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Ultra Unification: Quantum Fields Beyond the Standard Model

Strong, electromagnetic, and weak forces were unified in the Standard Model (SM) with spontaneous gauge symmetry breaking. These forces were further conjectured to be unified in a simple Lie group gauge interaction in the Grand Unification (GUT). Here I propose a theory beyond the SM and GUT by adding new gapped Topological Phase Sectors consistent with the nonperturbative global anomaly cancellation and cobordism constraints (especially from the baryon minus lepton number B – L, the electroweak hypercharge Y, and the mixed gauge-gravitational anomaly). Gapped Topological Phase Sectors are constructed via symmetry extension, whose low energy contains unitary Lorentz invariant topological quantum field theories (TQFTs): either 3+1d non-invertible TQFT (long-range entangled gapped phase), or 4+1d invertible or non-invertible TQFT (short-range or long-range entangled gapped phase). Alternatively, there could also be right-handed neutrinos, or gapless unparticle conformal field theories, or their combinations to altogether cancel the anomaly. We propose that a new high-energy physics frontier beyond the conventional 0d particle physics relies on the new Topological Force and Topological Matter including gapped extended objects (gapped 1d line and 2d surface operators or defects, etc., whose open ends carry deconfined fractionalized particle or anyonic string excitations). Physical characterizations of these gapped extended objects require the mathematical theories of cohomology, cobordism, or category. I will also fill in the dictionary between math, QFT, and condensed/quantum matter terminology, and elaborate on the global anomalies of Z2, Z4, Z16 classes useful for beyond SM. Work is based on https://doi.org/10.1103/PhysRevD.103.105024, arXiv:2012.15860, arXiv:2008.06499, arXiv:2006.16996, arXiv:1910.14668.