Andreas Albrecht: The arrow of time in cosmology, cosmic inflation and the emergence of classicality

I review well established ideas about the connection between cosmology and our observed thermodynamic arrow time, and update them with my own perspective on how cosmic inflation theory fits in this picture. I then discuss some of my current work the emergence of classicality, and how it relates to the above topics.

Andreas Albrecht II: Inflation theories

Charlie Bennett: Occam's razor, Boltzmann's brain and Wigner's friend: reconciling reversible dynamics with human experience

In a multipartite quantum system with local interactions, disequilibrium enables classicality (redundant correlations among parts of the system in a preferred basis), complexity (classical states containing internal evidence of a nontrivial causal history), and even enables complex systems to evade the Boltzmann brain problem, drawing valid inferences about the universe they inhabit. It is not clear how to retain these desirable features in cosmologies that eventually equilibrate to a positive temperature. I review some notions, such as "logical depth", that I have found helpful in formulating these questions.

Adam Brown: Complexity, Spacetime, and Quantum Mechanics

I will discuss a number of adventurous ideas, from what computational complexity can tell us about black holes and then emergence of spacetime to how chaos emerges in the classical limit of quantum theories.

Elizabeth Crosson: Thermal stability in universal adiabatic computation

Adiabatic quantum computation (AQC) is a method for performing universal quantum computation in the ground state of a slowly evolving local Hamiltonian, and in an ideal setting AQC is known to capture all of the computational power of the quantum circuit model. However, despite having an inherent robustness to noise as a result of the adiabatic theorem and the spectral gap of the Hamiltonian, it remains a longstanding theoretical challenge to show that fault-tolerant AQC can in principle be performed below some fixed noise threshold. There are many aspects to this challenge, including the difficulty of adapting known ideas from circuit model fault-tolerance as well as the need to develop an error model that is appropriately tailored for open system AQC. In this talk I will introduce a scheme for combining Feynman-Kitaev history state Hamiltonians with topological quantum error correction, in order to show that universal quantum computation can be encoded not only in the ground state but also in the finite temperature metastable Gibbs state of a local Hamiltonian. Using only local interactions with bounded strength and a polynomial overhead in the number of qubits, the scheme is designed to serve as a proof of principle that universal AQC can be performed at non-zero temperature, and also to further our understanding of the complexity of highly entangled thermal quantum systems.

Peter Gacs: Tutorial on description complexity and computational complexity

I will outline the main results and concepts on Kolmogorov complexity (better called description complexity or algorithmic entropy) and computational complexity (better called computation cost). The directions in which this tutorial will expand more will depend on the interests of the audience.

Michal Horodecki: Do black holes create polyamory?

Of course not, but if one believes that information cannot be destroyed in a theory of quantum gravity, then we run into apparent contradictions with quantum theory when we consider evaporating black holes. Namely that the no-cloning theorem or the principle of entanglement monogamy is violated. Here, we show that neither violation need hold, since, in arguing that black holes lead to cloning or non-monogamy, one needs to assume a tensor product structure between two points in space-time that could instead be viewed as causally connected. In the latter case, one is violating the semi-classical causal structure of space, which is a strictly weaker implication than cloning or non-monogamy. We show that the lack of monogamy that can emerge in evaporating space times is one that is allowed in quantum mechanics, and is very naturally related to a lack of monogamy of correlations of outputs of measurements performed at subsequent instances of time of a single system. A particular example of this is the Horowitz-Maldacena proposal, and we argue that it needn't lead to cloning or violations of entanglement monogamy. For measurements on systems which appear to be leaving a black hole, we introduce the notion of the temporal product, and argue that it is just as natural a choice for measurements as the tensor product. For black holes, the tensor and temporal products have the same measurement statistics, but result in different type of non-monogamy of correlations, with the former being forbidden in quantum theory while the latter is allowed. In the case of the AMPS firewall experiment we find that the entanglement structure is modified, and one must have entanglement between the infalling Hawking partners and early time outgoing Hawking radiation which surprisingly tame violation of entanglement monogamy.

Adrian Kent: Quantum Summoning in Space-Time

Summoning is an intrinsically relativistic quantum task, in which a party has to produce a quantum state at a space-time location that depends on data they receive at other points in space-time. One can think of it as characterising how quantum information can be distributed over space-time. In this tutorial review, I will introduce and motivate the task, and describe some recent (im)possibility theorems for summoning tasks.

Pawel Mazurek: Stabilizer description of Absolutely Maximally Entangled states and associated quantum error correction codes

Absolutely Maximally Entangled (AME) states, defined for N systems of dimension D each, are states whose reduction to any number of parties not bigger that N/2 is maximally mixed. Due to a correspondence between isometric maps and AME states, they serve as building blocks in a holographic toy model for AdS/CFT isomorphism [F. Pastawski, B. Joshida, D. Harlow, J. Preskill, JHEP 06 (2015) 149].

After presenting AME constructions for selected N and D, and characterization of uses of AME in quantum secret sharing schemes, we will focus on stabilizer language description of the mapping that they provide. Namely, we will show how generators of every stabilizer AME state determine logical operators and generators of a codespace of emerging quantum error correcting codes, for arbitrary N, and D being a power of a prime number. We show that spread of quantum information caused by entanglement swapping in networks defined by AME states is equivalent to concatenation of the corresponding quantum error correction codes.

Jonathan Oppenheim: Thermodynamics as an information theory and application to holographic CFTs

Tutorial on quantum thermodynamics for open and closed systems, with application to holographic CFTs.

Jonathan Oppenheim and Adam Brown: Black holes and firewalls

David Poulin: Self-correction in Wegner's 3D Ising lattice gauge theory

A self-correcting memory is a passive device that stores information robustly despite fluctuation of its external parameters like temperature, magnetic field, pressure, etc. It is well established that a memory can be stabilized locally using fault-tolerant cellular automaton error correction, but such a dynamical process consumes power. In contrast, a self-correcting memory is stabilized thermodynamically and does not require external power. In particular, we are interested in self-correcting memories that arise from systems composed of localized, bounded degrees of freedom interacting locally (e.g. Ising spins).

The prospect of quantum technologies has generated a growing interest for robust quantum memories, and the possibility of conceiving a self-correcting quantum memory in three spatial dimensions or less is being debated. Here, we take a step back and consider the simpler task of conceiving a classical self-correcting memory in three dimensions. We present a simple and well known lattice model and argue that it could serve as a self-correcting memory.

Renato Renner: Quantum theory cannot consistently describe the use of itself

Quantum mechanics may be used to describe systems that contain agents who themselves employ quantum mechanics to make predictions. In this talk I will describe a thought experiment to test the consistency of such a recursive use of the theory. The experiment consists of an agent who, upon observing the outcome of a measurement, must conclude that another agent has predicted with certainty a different outcome for this measurement. The agents' conclusions, although all derived within quantum mechanics, are thus inconsistent.

Jess Riedel: Wavefunctions branches as a foundation for probabilistic reasoning

When the wavefunction of a large quantum system unitarily evolves away from a low-entropy initial state, there is strong circumstantial evidence it develops "branches": a decomposition into orthogonal components that is indistinguishable from the corresponding incoherent mixture with feasible observations. Is this decomposition unique? Must the number of branches increase with time? These questions are hard to answer because there is no formal definition of branches, and most intuition is based on toy models with arbitrarily preferred degrees of freedom. Understanding branches is important to the foundations of quantum mechanics because the operational Copenhagen approach fails if branches recombine or destabalize, perhaps in the early universe, exotic materials, the distant future, or thermalizing systems. It is also crucial for anthropic reasoning in universes with many observers because the set of branches forms the fundamental (maximally fine-grained) sample space for classical probability distributions; probabilities computed with respect to incompatible sample spaces cannot be consistently combined.

Henry Stoltenberg: Decoherence in Fluctuations out of Equilibrium

A key part of the Boltzmann brain problem in a cosmological model consists of the relative likelihoods of a very low entropy past compared to a brief fluctuation from higher entropy state. To give a description consistent with our experiences, we need to not just consider the history of entropy change and the arrow of time but also the emergence of classical phenomena. I will discuss ongoing work in understanding decoherence in a system fluctuating out of equilibrium with a small toy model of qubits.