

Appendix A

Contributions to the Conference

This collection of essays draws on contributions to the conference “Quantum [Un]Speakables II: 50 Years of Bell’s Theorem”, which was organized by the editors of this volume and took place June 19–22, 2014.

The contributions at the conference were:

Invited talks¹

In chronological order.

Address to the conference participants

Mary Bell

European Organization for Nuclear Research (CERN), Geneva, Switzerland

Putting the scientist into the science

N. David Mermin

Cornell University, NY, USA

Xtreme nonlocality

Bradley G. Christensen and **Paul G. Kwiat**

University of Illinois at Urbana-Champaign, IL, USA

Quantum correlations in Newtonian space and time: faster than light communication or nonlocality

Nicolas Gisin

University of Geneva, Switzerland

Nicolas Gisin was unable to present his talk in person due to family reasons. Valerio Scarani presented the talk in his place.

¹Invited speakers are marked in bold.

Can quantum-mechanical description of causal relations be considered complete?

Caslav Brukner

Austrian Academy of Sciences, Austria

Designing Bell inequalities via Tsirelson bounds

Michael Epping, Hermann Kampermann and **Dagmar Bruß**,

Heinrich Heine University Düsseldorf, Germany

A GHZ experiment under strict Einstein locality conditions

Gregor Weihs

University of Innsbruck, Austria

On closing loopholes in Bell experiments

Sven Ramelow

Austrian Academy of Sciences, Austria

Search for hidden variables in neutron experiments

Helmut Rauch

Vienna University of Technology, Austria

Testing Bell's theorem in high energy physics

Beatrix Hiesmayr

University of Vienna, Austria

Quantum optics experiments using satellites

Rupert Ursin

Austrian Academy of Sciences, Austria

A full state in a single number

Valerio Scarani

National University of Singapore, Singapore

Physics above and below the Bell horizon: re-examining quantum foundations and glimpsing the post-quantum world via photonics

Andrew White

University of Queensland, Australia

Superconducting Xmon qubits with gate fidelity at the surface code threshold

John M. Martinis

University of California at Santa Barbara, CA, USA

The maximally entangled set of multipartite quantum states

Cornelia Spee¹, Julio Iñigo de Vicente Majúa² and **Barbara Kraus**¹

¹University of Innsbruck, Austria

²Charles III University of Madrid, Spain

Some Bell's theorem test loopholes added in the last 36 years

John F. Clauser

J. F. Clauser and Associates, CA, USA

Entanglement in massive systems: what do we learn?

Markus Aspelmeyer

University of Vienna, Austria

On spatial entanglement wave functions

Michael Horne

Stonehill College, MA, USA

Whose information? Information about what?

Jeffrey Bub

University of Maryland, MD, USA

Magic moments with John Bell: collaboration and friendship

Reinhold Bertlmann

University of Vienna, Austria

Public lecture: *From Einstein's intuition to quantum bits: a new quantum age*

Alain Aspect

École supérieure d'optique, France

Analyzing multiparticle quantum states: problems and solutions

Otfried Gühne¹, Matthias Kleinmann² and Tobias Moroder¹

¹University of Siegen, Germany

²University of the Basque Country, Spain

Quantum non-locality: a resource for information processing

Antonio Acín^{1,2} and Miguel Navascués³

¹The Institute of Photonic Sciences (ICFO), Spain

²Catalan Institution for Research and Advanced Studies (ICREA), Spain

³University of Bilkent, Turkey

On causal explanations of quantum correlations

Robert Spekkens

Perimeter Institute for Theoretical Physics, ON, Canada

Non-locality?—It ain't necessarily so

Marek Zukowski

University of Gdańsk, Poland

My struggle to face up to un-reality

Terence Rudolph

Imperial College London, UK

Heralded entanglement between distant atoms. Towards a loophole free test of Bell's inequality?

Harald Weinfurter

Ludwig Maximilian University of Munich, Germany

Quantum correlations: where, how and why

Adán Cabello

University of Sevilla, Spain

Bell violation with entangled photons, free of the fair-sampling assumption

Marissa Giustina^{1,2}, Alexandra Mech^{1,2}, Sven Ramelow^{1,2}, Bernhard Wittmann^{1,2}, Johannes Kofler^{1,3}, Jörn Beyer⁴, Adriana Lita⁵, Brice Calkins⁵, Thomas Gerrits⁵, Sae Woo Nam⁵, Rupert Ursin¹ and Anton Zeilinger^{1,2}

¹Austrian Academy of Sciences, Austria

²University of Vienna, Austria

³Max Planck Institute of Quantum Optics (MPQ), Germany

⁴Physikalisch-Technische Bundesanstalt, Germany

⁵National Institute of Standards and Technology (NIST), MD, USA

The dynamical roles played by mass and proper time in physics

Daniel Greenberger

City College of New York, NY, USA

Causation and the two Bell's theorems of John Bell

Howard Wiseman¹ and Eric G. Cavalcanti²

¹Griffith University, Australia

²University of Sydney, Australia

The freedom of choice assumption and its implications

Renato Renner

Swiss Federal Institute of Technology (ETH), Switzerland

Bell violation with entangled photons, free of the coincidence-time loophole

Jan-Åke Larsson

Linköping University, Sweden

John Bell and quantum information theory

Andrew Whitaker

Queen's University Belfast, UK

Steering, and maybe why Einstein didn't go all the way to Bell's argument

Reinhard F. Werner

Leibniz University of Hanover, Germany

Quantum mechanics in a new key

Simon B. Kochen

Princeton University, NJ, USA

New dimensions for entangled photons

Anton Zeilinger

Austrian Academy of Sciences, Austria

Poster presentations²

Quantum circuits cannot control unknown operations

Mateus Araújo

University of Vienna, Austria

Probing macroscopic realism via Ramsey correlations measurements

Ali Asadian¹, Caslav Brukner² and Peter Rabl¹

¹Vienna University of Technology, Austria

²Austrian Academy of Sciences, Austria

Non-locality of the multipartite W state upon losing parties

Jean-Daniel Bancal¹, **Tomer Jack Barnea**², Nicolas Brunner³, Péter Diviánszky³,
Nicolas Gisin², Tamás Vértesi³ and Yeong-Cherng Liang⁴

¹National University of Singapore, Singapore

²University of Geneva, Switzerland

³Hungarian Academy of Sciences, Hungary

⁴Swiss Federal Institute of Technology (ETH), Switzerland

Tripartite quantum state violating the hidden influence constraints

Tomer Jack Barnea¹, Jean-Daniel Bancal², Yeong-Cherng Liang^{1,3} and
Nicolas Gisin¹

¹University of Geneva, Switzerland

²National University of Singapore, Singapore

³Swiss Federal Institute of Technology (ETH), Switzerland

Quantifying the non-locality of experimental qutrits without Bell inequalities

Bänz Bessire¹, Marcel Pfaffhauser², Christof Bernhard¹, Alberto Montina²,
André Stefanov¹ and Stefan Wolf²

¹University of Bern, Switzerland

²University of Lugano, Switzerland

²Presenting authors are marked in bold.

*Compressed simulation of evolutions of the XY-model***Walter L. Boyajian**, Valentin Murg and Barbara Kraus

University of Innsbruck, Austria

*Fast and efficient detection of atomic states for a conclusive test of Bell's inequality***Daniel Burchardt**, Norbert Ortegel, Kai Redeker, Robert Garthoff, Markus Rau, Michael Krug, Markus Weber, Wenjamin Rosenfeld and Harald Weinfurter

Ludwig Maximilian University of Munich, Germany

and Max-Planck-Institute for Quantum Optics, Germany

*Detecting entanglement and nonlocality in path-entangled states***Valentina Caprara Vivoli**¹, Jean-Daniel Bancal², Charles Ci Wen Lim¹, Nicolas Sangouard¹, Pavel Sekatski³ and Nicolas Gisin¹¹University of Geneva, Switzerland²National University of Singapore, Singapore³University of Innsbruck, Austria*Analysis of entanglement photons generated by four-wave mixing in a nonlinear ring resonator***Thitinan Chittha**¹, Surasak Chiangga¹ and Till D. Frank²¹Kasetsart University, Thailand²University of Connecticut, CT, USA*On the spatial locations of quantum systems***John V. Corbett**

Macquarie University, Australia

*Entanglement properties of hypergraph states***Marti Cuquet**¹, Otfried Gühne², Frank E.S. Steinhoff², Tobias Moroder², Matteo A.C. Rossi³, D. Bruß⁴, B. Kraus¹ and C. Macchiavello⁵¹University of Innsbruck, Austria²University of Siegen, Germany³University of Milan, Italy⁴Heinrich Heine University Düsseldorf, Germany⁵University of Pavia, Italy*Multipartite quantum correlations—indefinite causal order and delocalized nonlocality***Florian Curchod**¹, Yeong-Cherng Liang^{2,1} and Nicolas Gisin¹¹University of Geneva, Switzerland²Swiss Federal Institute of Technology (ETH), Switzerland

Qudit based on the orbital angular momentum of light: an experimental tool for fundamental quantum mechanics

Vincenzo D'Ambrosio¹, Adán Cabello² and Fabio Sciarrino¹

¹Sapienza University of Rome, Italy

²University of Sevilla, Spain

Entanglement and nonlocality are inequivalent for any number of particles

Remigiusz Augusiak, **Maciej Demianowicz**, Jordi Tura and Antonio Acín

The Institute of Photonic Sciences (ICFO), Spain

Time domain matter-wave interferometry with nanoparticles

Nadine Dörre, Philipp Haslinger, Philipp Geyer, Jonas Rodewald and Markus Arndt

University of Vienna, Austria

Multisetting Bell inequalities for N spin-1 systems avoiding the Kochen-Specker contradiction

Arijit Dutta, Marcin Wiesniak and Marek Zukowski

University of Gdańsk, Poland

A Kolmogorovian account of probabilistic contextuality

Ehtibar Dzhafarov¹ and Janne Kujala²

¹Purdue University, IN, USA

²University of Jyväskylä, Finland

Quantum interference experiments with complex molecules

Sandra Eibenberger, Joseph Cotter, Xiayi Cheng, Lukas Mairhofer and Markus Arndt

University of Vienna, Austria

A construction of tripartite Bell inequalities

Michael Epping, Hermann Kampermann and Dagmar Bruß

Heinrich Heine University Düsseldorf, Germany

A glimpse into the post-quantum world: simulating stronger-than quantum correlations in photonic experiments

Martin Ringbauer, Dominic Berry, Andrew G. White and **Alessandro Fedrizzi**

University of Queensland, Australia

Indefinite causal order in multipartite scenarios

Adrien Feix

University of Vienna, Austria

*EPR paradox and quantum steering in a multimode optomechanical system*Qiongyi He^{1,2} and **Zbigniew Ficek**³¹Peking University, PR China²Collaborative Innovation Center of Quantum Matter, PR China³The National Centre for Mathematics and Physics (KACST), Saudi Arabia*Interface between path and OAM entanglement for high-dimensional photonic quantum information***Robert Fickler**^{1,2}, Radek Lapkiewicz^{1,2}, Marcus Huber^{3,4}, Martin Lavery⁵, Miles Padgett⁵ and Anton Zeilinger^{1,2}¹University of Vienna, Austria²Austrian Academy of Sciences, Austria³Autonomous University of Barcelona, Spain⁴The Institute of Photonic Sciences (ICFO), Spain⁵University of Glasgow, UK*Quantum entanglement of complex photon polarization patterns in vector beams***Robert Fickler**, Radek Lapkiewicz Sven Ramelow and Anton Zeilinger
Austrian Academy of Sciences, Austria*Are past events still real if we forget them?***Daniela Frauchiger** and Renato Renner

Swiss Federal Institute of Technology (ETH), Switzerland

*Implementing quantum control for unknown subroutines***Nicolai Friis**, Vedran Dunjko, Wolfgang Dür and Hans J. Briegel

Austrian Academy of Sciences, Austria

and University of Innsbruck, Austria

*Classical microwaves as a universal model system for quantum contextuality***Diego Frustaglia**, Jose-Pablo Baltanas, María-C Velazquez, Armando Fernandez, Vicente Losada, Manuel-Jose Freire and Adán Cabello

University of Sevilla, Spain

*Violations of entropic Bell inequalities with coarse-grained quadrature measurements for continuous-variable states*Zeng-Bing Chen, **Yao Fu** and Yu-Kang Zhao

University of Science and Technology of China, PR China

*(In)definite causal order with n parties***Christina Giarmatzi**¹ and Ognian Oreshkov²¹École polytechnique, France²Université libre de Bruxelles, Belgium

*Genuinely multipartite entangled states and orthogonal arrays***Dardo Goyeneche**¹ and Karol Życzkowski²¹University of Concepción, Chile²Jagiellonian University, Poland*Experimental test of a four-party GHZ-theorem***Chiara Greganti**

University of Vienna, Austria

*Almost quantum correlations*Miguel Navascués^{1,2}, **Yelena Guryanova**¹, Matty J. Hoban³ and Antonio Acín^{3,4}¹University of Bristol, UK²Autonomous University of Barcelona, Spain³The Institute of Photonic Sciences (ICFO), Spain⁴Catalan Institution for Research and Advanced Studies (ICREA), Spain*Error-disturbance uncertainty relation studied in successive spin-measurements***Yuji Hasegawa**

Vienna University of Technology, Austria

*Dynamics of genuine three-mode quantum steering in an optomechanical system*Meng Wang^{1,2}, **Qiongyi He**^{1,2} and Zbigniew Ficek³¹Peking University, PR China²Collaborative Innovation Center of Quantum Matter, PR China³The National Centre for Mathematics and Physics (KACST), Saudi Arabia*Towards a loophole-free Bell test with spin qubits in diamond***Bas Hensen**, Hannes Bernien, Wolfgang Pfaff, Machiel S. Blok, Lucio Robledo,

Tim H. Taminiau and Ronald Hanson

Delft University of Technology, Netherlands

*Entanglement swapping over a 143 km free-space link***Thomas Herbst**, Bernhard Wittmann, Rupert Ursin, Anton Zeilinger,

Thomas Scheidl, Matthias Fink and Johannes Handsteiner

Austrian Academy of Sciences, Austria

*Quantum entanglement and teleportation in pulsed cavity optomechanics***Sebastian G. Hofer**^{1,2}, Witlef Wieczorek¹, Markus Aspelmeyer¹ and Klemens Hammerer²¹University of Vienna, Austria²Leibniz University of Hanover, Germany

*Negative probabilities as deterministic relations between observable properties:
Why quantum physics must violate inequalities*

Holger F. Hofmann

University of Hiroshima, Japan

*Experimental evaluation of error and disturbance of Ozawa's inequality in
two-level systems*

Masataka Iinuma, Yutaro Suzuki, Ryuji Kinoshita and Holger F. Hofmann

University of Hiroshima, Japan

Towards the creation and detection of momentum entangled atom pairs

Michael Keller, Mateusz Kotyrba, Maximilian Ebner and Anton Zeilinger

Austrian Academy of Sciences, Austria

CHSH inequality: Quantum probabilities as conditional probabilities

Andrei Khrennikov

Linnaeus University, Sweden

Sequences of projective measurements in generalized probabilistic theories

Matthias Kleinmann

University of Siegen, Germany

Quantum theory as a causal inference: a nonlinear noncommutative approach

Ryszard Kostecki

Perimeter Institute for Theoretical Physics, ON, Canada

A (100×100) -dimensional entangled quantum system

Mario Krenn¹, Marcus Huber^{2,3,4}, Robert Fickler¹, Radek Lapkiewicz¹,
Sven Ramelow¹ and Anton Zeilinger¹

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²University of Bristol, U.K.

³The Institute of Photonic Sciences (ICFO), Spain

⁴University of Barcelona, Spain

Cavity cooling of free nanoparticles in high vacuum

Stefan Kuhn, Peter Asenbaum, Stefan Nimmrichter, Ugur Sezer and Markus Arndt

University of Vienna, Austria

*Randomness extraction from quantum systems with different levels of trust in the
working of the devices*

Yun Zhi Law, Jean-Daniel Bancal and Valerio Scarani

National University of Singapore, Singapore

The Colbeck-Renner claim on the completeness of quantum mechanics as a theorem

Klaas Landsman¹ and **Gijs J. Leegwater**²

¹Radboud University Nijmegen, Netherlands

²Erasmus University Rotterdam, Netherlands

Ψ -epistemic models are exponentially bad at explaining the distinguishability of quantum states

Matthew Leifer

Perimeter Institute for Theoretical Physics, ON, Canada

Quantum imaging with undetected photons

Gabriela B. Lemos, Victoria Borish, Garrett D. Cole, Sven Ramelow, Radek Lapkiewicz and Anton Zeilinger
Austrian Academy of Sciences, Austria

Simultaneously testing the Kochen-Specker and Bell theorems

Gustavo Cañas¹, Sebastián Etcheverry¹, Esteban S. Gómez¹, Carlos Saavedra¹, Guilherme B. Xavier¹, **Gustavo Lima**¹ and Adán Cabello²

¹University of Concepción, Chile

²University of Sevilla, Spain

Quantum mechanics with single atoms and photons

Philipp Müller, Pascal Eich, Stephan Kucera, José Brito, Christoph Kurz, Michael Schug and Jürgen Eschner
Saarland University, Germany

Causal inference in quantum networks

Jacques Pienaar and Caslav Brukner

Austrian Academy of Sciences, Austria

Macroscopic quantum systems and gravitational phenomena

Igor Pikovski

University of Vienna, Austria

Beyond local causality: causation and correlation after Bell

Matthew Pusey

Perimeter Institute for Theoretical Physics, ON, Canada

Entanglement control in a quantum dot-microcavity system by an external magnetic field applied

Luisa Fernanda Ramírez Ochoa¹, Herbert Vinck-Posada¹, Luis E. Cano², Paulo S.S. Guimaraes² and Boris A. Rodríguez³

¹National University of Colombia, Colombia

²Federal University of Minas Gerais, Brazil

³University of Antioquia, Colombia

Algorithmic synthetic unity

Allan F. Randall

York University, UK

Equivalence between adaptive and non-adaptive nonlocality distillation protocols

Jibrán Rashid and Stefan Wolf

University of Lugano, Switzerland

Tailored two-photon correlation and fair-sampling: a cautionary tale

Jacquiline Romero¹, Daniel Giovannini¹, Daniel S. Tasca¹, Steve M. Barnett² and Miles J. Padgett¹

¹University of Glasgow, UK

²University of Strathclyde, UK

Heralded entanglement of single neutral atoms for a conclusive test of Bell's inequality

Wenjamin Rosenfeld, Daniel Burchardt, Norbert Ortengel, Kai Redeker, Robert Garthoff, Julian Hofmann, Markus Weber and Harald Weinfurter

Ludwig Maximilian University of Munich, Germany

and Max-Planck-Institute for Quantum Optics, Germany

Bell inequalities from 1964 to 2014: a compendium

Denis Rosset¹, Jean-Daniel Bancal² and Nicolas Gisin¹

¹University of Geneva, Switzerland

²National University of Singapore, Singapore

Greenberger-Horne-Zeilinger theorem for N qudits

Junghee Ryu¹, Changhyoup Lee³, Marek Żukowski¹ and Jinhyoung Lee^{2,4}

¹University of Gdańsk, Poland

²Hanyang University, Korea

³National University of Singapore, Singapore

⁴Seoul National University, Korea

Noise tolerant entanglement verification in an untrusted quantum network

Dylan J. Saunders, Anthony J. Bennett and Geoff J. Pryde

Griffith University, Australia

Quantum communication with satellites, its preparatory terrestrial free-space demonstrations and future missions

Thomas Scheidl, Rupert Ursin and Anton Zeilinger
Austrian Academy of Sciences, Austria

Optimal LOCC conversion of 3-qubit states

Katharina Schwaiger
University of Innsbruck, Austria

On detecting the quantum correlations in the early universe

Yutaka Shikano¹, Yusuke Hayashi² and Masaaki Hashimoto²
¹Tokyo Institute of Technology, Japan
²Kyushu University, Japan

Internal structure of the Heisenberg and Robertson-Schrödinger uncertainty relations

Lubomír Skála
Charles University in Prague, Czech Republic

Improved quantum metrology using quantum error-correction

Wolfgang Dür¹, **Michalis Skotiniotis**¹, Florian Fröwis^{1,2} and Barbara Kraus¹
¹University of Innsbruck, Austria
²University of Geneva, Switzerland

Axiomatic approach for the function bound of all Bell's inequalities

Wonmin Son
National University of Singapore, Singapore

Remote entanglement preparation

Cornelia Spee¹, Julio Iñigo de Vicente Majúa² and Barbara Kraus¹
¹University of Innsbruck, Austria
²Charles III University of Madrid, Spain

Experimental reconstruction of complex joint probabilities for arbitrary photon polarization via sequential measurements of non-commuting observables

Yutaro Suzuki, Masataka Iinuma, Ryuji Kinoshita and Holger F. Hofmann
University of Hiroshima, Japan

Bit commitment based on Bell's theorem

Marcelo Terra Cunha
Federal University of Minas Gerais, Brazil

*Robust test of Bell's inequality with amplified NOON states***Falk Töppel**^{1,2,3} and Magdalena Stobńska^{4,5}¹Max Planck Institute for the Science of Light, Germany²Friedrich-Alexander University Erlangen-Nürnberg, Germany³Erlangen Graduate School in Advanced Optical Technologies, Germany⁴University of Gdańsk, Poland⁵Polish Academy of Sciences, Poland*Past of a quantum particle: speakable after all!***Lev Vaidman**

Tel Aviv University, Israel

*Single pairs of time-bin entangled photons***Marijn A. M. Versteegh**^{1,2,3}, Michael E. Reimer¹, Aafke A. van den Berg¹, Gediminas Juska⁴, Valeria Dimastrodonato⁴, Agnieszka Gocalinska⁴, Emanuele Pelucchi⁴ and Val Zwiller¹¹Delft University of Technology, Netherlands²Austrian Academy of Sciences, Austria³University of Vienna, Austria⁴University College Cork, Ireland*Exploiting Bell's inequality to extend the device-independent quantum key distribution*Giuseppe Vallone, Alberto Dall'Arche, Marco Tomasin and **Paolo Villoresi**

University of Padova, Italy

*Loophole-free Einstein Podolsky Rosen experiment via quantum steering***Bernhard Wittmann**^{1,2}, Sven Ramelow^{1,2}, Fabian Steinlechner², Nathan K. Langford², Nicolas Brunner³, Howard M. Wiseman⁴, Rupert Ursin² and Anton Zeilinger^{1,2}¹University of Vienna, Austria²Austrian Academy of Sciences, Austria³University of Bristol, UK⁴Griffith University, Australia*Genuine energy-time entanglement-based quantum key distribution over installed telecom fibers*Gonzalo Carvacho¹, Gabriel Saavedra¹, Alvaro Cuevas², Jaime Cariñe², Miguel Figueroa², Adán Cabello², Paolo Mataloni³, Gustavo Lima³ and **Guilherme B. Xavier**³¹University of Concepción, Chile²University of Sevilla, Spain³Sapienza University of Rome, Italy

Experimental methods of detecting steering for arbitrary dimensional states

Yu-Lin Zheng, Yi-Zheng Zhen, Nai-Le Liu, Kai Chen, Zeng-Bing Chen and Jian-Wei Pan

University of Science and Technology of China, PR China

Violation of Bell inequalities with time

Magdalena Zych

Austrian Academy of Sciences, Austria