

# Single weakly-bound NaCs molecule in optical tweezers

Yichao Yu

Kenneth Wang, Lewis Picard

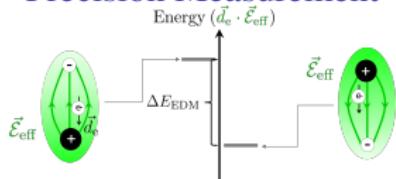
Jessie T. Zhang, William Cairncross

Ni Group/Harvard

June 5, 2020

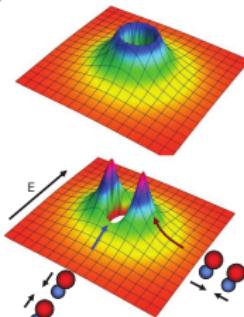
# Molecules

## Precision Measurement



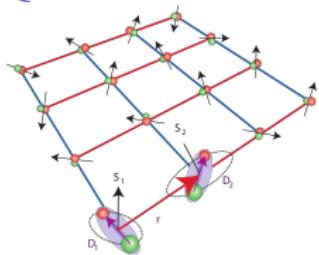
Science 343, p. 269-272 (2014)

## Quantum Chemistry



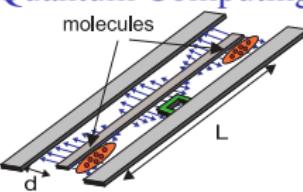
Nature 464, 1324 (2010)

## Quantum Simulation



Nat. Phys. 2, 341 (2006)

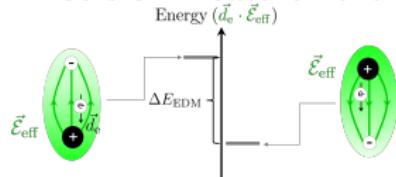
## Quantum Computing



PRL. 97, 33003 (2006)

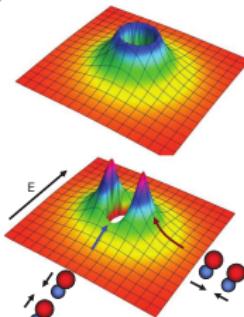
# Molecules

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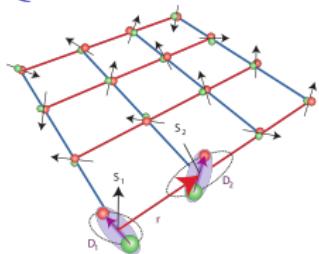
Science 343, p. 269-272 (2014)

## Quantum Chemistry



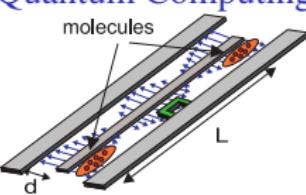
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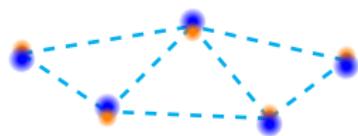
Nat. Phys. 2, 341 (2006)

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PRL. 97, 33003 (2006)

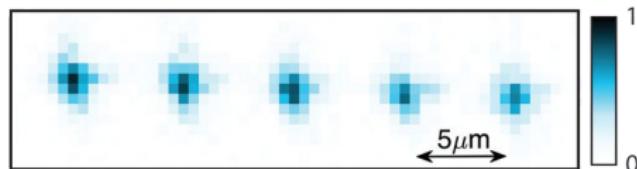
# Optical tweezers



- Single site imaging
- Single site addressing
- Flexible geometry
- ...

# Ultracold molecule in tweezers

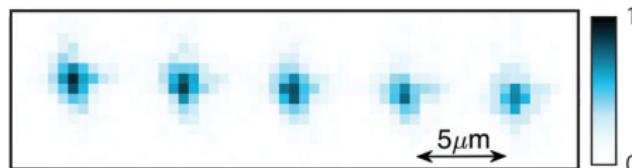
## Direct cooling



Science 365, p. 1156-1158 (2019)

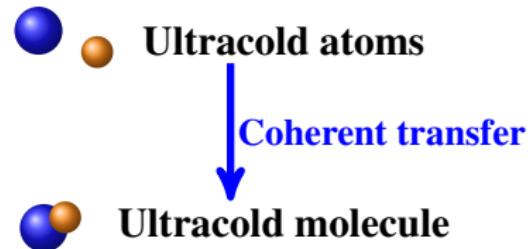
# Ultracold molecule in tweezers

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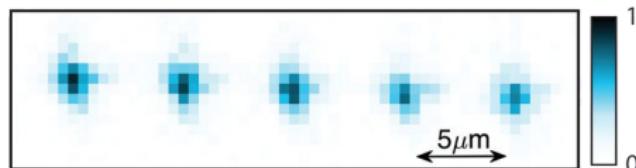
Science 365, p. 1156-1158 (2019)

## Assembly



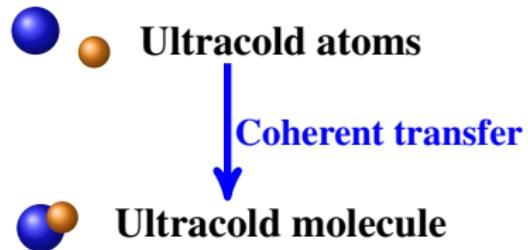
# Ultracold molecule in tweezers

## Direct cooling



Science 365, p. 1156-1158 (2019)

## Assembly



## Challenges

- Temperature in tweezer
- Quantum control

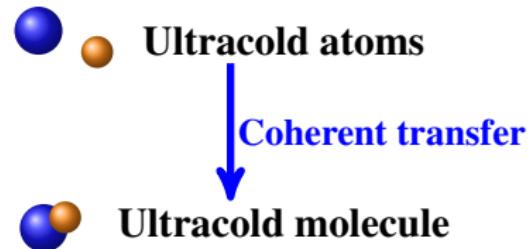
# Ultracold molecule in tweezers

## Direct cooling



Science 365, p. 1156-1158 (2019)

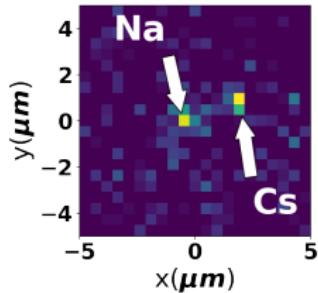
## Assembly



## Challenges

- Temperature in tweezer
- Quantum control
- Creating molecules
- Maintain coherence

## Loading

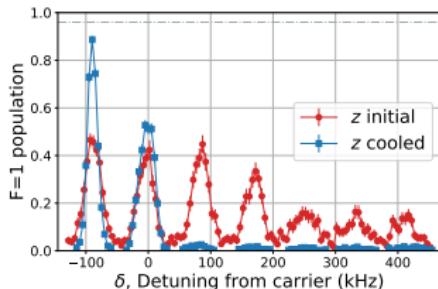


NJP. 19, 023007 (2017)

## Merging



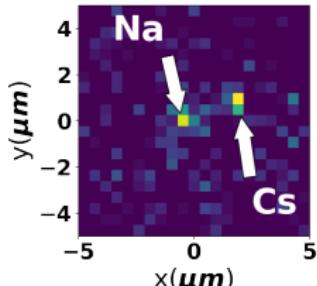
## Cooling



PRA. 97, 063423 (2018)

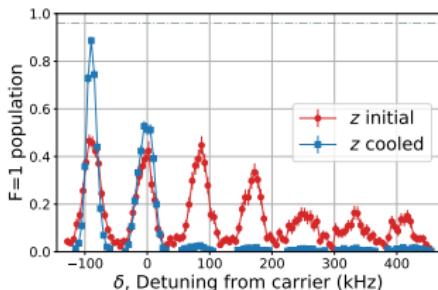
PRX. 9, 021039 (2019)

## Loading



NJP. 19, 023007 (2017)

## Cooling

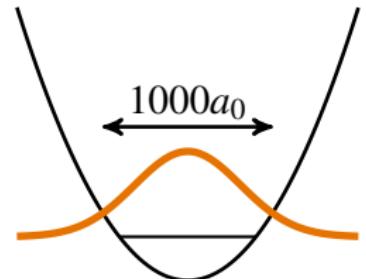


PRA. 97, 063423 (2018)

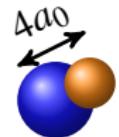
## Merging



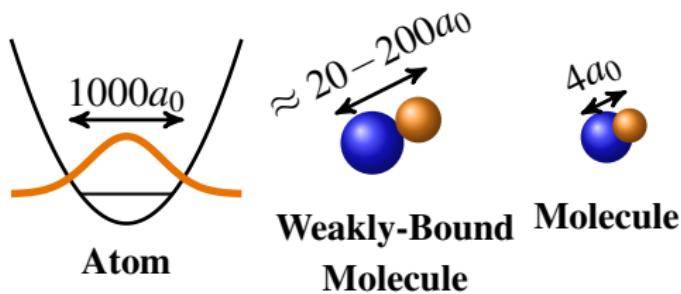
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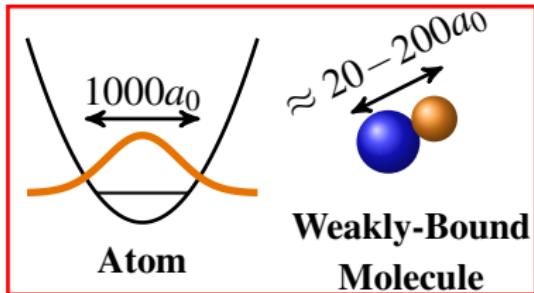


## Atom

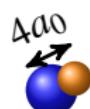


## Molecule

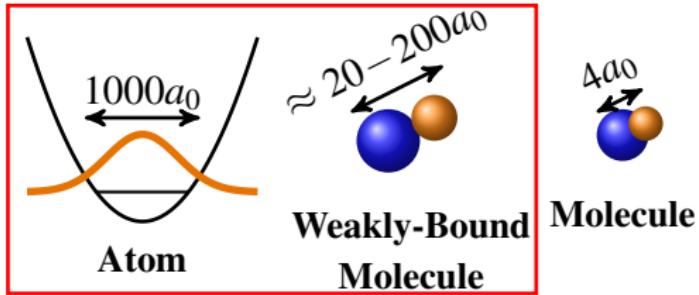




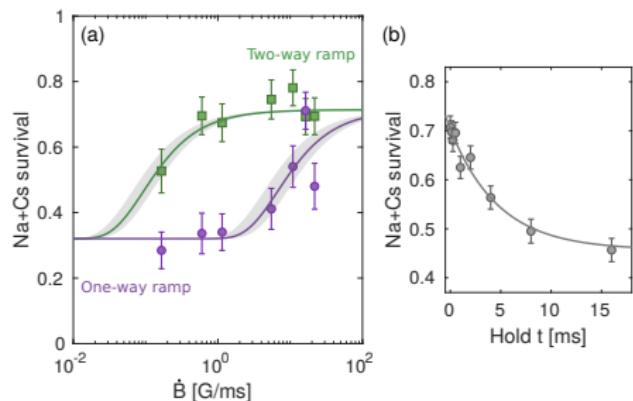
**Weakly-Bound Molecule**



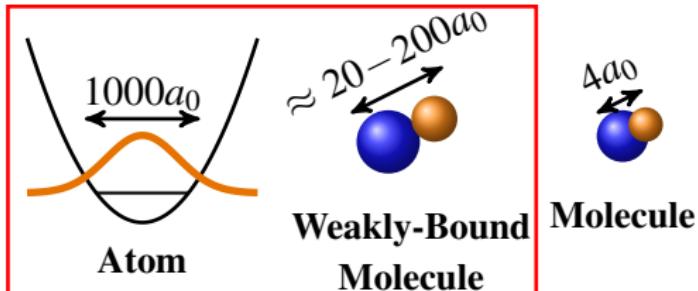
**Molecule**



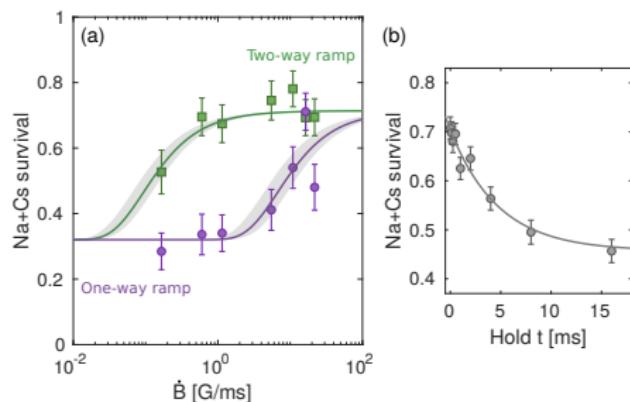
## Feshbach molecule



arXiv:2003.07850 (accepted by PRL)

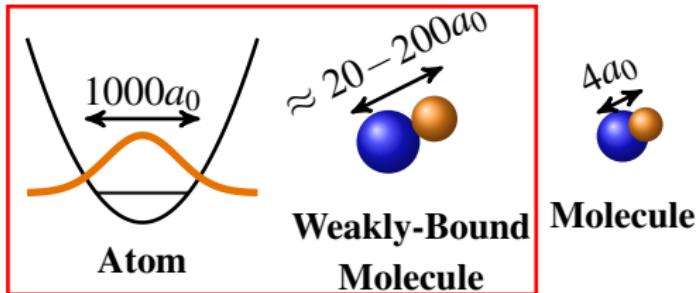


## Feshbach molecule



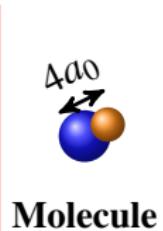
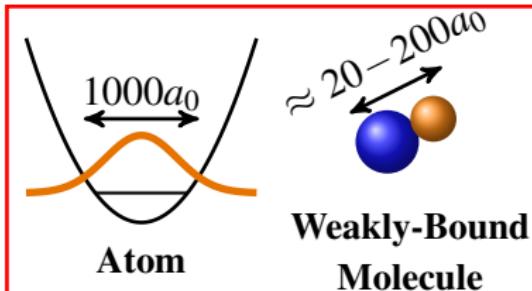
- Requires Feshbach resonance
- Usually large magnetic field

arXiv:2003.07850 (accepted by PRL)



## Optical transfer

- More general
- Faster

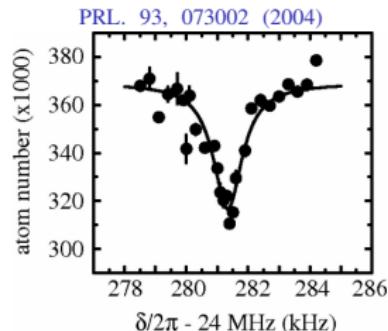


## Optical transfer

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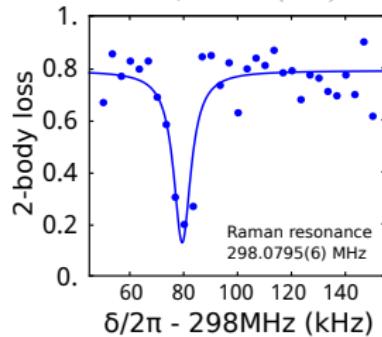
## Previous results

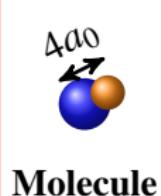
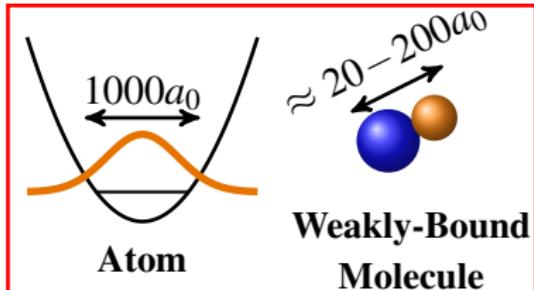
Rb<sub>2</sub> Science 287, p. 1016-1019 (2000)



Sr<sub>2</sub> PRL. 96, 203201 (2006)

NaCs PRX. 9, 021039 (2019)





## Optical transfer

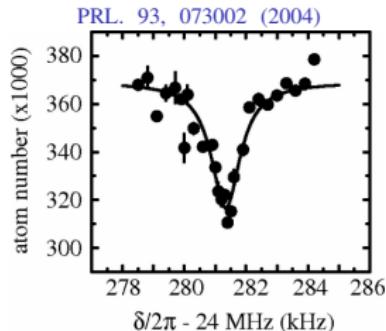
- More general
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## Limitations so far

- Incoherent due to scattering
- Rely on narrow line optical transition

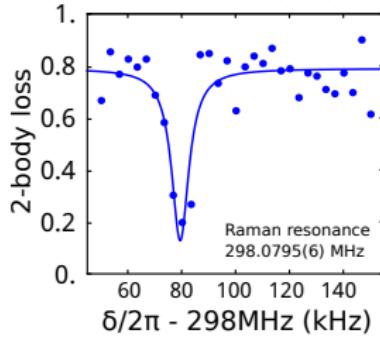
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$\text{Rb}_2$  Science 287, p. 1016-1019 (2000)

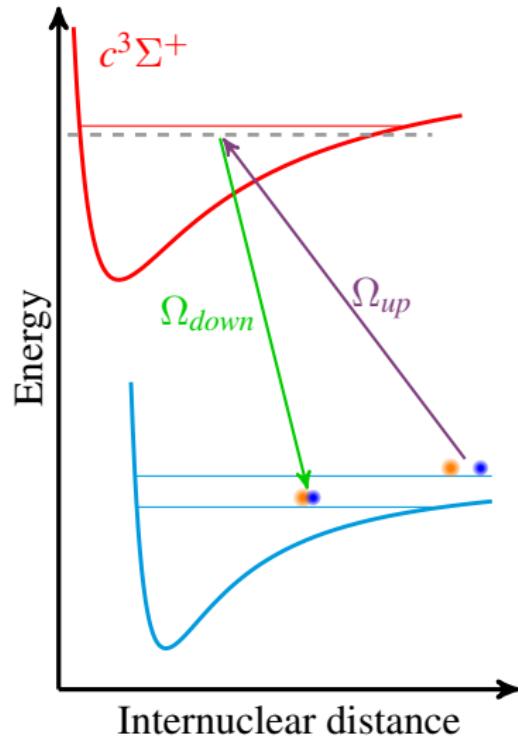


$\text{Sr}_2$  PRL. 96, 203201 (2006)

$\text{NaCs}$  PRX. 9, 021039 (2019)



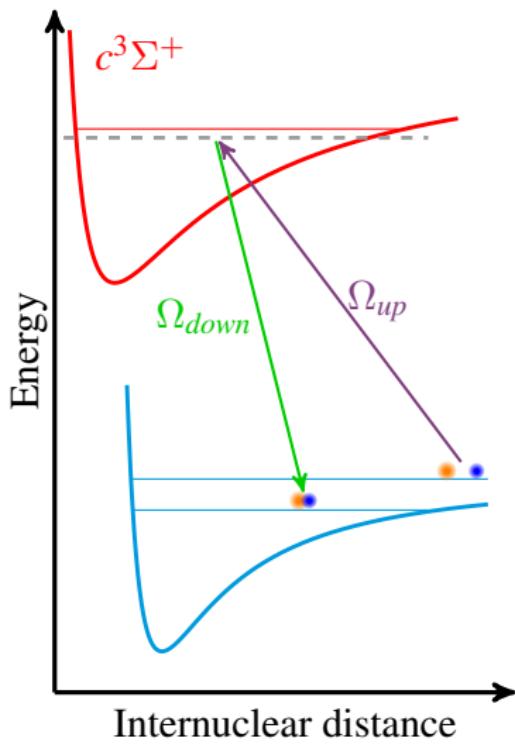
# Raman transfer



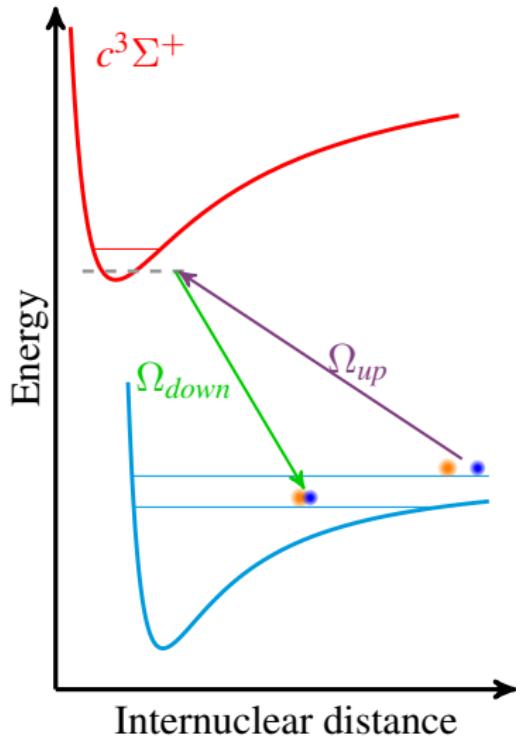
# Raman transfer

## Near threshold states

- Stronger coupling ( $\Omega_{up}$  and  $\Omega_{down}$ )
- Closely spaced
- Fast scattering



# Raman transfer



## Near threshold states

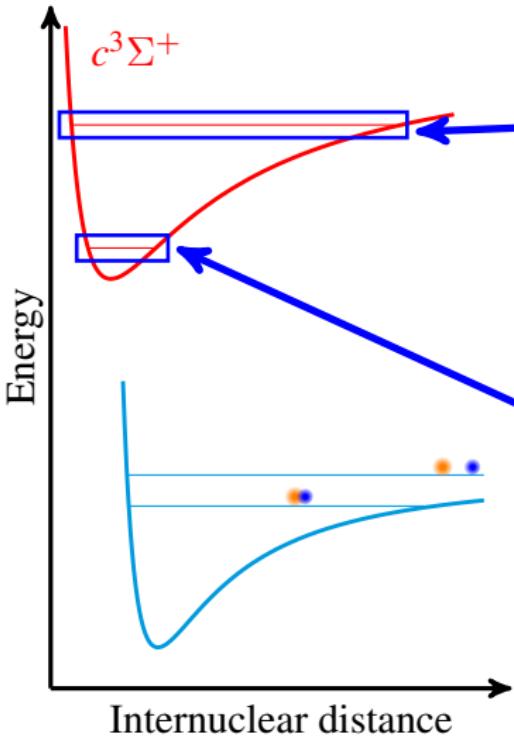
- Stronger coupling ( $\Omega_{up}$  and  $\Omega_{down}$ )
- Closely spaced
- Fast scattering

## Deeply bound states

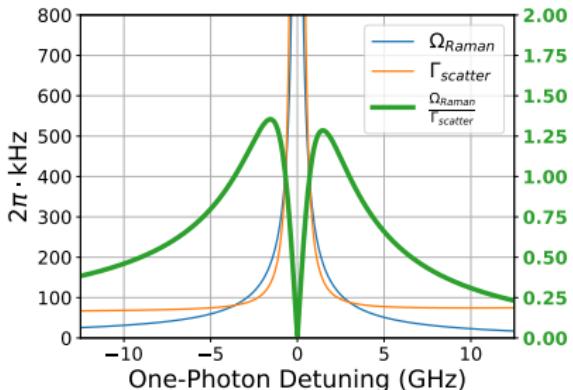
- Weaker coupling
- Sparsely spaced
- Allow larger detuning
- Slower scattering

arXiv:1701.03121(2017)

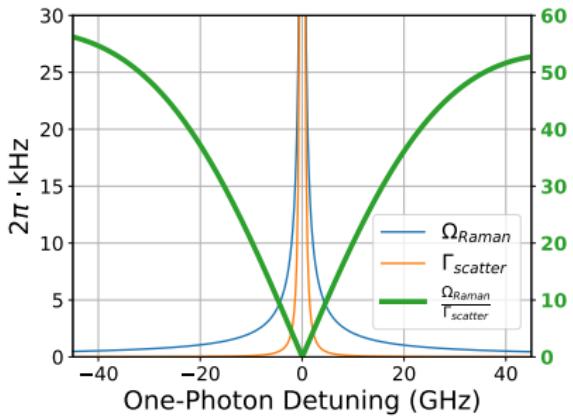
## Raman transfer



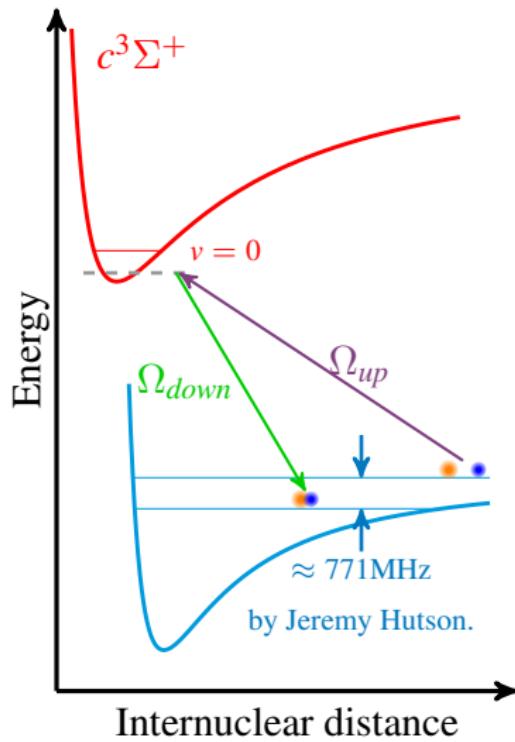
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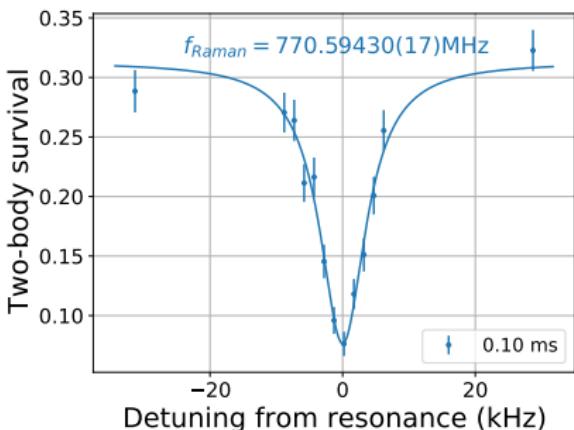
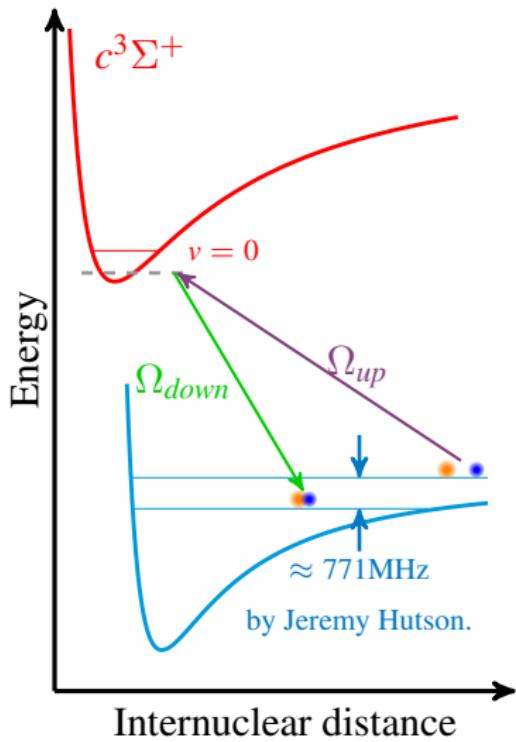
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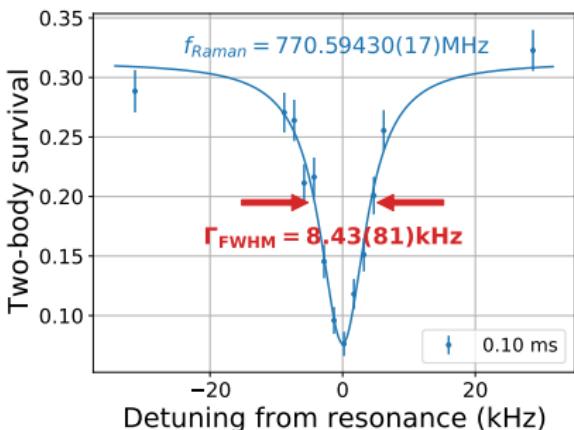
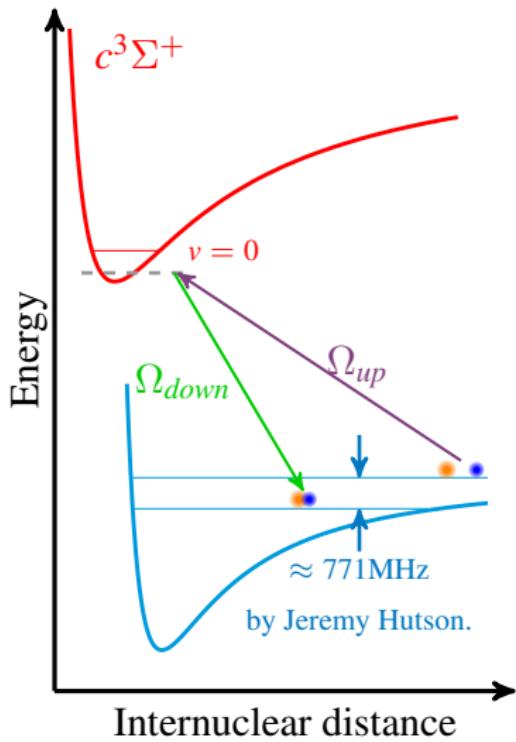
# Experiment



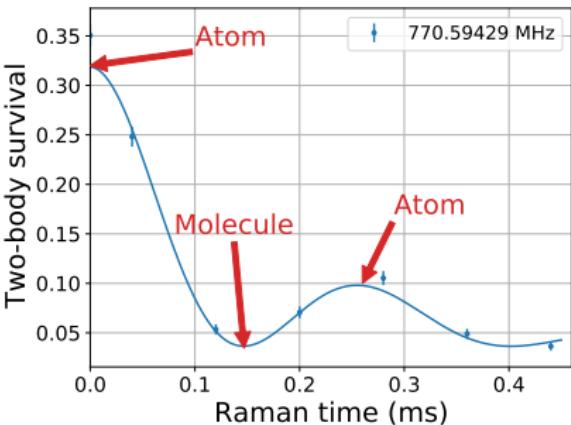
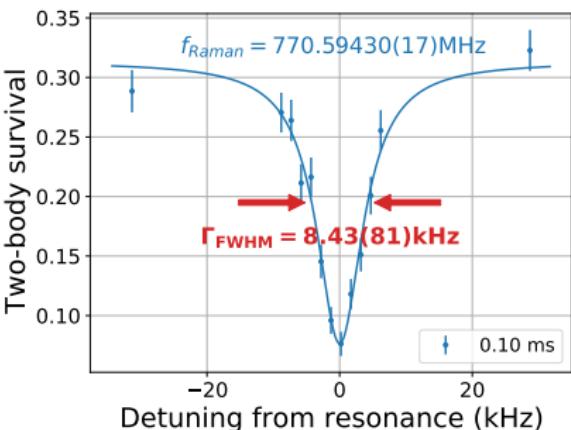
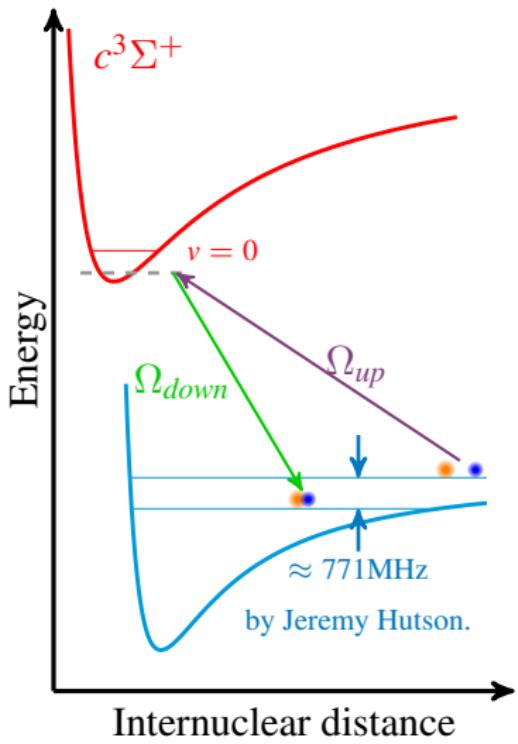
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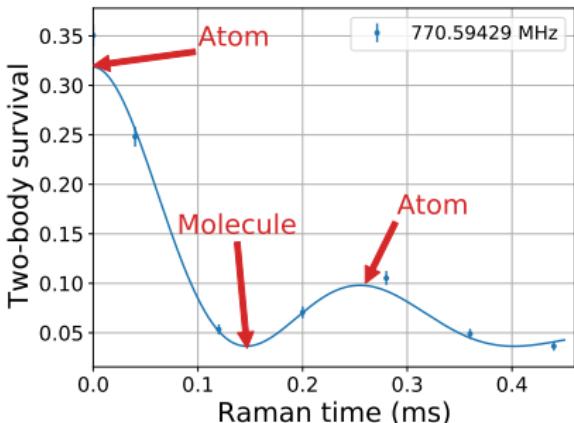
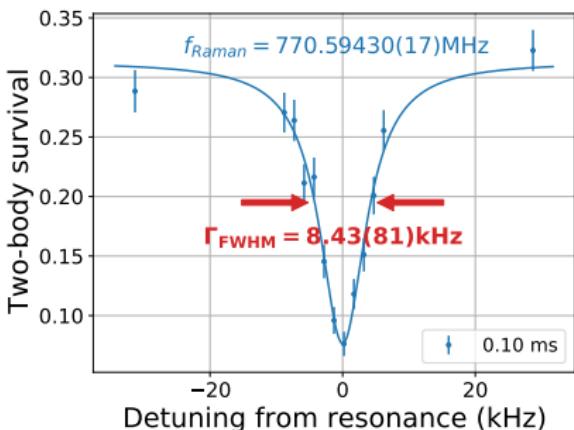
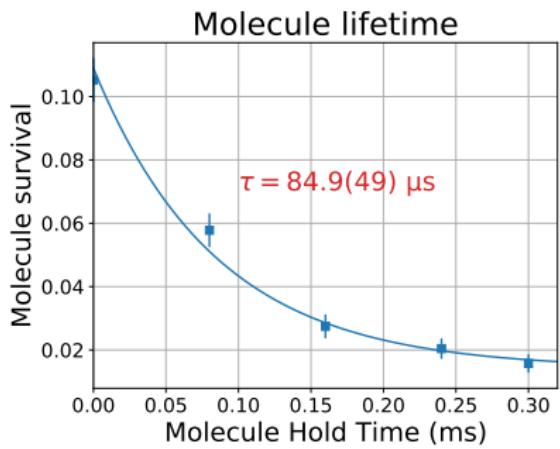


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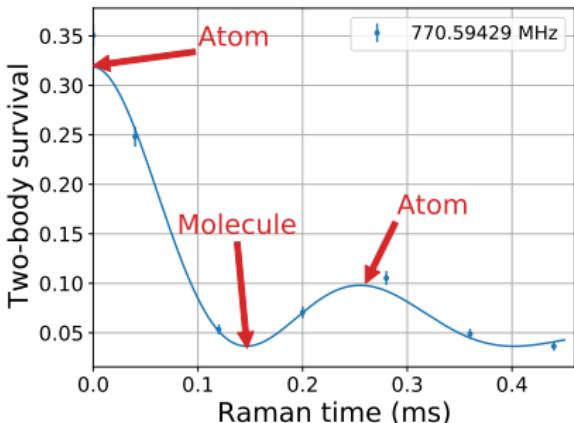
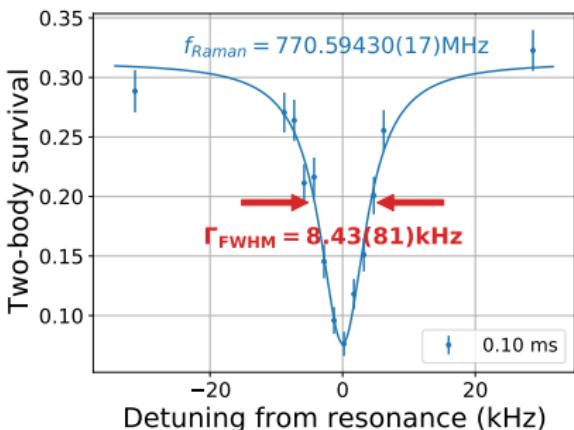
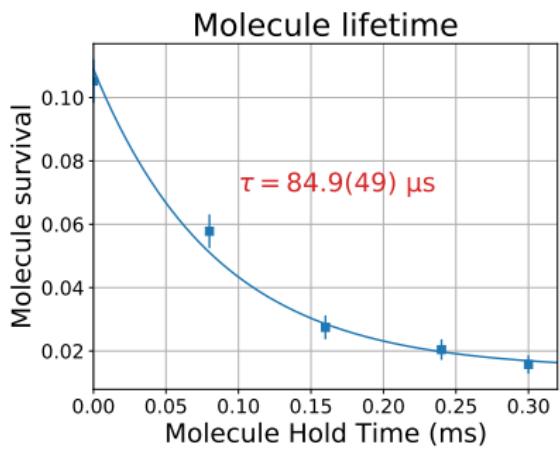
# Experiment

- Transferred 50% of ground state atom to molecule.
- > 50% of molecule in motional ground state.



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## Conclusion and Outlook

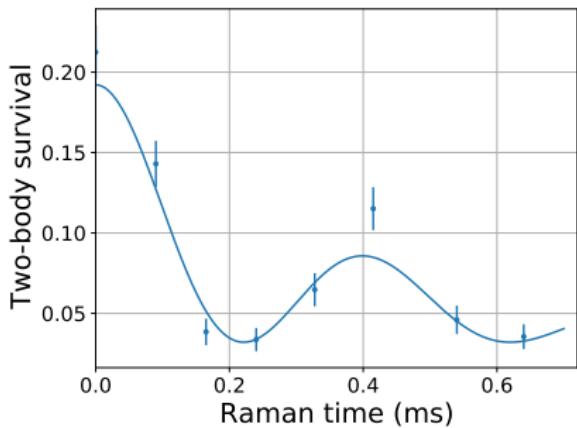
- Demonstrated formation of weakly-bound NaCs molecules while maintaining quantum control.
- Improve signal contrast.
- Feshbach molecule ( $\tau = 4.7(7)$  ms)

arXiv:2003.07850

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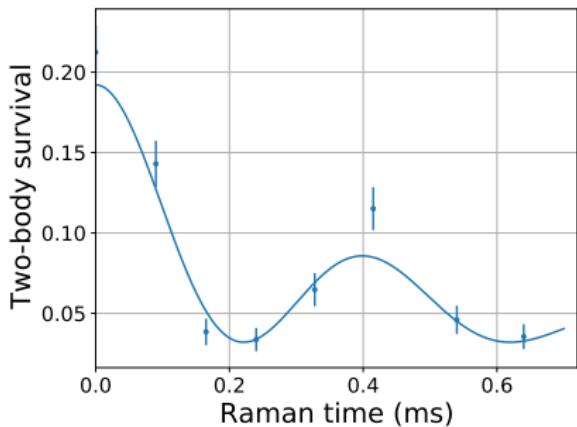
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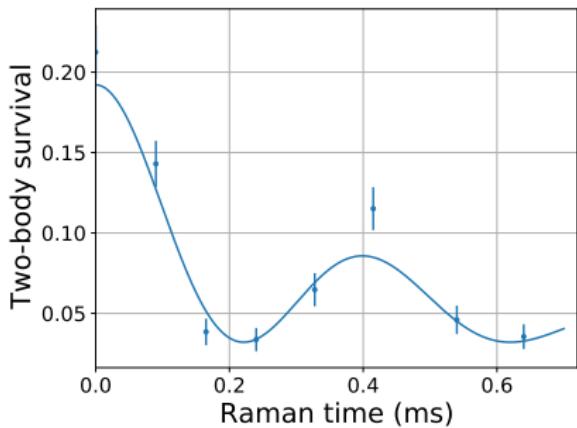
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Poster Q01.00108

