Ph.D. Project: Wigner function dynamics of spin systems

Discipline: Theoretical Physics
Advisor: Prof. Daniel Braun, Laboratoire de Physique Théorique, Université Toulouse Paul Sabatier
Email: braun@irsamc.ups-tlse.fr; http://www.lpt.ups-tlse.fr/danielbraun

The method of characteristics is a well-known procedure for solving a first-order differential equation. Applied to Liouville's equation for classical phase space density, the characteristics are the classical phase-space trajectories. Their knowledge leads to a huge reduction in computational complexity for classical N-particle systems compared to the direct propagation of the phase space density, as one needs to propagate only 6N coordinates instead of an exponentially large number of probabilities for phase space cells.

The objects that come closest to classical phase space densities in quantum mechanics are quasi-probability distributions such as the Wigner function. In principle it is possible to find deformed phase space trajectories which allow the propagation of the Wigner function. But the fact that the evolution equation of the Wigner function is in general of infinite order renders its solution through generalized phase space trajectories difficult. However, recently progress has been achieved in the nuclear physics community for finite dimensional spin-systems and Hamiltonians which are finite polynomials in the spin-components. In such cases, there can be a finite hierarchy of deformed phase space trajectories, and it has even been demonstrated that in certain cases spin-queezing or the creation of entanglement between different spins can be simulated with this method.

The aim of the Ph.D. thesis is to adapt this new method to interacting spin systems, and to thoroughly test its viability as a simulation tool.

The work will need strong analytical techniques, as well as strong programming skills. An initial training period in the form of a Master project ("stage M2") is possible, where the emphasis will be on the evolution of "quantumness" of simple spin systems [1-4].

This project is in the larger context of the scientific goals (**Quantum coherence and information)** of the Excelence Initiative NEXT selected by French Government (see http://www.lpt.ups-tlse.fr/spip.php?article764&lang=en for details).

[1] *Classicality of spin states*, O. Giraud, P. Braun, and D. Braun, Phys. Rev. A **78**, 042112 (2008); arXiv:0805.2592
[2] *Quantifying Quantumness and the Quest for Queens of Quantum*, Olivier Giraud, Petr A. Braun, Daniel Braun, New J. Phys. **12**, 063005 (2010), arXiv:1002.2158v1

[3] *Multiqubit symmetric states with high geometric entanglement*, J. Martin, O. Giraud, P.A. Braun, D. Braun, and T. Bastin, Phys. Rev. A **81**, 062347 (2010), arXiv:1003.0593v1
[4] *Parametrization of spin-1 classical states*, Olivier Giraud, Petr Braun, Daniel Braun, Phys. Rev. A **85**, 032101 (2012); arXiv:1110.0325

Information about the LPT: The Laboratoire de Physique Théorique (LPT) is an **AERES A⁺ rated lab** (A⁺ in all categories), jointly operated by the University Toulouse Paul Sabatier and CNRS. Between 2005 and 2009, its 21 permanent researchers produced about 300 articles in international per-reviewed journals, and contributed to more than 200 conferences (with 115 invited talks). It has scientific collaborations with more than 200 researchers from 130 different institutions in 22 different countries. LPT is to 85% financed through numerous contracts with the ANR (+4 in 2010), the European Union, as well as national and regional sources. It received the label "Laboratoire d'Excellence" (**LABEX**) in 2011, with the joint project NEXT, involving besides the LPT the laboratories LCAR, LCPQ, LCPNO, and the CEMES. Toulouse is after Paris the 2nd largest university-city in France, with about 100,000 students, and home of the Global Competitiveness Clusters Aerospace Valley, Canceropole, and Agrimip Innovation. The University Toulouse Paul Sabatier and CNRS Midi-Pyrenées operate a major part of France's leading labs in science and air and space engineering, such as the national high-field lab (LNCMP), national space center CNES, ONERA, and the Observatoire Midi-Pyrenées. Toulouse was recently selected for its "Initiative d'Excellence" (**IDEX**) by the French Government.