Scientists make counterintuitive observations in hybrid quantum systems

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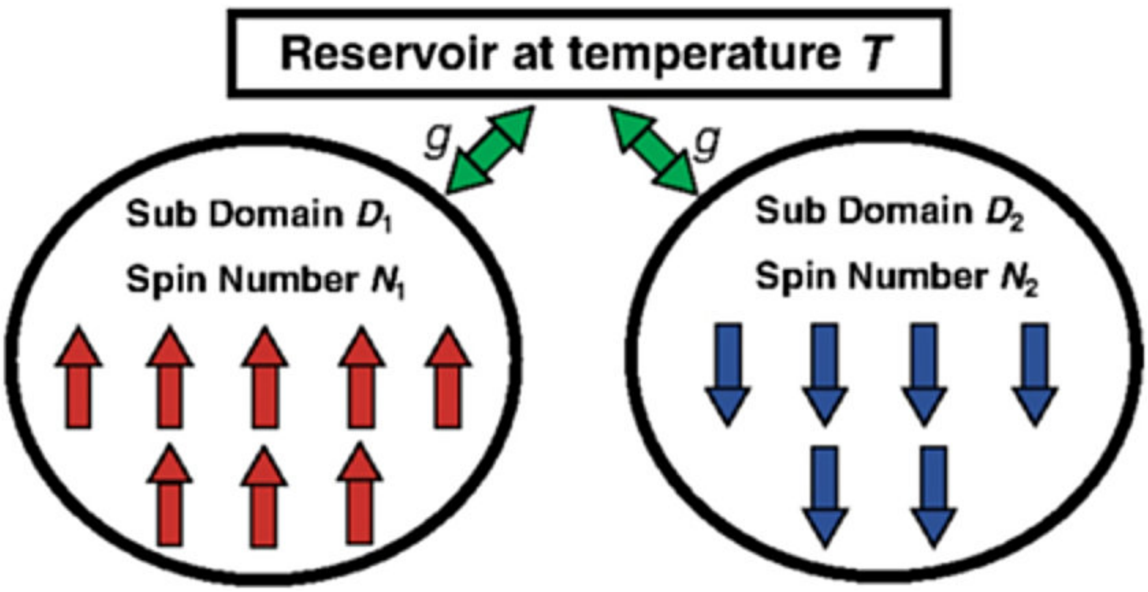

The image above shows the counter-intuitive behavior of a double spin subdomain system coupled to a single reservoir. Credit: *Physical Review Letters*

A team of researchers from the National Institute of Informatics (NII) in Tokyo and NTT Basic Research Laboratories (BRL, Nippon Telegraph and Telephone Corporation) in Japan have published an explanation of how quantum systems may be able to heat up by cooling down. Their paper appeared recently in *Physical Review Letters*.

"Heating by cooling sounds rather counterintuitive, but if the system has symmetries, decay could mean many things," says Kae Nemoto, a professor in the Principles of Informatics Research Division at NII which is part of the Inter-University Research Institute Corporation Research Organization of Information and Systems (ROIS).

Nemoto and her team examined a double sub-domain system coupled to a single constant temperature reservoir. Each sub-domain contained multiple spins—a form of angular momentum carried by elementary particles such as electrons and nuclei. The researchers considered the situation in which the spins within each sub-domain are aligned with respect to each other, but the sub-domains themselves are oppositely aligned (for instance all up in one and all down in the second). This creates a certain symmetry in the system.

As time progresses, the components of the subdomain decay in a process called relaxation.

"Usually, we expect both domains to decay to the reservoir temperature; however, when the two domains coupled with a reservoir maintain a certain symmetry, the decay process can apparently heat the smaller domain up, even beyond the high temperature limit," Nemoto said.

The researchers can control the domains to some extent, while the reservoir is actually a much larger, unknown entity that can be characterized by macroscopic parameters such as temperature. They use this system to predict new dynamics and explore the multiple levels of thermalization, such as the decay in one subdomain exciting the components of another subdomain.

"Cooling processes can now heat a subsystem up," Nemoto said. "Our case is mathematically rather simple, but it indicates the rich dynamics caused by quantum dissipative processes."

Since not all systems have symmetry, Nemoto and her team would like to further examine the complex interactions between the subdomains and reservoir. "We will investigate more of these counter-intuitive decay dynamics and show when and how exactly we can see these dynamics," Nemoto said, noting that these effects could be used to design and control quantum systems.

More information: Yusuke Hama et al, Relaxation to Negative Temperatures in Double Domain Systems, *Physical Review Letters* (2018). DOI: 10.1103/PhysRevLett.120.060403

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