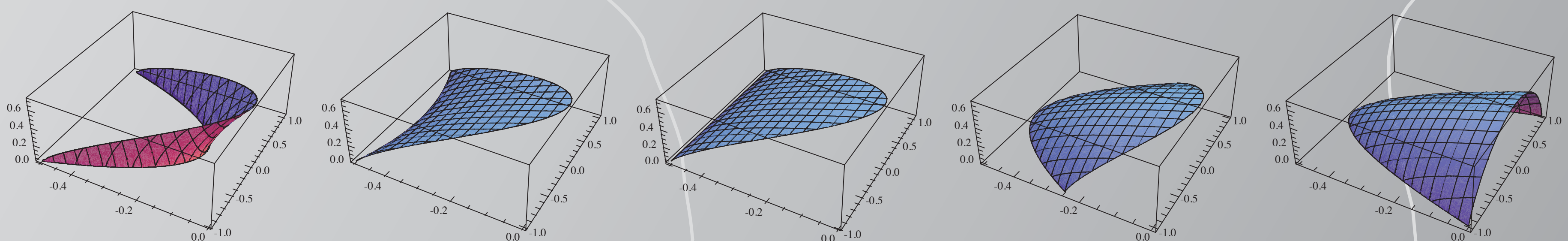


Current research programmes include the following:

## Statistical physics of phase transitions

Cooperative effects can lead to remarkable properties of many-body systems, and the occurrence of a phase transition is a prime example of such an effect. At a phase transition, the macroscopic properties of a many-particle system change abruptly under variation of a control parameter. Statistical physics is the theoretical framework providing the microscopic foundations of thermodynamics, allowing, at least in principle, to compute thermodynamic functions from the Hamiltonian of the system. One aspect of our research in this field is the attempt to predict the absence or presence of phase transitions by studying the topology and geometry of the

high-dimensional energy landscape generated by the Hamiltonian. A second field of research is statistical physics in the microcanonical ensemble, i.e. for systems not coupled to a thermal reservoir. For long-range interacting systems, thermodynamical (and dynamical) behaviour of such systems can be remarkably different from that of standard short-range systems, leading to surprising physical phenomena like nonequivalence of statistical ensembles, negative specific heat, and others. Applications include quantum spin systems as realized experimentally by means of ultracold atoms or molecules in optical lattices.



Microcanonical entropy as a function of energy and magnetization for a long-range interacting quantum spin system, plotted for different coupling parameters. The nonconcave functions in the first two plots indicate nonequivalence of microcanonical and canonical ensembles.

For more information on these projects, contact Prof Michael Kastner at [kastner@sun.ac.za](mailto:kastner@sun.ac.za)

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