

Interaction between single atoms in optical tweezers

Yichao Yu

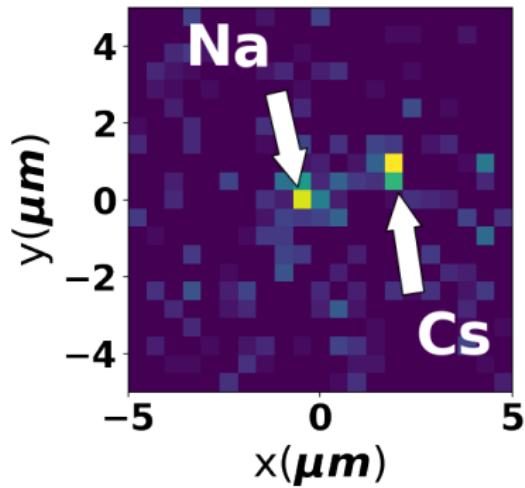
Lee Liu, Kenneth Wang, Lewis Picard, Jonathan Hood

Jessie T. Zhang, Eliot Fenton, Yen-Wei Lin

Ni Group/Harvard

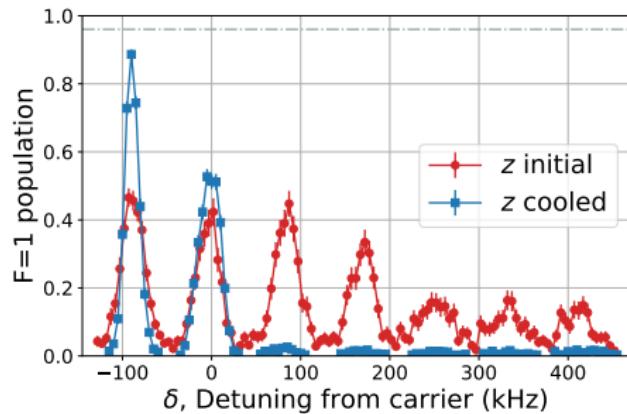
May 29, 2019

Loading



Loading probability per site: 60%
Post select on initial and final state.

Cooling

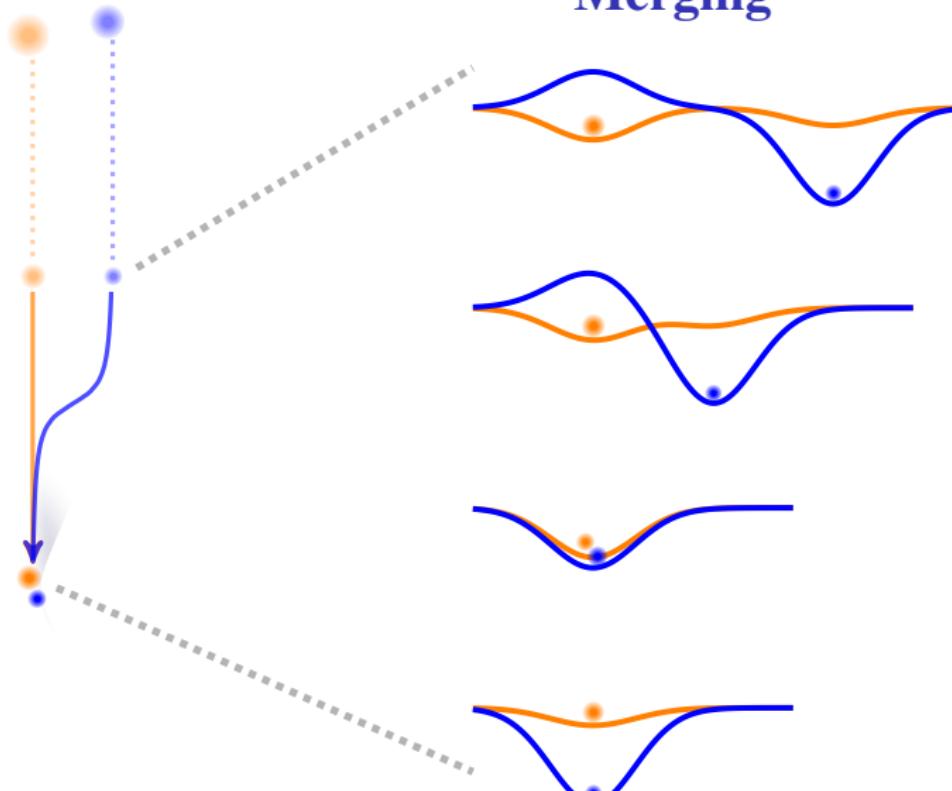


Cs: 96% ground state¹
Na: 94% ground state²

¹Phys. Rev. X 9, 021039

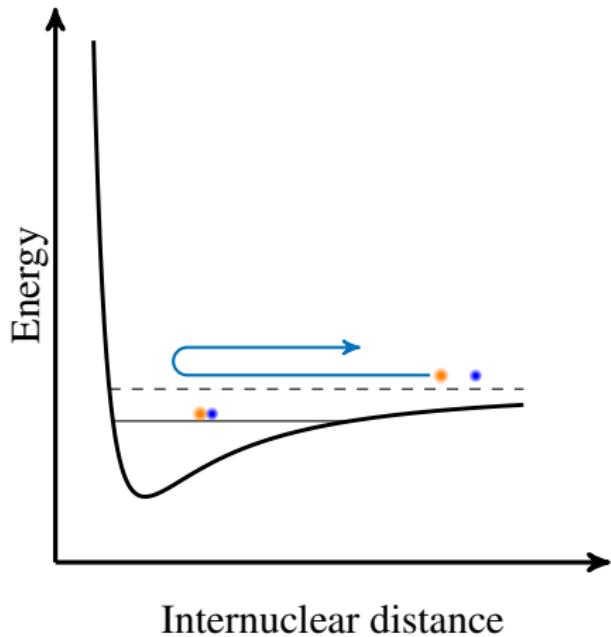
²Phys. Rev. A 97, 063423

Merging



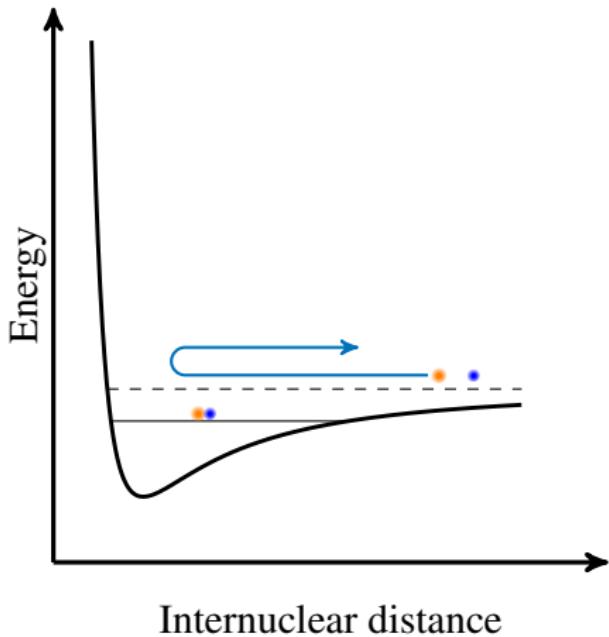
Scattering length a

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



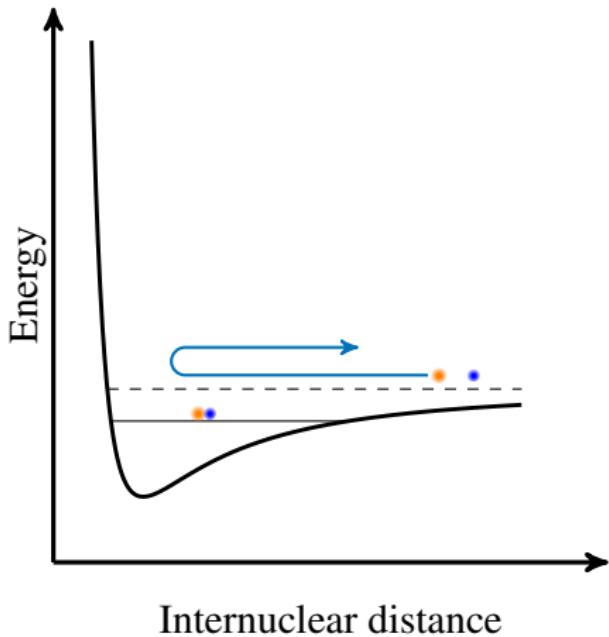
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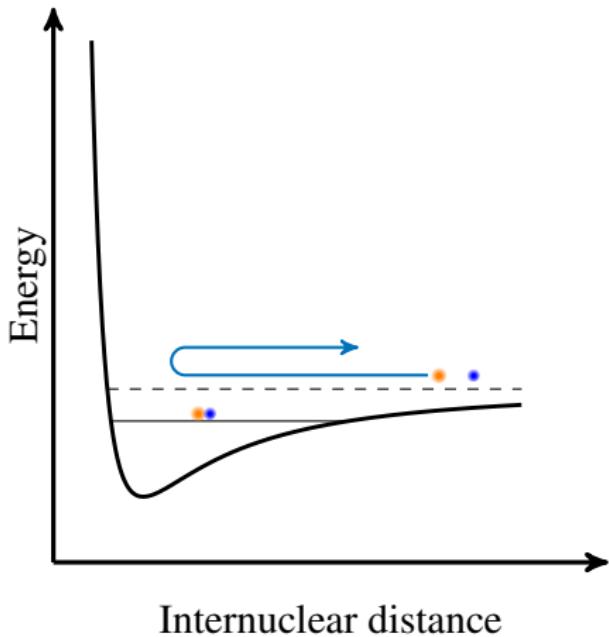
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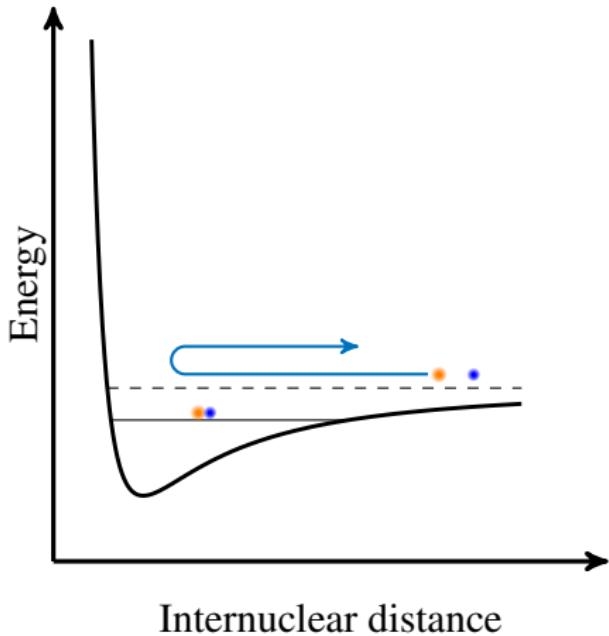
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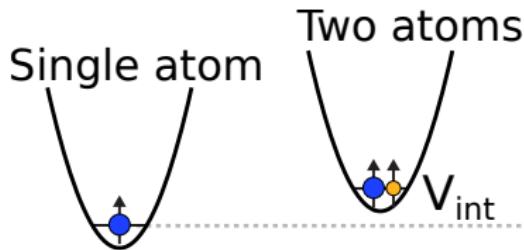


Scattering length a

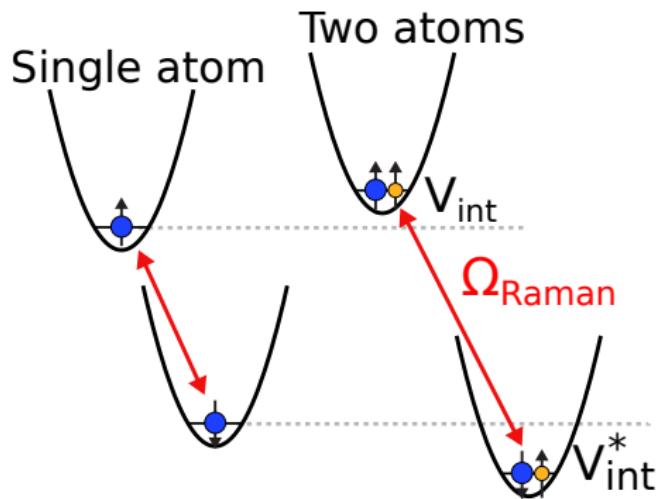
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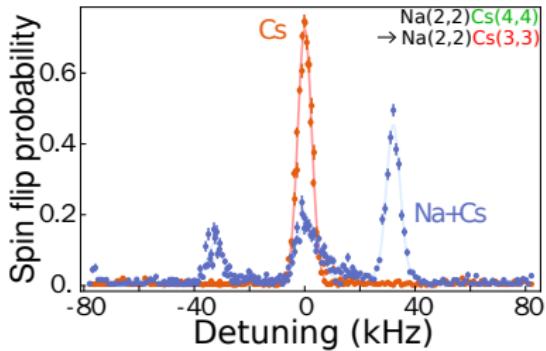
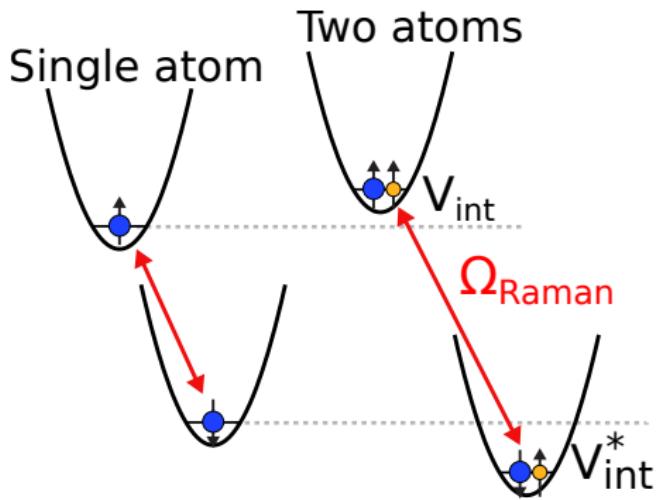
Interaction shift



Interaction shift



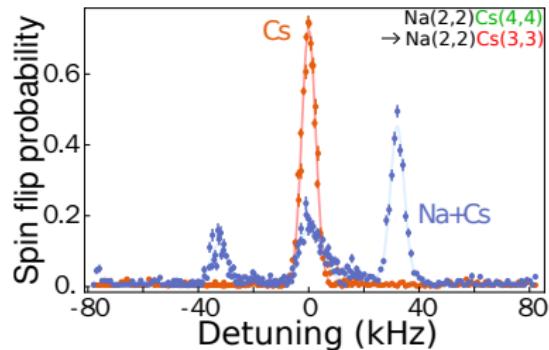
Interaction shift



Interaction shift

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

Interaction



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To center of mass
and relative coordinates

$$M = m_1 + m_2$$

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

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

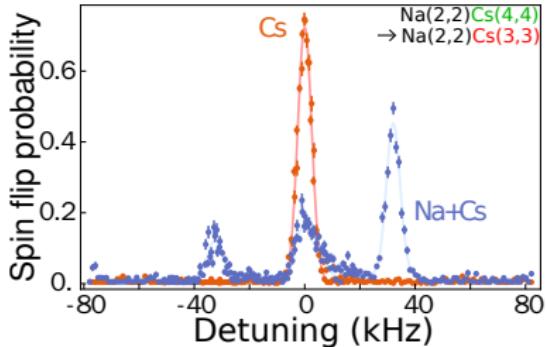
$$\omega_{R,i}^2 = \frac{m_2 \omega_{1,i}^2 + m_1 \omega_{2,i}^2}{m_1 + m_2}$$

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

$$x_{R,i} = x_{1,i} - x_{2,i}$$

$$P_i = p_{1,i} + p_{2,i}$$

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



Center of mass

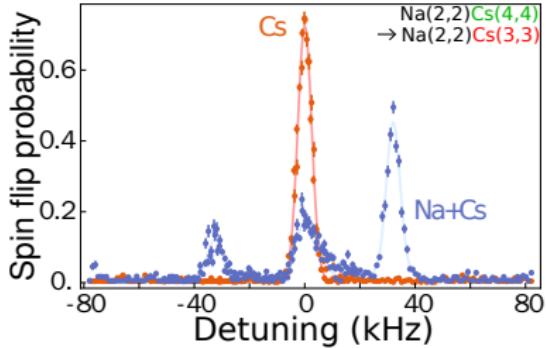
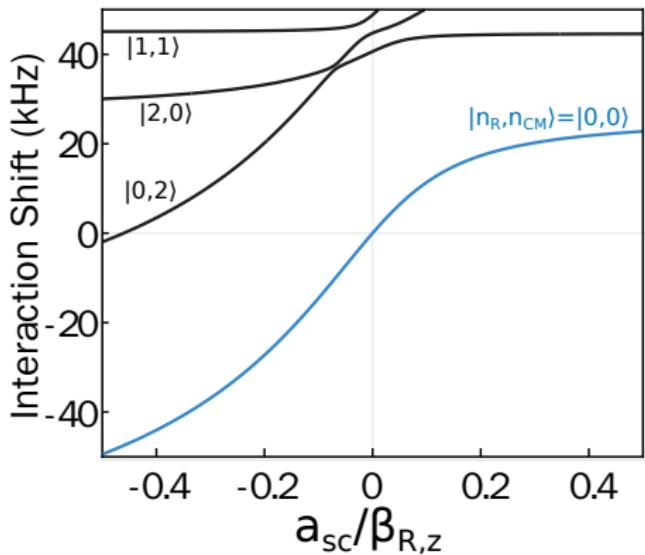
$$H = \underbrace{\sum_{i=x,y,z} \left(\frac{M \Omega_i^2 X_i^2}{2} + \frac{P_i^2}{2M} \right)}_{\text{Center of mass}} + \sum_{i=x,y,z} \left(\frac{\mu \omega_{R,i}^2 X_{R,i}^2}{2} + \frac{p_{R,i}^2}{2\mu} \right) + V_{int}(\vec{r}_R) + \sum_{i=x,y,z} \mu (\omega_{1,i}^2 - \omega_{2,i}^2) X_i X_{R,i}$$

Relative

$$H = \underbrace{\sum_{i=x,y,z} \left(\frac{\mu \omega_{R,i}^2 X_{R,i}^2}{2} + \frac{p_{R,i}^2}{2\mu} \right) + V_{int}(\vec{r}_R)}_{\text{Relative}} + \sum_{i=x,y,z} \mu (\omega_{1,i}^2 - \omega_{2,i}^2) X_i X_{R,i}$$

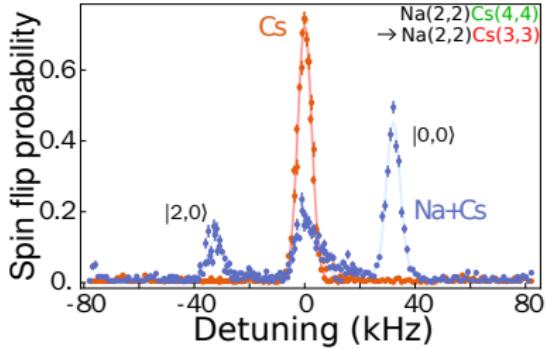
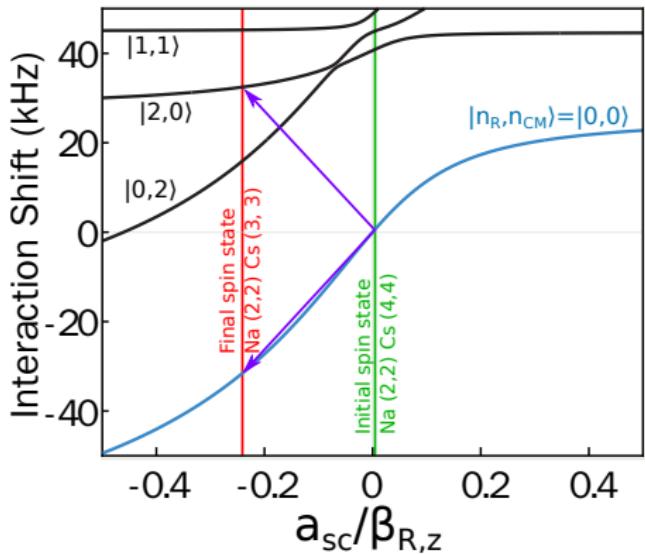
Mixing

Interaction shift



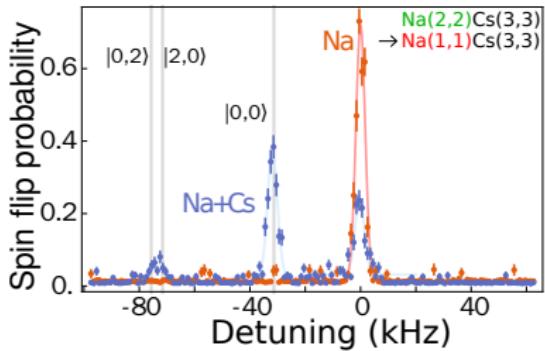
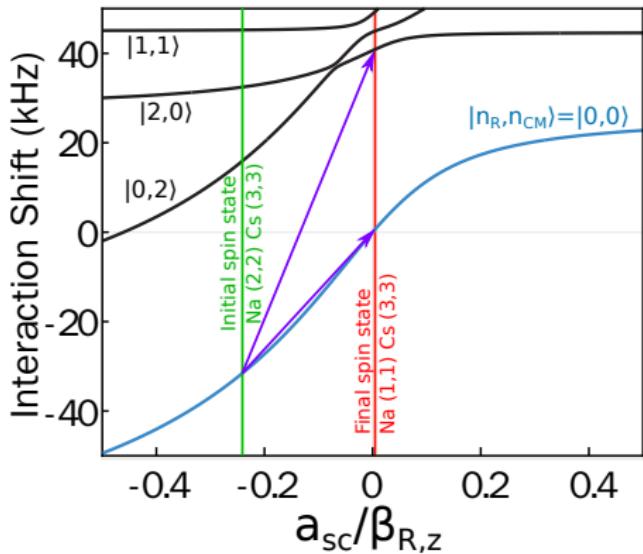
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Interaction shift



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

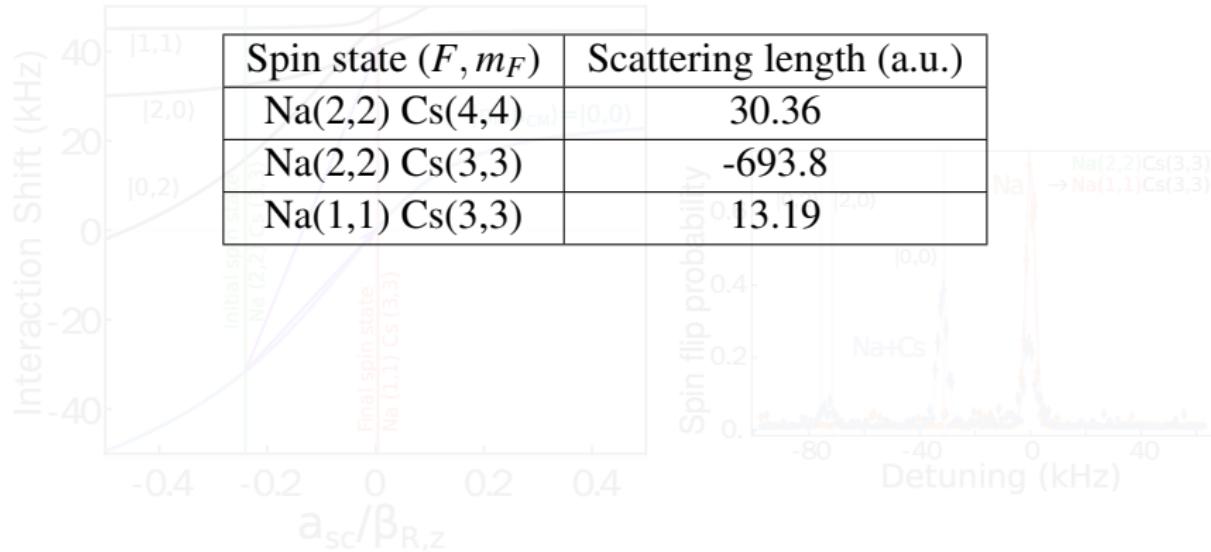
Interaction shift



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Interaction shift

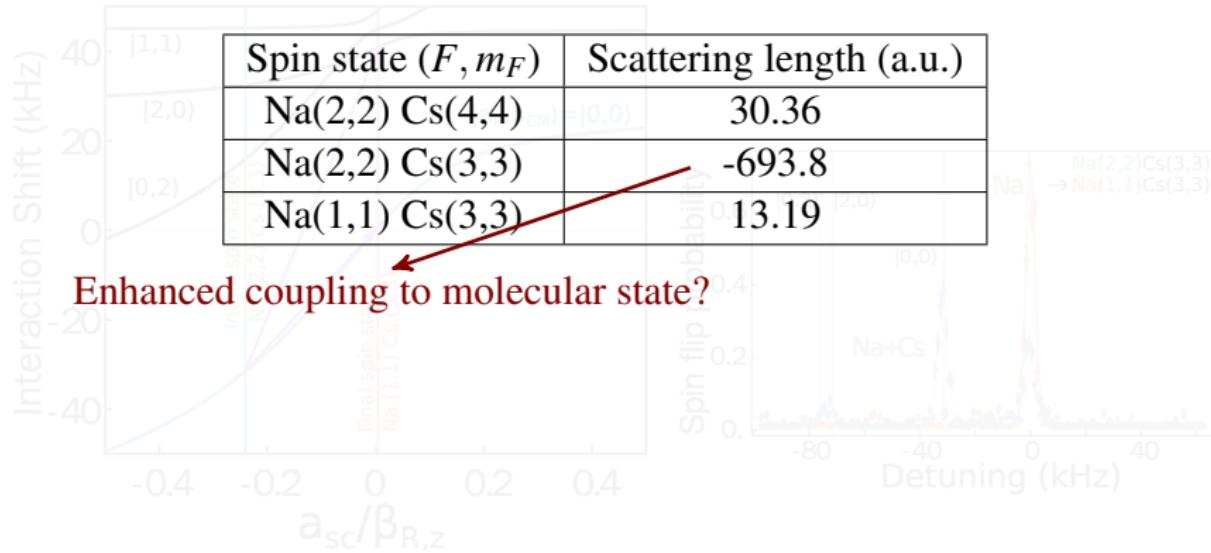
Combined with binding energy measurement on Na(2,2) Cs(4,4)



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Interaction shift

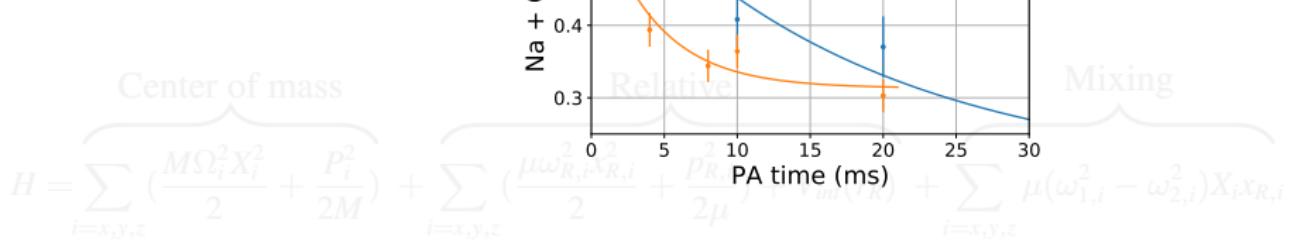
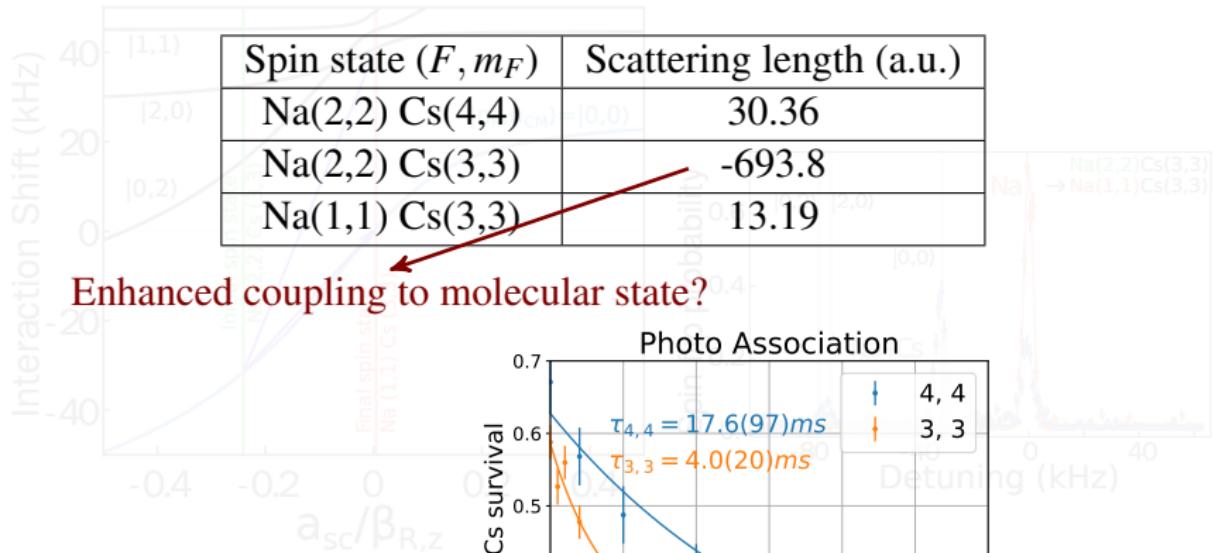
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Interaction shift

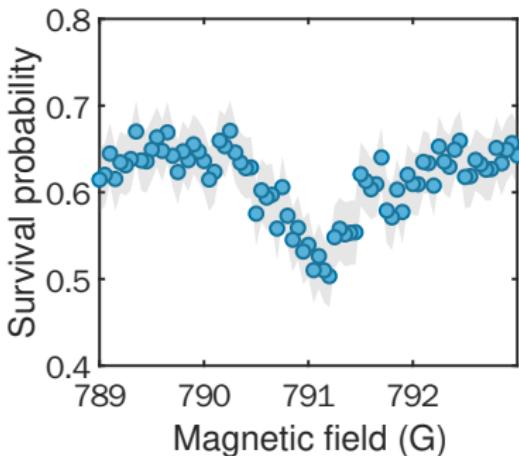
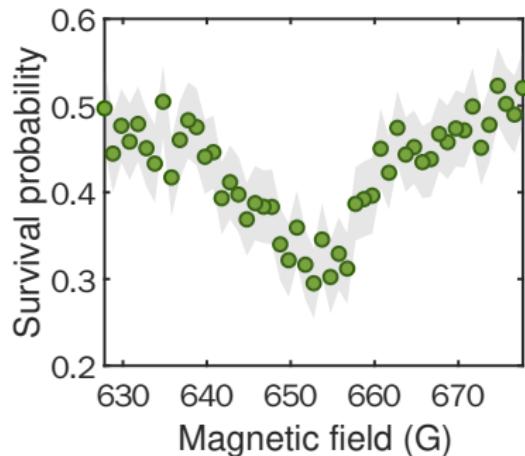
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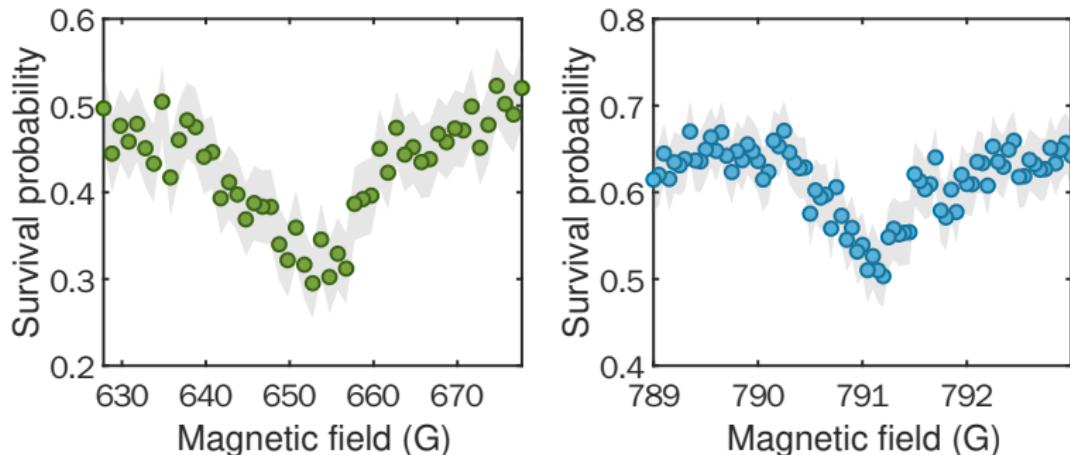
Na (1, -1) Cs (3, -3) Feshbach resonance



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



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



	<i>s</i> -wave	<i>p</i> -wave
Predicted (based on interaction shift) ¹	663 G	799 G
Measured	652(3) G	791.2(2) G

¹In 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.
Poster S01.00155 (Thursday afternoon)