Critical dynamics of non-equilibrium phase transitions

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CRC-TR 211 Strong-interaction matter under extreme conditions

Motivation

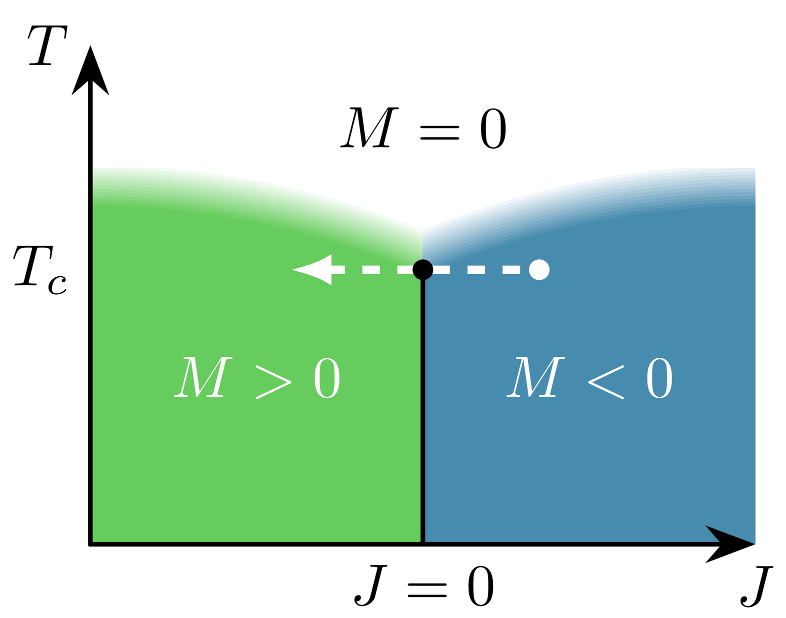
Heavy ion collisions: System undergoes **non-equilibrium trajectory** in QCD phase diagram

Near the critical point, the system is **guaranteed to fall out of equilibrium** due to the divergent relaxation time

→ Understanding of **dynamic critical behavior** in given universality class necessary

Model

Scalar ϕ^4 theory: $\mathscr{L}(\phi) = \frac{1}{2}(\partial^\mu\phi\, \partial_\mu\phi + \phi^2) - \frac{1}{4!}\phi^4 - J\phi$



$\mathbb{Z}_2$ **symmetry;** broken for $J \neq 0$

Langevin Dynamics: Coupling to heat bath of temperature T

Quench linearly through CP

$T(t) = T_c,\ J(t) = -r_J t$

Observables: Order Parameter $M = \frac{1}{V}\sum_x \phi_x$

Susceptibility $\chi = \frac{V}{T}(\langle M^2\rangle - \langle M\rangle^2)$, Skewness, Kurtosis

Kibble-Zurek Mechanism [1,2,3] & Scaling [4]

System falls out of equilibrium when rate of change in relaxation time is greater than relaxation rate

$$\dot{\xi}_t/\xi_t \gtrsim 1/\xi_t \quad \rightarrow \quad \dot{\xi}_t(t = t_{KZ}) = 1$$

At t_{KZ}, **correlations freeze** until equilibrium is reached again

Kibble-Zurek time and field in given quench protocol:

$$t_{KZ} \sim r_J^{-\nu_c z/(1+\nu_c z)} \qquad J_{KZ} \equiv J(t_{KZ}) \sim r_J^{1/(1+\nu_c z)}$$

Leads to **scaling Ansatz** of observables for behavior under scale transformation $l \rightarrow l/s$:

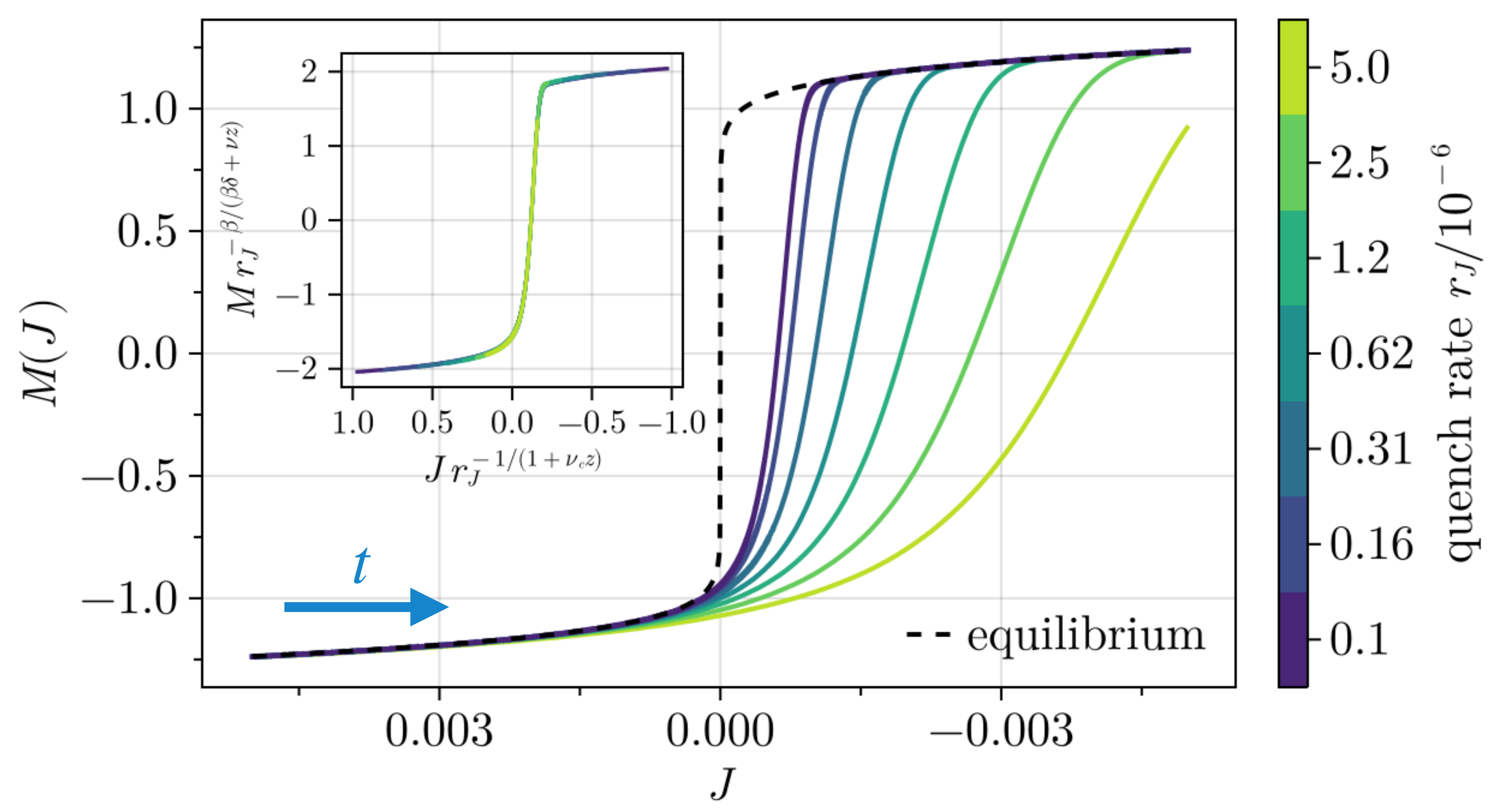
$$\kappa_n(J, r_J) \propto r_J^{(n-1-1/\delta)/(1+\nu_c z)} f_{\kappa_n}(J(t)/J_{KZ})$$

References

[1] T. W. B. Kibble, J. Phys. A 9 (1976) 1387–1398.
[2] W. H. Zurek, Nature 317 (1985) 505–508.
[3] W. H. Zurek, Phys. Rept. 276 (1996) 177–221.
[4] A. Chandran et al., Phys. Rev. B 86 (6) (2012) 064304.

Lattice Results for non-eq. scaling functions

Real time observables show good collapse on scaling functions ($d = 2, L = 766$)



Higher Cumulants