

Methods of EFT and LFT, Bad Honnef Physics School July 2023
Problems for Lecture 2 (Yannick Meurice)

1. Show that the one site version of the Hamiltonian for the Abelian Higgs model in the spin-1 approximation ($m_{max} = 1$) can be simulated with two Rydberg atoms located at a distance shorter than the Rydberg radius R_b . Derive the matching of the parameters of the simulator (Ω and Δ) with the parameters of the target model (U and X , note that Y is 0). In general, the Hamiltonian of an array of Rydberg atoms in their ground state $|g\rangle$ or Rydberg $|r\rangle$ state reads

$$H = \frac{\Omega}{2} \sum_i (|g_i\rangle \langle r_i| + |r_i\rangle \langle g_i|) - \Delta \sum_i n_i + \sum_{i<j} V_{ij} n_i n_j, \quad V_{ij} = \Omega R_b^6 / r_{ij}^6,$$

for a distance r_{ij} between the atoms labelled as i and j , $n_i = |r_i\rangle \langle r_i|$. The correspondence is $|gg\rangle \rightarrow |m=0\rangle$, $|gr\rangle \rightarrow |m=1\rangle$, $|rg\rangle \rightarrow |m=-1\rangle$, as proposed in Y. Meurice, "Theoretical methods to design and test quantum simulators for the compact Abelian Higgs model," Phys. Rev. D 104, 094513 (2021) <https://arxiv.org/abs/2107.11366>.

2. Using the notebook `2atomexample.ipynb`, simulate the two atom system of the previous problem and calculate the evolution of L_z^2 (or equivalently the sum of the probabilities for the $|rg\rangle$ and $|gr\rangle$ states). If you have an aws account that lets you use the braket service you may first experiment with the local simulator and then run on the actual QuEra hardware (for a fee). See <https://docs.aws.amazon.com/braket/index.html>

Otherwise you may install the amazon braket sdk on your own computer (no fee).

<https://github.com/aws/amazon-braket-sdk-python>

<https://pypi.org/project/amazon-braket-sdk/>

This sequence below seems to work (thanks Daniel Reitering!)

```
git clone https://github.com/aws/amazon-braket-sdk-python.git
cd amazon-braket-sdk-python
pip install .
```

Users need to get a local copy of `ahs_utils.py` on their python sys path. Two simple solutions are

Manually download https://github.com/aws/amazon-braket-examples/blob/main/examples/analog_hamiltonian_simulation/ahs_utils.py from github and place it in the same directory as the scripts/notebooks the user is running,

OR

Clone the braket example repo (<https://github.com/aws/amazon-braket-examples/tree/main>) with `git clone git@github.com:aws/amazon-braket-examples.git`, and create and run the user's python scripts and notebooks in the directory `./amazon-braket-examples/examples/analog_hamiltonian_simulation/`