Sloan Digital Sky Survey Extension

Presentation to the Physics Advisory Committee

Stephen Kent

April 2, 2004

- **Status of SDSS**
- **Science Case for a 3 year extension (2005-2008)**
- **Funding and Resources**

Sloan Digital Sky Survey (E885)

Goal:

- Conduct fundamental research in cosmology, particularly formation & evolution of galaxies and large scale structure

Approach:

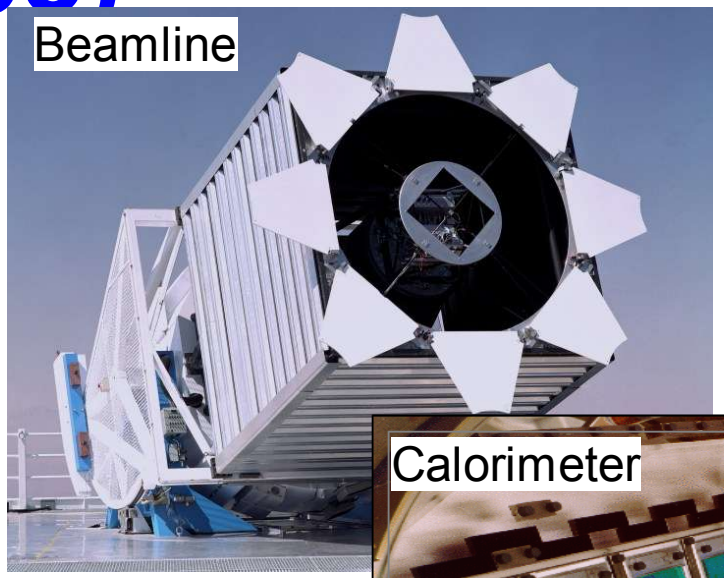
- Digital map of ¼ of sky in 5 bands
- Spectra of 1 million galaxies, 100,000 quasars

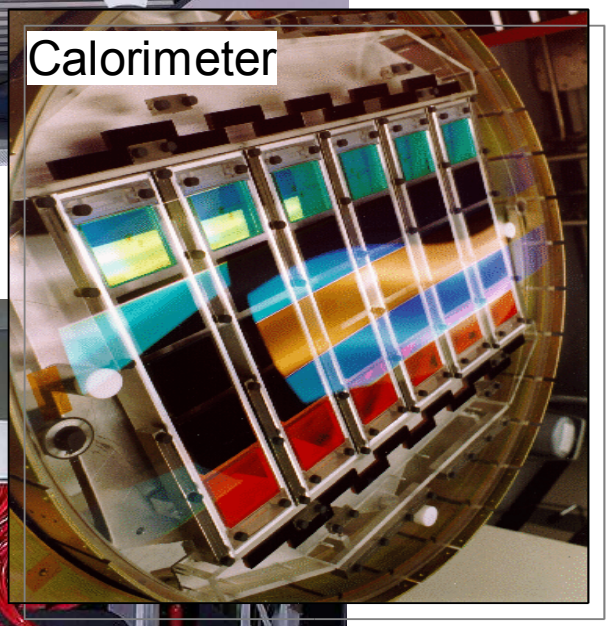
Resources:

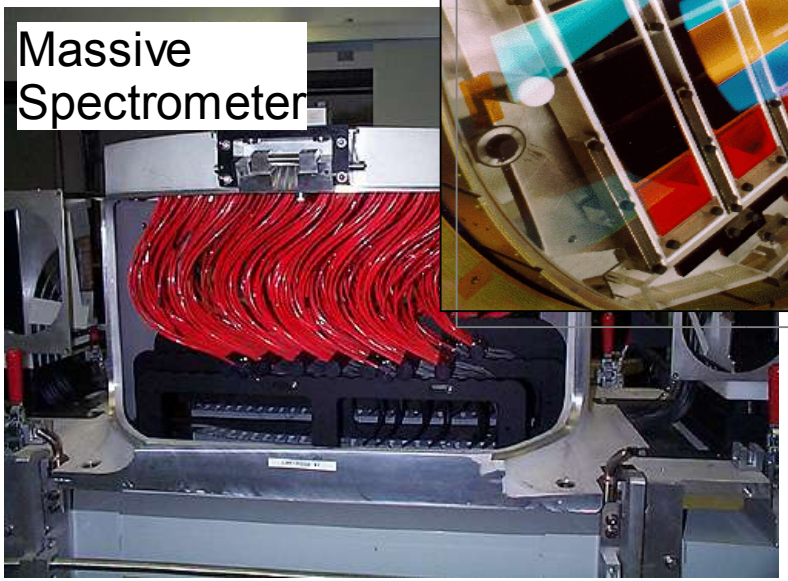
- 2.5 m telescope in New Mexico
- Large CCD mosaic camera
- 640 fiber spectrograph
- 13 partner institutions

Operations:

- 2000 to 2005







Current FNAL in SDSS

Role:

- Data acquisition
- Data processing
- Survey Planning
- Data distribution
- Support telescope and instrument systems

Science:

- Galaxy angular correlation functions (Dodelson)
- Weak lensing (Annis, Frieman, Lampeitl)
- Galaxy clusters (Annis, Kent, Tucker)
- Milky Way halo structure (Yanny, Kent)
- Galaxy evolution (Lin)
- QSO luminosity functions (Stoughton, Jester)
- Supernovae (Frieman, Lampeitl DeJongh, Marriner)
- Near Earth Asteroids (Kent)

Participants:

EAG

- 8 Scientists
- 4.5 CP

TAG

- 3 Scientists

PPD

- 1 Project manager
- 4 Engr/Tech (APO)

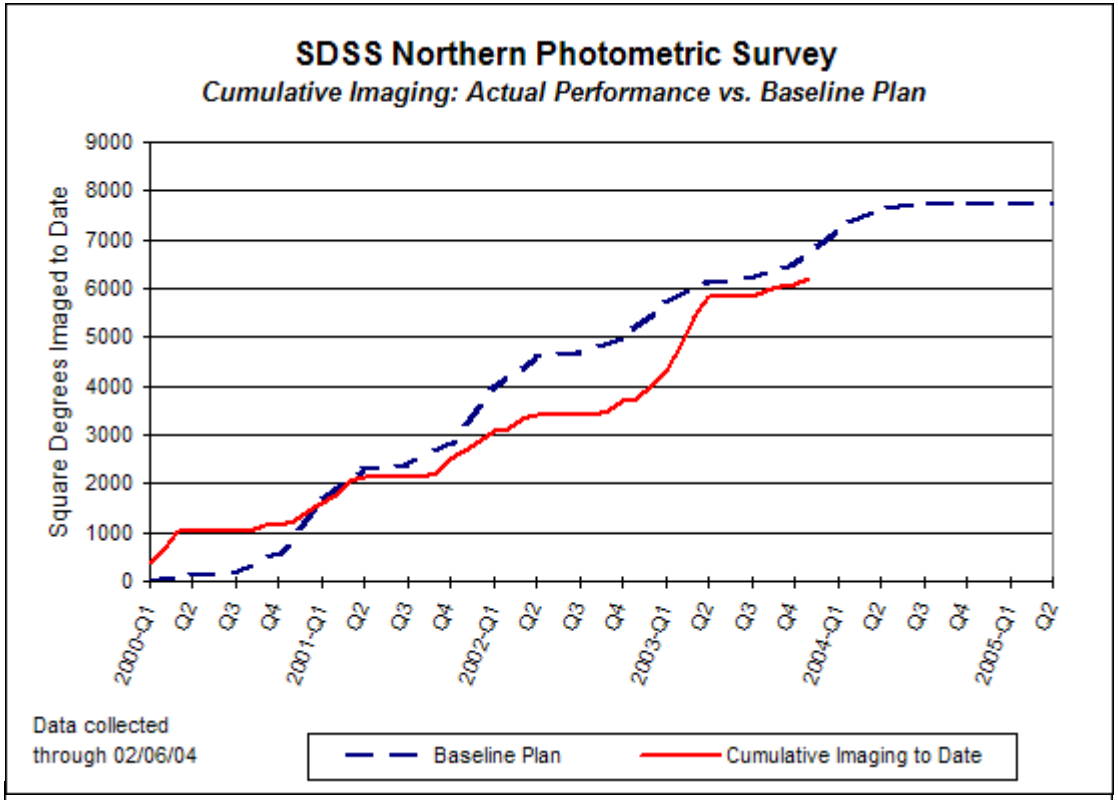
CD (outside EAG)

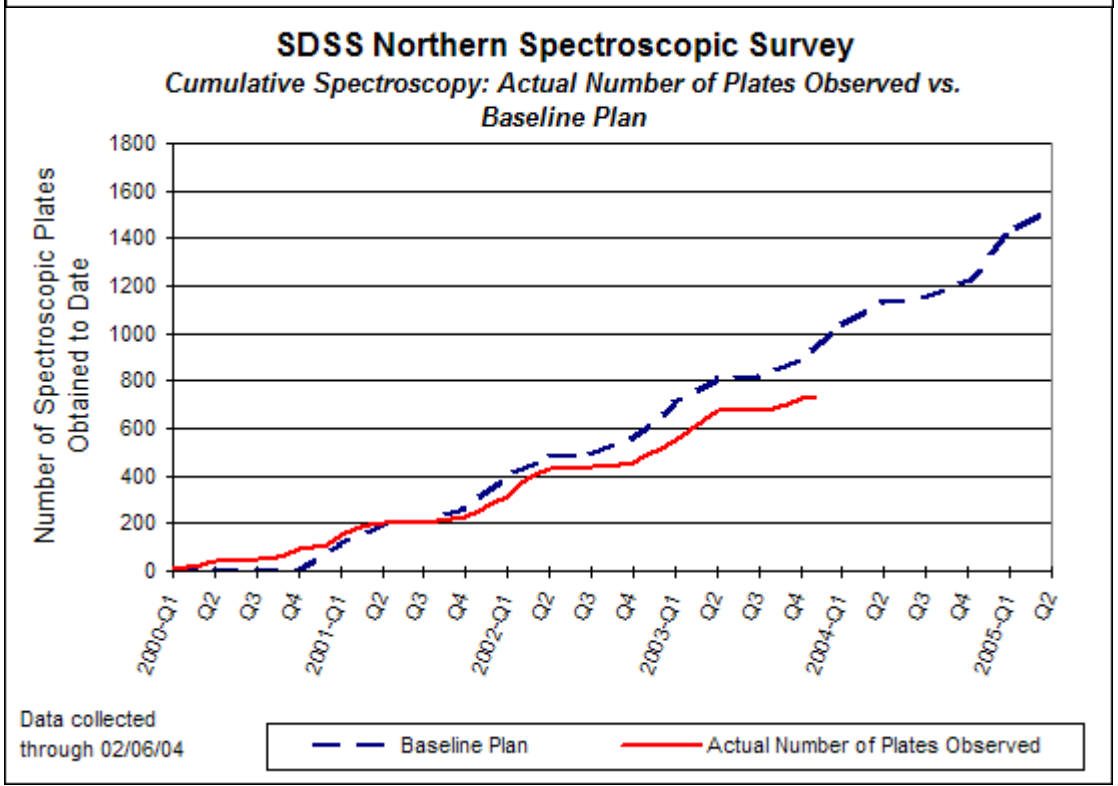
- 0.5 CP

Funding:

- Primarily FNAL in-kind
- ~2 FTE, some M&S provided by SDSS project

"Integrated Luminosity" vs. 5 Year Baseline





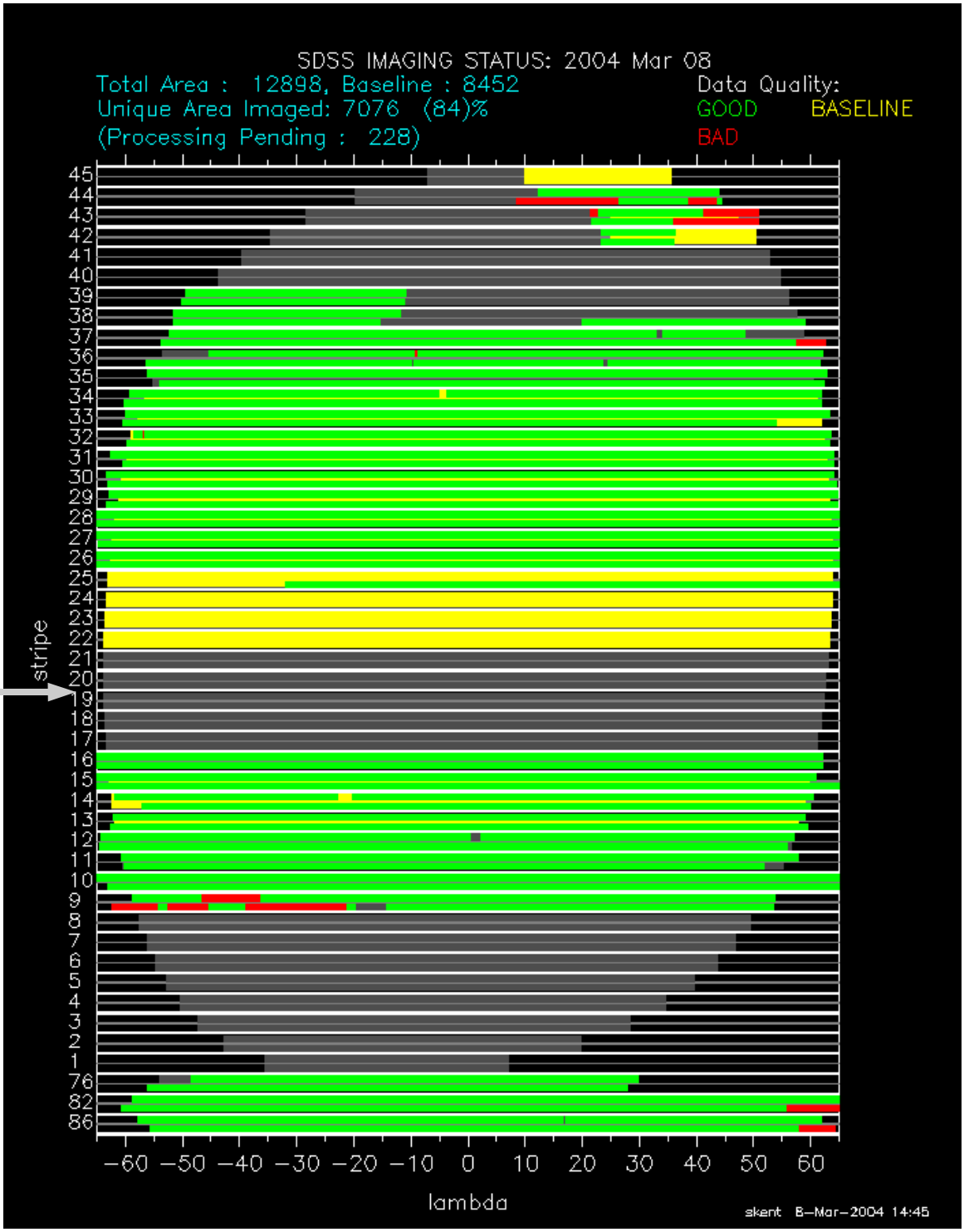
SDSS Current Status (Mar 2004)

Imaging: 82% as of March 11, 2004

Spectroscopy: 55% as of March 11, 2004

Current operations funded thru June, 2005

A proposal is being developed to continue operations for another 3 years (fill the gap)



Science Magazine

(Dec 2003)

Breakthrough Online
For an expanded version of this section, with references and links, see www.sciencemag.org/content/vol302/issue5653/#special

Breakthrough

#1 The Winner

Portraits of the earliest universe and the lacy pattern of galaxies in today's sky confirm that the universe is made up largely of mysterious dark energy and dark matter. They also give the universe a firm age and a precise speed of expansion.

Illuminating the Dark Universe

A lonely satellite spinning slowly through the void has captured the very essence of the universe. In February, the Wilkinson Microwave Anisotropy Probe (WMAP) produced an image of the infant cosmos, of all of creation when it was less than 400,000 years old. The brightly colored picture marks a turning point in the field of cosmology: Along with a handful of other observations revealed this year, it [illegible] about the nature of the universe that our cosmos is.

Five years ago, scientists on the cover sported the visage of Albert Einstein looking shocked by 1998's Breakthrough of the Year: the accelerating universe. Two teams of astronomers had seen the faint imprint of a ghostly force in the death rattles of dying stars. The apparent brightness of a certain type of supernova gave cosmologists a way to measure the expansion of the universe at different times in its history. The scientists were surprised to find that the universe was expanding ever faster, rather than decelerating, as general relativity—and common sense—had led astrophysicists to believe. This was the first sign of the mysterious "dark energy," an unknown force that counteracts the effects of gravity and flings galaxies away from each other.

Although the supernova data were compelling, many cosmologists hesitated to embrace the bizarre idea of dark energy. Teams of astronomers across the world rushed to test the existence of this irresistible force in independent ways. That quest ended this year. No longer are scientists trying to confirm the existence of dark energy; now they are trying to find out what it's made of, and what it tells us about the birth and evolution of the universe.

Lingering doubts about the existence of dark energy and the composition of the universe dissolved when the WMAP satellite took the most detailed picture ever of the cosmic microwave background (CMB). The CMB is the most ancient light in the universe, the radiation that streamed from the newborn universe when it was still a glowing ball of plasma.

This faint microwave glow surrounds us like a distant wall of fire. The writing on the wall—tiny fluctuations in the temperature (and other properties) of the ancient light—reveals what the universe is made of.

Long before there were stars and galaxies, the universe was made of a hot, glowing plasma that roiled under the competing influences of gravity and light. The big bang had set the entire cosmos ringing like a bell, and pressure waves rattled through the plasma, compressing and expanding and compressing clouds of matter. Hot spots in the background ra[illegible] compressed, de[illegible] universe, and co[illegible] rarefied regions [illegible]

Just as the tone of a bell depends on its shape and the material it's made of, so does the "sound" of the early universe—the relative abundances and sizes of the hot and cold spots in the microwave background—depend on the composition of the universe and its shape. WMAP is the instrument that finally allowed scientists to hear the celestial music and figure out what sort of instrument our cosmos is.

The answer was disturbing and comforting at the same time. The WMAP data confirmed the incredibly strange picture of the universe that other observations had been painting. The universe is only 4% ordinary matter, the stuff of stars and trees and people. Twenty-three percent is exotic matter: dark mass that astrophysicists believe is made up of an as-yet-undetected particle. And the remainder, 73%, is dark energy.

The tone of the cosmic bell also reveals the age of the cosmos and the rate at which it is expanding, and WMAP has nearly perfect pitch. A year ago, a cosmologist would likely have said that the universe is between 12 billion and 15 billion years old. Now the estimate is 13.7 billion years, plus or minus a few hundred thousand. Similar calculations based on WMAP data have also pinned down the rate of the universe's expansion—71 kilometers per second per megaparsec, plus or minus a few hundredths—and the universe's "shape": slate flat. All the arguments of the last few decades about the basic properties of the universe—its age, its expansion rate, its composition, its density—have been settled in one fell swoop.

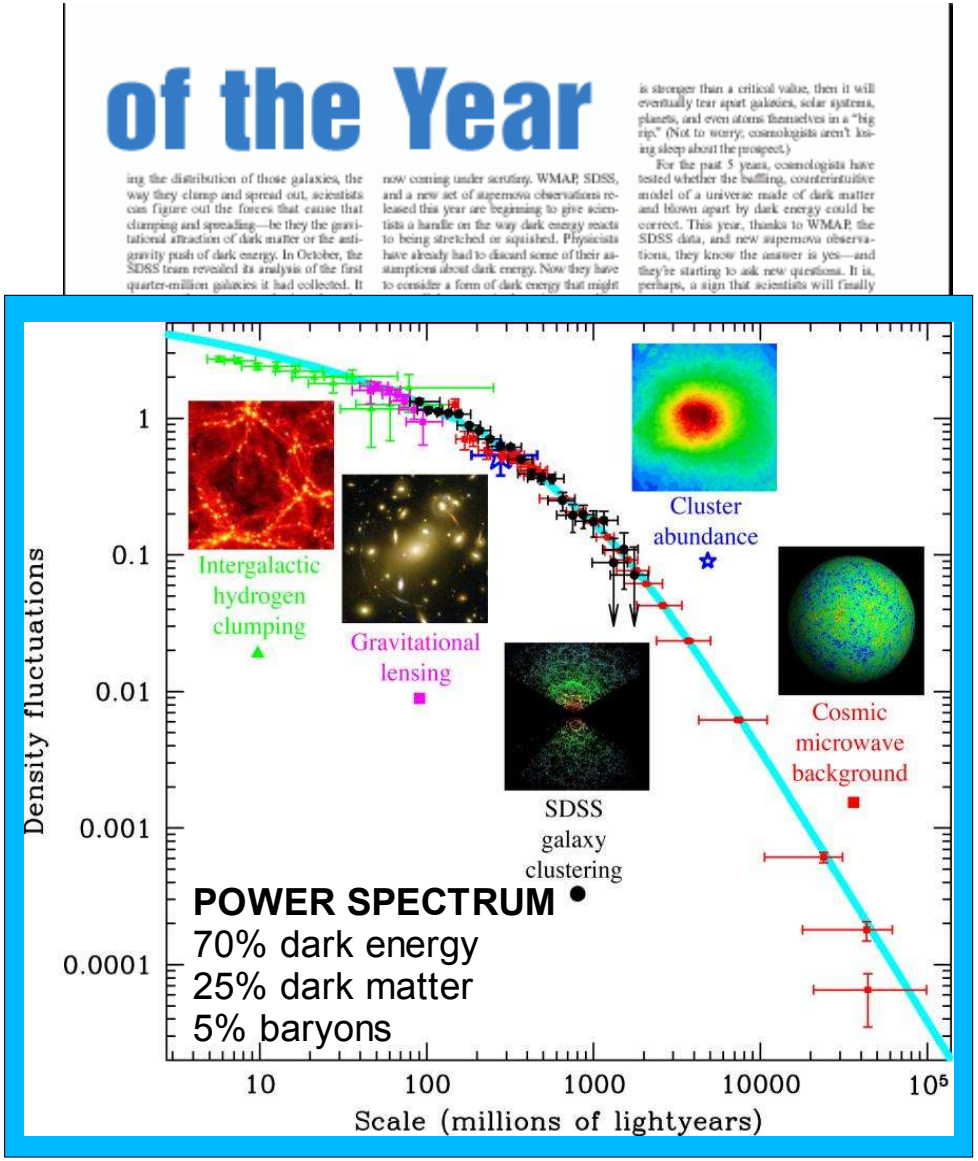
As important as WMAP is, it is not this year's only contribution to cosmologists' understanding of the history of the universe. The Sloan Digital Sky Survey (SDSS) is mapping out a million galaxies. By analyzing the distribution of those galaxies, the way they clump and spread out, scientists can figure out the forces that cause that clumping and spreading—be they the gravitational attraction of dark matter or the anti-gravity push of dark energy. In October, the SDSS team revealed its analysis of the first quarter-million galaxies it had collected. It [illegible] now coming under scrutiny. WMAP, SDSS, and a new set of supernova observations released this year are beginning to give scientists a handle on the way dark energy reacts to being stretched or squished. Physicists have already had to discard some of their assumptions about dark energy. Now they have to consider a form of dark energy that might [illegible] is stronger than a critical value, then it will eventually tear apart galaxies, solar systems, planets, and even atoms themselves in a "big rip." (Not to worry; cosmologists aren't losing sleep about the prospect.)

For the past 5 years, cosmologists have tested whether the baffling, counterintuitive model of a universe made of dark matter and blown apart by dark energy could be correct. This year, thanks to WMAP, the SDSS data, and new supernova observations, they know the answer is yes—and they're starting to ask new questions. It is, perhaps, a sign that scientists will finally

Through a glass, darkly. Microwave data observed by the WMAP satellite (*upper left*), supernovae (*lower left*), and galaxy clusters (*above*) all reveal a universe dominated by dark energy.

WMAP

SDSS



Data Release 2 to public

All data through June 30, 2002

SDSS Data Release 2

Sloan Digital Sky Survey

- Where to Start
- News and Updates
- Tutorials
- Data Products
- Data Access
- Sky Coverage
- Instruments
- Data Flow
- Algorithms
- Glossary
- Help and Feedback
- Search

The Sloan Digital Sky Survey (see www.sdss.org for general information) will map one-quarter of the entire sky and perform a redshift survey of galaxies, quasars and stars. The DR2 is the second major data release and provides images, imaging catalogs, spectra, and redshifts for download.

About DR2 explains what is new in DR2.

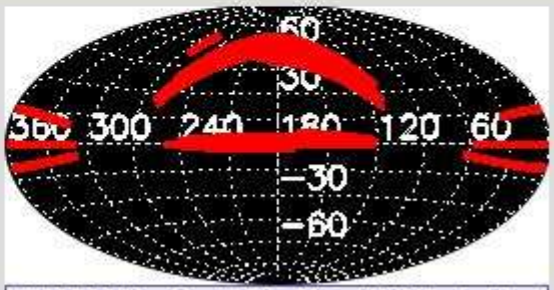
Please refer to the credits page for our sources of funding, participating institutions, how to acknowledge the use of SDSS data in your publications. Please also note how to refer to SDSS sources in your publications using the proper IAU nomenclature for SDSS sources.

Imaging

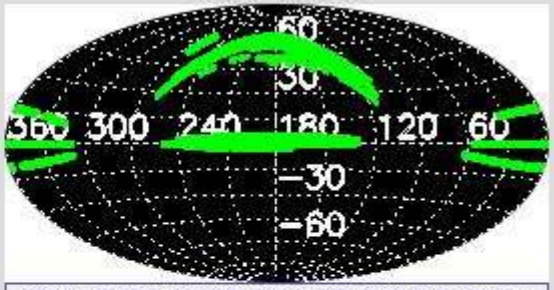
Footprint area	3324 sq. deg.
Imaging catalog	88 million unique objects
Data volume	images 5.0 TB; catalogs (DAS, fits format) 0.7 TB; catalogs (CAS, SQL database) 1.4 TB
Average wavelengths and magnitude limits (95% detection repeatability for point sources)	*u*: 3551Å, 22.0; *g*: 4686Å, 22.2; *r*: 6165Å, 22.2; *i*: 7481Å, 21.3; *z*: 8931Å, 20.5
PSF width	1.4" median in *r*
Photometric calibration	*r*: 2%; *u–g*: 3%; *g–r*: 2%; *r–i*: 2%; *i–z*: 3%
Astrometry	< 0.1" rms absolute per coordinate

Spectroscopy

Spectroscopic area	2627 sq. deg.



SDSS DR2 Imaging Sky Coverage (Aitoff projection of Equatorial coordinates)



SDSS DR2 Spectral Sky Coverage (Aitoff projection of Equatorial coordinates)

To the Future: SDSS Extension (2005-2008)

- Why?
  - Will be short of goal of a FILLED survey after 5 years
  - Unexpected discoveries offer opportunity for new science in Galactic Structure
  - Realization that SDSS telescope provides unique capability for supernova detection.
- How long?
  - The above programs can be accomplished with minimal conflict in a period of 3 years

Collaboration

- Astrophysical Research Consortium is legal "umbrella" for existing collaboration
  - Fermilab
  - U. of Chicago
  - Princeton
  - USNO
  - U. of Washington
  - Japanese Promotion Group
  - JHU
  - NMSU
  - Max-Planck Institute for Astronomy
  - Max-Planck Institute for Astrophysics
  - U. of Pittsburgh
  - LANL
  - IAS
- Many current partners are interested in extension; some new partners have expressed interest

Fermilab Scientists

- CD
  - J. Annis (L, S)
  - S. Kent (L, G)
  - R. Kron (L, G)
  - H. Lin (L)
  - J. Marriner (S)
  - J. Peoples (L)
  - C. Stoughton (L)
  - B. Yanny (G)
- PPD
  - F. DeJongh (S)
  - S. Dodelson (L)
  - J. Frieman (S, L)
  - A. Stebbins (L, S)
  -
  - L: Legacy
  - G: Galactic Structure
  - S: Supernovae

Budget

- Cost
  - $14.9 M over 3 years
- Funding
  - Proposal to Sloan Foundation ($5.4 M)
  - Proposal to NSF ($5.4 M)
  - Member Institutions ($4 M)
    - Cash
    - In-Kind

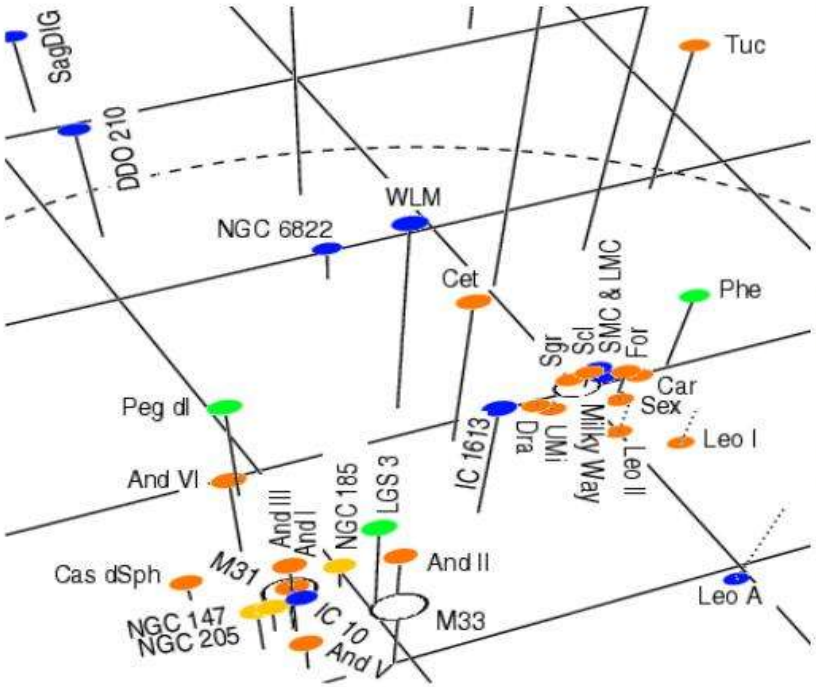
Data Collection Goals

- Legacy
  - Imaging: 762 sq deg
  - Spectroscopy: 495 plates
- Galactic Structure (SEGUE)
  - Imaging: 3600 sq deg
  - Imaging: 520 plates
- Supernovae
  - Imaging: 10 months dedicated

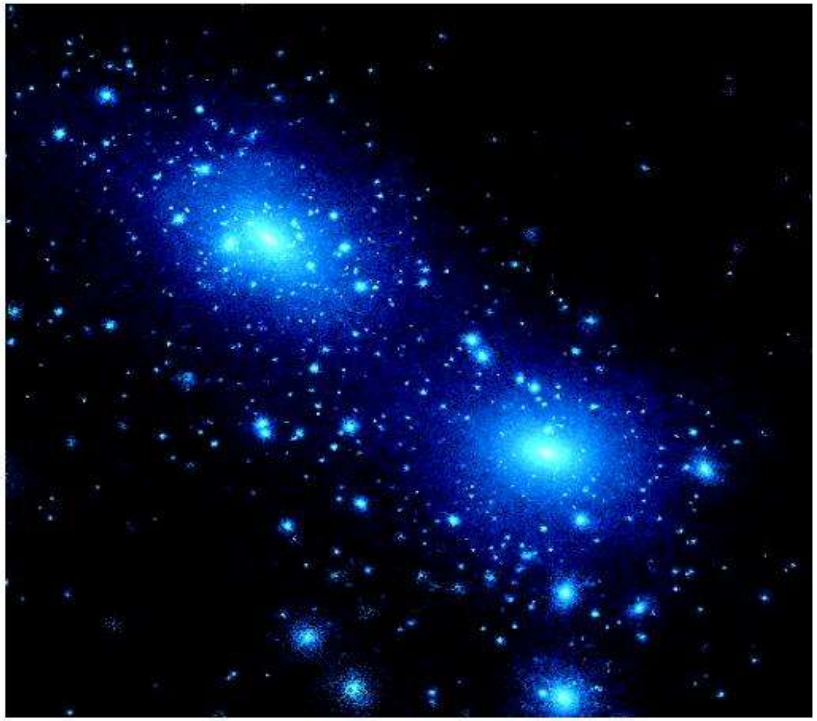
Legacy Survey

- SDSS data are unique
  - High precision
  - Joint imaging/spectroscopy
  - Large area
- Filled volume
  - Improve resolution of galaxy power spectrum by factor 3 (search for "baryon wiggles")
  - Measure higher order clustering with 45% improved accuracy (non-Gaussian initial conditions?)

The Missing Satellites Problem



The Local Group



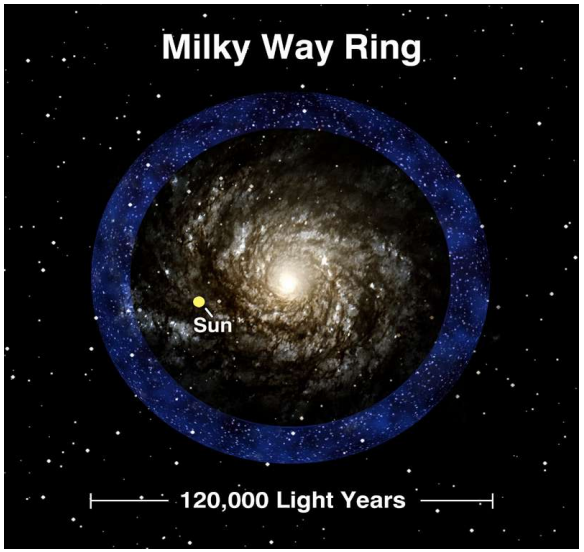
LCDM simulation

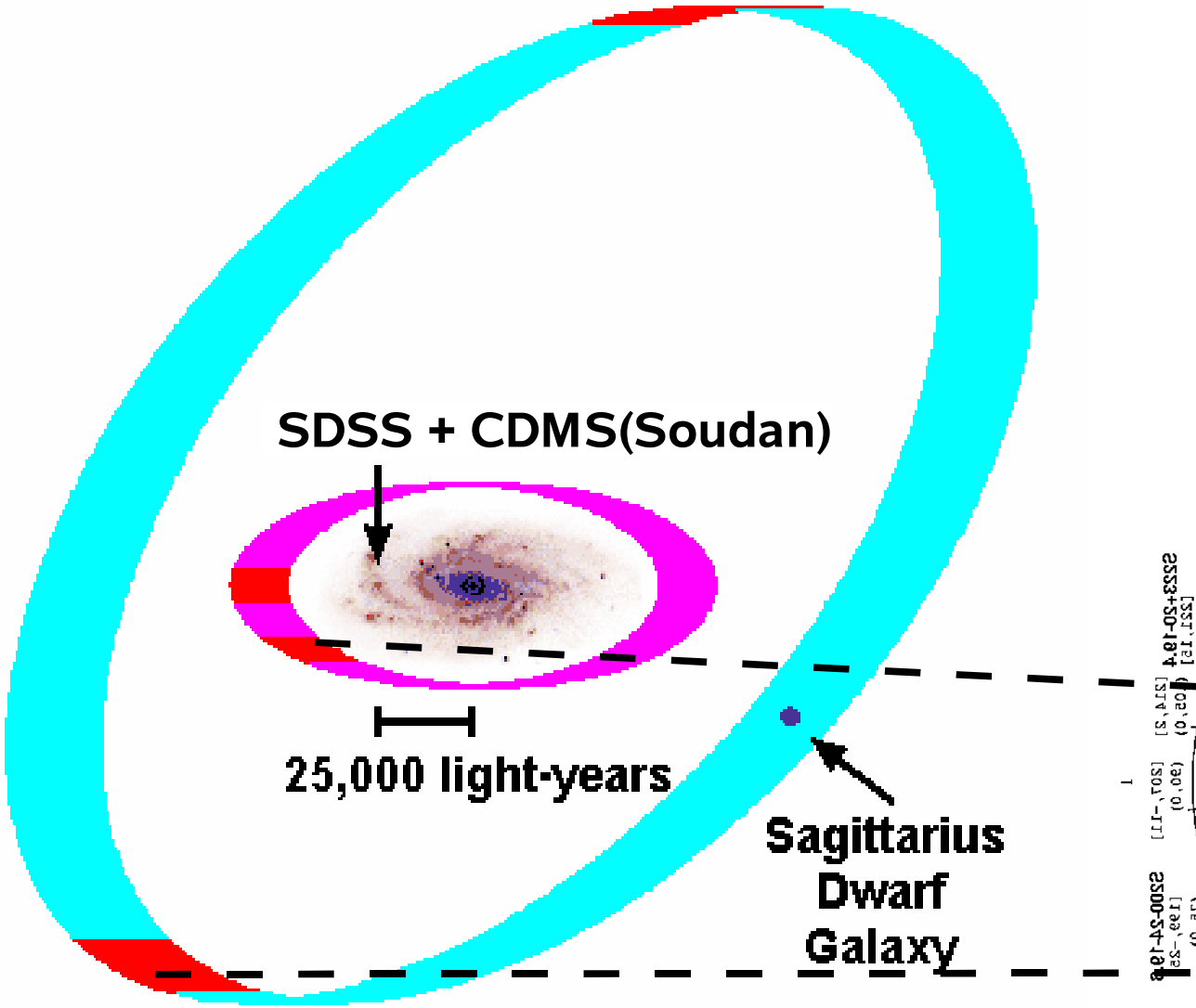
Kauffman, White & Guiderdoni 1993
Klypin, Kravtsov, Valenzuela & Prada 1999; Moore et al. 1999

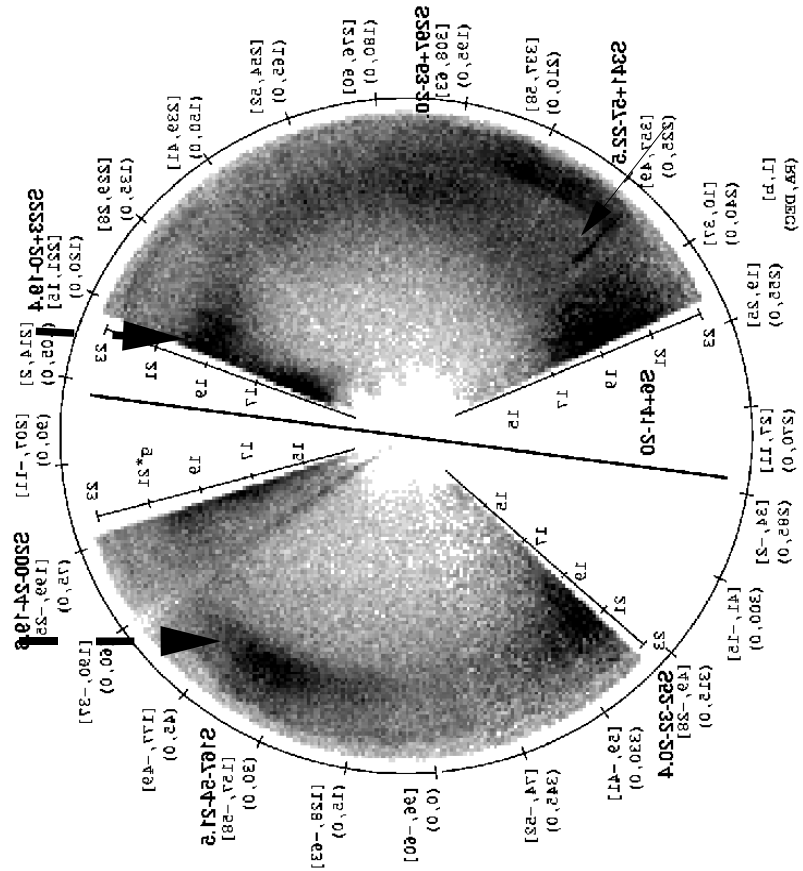
Numerical simulations of galaxy halo formation from cold, dark matter are now sufficiently accurate to make quantitative predictions for satellite galaxy populations around the Milky Way Galaxy.

Rings around the Galaxy

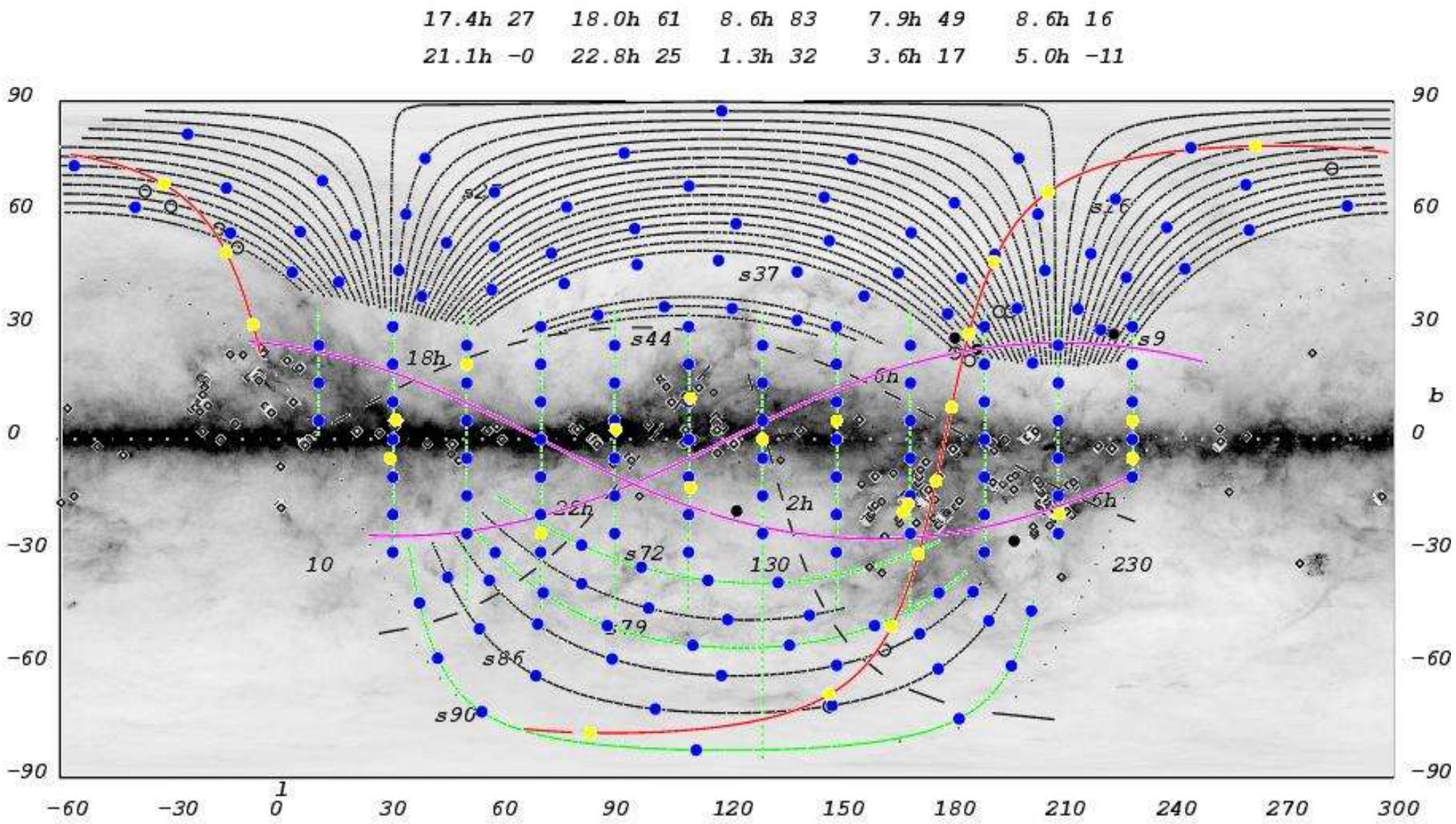
(Yanny & Newberg)







"Sloan Extension for Galactic Underpinnings and Evolution"

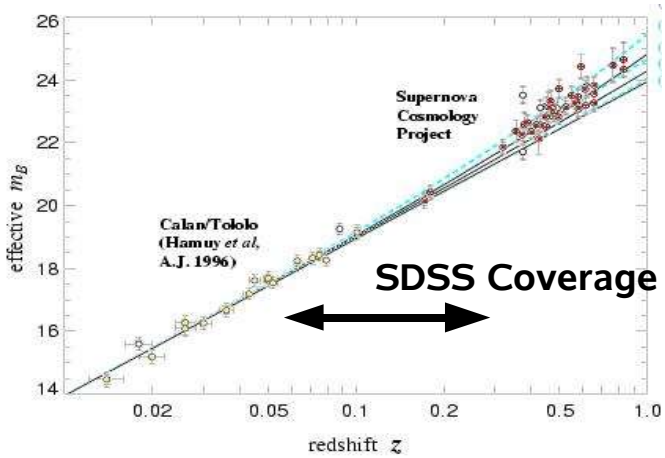


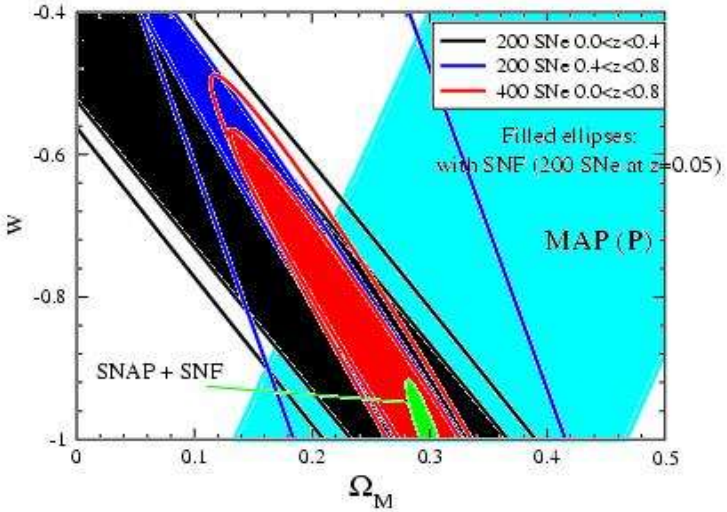
Supernova Program

Detection of supernova 2001eu from SDSS data

Goals:

- **200 supernovae with light curves 0.05 < z < 0.3**
- **Fill gap in redshift coverage of other SN surveys:**
  - **SN Factory: Z < 0.1**
  - **CFHT Legacy survey: z > 0.3**





FNAL tasks and resources

- Fermilab Interests
  - 13 scientists (EAG, PPD, AD)
- Tasks
  - DAQ upgrade
  - Survey planning
  - Plugplate design
  - Legacy, SEGUE, SNe data processing
  - Data distribution
  - Project Mgmt.
  - APO Technical Support
- Required resources
  - 4 FTE scientist
  - 10.5 FTE CP, admin, tech.
  - $200K M&S/yr
  - $300K DAQ upgrade (one time only) labor, M&S
- Funding
  - Expect significant cost sharing with SDSS project

EAG Balancing Act

- EAG currently has 8 scientists, 3.5 CP FNAL funded and working on astrophysics.
- Next few years
  - SDSS: 3 Scientists, 2.5 CPs
  - SNAP: 1.25 Scientists, 1 CP
  - DES: 1.5 Scientists, 0 CP
  - Research: 2.25 Scientists
- Remaining people for SDSS are either existing non-EAG scientists, existing CD people not in EAG or existing or planned CPs in EAG funded by ARC

Summary

- SDSS extension will deliver
  - Unique, high precision, homogeneous survey that delivers key science on large scale structure and a complete legacy dataset for future science
  - New insights into structure of Milky Way halo (a laboratory for dark matter physics)
  - Supernovae at low/intermediate redshifts to make a measurement of dark energy density and to serve as anchor for future high redshift SNe surveys such as SNAP/JDEM.