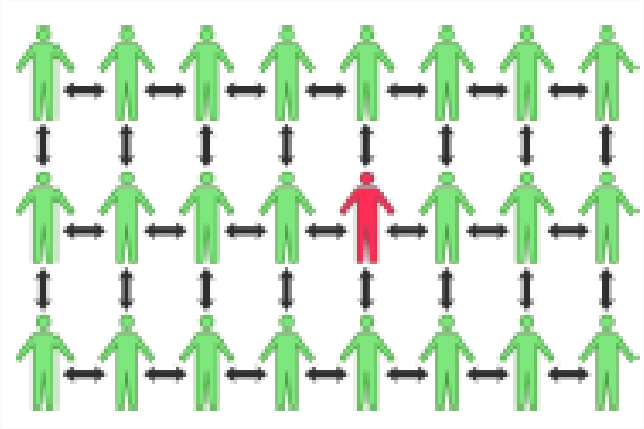
Verso i simulatori quantistici con atomi di Rybderg:
Risultati ottenuti e prospettive per il futuro

Oliver Morsch

INO-CNR and Dipartimento di Fisica, Pisa, Italy

Ry-Dy meeting, Pisa, 25.09.2017



C. Simonelli, M. Archimi, G. Masella, L. Asteria, D. Capecchi, F. Castellucci , M. Martinez-Valado, E. Arimondo, D. Ciampini

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

Funding: FET-RYSQ, PRIN

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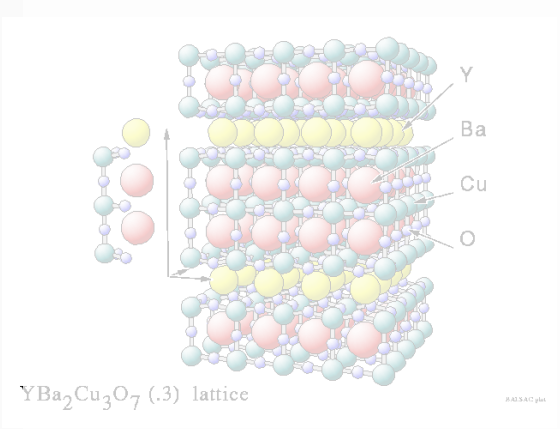
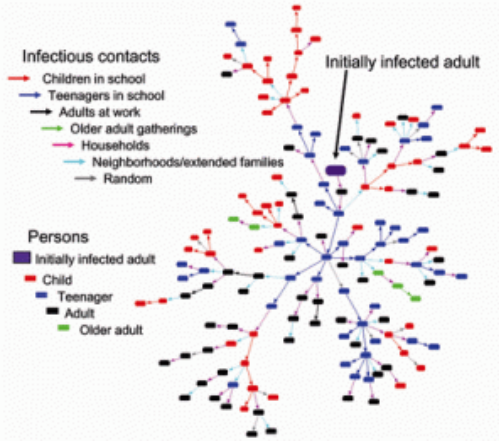
Our goal: simulating quantum percolation

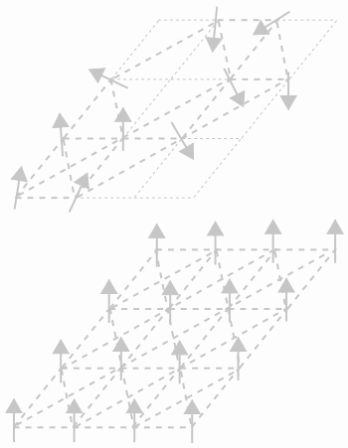


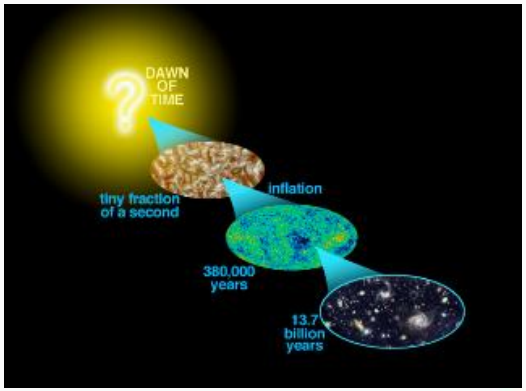


quantum

Percolation

classical





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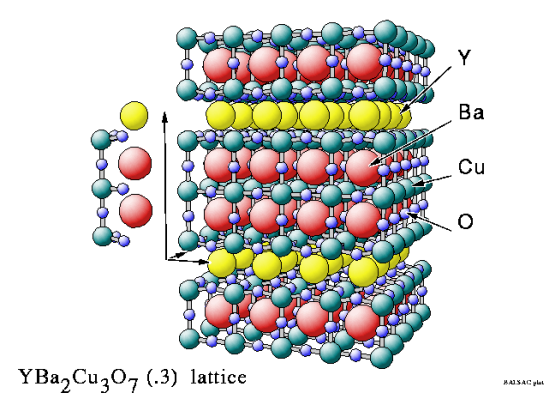
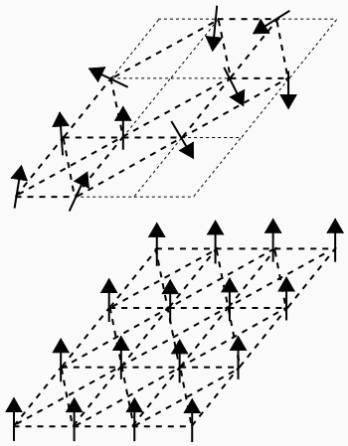
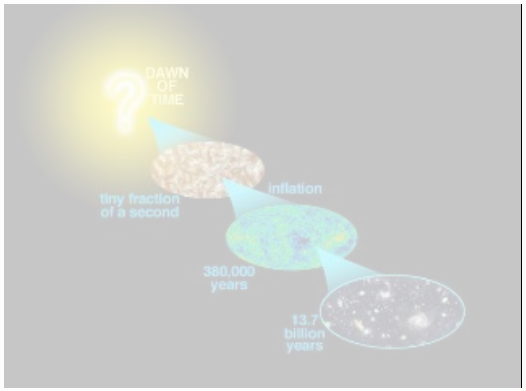
Our goal: simulating quantum percolation



quantum **Percolation** ***classical***

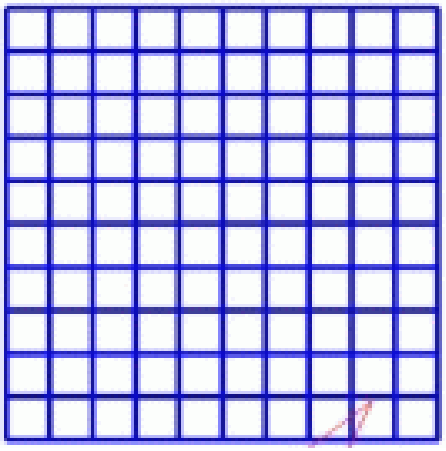




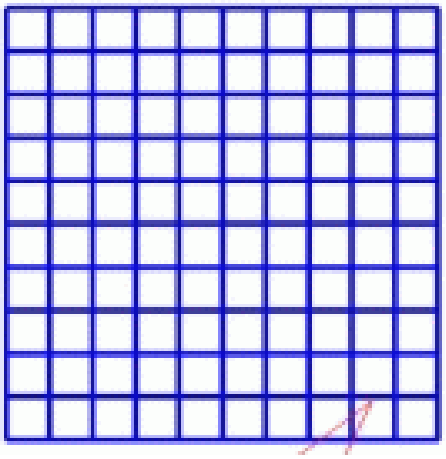
Overview

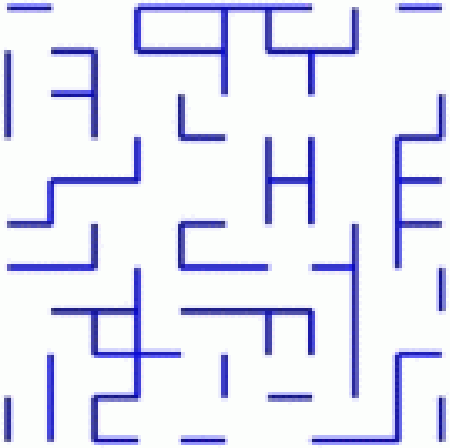
- Percolation and directed percolation
- Creating the basic processes with Rydberg atoms
- Experimental results on an absorbing state phase transition
- Towards quantum percolation

Percolation

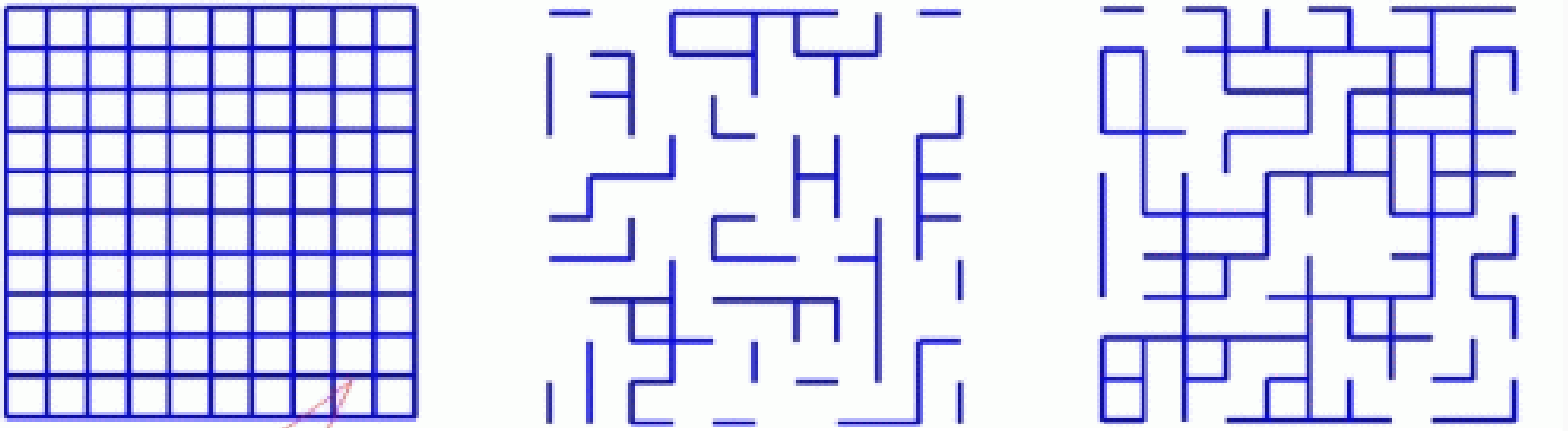


Percolation

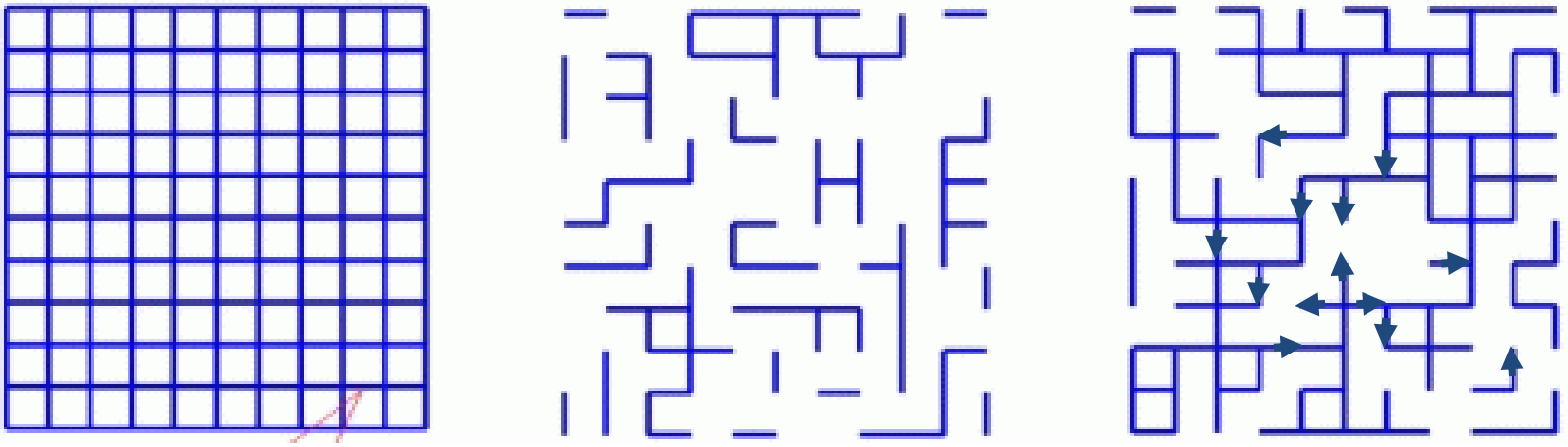




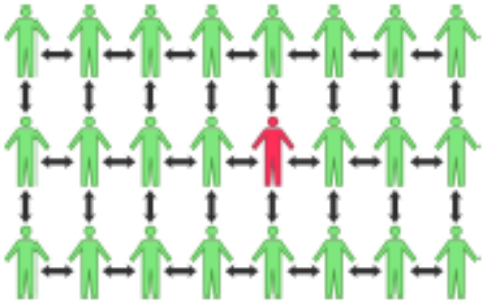
Percolation



Directed Percolation



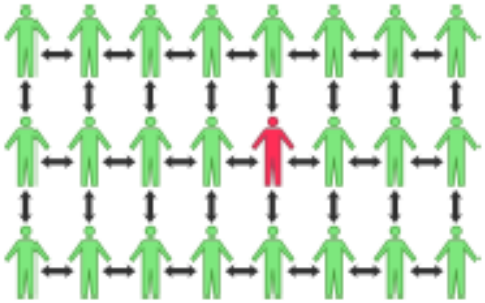
Directed Percolation

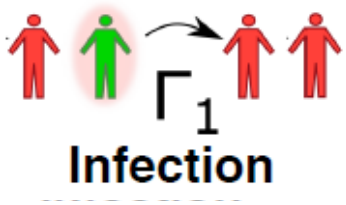


Directed percolation

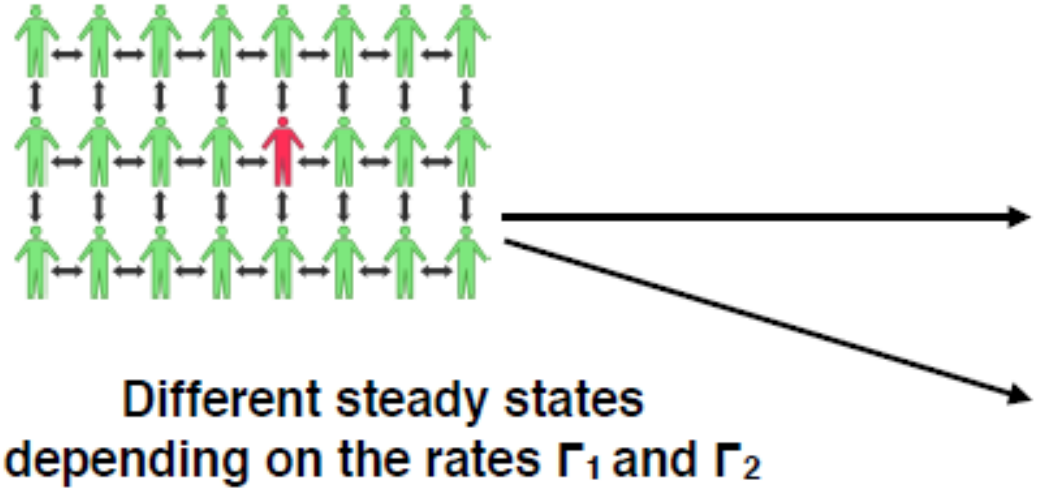
examples: wildfires,
turbulence, disease spreading…

Directed Percolation



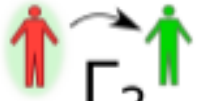


Directed Percolation



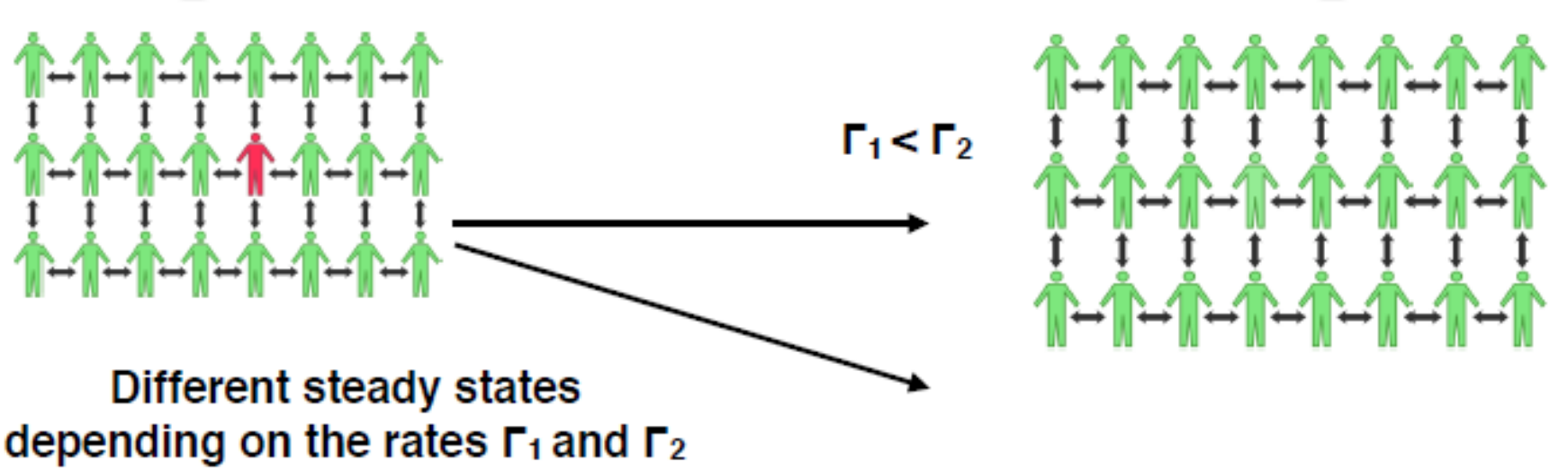
Different steady states
depending on the rates Γ_1 and Γ_2

Infection

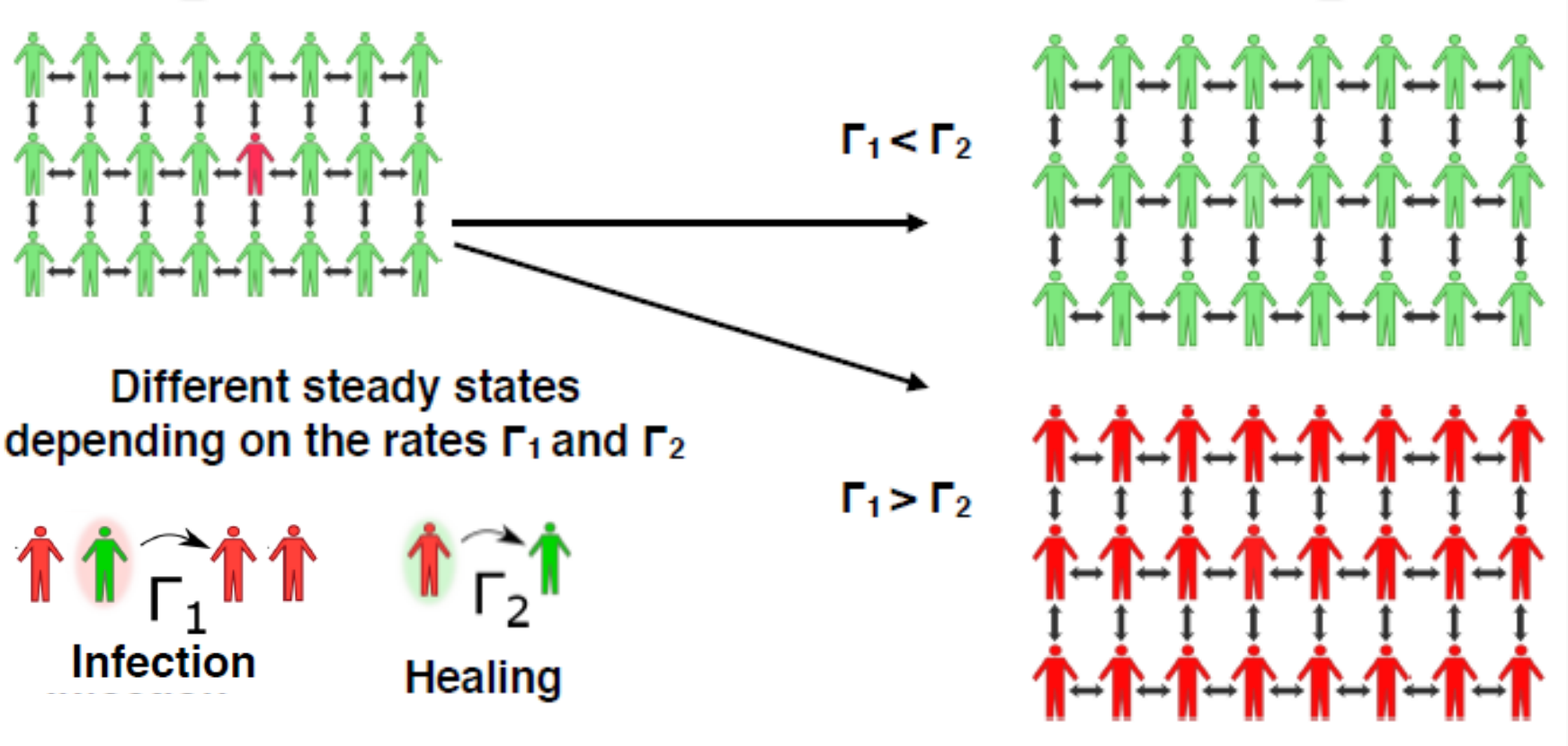


Healing

Directed Percolation

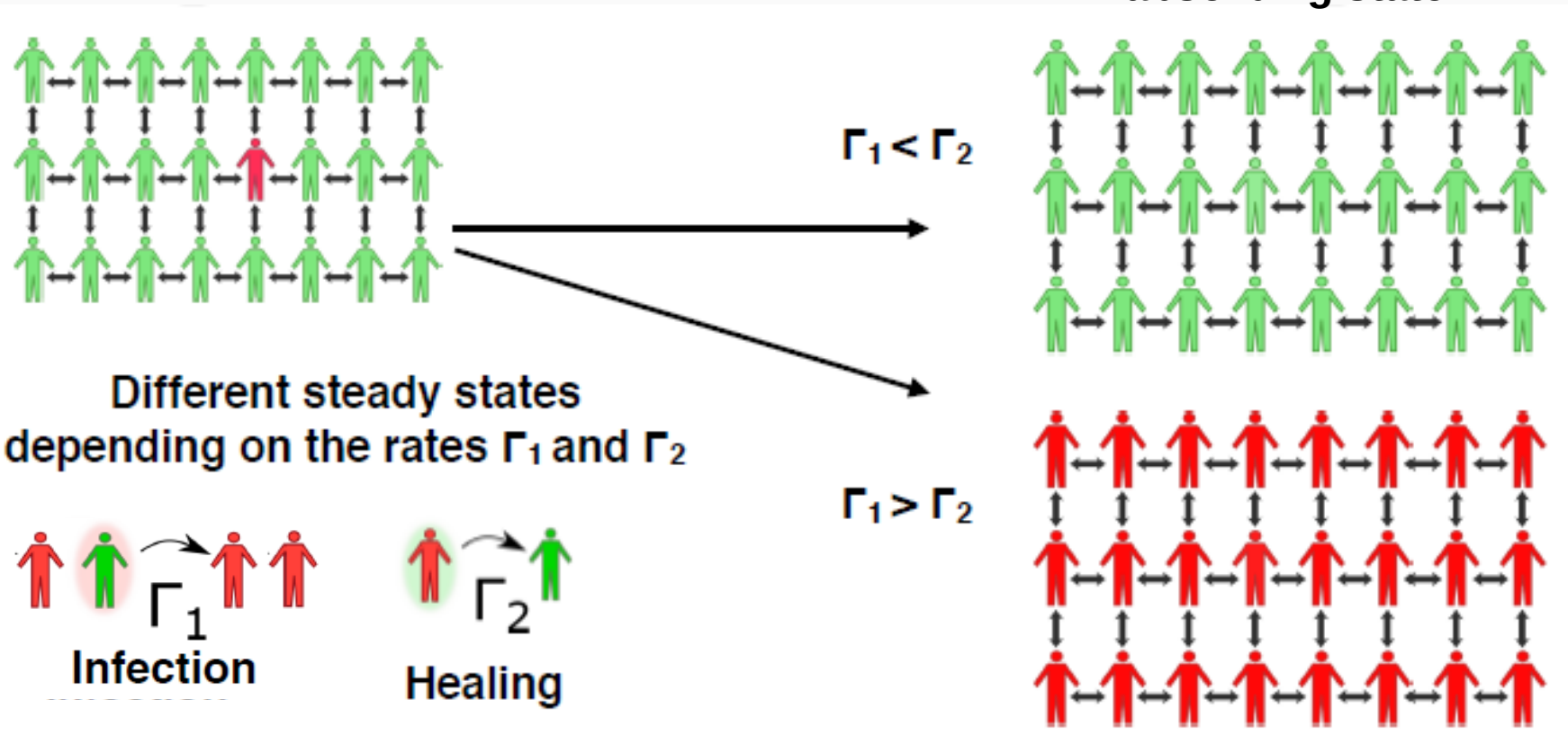


Directed Percolation



Directed Percolation

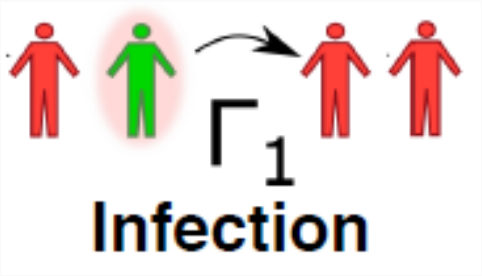
«absorbing state»



«active state»

Directed Percolation: The basic processes

Basic processes:



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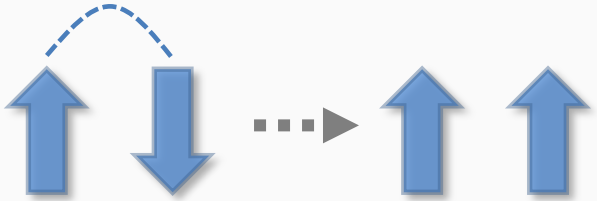
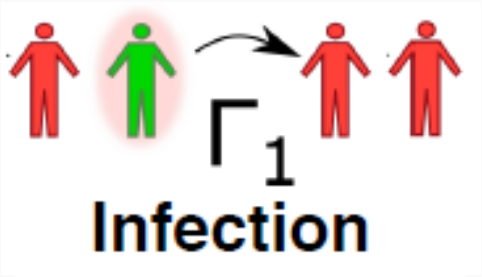
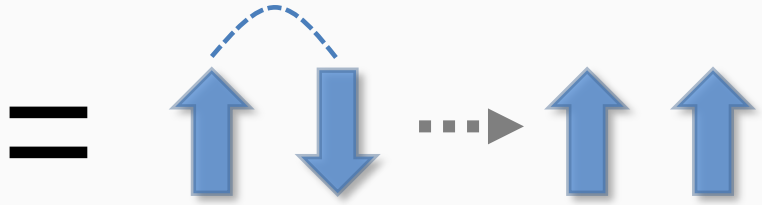


«offspring production»

Directed Percolation: The basic processes

Basic processes:

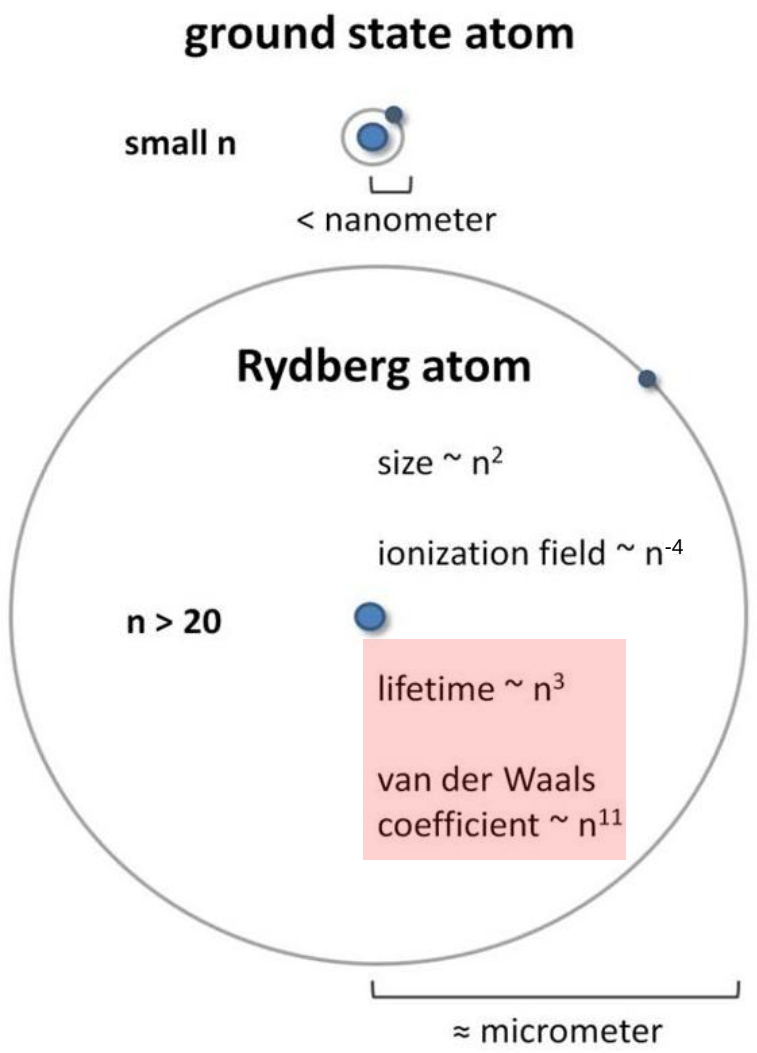




«offspring production»

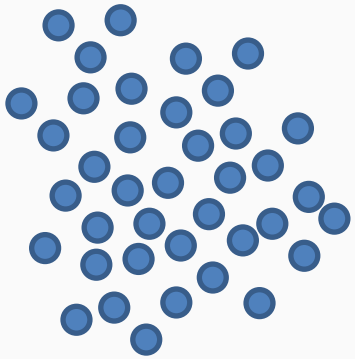
«sudden death»

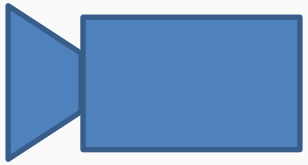
Rydberg atoms



Ex.: Rb n=70, ~ MHz at 10 μm
lifetime around 150 μs

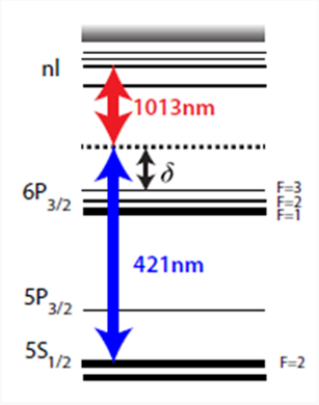
Excitation and detection of Rydberg atoms

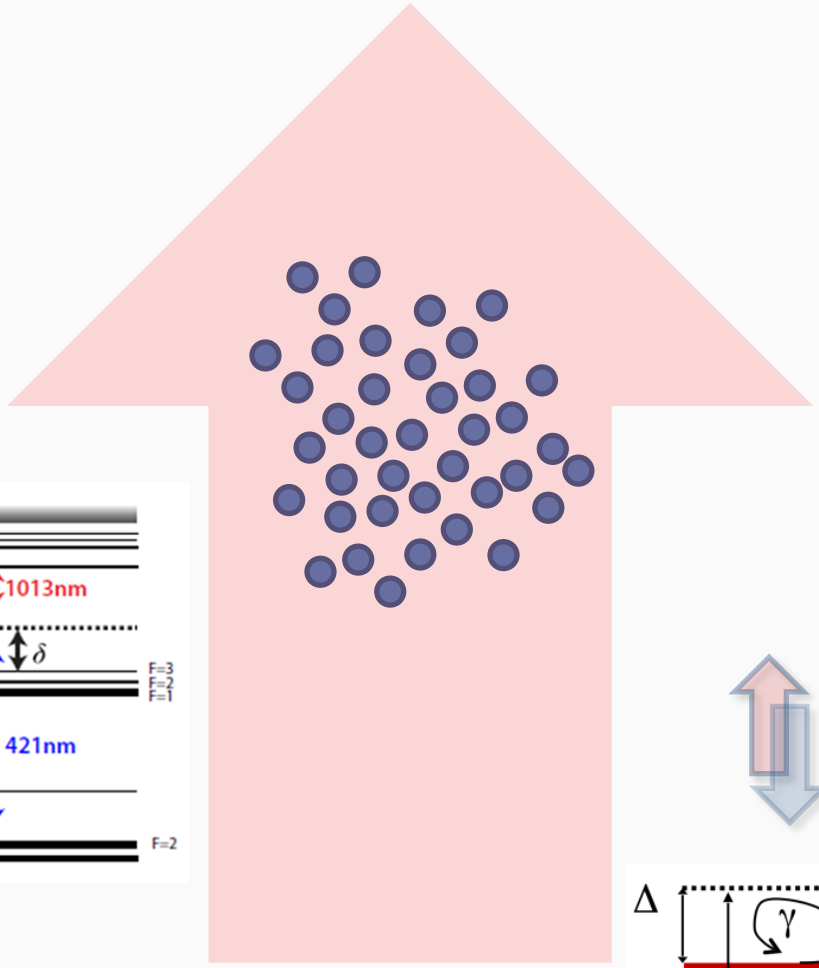


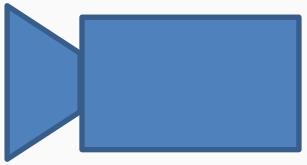


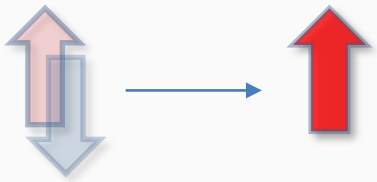
^{87}Rb atoms in a MOT
T ~ 150 micro Kelvin
N ~ few 10^5
size around 150 microns

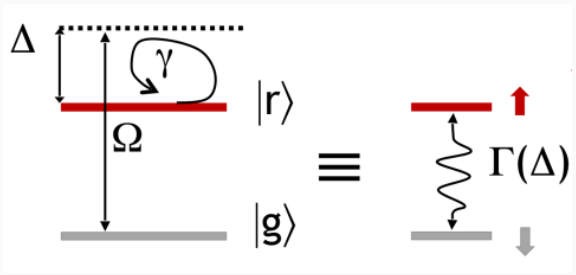
Excitation and detection of Rydberg atoms





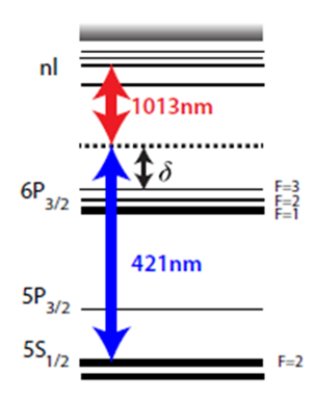


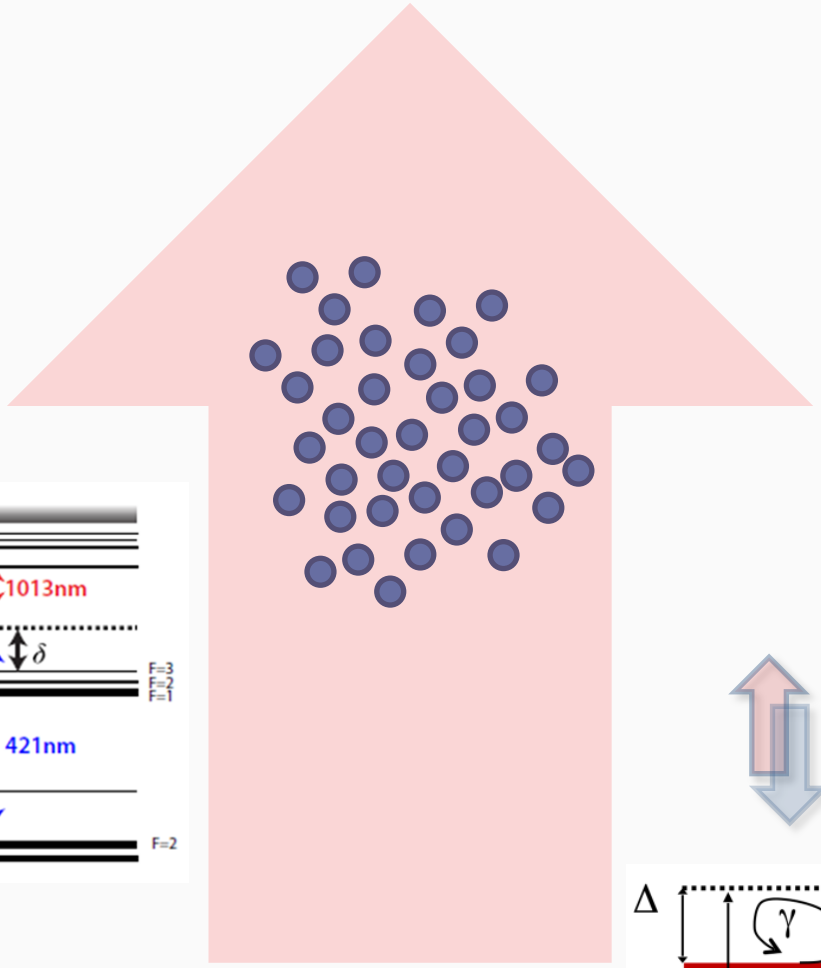


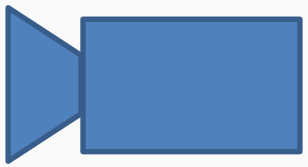


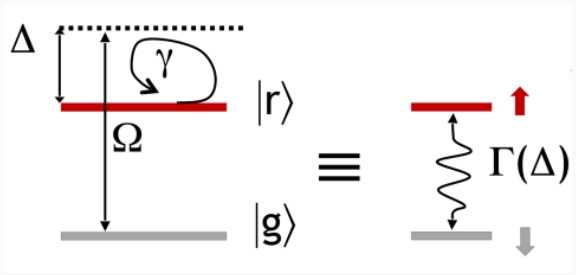
semi-classical dynamics

Excitation and detection of Rydberg atoms



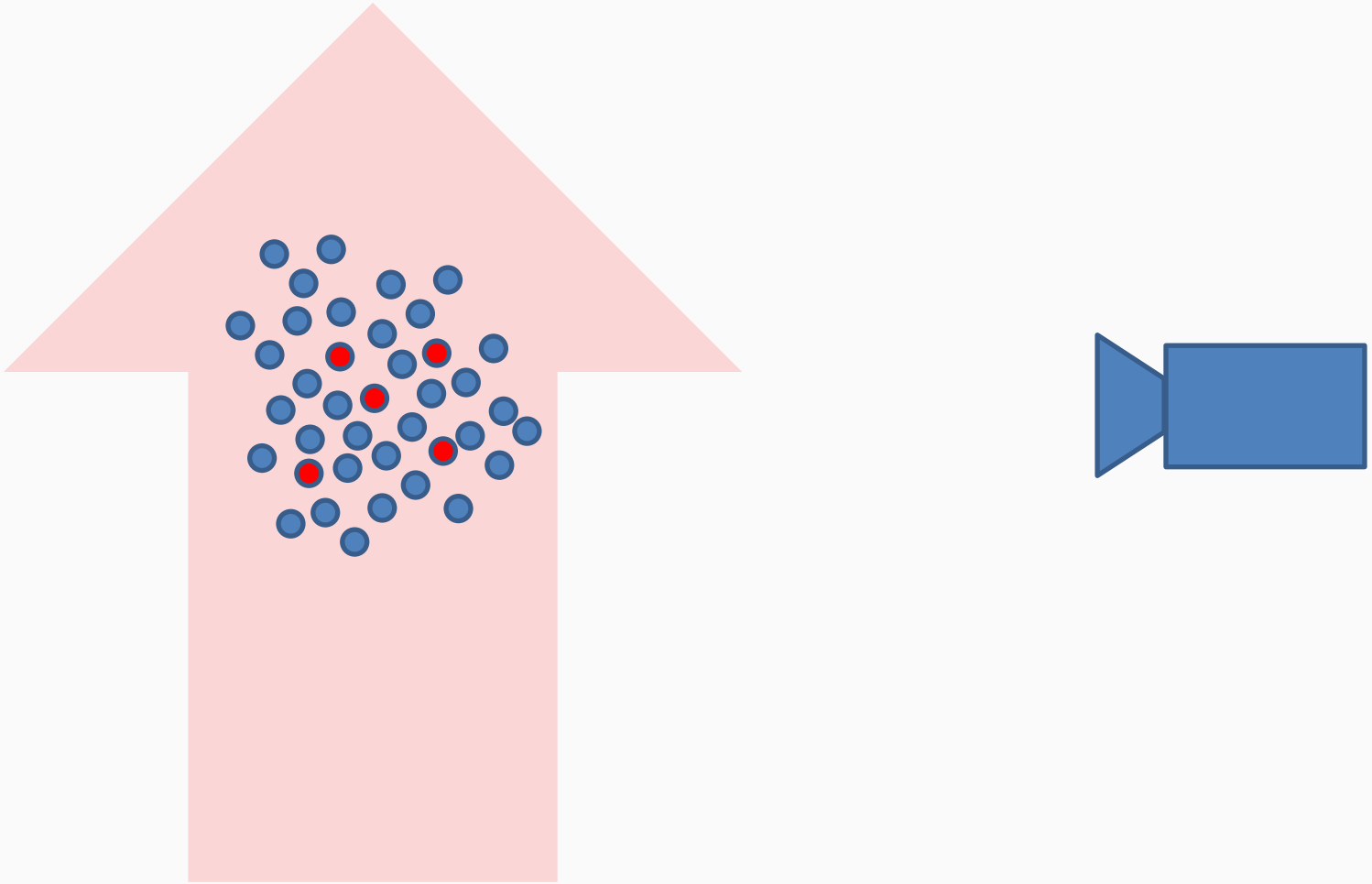




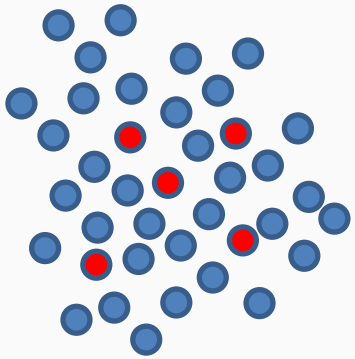


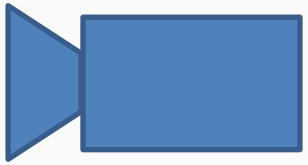
semi-classical dynamics

Excitation and detection of Rydberg atoms



Excitation and detection of Rydberg atoms

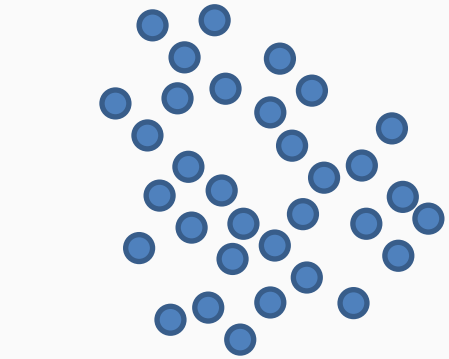


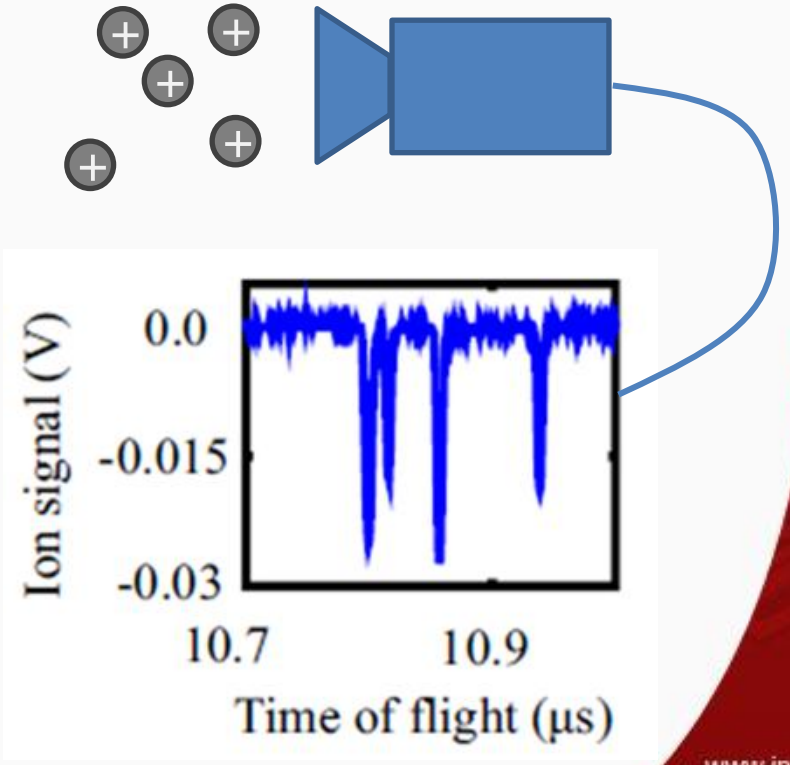


Excitation and detection of Rydberg atoms

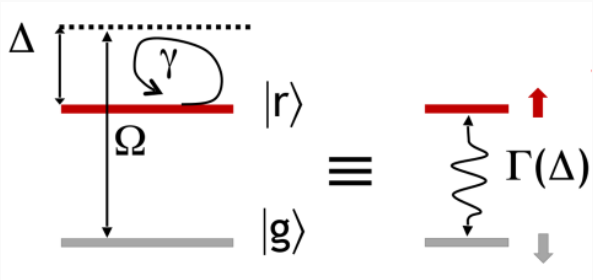
Excitation and detection of Rydberg atoms

electric field

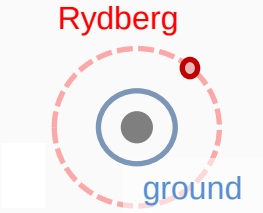




Facilitation



$$\Gamma_i(\Delta) = \frac{\Omega^2}{2\gamma}\left[1 + \left(\frac{\Delta}{\gamma}\right)^2\right]^{-1}$$



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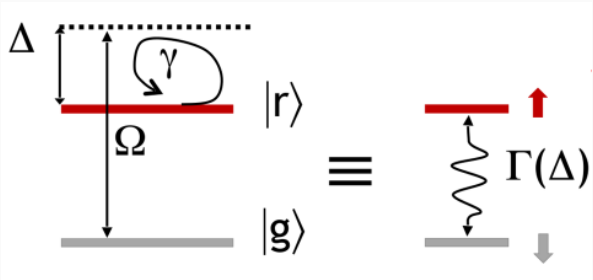
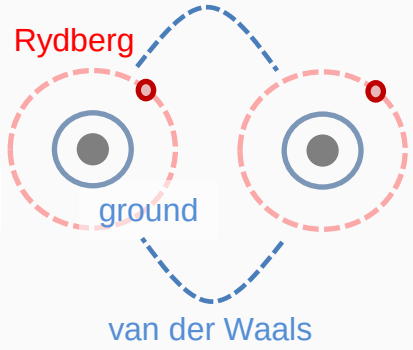


$$\Gamma_i(\Delta) = \frac{\Omega^2}{2\gamma}\left[1 + \left(\frac{\Delta - \frac{1}{\hbar}\sum_{i\neq j} V_{ij} n_j}{\gamma}\right)^2\right]^{-1}$$



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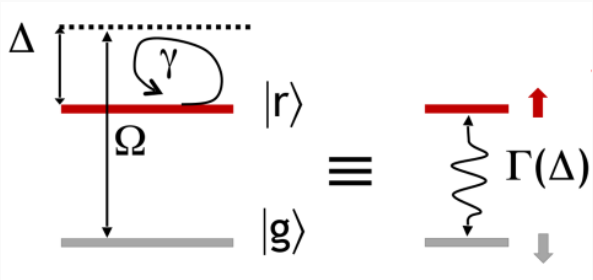

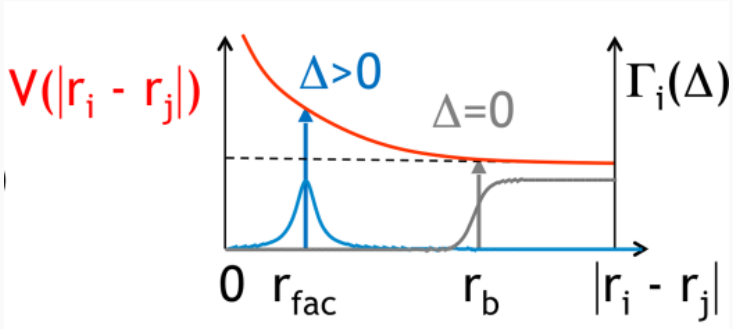

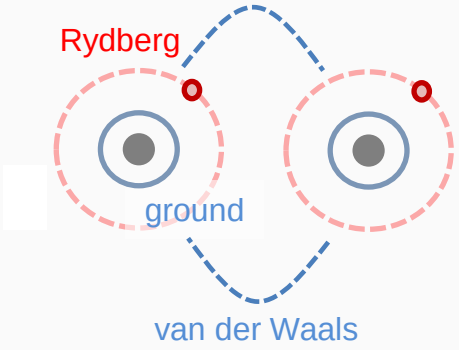

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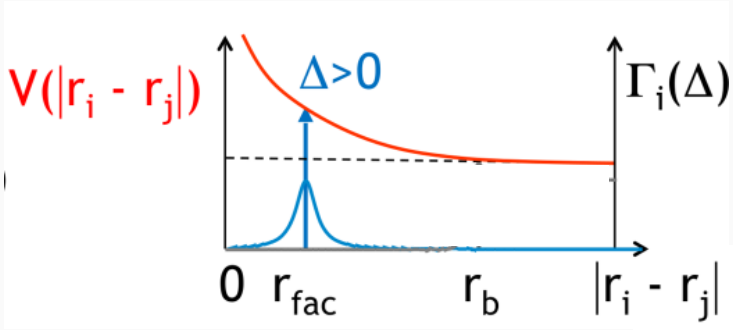
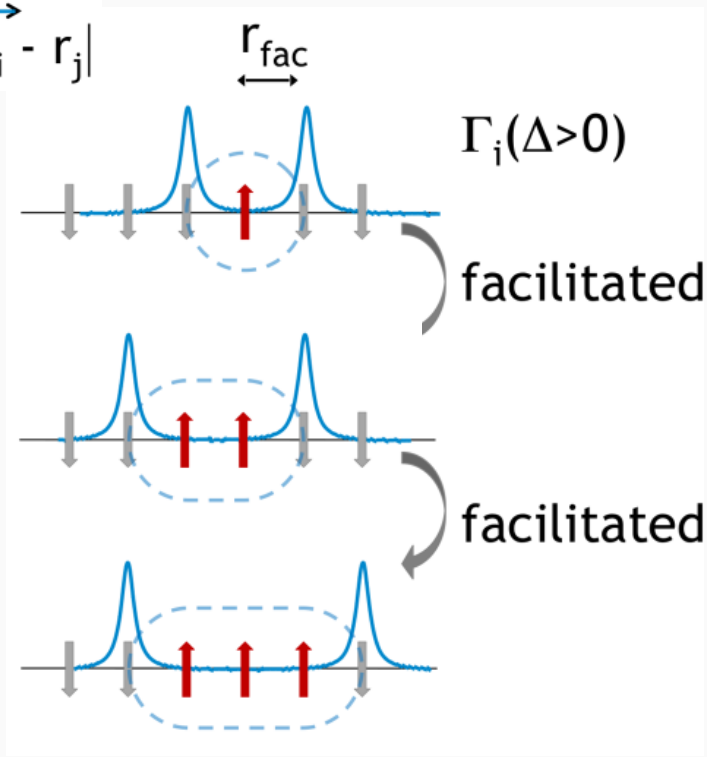


$r_{fac} \sim 7\ \mu m$



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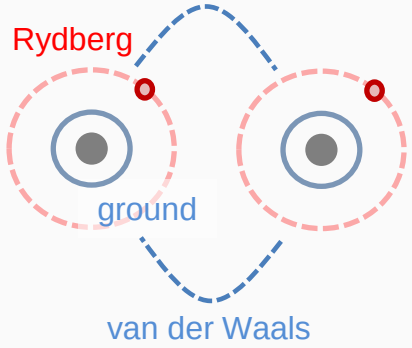
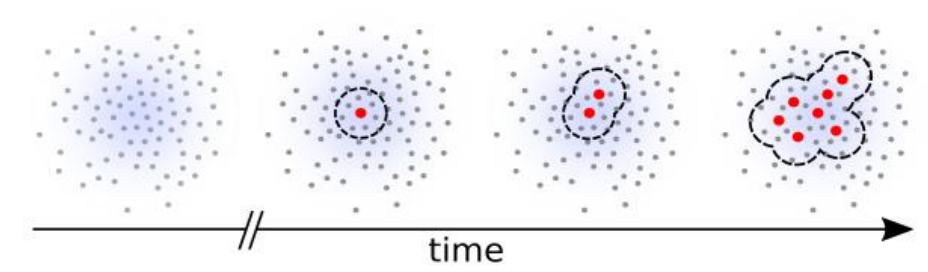
Directed percolation: basic processes



facilitated
excitation

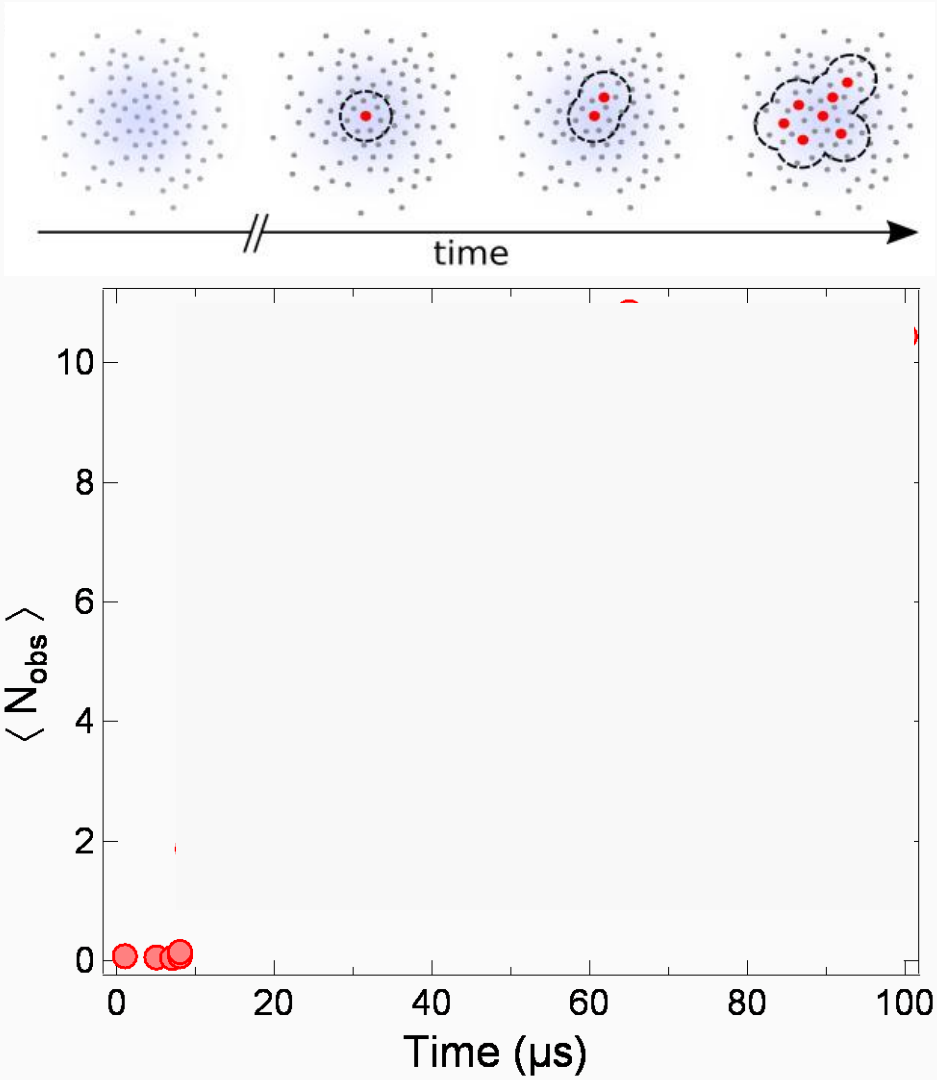
= offspring production

Seeding the facilitation process



C. Simonelli *et al.* , J. Phys. B 49, 154002 (2016)

Seeding the facilitation process



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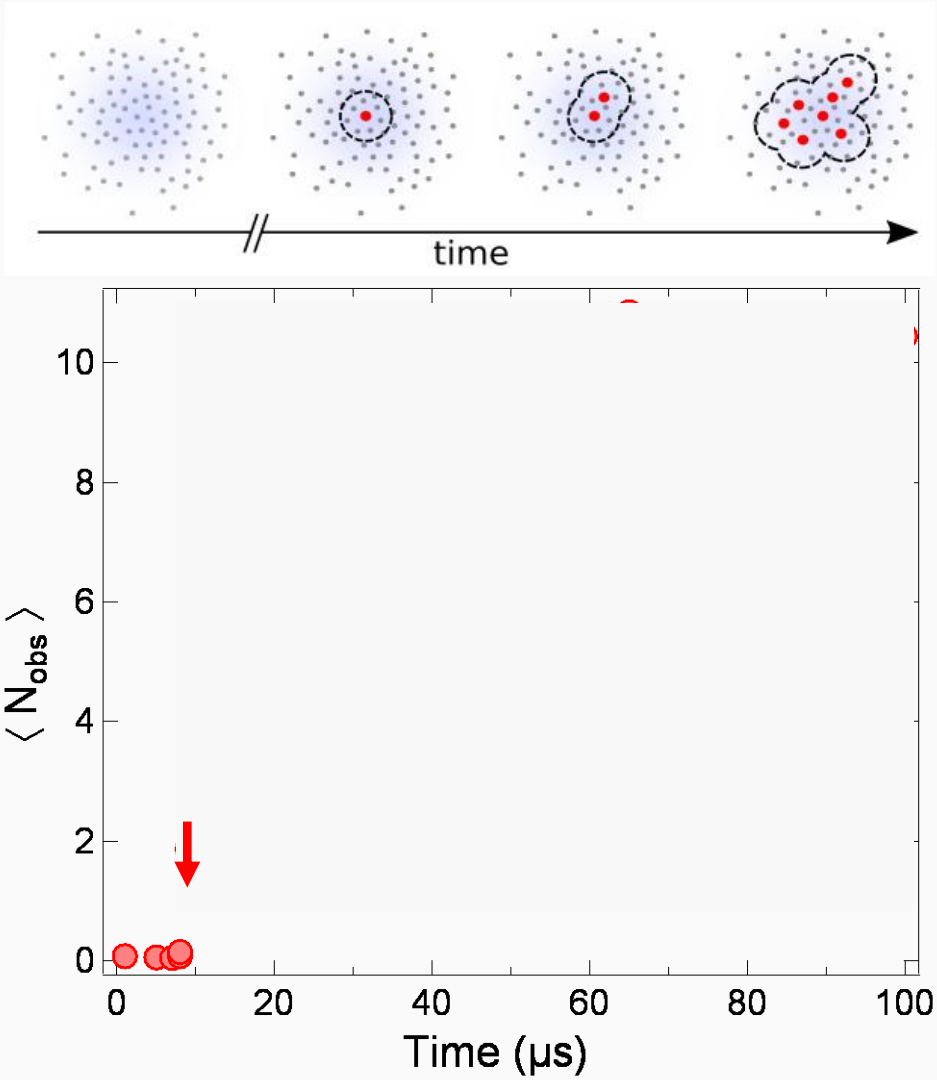

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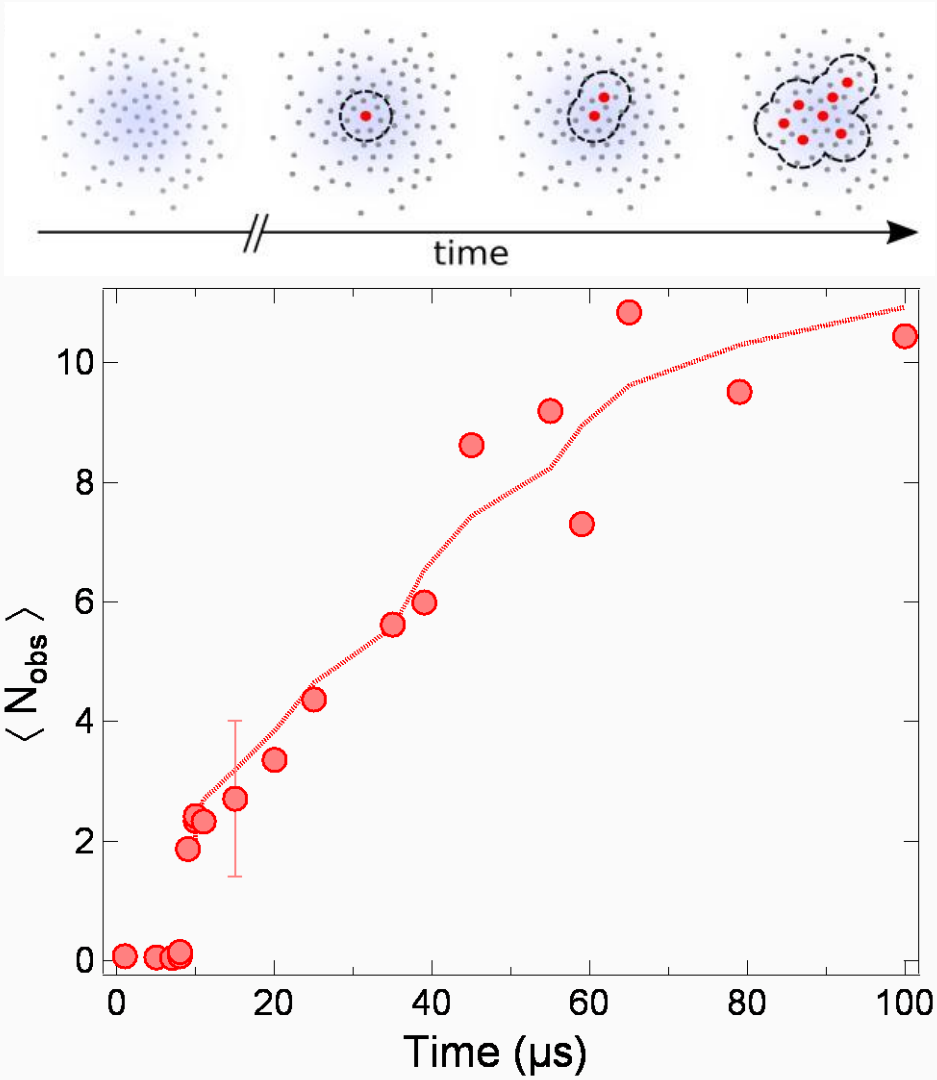

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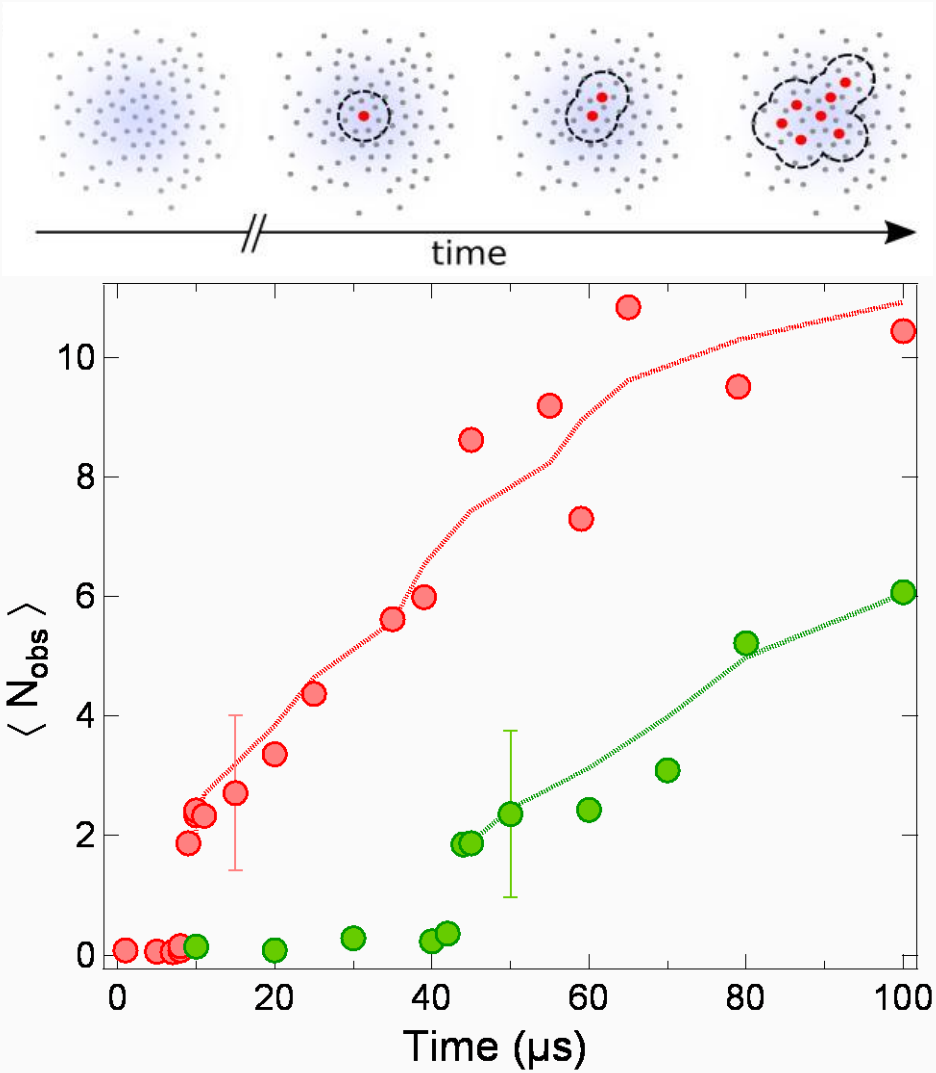
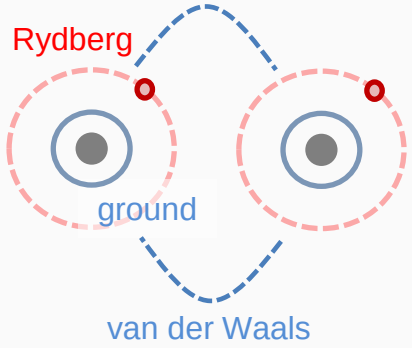


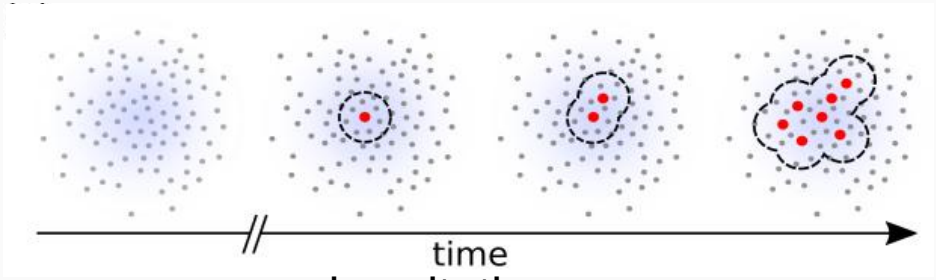
C. Simonelli *et al.* , J. Phys. B 49, 154002 (2016)

Directed percolation: basic processes



facilitated excitation

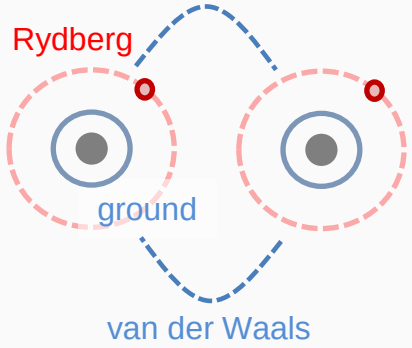
= offspring production



seed excitation

needed to prepare the system away from the absorbing state

Directed percolation: basic processes



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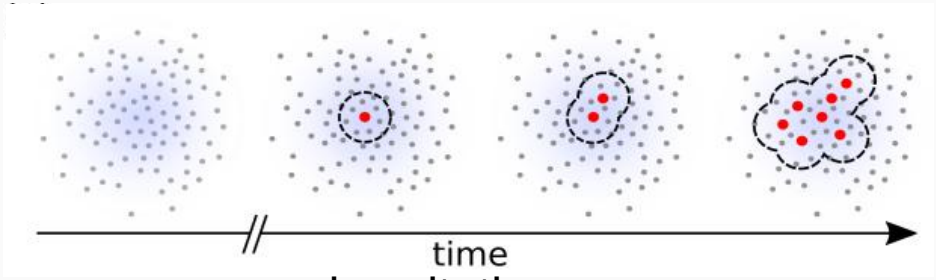

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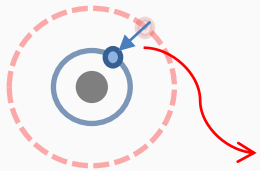
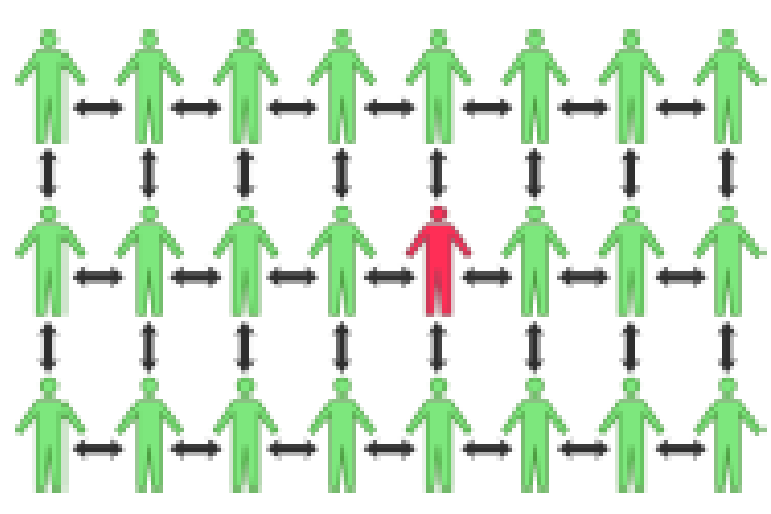


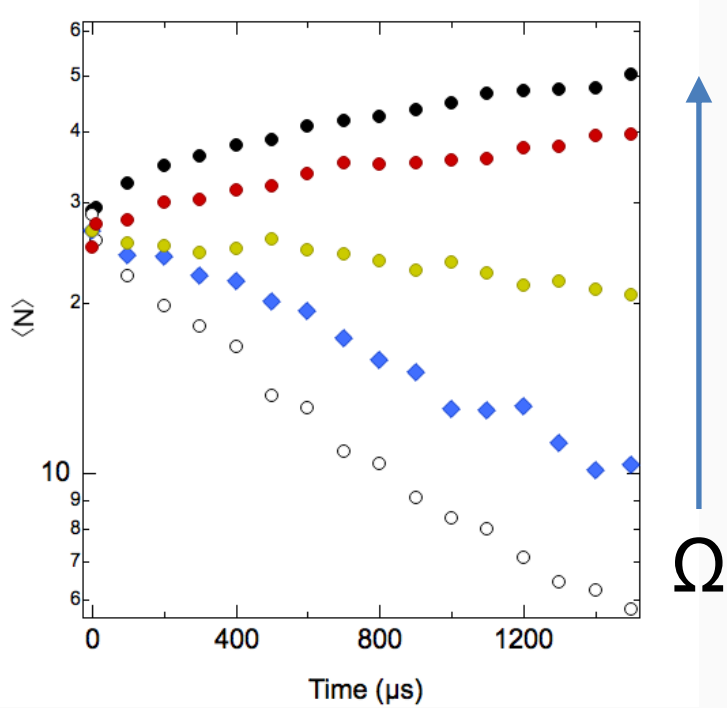
spontaneous decay

= sudden death

Absorbing state phase transition

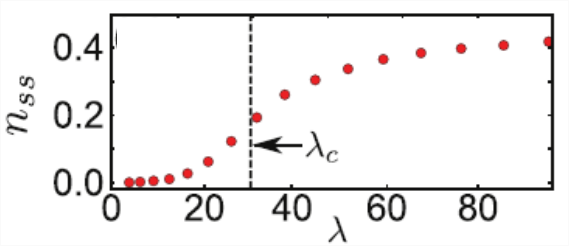
Experiment: Seed system with excitations; measure dynamics for varying driving strengths Ω





Absorbing state phase transition

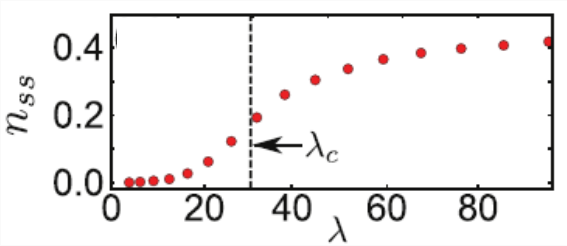
Experiment: Seed system with excitations; measure steady state for varying driving strengths Ω

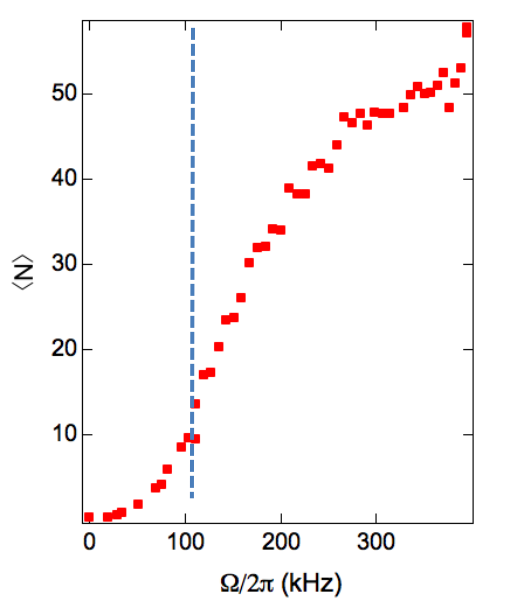


New J. Phys. 17 (2015) 072003

Absorbing state phase transition

Experiment: Seed system with excitations; measure steady state for varying driving strengths Ω



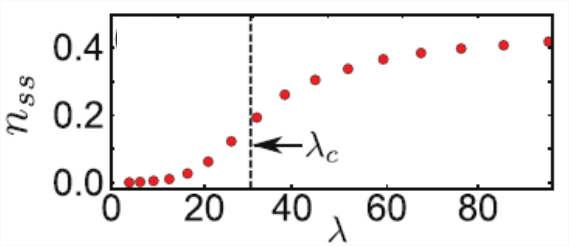


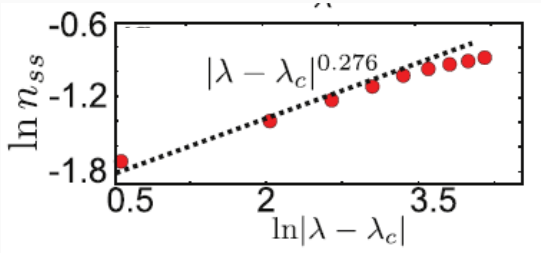
New J. Phys. 17 (2015) 072003

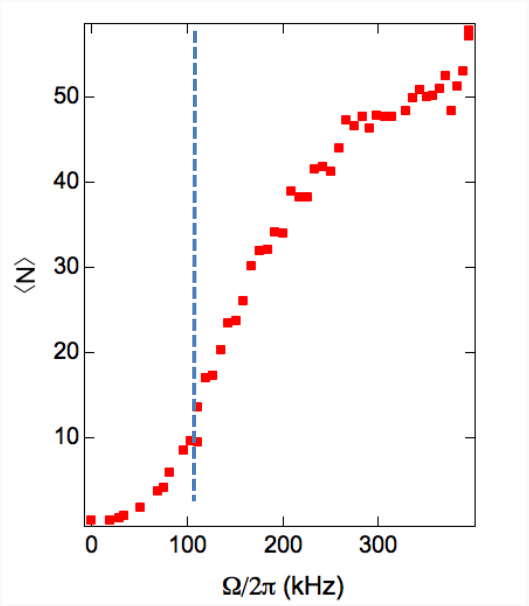
arXiv:1611.03288

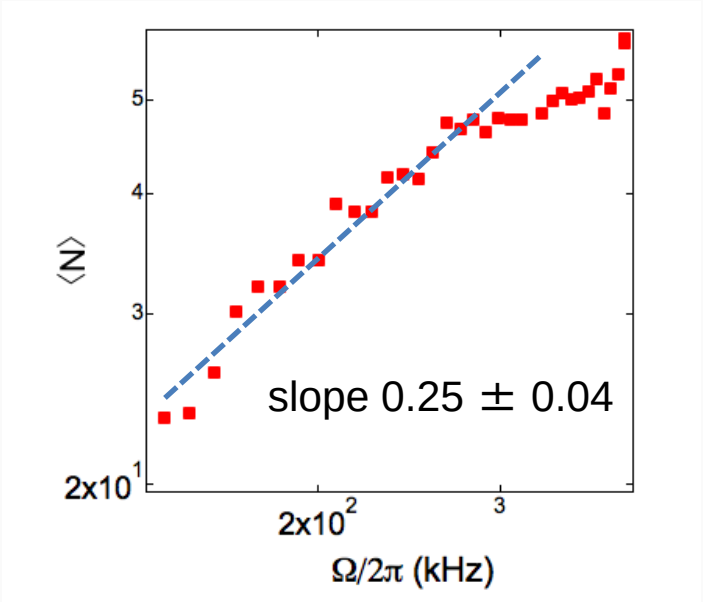
Absorbing state phase transition

Experiment: Seed system with excitations; measure steady state for varying driving strengths Ω









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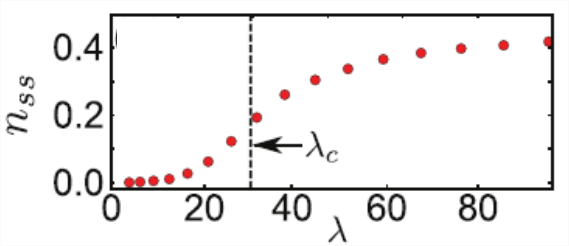

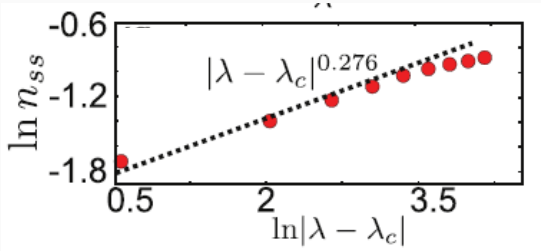

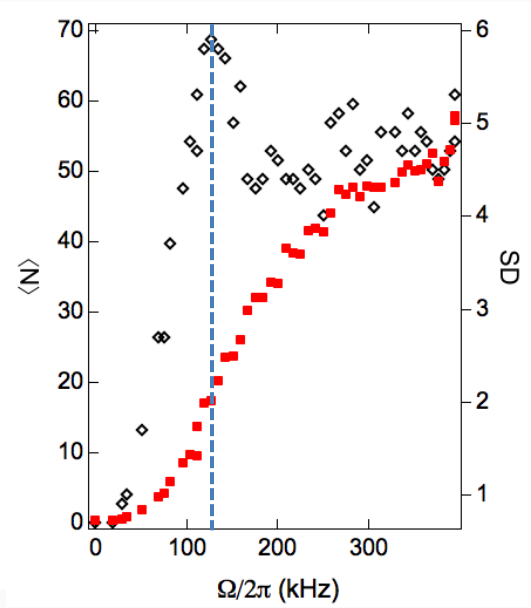

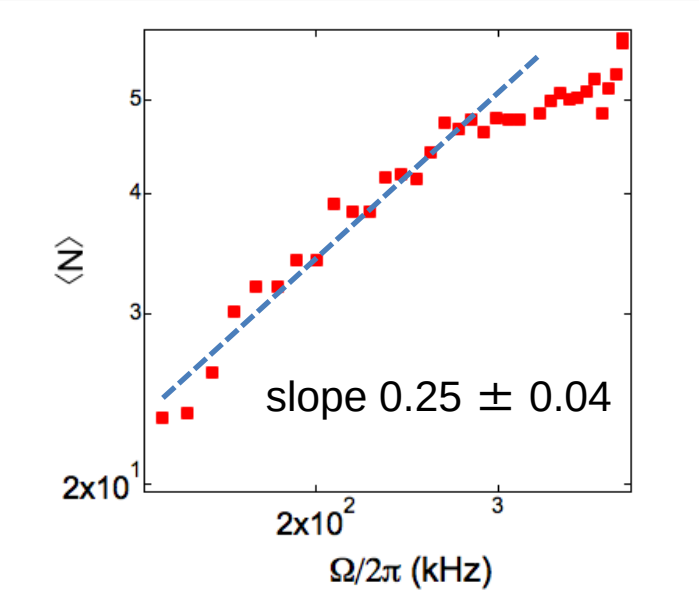

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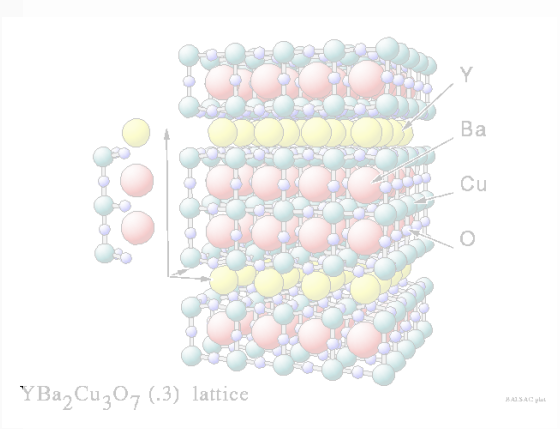
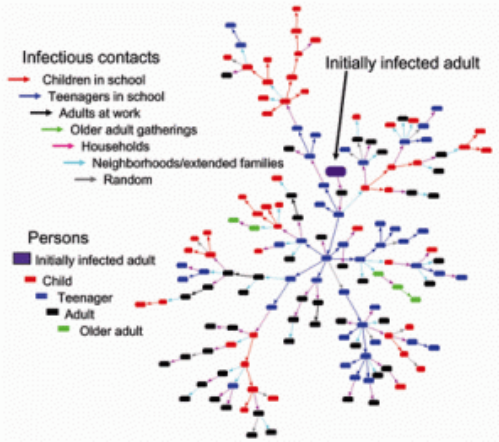
Towards quantum percolation

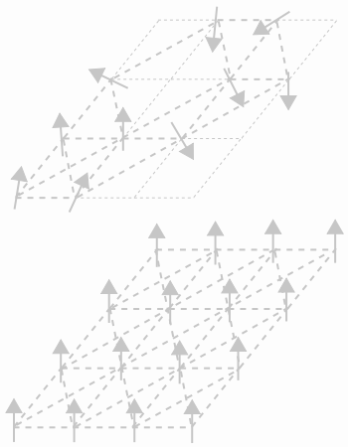


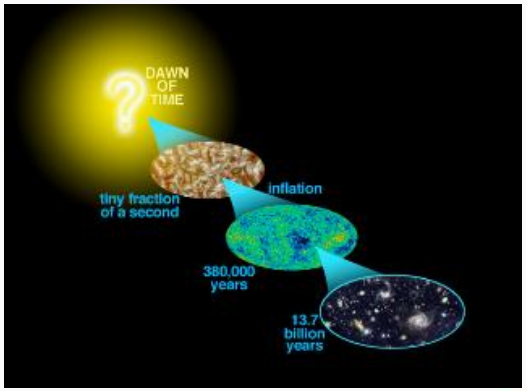


quantum

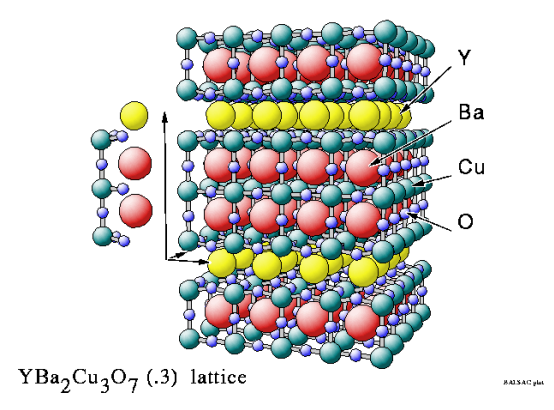
Percolation

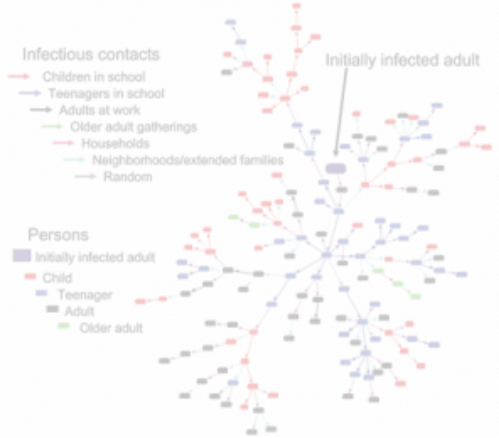
classical





Towards quantum percolation





quantum **Percolation** ***classical***