# RF spectrum of strongly interacting bose gase across d-wave resonance

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## Introduction

Compared to the general solid state system, the interaction can be easily tuned by Feshbach resonance in cold atom systems. Scattering resonances now enable resonance of different partial waves. For the fermion superfluid, the most studied in the past is the s-wave resonance.

In recent years, degenerate quantum gases near high-partial have been realized. Degenerate quantum gases near the high-partial wave, of the p-wave and d-wave have been realized. For p-waves, Christopher Luciuk et al.'s experiments were published in Nature Physics [3] in 2016, and Zhenhua Yu [4] et al. also proposed relevant theories. The related work of d-wave has been achieved [5][6].

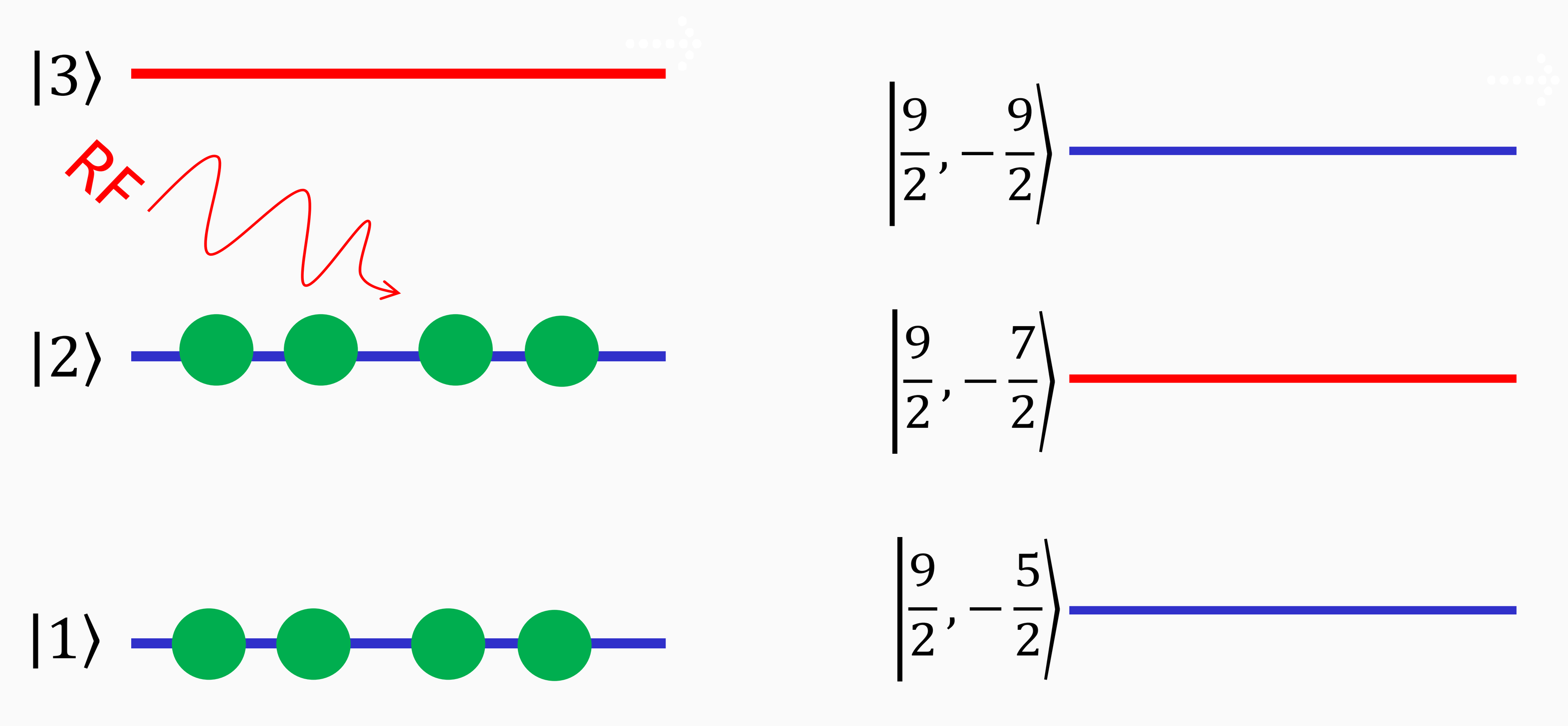
Nowadays, people are paying more and more attention to the quantum gas near the high-partial wave, because the high-partial-wave interaction has many different characteristics compared to the s-wave interaction. For example, high-partial-wave interactions are anisotropic. For d-waves, some topological states can be achieved.

RF spectrum is very helpful in understanding the interactions in cold atom systems. For example, in 2004, the RF spectrum experimentally strengthened the establishment of the BEC-BCS crossover for the fermion multi-body pairing in the strong interaction Fermi gas. By measuring the RF spectrum of the system at different temperatures, it is found that there is a shift in the RF spectrum at low temperatures, thus establishing the formation of pairing in the system.

## RF spectrum measurement process

It is assumed that an atom has three different internal states, which may be hyperfine structures of the same atom. Two of the states have interactions, and the other has no interaction with the two states.

There are generally two approaches in experiments. One is the initial state preparation in two interacting states, the initial state may is a superfluid state, and then one of the states is hit to another state that is not interacting, experimentally measured after a period of time. It can be shown by linear response theory that the number of particles on the state that has no interaction is related to the Green's function. There is also a case where the initial state is prepared in two states that do not interact, and then hit go to another state.

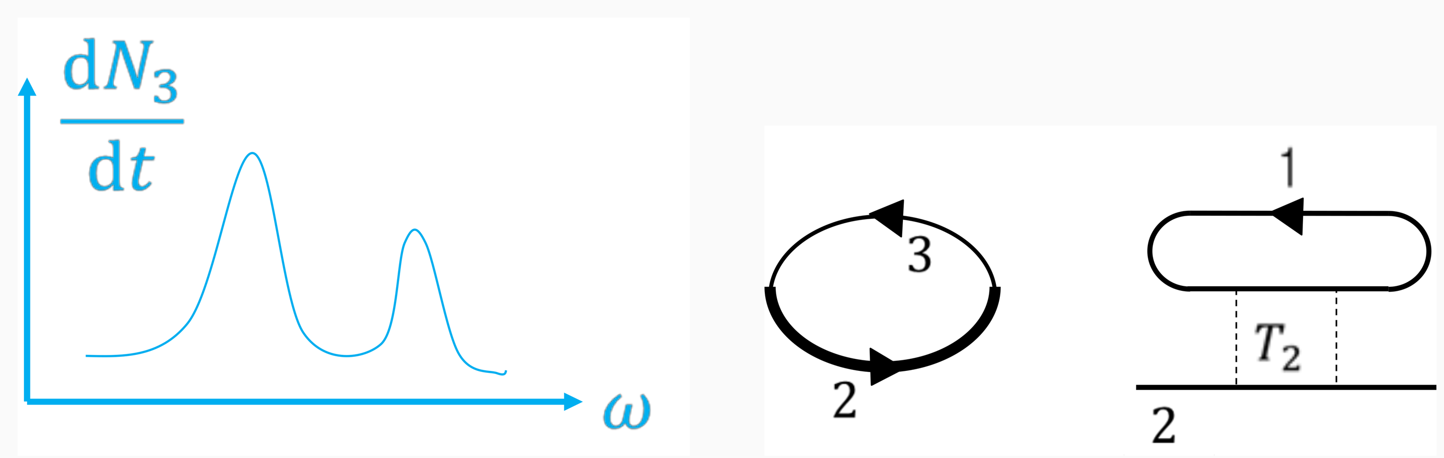



For example, Regal C A et al. [1] worked for $^{40}K$ in 2003. The initial state is prepared in the two hyperfine states of $^{40}K$ $|F=9/2, m_F=-9/2\rangle$ and $|9/2,-7/2\rangle$ , the initial state is not interacting, join after the RF pulse, the atom is moved from the state $|9/2,-7/2\rangle$ to $|9/2,-5/2\rangle$ , due to Feshbach resonance, $|9/2,-5/2\rangle$ and $|9/2,-9/2\rangle$ has a strong interaction.

## Theoretical Method

Theoretically, the calculation of the RF spectrum is based on the linear response theory. It is concluded that the derivative of the particle number versus time is related to the Green's function. As long as the Green's function is calculated, the corresponding RF spectrum can be obtained [1][2].

$$\frac{\mathrm{d}N_3}{\mathrm{d}t} \propto \mathrm{Im} \int G_3(k,-\tau) G_2(k,\tau) e^{-\mathrm{i}(\omega'+\mathrm{i}0^+)\tau} \mathrm{d}\tau \tag{1}$$




For the RF spectrum of the d-wave, no one has yet calculated it. We intend to use the Ladder diagram to calculate the self energy, then calculate the Green's function, and then obtain the corresponding RF spectrum, and then analyze the RF spectrum characteristics under different magnetic field regions near the d-wave resonance. This is the guiding significance of the experiment.

### Reference

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