

# Quantum Synchronization of Rydberg Atoms in Optical Tweezers

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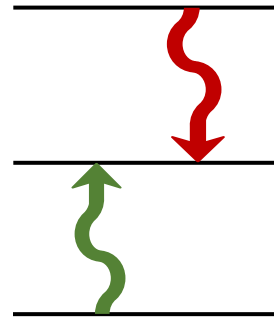
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# Quantum Synchronization

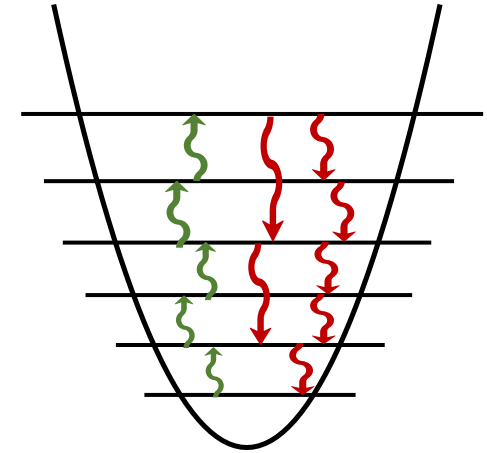
- Guided by classical phase synchronization
- Appears in nature
- How do we translate from  $\phi$  to  $\hat{\phi}$ ?

# Rydberg Atoms



- Rydberg atoms are highly excited
- We can treat the energy levels as a spin system

# Optical Tweezers



- Provide a harmonic trap for our atom

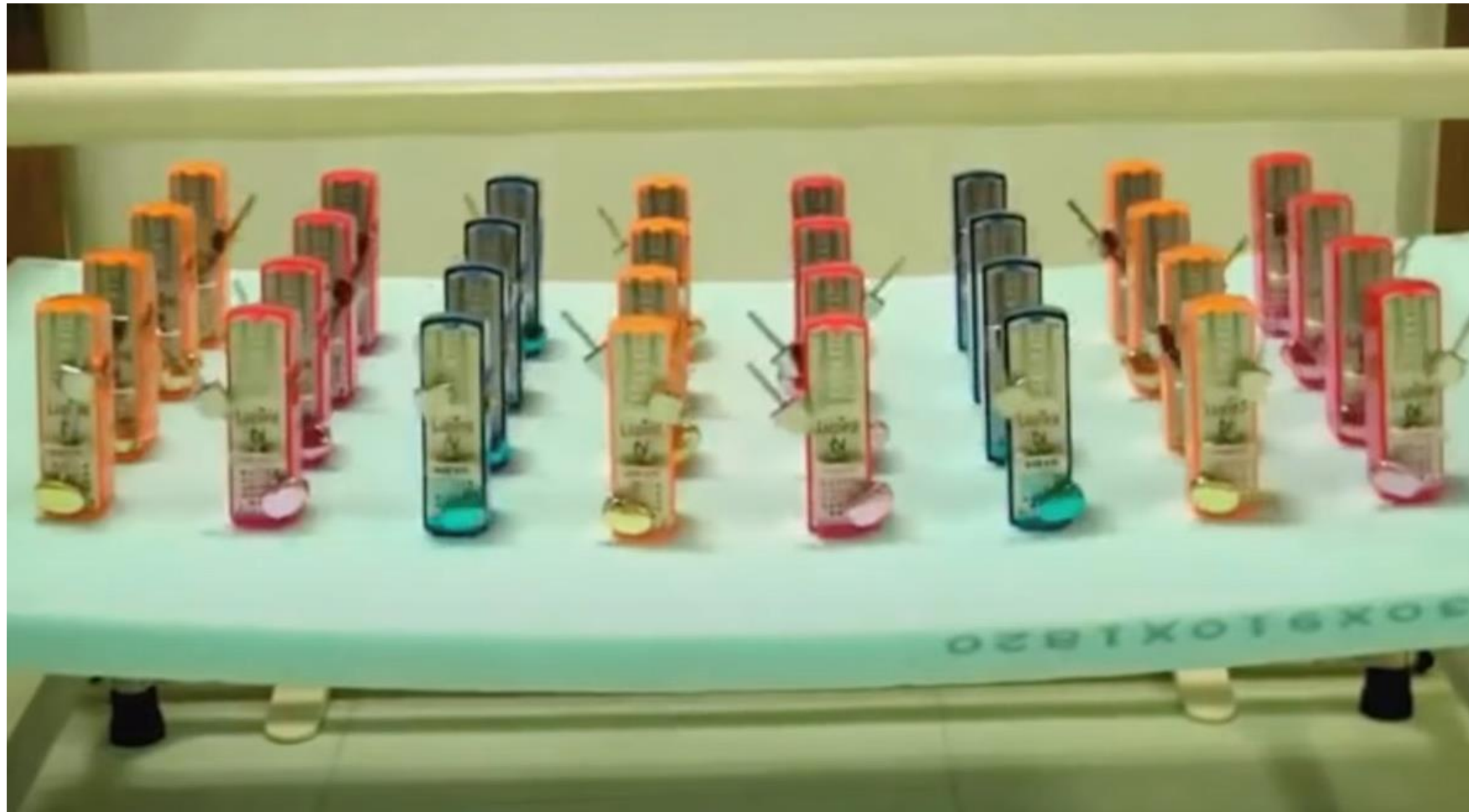
# Classical Synchronization

From: <https://www.youtube.com/watch?v=5v5eBf2KwF8>.



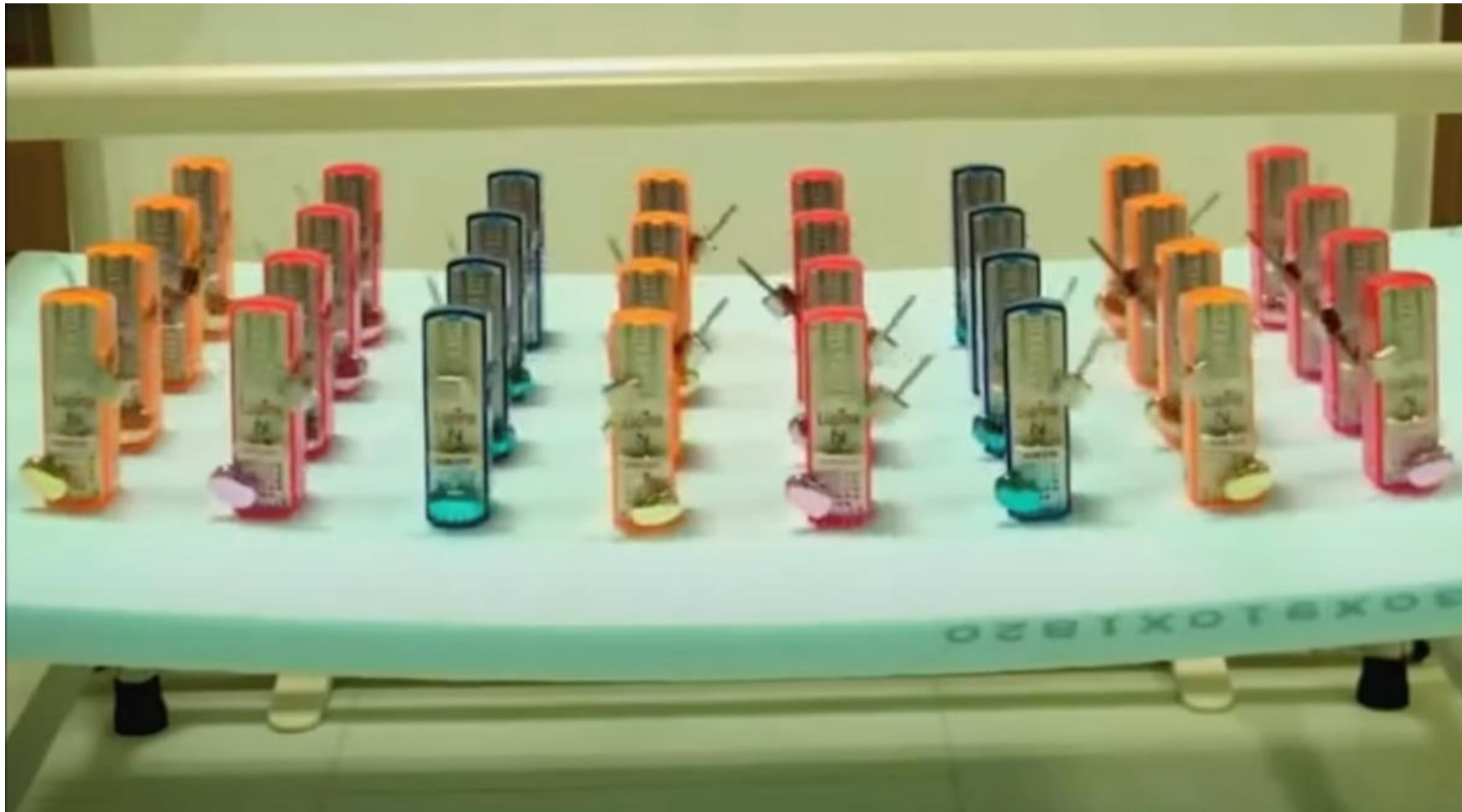
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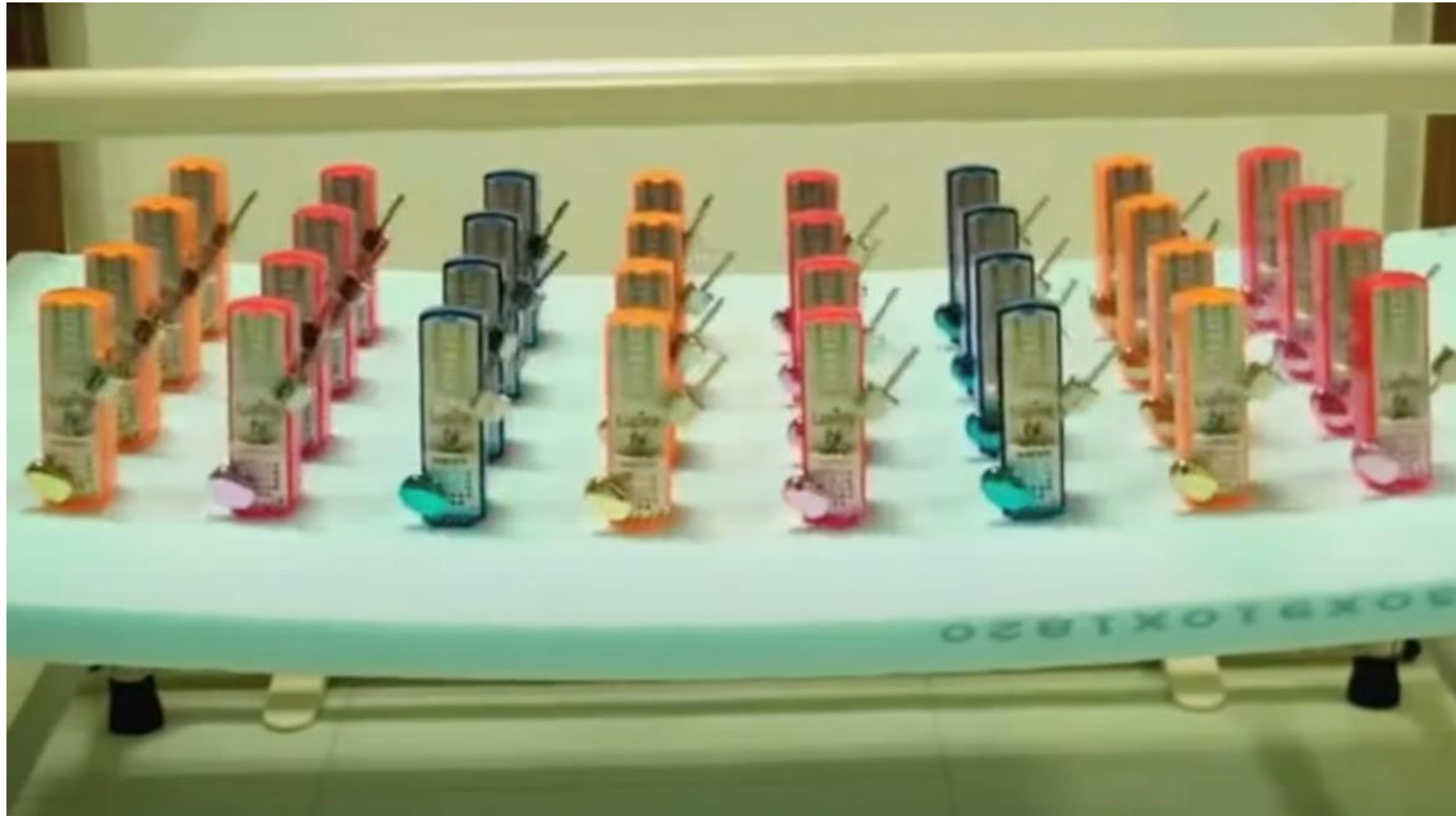
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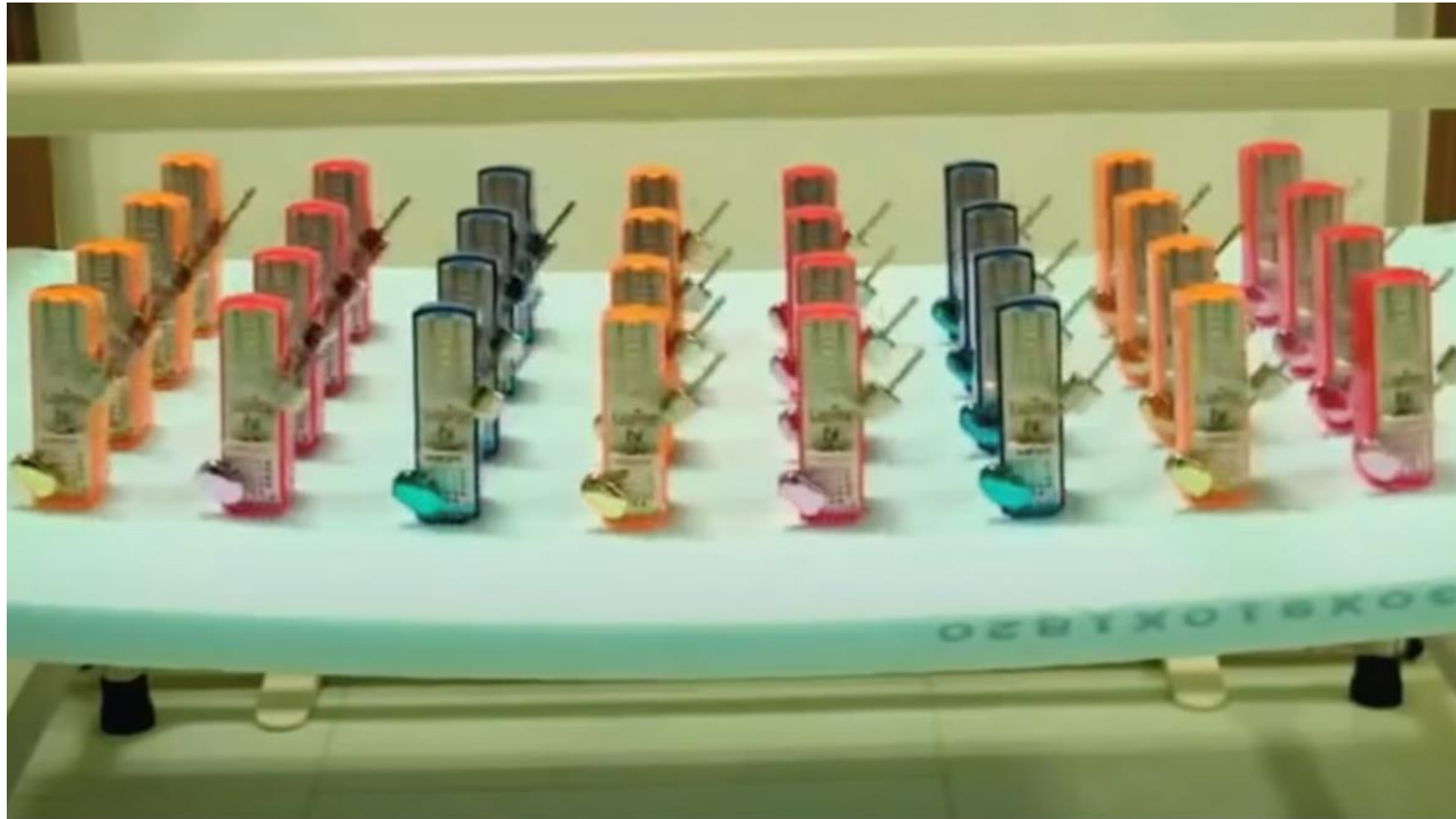
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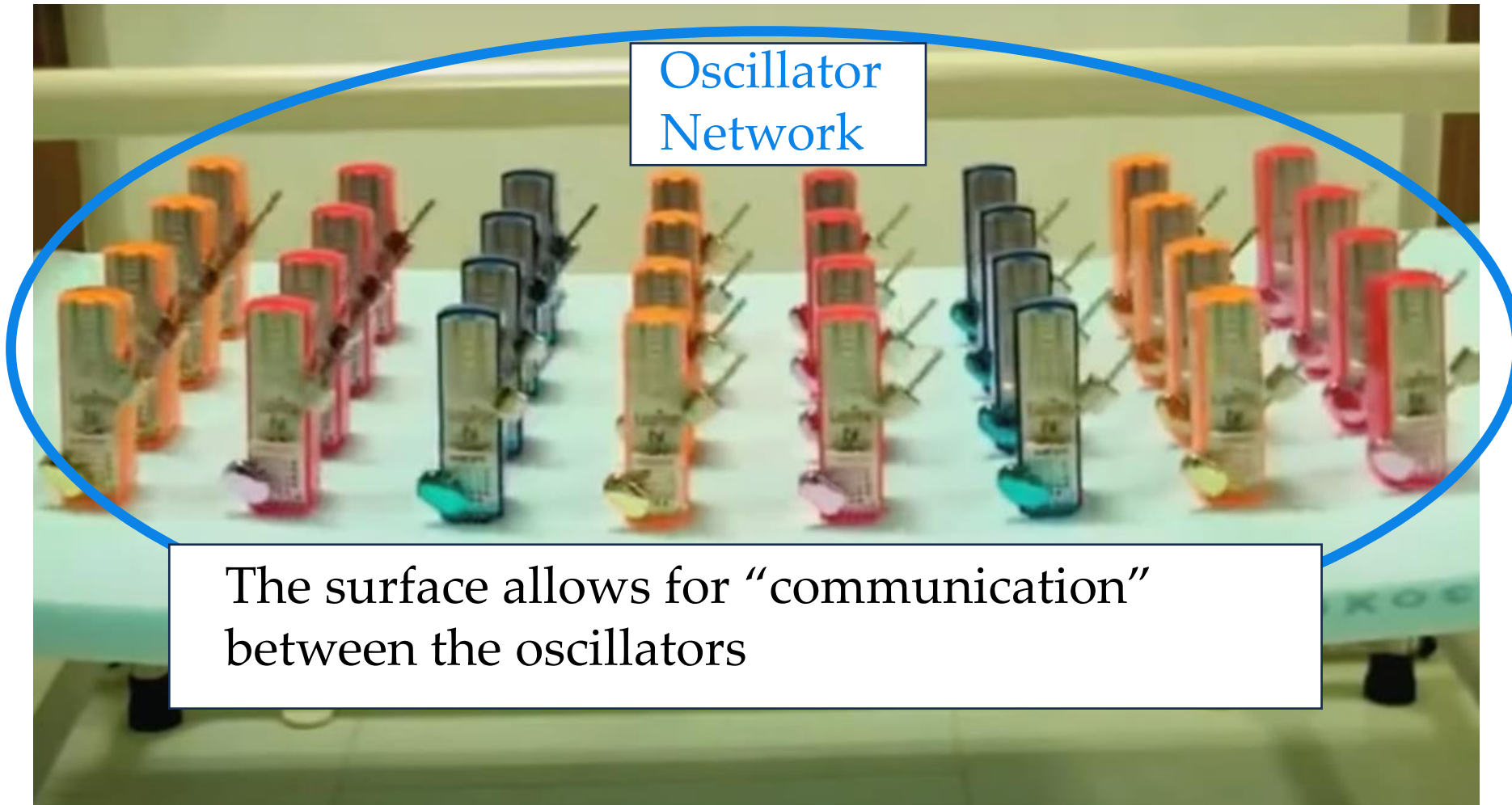
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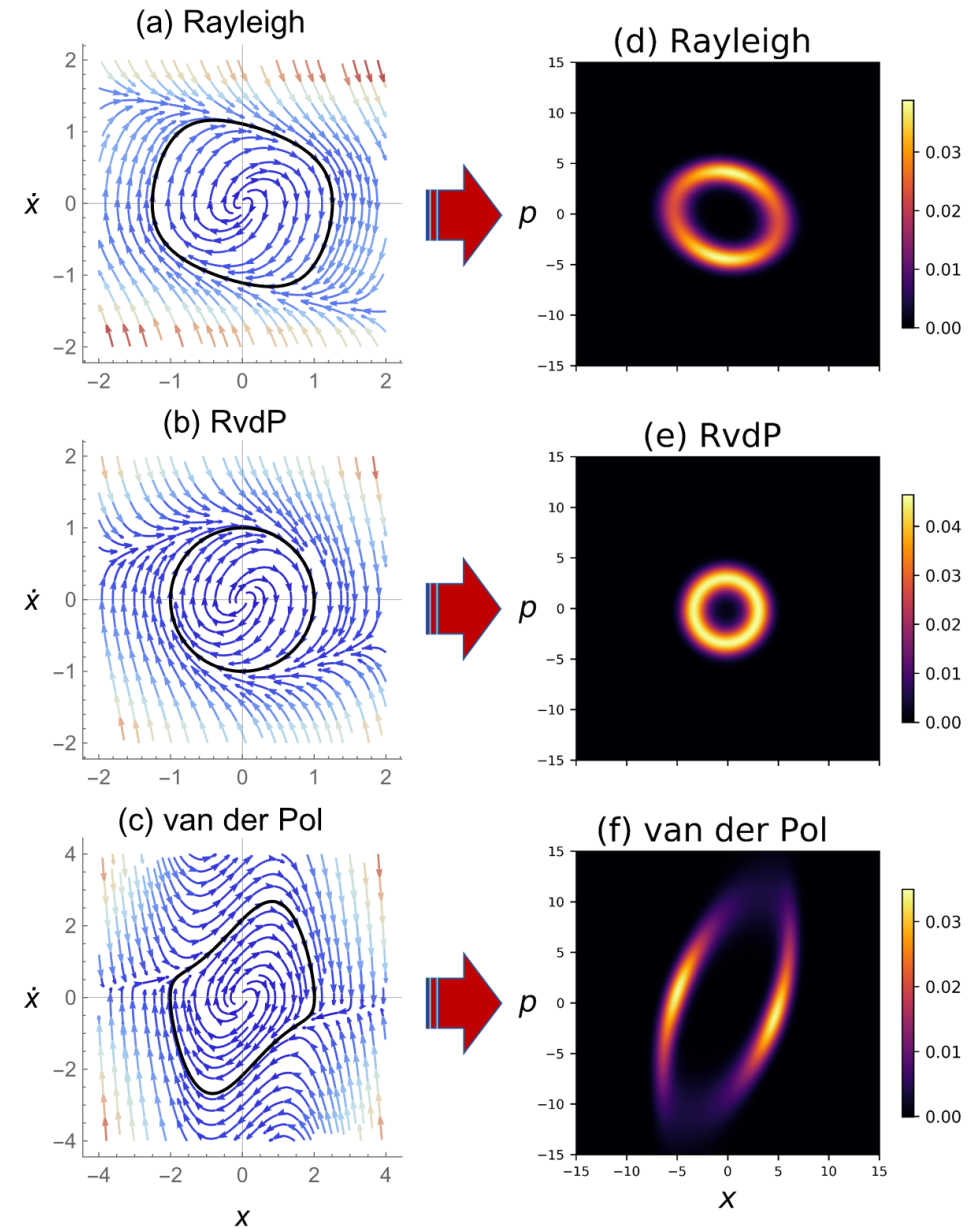
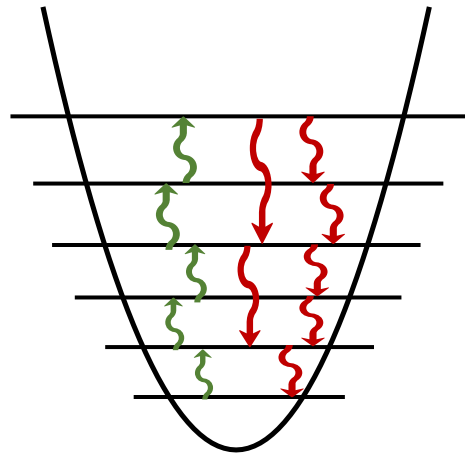




# Quantum Oscillators

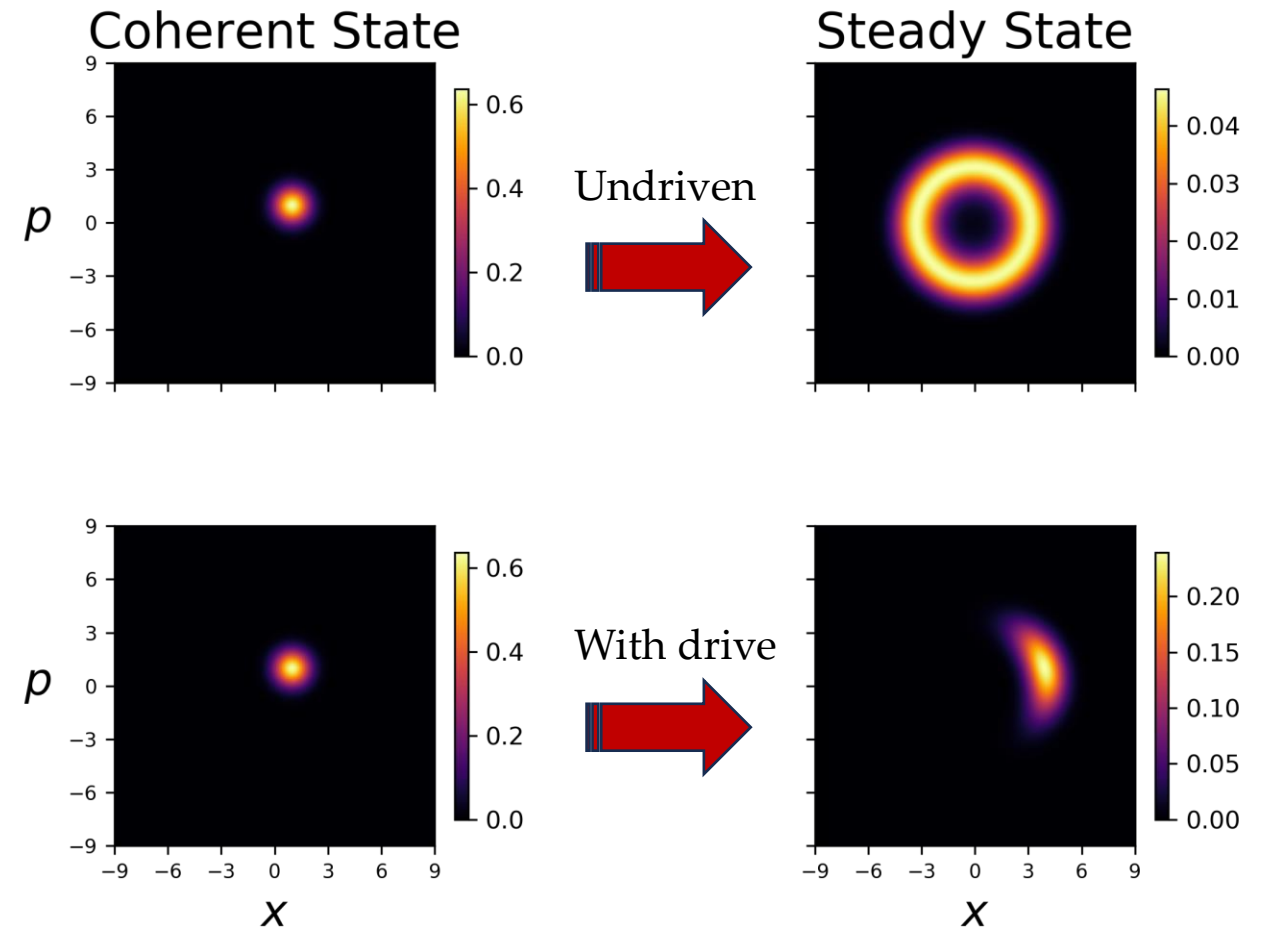
With Optical Tweezers

- Focus on the nonlinear Rayleigh-van der Pol family of oscillators
- Nonlinear quantum oscillators are open systems with incoherent 2-photon decays



# Quantum Synchronization

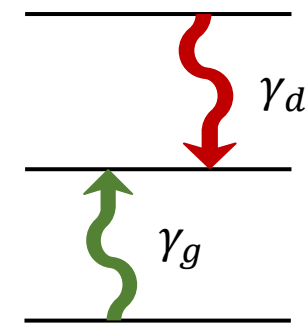
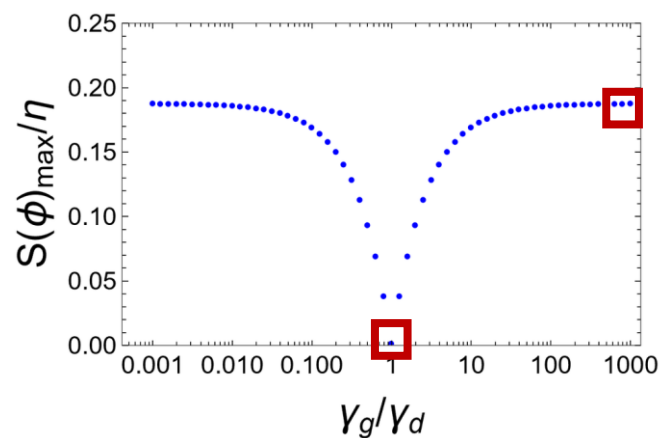
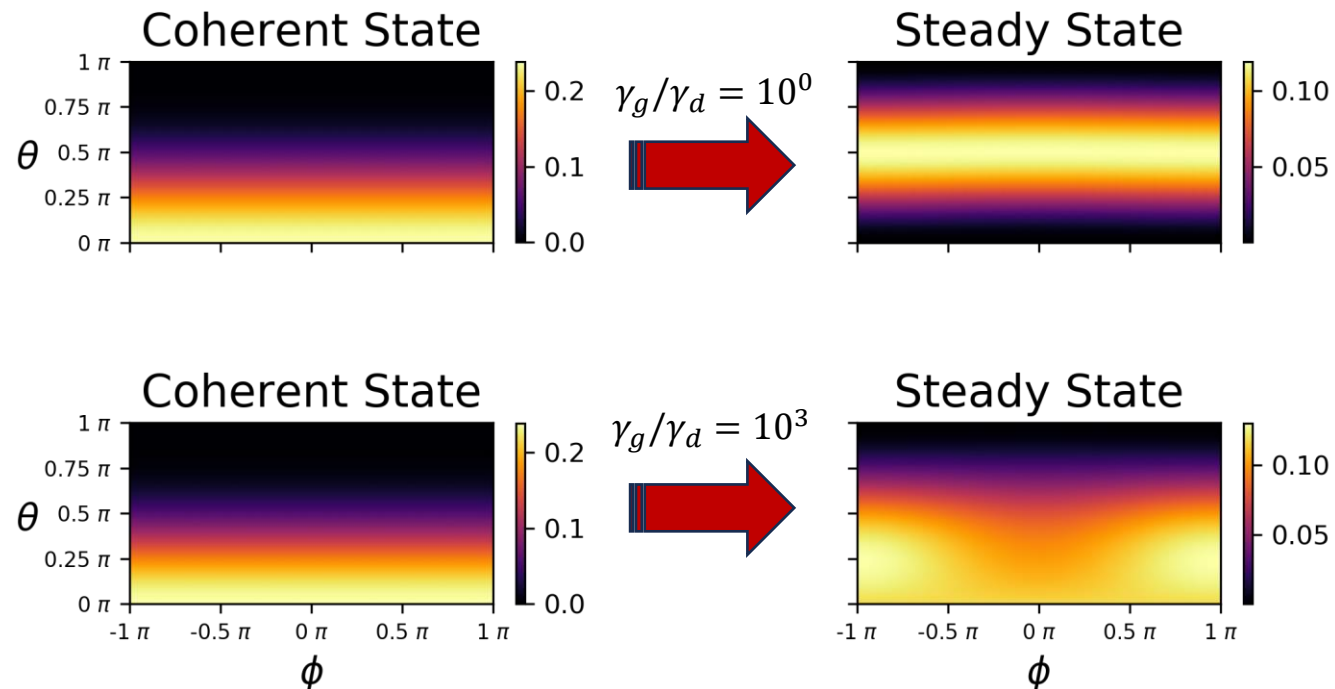
- Many definitions of synchronization (entanglement, mutual information, phase, etc.)
- For the spatial degrees of freedom, we measure phase localization ( $\hat{=}$  coherences)



# Spin System

Atomic energy levels

- Spin is abstract—there is no classical analog
- Synchronization blockades are revealed
- Half-integer and integer spins behave differently



# Goals

- Include coupling between the spin and spatial degrees of freedom
- Compare the coupling with an external drive
- Include multiple Rydberg atoms with Rydberg-Rydberg interactions

