Stochastic atom number dynamics in ultracold mixtures

Rohit Prasad Bhatt, Lilo Höcker, Jan Kilinc, Fred Jendrzejewski
Universität Heidelberg, Kirchhoff-Institut für Physik,
Im Neuenheimer Feld 227, 69120 Heidelberg, Germany
rohit.prasad@kip.uni-heidelberg.de

UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386

KIRCHHOFF-INSTITUT FÜR PHYSIK

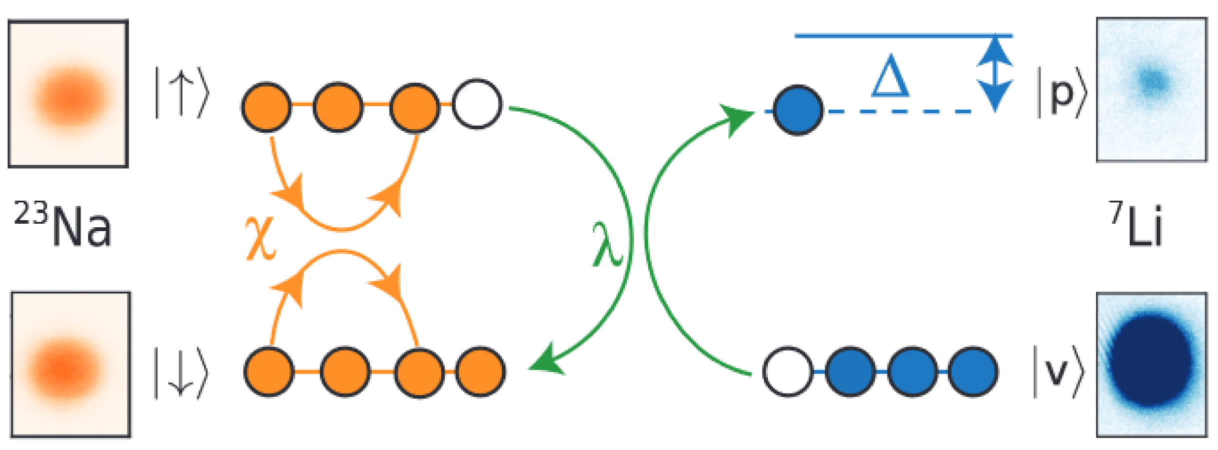
SynQS

Why quantum mixtures?

Dynamical gauge fields[1]

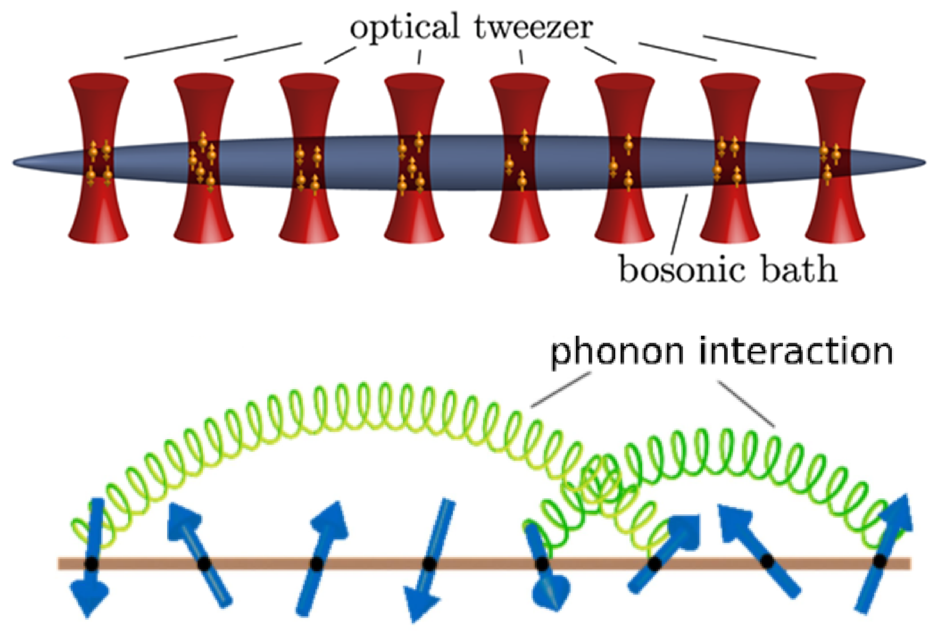
- Ingredients : gauge field (Na) and matter field (Li).
- Local U(1) symmetric coupling via spin changing collisions.

$$\hat{H}_{mixture} = \chi \hat{L}_z^2 + \frac{\Delta}{2}\left(\hat{b}_p^\dagger \hat{b}_p - \hat{b}_v^\dagger \hat{b}_v\right) + \lambda\left(\hat{b}_p^\dagger \hat{L}_- \hat{b}_v + \hat{b}_v^\dagger \hat{L}_+ \hat{b}_p\right)$$



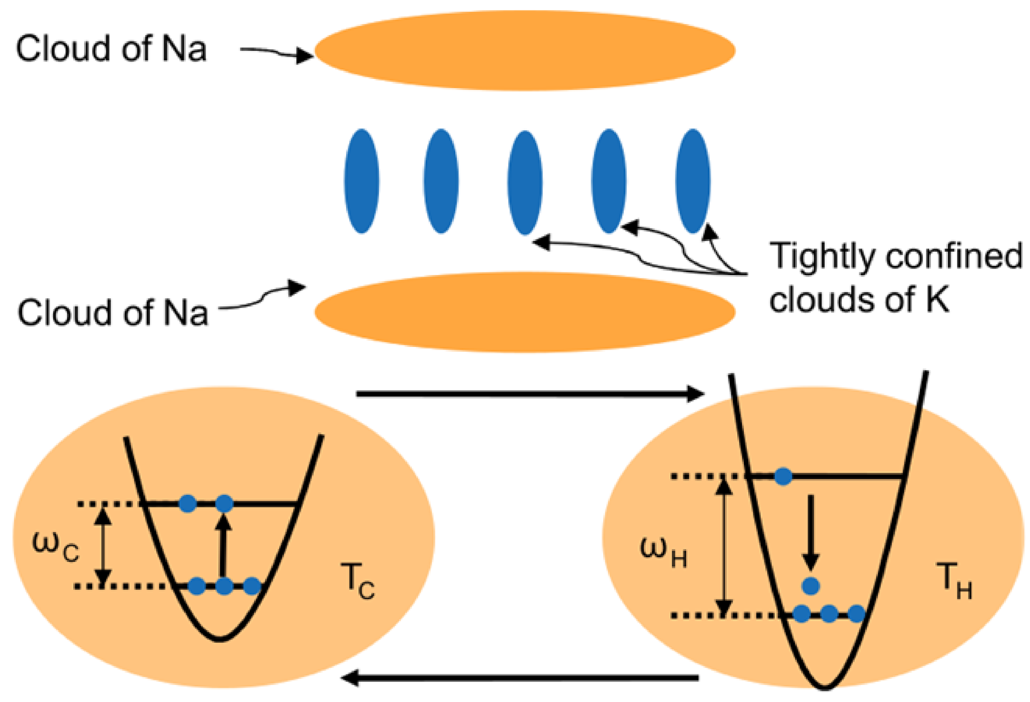
Quantum Computation[2]

- Qudits: collective spin of K atoms in tweezers.
- Universal gate set: qudit entanglement via phononic excitations (bath of Na atoms).



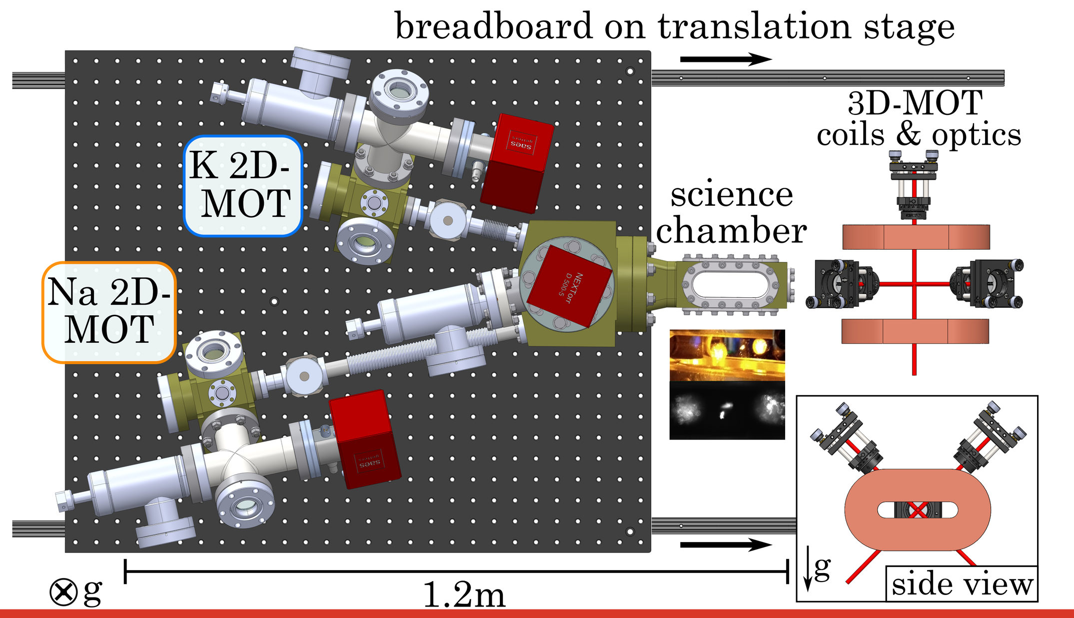
Quantum Thermodynamics[3]

- Goal: realizing the quantized Otto cycle.
- Implementation: single K atoms (working medium) transferred between two (hot and cold) baths of Na atoms.



Experiment setup

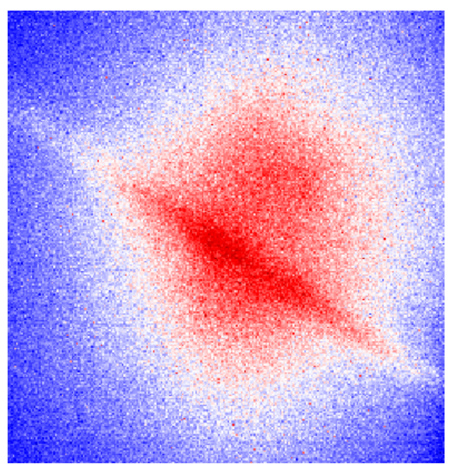
Why Na-K? : Bosonic and femionic K isotopes, easier tunability of scattering length[4−5] and faster spin dynamics.



Current work

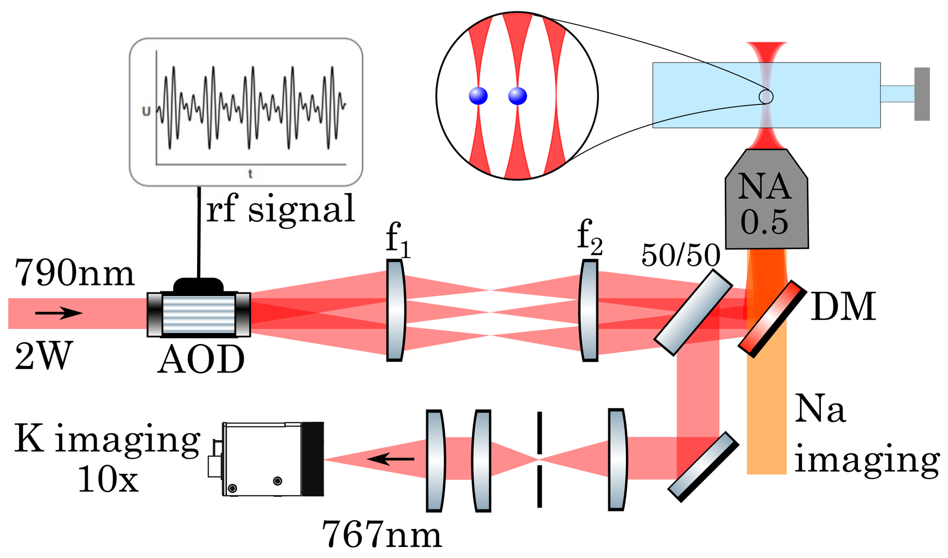
Magnetic trap and Dipole trap

- Bulk-machined, water-cooled electro-magnets[6]. Microwave evaporation of Na.
- Dipole trap laser: 100W at 1070nm.



Optical tweezers

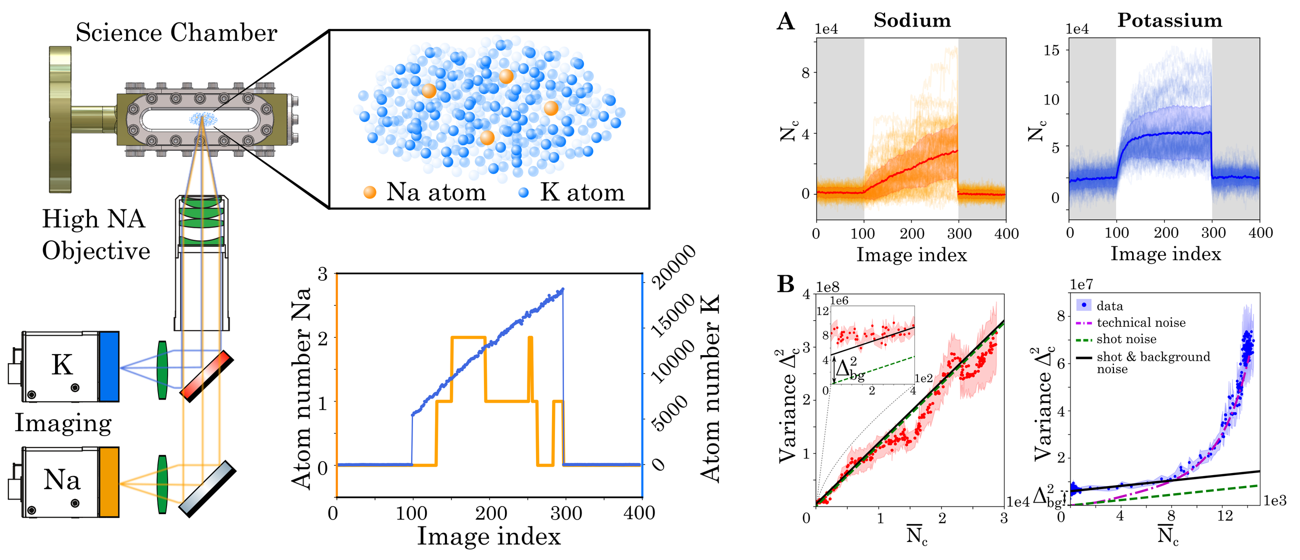
- Goal: defect-free tweezer array of sympathetically cooled K-atoms[7].



Recent study : stochastic atom number dynamics in a MOT[8]

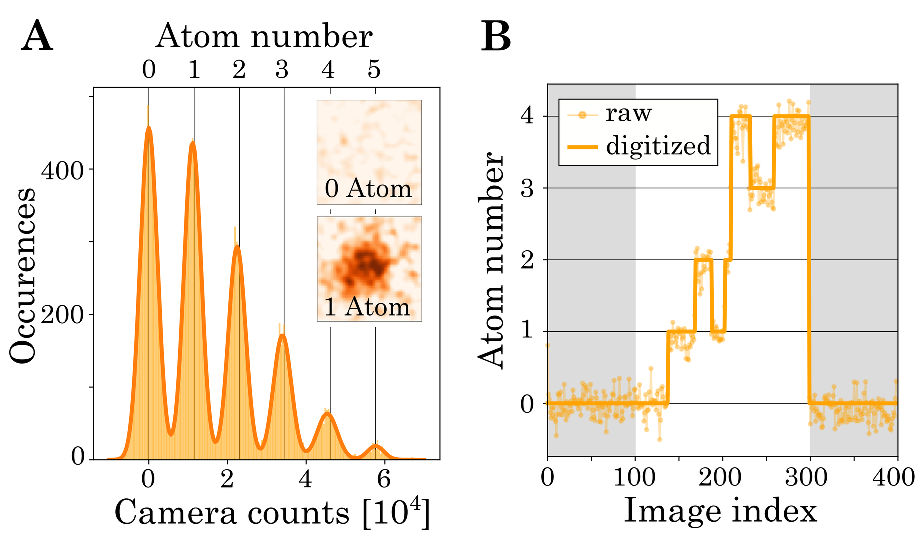
Atom Number Dynamics

- Observe atom number evolution of both species with fluorescence imaging.
- Characterization of atom number fluctuations using ensemble averaging.



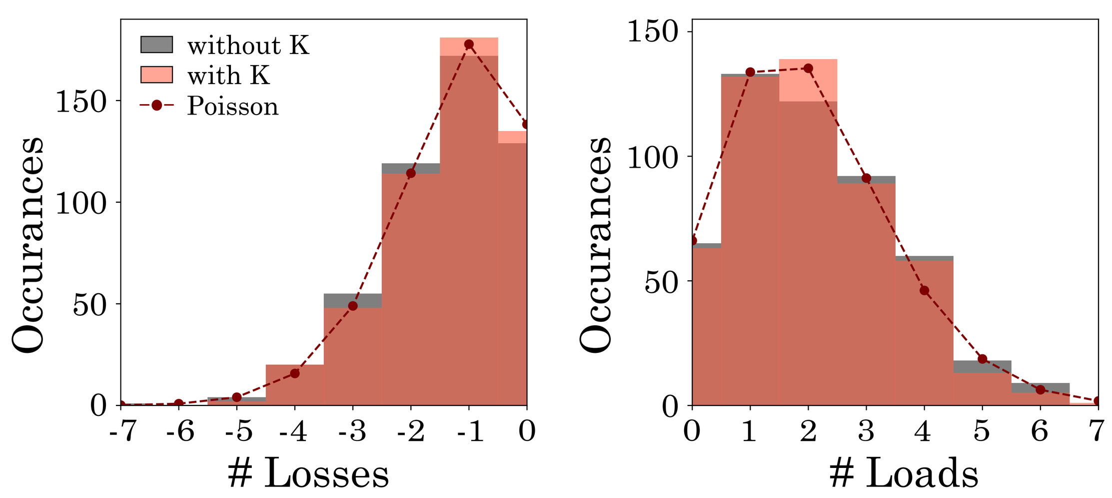
Single atom counting

- Single atom counting resolution up to 10 Na atoms.
- Full counting statistics helps to characterize load and loss dynamics.



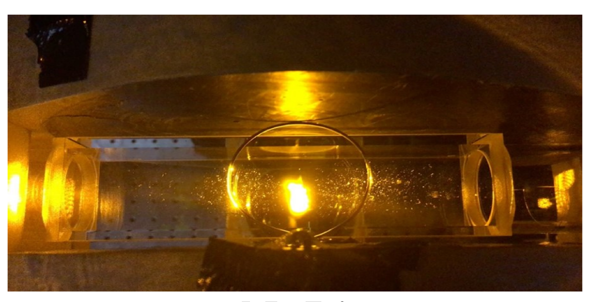
Interspecies interaction??

- A few Na atoms immersed into a large cloud of K atoms.
- No effect observed on the load and loss statistics of the sodium atom counts.

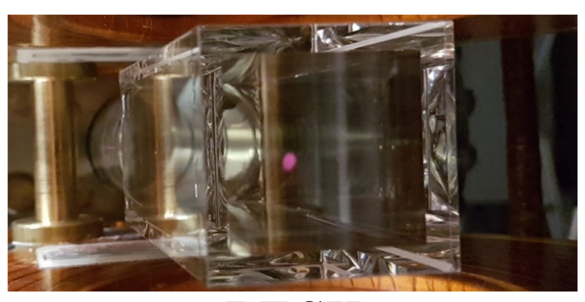


Outlook

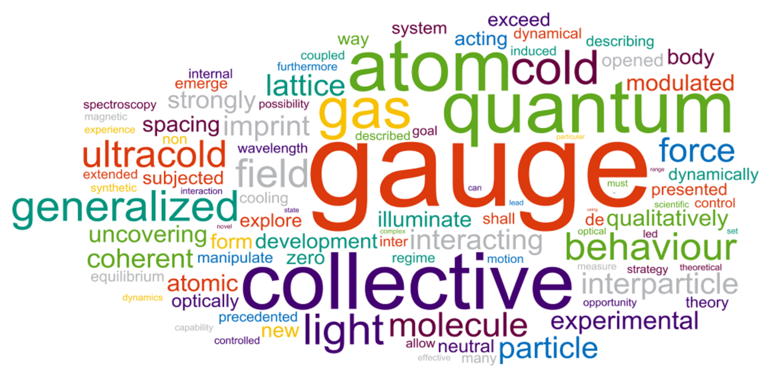
- Working towards achieving Na BEC in optical dipole trap and single K atoms in tweezers.
- Precise non-demolition technique will be used for temperature measurements[9].
- Remote execution of quantum circuits on coherent spins[2].


NaLi

+


BECK

=



References

1. Alexander Mil, et. al. Science : Vol. 367, Issue 6482, pp. 1128-1130 (2020).
2. Valentin Kasper et. al. arXiv: 2010.15923 (2020).
3. Wolfgang Niedenzu et. al. Quantum (3) 155 (2019).
4. Torben A. Schulze et. al. Phys. Rev. A 97, 023623.
5. Cheng-Hsun Wu et. al. Phys. Rev. Lett. 109, 085301.
6. K. Roux et. al. SciPost Phys. 6 (2019) 4, 0485.
7. Alexandre Cooper et. al. PhysRevX .8.041055.
8. Rohit P. Bhatt et. al. arXiv: 2101.01135 (2021).
9. M. Mehboudi et. al. Phys. Rev. Lett. 122, 030403.

isoQuant SFB1225

Emmy Noether-Programm DFG Deutsche Forschungsgemeinschaft