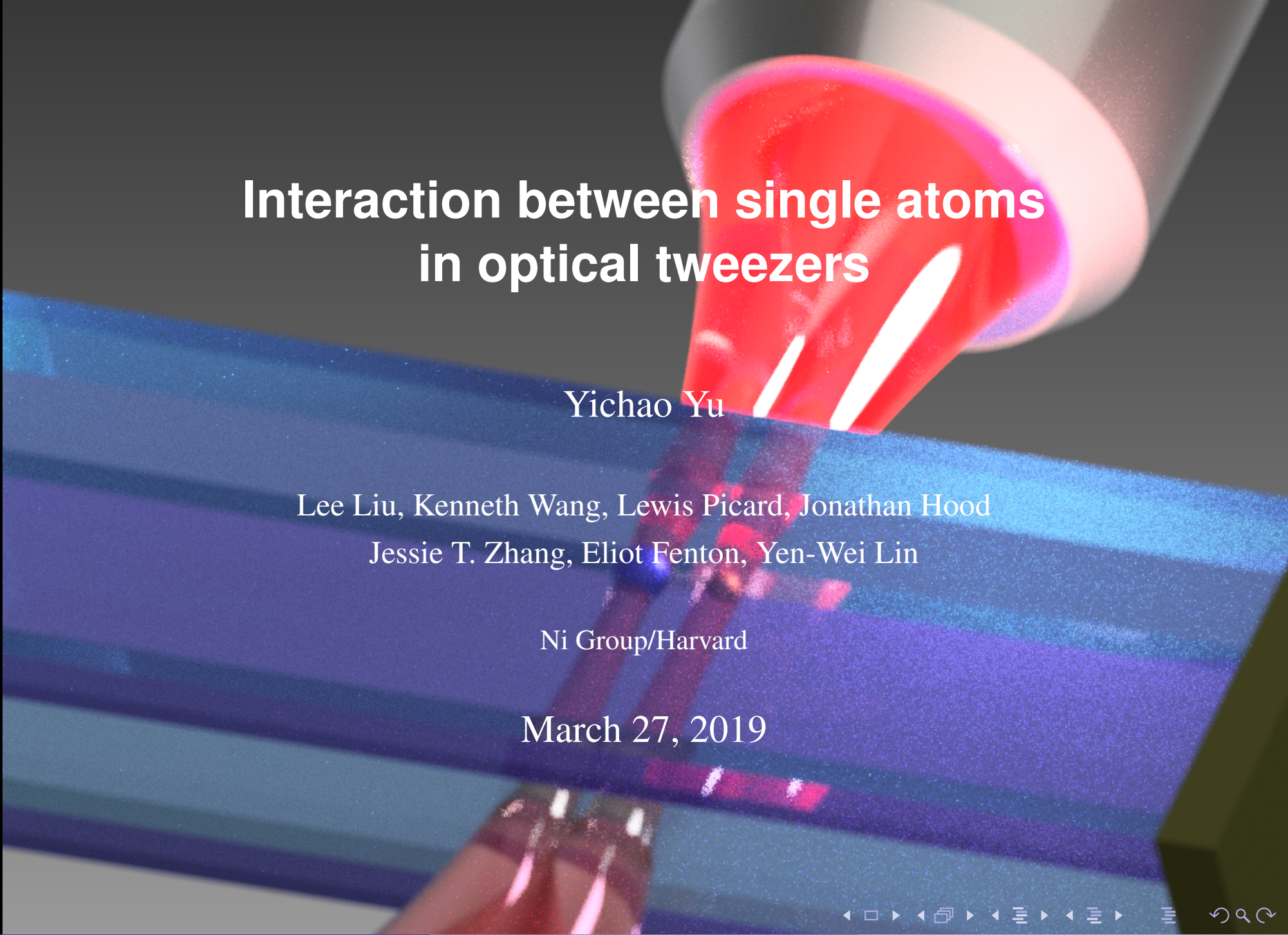


Interaction between single atoms in optical tweezers

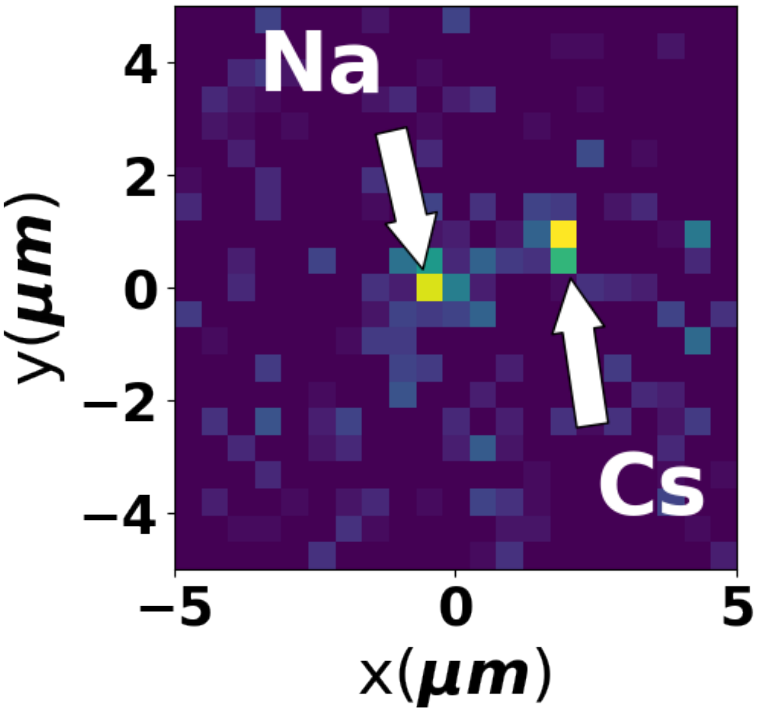
Yichao Yu

Lee Liu, Kenneth Wang, Lewis Picard, Jonathan Hood
Jessie T. Zhang, Eliot Fenton, Yen-Wei Lin

Ni Group/Harvard

March 27, 2019

Loading



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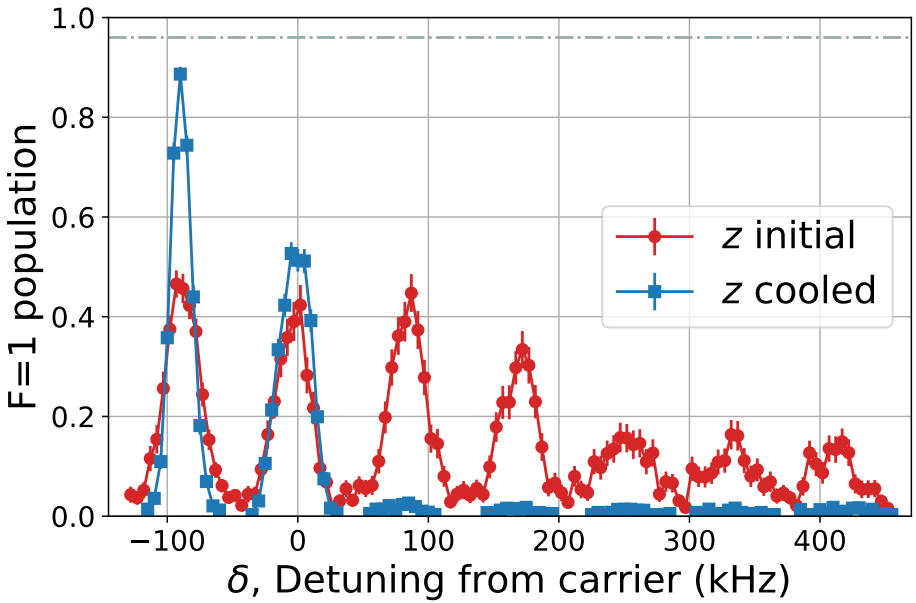
Cooling



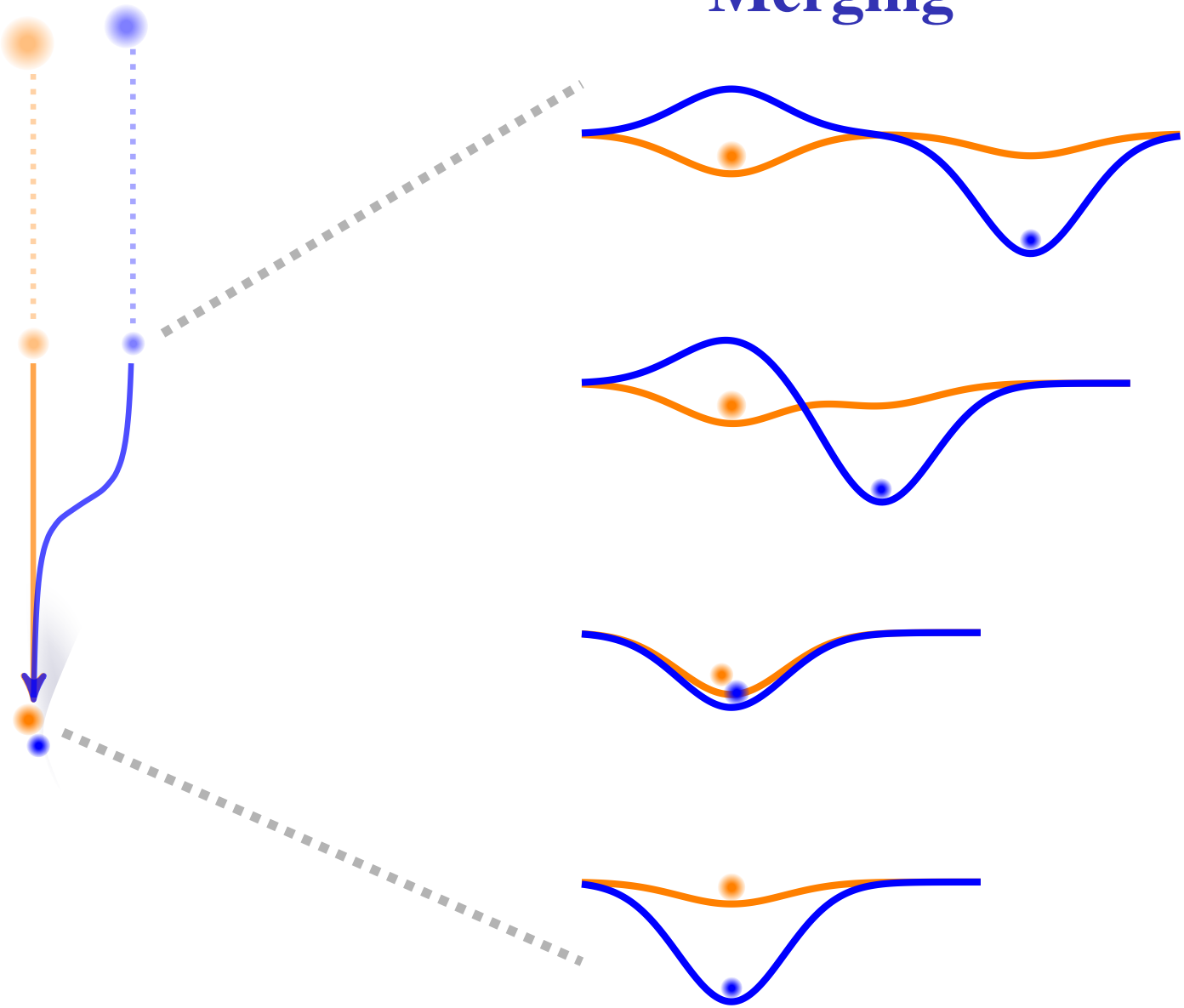
Cs: 96% ground state[1]

Na: 94% ground state[2]

[1] arXiv:1902.03935

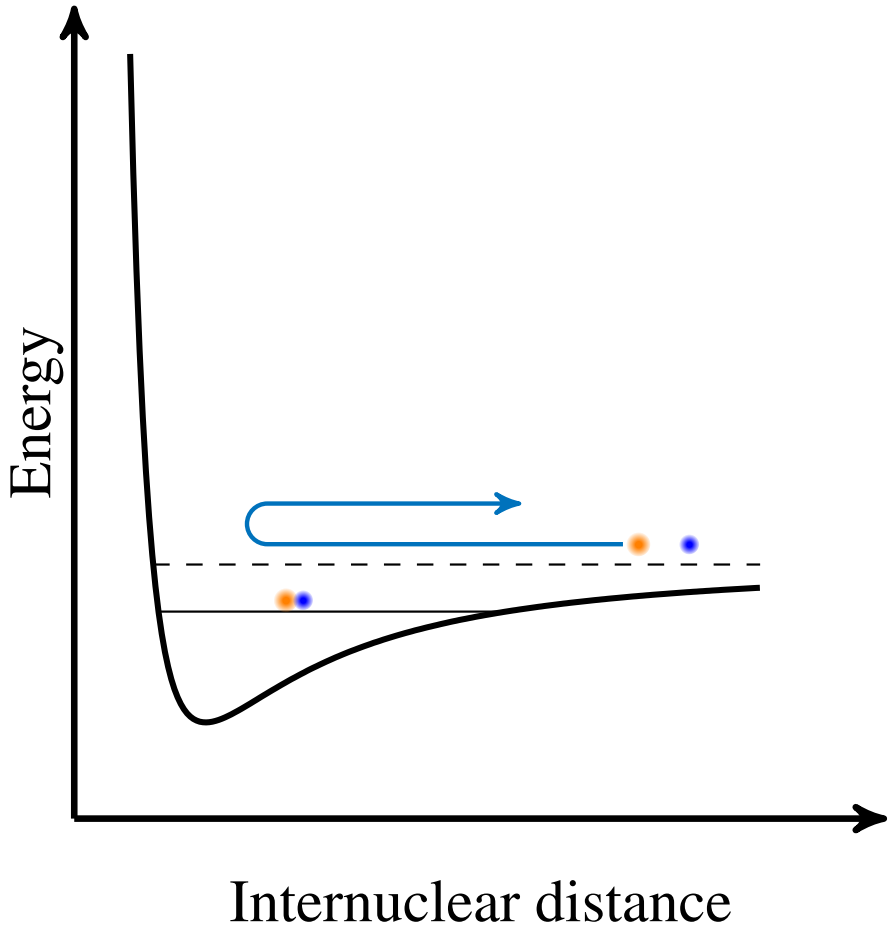
[2] Phys. Rev. A 97, 063423

Merging



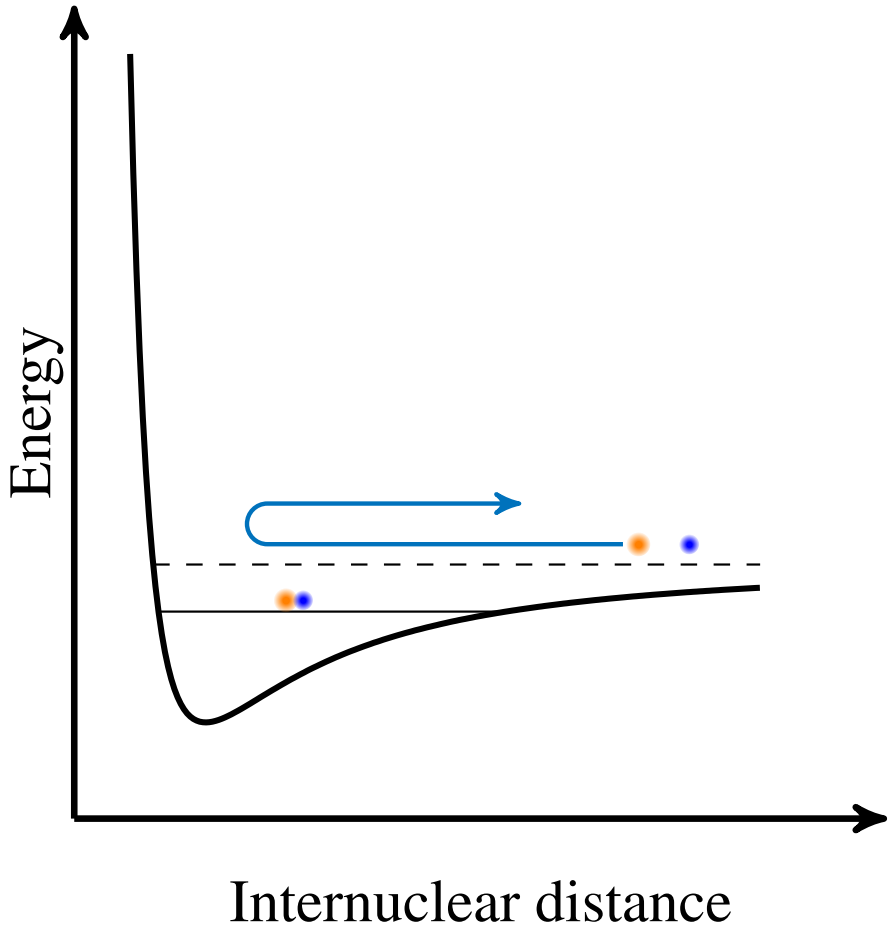
Scattering length a

- Binding energy
- Molecular potential
- Feshbach resonance
- Molecule formation



Scattering length a

- Binding energy
- Molecular potential
- Feshbach resonance
- Molecule formation
- ⋮



Scattering length a

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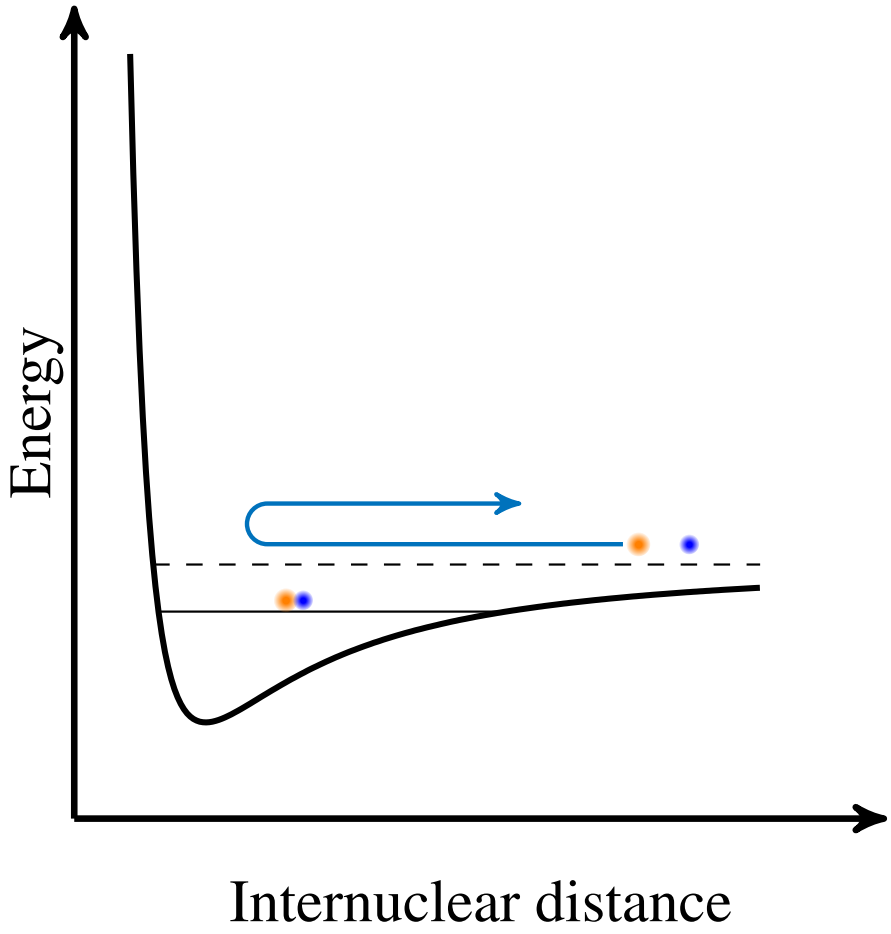

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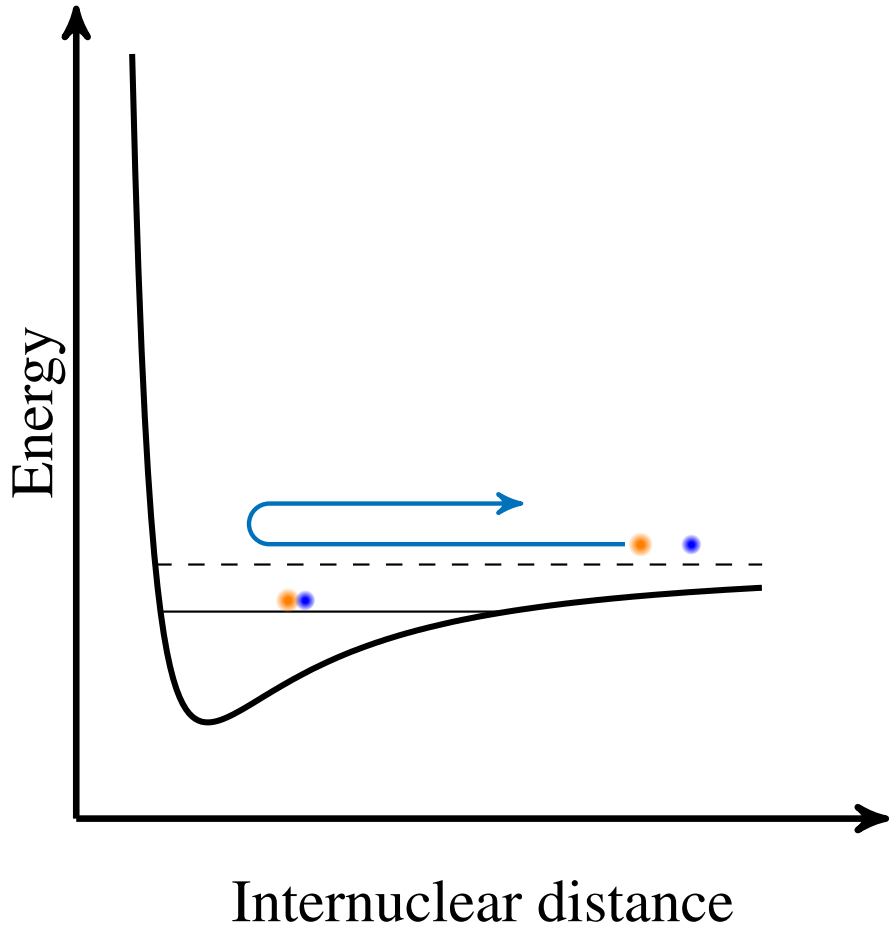

Scattering length a

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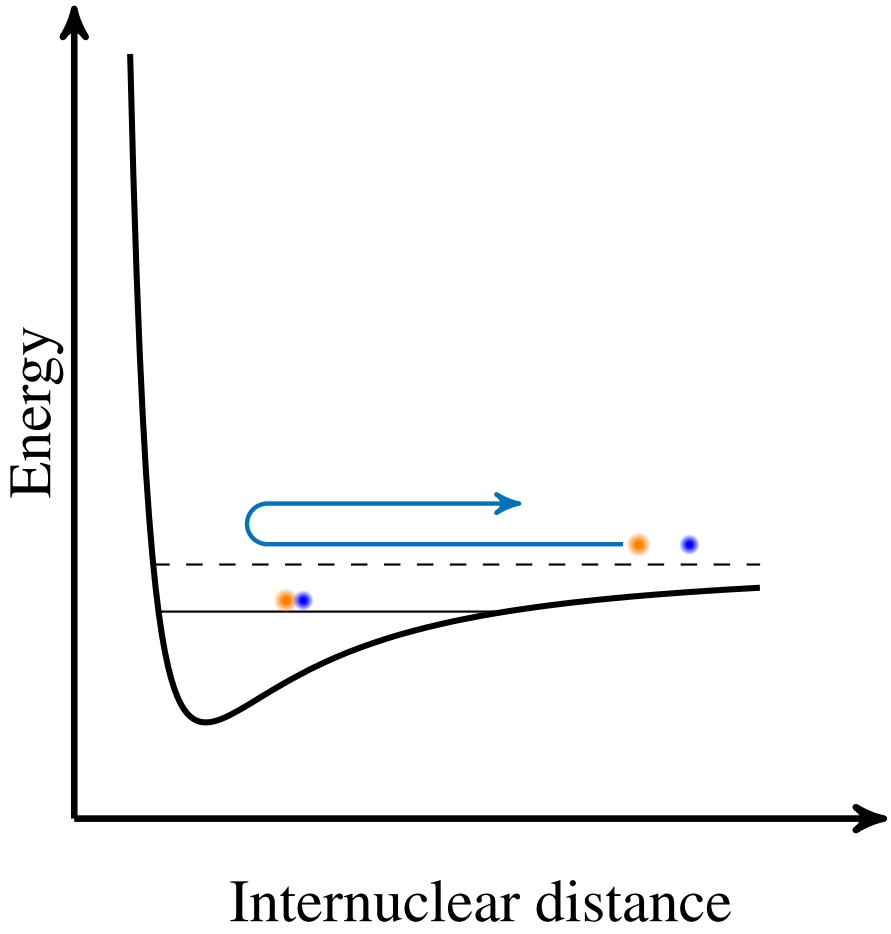
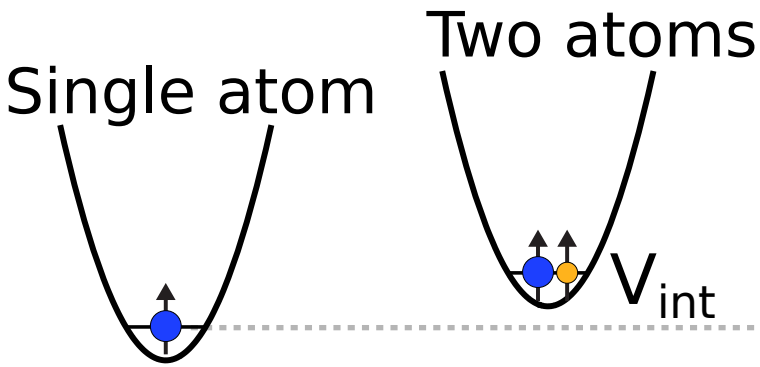
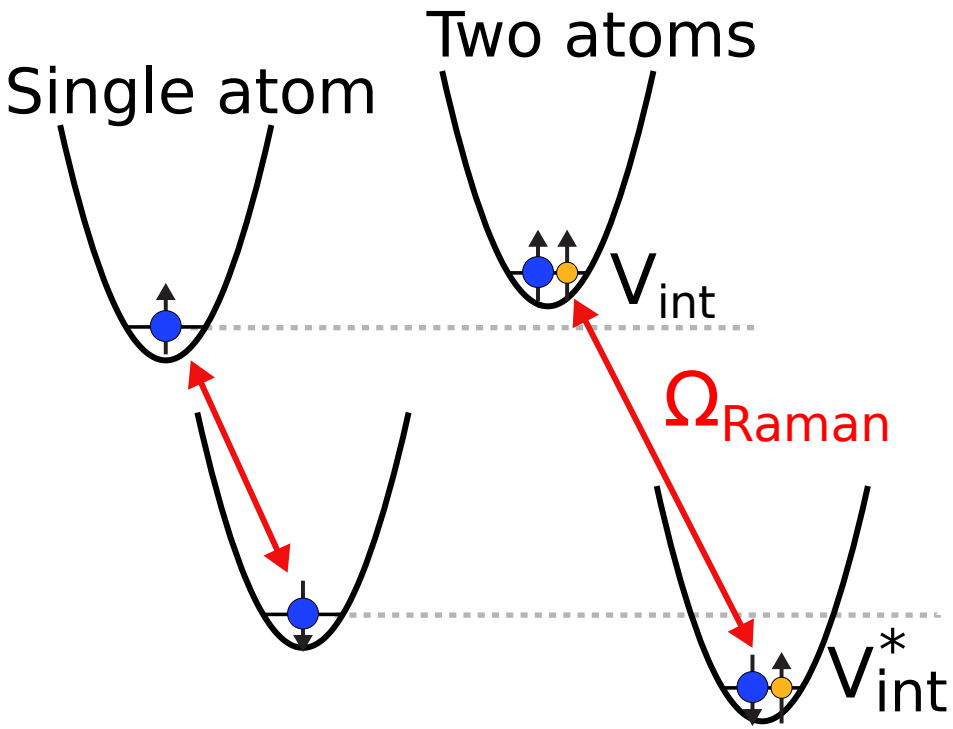
⋮



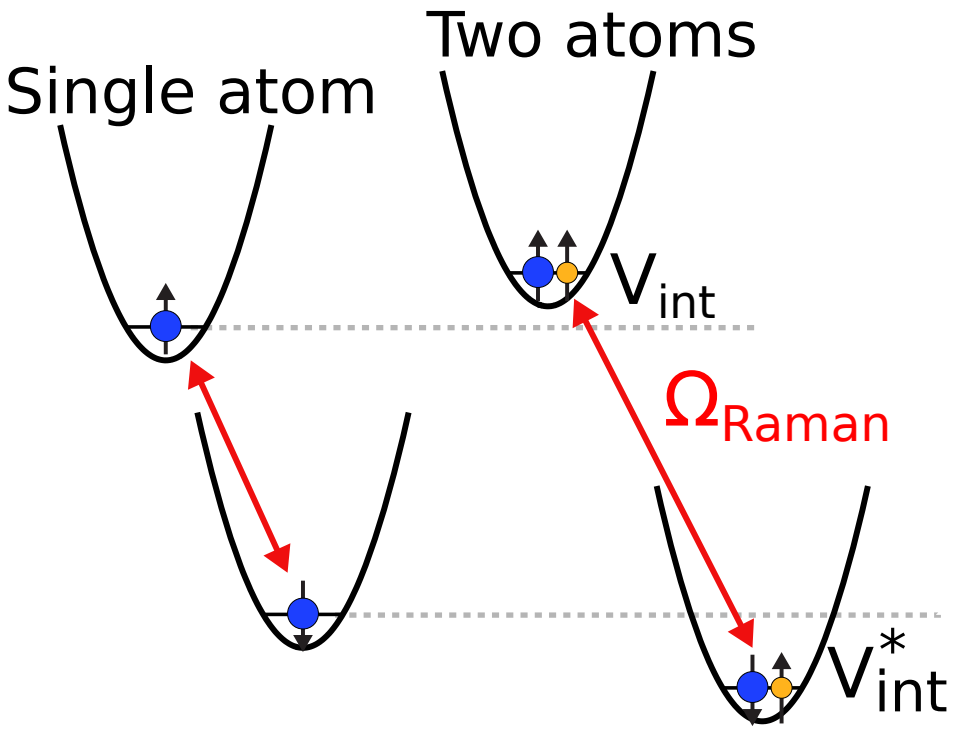
Interaction shift

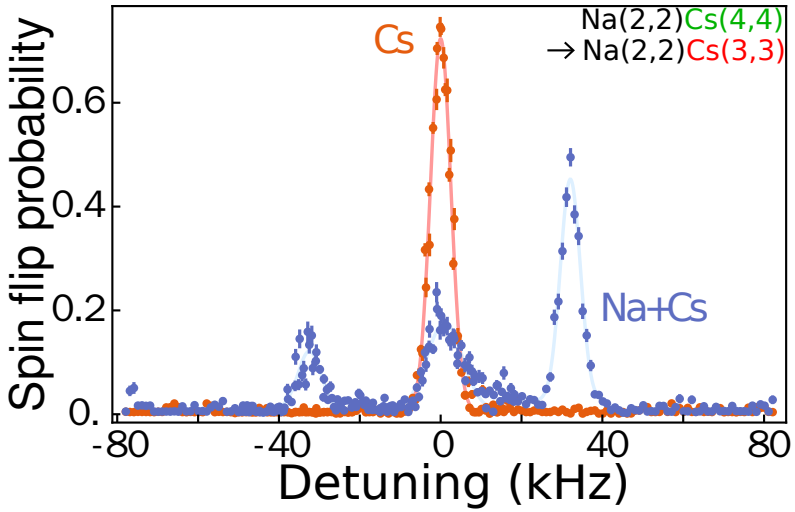


Interaction shift



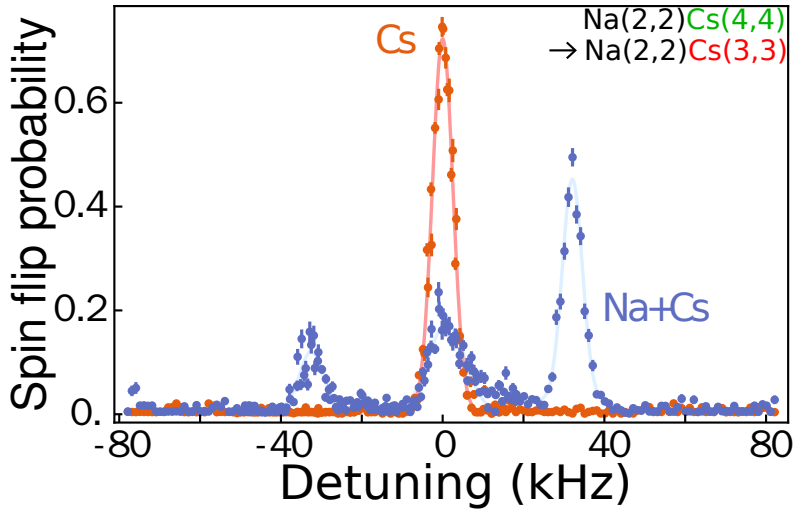
Interaction shift





Interaction shift

$$H = \underbrace{\sum_{i=x,y,z} \left(\frac{m_1\omega_{1,i}^2 x_{1,i}^2}{2} + \frac{p_{1,i}^2}{2m_1}\right)}_{\text{Na}} + \underbrace{\sum_{i=x,y,z} \left(\frac{m_2\omega_{2,i}^2 x_{2,i}^2}{2} + \frac{p_{2,i}^2}{2m_2}\right)}_{\text{Cs}} + \underbrace{V_{int}(\vec{r}_1 - \vec{r}_2)}_{\text{Interaction}}$$



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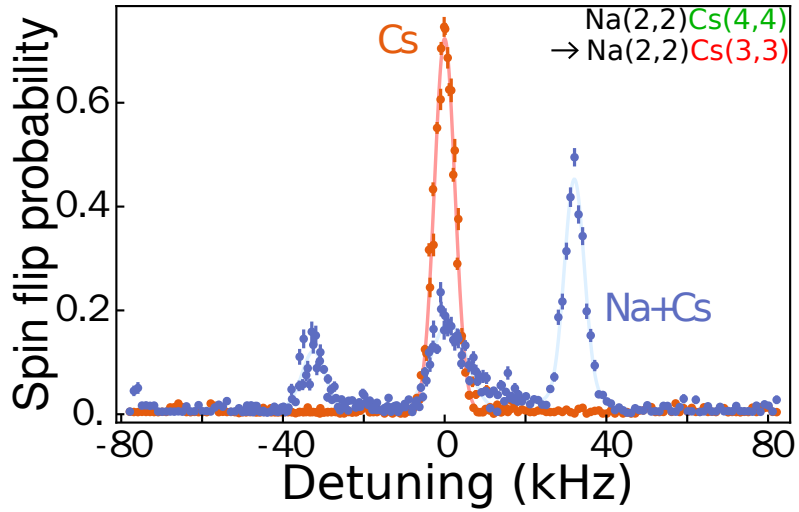
To center of mass and relative coordinates

$$M = m_1 + m_2 \qquad \mu = \frac{m_1 m_2}{m_1 + m_2}$$

$$\Omega_i^2 = \frac{m_1\omega_{1,i}^2 + m_2\omega_{2,i}^2}{m_1 + m_2} \qquad \omega_{R,i}^2 = \frac{m_2\omega_{1,i}^2 + m_1\omega_{2,i}^2}{m_1 + m_2}$$

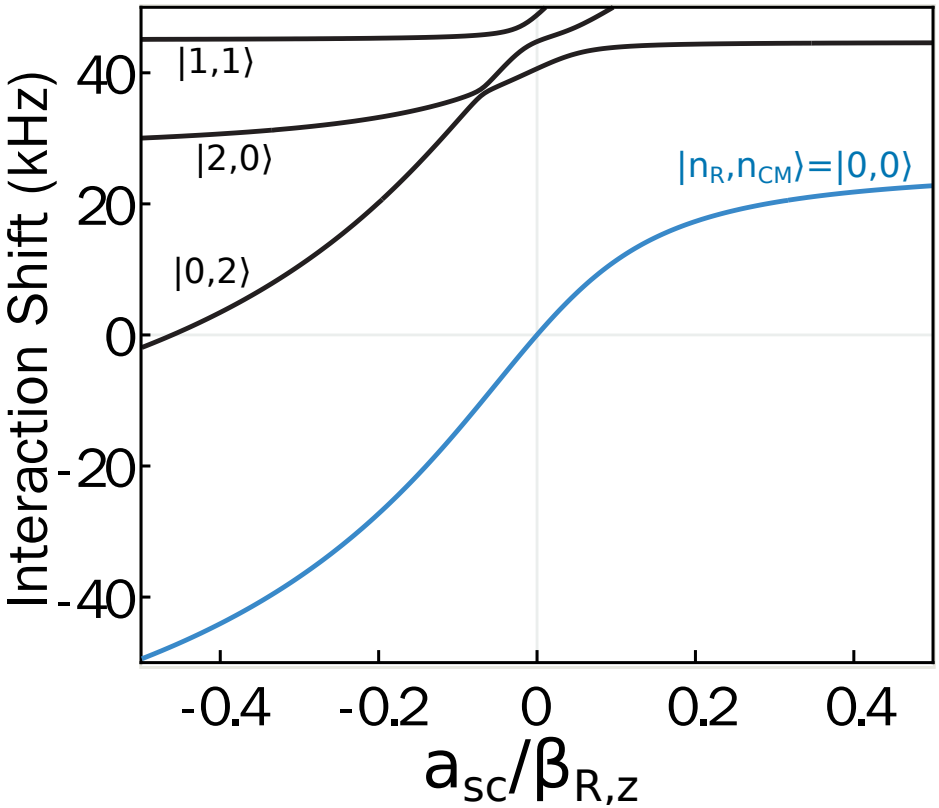
$$X_i = \frac{m_1 x_{1,i} + m_2 x_{2,i}}{m_1 + m_2} \qquad x_{R,i} = x_{1,i} - x_{2,i}$$

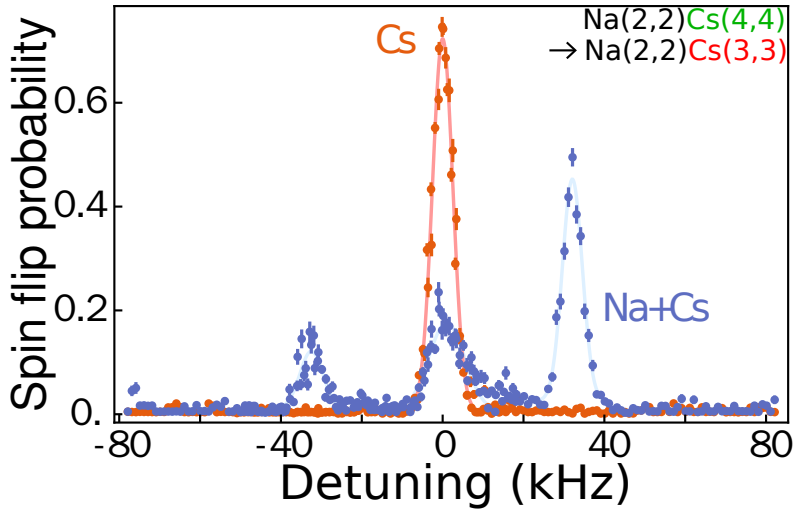
$$P_i = p_{1,i} + p_{2,i} \qquad p_{R,i} = \frac{m_2 p_{1,i} - m_1 p_{2,i}}{m_1 + m_2}$$



$$H = \overbrace{\sum_{i=x,y,z} \left(\frac{M\Omega_i^2 X_i^2}{2} + \frac{P_i^2}{2M}\right)}^{\text{Center of mass}} + \overbrace{\sum_{i=x,y,z} \left(\frac{\mu\omega_{R,i}^2 x_{R,i}^2}{2} + \frac{p_{R,i}^2}{2\mu}\right) + V_{int}(\vec{r}_R)}^{\text{Relative}} + \overbrace{\sum_{i=x,y,z} \mu(\omega_{1,i}^2 - \omega_{2,i}^2) X_i x_{R,i}}^{\text{Mixing}}$$

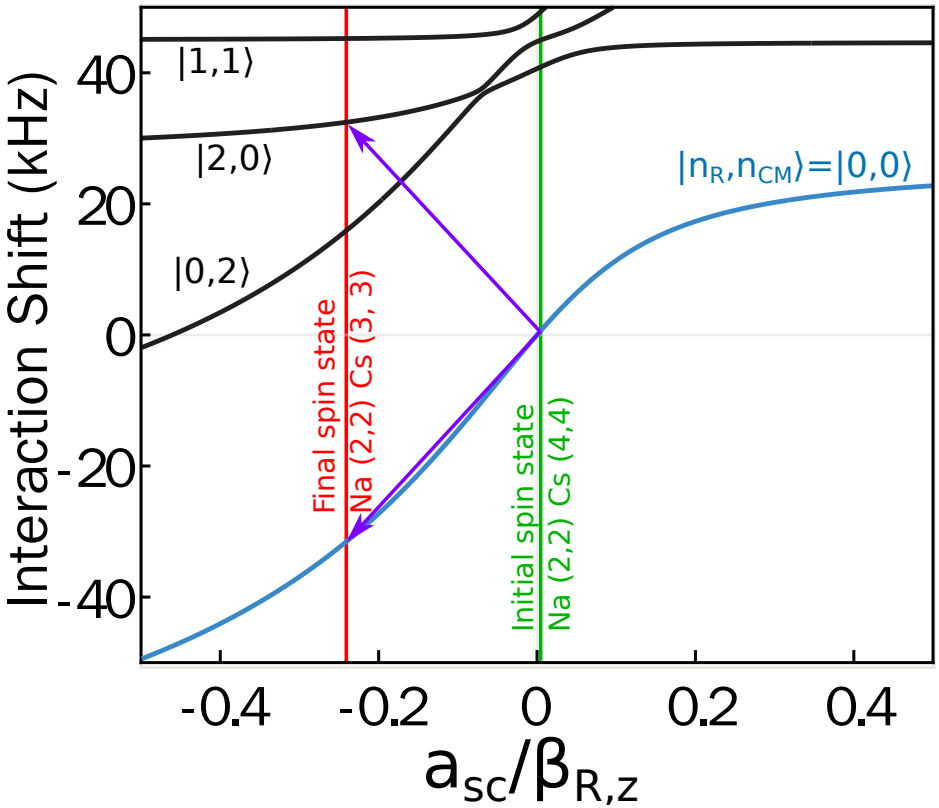
Interaction shift

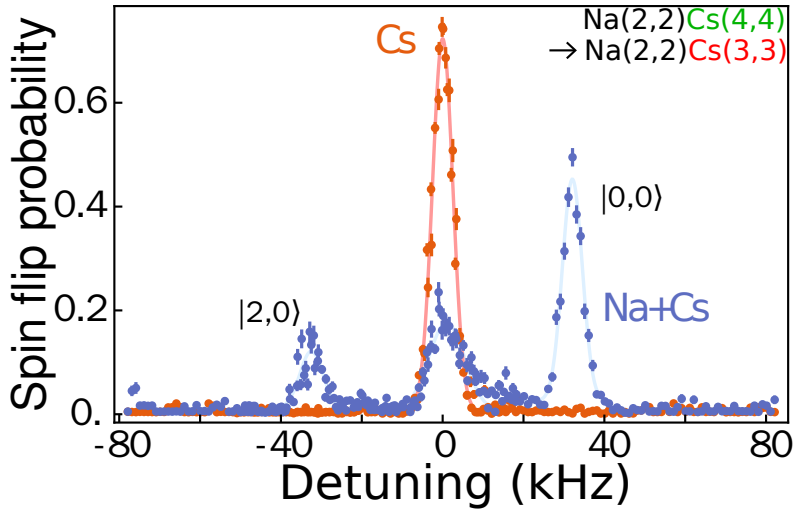




$$H = \overbrace{\sum_{i=x,y,z}\left(\frac{M\Omega_i^2 X_i^2}{2} + \frac{P_i^2}{2M}\right)}^{\text{Center of mass}} + \overbrace{\sum_{i=x,y,z}\left(\frac{\mu\omega_{R,i}^2 x_{R,i}^2}{2} + \frac{p_{R,i}^2}{2\mu}\right) + V_{int}(\vec{r}_R)}^{\text{Relative}} + \overbrace{\sum_{i=x,y,z}\mu(\omega_{1,i}^2 - \omega_{2,i}^2)X_i x_{R,i}}^{\text{Mixing}}$$

Interaction shift





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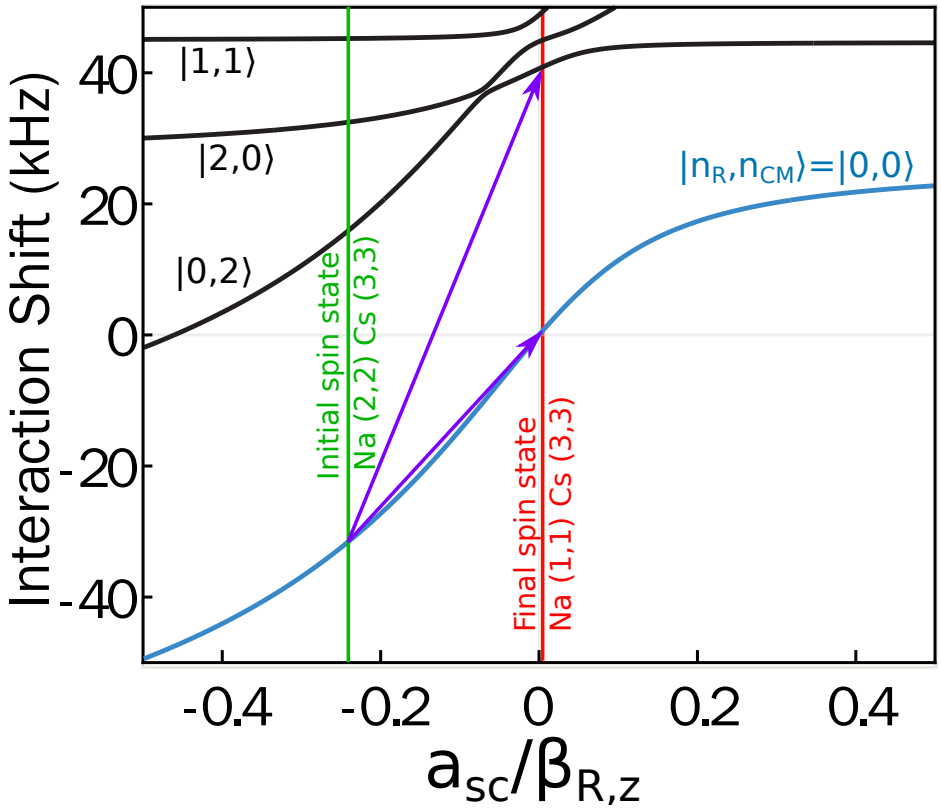
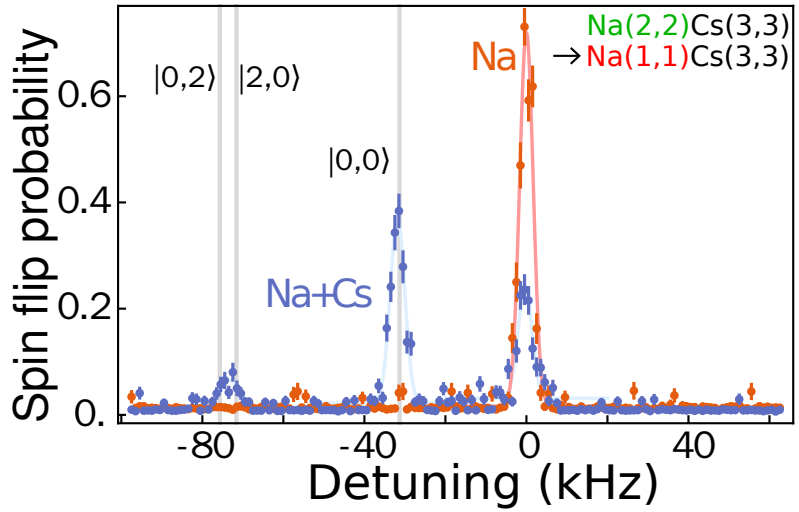
Interaction shift





$$H = \overbrace{\sum_{i=x,y,z}\left(\frac{M\Omega_i^2 X_i^2}{2} + \frac{P_i^2}{2M}\right)}^{\text{Center of mass}} + \overbrace{\sum_{i=x,y,z}\left(\frac{\mu\omega_{R,i}^2 x_{R,i}^2}{2} + \frac{p_{R,i}^2}{2\mu}\right) + V_{int}(\vec{r}_R)}^{\text{Relative}} + \overbrace{\sum_{i=x,y,z}\mu(\omega_{1,i}^2 - \omega_{2,i}^2)X_i x_{R,i}}^{\text{Mixing}}$$

Interaction shift

Combined with binding energy measurement on Na(2,2) Cs(4,4)

Spin state (F, m_F)	Scattering length (a.u.)
Na(2,2) Cs(4,4)	30.36
Na(2,2) Cs(3,3)	-693.8
Na(1,1) Cs(3,3)	13.19

Interaction shift

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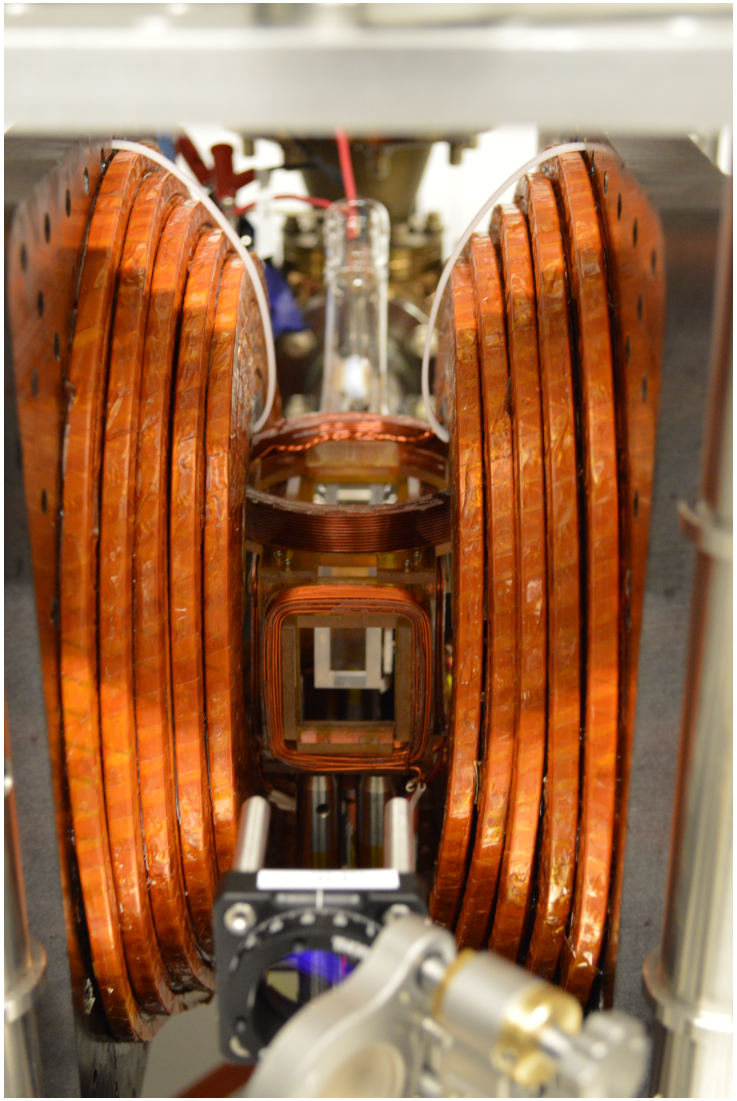
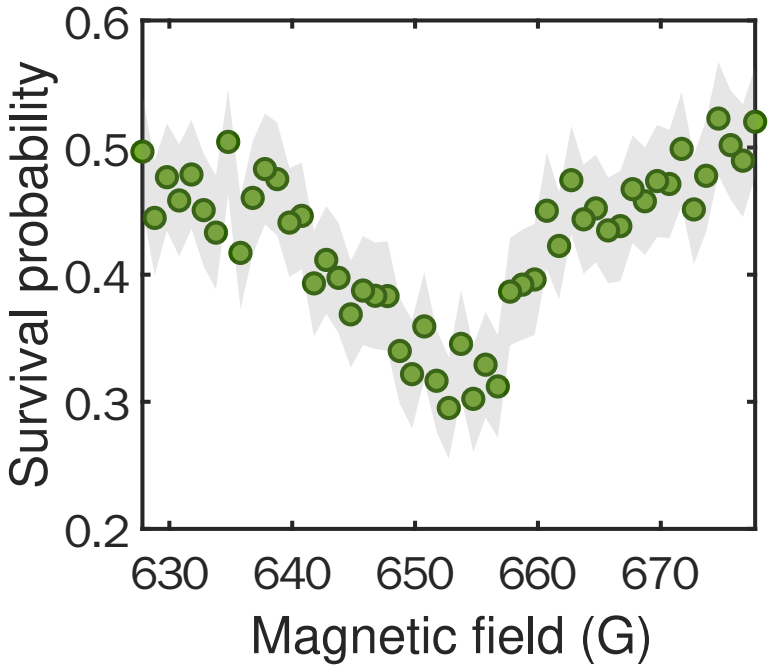
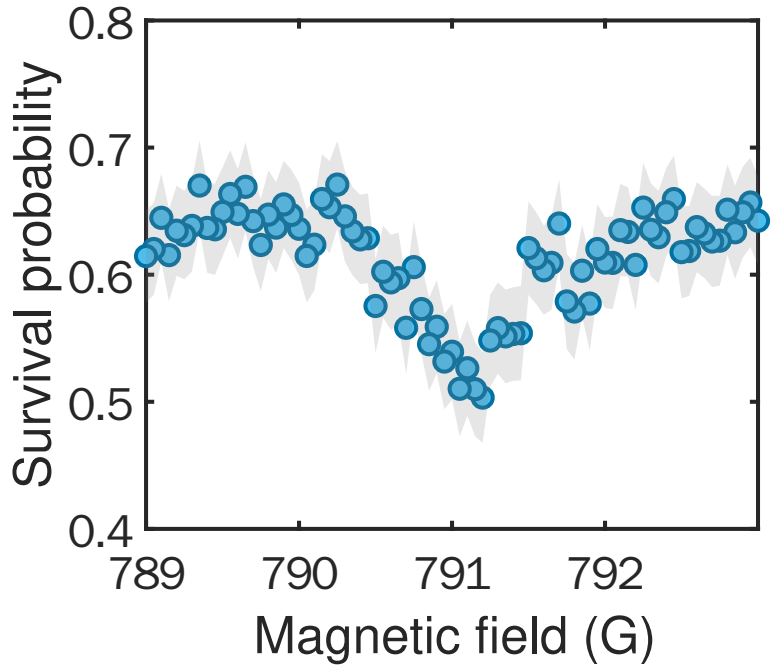
Enhanced coupling to molecular state?

Na (1, -1) Cs (3, -3) Feshbach resonance

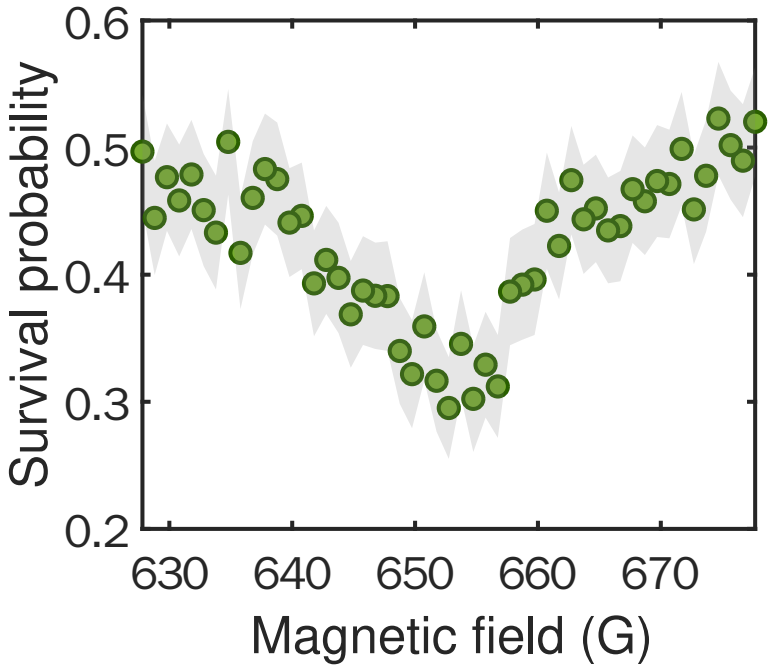


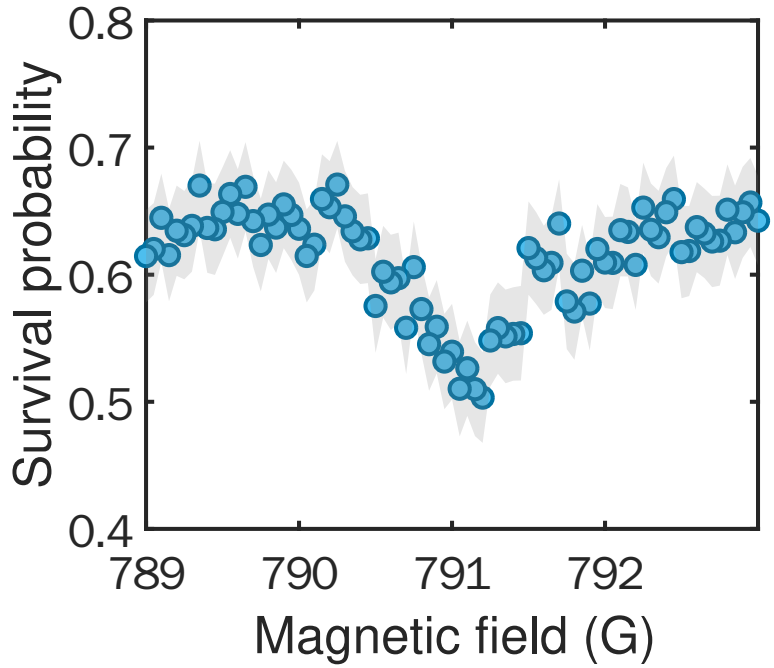
Na (1, -1) Cs (3, -3) Feshbach resonance





Na (1, -1) Cs (3, -3) Feshbach resonance





	s-wave	*p*-wave
Predicted (based on interaction shift)[1]	663 G	799 G
Measured	652(3) G	791.2(2) G

[1] In collaboration with Bo Gao

Conclusion

- Interaction shift of Na and Cs
- Feshbach resonance Na(1,-1) Cs(3,-3)

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Next step

- Make Feshbach molecules
- Optical molecule formation taking advantage of the large scattering length

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Thank you for your attention.