

# Quantum mapmakers complete first voyage through spin liquid

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The existence of a quantum spin liquid state was proposed in the 1970s but scientists have so far only had limited information about it

(PhysOrg.com) -- Scientists from Oxford University have mapped a state of matter called 'quantum spin liquid', whose existence was proposed in the 1970s but which has only been observed recently.

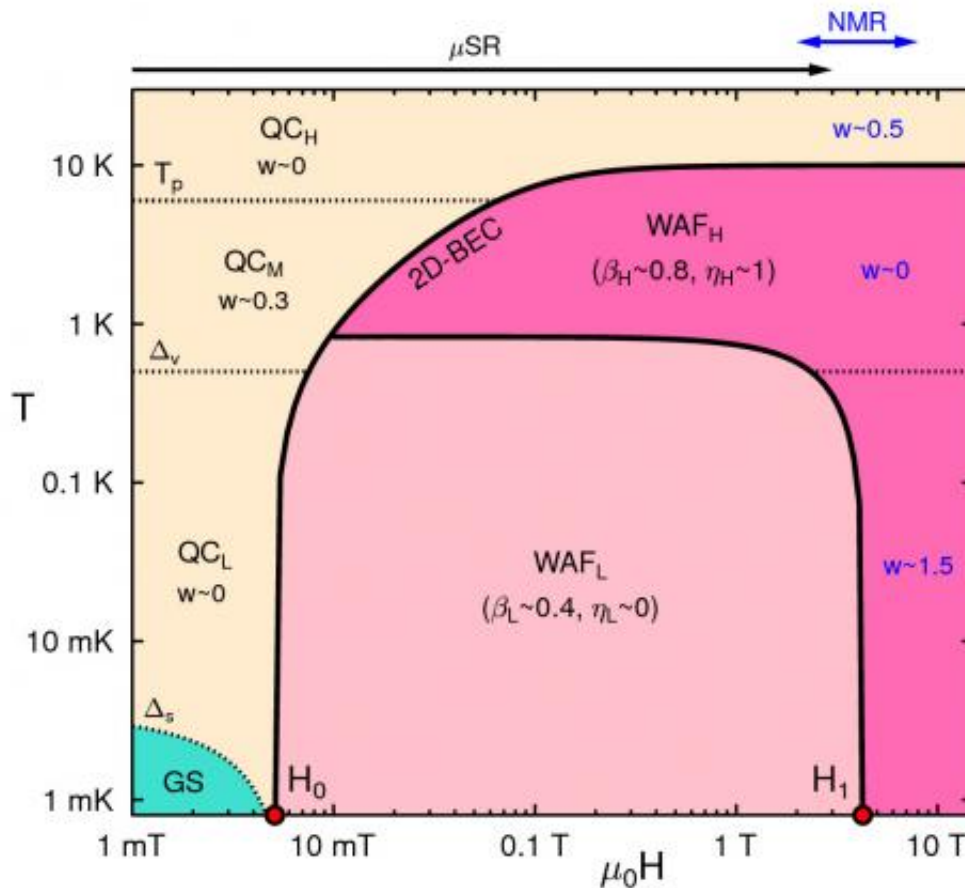
Until now there has been very limited information describing the [physical characteristics](#) of a quantum spin liquid state, but researchers from Oxford University's Department of Physics working with the Rutherford Appleton Laboratory have demonstrated the effect of temperature and magnetic field on this [state of matter](#). The results are published in a *Nature* paper.

The scientists mapped quantum spin liquid by implanting muons – sub-atomic particles which come from space but can also be produced in particle accelerators – into the spin liquid in order to measure the

microscopic magnetism. The experiments used the muon sources at ISIS in Oxfordshire and the Paul Scherrer Institute in Switzerland.

Professor Stephen Blundell of the Department of Physics explained: ‘Muons are an excellent tool for this kind of study because they are a very sensitive probe of weak magnetism and fluctuating states, just as we have now found in mapping the spin liquid state.’

The quantum spin liquid state that has been mapped by the team is found in 70 milligrams of tiny black crystals of the layered organic material  $\kappa$ -(BEDT-TTF)<sub>2</sub>Cu<sub>2</sub>(CN)<sub>3</sub> cooled to just a couple of hundredths of a degree above absolute zero. Despite it being extremely difficult to make the tiny plate-like crystals, the material is perfect for these experiments since it is on the border between being an insulator and a metal, a key requirement for the existence of the quantum spin liquid state.



The magnetic field - temperature phase diagram for  $k\text{-(BEDT-TTF)}_2\text{Cu}_2(\text{CN})_3$  obtained from muon spin rotation experiments and including previously reported NMR and thermodynamic measurements (Credit: Francis Pratt / ISIS / STFC)

Inside the material, magnetic atoms are arranged on triangular grids and behave as ‘quantum spins’. The interactions between these spins make them liquid-like, so they never freeze into one configuration. This behaviour is completely different to that of more familiar magnets found in everyday life in which, at some particular temperature, the quantum spins become locked into a particular configuration.

Dr Tom Lancaster of the Department of Physics said: ‘The organic material we have used is a really remarkable compound. This is because

its interactions seem perfectly tuned to achieve this spin [liquid state](#).'

Dr Francis Pratt of the Rutherford Appleton Laboratory said: 'Since the idea was proposed there have been over 800 papers published speculating on the properties of quantum spin liquids, but until now there has been very little experimental evidence to compare these ideas with.'

**More information:** "Magnetic and non-magnetic phases of a quantum spin-liquid" F L Pratt, P J Baker, S J Blundell, T Lancaster, S Ohira-Kawamura, C Baines, Y Shimizu, K Kanoda, I Watanabe and G Saito *Nature* 471, 612–616 (31 March 2011) , doi:10.1038/nature09910

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