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The book series Quantum Science and Technology is dedicated to one of today's most active and rapidly expanding fields of research and development. In particular, the series will be a showcase for the growing number of experimental implementations and practical applications of quantum systems. These will include, but are not restricted to: quantum information processing, quantum computing, and quantum simulation; quantum communication and quantum cryptography; entanglement and other quantum resources; quantum interfaces and hybrid quantum systems; quantum memories and quantum repeaters; measurement-based quantum control and quantum feedback; quantum nanomechanics, quantum optomechanics and quantum transducers; quantum sensing and quantum metrology; as well as quantum effects in biology. Last but not least, the series will include books on the theoretical and mathematical questions relevant to designing and understanding these systems and devices, as well as foundational issues concerning the quantum phenomena themselves. Written and edited by leading experts, the treatments will be designed for graduate students and other researchers already working in, or intending to enter the field of quantum science and technology.

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Lectures on General Quantum Correlations and their Applications

Springer

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Foreword

It is by now widely appreciated that quantum physics enables tasks that are much more difficult or even impossible to accomplish by relying on purely classical phenomena. The applications that benefit from "quantumness" include information processing (e.g., computing), high-precision measurements, and communications. The strategies that lead to these benefits vary, and their practical implementations often have to contend with limitations that are also quantum-specific (e.g., prohibition on cloning or decoherence) and can be "friend or foe", depending on the attempted implementation.

The obvious question that arose with the inception of the field quantum information concerns the "magic ingredient", the precise aspect of quantum theory that is responsible for this "quantum advantage". Quantum entanglement was the early suspect, and it remains in a lineup of possible culprits. By now, it is however abundantly clear that the list of possible suspects should be extended to include other, less flagrantly quantum correlations (e.g, these with non-zero discord). For example, while there are quantum algorithms that depend on entanglement in at least part of their execution, to date there is no general proof that entanglement is indispensable in every quantum computation. Moreover, in a number of relevant settings including quantum estimation and communication, one can get an advantage by suitably exploiting discord even in absence of entanglement.

This volume presents a collection of chapters authored by the leading contributors to the study of general quantum correlations and their applications and is organized in four parts. The first part of the book discusses the foundations of quantum correlations beyond entanglement and how to characterize them. Various forms of quantumness of states are exemplified and several quantitative methods are introduced, considering both bipartite and multipartite cases. In the second part of the book, operational interpretations and applications of quantum correlations come into play. Approaches from broadcasting and distribution of correlations to quantum metrology and cryptography are revisited, elucidating in particular the importance of such correlations for quantum information processing. In the third part of the book, the role of quantum correlations in the dynamics of open systems is explored. Sudden-change phenomena, robustness to decoherence and revivals are among the topics discussed, as well as quantumness indicators in interference and synchronization effects. Finally, the last part of the book revolves around physical realizations and experimental demonstrations. Investigations of quantum correlations in different physical systems like nuclear magnetic resonance, solid-state spin systems, and optical systems are reported.

The whole book samples the diversity of approaches found in the literature along the past years of research and overall constitutes a comprehensive source to guide and inspire both experienced researchers and beginners in the fascinating field of quantum correlations.

Felipe Fernandes Fanchini
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Contents

Part I Measures of Quantum Correlations Beyond Entanglement

Foundations of Quantum Discord 3
Vlatko Vedral

From Discord to Entanglement 9
Shunlong Luo

Monogamy of Quantum Correlations - A Review 23
Himadri Shekhar Dhar, Amit Kumar Pal, Debraj Rakshit, Aditi Sen(De) and Ujjwal Sen

Measurement-Induced Nonlocality and Quantum Correlations Under Local Operations 65
Xueyuan Hu, Ming-Liang Hu and Heng Fan

Quantum Correlations in Multipartite Quantum Systems 87
Thiago R. de Oliveira

Geometric Measures of Quantum Correlations with Bures and Hellinger Distances 105
D. Spehner, F. Illuminati, M. Orszag and W. Roga

Metrological Measures of Non-classical Correlations 159
Pieter Bogaert and Davide Girolami

Part II Operational Interpretations and Applications

Why Should We Care About Quantum Discord? 183
Aharon Brodutch and Daniel R. Terno

Local Broadcasting of Quantum Correlations 201
Marco Piani

Entanglement Distribution and Quantum Discord 217
Alexander Streltsov, Hermann Kampermann and Dagmar Bruß

Discord, Quantum Knowledge and Private Communications 231
Mile Gu and Stefano Pirandola

Quantum Discord in Quantum Communication Protocols. 241
Animesh Datta and Vaibhav Madhok

Non-Classical Correlations in Information Processing 257
Anil Shaji

Part III Quantum Correlations in Open Quantum Dynamics

The Local Detection Method: Dynamical Detection of Quantum Discord with Local Operations. 275
Manuel Gessner, Heinz-Peter Breuer and Andreas Buchleitner

The Sudden Change Phenomenon of Quantum Discord 309
Lucas C. Céleri and Jonas Maziero

Frozen and Invariant Quantum Discord Under Local Dephasing Noise 339
Göktuğ Karpat, Carole Addis and Sabrina Maniscalco

Overview on the Phenomenon of Two-Qubit Entanglement Revivals in Classical Environments 367
Rosario Lo Franco and Giuseppe Compagno

Quantum Correlations and Synchronization Measures 393
Fernando Galve, Gian Luca Giorgi and Roberta Zambrini

How Does Interference Fall? 421
Patrick J. Orlando, Felix A. Pollock and Kavan Modi

Part IV Physical Realizations and Experimental Progress

Quantum Discord and Entropic Measures of Quantum Correlations: Optimization and Behavior in Finite *XY* Spin Chains 455
N. Canosa, M. Cerezo, N. Gigena and R. Rossignoli

Experimental Investigation of the Dynamics of Quantum Discord in Optical Systems. 473
Jin-Shi Xu, Chuan-Feng Li and Guang-Can Guo

Experimental Investigation of Quantum Correlation in Solid-State Spin System 485
Jiangfeng Du, Fangzhou Jin and Xing Rong

Quantum Correlations in NMR Systems. 499
T.S. Mahesh, C.S. Sudheer Kumar and Udaysinh T. Bhosale

NMR Contributions to the Study of Quantum Correlations 517
Isabela A. Silva, Jefferson G. Filgueiras, Ruben Auccaise,
Alexandre M. Souza, Raimund Marx, Steffen J. Glaser,
Tito J. Bonagamba, Roberto S. Sarthour, Ivan S. Oliveira
and Eduardo R. deAzevedo