Electronic Supplementary Information

for "Tuning nano-skyrmions and nano-skyrmioniums in Janus magnets"

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S1. Numerical simulation method

Eq. (1) in the main text is numerically solved by Mumax3 package together with Eq. (2) [1, 2]. The magnetic dipolar interactions term E_{dem} is fully included in our simulations, which is commonly referred to as the demagnetization field. We consider a $1024 \times 1024 \times 0.4$ *nm* Janus magnetic monolayer with this size $1 \times 1 \times 0.4$ *nm* for the magnetic materials. $d_0 = 0.4$ nm is taken as the effective thickness of the monolayer Janus structure in the z-direction. The Gilbert damping constant $\alpha = 0.1$ is used, which does not affect the properties of stable states [3]. The periodic boundary condition (PBC) value is set as *(5, 5, 0)*. The initial configuration is given as random magnetic structures. The material parameters are $A = 11.2$ and 13.3 *pJ/m*, $K_u = 6.0$ and 4.1 MJ/m^3, $D = 9.1$ and 6.7 mJ/m^2, and $M_s = 0.914$ and 0.862 *MA/m* for Janus MnSTe and MnSeTe respectively [4]. The formulas of Berg and Lüscher are applied to calculate the 2D topological charge Q [5]. The fixed temperature $T = 4.2$ *K* is used in the whole simulations.

S2. The simulation results of MnSeTe

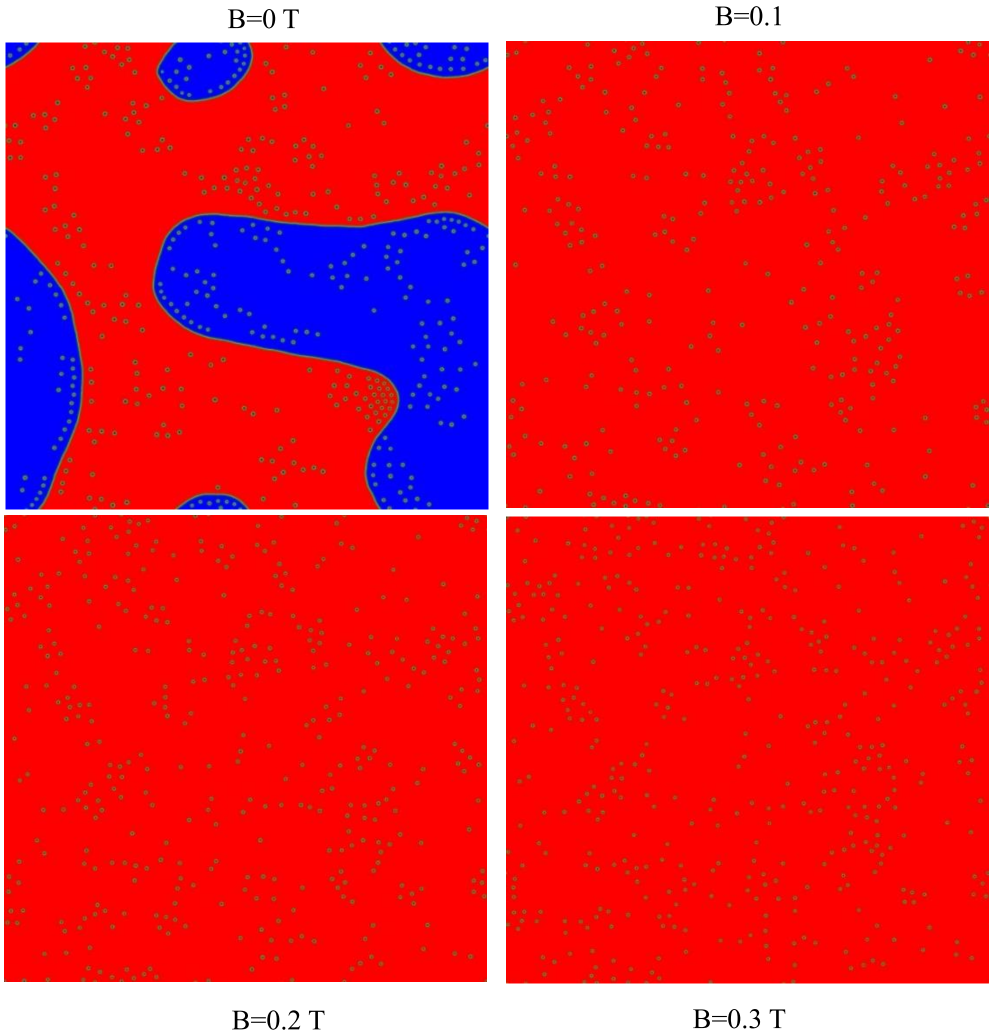


Fig. S1 Janus MnSeTe's spin textures are depicted for multiple magnetic fields in subfigures (*1024* x *1024* nm each).

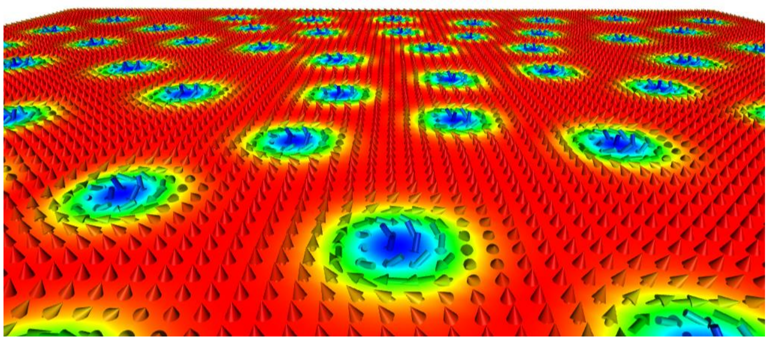


Fig. S2 The Skyrmion states of Janus MnSeTe for *B=0.1 T*.

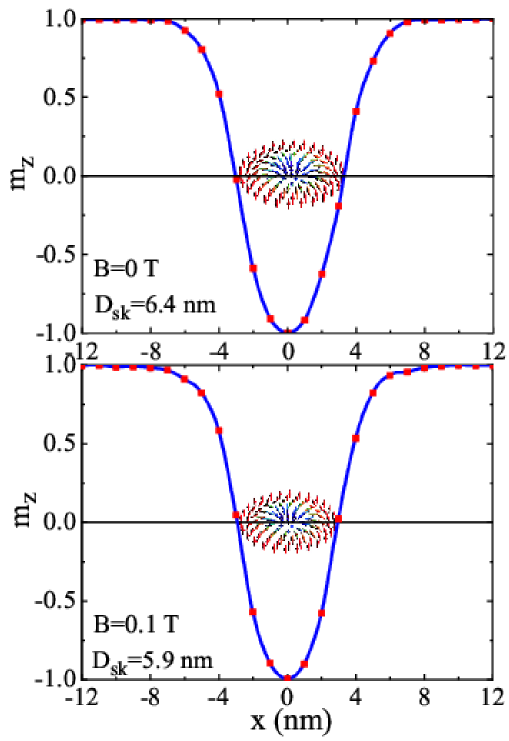


Fig. S3. The magnetization profile m_z at the center of the skyrmions ($y = 0$) for $B= 0$ T and $B=0.1$ T in monolayer MnSeTe. The inserts are the skyrmion profile in the *xy* plane respectively.

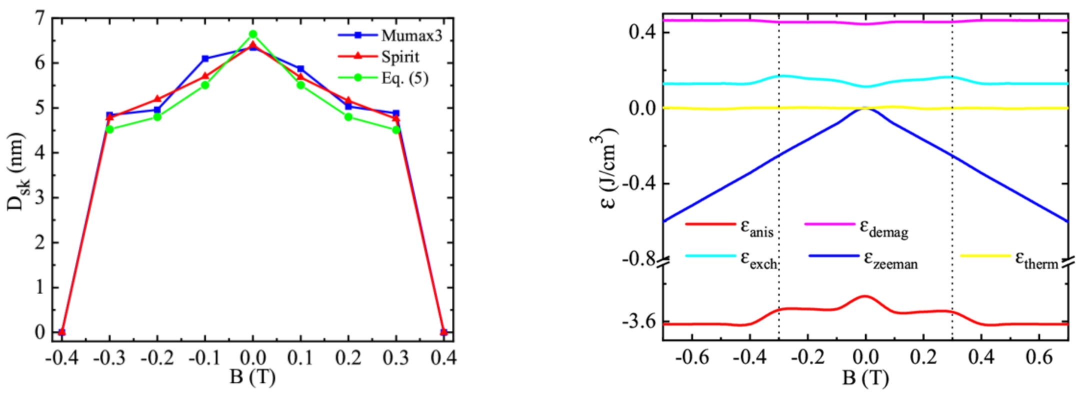
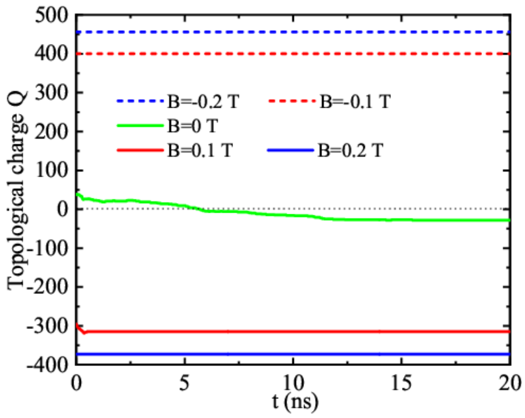


Fig. S4. (left) The evolution of the diameter of skyrmions, obtained by Mumax3 and Spirit respectively, and (right) The magnetic energy density ε as a function of the external magnetic field B for MnSeTe.



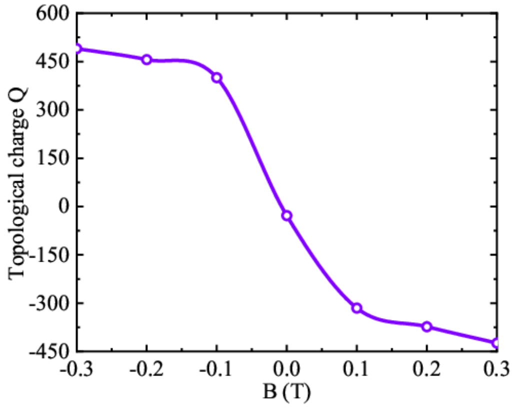


Fig. S5. (left) The evolution of the topological charge Q at the different magnetic fields B for MnSeTe. (right) The topological charge Q as a function of the external magnetic fields for MnSeTe.

S3. The evolution of the topological charge *Q* at the different magnetic fields B for MnSTe.

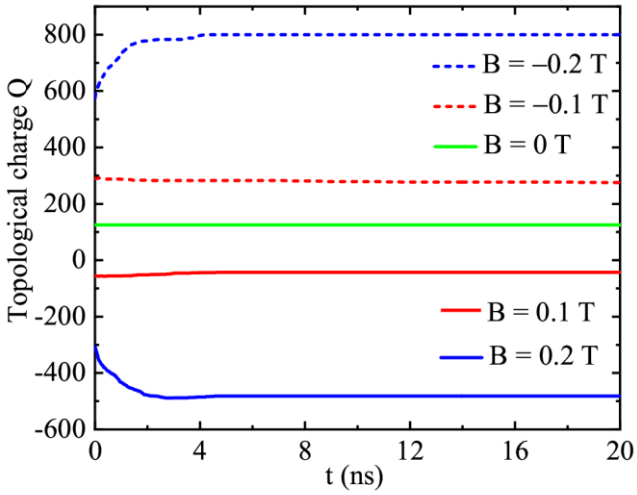


Fig. S6 The evolution of the topological charge Q at the different B for MnSTe.

In Fig. S5 and Fig. S6, the evolutions of the topological charge Q at the different B for MnSTe and MnSeTe Janus are plotted. It shows that $Q > 0$ for $B \leq 0$, whereas $Q < 0$ for $B > 0$ in Janus magnets. The stronger the magnetic field B, the longer it takes for the system to relax to a steady state. The switching of the magnetic topological charge is achieved by changing the direction of the external magnetic fields. This characteristic is also prominently shown in Fig. 3 in the main text.

References

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