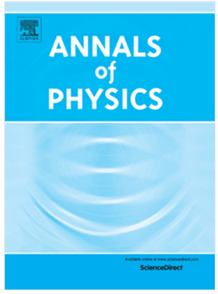
Accepted Manuscript



Characterization of the quantumness of unsteerable tripartite correlations

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PII: S0003-4916(18)30225-2
DOI: https://doi.org/10.1016/j.aop.2018.08.013
Reference: YAPHY 67741

To appear in: *Annals of Physics*

Received date : 24 October 2017
Accepted date : 21 August 2018

Characterization of the quantumness of unsteerable tripartite correlations

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Quantumness for a bipartite unsteerable quantum correlation is operationally characterized by the notion of super-unsteerability. Super-unsteerability refers to the requirement of a larger dimension of the random variable that the steering party has to preshare with the party to be steered in the classical simulation protocol to generate an unsteerable correlation than the local Hilbert space dimension of the quantum states (reproducing the given unsteerable correlation) at the steering party's side. In the present study, this concept of super-unsteerability is generalized by defining the notion of super-bi-unsteerability for tripartite correlations, which is unsteerable across a bipartite cut. Genuine super-bi-unsteerability is defined as the occurrence of super-bi-unsteerability across all possible bipartite cuts. Specific example of genuine super-bi-unsteerability for tripartite correlations has been presented. This study provides a tool to characterize the genuine quantumness of tripartite quantum correlations which are unsteerable across every bipartite cut.

I. INTRODUCTION

Quantum composite systems exhibit several nonclassical features such as entanglement [1], Einstein-Podolsky-Rosen (EPR) steering [2–4] and Bell nonlocality [5–7]. In the Bell scenario, local quantum measurements on certain spatially separated system leads to nonlocal correlations which cannot be explained by local hidden variable (LHV) theory [5]. However, it is well-known that quantum mechanics (QM) is not maximally nonlocal as there are post-quantum correlations, obeying the no-signalling (NS) principle, which are more nonlocal than QM. Popescu-Rohrlich (PR) box [8] is one such correlation. Nonlocality in QM is limited by the Tsirelson bound [9].

Motivated by the seminal argument by Einstein, Podolsky and Rosen (EPR) [2] demonstrating the incompleteness of QM, Schrodinger introduced the concept of 'quantum steering' [10]. The task of quantum steering [3, 4] is to prepare different ensembles at one part of a bipartite system by performing local quantum measurements on another part of the bipartite system in such a way that these ensembles cannot be explained by a local hidden state (LHS) model. In other words, quantum correlations, which are steerable, cannot be reproduced by local hidden variable-local hidden state (LHV-LHS) model. In recent years, studies related to quantum steering have been acquiring considerable interest, as witnessed by a wide range of studies [11–18]. Bell-nonlocal states form a subset of the steerable states which also form a subset of the entangled states [3, 19]. However, unlike quantum nonlocality and entanglement, the task of quantum steering is inherently asymmetric [20]. In this case, the outcome statistics of one subsystem (which is being steered) is due to valid QM measurements on a valid QM state. On the other hand, there is no such constraint for the other subsystem. Quantum steering has also applications in semi device independent scenario where the party, which is being steered, has trust on his/her quantum device but the other party's device is untrusted. Secure quantum key distribution (QKD) using quantum steering has been demonstrated [21], where one party cannot trust his/her devices.

Recently, it has been demonstrated that certain quantum information tasks may become advantageous even using separable states if they have quantum discord [22–24], which is a generalized measure of quantum correlations. This motivated the study of nonclassicality going beyond nonlocality. Certain separable states which have quantumness may improve quantum protocols if the shared randomness between the parties is finite [25]. This provides an operational meaning of the measures of quantumness such as quantum discord. In the context of classical simulation of local entangled states, Bowles et. al. [26] have shown that the statistics of all local entangled states can be simulated by using only finite shared randomness and they defined a measure which is the minimal dimension of that shared classical randomness. On the other hand, all the previous works have used unbounded shared randomness to simulate a given local entangled state. In Ref. [27], the minimal dimension of the shared classical randomness required to simulate any local correlation in a given Bell scenario have been demonstrated. Motivated by this, an interesting feature of certain local boxes, called superlocality, has been defined as follows: there exist

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