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Programmable XY-type interactions on trapped ions: parallel Ising-type interactions mediated via the same motional-modes

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The Mølmer–Sørensen (MS) scheme has facilitated Quantum Simulation of Ising-type ($J_{ij}^x \sigma_x^i \sigma_x^j$) interacting-spin-systems, leveraging collective motional-modes of ions. However, only a few experiments explored more complex models, like XY models that can simulate novel many-body systems such as superfluids and spin-liquids. Existing protocols used modified MS schemes that are only valid stroboscopically, restricted in their programmability, and break down for long times. We propose and experimentally demonstrate that the application of two spin dependent forces, applied at frequencies that are close but non-degenerate, can mediate parallel Ising interactions required for XY-type models ($J_{ij}^x \sigma_x^i \sigma_x^j + J_{ij}^y \sigma_y^i \sigma_y^j$) with independent control over the J_{ij}^x and J_{ij}^y terms [1]. This scheme inherits the programmability and scalability of MS Ising interactions and can be readily implemented in existing setups.

[1] N. Kotibhaskar, C.-Y. Shih, S. Motlakunta, A. Vogliano, L. Hahn, Y.-T Chen, and R. Islam Programmable XY-type couplings through parallel spin-dependent forces on the same
trapped ion motional modes, (2023), arXiv:2307.04922

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