The Trace Anomaly in the Standard Model and Gravity

Roberta Armillis, Claudio Corianò, Luigi Delle Rose, Antonio Quintavalle, Mirko Serino
Dipartimento di Fisica
Università del Salento and INFN, Via Arnesano, 73100, Lecce, Italy

In a rather recent work [1] it has been pointed out that the effect of the trace anomaly in QED is in the appearance of an anomaly pole in the correlator of the energy momentum tensor (T) with two vector currents J, which indicates the existence of additional scalar degrees of freedom in the effective action that describes the coupling of gravity to a gauge theory. The elaboration goes quite far, by showing that these massless exchanges are already present in a variational solution of the anomaly equation proposed long ago by Riegert [2], solution which is indeed supported in a perturbative framework by an analysis of the corresponding anomaly graphs.

In the case of anomalous gauge theories a similar pattern emerges, well known since the work of Dolgov and Zakharov [3], who showed the appearance of similar poles in the spectral density of the AVV gauge anomaly amplitude. More generally, the poles can also be extracted at 1 loop by a decomposition of the anomaly amplitude in terms of longitudinal and transverse form factors [4,5], the longitudinal one being responsible for the anomaly and characterized explicitly by a massless pole. An off-shell computation and a mapping from Rosenberg's form of the anomaly graph into the longitudinal/transverse formulation supports these conclusions [6].

This previous analysis and the correspondence with the results of [1], extended to the computation of the off shell correlator [7] has brought us to conclude [8] that anomaly poles are the common signature of gauge and conformal anomalies. It does not take a big leap to probably come to similar conclusions also in regard to gravitational anomalies, where again, one may expect the appearance of massless exchanges of similar type, although an explicit computation, in this case, is still missing.

The perturbative analysis of QED has been recently extended by us to QCD [9], by computing the TJJ correlator in a general kinematical domain, which provides more general results respect to the dispersive approach. The massless poles found in the study of anomalous gauge theories and in the TJJ correlator are indeed generic contributions, present under a general kinematics, not necessarily linked to the infrared limit of an anomaly amplitude. In fact off-shell correlators are equally characterized by pole contributions also in the UV region [7].

1. The gravitational coupling of gauge theories and the trace anomaly

Massless poles describe long range interactions, probably accounting for a phase of the effective theory - in this case of a gauge theory coupled to gravity - which is not yet fully understood at a phenomenological level, probably characterizing some mechanism of condensation. On this point, we just observe that for gauge anomalies, the derivative coupling of the anomaly pole to the anomalous gauge current can be traded with two pseudoscalars of Stückelberg type [10,11] (two gauged axions), one of them ghost-like. The appearance of a ghost in the spectrum is clearly the sign of an instability of the theory, here detected at a perturbative level. We just mention that ghost condensation has received some attention in the past [12], and some of those ideas, concerning infrared modifications of gravity, may apply to the auxiliary field formulation of these effective actions. Extensions of these analysis to the electroweak theory have been described recently [20]. The goal of this research activity is in the analysis of extensions of the Standard Model which include supersymmetry from the onset. In this respect, these results seem to indicate that there are clear gaps in our understading of the interaction between supersymmetric gauge theories and gravity, since superconformal invariance is expected to be a good symmetry in the ultraviolet, far above any symmetry breaking scale. In turn, the radiative breaking of this symmetry poses serious questions in regard to the consistencey of theories, such as gauged supergravities, which gauge the superconformal anomaly supemultiplet in its coupling to gravity.

REFERENCES

1. M. Giannotti and E. Mottola, Phys. Rev. D79 (2009) 045014, 0812.0351.
2. R.J. Riegert, Phys. Lett. B134 (1984) 56.
3. A.D. Dolgov and V.I. Zakharov, Nucl. Phys. B27 (1971) 525.
4. M. Knecht, S. Peris, M. Perrottet and E. de Rafael, JHEP 03 (2004) 035, hep-ph/0311100.
5. F. Jegerlehner and O.V. Tarasov, Phys. Lett. B639 (2006) 299, hep-ph/0510308.
6. R. Armillis, C. Corianò, L. Delle Rose and M. Guzzi, JHEP 12 (2009) 029, 0905.0865.
7. R. Armillis, C. Corianò and L. Delle Rose, Phys. Rev. D81 (2010) 085001, 0910.3381.
8. R. Armillis, C. Corianò and L.Delle Rose, Phys. Lett. B682 (2009) 322, 0909.4522.
9. R. Armillis, C. Corianò and L. Delle Rose, (2010), 1005.4173.
10. R. Armillis, C. Corianò, M. Guzzi and S. Morelli, JHEP 10 (2008) 034, 0808.1882.
11. C. Corianò, M. Guzzi and S. Morelli, Eur. Phys. J. C55 (2008) 629, 0801.2949.
12. N. Arkani-Hamed, H.C. Cheng, M. A. Luty and S. Mukohyama, JHEP 05 (2004) 074, hep-th/0312099.
13. M.J. Duff, Nucl. Phys. B125 (1977) 334.
14. E. Mottola and R. Vaulin, Phys. Rev. D74 (2006) 064004, gr-qc/0604051.
15. F.R. Urban and A.R. Zhitnitsky, Phys. Lett. B688 (2010) 9, 0906.2162.
16. F.R. Urban and A.R. Zhitnitsky, Nucl. Phys. B835 (2010) 135, 0909.2684.
17. A.A. Starobinsky, Phys. Lett. B91 (1980) 99.
18. F.R. Klinkhamer and G.E. Volovik, Phys. Rev. D79 (2009) 063527, 0811.4347.
19. D.W. Jung and J.Y. Lee, JHEP 03 (2009) 123, 0902.0464.
20. C. Corianò, L. Delle Rose, A. Quintavalle, M. Serino arXiv [hep-ph] 1102.4558