

**Title:** Supplementary Movie 1:

**Description:** Single-skyrmion motion ( $N_{\text{sk}} = +1$ ) induced by 150-ns electric current pulses with a density of  $j = -6.06 \times 10^{10} \text{ A m}^{-2}$ .

**Title:** Supplementary Movie 2:

**Description:** Single-skyrmion motion ( $N_{\text{sk}} = +1$ ) induced by 150-ns electric current pulses with a density of  $j = 6.32 \times 10^{10} \text{ A m}^{-2}$ .

**Title:** Supplementary Movie 3:

**Description:** Single-skyrmion motion ( $N_{\text{sk}} = +1$ ) induced by 150-ns electric current pulses with a density of  $j = -5.05 \times 10^{10} \text{ A m}^{-2}$ .

**Title:** Supplementary Movie 4:

**Description:** Single-skyrmion motion ( $N_{\text{sk}} = -1$ ) induced by 150-ns electric current pulses with a density of  $j = -4.82 \times 10^{10} \text{ A m}^{-2}$ .