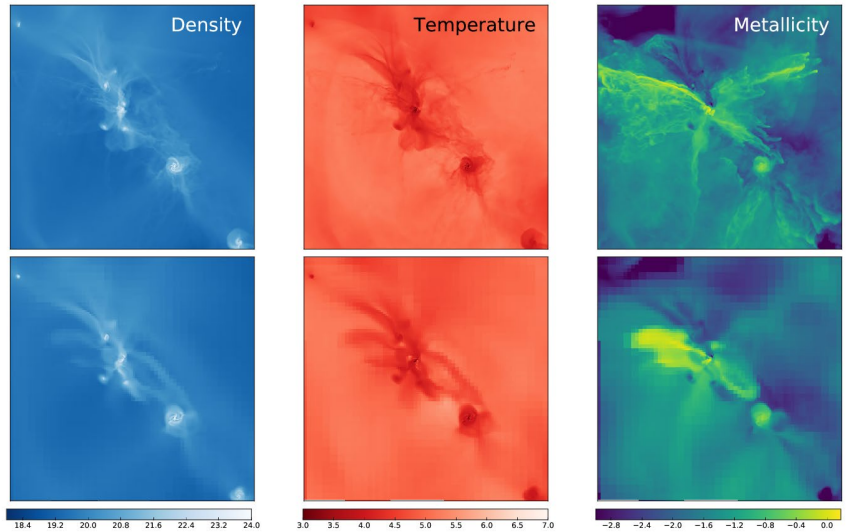
BLUE WATERS
SUSTAINED PETASCALE COMPUTING

Allocation: NSF PRAC/4000 Knh
PI: Brian O'Shea
Michigan State University
Space Science

SIMULATING GALAXY FORMATION ACROSS COSMIC TIME



This figure shows a projection of (left to right) gas density, temperature, and metal content for two simulations: one with an enhanced spatial refinement in the circumgalactic gas (top row), and one using standard refinement methods (bottom row).

Research Challenge

To understand two critical issues in galaxy formation:

1. the formation of the earliest generations of galaxies and their connections to the Milky Way through hierarchical structure formation,
2. the "baryon cycle" in galaxies like the Milky Way—how gas gets into and out of galaxies, and what it does while it is there.

Methods & Codes

Enzo is an open-source and community-developed software platform for studying cosmological structure formation. It allows for inclusions of all of the critical physical components needed to study galaxy formation—gravity, dark matter dynamics, fluid dynamics, the microphysics of plasmas, and prescriptions for star formation and feedback—and to do so using a tool that can scale to large numbers of CPUs. All analysis was done with the program **yt**.

Results & Impact

- While stellar-mass black holes are not capable of growing into billion-solar-mass objects by the time that they can be observed (a billion years after the Big Bang), it is possible for massive gas clouds to directly collapse into much more massive objects that can easily seed black holes.
- Simulations show that increased physical resolution in the circumgalactic medium is incredibly important. Increasing the resolution by more than an order of magnitude beyond previous state-of-the-art calculations resulted in the appearance of both spatial and chemical features that are seen in observations but not in previous models.

Why Blue Waters

Blue Waters is the only machine available to the academic community that fits all of the requirements for this research, which involves simulations to properly model galaxies in both the early universe and the present day: large memory and disk space, high bandwidth and low-latency communication.