

# The influence of a further-neighbour spin-spin interaction on a rotating magnetoelectric effect in a spin-electron model with a doubly decorated square lattice

H. Čenčariková<sup>1</sup> and J. Strečka<sup>2</sup>

<sup>1</sup>*Institute of Experimental Physics, Slovak Academy of Sciences,  
Watsonova 47, 040 01 Košice, Slovakia*

<sup>2</sup>*Department of Theoretical Physics and Astrophysics,  
Faculty of Science, P. J. Šafárik University,  
Park Angelinum 9, 040 01 Košice, Slovakia*

Exact analytical calculations have been used to study the influence of a further-neighbour spin-spin interaction on a rotating magnetoelectric effect in a hybrid spin-electron model on a doubly-decorated square lattice. The special attention has been focused on a ground-state analysis and a thermal behaviour at a quarter- and a half-filled case. It was found that the competition between the non-zero spin-spin interaction, electron hopping and applied electric field gives rise to novel spatially (an)isotropic magnetic states, whose frontiers are influenced by a spatial orientation of an applied electric field. It is shown that the thermal stability of spontaneous long-range order can be enhanced by a rotating magnetoelectric effect, which may result in an enhancement of the critical temperature. The further-neighbour spin-spin interaction may cause a striking magnetic reentrance with either two or three consecutive critical points for both studied electron fillings.