1 Estimation of systematic uncertainty in LDA due to trap parameters

To get an idea of the systematic uncertainty in the LDA temperature estimation we will focus on the data point at $U_0/t_0 = 11.1$. We make the following three assumptions:

1. **We have accurate knowledge of the atom number.** For the point at $U_0/t_0 = 11.1$ it is $N = 1.68 \times 10^5$ atoms.

2. **The central density of the sample is** $1 \leq n \leq 1.3$**.** It turns out that if the atoms were to be all at $n < 1$ then the temperature necessary to reproduce our data would be very low, so we discard this scenario. Experimentally we varied the atom number to obtain the largest Bragg scattering signals, we will use this as a guarantee that $n \geq 1$ at the center. For the assumed upper limit on n we have the insitu images of the cloud, which indicate that the central density is $n \simeq 1.1 - 1.2$, however there may be a systematic uncertainty in the density measurement, so we extend the upper limit to $n \leq 1.3$

3. **The interaction strength is** $10.2 \leq U_0/t_0 \leq 12.0$**.** The quantity that we calibrate more accurately in our trap is the lattice depth at the center. From the lattice modulation spectroscopic feature we have an uncertainty in the lattice depth of $\pm 3\%$. The scattering length is known accurately since the field is easily calibrated. The field to scattering length correspondance is well known[1]. The $\pm 3\%$ error on the lattice depth translates to $\pm 8\%$ on U_0/t_0, which corresponds to the range given above.

The trap parameters that go into the LDA are:

- Lattice depth, v_0
- Compensation depth, g_0
- Lattice waist, w_{IR}
- Compensation waist, w_{GR}

In what follows we will vary each parameter independently, and also will vary the depths and the waists together. We will see how this affects the temperature determination using the experimental data point at U_0/t_0 which has $S_{\boldsymbol{\pi}} = 1.96 \pm 0.12$

1.1 Lattice depth

We vary the lattice depth v_0 from $v_0 = 6.8\,E_r$ to $v_0 = 7.2\,E_r$ and calculate the LDA for various temperatures. For every point we adjust the global chemical potential so that the atom number is $N = 1.68 \times 10^5$ as measured in the experiment. The results are shown in Fig. 1. We will do similar variations for all the other parameters, but will only include a detailed explanation of the results in the caption of Fig. 1. The figures for the other parameters will follow the same logic.
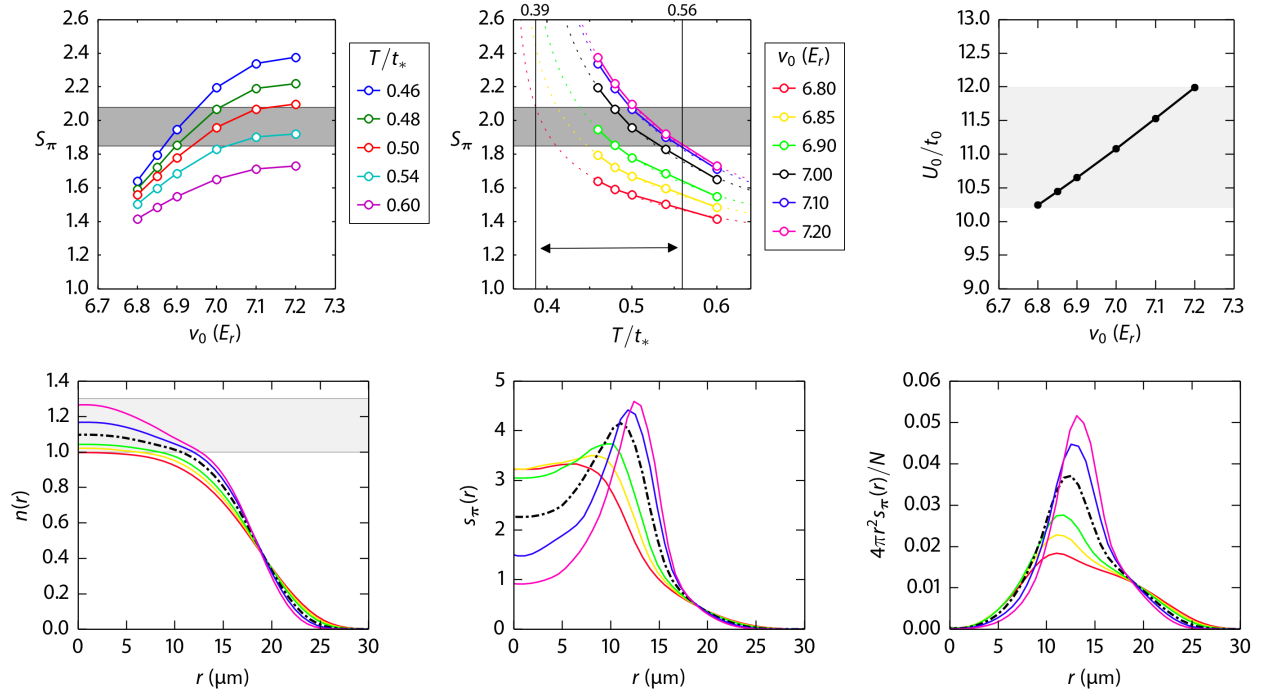
Figure 1: The top left panel shows the variation of the trap averaged S_π with lattice depth for various temperatures. The shaded area represents the experimental measurement. The same data can be plotted as a function of temperature for every value of v_0 as shown in the top central panel. The top central panel can be used to perform thermometry. Notice that we use the color black for the results at the nominal value of the varied parameter (in this case $v_0 = 7\,E_r$). The relevant range for the varied parameter is obtained from conditions 2. and 3. in the list given at the beginning of this document. Condition 2 is represented in the bottom left panel, which shows the density distribution. If a value of the varied parameter produces a central density outside the shaded area ($1 \leq n \leq 1.3$), then it is not compatible with our experimental observations. Similarly, condition 3 is represented in the top right panel. If a value of the varied parameter produces a value of U_0/t_0 outside the shaded area then it is not consistent with our lattice depth calibration. In this case, condition 3 is the most restrictive and tells us that the relevant range for v_0 is approximately $6.80\,E_r < v_0 < 7.2\,E_r$. We then go back to the top central panel and for this range find what are the maximum and minimum temperatures consistent with our measurement. Since we cannot produce LDA results at arbitrarily low T/t_* we fit the available temperature data to a third degree polynomial and extrapolate. In this way we obtain a range in T/t_* that represents the systematic uncertainty of the parameter under study. A **major** caveat is that the third degree polynomial extrapolation will most certainly **not** capture the divergent behaviour of S_π as T_N is approached.
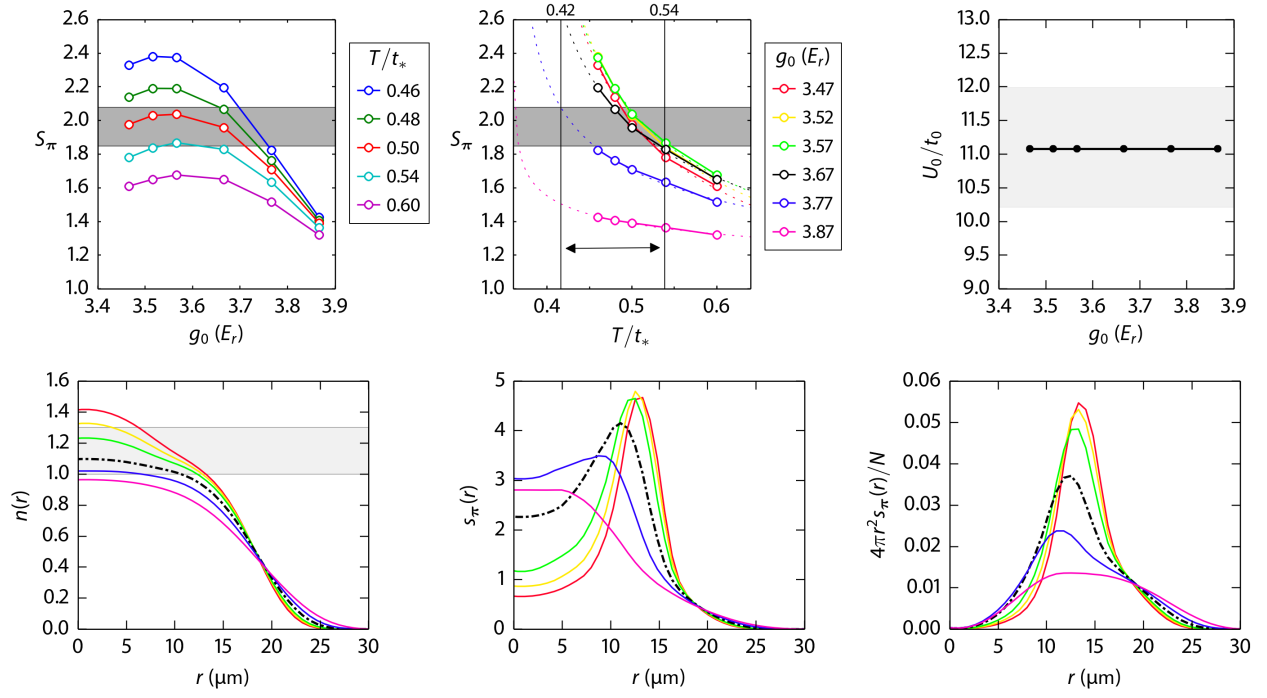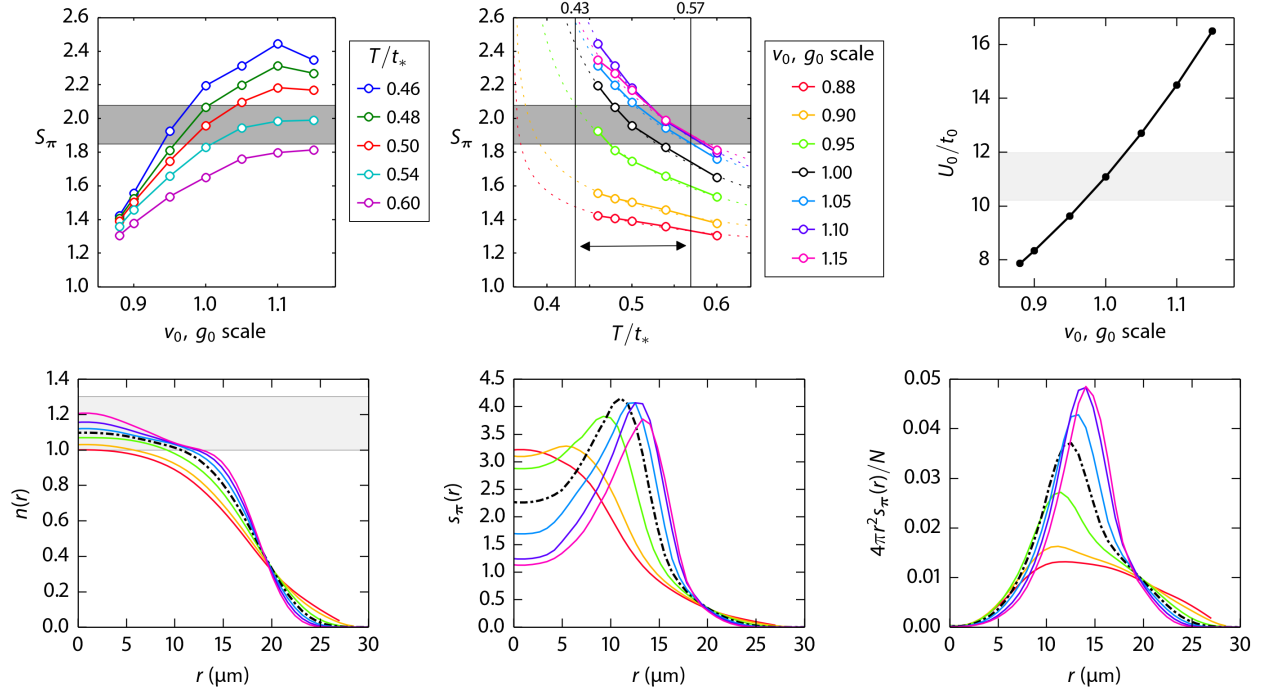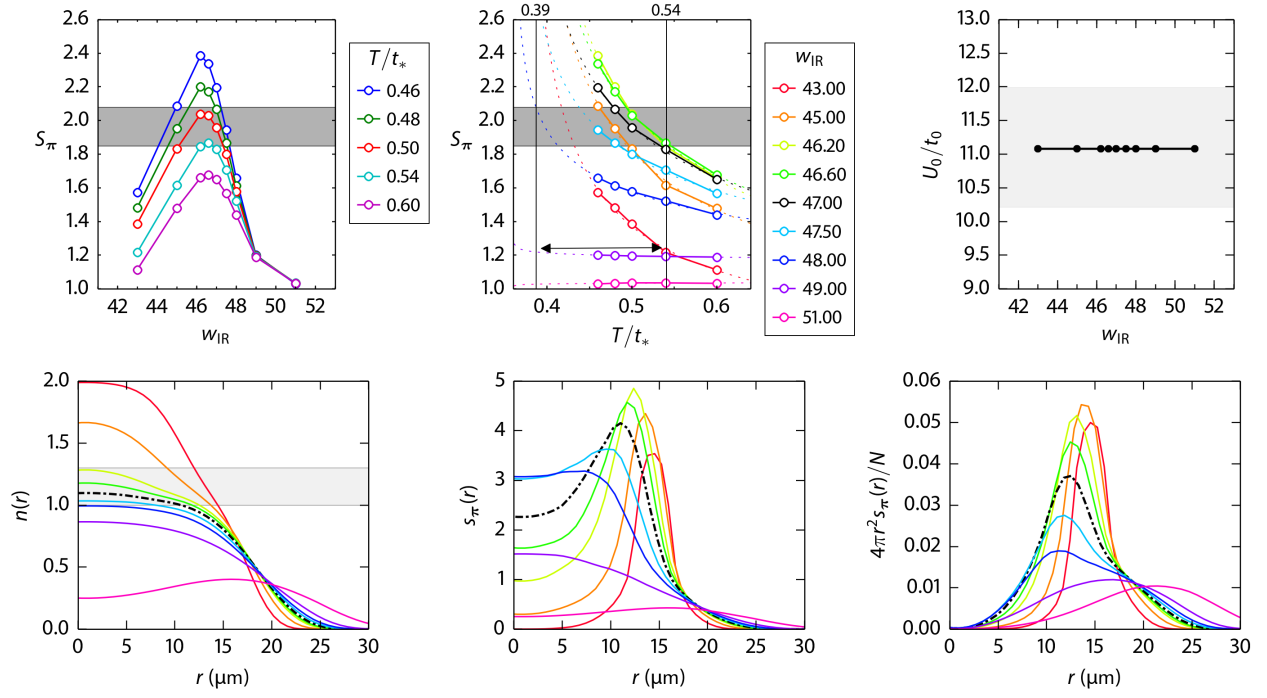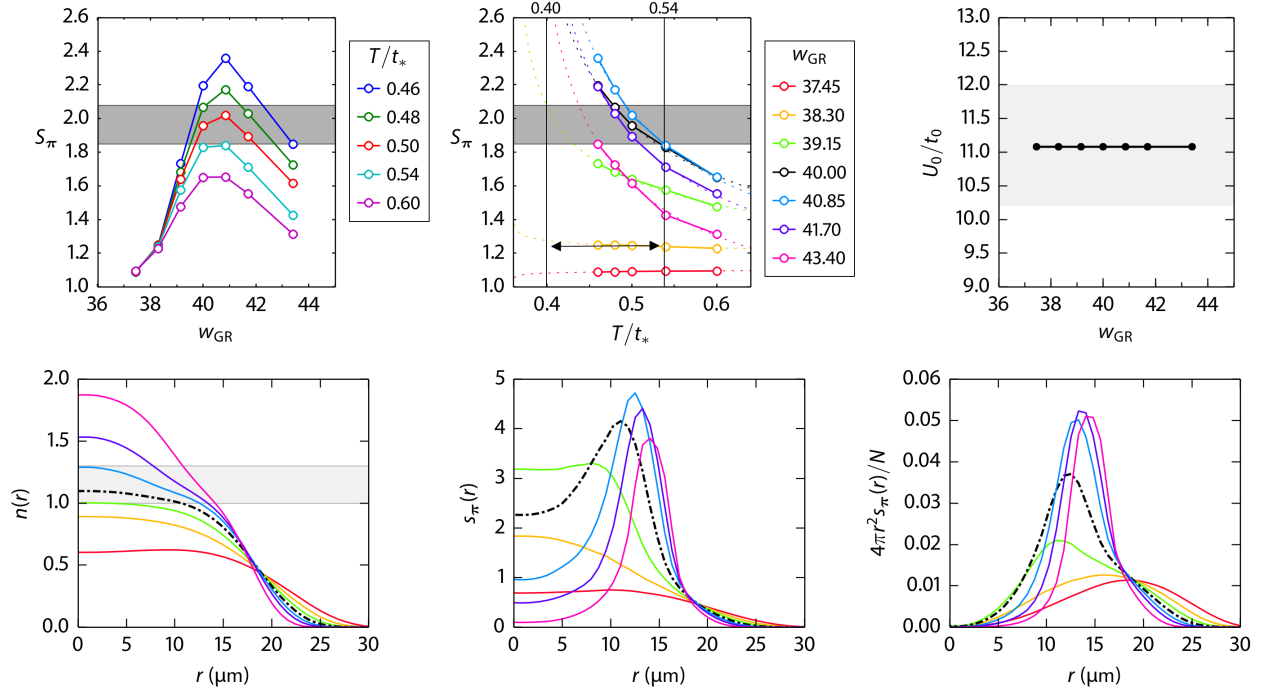
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Figure 2

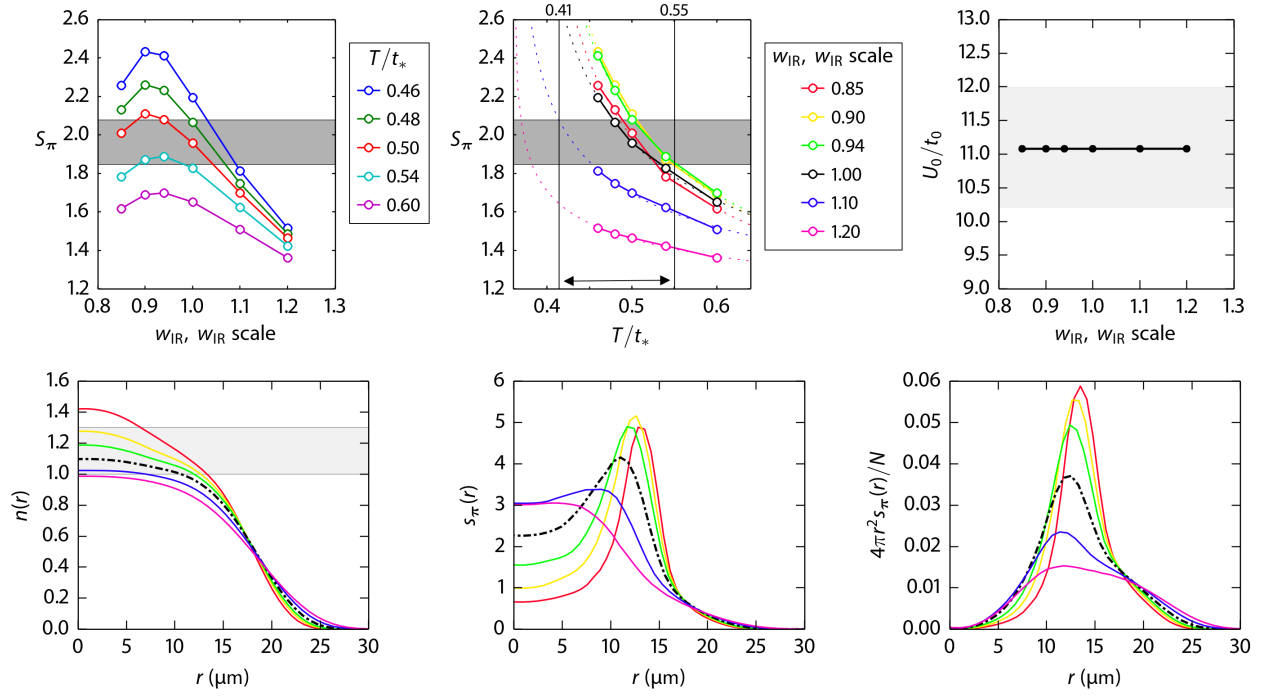
Figure 3

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Figure 4

Figure 5

Figure 6

References

[1] G. Zürn, T. Lompe, A. N. Wenz, S. Jochim, P. S. Julienne, and J. M. Hutson, "Precise Characterization of ^{6}Li Feshbach Resonances Using Trap-Sideband-Resolved RF Spectroscopy of Weakly Bound Molecules," Phys. Rev. Lett. **110,** 135301 (2013).