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Correlated Dirac eigenvalues and axial anomaly in chiral symmetric QCD

We introduce novel relations between the derivatives ($\partial^n\rho/\partial m_l^n$) of the Dirac eigenvalue spectrum (ρ) with respect to the light sea quark mass (m_l) and the $(n+1)$-point correlations among the eigenvalues (λ) of the massless Dirac operator. Using these relations we present lattice QCD results for $\partial^n\rho/\partial m_l^n$ $(n=1,2,3)$ for m_l corresponding to pion masses $m_\pi = 160 - 55$˜MeV, and at a temperature of about 1.6 times the chiral phase transition temperature. Calculations were carried out using (2+1)-flavors of highly improved staggered quarks with the physical value of strange quark mass, three lattice spacings $a = 0.12, 0.08, 0.06$˜fm, and lattices having aspect ratios $4-9$. We find that $\rho(\lambda\to 0, m_l)$ develops a peaked structure. This peaked structure arises due to non-Poisson correlations within the infrared part of the Dirac eigenvalue spectrum, becomes sharper as $a\to 0$, and its amplitude is proportional to m_l^2. We demonstrate that this $\rho(\lambda\to 0, m_l)$ is responsible for the manifestations of axial anomaly in 2-point correlation functions of light scalar and pseudo-scalar mesons. After continuum and chiral extrapolations we find that axial anomaly remains manifested in 2-point correlation functions of scalar and pseudo-scalar mesons in the chiral limit.

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