# AGPhil 3: Complex and Open Systems

Time: Tuesday 9:30–13:00 Location: H 2033

**Invited Talk** AGPhil 3.1 Tue 9:30 H 2033
**Open Quantum Systems: Where is the system and where is the reservoir ?** — •Joachim Ankerhold — Institut für Theoretische Physik, Universität Ulm

The conventional treatment of open quantum systems, as they appear e.g. in condensed phase structures, starts from a separation between a subunit, which contains a smaller number of interesting degrees of freedom and is termed the 'system', and a much larger subunit, termed the bath or 'reservoir', which in many cases carries a macroscopically large number of degrees of freedom. These so-called 'system+reservoir' models have been very successfully applied in various fields in physics to describe decoherence and relaxation processes. Accordingly, one considers the reduced density operator of the system and derives for the time evolution e.g. approximate reduced equations of motion or formally exact expressions in terms of path integrals. Beyond the regime of very weak system-reservoir interaction (typical for quantum optical systems), however, an understanding of reduced system properties becomes often a non-trivial matter. In this talk, I will discuss some examples to shed light on the limitations of our naive picture, namely, the failure of classical concepts for certain observables, the existence of coherent reduced dynamics only due to a reservoir, and the appearance of a classical reduced system in the deep quantum domain.

**Invited Talk** AGPhil 3.2 Tue 10:15 H 2033
**On the relation between the second law of thermodynamics, classical mechanics, and quantum mechanics** — •Barbara Drossel — Institut für Festkörperphysik, TU Darmstadt

In textbooks on statistical mechanics, on finds often arguments based on classical mechanics, phase space and ergodicity in order to justify the second law of thermodynamics. However, the basic equations of motion of classical mechanics are deterministic and reversible, while the second law of thermodynamics is irreversible and not deterministic, because it states that a system forgets its past when approaching equilibrium. I will argue that all "derivations" of the second law of thermodynamics from classical mechanics include additional assumptions that are not part of classical mechanics. The same holds for Boltzmanns H-theorem. Furthermore, I will argue that the coarse-graining of phase-space that is used when deriving the second law cannot be viewed as an expression of our ignorance of the details of the microscopic state of the system, but reflects the fact that the state of a system is fully specified by using only a finite number of bits, as implied by the concept of entropy, which is related to the number of different microstates that a closed system can have. While quantum mechanics, as described by the Schroedinger equation, puts this latter statement on a firm ground, it cannot explain the irreversibility and stochasticity inherent in the second law.

**Coffee break**

AGPhil 3.3 Tue 11:30 H 2033
**What can we learn from a real-time analysis of nonequilibrium quantum many-body systems?** — •Michael Moeckel — Max-Planck-Institute for Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching

The interplay of nonequilibrium initial conditions and quantum many-body correlations currently receives new attention in condensed matter theory. Strong quantum many-body correlations can be imposed either by (many-) particle interactions or by the quantum statistics of the particles itself. Nonequilibrium conditions allow to initialize a quantum many-body system in an excited state. Then, its subsequent dynamics is determined by a unitary evolution in the Hilbert space.

In a large class of quantum dynamics experiments, e.g. in pump-probe laser spectroscopy of complex materials, the resulting trajectory in Hilbert space is assessed: From the temporal evolution of expectation values of particular observables researchers conclude on the properties of the (static) complex quantum system. The reasoning behind this approach is commonly based on an analogous understanding of energy-time uncertainty as it is motivated by Fermi's Golden Rule: Large energy transitions occur already at short times, while small energy details become observable only on large time scales of the dynamics.

In my presentation I will briefly review current experimental and theoretical work, analyze necessary prerequisites for gaining substantial information from such setups and address the question to which extent intrinsic quantum correlations can be made visible by "mapping them into the time domain".

AGPhil 3.4 Tue 12:00 H 2033
**Scientific Models of Living Phenomena: An Epistemic Overview of Condensed Matter Physics of Complex Biological Systems.** — •Daniele Macuglia — Morris Fishbein Center and The Committee on the Conceptual and Historical Studies of Science, The University of Chicago, 1126 E. 59th St., Chicago, IL 60637, USA.

This essay focuses on the legitimacy of studying complex biological systems by means of modeling strategies typically employed by condensed matter physicists. Some of the most important examples of complex systems do indeed belong to the biological sciences and include living phenomena such as cells, ecosystems and neural networks. These systems are ultimately composed of fundamental particles that interact by means of fundamental physical laws and it is legitimate to think of a level at which the physical and biological descriptions might meet. Yet this view is affected by a remarkable epistemic impasse that calls closer attention to the role of modeling and idealization at the physics-biology interface. Whereas condensed matter physics proceeds by modeling strategies that due to their high level of idealization are often deemed unsuitable for biological investigations, biological scientists do normally focus on a set of very narrow and context-dependent issues for which modeling is often problematic. By analyzing specific examples taken from the literature in both philosophy and the hard sciences, this paper shows what kind of conceptual and methodological difficulties might arise when studying complex biological systems by means of condensed matter physical approaches. It also describes alternative theoretical frameworks to possibly overcome them.

AGPhil 3.5 Tue 12:30 H 2033
**Thermodynamics excludes a physical origin of life in open systems** — •Thomas Seiler — Stuttgart

Entropy determines that all processes in nature proceed from less probable distributions to more probable ones. An objection to this premise is that the constraints of thermodynamics are not valid for open systems - in which biological structures exist.

However, the limits of open systems can be illustrated by the example of machines that reduce entropy such as refrigerators. They transfer heat from a cold volume to a warm volume. This highly improbable phenomenon can only happen because a complex cooling mechanism exists already. A further example of order increasing in open systems is the formation of crystals, e.g. snow-flakes. When heat is removed, a phase-transition leads to the appearance of macroscopic regularity which reflects a molecular regularity.

The emergence of life does not belong to such processes since these are the physical ways in which a hidden pre-existing order is made visible. No really new order or information is generated in open systems. Either the information content was already present in a complex machine or it already existed in the symmetry of the underlying molecules or in the feedback mechanism of a dissipative structure.

On the other hand, there is no physical arrangement containing the information needed to built up life from non-life or complex creatures from simpler creatures. Their physical emergence is excluded by the second law of thermodynamics because they do not belong to those pre-programmed structures which open systems can form.