# Universality in condensation of exciton-polaritons

Michał Matuszewski and Emilia Witkowska
*Instytut Fizyki PAN, Aleja Lotników 32/46, 02-668 Warsaw, Poland*

**We consider the condensation of exciton-polaritons, which is an example of an uncommon phase transtion, in which the transition connects an intrinsically nonequlilbrium state to a quasi-equilibrium state. We show that this process can lead to the formation of domains of polaritons and uncondensed excitons, and demonstrate scaling laws that give an estimate for the number of created domain walls.**

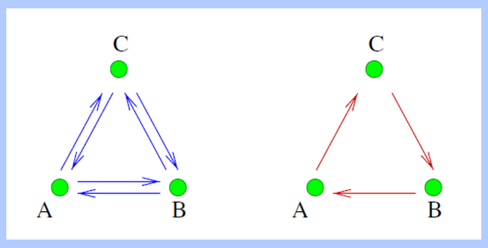
## Universality

- Term coined by experimentalists observing similar critical behaviour in apparently unrelated physical systems
- ***Critical exponents*** depend only on the symmetry properties of the model, defining the ***universality class***

$$\xi \propto |\varepsilon|^{-\nu}$$ correlation length

$$\tau \propto |\varepsilon|^{-z\nu}$$ relaxation time

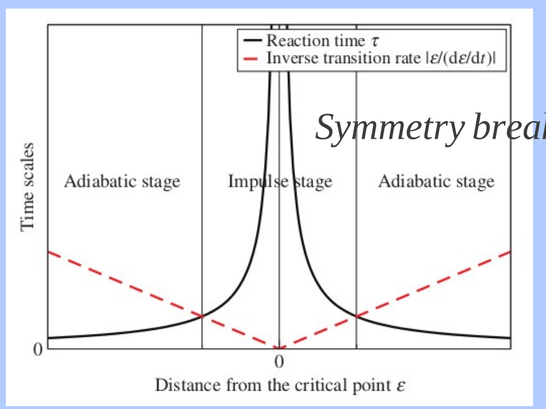
## Equilibrium and nonequilibrium systems



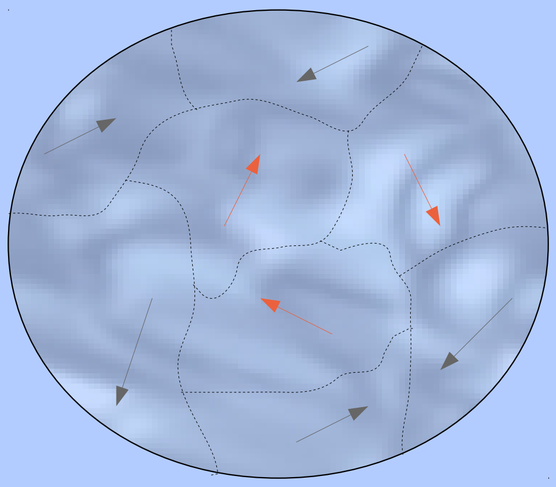

- *Close to equilibrium*: Boltzman statistics, ensembles, equipartition, etc.
- *Far from equilibrium*: Percolations, growing surfaces, traffic jams, social networks...

## The Kibble-Żurek mechanism

- 2nd order phase transition to a symmetry broken phase: system goes out of equilibrium close to the critical point. Defects are created: domain walls, vortices, strings, etc.
- Early universe, liquid helium, superconductors, liquid crystals, ultracold gases...



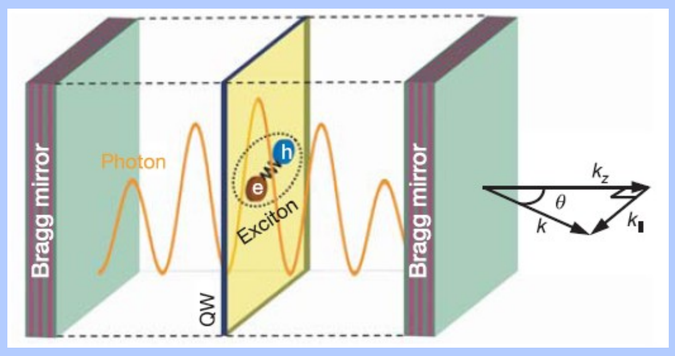

*Symmetry breaking*

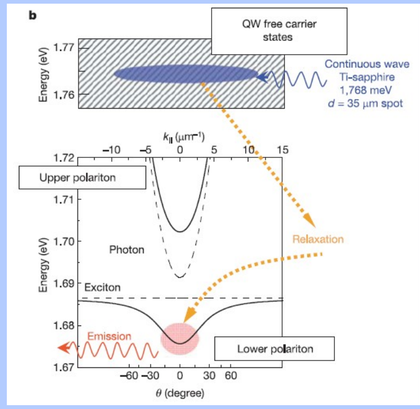


$$N_d \sim \hat{\xi}^{-d} \sim \tau_Q^{-d\nu/(1+z\nu)}$$

## Exciton-polaritons

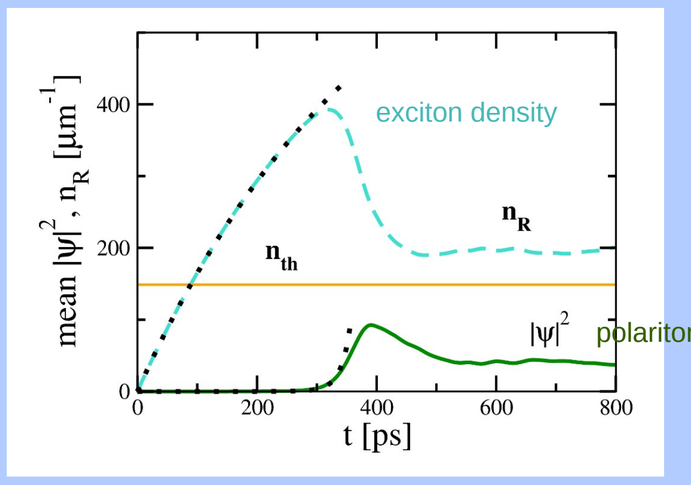
- Strong coupling between excitons and photons in a microcavity
- Dressed states of exciton and photons are quasiparticles called polaritons
- Extremely small effective mass, strong interparticle interactions
- Bose-Einstein condensation can occur even at room temperature



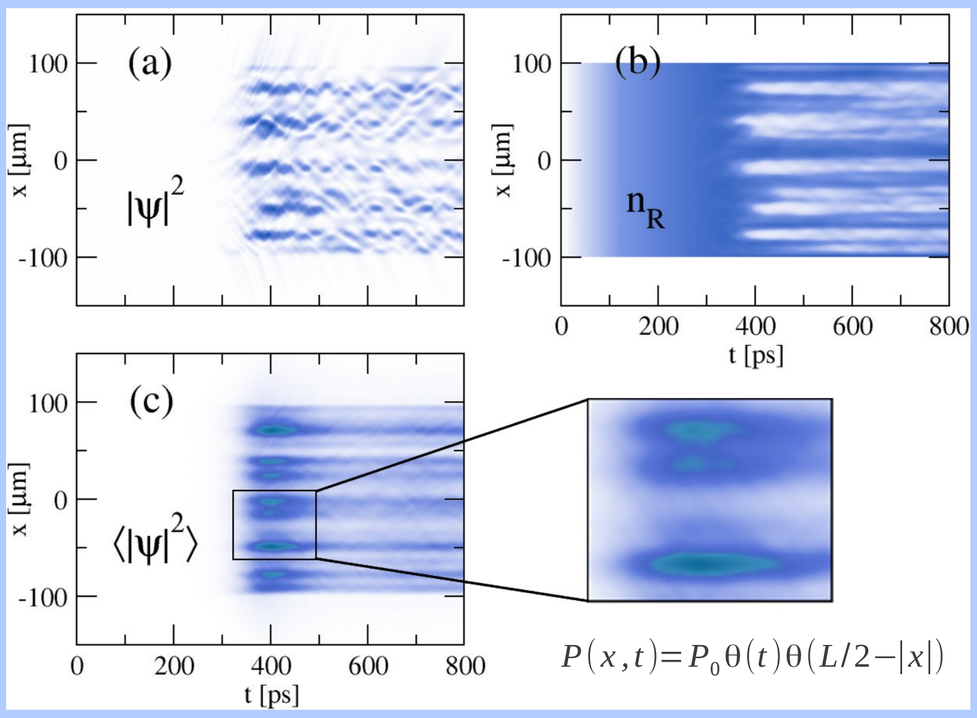




## Polariton condensation in a nanowire

- We model condensation in the Truncated Wigner approximation
- Flat pump over a large area turned on quickly



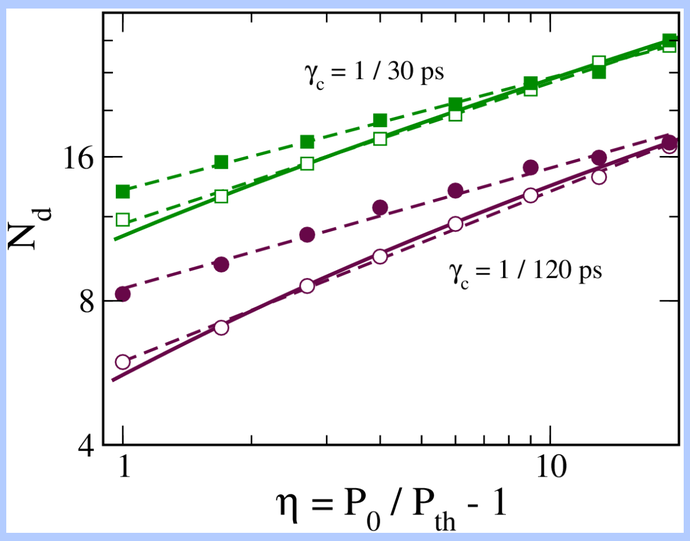

- When $n_R < n_{th}$, the steady state is nonequilibrium
- When $n_R > n_{th}$, the steady state is a quasiequilibrium condensate




M. Matuszewski, and E. Witkowska, arXiv:1212.0805.

## Our explanation

1. Condensation takes place when polariton interactions are strong enough to overcome nonequilibrium processes
2. The domain size is determined by the healing length at this instant




| Kibble-Żurek mechanism | Polariton condensation |
|---|---|
| Adiabatic → Impulse → Adiabatic | Nonequilibrium → Close to Equilibrium |
| Competition between transition time and reaction time | Competition between nonequilibrium timescale and interaction time |
| Number of defects determined by the correlation length before the transition | Number of defects determined by the healing length after the transition |