**Overview:** Observations show that magnetic fields are ubiquitous in the universe. They can be seen in intergalactic space, and organized, dynamically important magnetic fields thread the interstellar medium in galaxies across cosmic time and regardless of galaxy size or morphology. Molecular clouds form out of this magnetized plasma, and measurements show that these clouds have substantial magnetic fields as well, which may be critical to star formation, one of the most important unsolved problems in astrophysics. While magnetic fields have been observed in all of these astrophysical regimes, and there is a clear sequence of events – galaxies form molecular clouds, which in turn are the sites of star formation – the ways in which magnetic fields tie galaxies to molecular clouds, and thus potentially affect star formation and the initial stellar mass function, are poorly understood theoretically. There is a clear need for a detailed, self-consistent model of cosmological structure formation that can trace the evolution of magnetized gas to the physical scales relevant for star formation.

Our objective in this project is to understand how galactic-scale magnetic fields affect the formation and evolution of molecular clouds, and in turn how magnetic fields ejected from stars forming in these clouds are amplified and ordered within galaxies. We will pursue this goal through the use of magnetohydrodynamic (MHD) cosmological simulations of galaxy formation, which we will use to inform (and be informed by) idealized, high-resolution MHD simulations of isolated galaxies that resolve the formation of magnetized molecular clouds. This will both determine the impact of magnetic fields on the bulk properties of these clouds and model the way in which fields are returned from stars to the interstellar medium. Throughout our theoretical exploration, we will be motivated by, and compare our results to, observations of magnetic fields in the Milky Way, in nearby galaxies and the intergalactic medium, and in the high redshift universe. The end result of this project will be a deep understanding of the connection between galaxies, molecular clouds, and the magnetic fields that permeate these objects.

**Intellectual merit:** This project is novel because it will use high resolution magnetohydrodynamics simulations to self-consistently follow the evolution of plasma over a huge range of astrophysically important length, density, and temporal scales, thus bridging the gap between the cosmological structure formation that results in galactic-scale magnetic fields and the star-forming molecular clouds that form out of the magnetized interstellar medium. This is crucial because an improved understanding of how magnetized molecular clouds form within galaxies will lead to more accurate initial conditions for targeted studies of star formation, and will provide an opportunity to model that critical process in a more realistic way. The results of this project will facilitate our interpretation of observations of magnetic fields in the intergalactic medium, in both high redshift and nearby galaxies, and in the Milky Way galaxy itself.

**Broader impacts**: Our proposed work will have significant impact on scientists in training, who will learn to use cutting-edge numerical tools will develop critical skills in scientific software development and data analysis. We will involve undergraduate and graduate students at MSU and a postdoctoral researcher at FSU in our research efforts, including students from under-represented groups. The tools developed as part of this work will be incorporated into widely used open-source software projects and all simulation and analysis data products will be made publicly available, maximizing the return on this investment by enabling the community to more easily build upon this work. Scientific results from this program will be visualized by members of our collaboration, and will be disseminated to the public via our pre-existing collaborations with planetariums and museums, via the Internet, and as part of outreach talks given by members of this project. The simulation data produced as a result of this project will be used in courses at both MSU and FSU, and the curricular materials will be made available via the Internet.