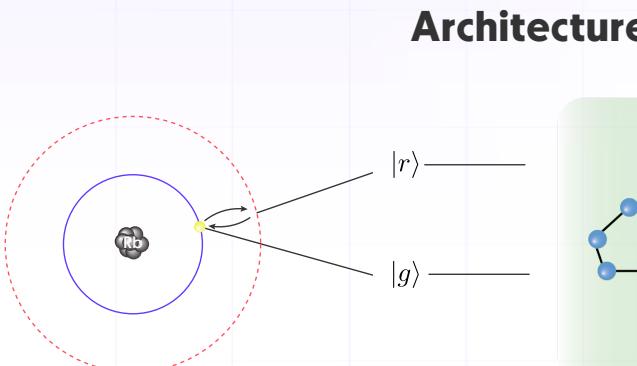


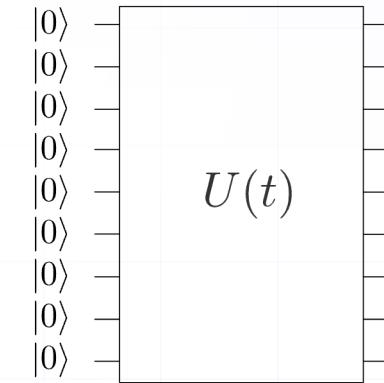
IQuEra>

# Session II: Rabi & phases

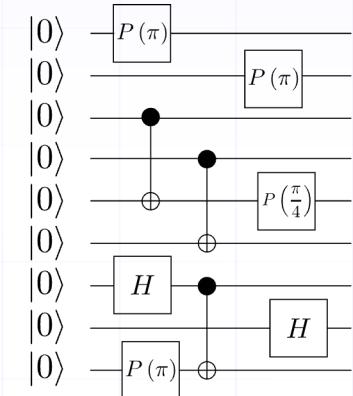
# The story so far...



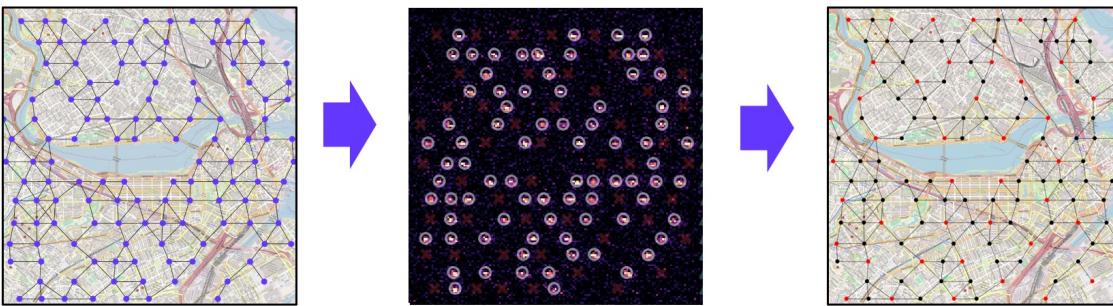
## Analog operation



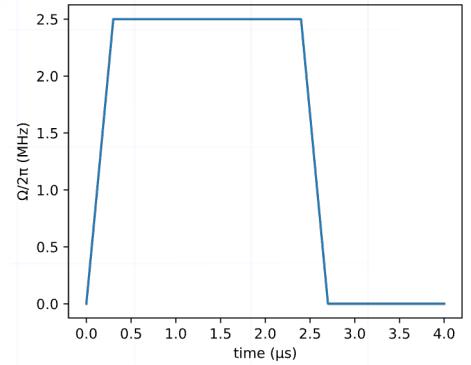
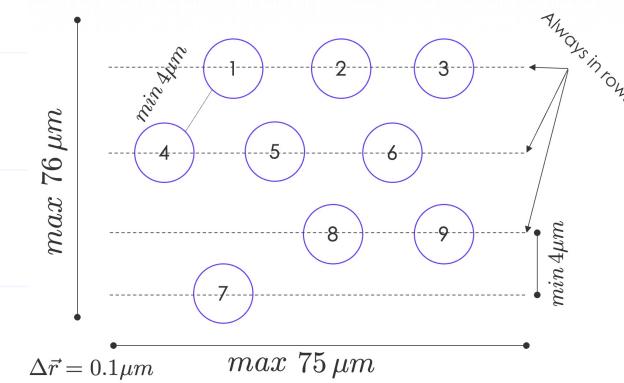
## Digital operation



## FPQA paradigm

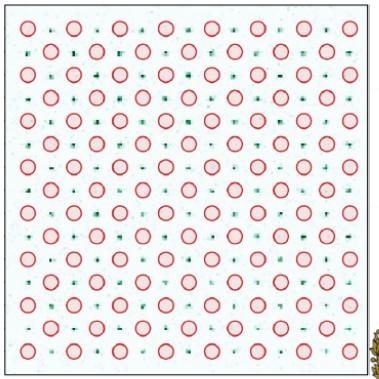


## Hardware constraints



# Major platform victories

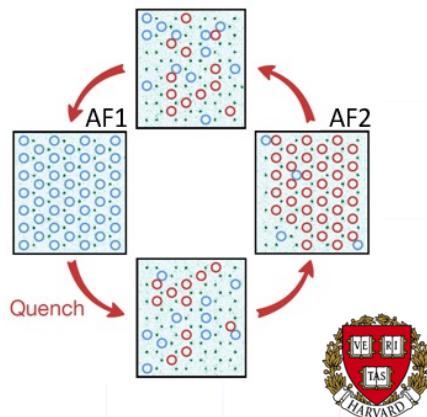
Quantum phase transitions and critical dynamics



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

Some of the largest coherent quantum simulations ever

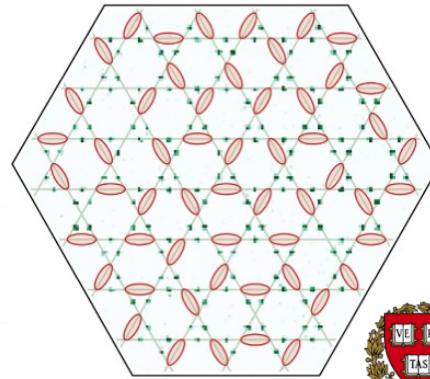
Controlling quantum many-body scars



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

First scientific discovery genuinely led by quantum computers

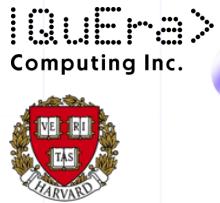
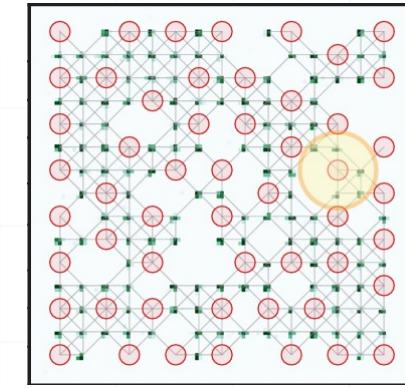
Quantum spin liquids



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

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

Maximum Independent Set Optimization



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

Quantum scaling demonstration for optimization problems

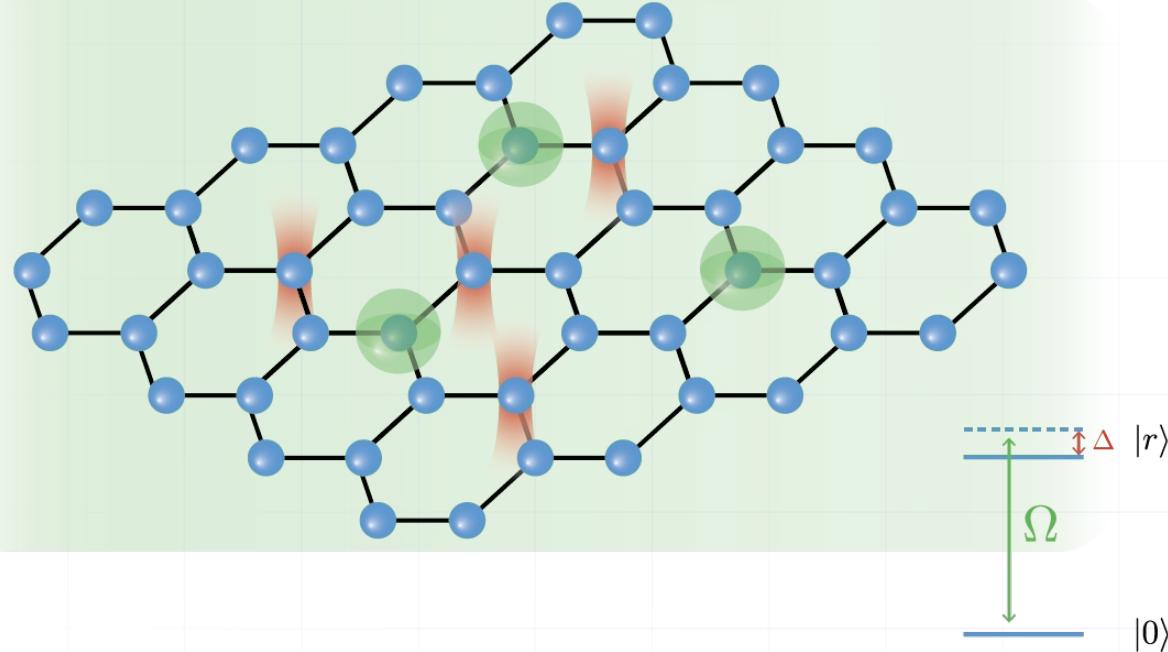
# Learning objectives

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

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



$$n_i = 1 * |r_i\rangle\langle r_i| + 0 * |g_i\rangle\langle g_i|$$

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

# Rabi oscillations

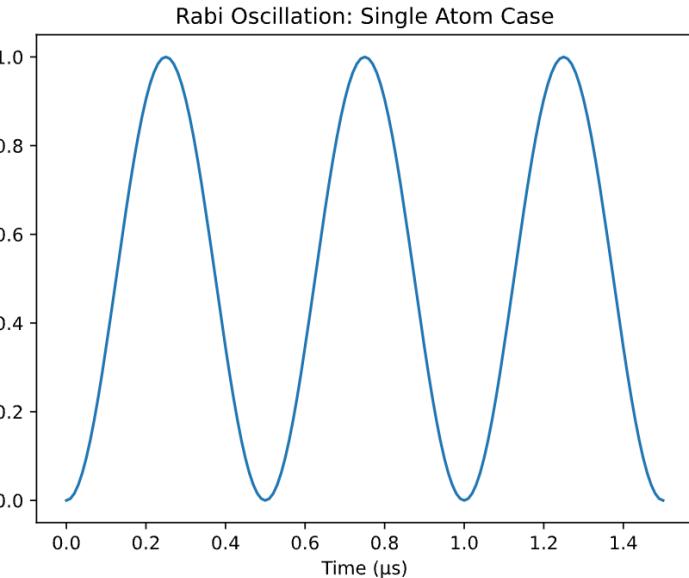
$$H = \frac{\Omega}{2} \sigma_x$$

$$|\psi(0)\rangle = |g\rangle$$

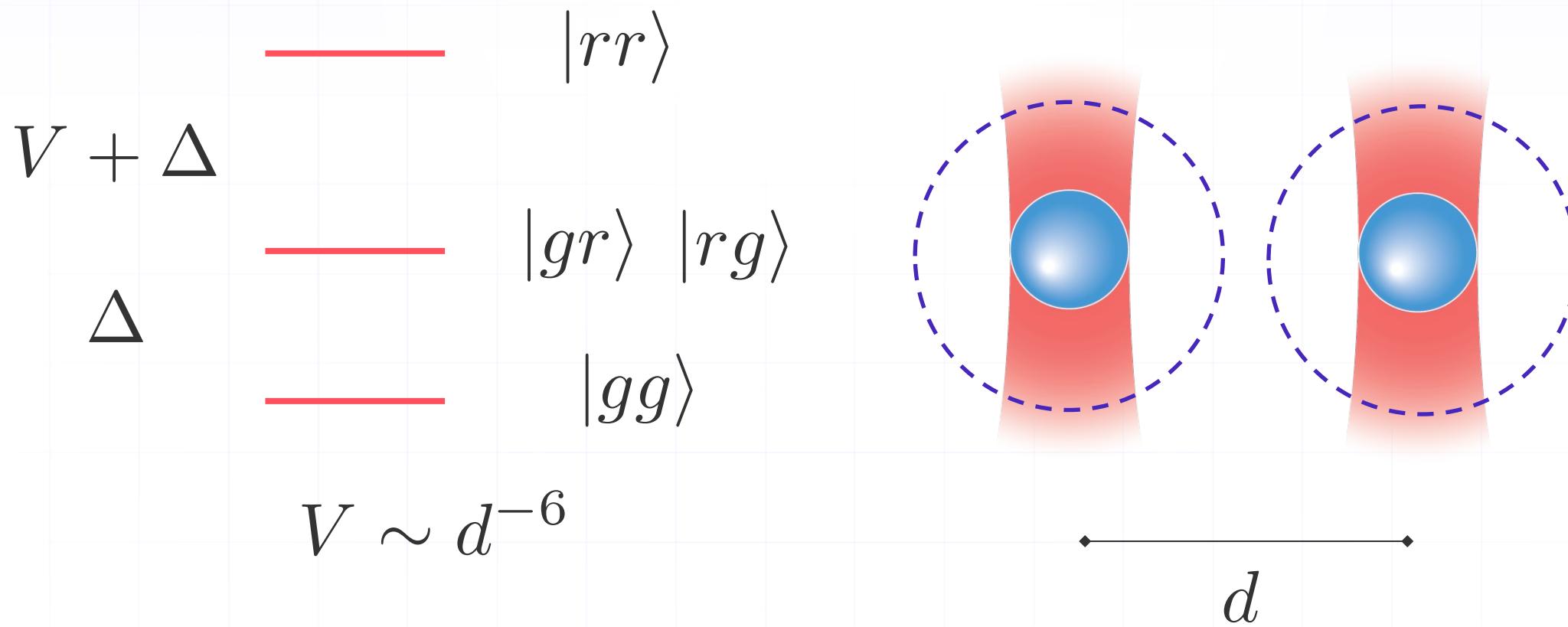


$$|\psi(t)\rangle = \cos \frac{\Omega}{2}t |g\rangle - i \sin \frac{\Omega}{2}t |r\rangle$$

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



# Rydberg blockade: phenomenology



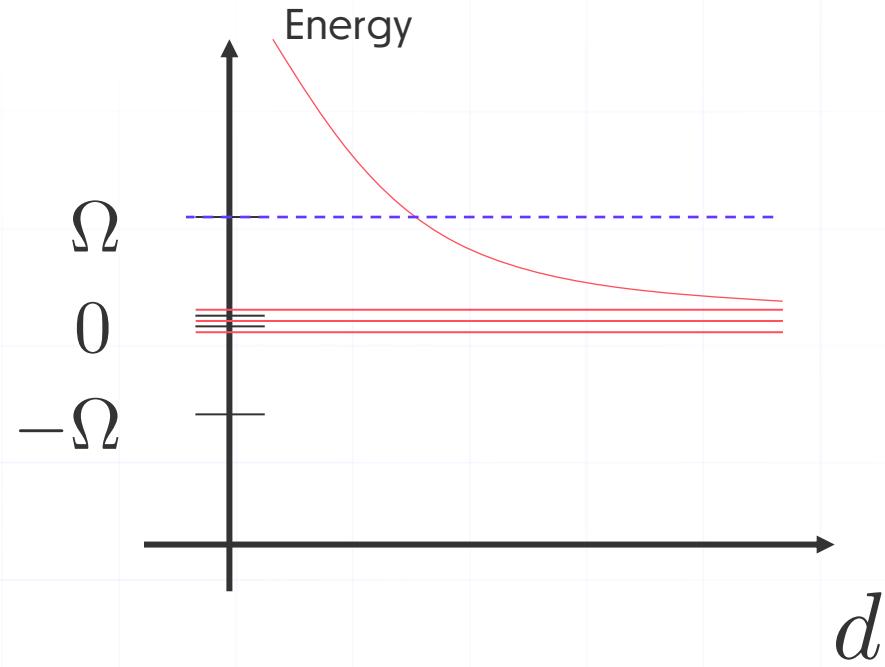
# Rydberg blockade paradigm

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

$$V_{12} = \frac{C_6}{d^6}$$

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

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



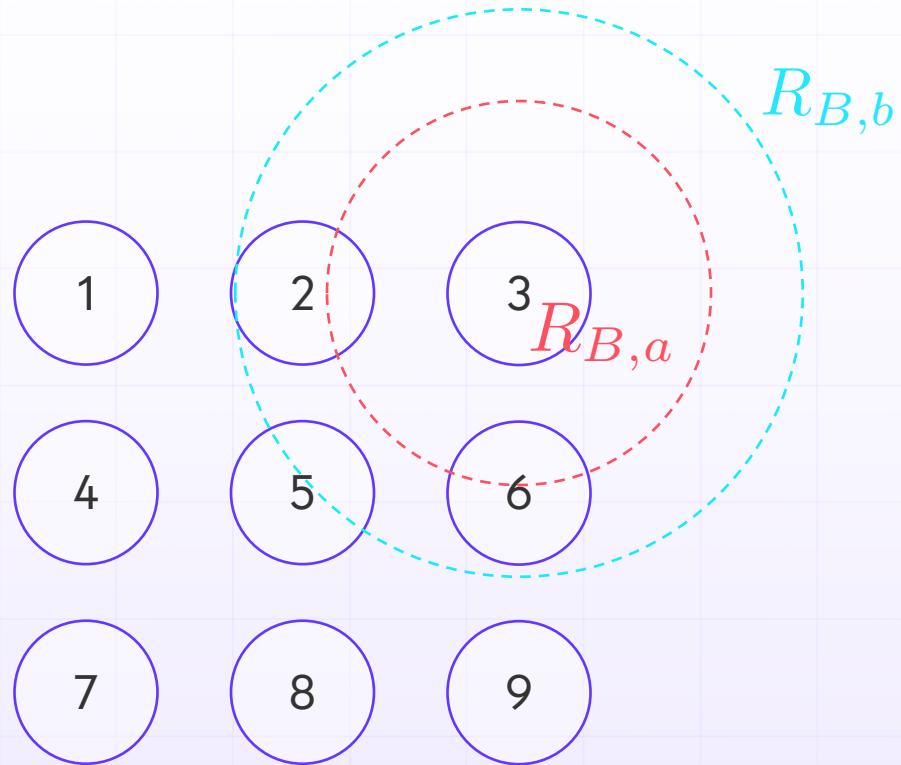
Oscillations/superposition stuck in manifold:

$|gg\rangle, |gr\rangle, |rg\rangle$

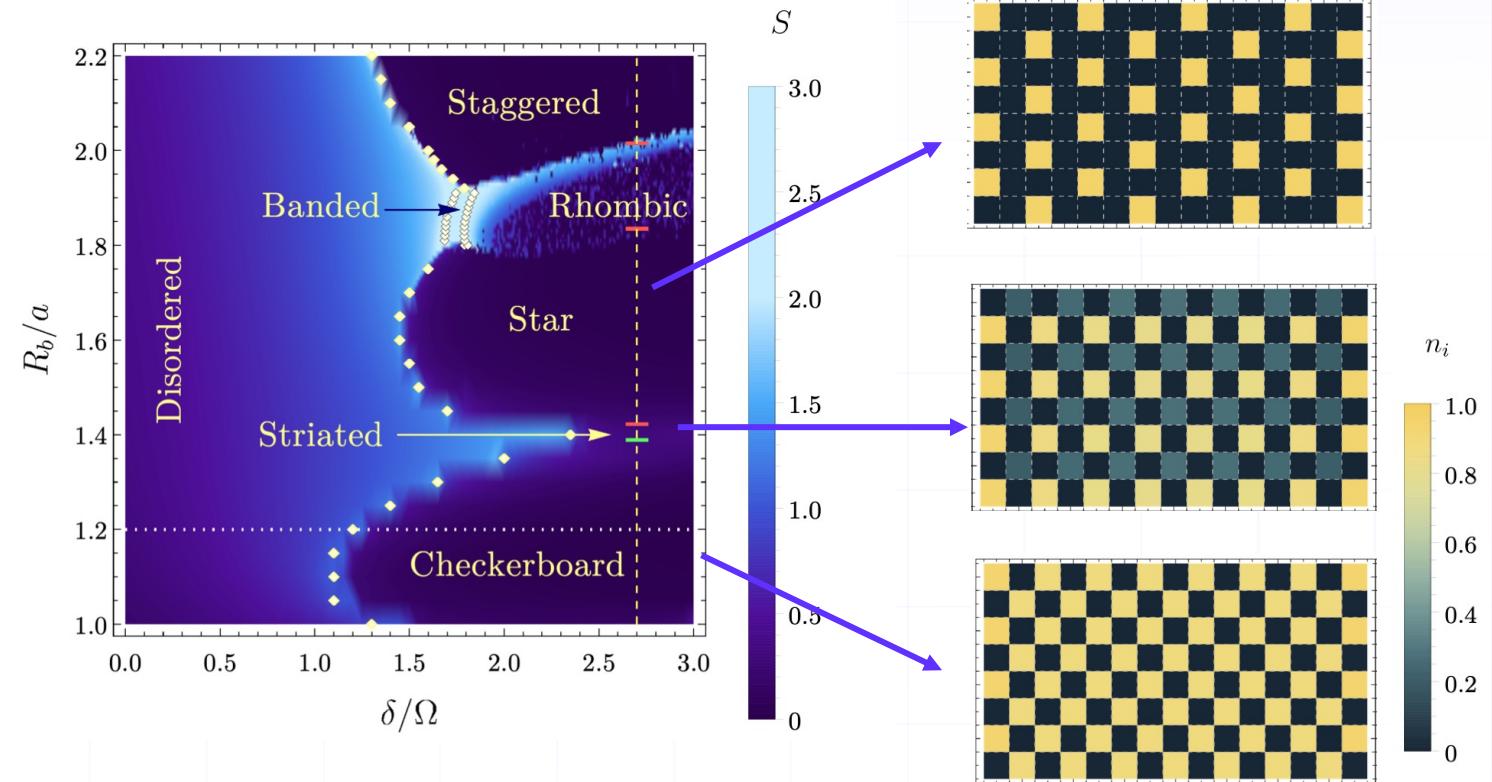
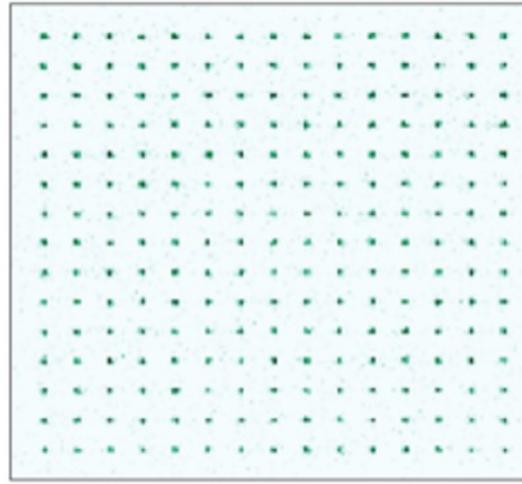
IQuEra>

**When many qubits  
come together**

# Activity: Find excitation patterns



# (Ordered) Quantum phases

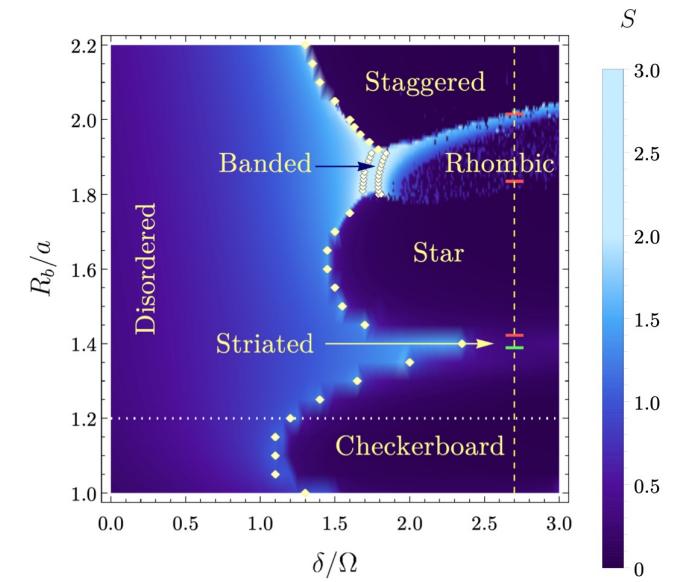
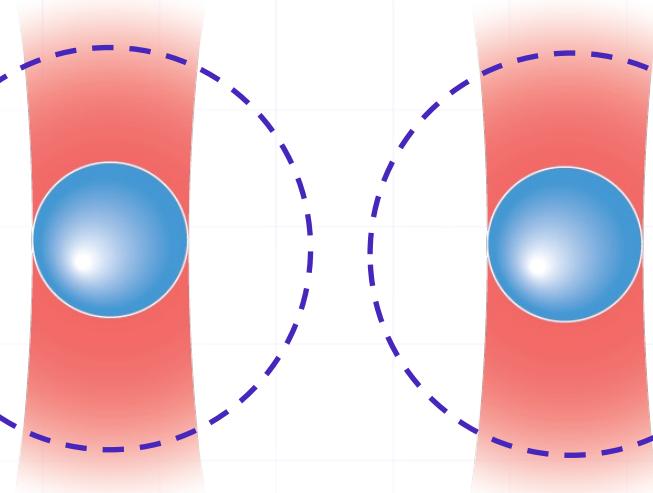


# Summary

Algorithm design

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

Rydberg blockade & quantum phases



# Today's story (LO's)

Now you are able to:

- **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