I calculate the quark contributions to the axial and tensor charges and the spin structure of the proton, which are related, respectively, through the transformations to their nonrelativistic quark model expectations. The result indicates that the valence current quark spins carry 1/3 of the proton spin, the total contribution of quark spins to the proton spin satisfies $\Delta \Sigma = 1/3 + \Delta \Sigma_{sea} \leq 1/3$, and the quarks (their spin plus orbital contributions) contribute about one half of the proton spin at scale of 1 GeV. The valence current quark contributions to the proton tensor charge are also obtained.

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The axial and tensor charges of the nucleon are the fundamental observables characterizing nucleon’s properties. Measurement of these charges leads to valuable insight into the spin-dependent quark substructure of the nucleon because these charges are related through deep-inelastic sum rules to the quark helicity distribution $\Delta q(x)[1]$ and the transversity distribution $h_1(x)[2]$, respectively. In recent years, of particular interest has been the flavor’s singlet-axial charge which measures the contribution of quark spins to the nucleon spin. From recent data on polarized deep-inelastic scattering(DIS)[3], one finds that about 30% of the nucleon spin is carried by quark spins[4], which deviates significantly from the expectation of the simple nonrelativistic constituent quark model(sNCQM). This discrepancy caused it to be called "nucleon spin crisis". As for nucleon’s tensor charge[5,6], a first measurement of $h_1(x)$ (hence the tensor charge) will be undertaken at RHIC with transversely polarized Drell-Yan process and other processes[7]. Here one of important issues for understanding the proton spin puzzle and for predicting reliably the proton tensor charge is the relationship between the current (parton) quark and constituent quark contributions to the axial and tensor charges and to the spin structure of the nucleon[8], since in DIS and Drell-Yan processes one probes the contribution from current quarks rather than constituent quarks. This Letter attempts to provide answers to them.

In this Letter I present a quark model calculation of the quark contributions to the axial and tensor charges and the spin structure of the proton, which are related, respectively, through the transformations to their sNCQM’s expressions. One thus shows that the valence

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constituent quark contributions to the axial and tensor charges and the spin structure of
the proton in the traditional valence quark model include the contributions from the valence
current quarks and the sea-(q\bar{q})-pairs which can be separated from each other. Antiquark
polarizations, which can not be got through the trasformations hence must arise from the
contributions beyond the traditional three quark structure of nucleon such as the QCD
anomaly etc, are introduced in the axial and tensor charges by definition and are found to
be significant. Furthermore, I show a decomposition of the proton spin in the quark model,
which is related through a transformation to the spin structure in sNCQM, and compare such
a decomposition with the spin sum rule in QCD. One finds that in the chiral limit of current
quark mass $m_{cu} = 0$ the valence current quark spins carry $\frac{1}{3}$ of the proton spin, which is a
basic origin of quark spin contribution measured in polarized DIS, suggestig that precise
measurements for the quark spin contribution $\Delta \Sigma = 1$ at which the operators are renormalized, or physically the nucleon wavefunction is probed.

The nucleon axial and tensor charges can be written in terms of the nucleon matrix ele-
ments of the axial quark current $\bar{q}\gamma^\mu\gamma^5 q$ and the tensor quark current $\bar{q}i\sigma^{\mu\nu}\gamma^5 q$, respectively:

$$\langle PS|\bar{q}\gamma^\mu\gamma^5 q|_{\mu^2}|PS\rangle = 2\Delta q(\mu^2) S^\mu, \quad (1)$$

$$\langle PS|\bar{q}i\sigma^{\mu\nu}\gamma^5 q|_{\mu^2}|PS\rangle = 2\delta q(\mu^2)(S^\mu P^\nu - S^\nu P^\mu) \quad (2)$$

with $q = u, d, s$, where $P$ and $S$ are the nucleon four-momentum and spin vector, $\mu^2$ is a scale
at which the operators are renormalized, or physically the nucleon wavefunction is probed. $\Delta q$ and $\delta q$ are related to the quark distributions by $\Delta q = \int_0^1 dx [\Delta q(x) + \Delta \bar{q}(x)] = \Delta q_v + \Delta \bar{q}, \delta q = \int_0^1 dx (h_1(x) - \bar{h}_1(x)) = \delta q_u - \delta \bar{q}$. Thus $\Delta q$ measures $q$-flavor contribution to the
nucleon spin, and $\Delta q_v$ ($\Delta \bar{q}$) is longitudinal quark (antiquark) polarization in longitudinal
polarized nucleon, while $\delta q_u$ ($\delta \bar{q}$) is transverse quark (antiquark) polarization in transverse
polarized nucleon. If one separates the quarks (partons) into valence current quarks and
sea quarks and assumes that antiquarks are all in the sea[10], one may write $\Delta q$ and $\delta q$ as:
$\Delta q = \Delta q_v + \Delta q_\bar{q} = \Delta q_v + \Delta q_s + \Delta \bar{q} = \Delta q_v + \Delta q_{sea}, \text{ and } \delta q = \delta q_u - \delta \bar{q} = \delta q_u + \delta q_s - \delta \bar{q} = \delta q_v$. The
sea quarks do not contribute to $\delta q$ because the tensor current operator is odd under charge
conjugate. Therefore, $\delta q$ only counts the valence current quarks of opposite transversity.

One now calculates $\Delta q$ and $\delta q$ based on Eqs.(1) and (2) by using the quark model. In
the rest frame of the nucleon, Eqs.(1) and (2) become $\langle PS|\bar{q}\gamma^i\gamma^5 q|_{\mu^2}|PS\rangle = 2\Delta q(\mu^2) S^i$ and
$\langle PS|\bar{q}i\sigma^{\mu\nu}\gamma^5 q|_{\mu^2}|PS\rangle = 2\delta q(\mu^2) S^i$, where $\mu^2$ takes 1 $GeV^2$, the scale that the constituent
quark picture works. One notices that in these matrix elements the nucleon wavefunction in
the quark model can be written in terms of the Dirac spinor for the quarks, while in the
NCQM the nucleon wavefunction is traditionally written in terms of the Pauli spinor for
the quarks. Thus, by transforming identically the Dirac spinor into the Pauli spinor and
some calculations, I find that the axial charge $\Delta q$ and the tensor charge $\delta q$ defined by these
matrix elements are related to their sNCQM expressions, $\Delta q_{NR}$ and $\delta q_{NR}$, as follows

$$\Delta q_v = \langle M_A \rangle \Delta q_{NR}, \quad (3)$$

$$\delta q_v = \langle M_T \rangle \delta q_{NR} \quad (4)$$

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with
\[ M_A = \frac{1}{3} + \frac{2m}{3E}, \quad M_T = \frac{2}{3} + \frac{m}{3E}, \]
and
\[ 2\delta q_q = \Delta q_q + \Delta q_{NR}, \]
where \( \Delta q_{NR} = \langle P \uparrow | \chi_s^+ \sigma_3 \chi_s | P \uparrow \rangle \), \( m \) and \( E = \sqrt{m^2 + \vec{k}^2} \) are quark mass and energy, respectively, and \( \langle M_{A,T} \rangle \) are the expectation values of transformation matrices \( M_{A,T} \) in the nucleon state. In the sNCQM, the transverse polarized quarks are in the transverse spin eigenstates, which by rotational invariance implies \( \delta q_{NR} = \Delta q_{NR} \). For the proton, one has \( \Delta u_{NR} = \frac{4}{3}, \Delta d_{NR} = -\frac{1}{3}, \Delta s_{NR} = 0, \Delta \Sigma_{NR} = \Delta u_{NR} + \Delta d_{NR} + \Delta s_{NR} = 1 \), which expresses that the proton spin is carried by the spins of the three static constituent quarks.

The derivation of Eqs. (3)-(6) is sketched below. One expands the quark field operators in the nucleon matrix elements of quark currents in terms of a complete set of quark and antiquark wavefunctions. The \( \Delta q(\delta \bar{q}) \) then separates into two parts: One part includes the contributions from quark states only, which corresponds to \( \Delta q_q(\delta q_q) \). Another part includes the contributions of antiquark states, which gives \( \Delta \bar{q}(\delta \bar{q}) \). Now choosing third \((i = 3)\) component and in terms of plane wave solutions, one can write the identical transformations from the Dirac spinor to the Pauli spinor for the quark axial and tensor currents as
\[ \bar{u}_s'(k)\gamma^3\gamma^5 u_s(k) = \left(1 - \frac{k^2}{E(E + m)}\right)\chi_s^+\sigma_3\chi_s, \]
\[ \bar{u}_s'(k)\gamma^0\gamma^3\gamma^5 u_s(k) = \left(\frac{m}{E} + \frac{k^2}{E(E + m)}\right)\chi_s^+\sigma_3\chi_s, \]
which lead to \( M_A = 1 - \frac{k^2}{E(E + m)} \), \( M_T = \frac{m}{E} + \frac{k^2}{E(E + m)} = 1 - \frac{k^2}{E(E + m)} \). Hence one finds
\[ M_A + M_T = 1 + \frac{m}{E}, \]
\[ 1 + M_A = 2M_T, \]
where one assumed \( \langle k^2 f(k^2) \rangle = 2\langle k^2 f(k^2) \rangle \). Eq. (7) was discussed earlier by Close[10]. The relation (10) was also obtained by Schmidt and Soffer[6] from the Melosh rotation[11]. Solution of combined Eqs. (9) and (10) yields Eq. (5). Combining Eqs. (3)-(5) leads to Eq. (6). Note that there is no transformation relation between \( \Delta \bar{q}(\delta \bar{q}) \) and \( \Delta q_{NR}(\delta q_{NR}) \) because \( \Delta \bar{q}(\delta \bar{q}) \) given through the expansion of the quark field operators contains antiquark creation and annihilation operators but there is no net antiquark in the sNCQM.

It is interesting to remark that \( \Delta q_q \) and \( \delta q_q \) given by Eqs. (3)-(5) split up into two parts arising respectively from the valence current quark contributions, \( \Delta q_v \) and \( \delta q_v \), and the sea-(\( q\bar{q} \))-pair contributions, \( \Delta q_m \) and \( \delta q_m \): \( \Delta q_q = \Delta q_v + \Delta q_m \), \( \delta q_q = \delta q_v + \delta q_m \), where
\[ \Delta q_v = \langle \frac{1}{3} + \frac{2m_{cu}}{3E} \rangle \Delta q_{NR}, \quad \delta q_v = \langle \frac{2}{3} + \frac{m_{cu}}{3E} \rangle \delta q_{NR}, \]

\[ \Delta q_m = \left( \frac{2m_{dy}}{3E} \right) \Delta q_{NR}, \quad \delta q_m = \left( \frac{m_{dy}}{3E} \right) \delta q_{NR}, \]  

(12)

where one has written the constituent quark mass as \( m = m_{\text{cu}} + m_{dy} \), the sum of the current-quark and dynamical masses. To understand the physical contents of Eqs.(11)-(12), one considers following cases. (a) \( m/E \to 0 \), or \( |\vec{k}| \to \infty \), i.e. the ultra-relativistic limit of quark motion. In this limit, Eqs.(3)-(5) reduce to \( \Delta q \to \frac{1}{3} \Delta q_{NR} \) and \( \delta q \to \frac{2}{3} \delta q_{NR} \), which are just the results for the free valence quarks with zero masses, i.e. the free valence current quarks. In this limit the valence current quarks are such free quarks due to the QCD asymptotic freedom. This shows that the contributions given by Eq.(11) come from the valence current quarks, where the terms \( \sim \langle \overline{q}q \rangle \) are the correction from current quark mass. (b) \( m/E \neq 0 \), which corresponds to the case of quark motion with finite momentum (due to confinement) in the region between the chiral symmetry breaking scale (\( \sim 1 \text{GeV} \)) and the confinement scale, where the constituent quark picture works. One notices that in the matrix elements(1) and (2) the information on sea-quark is contained in the quark's dynamical mass parameter if the nucleon wavefunction takes the traditional three-quark structure. In fact, in this nonperturbative region the quarks propagate in a ground state filled with \((qq)\) condensates generated by spontaneous chiral-symmetry breaking and hence gains the dynamical mass \( m_{dy} \), forming the constituent quarks. So \( m_{dy} \) arises from the contribution of \((qq)\)-pair cloud (sea) which surrounds the valence current quark and is described by the quark condensate \( \langle \overline{q}q \rangle \) [12]. It implies that \( \Delta q_m \) and \( \delta q_m \) given by Eq.(12) represent phenomenologically the polarizations of the \((qq)\)-pairs in the cloud-sea or sea-\((qq)\)-pairs briefly. The remainders of polarizations are from valence current quarks given by Eq.(11). It is worth to emphasize that the separation of polarizations into valence and sea-\((qq)\)-pair components follows the general picture of the constituent quark structure[13]. In the nonrelativistic limit \( |\vec{k}| = 0 \), \( M_A^m \to 2/3 \), \( M_T^m \to 1/3 \), hence \( M_A = M_T = 1 \), which is then consistent.

Since there is no transformation relation between \( \Delta \overline{q}(\delta \overline{q}) \) and \( \Delta q_{NR}(\delta q_{NR}) \), the complete expressions for \( \Delta q \) and \( \delta q \) should include antiquark contributions, \( \Delta \overline{q} \) and \( \delta \overline{q} \), by definition:

\[ \Delta q = \Delta q_v + \Delta q_m + \Delta \overline{q} = \Delta q_v + \Delta q_{\text{sea}}, \]  

(13)

\[ \delta q = \delta q_v + \delta q_m - \delta \overline{q} = \delta q_v, \]  

(14)

where \( \Delta q_v \), \( \Delta q_m \), \( \delta q_v \) and \( \delta q_m \) are given through transformations(11)-(12) by the symmetric three-quark structure of the nucleon. \( \Delta q_{\text{sea}} = \Delta q_m + \Delta \overline{q} \). \( \Delta \overline{q}(\delta \overline{q}) \) may be understood as a result accompanying the current operator renormalization which leads to the gluon anomaly contribution[14], or more physically the contribution from high Fock states beyond the traditional three-quark structure such as \(|qqq\rangle \) which may also lead to the contribution of identifying with the gluon anomaly as discussed by Brodsky etc[15] or \(|qqq(q\overline{q})\rangle \) etc in the more realistic nucleon wavefunction.

According to the above recipe, now one first calculates the proton axial charge. By using Eq.(11), one immediately obtains the contributions of the valence current quark spins to the axial charge hence to the proton spin (in the chiral limit with \( m_{cu} = 0 \)):

\[ \Delta u_v = 4/9, \quad \Delta d_v = -1/9, \quad \Delta s_v = 0, \]  

\[ \Delta \Sigma_v = \Delta u_v + \Delta d_v + \Delta s_v = 1/3, \]  

(15)
which indicates that valence current quark spins carry 1/3 of the proton spin. This result is consistent with the asymptotic limit of perturbation QCD calculation obtained by Ji et al [9].

To determine the polarizations of antiquarks and quarks in the quark-sea inside the proton, \( \Delta \bar{q}, \Delta q_m \) and \( \Delta q_{sea} \), one needs the complete proton wavefunction of which so far nobody is known. Instead, here one first gets \( \Delta q_{sea} \) from fitting the experimental values, and then uses transformation (12) to estimate \( \Delta q_m \), thus getting \( \Delta \bar{q} \) by Eq. (13). From recent data on polarized lepton-nucleon DIS experiments, Ellis and Karliner have shown [4]

\[
\Delta u = 0.82, \Delta d = -0.44, \Delta s = -0.11, \Delta \Sigma = 0.27
\]  

(16)

with an estimated error of 0.03 for each flavor’s contribution. Substituting the values given by Eqs. (15) and (16) into Eq. (13), one obtains the sea polarizations inside the proton:

\[
\Delta u_{sea} = 0.38, \Delta d_{sea} = -0.33, \Delta s_{sea} = -0.11, \Delta \Sigma_{sea} = -0.06.
\]  

(17)

Furthermore, one estimates \( \Delta q_m \) by using Eq. (12), where the parameter \( \langle \frac{E}{p} \rangle \) can be fixed by requiring \( \Delta u_q - \Delta d_q = 1.257 \), which gives \( \langle \frac{E}{p} \rangle = 0.631 \approx 5/8 \). Thus one estimates

\[
\Delta u_m = 0.56, \Delta d_m = -0.14, \Delta s_m = 0, \Delta \Sigma_m = 0.42.
\]  

(18)

Comparing Eq. (17) with Eq. (18), one then has

\[
\Delta \bar{u} = -0.18, \Delta \bar{d} = -0.19, \Delta \bar{s} = -0.11, \Delta \bar{\Sigma} = -0.48.
\]  

(19)

These numerical results show the following picture: From the point of view of the current quark picture, the valence constituent quark spin contributions given in the traditional symmetric quark model include the contributions from the valence current quarks and the sea-(q\( \bar{q} \))-pairs: \( \Delta \Sigma_q = \Delta \Sigma_v + \Delta \Sigma_m = 0.33 + 0.42 = 0.75 \), where the valence current quark spins contribute 1/3 of the proton spin. Antiquarks inside the proton are significantly polarized in the direction opposite to the proton spin, while the sea-(q\( \bar{q} \))-pairs are polarized with the same direction as the valence current quark polarizations (see Eqs. (15) and (18)). As a result, the total contribution of sea polarization, \( \Delta \Sigma_{sea} = \Delta \Sigma_m + \Delta \Sigma_{sea} \), seems to be suppressed because of large cancellation between \( \Delta \Sigma_m \) and \( \Delta \Sigma_{sea} \) as shown by Eq. (17). Eq. (17) implies \( \Delta \Sigma_{sea} \leq 0 \). Combining it with Eq. (15) indicates that the total contribution of quark spins to the proton spin \( \Delta \Sigma = \Delta \Sigma_v + \Delta \Sigma_{sea} \) in the chiral limit with \( m_{cu} = 0 \) satisfies

\[
\Delta \Sigma = 1/3 + \Delta \Sigma_{sea} \leq 1/3,
\]  

(20)

which indicates the physical origin why \( \Delta \Sigma \) extracted from the recent global fit to experimental data remains around 0.3 [4]. Including the correction from the current quark mass, which is estimated by Eq. (11) with \( m^{(u)} = 4MeV, m^{(d)} = 8MeV \) and \( m = 320MeV \), one finds \( \Delta \Sigma_v = 0.337 \) and \( \Delta \Sigma = 0.337 + \Delta \Sigma_{sea} \), where \( \Delta \Sigma_{sea} = \Delta u_{sea} + \Delta d_{sea} + \Delta s_{sea} + \ldots \).

To understand the origin of the proton spin more clearly, let me make more complete analysis to the proton spin structure. In QCD, the proton spin is defined as the expectation value of the total angular momentum operator \( \hat{J} \) of QCD in the nucleon state, where \( \hat{J} \) splits up into quark spin and orbital and gluon angular momentum components [9,16]. The quark model might be imagined as the low-energy limit of QCD, where the gluons are integrated...
out and the quarks become the effective degrees of freedom of QCD. Thus, in the spirit of
the quark model, $\hat{J}$ separates into quark spin and orbital parts which have same form as
that in QCD[9,16]. The third component of $\hat{J}$ reads

$$\hat{J}^3 = \int d^3x [\frac{1}{2} \bar{q} \gamma^3 \gamma^5 q + i \bar{q} \gamma^0 (x^1 \partial^2 - x^2 \partial^1) q].$$

(21)

By the same procedure as the derivation of Eqs.(3)-(5), one obtains that the quark orbital
contribution is related to the sNCQM's spin contribution (for each quark flavor) by

$$L^{(q)}_3 = \langle M_L \rangle \Delta q_{NR}$$

(22)

with $M_L = \frac{E^2}{3E(E+m)} = \frac{1}{3} - \frac{m}{3E}$. Combining Eqs.(3), (5), (22) with(21), one then obtain a
spin sum rule

$$\frac{1}{2} = \frac{1}{2} \Delta \Sigma_v + \frac{1}{2} \Delta \Sigma_m + L_{zq},$$

(23)

where $L_{zq} = L^{(u)}_3 + L^{(d)}_3 = \frac{1}{3} - \langle \frac{m}{3E} \rangle$. One may write $L_{zq} = L_{zv} + L_{zm}$, where $L_{zv} = 1/3$ and
$L_{zm} = -\langle \frac{m}{3E} \rangle$, that is, the quark orbital contribution separates into valence current quark
plus sea-($q\bar{q}$)-pair parts. It is interesting that $\frac{1}{2} \Delta \Sigma_m + L_{zm} = 0$, i.e. the orbital and spin
contributions of sea-($q\bar{q}$)-pairs cancel each other. As a result, Eq.(23) in fact becomes

$$\frac{1}{2} = \frac{1}{2} \Delta \Sigma_v + L_{zv}, \quad \Delta \Sigma_v = L_{zv} = \frac{1}{3},$$

(24)

which clearly indicates that $\Delta \Sigma_v$ indeed is the valence current quark spin contribution to
the proton spin and that the basic origins of the proton spin in the symmetric (valence)
quark model are valence current quark spin and orbital contributions. The fractions of the
proton spin are re-shared due to the excitations of the sea-($q\bar{q}$)-pairs, which is expressed by
Eq.(23) where the spin of the proton is shared by the valence current quark spin, spin of sea-
($q\bar{q}$)-pair and quark orbital contributions. Their values are $\frac{1}{6}$, 0.21, and 0.12, respectively, at
scale of 1GeV. Only in the nonrelativistic limit $E = m$, $L_{zq}$ disappears and hence Eq.(23)
reduces to $\Delta \Sigma_{NR} = 1$, which of course is not a realistic case because $L_{zq} \neq 0$ as long as quarks have non-zero momentum as shown by Eq.(22). One may ask why one did not find
$\Delta \Sigma_q = \Delta \Sigma_v + \Delta \Sigma_m = 0.75$ from polarized DIS? The reason is that in polarized DIS what
one probes is the total contribution of quark spins, $\Delta \Sigma = \Delta \Sigma_v + \Delta \Sigma_m + \Delta \Sigma$. Its value $\leq 1/3$.
This result clearly indicates the physical origin of the discrepancy between the traditional
quark model expectation $\Delta \Sigma_q$ and the measured value $\Delta \Sigma$ in polarized DIS: Antiquarks are significantly polarized inside the proton, which has not been counted in the traditional
quark model of the proton. Besides this, the sNCQM has neglected the quark motion effects
which lead to the reduction of $\Delta \Sigma_{NR}$ and the presence of quark orbital angular momentum.

Considering the contents of $\Delta \Sigma$ measured in polarized DIS, one now rewrites Eq.(23) as

$$\frac{1}{2} = \frac{1}{2} \Delta \Sigma + L_{zq} + J_q,$$

(25)

where $J_q = -\frac{1}{2} \Delta \Sigma$. Eq.(25) can be compared with the spin sum rule in QCD[16]. In fact,
as mentioned before, $\Delta \Sigma$ may be understood as a result due to existing the gluon anomaly
contribution. Thus Eq. (25) means that the fractions of the proton spin are further re-shared due to the existence of the gluon degrees of freedom. Numerically one has \( \frac{1}{2} \Delta \Sigma = 0.14 \), \( L_{zq} \simeq 0.12 \) and \( J_q = \frac{1}{2} \Delta \Sigma \simeq 0.24 \). Thus \( J_q = \frac{1}{2} \Delta \Sigma + L_z \simeq 0.26 \), and \( J_q \leq 0.29 \) by Eq. (20). This estimate shows that quarks (their spin plus orbital contributions) carry about one half of the proton spin at scale of 1 GeV. The remainder of the proton spin is carried by gluons, which may be estimated in number by the absolute value of the antiquark contribution to the proton spin in the quark model.

Now one turns to the tensor charge of the proton. Since the proton tensor charge measures the contributions from valence current quarks only, one can naturally obtain it by using Eq. (11). The result is (in the chiral limit with \( m_{cu} = 0 \)):

\[
\delta u = \frac{8}{9}, \quad \delta d = -\frac{2}{9}, \quad g^{(v)}_T = \frac{10}{9}, \quad g^{(s)}_T = \frac{2}{3}, \quad (26)
\]

where \( g^{(v)}_T = \delta u - \delta d \), and \( g^{(s)}_T = \delta u + \delta d \) are the proton's isovector and isoscalar tensor charges, respectively. One may argue the reliability of the result given by Eq. (26). Indeed, by using Eqs. (4) and (5) one obtains the tensor charge of the proton in the symmetric quark model: \( \delta u_q = \frac{8}{9} + \frac{4}{9} \times 0.631 = 1.17 \), \( \delta d_q = -\frac{2}{9} - \frac{1}{9} \times 0.631 = -0.29 \), which are exactly values obtained in the MIT bag model [5] and in the Melosh rotation approach [6]. However, one should recall that these values include the contributions from both valence current quarks and the sea- (q \( \overline{q} \))-pairs: \( \delta q_q = \delta q_v + \delta q_m \). As pointed out before, the high Fock states in the more realistic nucleon wavefunction may contribute \( \delta \overline{q} \), thus leading to \( \delta q_m - \delta \overline{q} = 0 \) because sea quarks do not contribute to the tensor charge. As a result, one has \( \delta q = \delta q_v \). Therefore, the result given by Eq. (26) expresses the proton tensor charge in the chiral limit at the scale \( \mu_0 \simeq 1 \) GeV. The correction from current quark mass, estimated by Eq. (11), for \( \delta u \) is 0.004 and for \( \delta d \) is -0.002. The tensor charge at any scale \( \mu \) can be obtained through the evolution equation \( \delta q(\mu^2) = \delta q(\mu_0^2)[\alpha_s(\mu^2)/\alpha_s(\mu_0^2)]^{\frac{\alpha_s(\mu_0^2)}{4\pi}\alpha(\mu^2)} \), where \( n_f \) is the number of quark flavors. It is expected that the future experiments will test the present prediction.

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