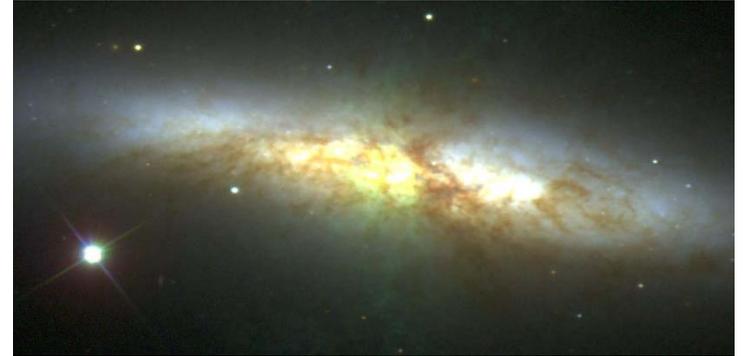


# Experimental Astrophysics Group: SDSS and JDEM R&D



Stephen Kent  
March 13, 2004



- **Experimental Astrophysics Group (CD) and SDSS (Sloan Digital Sky Survey)**
- **To the future: SDSS Extension**
- **To the future: SNAP/JDEM**
- ***To the future: DECAM (Dark Energy Camera)***

# Experimental Astrophysics Group

- Staff Scientists

- Stephen Kent
- Chris Stoughton
- Jim Annis
- Rich Kron
- Huan Lin
- (John Peoples)
- Douglas Tucker
- Brian Yanny
- John Marriner

- Postdocs

- Hubert Lampeitl
- Sebastian Jester

- Computing Professionals

- Jen Adelman
- Nikolai Kuropatkine
- Dan Yocum
- John Hendry
- John Inkmann
- Vijay Sekhri (NVO/iVDGL)

- Students

- Brian Wilhite (UC)

- Visitors/Guests

- Susan Kayser



# Sloan Digital Sky Survey (E885)

## Goal:

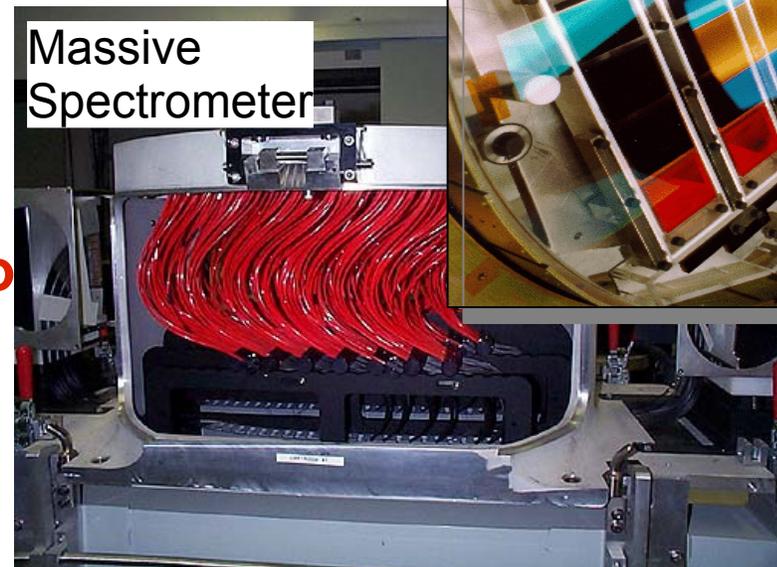
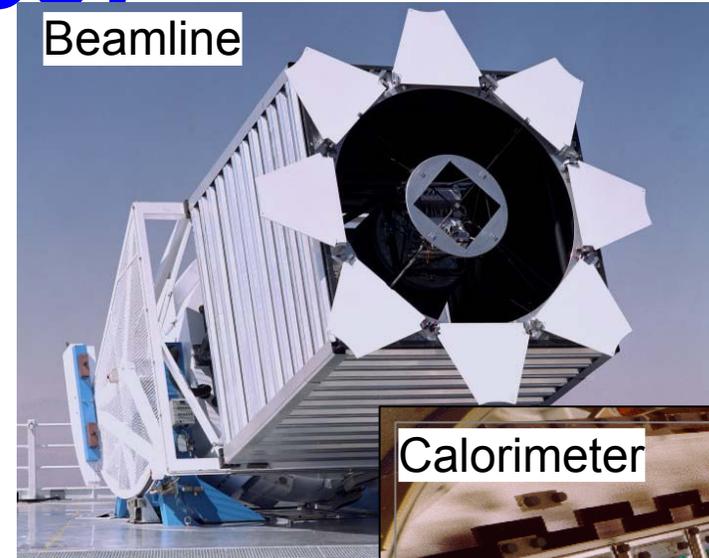
Conduct fundamental research in cosmology, particularly formation & evolution of galaxies and large scale structure

## Approach:

Digital map of  $\frac{1}{4}$  of sky in 5 bands  
Spectra of 1 million galaxies,  
100,000 quasars

## Resources:

2.5 m telescope in New Mexico  
Large CCD camera  
640 fiber spectrograph  
11 partner institutions





# 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)  
Galaxy clusters (Annis, Kent, Tucker)  
Milky Way halo structure (Yanny, Kent)  
Galaxy evolution (Lin)  
QSO luminosity functions (Stoughton)  
Near Earth Asteroids (Kent)

## Participants

EAG

TAG

PPD

Bill Boroski

French Leger

Carlos Gonzalez

Steve Bastian

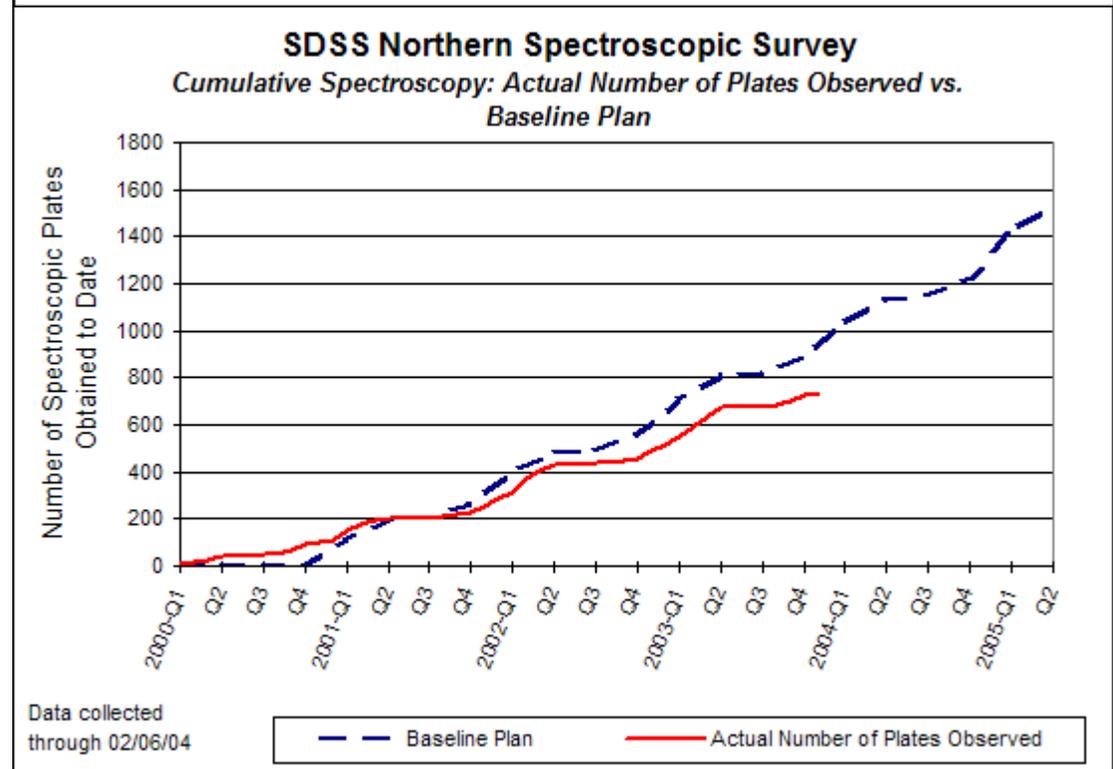
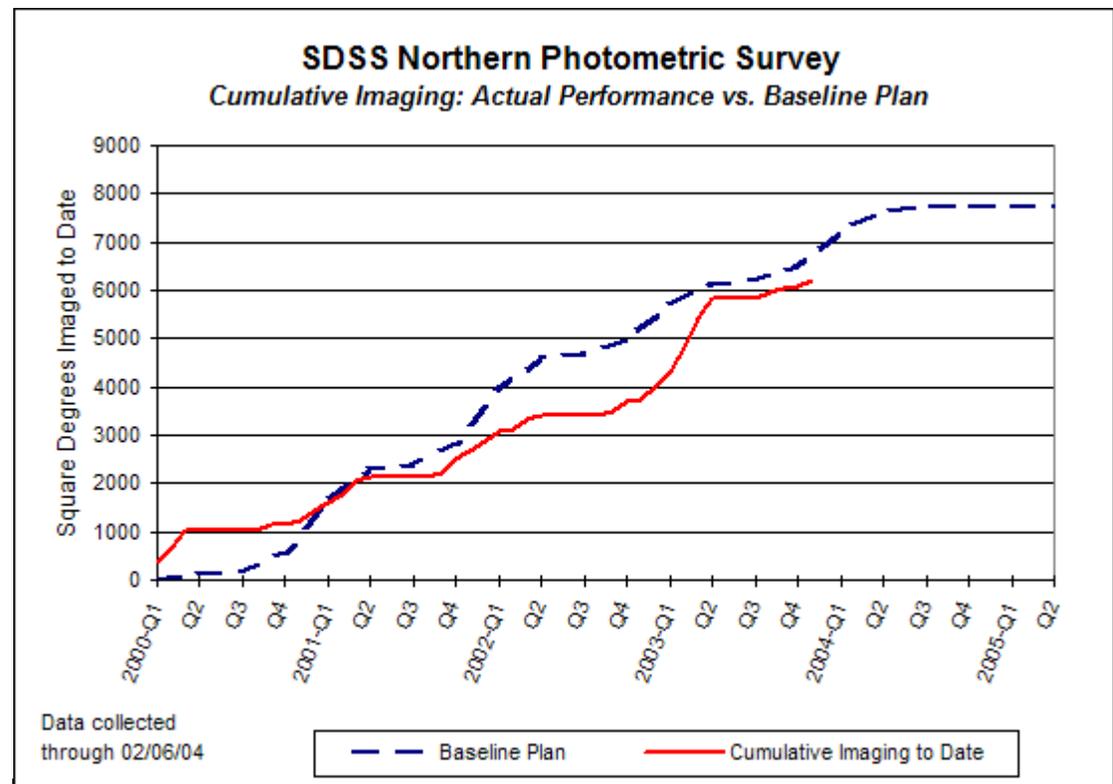
Comp. Comm. Fab. (CD)

Don Holmgren

Eric Neilsen

Ron Rechenmacher

# Delivered "beam" vs. 5 Year Baseline





# SDSS Current Status (Mar 2004)

Imaging: 82% as of March 11, 2004

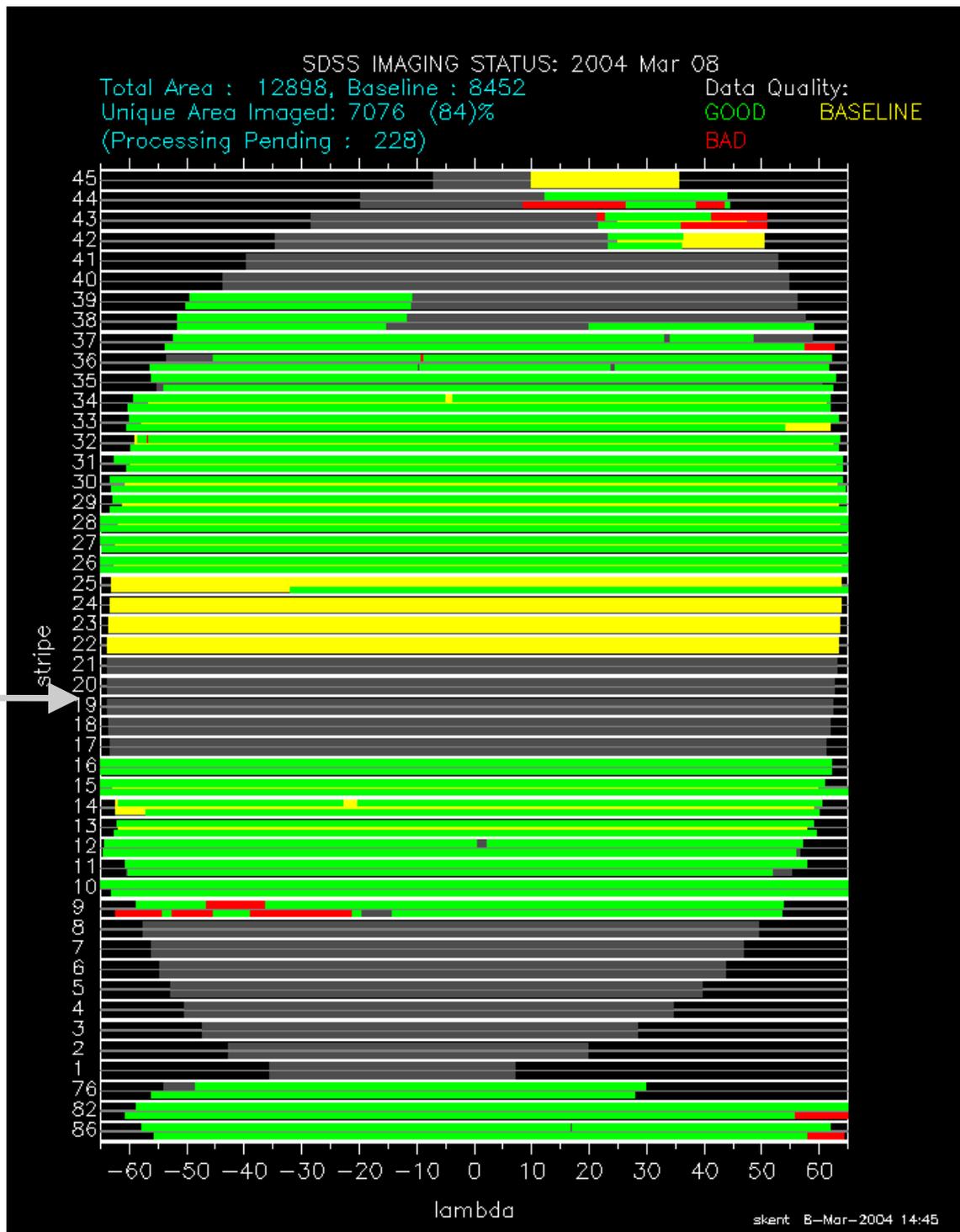


Spectroscopy: 55% as of March 11, 2004



Current operations funded thru June, 2005

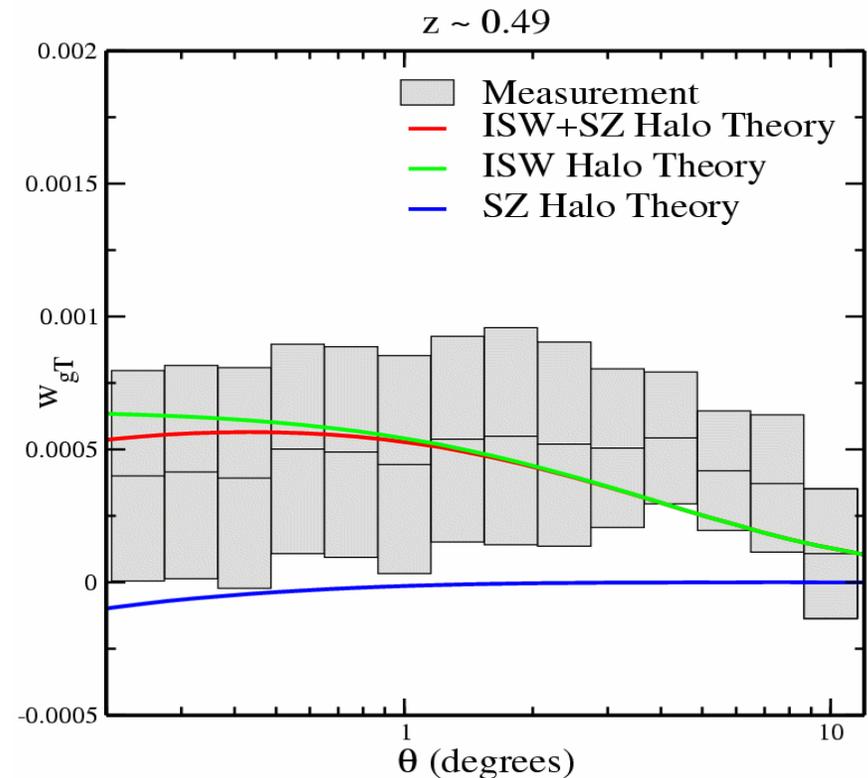
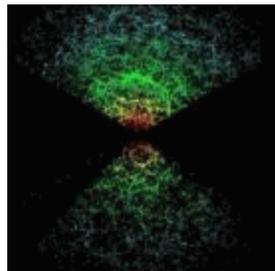
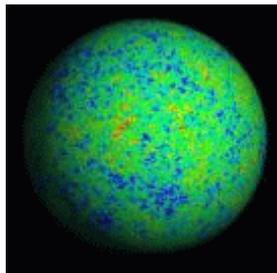
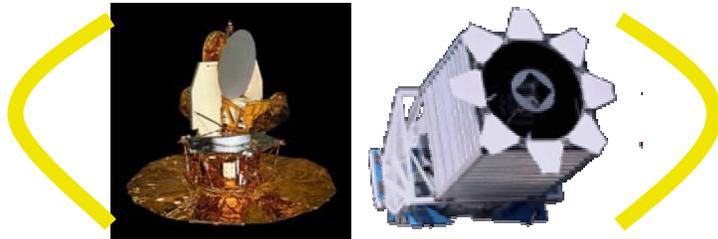
A proposal is being developed to continue operations for another 3 years (fill the gap).



# Research Highlights

- 50 papers submitted by collaboration in past year.
- 40 papers submitted by noncollaboration based on publicly released data (EDR and DR1)
- **Correlating SDSS with WMAP (Scranton et al 2003)**

Integrated Sachs-Wolfe Effect



# Science Magazine

(Dec 2003)

Breakthrough Online  
For an expanded version  
of this section, with refer-  
ences and links, see www.  
sciencemag.org/content/  
vol332/issue3553/#special

## Breakthrough

### #1 The Winner

## Illuminating the Dark Universe

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.

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

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

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 dazzling 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 matter 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": flat. All the arguments of the last few decades about the basic properties of the universe—its age, its expansion rate, its composition, its destiny—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

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 radiation, dark matter, and 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

## WMAP

Two years ago, scientists cover reported 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 had rushed to test the existence of this invisible 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.



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

fire. The writing on the wall—tiny fluctuations in the temperature (and other properties)

## SDSS

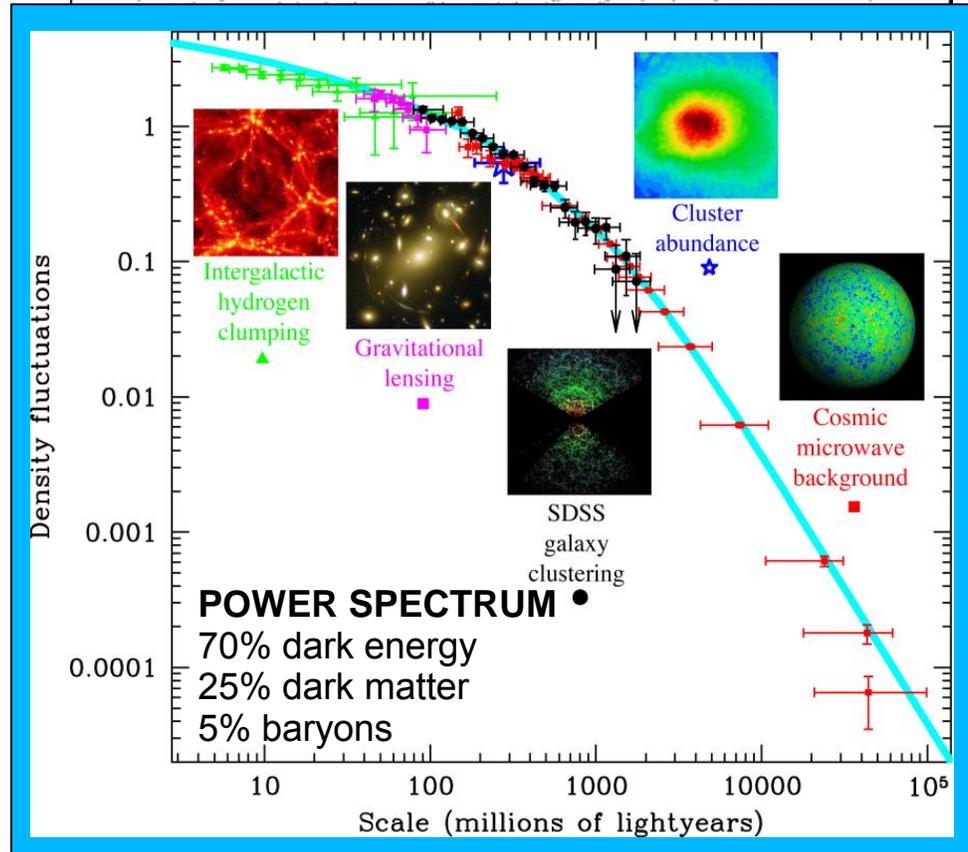
## of the Year

ing 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

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

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.)

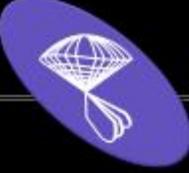
For the past 5 years, cosmologists have tested whether the billiard, counterintuitive model of a universe made of dark matter and blown apart by dark energy could be correct. This year, thanks to WMAP, the SDSS data, and new supernova observations, they know the answer is yes—and they're starting to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





# Data Release 2 to public imminent

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](http://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.

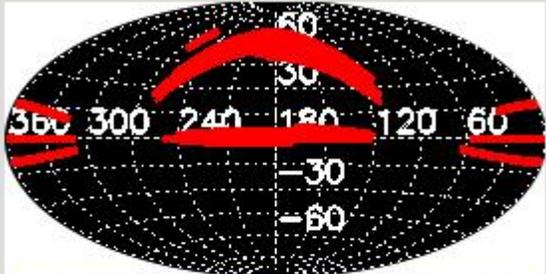
Please refer to the [credits page](#) for our sources of funding, participating institutions, how to acknowledge the use of SDSS data in your publications. Please also note how to refer to SDSS sources in your publications using the proper [IAU nomenclature for SDSS sources](#).

### Imaging

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

### Spectroscopy

Spectroscopic area	2627 sq. deg.
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SDSS DR2 Imaging Sky Coverage (Aitoff projection of Equatorial coordinates)



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

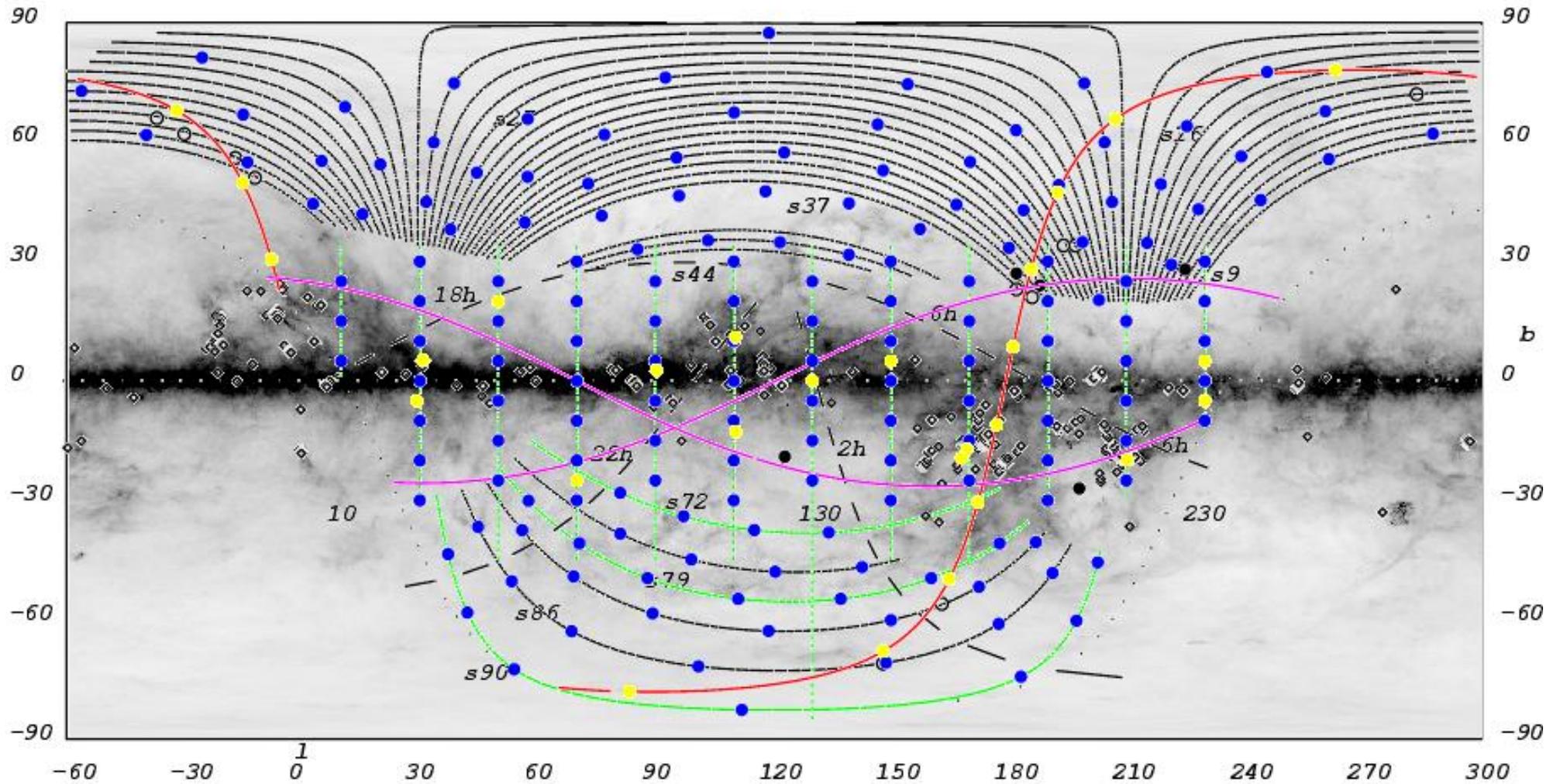
# To the Future: SDSS Extension (2005-2008)

- **Why?**

- **Will be short of goal of a FILLED survey after 5 years**
  - 762 sq deg (.5 yrs)
  - 495 plates (2.1 yrs)
- **Unexpected discoveries offer opportunity for new science in Galactic Structure**
  - 3600 sq deg
  - 520 plates
- **Realization that SDSS telescope provides unique capability for supernova detection.**
  - 10 months dedicated

# "Sloan Extension for Galactic Underpinnings and Evolution"

17.4h 27	18.0h 61	8.6h 83	7.9h 49	8.6h 16
21.1h -0	22.8h 25	1.3h 32	3.6h 17	5.0h -11



# FNAL tasks and resources

- **Fermilab Interests**

- 14 scientists (EAG, PPD, BD)

- **Tasks**

- DAQ upgrade
- Survey planning
- Plugplate design
- Legacy, SEGUE, SNe data processing
- Data distribution
- Project Mgmt.

- **Required resources**

- 4 FTE scientist
- 6.1 FTE CP, admin, tech.
- \$200K M&S/yr
- \$300K DAQ upgrade

- **Funding**

- Expect significant cost sharing with SDSS project

# Dark Energy - A Problem for the Coming Decade

- **National Research Council Report, "Connecting Quarks with the Cosmos" (2003):**
  - *Dark energy must be probed by multiple, complementary methods with independent systematic errors and different cosmological parameter degeneracies.*
- **How?**
  - *Supernovae - most accurate, fewest biases*
  - *Galaxy Clusters, Weak Lensing, Galaxy correlation functions*
  - *Ground is Good - Space is Better*



## To the future ...What is SNAP?

- **SNAP is a proposed space-based mission to probe the nature of dark energy and the accelerating universe.**

- *A deep survey of Type Ia SNe, which are thought to be standard candles.*

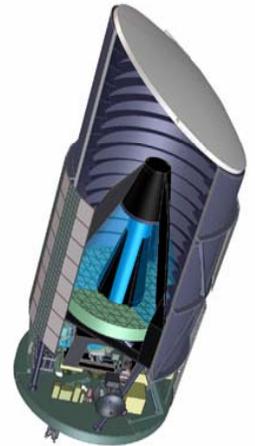
- **Expect to see ~2000 SNe Ia in 2-3 yrs**

- *A 300 sq. deg. wide-field survey to measure weak lensing Independent measurement of dark energy*

- <http://snap.lbl.gov>

- **SNAP is an important goal for DOE in this decade.**

- *Centered at and managed from LBNL*



# What will SNAP Measure?

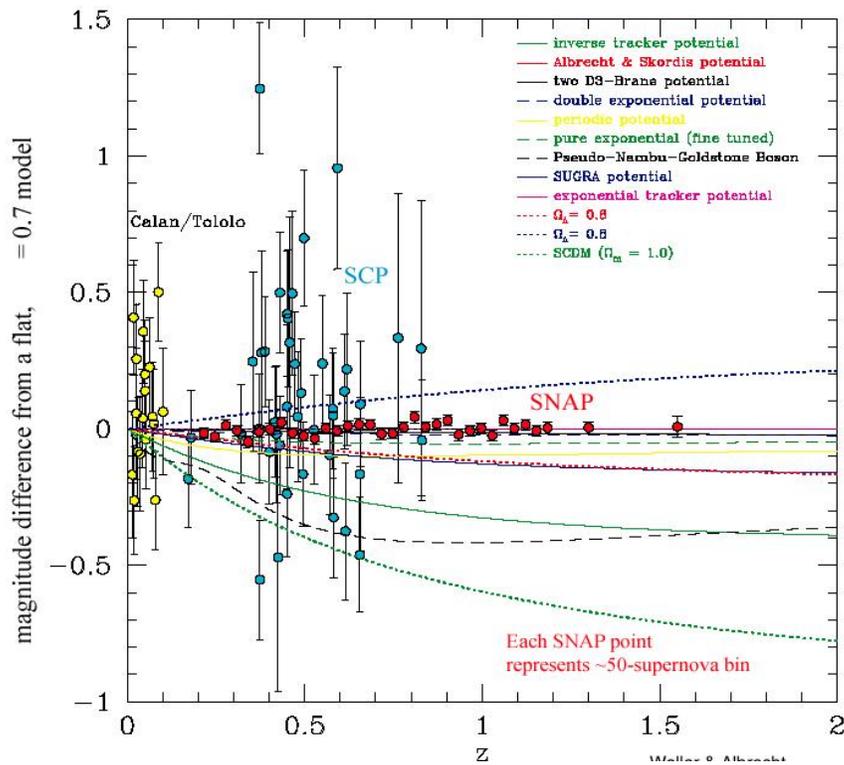


## Dark Energy Eqn. of State

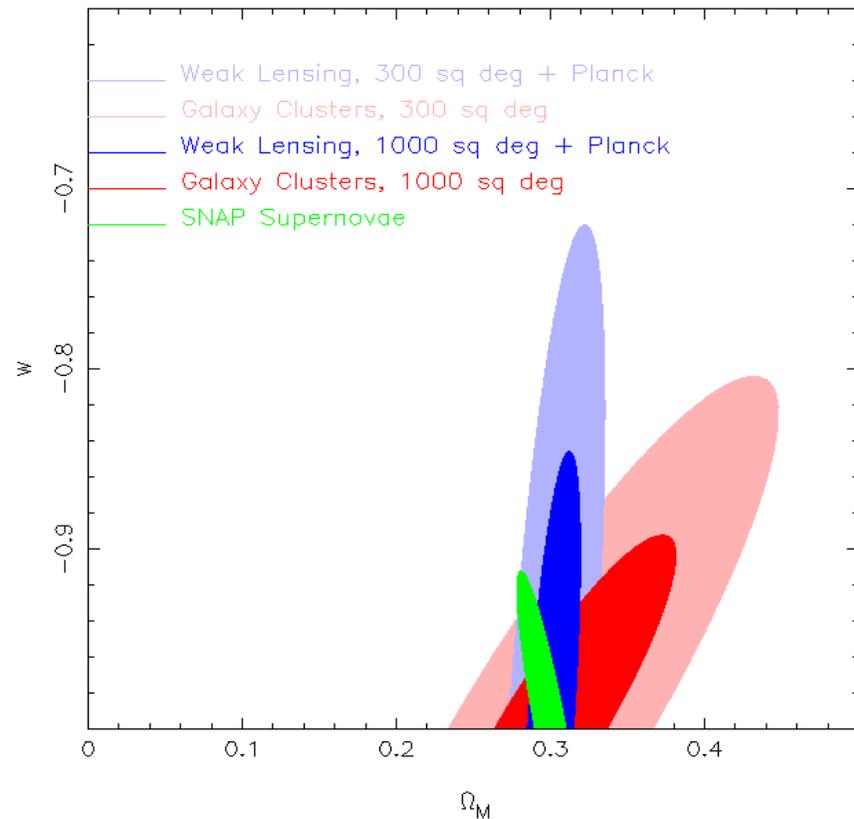
$$P = w\rho$$

$w = -1$  Cosmological Constant

$w < -1$  Quintessence



Dark Energy Sensitivity

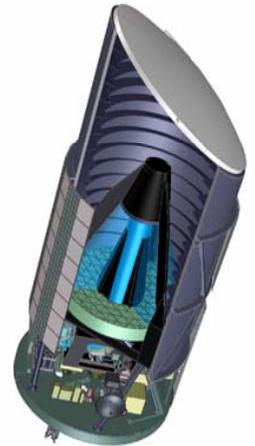


Supernovae are one of many techniques to measure Dark Energy



## Current Status

- .16 Fermilab scientists applied for and were granted admission to the SNAP collaboration.**
- .September 2003 - NASA and DOE announce Joint Dark Energy Mission as of three Einstein Probes.**
  - .SNAP will be proposed as the Dark Energy Experiment for JDEM***
  - .SNAP is in R&D phase within DOE - proposal due ~January 2006***
- .Jan 2004 President announces new initiative for robotic and manned missions to Moon and Mars**
  - .NASA OSS budget to increase***
  - .New funding for JDEM not in NASA's current 5 year plan.***



# Contributions to R&D Program



- . **Science & Simulations**
- . **Photometric Calibration**
  - . *Expertise due to SDSS work*
- . **Scientific Software & Archiving**
  - . *Expertise due to SDSS work*
- . **Electronics**
  - . *Solid-state recorder*
  - . *Data compression hardware*
    - . Both of above could help wide-field survey
- . **Radiation Shields**
  - . *Cosmic-ray, light baffle, thermal*
  - . *Involved in all three; concentrate on cosmic-ray shield and integration*
    - . Uses GEANT & MARS design tools
    - . Serious mechanical & thermal engineering requires solid modeling and sophisticated FEA

# To the Future - Dark Energy Camera

- **Proposal to construct mosaic camera for 4 meter telescope at CTIO (Chile)**
- **Receive ~ 600 nights observing time**
- **Conduct 4000 square degree imaging survey**
- **Overlap with Sunyaev-Zel'dovich Effect (SZE) cluster survey being done with South Pole Telescope - Measure dark energy using galaxy clusters**

# Participants

- **Fermilab**
- **U. Chicago**
- **LBNL**
- **Fermilab Members**

- **Jim Annis**
- **Brenna Flaughner**
- **Huan Lin**
- **Doug Tucker**
- **John Peoples**
- **Chris Stoughton**

**U. Illinois (U-C)**

**Cerro Tololo Inter-American  
Observatory**

**William Wester**

**Steve Kent**

**Josh Frieman**

**Albert Stebbins**

**Scott Dodelson**

# Current Status

- **Proposal, cost estimate in preparation.  
Deadline Aug 2004**
- **Schedule:**
  - **Deliver camera 2008**
  - **5 year survey to 2013**

# 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**
  - **DECAM: 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**