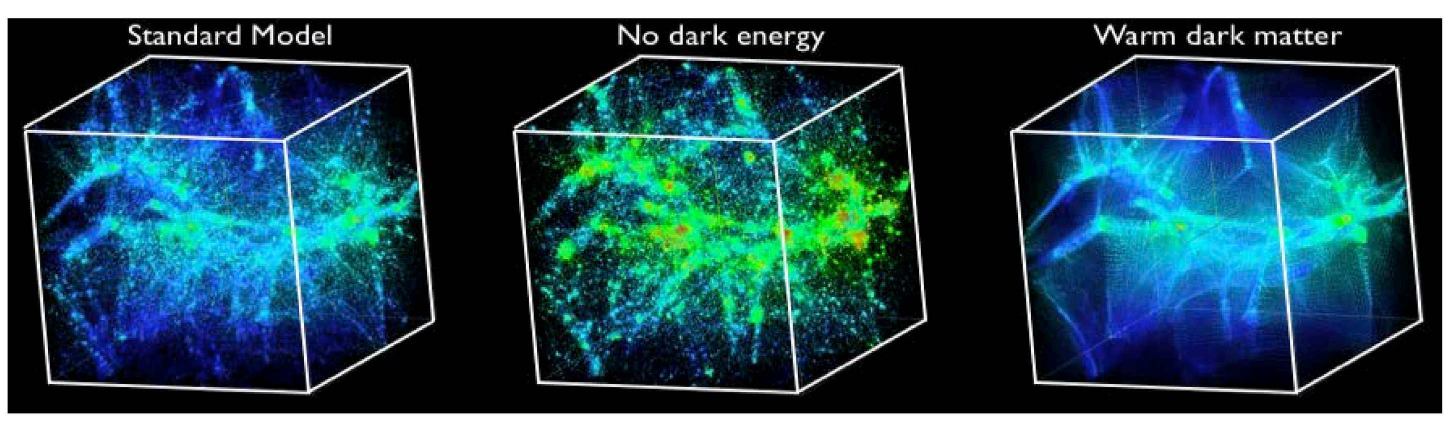
SciDAC Project: Computation-Driven Discovery for the Dark Universe

Project Director: Salman Habib (ANL)

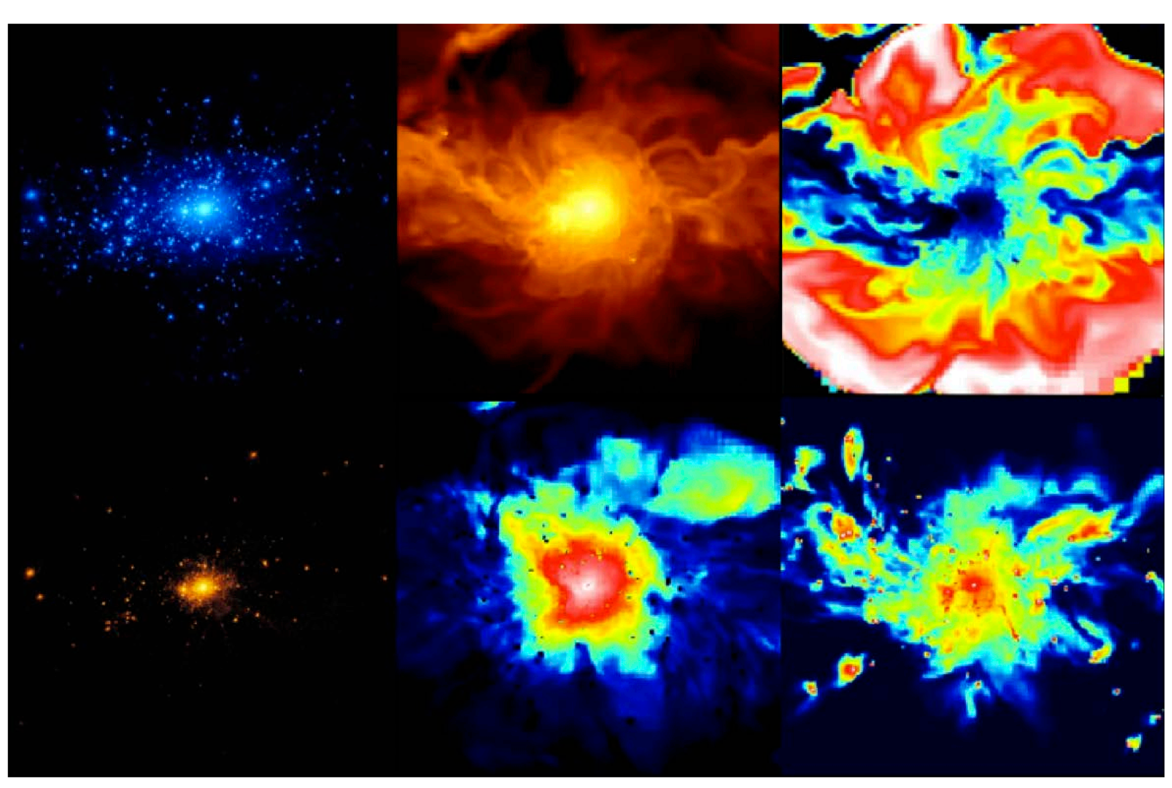
PIs: Katrin Heitmann (ANL), Anze Slosar (BNL), Scott Dodelson (FNAL), Peter Nugent (LBNL), James Ahrens (LANL), Risa Wechsler (SLAC/Stanford)

The Cosmic Frontier presents fundamental discovery opportunities related to dark energy, dark matter, the masses of neutrinos and their hierarchy, and unique probes of inflation and the early Universe. Large-scale surveys of the sky across multiple wavebands are collecting massive amounts of data that hold the key to a deeper understanding of the Universe. High performance computing is a powerful tool of discovery in extracting insights and making precision predictions for these observations. Our new SciDAC Partnership project brings together a National Laboratory-based collaboration – in partnership with the SciDAC Institutes – to build next generation computational cosmology prediction and analysis frameworks that are directly targeted to current and future observations.

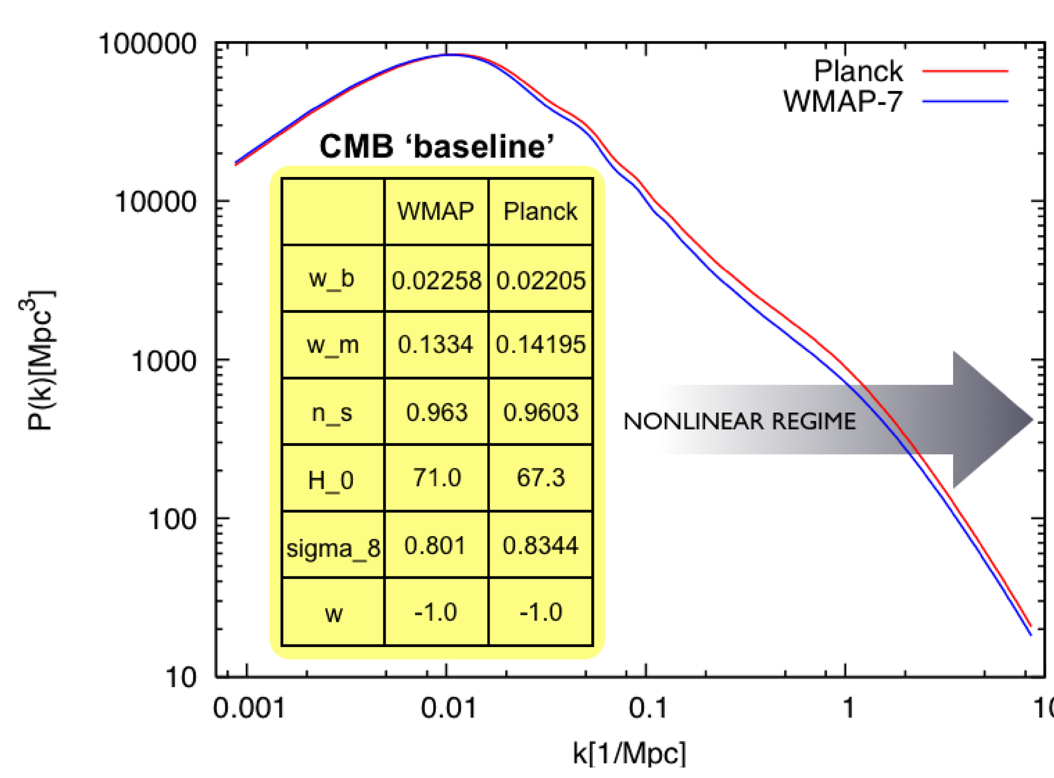
Argonne NATIONAL LABORATORY · BERKELEY LAB · BROOKHAVEN NATIONAL LABORATORY · Fermilab · SLAC NATIONAL ACCELERATOR LABORATORY · Los Alamos NATIONAL LABORATORY EST.1943 · FASTMATH · QUEST · SDAV



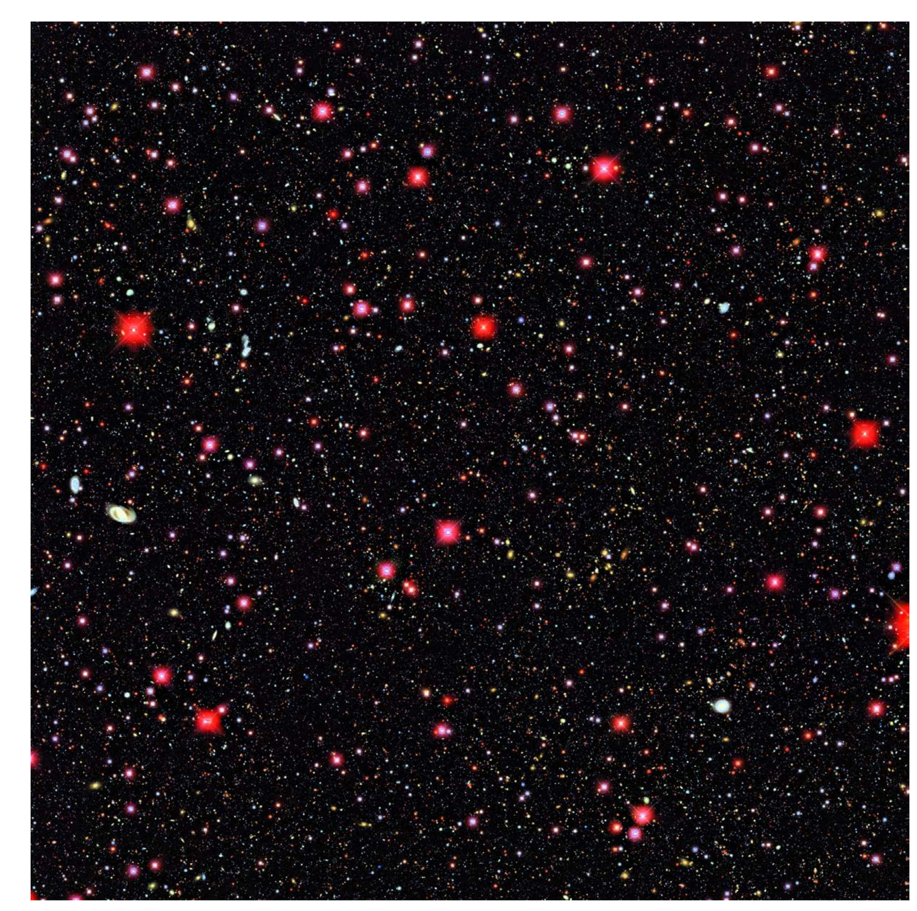
Simulated dark matter distribution for different cosmological models (colors represent velocity magnitudes), demonstrating the sensitivity of large scale structure to new physics.



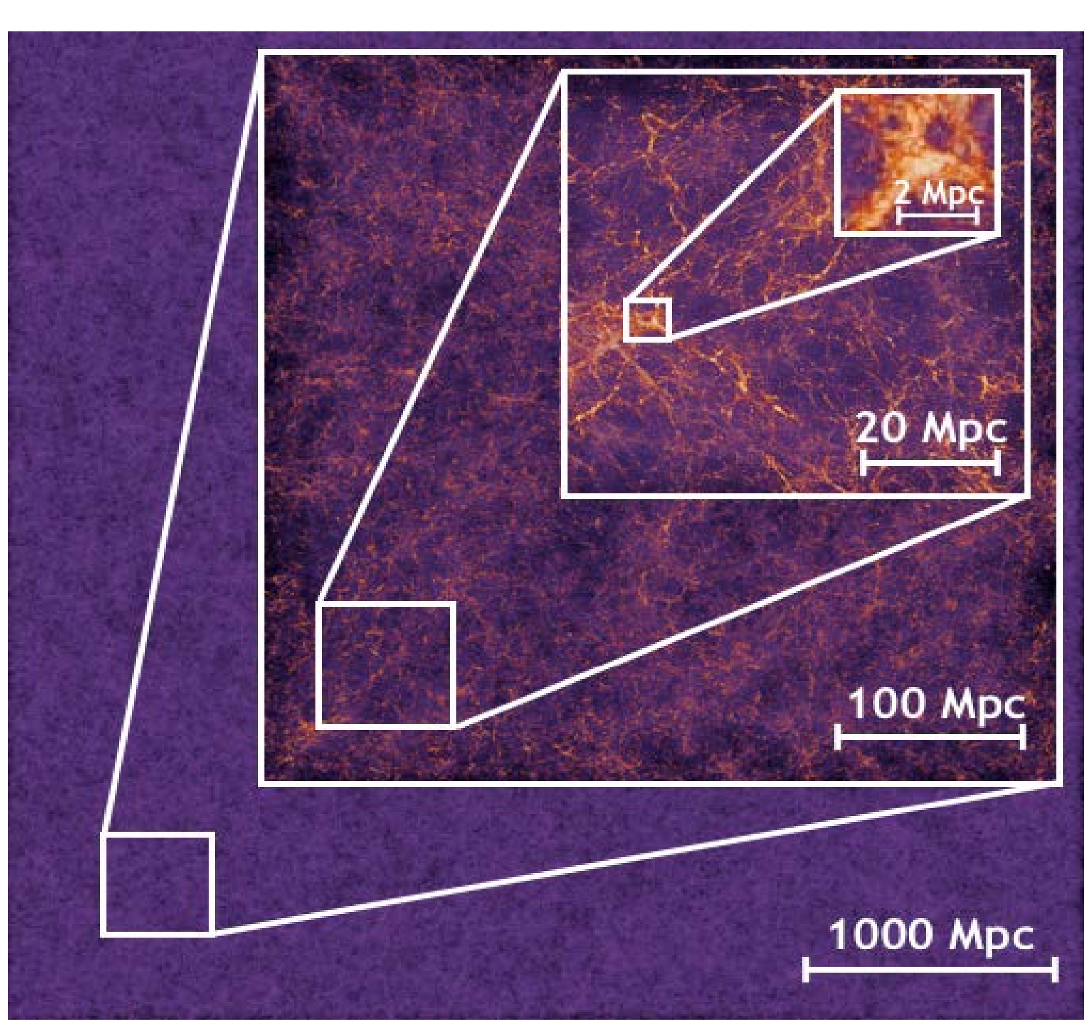
Cluster simulation with the ART (Adaptive Refinement Tree) code. Left to right: dark matter density, gas density, entropy (top panels); stars, metallicity, gas temperature (bottom panels).



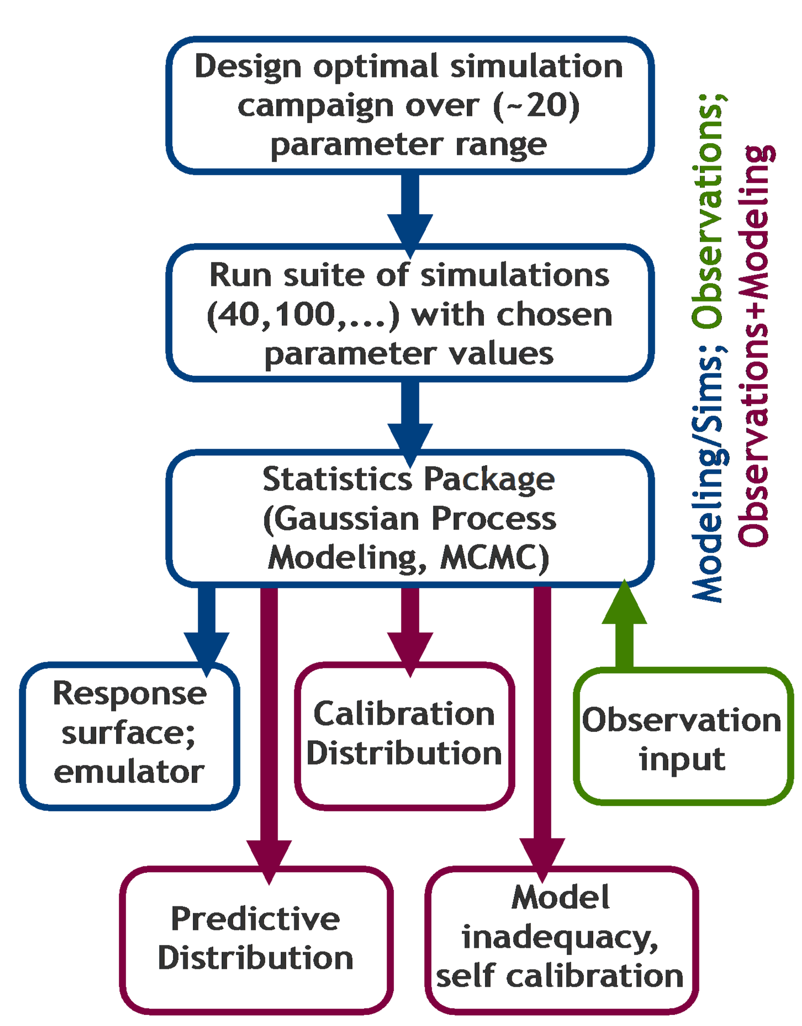
Nonlinear matter power spectrum prediction for the Planck results compared to WMAP-7 using the accurate emulator technology co-developed with members of QUEST.



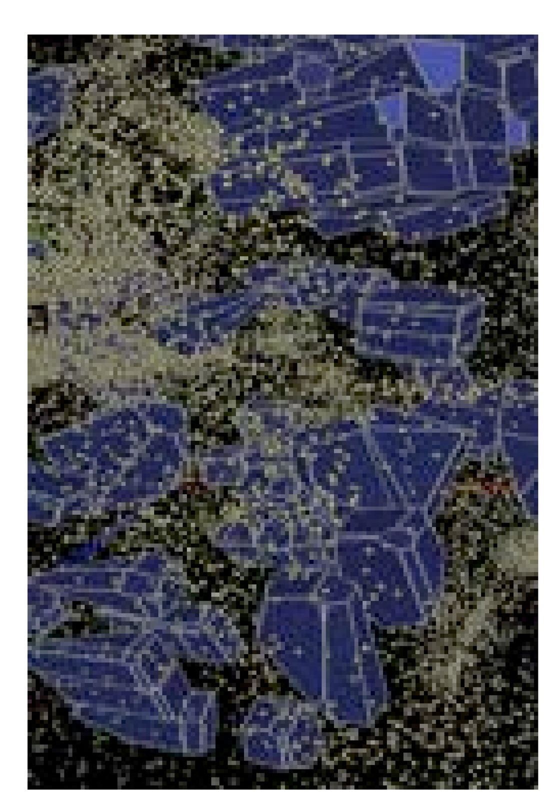
A patch of the sky as seen by the Deep Lens Survey (DLS) covering an area roughly equivalent to that of the full moon. The Large Synoptic Survey Telescope (LSST) will not only go deeper but it will cover an area 50,000 times that of this image.



Density field in a 1.07 trillion particle simulation with the HACC (Hardware/Hybrid Accelerated Cosmology Code) framework (2012 and 2013 Gordon Bell Award Finalist) on Mira at Argonne. HACC runs at full scale on all architectures, including Titan at Oak Ridge.



The Cosmic Calibration Framework developed in collaboration with QUEST enables the solution of previously intractable cosmic inverse problems even with large numbers of parameters and sparse sampling.



Simulations run under this SciDAC-3 project will generate very large volumes of data -- so large that it is not possible to store the raw data and post-process it. Consequently, an *in situ* analysis and visualization capability including data reduction and compression is being developed in collaboration with SDAV. Shown on the left is an *in situ* Voronoi tessellation used to characterize voids in a cosmological simulations, implemented using the DIY library developed and supported by SDAV.

The Titan and Mira systems at Oak Ridge and Argonne; HACC runs at extreme performance on both architectures.

Next-Generation N-Body Code Framework and Tools:
- HACC framework development/deployment
- New generation of analysis tools
- New parallel multi-scale initializer
- Large-volume, multi-probe simulation campaign

Next-Generation Cosmological Hydrodynamics Codes
- ART scalability improvement
- Nyx development/deployment
- Ly-alpha power spectrum
- Baryonic effects on weak lensing

Enabling Inference with new UQ techniques
- Cosmic emulator development
- Error control and covariance estimation
- Analysis and visualization of large datsets

Cosmic Frontier Computing Collaboration