

# One-to-one quantum simulation of the low-dimensional frustrated quantum magnet TmMgGaO<sub>4</sub> with 256 qubits

Sergi Julià-Farré

L. Leclerc, G. S. Freitas, G. Villaret, [...], M. Lee, C. Dalyac, A. Browaeys, and A. Dauphin.

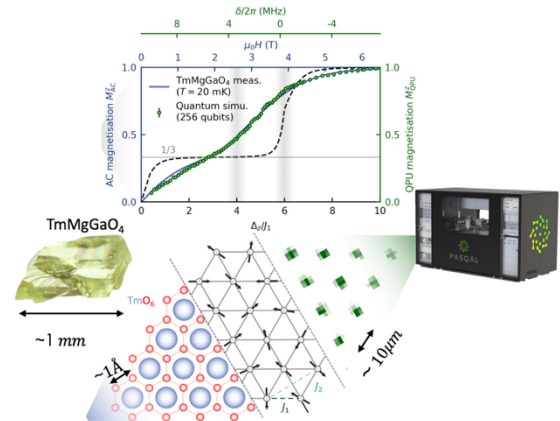
PASQAL SAS, 24 Emile Baudot, Palaiseau, France

[sergi.julia-farre@pasqal.com](mailto:sergi.julia-farre@pasqal.com)

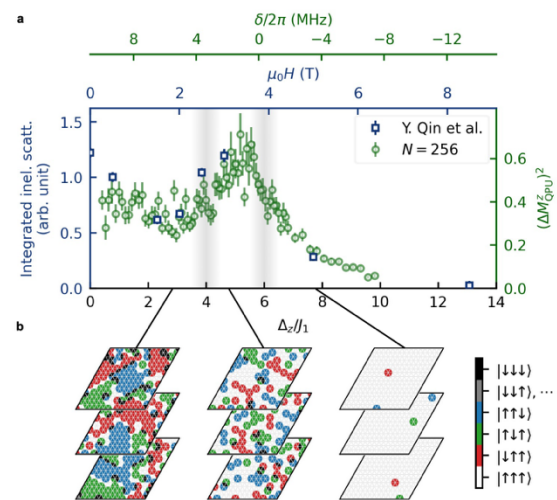
Rydberg-atom quantum processing units (QPUs) operated in analogue mode provide a versatile platform for simulating low-dimensional quantum materials, particularly in large-scale regimes where entanglement limits classical numerical methods. To date, however, analogue simulators have largely focused on universal Hamiltonians rather than material-specific comparisons.

In this talk [1], we report on the use of a Rydberg-atom QPU to study the bulk-layered frustrated quantum magnet TmMgGaO<sub>4</sub> [2]. Magnetisation measurements obtained from the quantum simulator show excellent agreement with new measurements in a magnetic laboratory facility (Fig. 1), realizing the original goal of quantum simulators [3]. Based on this quantitative correspondence, we investigate the same antiferromagnetic phase transition on both platforms, despite the magnetic energy scales differing by five orders of magnitude. We further probe the role of quantum fluctuations via snapshot analysis, connecting our results to integrated inelastic neutron scattering (INE) data [4] (Fig. 2). Finally, we access, with the simulator, non-equilibrium dynamics on picosecond material timescales, including frequency response and thermalisation of observables.

- [1] L. Leclerc, S. Julià-Farré, et al. (to appear on the arxiv).
- [2] Li et al., PRX 1 (2020) 011007
- [3] Feynman, IJTP 6 (1982) 467
- [4] Qin et al., Sci. Bull. 1 (2022) 38



**Figure 1:** (top) Low-temperature TmMgGaO<sub>4</sub> magnetization as a function of the longitudinal magnetic field. Sample measurement shows excellent agreement with QPU ground-state simulation. Dashed line corresponds to the quasi-classical limit of the model, highlighting the nontrivial impact of quantum fluctuations. (bottom) Sketch of the QPU analogue simulation of the microscopic model of the sample.



**Figure 2:** Connection between QPU magnetic fluctuations and INE data from [3]. Individual QPU snapshots provide a microscopic explanation of the material behaviour.