

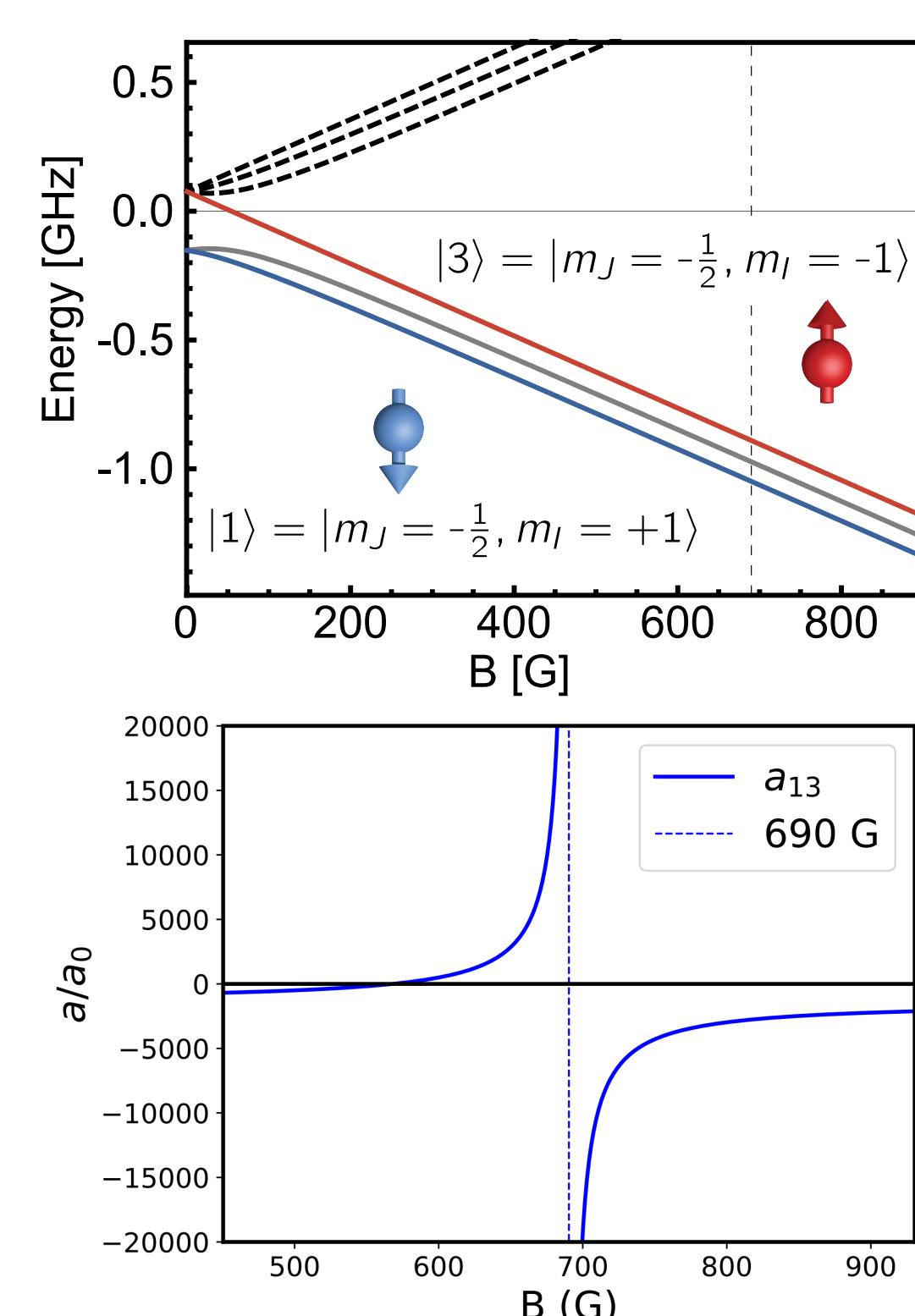
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Unitary Fermi Gas in a Box Potential

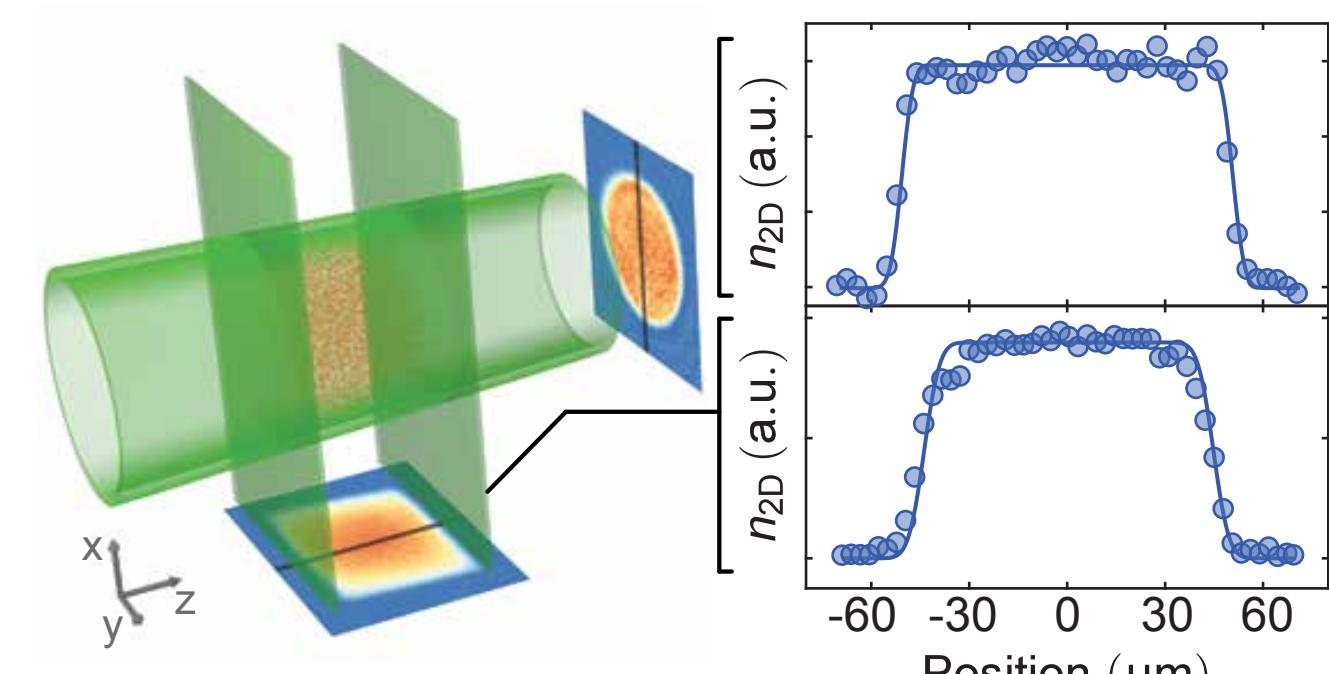
Unitary Fermi Gas

- Strongly-interacting fermion systems - difficult to analyze a priori
- Relevant to systems ranging from neutron stars to high- T_c superconductors
- Unitary Fermi gas is scale-invariant
- Realize unitary with $|1\rangle - |3\rangle$ Feshbach resonance in ${}^6\text{Li}$
- Evaporatively cool spin mixture to below T_F



Box Potential [1]

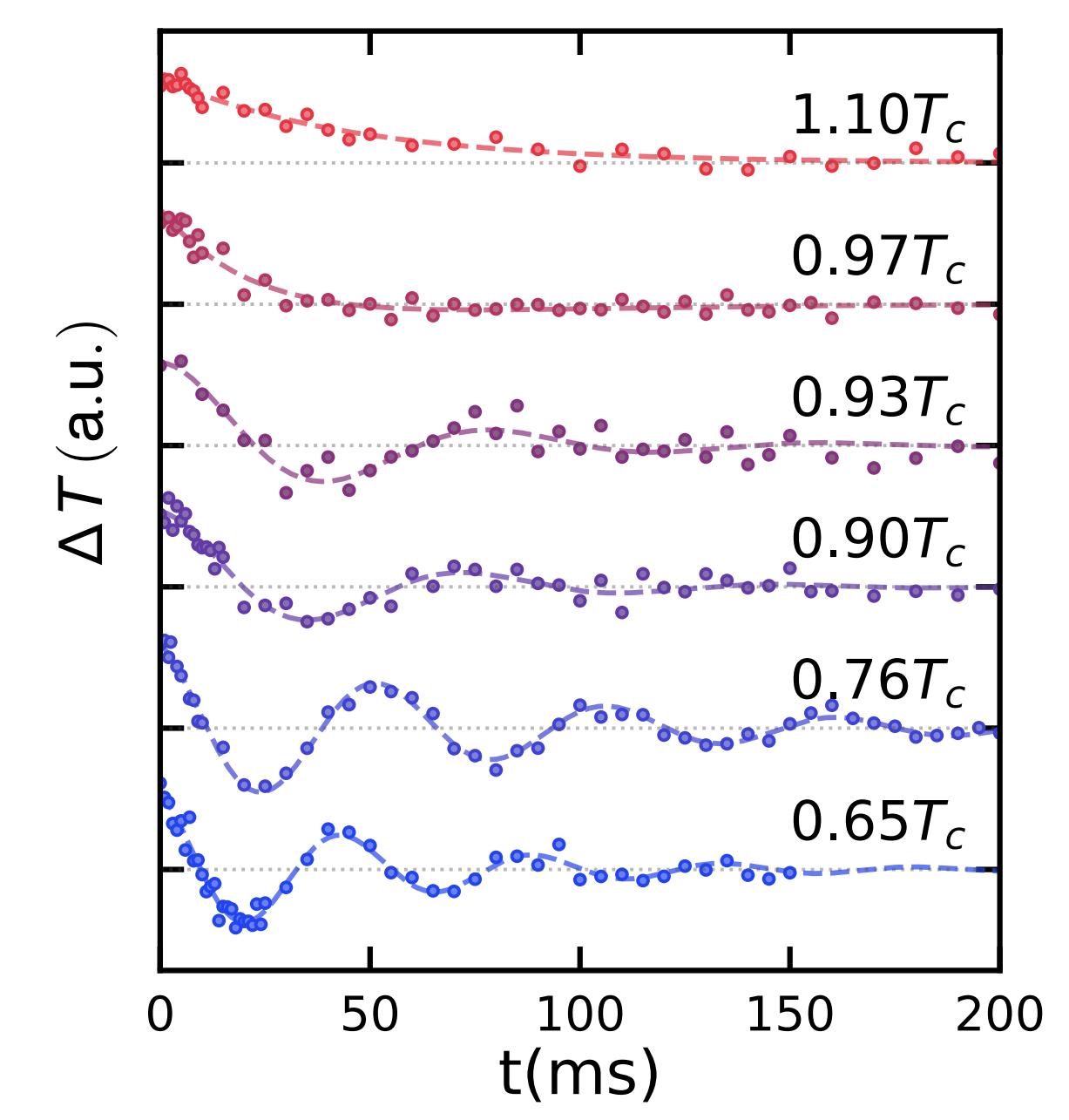
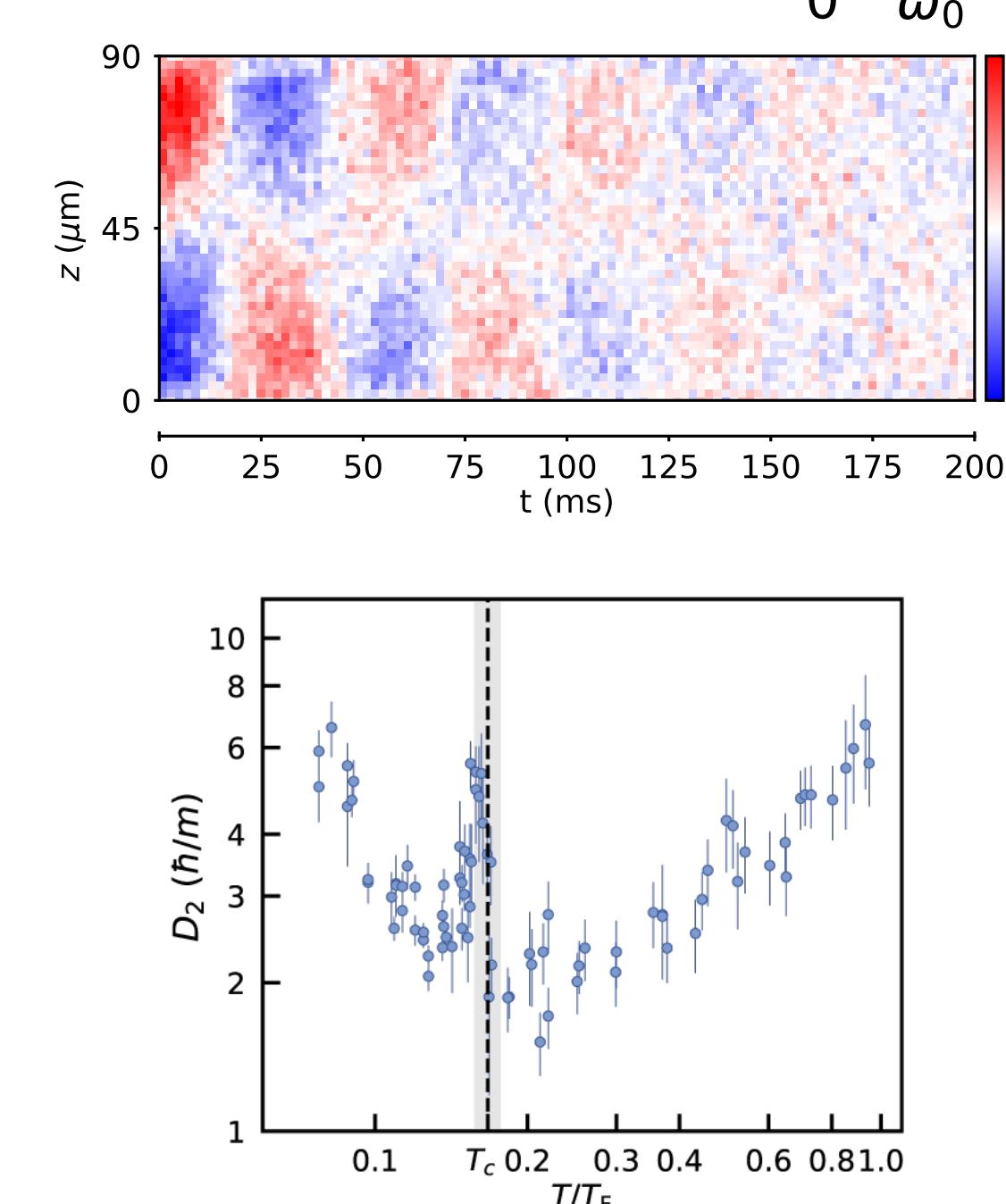
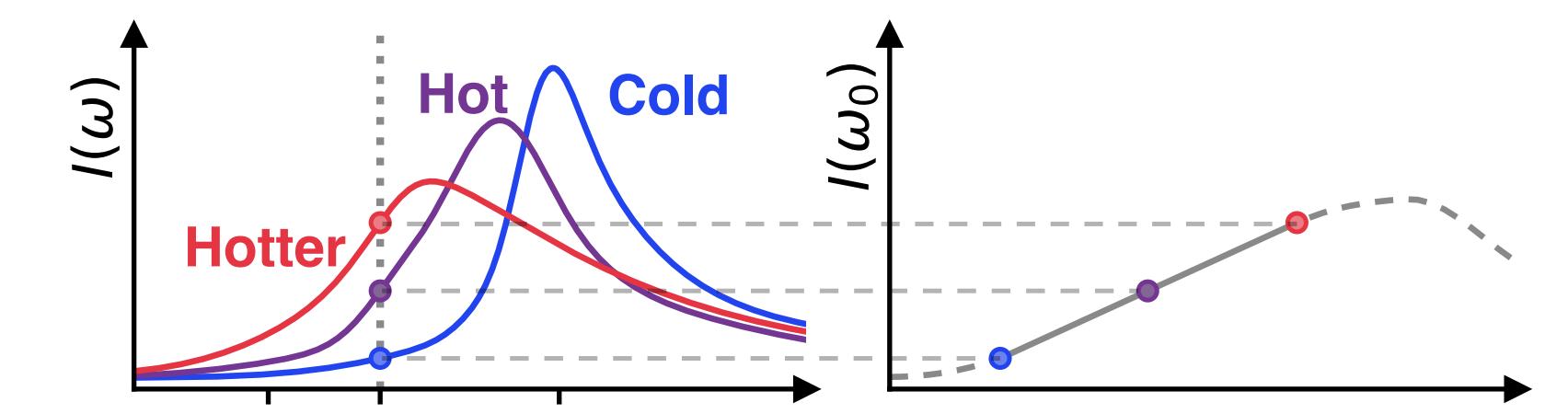
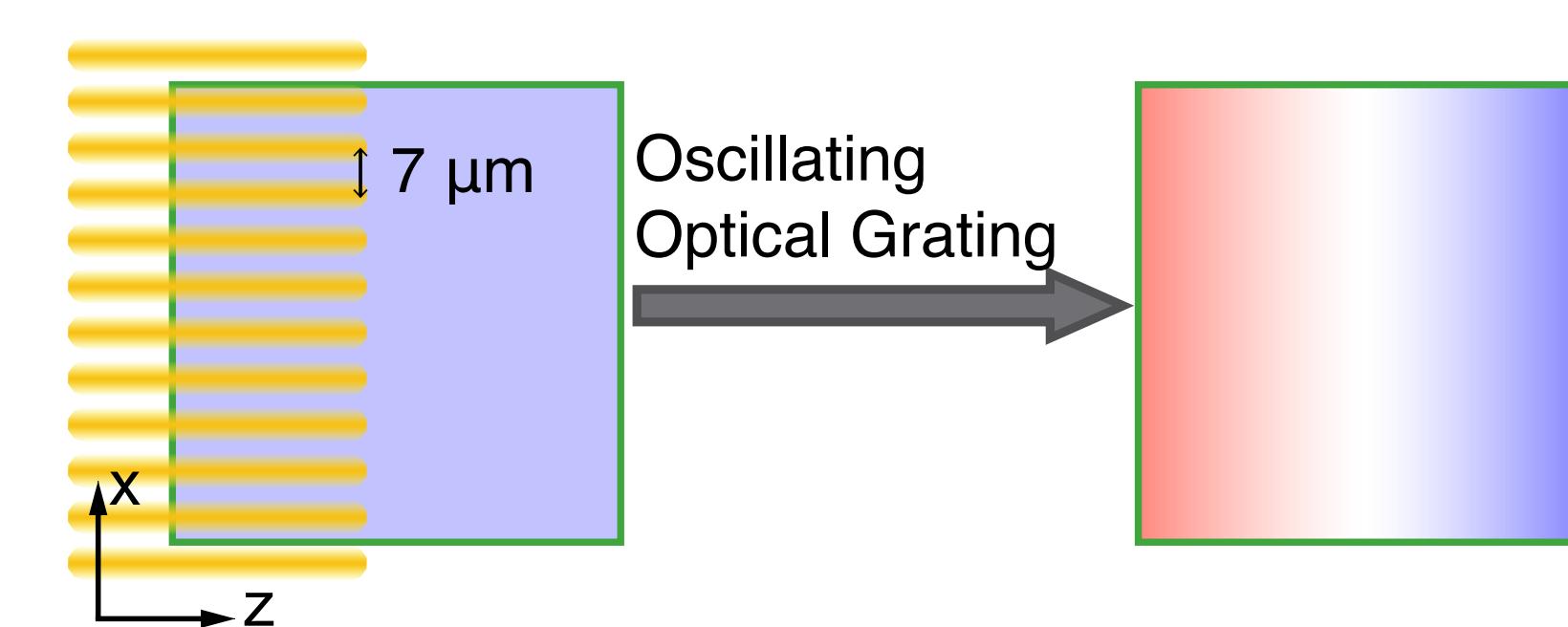
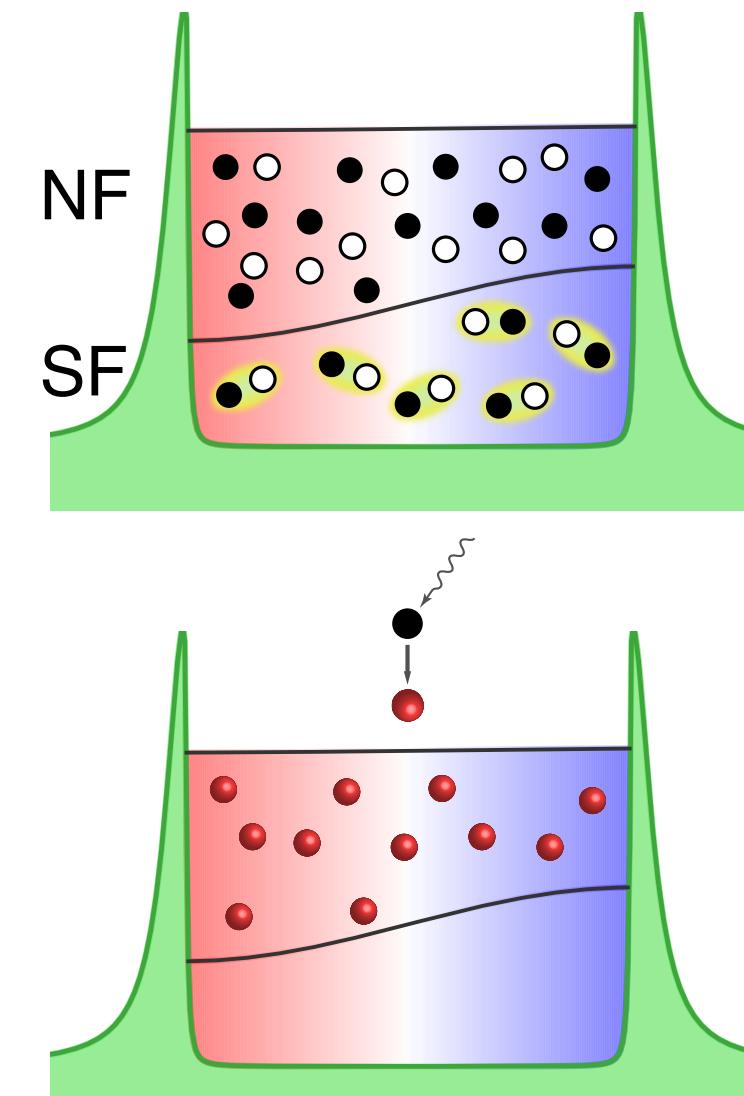
- Hollow blue-detuned beams realize (quasi flat potential)
- Reduces influence of trap averaging & targets smaller range of densities
- Residual harmonic trap in axial dimension allows momentum-space imaging



Temperature Response – Second Sound [3]

Second Sound

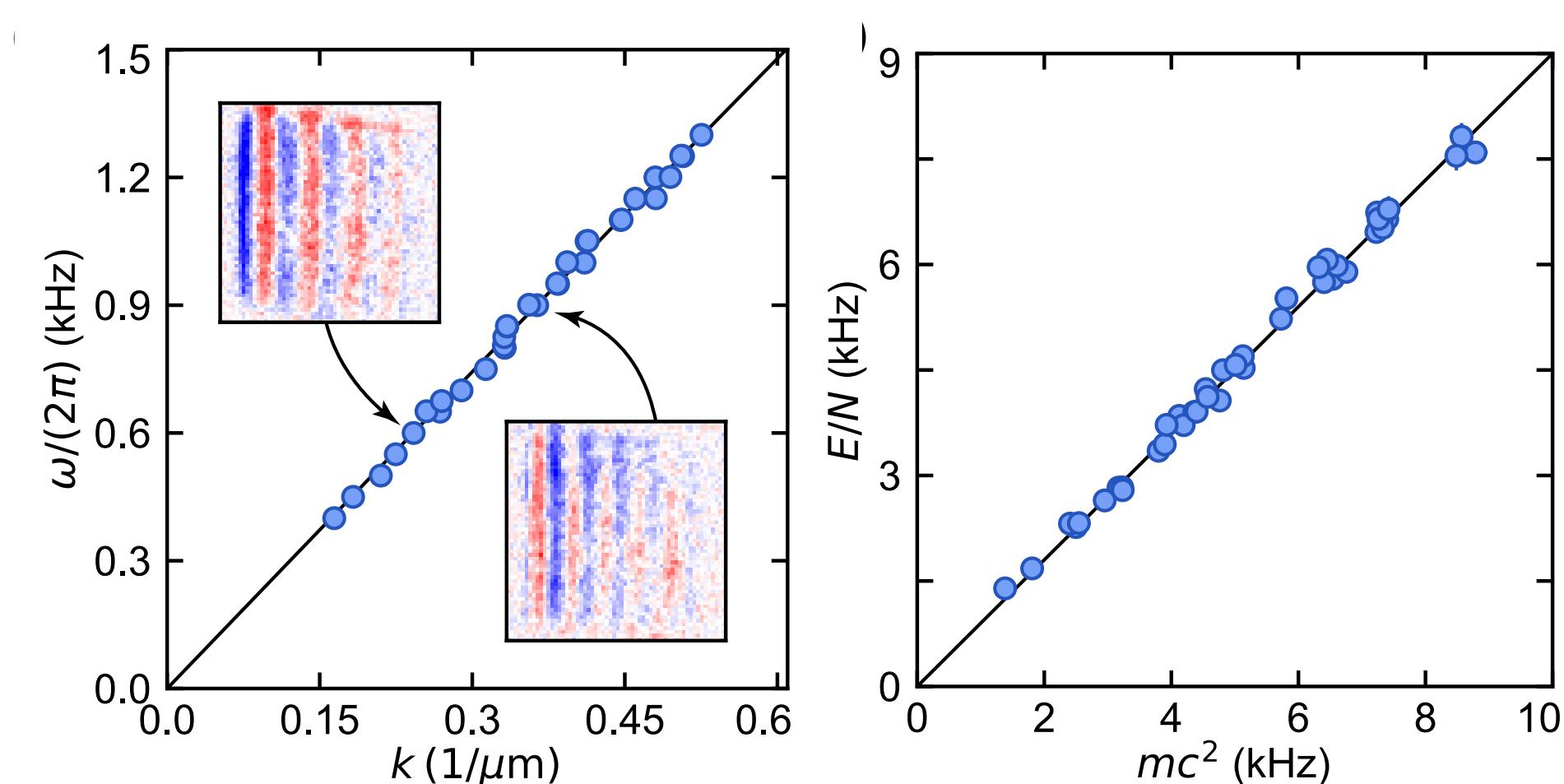
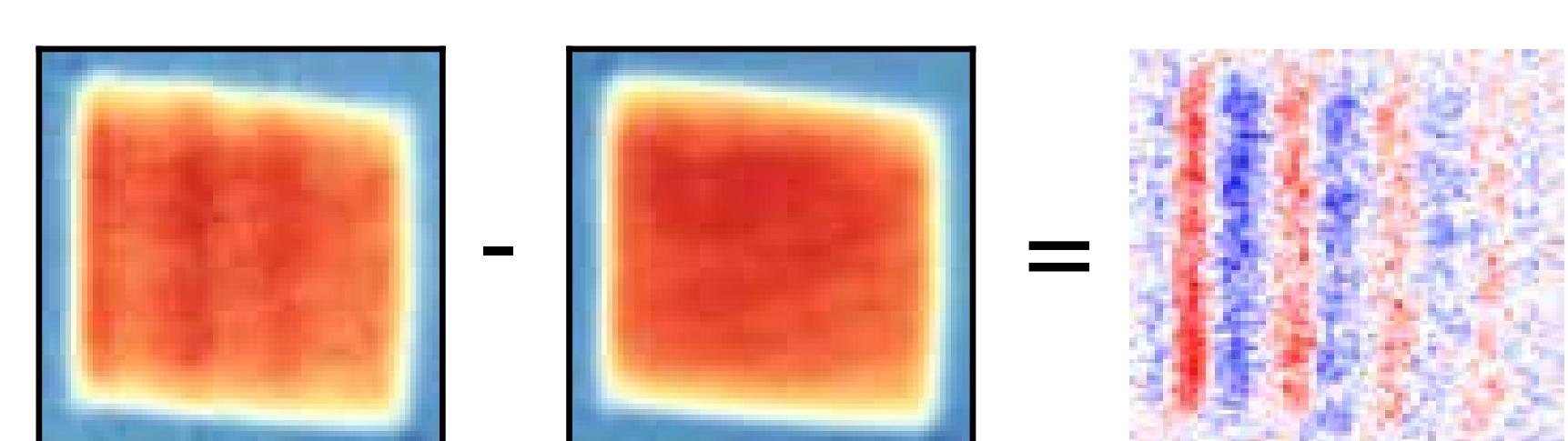
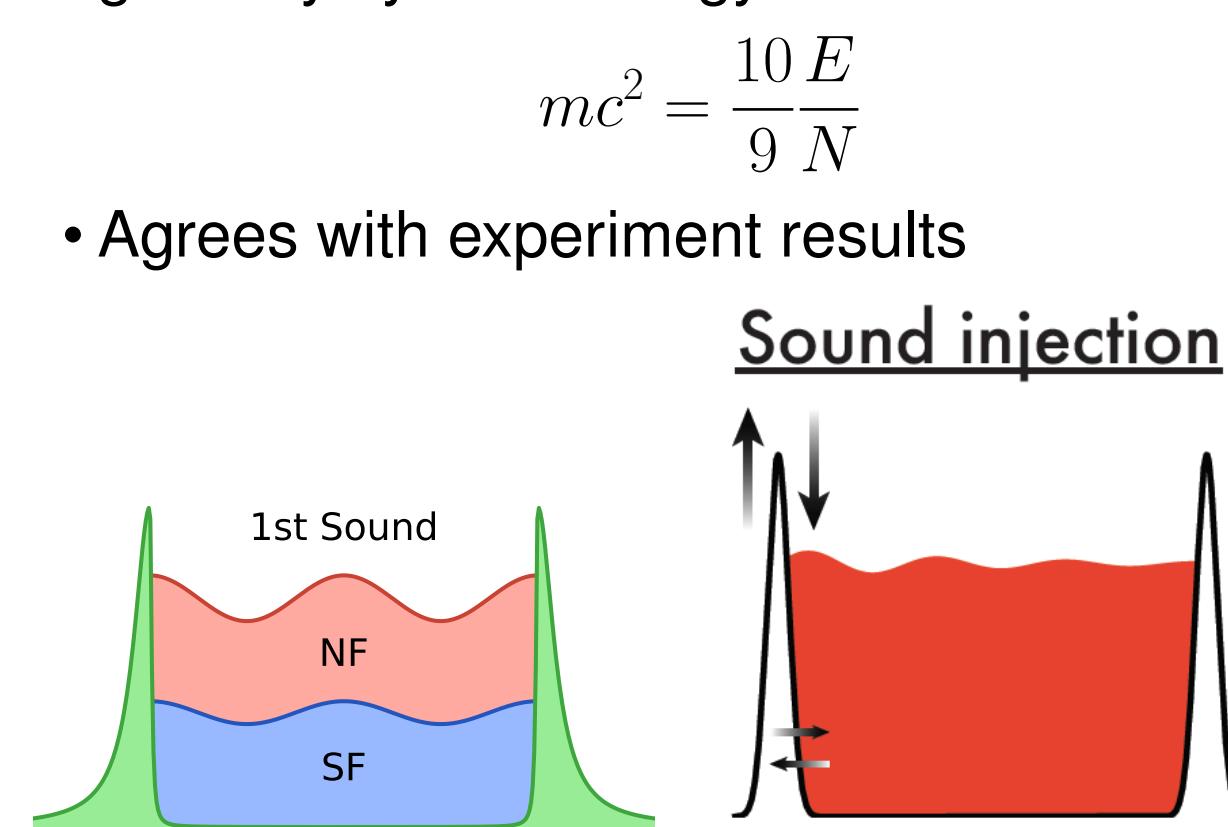
- Temperature oscillations: out-of-phase oscillations of normal and superfluid phase
- Excite oscillations by driving high-frequency sound waves to locally heat the gas
- Measure temperature locally using RF spectroscopy
- Second sound is only present below the superfluid transition temperature
- Damping rate of second sound gives thermal conductivity



Density Response – First Sound [2]

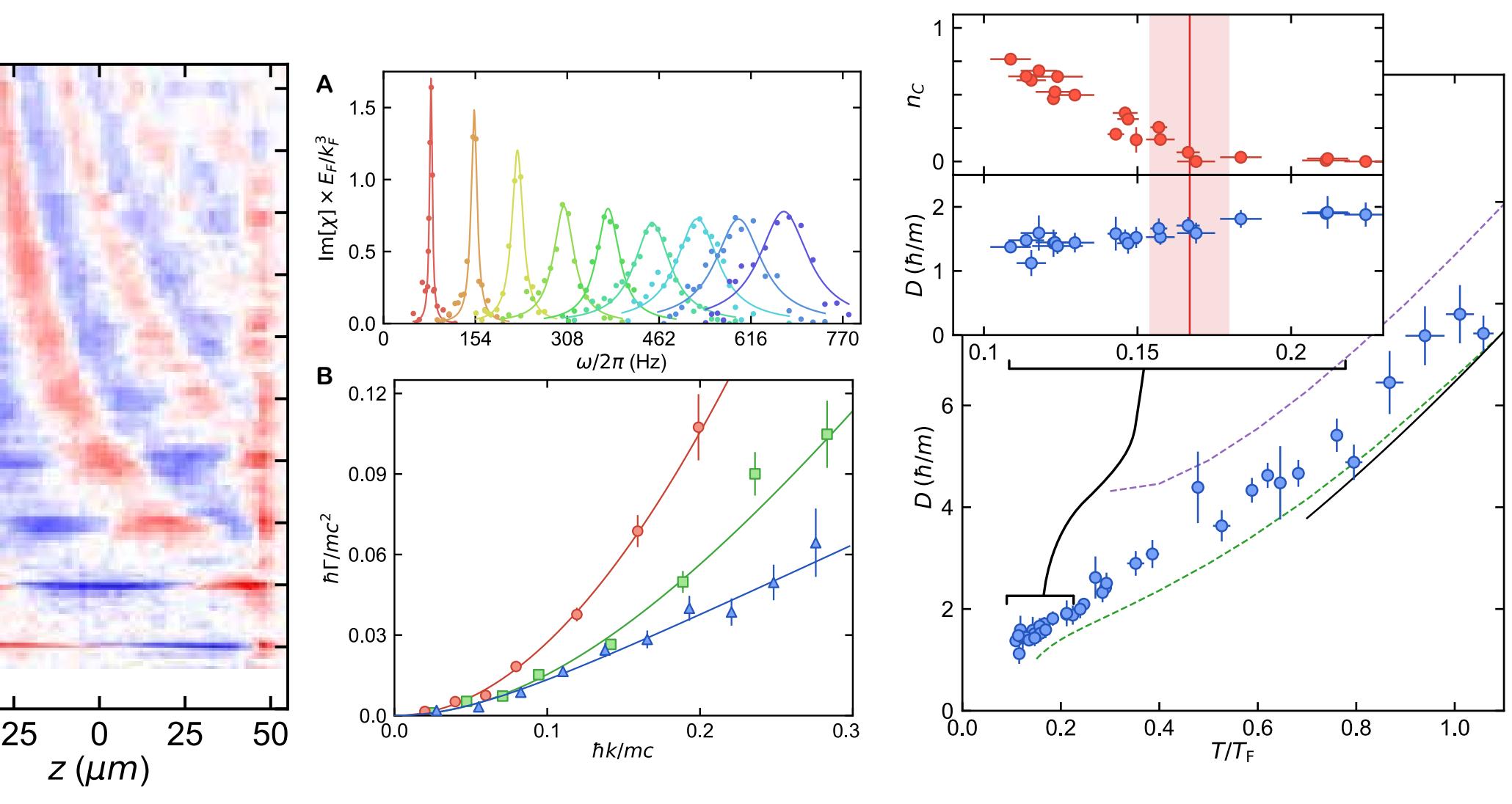
First Sound

- Density oscillations: in-phase oscillation of normal and superfluid phase
- Excite by shaking box walls
- Image density waves in-situ – extract wavevector k for a given ω to get c
- Speed of sound in scale-invariant system given by system energy



Resonant Modes and Dissipation

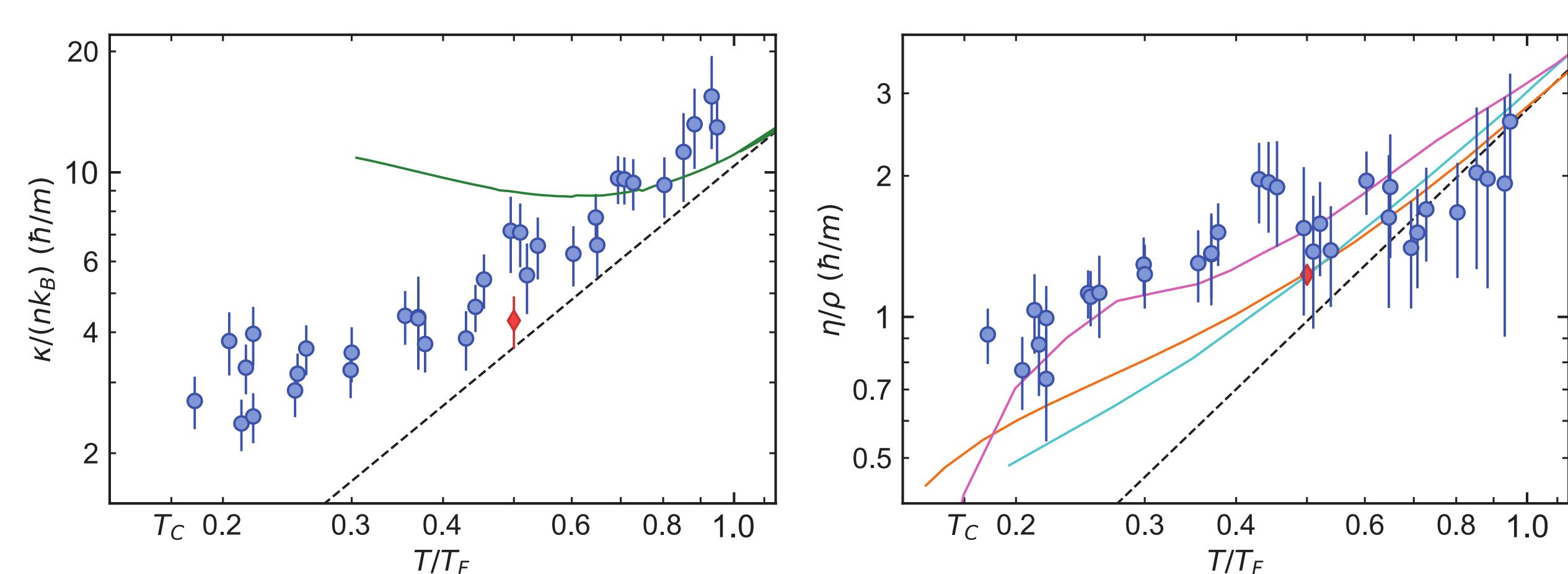
- Sound speed constrained by scale invariance, but dissipation is not
- Hydrodynamics predicts damping rate $\Gamma \propto k^2$, with proportionality constant D_s , the sound diffusivity
- D_s depends on shear viscosity and thermal conductivity
- Measure damping vs. k using width of resonant box modes – extract D_s



Hydrodynamics - Transport Properties

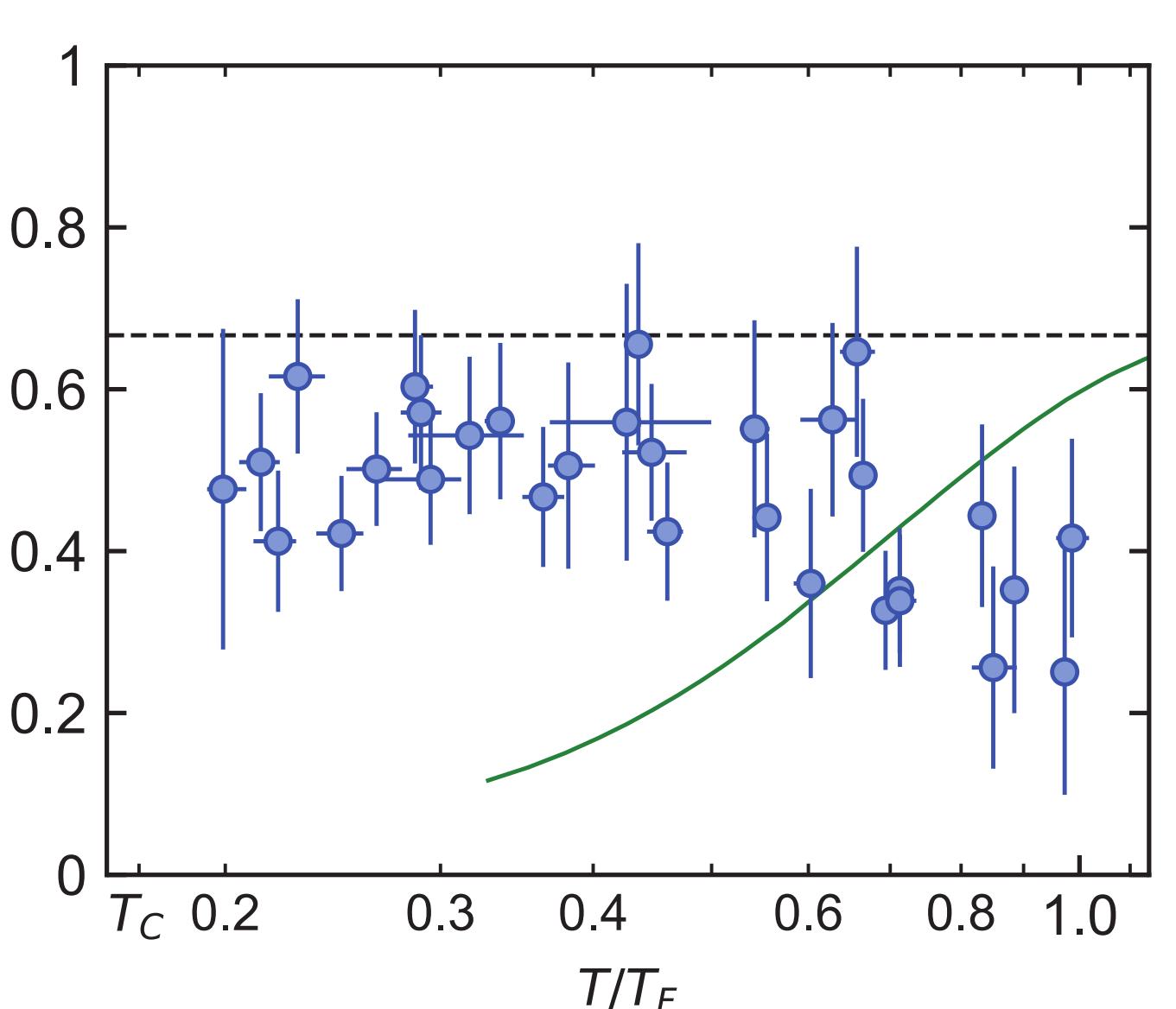
Hydrodynamic Quantities

- Hydrodynamic quantities above T_c : shear viscosity η and thermal conductivity κ
- Bulk viscosity vanishes for scale-invariant systems; below T_c , superfluidity density is conserved
- First sound dissipation given by κ and η ; second sound dissipation by κ and c_p
- Together with equation of state [4], first and second sound give η and ρ above T_c



Results

- Viscosity in reasonable agreement with prior results and theory
- Thermal conductivity differs strongly from theory predictions near T_c
- Prandtl number $\frac{c_p \eta}{\kappa}$, ratio of momentum to thermal diffusivity, remains close to typical $2/3$ value for gases



Red diamond [5], green line [6], pink line [7], cyan line [8], orange line [9]

References

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 [2] P.B. Patel et al., *Science* 2020
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Content

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