研究プロジェクト名：　New and enhanced properties arising from curvature and topology in magnetic gyroids

概要：　We propose to investigate the properties of nanoscale magnetic gyroid networks, (Figure 1A) which are predicted to exhibit enhanced properties and new effects through the interaction of their 3D curvature and topology with charge carriers and spin waves. We aim to understand such emergent effects and then apply them to realize novel spintronic devices.

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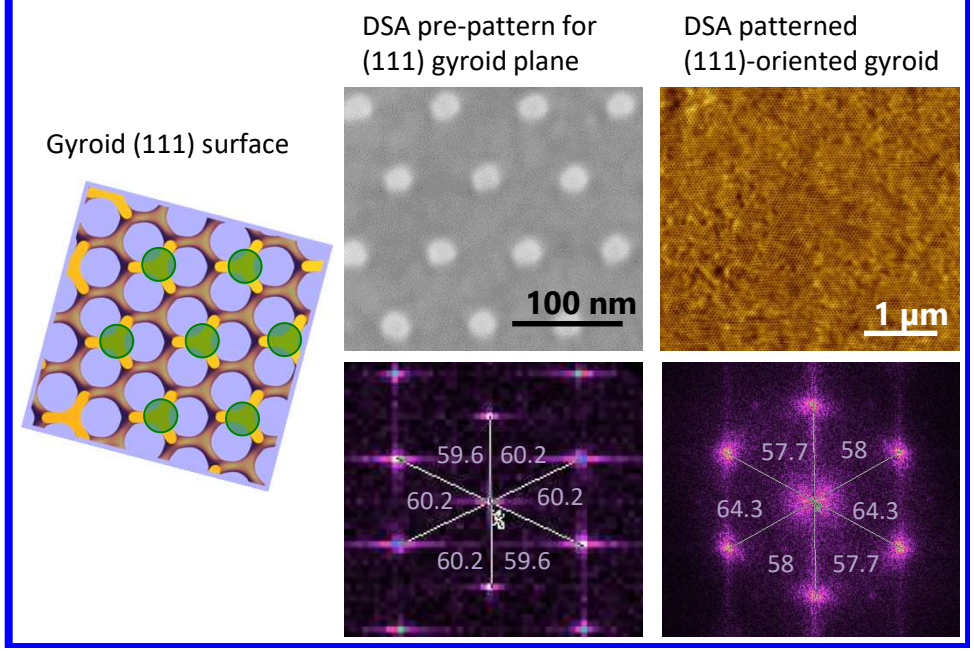
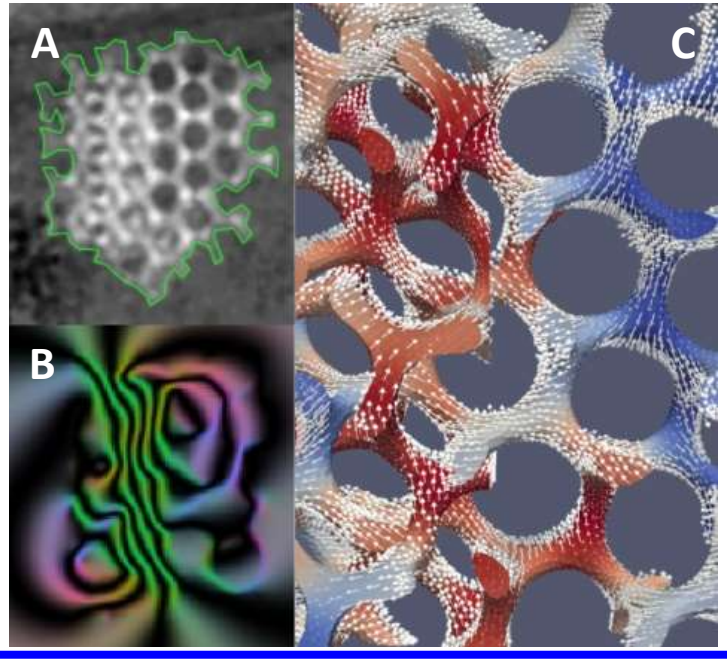
We aim to employ substrate pre-patterning (directed self-assembly) to fully control the orientation of the gyroid's chiral axes, which we have so far achieved for the (111) gyroid plane (chiral axis out of plane). Apart from defect-free gyroids, we will also investigate gyroids containing half-integer topological defects, following our X-ray nanotomography observations of such defects in gyroids (manuscript in preparation), so that we may gain a comprehensive understanding of magnetotransport and spin-wave transmission in gyroid nanostructures.



研究プロジェクト名：　New and enhanced properties arising from curvature and topology in magnetic gyroids

概要：　Elucidated the 3D magnetization configuration of nanoscale magnetic gyroids (Figure 1A) by off-axis electron holography (Figure 1B) and finite-element micromagnetic simulations (Figure 1C), for the purpose of evaluating gyroids as meta-materials for spintronics and novel magnetic devices.

研究成果（実施状況）： Nanoscale NiFe gyroids possess a ferromagnetic remanent state with evidence of frustration, displaying short-range order based on interacting vertex pairs. These results open possibilities for gyroids as stochastic/neuromorphic computing architectures and 3D magnonic crystals. Analysis of polarized neutron scattering data and X-ray tomographic imaging of improved Ni and Au gyroid samples is currently in progress.



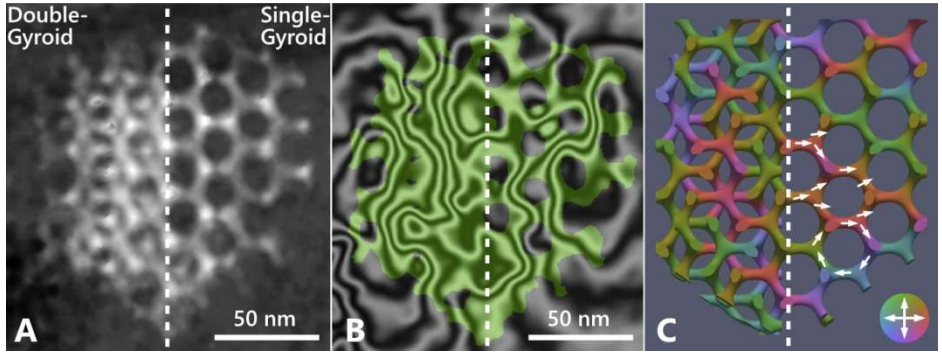
主要発表論文等：

[1] J. Llandro et al., Advanced Materials, submitted (Mar 2019).

研究プロジェクト名：　New and enhanced properties arising from curvature and topology in magnetic gyroids

概要：　$Ni_{75}Fe_{25}$ nanoscale gyroids were fabricated (Figure 1A) and their 3D magnetization configurations were elucidated by off-axis electron holography (Figure 1B) and finite-element micromagnetic simulations (Figure 1C), for the purpose of evaluating gyroids as meta-materials for fundamental and applied spintronics.

研究成果（実施状況）：　Nanoscale Ni-Fe gyroids were found to adopt an intricate remanent state with no unique equilibrium configuration, in which frustration causes some vertex pairs to adopt high-energy magnetization states. The ability of the gyroid to adopt high-entropy states is promising for reservoir computing applications (published). Detailed analysis of bulk and interface morphology of gyroids via 3D X-ray nanotomography has been successfully completed, with highest-achieved resolution for this technique (in preparation).



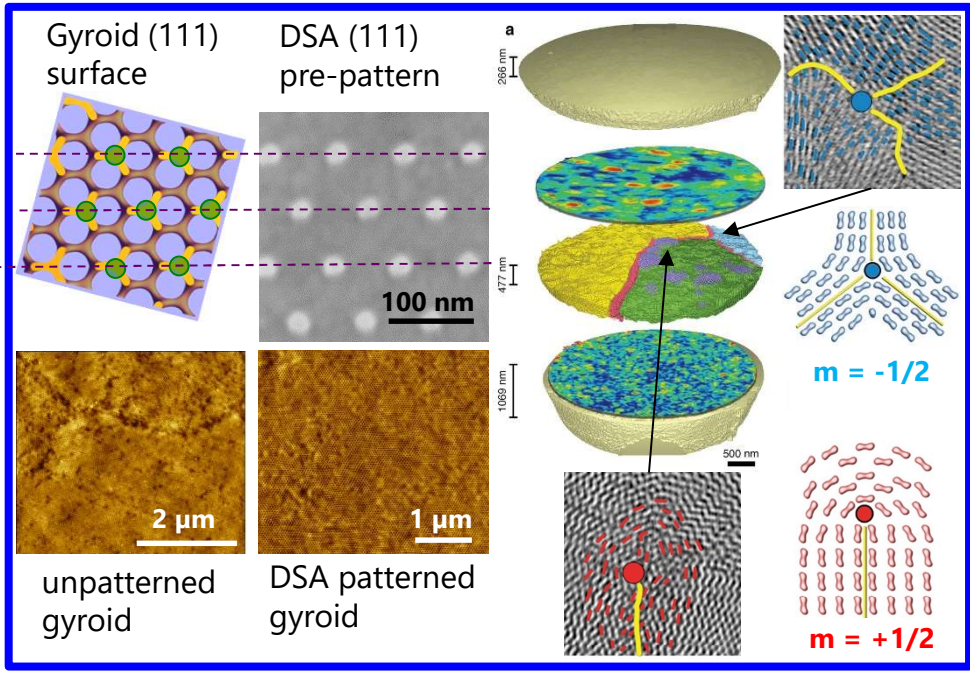
主要発表論文等： [1] J. Llandro et al., Nano Letters (2020).
DOI: 10.1021/acs.nanolett.0c00578

研究プロジェクト名：　New and enhanced properties arising from curvature and topology in magnetic gyroids

概要：　After imaging the magnetization states of $Ni_{75}Fe_{25}$ nanoscale gyroids [1], we investigated the morphology of gyroids via analysis of 3D X-ray nanotomography data, SEM and AFM and how it may be controlled via substrate pre-patterning, in order to enhance signatures of topological effects in magnetotransport.

研究成果（実施状況）：

Directed self-assembly via substrate pre-patterning is effective in gyroids at eliminating domain boundaries and improving ordering. The next step, controlling chiral-axis orientation, is in progress. Analysis of X-ray nanotomography data revealed half-integer topological defects in gyroids which combine features of those observed in soft-matter systems like liquid crystals and also of those in condensed matter (manuscript in preparation).



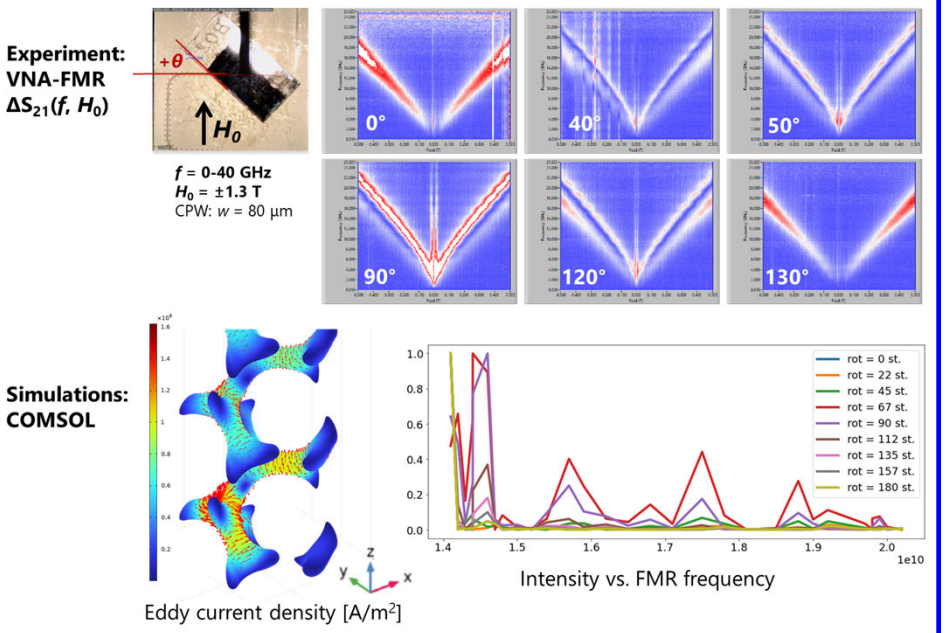
主要発表論文等： [1] J. Llandro et al., Nano Lett. 20, 3642 (2020).

研究プロジェクト名：　New and enhanced properties arising from curvature and topology in magnetic gyroids

概要：　We aim to enhance signatures of topological effects on spin transport in magnetic gyroids with well-determined ordering and orientation. In single-domain Ni gyroid films, we observed strong angular dependence of the spin-wave transport due to the interaction of the inhomogeneous gyroid magnetization revealed in our previous work [1] and induced eddy currents localized in the gyroid branches.

研究成果（実施状況）：

We observed that in single-domain Ni gyroid films on a coplanar waveguide that the FMR response is strongly modified by the angle between the magnetic field and the sample long axis. Between 40 and 120, a second mode appears which exchanges energy with the fundamental as a function of angle, and both modes display a non-reciprocal component consistent with the chiral nature of the gyroid. Ongoing COMSOL simulations suggest that the microwave field induces eddy currents localised in the gyroid branches, which interact with the highly inhomogeneous gyroid magnetization [1] more strongly as the magnetic field angle matches the high-symmetry directions of the gyroid network (manuscript in preparation).



主要発表論文等： [1] J. Llandro et al., Nano Lett. 20, 3642 (2020).