

# Quark flavor distribution functions for the octet baryons in the chiral quark constituent model

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The quark flavor distribution functions of the octet baryons ( $N$ ,  $\Sigma$ ,  $\Xi$ , and  $\Lambda$ ) have been calculated in the chiral constituent quark model. In particular, the valence and sea quark flavor distribution functions of the scalar density matrix elements of octet baryons have been computed explicitly. The implications of chiral symmetry breaking and SU(3) symmetry breaking have been discussed in detail for the sea quark asymmetries, a fraction of a particular quark (antiquark) present in a baryon, flavor structure functions and the Gottfried integral. The meson-baryon sigma terms  $\sigma_{\pi B}$ ,  $\sigma_{KB}$ , and  $\sigma_{\eta B}$  for the case of  $N$ ,  $\Sigma$ , and  $\Xi$  baryons have also been calculated. The results have been compared with the recent available experimental observations for the case of  $N$ , and how the future experiments for  $\Sigma$ ,  $\Xi$ , and  $\Lambda$  can provide important constraints to describe the role of nonvalence (sea) degrees of freedom has been discussed.

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## I. INTRODUCTION

The fact that the quarks are pointlike constituents was revealed in the deep inelastic scattering (DIS) [1]. These pointlike constituents were identified as the valence or constituent quarks with  $1/2$  spin in the naive quark model (NQM) [2–5]. This was further confirmed by the measurements of polarized structure functions of the proton, to have a deeper insight into the internal structure of the baryons, in the DIS experiments [6–9]. Surprisingly, these DIS results provided the first evidence that the valence quarks of the proton carry only about 30% of its spin, clearly indicating that they should be surrounded by an indistinct sea of quark-antiquark pairs. Recently, experiments measuring the weak and electromagnetic form factors from the elastic scattering of electrons have provided considerable insight on the role played by strange quarks in the charge, current, and spin structure of the nucleon. For example, SAMPLE at MIT-Bates [10], G0 at JLab [11], PVA4 at MAMI [12], and HAPPEX at JLab [13] have provided considerable insight on the role played by strange quarks when the nucleon interacts at high energies and have clearly indicated explicitly the nonvalence contribution in the nucleon that is otherwise absent in the NQM picture. Even though the internal structure of the nucleon has been extensively studied over the past 40 or 50 years, because of confinement, the knowledge has been rather limited, and it is still a big challenge to perform the calculations from the first principles of QCD, and as a result, the study of the composition of hadrons still remains to be a major unresolved issue in high-energy spin physics.

Apart from the spin structure, several interesting facts have also been revealed regarding the flavor structure of the sea quark content in the nucleon. A major surprise was found when the famous DIS experiments by the New Muon Collaboration (NMC) in 1991 [14] established the sea

quark asymmetry of the unpolarized quarks in the case of the nucleon by measuring the violation of the Gottfried sum rule (GSR) ( $\int_0^1 [\bar{d}(x) - \bar{u}(x)] dx$ ) [15]. This was subsequently confirmed by two independent experiments in various  $0 \leq x \leq 1$  ranges: first, from the Fermilab E866 experiments [16], measuring a large sea quark asymmetry ratio  $\bar{d}/\bar{u}$  as well as  $\bar{d} - \bar{u} \neq 0$ , and the other from the Drell–Yan cross section ratios of the NA51 experiments [17]. More recently, HERMES has presented another  $u - d$  sea quark asymmetry  $\frac{\bar{d}-\bar{u}}{u-d}$  [18], confirming the violation of the GSR. There was a clear indication from these results that the structure of the nucleon is not limited to  $u$  and  $d$  quarks and the origin of the sea quarks should be non-perturbative in nature because the conventional expectation that the sea quarks perhaps can be obtained through the perturbative production of the quark-antiquark pairs by gluons producing nearly equal numbers of  $\bar{u}$  and  $\bar{d}$ .

In addition, the information on the strange sea is obtained from the neutrino-induced DIS experiments [19] as well as through the charm production with dimuon events in the final states of the experiments CDHS [20], Chicago-Columbia-Fermilab-Rochester (CCFR) [21,22], CHARMII [23], NOMAD [24,25], NuTeV [26], and CHORUS [27]. It has been emphasized in the neutrino-induced DIS experiments that the valence quark distributions dominate for  $x > 0.3$ , and it is a relatively clean region to test the valence structure of the nucleon as well as to estimate the structure functions and related quantities, whereas the sea quarks dominate for the  $x < 0.3$ . These experiments have renewed considerable interest in the sea quark flavor structure as well as asymmetries, and they point out the need for additional refined data. In this regard, the ongoing Drell–Yan experiment at Fermilab [28] and a proposed experiment at J-PARC facility [29] are working toward extending the kinematic coverage and improving the accuracy of the sea quark asymmetry.

In the context of low-energy experiments [26,30], the pion-nucleon sigma term ( $\sigma_{\pi N}$ ) has received much attention in the past. It has been determined precisely from the pion-nucleon scattering experiments [31–34] as well as hadron spectroscopy [35]. The results from both the methods, however, differ substantially. The  $\sigma_{\pi N}$  term is known to have intimate connection with the dynamics of the nonvalence quarks and is an important fundamental parameter to test the chiral symmetry breaking effects and thereby determine the scalar quark content of the nucleon. In addition, it also provides a restriction on the contribution of strangeness to the parameters measured in low energy [36] since the strange quarks constitute purely sea degrees of freedom. Our experimental information about the other meson-baryon sigma terms  $\sigma_{\pi B}$ ,  $\sigma_{KB}$ , and  $\sigma_{\eta B}$ , for the case of  $N$ ,  $\Sigma$ ,  $\Xi$ , and  $\Lambda$  baryons, is also rather limited because of the difficulty in the measurements due to their short lifetimes. The low-energy determination of  $\sigma_{MB}$  would undoubtedly provide vital clues to the nonperturbative aspects of QCD.

Even though there has been considerable progress in the past few years to understand the origin of the sea quark flavor structure, there is no consensus regarding the various mechanisms that can contribute to it. This has motivated a large amount of effort to understand the origins of the nucleon sea. The broader question of nonvalence quark contribution to the unpolarized distributions of sea quarks, sea quark asymmetry, and structure function has been discussed [37–48]. One of the most successful nonperturbative approaches is the chiral constituent quark model ( $\chi$ CQM) [49]. The basic idea is based on the possibility that chiral symmetry breaking takes place at a distance scale much smaller than the confinement scale. The  $\chi$ CQM uses the effective interaction Lagrangian approach of the strong interactions in which the effective degrees of freedom are the valence quarks and the internal Goldstone bosons (GBs) that are coupled to the valence quarks [50–53]. The  $\chi$ CQM successfully explains the “proton spin problem” [53], magnetic moments of octet and decuplet baryons including their transitions and the Coleman–Glashow sum rule [54], hyperon  $\beta$  decay parameters [55], magnetic moments of octet baryon resonances [56], magnetic moments of  $\Lambda$  resonances [57], charge radii, the quadrupole moment, [58] etc. The model is successfully extended to predict the important role played by the small intrinsic charm content in the nucleon spin in the  $SU(4)$   $\chi$ CQM and to calculate the magnetic moment and charge radii of charm baryons including their radiative decays [59]. In view of the above developments in the  $\chi$ CQM, it become desirable to extend the model to calculate the quark flavor distribution functions and related quantities of the octet baryons of which the knowledge would undoubtedly provide vital clues to the nonperturbative aspects of QCD.

The purpose of the present communication is to determine the quark flavor distribution functions of the octet

baryons in the chiral constituent quark model, which is one of the most successful models to phenomenologically estimate the quantities affected by chiral symmetry breaking and  $SU(3)$  symmetry breaking. In particular, we would like to understand in detail the implications of the scalar density matrix elements of octet baryons in terms of the valence and sea quark flavor distribution functions, related sea quark asymmetries, fractions of quarks and antiquarks present in a baryon, flavor structure functions, and the Gottfried integral. Further, it would be interesting to extend the calculations to predict the meson-baryon sigma terms  $\sigma_{\pi B}$ ,  $\sigma_{KB}$ , and  $\sigma_{\eta B}$  for the case of  $N$ ,  $\Sigma$ ,  $\Xi$ , and  $\Lambda$  baryons. The results can be compared with the recent available experimental observations and can also provide important constraints on the future experiments to describe the role of nonvalence degrees of freedom.

## II. CHIRAL CONSTITUENT QUARK MODEL

The  $\chi$ CQM was introduced by Weinberg and further developed by Manohar and Georgi [49]. The underlying idea is that the set of internal GBs couple directly to the valence quarks in the interior of hadron, but not at so small distances that perturbative QCD is applicable.

The dynamics of light quarks ( $u$ ,  $d$ , and  $s$ ) and gluons can be described by the QCD Lagrangian

$$\mathcal{L} = -\frac{1}{4}G_{\mu\nu}^a G_{\mu\nu}^a + i\bar{\psi}_R \not{D}\psi_R + i\bar{\psi}_L \not{D}\psi_L - \bar{\psi}_R M \psi_L - \bar{\psi}_L M \psi_R, \quad (1)$$

where  $G_{\mu\nu}^a$  is the gluonic gauge field strength tensor,  $D^\mu$  is the gauge-covariant derivative,  $M$  is the quark mass matrix, and  $\psi_L$  and  $\psi_R$  are the left- and right-handed quark fields, respectively,

$$\Psi_L \equiv \begin{pmatrix} u_L \\ d_L \\ s_L \end{pmatrix} \quad \text{and} \quad \Psi_R \equiv \begin{pmatrix} u_R \\ d_R \\ s_R \end{pmatrix}. \quad (2)$$

Since the mass terms change sign as  $\psi_R \rightarrow \psi_R$  and  $\psi_L \rightarrow -\psi_L$  under the chiral transformation ( $\psi \rightarrow \gamma^5 \psi$ ), the Lagrangian in Eq. (1) no longer remains invariant. In case the mass terms in the QCD Lagrangian are neglected, the Lagrangian will have global chiral symmetry of the  $SU(3)_L \times SU(3)_R$  group. Since the spectrum of hadrons in the known sector does not display parity doublets, the chiral symmetry is believed to be spontaneously broken around a scale of 1 GeV as

$$SU(3)_L \times SU(3)_R \rightarrow SU(3)_{L+R}. \quad (3)$$

As a consequence, there exists a set of massless particles, referred to as the Goldstone bosons, which are identified with the observed ( $\pi$ ,  $K$ ,  $\eta$  mesons). Within the region of the

QCD confinement scale ( $\Lambda_{\text{QCD}} \approx 0.1 - 0.3$  GeV) and the chiral symmetry breaking scale  $\Lambda_{\chi\text{SB}}$ , the constituent quarks, the octet of GBs ( $\pi$ ,  $K$ ,  $\eta$  mesons), and the *weakly* interacting gluons are the appropriate degrees of freedom.

The effective interaction Lagrangian in this region can be expressed as

$$\mathcal{L}_{\text{int}} = \bar{\psi}(i\mathcal{D} + \mathcal{V})\psi + ig_A \bar{\psi} A \gamma^5 \psi + \dots, \quad (4)$$

where  $g_A$  is the axial-vector coupling constant. The gluonic degrees of freedom can be neglected, owing to a small effect in the effective quark model at the low-energy scale. The vector and axial-vector currents  $V_\mu$  and  $A_\mu$  are defined as

$$\begin{pmatrix} V_\mu \\ A_\mu \end{pmatrix} = \frac{1}{2} (\xi^\dagger \partial_\mu \xi \pm \xi \partial_\mu \xi^\dagger), \quad (5)$$

where  $\xi = \exp(2i\Phi/f_\pi)$ ,  $f_\pi$  is the pseudoscalar pion decay constant ( $\approx 93$  MeV) and  $\Phi$  is the field describing the dynamics of GBs as

$$\Phi = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \beta \frac{\eta}{\sqrt{6}} & \pi^+ & \alpha K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \beta \frac{\eta}{\sqrt{6}} & \alpha K^0 \\ \alpha K^- & \alpha \bar{K}^0 & -\beta \frac{2\eta}{\sqrt{6}} \end{pmatrix}. \quad (6)$$

Expanding  $V_\mu$  and  $A_\mu$  in the powers of  $\Phi/f_\pi$ , we get

$$V_\mu = 0 + O((\Phi/f_\pi)^2), \quad (7)$$

$$A_\mu = \frac{i}{f_\pi} \partial_\mu \Phi + O((\Phi/f_\pi)^2). \quad (8)$$

The effective interaction Lagrangian between GBs and quarks from Eq. (4) in the leading order can now be expressed as

$$\mathcal{L}_{\text{int}} = -\frac{g_A}{f_\pi} \bar{\psi} \partial_\mu \Phi \gamma^\mu \gamma^5 \psi, \quad (9)$$

which can be reduced to

$$\mathcal{L}_{\text{int}} \approx i \sum_{q=u,d,s} \frac{m_q + m_{q'}}{f_\pi} \bar{q}' \Phi \gamma^5 q = i \sum_{q=u,d,s} c_8 \bar{q}' \Phi \gamma^5 q, \quad (10)$$

using the Dirac equation  $(i\gamma^\mu \partial_\mu - m_q)q = 0$ . Here,  $c_8 (= \frac{m_q + m_{q'}}{f_\pi})$  is the coupling constant for the octet of GBs, and  $m_q(m_{q'})$  is the quark mass parameter. The Lagrangian of the quark-GB interaction, suppressing all the space-time structure to the lowest order, can now be expressed as

$$\mathcal{L}_{\text{int}} = c_8 \bar{\psi} \Phi \psi. \quad (11)$$

The QCD Lagrangian is also invariant under the axial  $U(1)$  symmetry, which would imply the existence of a ninth GB. This breaking symmetry picks the  $\eta'$  as the ninth GB. The effective Lagrangian describing interaction between quarks and a nonet of GBs, consisting of an octet and a singlet, can now be expressed as

$$\begin{aligned} \mathcal{L}_{\text{int}} &= c_8 \bar{\psi} \Phi \psi + c_1 \bar{\psi} \frac{\eta'}{\sqrt{3}} \psi = c_8 \bar{\psi} \left( \Phi + \zeta \frac{\eta'}{\sqrt{3}} I \right) \psi \\ &= c_8 \bar{\psi} (\Phi') \psi, \end{aligned} \quad (12)$$

where  $\zeta = c_1/c_8$ ,  $c_1$  is the coupling constant for the singlet GB and  $I$  is the  $3 \times 3$  identity matrix.

The fluctuation process describing the effective Lagrangian is

$$q^\pm \rightarrow \text{GB} + q'^\mp \rightarrow (q\bar{q}') + q'^\mp, \quad (13)$$

where  $q\bar{q}' + q'$  constitute the sea quarks [50,51,53]. The GB field can be expressed in terms of the GBs and their transition probabilities as

$$\Phi' = \begin{pmatrix} \frac{\pi^0}{\sqrt{2}} + \beta \frac{\eta}{\sqrt{6}} + \zeta \frac{\eta'}{\sqrt{3}} & \pi^+ & \alpha K^+ \\ \pi^- & -\frac{\pi^0}{\sqrt{2}} + \beta \frac{\eta}{\sqrt{6}} + \zeta \frac{\eta'}{\sqrt{3}} & \alpha K^0 \\ \alpha K^- & \alpha \bar{K}^0 & -\beta \frac{2\eta}{\sqrt{6}} + \zeta \frac{\eta'}{\sqrt{3}} \end{pmatrix}. \quad (14)$$

The transition probability of chiral fluctuation  $u(d) \rightarrow d(u) + \pi^{+(-)}$ , given in terms of the coupling constant for the octet GBs  $|c_8|^2$ , is defined as  $a$  and is introduced by considering nondegenerate quark masses  $M_s > M_{u,d}$ . In terms of  $a$ , the probabilities of transitions of  $u(d) \rightarrow s + K^{+(0)}$ ,  $u(d, s) \rightarrow u(d, s) + \eta$ , and  $u(d, s) \rightarrow u(d, s) + \eta'$  are given as  $\alpha^2 a$ ,  $\beta^2 a$ , and  $\zeta^2 a$ , respectively [50,51]. The parameters  $\alpha$  and  $\beta$  are introduced by considering nondegenerate GB masses  $M_K, M_\eta > M_\pi$ , and the parameter  $\zeta$  is introduced by considering  $M_{\eta'} > M_K, M_\eta$ . These parameters provide the basis to understand the extent to which the sea quarks contribute to the structure of the baryon. The hierarchy for the probabilities, which scale as  $\frac{1}{M_q^2}$ , can be obtained as

$$a > \alpha^2 a \geq \beta^2 a > \zeta^2 a. \quad (15)$$

The sea quark flavor distribution functions can be calculated in the  $\chi$ CQM by substituting for every valence (constituent) quark

$$q \rightarrow P_q q + |\psi(q)|^2, \quad (16)$$

where the transition probability of no emission of GB  $P_q$  can be expressed in terms of the transition probability of the emission of a GB from any of the  $u, d, s$  quark as

$$P_q = 1 - P_{[q,GB]}, \quad (17)$$

with

$$P_{[u,GB]} = P_{[d,GB]} = a \left( \frac{3}{2} + \alpha^2 + \frac{\beta^2}{6} + \frac{\zeta^2}{3} \right), \quad \text{and}$$

$$P_{[s,GB]} = a \left( 2\alpha^2 + \frac{2\beta^2}{3} + \frac{\zeta^2}{3} \right), \quad (18)$$

whereas  $|\psi(q)|^2$  is the transition probability of the  $q$  quark calculated from the Lagrangian, expressed as

$$|\psi(u)|^2 = a \left[ \frac{7}{4} + \frac{\beta}{6} + \frac{\zeta}{3} + \frac{\beta\zeta}{9} + \alpha^2 + \frac{7\beta^2}{36} + \frac{4\zeta^2}{9} \right] u$$

$$+ \left[ \frac{1}{4} + \frac{\beta}{6} + \frac{\zeta}{3} + \frac{\beta\zeta}{9} + \frac{\beta^2}{36} + \frac{\zeta^2}{9} \right] \bar{u}$$

$$+ \left[ \frac{5}{4} - \frac{\beta}{6} - \frac{\zeta}{3} + \frac{\beta\zeta}{9} + \frac{\beta^2}{36} + \frac{\zeta^2}{9} \right] (d + \bar{d})$$

$$+ \left[ -\frac{2\beta\zeta}{9} + \alpha^2 + \frac{\beta^2}{9} + \frac{\zeta^2}{9} \right] (s + \bar{s}), \quad (19)$$

$$|\psi(d)|^2 = a \left[ \frac{7}{4} + \frac{\beta}{6} + \frac{\zeta}{3} + \frac{\beta\zeta}{9} + \alpha^2 + \frac{7\beta^2}{36} + \frac{4\zeta^2}{9} \right] d$$

$$+ \left[ \frac{1}{4} + \frac{\beta}{6} + \frac{\zeta}{3} + \frac{\beta\zeta}{9} + \frac{\beta^2}{36} + \frac{\zeta^2}{9} \right] \bar{d}$$

$$+ \left[ \frac{5}{4} - \frac{\beta}{6} - \frac{\zeta}{3} + \frac{\beta\zeta}{9} + \frac{\beta^2}{36} + \frac{\zeta^2}{9} \right] (u + \bar{u})$$

$$+ \left[ -\frac{2\beta\zeta}{9} + \alpha^2 + \frac{\beta^2}{9} + \frac{\zeta^2}{9} \right] (s + \bar{s}), \quad (20)$$

$$|\psi(s)|^2 = a \left[ \frac{4\beta\zeta}{9} + 2\alpha^2 + \frac{10\beta^2}{9} + \frac{4\zeta^2}{9} \right] s$$

$$+ \left[ \frac{4\beta\zeta}{9} + \frac{4\beta^2}{9} + \frac{\zeta^2}{9} \right] \bar{s}$$

$$+ \left[ -\frac{2\beta\zeta}{9} + \alpha^2 + \frac{\beta^2}{9} + \frac{\zeta^2}{9} \right] (u + \bar{u} + d + \bar{d}). \quad (21)$$

The flavor structure for the baryon of the type  $B(q_1 q_2 q_3)$  for the case of octet baryons having  $q_1, q_2, q_3 = u, d, s$  is expressed as

$$P_{q_1} q_1 + P_{q_2} q_2 + P_{q_3} q_3 + |\psi(q_1)|^2 + |\psi(q_2)|^2 + |\psi(q_3)|^2. \quad (22)$$

### III. QUARK FLAVOR DISTRIBUTION FUNCTIONS

The quark flavor distribution functions can be calculated from the scalar matrix elements of the octet baryons and can be defined as [50]

$$\hat{B} \equiv \langle B | \mathcal{N}_{q\bar{q}} | B \rangle, \quad (23)$$

where  $|B\rangle$  is the SU(6) baryon wave function (detailed in Ref. [60]) and  $\mathcal{N}_{q\bar{q}}$  is the number operator measuring the sum of the quark and antiquark numbers,

$$\mathcal{N}_{q\bar{q}} = \sum_{q=u,d,s} (n_q q + n_{\bar{q}} \bar{q})$$

$$= n_u u + n_{\bar{u}} \bar{u} + n_d d + n_{\bar{d}} \bar{d} + n_s s + n_{\bar{s}} \bar{s}$$

$$= (n_u - n_{\bar{u}})u + (n_d - n_{\bar{d}})d + (n_s - n_{\bar{s}})s, \quad (24)$$

with the coefficients  $n_{q(\bar{q})}$  being the number of  $q(\bar{q})$  quarks with electric charge  $e_q(e_{\bar{q}})$ . We have also used  $q = -\bar{q}$  for a given baryon in the above equation.

The quark flavor distribution functions of the baryon receive contribution from the valence as well as the sea quark distribution functions as

$$q^B = q_V^B + q_S^B. \quad (25)$$

Since the antiquark distribution functions come purely from the sea quarks, therefore we can replace the sea quark distribution functions with the antiquark distribution functions as

$$q^B = q_V^B + \bar{q}^B. \quad (26)$$

The normalization conditions for the valence quark distribution functions of the octet baryons can be summarized in Table I. The antiquark densities of the octet baryons  $p, n, \Sigma^+, \Sigma^-, \Xi^0, \Xi^-,$  and  $\Lambda^0$  can easily be calculated using Eqs. (16), (17), (19), (20), and (21). The results have been presented in Table II.

To study the flavor structure of the baryons, we can define the fraction of a particular quark and antiquark present in a baryon relative to the total number of the quarks and antiquarks as

$$f_q^B = \frac{q^B + \bar{q}^B}{\sum (q^B + \bar{q}^B)}, \quad (27)$$

TABLE I. The normalization conditions for the valence quark distribution functions of the octet baryons integrated over the Bjorken variable  $x$ .

Baryon	$\int_0^1 u_V^B(x) dx$	$\int_0^1 d_V^B(x) dx$	$\int_0^1 s_V^B(x) dx$
$p(uud)$	2	1	0
$n(udd)$	1	2	0
$\Sigma^+(uus)$	2	0	1
$\Sigma^-(dds)$	0	2	1
$\Xi^0(uss)$	1	0	2
$\Xi^-(dss)$	2	1	0
$\Lambda^0(uds)$	1	1	1

TABLE II. The sea quark (antiquark) distribution functions for the octet baryons.

Baryon	$\bar{u}^B$	$\bar{d}^B$	$\bar{s}^B$
$p( uud )$	$\frac{a}{12}(21 + \beta^2 + 4\zeta + 4\zeta^2 + \beta(2 + 4\zeta))$	$\frac{a}{12}(33 + \beta^2 - 4\zeta + 4\zeta^2 + \beta(-2 + 4\zeta))$	$3a(\alpha^2 + \frac{1}{9}(\beta - \zeta)^2)$
$n( udd )$	$\frac{a}{12}(33 + \beta^2 - 4\zeta + 4\zeta^2 + \beta(-2 + 4\zeta))$	$\frac{a}{12}(21 + \beta^2 + 4\zeta + 4\zeta^2 + \beta(2 + 4\zeta))$	$3a(\alpha^2 + \frac{1}{9}(\beta - \zeta)^2)$
$\Sigma^+( uus )$	$\frac{a}{6}(3 + 6\alpha^2 + 2\beta + \beta^2 + 4\zeta + 2\zeta^2)$	$\frac{a}{6}(15 + 6\alpha^2 - 2\beta + \beta^2 - 4\zeta + 2\zeta^2)$	$\frac{a}{3}(6\alpha^2 + 2\beta^2 + \zeta^2)$
$\Sigma^-( dds )$	$\frac{a}{6}(15 + 6\alpha^2 - 2\beta + \beta^2 - 4\zeta + 2\zeta^2)$	$\frac{a}{6}(3 + 6\alpha^2 + 2\beta + \beta^2 + 4\zeta + 2\zeta^2)$	$\frac{a}{3}(6\alpha^2 + 2\beta^2 + \zeta^2)$
$\Xi^0( uss )$	$a(2(\alpha^2 + \frac{1}{9}(\beta - \zeta)^2) + \frac{1}{36}(3 + \beta + 2\zeta)^2)$	$a(1 + 2(\alpha^2 + \frac{1}{9}(\beta - \zeta)^2) + \frac{1}{36}(-3 + \beta + 2\zeta)^2)$	$\frac{a}{3}(3\alpha^2 + 3\beta^2 + 2\beta\zeta + \zeta^2)$
$\Xi^-( dss )$	$a(1 + 2(\alpha^2 + \frac{1}{9}(\beta - \zeta)^2) + \frac{1}{36}(-3 + \beta + 2\zeta)^2)$	$a(2(\alpha^2 + \frac{1}{9}(\beta - \zeta)^2) + \frac{1}{36}(3 + \beta + 2\zeta)^2)$	$\frac{a}{3}(3\alpha^2 + 3\beta^2 + 2\beta\zeta + \zeta^2)$
$\Lambda^0( uds )$	$\frac{a}{6}(9 + 6\alpha^2 + \beta^2 + 2\zeta^2)$	$\frac{a}{6}(9 + 6\alpha^2 + \beta^2 + 2\zeta^2)$	$\frac{a}{3}(6\alpha^2 + 2\beta^2 + \zeta^2)$

where  $q^B$  and  $\bar{q}^B$  are the number of quarks and antiquarks for the octet baryon  $B$  and  $\sum(q^B + \bar{q}^B)$  is the sum of all the quarks and antiquarks present.

Further, we can define

$$\begin{aligned} f_0^B &= f_u^B + f_d^B + f_s^B, \\ f_3^B &= f_u^B - f_d^B, \\ f_8^B &= f_u^B + f_d^B - 2f_s^B. \end{aligned} \quad (28)$$

Other relevant quantities are the suppression factors ( $\rho^B$  and  $\kappa^B$ ) of the strange quark content with respect to the nonstrange quarks and sea quarks,

$$\begin{aligned} \rho_s^B &= \frac{s^B + \bar{s}^B}{u^B + d^B}, \\ \kappa_s^B &= \frac{s^B + \bar{s}^B}{\bar{u}^B + \bar{d}^B}, \end{aligned} \quad (29)$$

and the ratio of total number of the antiquarks and quarks,

$$\frac{\sum \bar{q}^B}{\sum q^B}. \quad (30)$$

To calculate the phenomenological quantities pertaining to the valence and sea quark flavor distribution functions, we first fix  $\chi$ CQM parameters pertaining to the probabilities of fluctuations to pions,  $K$ ,  $\eta$ ,  $\eta'$  coming in the sea quark distribution functions by taking into account strong physical considerations and carrying out a fine-grained analysis using the well-known experimentally measurable quantities pertaining to the spin and flavor distribution functions. The input parameters and their values have been summarized in Table III.

Using the above set of parameters, the results of our calculations pertaining to the sea quark flavor distribution functions and related flavor dependent functions discussed above for the case of  $N$ ,  $\Sigma$ ,  $\Xi$ , and  $\Lambda$  baryons have been

TABLE III. Input parameters.

Parameter $\rightarrow$	$a$	$\alpha$	$\beta$	$\zeta$	$\frac{m_s}{\bar{m}}$
Value	0.114	0.45	0.45	-0.75	22–30 MeV

presented in Table IV. The present experimental situation, for the case of  $N$ , as obtained from the DIS and Drell–Yan experiments [14,16,17], is given as

$$\begin{aligned} \bar{u}^N - \bar{d}^N_{\text{NMC}} &= -0.147 \pm 0.024, \\ \bar{u}^N / \bar{d}^N_{\text{NA51}} &= 0.51 \pm 0.09, \\ \bar{u}^N - \bar{d}^N_{\text{E866}} &= -0.118 \pm 0.018, \\ \bar{u}^N / \bar{d}^N_{\text{E866}} &= 0.67 \pm 0.06, \\ f_s^N_{\text{CCFR}} &= 0.076 \pm 0.02, \\ f_3^N / f_8^N_{\text{CCFR}} &= 0.21 \pm .05, \\ \rho_s^N_{\text{CCFR}} &= 0.099 \pm 0.009, \\ \kappa_s^N_{\text{CCFR}} &= 0.477 \pm 0.051, \\ \frac{\sum \bar{q}^N}{\sum q^N} &= 0.245 \pm 0.005. \end{aligned} \quad (31)$$

 TABLE IV. The  $\chi$ CQM results for the sea quark flavor distribution functions and related flavor-dependent functions for the  $N$ ,  $\Sigma$ ,  $\Xi$ , and  $\Lambda$  octet baryons.

Quantity $\downarrow B \rightarrow$	$N$	$\Sigma$	$\Xi$	$\Lambda$
$\bar{u}^B$	0.221	0.099	0.947	0.217
$\bar{d}^B$	0.339	0.335	0.213	0.217
$\bar{s}^B$	0.091	0.068	0.046	0.068
$\bar{u}^B / \bar{d}^B$	0.652	0.295	0.445	1
$\bar{u}^B - \bar{d}^B$	-0.118	-0.236	-0.118	0
$f_u^B = \frac{u^B + \bar{u}^B}{\sum(u^B + \bar{u}^B)}$	0.567	0.549	0.321	0.358
$f_d^B = \frac{d^B + \bar{d}^B}{\sum(d^B + \bar{d}^B)}$	0.390	0.167	0.115	0.358
$f_s^B = \frac{s^B + \bar{s}^B}{\sum(s^B + \bar{s}^B)}$	0.042	0.283	0.564	0.284
$f_0^B = f_u^B + f_d^B + f_s^B$	1	1	1	1
$f_3^B = f_u^B - f_d^B$	0.177	0.381	0.206	0
$f_8^B = f_u^B + f_d^B - 2f_s^B$	0.874	0.149	-0.693	0.149
$\frac{f_3^B}{f_8^B}$	0.203	2.563	-0.297	0
$\rho_s^B = \frac{s^B + \bar{s}^B}{u^B + d^B}$	0.051	0.622	0.632	0.467
$\kappa_s^B = \frac{s^B + \bar{s}^B}{\bar{u}^B + \bar{d}^B}$	0.323	4.920	6.798	2.617
$\frac{\sum \bar{q}^B}{\sum q^B}$	0.178	0.143	0.105	0.143

The NQM, which is quite successful in explaining a good deal of low-energy data [2–4], has the following predictions for the above-mentioned quantities:

$$\begin{aligned}
 \bar{u}^N - \bar{d}^N &= 0, \\
 \bar{u}^N / \bar{d}^N &= -, \\
 f_s^N &= 0, \\
 f_3^N / f_8^N &= \frac{1}{3}, \\
 \rho_s^N &= 0, \\
 \kappa_s^N &= 0, \\
 \frac{\sum \bar{q}}{\sum q} &= 0.
 \end{aligned} \tag{32}$$

From Table IV and Eqs. (31) and (32), we find that the important measurable quark distribution functions seem to be in agreement with the most recent phenomenological/experimental results available that the NQM is unable to explain. For example, the  $\chi$ CQM results clearly indicate that the nucleon sea contains a higher number of  $\bar{d}^N$  quarks than the  $\bar{u}^N$  quarks, as indicated by DIS and Drell–Yan experiments [14,16,17]. The  $\chi$ CQM result for  $\bar{u}^N / \bar{d}^N$  is 0.652 and is clearly in agreement with the latest DIS results available for the case of nucleon  $\bar{u}^N / \bar{d}^N = 0.67 \pm 0.06$  [16]. It is also quite in agreement with the results of Drell–Yan experiment giving  $\bar{u}^N / \bar{d}^N = 0.51 \pm 0.09$  [17]. For the case of  $\bar{u}^N - \bar{d}^N$ , the  $\chi$ CQM gives  $-0.118$ , which is completely in agreement with the result of the latest Fermilab E866 experiment  $\bar{u}^N - \bar{d}^N = -0.118 \pm 0.018$  [16]. The result of the earlier NMC experiment is on the higher side,  $\bar{u}^N - \bar{d}^N = -0.147 \pm 0.024$  [14].

For the case of  $f_s^N$ , the NQM results show that this fraction of strange quarks is zero, whereas the  $\chi$ CQM result comes out to be 0.042, which is close to the available data from CCFR,  $f_s^N = 0.076 \pm 0.02$  [21,22]. Similarly,  $\rho_s^N$  and  $\kappa_s^N$  are predicted to be zero in NQM, but the  $\chi$ CQM predicts them to be 0.051 and 0.323, respectively. The results when compared with the available data  $\rho_s^N = 0.099 \pm 0.009$  and  $\kappa_s^N = 0.477 \pm 0.051$  [21,22] clearly indicate that the  $\chi$ CQM predicts these quantities with the right magnitude and sign. Further, the ratio of the total number of the antiquarks and quarks in the  $\chi$ CQM for the case of the nucleon is  $\frac{\sum \bar{q}^N}{\sum q^N} = 0.178$  as compared to the available phenomenological result  $\frac{\sum \bar{q}^N}{\sum q^N} = 0.245 \pm 0.005$ . Our results for the quantities discussed above are also in agreement with the results predicted by other model calculations [37–42].

Since the understanding of the deep inelastic results as well as the dynamics of the constituents of the nucleon constitute a major challenge for any model trying to explain

the nonperturbative regime of QCD, the success of the  $\chi$ CQM not only justifies but also strengthens our conclusion regarding the qualitative and quantitative role of the sea quarks in the right direction. The nonvanishing values for strangeness-dependent quantities for the case of the nucleon indicate that the chiral symmetry breaking as well as SU(3) symmetry breaking are essential to understand the significant role played by the strange quarks in the nucleon. Since no data are available for the  $\Sigma$ ,  $\Xi$ , and  $\Lambda$  octet baryons, any future measurement of these would have important implications for the subtle features of the  $\chi$ CQM.

#### IV. FLAVOR STRUCTURE FUNCTIONS AND THE GOTTFRIED INTEGRAL

The basic flavor structure functions  $F_1$  and  $F_2$  are defined as

$$F_2^B(x) = x \sum_{u,d,s} e_q^2 [q^B(x) + \bar{q}^B(x)], \tag{33}$$

$$F_1^B(x) = \frac{1}{2x} F_2^B(x). \tag{34}$$

Using the quark distribution functions from Eq. (26), the structure function  $F_2$  for the baryons can be expressed as

$$\begin{aligned}
 F_2^p(x) &= \frac{4}{9} x (u_V^p(x) + 2\bar{u}^p(x)) + \frac{1}{9} x (d_V^p(x) + 2\bar{d}^p(x)) \\
 &\quad + s_V^p(x) + 2\bar{s}^p(x), \\
 F_2^{\Sigma^+}(x) &= \frac{4}{9} x (u_V^{\Sigma^+}(x) + 2\bar{u}^{\Sigma^+}(x)) + \frac{1}{9} x (d_V^{\Sigma^+}(x) + 2\bar{d}^{\Sigma^+}(x)) \\
 &\quad + s_V^{\Sigma^+}(x) + 2\bar{s}^{\Sigma^+}(x), \\
 F_2^{\Xi^0}(x) &= \frac{4}{9} x (u_V^{\Xi^0}(x) + 2\bar{u}^{\Xi^0}(x)) + \frac{1}{9} x (d_V^{\Xi^0}(x) + 2\bar{d}^{\Xi^0}(x)) \\
 &\quad + s_V^{\Xi^0}(x) + 2\bar{s}^{\Xi^0}(x), \\
 F_2^{\Lambda^0}(x) &= \frac{4}{9} x (u_V^{\Lambda^0}(x) + 2\bar{u}^{\Lambda^0}(x)) + \frac{1}{9} x (d_V^{\Lambda^0}(x) + 2\bar{d}^{\Lambda^0}(x)) \\
 &\quad + s_V^{\Lambda^0}(x) + 2\bar{s}^{\Lambda^0}(x).
 \end{aligned} \tag{35}$$

The deviation from the Gottfried sum rule [15] can be obtained from the structure functions of different isospin multiplets measured through the Gottfried integral  $I_G^{B_1 B_2}$  for the octet baryons. This experimentally observed quantity measures the asymmetry between the  $\bar{u}^B$  and the  $\bar{d}^B$  quarks content in the sea quarks. The Gottfried integrals can be simplified and expressed as

$$\begin{aligned}
 I_G^{pn} &\equiv \int_0^1 \frac{F_2^p(x) - F_2^n(x)}{x} dx = \frac{1}{3} + \frac{2}{3}[\bar{u}^p - \bar{d}^p], \\
 I_G^{\Sigma^+\Sigma^0} &\equiv \int_0^1 \frac{F_2^{\Sigma^+}(x) - F_2^{\Sigma^0}(x)}{x} dx \\
 &= \frac{1}{3} + \frac{2}{9}[4\bar{u}^{\Sigma^+} + \bar{d}^{\Sigma^+} - 4\bar{u}^{\Sigma^0} - \bar{d}^{\Sigma^0}], \\
 I_G^{\Sigma^0\Sigma^-} &\equiv \int_0^1 \frac{F_2^{\Sigma^0}(x) - F_2^{\Sigma^-}(x)}{x} dx \\
 &= \frac{1}{3} + \frac{2}{9}[4\bar{u}^{\Sigma^0} + \bar{d}^{\Sigma^0} - 4\bar{d}^{\Sigma^-} - \bar{u}^{\Sigma^-}], \\
 I_G^{\Xi^0\Xi^-} &\equiv \int_0^1 \frac{F_2^{\Xi^0}(x) - F_2^{\Xi^-}(x)}{x} dx \\
 &= \frac{1}{3} + \frac{2}{3}[\bar{u}^{\Xi^0} - \bar{d}^{\Xi^-}]. \tag{36}
 \end{aligned}$$

The normalization conditions for the valence quarks used to derive the above equations have been taken from Table I, whereas the sea quark contributions corresponding to each baryon obey the following normalization conditions:

$$\begin{aligned}
 \int_0^1 \bar{d}^n(x) dx &= \int_0^1 \bar{u}^p(x) dx, \\
 \int_0^1 \bar{u}^n(x) dx &= \int_0^1 \bar{d}^p(x) dx, \\
 \int_0^1 \bar{s}^n(x) dx &= \int_0^1 \bar{s}^p(x) dx, \\
 \int_0^1 \bar{u}^{\Xi^-}(x) dx &= \int_0^1 \bar{d}^{\Xi^0}(x) dx, \\
 \int_0^1 \bar{d}^{\Xi^-}(x) dx &= \int_0^1 \bar{u}^{\Xi^0}(x) dx, \\
 \int_0^1 \bar{s}^{\Xi^-}(x) dx &= \int_0^1 \bar{s}^{\Xi^0}(x) dx. \tag{37}
 \end{aligned}$$

A measurement of the Gottfried integral for the case of the nucleon has shown a clear violation of Gottfried sum rule from  $\frac{1}{3}$ , which can find its explanation in a global quark sea asymmetry  $\int_0^1 (\bar{d}(x) - \bar{u}(x)) dx$  that has been measured in the NMC and E866 experiments [14,16]. It is clear from Eq. (36) that the flavor symmetric sea ( $\bar{u}^B = \bar{d}^B$ ) leads to  $I_G = \frac{1}{3}$ . Similarly, for the case of  $\Sigma^+$ ,  $\Sigma^0$ , and  $\Xi^0$ , the Gottfried sum rules should read  $I_G^{\Sigma^+\Sigma^0} = \frac{1}{3}$ ,  $I_G^{\Sigma^0\Sigma^-} = \frac{1}{3}$ , and  $I_G^{\Xi^0\Xi^-} = \frac{1}{3}$  for symmetric sea quarks. However, due to the  $\bar{d}(x) - \bar{u}(x)$  asymmetry in the case of octet baryons, a lower value of the Gottfried integrals is obtained, and the numerical values are given as

$$\begin{aligned}
 I_G^{pn} &= 0.254, \\
 I_G^{\Sigma^+\Sigma^0} &= 0.640, \\
 I_G^{\Sigma^0\Sigma^-} &= 0.569, \\
 I_G^{\Xi^0\Xi^-} &= 0.254. \tag{38}
 \end{aligned}$$

For the case of the nucleon, the  $\chi$ CQM result ( $I_G^{pn} = 0.254$ ) is in good agreement with the available experimental data of E866 [16]. We have  $I_G^{pn} = \frac{1}{3} + \frac{2}{3}[\bar{u}^p - \bar{d}^p] = 0.266 \pm 0.005$  from the NMC results [14] and  $I_G^{pn} = 0.254 \pm 0.005$  from the E866 results [16]. Since no experimental results are available for the other octet baryons, new experiments aimed at measuring the flavor content of the other octet baryons are needed for profound understanding of the nonperturbative properties of QCD as well as to understand the important role of the sea quarks at a low value of  $x$ .

## V. MESON-BARYON SIGMA TERMS

The meson-baryon sigma term ( $\sigma_{MB}$ ) corresponding to the pseudoscalar mesons and octet baryons is affected by the contributions of the sea quark. It can be defined in terms of the scalar quark content  $[(q\bar{q})_M]$  of the particular meson  $M$  ( $\pi$ ,  $K$ , and  $\eta$ )

$$\sigma_{MB} = \hat{m} \langle B | (q\bar{q})_M | B \rangle, \tag{39}$$

where  $\hat{m}$  is the average value of current  $u$ ,  $d$ , and  $s$  quark masses evaluated at fixed gauge coupling. For example, we have

$$\sigma_{\pi B} = \hat{m} \langle B | \bar{u}u + \bar{d}d | B \rangle. \tag{40}$$

The kaon-nucleon sigma term ( $\sigma_{KB}$ ) can be expressed in terms of the scalar quark content of  $u$  and  $d$  quarks as

$$\sigma_{KB} = \frac{\sigma_{KB}^u + \sigma_{KB}^d}{2}, \tag{41}$$

where

$$\sigma_{KB}^u = \frac{\hat{m} + m_s}{2} \langle B | \bar{u}u + \bar{s}s | B \rangle,$$

and

$$\sigma_{KB}^d = \frac{\hat{m} + m_s}{2} \langle B | \bar{d}d + \bar{s}s | B \rangle.$$

Similarly, the  $\eta$ -nucleon sigma term ( $\sigma_{\eta B}$ ) can be expressed as

$$\sigma_{\eta B} = \frac{1}{3} \langle B | \hat{m}(\bar{u}u + \bar{d}d) + 2m_s\bar{s}s | B \rangle. \tag{42}$$

The  $\sigma_{KB}$  and  $\sigma_{\eta B}$  can be expressed in terms of the  $\sigma_{\pi B}$  and  $y_B$ ,

$$\sigma_{KB} = \frac{\hat{m} + m_s}{2\hat{m}} (1 + 2y_B) \sigma_{\pi B}, \tag{43}$$

$$\sigma_{\eta B} = \frac{1}{3} \hat{\sigma} + \frac{2(m_s + \hat{m})}{3\hat{m}} y_B \sigma_{\pi B}, \tag{44}$$

TABLE V. The  $\chi$ CQM results for the meson-baryon sigma terms for the quark mass ratio  $\frac{m_s}{\hat{m}} = 22$ .

Quantity	$N$	$\Sigma$	$\Xi$	$\Lambda$
$y_B$	0.044	0.396	1.294	0.396
$\sigma_{\pi B}$	31.325	137.568	-17.974	137.568
$\sigma_{KB}$	195.952	1417.75	-370.992	1417.75
$\sigma_{\eta B}$	30.635	845.167	-347.328	845.167
$\sigma_B^s$	15.145	599.483	-256.003	599.483

where we have defined

$$\hat{\sigma} = \hat{m} \langle B | \bar{u}u + \bar{d}d - 2\bar{s}s | B \rangle, \quad (45)$$

and

$$y_B = \frac{\langle B | \bar{s}s | B \rangle}{\langle B | \bar{u}u + \bar{d}d | B \rangle}. \quad (46)$$

In terms of  $\hat{\sigma}$  and  $y_B$ , we can also define  $\sigma_{\pi B}$  as

$$\sigma_{\pi B} = \frac{\hat{\sigma}}{1 - 2y_B}. \quad (47)$$

Another important parameter pertaining to the strangeness content in a baryon is the strangeness sigma term

$$\sigma_s^B = m_s \langle B | \bar{s}s | B \rangle = \frac{1}{2} y_B \frac{m_s}{\hat{m}} \sigma_{\pi B}. \quad (48)$$

Using the respective antiquark flavor distribution functions from the Table II, the meson-baryon sigma terms can be calculated, and the results for the meson-baryon sigma terms for  $N$ ,  $\Sigma$ , and  $\Xi$  have been presented in Table V. Since the  $\sigma$  terms are characterized by the light quark mass ratio  $\frac{m_s}{\hat{m}}$ , in addition to the parameters of the  $\chi$ CQM listed in

Table III, we have used the most widely accepted range for  $\frac{m_s}{\hat{m}}$  as 22 – 30 MeV [61]. From Table V, we find that the  $\sigma$  terms are positive for the case of  $N$  and  $\Sigma$ ; however, they are negative for the case of  $\Xi$ . This is clearly due to the dominance of the  $s$  quarks in the valence structure of  $\Xi$  due to which a higher value of  $y_B$  [Eq. (46)] is obtained. This leads to a negative value of  $\sigma_{\pi B}$  as defined in Eq. (47).

The strangeness fraction of the nucleon from Eq. (27) can be related to the strangeness content from Eq. (46) as

$$f_s^N = \frac{y_N}{1 - y_N}, \quad (49)$$

which in terms of  $\sigma_{\pi N}$  and  $\hat{\sigma}$  can be expressed as

$$f_s^N = \frac{\sigma_{\pi N} - \hat{\sigma}}{3\sigma_{\pi N} - \hat{\sigma}}. \quad (50)$$

According to NQM, the valence quark structure of the nucleon does not involve strange quarks. The validity of the Okubo-Zweig-Iiuzuka rule [62] in this case would imply  $y_N = f_s^N = 0$  or  $\hat{\sigma} = \sigma_{\pi N}$ . For  $\frac{m_s}{\hat{m}} = 22$ , the value of  $\sigma_{\pi N}$  comes out to be close to 28 MeV. However, the most recent analysis of experimental data gives higher values of  $\sigma_{\pi N}$ , which points toward a significant strangeness content in the nucleon. The  $\chi$ CQM results, giving a comparatively higher value of  $\sigma_{\pi N}$ , justify the mechanism of chiral symmetry breaking and SU(3) symmetry breaking. Since no data are available for the  $KN$  and  $\eta N$  sigma terms nor for all the  $MB$  terms corresponding to  $\Sigma$  and  $\Xi$  baryons, the future DAΦNE experiments [63] for the determination of  $KN$  sigma terms as well as information from the hyperon-antihyperon production in heavy ion collisions will provide information of the contribution of the sea quark. The results can, however, be compared with the other available phenomenological and theoretical results presented in Table VI.

TABLE VI. Phenomenological results of some other theoretical approaches for strangeness content in the nucleon and meson-nucleon sigma terms.

Phenomenological results of other theoretical approaches	$y_N$	$\sigma_N^s$	$\sigma_{\pi N}$ (MeV)	$\sigma_{KN}$ (MeV)	$\sigma_{\eta N}$ (MeV)
Koch <i>et al.</i> [31]	...	...	64 ± 8	...	...
Gasser <i>et al.</i> [32]	0.11 ± 0.07	...	45 ± 8	...	...
Pavan <i>et al.</i> [33]	0.23	...	79 ± 7	...	...
Hite <i>et al.</i> [34]	...	...	81 ± 6	...	...
QCD sum rules [64]	0.17 ± 0.03	161 ± 66	53 ± 24	...	...
Lattice QCD, Fukugita <i>et al.</i> [65]	0.33 ± 0.07	...	40 – 60	451 ± 54	...
Lattice QCD, Dong <i>et al.</i> [66]	0.36 ± 0.03	...	49.7 ± 2.6	362 ± 13	...
Perturbative quark model [67]	0.076 ± 0.012	...	45 ± 5	312 ± 37	72 ± 16
Heavy baryon chiral perturbation theory [68]	0.12 ± 0.03	150 ± 50	45	...	...
SU(3) Nambu–Jona-Lasinio soliton model [69]	0.13	...	40.80	...	...
Chiral quark-soliton model [70]	...	...	67.9	...	...
Meson-cloud model [71]	...	260	45	...	...

## VI. SUMMARY AND CONCLUSIONS

To summarize, the quark flavor distribution functions of the octet baryons ( $N$ ,  $\Sigma$ ,  $\Xi$ , and  $\Lambda$ ) have been phenomenologically estimated in the  $\chi$ CQM since the understanding of the DIS results as well as the dynamics of the constituents of the baryon constitute a major challenge for any model trying to explain the nonperturbative regime of QCD. These quantities have important implications for the sea quark contributions, chiral symmetry breaking, and SU(3) symmetry breaking. The valence and sea quark flavor distribution functions of the scalar density matrix elements of octet baryons have been computed explicitly for the  $u$ ,  $d$ , and  $s$  quarks in each baryon. To understand the role of sea quarks in understanding the important experimentally measurable quantities, the implications of this model have been studied for the sea quark asymmetries, a fraction of a particular quark (antiquark) present in a baryon, flavor structure functions and the Gottfried integral. The  $\chi$ CQM results are in agreement with the most recent phenomenological/experimental results available and justify the qualitative and quantitative role of the sea

quarks in the right direction. This can perhaps be substantiated further by measurements for the other octet baryons. The recent available experimental results pointing out a significant contribution of the strangeness in the nucleon also find an answer in this model that gives a significant strangeness fraction of the nucleon. The meson-baryon sigma terms  $\sigma_{\pi B}$ ,  $\sigma_{KB}$ , and  $\sigma_{\eta B}$  for the case of  $N$ ,  $\Sigma$ , and  $\Xi$  baryons have also been calculated. Since no data are available for the  $\Sigma$  and  $\Xi$  octet baryons, any future measurement of these would have important implications for the subtle features of the  $\chi$ CQM. To conclude, chiral symmetry breaking is the key to understanding the contribution of the sea quarks in the nonperturbative regime of QCD, in which, at the leading order, the valence quarks and the weakly interacting Goldstone bosons constitute the appropriate degrees of freedom.

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