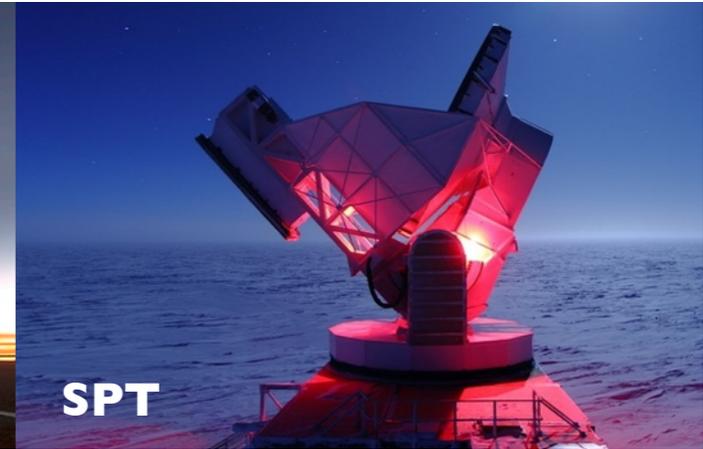


ANL Cosmic Frontier Theory Group

Salman Habib
HEP and MCS Divisions
Argonne National Laboratory

Dark Energy
Dark Matter
Neutrinos
Inflation



ANL Cosmic Frontier Theory Group & Collaborators

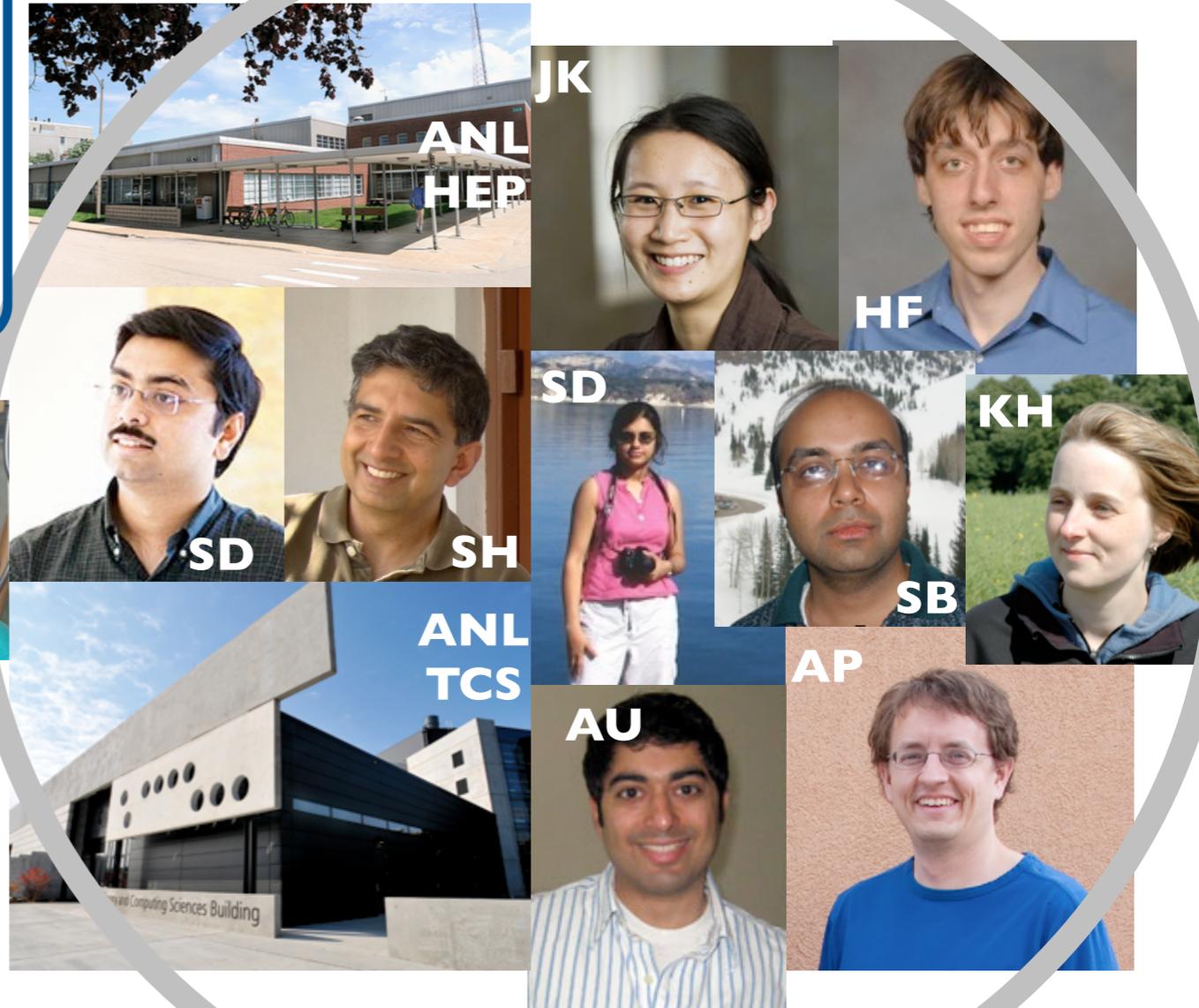
HEP staff:

Salman Habib, Katrin Heitmann

Post-docs:

Lindsey Bleem, Sanghamitra Deb, Sudeep Das, Juliana Kwan, Adrian Pope, Amol Upadhye (HEP), Suman Bhattacharya (HEP/Chicago), Hal Finkel (ALCF)

Students: Brandon Chiarito (Chicago), Nick Frontiere (UCLA), Jay Takle (Rutgers)



Argonne Leadership Computing Facility staff:
 Mark Hereld, Joe Insley, Vitali Morozov,
 Tom Peterka, Venkatram Vishwanath,
 Tim Williams, --



Group Support

- **Staff Members**

- Salman Habib (LDRD/HEP)
- Katrin Heitmann (LDRD/HEP/NASA)
- Eve Kovacs (HEP, part-time)

- **Post-Docs**

- Suman Bhattacharya (NASA/NSF)
- Lindsey Bleem (ANL Director's Fellow)
- Sudeep Das (ANL Schramm Fellow)
- Sanghamitra Deb (HEP/LDRD)
- Hal Finkel (ASCR)
- Juliana Kwan (NASA/LDRD)
- Adrian Pope (ANL Compton Fellow)
- Amol Upadhye (ANL Director's Fellow)

- **Students**

- Brandon Chiarito (LDRD)
- Nick Frontiere (LDRD)
- Jay Takle (LDRD)

- **ANL Collaborators**

- Mark Hereld (ASCR)
- Joe Insley (ASCR)
- Vitali Morozov (ASCR)
- Ravi Madduri (HEP)
- Tom Peterka (ASCR/LDRD)
- Venkat Vishwanath (ASCR)

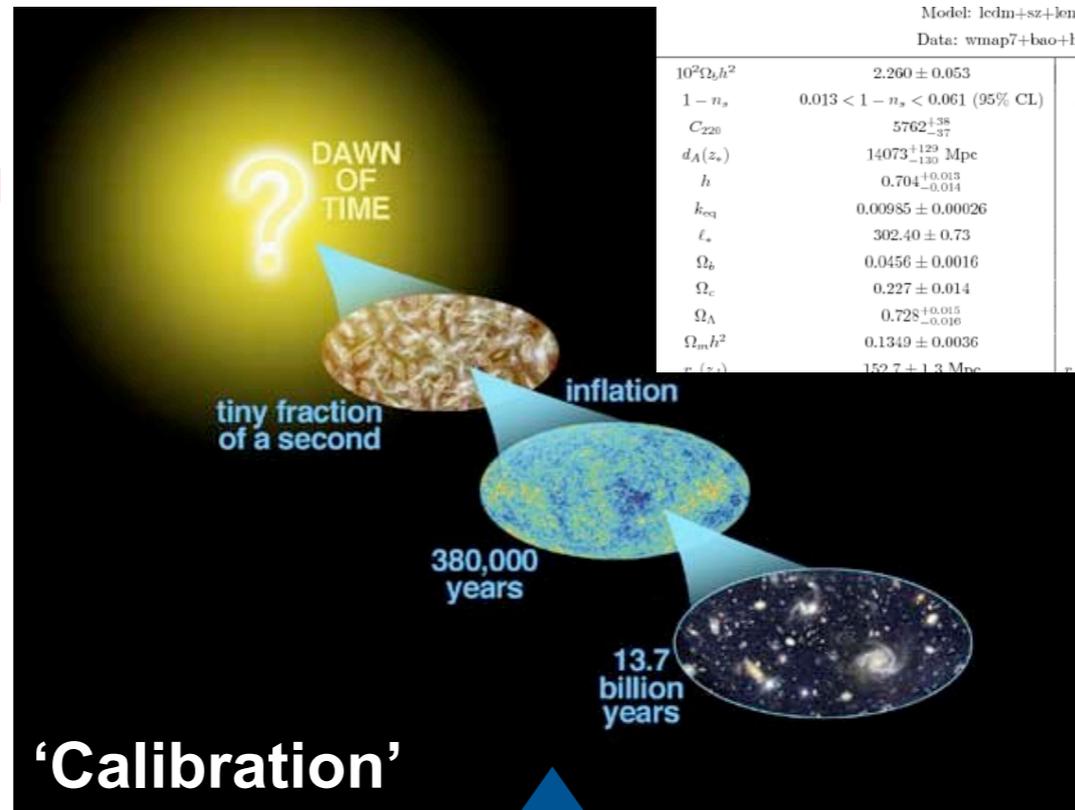
ASCR: Advanced Scientific
Computing Research
LDRD: Lab-Directed R&D



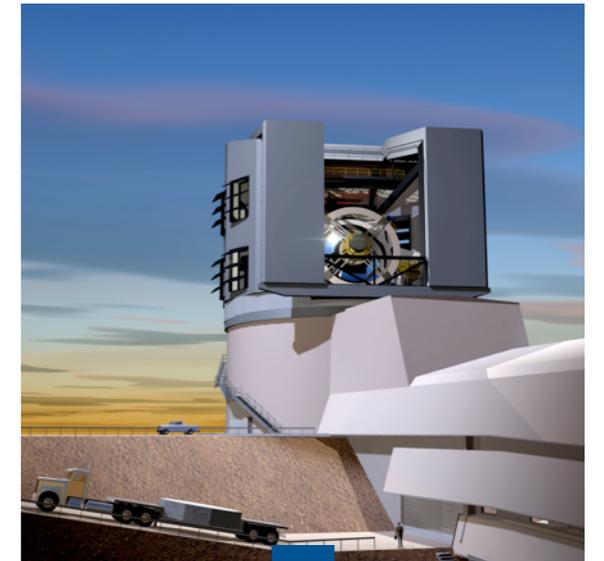
Precision Cosmology: Calibrating the Universe

Supercomputer Simulation Campaign

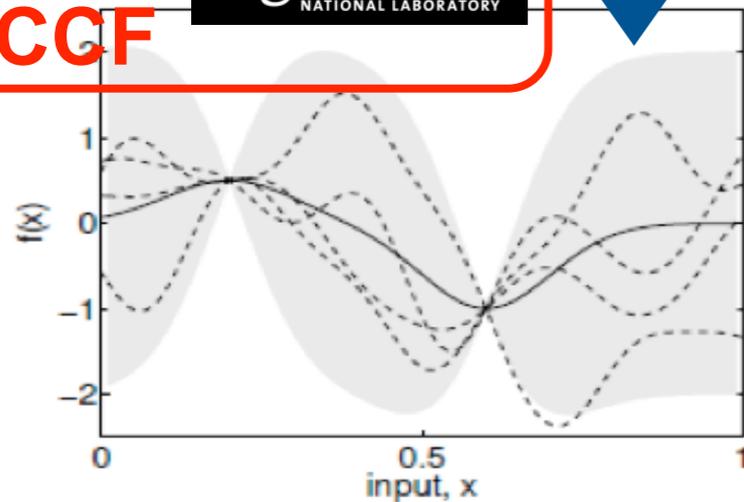
HACC= Hardware/Hybrid Accelerated Cosmology Code Framework



Mapping the Sky with Survey Instruments



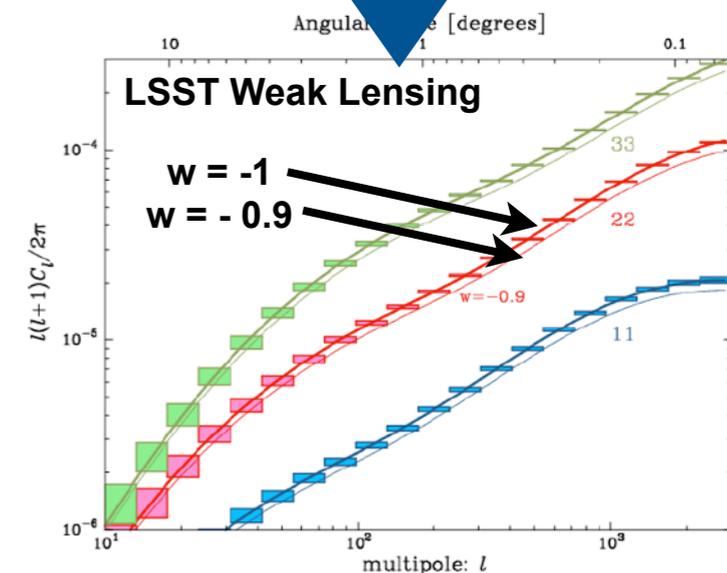
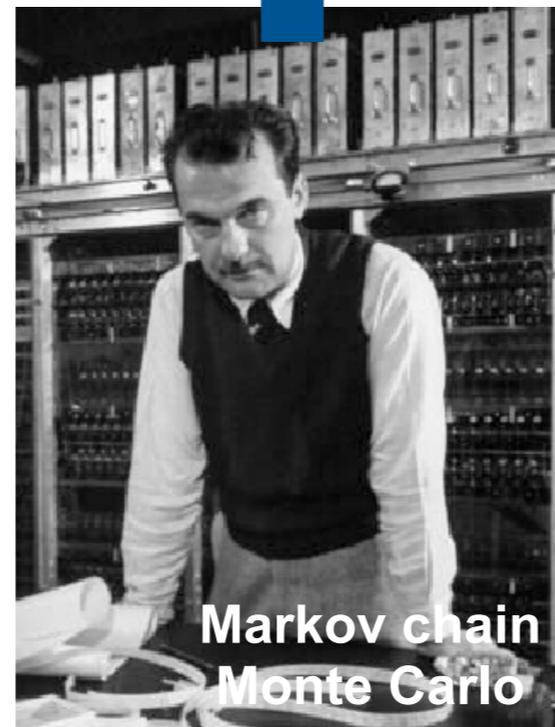
HACC + CCF



'Precision Oracle'

Emulator based on Gaussian Process Interpolation in High-Dimensional Spaces

CCF= Cosmic Calibration Framework

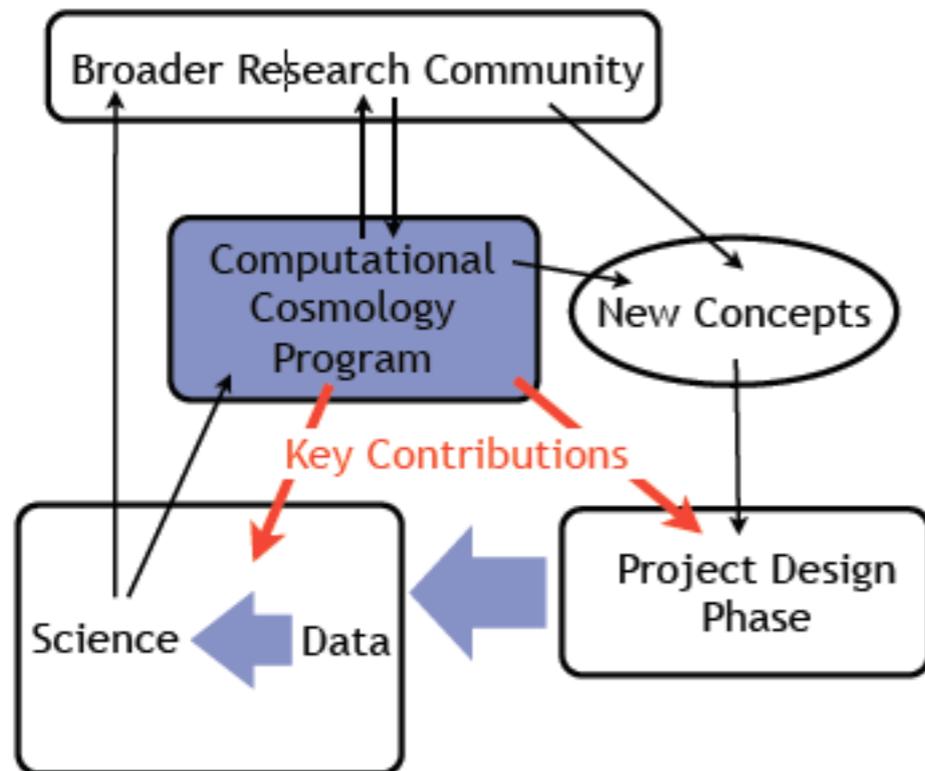


Observations: Statistical error bars will 'disappear' soon!



Cosmic Frontier Theory Group Highlights

- **Establishment of Cosmic Frontier Computing Collaboration, CFCC**



- **New HACC (Hardware/Hybrid Accelerated Cosmology Code) Framework**

- Scales to **'million-core'** systems at very high performance levels
- Finalist for 2012 Gordon Bell Award

- **New SciDAC-3 Project for Computational Cosmology**

- ANL is lead Lab for 'Computation-Driven Discovery for the Dark Universe' project
- HPC as a discovery tool for the Cosmic Frontier; joint development with ASCR

- **ANL joins LSST as Institutional Member**

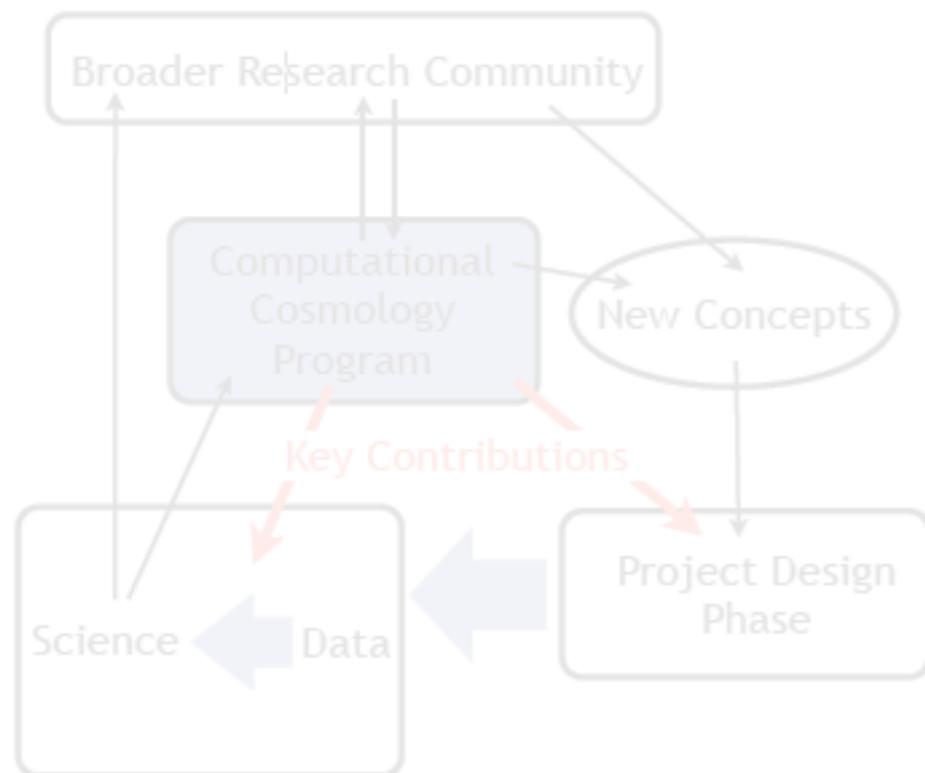
- Large data initiative at Argonne
- Major role for ANL computational cosmology

- **PDACS Project initiated at ANL**

- Cosmological data/analysis services at scale
- ANL/FNAL/LBNL collaboration with university partners
- Hardware support at ANL/JHU/NERSC

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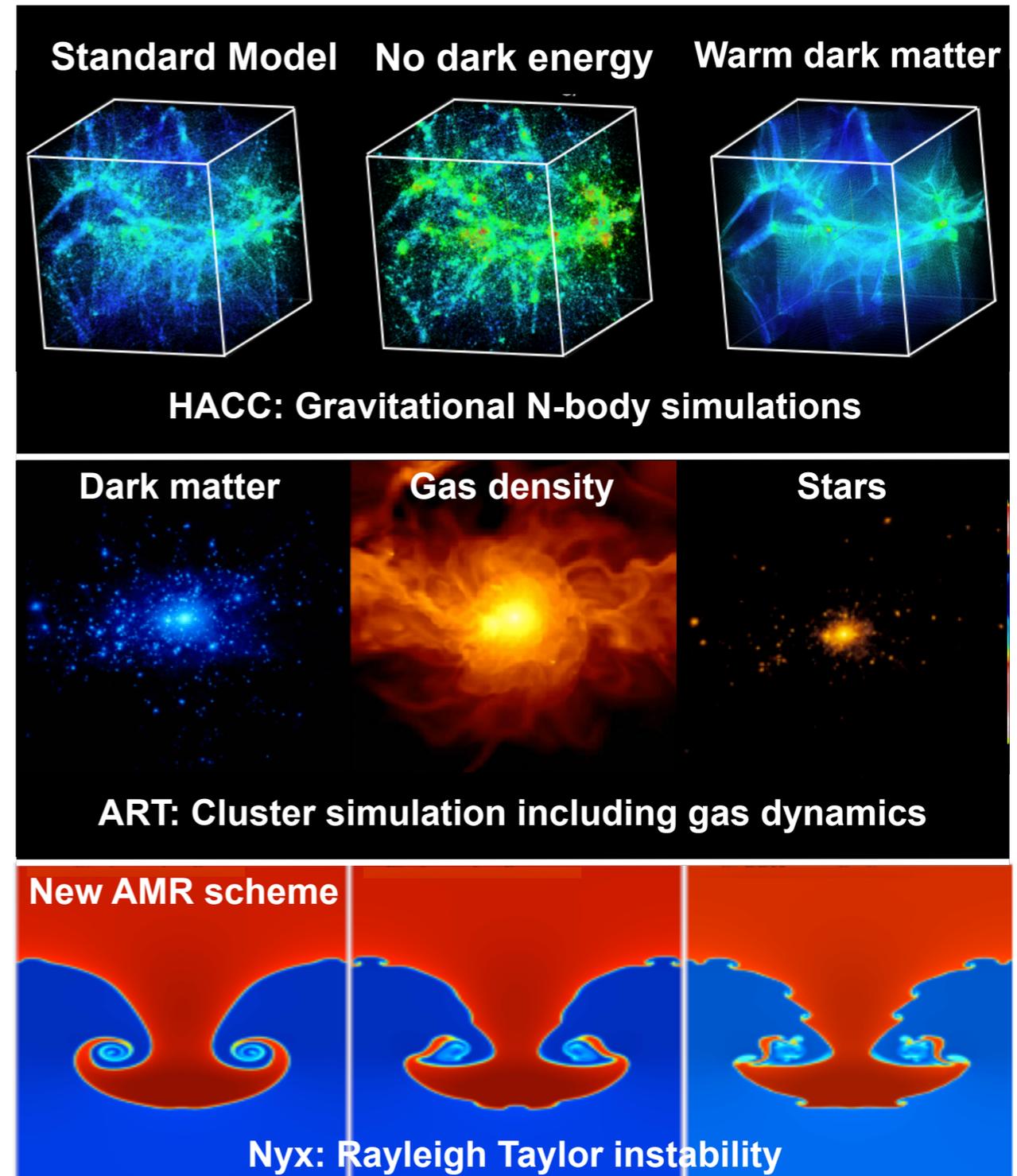
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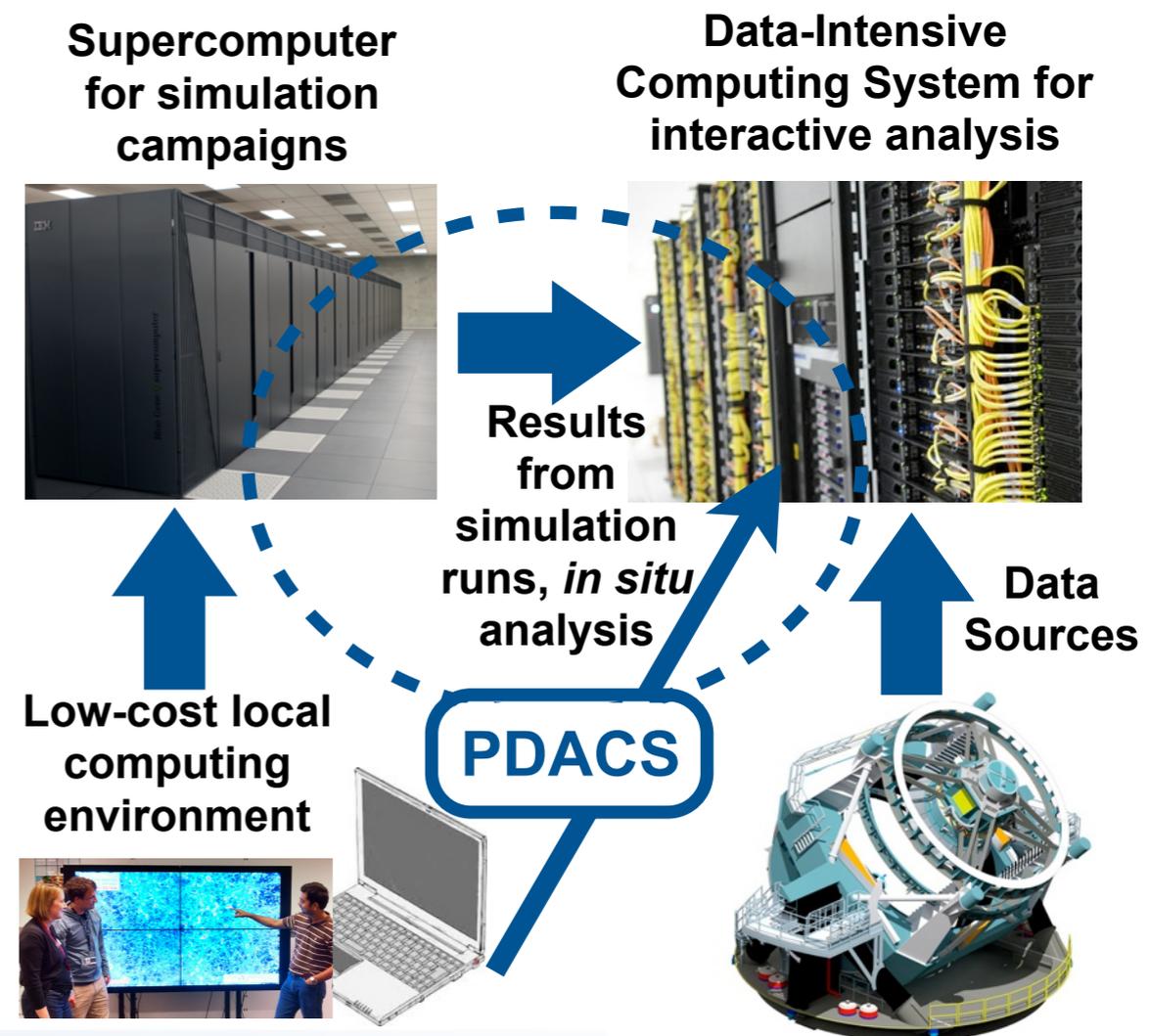
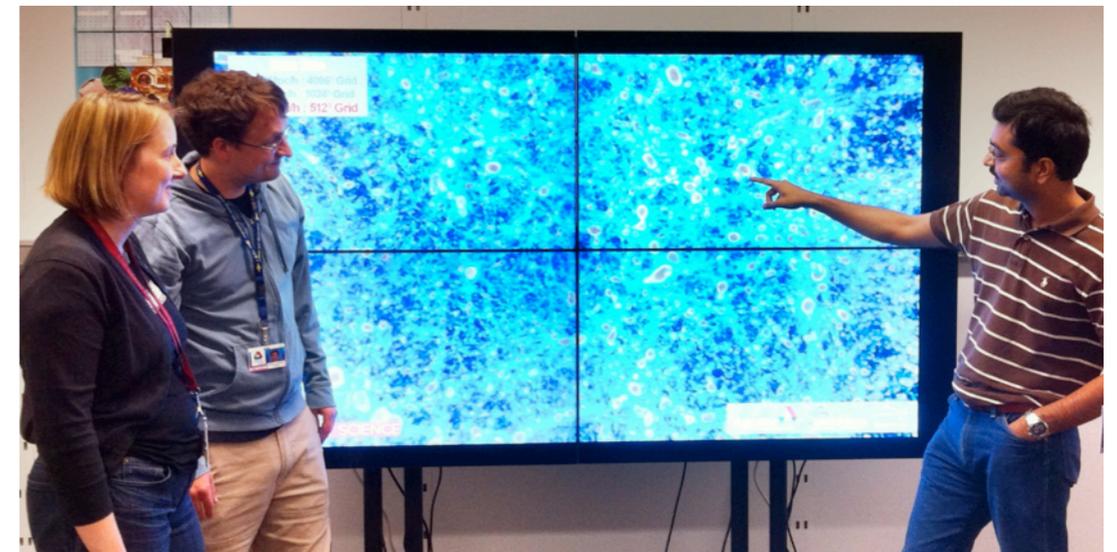
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- **Aims for New SciDAC 3 Project**
 - Build next-generation computational cosmology prediction and analysis frameworks for current and future surveys
 - Explore the physics of dark energy, dark matter, neutrinos, and the early Universe via large-scale structure probes
 - Further development of three large-scale high-performance cosmology simulation codes: HACC (@ANL), ART (@Fermilab), Nyx (@LBNL)
 - Make full use of DOE's Leadership class systems: Mira (ANL), Jaguar/Titan (ORNL), Hopper (NERSC)
- **Connections to ASCR SciDAC Institutes**
 - FastMath (AMR), SDAV (analysis, I/O), QUEST (UQ)



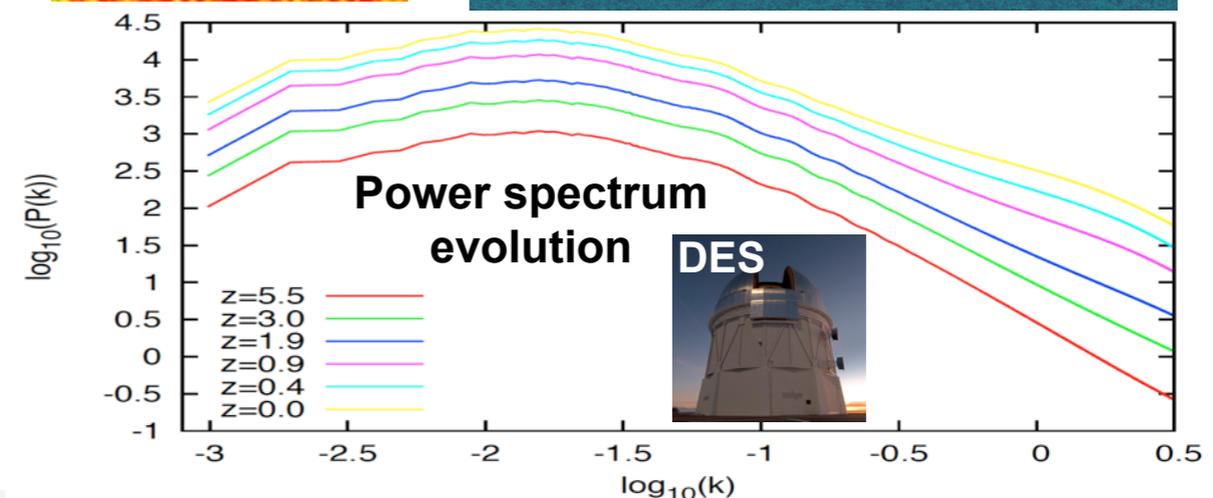
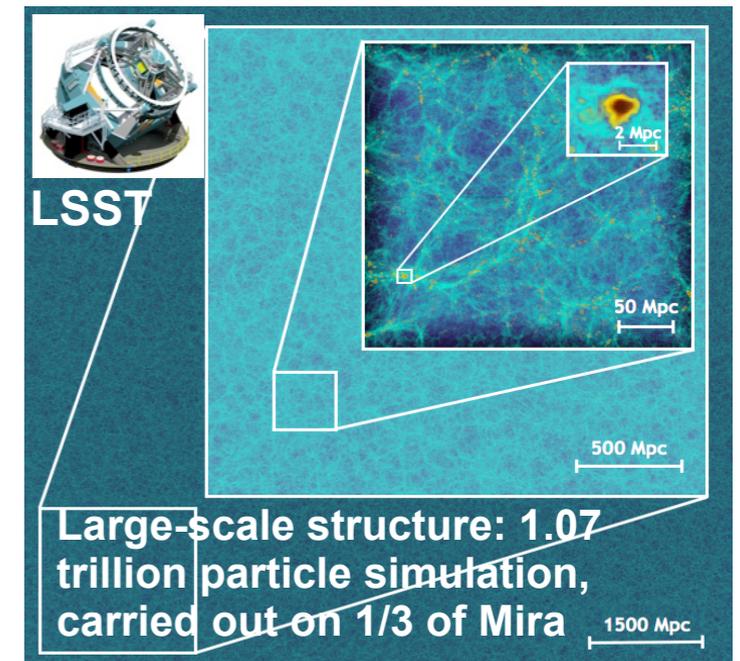
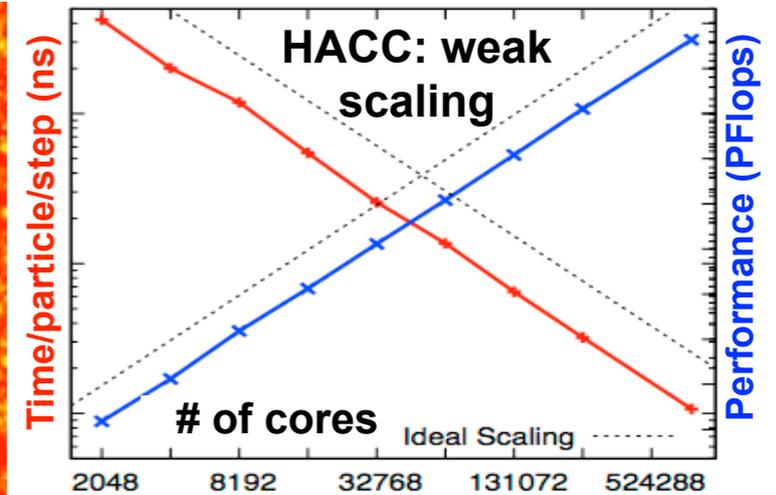
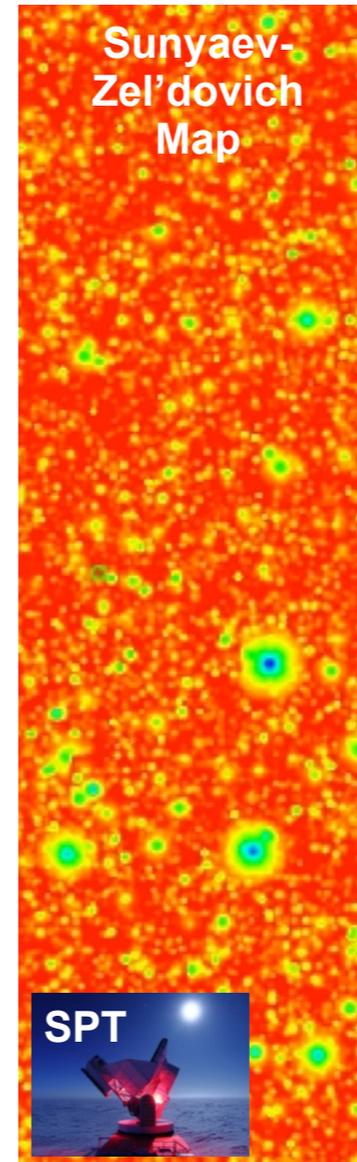
Leadership Computing: HACC Framework

- **Leadership Computing and HEP**
 - Cores available on 3 DOE supercomputers (at ALCF, NERSC, OLCF) = 1.2M (10.5 billion CPU-hrs/year) -- **ALL** of LHC analysis requires ~175K cores (1.5 billion CPU-hrs/year)
 - Our planned allocation for computational cosmology with HACC is similar in scale to that for ATLAS analysis worldwide (200+ million CPU-hrs/year)
- **HACC: Awarded Early Science Project on Mira (150M CPU hours) to create “Mira Universe”**
 - ~100 models varying 10 cosmological parameters, close collaboration with surveys (DES/LSST/BOSS) to make simulation suite most useful
- **ALCC (ASCR Leadership Computing Challenge) Award for Neutrino Cosmology**
 - Precision simulations for probing neutrino masses/species with large-scale structure probes (DES/SPT)



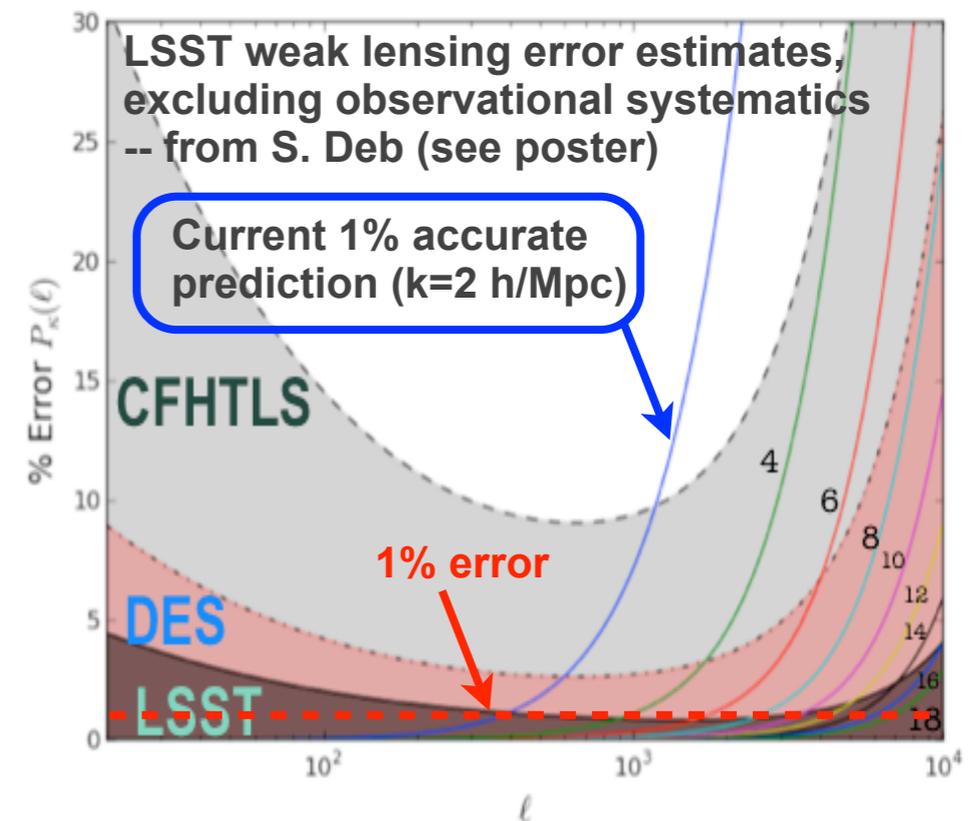
HACC Overview

- **Next-Generation Surveys and N-body Simulations**
 - High-resolution, multi-trillion particle simulations -- scaling to the million-core level required
 - Other codes (e.g., Gadget, now used for DES) scale to ~10K cores -- do not meet requirements
- **HACC: Meets Survey Requirements Today**
 - Only cosmology code world-wide to run on all HPC architectures: Clusters, Cell- and GPU-accelerated, Blue Gene systems, Intel MIC, --
 - Gordon Bell Award finalist at SC12 for high-performance computing, > 50% of peak performance (> 5 PFlops) on the full Mira system at > 90% parallel efficiency (million way parallelism), ~2 trillion particle simulation
- **Wide Set of Applications**
 - Baryon acoustic oscillations, clusters, cross-correlations, galaxy clustering, mock catalogs, redshift space distortions, weak lensing, --



Argonne and LSST

- **ANL now an institutional member of the LSST Project**
 - Salman Habib (HEP) is the ANL representative
 - Roles in leadership computing/large data; collaboration in these areas being explored with NCSA
 - Key role in supernova program, other areas being investigated
- **ANL has important responsibilities in the LSST Dark Energy Science Collaboration (DESC)**
 - Katrin Heitmann (HEP) is the convener for cosmology simulations within the DESC
 - HACC is optimized for LSST simulations: Simulation/Prediction tools, control of systematic errors, next-generation emulators, covariances, mock catalogs
 - Simulation/Analysis interface based on PDACS effort and NERSC data-intensive computing pilot project
 - Large data testbed collaboration with MCS Division using the Magellan platform



Summary

- **Highlights of Scientific Developments:**

- ▶ Excellent 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 (science details at poster session):**

- ▶ DES and LSST membership, collaboration with SPT
- ▶ 17 publications (some still under review), several more close to completion
- ▶ 37 talks (30 invited -- 15 invited talks by postdocs)

- **New Initiatives:**

- ▶ Cosmic Frontier Computational Cosmology (CFCC): Collaboration between 5 HEP Labs (ANL, BNL, Fermilab, LBNL, SLAC), S. Habib spokesperson
- ▶ SciDAC-3 award, collaboration between 6 National Labs, led by ANL
- ▶ Pilot project “Portal for Data Analysis Services for Cosmological Simulations” (PDACS) at ANL/NERSC/JHU, in collaboration with Fermilab
- ▶ Early Science Project on Mira, ALCC Neutrino project on Jaguar/Intrepid, INCITE submitted

