Supplementary Materials: Coexistence of ferromagnetic and stripe spin fluctuations in YFe_2Ge_2

I. X-ray diffraction measurements

YFe_2Ge_2 single crystals were grown out of Sn flux. Representative single crystals with shiny cleaved surfaces are shown in Fig. S1a. X-ray diffraction (XRD) measurements revealed that all of the reflections from the cleaved surface could be indexed by (0, 0, *L*) peaks of tetragonal YFe_2Ge_2 (Fig. S1b). The full-width at half maximum (FWHM) of the rocking curve of the (0, 0, 8) peak was 0.073° (Fig. S1c), indicating a high crystallization quality. The Rietveld refinements on the X-ray powder diffraction pattern of the ground single crystals found no detectable impurity phases (Fig. S1d). The refined structural parameters are listed in Table S1, which are consistent with previous reports [1].

II. Raw constant energy images measured on the AMATERAS time of flight spectrometer

Fig. S2 shows the raw constant energy images at 4 K, in which the stripe and the in-plane ferromagnetic spin fluctuations can be clearly seen. An aluminum sample holder/environment was used for our neutron scattering measurements. The phonon background from the polycrystalline aluminum sample holder/environment only depends on the amplitude of **Q**, which was estimated from the scattering away from the magnetic signals and subtracted. The background-subtracted images are presented in Fig. 1.

III. Polarized inelastic neutron scattering measurements on YFe_2Ge_2

In order to unambiguously confirm that the stripe and the ferromagnetic spin excitations are magnetic, we have performed polarized neutron scattering measurements on BT-7 triple-axis spectrometer at the NIST Center for Neutron Research [3, 4]. Typical initial flipping ratio in the experiment was ~ 25 and small corrections for the polarization inefficiencies have been applied. Fig. S3a illustrates the constant energy scan along the *H* direction around the ferromagnetic wave vector (0, 0, 1.5) and the stripe wave vector (0.5, 0, 1.5) with the neutron polarization direction, controlled by a small guide field, parallel to the momentum transfer **Q** (defined as x). In this configuration, all magnetic signals appear in the spin-flip (SF) channel

and the non-spin-flip (NSF) channel contains only the structural contributions. The strong and clear peaks are observed in the SF channel for both the ferromagnetic and the stripe spin excitations while the signal in the NSF channel is featureless. These results unambiguously demonstrate that the excitations at the stripe and ferromagnetic wavevectors are purely magnetic. On the other hand, the elastic polarized neutron scattering data at the stripe (0.5, 0, 1.5) and the ferromagnetic (1, 0, 0.5) wavevectors are featureless in the SF channel, indicating the absence of magnetic order in YFe_2Ge_2 at 1.5 K (Fig. S3b and S3c).

IV. Simulated spin excitation spectrum using a linear combination of the stripe model and in-plane ferromagnetic model

Here we try to simulate spin excitation spectrum using a linear combination of the stripe model and in-plane ferromagnetic model, assuming the effective Heisenberg Hamiltonian $H = J_{1a}\sum_{i,j}\mathbf{S}_i \cdot \mathbf{S}_j + J_{1b}\sum_{i,j}\mathbf{S}_i \cdot \mathbf{S}_j + J_2\sum_{i,j}\mathbf{S}_i \cdot \mathbf{S}_j + J_c\sum_{i,j}\mathbf{S}_i \cdot \mathbf{S}_j - J_s\sum_i(S_i^z)^2$ for both two models, in which J_{1a}, J_{1b} and J_c are the nearest neighbour exchange coupling constants, J_2 is the next nearest neighbour coupling constant, J_s is the single ion anisotropy. The dynamic spin structure factor is modelled as $S_{tot} = \eta S_{stripe} + (1 - \eta)S_{ferro}$, representing for a linear combination of the stripe model and in-plane ferromagnetic model, in which η is the linear combination coefficient. Fig. S4 illustrates a representative result of our simulation. The exchange coupling parameters used for simulation for the stripe model are SJ_{1a} = -12.5 meV, SJ_{1b} = -15 meV, SJ_2 = 10 meV, SJ_c = 5 meV; for the ferromagnetic model, $SJ_{1a} = SJ_{1b}$ = -30.5 meV, SJ_2 = 10 meV and SJ_c = 5 meV. The coefficient η is about 0.34, which is the phase fraction for the stripe phase.

TABLE S 1: Refined structure parameters of YFe_2Ge_2 via X-ray powder diffraction measurement at 300 K. Space group: *I*4/mmm (No. 139). Atomic position: Y: 2a (0, 0, 0); Fe: 4d (0, 0.5, 0.25); Ge: 4e (0, 0, z).

	Refined composition	YFe_2Ge_2
	a (Å)	3.95835(9)
	c Å)	10.43385(26)
Y atom	B_{iso} *(Å^2)*	0.069(48)
Fe atom	B_{iso} *(Å^2)*	0.242(57)
Ge atom	*z*	0.37868(14)
	B_{iso} *(Å^2)*	0.009(44)
	R_p	3.30
	wR_p	4.24
	χ^2	1.90

[1] J. S. Chen, K. Semeniuk, Z. Feng, P. Reiss, P. Brown, Y. Zou, P. W. Logg, G. I. Lampronti, and F. M. Grosche, Phys. Rev. Lett. **116**, 127001 (2016).

[2] J. Rodrguez-Carvajal, *Physica(Amsterdam)*, **192B**, 55 (1993).

[3] J. W. Lynn, Y. Chen, S. Chang, Y. Zhao, S. Chi, W. Ratcliff, II, B. G. Ueland, and R. W. Erwin, Journal of Research of NIST **117**, 61-79 (2012).

[4] W. C. Chen, G. Armstrong, Y. Chen, B. Collett, R. Erwin, T. R. Gentile, G. L. Jones, J. W. Lynn, S. McKenney and J. E. Steinberg, *Physica* B, **397**, 168 (2007).

[5] S. Toth and B. Lake, J. Phys.: Condens. Matter **27**, 166002 (2015).

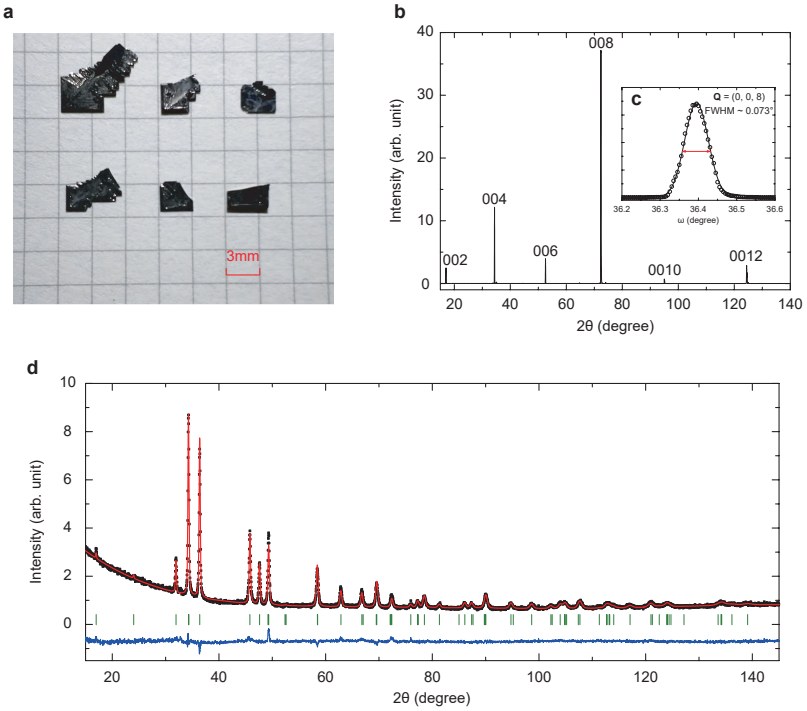

FIG. S 1: Photograph and X-ray diffraction patterns of YFe_2Ge_2. (a) Photograph of representative YFe_2Ge_2 single crystals. (b) X-ray diffraction pattern on YFe_2Ge_2 single crystal. (c) Rocking curve of the (0, 0, 8) reflection peak; the red bar indicates the FWHM. (d) Observed (black) and calculated (red) X-ray diffraction pattern of ground single crystals. The difference between the observed and calculated intensities are shown in the blue curve. Refinements were performed using the FULLPROF program [2]. The X-ray has a wavelength of 1.54 Å.

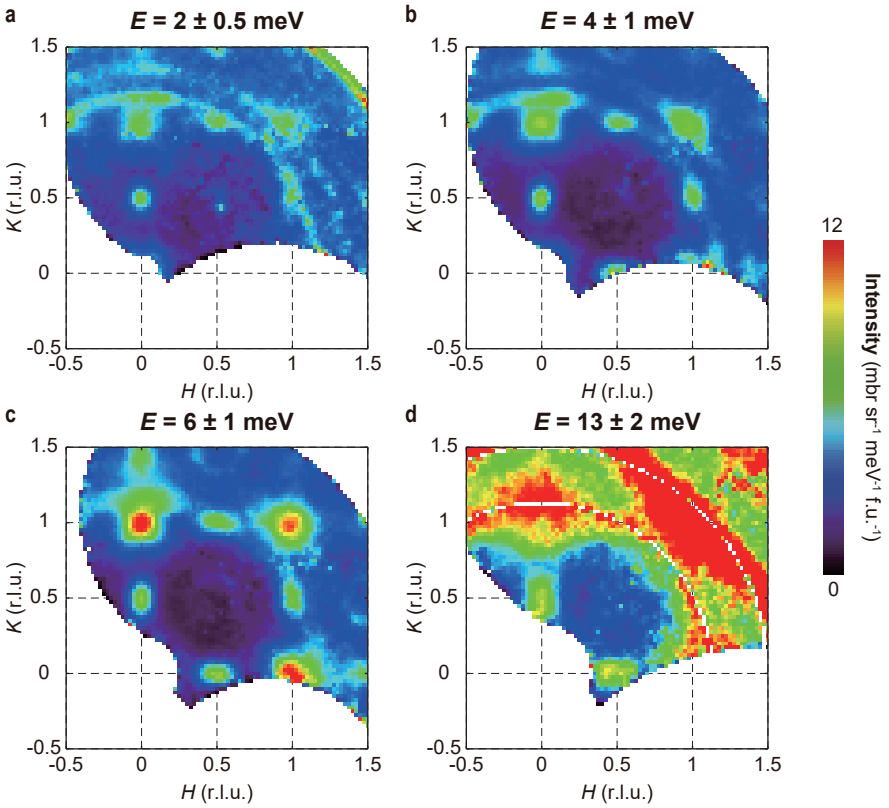

FIG. S 2: Raw constant energy images measured on AMATERAS at indicated energies and 4 K. The corresponding background-subtracted data are shown in Fig. 1b-e.

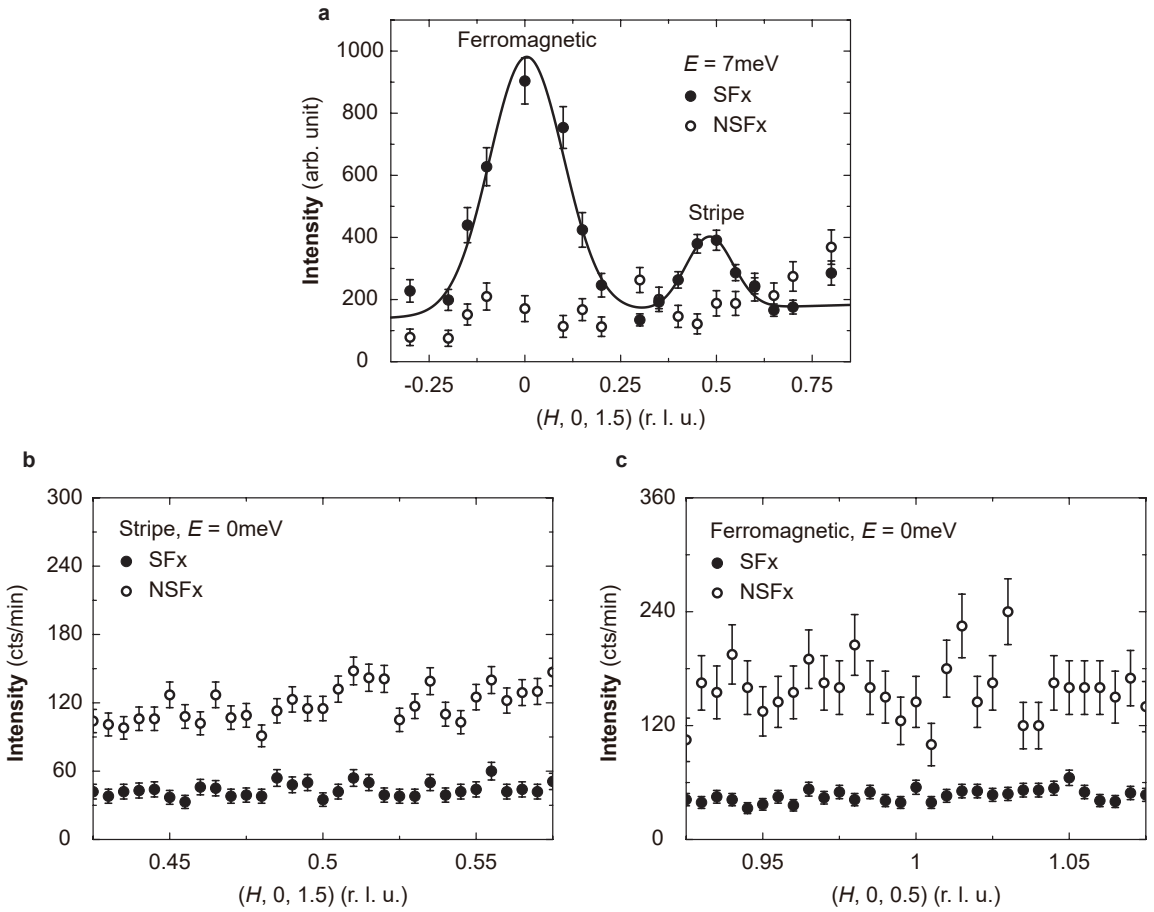

FIG. S 3: Polarized neutron scattering data in the SF and NSF channels at (a) E = 7 meV at the stripe and ferromagnetic wavevectors (b) E = 0 meV at the stripe wavevector (c) E = 0 meV at the ferromagnetic wavevector. The solid line represents for the Gaussian fitting of the spin excitations in the SF channel.

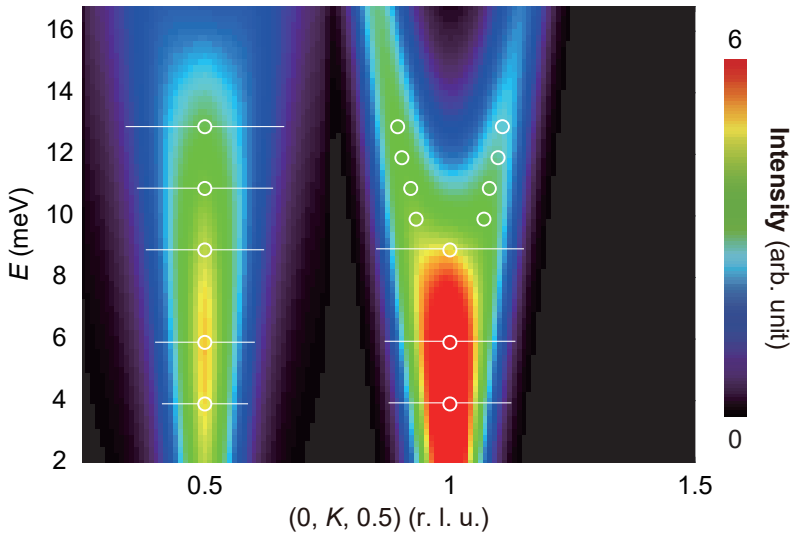

FIG. S 4: The simulated dispersions of the stripe and the ferromagnetic spin excitations in YFe_2Ge_2 using the parameters given in the main text. The open circles and the horizontal bars represent for the peak positions and the full-width at half maximum (FWHM) determined from the experiment results, respectively. The spin excitation spectrum was simulated using the SPINW program [5] for the Heisenberg model.