Comment on "Proton Spin Structure from Measurable Parton Distributions"

The identifications of transverse boost and rotation operators in light-front theory done in Ref. [1] is incorrect. The simple parton interpretation claimed is, in fact, for the transverse boost operator. Manifestation of Lorentz symmetry as claimed in the context of their calculation involving a transverse Pauli-Lubanski polarization vector is unsupported.

The identifications of the transverse rotation and the transverse boost operators done in Ref. [1] following Ref. [2] by the same authors is incorrect, as also pointed out in Ref. [3]. The correct identifications and the associated sum rules in light-front QCD were investigated by us [4–6] a decade ago. In the following, we elaborate on this.

According to Ref. [2], "In order to obtain the boost-invariant spin sum rule ... we construct the polarization through the Lorentz-covariant Pauli-Lubanski vector." (Note that the terms spin and polarization are used interchangeably throughout Ref. [1], and the difference between the two, if any, is never really clarified.) However, the transverse components of the Pauli-Lubanski operator W^i's ($i = 1, 2$) are *not boost invariant* in light-front dynamics (for a review, see Ref. [7]), whereas the intrinsic spin operators $\mathcal{J}^i$ are [8,9]. The two are related by $M\mathcal{J}^i = W^i - P^i\mathcal{J}^3$ and are the same only in the $P^i = 0$ frame up to a constant factor. In our works in Refs. [4–6], we start from $\mathcal{J}^i$ and naturally arrive at frame-independent results. In Refs. [1,2], they start from W^i, and their subsequent results and conclusions, if at all valid (see additional comments below), hold only in the $P^i = 0$ frame, contrary to their claim.

In Ref. [2], after Eq. (9), $J^{+\sigma}$ is identified as an angular momentum operator and $J^{-\sigma}$ is identified as a boost operator. This is wrong. For $\sigma = \perp$, which are the relevant components under discussion, it is well known that $J^{+\sigma}$, which are kinematical, are the transverse boost operators and $J^{-\sigma}$, which are dynamical, are the transverse rotation operators. The simple parton interpretation claimed is, in fact, for the transverse boost operator in Eq. (2) in Ref. [1].

Contrary to the statement made in Ref. [2] that "we take no contribution to $W_i^\perp$ from the energy-momentum tensor T^{+-}," we find [10] that (i) both the form factors A_i and $\bar{C}_i$ contribute to the matrix element of T_i^{+-} in a transversely polarized state, (ii) there is no relative suppression factor between these two contributions, and (iii) the contribution to $W_i^\perp$ from T_i^{++} contains only the form factor B_i and not the form factor A_i. (Incidentally, the last finding is already a well-established result [11].)

Thus, we conclude that in Ref. [2], (i) there is no justification for ignoring the contribution of $\bar{C}_i$ to $W_i^\perp$ as has been done, (ii) the claim in Eq. (29) is unsupported, and (iii) so are the claims made after Eq. (30) that "T_i^{++} and $T_i^{+\perp}$ contribute separately 1/2 of the nucleon spin" and "This is a simple result of Lorentz symmetry." In fact, borrowing one of their arguments for dropping $\bar{C}_i$, it follows that since the B form factor does not contribute to transverse spin sum rules (as $B_q + B_g = 0$, where q and g denote quark and gluon parts), the matrix element of T^{++} does not contribute at all, contrary to the claim in Eq. (29). Moreover, if the higher-twist contribution is replaced by the leading-twist contribution as they claim due to Lorentz symmetry, the distinction between leading and subleading contributions is washed away. Last, based on the extra factor of P^+ in Eq. (2) for the transverse boost matrix element, compared to Eq. (3) for the matrix element of helicity, Ref. [1] claims that nucleon helicity is a subleading quantity whereas transverse polarization is a leading quantity. This claim has no basis.

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[1] X. Ji, X. Xiong, and F. Yuan, Phys. Rev. Lett. **109**, 152005 (2012).
[2] X. Ji, X. Xiong, and F. Yuan, Phys. Lett. B **717**, 214 (2012).
[3] E. Leader and C. Lorce, preceding Comment, Phys. Rev. Lett. **111**, 039101 (2013).
[4] A. Harindranath and R. Kundu, Phys. Rev. D **59**, 116013 (1999).
[5] A. Harindranath, A. Mukherjee, and R. Ratabole, Phys. Lett. B **476**, 471 (2000).
[6] A. Harindranath, A. Mukherjee, and R. Ratabole, Phys. Rev. D **63**, 045006 (2001).
[7] S. J. Brodsky, H.-C. Pauli, and S. S. Pinsky, Phys. Rep. **301**, 299 (1998).
[8] D. E. Soper, Ph. D. thesis, Stanford University, 1971.
[9] H. Leutwyler and J. Stern, Ann. Phys. (N.Y.) **112**, 94 (1978).
[10] A. Harindranath, Rajen Kundu, and Asmita Mukherjee (to be published).
[11] S. J. Brodsky, D. S. Hwang, B.-Q. Ma, and I. Schmidt, Nucl. Phys. **B593**, 311 (2001).

