Bound on tri-partite Hardy's nonlocality respecting all bi-partite principles

Subhadipa Das[1] * Manik Banik[2] † MD. Rajjak Gazi[2] ‡ Ashutosh Rai[1] §
Samir Kunkri[3] ¶

[1] *S.N. Bose National Center for Basic Sciences, Block JD, Sector III, Salt Lake, Kolkata-700098, India*
[2] *Physics and Applied Mathematics Unit, Indian Statistical Institute, 203 B.T. Road, Kolkata-700108, India*
[3] *Mahadevananda Mahavidyalaya, Monirampore, Barrakpore, North 24 Parganas-700120, India*
[4] *The Institute of Mathematical Sciences (IMSc.), CIT Campus, Taramani, Chennai-600113, India*

Abstract. Recently, Gallego et al. [Phys. Rev. Lett. 107, 210403 (2011)] proved that any future information principle aiming at distinguishing between quantum and postquantum correlation must be intrinsically multipartite in nature. We establish similar results by using the device-independent success probability of Hardy?s nonlocality argument for tripartite quantum systems. We construct an example of a tripartite Hardy correlation which is postquantum but satisfies not only the all-bipartite information principle but also the guess-your-neighbor?s-input (GYNI) inequality.

Keywords: information principle,quantum,post quantum, Hardy's nonlocality

Motivation—Recently, understanding the correlations among distant observers which are compatible with our current description of nature based on quantum mechanics has generated much interest. It has been shown that some general physical prin- ciples can restrict the set of no-signaling correlations amongdistant observers to a significant degree. Information theo- retic principles like information causality [1] and nontrivial communication complexity [2, 3] are novel proposals to single out the quantum correlations from the rest of the no-signaling correlations when two distant observers (or in some cases, even when more than two observers [5]) are involved. However, by applying the known information principles to the bipartite case, it has not been possible to derive the full set of quantum correlations resulting from the Hilbert space structure of quantum mechanics.

For a multipartite (more than two subsystems) scenario, the situation becomes even more complex and extremely challenging. Very recently, some interesting results [4, 5] have been produced when more than two distant observers are involved. In [4], Gallego et al. provide an example of the tripartite no-signaling correlation, which is time-ordered- bilocal (TOBL) [6, 7, 8] and therefore respects any bipartite information principle, yet this correlation is nonquantum (unphysical) since it violates the guess-your-neighbor?s-input (GYNI) inequality [9]. Thus this result demonstrates that in general any biprinciple is insufficient for deriving the set of all multiparty quantum (physical) correlations. The nonquantum nature of this correlation is shown through violation of an inequality in [5], which is satisfied by all quantum correlations; however, incontrast with [4], this example respects the GYNI inequality.

Results—We give a TOBL correlation which is nonquantum since it exceeds the maximum success probability of Hardy argument for tripartite quantum correlations. To show this, first we prove that in quantum mechanics the maximum success probability of the Hardy argument for a tripartite system is 0.125; earlier this result was known to hold only for projective measurement on three-qubits systems [10]. Then we explicitly construct a tripartite correlation in a general probabilistic theory with the following properties:(i) the correlation is TOBL and hence satisfies all bipartite information principles, and (ii) the correlation shows Hardy nonlocality with the success probability taking the value 0.2, which is greater than the maximum value 0.125 that canbe achieved within quantum mechanics. Interestingly, the example we provide respects all known GYNI inequalities [9] and hence stands as good candidate to rule out GYNI as the principle which distinguishes quantum from postquantum.

In this way we establish that this device-independent value is a potential witness for tripartite postquantum correlations. Our example also satisfies most general GYNI inequalities. A newly proposed multipartite principle, namely local orthogo- nality (LO) [11], when applied to a single copy of tripartite no-signaling correlations is equivalent to the GYNI game. Of course, the witnessing power of the LO principle for detecting unphysical correlations increases when many copies of a correlation are considered, but the problem becomes computationally hard with an increasing number of copies. So it will be interesting to study multiple copies of the correlation provided in this work under the LO principle

*sbhdpa.das@bose.res.in
†manik11ju@gmail.com
‡rajjakgazimath@gmail.com
§arai@bose.res.in
¶skunkri@yahoo.com

References

[1] M. Pawlowski, T. Paterek, D. Kaszlikowski, V. Scsrani, A. Winter, and M. Zukowski, Nature (London) 461, 1101 (2009).

[2] W. van Dam, Ph.D. thesis, University of Oxford, 2000.

[3] Wim van Dam, arXiv:quant-ph/0501159.

[4] R. Gallego, L. E. Wurflinger, A. Acin, and M. Navascues, Phys. Rev. Lett. 107, 210403 (2011).

[5] T. H. Yang, D. Cavalcanti, M. L. Almeida, C. Teo, and V. Scarani, New J. Phys. 14, 013061 (2012).

[6] S. Pironio, J. D. Bancal, and V. Scarani, J. Phys. A: Math. Theor. 44, 065303 (2011).

[7] R. Gallego, L. E. Wurflinger, A. Acin, and M. Navascues, Phys. Rev. Lett. 109, 070401 (2012).

[8] J. Barrett, S. Pironio, J.-D. Bancal, and N. Gisin, arXiv:1112.2626v1 [quant-ph].

[9] M. L. Almeida, J. D. Bancal, N. Brunner, A. Acin, N. Gisin, and S. Pironio, Phys. Rev. Lett. 104, 230404 (2010).

[10] S. K. Choudhary, S. Ghosh, G. Kar, S. Kunkri, R. Rahaman, and A. Roy, Quant. Inf. Comp. 10, 0859 (2010).

[11] T. Fritz, A. B. Sainz, R. Augusiak, J. B. Brask, R. Chaves, A. Leverrier, and A. Ac ?n, arXiv:1210.3018v2 [quant-ph]