The equivalent of a new quantum liquid?

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"Physicists usually study anyons when there are a few of them and they are far separated," Adrian Feiguin, a researcher at Microsoft Research Station Q at the University of California, Santa Barbara tells *PhysOrg.com*. "One of the questions we wanted to address was: What happens if you have many anyons close together?"

Feiguin is part of a team that seeks to answer that question in a piece titled "Interacting Anyons in Topological Quantum Liquids: The Golden Chain," published by *Physical Review Letters*.

Feiguin and his colleagues, Simon Trebst, Alexei Kitaev (also associated with the California Institute of Technology in Pasadena), Zhenghan Wang and Michael Freedman at Microsoft Research Station Q were joined by peers Andreas Ludwig from UC Santa Barbara and Matthias Troyer from the Eidgenössische Technische Hochschule Zürich in Switzerland. They believe that they have solved the first model system of interacting anyons of topological origin.

Anyons are exotic particles that exist in two-dimensional quantum liquids. In three dimensions, particles find themselves constrained tightly, and are restricted: they can only be fermions or bosons. With systems in two dimensions, however, quantum states range continuously between bosons and fermion, and give rise to anyonic quasi-particles. These quasi-particles are called anyons (term given by Frank Wilczek), and they are capable of having "any" phase when the particles interchange.

Feiguin explains that there are two main camps of anyons: Abelian and non-Abelian. “With anyons,” he says, “we can wrap one anyon around another to make a braid. With Abelian anyons, it doesn’t matter which order you wrap, say, a set of three anyons. But with non-Abelian anyons, the order does matter.” It is these non-Abelian anyons that Feiguin and his peers are working with, and these are the anyons that present possibilities for more efficient and practical quantum computing.

“Topological states with non-Abelian anyons describe a new phase of matter. When there are excitations in the topological quantum liquids, there are gaps between the excitations and the ground state,” Feiguin explains. “The topological origin and the gap protect the anyons from environmental decoherence.” The exciting thing about using anyons in quantum computation, he says, is the fact that the topological protection provided by the gap can make quantum information processing more robust, because it is insensitive to local noise.

So, what *does* happen when anyons come close together and begin interacting? The authors constructed and solved a model of a chain of interacting non-Abelian anyons to find out. They discovered that their anyons formed a new quantum liquid which is equivalent to a special type of quantum spin chain which is, in Feiguin’s words, “described by a classical model at the critical point.” But the story doesn’t end there. He says that the team is continuing its investigation because “there are many models of interacting anyons that you can build.”

Feiguin points out that experiments have yet to be done. “Right now this is just in the theory stage,” he says, “but there are efforts in the experimental direction. Progress is being made. The technology just isn’t quite there yet.” He also points out that while this anyon chain could point to a better model of quantum computing, it is not a computer model. “This is a way of understanding anyons and what happens when they interact.”