

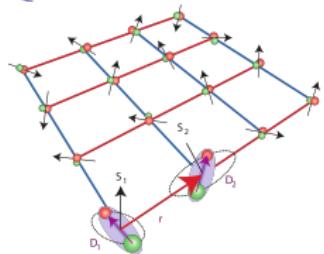
Building Single Molecules from Single Atoms

Yichao Yu

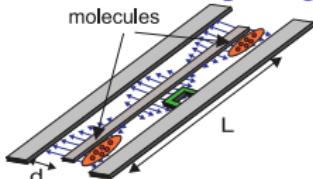
Ni Group/Harvard

Jul. 2020

Quantum Simulation



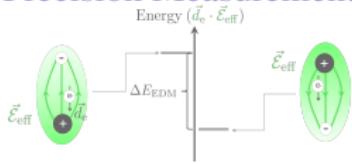
Quantum Computing



PRL. 97, 33003 (2006)

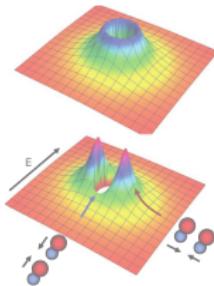
Nat. Phys. 2, 341 (2006)

Precision Measurement



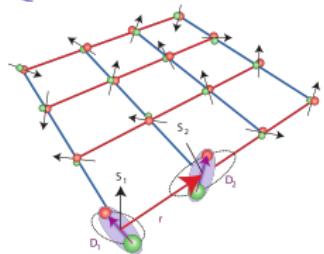
Science 343, p. 269-272 (2014)

Quantum Chemistry



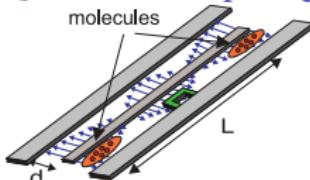
Nature 464, 1324 (2010)

Quantum Simulation



Nat. Phys. 2, 341 (2006)

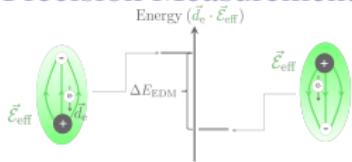
Quantum Computing



PRL. 97, 33003 (2006)

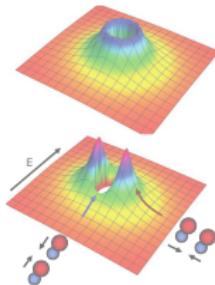
- Full quantum control
- Entanglement
- ...

Precision Measurement



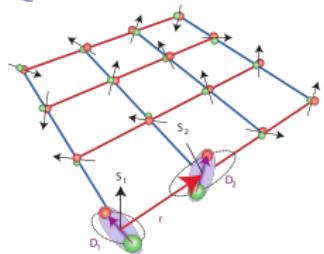
Science 343, p. 269-272 (2014)

Quantum Chemistry



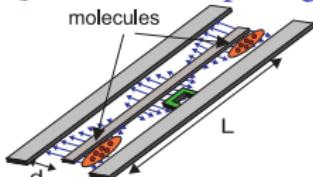
Nature 464, 1324 (2010)

Quantum Simulation



Nat. Phys. 2, 341 (2006)

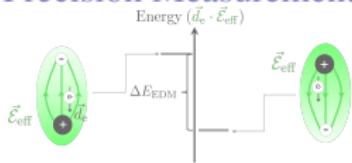
Quantum Computing



PRL. 97, 33003 (2006)

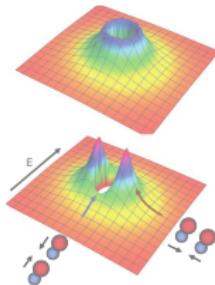
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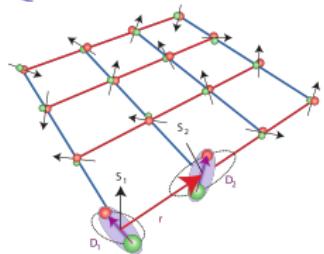
Quantum Chemistry



Nature 464, 1324 (2010)

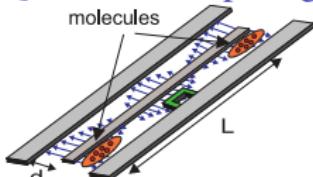
New Approach?

Quantum Simulation



Nat. Phys. 2, 341 (2006)

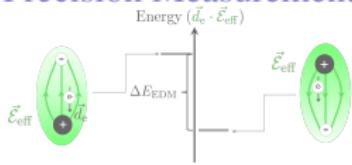
Quantum Computing



PRL. 97, 33003 (2006)

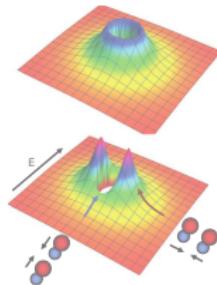
- Full quantum control
- Entanglement
- ...

Precision Measurement



Science 343, p. 269-272 (2014)

Quantum Chemistry

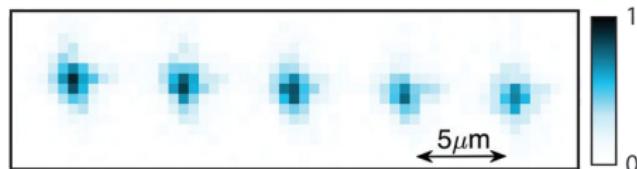


Nature 464, 1324 (2010)

New Approach!

Ultracold molecule in tweezers

Direct cooling



Science 365, p. 1156-1158 (2019)

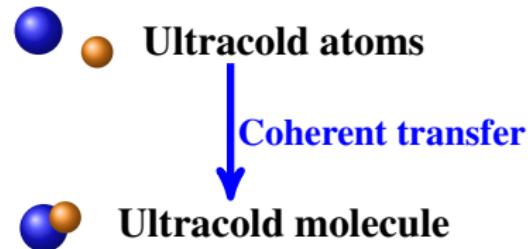
Ultracold molecule in tweezers

Direct cooling



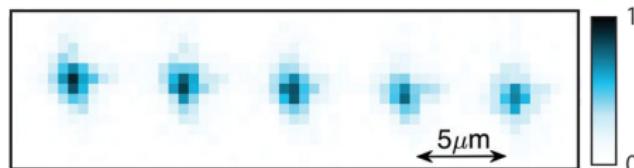
Science 365, p. 1156-1158 (2019)

Assembly



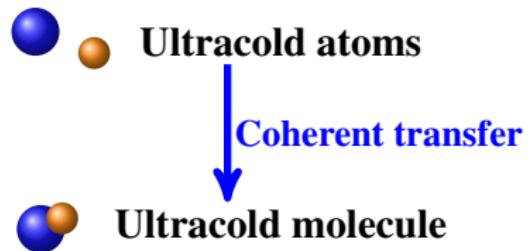
Ultracold molecule in tweezers

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Science 365, p. 1156-1158 (2019)

Assembly

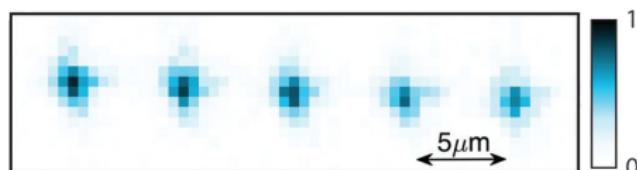


Challenges

- Temperature in tweezers
- Quantum control

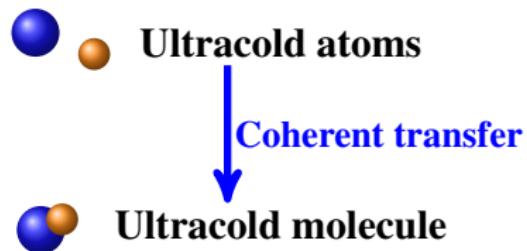
Ultracold molecule in tweezers

Direct cooling



Science 365, p. 1156-1158 (2019)

Assembly



Challenges

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

Outline

1 Experiment overview

2 Atom state control

- Raman sideband cooling of Na atoms

3 Optical molecule creation

4 Conclusion

Experiment overview

Outline

1 Experiment overview

2 Atom state control

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Raman sideband cooling

Outline

1 Experiment overview

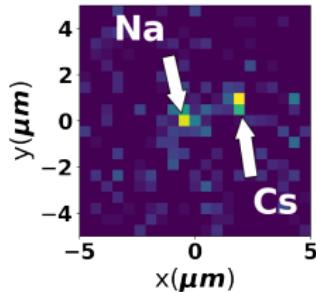
2 Atom state control

- Raman sideband cooling of Na atoms

3 Optical molecule creation

4 Conclusion

Loading

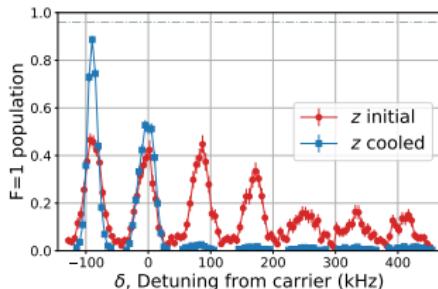


NJP. 19, 023007 (2017)

Merging

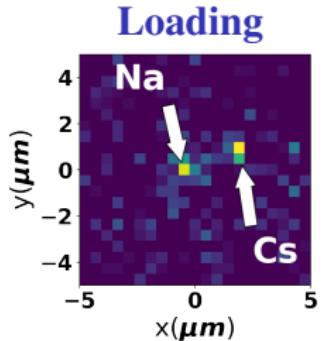


Cooling

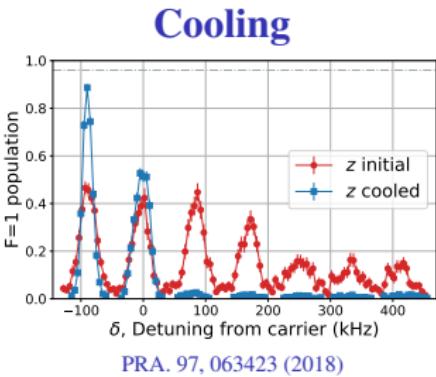


PRA. 97, 063423 (2018)

PRX. 9, 021039 (2019)

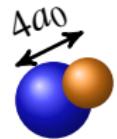
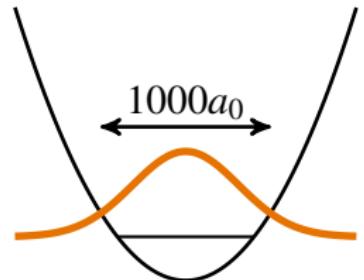


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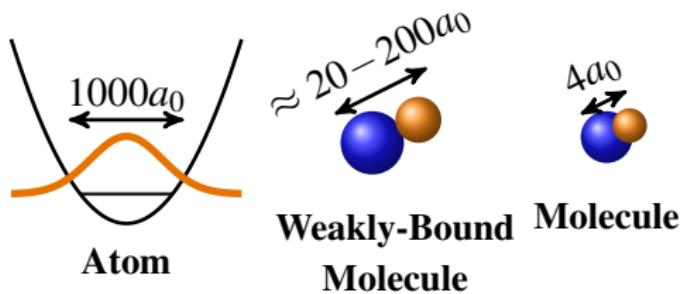


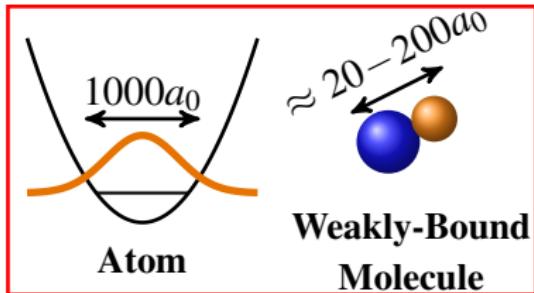
PRA. 97, 063423 (2018)

Merging



Molecule

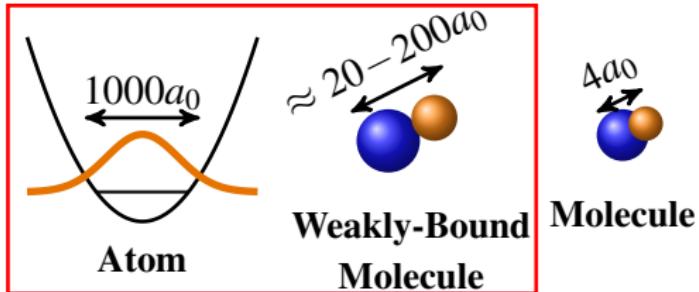




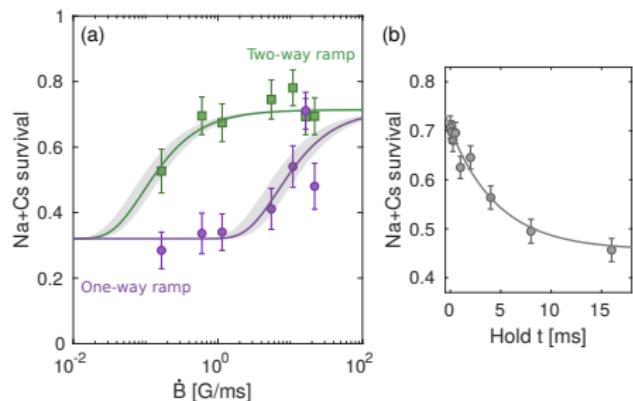
Weakly-Bound

Molecule

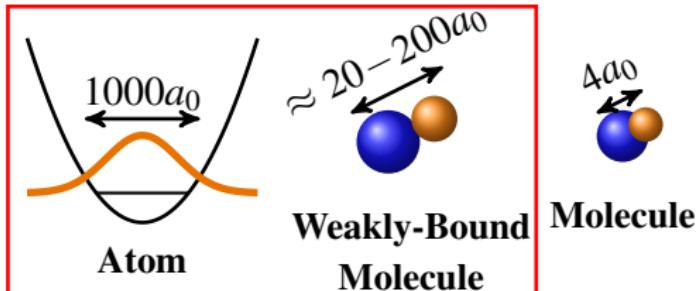
Molecule



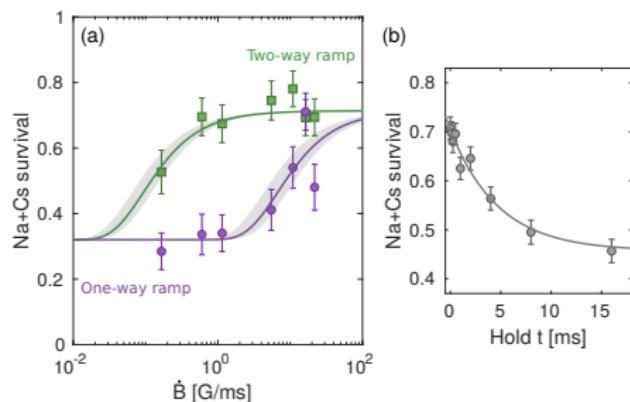
Feshbach molecule



PRL. 124, 253401 (2020)

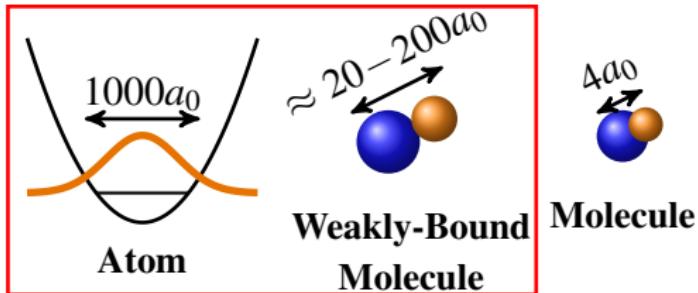


Feshbach molecule



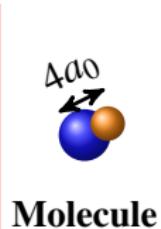
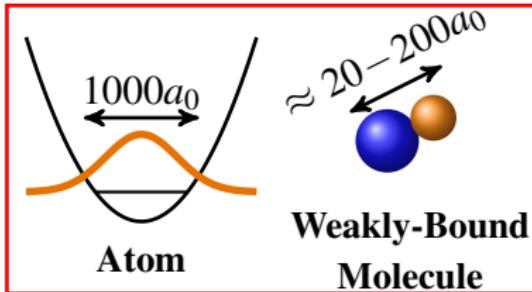
- Requires Feshbach resonance
- Usually large magnetic field

PRL. 124, 253401 (2020)



Optical transfer

- More general
- Faster

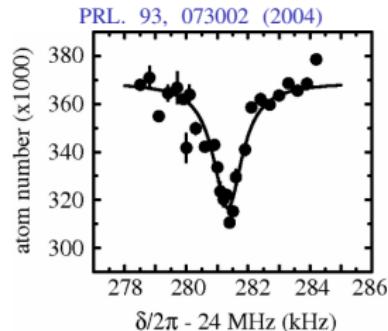


Optical transfer

- More general
- Faster

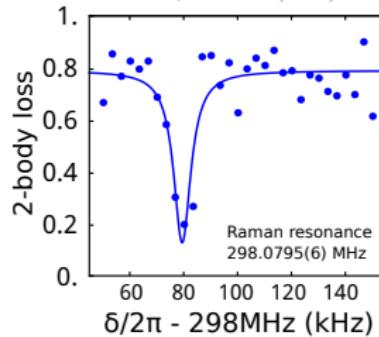
Previous results

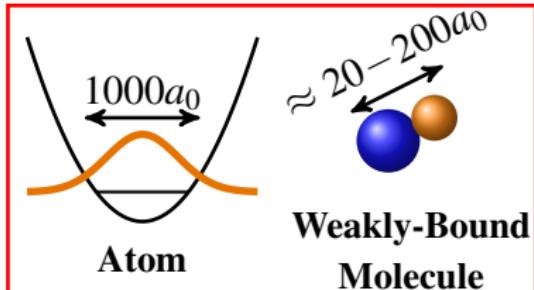
Rb_2 Science 287, p. 1016-1019 (2000)



Sr_2 PRL. 109, 115302 (2012)

NaCs PRX. 9, 021039 (2019)





Optical transfer

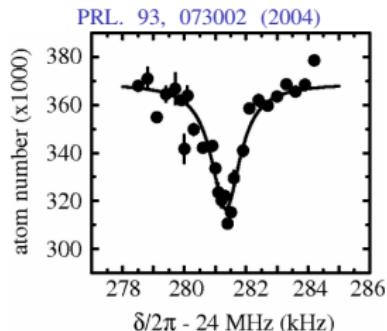
- More general
- Faster

Limitations so far

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

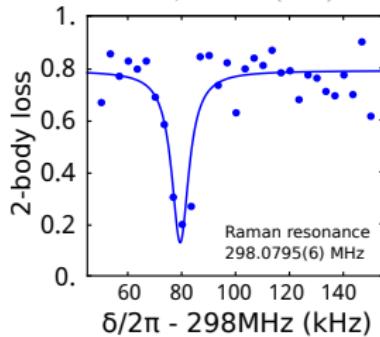
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Rb_2 Science 287, p. 1016-1019 (2000)

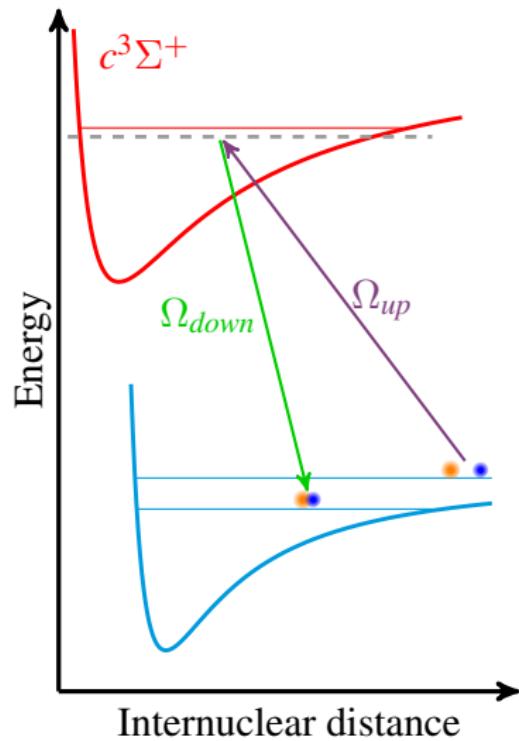


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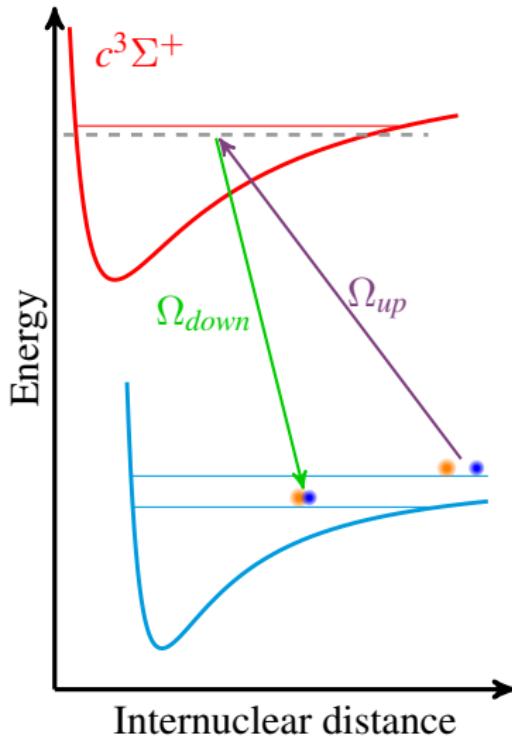
Raman transfer



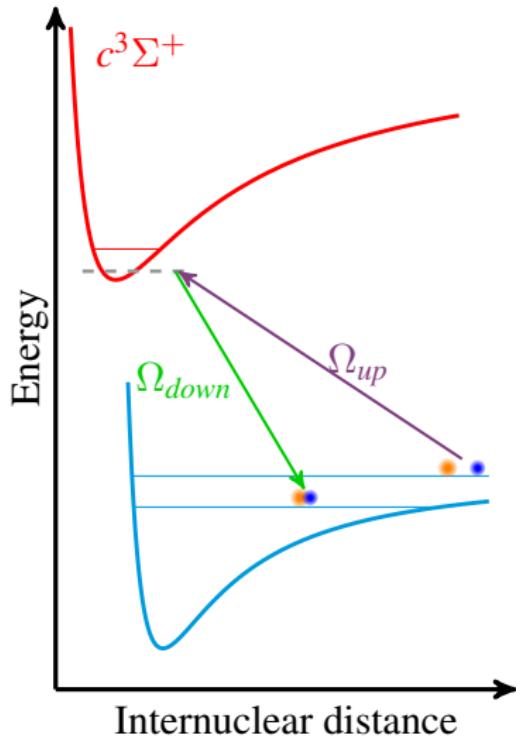
Raman transfer

Near threshold states

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



Raman transfer



Near threshold states

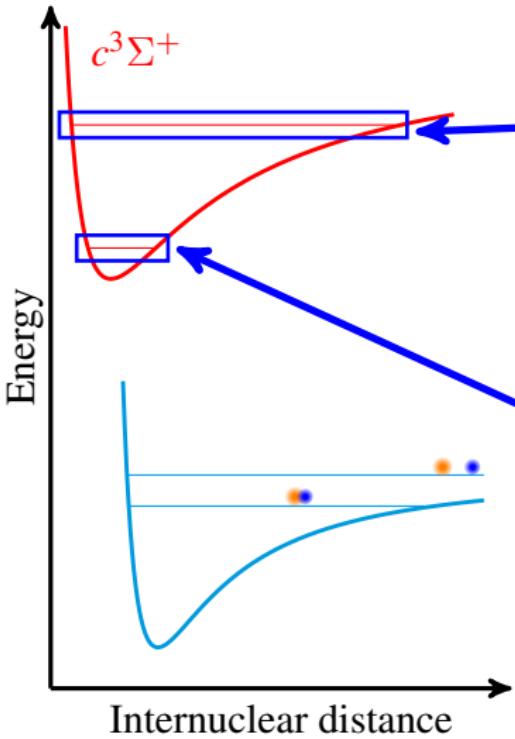
- Stronger coupling (Ω_{up} and Ω_{down})
- Closely spaced
- Fast scattering

Deeply bound states

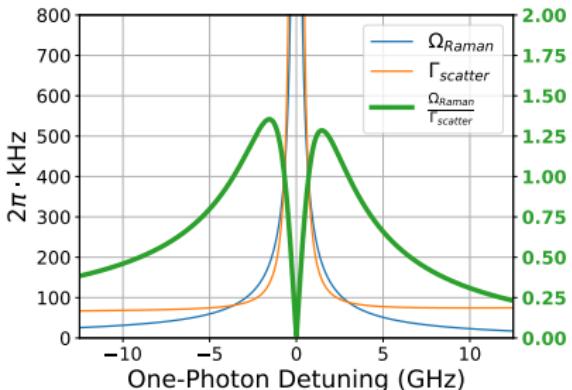
- Weaker coupling
- Sparsely spaced
- Allow larger detuning
- Slower scattering

arXiv:1701.03121(2017)

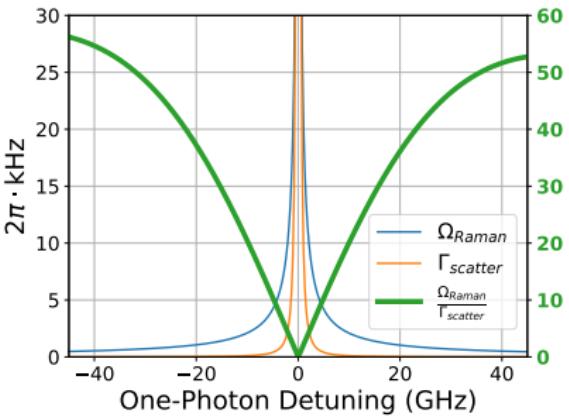
Raman transfer



Near threshold states



Deeply bound states



Conclusion

