Synopsis of

Some Studies in Coupling Constants and Transition Form Factors of Eta and Eta-Prime Mesons

A THESIS

to be submitted by

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for the award of the degree

of

DOCTOR OF PHILOSOPHY

Thesis Supervisor

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The area of hadronic physics is compelling as it accommodates many key issues originated by the complexity of a hadronic world. Origin and dynamics of chiral symmetry breaking and confinement, the proton-spin problem, origin of hadronic masses from their constituents, validity of Quantum Chromodynamics (QCD), are subjects of utmost concern. In that intricate sphere of hadrons, the pseudoscalar mesons, η and η' mesons trigger active research on both the theory and experimental sides due to their distinctive characteristics. Significant mixing of flavor-octet and flavor-singlet eigenstates, mixing of singlet with gluons, explicit breaking of $U(1)_A$ classical symmetry make the study of η and η' mesons more complex and engaging. Study of η and η' mesons plays an important role in understanding low-energy dynamics of QCD. These features provide strong motivation to work on aspects involving production and interaction of η and η' mesons.

This thesis describes our studies on the coupling constants of nucleons with η and η' mesons and electromagnetic transition form factors of η and η' mesons. It is divided in four chapters.

First chapter introduces the research area of hadronic physics and its key aspects. It provides motivation and objectives of the present work.

In the second chapter, coupling constants of η and η' mesons with nucleon are studied. Study of these coupling constants is vital for both particle physics and nuclear physics. In this thesis, an attempt is made to give a reliable determination of $g_{\eta NN}$ and $g_{\eta' NN}$ using a well-tested QCD sum rule approach. Values of both coupling constants at the physical points are achieved by linear extrapolation of results achieved at non-physical kinematical points. As a crucial addition, characteristic contribution coming from a pseudoscalar gluonic operator is included. This results in substantial contribution to both $g_{\eta NN}$ and $g_{\eta' NN}$. An OZI-violating contribution to these coupling constants is also highlighted. In all, this study attempts to elucidate the role of non-perturbative gluon dynamics and axial U(1) anomaly in η-η' physics.

Third chapter comprises of a study of electromagnetic transition form factors (TFFs) of η and η' mesons. TFFs of hadrons are non-perturbative objects which act as a tool to

test the predictions based on QCD. TFFs of η and η' have an essential role in determining the quark-gluon structure of these mesons. In this thesis, twist-six corrections to TFFs of η and η' mesons are calculated using collinear factorization approach. These corrections are important as it is imperative to have a better understanding of sub-leading terms in the momentum expansion in order to test the theoretical predictions. Along with twist-six corrections, corrections due to finite meson-mass and quark-mass are also included in this work. Results obtained from these corrections make it clear that twist-six contribution is smaller in magnitude than its counterpart for twist-four for η-meson, but for η', these two contributions are comparable. Results obtained by superimposing our results of twist-six corrections on the existing results up to twist-four corrections are compared with the data. Thus, this work makes an effort to update the existing theoretical results on TFFs of η and η' by including higher twist corrections.

Fourth chapter gives a summary of the thesis and the future scopes in light of these calculations.

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List of Publications

Papers in peer reviewed Journals

1. Janardan P. Singh, **Shesha D. Patel**, "Sub-leading power corrections to transition form factors of η and η' mesons from twist-six contributions", J. Phys. G: Nucl. Part. Phys. **45**, 125002 (2018).

2. Janardan P. Singh , **Shesha D. Patel**, "Eta-nucleon and eta-prime-nucleon coupling constants in QCD and the role of gluons", Physics Letters B. **791** , 249 (2019).

Papers in Conference Proceedings

1. Janardan P. Singh, **Shesha D. Patel**, "Twist-six corrections to $\eta - \gamma$ and $\eta' - \gamma$ transition form factors in QCD", Springer Proc. Phys. **203** 79 (2018).