QSS09 - Jun Ye - Questions & Answers

Jun Ye

Bill Phillips: Is the p-wave barrier to collisions of fermions any different in the way it protects against collisions depending on whether the fermions are atoms or polar molecules?

JUN: Well, the main difference is that molecules such as KRb can have lossy bimolecular chemical reactions. So once a pair of molecules can get sufficiently close to each other, tunneling through the p-wave barrier, there is a very high probability that this pair of molecules will be lost.

Bill Phillips: Could you say more about why the decaying contrast of the superposition state is oscillating and that oscillation does not seem to decay.

JUN: The contrast decay of the Ramsey fringe arise from adding up a number of oscillations of different frequencies and amplitudes. In fact, if one performs a Fourier analysis of the decay, one can find multiple frequency components corresponding to exchange interactions of various neighboring pairs of molecules. The most dominant one corresponds to the nearest neighboring pair, and its signature is most visible. One can actually use a sequence of pulses to disentangle the pairs of molecules that are entangled after spin exchange, and thus remove such an oscillatory signature from the fringe contrast.

Yaakov Yudkin: What is the reason you choose to work with one boson and one fermion? Just because of the favorable experimental properties of K and Rb or is there anything fundamental about the choice?

JUN: As we all know, Debbie Jin loved Fermions! Just like atoms, Fermionic molecules provide fundamentally different properties than bosonic molecules. The first instance we encountered, soon after the first creation of such molecules in the quantum regime, is the p-wave loss associated with bi-molecular chemical reaction.

Bill Phillips: Further to question about why one fermion and one boson: Isn't a gas of fermionic molecules more stable than a gas of similarly dipolar bosonic molecules?

JUN: Yes. Clearly p-wave barrier provided a very noticeable protection against loss. In our early experiment, we flipped the nuclear spin on one of the molecules, and then the bi-molecular reaction proceeded with a 100 times faster rate.

Mehedi Hasan: Would you please elaborate a little on the fact that the Optical Density of the KRb molecule (shown with the three ODs of K, Rb, and KRb) is doughnut-shaped?

JUN: You must be referring to the slide on "quantum synthesis of molecules" when we were using dual insulators in a 3D lattice to create KRb. The doughnut-shaped OD image is actually not for KRb, but for K. The purpose of that image is to show that we can overlap Rb MOTT on top of the K band insulator. When we spin flip the Rb, it leads to a loss of K, creating a hole in the K distribution. Sorry that I did not go over this during the talk.

Tout Wang: Can you say more about the Zeno effect explanation for suppressed losses? Is it that the short-range molecular complex losses Zeno-suppress spin dephasing of the spin-polarized fermionic molecules, which would otherwise allow fermions to approach at short range? Why does this start at T/Tf ~ 1 and not already below the p-wave barrier at ~mK temperature scales?

JUN: I refer you to a paper that Ana Maria Rey's group is working on and should soon appear on the arXiv. I think I answered this question already during the talk, but briefly, the idea is that the

K2Rb2 complex loss rate is enhanced by the presence of other KRb molecules. Hence as the density continues to build there is a counter-intuitive suppression of KRb loss. Personally, I like the explanation of p-wave contact better, but I realize we will need to provide more experimental measurement, not only on loss but also on interactions, to fully establish this as a mechanism for suppression of reaction in the degenerate regime. We will see if we can make these measurements in the 2D gas, now that we can create a strongly interacting gas there.

Bill Phillips: A measured loss that is less than what is predicted seems like a violation of Murphy's Law. What about that?

JUN: Bill, Yes I agree. And we all know Murphy's Law should not violated too often, although occasional violation brings a lot of joy! We are still exploring this effect. If you have suggestions we will love to hear. Please see the question from Tout above.

What are the prospects of upgrading such molecular experiments with quantum-gas-microscope-type imaging optics to achieve local control and programmability with systems of dipolar molecules?

JUN: We would love to implement a quantum gas microscope on molecules. We have thought about some potential schemes, for example, see a proposal paper we published in 2018, J. P. Covey, L. De Marco, O. L. Acevedo, A. M. Rey, and J. Ye, "An approach to spin-resolved molecular gas microscopy," New J. Phys. 20, 043031 (2018), where we discuss a technique to simultaneously detect two rotational levels, thus providing site-resolved and spin-resolved detection. Currently our imaging resolution is about 1 um, and we will need to use larger spaced lattice to achieve individual site resolution. But I don't see any reason for not investing some real money to get a good microscope lens matched with our glass cell. Individual 2D layers of molecules have been achieved already in the lab.

Bill Phillips: Since you can go from 3D to 2D continuously, can you imagine experiments where some sense of being in a fractional dimension is important (not something as mundane as loss rates), something that is fundamentally about dimensionality being fractional in the way that it is for some fractal situations?

JUN: Bill, let's also discuss the question of fractional dimension. This may take some back and forth discussion for me to fully understand what you are exploring. For example, right now we can see how the loss rate can be controlled as we move from 3D to 2D continuously, it will be interesting to see how the elastic interactions affect the gas dynamics as we do so.