ICTP SAIFR
International Centre for Theoretical Physics
South American Institute for Fundamental Research

Minicourse on Introduction to Quantum Computation and Simulability (Oct. 15-19, 2018) - Place: IFT-UNESP-3rd Floor - Room 3

	Monday, Oct. 15	Tuesday, Oct. 16	Wednesday, Oct. 17	Thurday, Oct. 18	Friday, Oct. 19
09:30 - 10:30	Registration				
10:30 - 12:00	**Lecture 1 (Daniel Brod)** - General overview of the field: Historical timeline of quantum computing. The postulates of quantum mechanics. Information-theoretic-flavored consequences of postulates: entanglement, super-dense coding, quantum teleportation and no-cloning.	**Lecture 4 (Daniel Brod)** - Introduction to computational complexity theory (I): Decision problems. P vs. NP. Reductions and NP-hardness. BPP and BQP.	**Lecture 7 (Daniel Brod)** - Introduction to computational complexity theory (II): Complexity-theoretic conjectures and separations between complexity classes. The polynomial hierarchy. PostBPP, postBQP and #P. The postselection argument for quantum supremacy	**Lecture 10 (Ernesto Galvão)** - Non-universal, but hard-to-simulate (intermediate) models of quantum computation. Notions of quantum simulation (weak versus strong simulations), adaptiveness. Revisiting Clifford circuits.	**Lecture 13 (Daniel Brod) -** The race for quantum supremacy (II): Experimental considerations. Linear-optical experiments. Noisy Boson-Samplers and random quantum circuits.
12:00 - 14:00	**LUNCH**				
14:00 - 15:30	**Lecture 2 (Ernesto Galvão)** - Quantum algorithms and circuits: Example of a simple quantum algorithm (e.g. Deutsch-Jozsa algorithm), universality and universal set of gates (Solovay-Kitaev theorem). Pauli group, Clifford circuits, IQP circuits, and other simple circuits.	**Lecture 5 (Ernesto Galvão)** - Measurement-based quantum computing (MBQC) (I): Introduction to Bell non-locality. Graph states and stabilizer formalism. 1-bit teleportation as a MBQC primitive. Universality constructions, adaptiveness.	**Lecture 8 (Ernesto Galvão)** - Measurement-based quantum computing (II): Time-ordering, computational depth. How to implement Clifford and IQP circuits in the measurement-based approach. Contextuality and non-locality as resources for MBQC. Applications: blind quantum computation (and other protocols).	**Lecture 11 (Daniel Brod)** - The race for quantum supremacy (I): Boson-Sampling and random quantum circuits (Google's approach).	**Lecture 14 (Leandro Aolita)** - Validating many-body quantum technologies (I). State learning: quantum-state tomography. State verification: direct fidelity estimation (Chernoff bounds and importance sampling) and fidelity witnesses. Verification of quantum simulations example: Boson-Sampling.
15:30 - 16:00	**COFFEE BREAK**				
16:00 - 17:30	**Lecture 3 (Leandro Aolita)** - Physical states and the illusion of Hilbert space: Exponentially many classical states versus doubly exponentially many quantum ones. Definition of physical states (local Hamiltonian dynamics). All classical states are physical. All physical states can be prepared efficiently on a universal quantum computer. Counting the number of physical states (epsilon-nets): the vast majority of states in Hilbert space are non-physical. Computational complexity as a new fundamental physical axiom?	**Lecture 6 (Leandro Aolita)** - The "physical corner" of Hilbert space (I) - Matrix product states (MPS): Definition of MPSs. Tensor-network graphical notation. Properties: Poly-many parameters, exponential decay of correlations, entanglement area law, local gapped parent Hamiltonians, etc. Canonical decomposition of MPSs and the efficient classical simulation of states with low long-range entanglement (successive Schmidt decomposition). Essentials about higher spatial-dimensional generalizations: projected entangled pairs (PEPS).	**Lecture 9 (Leandro Aolita)** - The "physical corner" of Hilbert space (II) - Neural-network states: Restricted Boltzmann machines (RBMs). Unsupervised machine learning notions. Quantum RBM states as non-local state Ansatz. Connection with tensor-networks: quantum RBM states can more efficiently describe long-range entanglement (volume law). Deep quantum RBMs can efficiently describe universal quantum computations.	**Lecture 12 (Ernesto Galvão)** - Sampling problems. Rejection sampling, other approaches to simulation. IQP circuits, DQC-1 model.	**Lecture 15 (Leandro Aolita)** - Validating many-body quantum technologies (II). Verification of universal quantum computations: Delegated and verifiable quantum computing. Interactive-proof schemes versus measurement-only schemes.