Only ConnectOnly Connect by Greg Egan Appearance of the Border | “Only Connect” | Decoherence | Spin Networks Schild’s Ladder contents Back to home page | Site Map | Framed Site Map It’s beginning to look as if E.M.

Forster’s famous dictum was superfluous. A theory in which the building

blocks of the universe are mathematical structures, known as graphs, which do nothing but connect, has just passed its first experimental test. A graph can be drawn as a set of points, called nodes, and a set of lines joining the nodes, called edges. Details such as the length and shape of the edges aren’t part of the graph itself, though; the only thing that distinguishes one graph from another are the connections between the nodes. The number of edges that meet at any given node is known as its valence. In Quantum Graph Theory, or QGT, a quantum state describing both the geometry of space and all the matter fields present is built up from combinations of graphs. The theory reached its current form in the work of the Javanese mathematician Kusnanto

Sarumpaet, who published a series of six papers from 2035 to 2038 showing that both General Relativity and the Standard Model of particle physics could be seen as approximations to QGT. Sarumpaet’s graphs have a fascinating

lineage, dating back to Michael Faraday’s notion of “lines of force” running between electric charges, and William Thomson’s theory of atoms as knotted “vortex tubes”. Closer ancestors are Roger Penrose’s spin networks, trivalent graphs with each edge labelled by a half integer, corresponding to a possible value of the spin of a quantum particle. Penrose invented these networks in the early 1970s, and showed that the set of all directions in space could be generated from simple, combinatorial principles by imagining an exchange of spin between two parts of a large network. Generalisations of spin networks later appeared in certain kinds of Quantum Field Theory. Just as a wave

function assigns an amplitude to every possible position of a particle, a spin network embedded in a region of space can be used to assign an amplitude to every possible configuration of a field. The quantum states defined in this way consist of lines of flux running along the edges of the network. In the 1990s, Lee Smolin and Carlo Rovelli discovered an analogous result in quantum gravity, where spin network states have a simple geometric

interpretation: the area of any surface depends entirely on the edges of the network that intersect it. These edges can be thought of as quantised “flux lines of area”, and in quantum gravity area and other geometric measurements take on a discrete spectrum of possible values. It then makes sense to

quantise the topology as well, with the nodes and edges of the network

replacing the usual idea of space as a continuum of points. In the first decades of the new millennium, John Baez, Fotini Markopoulou, José-Antonio Zapata and others did ground-breaking work on the possible dynamical laws for spin networks, assigning quantum amplitudes to the process of one network evolving into another. In the 2030s, Sarumpaet began to synthesise these results into a new model, based on graphs of arbitrary valence with unlabelled edges. The geometry of three-dimensional space arises from

tetravalent graphs, with the four edges emerging from each node giving area to the faces of a "quantum tetrahedron". Allowing graphs of higher valence runs the risk of producing an explosion of unwanted dimensions, but Sarumpaet found a simple dynamical law which always leads to the average valence

stabilising at four. However, trivalent and pentavalent nodes — which have come to be known as "dopant" nodes, in analogy with the impurities added to semiconductors — can persist under the Sarumpaet rules if they're arranged in special patterns: closed, possibly knotted chains of alternating valence.

These loops of dopant nodes, classified by their symmetries and mutual

interactions, match up perfectly with the particles of the Standard

Model. Since the area associated with the edges of a quantum graph is of the order of a few square Planck lengths, some 1050 times smaller than the

surface area of a hydrogen atom, it was once feared that QGT would remain untestable for centuries. However, in 2043 computer simulations identified a new class of "polymer states": long, open chains of dopant nodes that were

predicted to have energies and half-lives within the grasp of current

technology to create and detect. A search for polymer states that commenced at the Orbital Accelerator Facility in 2049 has now yielded its first

success. If the result can be repeated, Sarumpaet's graphs will shift rapidly from being merely the most elegant known description of the universe, to the most likely one. Appearance of the Border | "Only Connect" | Decoherence | Spin Networks Schild's Ladder contents Back to home page | Site Map |

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