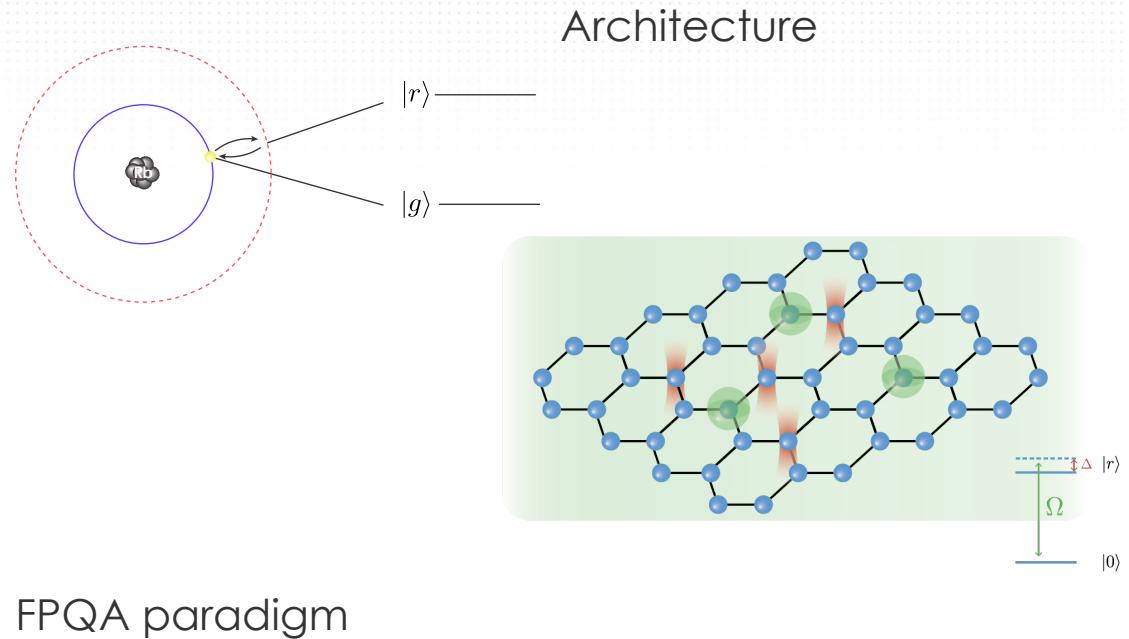
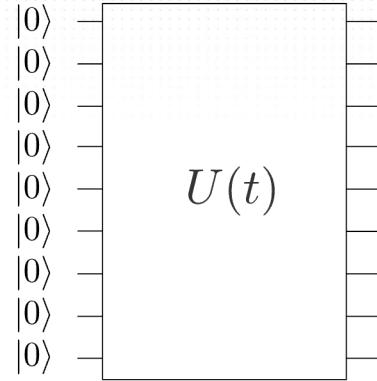


# SESSION II: RABI & PHASES

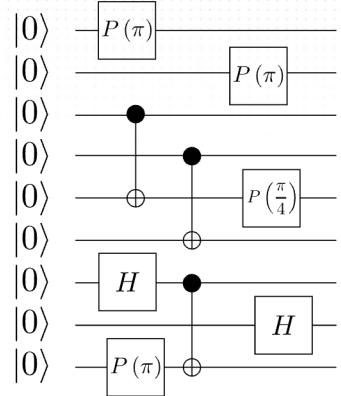
# The story so far...



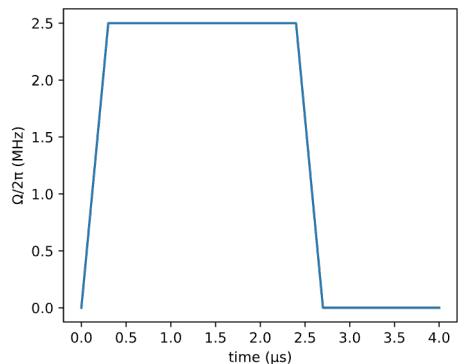
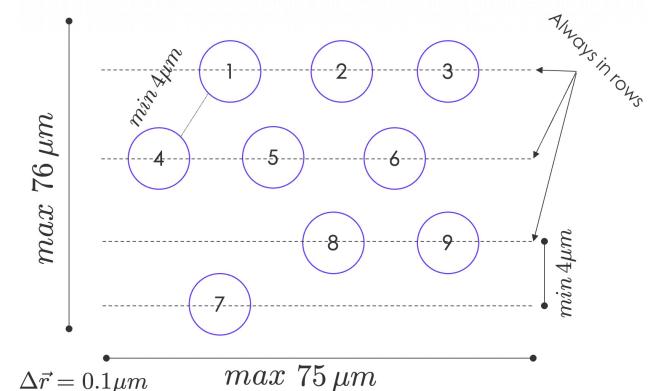
Analog operation



Digital operation

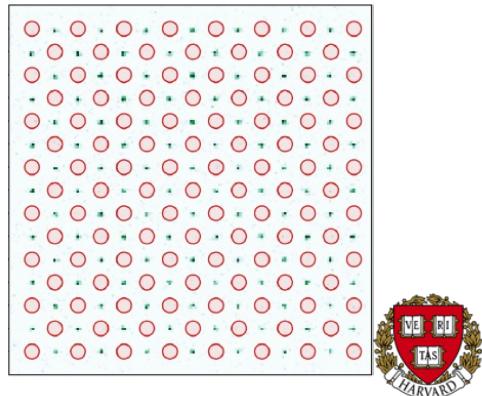


Hardware constraints



# Major platform victories

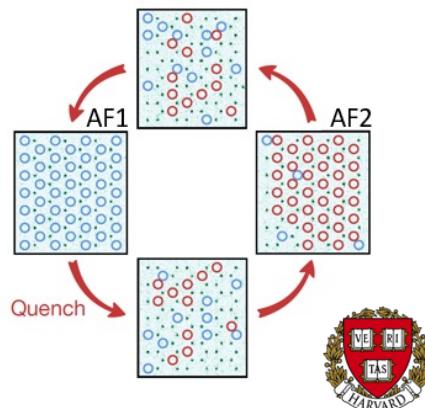
Quantum phase  
transitions and critical  
dynamics



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

Some of the largest  
coherent quantum  
simulations ever

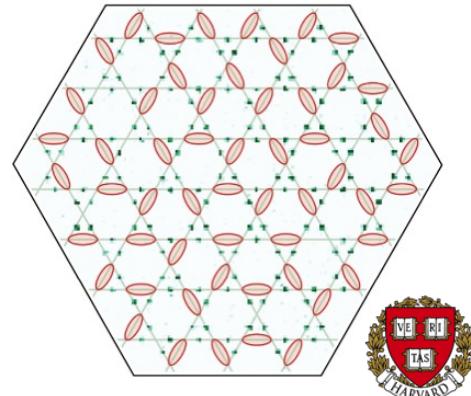
Controlling quantum  
many-body scars



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

First scientific  
discovery genuinely  
led by quantum  
computers

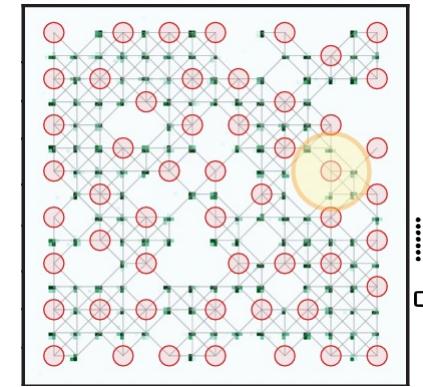
Quantum spin liquids



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

!QUREa>  
COMPUTING INC.

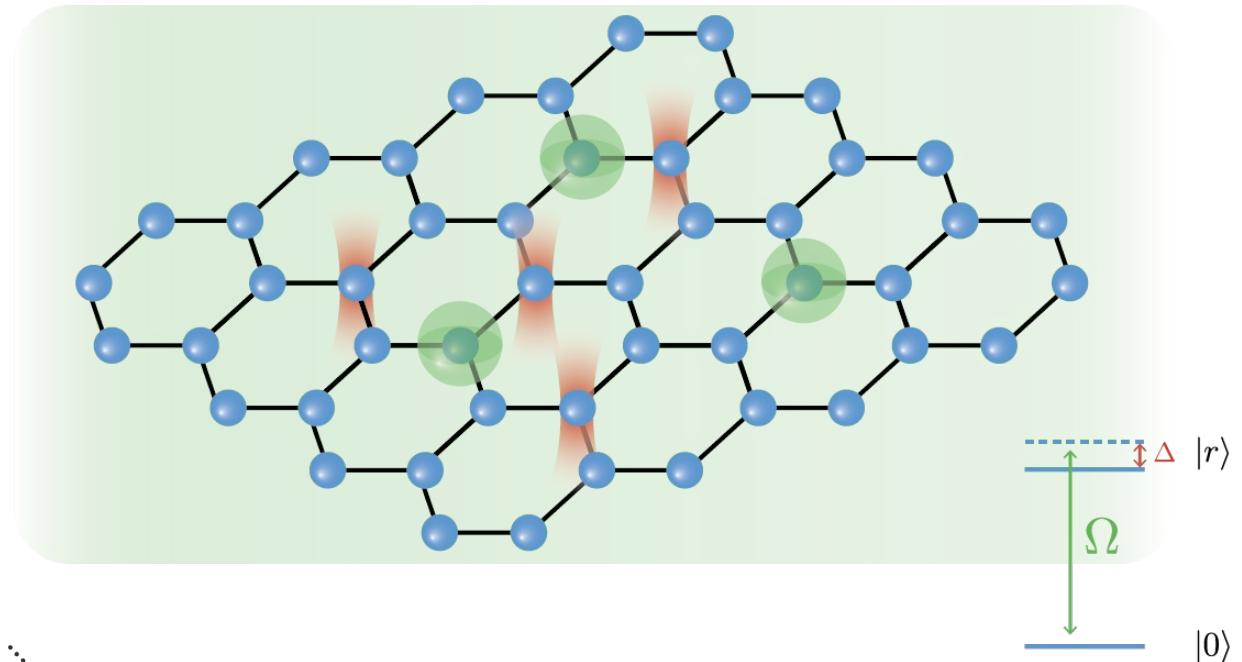
# Today's story (LO's)

**By the end of the workshop, 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

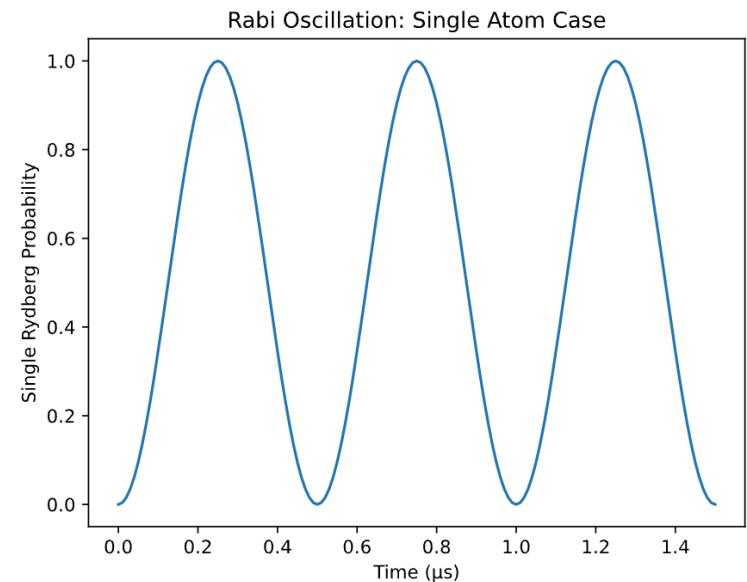
$$H = \frac{\Omega}{2} \sigma_x \quad |\psi(0)\rangle = |g\rangle$$



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

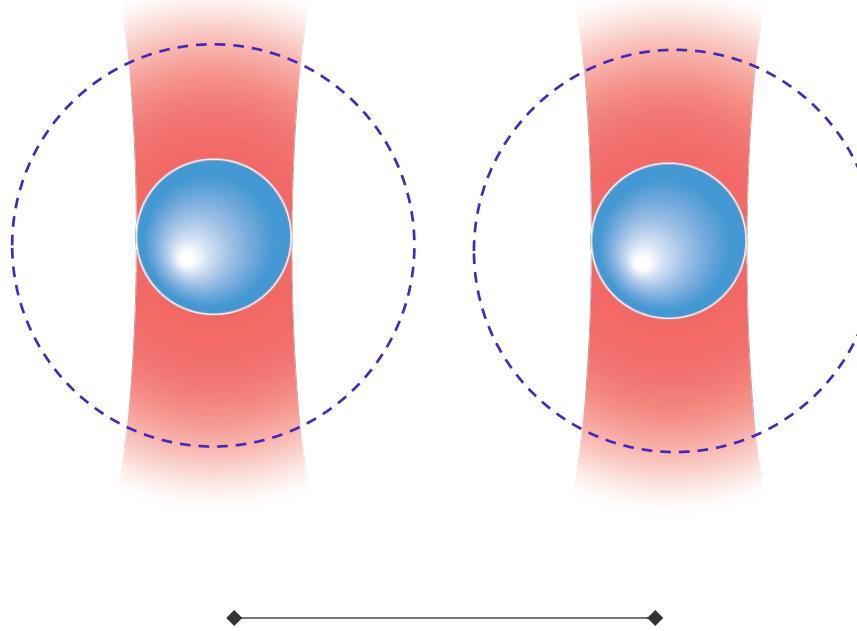
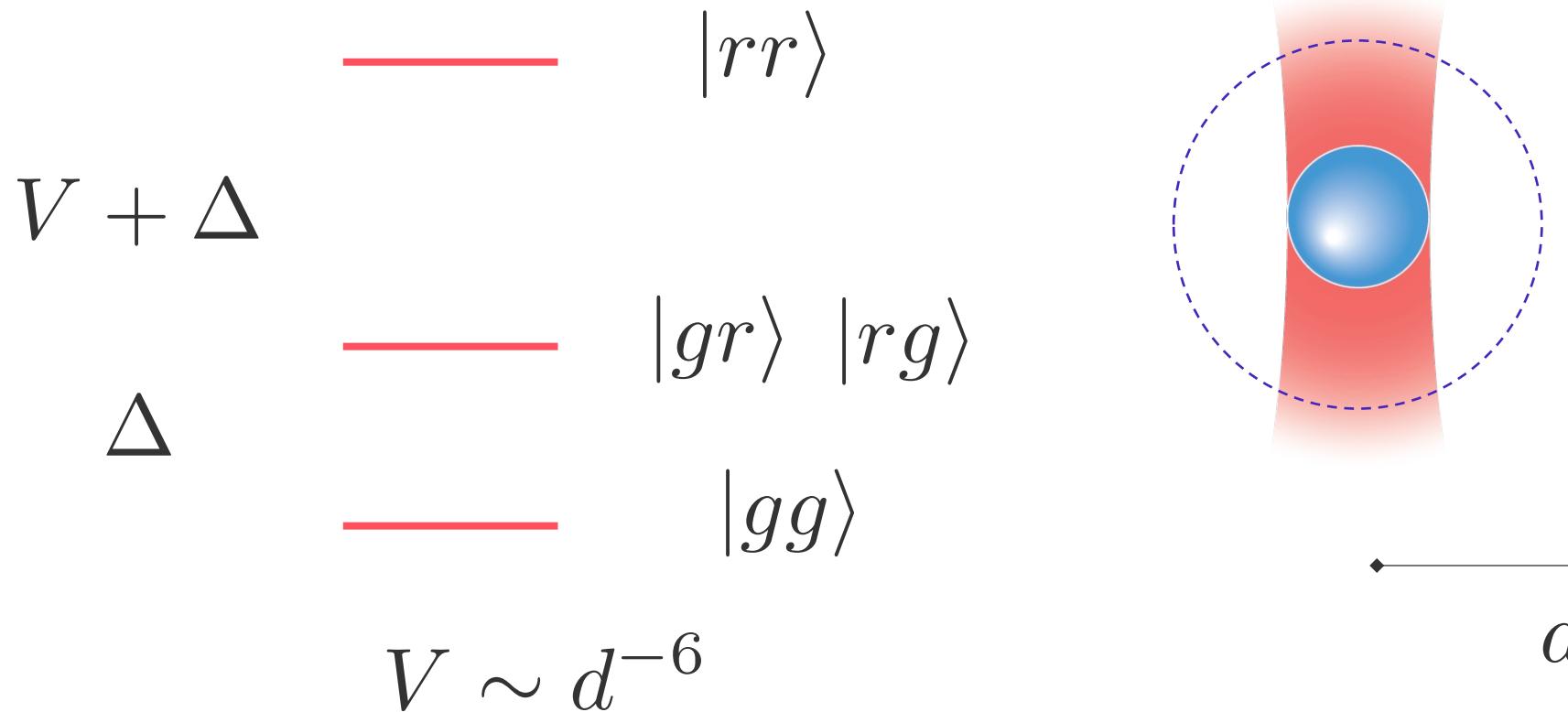
Activity: let's put this on Bloqade!

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



# When many qubits come together

# Rydberg blockade: phenomenology



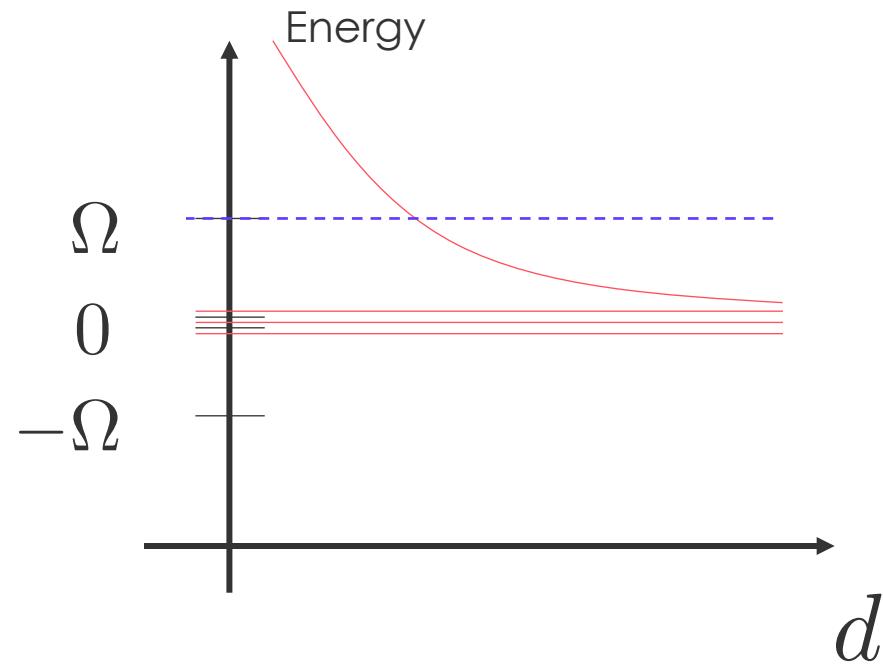
# Rydberg blockade paradigm

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

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

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

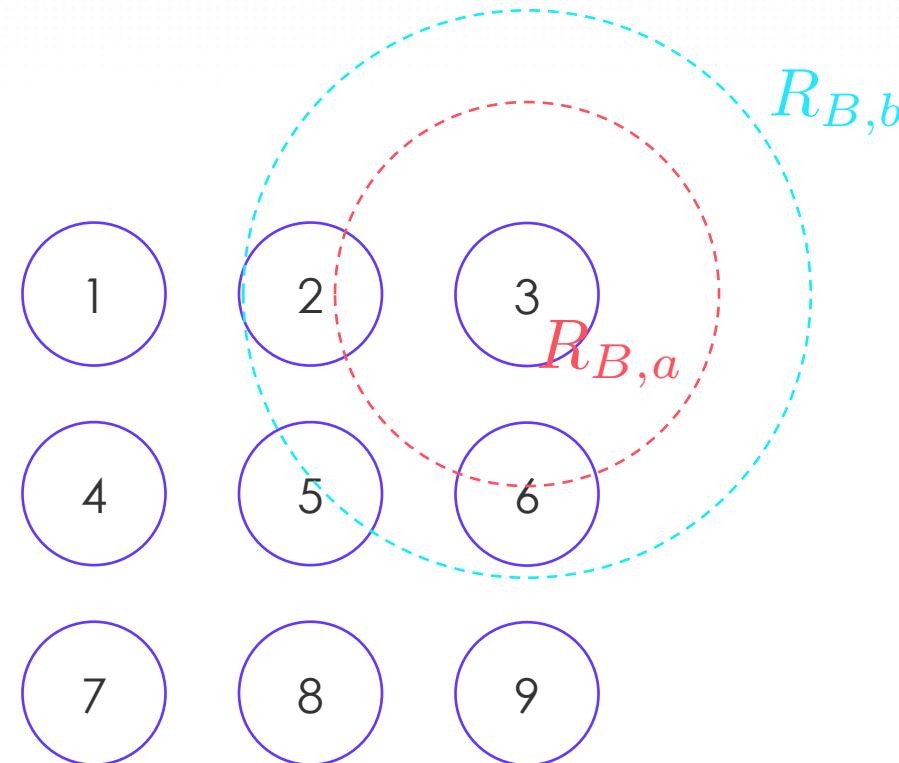
$$R_b = (C_6/\Omega)^{1/6}$$



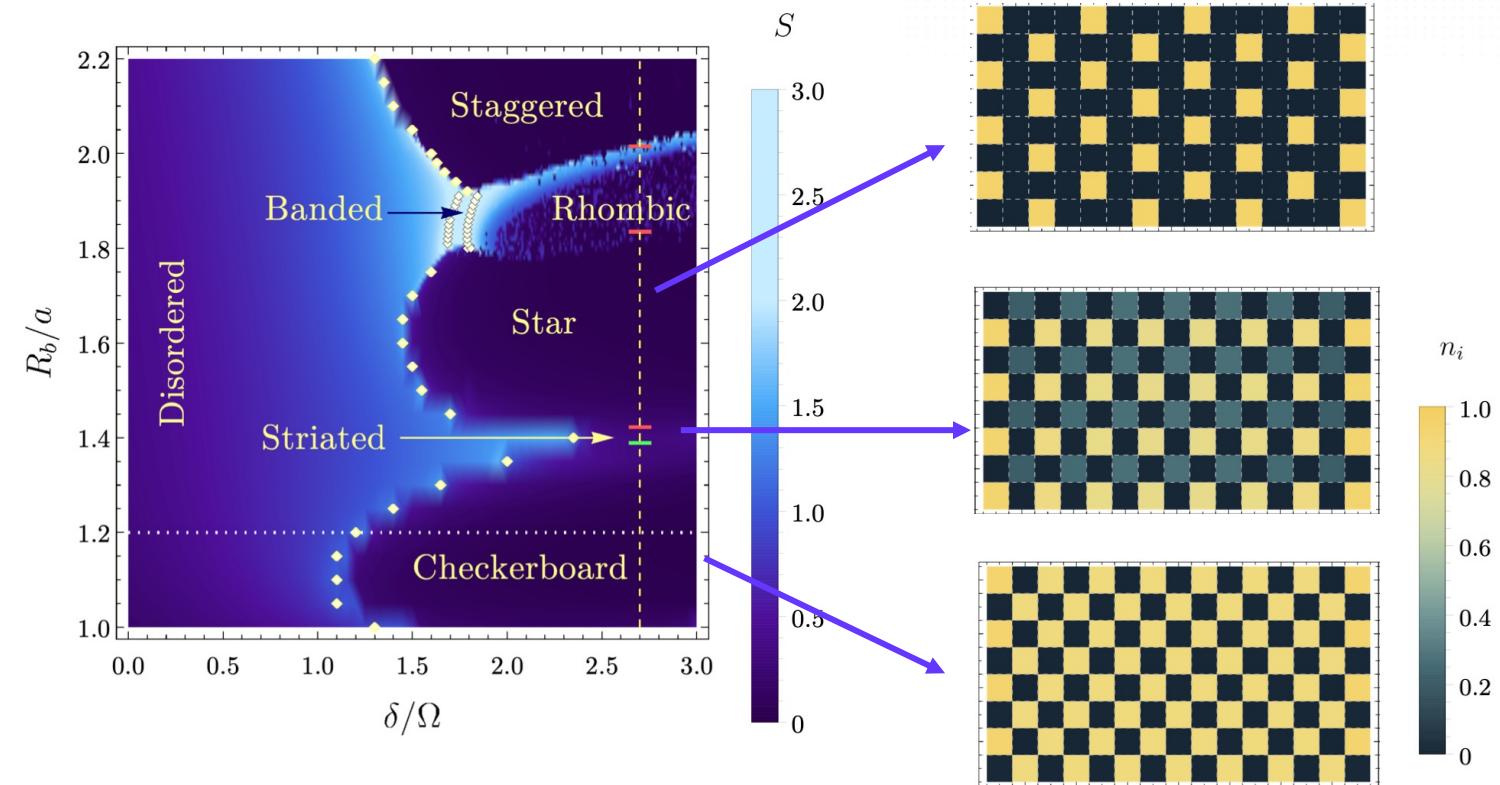
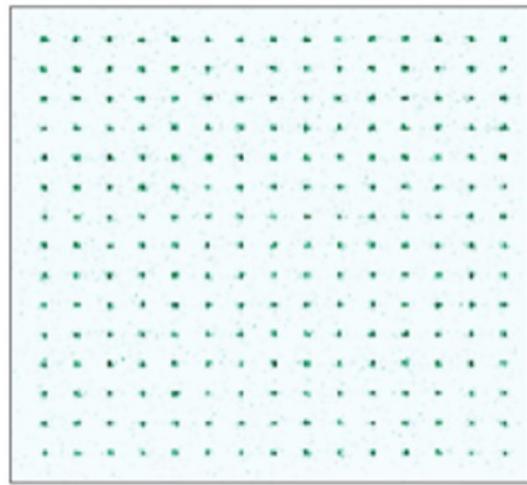
(QUEFa)

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

# Activity: Find excitation patterns



# (Ordered) Quantum phases

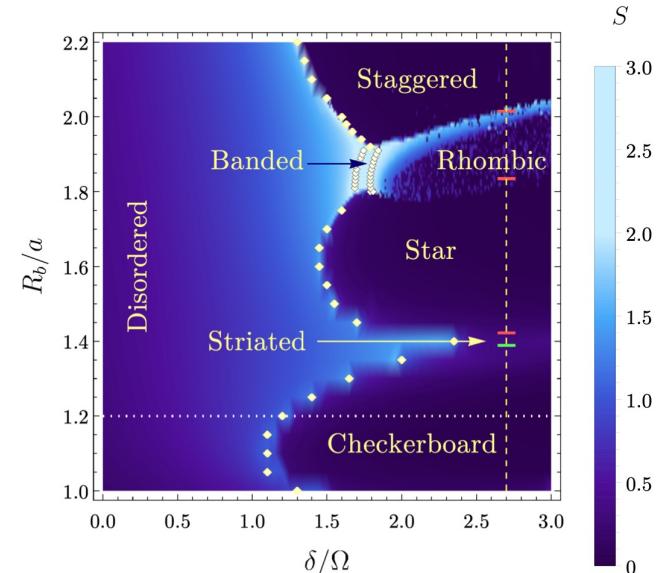
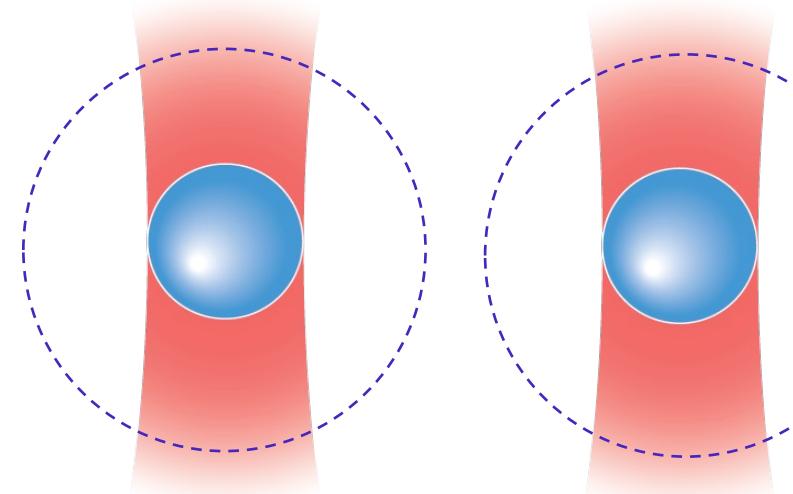


# Summary

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

# How to continue by myself?

BLOQADE



aws



ACCESS AT  
**AMAZON BRAKET**  
**(research credits available)**

Other access points:



PENNYLANE

(coming soon)