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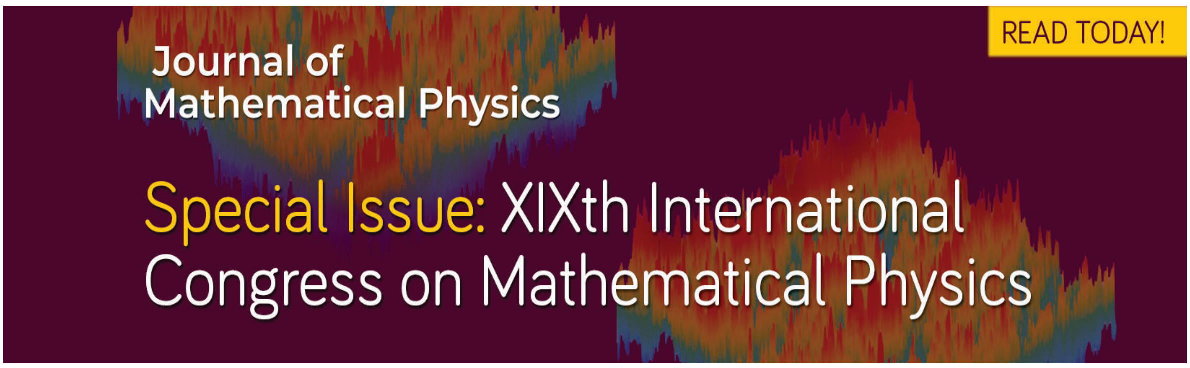

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New concise upper bounds on quantum violation of general multipartite Bell inequalities

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Last years, bounds on the maximal quantum violation of *general* Bell inequalities were intensively discussed in the literature via different mathematical tools. In the present paper, we analyze quantum violation of general Bell inequalities via *the LqHV (local quasi hidden variable) modelling framework,* correctly reproducing the probabilistic description of every quantum correlation scenario. The LqHV mathematical framework allows us to derive for all d and N a new upper bound $(2d-1)^{N-1}$ on the maximal violation by an N-qudit state of all general Bell inequalities, also, new upper bounds on the maximal violation by an N-qudit state of general Bell inequalities for S settings per site. These new upper bounds essentially improve all the known precise upper bounds on quantum violation of general multipartite Bell inequalities. For some S, d, and N, the new upper bounds are attainable. *Published by AIP Publishing.* [http://dx.doi.org/10.1063/1.4982961]

I. INTRODUCTION

Quantum violation of Bell inequalities[1] is now used in many quantum information tasks and is also important for the analysis of nonlocal games strategies in computer science. The most analytically studied[2–5] cases of quantum violation of specific Bell inequalities refer to the Clauser-Horne-Shimony-Holt (CHSH) inequality and the Mermin-Klyshko inequality. It is also well known that the maximal quantum violation of *correlation* bipartite Bell inequalities cannot[6] exceed the real Grothendieck's constant $K_G^{(\mathbb{R})} \in [1.676, 1.783]$ independently of a dimension of a bipartite quantum state and numbers of settings and outcomes per site. But this is not already the case for quantum violation of bipartite Bell inequalities on joint probabilities, and last years, bounds on the maximal quantum violation of Bell inequalities were intensively discussed in the literature via different mathematical tools.[7–15]

To our knowledge, the maximal violation by an N-qudit quantum state of *general*[16] Bell inequalities for arbitrary numbers of measurement settings and outcomes at each site admits the following upper bounds.

- $N = 2$: (a) for an arbitrary two-qudit state, the precise[17] upper bound $(2d-1)$ in Eq. (64) of Ref. 9 and the precise upper bound $2d$ in Proposition 5.2 of Ref. 14; (b) for the two-qudit Greenberger-Horne-Zeilinger (GHZ) state, the upper bound $Cd/\sqrt{\ln d}$, found up to a universal constant in Theorem 0.3 of Ref. 11.
- $N \geq 3$: (c) for the N-qudit GHZ state, the precise upper bound $(2^{N-1}(d-1)+1)$ in Eq. (58) of Ref. 9; (d) for an arbitrary N-qudit state, the precise upper bound $(2^{N-1}d^{N-1} - 2^{N-1} + 1)$ in Eq. (62) of Ref. 9 and the precise upper bound $(2d)^{N-1}$ in comments after Proposition 5.2 in Ref. 14.

In the present paper, we analyze the maximal quantum violation of general Bell inequalities via *the LqHV (local quasi hidden variable) modelling framework,* introduced and developed in Refs. 9, 18, and 19. A general correlation scenario admits a LqHV model if and only if it is nonsignaling.[20] Therefore, the probabilistic description of each quantum correlation scenario admits[9] the LqHV modelling. Moreover, the probabilistic description of all projective N-partite joint quantum measurements on an N-qudit state can be reproduced[21] via the single LqHV model specified in Ref. 13.