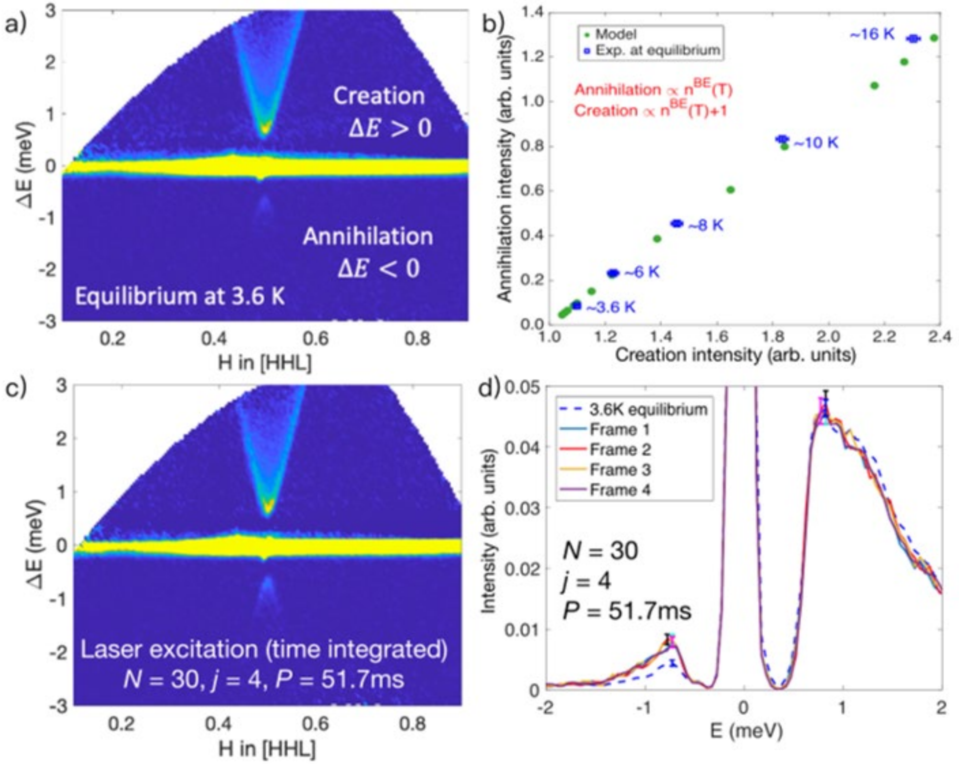
Violation of Detailed Balance in Nonequilibrium Magnons Observed by Laser-Pump Neutron Scattering



Violation of detailed balance measured by laser-pump neutron scattering. Laser excitation selectively enhances magnon annihilation intensity while leaving magnon creation unchanged, providing direct evidence for a nonequilibrium steady state in a driven quantum magnet.

C. Hua, B. L. Winn, C. Sarkis, G. Sala, T. Egami and D. A. Tennant. *Violation of detailed balance in non-equilibrium magnons observed by inelastic neutron scattering,* **Nature Communications 17**, 3535 (2026).

Scientific Achievement

Developed the first laser-pump neutron-scattering method capable of directly observing long-lived nonequilibrium magnons through the violation of detailed in a quantum magnet.

Significance and Impact

Introduces an entirely new experimental capability for studying driven quantum matter, enabling momentum-resolved measurements of nonequilibrium quantum dynamics and dissipative processes.

Research Details

- Combined synchronized nanosecond laser excitation with inelastic neutron scattering to create and probe nonequilibrium magnons.
- Demonstrated direct violation of detailed balance between magnon creation and annihilation processes in a two-dimensional Heisenberg antiferromagnet.
- Discovered long-lived nonequilibrium steady-state magnons sustained by slow magnon-phonon relaxation.
- Established a theoretical framework connecting detailed balance violation to quantum transport and out-of-time-ordered correlations in open quantum systems.

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- **NQISRC Intellectual Role:** *[Lead]*
  - The Quantum Science Center supported the theoretical development connecting nonequilibrium neutron scattering measurements to quantum transport and open quantum system dynamics, providing the conceptual framework that interprets the observed violation of detailed balance
- **NQISRC Funding Role:** *[Minority]*
- **Explanation of Funding Institution Contributions:**
  - The DOE Quantum Science Center supported the theoretical description of nonequilibrium magnons and the quantum transport framework used to interpret the neutron scattering measurements. DOE Basic Energy Sciences supported the experimental laser-neutron capability, neutron measurements, simulations, and data analysis. Together these complementary investments established a new platform for studying nonequilibrium quantum materials.