

Scaling laws of superfluid turbulence

B. N., D. Sexty, T Gasenzer: Phys. Rev. B, Rapid Comm. (2011)

B. N., J. Schole, D. Sexty, T. Gasenzer: in preparation

Boris Nowak

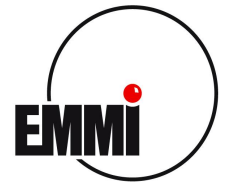


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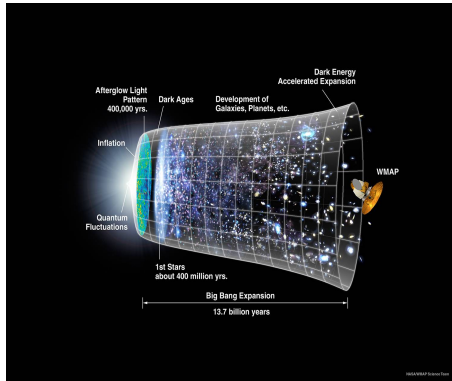
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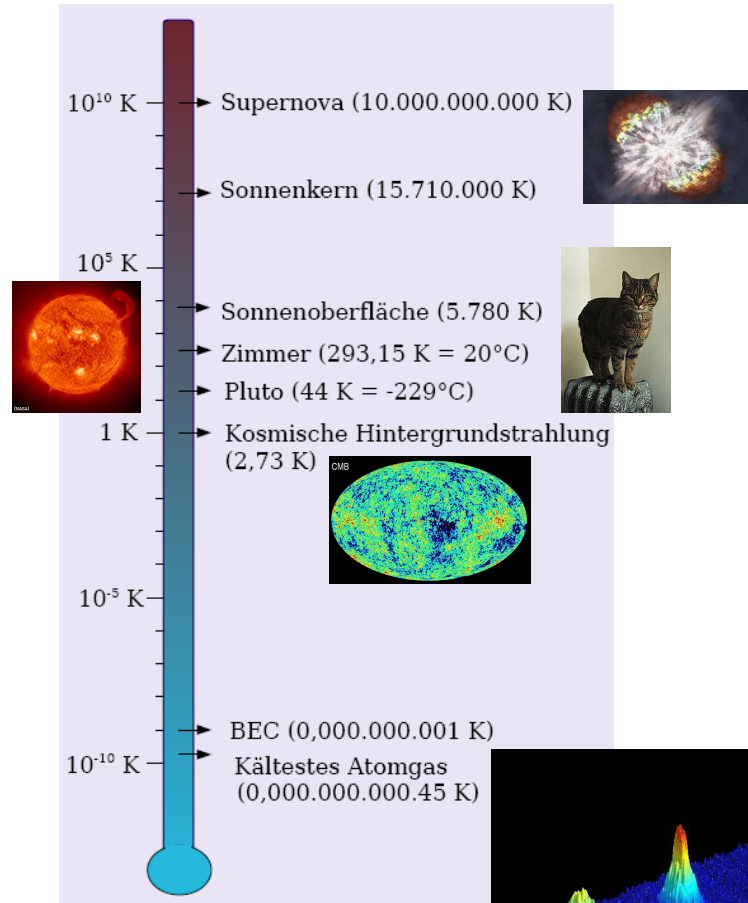


Center for
Quantum
Dynamics

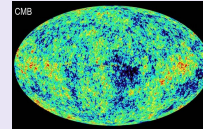
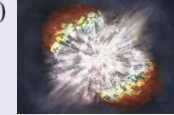
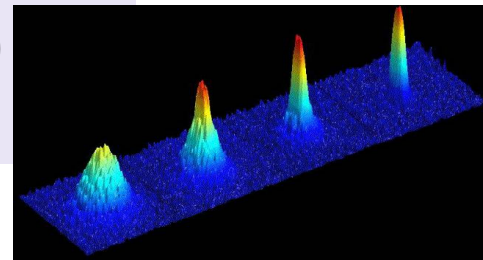
Nonequilibrium Quantum Gases



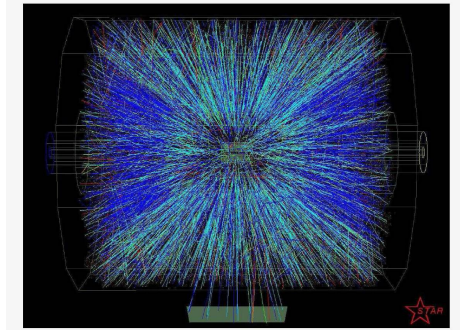
Early universe



Ultracold gases



Result of colliding two Gold nuclei (Relativistic Heavy Ion Collider, BNL):



Heavy-ion collisions



Nonequilibrium Dynamics



Initial state:
Far from equilibrium



Transient state:
e.g. Turbulence
(Nonthermal fixed point)



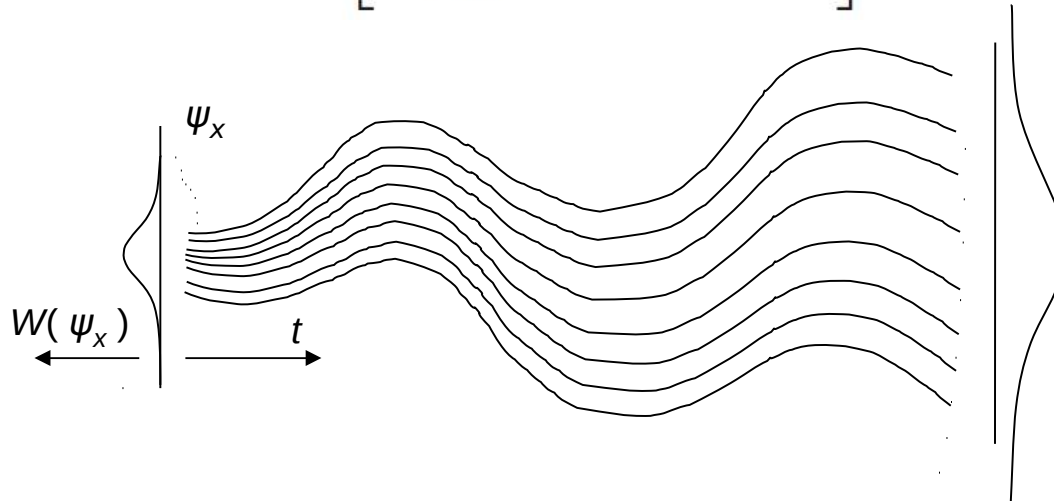
Final state:
Thermal equilibrium



Semiclassical simulations

Classical field equation for a nonrelativistic complex scalar field:

$$i\partial_t\psi(\mathbf{x}, t) = \left[-\frac{\partial_{\mathbf{x}}^2}{2m} + g|\psi(\mathbf{x}, t)|^2 \right] \psi(\mathbf{x}, t)$$



Radial occupation number:

$$n(\mathbf{k}) = \langle \Psi^*(\mathbf{k})\Psi(\mathbf{k}) \rangle \quad \begin{array}{l} + \text{ path average} \\ + \text{ angle average} \end{array}$$

e.g. P. B. Blakie et al.: Adv Phys. (2008)



Movie

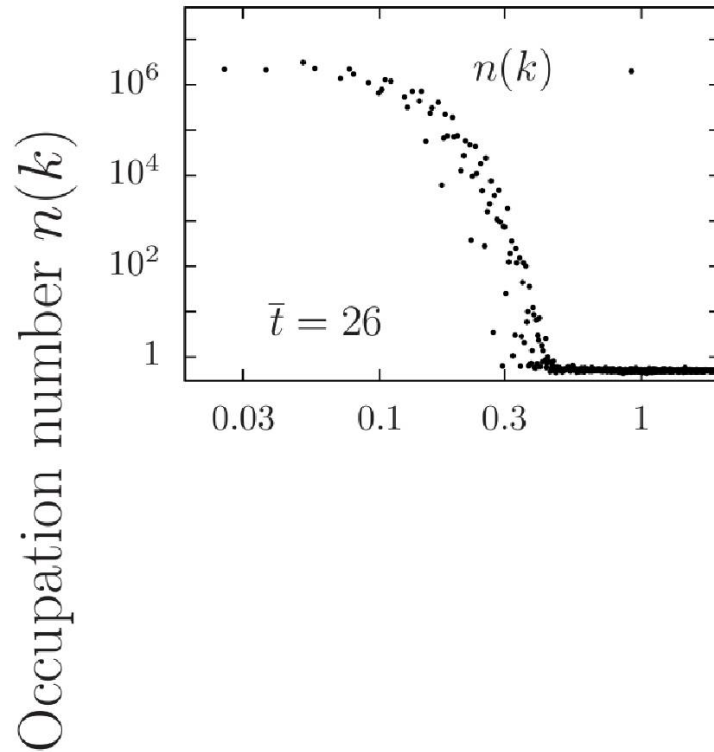
Vortex dynamics and spectrum in 2D (single run)

Radial occupation number:

$$n(\mathbf{k}) = \langle \Psi^*(\mathbf{k})\Psi(\mathbf{k}) \rangle \quad \begin{array}{l} (+ \text{ path average}) \\ + \text{ angle average} \end{array}$$



2D simulations

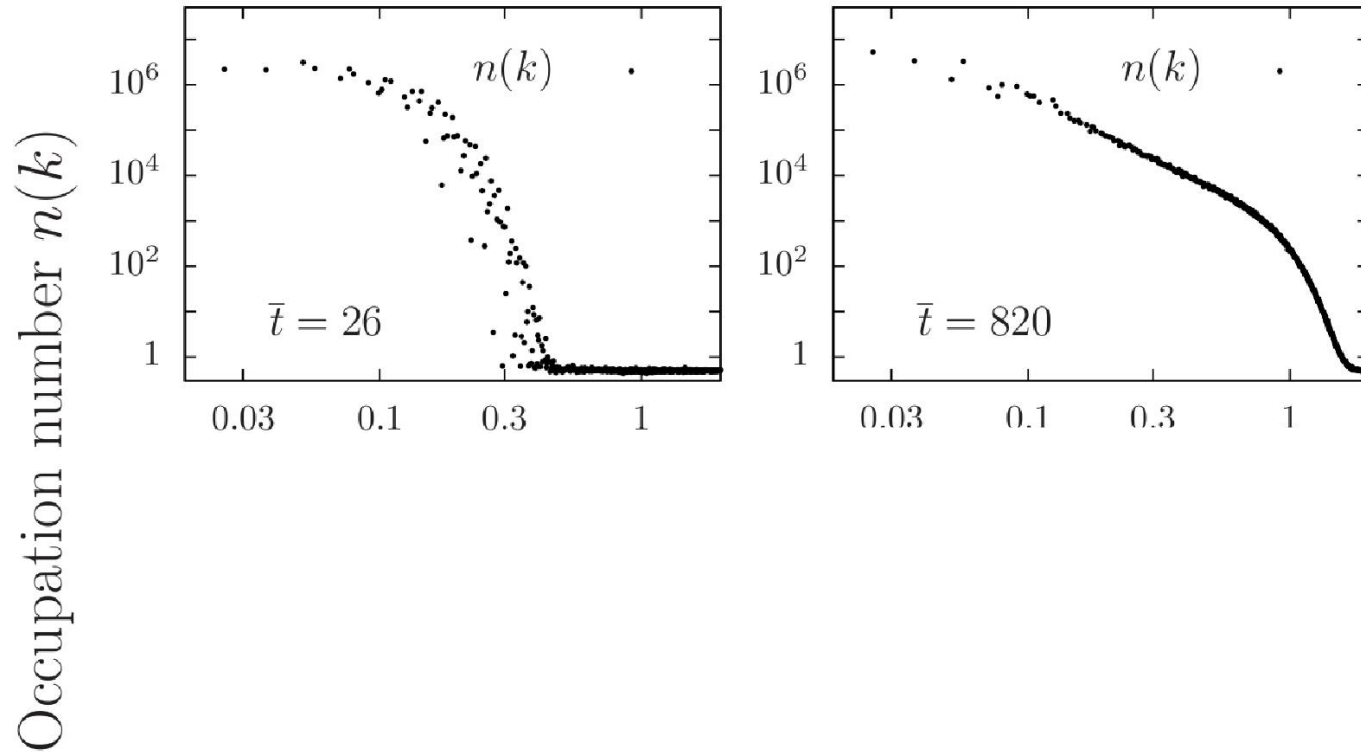


Radial momentum k

B. N., D. Sexty, T Gasenzer: Phys. Rev. B, Rapid Comm. (2011)



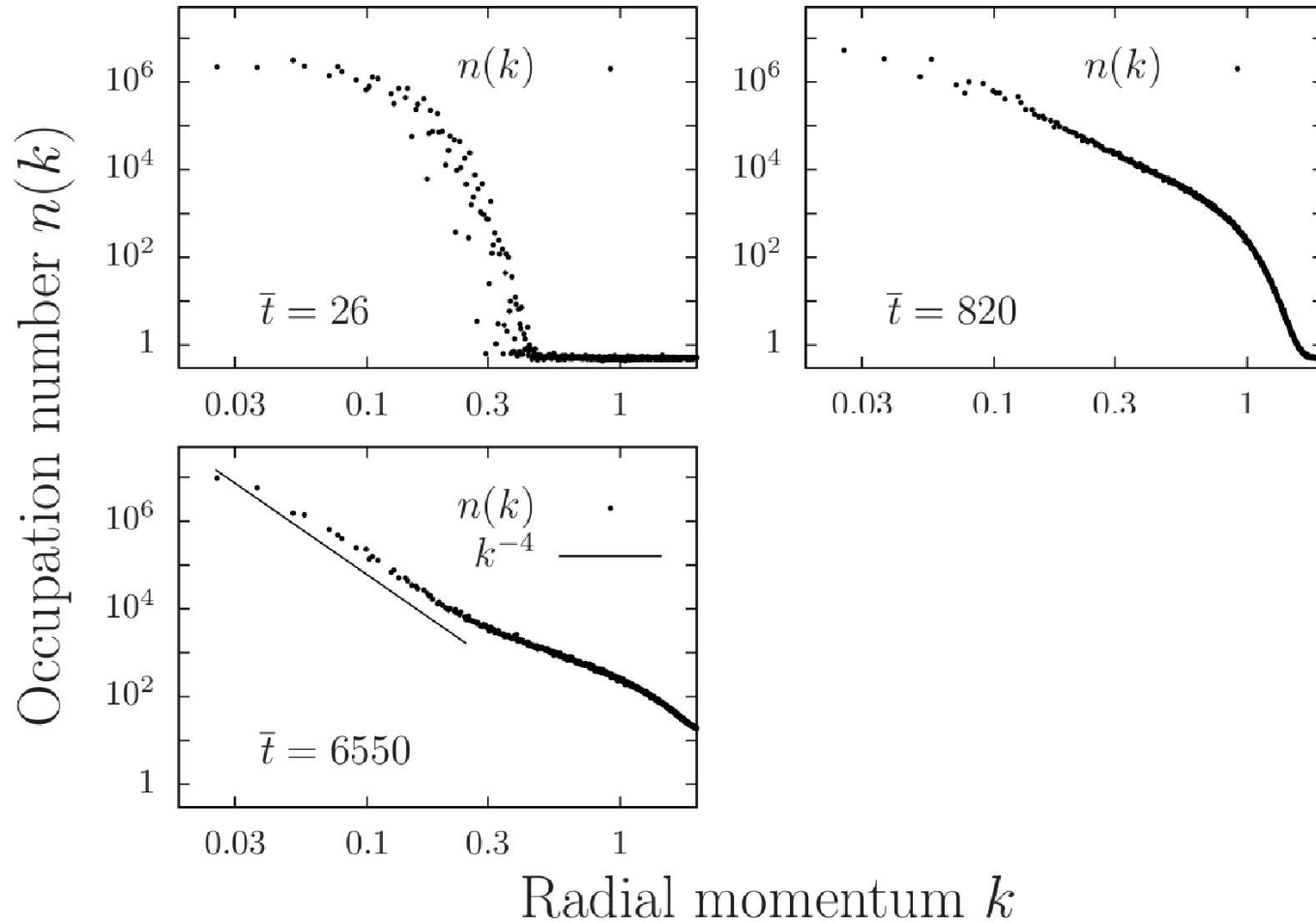
2D simulations



B. N., D. Sexty, T Gasenzer: Phys. Rev. B, Rapid Comm. (2011)



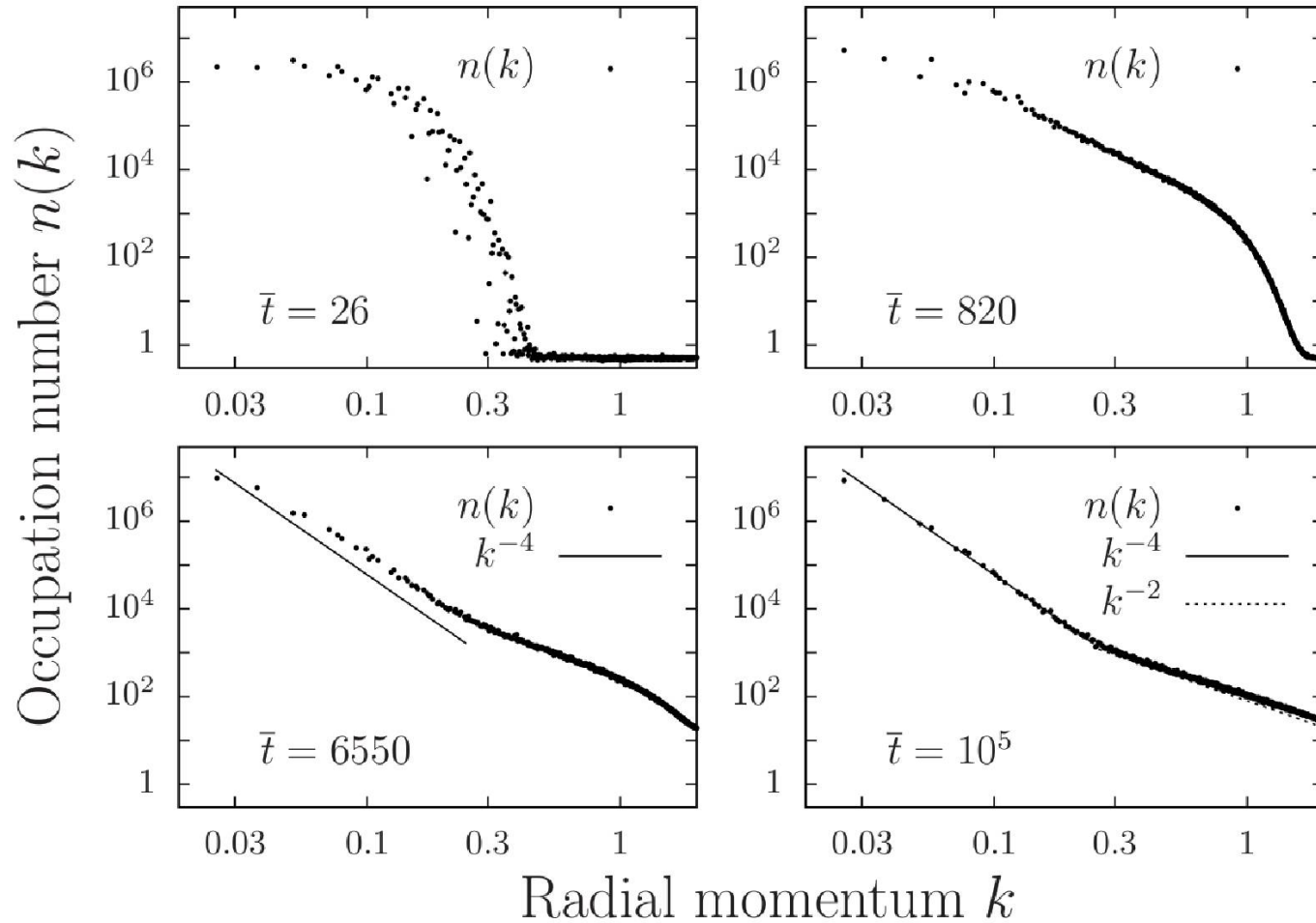
2D simulations



B. N., D. Sexty, T Gasenzer: Phys. Rev. B, Rapid Comm. (2011)



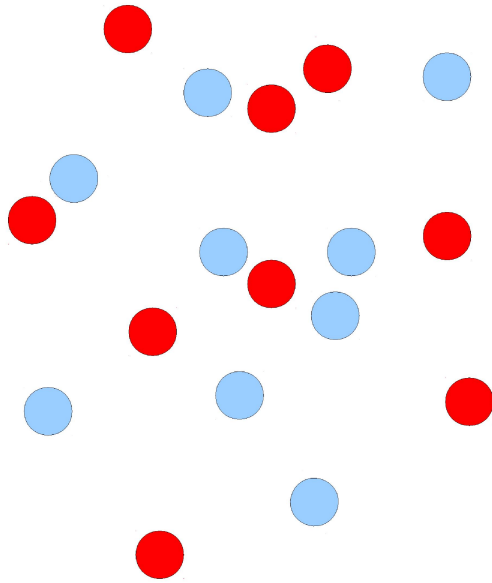
2D simulations



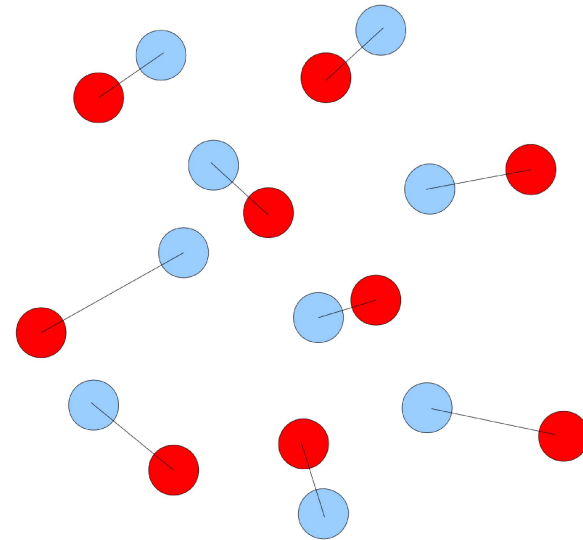
B. N., D. Sexty, T Gasenzer: Phys. Rev. B, Rapid Comm. (2011)



2D statistics of vortices



$$n_k \sim k^{-4}$$

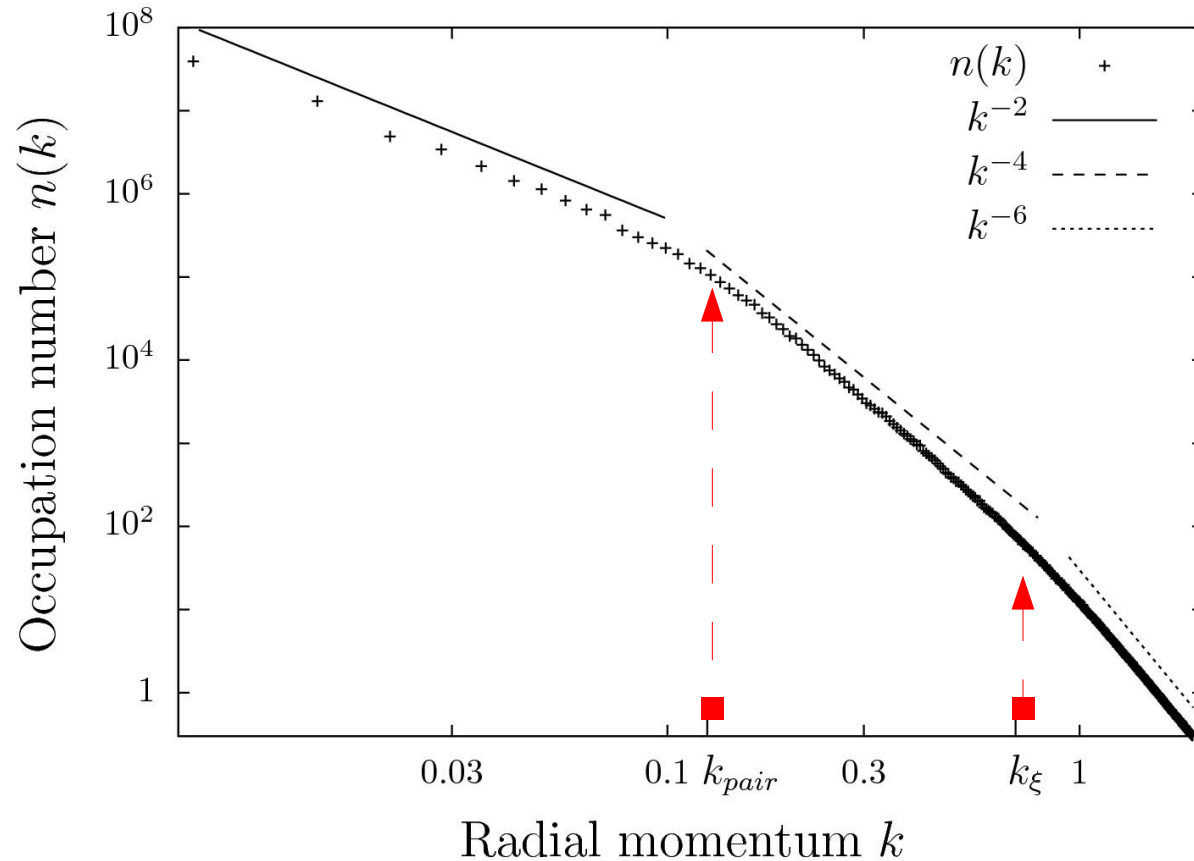


$$\begin{aligned} n_k &\sim k^{-2} & k < k_{\text{pair}} \\ n_k &\sim k^{-4} & k > k_{\text{pair}} \end{aligned}$$

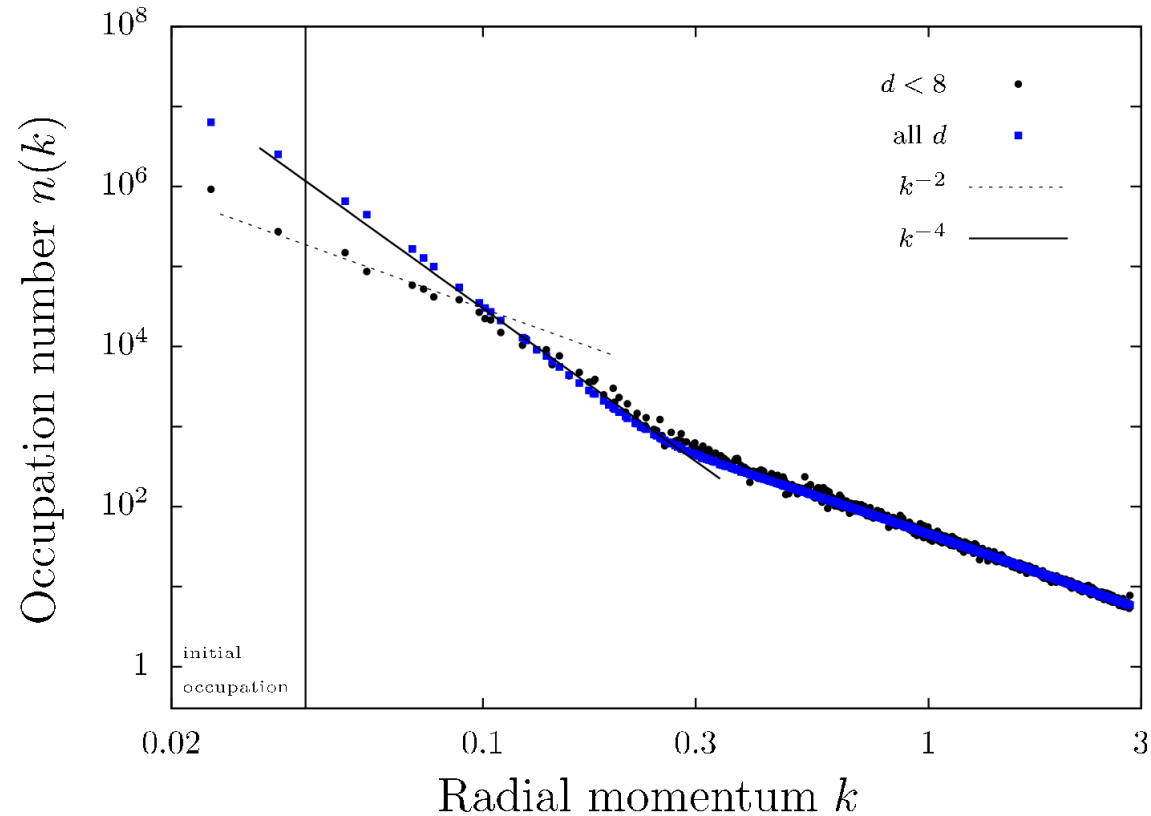
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Scaling transitions in 2D

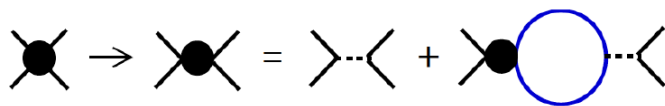
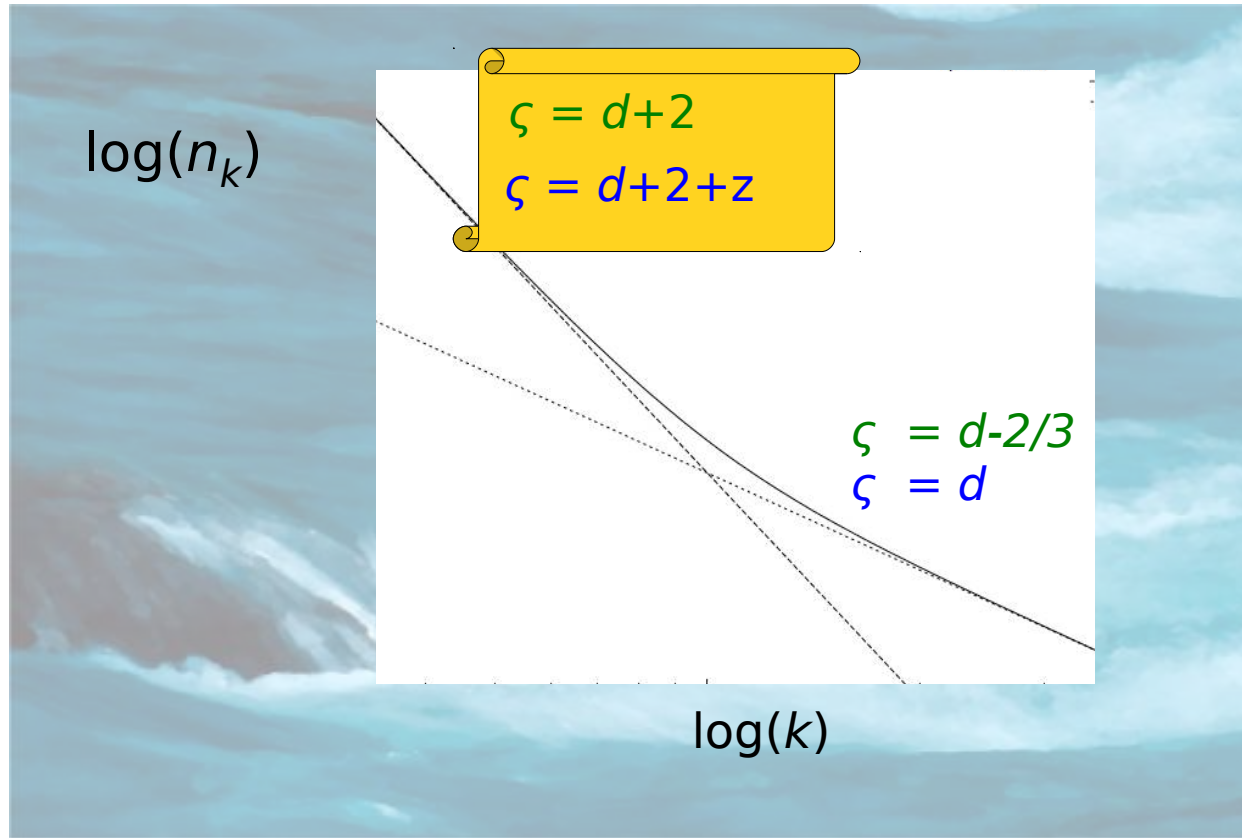


Pair-scaling in simulations



Nonthermal fixed points

$$n_k \sim k^{-\zeta}$$

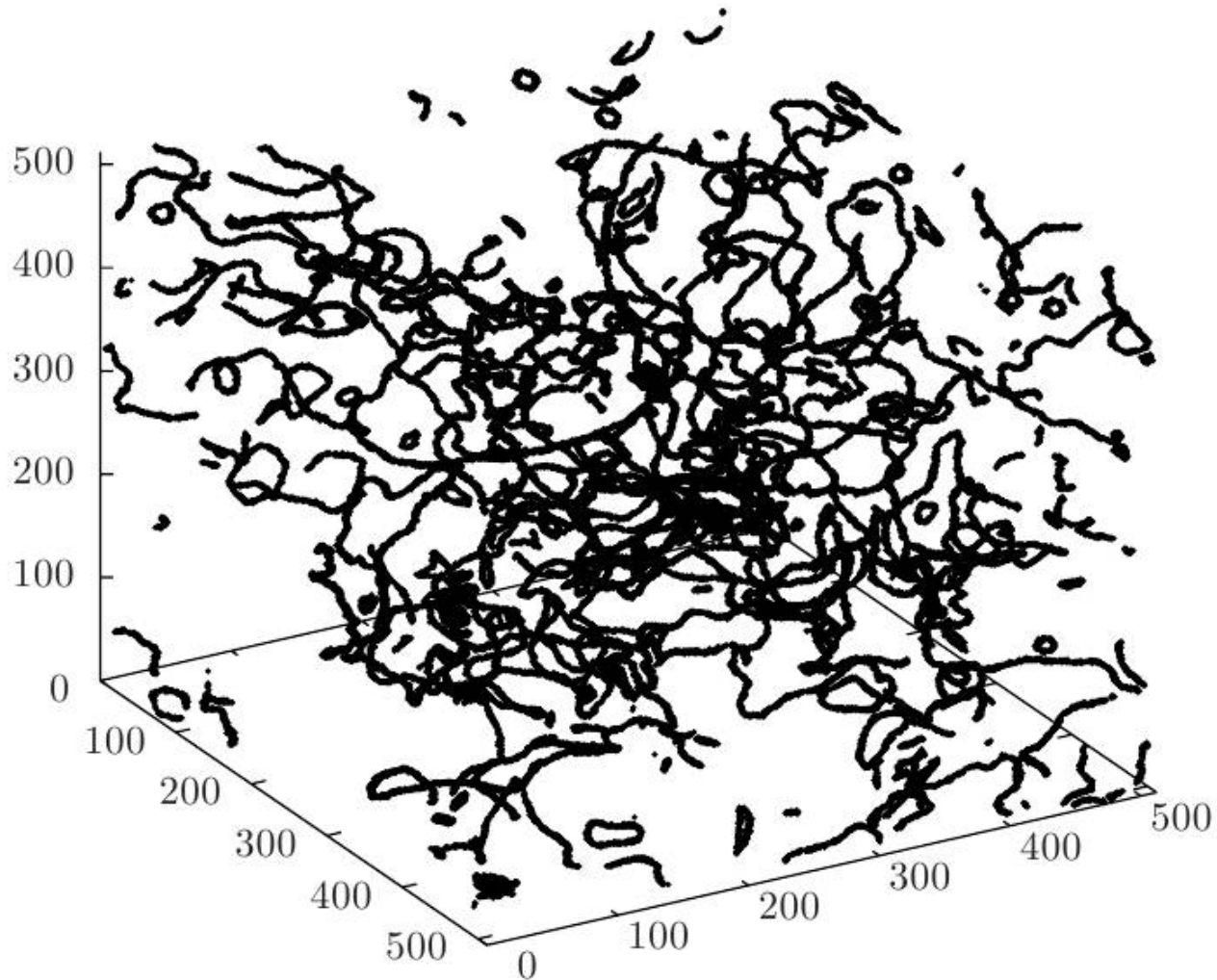


J. Berges, A. Rothkopf, J. Schmidt, PRL (2008)

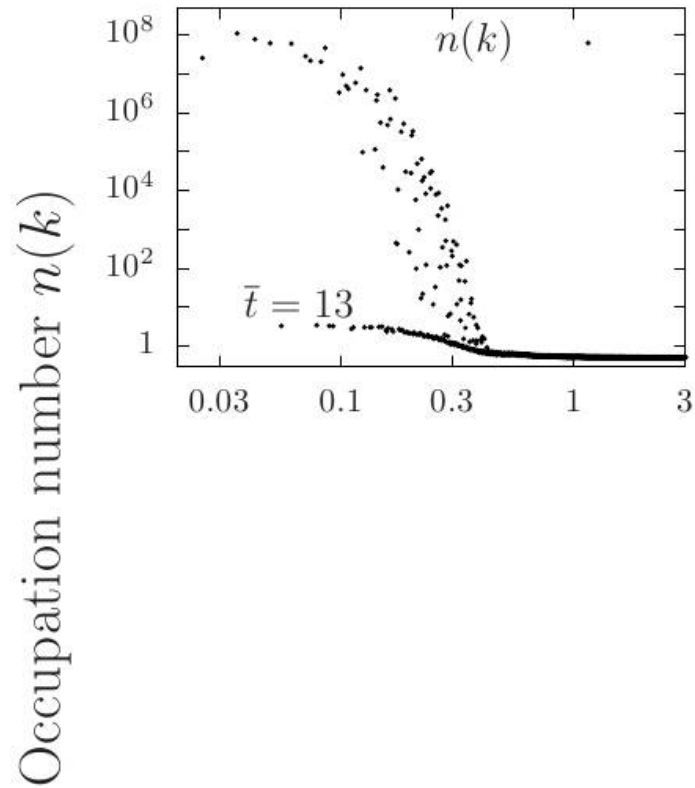
C. Scheppach, J. Berges, T. Gasenzer, PRA (2010)



3D simulations



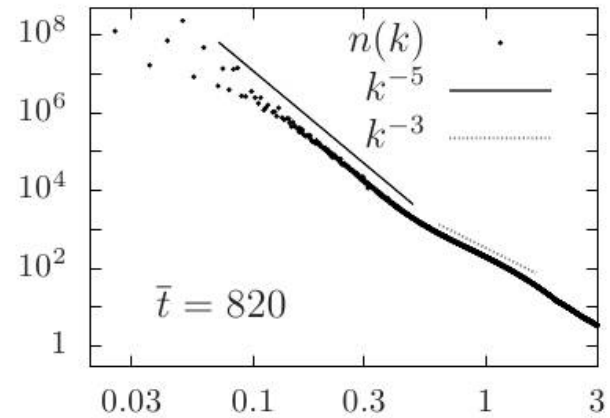
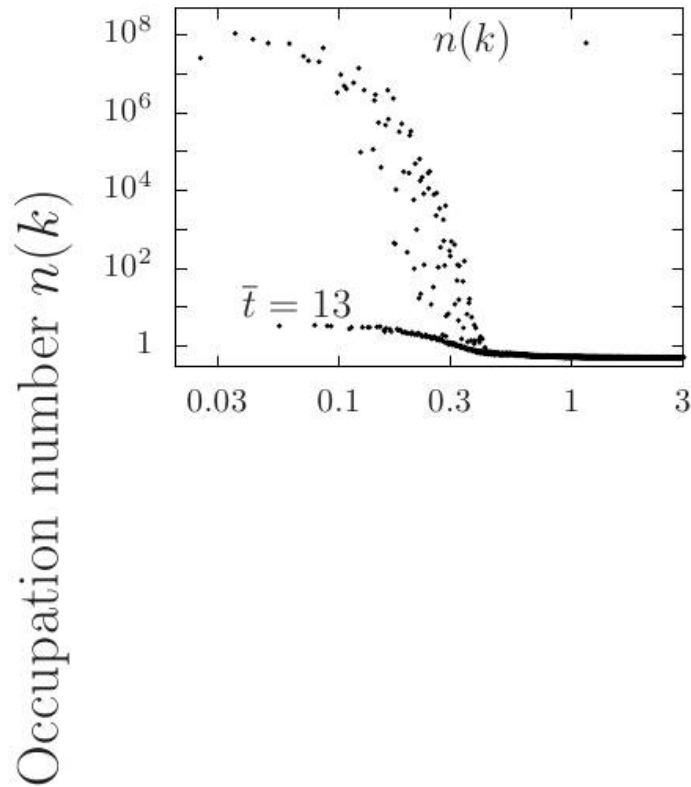
3D simulations



Radial momentum k



3D simulations

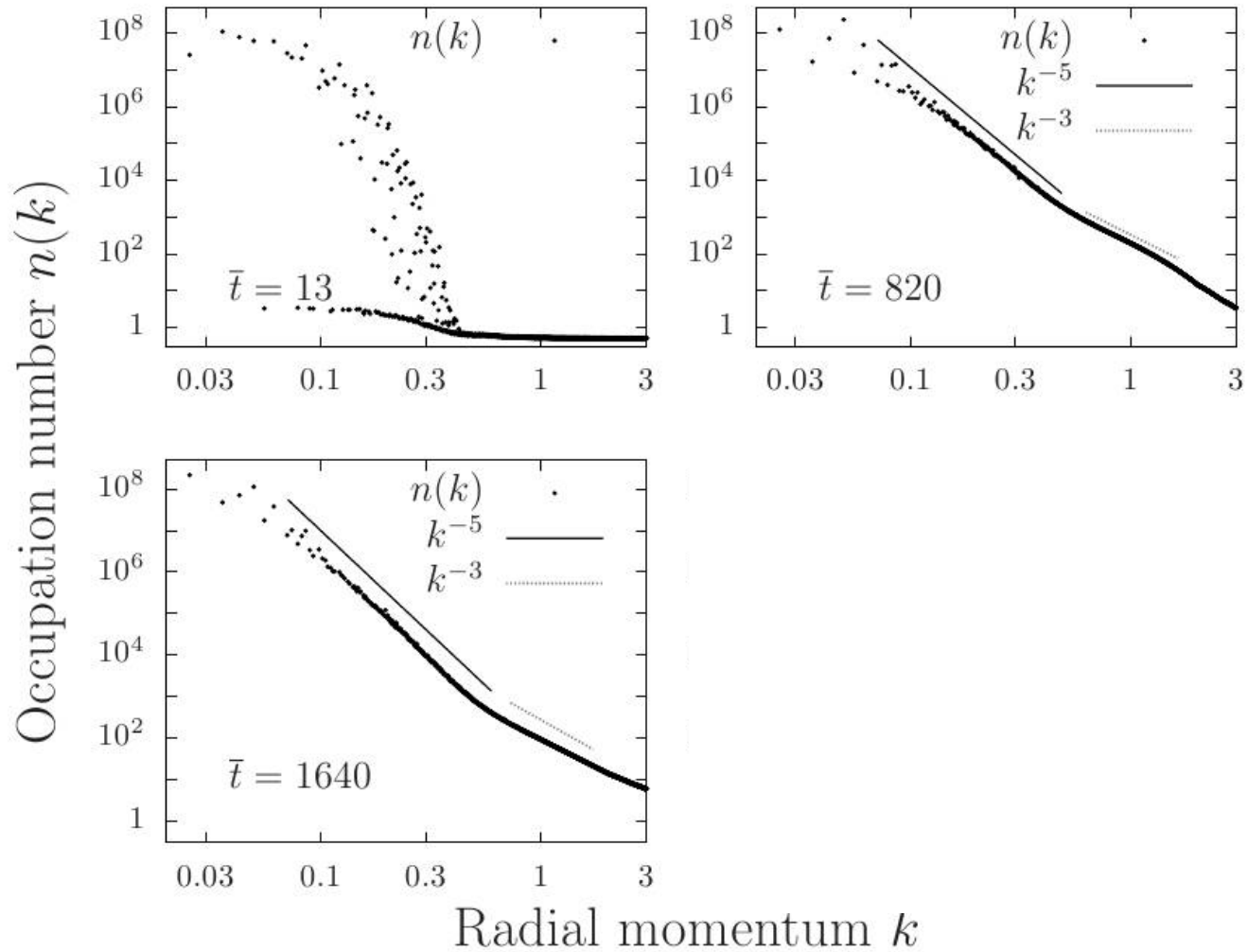


$$\zeta = d+2$$
$$\zeta = d$$

Radial momentum k



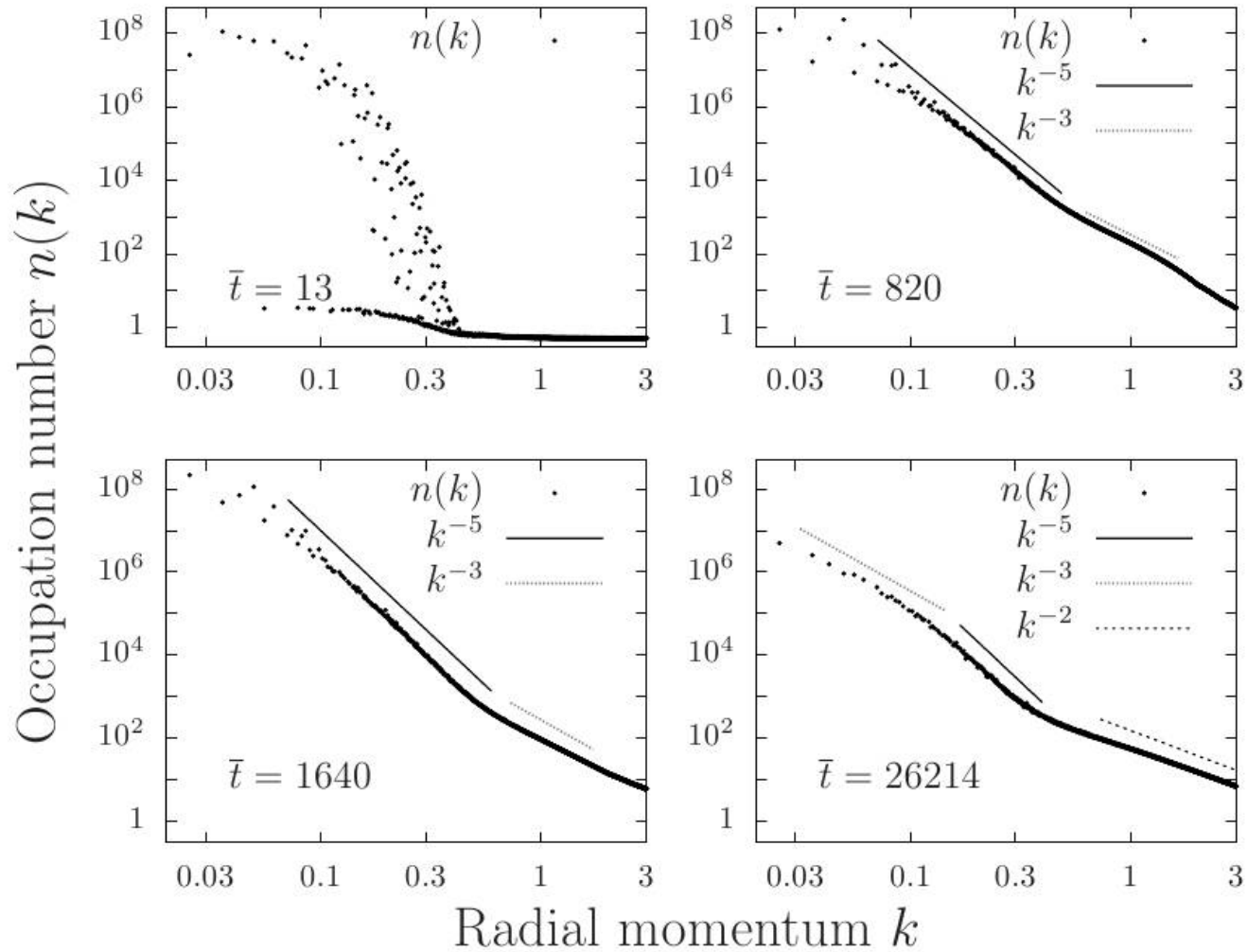
3D simulations



$$\zeta = d+2$$
$$\zeta = d$$



3D simulations



$$\zeta = d+2$$
$$\zeta = d$$



Pair-scaling in 3D

