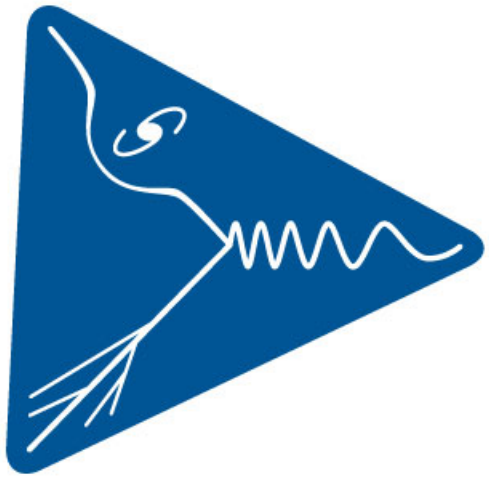


Computational Cosmology Initiative

FCPA Retreat

Nick Gnedin

Scott Dodelson

Andrey Kravtsov

(with the moral support from our SLAC and LBL colleagues)

Retreat:

…

a period of group withdrawal for prayer, meditation, study, or instruction under a director.

Merriam-Webster dictionary

Dark Energy Landscape

- **Stage II**:

  SNLS, ESSENCE, SDSS-II, CfASP, NSF, KAIT, CSP, QUEST, HST, PanSTARRS-1, PISCO, SPT, ACT, XCS, RCS2, DLS, KIDS, DEEP2

- **Stage III**:

  DES, HETDEX, WFMOS, PanSTARRS-4, ODI, 1000PLS, ALPACA, CIX, CCAT, CRT

- **Stage IV**:

  LSST, JDEM, SKA

Dark Energy Probes

- **Supernovae Ia** (standard candles)**:**

  luminosity distance vs redshift
- **Weak Lensing** (power spectrum):

  angular-diameter distance vs redshift, *growth rate* of structure
- **Baryon Acoustic Oscillations** (standard ruler):

  angular-diameter distance and *Hubble constant* vs redshift
- **Clusters of Galaxies (**number counts vs redshift):

  angular-diameter distance vs redshift, *Hubble constant* vs redshift, *growth rate* of structure

Simulation Uses

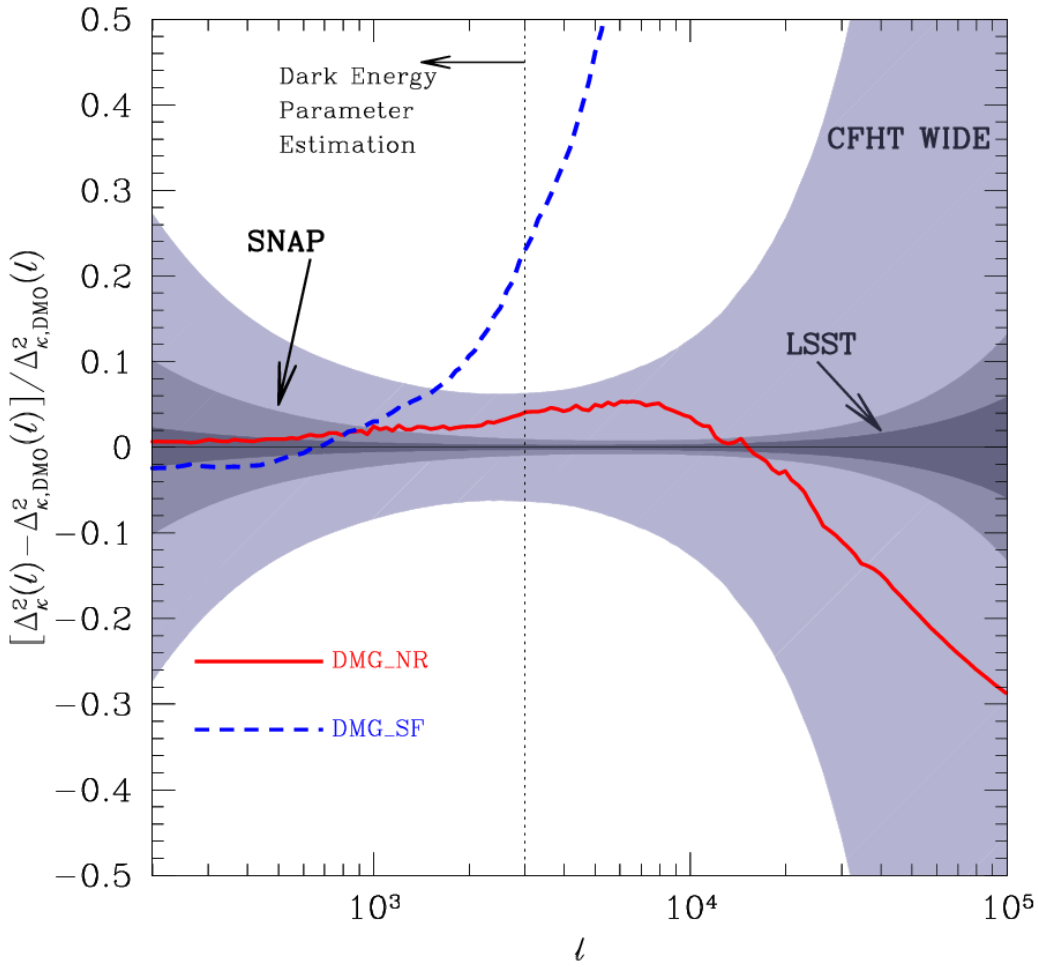
- **Mission support [***very important***]:**
  - covariance matrices
  - mock catalogs for pipeline development
- **Interpretation of results [***important and interesting***]**:
  - calculation of observables
  - calibration of systematic effects
- **Exploration [***most interesting***]**:
  - understanding the formation and evolution of cosmic structure
  - prediction of expected signals from future missions

Mission Support

- **Mock catalogs for DES pipeline development**
  - Large volume, high resolution simulations
  - Large number of separate simulations
  - About **10 million** CPU hours required
- **Sky models for CRT design and specifications**
  - Horizon-size volume, modest resolution
  - Large number of separate simulations
  - About **5-10 million** CPU hours required
- **Mock catalogs for JDEM**
  - something even bigger…

Interpretation of Results: Weak Lensing

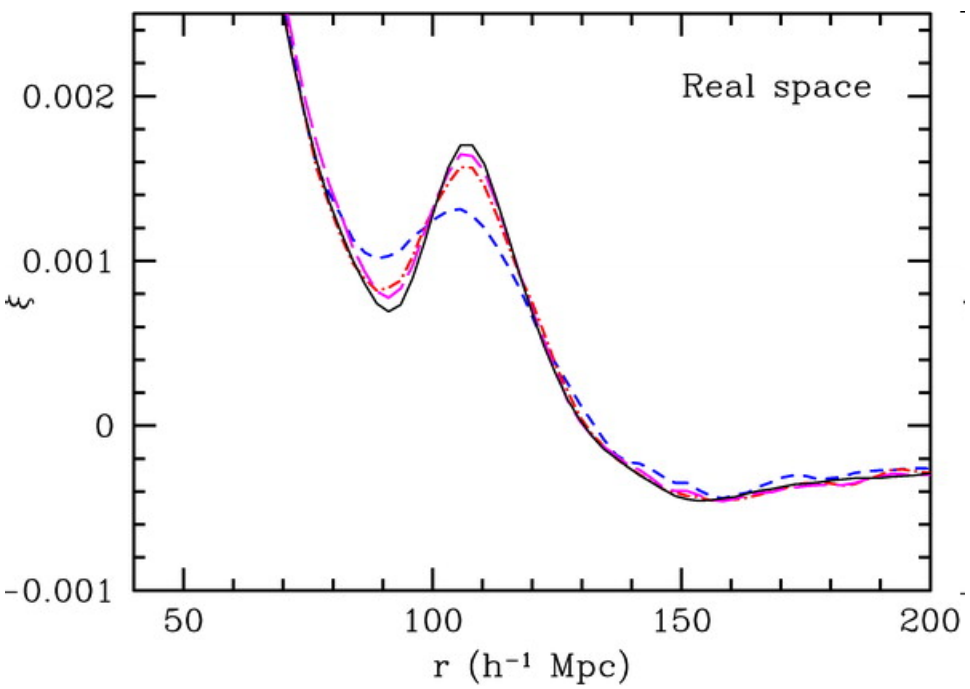
- Directly probes the matter distribution.
- Unfortunately, we exist.
- *Baryonic effects can be calibrated by simulations*.
- The required computational effort is massive.



(Rudd, Zentner, Kravtsov 2007; Zentner, Hu, Rudd 2008)

Interpretation of Results: Baryon Acoustic Oscillations

- Most clean test for dark energy (potentially).
- Nonlinear effects degrade the cosmic signal.
- Almost all of that degradation can be calibrated out with simulations.

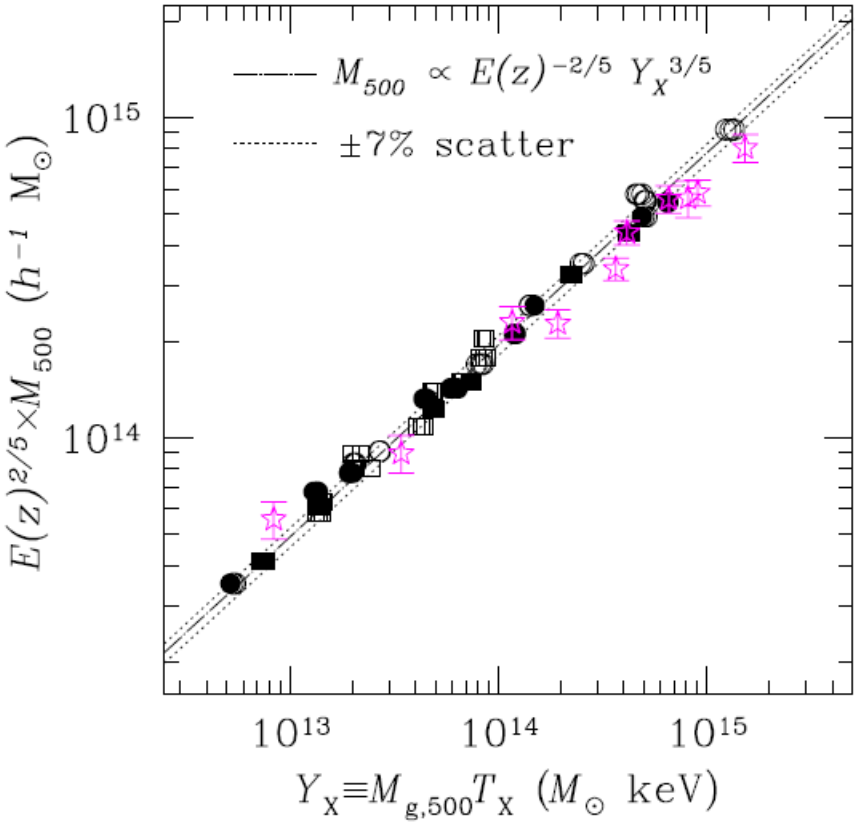


many more examples exist…

(Seo et al 2007)

Interpretation of Results: Clusters of Galaxies

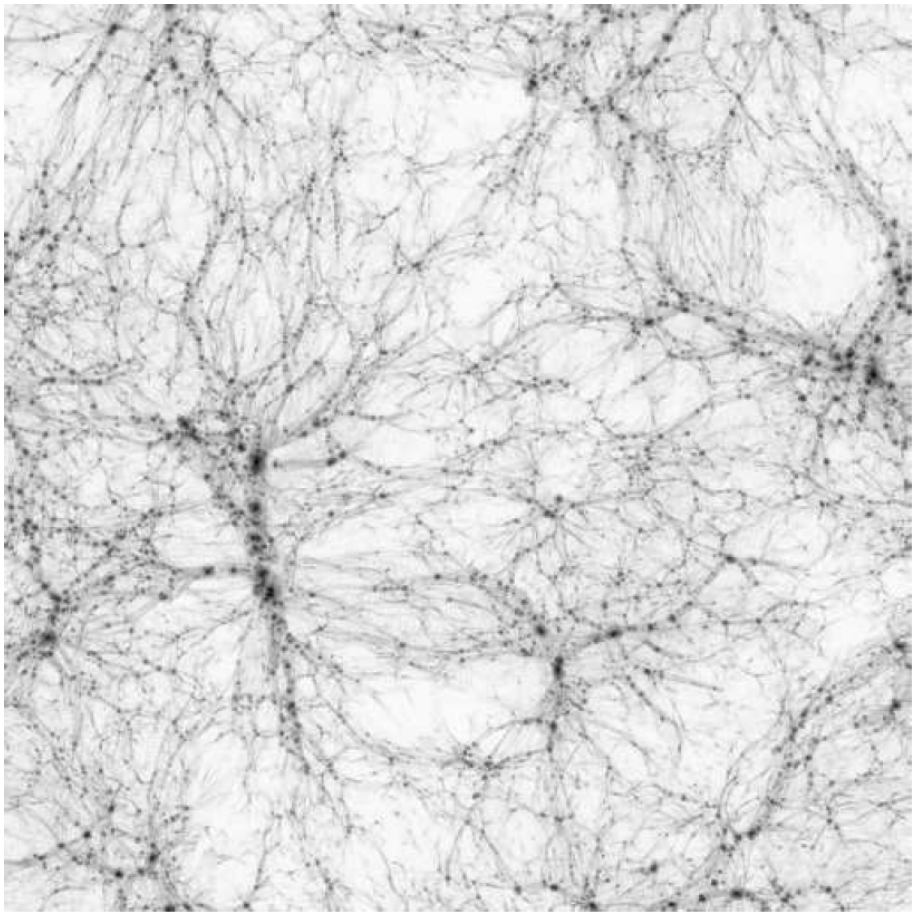
- Sensitive probes to DE (live on exponential tail).
- Complex physical systems, intrinsic scatter of scaling relations cannot be removed.
- Distribution of scatter can be included in parameter estimation.
- Simulations measure this distribution.



(Nagai et al 2007)

Exploration: LSS of DGP Gravity

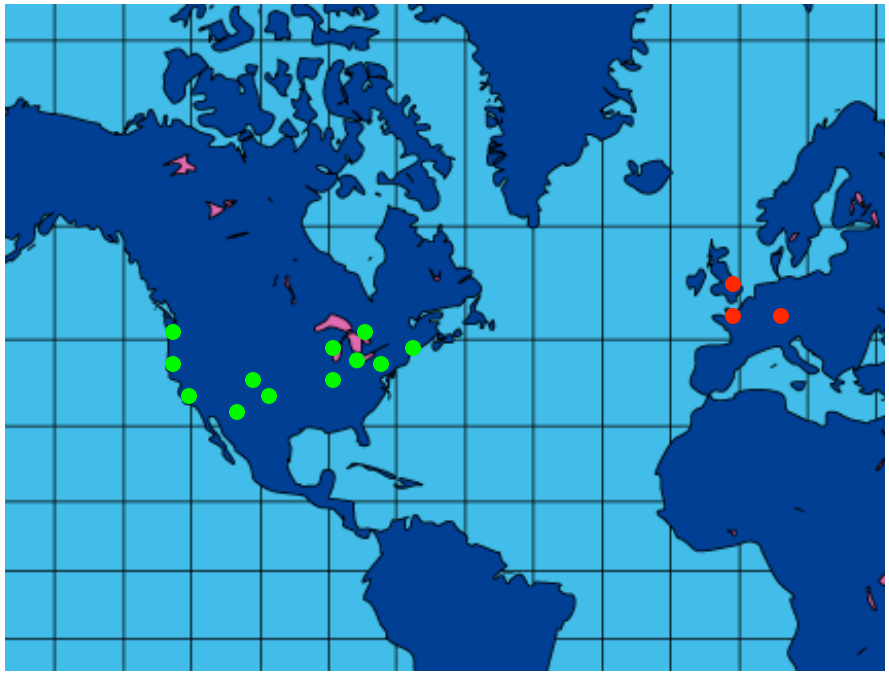
- Opportunity creates possibility.
- Existence of the FNAL-KICP cluster led to the first-ever simulation of large-scale structure in DGP gravity.



(Schmidt 2009)

many more examples exist…

Computational Cosmology in the World



- **Europe**: Research mostly done by large groups:

  Virgo Consortium [>30 people] (Germany + UK)

  Project Horizon [>20 people] (France)

- **USA/Canada**: Large number of small groups (5-8 people)
  Chicago (FNAL+KICP), UWashington, Harvard, CITA, SLAC, LANL, Princeton, UCLA, UIUC, Berkeley, UMass…

Computing Needs

- Modern state-of-the art cosmological simulations require between 1 and 10 million CPU-hours.
- National supercomputing centers can allocate that much time for a single, “biggest-ever” simulation.
- They are reluctant to support “down-to-earth” work like measuring covariance matrices for DE experiments with sets of 100 of intermediate-size simulations (1 billion particles).
- Even rudimentary analysis of modern simulations requires substantial computational resources and intermediate-level computing capabilities.

Solution (a-la LQCD)

- National consortium/collaboration (the level of integration may vary)

- Powerful local, intermediate-level resources (10,000 CPU, spread over several places: FNAL, SLAC, LBL)
  - Analysis and visualization
  - Launching pad for national centers (100,000 CPU scale; development, porting, scaling)
  - Large sets of moderate-scale simulations

- United approach to funding agencies and national supercomputer centers.

Why Do It?

- **Mission support:**
  - exploit local expertise
  - guarantee deliverables on time
- **Interpretation of results**:
  - we have the expertise (and enthusiasm to use it)
  - national supercomputer centers are not very interested in this type of work
- **Exploration**:
  - service to all US simulation community
  - maintain competitiveness on the Cosmic Frontier

Progress So Far

- build-up local resources on par with other US groups
- create a Chicago-wide collaboration (FNAL, KICP, ANL)
- move towards a national consortium (LBL, SLAC)
- secure long-term funding
  - ✓ white paper presented at Mar 2009 HEP retreat
  - ✓ full proposal from FNAL+SLAC+LBL is invited, currently in preparation

Key Questions

- **Will the proposed science goal be seen as compelling on the national scene (i.e. to PASAG) and within the DOE mission?**
  - Mission support and interpretation of results is critical to ***all*** DOE dark energy missions.
  - Theory has always been a driving force for the exploration of the Cosmic Frontier.
  - Chances are you won't get your next experiment unless you can point to a simulation that supports its science goals.

Key Questions

- **What is the main science goal and what is the expected timescale for achieving it?**
  - Primary goal: exploration of the Cosmic Frontier.
  - Simulation support will be needed as long as there are dark energy experiments.
  - Current needs of DES, CRT, JDEM can be achieved on a 3-4-6 year time scale.

Key Questions

- **What are the risks that the main science goal will not be achieved?**
  - Simulation technology is mature; several high performance codes exist.
  - Performance enhancements are needed, but the pathway is clear.
  - This is a better investment than your retirement fund.

Key Questions

- **How does the planned program address these risks?**
  - Support for 3 different numerical codes.
  - Collaboration with computer scientists.
  - Support of Fermilab's Computing Division.

Key Questions

- **Why is Fermilab (+SLAC & LBL) the best place to take this initiative?**
  - DOE labs have the most experience in large data management and high performance computing (yes, more than national supercomputer centers).
  - US university groups are splintered; the computing and data management challenges are beyond university capabilities.
  - Other similar collaborations (LQCD, accelerator simulations) are our neighbors – and willing to share their experience with us!

Key Questions

- **What are the chances that others will reach the main science goal before we do?**
  - US groups lack the necessary computational resources to provide adequate simulation support to DOE missions.
  - Only European groups have access to adequate resources. Their science interests are not fully aligned with the DOE missions, though.
  - It is not very likely that the Cosmic Frontier will be fully explored in the next ~5 years…