Particle, Astroparticle and Quantum Field Theory Group

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1. Vacuum stability of the effective potential and neutrino masses

The research interests of the group cover the theory of the fundamental interactions, with application to astroparticle theory and cosmology, together with quantum field theory.
In the context of elementary particle theory, the activity of 2014 has concerned some high precision studies of the effective potential of specific extensions of the Standard Model and their perturbative stability under the renormalization group (RG) evolution. The stability requirement allows to identify the critical regions in the parameter space of a given model where the evolution can be extended up to the Planck scale. Particular attention has been devoted to some $U(1)$ extensions of the Standard Model of the elementary particles. In this case it has been shown that the mechanism used for the generation of the masses of the neutrinos, in compliance with the Standard Model, imposes significant constraints on the parameters of the mechanism itself. Several of these mechanisms, such as the Type-1 or the inverse seesaws, require extra right-handed neutrinos in order to generate in the neutrino mass matrix the small mass eigenvalues which are predicted by the experiments on flavour oscillations. It has been shown that the requirement of perturbative stability imposes significant contraints on the masses of the right handed neutrinos, peculiar to each given mechanism. A general analysis has shown that the Yukawa couplings of the heavy neutrinos play an important role in stabilizing/destabilizing the vacuum, correcting previous results by other groups on the RG evolution. These investigations indicate that the issue of perturbative stability in the Standard Model, which appears to be extraordinarily sensitive to the top quark mass and to the numerical constraints coming from the matching conditions at the electroweak scale, could play a far less significant role in an extended scenario. It seems plausible that a more general analysis of the neutrino flavour sector may reduce such a dependence.

2. Particle propagation in curved spacetimes and quantum effects in gravitational lensing

Gravitational lensing has emerged along the years as an important method in order to describe the structure of the Universe, both at a planetary scale, in the form of *microlensing*, and the matter distribution at cosmological scales by *weak lensing*. Gravitational lensing is formulated using classical general relativity (GR). We have recently proposed an extension of the classical GR approach which would allow, at a phenomenological level, to include some important quantum effects in lensing, which cover both the strong and the weak lensing regime. A prerequisite of this analysis has been the investigation of the interactions between gravity, treated as an external field, and the particles of the Standard Model. We have developed a formalism for the analysis of gravity interacting with photons and fermions, which in the flat spacetime limit is induced by the TVV and Tff vertices, involving the energy-momentum tensor (T) of the Standard Model, fermion (f) and vector (V) currents. These studies have been performed building upon our previous investigations of these vertices and their renormalizability in the Standard Model.

3. Supersymmetric effective actions and anomalies

The question whether the Higgs is a fundamental scalar or a composite particle remains unanswered at this time, but most likely it will be answered in the near future at the LHC, in the next scheduled run. In the meanwhile, there are some puzzling features of the Standard Model which suggest that the Higgs could be accompanied by an extra composite state, which is the Nambu-Goldstone mode of a broken conformal symmetry. According to recent analyses, this state could be the physical manifestation of the trace anomaly in the Standard Model, in analogy to the pion, which is interpolated by the chiral current and by the corresponding AVV

(axial-vector/vector/vector) interaction in QCD. In this case, as for the case of chiral symmetry, the description of the dynamics involving this extra state would require a nonlinear realization, with an extra potential which is necessary in order to lift its mass by a small finite amount. Evidence in favour of this scenario comes directly from perturbation theory, and has brought us to propose that all the anomalies, conformal or chiral, are mediated, according to perturbation theory, by effective scalar or pseudoscalar degrees of freedom. We have investigated the effective action of the superconformal (the Ferrara-Zumino) multiplet, where chiral and conformal anomalies share similar signatures, being part of the same multiplet. We have shown in perturbation theory that the anomaly of this multiplet is associated with the exchange of three composite states in the 1PI superconformal anomaly action. They are identified with the anomaly poles present in the effective action, extracted from a supersymmetric correlator JVV in $N = 1$ Super Yang-Mills theory containing the superconformal hypercurrent J and two vector currents V, and correspond to the dilaton, the dilatino and the axion.

REFERENCES

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