**USING BLUE WATERS TO UNDERSTAND THE ORIGINS OF GALAXIES AND THE NATURE OF DARK MATTER**

**Research Challenge**
At a fundamental level, the study of galaxies and stars seeks to answer the question, “How did we get from the Big Bang to the Milky Way?” This is an immensely challenging question involving the interplay among gravity, fluid dynamics, radiation and matter, and stars exploding as supernovae, giving rise to explosive outflows of material from galaxies that can reach across the observable universe.

The research team seeks to understand the origin and nature of galaxies, using massively parallel simulations that follow the birth and evolution of galaxies and stars from the very early universe to the present day.

**Methods & Codes**
The research team has run a large suite of cosmological, high-resolution simulations including detailed treatments of the physics of the interstellar medium, star formation, feedback in radiation and supernovae, magnetic fields, and cosmic rays. The simulations use the Feedback In Realistic Environments (FIRE) physics methods in the GIZMO code, a new massively parallel multimethod, hybrid Lagrangian–Eulerian finite-element, high-order, radiation-magnetohydrodynamics code (unique in numerical methods and physics-supported).

**Results & Impact**
Our cosmological simulations target galaxies from the faintest dwarfs through the Milky Way at the ultra-high-resolution and realism required to leverage the next generation of observations. These simulations model the physics of galaxy formation, uniquely incorporating not only all of the important stellar feedback mechanisms but also magnetic fields, physical (anisotropic) Braginskii conduction and viscosity, passive scalar (metal) diffusion, and explicit, multiwavelength radiation hydrodynamics. It has revealed fundamental new insights into how stars alter their galactic environments and has changed our observational inferences about the nature of dark matter in those galaxies.

**Why Blue Waters**
Blue Waters is critical for this research because the enormous computational challenges enumerated above require >100 million CPU-hours on tens of thousands of processors and requiring tens of terabytes of active memory to store and evolve the immensely complex physical systems, and the simulations produce petabytes of data products. No other current facility enables this research.