CHAPTER

VI

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SUMMARY AND CONCLUSION

Nucleon is a microscopic system with complicated structure The dominant role, in determining its constitution and properties, is played by QCD At low energies QCD is a non perturbative and intractable Hence models play a major role in the studies of nucleonic properties QCD allows existence of rich sea of virtual quarks, antiquarks and gluons accompanied by the valence quarks Naturally this sea plays an important role in determining the properties of nucleons Since a fully dynamical calculation with several constituents is a difficult task, the statistical ideas may be important in understanding some of the properties of nucleons We have used a statistical model in which a nucleon is taken as an ensemble of quark-gluon Fock states and where a probability to find a Fock state is decided by the principle of balance or principle of detailed balance These quarks and gluons have to be understood as 'intrinsic' partons of the nucleon

The total flavor-spin-color wave function of a spin-up nucleon has been decomposed in a three-quark core and a sea with definite spin and color quantum numbers and the respective expansion coefficients have been determined The sea is taken to be flavorless but with angular momentum and color quantum numbers which, when combined with the corresponding quantum numbers of three-quark core makes nucleon spin 1/2 and colorless system respectively We have used the simplifying approximations in which a quark in the core is not antisymmetrized with an identical quark in the sea, and have treated quarks and gluons as nonrelativistic particles moving in S-wave (except for a single $\bar{q}q$ sea which has been treated separately) motion Some justification to this approximation comes from the fact that the sum of relativistic quark spin and orbital angular momentum is equal to the sum of nonrelativistic quark spin and orbital angular momentum, and the fact that the quark orbital angular momentum contribution has been shown by some authors to be small We have also not taken into account any contribution of the s-quark and other heavy quarks, and accounted for only ~86% of the total Fock states The number of strange quark-antiquark pairs in the statistical model is 0 05 in the nucleon as compared to the average number of particles which is 5 57 We assume that the rest of the quark-gluon sea spanning~14% of the Fock states of the nucleon also decomposes in color- and spin-subspaces in approximately the same proportion as what we have done explicitly Furthermore, for the decomposition of a particular Fock state into substates with definite spin and color quantum numbers, it was assumed, in the spirit of statistical approach, that each of these substates occur with equal probability With these substates, we have calculated the quarks' contribution to the spin of the nucleon, the ratio of the magnetic moments of the nucleons, their weak decay constant and the ratio of SU(3) reduced matrix elements of the axial current All of these quantities refer to the integrated result of the Bjorken variable The Melosh rotation effects, which come from the relativistic effect of the quarks' intrinsic transversal motion inside the nucleon, have also been taken into account The stability of our result against some plausible changes in some physical parameters have been checked by considering two modifications of our above model In one model $\bar{q}q$ pairs in the sea have been assumed to appear in colorless pseudoscalar form, and in the other states with higher multiplicities have been assumed to be suppressed, their probability being inversely proportional to their multiplicities

Pion-nucleon coupling plays an important role in investigation of low energy properties of nucleons Pion being the lightest meson, provides the longest range of the nuclear force In effective Lagrangian, the pions and nucleons provide the lightest degrees of freedom in the respective categories and the study of their interactions can provide a basis for the study of interaction among heavier hadrons Hence determination of $g_{\pi NN}$ and its isospin splitting is of interest for particle physics as well as nuclear physics Even within the hadronic boundary, Goldstone boson exchange model successfully describes diverse phenomenon The pions generate the non trivial sea to nucleons This has been used to study the flavor symmetry breaking and the spin structure of the nucleons

The study of charge symmetry breaking in $g_{\pi NN}$ is an important step for the investigation of charge symmetry breaking effects in NN interaction We have used QCD sum rule, a nonperturbative method, to study the charge splitting in $g_{\pi NN}$ Within this approach, we have made a systematic study of various factors contributing to δg the nucleon mass difference, the quark mass difference, the isospin splitting in $\langle \bar{q}q \rangle$, mixing between π^0 and η, and the charge difference between u and d quarks The nucleon mass difference has been found to make the largest contribution while electromagnetic interaction of quarks makes the lowest contribution

$g_{\pi NN}$ and δg (the splitting in the diagonal pion-nucleon coupling constant) are quantities which can not be measured directly from experiments, but these are phenomenologically important quantities that appear in numerous problems related to nucleons in particle physics and nuclear physics The successful application of this approach for $g_{\pi NN}$ and δg will encourage us to apply it for other hadronic couplings

In the final part of the thesis, we have studied the effect of the gluonic topological charge density, Q, on nucleon's mass and spin The coupling of Q to a nucleon gives rise to OZI-violating η -nucleon and η' -nucleon interactions We have studied one-loop self-energy of a nucleon arising due to these interactions using heavy baryon chiral perturbation theory The small value of $g_A^0\big|_{DIS}$, the flavor-singlet axial charge measured in deep inelastic scattering, points to substantial violations of the OZI rule in the flavor- singlet $J^P=1^+$ channel. One possible explanation for this from the flavor-singlet Goldberger-Treiman relation is the existance of large positive value of the one-particle irreducible coupling of the topological charge density to the nucleon g_{QNN} ~2 45 We have calculated the nucleon self-energy due to this kind of gluonic interaction, which will be over and above the contributions associated with meson exchange models Conventional type of form factors have been used to regularize the divergences appearing in one loop calculation of the self-energy The nontrivial structure of the QCD vacuum also contributes to the self-energy of the nucleon through non vanishing value of $\langle Q^2\rangle$ Taking all this into account, we estimate the total contribution to the nucleon mass from its interaction with the topological charge density to be around -(2.5-7 5)% of the nucleon mass, as compared to -(10-20)% of the nucleon mass coming from one-loop pion diagrams

The 'proton spin' problem arises due to lack of our understanding the dynamical origin of the OZI violating inequality wherein the measurement shows that the singlet axial charge of proton is less than the corresponding octet charge It can be shown that the singlet axial charge of a nucleon is related to the first derivative of the susceptibility at zero momentum transfer, $\chi'(0)$ It is in this context that, our evaluation of $\chi'(0)$, is relevant for the study of nucleonic properties

Our statistical model calculation of nucleonic properties can be improved by incorporating more Fock states and by involving strange quark-antiquark pairs in the sea of the nucleon We can extend our calculation of charge symmetry breaking of pion-nucleon coupling to the full isospin symmetry breaking by including the couplings of charged pions to the nucleons as well In the nucleon self-energy calculation due to interaction of topological charge density with the nucleon, the divergences can be renormalized by introducing counterterms in the effective Lagrangian Finally, one can try to find the contribution of quarks to the nucleon spin by using the value of $\chi'(0)$ that we have obtained

We conclude that nucleon is a many body complex system whose low-energy behaviour is determined mainly by strong interaction Non-perturbative approach to QCD, such as QCD sum rule and the QCD based effective theory, and the models such as a statistical model, have a complementary role in exposing different aspects of nucleonic properties