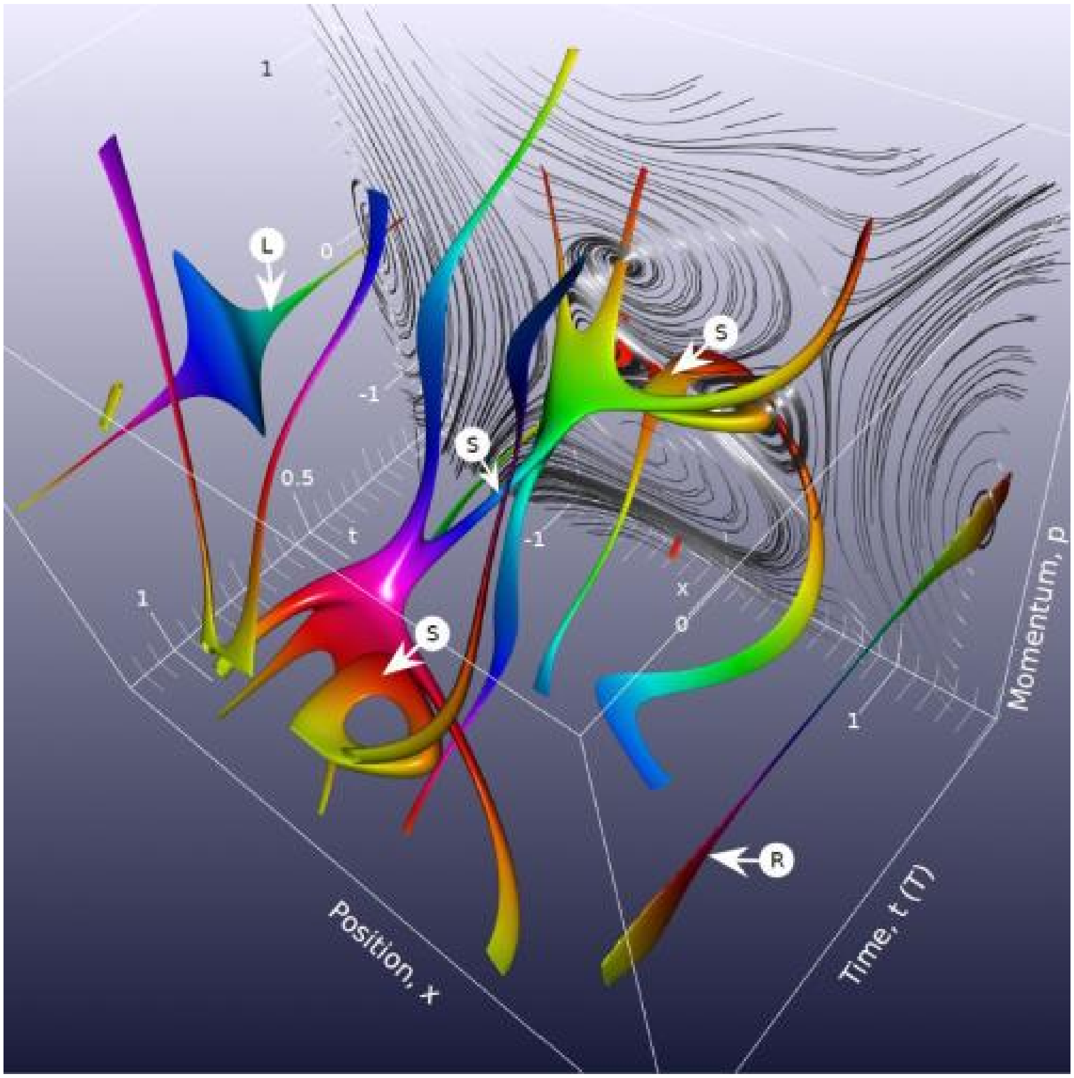
Revealing quantum flow

December 28 2012



Wigner flow's stagnation points' positions across phase space as a function of time. Credit: University of Hertfordshire

(Phys.org)—UK-based physicist Ole Steuernagel from the University of Hertfordshire, alongside Dimitris Kakofengitis and Georg Ritter, have found that a new powerful tool they call 'Wigner flow' is the quantum analogue of phase space flow.

Wigner flow provides information for quantum dynamics similar to that gleaned from phase space trajectories in classical physics. Wigner flow can be used for the visualisation of quantum dynamics. Additionally, and perhaps even more importantly, Wigner flow helps with the abstract analysis of quantum dynamics using topological methods.

Ole Steuernagel, from the University's Science and Technology Research Institute, said: "Because trajectories are missing in quantum phase space, physicists did not pay much attention to the associated flow-fields, although these do exist. Now, our research shows that quantum phase space flow is well worth studying."

In classical physics, phase space trajectories give rise to flow-fields representing the dynamics of the system along its trajectories; they yield additional insight into a system's behaviour.

Quantum theory phase space trajectories do not exist because Heisenberg's uncertainty principle does not allow for the formation of sharply defined trajectories. But quantum physicists have not given up entirely on phase space. The study of the next best thing, the movement of quantum physics' phase space-based probability distributions has actually boomed in recent years.

Sophisticated schemes for the reconstruction of the most prominent of these distributions, 'Wigner's function', from experimental data, have set quantum phase space analysis on a firm footing. Yet, since quantum trajectory studies cannot be carried out, some of the power of established classical methods is missing.

The researchers have been studying Wigner flow, which is based on the dynamics of Wigner's function, and have shown that it reveals new and surprising features of quantum phase space dynamics. It forms, for example, vortices that spin the 'wrong' way round and which appear in the 'wrong' part of phase space, when viewed from a classical physics standpoint. So, such dynamical patterns are manifestations of the quantum nature of the system.

On top of such new riches the team has established the existence of a conservation law that reveals a new type of topological order for quantum dynamics. As an application they have shown that Wigner flow sheds new light on quantum tunnelling, the fundamental process that governs the workings of electronic computer circuits, and also the decay of radio-nuclides.

More information: The paper "Wigner flow reveals topological order in quantum phase space dynamics" is published in *Physical Review Letters*.

Provided by University of Hertfordshire