Nonequilibrium tricritical behaviour in anisotropic XY ferromagnet

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Acknowledgements

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Brief review

(A) T. Yasui, H. Tutu, M. Yamamoto, and H. Fujisaka, *Dynamic phase transitions in the anisotropic XY spin system in an oscillating magnetic field,* **Phys. Rev. E 66 (2002) 036123.**

(B) Tharnier O. Puel, Stefano Chesi, Stefan Kirchner, and Pedro Ribeiro, *Nonequilibrium phases and phase transitions of the XY model,* **Phys. Rev. B 103 (2021) 035108**

(C) Mainak Pal, William D. Baez, Pushan Majumdar, Arnab Sen, and Trinanjan Datta, *Dynamical phase transitions in XY model: a Monte Carlo and mean-field theory study*, **arxiv:2402.07505**

(D) M. Acharyya, *Multiple dynamic phase transitions in anisotropic Heisenberg ferromagnet driven by polarised magnetic field*, **Phys. Rev. E 69 (2004) 027105**

(E) M. Acharyya, *Driven spin wave modes in XY ferromagnet: Nonequilibrium Phase Transition*, **Phase Transitions 91 (2018) 793**

Driven Anisotropic XY model

$$H = -J\sum\left[\left(1+\Omega\right)S_i^x S_j^x+\left(1-\Omega\right)S_i^y S_j^y\right]-\sum\vec{h}\left(x,y,z,t\right)\cdot\vec{S}_i$$

Bilinear exchange anisotropy (Ω)

$$H = -J\sum\left[S_i^x S_j^x+S_i^y S_j^y\right]-D\sum\left[\left(S_i^x\right)^2-\left(S_i^y\right)^2\right]-\sum\vec{h}\left(x,y,z,t\right)\cdot\vec{S}_i$$

Single site anisotropy (D)

$$\vec{h}\left(x,y,z,t\right) = h_{0x}\cos\left(kz-\omega t\right)\hat{x}+h_{0y}\sin\left(kz-\omega t\right)\hat{y}$$

Elliptically polarized propagating magnetic field wave

$$k=\frac{2\pi}{\lambda} \qquad \omega = 2\pi f$$

Monte Carlo Simulation

Random updating

Metropolis single spin flip

$$P\left(\vec{S}_{old} \rightarrow \vec{S}_{new}\right) = Min\left[1, \exp\left(-\delta E / KT\right)\right]$$

Quantities calculated

Instantaneous magnetisation

$$m_x(t)=\frac{1}{L^3}\sum S_i^x \qquad m_y(t)=\frac{1}{L^3}\sum S_i^y$$

$$\vec{m}=im_x+jm_y$$

Time averaged magnetisation on a full cycle of propagating field wave

$$Q_x=\frac{\omega}{2\pi}\int m_x(t)\,dt \qquad Q_y=\frac{\omega}{2\pi}\int m_y(t)\,dt$$

$$\vec{Q}=iQ_x+jQ_y$$

Order parameter

$$\langle\vec{Q}\rangle=i\langle Q_x\rangle+j\langle Q_y\rangle$$

Dynamic energy density

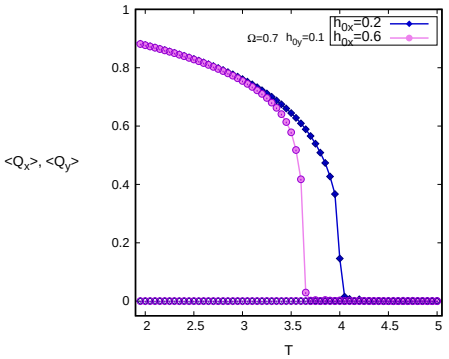
$$E=\frac{\omega}{2\pi L^3}\int H(t)\,dt$$

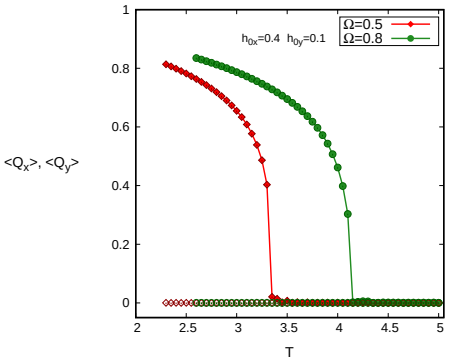
Variance of order parameter

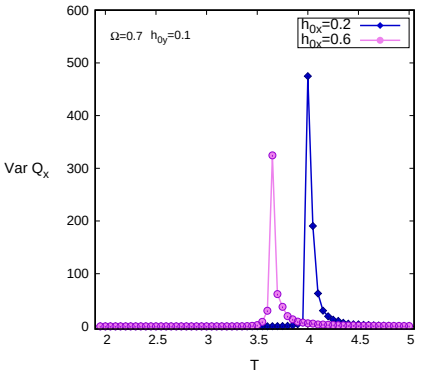
$$Var(Q_x)=\langle Q_x^2\rangle-\langle Q_x\rangle^2 \qquad Var(Q_y)=\langle Q_y^2\rangle-\langle Q_y\rangle^2$$

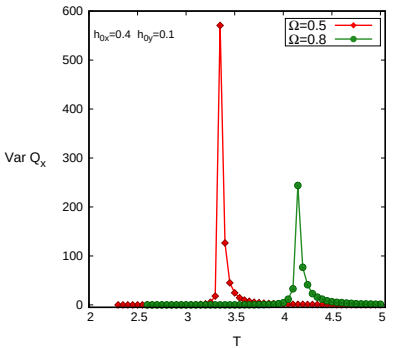
Binder cumulant → $$U_L = 1-\frac{\langle Q_x^4\rangle}{3\langle Q_x^2\rangle^2}$$

Continuous transition (Ω anisotropy)









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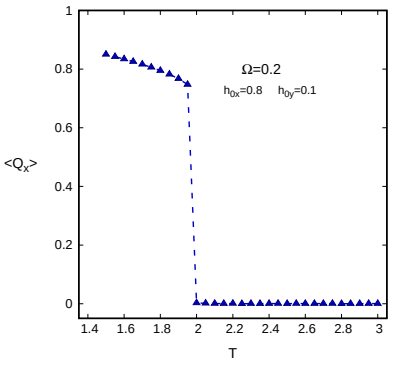
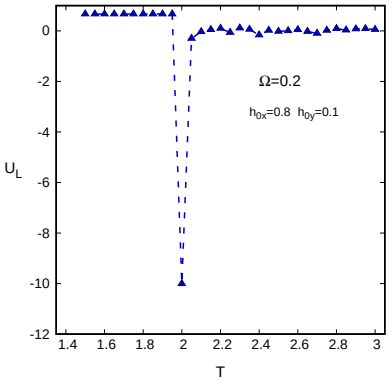
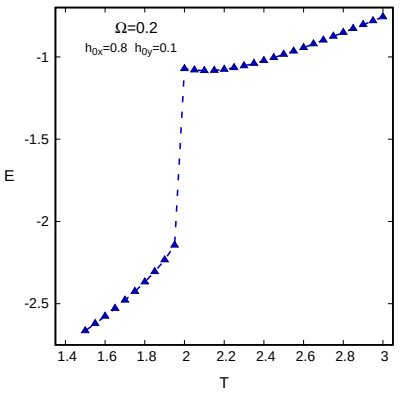
Discontinuous transition (Ω anisotropy)







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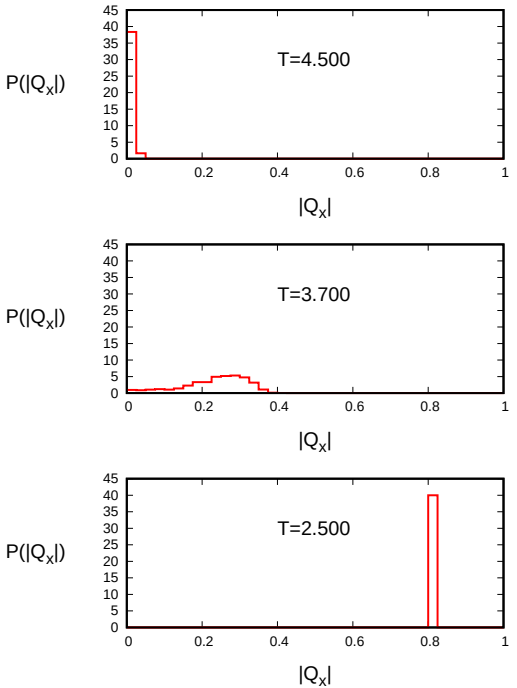
Distribution of order parameter across the transition temperature(Ω anisotropy)

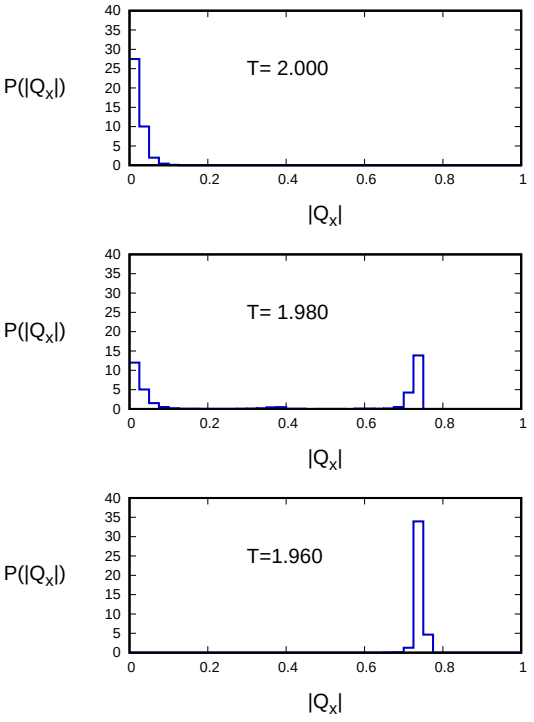


$p = 3.0, \quad r = 0.25$

$h_{ox}=0.3 \ , \ h_{oy}=0.1 \ , \ \Omega=0.6$

Continuous transition

Distribution of order parameter across the transition temperature (Ω anisotropy)



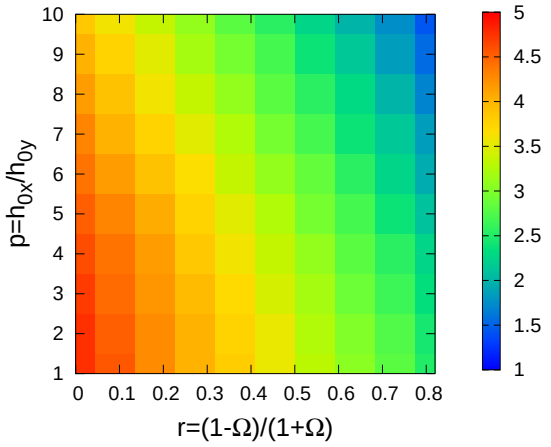
$p = 8.0, \quad r = 0.67$

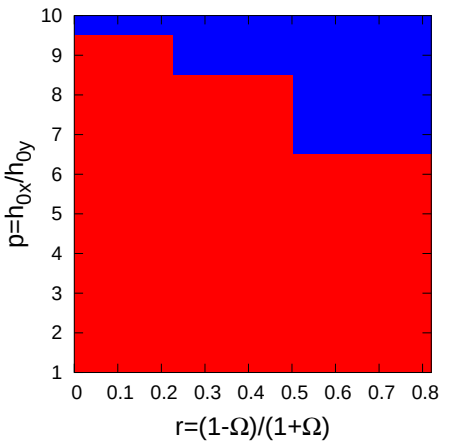
$\Omega = 0.2, \quad h_{ox} = 0.8 \quad , h_{oy} = 0.1$

Discontinuous transition

Phase diagram

(Bilinear exchange anisotropy(Ω))





(a) The image plot of transition temperature (phase diagram) in p-r plane. The transition temperature is obtained from the position of maximum of Var(Qx).

(b) The natures(continuous/discontinuous) of transition marked by different color. We use following color code: first order(blue) and second order(red).

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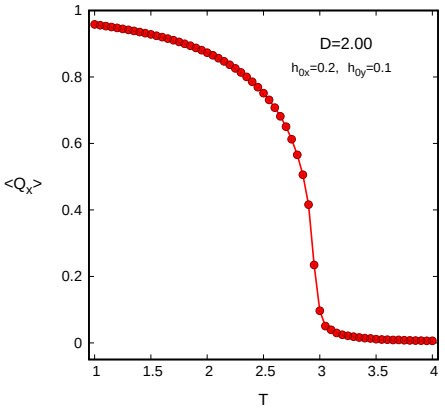
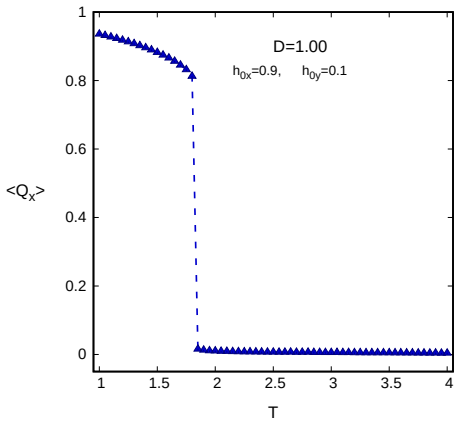
Continuous and discontinuous transition (Single site anisotropy(D))





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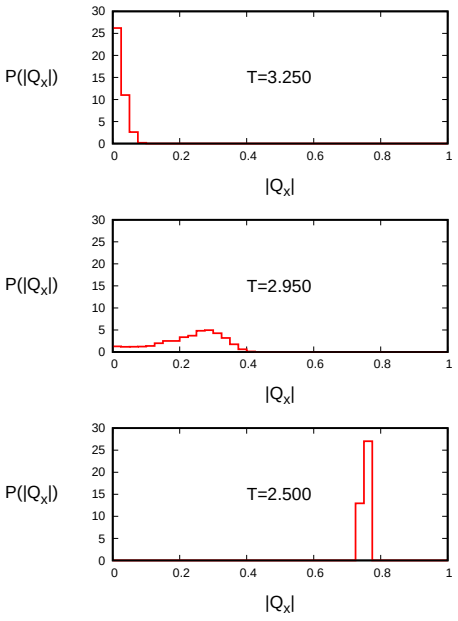
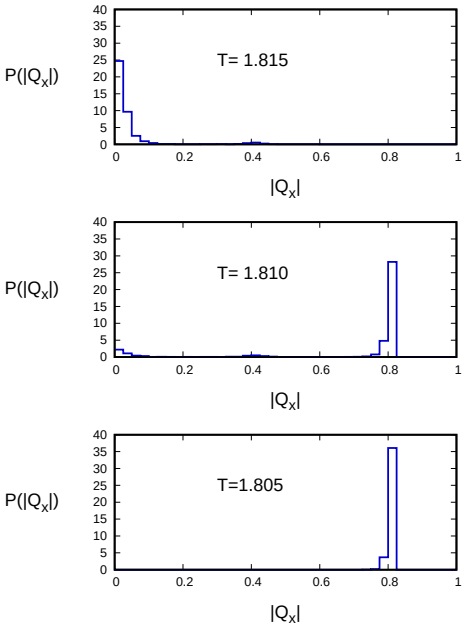
Distribution of order parameter across the transition temperature (D anisotropy)



$D=2.0 \quad h_{ox}=0.2 \quad h_{oy}=0.1$

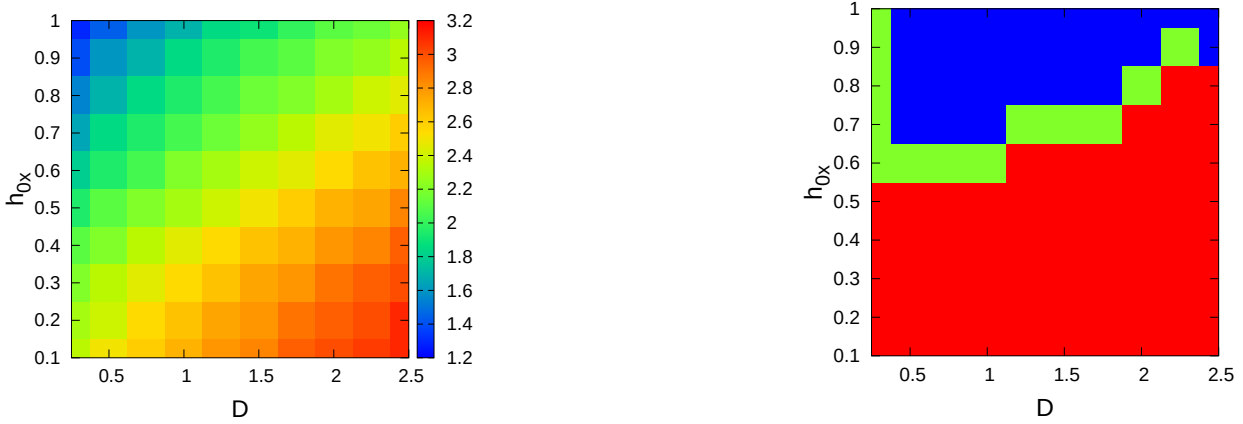
Continuous transition



$D=1.0 \quad h_{ox}=0.9 \quad h_{oy}=0.1$

Discontinuous transition

Phase diagram
(Single site anisotropy (D))



(a) The image plot of transition temperature (phase diagram) in h-D plane. The transition temperature is obtained from the position of maximum of Var(Qx).
(b) The natures(continuous/discontinuous) of transition marked by different color. We use following color code: first order(blue) and second order(red).

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Concluding remarks

Anisotropic XY ferromagnet, driven by elliptically polarized magnetic field wave, shows the nonequilibrium tricritical behaviour.

Thank you