PCAC, Chiral Symmetry Restoration, Naturalness and the Absence of Higgs-Mass Fine-Tuning

The Standard Model (SM), and the scalar sector of its zero-gauge-coupling limit -- the chiral-symmetric limit of the Gell Mann-Levy Model (GML) -- have been shown not to suffer from a Higgs Fine-Tuning (FT) problem due to ultraviolet quadratic divergences (UVQD). In GML all UVQD are absorbed into the mass-squared of pseudo Nambu-Goldstone (pNGB) bosons. Since chiral SU(2)_{L-R} symmetry is restored as the pNGB mass-squared or as the Higgs vacuum expectation value (VEV) are taken to zero, small values of these quantities and of the Higgs mass are natural, and therefore not Fine-Tuned.

Our results on the absence of FT also apply to a wide class of high-mass-scale (M_{Heavy}>>m_{Higgs}) extensions to a simplified SO(2) version of GML. We explicitly demonstrate naturalness and no-FT for two examples of heavy physics, both SO(2) singlets: a heavy (M_S >> m_{Higgs}) real scalar field (with or without a VEV); and a right-handed Type 1 See-Saw Majorana neutrino with M_R >> m_{Higgs}. We prove that for |q^2| << M_{Heavy}^2, the heavy degrees of freedom contribute only irrelevant and marginal operators. The crucial common property of such high-mass-scale extensions is that they respect chiral SO(2)_{L-R} symmetry. GML is therefore natural and not FT, not just as a stand-alone renormalizable field theory, but also as a low energy effective theory with certain high-mass-scale extensions.

Phenomenological consequences include the renewed possibility of thermal lepto-genesis, and subsequent baryon-number asymmetry, in the neutrino-MSM. We conjecture that, since gravity couples democratically to particles, certain quantum gravitational theories that respect chiral symmetry will also retain low-energy naturalness, and avoid FT problems for GML (and maybe the SM). Absent a SM FT problem, there should be no expectation that LHC will discover physics beyond the SM which is unrelated to neutrino mixing, the only known experimental failure of the SM.