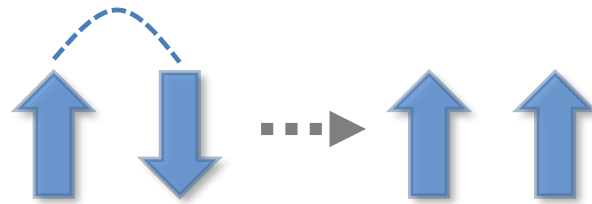


Studying absorbing-state phase transitions in a cold Rydberg gas

Oliver Morsch
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ICQSIM, Paris, 15/11/2017



C. Simonelli, M. Archimi, E. Arimondo, D. Ciampini

Collaboration: R. Gutierrez, M. Marcuzzi, I. Lesanovsky

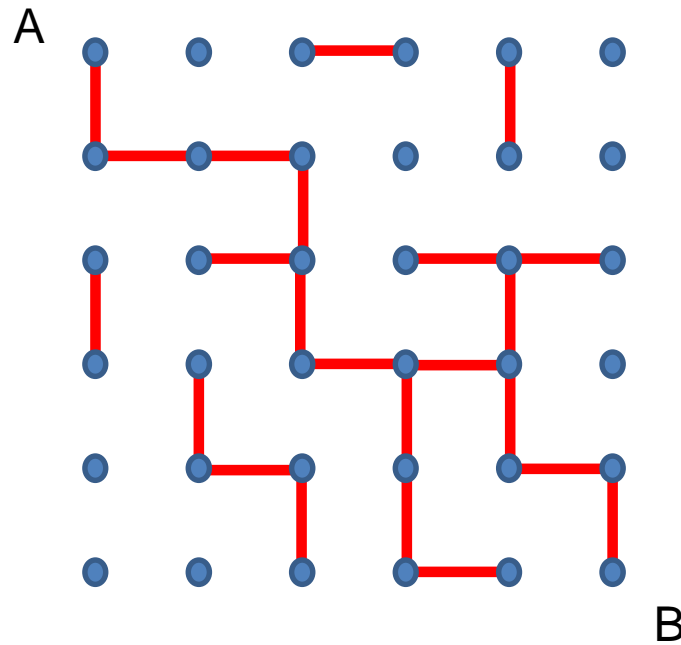
Funding: FET-RYSQ



Outline

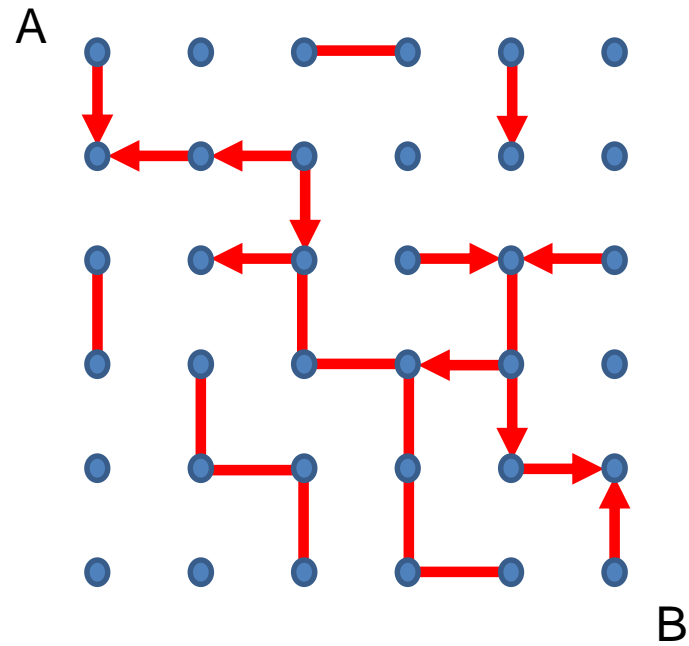
- (Directed) percolation and absorbing state phase transitions
- The basic processes with Rydberg atoms
- Experimental results
- Outlook

Percolation

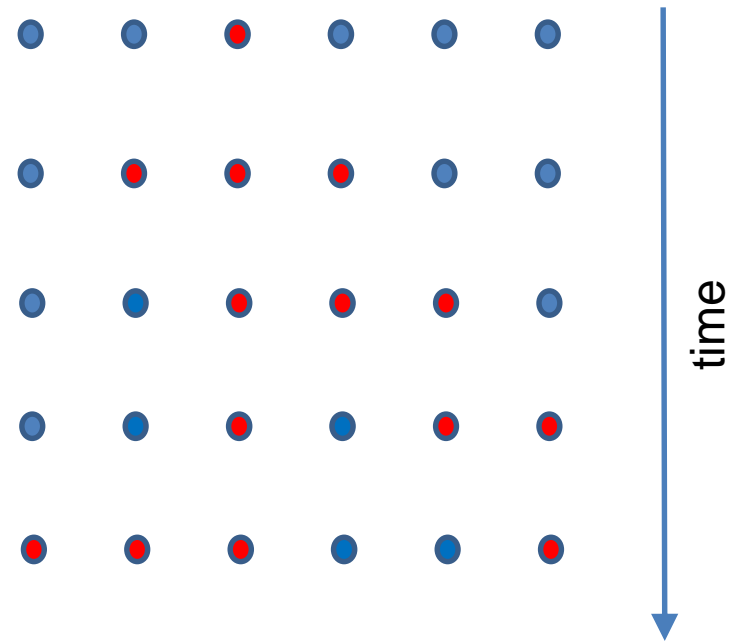
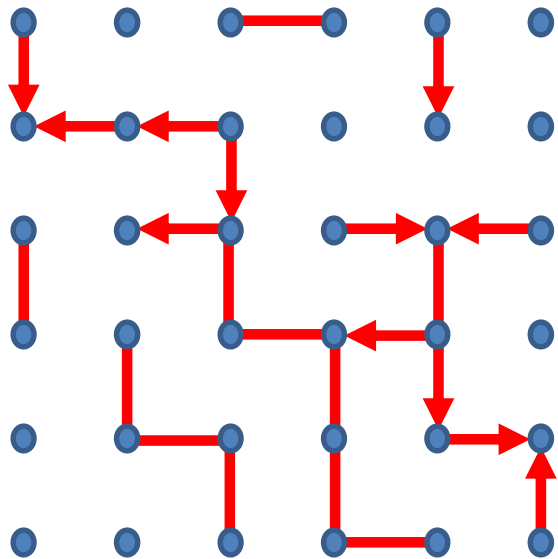


link probability $p > p_{\text{crit}} \Rightarrow$ system «percolates»

«Directed» percolation



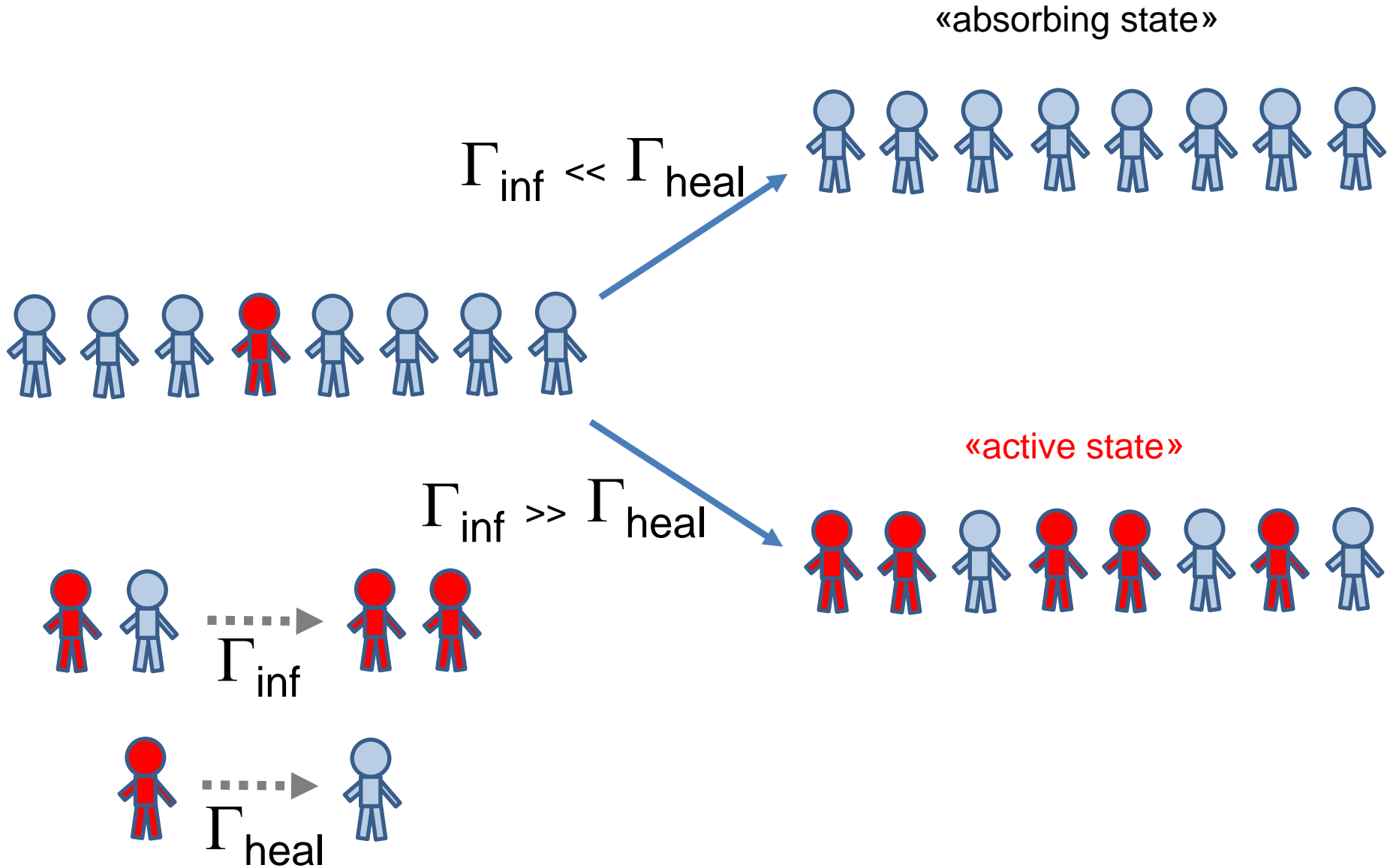
«Directed» percolation



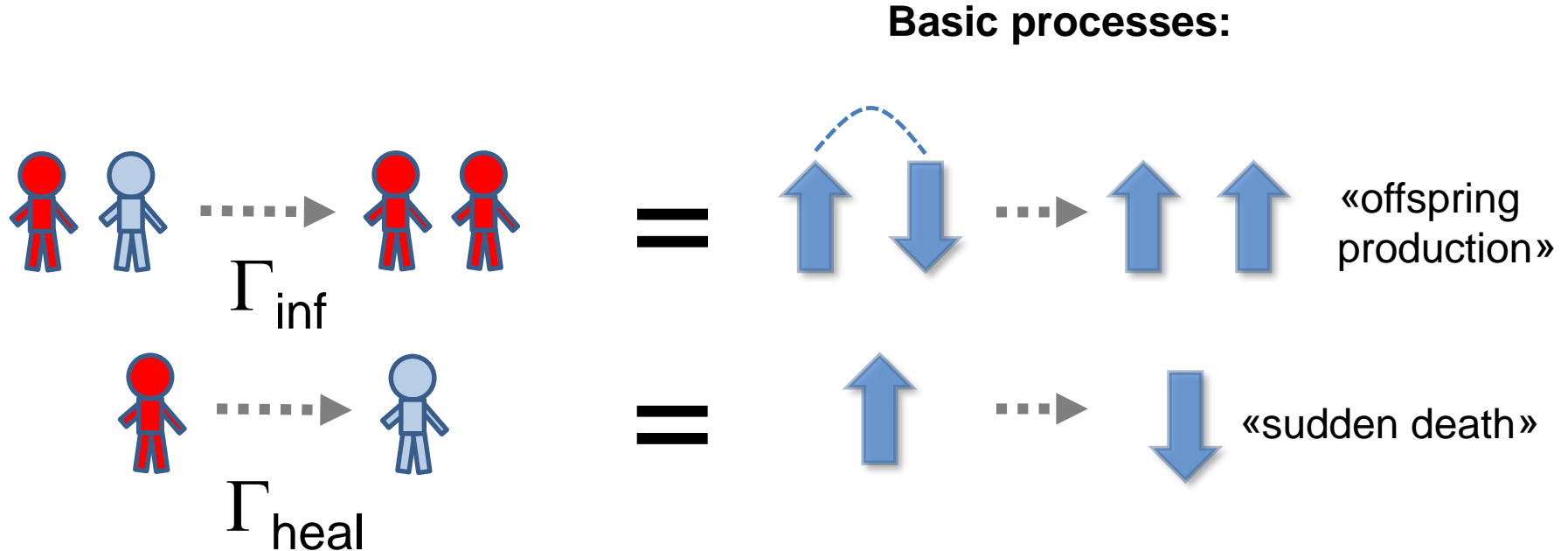
Non-equilibrium phase transition

Examples: wildfires, turbulence,
spreading of infectious diseases

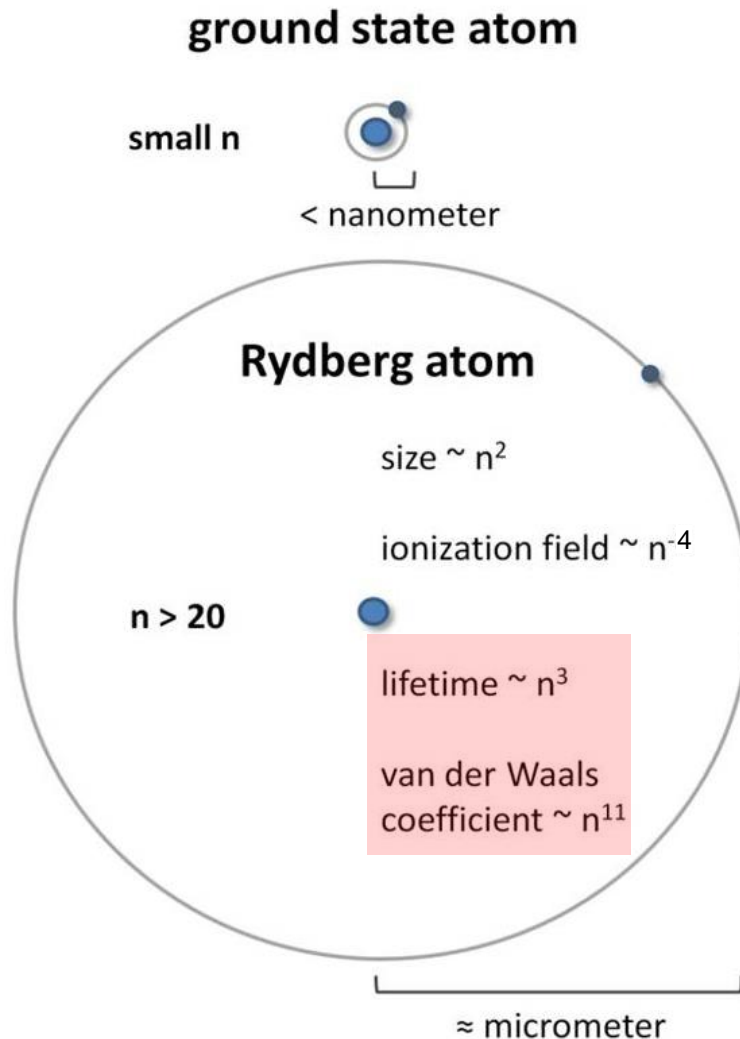
«Infection model» exhibits absorbing state phase transition



Basic processes leading to an absorbing state phase transition

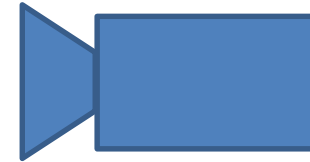
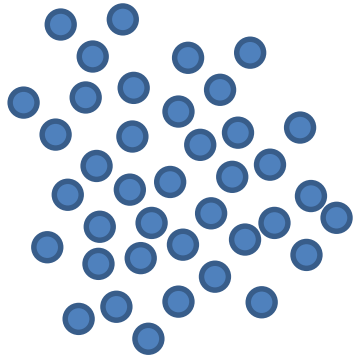


Rydberg atoms are long-lived and interact strongly



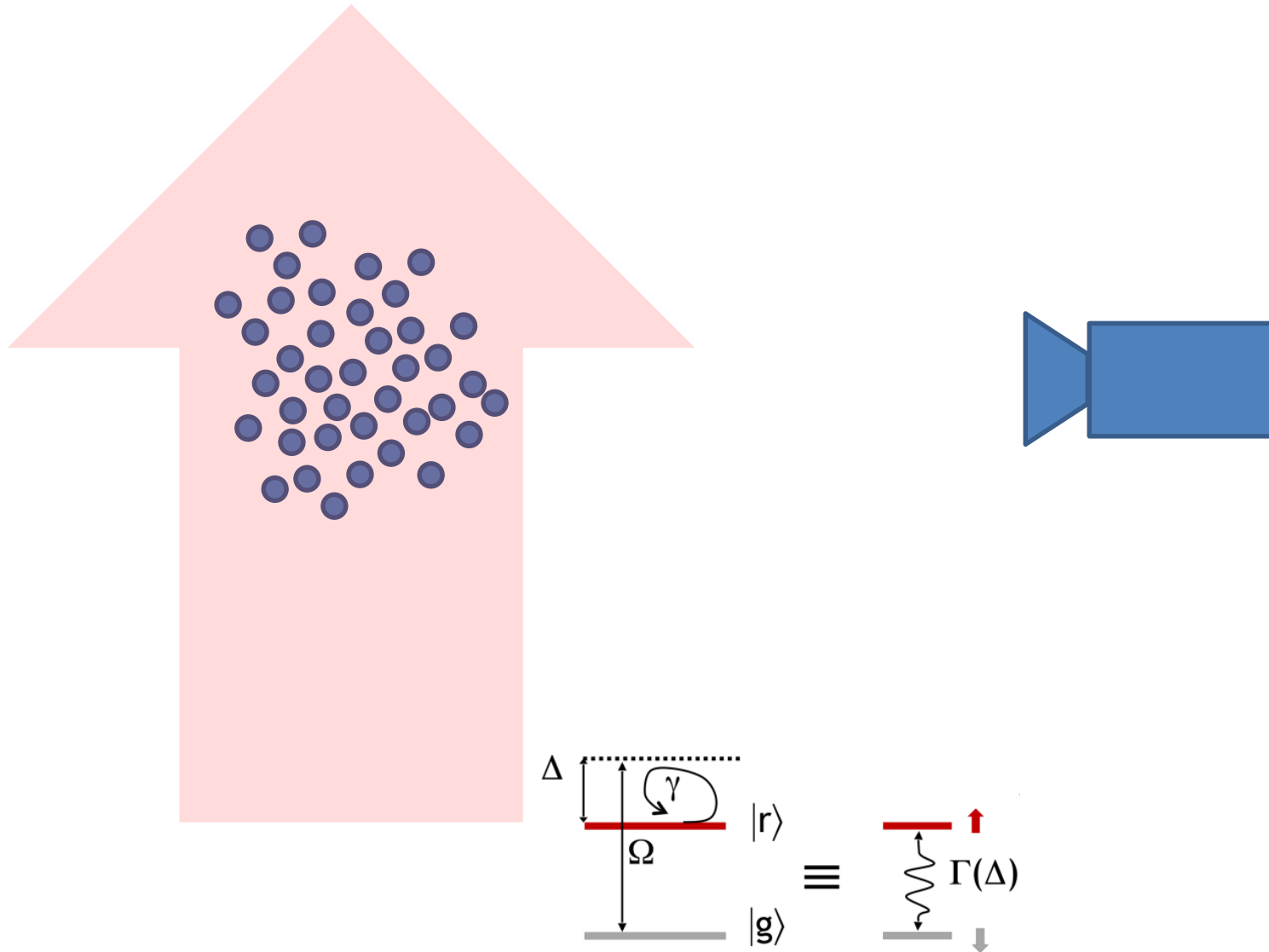
Ex.: Rb $n=70$, \sim MHz at $10 \mu\text{m}$
lifetime around $150 \mu\text{s}$

Realizing and probing many-body dynamics with Rydberg gases

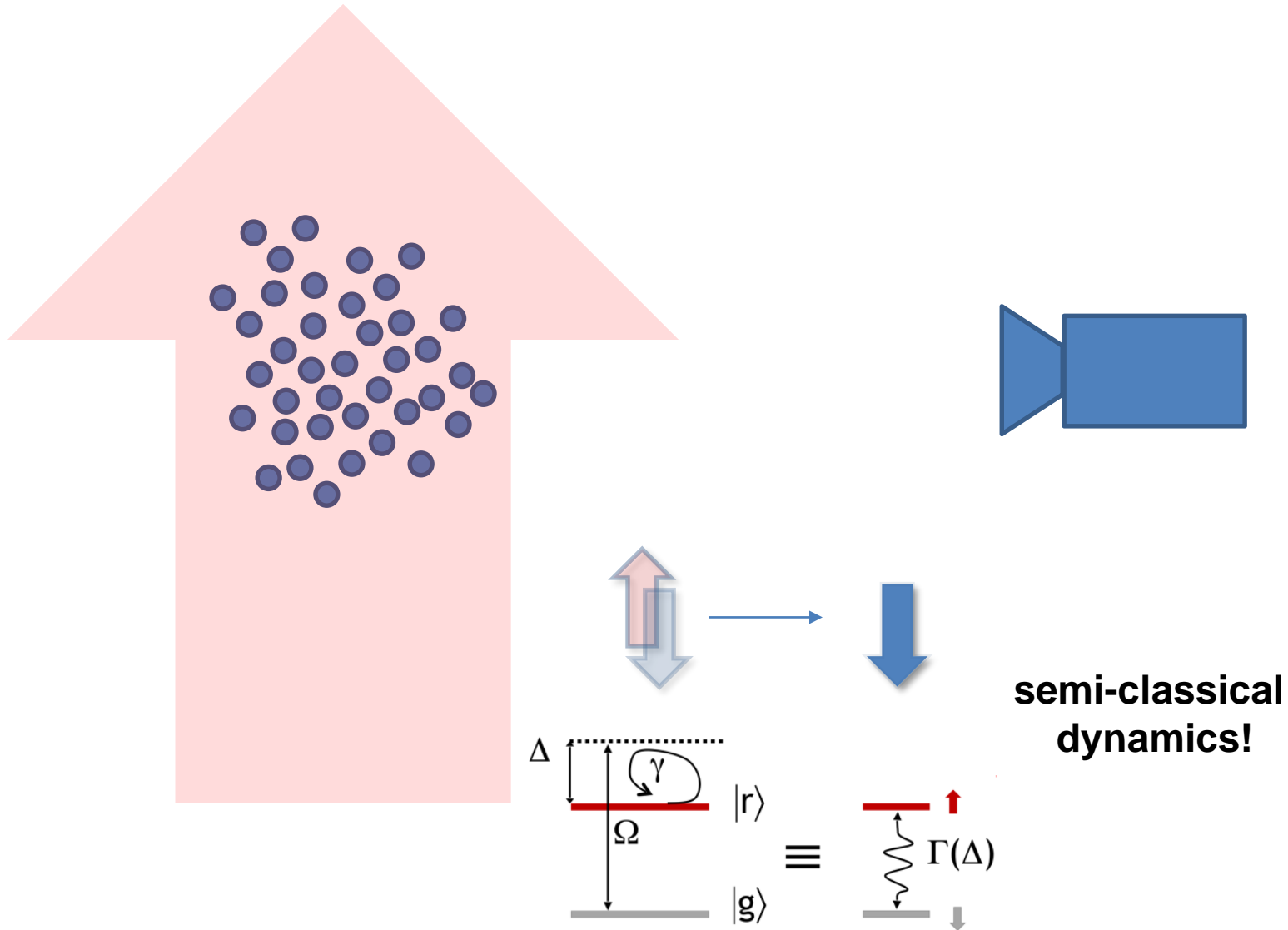


^{87}Rb atoms in a MOT
T ~ 150 micro Kelvin («frozen gas»)
N ~ few 10^5
size around 150 microns

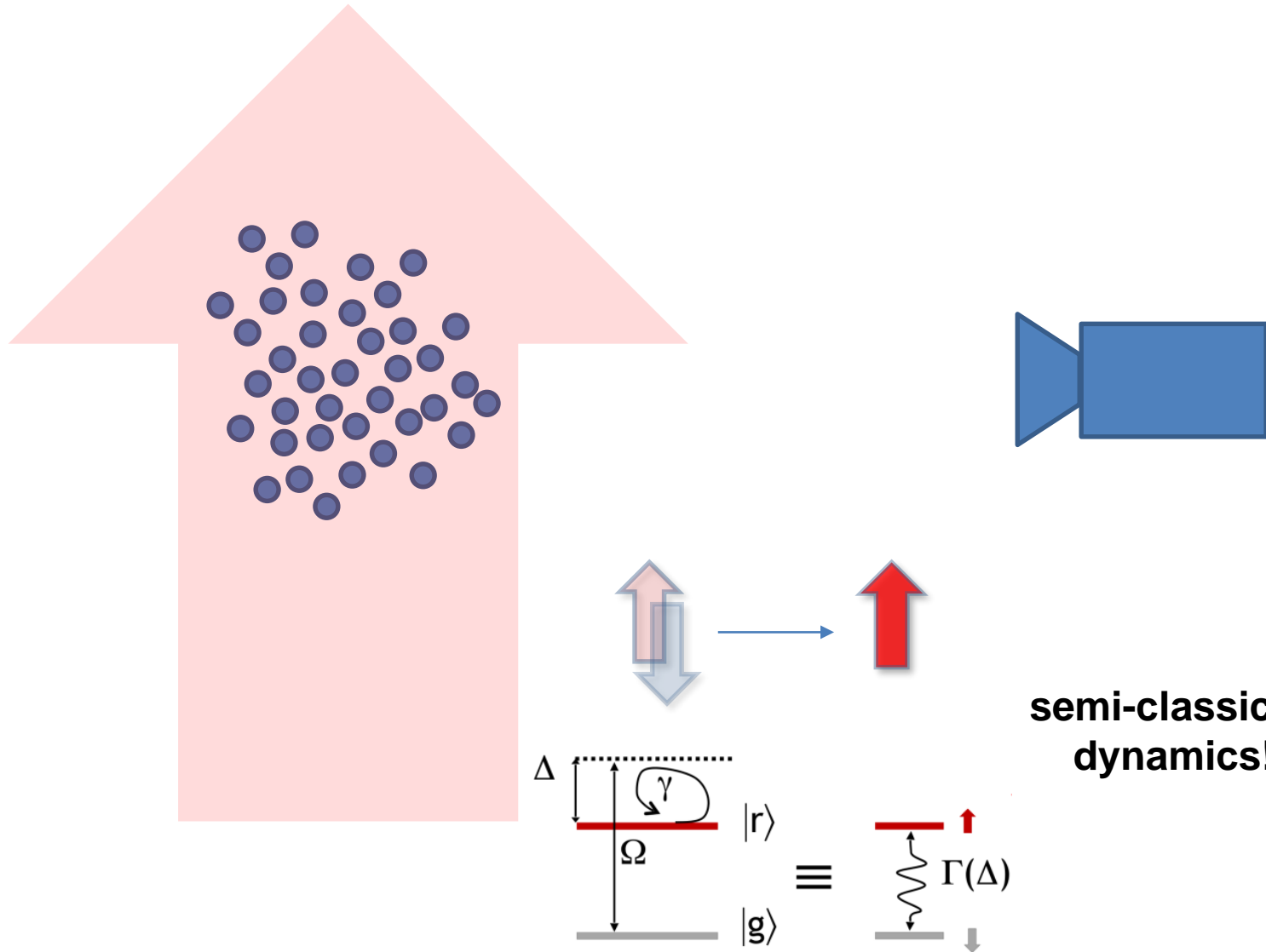
Realizing and probing many-body dynamics with Rydberg gases



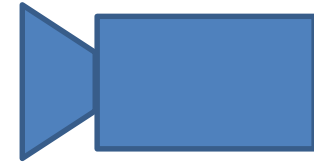
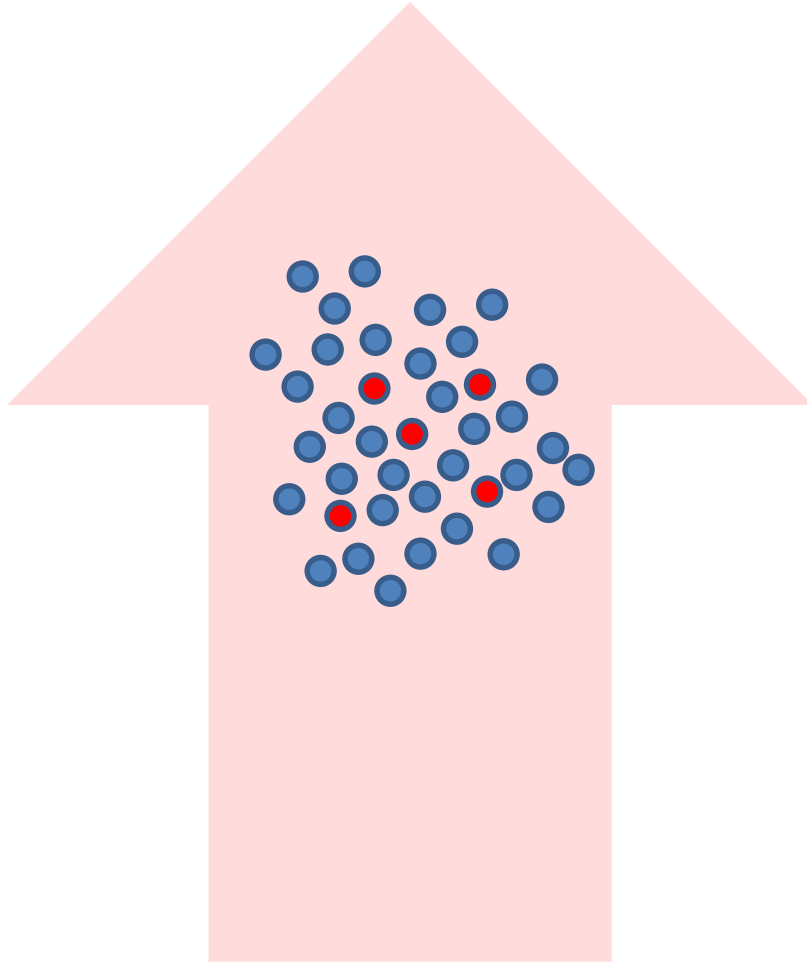
Realizing and probing many-body dynamics with Rydberg gases



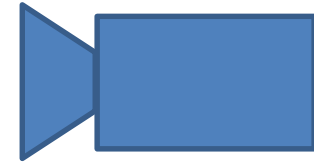
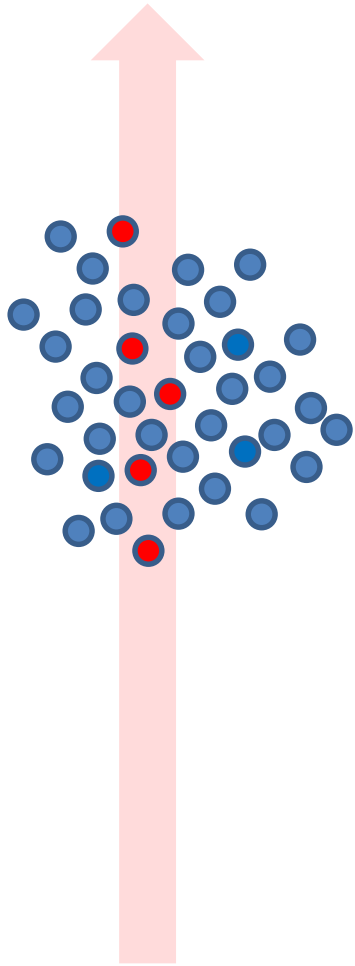
Realizing and probing many-body dynamics with Rydberg gases



Many-body dynamics takes place...

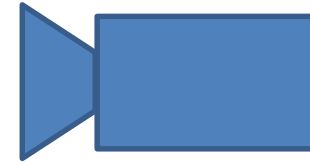
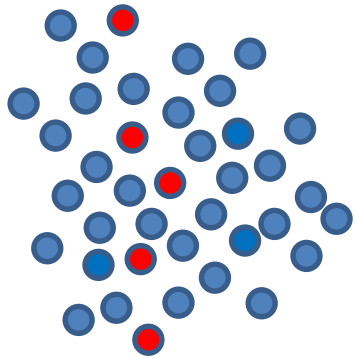


Many-body dynamics takes place...

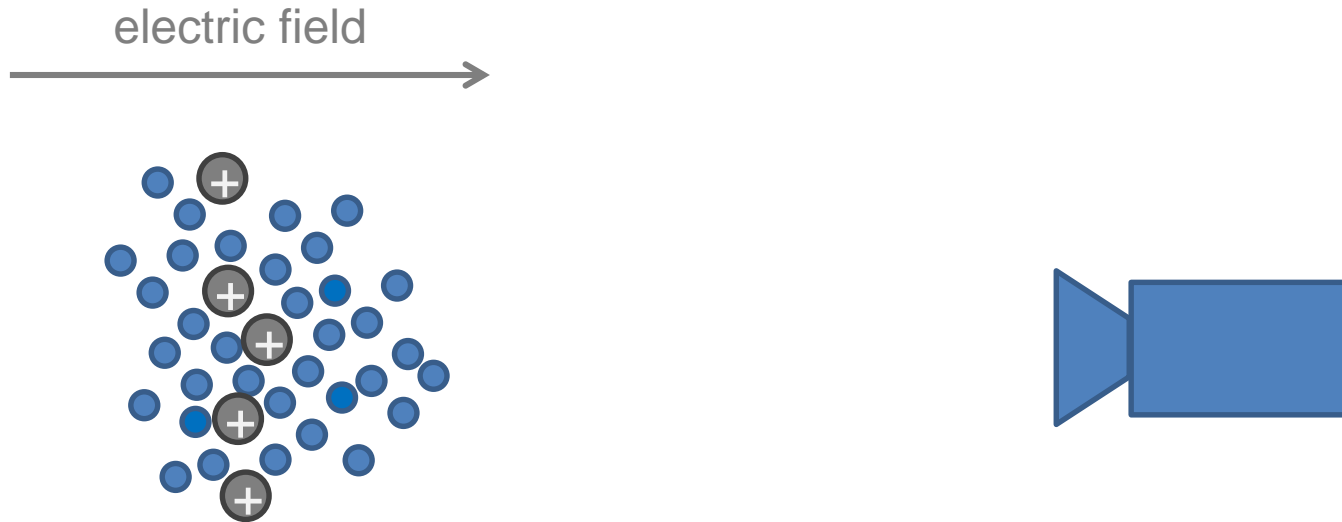


effective 1D dynamics

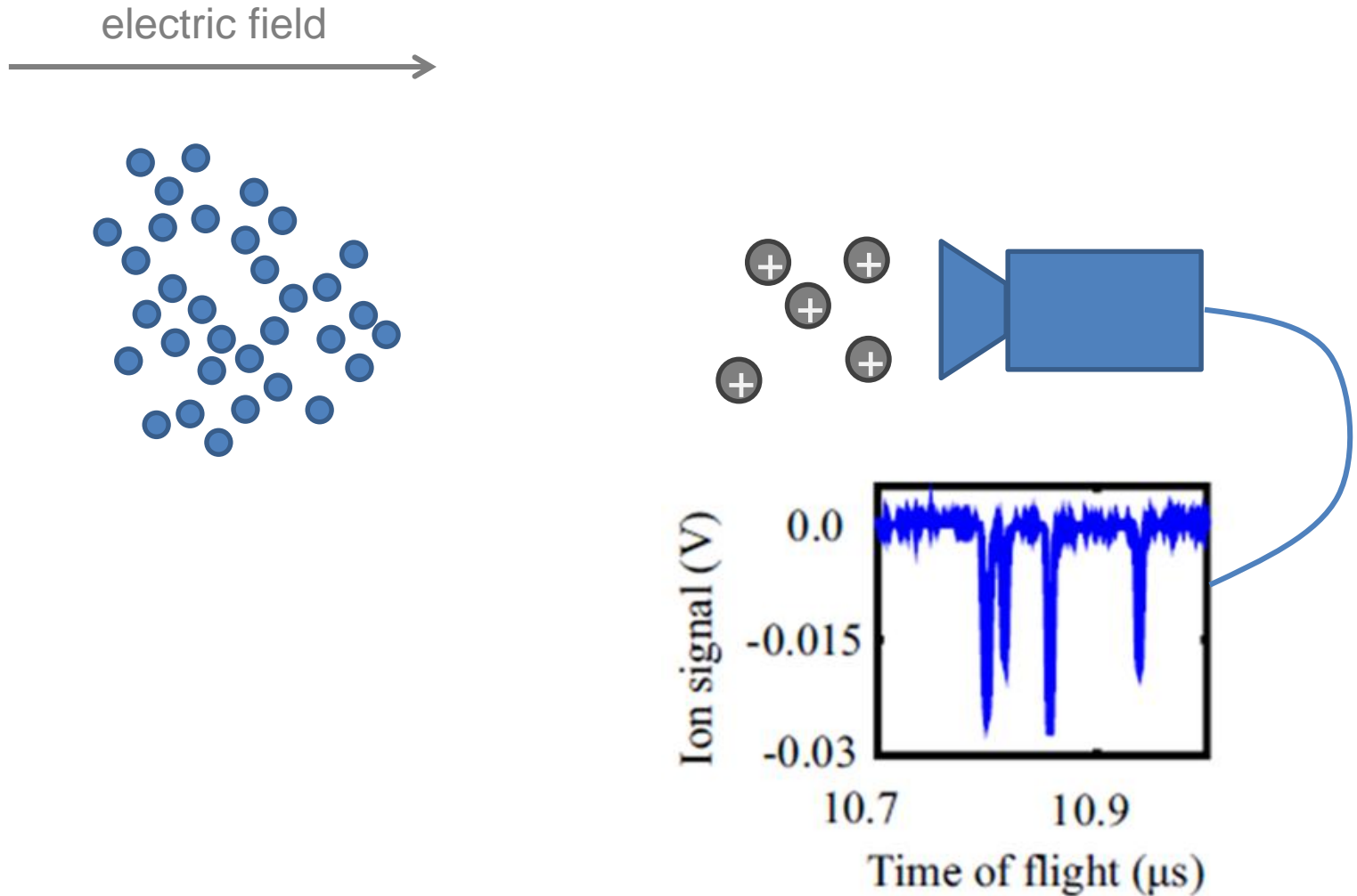
... then the system is probed using field ionization



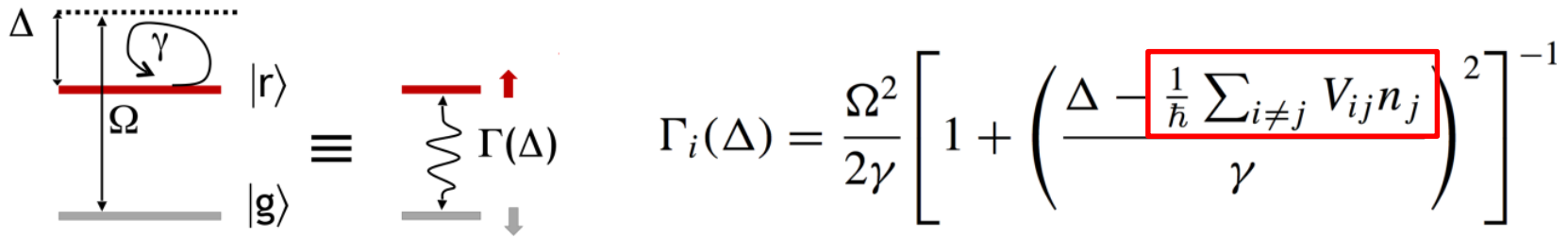
... then the system is probed using field ionization



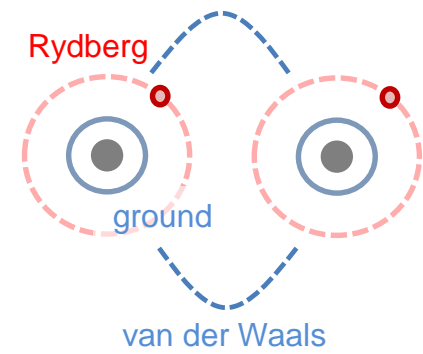
... then the system is probed using field ionization



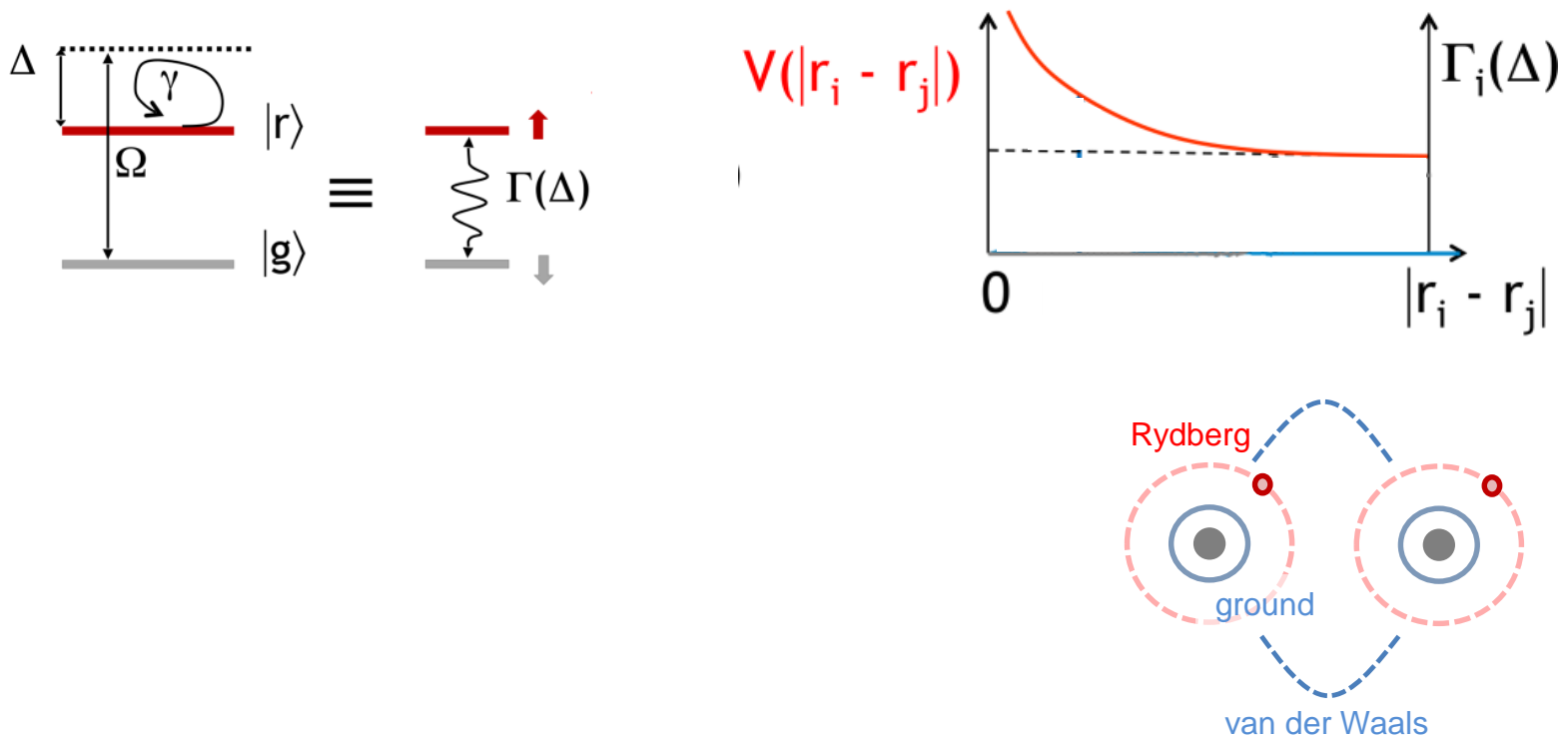
Off-resonant driving leads to facilitated excitation



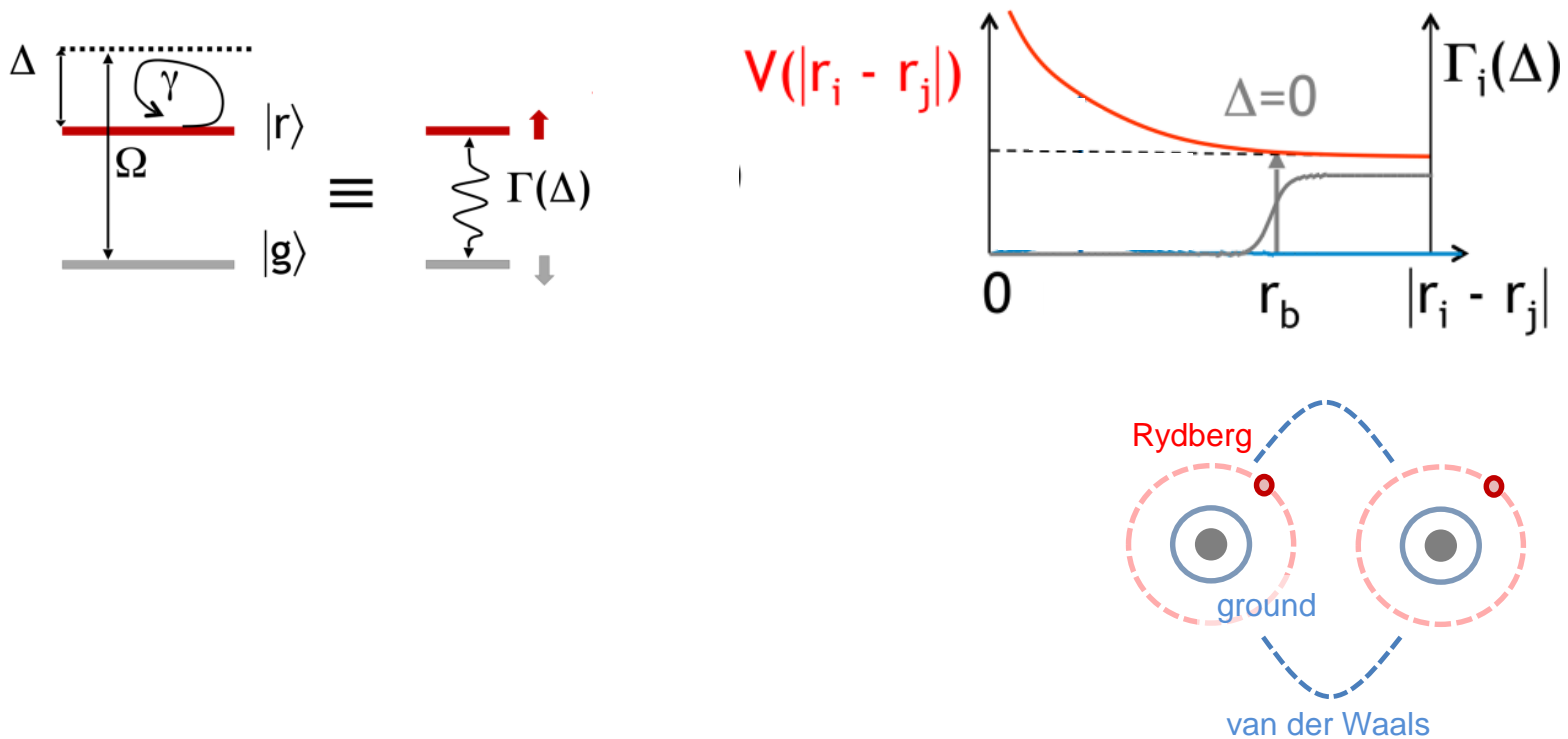
$$\Gamma_i(\Delta) = \frac{\Omega^2}{2\gamma} \left[1 + \left(\frac{\Delta - \frac{1}{\hbar} \sum_{i \neq j} V_{ij} n_j}{\gamma} \right)^2 \right]^{-1}$$



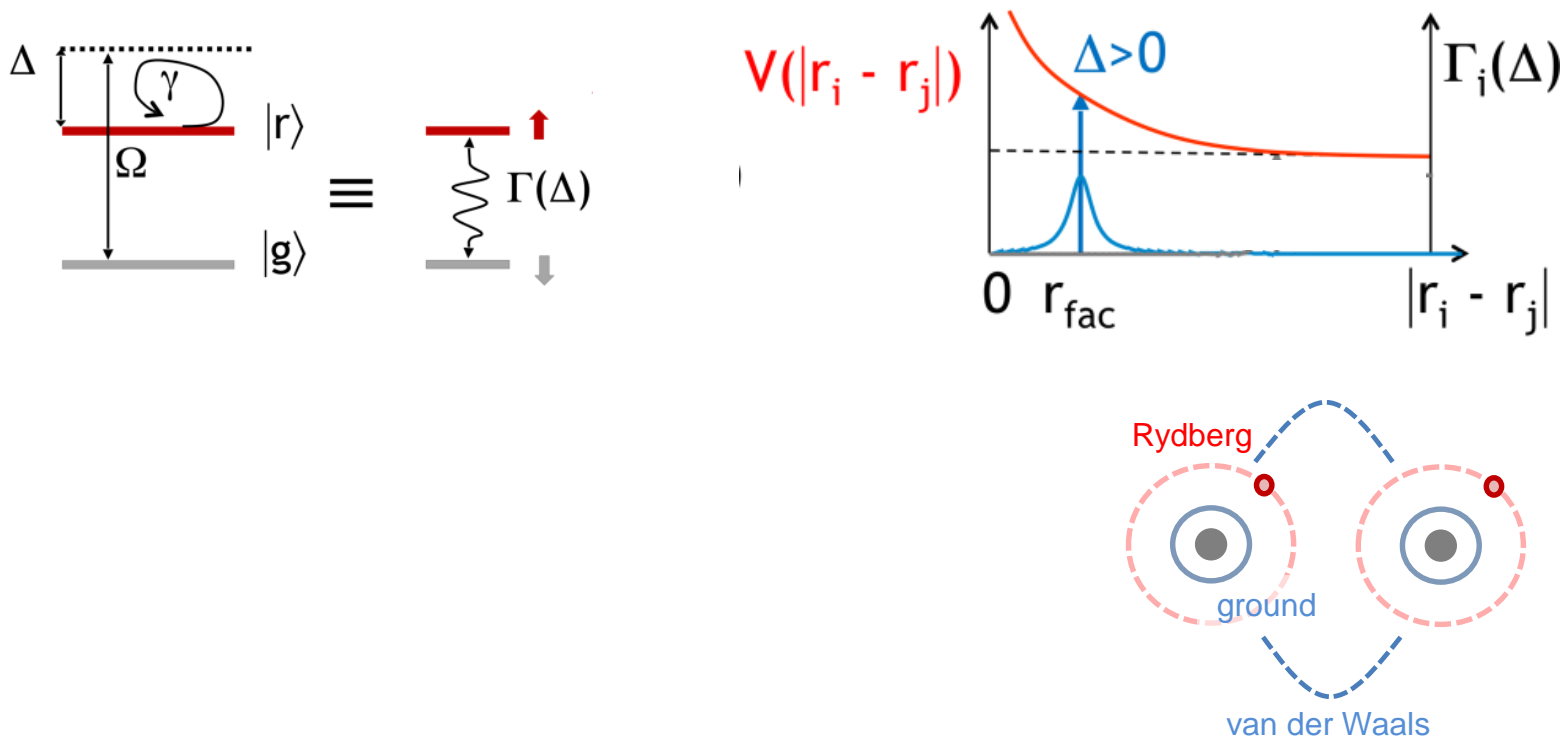
Off-resonant driving leads to facilitated excitation



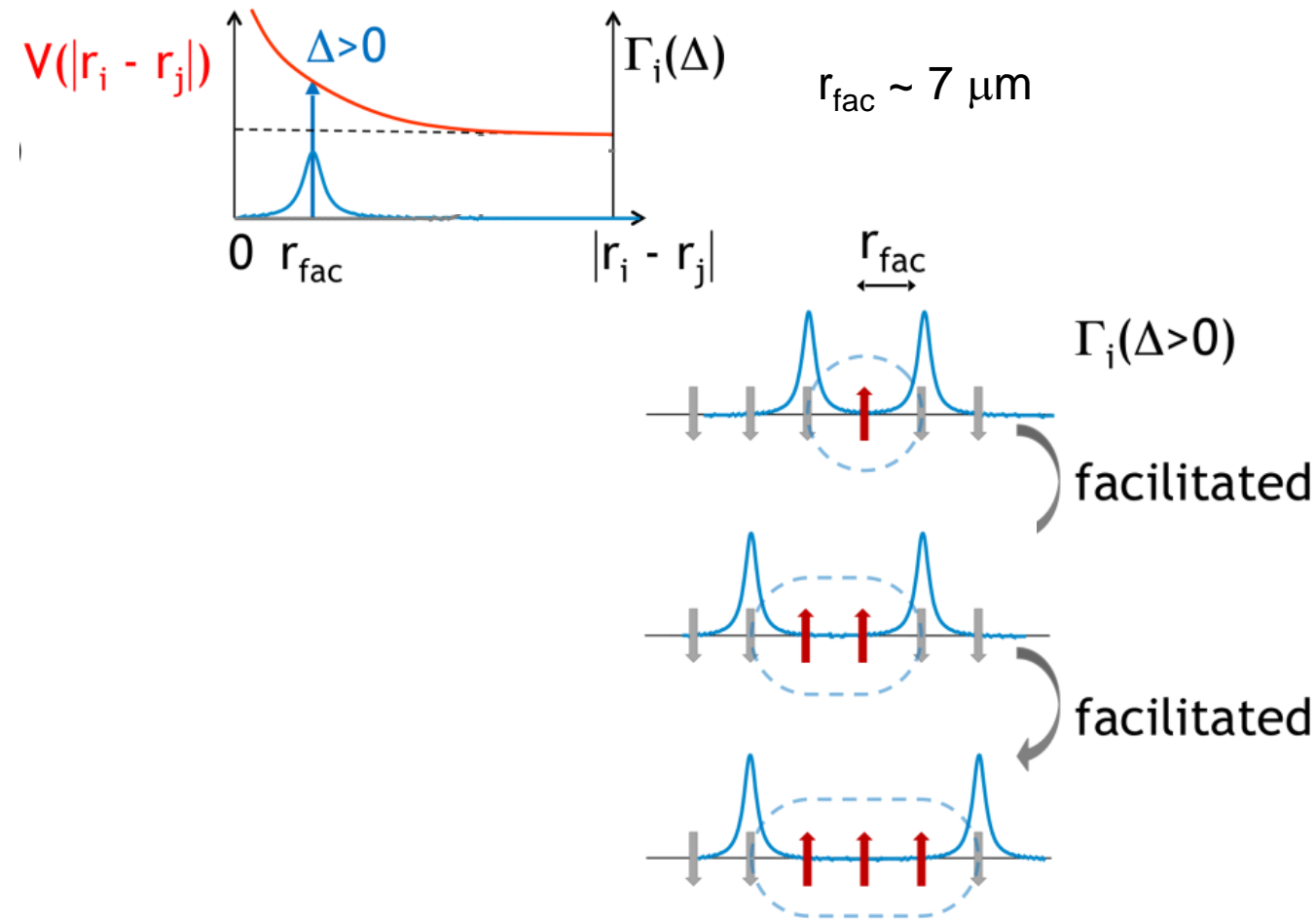
Off-resonant driving leads to facilitated excitation



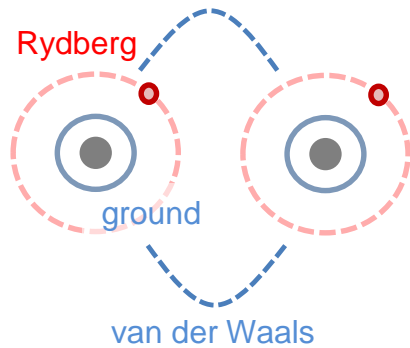
Off-resonant driving leads to facilitated excitation



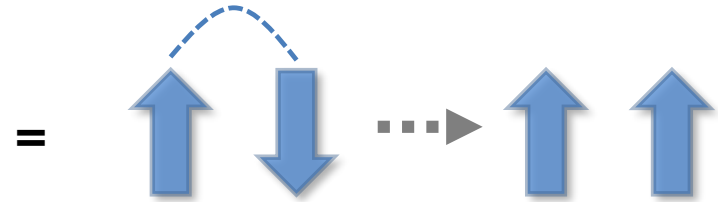
Facilitation dynamics = «offspring production»



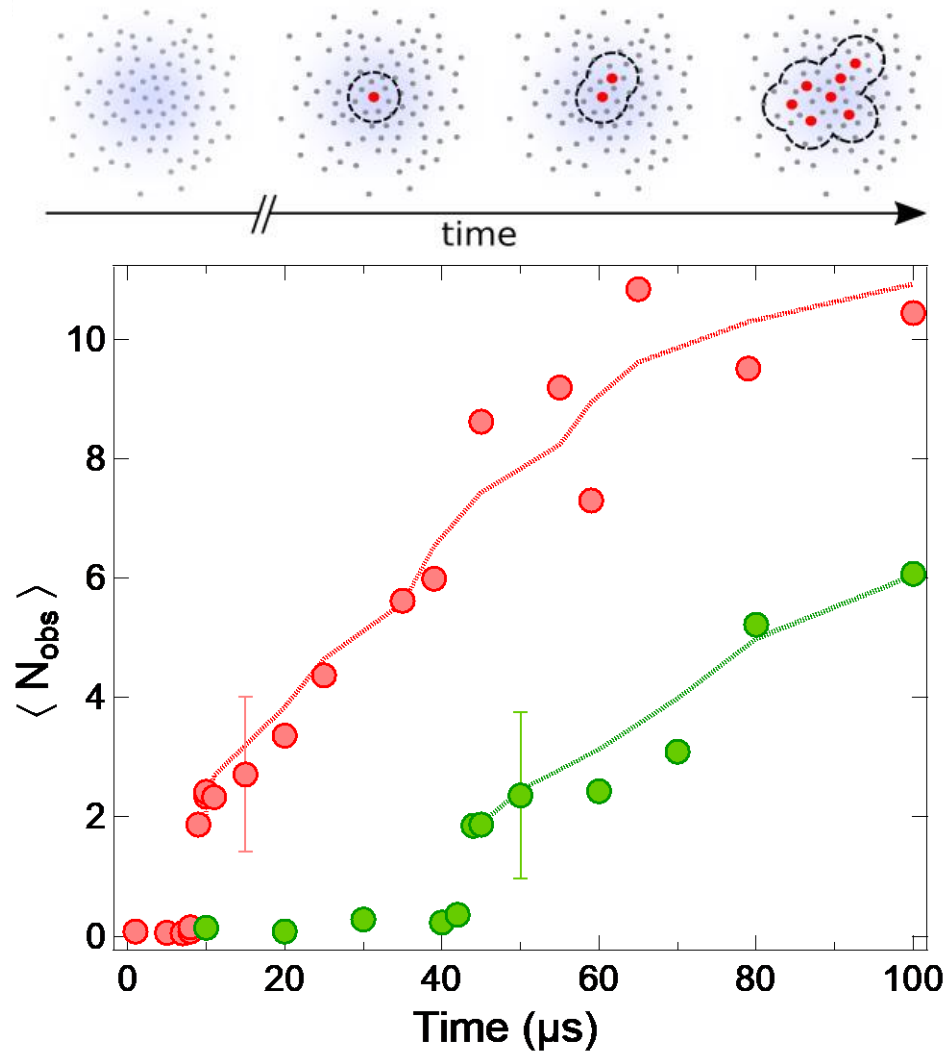
Facilitation dynamics = «offspring production»



facilitated
excitation

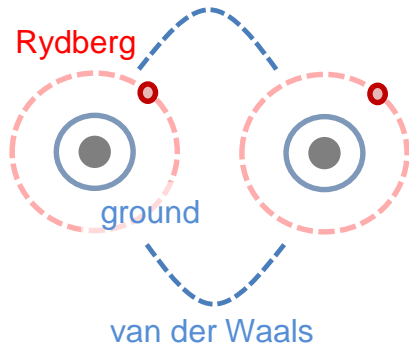


Facilitation dynamics needs to be seeded



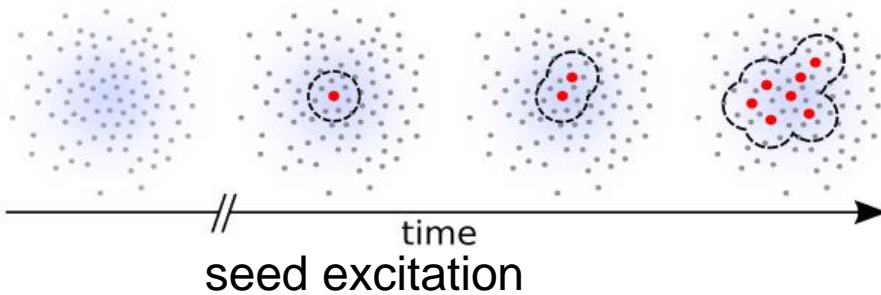
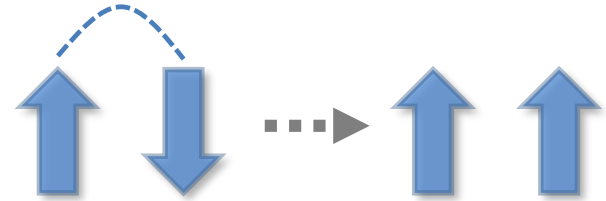
(see also work by
R. Löw (Stuttgart))

Facilitation and decay realize the basic processes for absorbing state phase transition

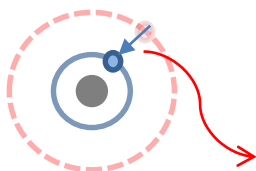


facilitated excitation

=



needed to prepare the system away from the absorbing state



spontaneous decay

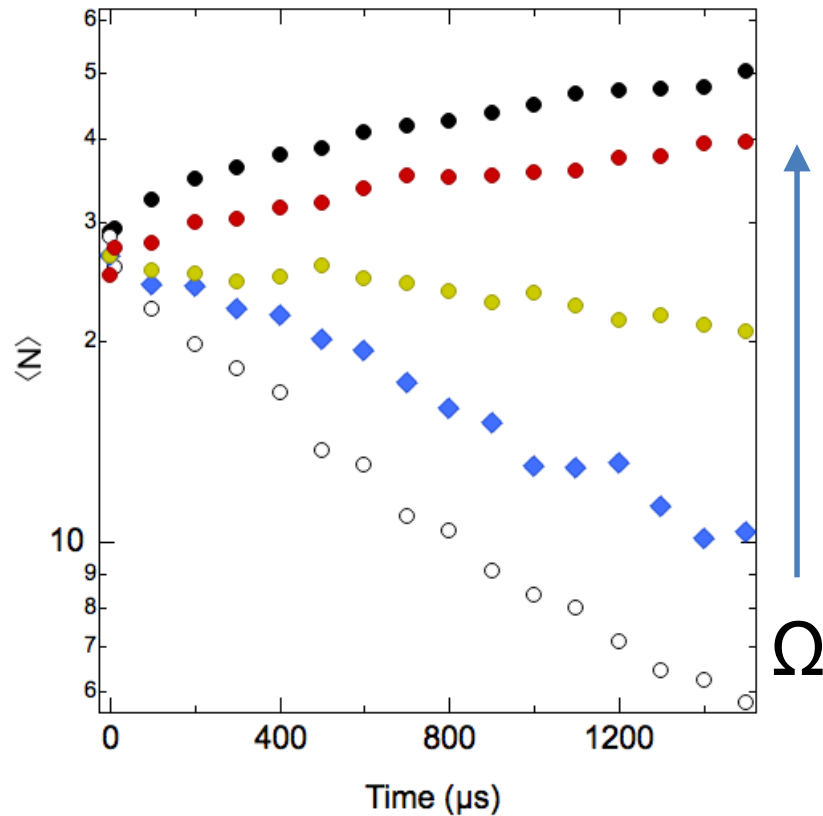
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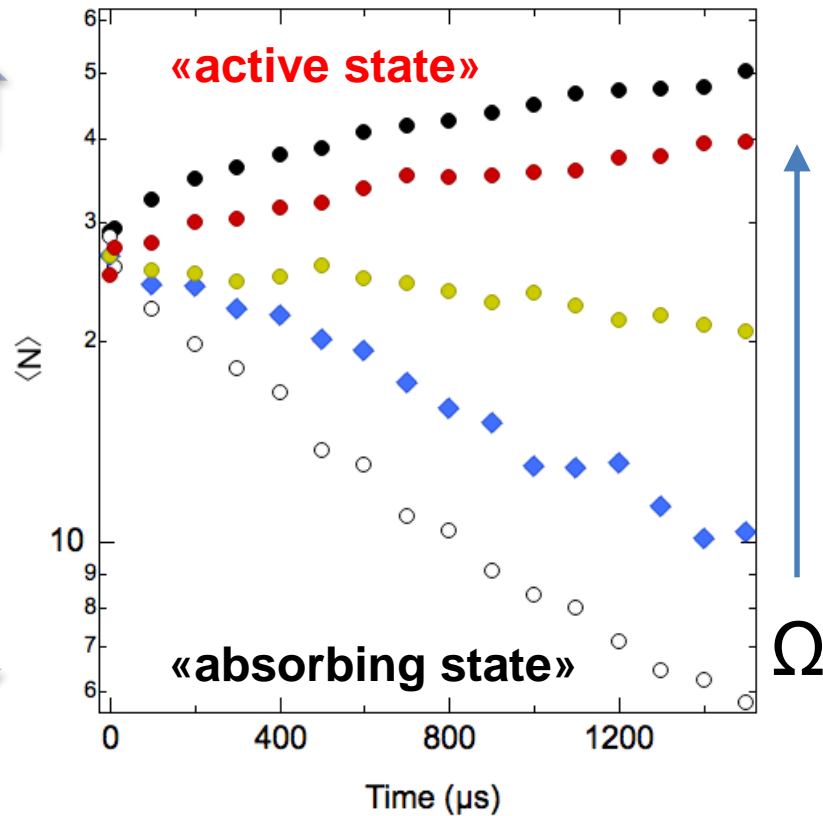
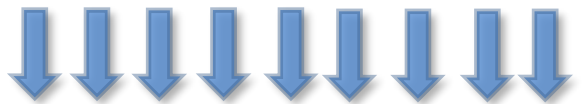
Absorbing state phase transition probed by varying the driving (facilitation) strength



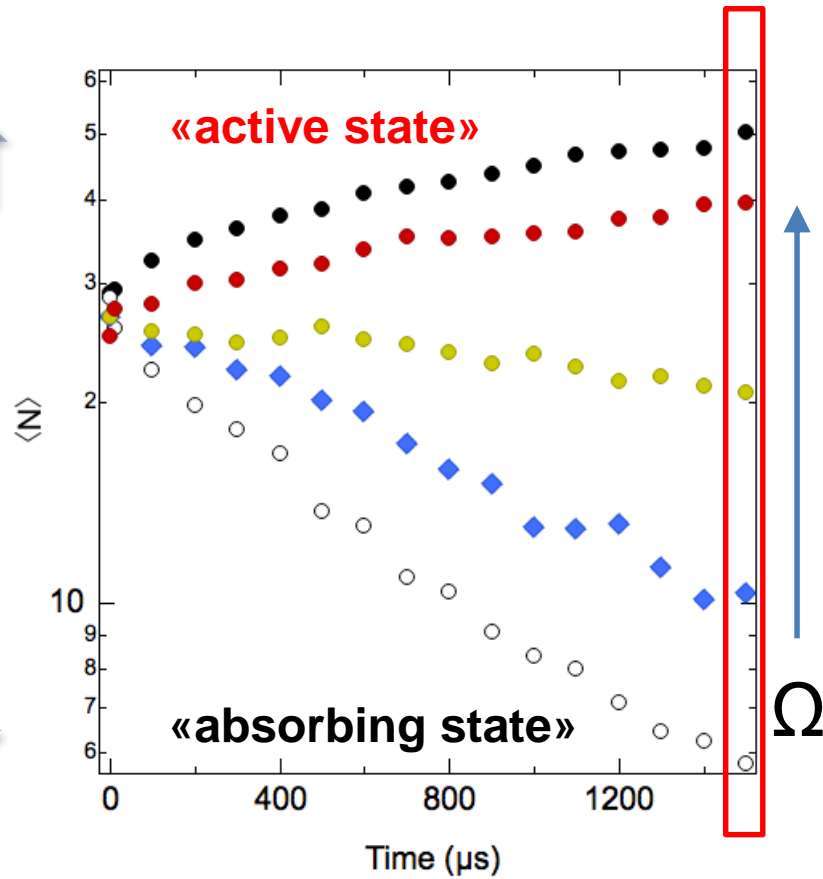
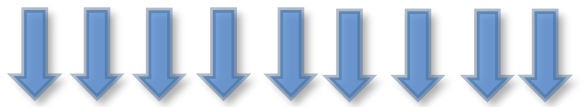
system is initially seeded



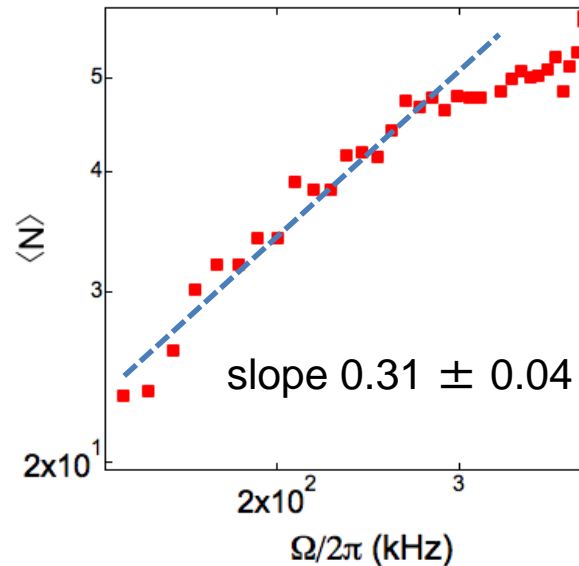
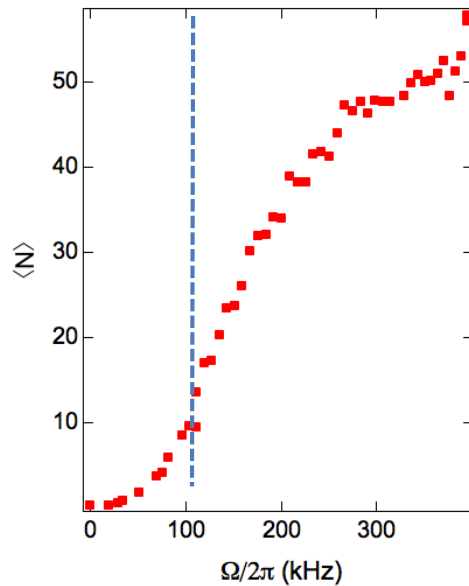
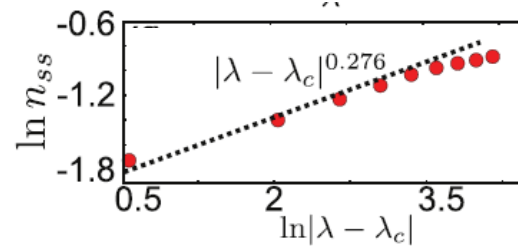
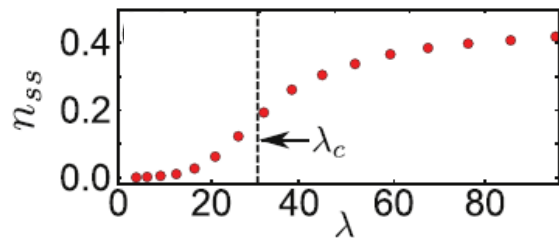
Absorbing state phase transition probed by varying the driving (facilitation) strength



Absorbing state phase transition probed by varying the driving (facilitation) strength

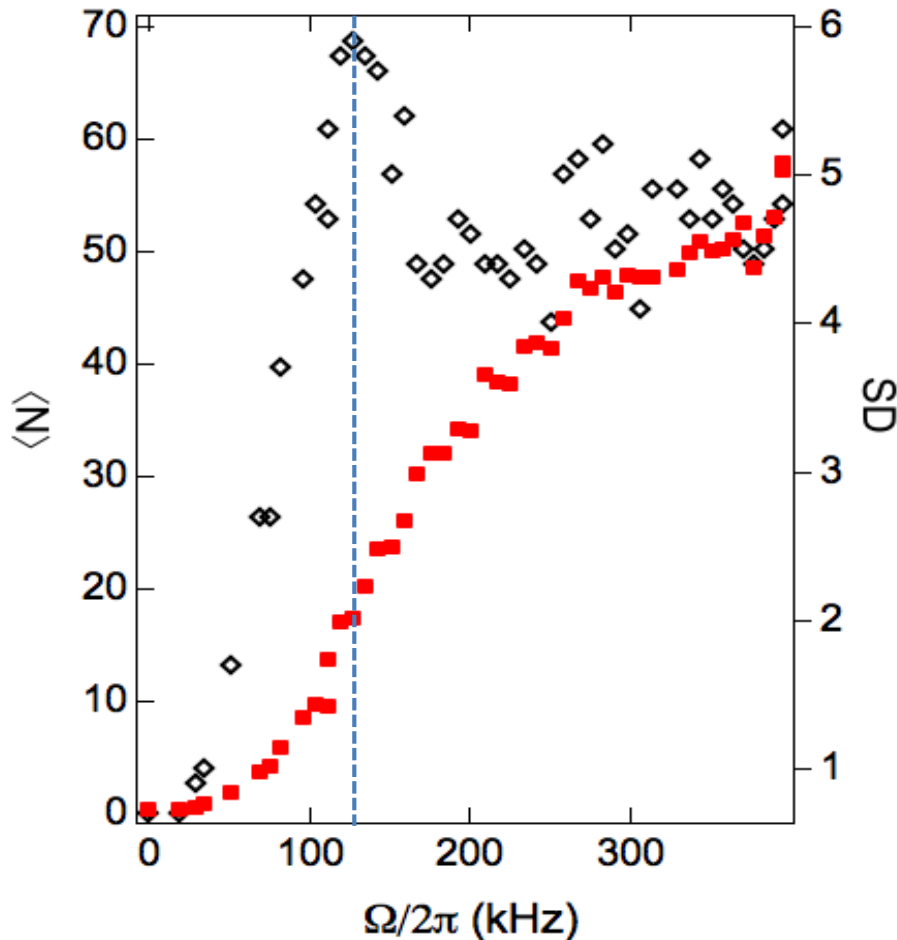


A crossover between absorbing and active states is observed

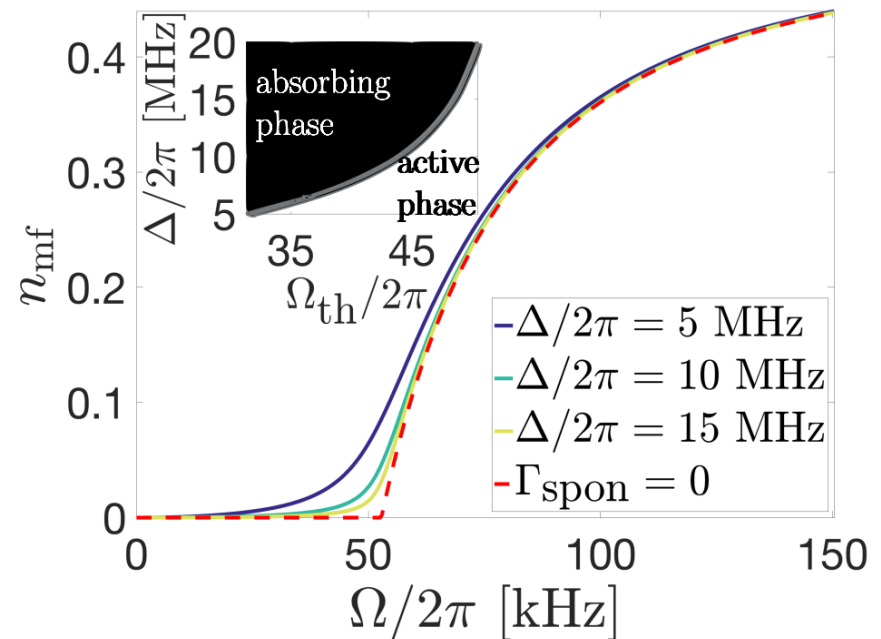


Compatible with 1D directed percolation ($\beta \leftrightarrow 0.276$)

The critical point is signalled by a peak in the fluctuations



Phys. Rev. A **96**, 043411

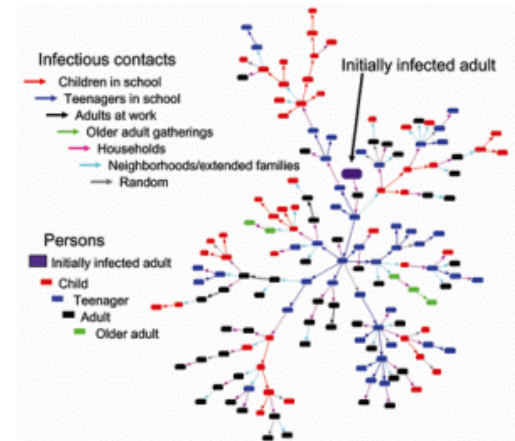


Refinements:

- spontaneous excitations
- atomic motion

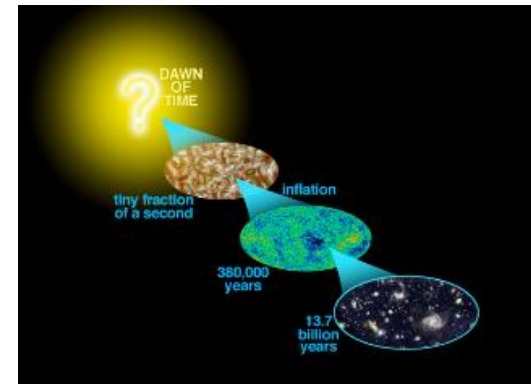
(see also work by S. Whitlock)

Outlook: towards quantum percolation

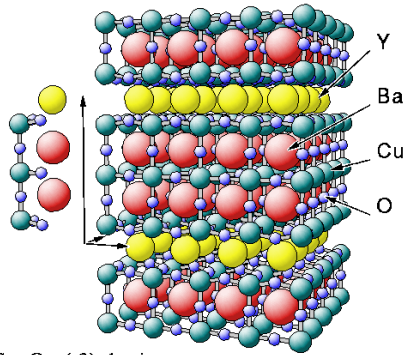


Percolation

classical

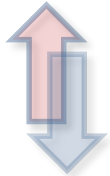


Outlook: towards quantum percolation



$\text{YBa}_2\text{Cu}_3\text{O}_7$ (.3) lattice

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quantum

Percolation

