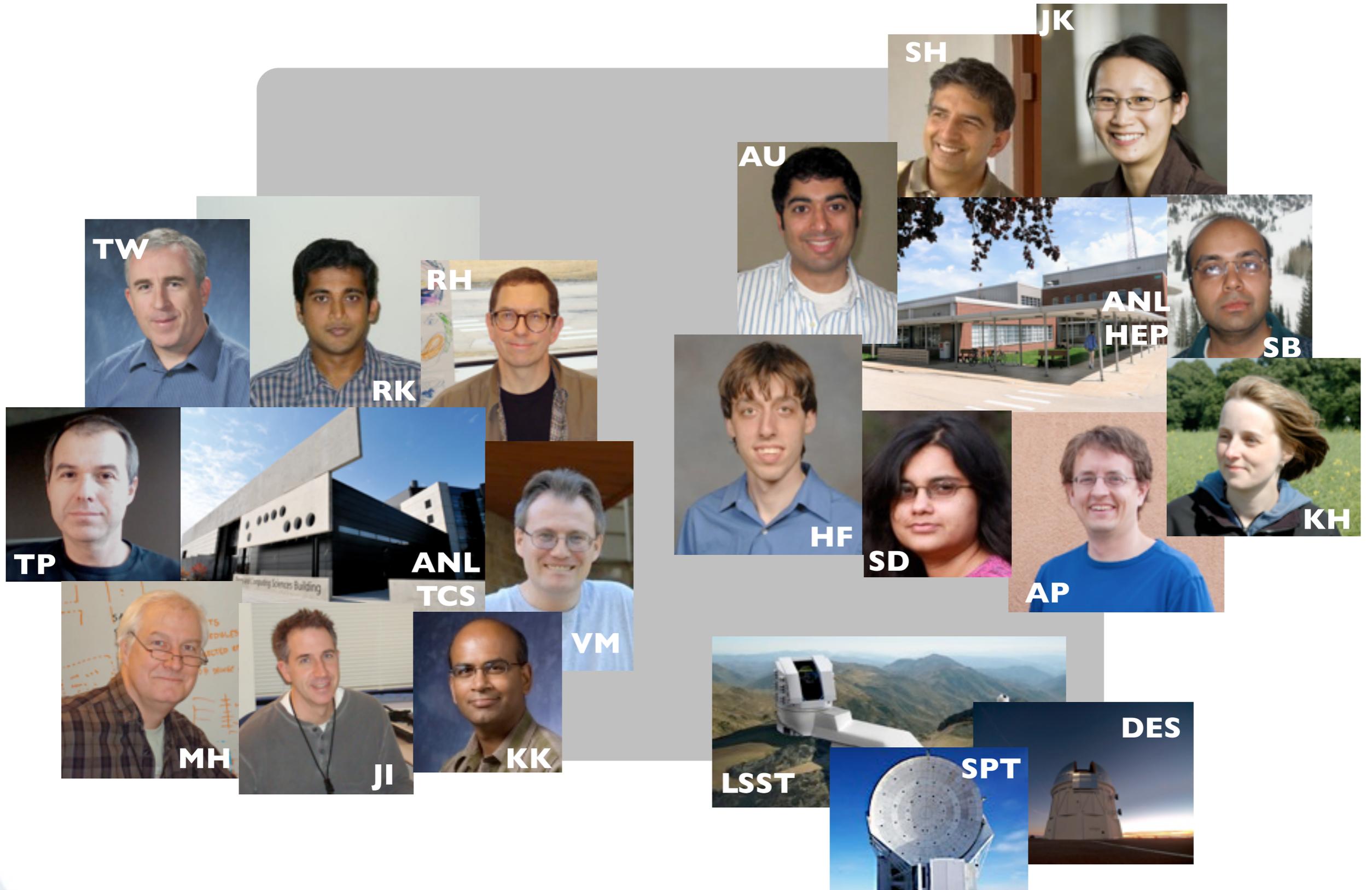


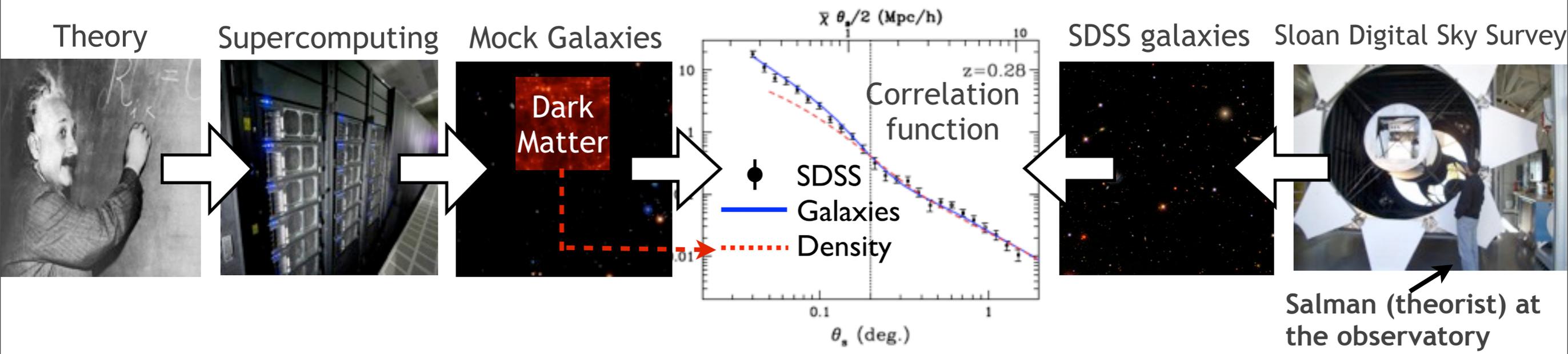
Cosmic Frontier Theory, Analysis & Computation

Katrin Heitmann
High Energy Physics Division
Mathematics & Computer Science Division
Argonne National Laboratory

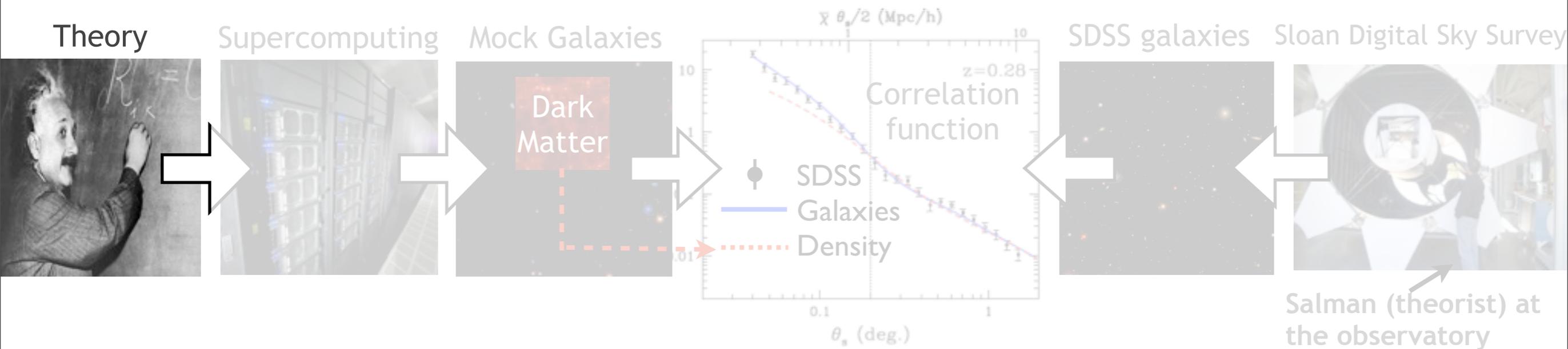
Our Group and our Collaborators in MCS & ALCF Divison



Connecting Theory and Observations: Thrusts of the ANL Cosmic Frontier Theory Group



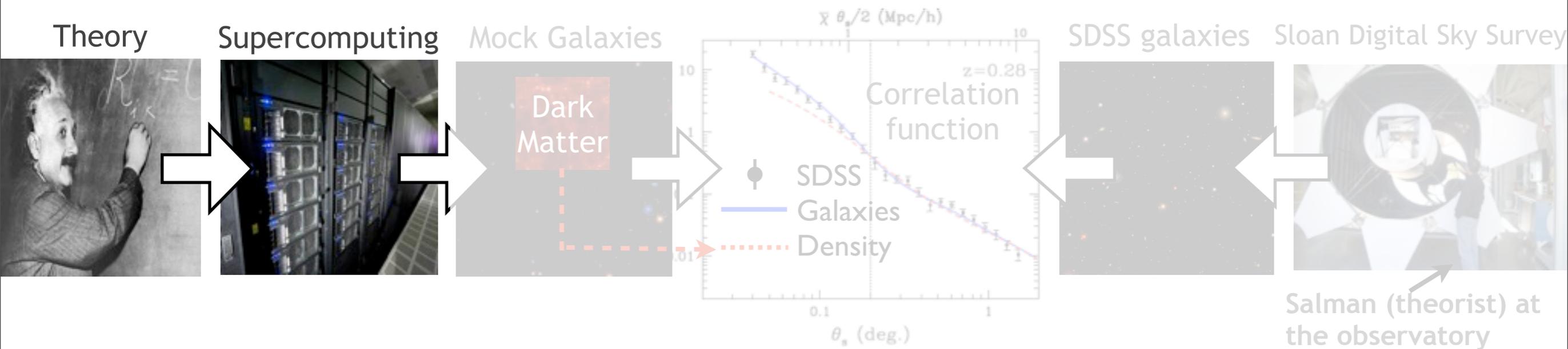
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- **Theory:** Derive signatures of new physics beyond the Standard Model of Cosmology
 - ▶ Inflation, modified gravity, non-gaussianity, neutrinos ... (everybody)
 - ▶ Nonparametric reconstruction of the dark energy equation of state (KH, SH)
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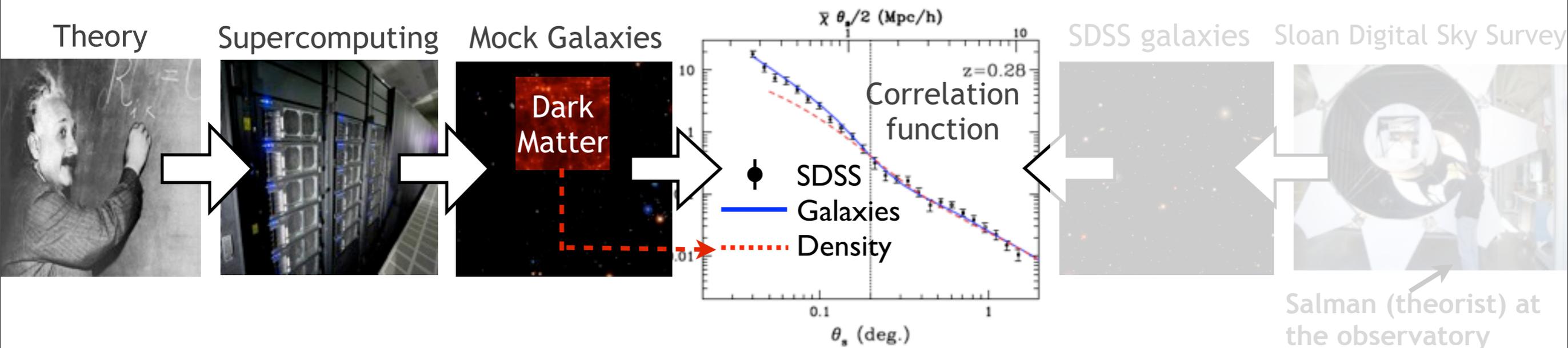
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 - ▶ Port to Argonne's BlueGene systems successfully completed (AP, HF, SH, KH)
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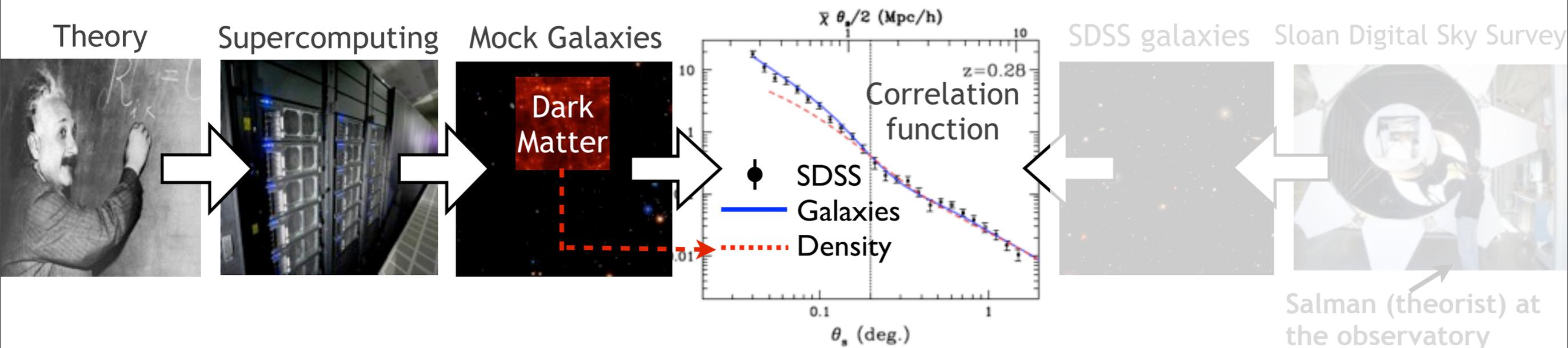
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 - ▶ Cosmic Calibration Framework (KH, SH, JK, SB, SD, AP)
 - ▶ Mock catalogs via different methods (JK, SH, KH, AP)



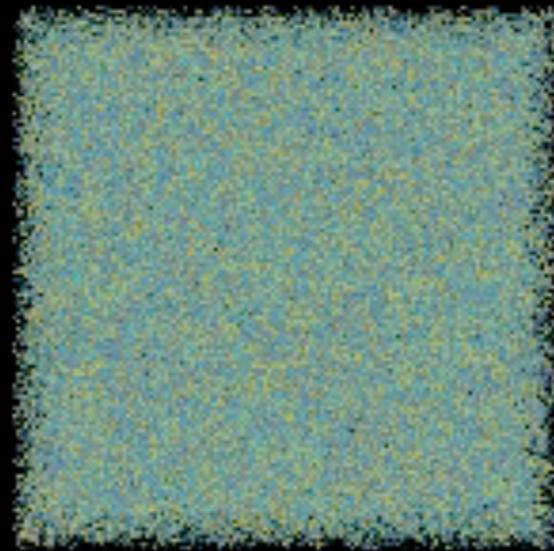
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HACC simulation, 8 billion particle run, 2 Gpc/h volume
HACC design strategy: Straightforward port to diverse set of supercomputing architectures, survey scale simulations in matter of days



Visualization: Joe Insley, Mark Hereld, Mike Papka

HACC Port to the BG/Q Systems

- H(ardware) A(ccelerated) C(osmology) C(ode) port is making *very* good progress
- Very good performance on VEAS (Very Early Access System), 1 rack, 1024 nodes
- Test runs up to 16 racks at IBM:

Creating rho(x,y,z)	3	39.77	17.78
Poisson solve	3	51.94	23.23
Particle move	3	2.04	0.9123
Output	3	0.53	0.237

PXCH buffer = $2 * 1943590 = 3.707104$ MB
InitialExchange TotalAliveParticles 1073741824000

One trillion+ particles!

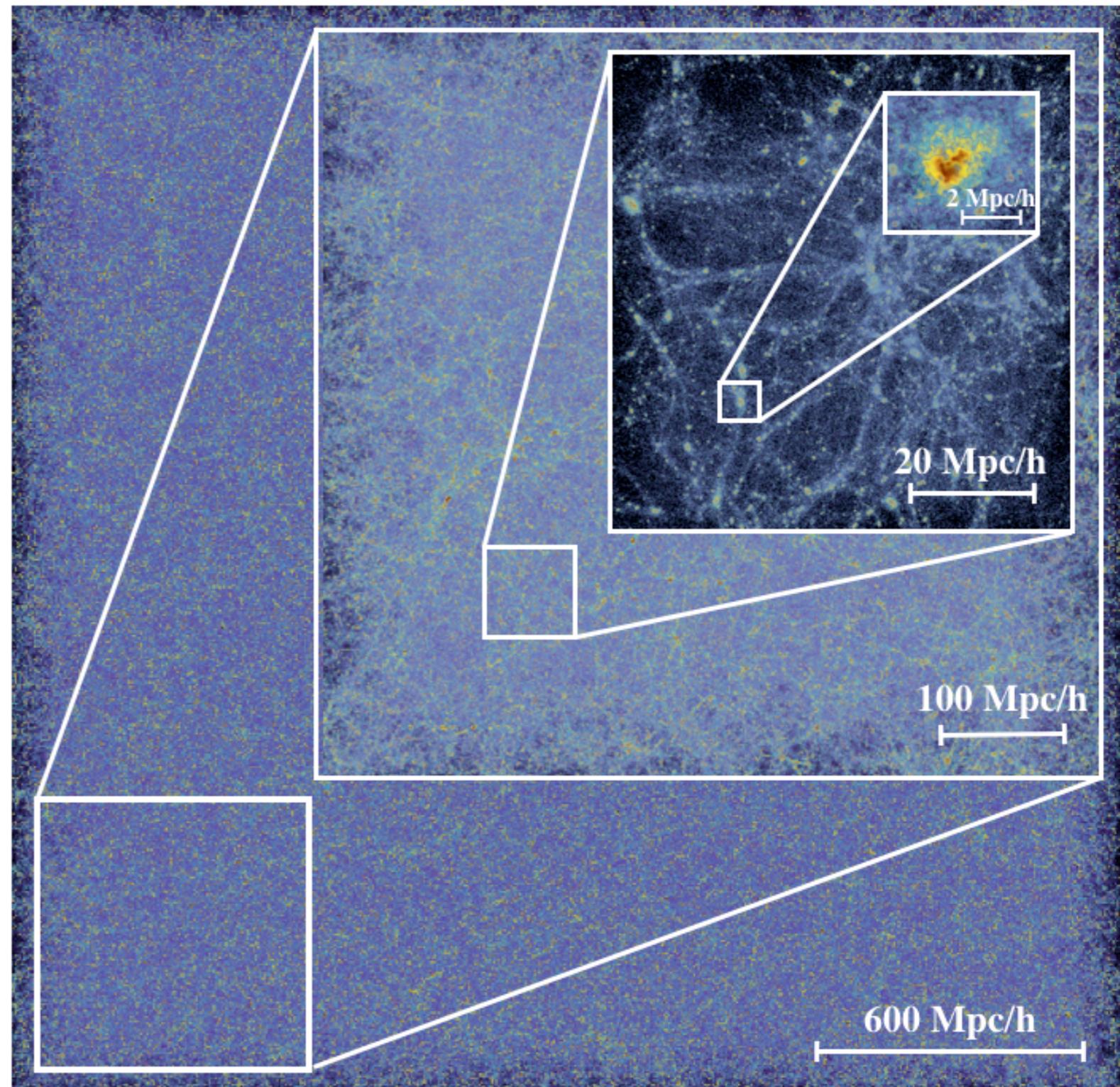
(largest cosmology run in the past:
~300 billion particles)

- Mira, ALCF's new BG/Q, will have 48 racks, our group has 150 Mill CPU hours as part of Early Science Projects



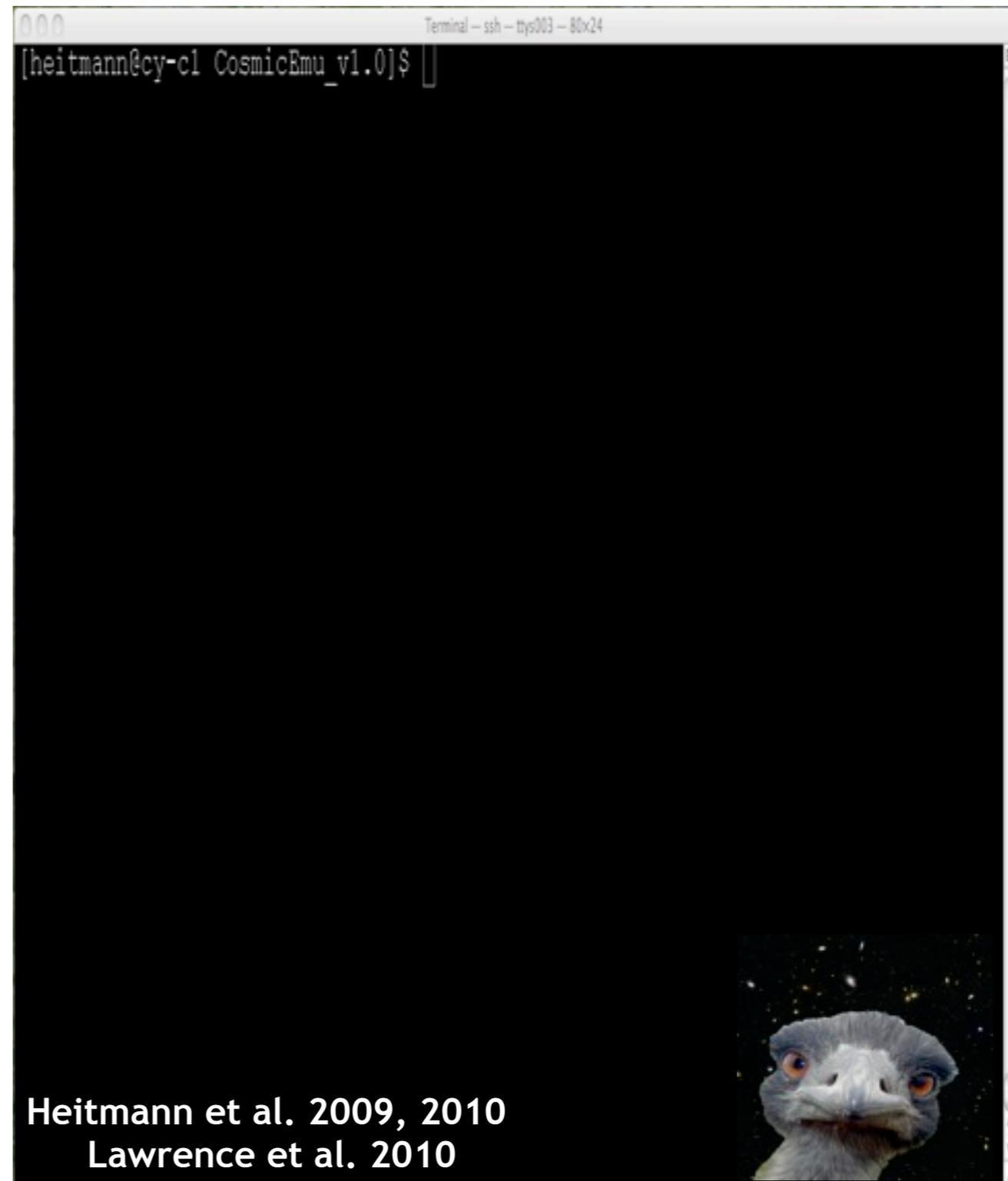
HACC Port to the BG/Q Systems

- **First science simulation on the Very Early Access System (VEAS) at ANL**
 - ▶ 68 billion particle simulation in 2.4 Gpc/h volume, 5 kpc/h force resolution
- **As part of the ESP: create the “Mira Universe”**
 - ▶ ~100 models varying 10 cosmological parameters
 - ▶ Close collaboration with surveys (DES/LSST) to make simulation suite most useful
- **Submission for Gordon Bell award for excellent performance, fast time to solution (one of the most prestigious awards in HPC world)**

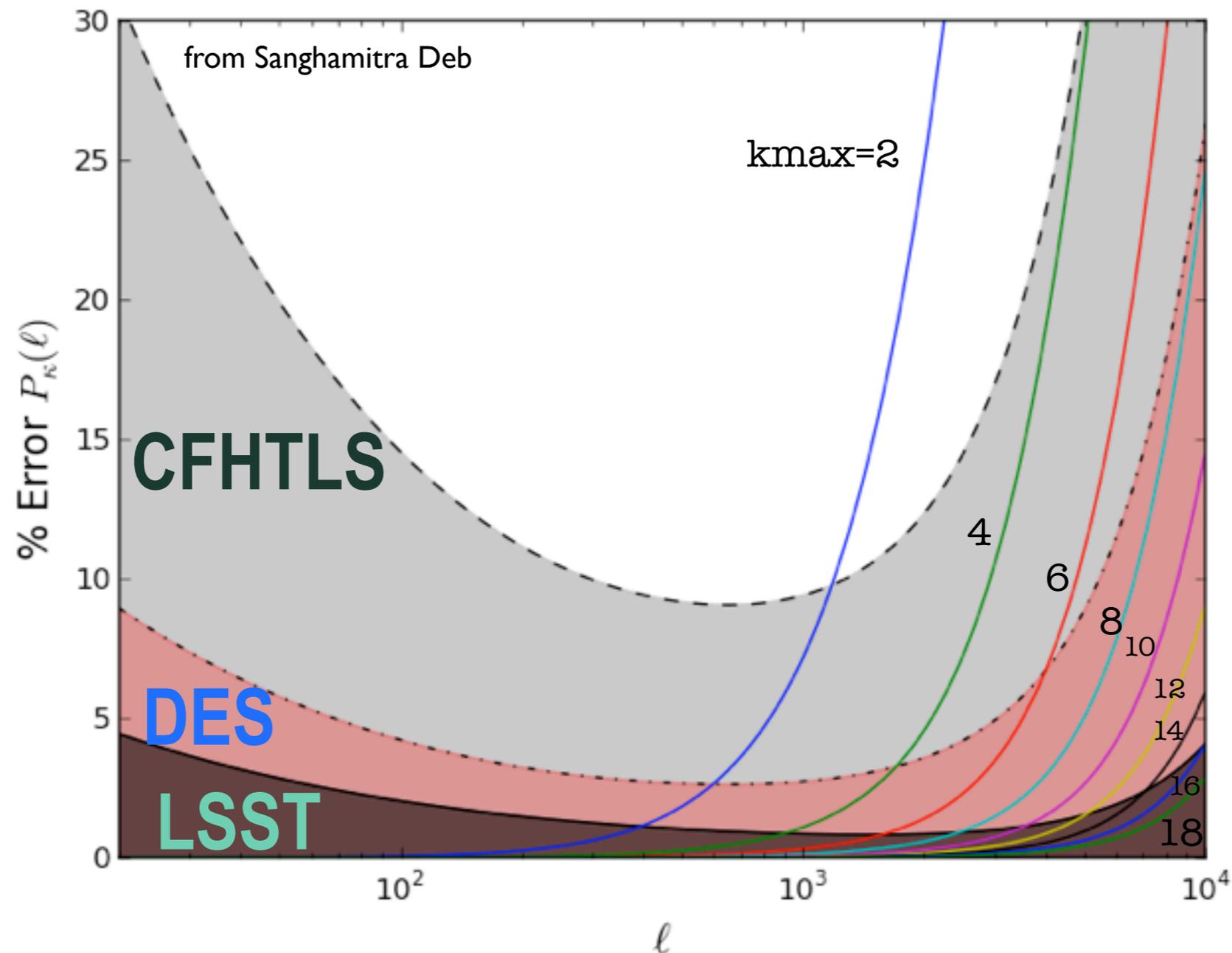


Cosmic Calibration Framework -- LSSFast

- Analysis of large scale structure data via MCMC requires 10,000 - 100,000 model predictions
- Brute force approach (i.e. simulation): with 24/7 access to 2000 node compute cluster analysis would take ~30 years
- Equivalent to CAMB for CMB analysis we need “LSSFast” for diverse set of large scale structure probes
- Our group has developed the Cosmic Calibration Framework
 - ▶ High-precision predictions from limited number of simulations
 - ▶ Sophisticated statistical framework based on advanced design and interpolation methods
- Demonstrated for matter power spectrum, now extensions to:
 - ▶ Shear power spectra
 - ▶ Concentration mass relation
 - ▶ Velocity power spectra



CCCF -- Weak Lensing Requirements



- Question: to what wavenumber do we need an accurate prediction of the matter power spectrum to generate a shear-power spectrum for e.g. DES?
- In collaboration with DES lensing team: Extension of the current emulator out to higher wavenumbers and redshifts
- In future: baryonic effects



Summary

- **Highlights of Scientific Developments:**
 - ▶ Great progress with HACC framework and integrated analysis tools, including weak lensing, N-point functions, velocity power spectra, halo/sub-halo finding...
 - ▶ Extension of Cosmic Calibration Framework tools in close collaboration with DES weak lensing group
 - ▶ Combination of CCF and HACC provides powerful tool for extracting signatures of new physics beyond the Standard Model from ongoing and upcoming surveys
- **General Accomplishments:**
 - ▶ DES and LSST membership in progress, collaboration with SPT
 - ▶ 17 publications (some still under review), several more close to completion
 - ▶ 31 talks (27 invited, 12 invited talks by postdocs)
- **New Initiatives:**
 - ▶ Cosmic Frontier Computational Cosmology (CFCC): Collaboration between 5 HEP Labs (ANL, BNL, Fermilab, LBNL, SLAC), S. Habib spokesperson
 - ▶ Pilot project on “Analysis and Surviving of Data from Large Scale Cosmological Simulations” at NERSC/LBNL
 - ▶ Early Science Project on Mira



Publications

- Amol Upadhye, Jason H. Steffen, and Aaron S. Chou, "Designing dark energy afterglow experiments", ePrint arXiv:1204.5476 (2012)
- Amol Upadhye, Wayne Hu, and Justin Khoury, "Quantum Stability of Chameleon Field Theories," ePrint arXiv:1204.3906, submitted to PRL (2012)
- O.K. Baker, A. Lindner, Y.K. Semertzidis, A. Upadhye, K. Zioutas, "Detection of radiation pressure from solar chameleons," ePrint arXiv:1201.6508 (2012)
- Keith Baker, Axel Lindner, Amol Upadhye, Konstantin Zioutas, "A chameleon helioscope," ePrint arXiv:1201.0079 (2012)
- Suman Bhattacharya, Daisuke Nagai, Laurie Shaw, Tom Crawford, Gilbert Holder, "Bispectrum of the Sunyaev-Zel'dovich Effect", ePrint arXiv: 1203.6368
- Suman Bhattacharya, Salman Habib, Katrin Heitmann, "Dark Matter Halo Profiles of Massive Clusters: Theory vs. Observations", ePrint arXiv: 1112.5479
- Juliana Kwan, Geraint Lewis, Eric Linder, Mapping Growth and Gravity with Robust Redshift Space Distortions, ApJ 748, 78 (2012)
- Sanghamitra Deb, Andrea Morandi, Kristian Pedersen, Signe Riemer-Sorensen, David Goldber, Hakon Dahle, "Mass Reconstruction using Particle Based Lensing, ePrint arXiv:1201.3636
- Matthew R. Norman, Hal Finkel. "Multi-Moment ADER-Taylor Methods for Systems of Conservation Laws with Source Terms in One Dimension," 2012. (accepted for publication in the Journal of Computational Physics, 2012)
- Hal Finkel, "An Iterated, Multipoint Differential Transform Method for Numerically Evolving PDE IVPs," 2011. arXiv:1102.3671 (accepted for publication in the Journal of Computational Science & Discovery (2012)



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- Salman Habib, Vitali Morozov, Hal Finkel, Adrian Pope, Katrin Heitmann, Kalyan Kumaran, Tom Peterka, David Daniel, Patricia Fasel, Nicholas Frontiere, Zarija Lukic, “The Universe at Extreme Scales: Multi-PetaFlop Sky Simulations on the BG/Q”, submitted for Gordon Bell competition
- Tom Peterka, Juliana Kwan, Adrian Pope, Hal Finkel, Katrin Heitmann, Salman Habib, “Meshing the Universe: Identifying Voids in Cosmological Simulations Through In-situ Voronoi Tessellation”, submitted to Pacific Vis
- Sergei Shandarin, Salman Habib, Katrin Heitmann, “The Cosmic Web, Multi-Stream Flows, and Tessellation”, Phys. Rev. D85, 083005 (2012)
- Tracy Holsclaw, Ujjaini Alam, Bruno Sanso, Herbie Lee, Katrin Heitmann, Salman Habib, David Higdon, “Nonparametric Reconstruction of the Dark Energy Equation of State from Diverse Data Sets”, Phys. Rev. D84, 083501 (2011)
- Uliana Popov, Eddy Chandra, Katrin Heitmann, Salman Habib, James Ahrens, Alex Pang, “Analyzing the evolution of large scale structures in the universe with velocity based methods”, Pacific Visualization Symposium (PacificVis), 2012 IEEE
- Tracy Holsclaw, Bruno Sanso, Herbie Lee, David Higdon, Katrin Heitmann, Ujjaini Alam, Salman Habib, “Gaussian Process Modeling of Derivative Curves”, Technometrics (2012)
- David Higdon, M. Pratola, J. Gattiker, C. Jackson, M. Tobis, S. Habib, K. Heitmann, S. Price, “Computer Model Calibration Using The Ensemble Kalman Filter”, Technometrics, submitted.

