The XXVI International Scientific Conference of Young Scientists and Specialists (AYSS-2022)

LONG AND SHORT-RANGE INTERACTIONS, PHASE TRANSITIONS AND CROSSOVERS OF DIPOLAR SPIN ICE ON CAIRO LATTICE

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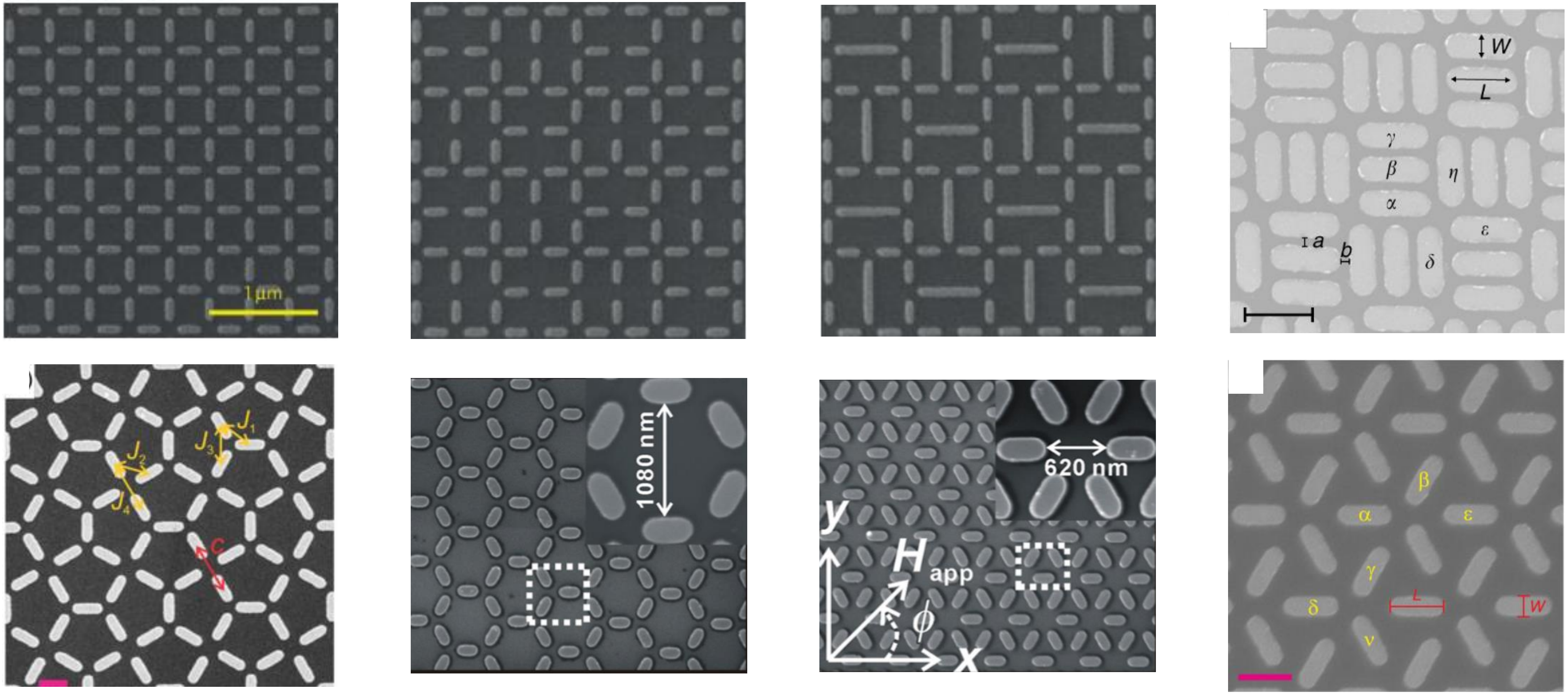
2022



[1] Thermally induced magnetic relaxation in building blocks of artificial kagome spin ice / A. Farhan [et al.] // Physical Review B. (2014) - V. 89, no. 21. - P. 214405
[2] Makarova K. et al. Low-energy states, ground states, and variable frustrations of the finite-size dipolar Cairo lattices //Physical Review E. – 2021. – T. 103. – №. 4. – C. 042129.
[2] Emergent ice rule and magnetic charge screening from vertex frustration in artificial spin ice / I. Gilbert [et al.] // Nature Physics. (2014) - V. 10, no. 9. - P. 670–675
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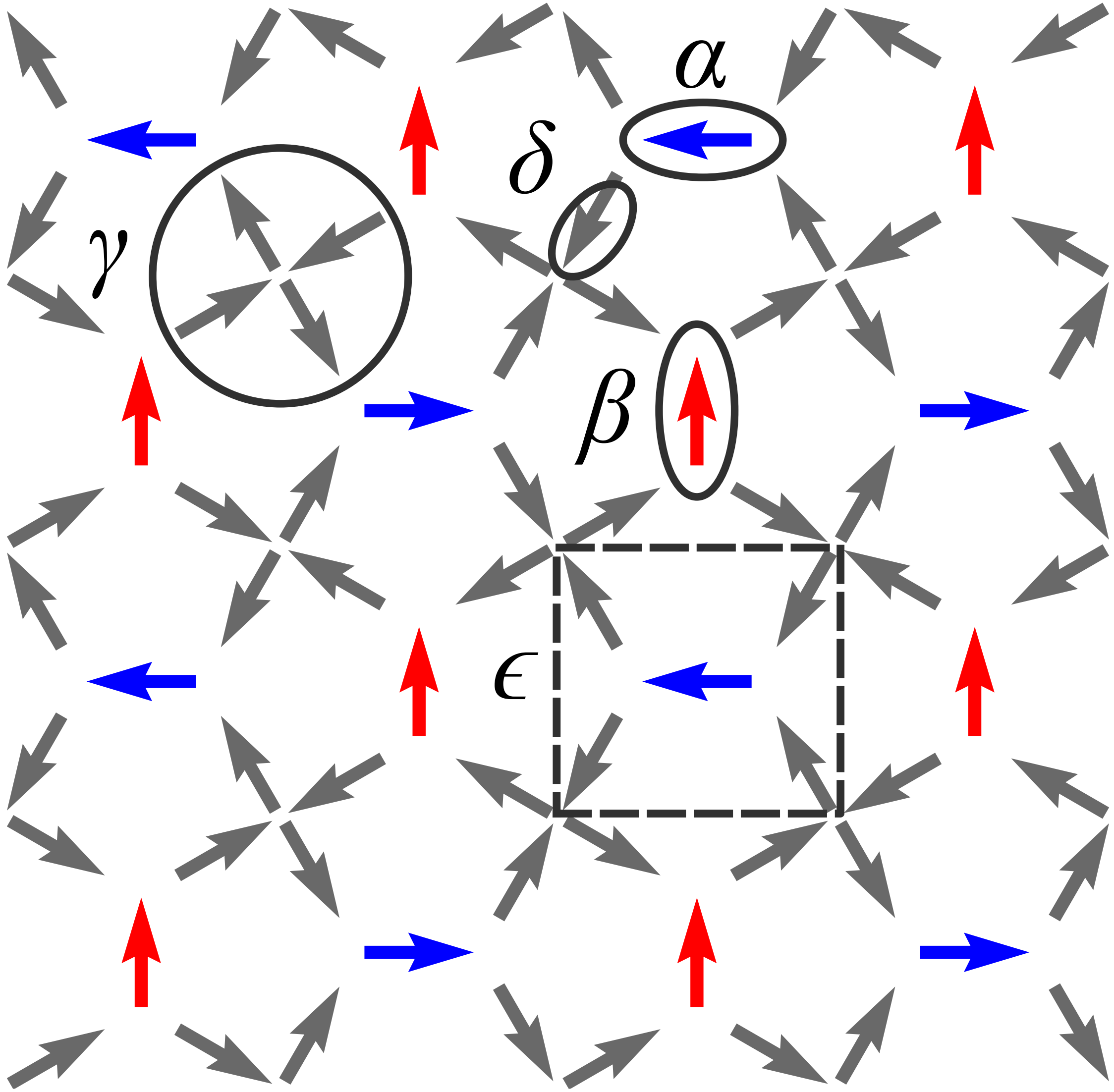


Hamiltonian:

$$H = \sum_{<i,j>} s_i \times s_j \times E_{dip}^{ij} + \sum_i (\vec{m}_i \vec{H}),$$

where $s_{ij} = \pm 1$

energy:

$$E_{dip}^{ij} = \frac{\vec{m}_i \vec{m}_j}{|\vec{r}_{ij}|^3} - 3\frac{(\vec{m}_i \vec{r}_{ij})(\vec{m}_j \vec{r}_{ij})}{|\vec{r}_{ij}|^5},$$

$\vec{r}_{ij}$ - radius-vector between i and j dipoles.

Heat capacity

$$C(T) = \frac{dU}{dT} = \frac{< E^2 > - < E^2 >}{k_B\, T^2 \cdot N}.$$

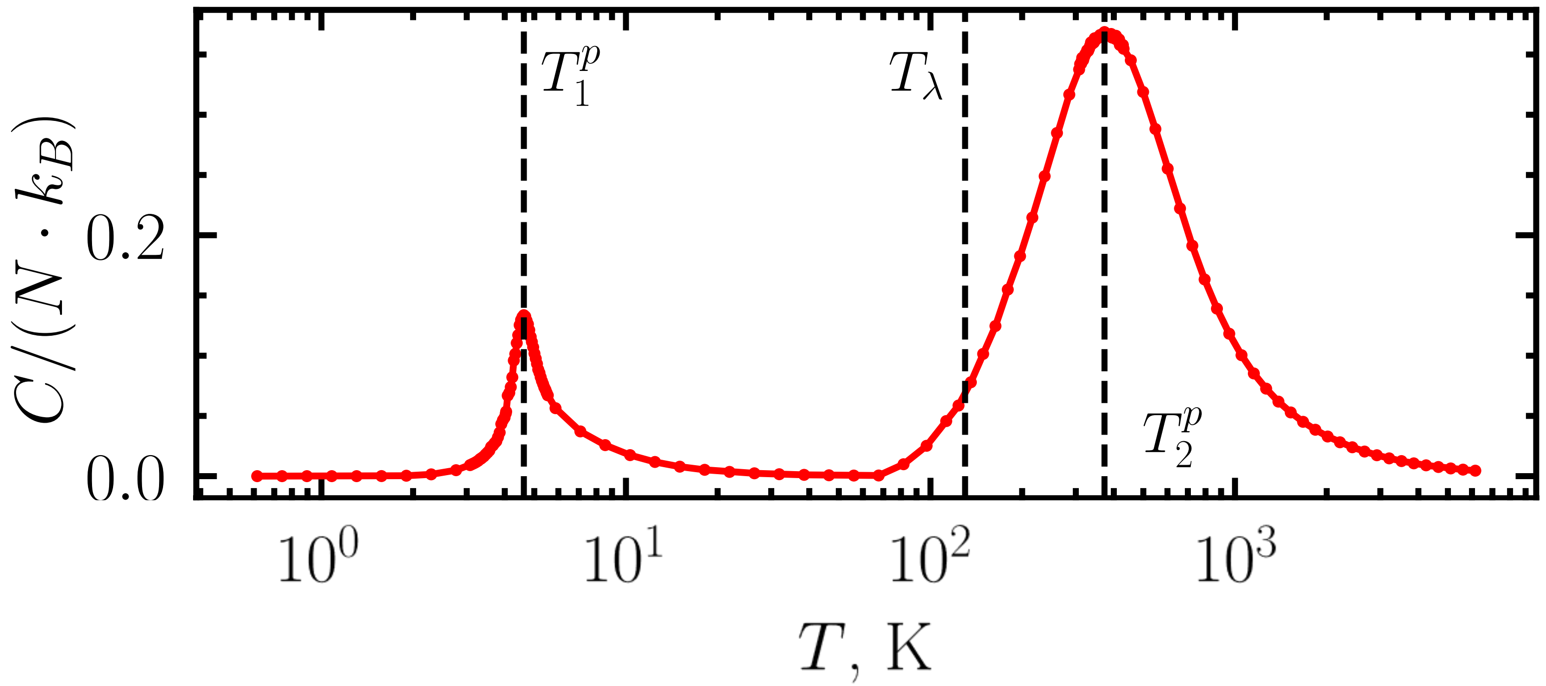
Magnetic susceptibility

$$< \chi_x > = \frac{< {m_x}^2 > - < m_x >^2}{k_B\, T \cdot N}$$

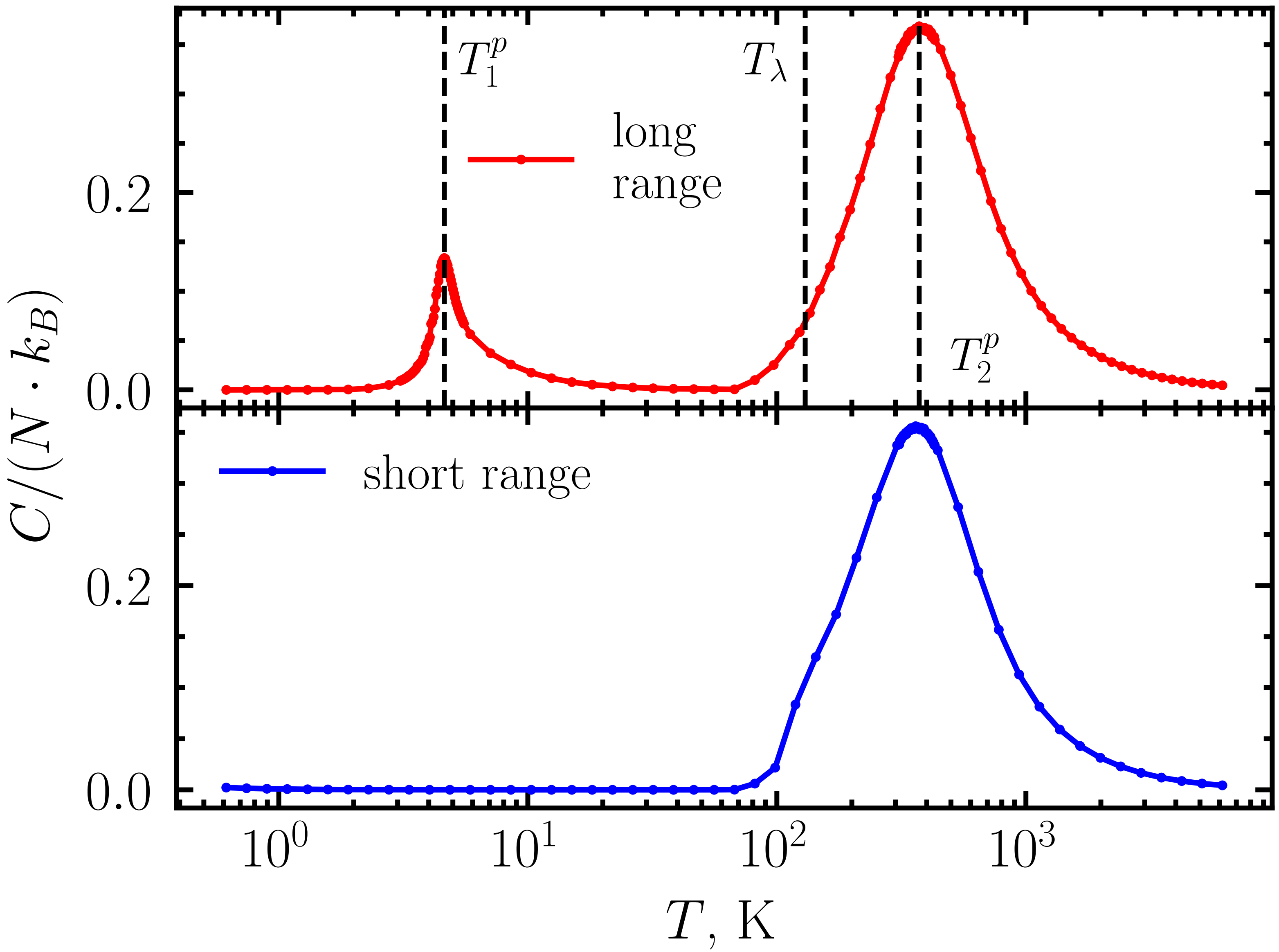
$$< \chi_y > = \frac{< {m_y}^2 > - < m_y >^2}{k_B\, T \cdot N}$$

<> - Average of Gibbs distribution

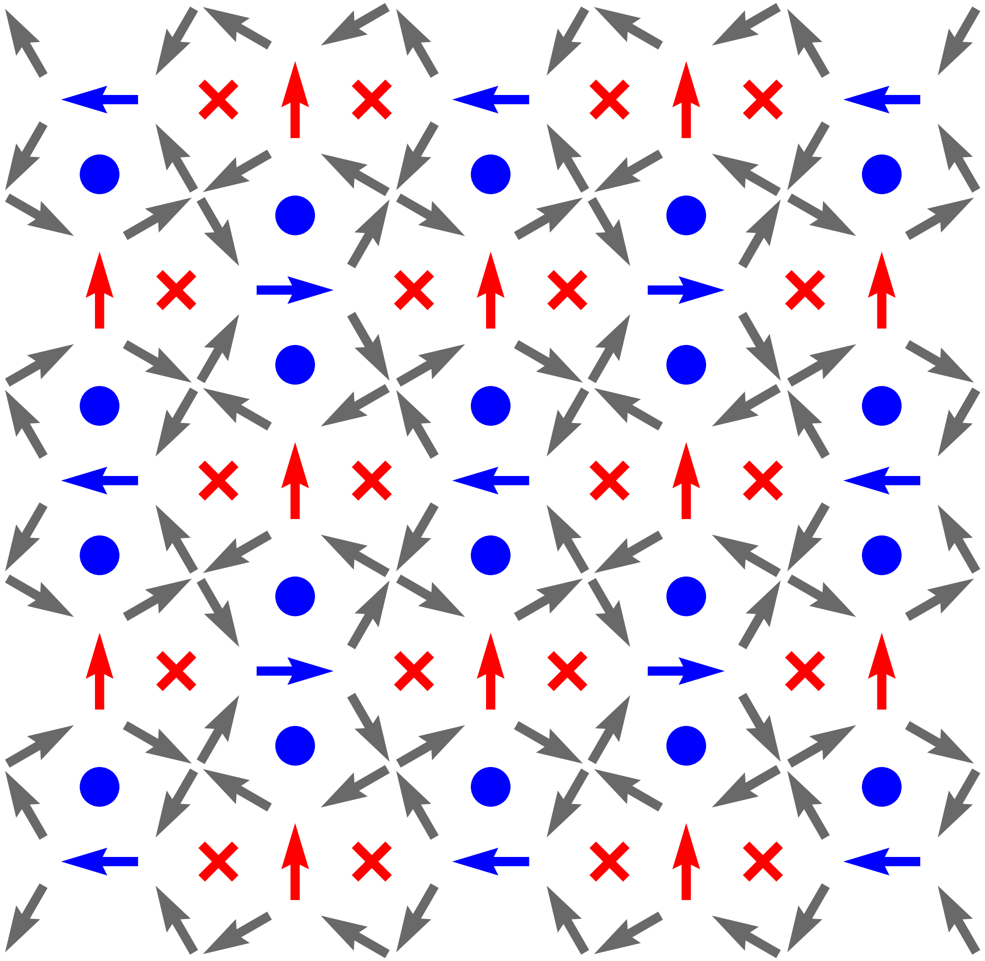
Heat capacity, N=5120, PBC



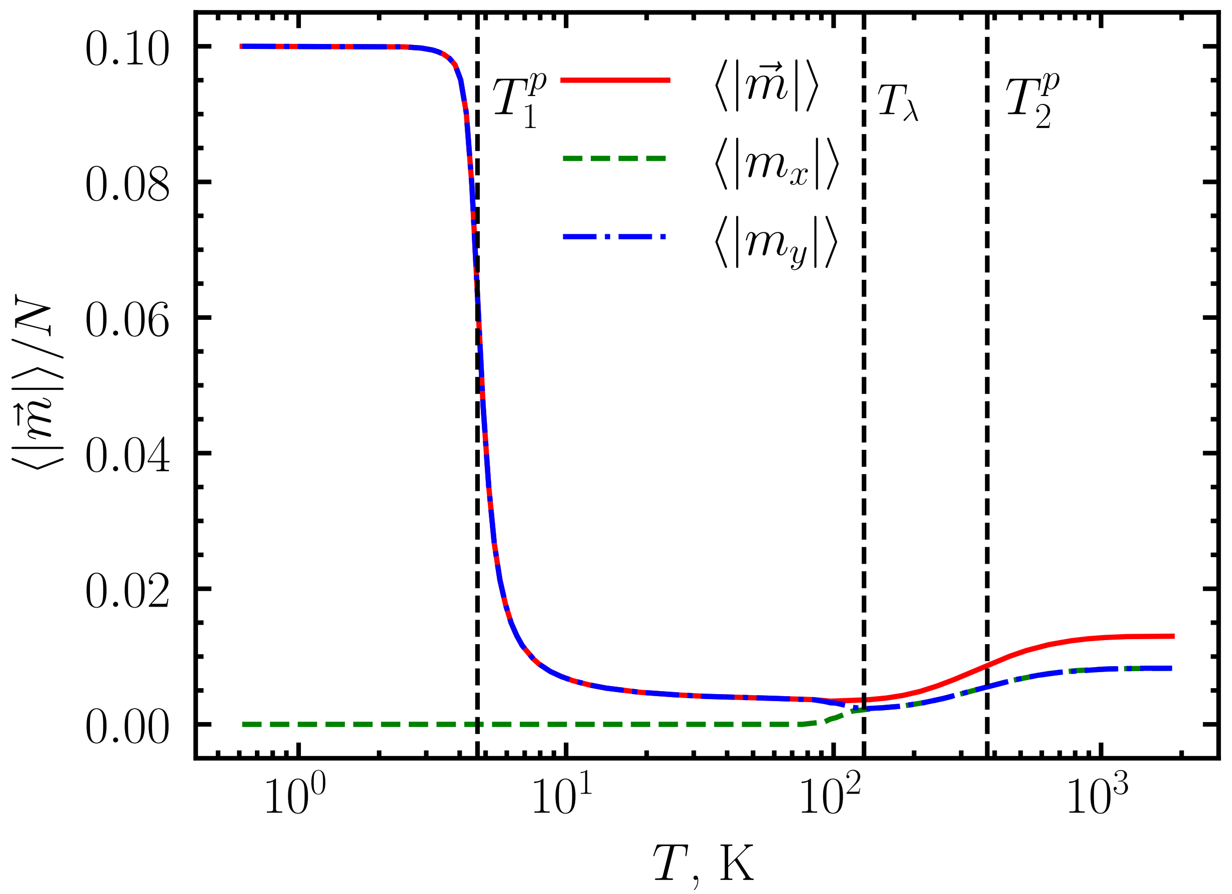
Heat capacity, ***N***=5120, PBC

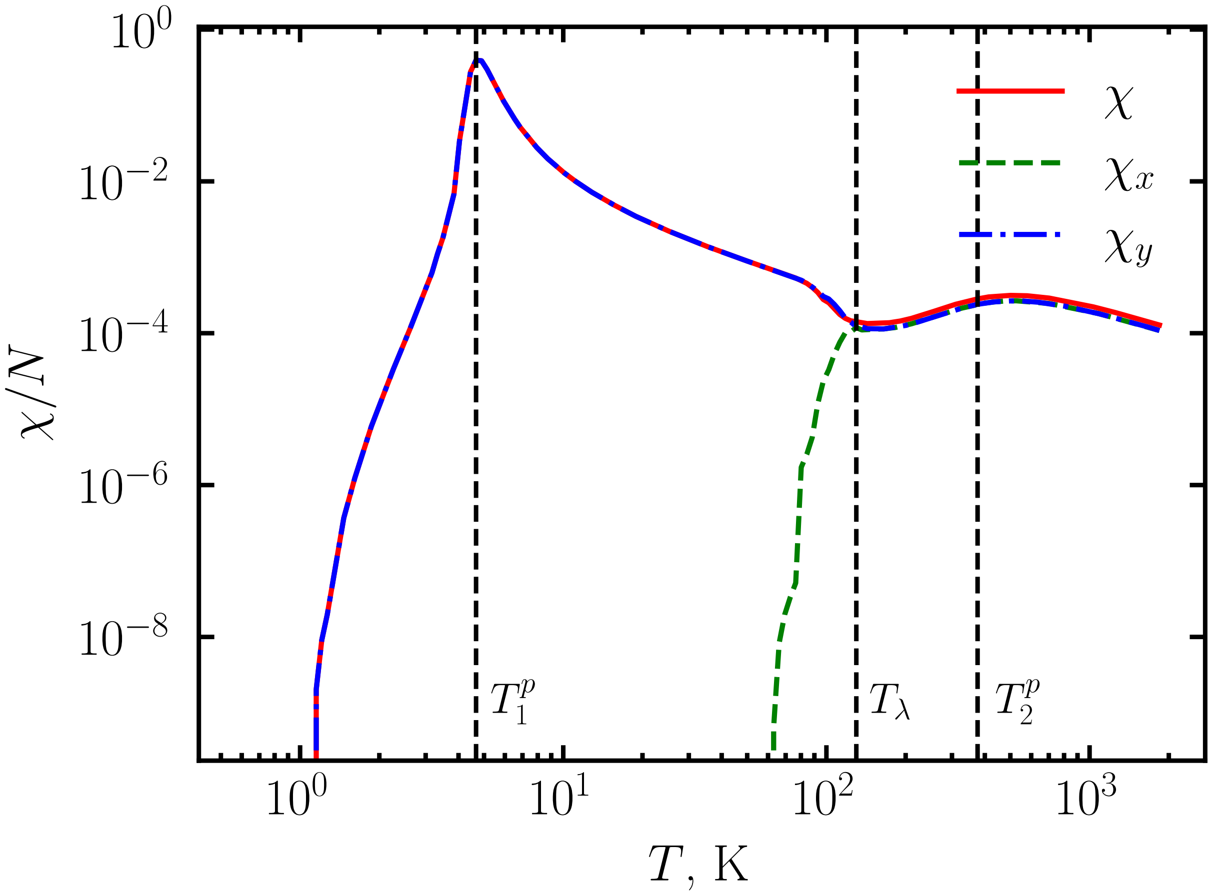


The ground state



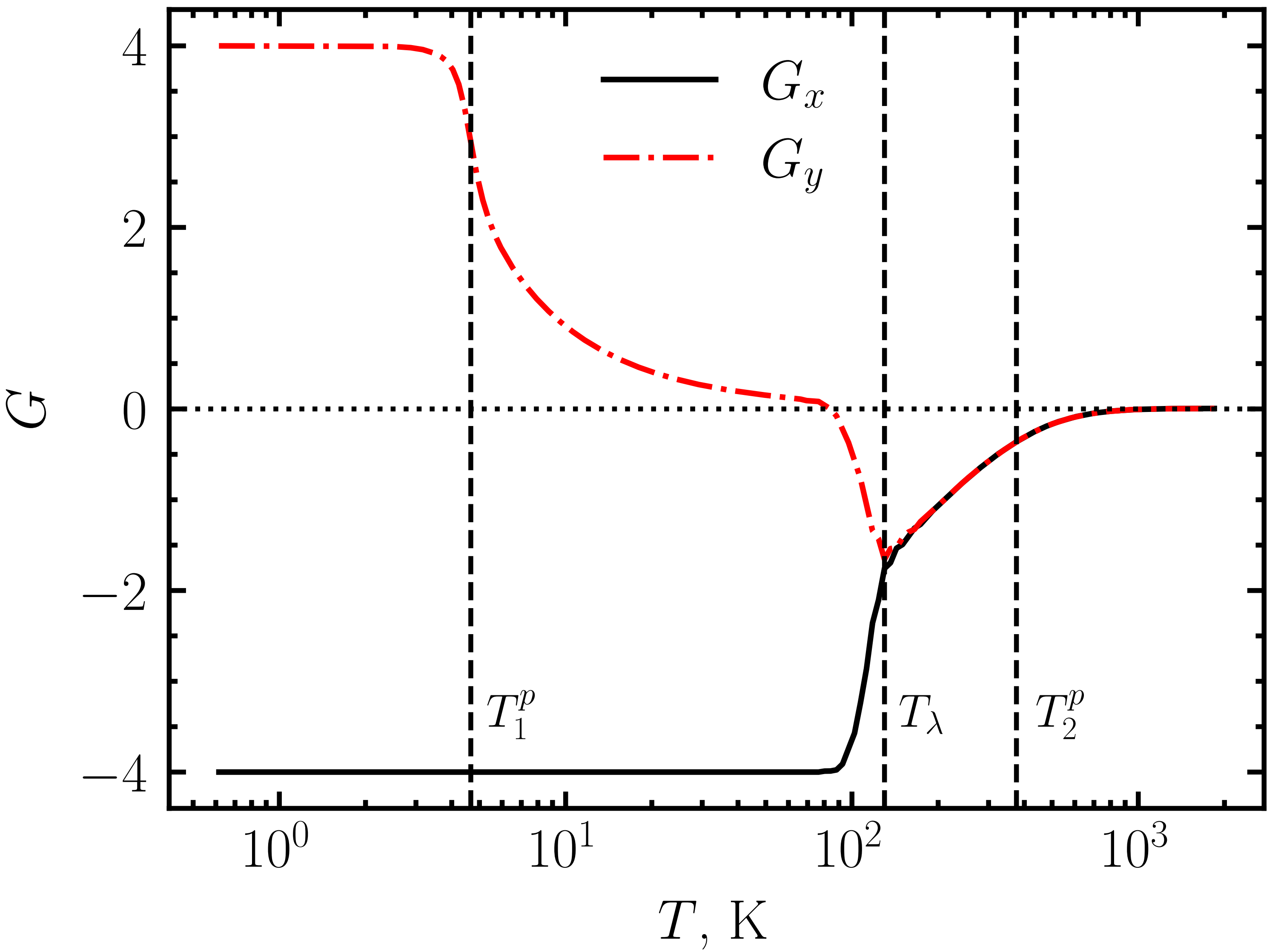
Magnetization and Susceptibility





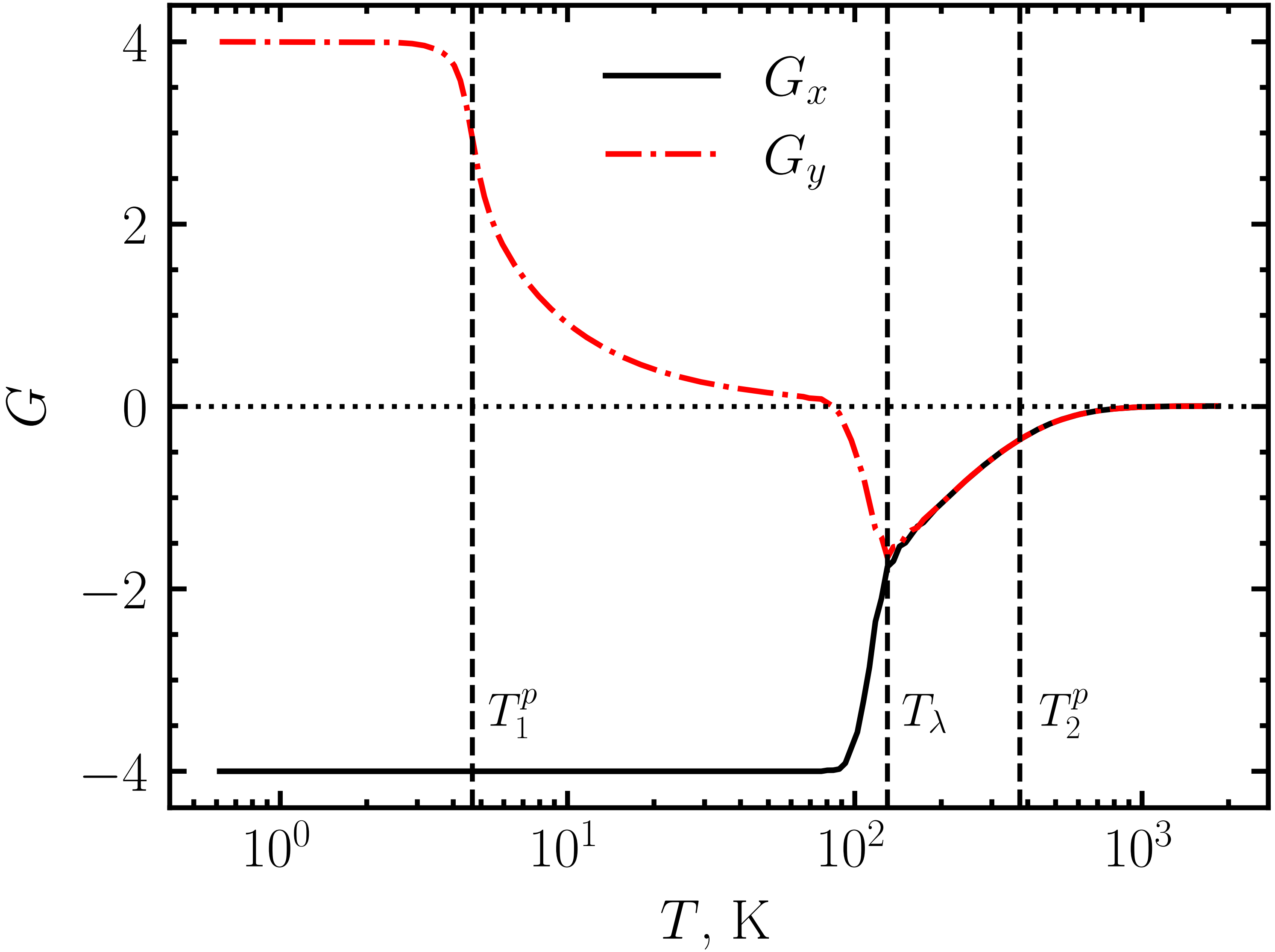
Correlation between long-distanced spins

$$G = \sum_{i}^{n} \sum_{j}^{m} \frac{E_{i,j}}{|E_{i,j}|} / n$$

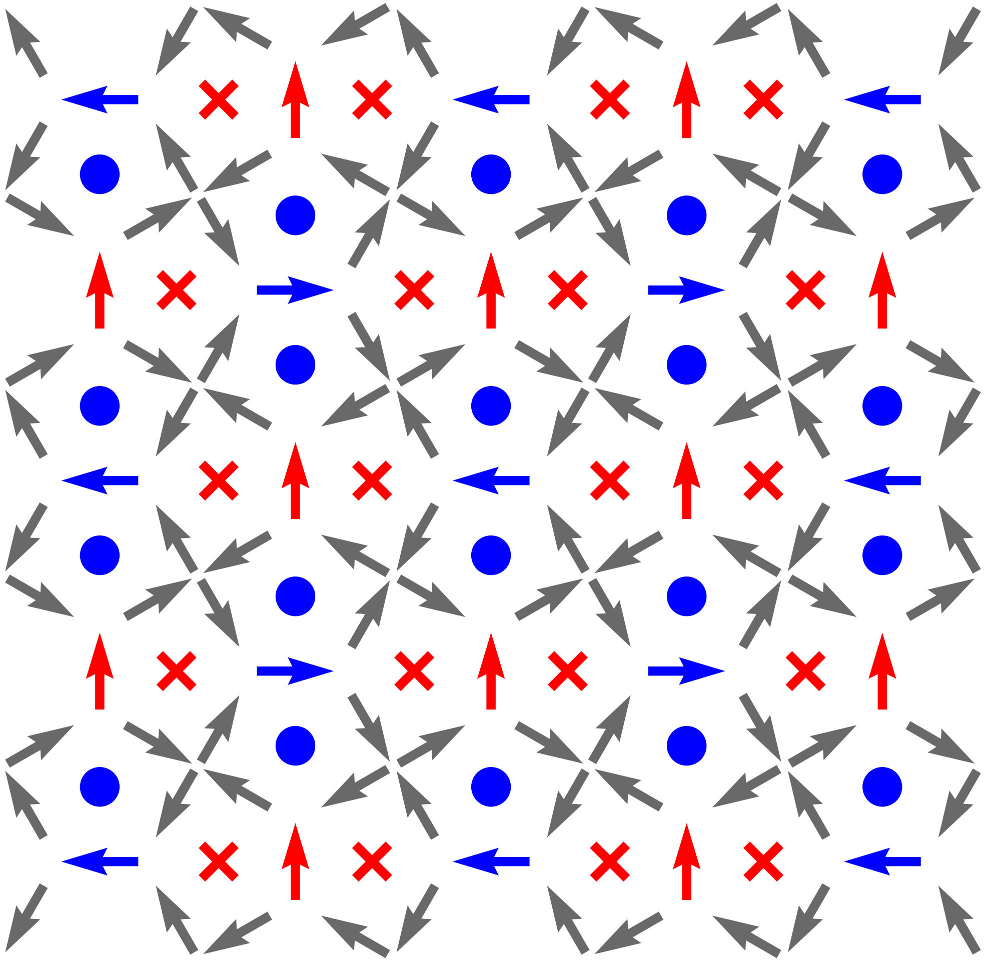


Correlation between long-distanced spins

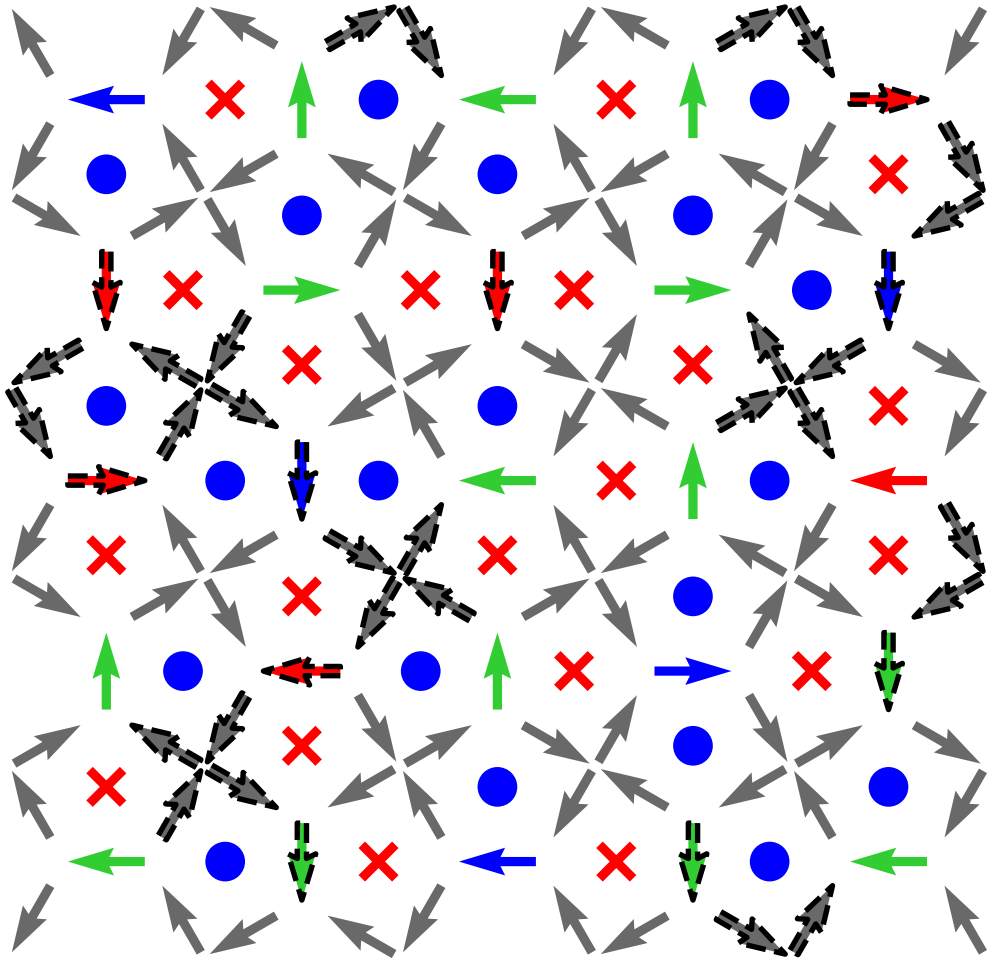
$$G = \sum_{i}^{n}\sum_{j}^{m}\frac{E_{i,j}}{|E_{i,j}|}/n$$



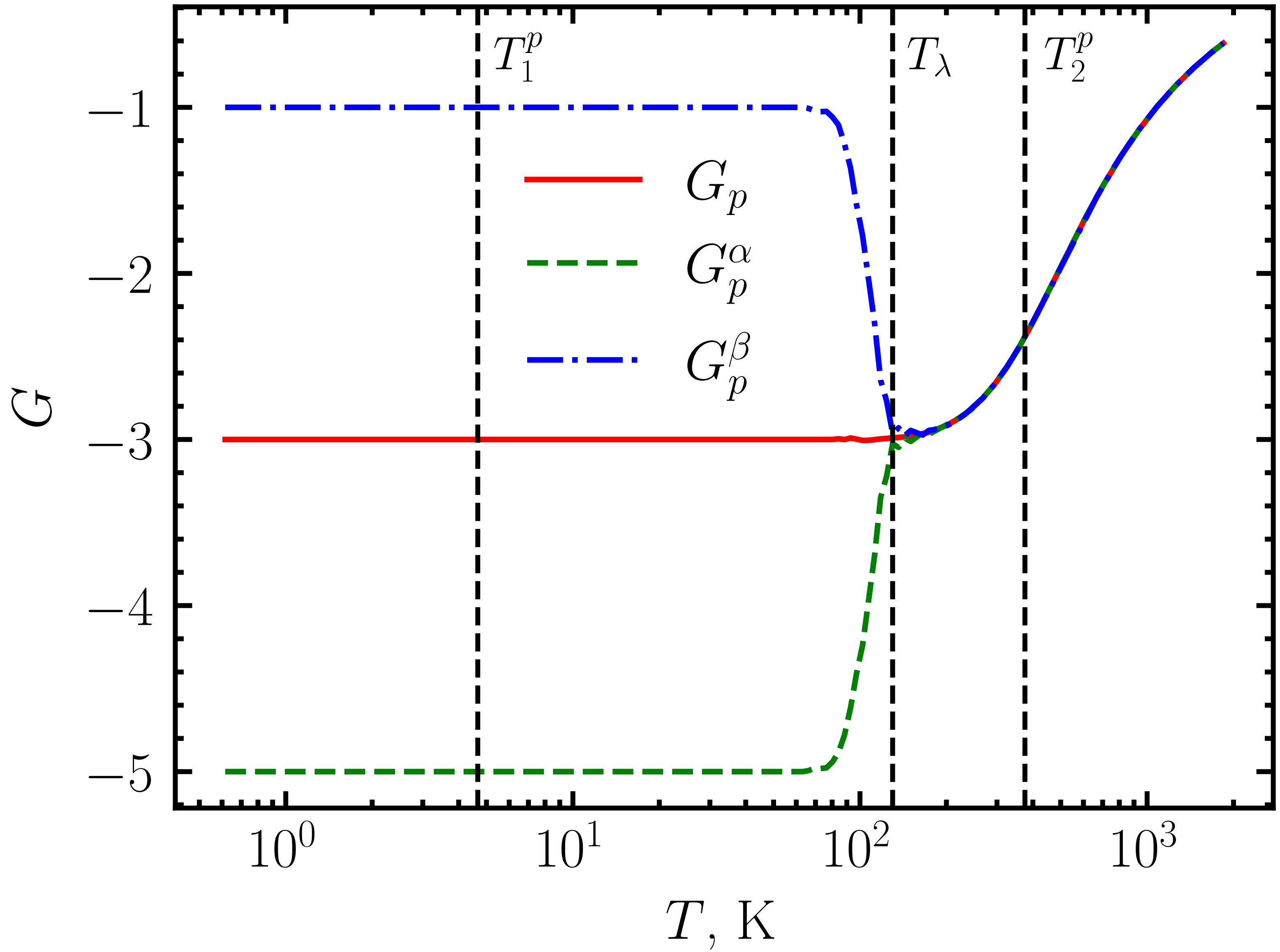
The ground state



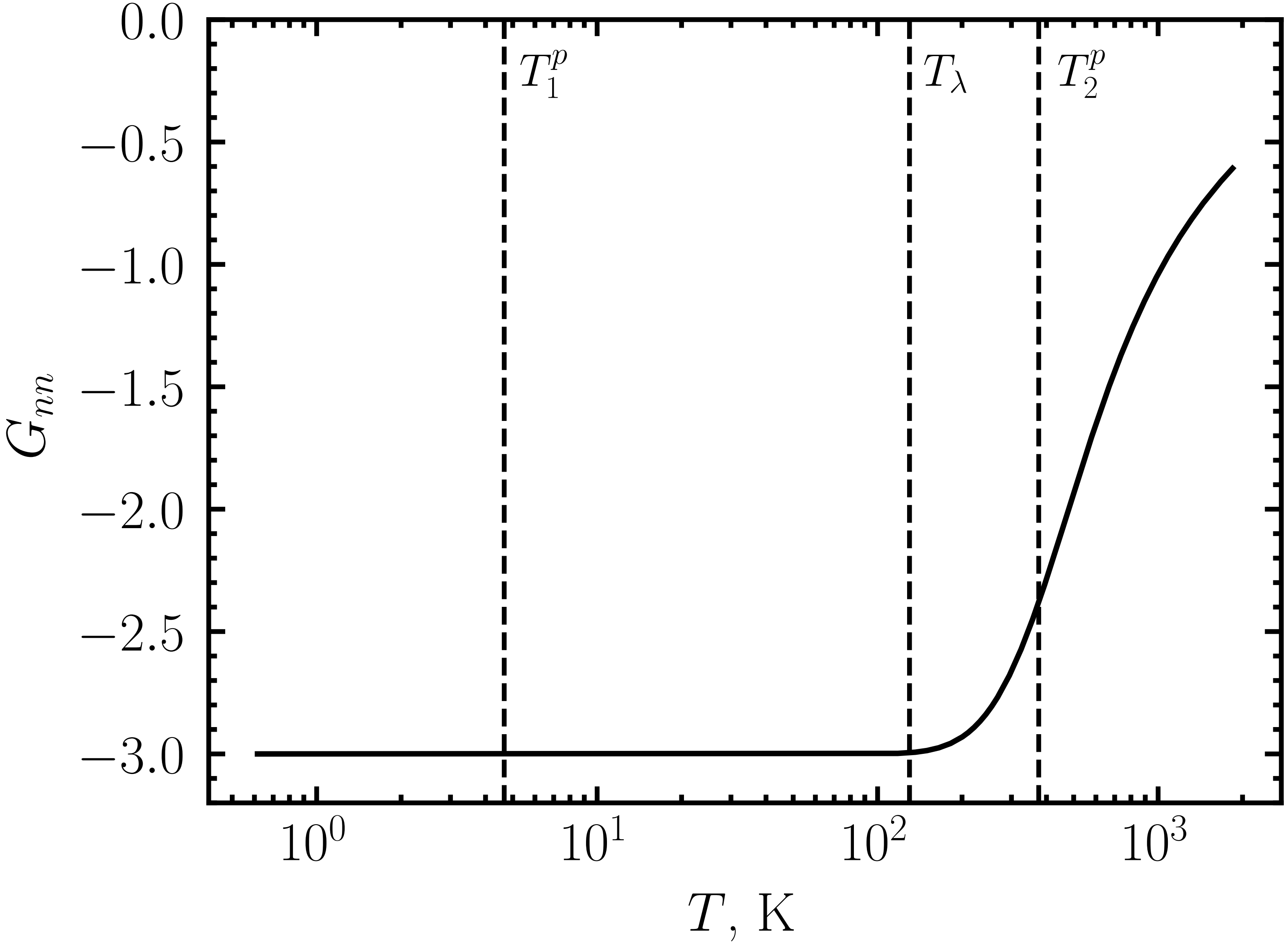
Semi-disordered state



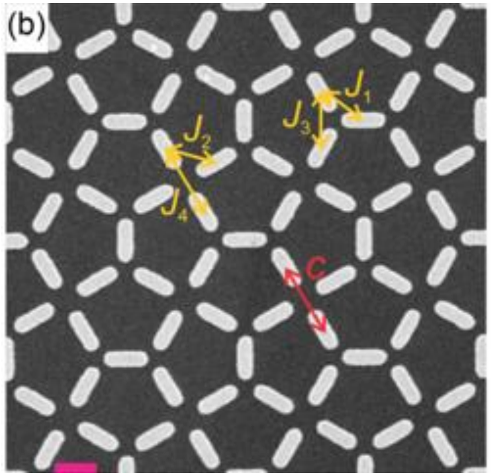
Correlations inside pentagons



Correlations inside pentagons



The experiment



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Dipolar Cairo lattice: Geometrical frustration and short-range correlations

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We have studied low-energy configurations in two-dimensional arrays consisting of Ising-type dipolar coupled nanomagnets lithographically defined onto a two-dimensional Cairo lattice, thus dubbed the dipolar Cairo lattice. Employing synchrotron-based photoemission electron microscopy (PEEM), we perform real-space imaging of moment configurations achieved after thermal annealing. These states are then characterized in terms of vertex populations, spin- and emergent magnetic charge correlations, and a topology-enforced emergent ice rule. The results reveal a strong dominance of short-range correlations and the absence of long-range order, reflecting the high degree of geometrical spin frustration present in this example of an artificial frustrated spin system.

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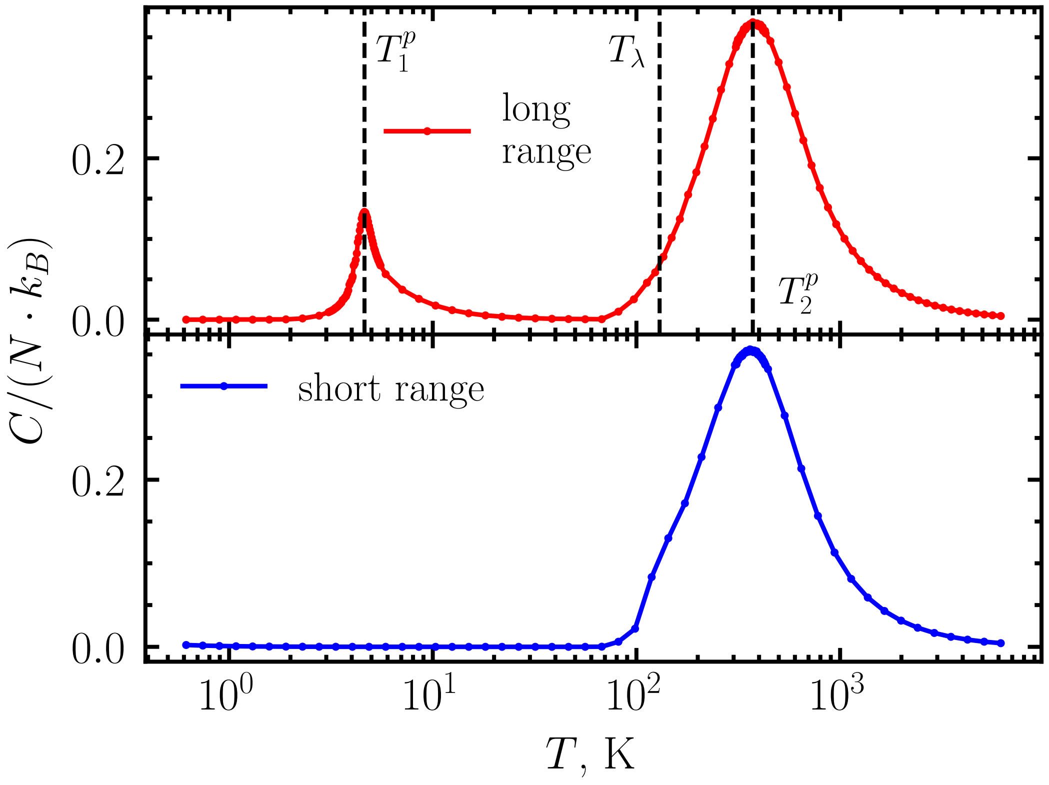
The experiment

The prepared structures were kept at room temperature and in vacuum for several days. Then, the samples were transferred into the PEEM and cooled down 20–30 K below the temperature where thermally-induced moment fluctuations start to occur within the nanomagnets on the time scale of several seconds. <u>Cooling below the so-called blocking temperature (TB = 130 K in our system) ensures that configurations remain frozen during XMCD imaging after thermal annealing</u>.



T_λ = 129.921 K in our model

Saccone M. et al. Physical Review Materials. – 2019. – T. 3. – №. 10. – C. 104402.

Conclusions

1. Long-range order in 2D magnetic systems can be checked in the experiment.
2. The system seemed frozen at 130 K in the experiment because of the long relaxation times at low temperatures.
3. The temperature of LRO phase transition may be shifted by fine tuning of volume of islands and lattice parameters.

Thank you for attention!

Height of heat capacity peaks