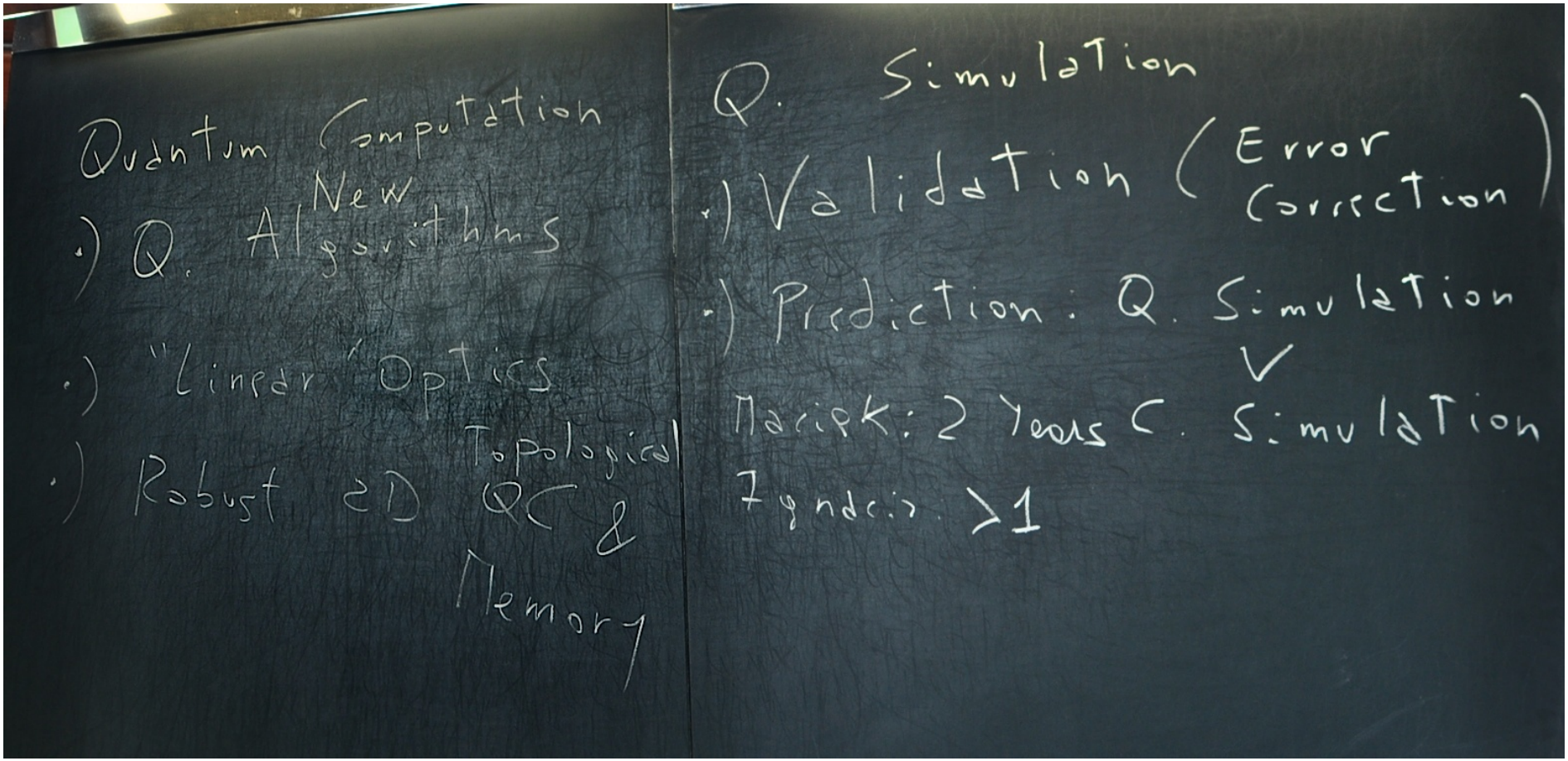
Future of QI (2011-25)

The Benasque Quantum Information Workshops
2011 – 2025

compiled by Antonio Acín, Adán Cabello, and Géza Giedke

July 2025

2011


Quantum Computation
New
Q. Algorithms
"Linear" Optics
Topological
Robust 2D QC &
Memory
Q. Simulation
Validation (Error Correction)
Prediction: Q. Simulation
Nature: 2 years C. Simulation
Typically: >1

+5 more...

2013

QUANTUM INFORMATION THEORY

- NPT BOUND ENTANGLEMENT (PPTC ⇒ UNDIST)
- Quantum violate Ingleton ≥ 0
- Characterization M-part. entanglement + apps

- Q. Discord ??
* Unw. Q.c. with Q. Walks
* Unifying Q. Correlat. ⇐ Discord
* Q.C. with little entang.
- Charact. LOCC + POVM (measurements) LOSR
- Rôle ent. in Q.C
* Security Device-indep QKD
- General framework security dev. indep
- Certification space-like separation dev-ind
- Example non-zero C.C. Channels
- $PPT^2 \Rightarrow$ E. Breaking

NEMTIAR VS MESSI

FOUNDATIONS OF QUANTUM PHYSICS

* PBR THEOREM
* Activation Q. non-locality
- B.E.S violate B ineq
- Beyond B. ineq.
- PRINCIPLES FOR Q CORRELATIONS
* Q. Thermod: Landauer pple + 2nd law
RELATIVITY
- [illegible] & QT IN LOW. ENERGY PHYSICS
- Firewall in BH.
- ARE LEGGETT-GARG INEQUALITIES USEFUL?
- Decidability in QIT
- NON-LOCALITY IN MANY-BODY PHYSICS
- MULT. PRINCIPLES ENOUGH?
- LIFE AFTER LOOPHOLE-FREE BI?
- TSIRELSON'S PROBLEM

MANY-BODY PHYSICS

* TIME-DEPENDENT VARIATIONAL PRINCIPLE
* CRITICALITY IN OPEN Q SYSTEMS
- EFFICIENT SIMULATION OF Q DYNAMICS
- CLASS. PHASES HIGHER-D
- Approxs. (truncation) TN
- Thermalization physical syst.
- Non-eq. inequalities (Quantum)
- Simulation TN HEP
- TN $\overset{?}{\Longleftrightarrow}$ AdS/CFT
- Relations fluct-entanglement
- LOW-ENERGY EFFECTIVE THEORIES
- ∃ self protecting Q.M. in D<4

QUANTUM OPTICS & IMPLEMENTATIONS

* GROUND STATE OF NANOMECHANICAL RESONATOR
- What is D-wave doing?
- IMPLEMENTATIONS OF DI STUFF
* DETECTION-LOOPHOLE FREE PHOTONIC EXPERIMENT
- Def. entang. bosons/fermions
- LIMITATIONS OF Q SIMULATION
- Boson sampling (Limitations)
* SUPERCONDUCTING QUBITS
* SIMULATION OF HIGH-ENERGY PHYSICS IN OPTICAL LATTICES
- CHEAP QKD
- SATELLITE-BASED Q COMM
- CERTIFICATION OF Q SIMULATION
- LONG-DISTANCE ENT. BASED QC
- EXP IMPL. OF PBL-LIKE THEOREMS?
- MANY-BODY STATE PREPARATION

2013: Achievements in the last few years

Quantum Info

- Universal qc w/ q walk
- Unifying q correlations
- QC w/ little entanglement
- security device-indep QKD

Foundations QP

- PBR Theorem
- activation of q nonlocality
- Q thermo: Landauer's principle & 2nd Laws

Q Optics & Implementations

- ground state nanomech syst
- detection-loophole-free photonic Bell exp
- superconducting qubits
- q sim.: high-energy physics in opt lattices
- q sim.: beating class comp

Many-Body Physics

- complexity of Hamiltonians
- criticality in open systems
- time-dependent variational principle

2013: Open Problems I

Quantum Info

- NPT bound entanglement
- Q violation Ingleton ineq
- m-partite entanglement: characterization & applic
- Q discord ??
- LOCC: characterization
- rôle of entanglement in QC
- device-indep: general framework security; certification of spacelike sep
- non-additivity of EOF/class capacity: examples
- QC more powerful than CC?
- $\mathrm{PPT}^2 \Rightarrow$ ent breaking

Foundations QP

- bound ent violate Bell Ineq?
- beyond Bell Ineq
- principles for Q correlations
- relativity & QM in low-energy physics
- QI + relativity
- B.H. info paradox / firewall
- are Leggett-Garg Ineq useful?
- decidability in QIT
- non-locality in many-body phys
- life after loophole-free Bell Exp
- Tsirelson's Problem
- Q chaos & entanglement

2013: Open Problems II

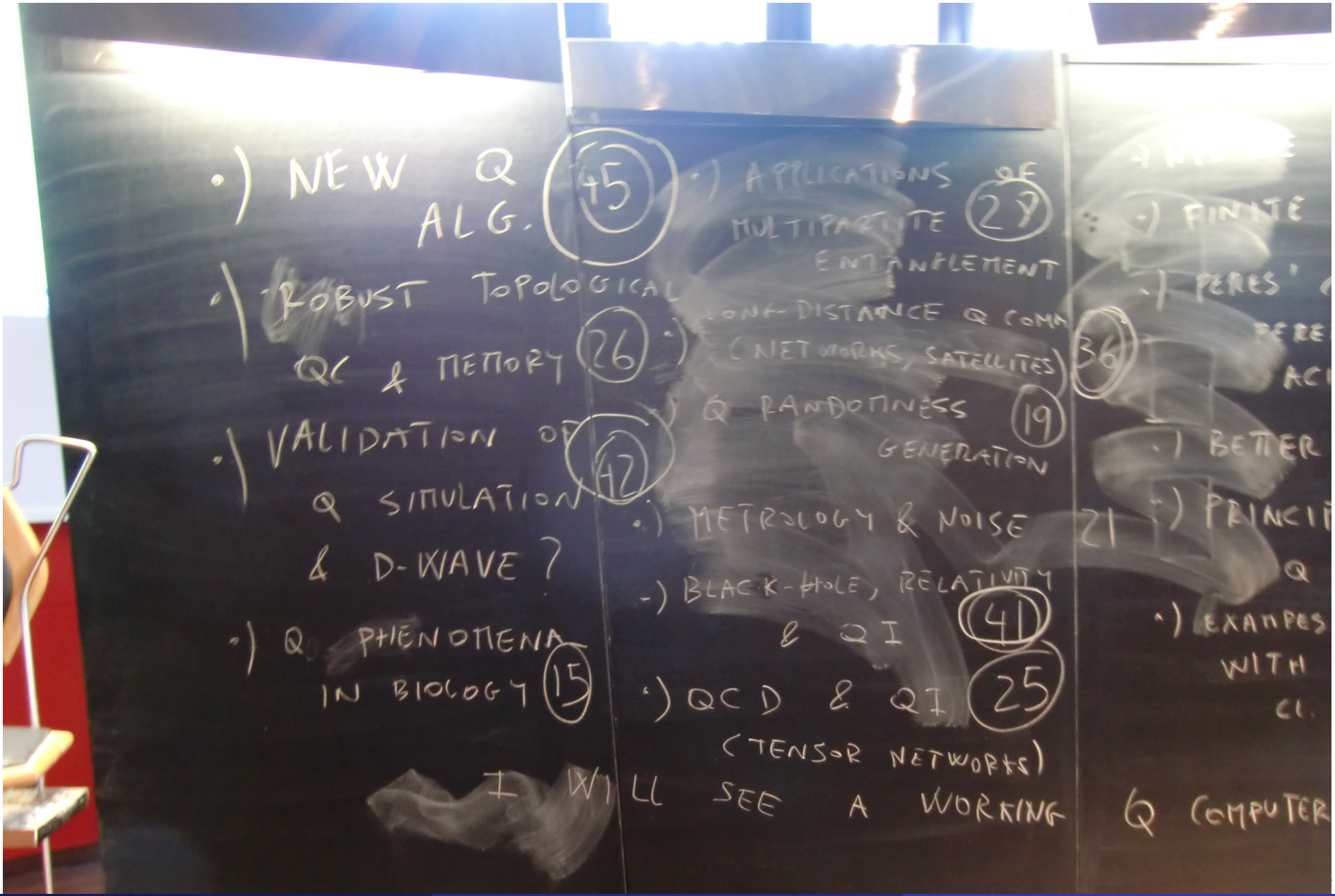
Many-Body Physics

- efficient sim of Q Dynamics
- classific phases higher D
- approx TN
- thermalization
- non-equilib inequalities (quantum)
- simulation TN HEP
- TN $\overset{?}{\Leftrightarrow}$ AdS/CFT
- relation fluctuat $\leftrightarrow$ entang.
- low-energy effective theories
- self-protect. Q Mem. $D < 4$?
- robustness topolog memories

Q Optics & Implementations

- what is D-Wave doing?
- implementations of QI stuff
- Q networks
- cheap QKD
- satellite-based Q Comm
- certification of Q Sim
- long-distance ent-based QC
- exp test of PBR-like theorems
- many-body state prep
- def ent of bosons/fermions
- limitations of Q simulations
- Boson Sampling (limitations)

2013 – Concluding Session



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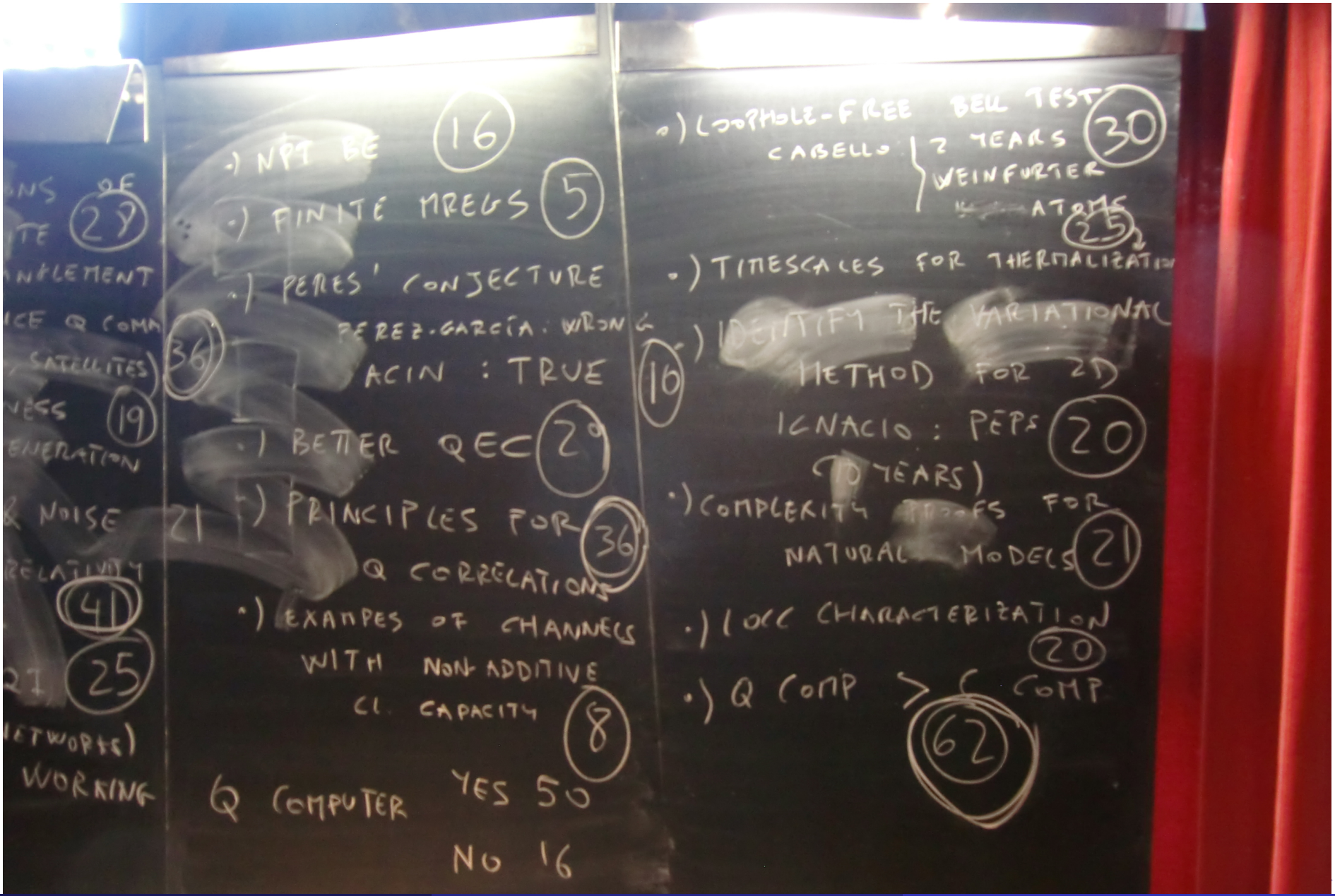

The Top 10 of Open QIS Challenges 2013

1. Q computation more powerful than classical? **(62)**
2. New q algorithms **(45)**
3. Certification of q simulation **(42)**
4. Black Holes, general relativity & q information (black hole information paradox) **(41)**
6. Long-distance q communication (networks, satellites) **(36)**
6. Principles for q correlations **(36)**
7. Loophole-free Bell test (30)
8. better QECC (29)
9. robust topological QC & QMemory (26)
10. timescales for thermalization (25)
10. high-energy physics and QI (tensor networks) (25)

2015

2015 Open Problems

OPEN PROBLEMS SESSION Benasque 2015 *Adán Cabello & Géza Giedke* July 8th, 2015

208	INFORMATION/COMPUTATION
30	**black holes & holography**
30	**demonstrate supremacy/speedup of QC**
28	**better quantum error correcting codes**
21	**multipartite entanglement**
16	**QFT and tensor networks**
10	macroscopic qubits/QI
10	quantum artificial intelligence (machine learning, etc.)
10	the existence of NPT bound entanglement

176	FOUNDATIONS
28	**principles for quantum correlations**
26	**encorporating time into the foundations of QT**
19	**quantum mechanics and relativity at low energies**
17	**experiment to rule out realist interpretation**
15	**role of causality**
13	quantum thermo: work and heat?
12	are all states useful?
11	protocols using QT + relativity

178	MANY-BODY PHYSICS
32	**better numerical algorithms for simulation**
24	**Quantum PCP conjecture**
19	**understanding the interplay of equilibration/transport/localization**
18	**entanglement detection**
18	**variational methods/tensor networks for field theories/continuous models in >= 2D**
14	uses for many-body phases
13	classifying topological phases in D=2 or higher
12	timescales of equlibration (also thermalization)

170	IMPLEMENTATIONS
25	**experimental demonstration of a protocol enhanced by quantum error correction**
25	**a 2D topological (e.g. surface) code**
24	**a quantum computer**
23	**long-distance quantum teleportation**
23	**q. chemistry simulation**
22	gravity tested in the lab
20	quantum repeaters
8	more efficient process tomography

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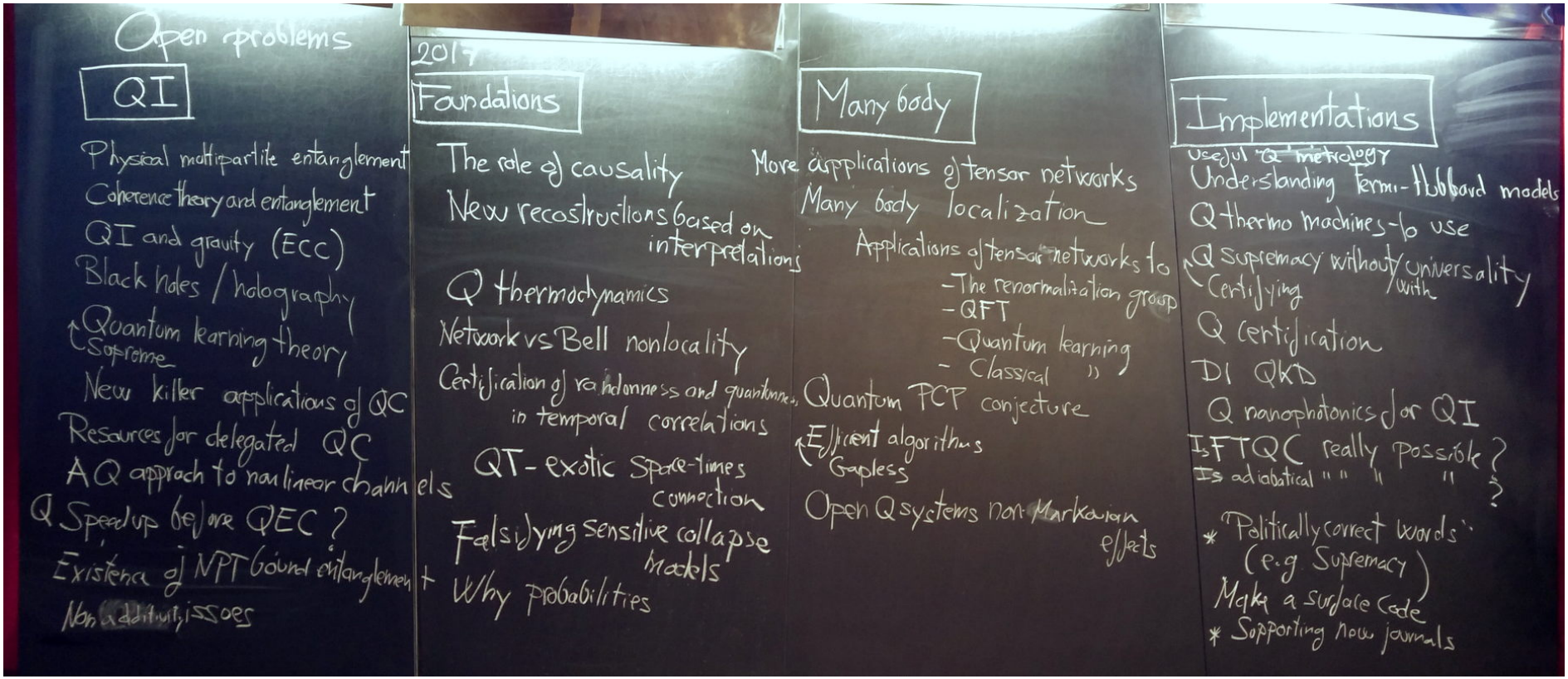
2017


Open problems
QI
Physical multipartite entanglement
Coherence theory and entanglement
QI and gravity (Ecc)
Black holes / holography
Quantum learning theory
(Supreme)
New killer applications of QC
Resources for delegated QC
AQ approach to non linear channels
Q Speed up before QEC ?
Existence of NPT bound entanglement
Non additivity issues
2017
Foundations
The role of causality
More
New reconstructions based on interpretations
Q thermodynamics
Network vs Bell nonlocality
Certification of randomness and quantumness in temporal correlations
QT - exotic Space-times connection
Falsifying sensitive collapse models
+ Why probabilities
Many body
More applications of tensor networks
Many body localization
Applications of tensor networks to
- The renormalization group
- QFT
- Quantum learning
- Classical))
Quantum PCP conjecture
(Efficient algorithms
Gapless
Open Q systems non Markovian effects
Implementations
Useful Q metrology
Understanding Fermi-Hubbard models
Q thermo machines - to use
Q supremacy without universality
(Certifying
with
Q certification
DI QKD
Q nanophotonics for QI
Is FTQC really possible ?
Is adiabatical " " " " ?
* "Politically correct words"
(e.g Supremacy)
Make a surface code
* Supporting new journals

2017 Open Problems I

QI

- physical multipartite entanglement
- coherence theory and entanglement
- QI and gravity (ECC)
- Black Holes / holography
- (supreme) quantum machine learning
- new killer applications for QC
- resources for delegated QC
- q approach to nonlinear channels
- q speedup before QECC?
- NPT bound entanglement?

Foundations

- role of causality
- new reconstructions based on interpretations
- q thermodynamics
- network vs Bell nonlocality
- certification of randomness and quantumness in temporal correlations
- QT–exotic space-times connection
- falsifying sensitve collapse models
- why probabilities?

2017 Open Problems I

Many-body

- more applications tensor networks
- many-body localization
- applications of TN to: RNG, QFT, q learning, c learning
- quantum PCP conjecture
- efficient algorithms for gapless systems
- open q systems w non-Markovian effects

Implementations

- useful q metrology
- understanding Fermi-Hubbard model
- q thermo machines to use
- certifying q supremacy without (or with) universality
- q certification
- device-independent QKD
- q nanophotonics for QIP
- is FTQC really possible?
- is adiabatic QC really possible?
- make a surface code

Bets over the years

- NPT bound entanglement? 2011 Ruskai: No
- general composable security proof for DI-QKD 2011 Winter: yes; Acín: 2 yrs
- Peres' Conjecture? 2011 Perez-García: False ✓
  Vertesi and Brunner 2014
- optimal states for 1-mode Gaussian channels? 2011 García-Patrón: vacuum (✓)
- loophole-free Bell test
  2011 Kleinmann: $>$ 2y ✓2013 Cabello: 2y, Weinfurter (✓)
  2015: Hensen et al; Giustina et al; Shalm et al
- D-wave QC? 2011 Cirac: No (2y) ✓
- q repeater better than direct transmission 2011 Brask Bohr: 3y
- q sim better than c sim Lewenstein: 2y; Cirac: $>$ 1y
- **the** variational method? 2013 Cirac: PEPS (10y)
- business interest in QC will increase 2015 Latorre: yes (2y) ✓

Voted predictions

- a universal quantum computer within our lifetimes?

  in 2013: **YES: 50**; NO: 16 in 2015: **YES: 60**; NO: 11; ABS: 5.

- predictions 2017 (for 2019):

  • quantum computers with X qubits and 10^3 gates:
  (A) $>$ 100 qubits (3; 4%) (B) $50-100$ (**37; 58%**) (C) <50 (24; 38%)

  • device-independent QKD:
  (A) $<$ 1km (3; 6%) (B) $1-10$km (**35; 71%**) (C) $>$ 10k (11, 23%)

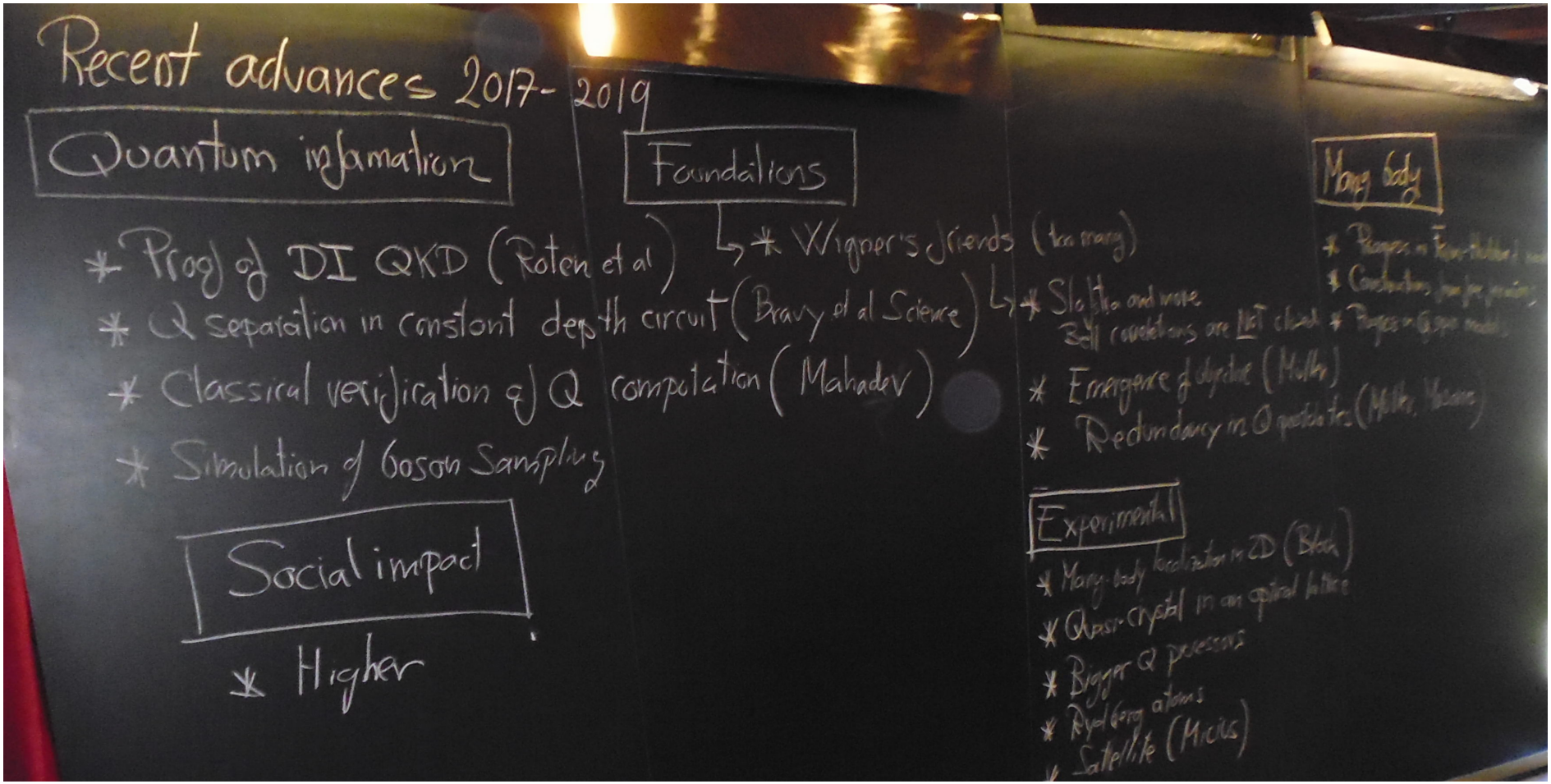
  • reliable phase diagram Hubbard model:
  (A) Yes (9; 29%) (B) NO (22; 71%)

  • q metrology: commercial device using
  (A) only entanglement (24; 61%) (B) entanglement and (Q?)EC (2; 5%) (C) none (13, 33%)

2019

recent advances – major open problems – bets/predictions

The 2019 Quantum Information Workshop



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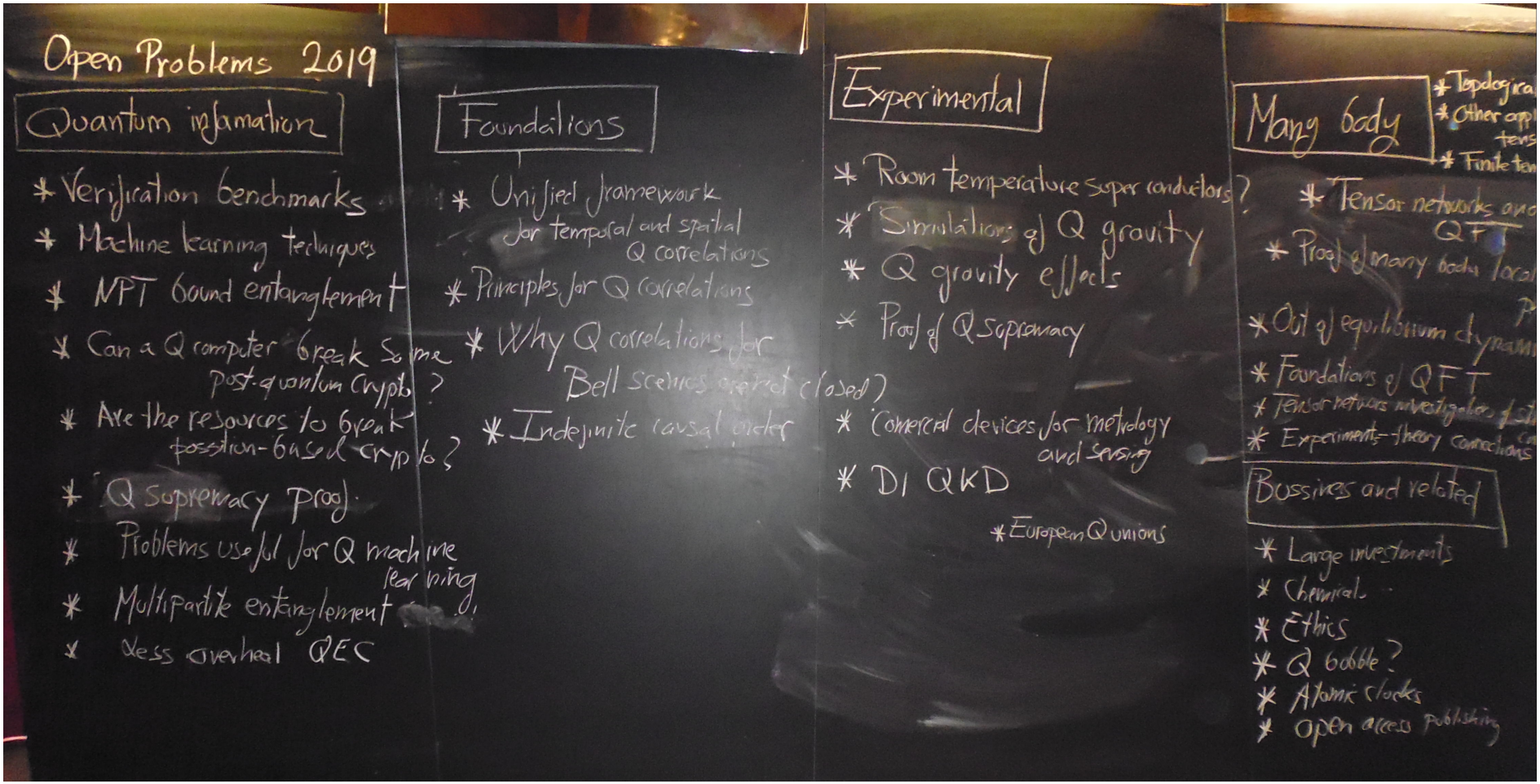


The 2019 Quantum Information Workshop

2019: Recent advances

Quantum Information

- Proof of DI QKD (Arnon-Friedman et al., '16)
- Q separation constant-depth circuit (Bravyi, Gosset, Koenig '18)
- Classical verification of QC (Mahadev, 2018)
- Simulation of Boson sampling

Quantum foundations

- Wigner's friend (Frauchinger & Renner)
- Bell correlations (Slofstra 2017...)
- Emergence object. reality (Müller)
- Redundancy in Q postulates (Masanes, Galley, Müller 2018)

Many-body

- Fermi Hubbard (Corboz et al.)
- Constructions from free fermions
- Frustrated q spin models not tractable by Q Monte Carlo

Implementations

- Many-body localization in 2d (Bloch)
- Quasicrystals in optical lattices (Bloch?)
- Tweezer technology (Lukin)
- Scaling up to 50 qubits (ions, atoms, and sc qubits)
- Satellite (Micius)

2019: Open problems I

Quantum information

- verification & benchmarks of QC
- quantum machine learning
- NPT bound entanglement?
- Can QC break post-q crypto?
- Resources to break position-based crypto
- Q supremacy proof
- Problems useful for QML
- Multipartite entanglement
- QEC: Higher-threshold error correcting codes with less overhead

Many-body

- TNs and QFT
- Proof of MBL phase
- Out-of-equilibrium dynamics
- Foundations of QFT
- TN investigations of strong correlations
- Experiment theory corrections
- Classification of topological phases in 3D
- Applications of TNs outside QMB physics
- Finite temperature results

2019: Open problems II

Foundations

- Unified Framework for temporal and spatial Q correlations
- Principles (and bounds) for Q correlations
- Why are Q correlations for bell scenarios not closed?
- Indefinite causal order

Business & Societal

- large investments (financial, chemical,...)
- ethics?
- q bubble? and consequences?
- open access publishing

Implementations/Experiment

- Room-temp SC
- QSim of Q gravity
- detection of Q Gravity effects
- Proof of Q supremacy
- Commercial devices for metrology and sensing
- DI QKD

2019 Voted Predictions

Will it be shown within 2 years that...?

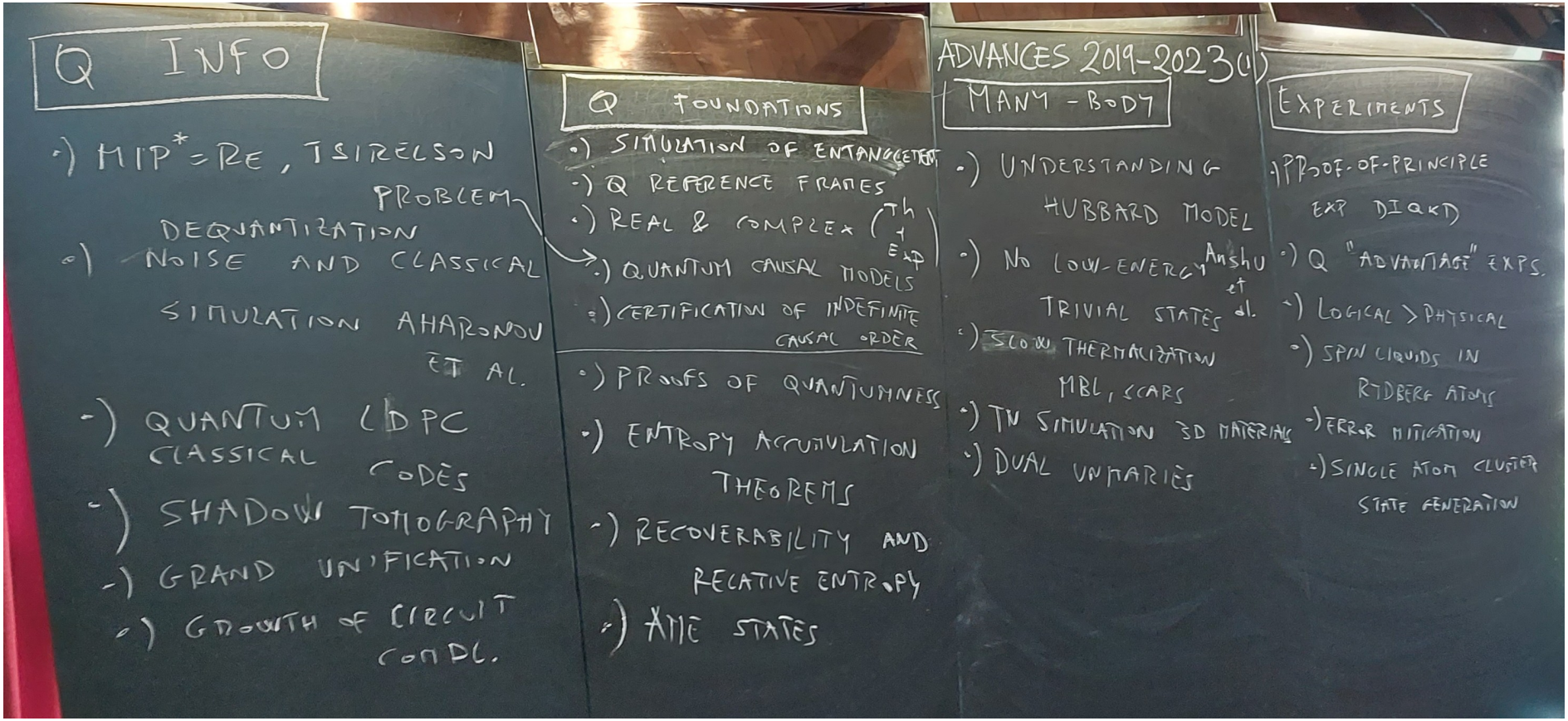
- QC is better than CC
  YES: 9; **No: 30**
- q supremacy proof without depth restrictions
  YES: 9; NO: 7
- Slofstra "problem" is not a problem: YES: Adán, Alex, Barbara; NO: David, Pepe
- usable DI-QKD ($>$ 1Mbit/s)
  YES: 8; **NO: 23**
- QECC-corrected (& improved) qubit: **YES: 30**; NO: 8
- q supremacy
  YES: 20; **NO: 23**
- reliable algorithm for simulating dynamics ($\geq$ 1d):
  YES: 8; **NO: 21**
- major qtech investment ($\geq$ 100MEUR) by *European* company? **YES: 28**; NO: 7
- will investment hurt the way we do science? **YES: 26**; NO: 17

A fault-tolerant scalable QC within your lifetime? **YES: 40**; NO: 12

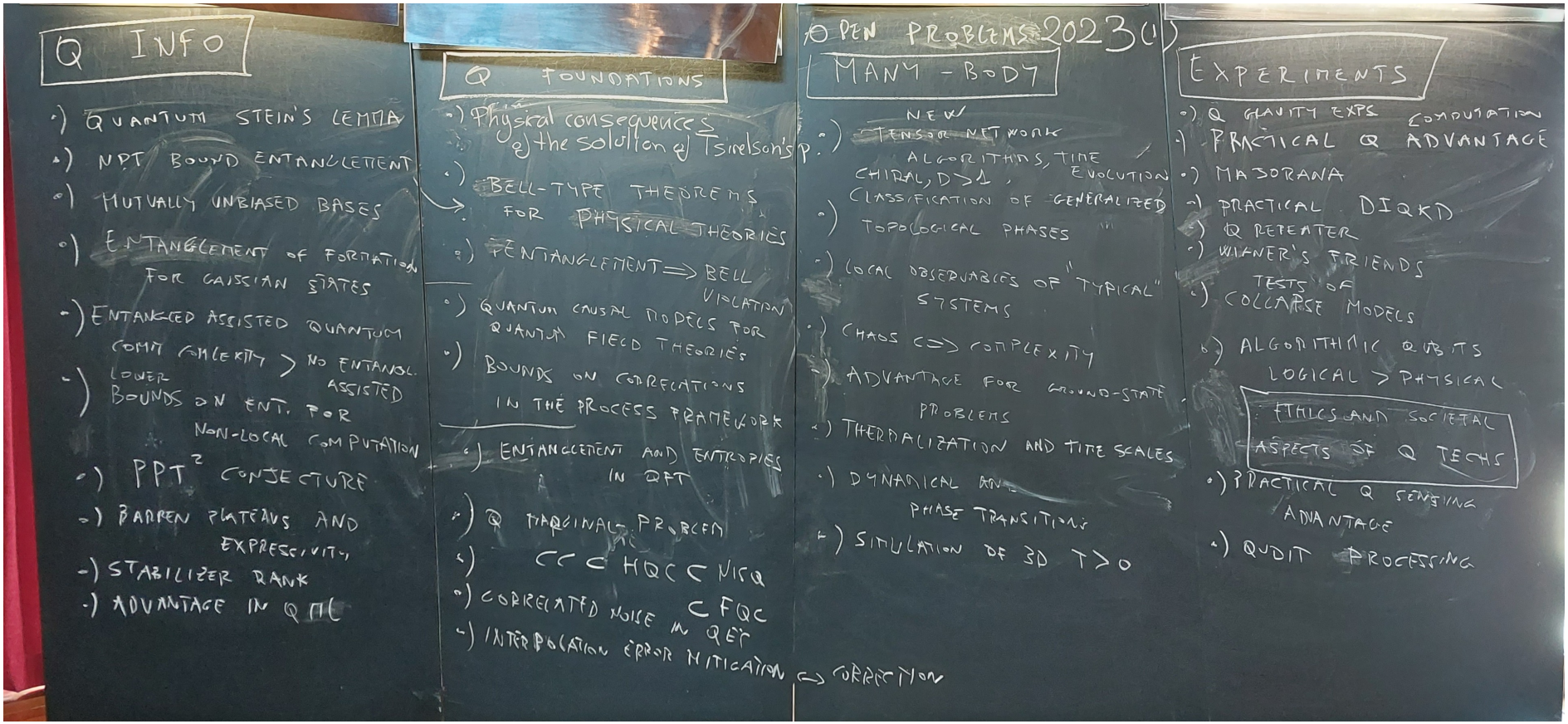
2023

recent advances – major open problems – (bets/predictions)

The 2023 Quantum Information Workshop



The 2023 Quantum Information Workshop



2023: Recent advances

Quantum Information

- MIP* = RE; Tsirelson prob [Ji et al.]
- dequantization, noise and classical simulation (Aharonov et al.)
- classical and quantum LDPC codes [Panteleev and Kalachev]
- shadow tomography [Huang et al.]
- q singular value decomposition / grand unification of q algorithms [Gilyén et al.]
- growth of circuit complexity [Haferkamp *et al.*]
- proofs of quantumness [e.g., Brakerski et al.]
- entropy accumulation theorems [e.g., Metger et al.]
- recoverability & rel entropy in v Neumann algebras/QFT [Faulkner et

Quantum foundations

- simulation of entanglement [Renner et al.]
- q reference frames [Giacomini et al.] (2017)
- "real and complex" [Renou et al.]
- q causal models [Barrett et al.]
- certification of indefinite causal order [van der Lugt et al.]

2023: Recent advances II

Many-body

- understanding the Hubbard model [Review by Qin et al.]
- no low-energy trivial states [Anshu et al.]
- slow thermalization, many-body scars (review), many-body localization
- tensor-network simulations of 3d materials
- dual unitaries [Bertini et al.]

Experiments

- proof-of-principle DI-QKD [Nadlinger et al. and Zhang et al.]
- q “advantage” experiments [Arute et al.]
- logical qubit better than physical [Ryan-Anderson et al.]
- max-cut and spin-liquids in Rydberg atoms [Ebadi et al., Semeghini et al.]
- error mitigation [Review by Cai et al.]
- single-atom cluster-state generation [Thomas et al.]

Most popular advances 2019-23 acc. to SciRate I

287 MIP*=RE, Ji *et al.*, arXiv:2001.04383 (✓)

197 Exponential quantum speedup in simulating coupled classical oscillators, Babbush *et al.*, arXiv:2303.13012

183 NLTS Hamiltonians from good quantum codes, Anshu *et al.*, arXiv:2206.13228 (✓)

179 Information-theoretic bounds on quantum advantage in machine learning, Huang *et al.*, arXiv:2101.02464

171 The Complexity of NISQ, Chen *et al.*, arXiv:2210.07234

162 Predicting Many Properties of a Quantum System from Very Few Measurements, Huang *et al.*, arXiv:2002.08953 (✓)

162 A polynomial-time classical algorithm for noisy random circuit sampling, Aharonov *et al.*, arXiv:2211.03999 (✓)

156 Fault-Tolerant Operation of a Quantum Error-Correction Code, Egan *et al.*, arXiv:2009.11482

Most popular advances 2019-23 acc. to SciRate II

150 Provably efficient machine learning for quantum many-body problems, Huang *et al.*, arXiv:2106.12627

148 Linear growth of quantum circuit complexity, Haferkamp *et al.*, arXiv:/2106.05305 (✓)

146 The Quantum Fourier Transform Has Small Entanglement, Chen *et al.*, arXiv:2210.08468

146 Building a fault-tolerant quantum computer using concatenated cat codes, Chamberland *et al.*, arXiv:2012.04108

143 Quantum advantage in learning from experiments, Huang *et al.*, arXiv:2112.00778

142 Efficient tensor network simulation of IBM's kicked Ising experiment, Tindall *et al.*, arXiv:2306.14887

142 Efficient classical simulation of random shallow 2D quantum circuits, Napp *et al.*, arXiv:2001.00021

Most popular advances 2019-23 acc. to SciRate III

137 Exponentially tighter bounds on limitations of quantum error mitigation, Quek *et al.*, arXiv:2210.11505

137 The Power of Adiabatic Quantum Computation with No Sign Problem, Hastings, arXiv:2005.03791

137 Dissipative ground state preparation and the Dissipative Quantum Eigensolver, Cubitt, arXiv:2303.11962

- (list leaves out review articles...)

2023: Open problems I

Quantum information

- q Stein's lemma
- NPT bound entanglement
- mutually unbiased bases
- EoF for Gaussian states
- ent-assisted q comm complexity
- lower bounds on ent for non-local computation
- PPT^2 conjecture
- barren plateaus and expressivity
- stabilizer rank
- advantage in QML
- $\mathrm{CC} \overset{?}{\subset} \mathrm{hQC} \overset{?}{\subset} \mathrm{NISQ} \overset{?}{\subset} \mathrm{FQC}$
- corr noise in QEC
- interpolation error mitigation — error correction

Many-body

- new tensor-network algorithms, time-ev, chiral PEPS (d>1)
- classific of gen. topolog. phases
- local observables of "typical" systems
- chaos $\Leftrightarrow$ complexity
- advantage for ground-state problems?
- thermalization and time scales; ETH
- dynamical and complexity phase transitions
- simulations of 3d, $T > 0$ systems

2023: Open problems II

Foundations

- physical consequences of solution of Tsirelson's problem
- Bell-type theorems for physical(?) theories
- entanglement $\Rightarrow$ Bell violation?
- q causal models for QFT
- bounds on correlations in process framework
- entanglement and entropies in QFT
- q marginal problem

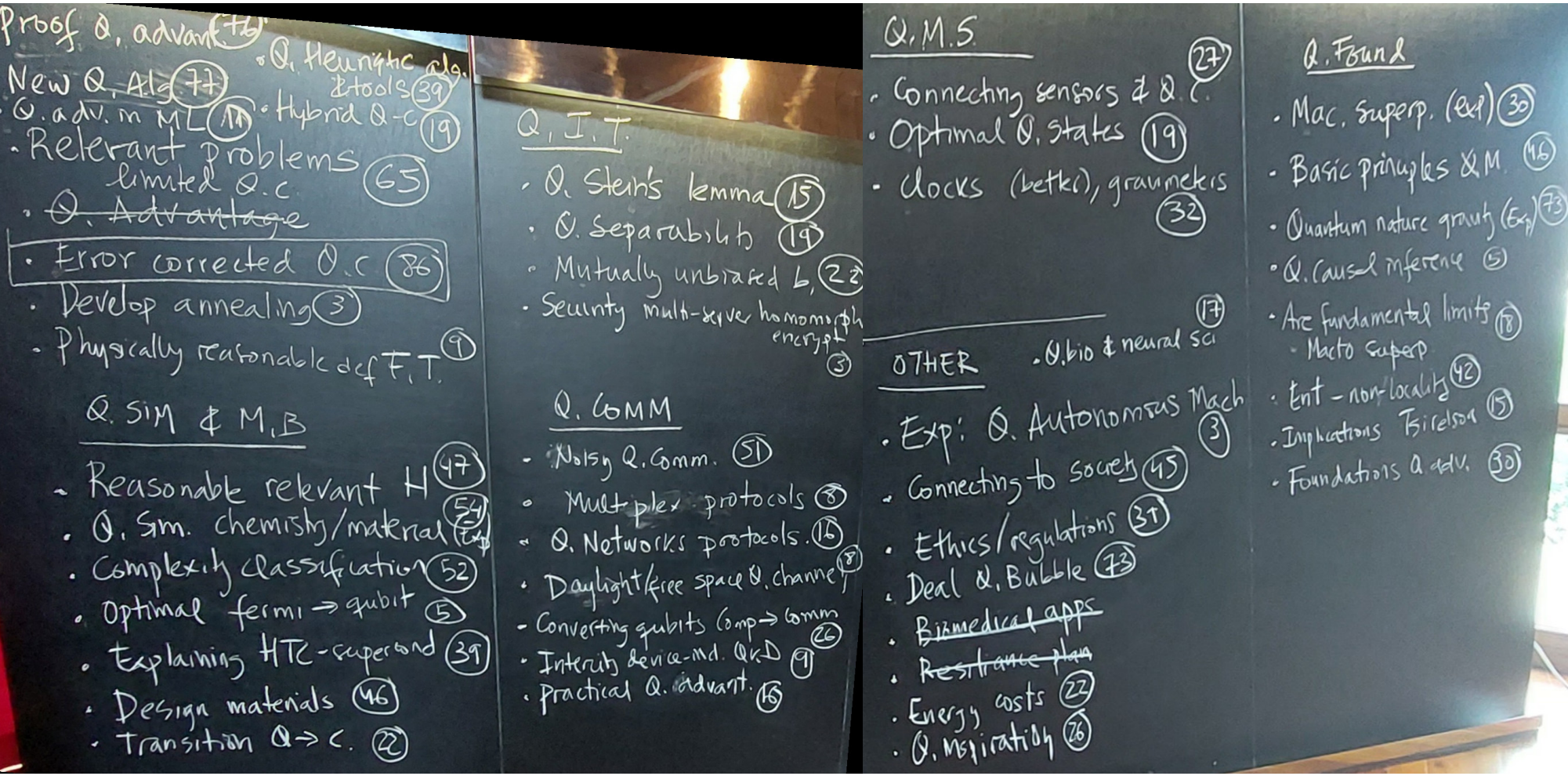
Experiment

- practical q advantage
- practical DI-QKD
- q repeater
- Wigner's friends
- tests of collapse models
- practical q sensing advantage
- qudit processing
- Majoranas
- q gravity experiments

Business & Societal

- ethics of q tech

Open Problems Session (3rd week) I



Open Problems Session (3rd week) II

Quantum Computing

- proof of q advantage
- new q algorithms
- relevant problems for limited QC
- error corrected QC
- develop annealing
- q advantage in machine learning
- physically reasonable def of fault-tolerance
- q heuristic algorithms and tools
- hybrid classical-q computing

QIT

- q Stein's lemma
- q separability
- mutually unbiased bases
- security of multi-server homomorphic encryption

Quantum Measurement/Sensing

- connecting sensors & QC
- optimal q states
- better clocks, gravimeters

Open Problems Session (3rd week) III

Quantum Simulation & many-body

- reasonable relevant Hamiltonians
- q sim of chemistry/materials
- complexity classification
- optimal mapping fermions $\rightarrow$ qubits
- explaining high-T_c superconductivity
- design materials
- transition q $\rightarrow$ c

Quantum Communication

- noisy q comm
- multiplex protocols
- q network protocols
- daylight/free-space q channel
- converting comp to comm qubits
- inter-city device-independent QKD
- practical q advantage

Open Problems Session (3rd week) IV

Quantum Foundations

- macro superpositions (exp)
- basic principles for QM
- q nature of gravity (exp)
- q causal inference
- fundamental limits to macro superpos?
- entanglement $\leftrightarrow$ non-locality
- implication of sol to Tsirelson's problem
- foundation of q advantage

Other

- q autonomous machines (exp)
- connecting to society
- ethics/regulations
- deal w/ q bubble
- energy costs
- q inspiration
- q bio & neuro science

Open Problems Session (3rd week; ranked) I

Quantum Computing

- error corrected QC **(86)**
- new q algorithms **(77)**
- proof of q advantage **(76)**
- relevant problems for limited QC (65)
- q heuristic algorithms and tools (39)
- hybrid c-q computing (19)
- q advantage in machine learning (11)
- physically reasonable def of fault-tolerance (9)
- develop annealing (3)

QIT

- mutually unbiased bases (22)
- q separability (19)
- q Stein's lemma (15)
- security of multi-server homomorphic encryption (3)

Quantum Measurement/Sensing

- better clocks, gravimeters (32)
- connecting sensors & QC (27)
- optimal q states (19)

Open Problems Session (3rd week; ranked) II

Quantum Simulation & many-body

- q sim of chemistry/materials **(54)**
- complexity classification (52)
- reasonable relevant Hamiltonians (47)
- design materials (46)
- explaining high-T_c supercond (39)
- transition q $\rightarrow$ c (22)
- optimal mapping fermions $\rightarrow$ qubits (5)

Quantum Communication

- noisy q comm (51)
- converting comp to comm qubits (26)
- q network protocols (16)
- practical q advantage (16)
- inter-city device-independent QKD (9)
- multiplex protocols (8)
- daylight/free-space q channel (8)

Open Problems Session (3rd week; ranked) III

Quantum Foundations

- q nature of gravity (exp) **(73)**
- basic principles for QM (46)
- entanglement $\leftrightarrow$ non-locality (42)
- macro superpositions (exp) (30)
- foundation of q advantage (30)
- fundamental limits to macro superpos? (18)
- implication of sol to Tsirelson's problem (15)
- q causal inference (5)

Other

- deal w/ q bubble **(73)**
- connecting to society (45)
- ethics/regulations (31)
- q inspiration (26)
- energy costs (22)
- q bio & neuro science (17)
- q autonomous machines (exp) (3)

2025

recent advances – major open problems – (bets/predictions)

The 2025 Quantum Information Workshop

Open Problems Session 2025 (ranked) I

Quantum Computing

- physical limits of q error correction **(52)**
- foundations of q advantage (50)
- structure in super-quadratic speedups (36)
- scalability & interconn. (34)
- q computations beyond "heroic"; non-lin q comp (17)
- AI for q compilation & error correction (17)
- representation theory of Clifford (16)
- modular q software (13)
- Gaussian permanent conjecture (6)
- cost of QRAM (9)
- q recursion (5)
- security by design w/ q comp (3)

QIT

- q magic **(16)**
- usefulness of PPT ent (13)
- PPT constraints: analytical bounds (10)
- intrinsic randomness (arb no of parties and meas) (9)

Open Problems Session 2025 (ranked) II

Quantum Foundations

- exp signatures of q gravity **(48)**
- gravitationally mediated ent signature of q gravity? (33)
- gap between tensor & commuting correlations (31)
- relation non-locality $\leftrightarrow$ ent (31)
- non-local games in q field theory (19)
- are all ent states associated to some non-locality (16)
- games w/ fermionic or anyonic advantage (16)
- algorithmic characterization of comm. corr. beyond Bell (14)

Quantum Simulation & many-body

- robust q simulation **(54)**
- complexity of q chemistry (40)
- tensor network states for volume-law systems (25)
- area law in any dimension (16)

Quantum Sensing

- q sensing for high-energy physics & tests beyond std model **(21)**
- practical q advantage in NMR (14)

Open Problems Session 2025 (ranked) III

Quantum Communication

- long-distance, large-rate, robust DI-QKD **(25)**
- multi-party crypto and sensing: applications (17)
- contextuality: applications (9)

Other

- implications of q comp for society **(56)**
- q ethics policy (ethical society of physicists) (40)
- energy advantage (32)
- unbiased predictions o q tech (15)

IQOQI-List of Open Problems in Quantum Information

Open Quantum Problems

https://oqp.iqoqi.oeaw.ac.at/open-quantum-problems

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2	Undistillability implies ppt?	D. Bruß	2000/03/02	2006/08/16	Entanglement theory
5	Maximally entangled mixed states	K. Audenaert	2001/11/08	-	Entanglement theory
8	Qubit formula for Relative Entropy of Entanglement	J. Eisert	2003/06/20	-	Entanglement theory
12	Bell Inequalities for long range vacuum correlations	R. Verch	2002/01/22	-	Quantum foundations
13	Mutually unbiased bases	B.-G. Englert	2003/01/31	2004/01/07	Quantum communication
14	Tough error models	E. Knill	2003/01/31	-	Quantum computation
15	Separability from spectrum	E. Knill	2003/01/31	2013/09/08	Entanglement theory
16	Complexity of product preparations	E. Knill	2003/01/31	-	Quantum computation
20	Reversible entanglement manipulation	M. Plenio	2005/02/08	2023/01/23	Entanglement theory
23	SIC POVMs and Zauner's Conjecture	D. Gross	2005/02/17	-	Quantum communication
24	Secret key from all entangled states	P. Horodecki	2005/03/15	-	Quantum communication
25	Lockable entanglement measures	P. Horodecki	2005/03/15	-	Entanglement theory
26	Bell inequalities holding for all quantum states	R. Gill	2010/04/19	-	Quantum foundations
27	The power of CGLMP inequalities	R. Gill	2006/02/28	-	Quantum foundations
29	Entanglement of formation for Gaussian states	O. Krüger	2005/04/20	-	Entanglement theory
31	Individual measurement strategies on geometrically uniform states	J. Bae	2005/10/06	-	Quantum communication
32	Bell inequalities: many questions, a few answers	N. Gisin	2007/02/02	2016/12/01	Quantum foundations
34	The geometry of quantum nonlocality	W. Slofstra and M. Navascués	2017/04/26	-	Quantum foundations
35	Existence of absolutely maximally entangled pure states	F. Huber	2017/05/19	-	Quantum computation
36	Composition of decoherence functionals	M. Navascués	2017/05/19	-	Quantum foundations
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39	Steering bound for qubits and POVMs	R. F. Werner	2017/05/19	-	Entanglement Theory
40	Refinement of the Bessis-Moussa-Villani conjecture	D. Hägele	2017/05/19	-	Many-Body Quantum Information Theory
41	All rank inequalities for reduced states of quadripartite quantum states	M. Huber, N. Linden and A. Winter	2017/05/20	-	Entanglement theory
42	Reversible dynamics on composite systems	B. Dakic and M. Müller	2017/05/20	-	Quantum foundations
43	Are all extensibly causal processes purifiable?	M. Araújo and C. Brukner	2017/05/22	-	Quantum foundations
44	Complexity of the separability problem	Henry Yuen	16/01/2023		Quantum complexity theory
45	Single-prover interactive proofs for quantum computations	Henry Yuen	16/01/2023		Quantum complexity theory
46	Thermodynamic implementation of Gibbs-Preserving Maps	Philippe Faist	16/01/2023		Quantum thermodynamics
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