SU(N) symmetry with ultracold molecules

Bijit Mukherjee[1,†], **Jeremy M. Hutson**[2], **and Kaden R. A. Hazzard**[3,4]

[1]Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warszawa, Poland
[2]Joint Quantum Centre (JQC) Durham-Newcastle, Department of Chemistry, Durham University, South Road, Durham DH1 3LE, United Kingdom
[3]Department of Physics and Astronomy, Rice University, Houston, TX 77005, United States of America
[4]Smalley-Curl Institute, Rice University, Houston, TX 77005, United States of America
[†]bijit.mukherjee@fuw.edu.pl

Quantum systems with SU(N) symmetry offer fascinating settings for quantum many-body physics [1, 2]. They have been studied for the insights they provide into complex materials and their ability to stabilize exotic ground states. Ultracold alkaline-earth-like atoms (Sr and Yb) were predicted to exhibit SU(N) symmetry for N up to 10, where $N = 2I + 1$ and I is their nuclear spin [3]. Subsequent experiments have revealed rich many-body physics. However, atomic systems realize this symmetry only for fermions with repulsive interactions. In this poster, I will show that ultracold molecules shielded from destructive collisions with static electric fields or microwaves are potential candidates for exhibiting SU(N) symmetry [4]. This is because the deviations of the s-wave scattering length for collisions of shielded molecules in different spin states from the spin-free value are very small, on the order of few percent. Experimentally accessible molecules offer large N for both bosonic (up to $N = 36$) and fermionic (up to $N = 72$) systems, with both attractive and repulsive interactions. We have carried out coupled-channel scattering calculations on pairs of CaF, NaK, NaRb, and NaCs molecules including their spin structure with external static electric fields [5]. We show that all the molecules under optimal shielding conditions have the properties required for SU(N) symmetry: the collisions are principally elastic, and the scattering lengths depend only weakly on the spin states of the molecules. We also calculated the rates of spin-changing inelastic collisions and found they are non-negligible for specific spin states affecting the overall molecular lifetime. However they are sufficiently low that the SU(N) symmetry is preserved. Additionally, we have developed a 1D semiclassical model of the spin dependence that satisfactorily explains the results obtained from the computationally demanding coupled-channel calculations [4, 5].

We predict that molecules with an SU(N) symmetry will offer vast new possibilities for quantum simulation and many-body physics. The high spin symmetry will enhance quantum fluctuations and stabilize exotic states of matter such as chiral spin liquids. It will also allow the study of dynamical phenonema such as prethermalization in nonequilibrium quantum systems.

References

[1] C. Wu, J.-P. Hu and S.-C. Zhang *Phys. Rev. Lett.* **91**, 186402 (2003).

[2] A. V. Gorshkov *et al. Nat. Phys.* **6**, 289 (2010).

[3] M. Cazalilla and A. M. Rey *Rep. Prog. Phys.* **77**, 124401 (2014).

[4] B. Mukherjee, J. M. Hutson and K. R. A. Hazzard *New J. Phys.* **27**, 013013 (2025).

[5] B. Mukherjee and J. M. Hutson *Phys. Rev. Res.* **7**, 013099 (2025).