

Single weakly-bound NaCs molecule in optical tweezers

Yichao Yu

Kenneth Wang, Lewis Picard

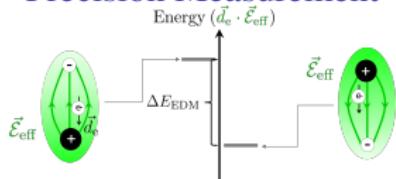
Jessie T. Zhang, William Cairncross

Ni Group/Harvard

June 5, 2020

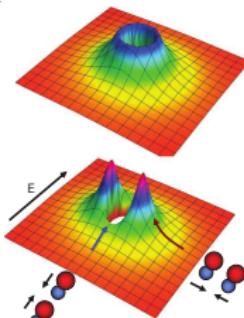
Molecules

Precision Measurement



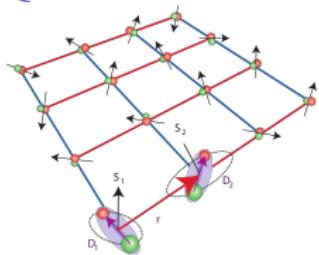
Science 343, p. 269-272 (2014)

Quantum Chemistry



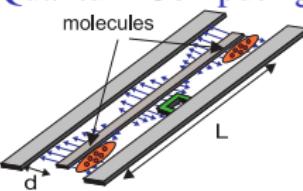
Nature 464, 1324 (2010)

Quantum Simulation



Nat. Phys. 2, 341 (2006)

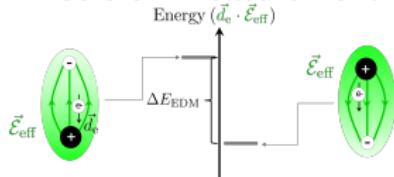
Quantum Computing



PRL. 97, 33003 (2006)

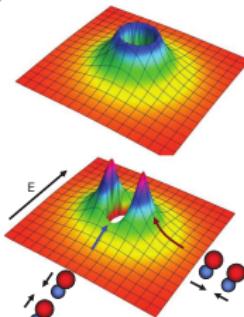
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Precision Measurement



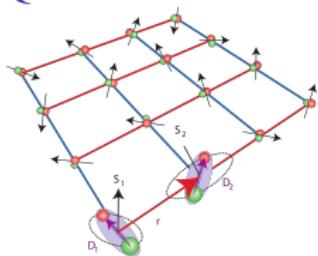
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Quantum Chemistry



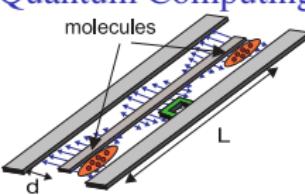
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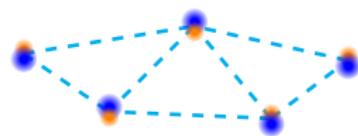
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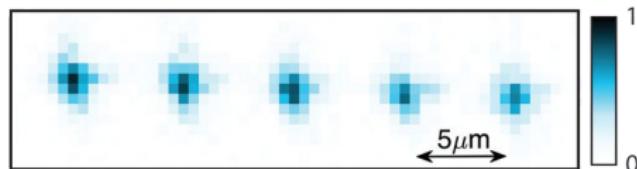
Optical tweezers



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

Ultracold molecule in tweezers

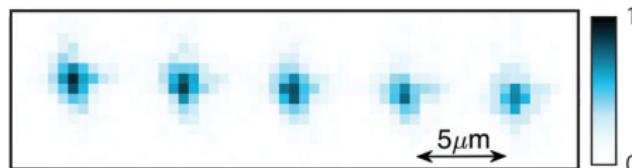
Direct cooling



Science 365, p. 1156-1158 (2019)

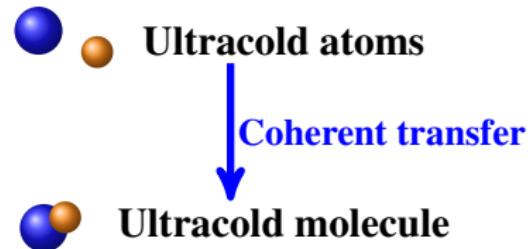
Ultracold molecule in tweezers

Direct cooling



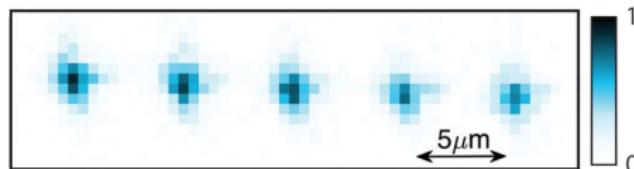
Science 365, p. 1156-1158 (2019)

Assembly



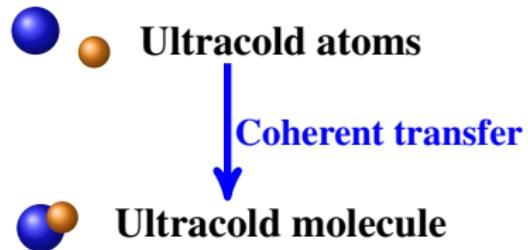
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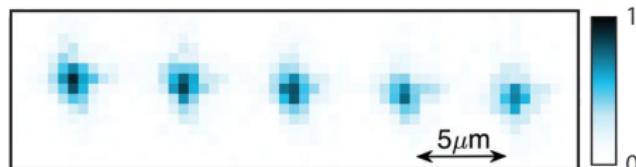


Challenges

- Temperature in tweezers
- Quantum control

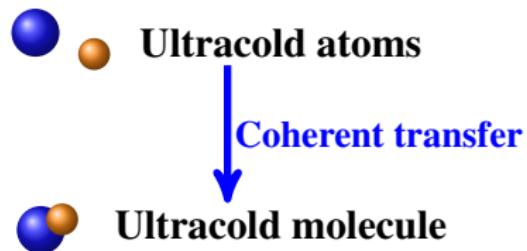
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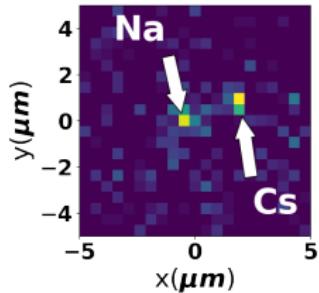
Assembly



Challenges

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

Loading

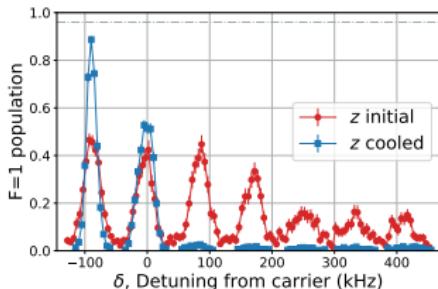


NJP. 19, 023007 (2017)

Merging



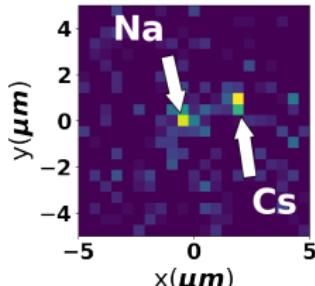
Cooling



PRA. 97, 063423 (2018)

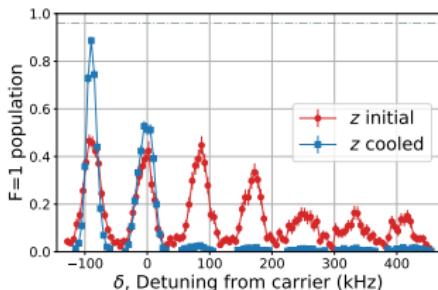
PRX. 9, 021039 (2019)

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NJP. 19, 023007 (2017)

Cooling

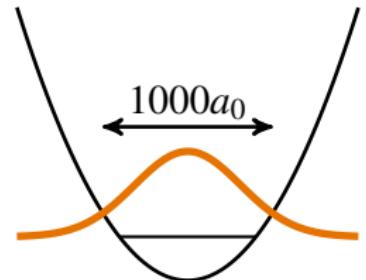


PRA. 97, 063423 (2018)

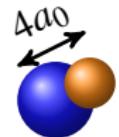
Merging



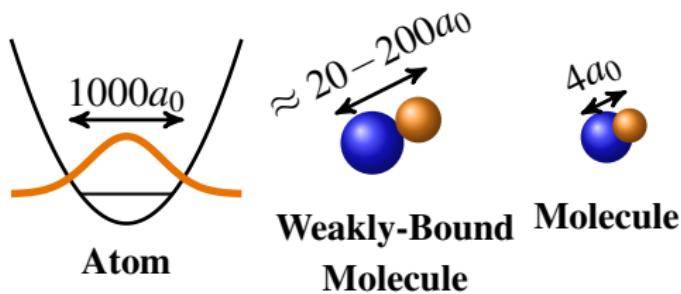
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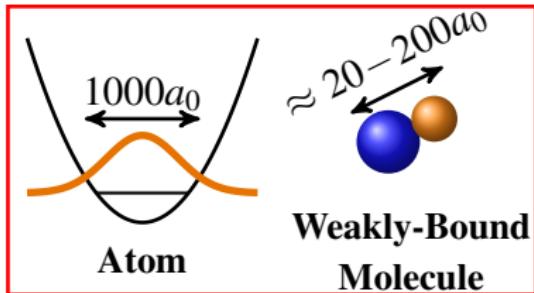


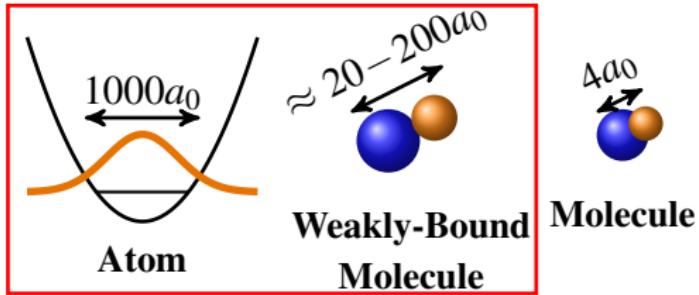
Atom



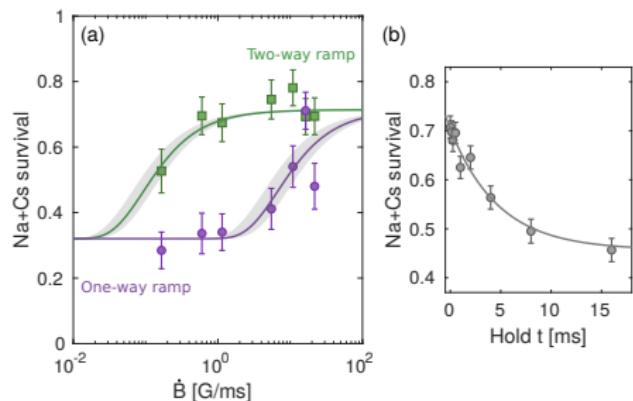
Molecule



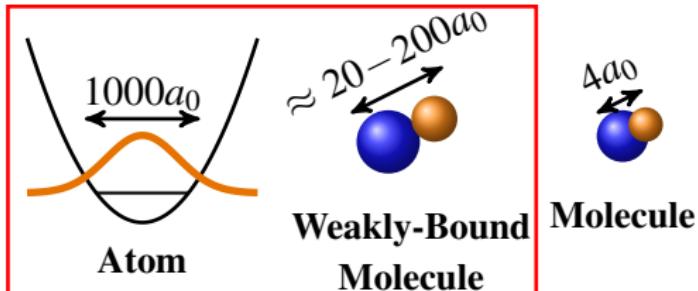




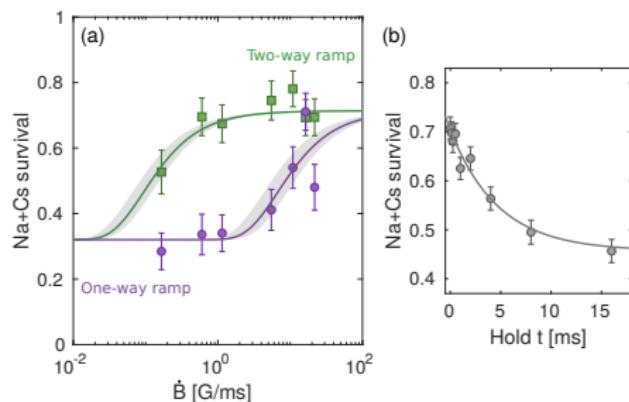
Feshbach molecule



arXiv:2003.07850 (accepted by PRL)

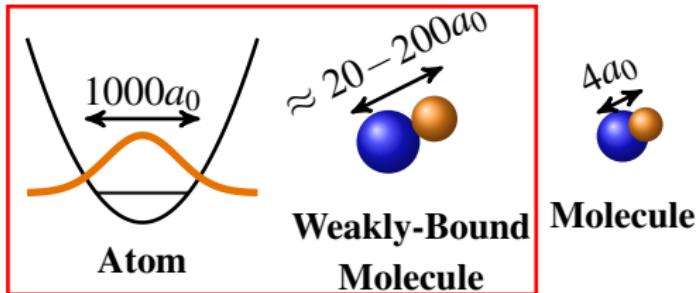


Feshbach molecule



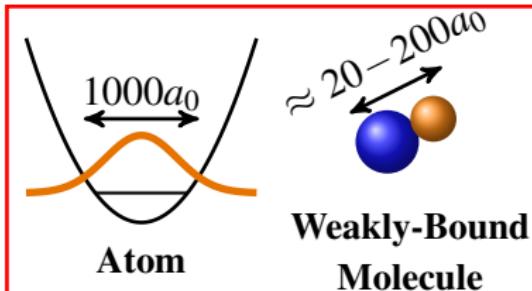
- Requires Feshbach resonance
- Usually large magnetic field

arXiv:2003.07850 (accepted by PRL)



Optical transfer

- More general
- Faster



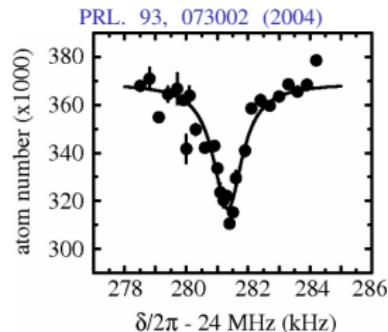
Molecule

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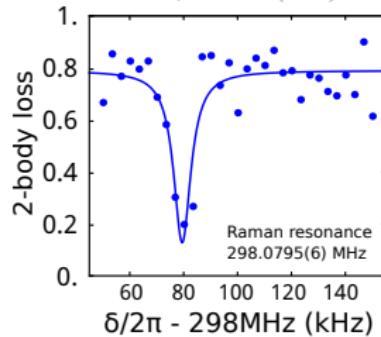
Previous results

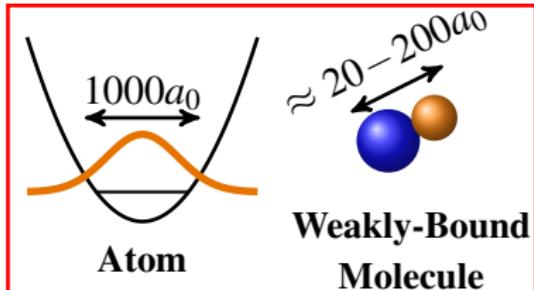
Rb_2 Science 287, p. 1016-1019 (2000)



Sr_2 PRL. 109, 115302 (2012)

NaCs PRX. 9, 021039 (2019)





Molecule

Optical transfer

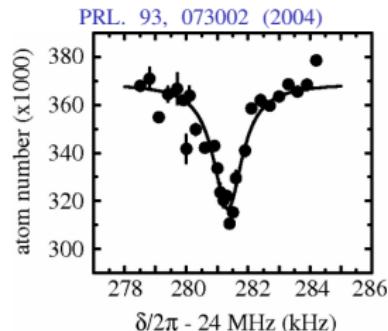
- More general
- Faster

Limitations so far

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

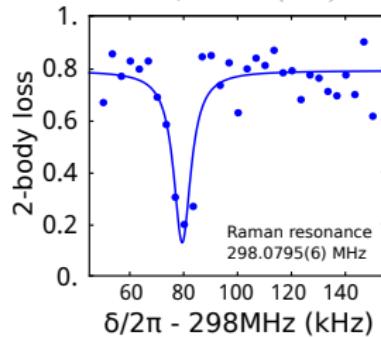
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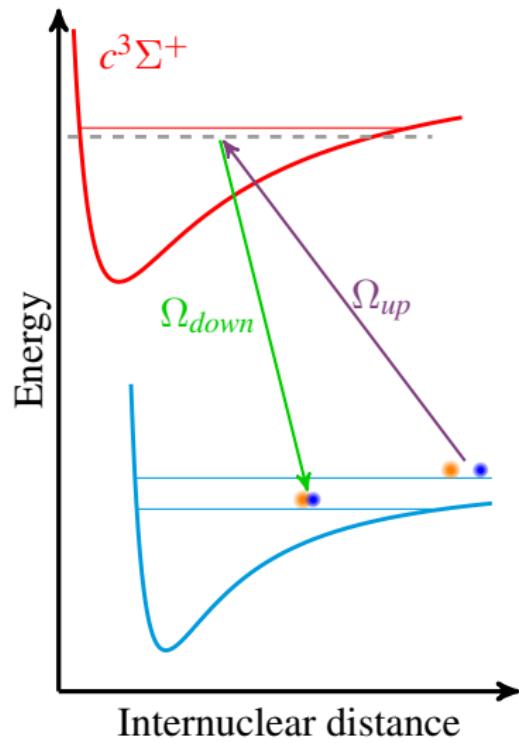


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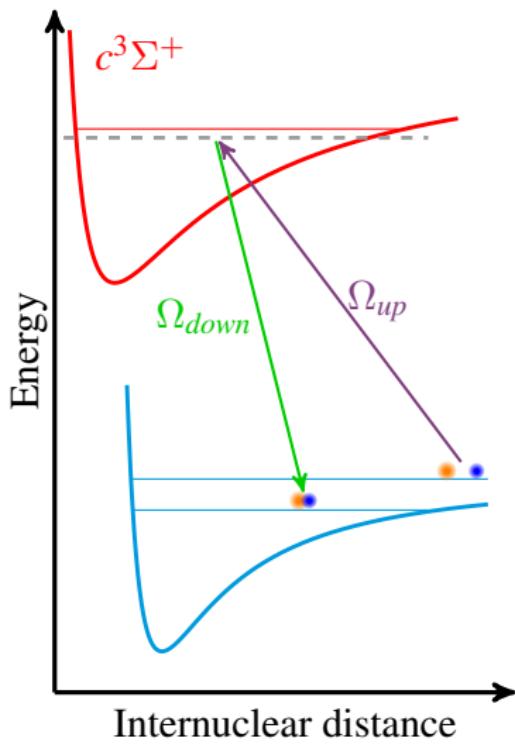
Raman transfer



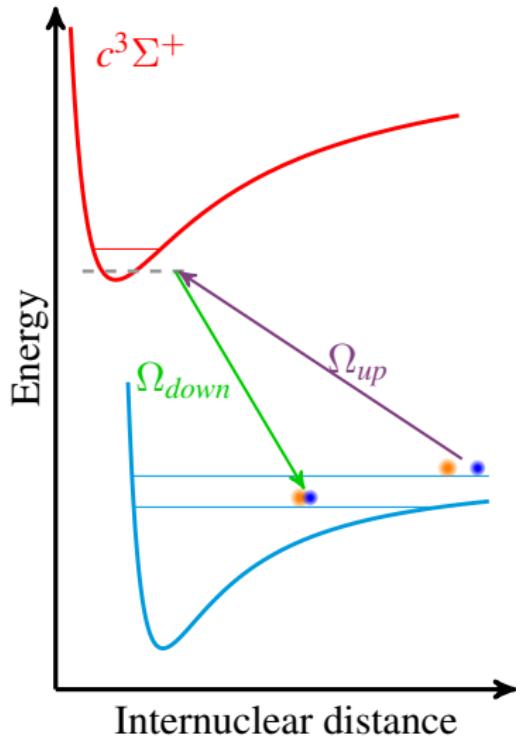
Raman transfer

Near threshold states

- Stronger coupling (Ω_{up} and Ω_{down})
- Closely spaced
- Fast scattering



Raman transfer



Near threshold states

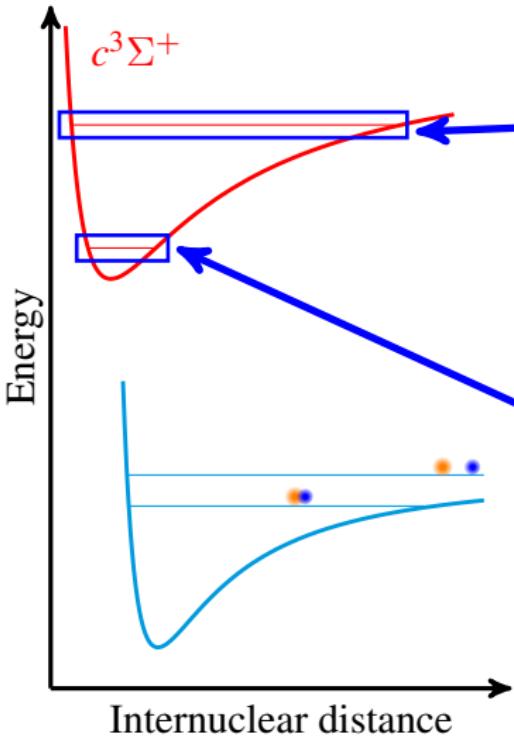
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- Closely spaced
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Deeply bound states

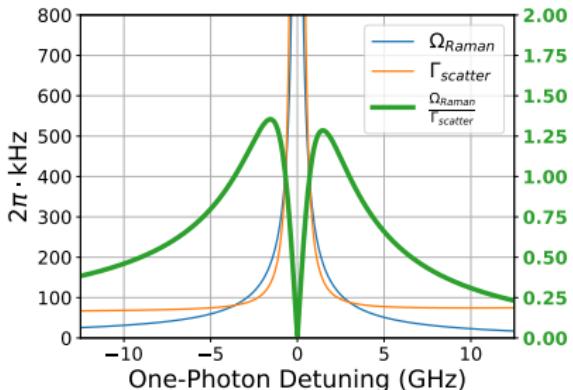
- Weaker coupling
- Sparsely spaced
- Allow larger detuning
- Slower scattering

arXiv:1701.03121(2017)

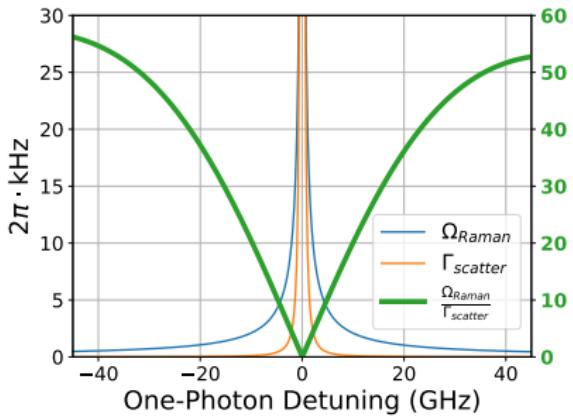
Raman transfer



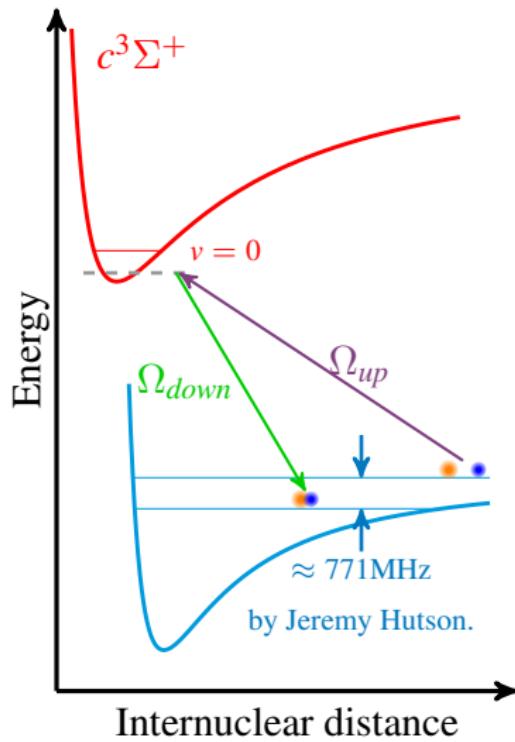
Near threshold states



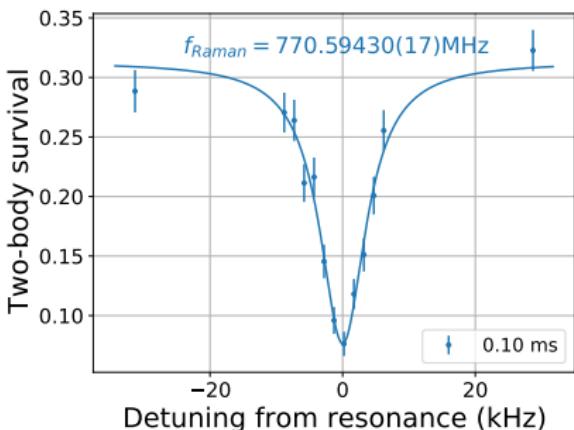
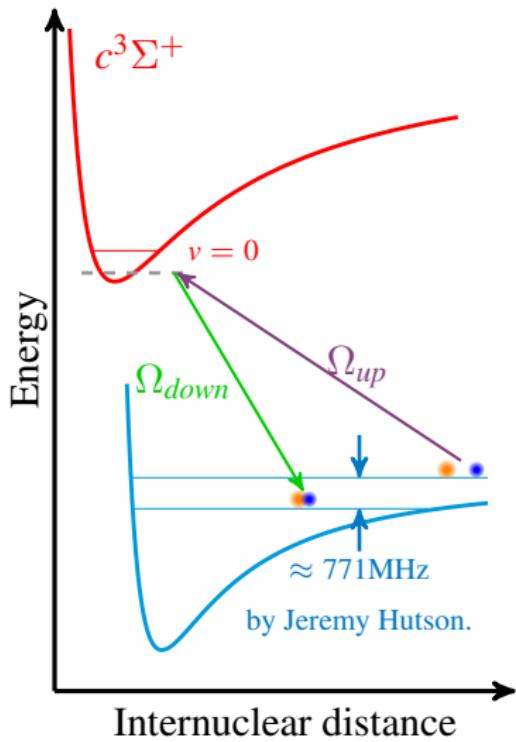
Deeply bound states



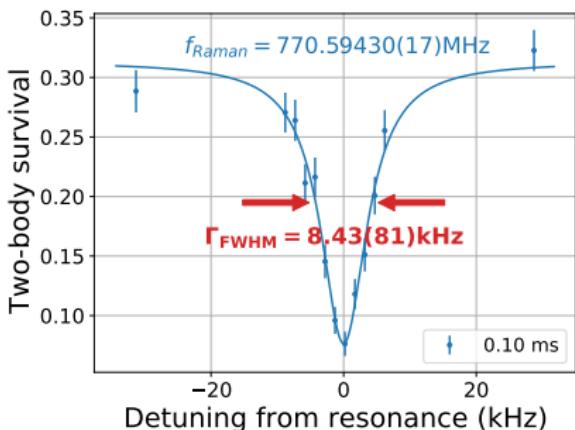
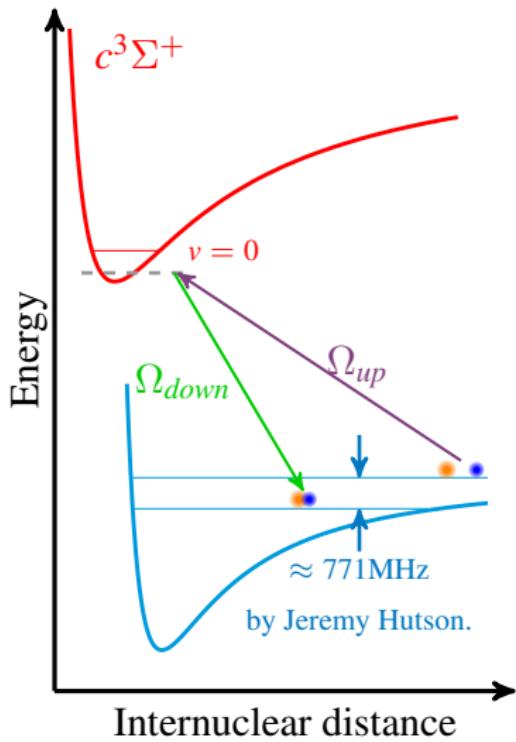
Experiment



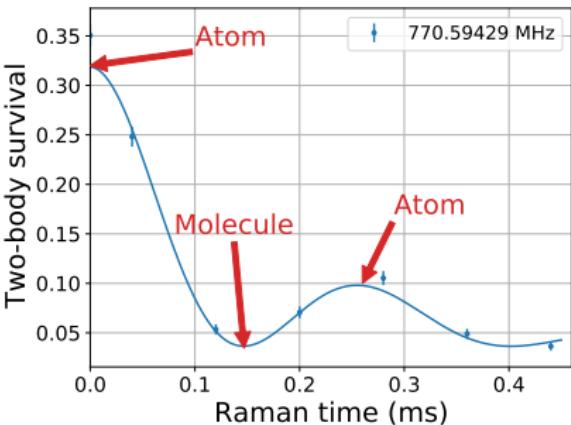
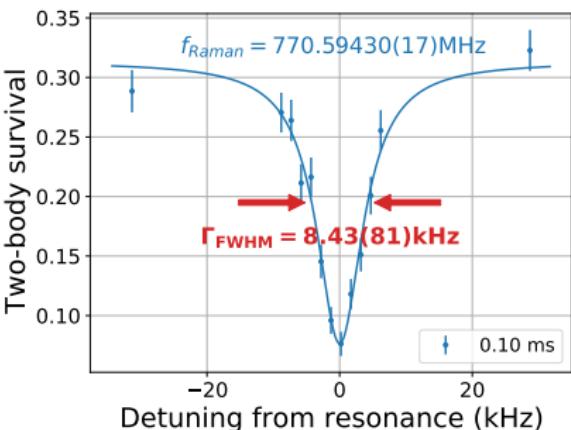
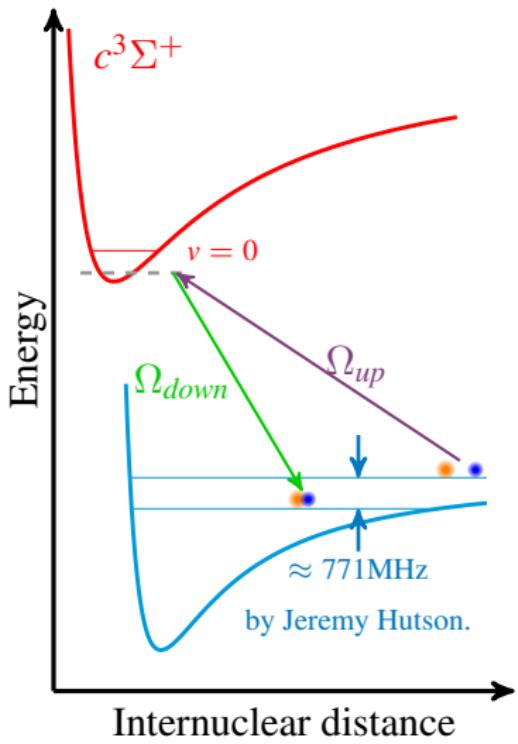
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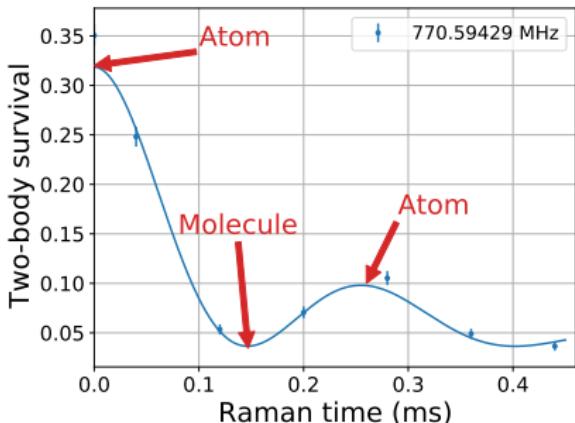
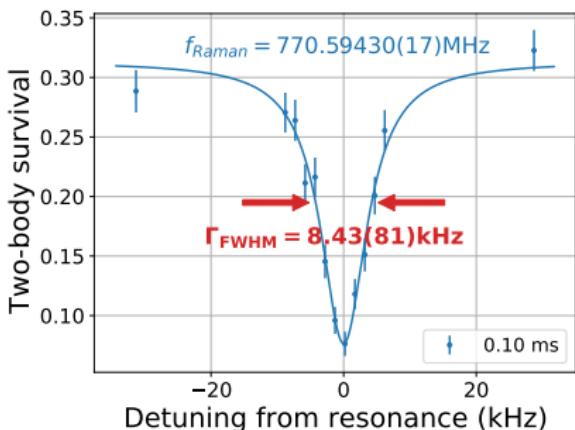
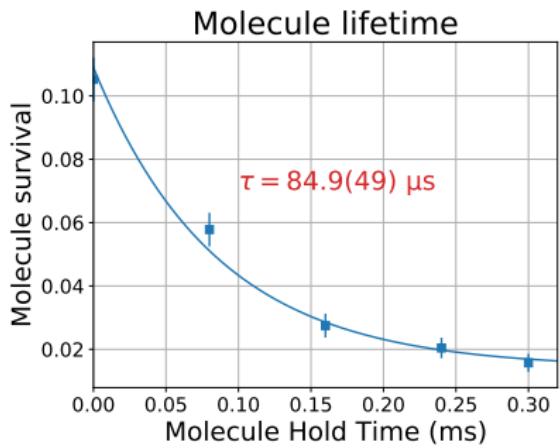


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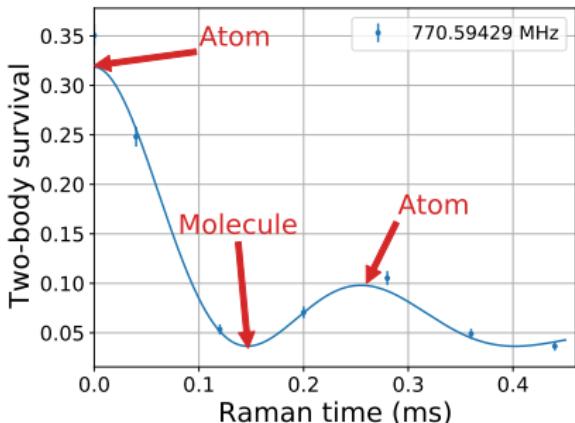
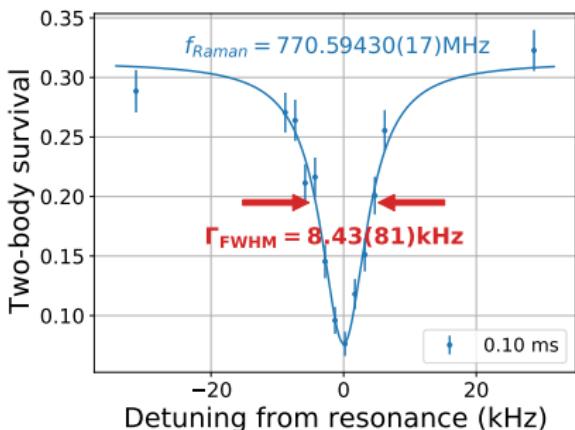
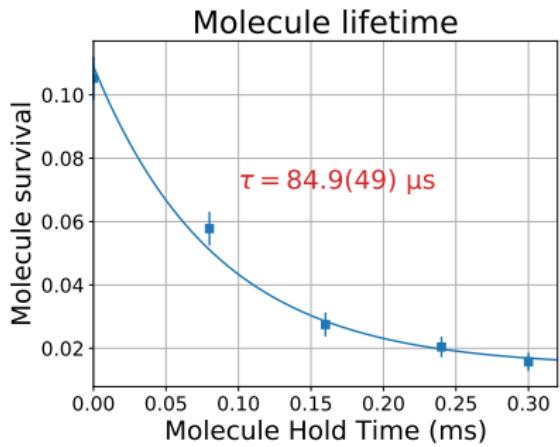
Experiment

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



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Conclusion and Outlook

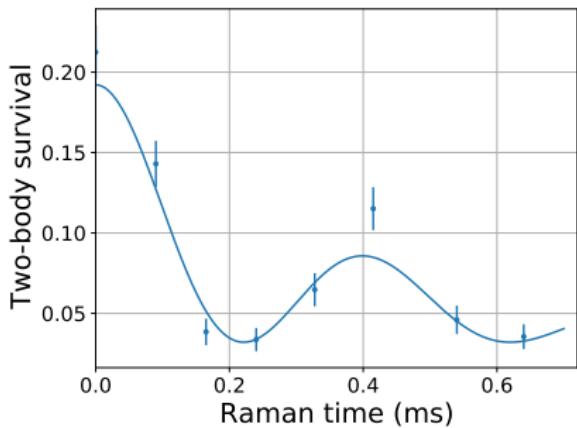
- Demonstrated formation of weakly-bound NaCs molecules while maintaining quantum control.
- Improve signal contrast.
- Feshbach molecule ($\tau = 4.7(7)$ ms)

arXiv:2003.07850

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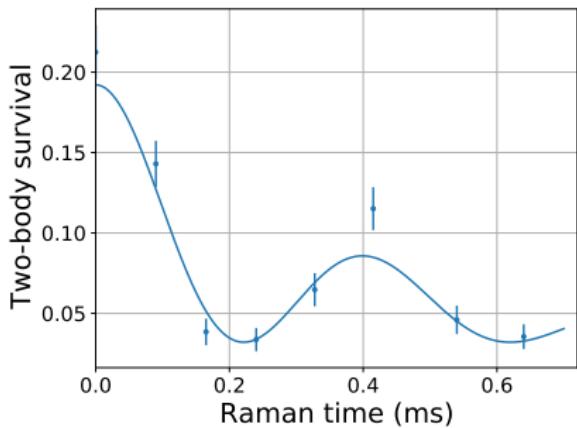
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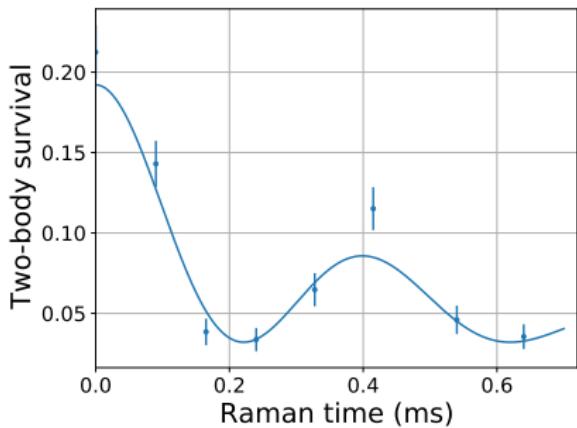
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Poster Q01.00108

