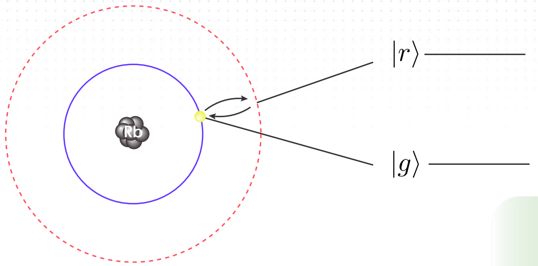
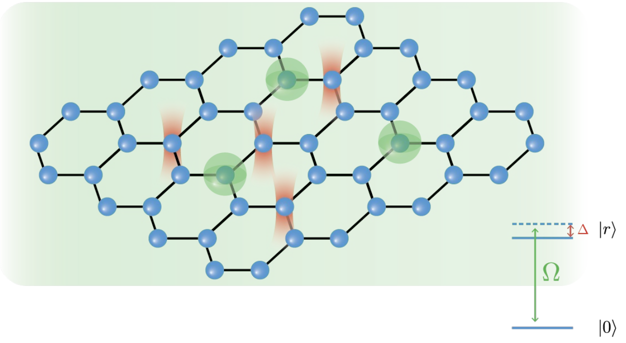
SESSION II: RABI & PHASES

|QuEra⟩

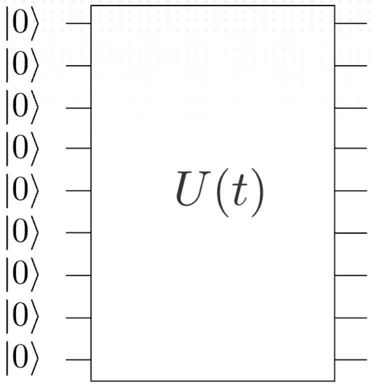
The story so far...

Architecture

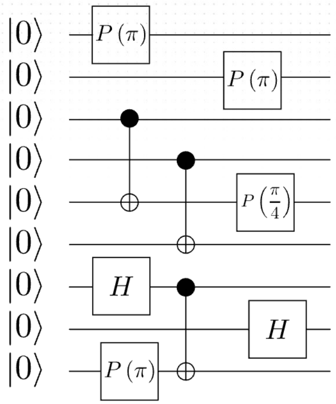




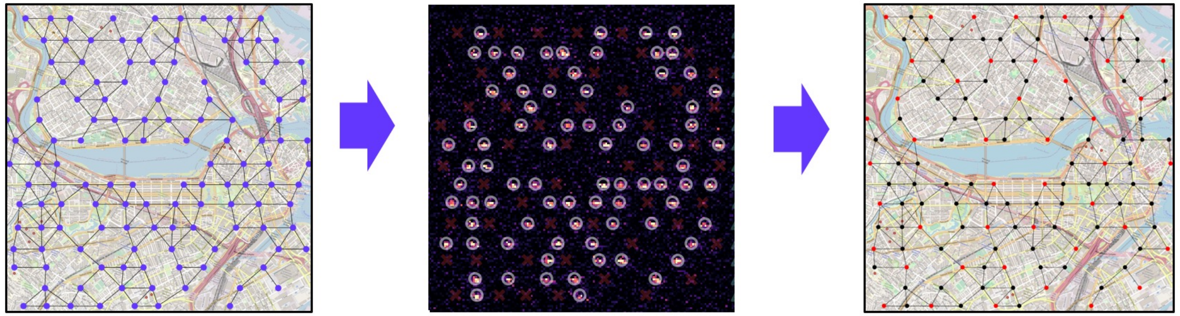
Analog operation



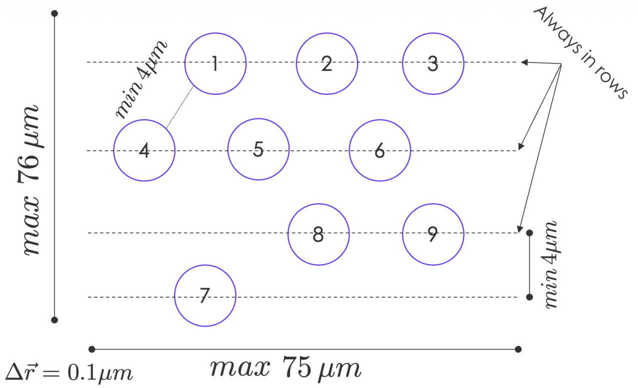
Digital operation

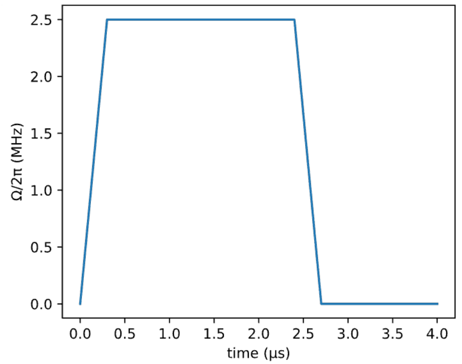


FPQA paradigm



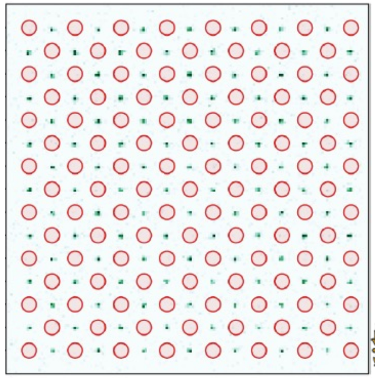
Hardware constraints





Major platform victories

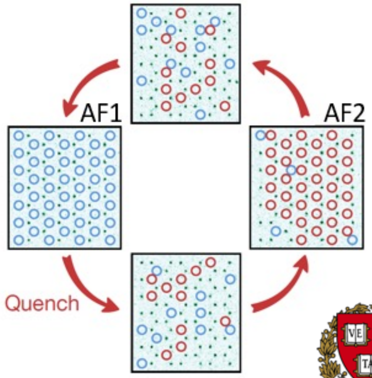
Quantum phase transitions and critical dynamics



Ebadi, et al., Nature, **595**, 227 (2021)

Some of the largest coherent quantum simulations ever

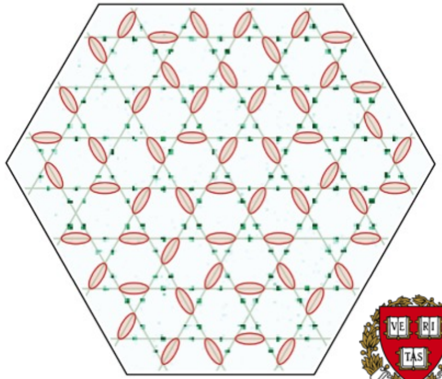
Controlling quantum many-body scars



Bluvstein, et al., Science, **371**, 1355 (2021)

First scientific discovery genuinely led by quantum computers

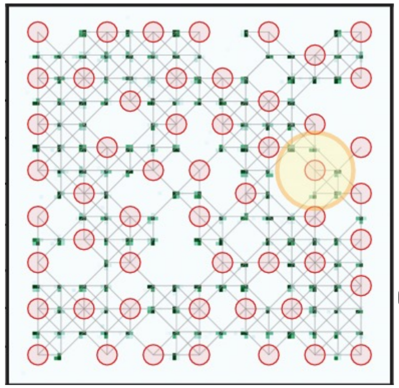
Quantum spin liquids



Semeghini, et al., Science, **374**, 1242 (2021)

First realization of a complex quantum phase sought after for 50 years

Maximum Independent Set Optimization



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Ebadi, et al., Science, **376**, 6598 (2022)

Quantum scaling demonstration for optimization problems

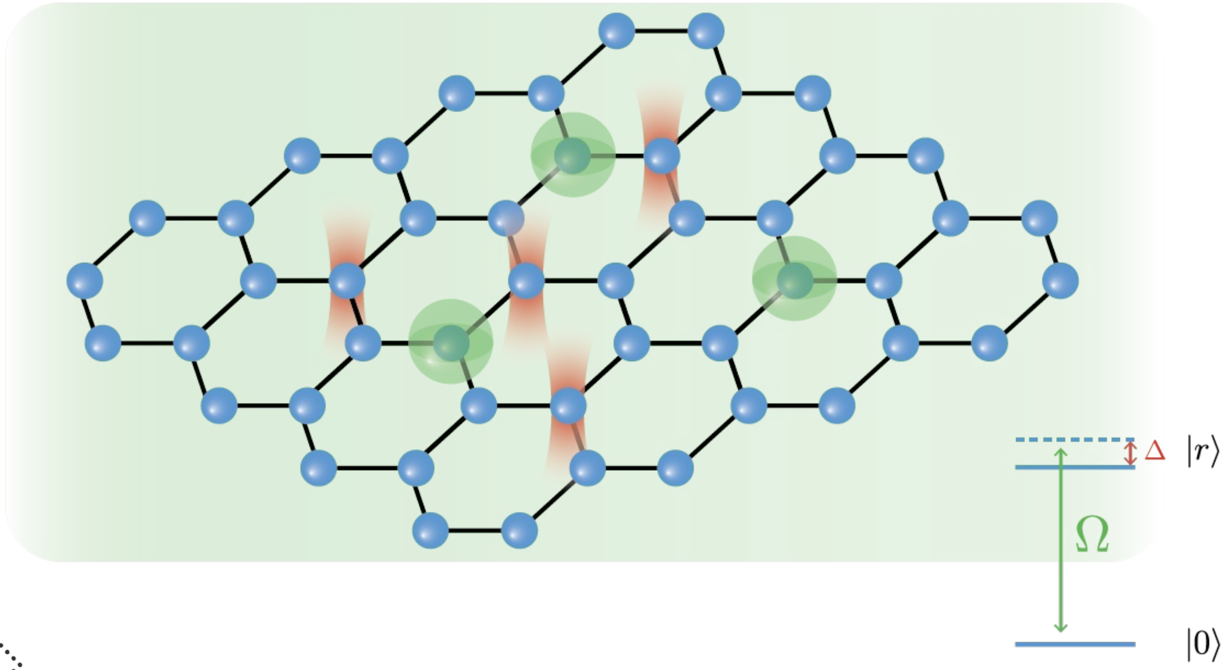
Learning objectives

By the end of the session, you will be able to:

- **Describe** the Rydberg blockade **phenomenon**
- **Compute** the **dynamics** of multi-qubit Rydberg systems **describing** the effects of the **blockade** on **Rabi** oscillations
- **Analyze** Rydberg phases on square lattices

Analog quantum dynamics control

$$H = \sum_i \frac{\Omega(t)}{2}\left(e^{i\phi(t)}|g_i\rangle\langle r_i| + e^{-i\phi(t)}|r_i\rangle\langle g_i|\right)$$



$$n_i = 1 * |r_i\rangle\langle r_i| + 0 * |\mathrm{g}_i\rangle\langle \mathrm{g}_i|$$

$$V_{ij} \sim d_{ij}^{-6}$$

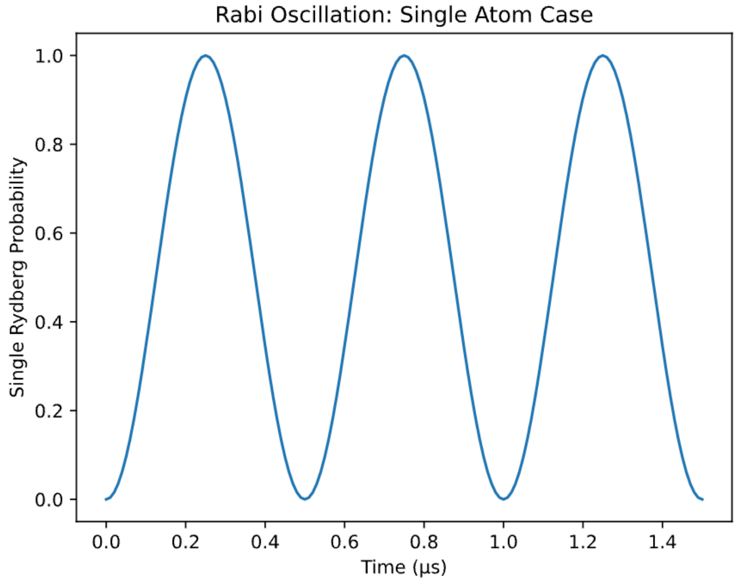
Rabi oscillations

$$H = \frac{\Omega}{2}\sigma_x \qquad |\psi(0)\rangle = |g\rangle$$

$$|\psi(t)\rangle = -i\sin\frac{\Omega}{2}t|g\rangle + \cos\frac{\Omega}{2}t|r\rangle$$

Activity: let's put this on Bloqade!

$$n(t) = \langle\psi(t)|\hat{n}|\psi(t)\rangle = \cos^2\frac{\Omega}{2}t$$



When many qubits come together

Rydberg blockade: phenomenology

$|rr\rangle$

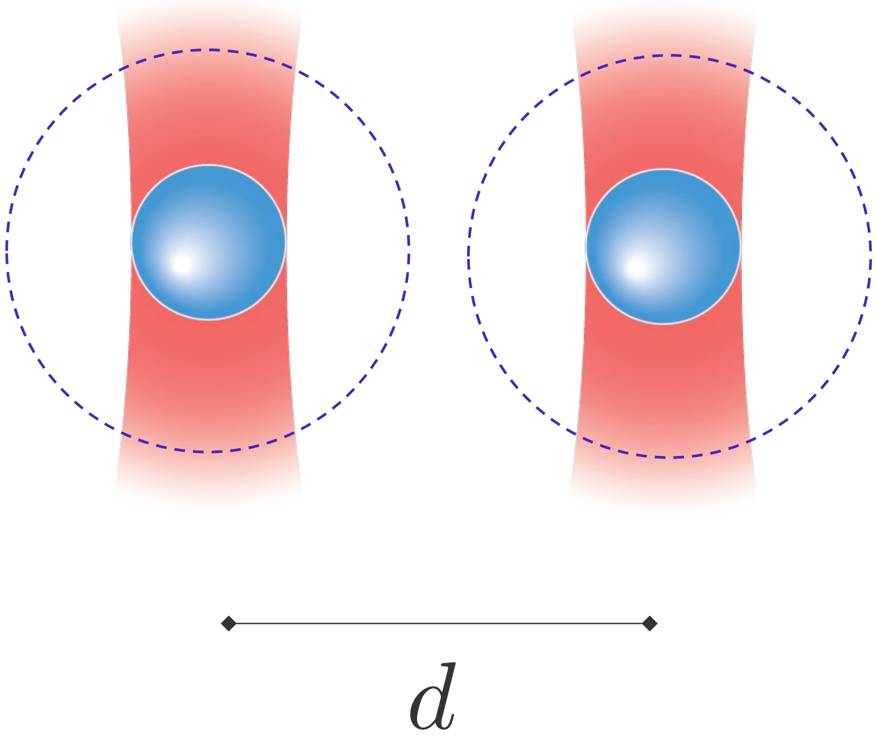
$V + \Delta$

$|gr\rangle \quad |rg\rangle$

Δ

$|gg\rangle$

$$V \sim d^{-6}$$

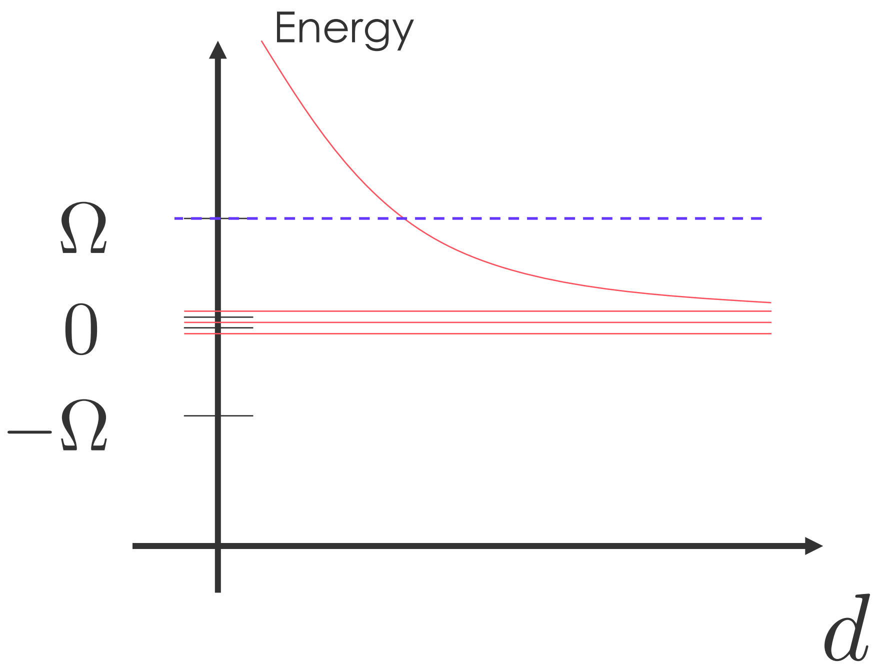


Rydberg blockade paradigm

$$H_{12} = \frac{\Omega}{2}(|g_1\rangle\langle r_1| + |g_2\rangle\langle r_2| + H.c.) + V_{12}n_1n_2 \qquad V_{12} = \frac{C_6}{d^6}$$

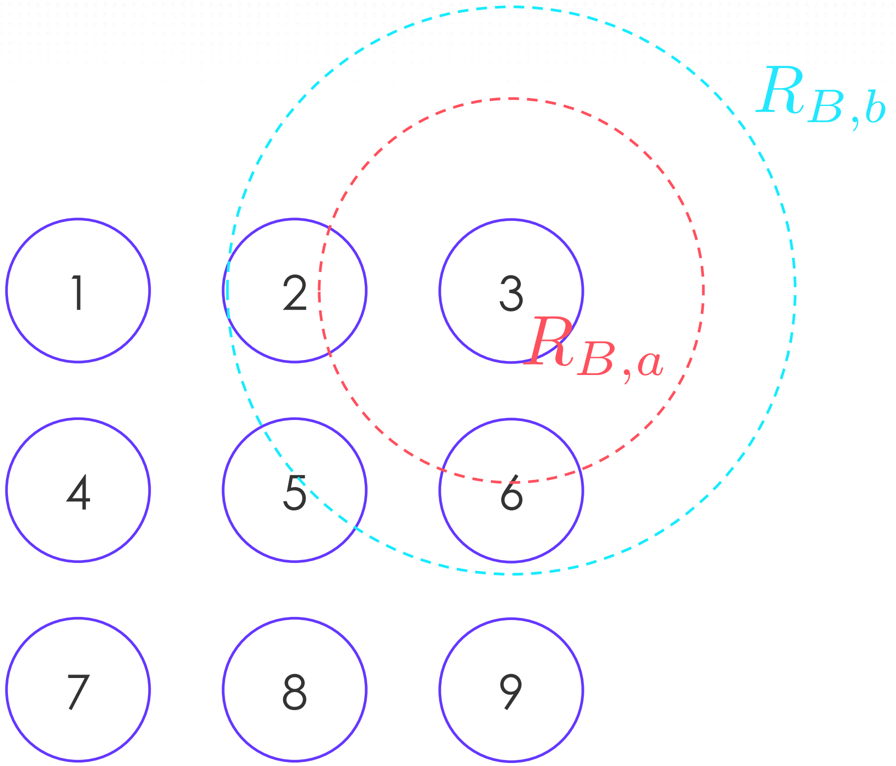
$$= \begin{bmatrix} 0 & \cancel{\frac{\Omega}{2}} & \cancel{\frac{\Omega}{2}} & 0 \\ \cancel{\frac{\Omega}{2}} & 0 & 0 & \cancel{\frac{\Omega}{2}} \\ \cancel{\frac{\Omega}{2}} & 0 & 0 & \cancel{\frac{\Omega}{2}} \\ 0 & \cancel{\frac{\Omega}{2}} & \cancel{\frac{\Omega}{2}} & \cancel{V_{12}} \end{bmatrix}$$

$$R_b = (C_6/\Omega)^{1/6}$$

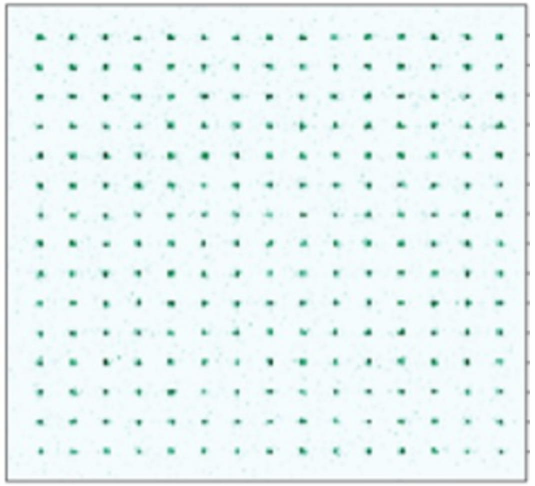


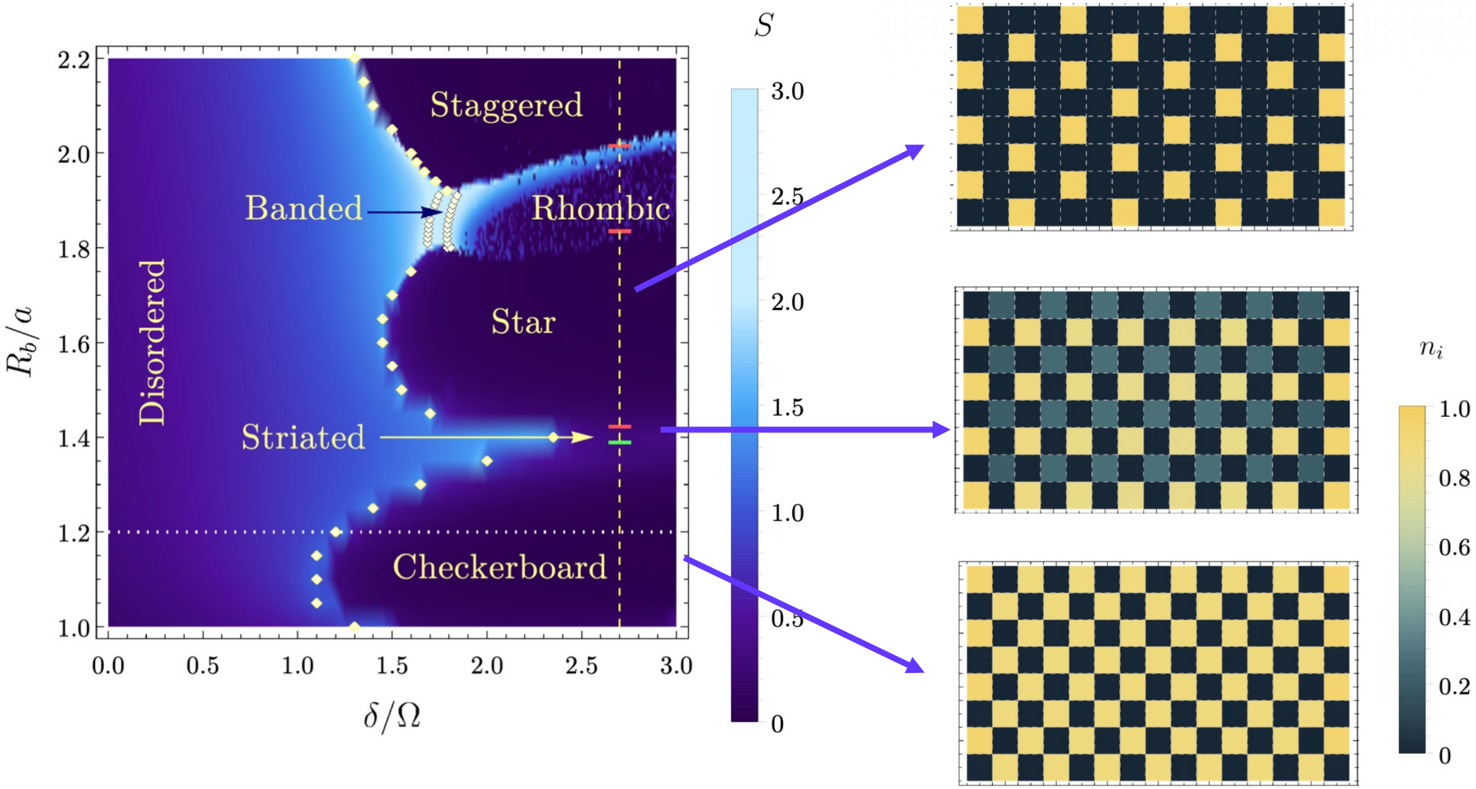
Oscillations/superposition stuck in manifold: $|gg\rangle, \ |gr\rangle, \ |rg\rangle$

Activity: Find excitation patterns



(Ordered) Quantum phases





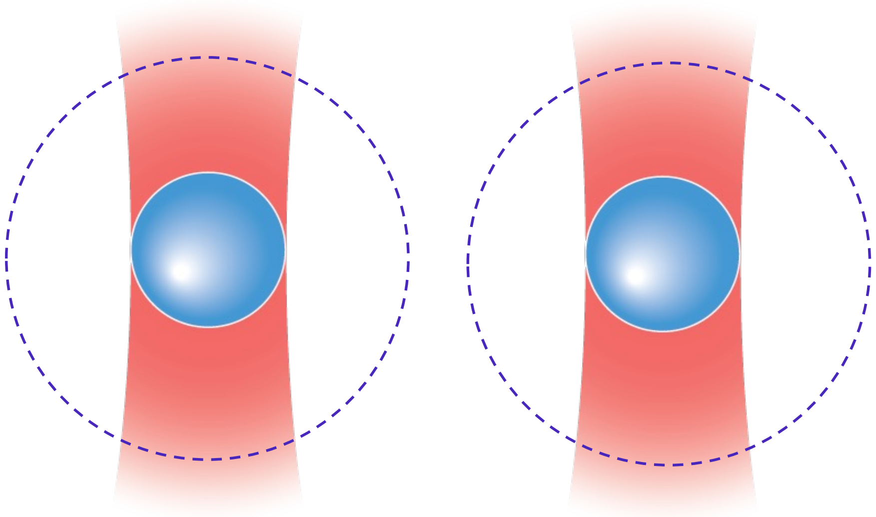
R. Samajdar et al., Phys. Rev. Lett. 124, 103601 (2020)

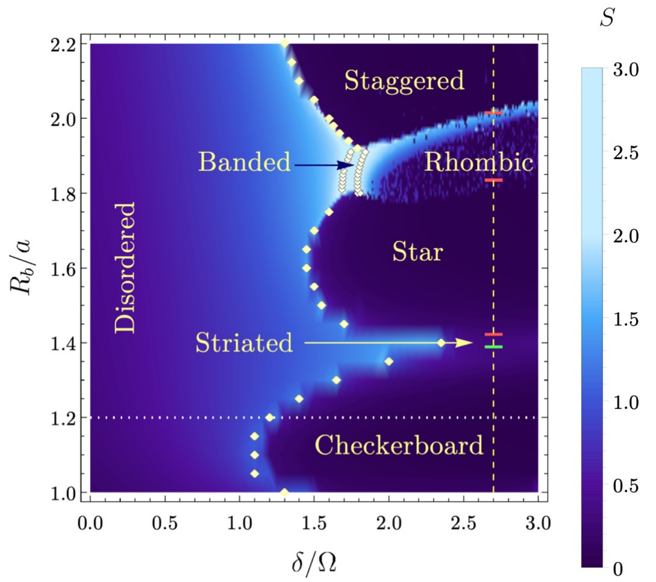
Summary

Algorithm design

$$\frac{H}{\hbar} = \sum_i \frac{\Omega(t)}{2}\left(e^{i\phi(t)}|g_i\rangle\langle r_i| + e^{-i\phi(t)}|r_i\rangle\langle g_i|\right) - \sum_i \Delta_\mathrm{i}(t) n_i + \sum_{i<j} V_{ij} n_i n_j$$

Rydberg blockade & quantum phases





Today’s story (LO’s)

Now you are able to:

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