

# Quantum Magnetism with Lithium-7

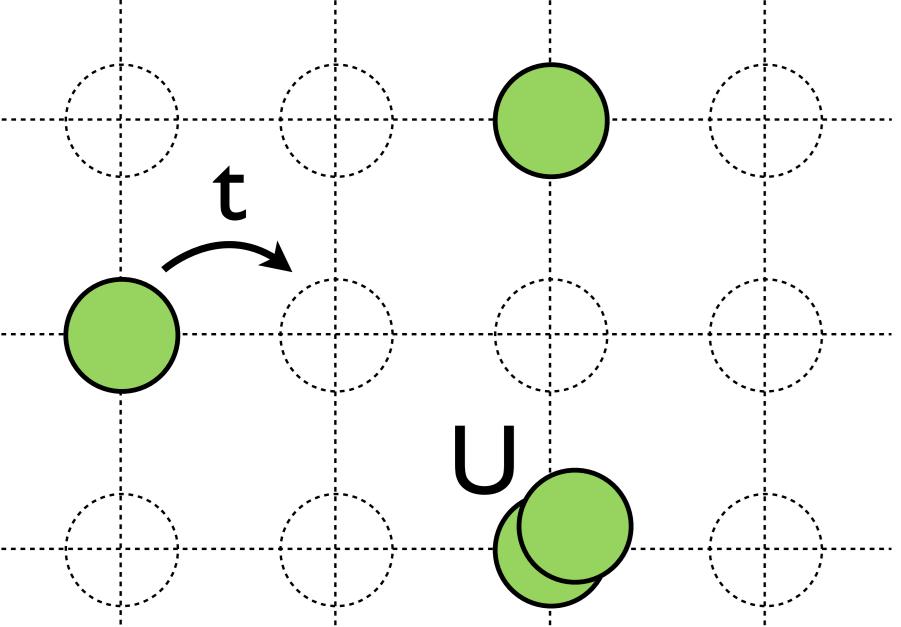
Niklas Jepsen, Ivana Dimitrova, Jesse-Amato-Grill, William Lunden, Yichao Yu, Michael Messer, Wolfgang Ketterle



MIT-Harvard Center for Ultracold Atoms, Research Laboratory of Electronics Department of Physics, Massachusetts Institute of Technology, Cambridge

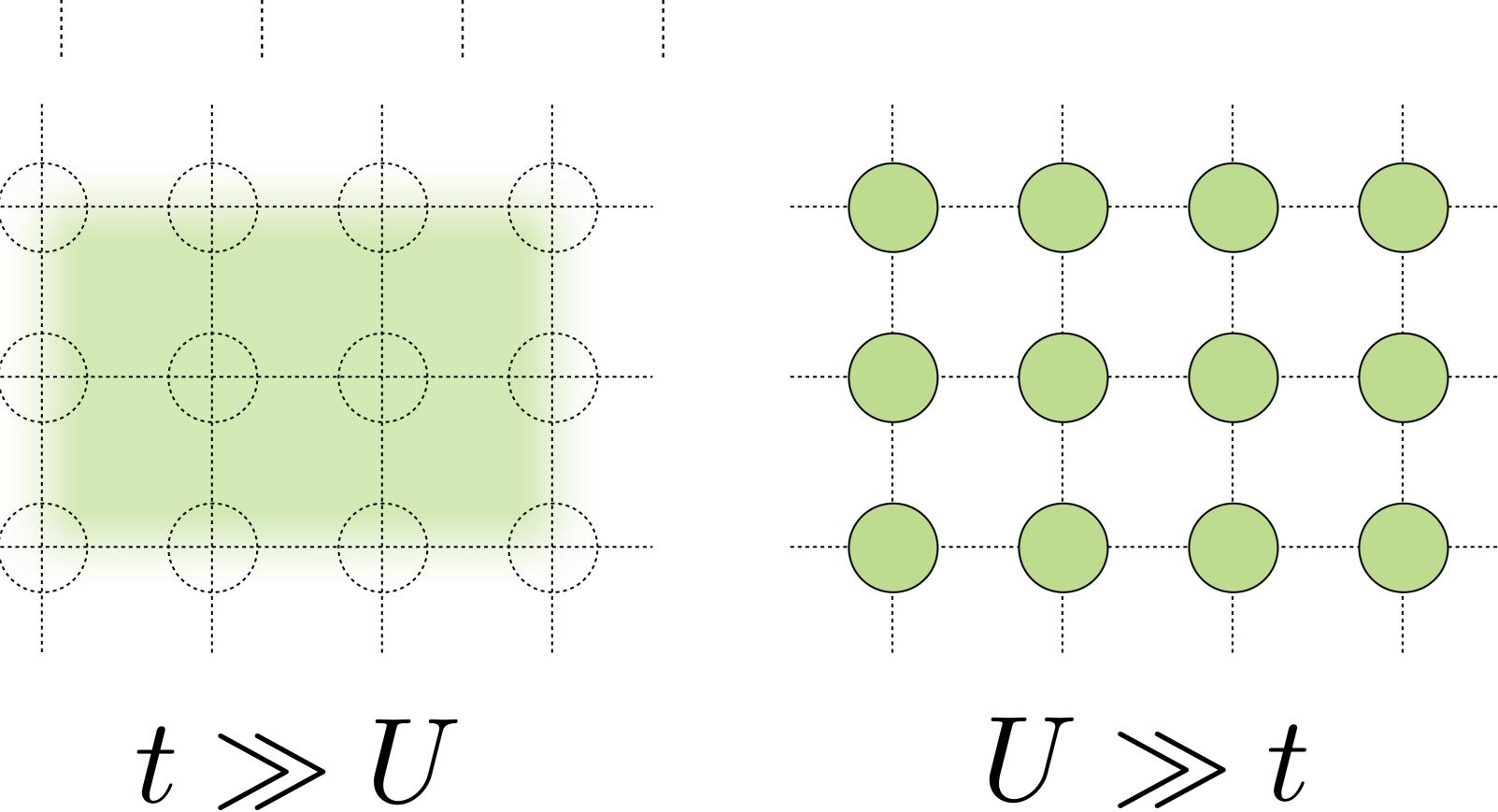
#### Hubbard model

$$H = -\sum_{\langle i j \rangle} \left( t a_i^{\dagger} a_j + h.c. \right) + \frac{1}{2} \sum_i U n_i (n_i - 1)$$



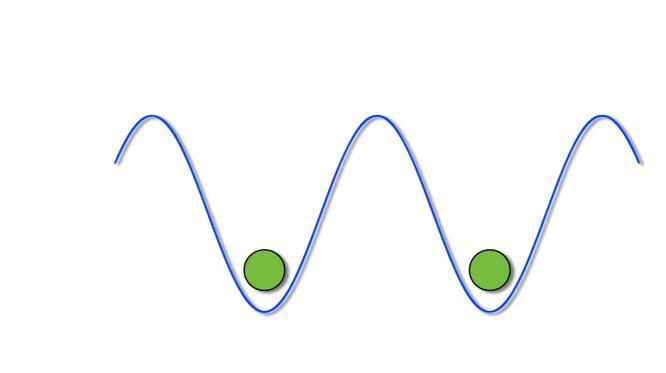
t: hopping

U: interaction

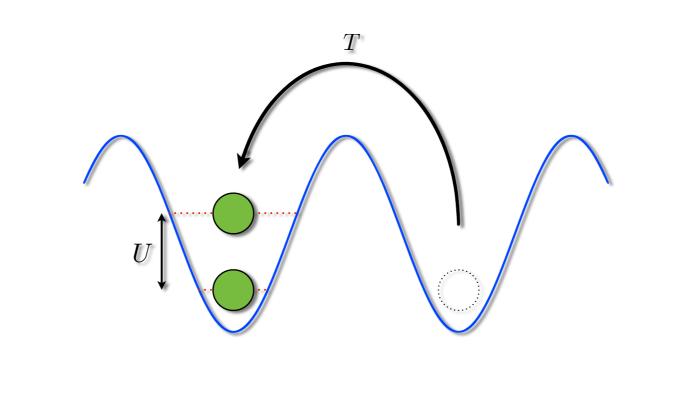


### Superexchange

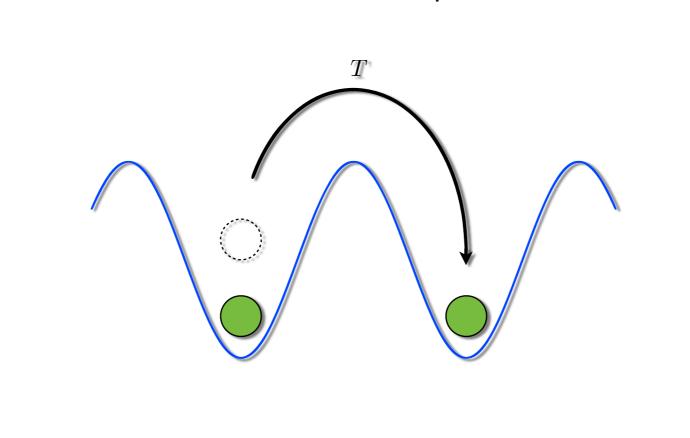
Super-exchange induces spin-interactions  $J = t^2/U$ 



(e) Neighboring atoms



(f) Virtual Excitation of energy U



(g) Particle hops back

will be enhanced in our experiment by

(I)
Small mass
of Li-7

Smaller lattice spacing by green optical lattice

(3)
Tunable interaction U
by Feshbach resonance

- $\Rightarrow$  Higher critical temperature for magnetic ordering ( $k_BT_c\sim t^2/U$ )
- ⇒ Faster spin dynamics within experimentally relevant timescales

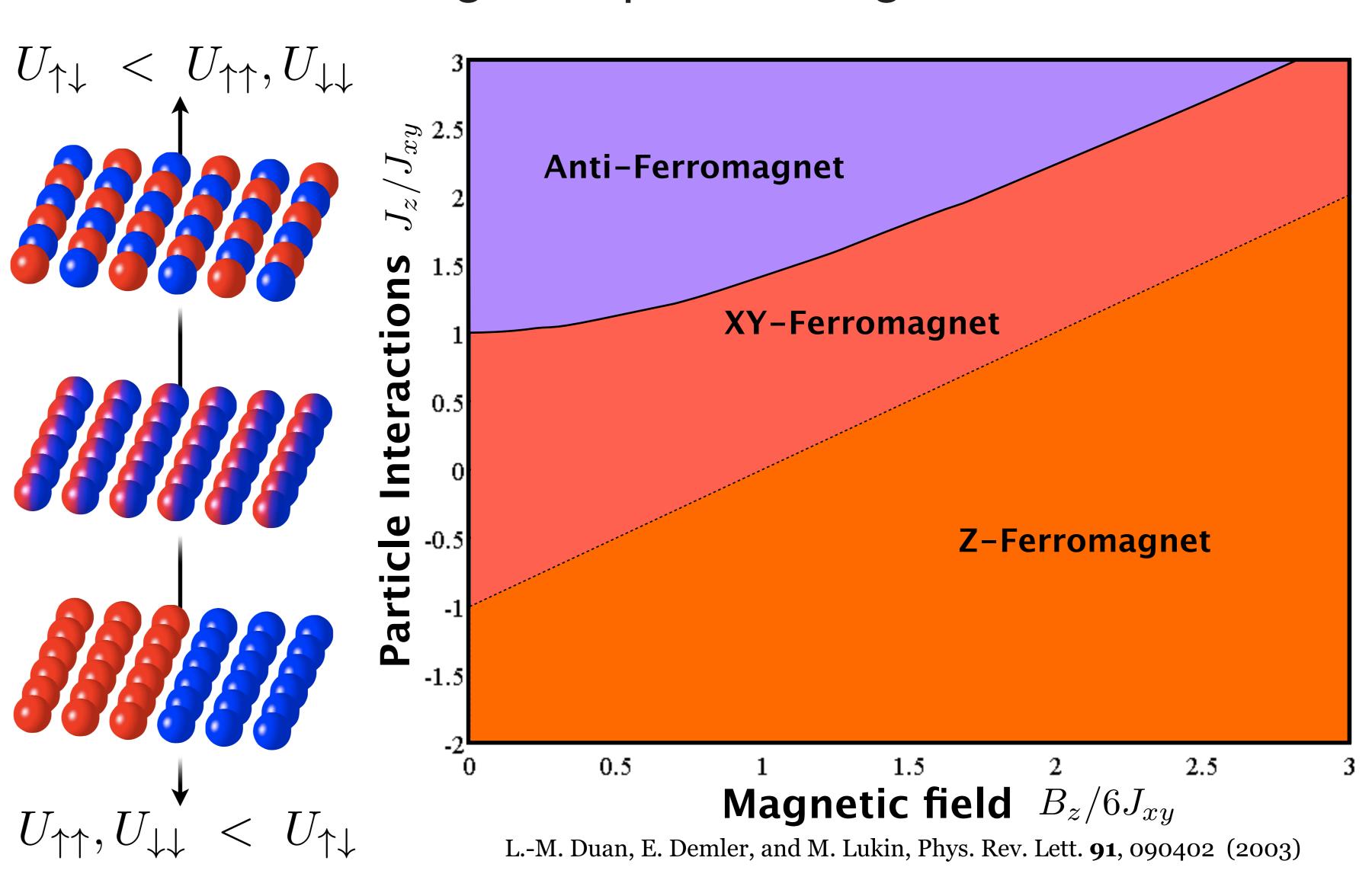
#### Heisenberg model

Anisotropic Heisenberg Model (XXZ model)

$$H = \sum_{\langle i,j \rangle} [J_z s_i^z s_j^z - J_{xy}(s_i^x s_j^x + s_i^y s_j^y)] - B_z \sum_i s_i^z$$

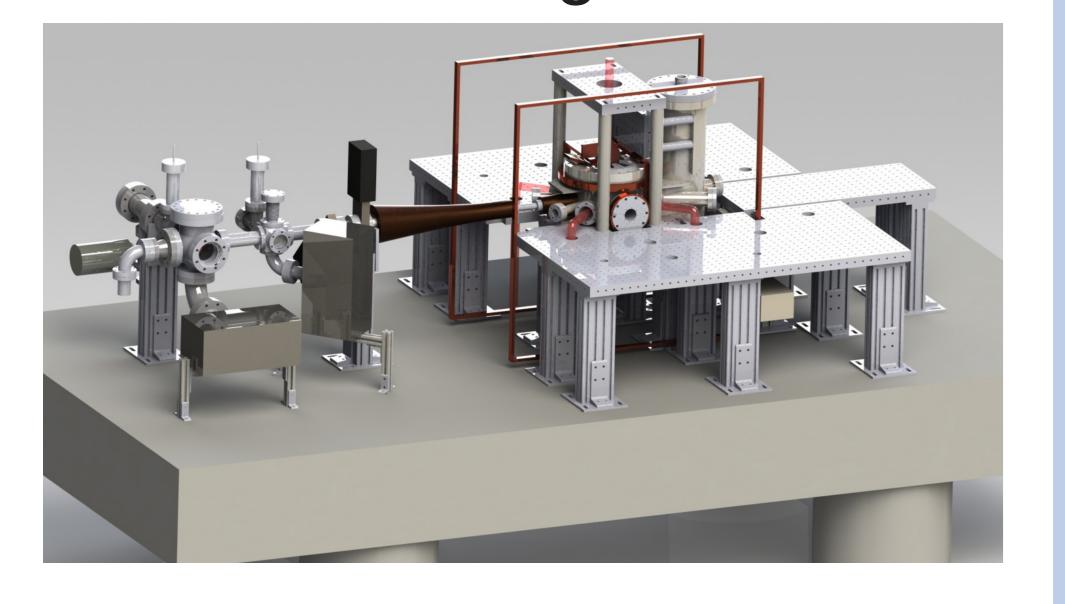
$$J_{z}=rac{t_{\uparrow}^{2}+t_{\downarrow}^{2}}{2U_{\uparrow\downarrow}}-rac{t_{\uparrow}^{2}}{U_{\uparrow\uparrow}}-rac{t_{\downarrow}^{2}}{U_{\downarrow\downarrow}} \qquad J_{xy}=rac{t_{\uparrow}t_{\downarrow}}{2U_{\uparrow\downarrow}}$$

Magnetic phase diagram



#### Experimental setup

# Design

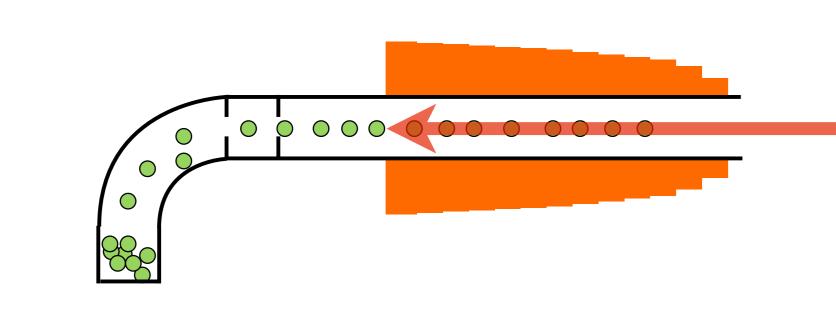


Realization

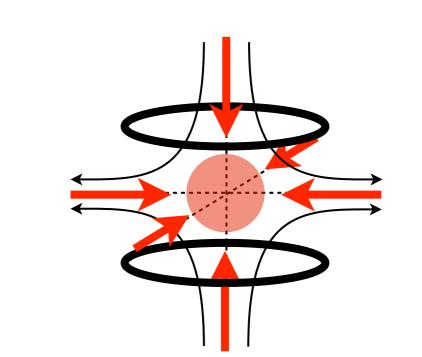


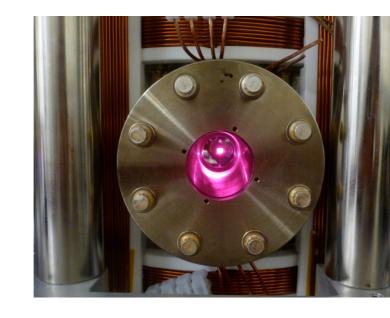
#### 1. Zeeman slowing & MOT

Zeeman slower



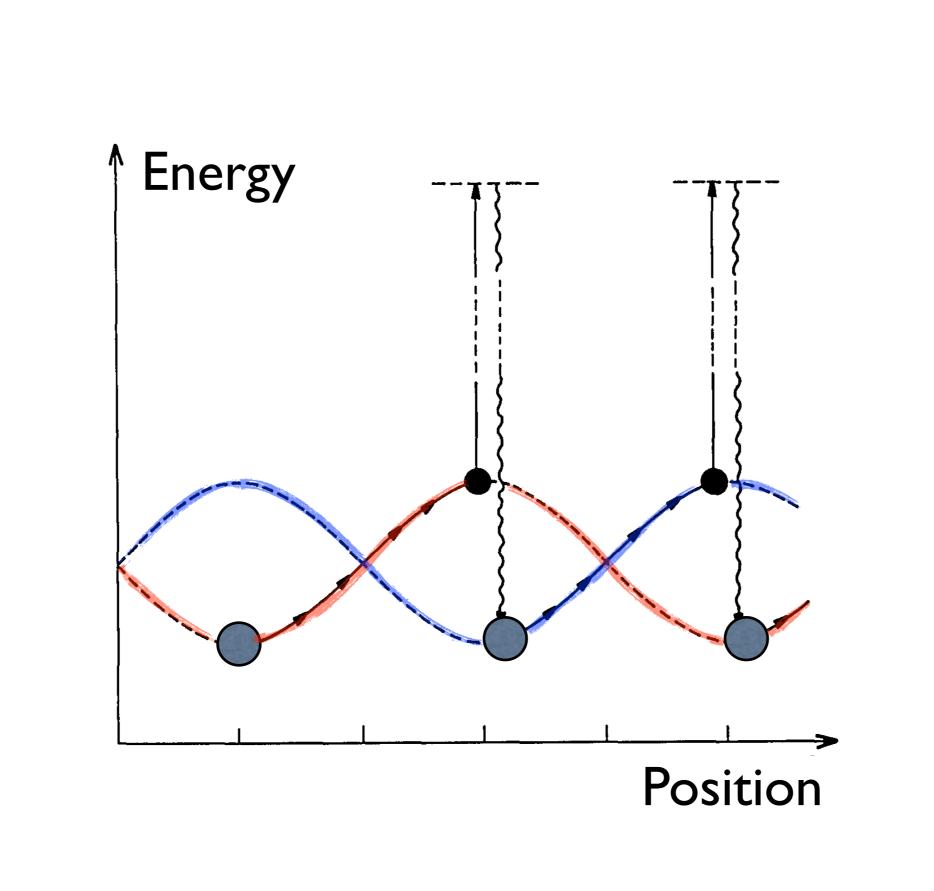
Magneto-optical trap





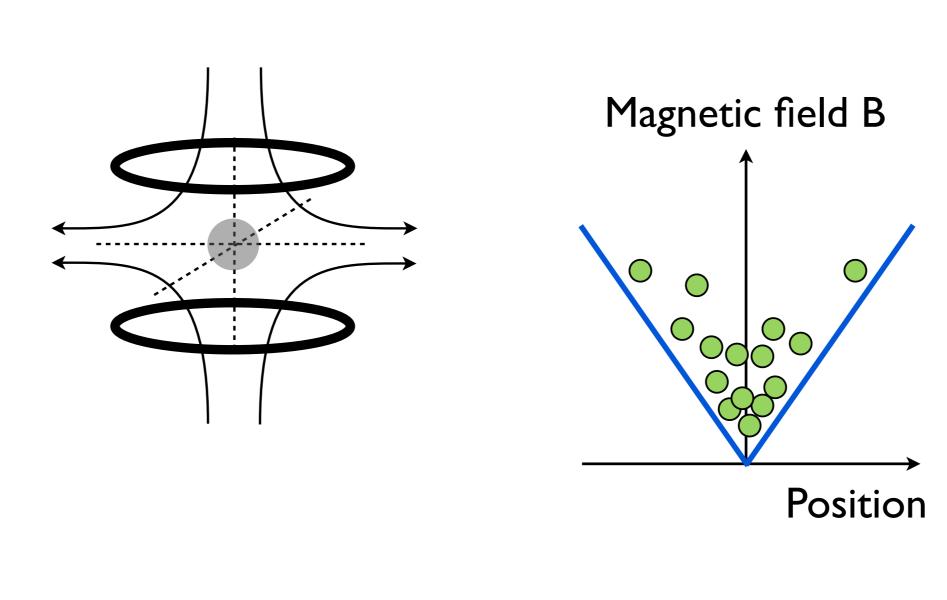
## 2. Sub-Doppler cooling

Similar to Sisyphus cooling

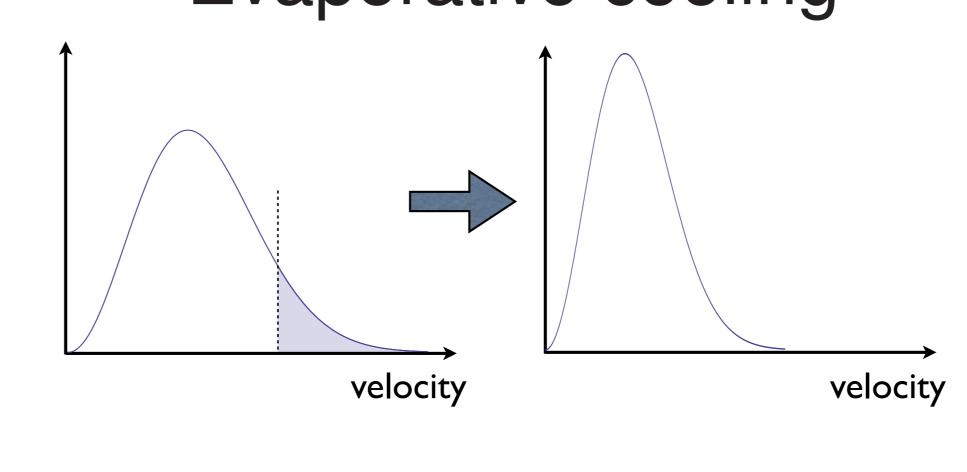


# 3. Magnetic trap & evaporation

Magnetic trap

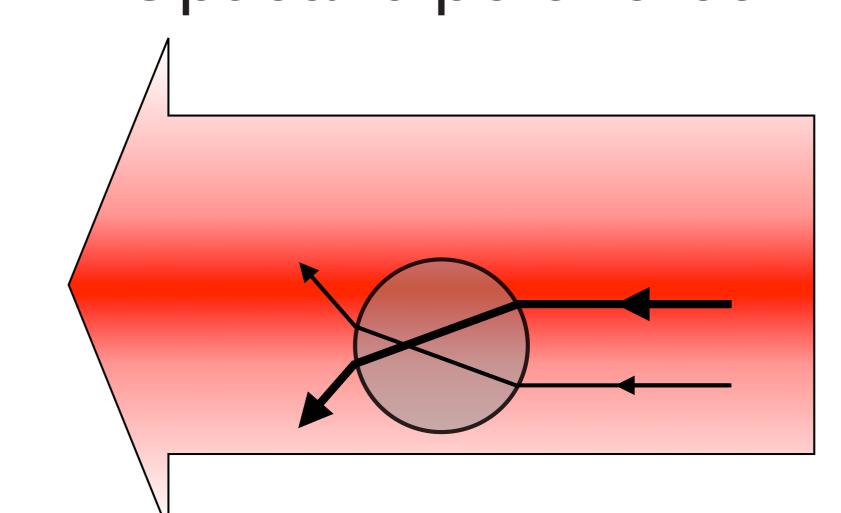


Evaporative cooling

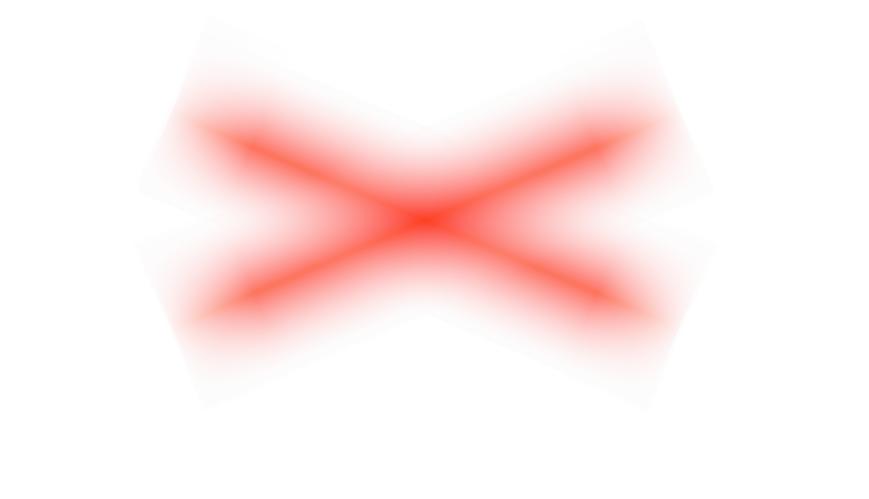


#### 4. Optical trap

Optical dipole force



Crossed dipole trap



## 5. Optical lattice

