

What if ... fundamental mathematics constrains the physics?

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In physics I have always been optimistic that ultimately we humans will determine the complete set of fundamental rules for the Universe. But what could be the underlying source of these rules? The source must be unique and must directly - or almost directly - lead to the Standard Model of leptons and quarks that works so well already. I suspect these rules all arise from symmetries. Therefore I turn to fundamental mathematics as the source of the fundamental physics rules. You can appreciate the consequences here: if the fundamental physical properties of the Universe are determined by fundamental mathematics, i.e., Nature is mathematical, then we can use the mathematics to list all the rules, the ones we know already and the ones yet to be discovered. We would then be able to determine what is ultimately possible and eliminate what is not possible in physics.

So I turn to fundamental mathematics in order to find the source, hoping to use the inherent logical connections among its three main branches of algebra, geometry, and analysis to lead me to the promised land. However, Gödel's incompleteness theorem may be an impediment. It proves that there is no such thing as a complete logic system, that every logic system contains TRUE statements which cannot be proven true. Such statements are usually self-referential such as: "This statement is false." Thus, there seems to be this built-in limit to knowing everything. But perhaps there is no limit to being able to determine the ultimate source for all the rules of Nature and what these rules actually are. The only limit may be in predicting specific consequences of the rules for each physical event according to quantum mechanics, which is deterministic but provides only amplitudes and quantum probabilities for the possible outcomes.

If I assume that Nature is an expert mathematician, I can ask: "Where would Nature begin?" Number theorists might suggest the prime numbers. Topologists might suggest knot theory. Mathematicians in analysis might suggest elliptic modular functions. Amazingly, all these areas of mathematics and more can be logically linked to group theory, indeed, to the symmetries of the largest simple group called the Monster. As a physicist, I can think of no better place to begin because the Monster group is unique, for I expect our Universe to be unique. In fact, I hope that no other universe is possible, i.e., that the only fundamental physical rules are the ones we observe, dictated by the fundamental mathematics as their source.

Beginning with the mathematical properties of the Monster group, can we lay out a unique connection to the leptons and quarks of the Standard Model of particle physics? That is the challenge. If such a direct and unique pathway can be achieved, then severe limitations will exist on the many yet-to-be observed speculations found in the literature, such as (1) dark energy, (2) dark matter, (3) supersymmetric fundamental particles, (4) other proposed but undetected particles, including the Higgs, axions, MACHOS, WIMPS, unparticles, etc., (5) multiple universes with rules and physical constants different from ours, (6) time travel, time warps, and time tunnels, (7) physical spacetimes larger than 4 dimensions, (8) etc. Hopefully, if fundamental mathematics dictates all of fundamental physics, many or all of the above speculations can be eliminated! Then we would be left with "what is ultimately possible in physics" to be worked out using the rules that we now understand better.

Do we have any chance of success? YES, is the general answer. And the proof may be the appearance of the 4th family of quarks at the Large Hadron Collider (LHC) in the year ahead. If a b' quark at about 80 GeV and its family partner t' quark at a whopping 2600 GeV show up, then the probability is very close to unity that fundamental mathematics dictates the fundamental physics rules of the Universe. The most obvious need for the existence of this 4th quark family is that it will resolve two outstanding problems: (1) the baryon asymmetry of the Universe by increasing the Jarlskog invariant by 13 orders of magnitude, and (2) reducing the muon $g-2$ discrepancy between theory and experiment.

Most mathematical details have been worked out already if one is willing to begin with a discrete 4-D spacetime at the Planck distance scale (see the references). The key steps to uniquely connecting the Standard Model and relativity to the Monster group involve finite binary rotation groups in 3-D for leptons and 4-D for quarks, icosians for the fundamental interactions of the Standard Model, the finite group $\text{Weyl } E_8 \times \text{Weyl } E_8 = \text{'discrete' } SO(9,1)$, and the j -invariant of elliptic modular functions and its connection to the Monster. Phew - that was a mindful! Nature appears to be a very clever mathematician.

References:

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