**Astronomy 41100: The Science of the Dark Energy Survey**
**Fall Quarter, 2010**
**Class: Fridays 1:30-4:20 pm (with a 10-minute break 2:50-3:00 pm), AAC 123**
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The discovery of cosmic acceleration in 1998 has since been confirmed by further observations of supernovae, the cosmic microwave background, and large-scale structure. In coming years, we aim to understand the physical cause of this surprising phenomenon: is it dark energy or does General Relativity need to be modified? If dark energy, is it the cosmological constant (the energy of the vacuum) or something else? This seminar course will focus on the use of the Dark Energy Survey (DES), and by extension other surveys, to probe the origin of cosmic acceleration. The DES instrument (the Dark Energy Camera) is now (Fall 2010) in the final months of construction and integration at Fermilab and will have first light on the Blanco 4-meter telescope at CTIO in October 2011. In 2012, the 5-year, multi-band, optical-NIR Dark Energy Survey will begin.

This course will cover the techniques for probing dark energy in detail, with particular emphasis on weak lensing, clusters, baryon acoustic oscillations, and supernovae, and explore how DES will realize these techniques. We will study photometric redshift techniques for turning multi-band photometry into approximate redshift estimates. We will familiarize ourselves with the main hardware and software components of the project: the telescope, the camera and its CCD detectors, the filters, the corrector optics, the software system that turns raw data into calibrated astronomical images and catalogs, and science analysis tools. We will explore simulated images that are being used to test the data management system and will carry out science analyses with these realistic, simulated DES data. By the end of the course, those interested in participating in DES should have the basic tools to jump into the project and take part in science analysis.

The course will start with lectures reviewing cosmic acceleration and the techniques for probing dark energy, continue with more specialized talks and discussions, including guest lectures, on various aspects of the Dark Energy Survey project, discuss forecasts for DES constraints, and finish with science results—including student presentations—from DES simulations.

## Required Work

Toward the end of the quarter, students will write up and orally report on research projects (either scientific or technical) related to DES that they will carry out starting earlier in the quarter. There will be some short exercises along the way.

**Class Schedule:**

Fri. Oct. 1
Fri. Oct. 8: NO CLASS
Fri. Oct. 15
Wed. Oct. 20-Fri. Oct. 22: Multi-day Field Trip: attend as much of the DES Collaboration meeting at Fermilab as you can: http://astro.fnal.gov/desfall2010/Home.html
Fri. Oct. 29
Fri. Nov. 5
Fri. Nov. 12
Fri. Nov. 19
Fri. Nov. 26: NO CLASS (Thanksgiving break)
Fri. Dec. 3
Fri. Dec. 10

- **Cosmology, Acceleration, and Dark Energy::**

- Cosmology mini-review:
  - Expanding Universe Kinematics; $H_0$, $q_0$
  - Expanding Universe Dynamics: Friedmann equations
  - Dark Energy, acceleration, and the equation of state parameter

- Friedmann-Robertson-Walker Observables:
  - The metric for homogeneous and isotropic Universes
  - Distances and the Hubble diagram; lookback time
  - Evidence for cosmic acceleration from supernovae
  - Linear growth of structure and ΛCDM

- Theoretical Approaches to Cosmic Acceleration:
  - Cosmological constant and vacuum energy
  - Light Scalar Fields (aka quintessence)
  - Modified Gravity and growth of structure

- Guest mini-lecture: Characterizing Dark Energy, Andy Albrecht (Oct. 15)
  - Parametrizing the Equation of State
  - Reconstructing Dark Energy
  - Principal Component Analysis
  - Parametrizing Linear Growth

- **Probes of Acceleration and Dark Energy:**

- Supernovae:
  - Type Ia Supernovae as Calibrated Candles
  - Light-curve fitting methods: MLCS, SALT,...
  - Dust extinction and other systematics
  - Possible guest lecture: Theory of SNe Ia
  - Current results

- Clusters:
  - Counting Clusters: probing geometry and growth
  - Cluster probes: X-ray, Sunyaev-Zel'dovich, Optical, Weak Lensing
  - Mass-observable relation, self-calibration, systematics
  - Possible guest lecture: optical cluster-finding methods

- Weak Gravitational Lensing:
  - Introduction to Gravitational Lensing and Shear
  - Cosmic Shear and Galaxy-galaxy lensing as probes of geometry and growth
  - Shear systematics

- CMB:
  - CMB anisotropies and structure formation
  - Features in the CMB angular power spectrum
  - WMAP constraints on cosmological parameters
  - Expectations from Planck

- Large-scale structure:
  - Baryon Acoustic Oscillations
  - Predictions for BAO from N-body and Perturbation Theory
  - Effects of non-linearity, bias, and redshift distortions
  - Redshift Distortions as a probe of the growth rate

- Photometric Redshifts:
  - Photo-z methods: template; empirical approaches
  - Forecasting DES+VHS photo-z's
  - Photo-z errors and systematics

- **The Dark Energy Survey:**

- Overview of the Dark Energy Survey:
  - Translating DE probes into survey parameters: area, depth, filters

- The Dark Energy Camera
- Guest mini-lecture: DES Survey Strategy and its optimization, J. Annis (Nov. 5)
- Guest mini-lecture: CCDs and DECam, J. Estrada (Nov. 12)
- Guest mini-lecture: DECam optics and optical design, S. Kent (Nov. 19)
- Optimizing the DES Supernova Survey
- Calibrating large photometric surveys

- Forecasting Constraints from DES:
  - Fisher matrix
  - Figures of Merit and forecast constraints from DES
  - Combining multiple probes, testing DE vs. modified gravity

- DES simulations:
  - From N-body simulations to simulated DECam images
  - The DES Data Management System: turning raw into reduced images and creating catalogs of stars and galaxies
  - Technical issues: Sextractor, galaxy photometry, star-galaxy separation, deblending
  - Data Challenge 5: accessing and analyzing mock DES data
  - Results of DC5 analyses

**Useful References**

We'll make reference to the original literature as we go along. The following include some reviews and descriptions and forecasts:

Frieman, Lectures on Dark Energy and Cosmic Acceleration, AIP Conf. Series, Vol. 1057, pp. 87-124 (2008); astro-ph/0904.1832
Frieman, Turner, and Huterer, ARAA, 46, 385 (2008); astro-ph/0803.0982: general review
Linder, astro-ph/0801.2968: review
Albrecht, etal, Dark Energy Task Force Report, astro-ph/0609591
Albrecht, etal, Figure of Merit Science Working Group Report, astro-ph/0901.0721
Lahav, et al, astro-ph/0910.4714: forecast neutrino mass constraints from DES LSS
Bernstein, etal., DES Supernova Simulations and Survey Strategy (draft)
Mohr, etal., The DES Data Management System, astro-ph/0807.2515
Banerji, etal. Photo-z's for DES and LSS, astro-ph/0711.1059
The Dark Energy Survey, astro-ph/0510346
Annis, etal, Constraining Dark Energy with DES: Theoretical Challenges, astro-ph/0510195
Shapiro, etal, DES forecasts and modified gravity, astro-ph/1004.4810
DES Science Proposal (2007)