Ghost Glueball and Pseudoscalar Mixing

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Abstract

We comment on some work of Rosenzweig, Schechter, and Trahern who construct an effective Lagrangian for QCD involving a pseudoscalar ghost glueball field. We point out that a successful description of pseudoscalar mixing we wrote down some years ago indeed requires a pseudoscalar ghost.

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Recently Veneziano¹ has invoked a ghost field in connection with the saturation of the anomalous chiral Ward identities in a $1/N$ expansion context, obtaining results similar to those of Witten² who explicitly constructs effective Lagrangians including glueball fields. Shortly following this work, Rosenzweig, Schechter, and Trahern (RST)³ constructed an effective Lagrangian which appears to combine all the merits of the old linear sigma model (i.e., correct symmetries and symmetry breaking) with the correct QCD structure for the anomalous $U(1)$ current,

$$\partial_\mu j_\mu^5 = \partial_\mu K_\mu = \sqrt{N_f} \frac{g^2}{16\pi^2} F\tilde{F} \quad .$$

RST argue that K_μ acts as a ghost field (negative kinetic energy) and that the gauge invariant pseudoscalar glueball field proportional to $\partial_\mu K_\mu$ has, correspondingly, a negative squared mass. They emphasize that this negative squared mass is crucial to the generation of a (positive) squared mass for the η' .

In this comment on the above work we would like to point out that some years ago we constructed⁴ a mixing model⁵ for the pseudoscalar nonet to predict a host of pseudoscalar decays and production amplitudes. The model mixes a glueball (called by us then an "0" meson after Freund and Nambu⁵) with the η , η' , and η_c . The η_c effectively decouples from the problem because of its large mass.⁶ The theory is given by the $SU(3)$ symmetric glueball interaction

$$Q = \begin{pmatrix} 0 & 0 & \sqrt{2f} \\ 0 & 0 & f \\ \sqrt{2f} & f & 0 \end{pmatrix}$$

acting to correct the ideally mixed bare propagator.

$$P = \begin{pmatrix} (s - \bar{m}_\eta^2)^{-1} & 0 & 0 \\ 0 & (s - \bar{m}_{\eta'}^2)^{-1} & 0 \\ 0 & 0 & (s - \bar{m}_0^2)^{-1} \end{pmatrix}.$$

With $m_\eta^2 = m_\pi^2$ and $m_{\eta'}^2 = 2m_K^2 - m_\pi^2$ and the physical masses m_η^2 and $m_{\eta'}^2$, as input, we have the full propagator

$$\pi^{\alpha\beta} = (P^{-1} - Q)^{-1} = \sum_i \frac{v_i^\alpha v_i^\beta}{s - m_i^2}$$

where m_i = solutions of $|\pi| = 0$ and

$$v_i = \frac{\sqrt{2}f(m_i^2 - m_\eta^2), f(m_i^2 - m_{\eta'}^2), 1}{1 + \left(\frac{2f^2}{m_i^2 - m_\eta^2} + \frac{f^2}{m_i^2 - m_{\eta'}^2} \right)^{\frac{1}{2}}}.$$

The theory is completely determined, including the glueball mass, by the known masses of the pseudoscalars. The output is the quark and glue content of the η and the η' as reported in reference 4. From these one predicts

$$\left. \frac{d\sigma(\pi^- p \rightarrow \eta n)}{d\sigma(\pi^- p \rightarrow \eta' n)} \right|_{t=0} = 2.05(\exp 2.0 \pm .4)^7$$

$$\Gamma(\varphi \rightarrow \eta \gamma) = 44.5 \pm 10 \text{ KeV}(\exp 65 \pm 15 \text{ KeV})^8$$

$$\Gamma(\psi \rightarrow \eta' \gamma) / \Gamma(\psi \rightarrow p \pi) = .02(\exp < 0.1)^9$$

where the experimental results are in parenthesis. Other as yet untested predictions can be found in reference 4. The results are excellent. We did not, in reference 4, report the mass of the glueball because we were thinking

in terms of an effective interaction ("The cylinder") rather than a real particle, consistent with the ghost picture of references 1, 2, and 3. The mass squared of the glueball of the model is, however, an output of the model and is given by¹⁰

$$m_0^2 = -0.66 \text{ MeV}^2.$$

Thus the extra channel required to explain pseudoscalar mixings indeed corresponds to a ghost channel in agreement with the treatment of RST.

References

1. G. Veneziano, TH.2651-CERN (1979).
2. E. Witten, Harvard preprint 79/A014 (1979).
3. C. Rosenzweig, J. Schechter, and G. Trahern, Syracuse preprint SU-4217-148.
4. J. Bolzan, W. Palmer, and S. Pinsky, Phys. Rev. D 14, 1920 (1976).
5. For a related model cited in reference 3, see N. Fuchs, Phys. Rev. D 14, 1912 (1976). However, from our point this model double counts in that one of the two interactions proposed by Fuchs is the second order iteration of the other (cf Eqs.(1) and (2) of reference 4). In addition Fuchs has a positive glueball squared mass.
6. For simplicity here we formulate the model neglecting the small mixing with the charm-anti-charm channel, which has little effect on η , η' mixing, but is of interest with respect to Zweig rule violating η_c decays. For discussion, see reference 4.
7. N. R. Stanton, et al., The Ohio State University preprint COO-1545-266 (1979).
8. Vannucci, et al., Phys. Rev. D 15, 1814 (1977).
9. Particle Data Group, Phys. Letts. 75B (1978).
10. The Ohio State University Thesis, J. Bolzan (1976).