/3 and -1/3 while for the 1-simplex they are 1/2 and -1/2 and for the 0-simplex point they are 0 and -1. (4)
6. With Action remaining finite and well-behaved, a 2-simplex can be collapsed to a 1-simplex (line) and then to a 0-simplex (point),(5), thereby creating a family of curvature-carrying simplexes.
7. Only equal and opposite 2-simplexes are created in a Regge lattice, which is interpreted as "the boundary of the boundary is zero", and is the symmetry associated with conservation of curvature. (2)

Along with these basic structural properties, Regge calculus is conveniently quantised,(2,5), through the Action which is just the product of the Area and the Deficit Angle of the 2-simplex.

As Action is to be measured in units of "h", Planck´s Constant, in this quantised Regge lattice, then Area of the 2-simplex will also be measured in units of "h". Any observable change in this Area, $\Delta x \Delta t$, must be equal or greater than "h" implying, $\Delta x \Delta t \geq h$, which is, of course, Heisenberg´s Uncertainty Principle.

Regge calculus of a (2+1)-dimensional space-time has been shown (6) to yield particle masses proportional to the deficit angle. A simple generalisation into 4 dimensions indicates that the masses associated with the legs of the 2-simplex are proportional to the leg-lengths. It is also shown (6) that the Bianchi Identities in (2+1) Regge calculus yield the usual results for relativistic particle collisions and also satisfy the constraints of conservation of momentum.

Concerning stability of these 2-simplexes, we can readily expect the closer a system is to an isosceles triangle, i.e. total symmetry, the more stable its existence. It has also been shown (4) that when electromagnetism is invoked in the lattice that the 2-simplex carries currents which are conserved.

We now examine the equivalence of the above properties of Regge 2-simplex triangles with the accepted models of quantum matter.

QUARKS AND REGGE LATTICES

We list below the quark properties that correspond directly with the above list for Regge 2-simplexes :

1. Baryons are composed of 3 quarks which are vectors (spinors) which have been postulated previously to exist as triangular systems (7).
2. The quarks are confined within the particle, Color force having the capability of combining the various "colors" of quarks into "white" particles. Thus by giving each leg of the 2-simplex a specific color and demanding closure through vector addition, confinement is color.
3. The 3 quarks carry the energy-momentum of the particle just as the legs of the 2-simplex do the same in Regge lattices.
4. There are six fundamental quark flavors just as there are six fundamental invariants of the Regge lattice.
5. The basic quantum numbers of the quarks are 2/3 and -1/3 and obey the same quantum rules as the invariants of the Regge lattice.
6. Particles form families of baryons (3 quarks), mesons (2 quarks in a line) and leptons (point particles) just as curvature (matter) in Regge lattices is localised on 2-, 1-, 0-simplex families. Particles and simplexes encompass SU(3), SU(2) and O(1) symmetries.
7. Pair production creates a particle together with its anti-particle, and single particles cannot be created alone, c.f. 2-simplexes.

The most stable of the particle families contains the proton, in which are postulated to exist three equal mass quarks. In the Regge 4-dimensional lattice, mass is proportional to length of the 2-simplex leg and so the most stable triangle should be isosceles. The collapse of this isosceles 2-simplex to a 0-simplex should retain its stability which corresponds with the observation of electron permanence.

STRINGS AND REGGE CALCULUS

The "string" model of particles was designed and constructed to satisfy certain properties of hadrons, which are modeled as flexible, extensible strings in rapid rotation. But such a string is a 4-vector and thus corresponds with a 1-simplex in Regge calculus.

Strings can be closed so that, we claim, a triangular string will be equivalent to the 2-simplex. From string theory alone (7), it has not been clear what structure to assign to a baryon. Several shapes have been proposed including a three-pointed star and the triangle, which we have seen are fundamental coordinate systems of the 2-simplex. For the meson, the open string is postulated which has the same linear geometry as the 2-simplex that has collapsed to a 1-simplex.

A string is postulated to possess both kinetic energy and potential energy of tension. The magnitude of the potential energy is found to be proportional to the string length just as the energy-momentum in Regge lattices lies on the legs of the 2-simplex and is proportional to leg length. Kinetic energy of the string is comparable to the energy of the currents that can flow through the legs of the 2-simplex (4).

Recently, a "superstring" theory has been developed which some theorists claim as a potentially all-inclusive unified theory (8). This model has the universe consisting not only of the usual 4 space-time dimensions but an additional 6 unobservable dimensions. Elementary particles are regarded as 1-dimensional strings of length about 10 cm, which is a Planck Length. Apart from the unobservable 6 dimensions, the basic results of this "superstring" model are similar to the known properties of the quantum Regge lattice outlined above.

In summary, the basic properties of the "string" model of hadrons have numerous counterparts in this Regge lattice structure.

CONCLUSIONS

The argument that space-time at the quantum level is discrete and not continuous is not a new one. The novelty is in the concept of using Regge calculus not as a space-time background but as an actual real dynamical lattice in which the fundamental particles are components.

The large number of correlations with the "quark" and "string" phenomenological models, both eminently successful theories, lends much credence to the acceptance of this simplicial view of quantum space-time. The fact that these properties are inherent to Regge calculus rather than imposed on the model by the theorist is a unique aspect.

The minimum area of these quantum 2-simplexes must be, from the Uncertainty Principle, "h", Planck´s Constant, so that the minimum leg length is about 10 cm, a Planck Length. But from scattering experiments it is observed that the size of fundamental particles is about 10 cm or greater. Modern physics argues that charged particles are subject to a phenomena termed screening where the vacuum is polarised by a bare charge thereby increasing its apparent size e.g. the electron which is known to be a point particle. Thus our quantum 2-simplexes may have any size between these two limits in order to satisfy particle constraints.

We are investigating possible tests of this Regge lattice in terms of particle properties including the relative masses of protons to electrons, anomalous magnetic moments of hadrons, and the phenomena of Regge trajectories wherein the angular momentum of hadrons is found to be proportional to the square of their energies.

We have attempted to stick to hard facts in this comparison of the Regge lattice with observed particle phenomena. The idea of space-time and gravity on the quantum level manifesting as particles inherent to the lattice will, no doubt, require new conceptual understanding.

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RESUME

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