Astronomy 411: The Science of the Dark Energy Survey
Fall Quarter, 2016
Class: Wednesdays, Fridays 1:30-2:50 pm in ERC 583
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best)

The discovery of cosmic acceleration in 1998 has since been confirmed by further observations of supernovae, the cosmic microwave background (CMB), 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 informal 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. DES is now in its fourth observing season using the new Dark Energy Camera on the Blanco 4-meter telescope at CTIO.

This course will cover the techniques for probing dark energy in detail, with particular emphasis on weak and strong lensing, clusters, large-scale structure, cross-correlations with the CMB, and supernovae, and explore how DES will realize these techniques. We will familiarize ourselves with the main hardware and software components of the project that turn astronomical photons into calibrated astronomical images and catalogs, and science analysis tools. Students will be given access to proprietary DES data and learn basic techniques for querying the database and looking at the data. Students will formulate projects involving analysis of the data, depending on their interests and level of expertise, and report on their findings later in the quarter. 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, and those already involved will hopefully have their skills and knowledge enhanced.

The course will start with lectures reviewing cosmic acceleration and the techniques for probing dark energy, continue with more specialized talks and discussions on various aspects of the Dark Energy Survey project, including discussion of early DES science papers, and finish with student presentations on DES data exploration and analysis. Exact choice of topics to be covered below will depend on interests and background of the students. Useful class projects would include updating the DES Wikipedia page and the DES public website darkenergysurvey.org.

Required Work

Toward the end of the quarter, students will write up and orally report on research projects related to DES that they will carry out starting earlier in the quarter. There may

be some short exercises along the way.

Class Schedule:

For Wednesday classes, we will overlap with the weekly meeting of the local DES research group: those group meetings will run 1-2 pm, and class will then run from 2 to 2:50 pm; students are strongly encouraged to come for the group meetings, as that is an excellent way to learn more about DES research. On the first Wed. of each month, the group meetings will instead run from 2:30-3:30 pm, so class will run from 1:30-2:30 pm on those days. Classes will include some tutorials and guest lecturers on selected topics.

Wed. classes will be in ERC 345, Fri. classes in 583.

Wed. Sept. 28
Fri. Sept. 30
Wed. Oct. 5
Fri. Oct. 7: Liz Buckley-Geer on Strong Lensing & Science Portal
Wed. Oct. 12
Fri. Oct. 14: DES database tutorial with Matias Carrasco-Kind
Wed. Oct. 19
Fri. Oct. 21: Dan Scolnic on SN Cosmology
Wed. Oct. 26 Photometric Redshifts with Huan Lin
Fri. Oct. 28: DES data pipeline with Brian Yanny
Wed. Nov. 2
Fri. Nov. 4: Elisabeth Krause on Weak Lensing and Multi-probe analysis
Wed. Nov. 9
Fri. Nov. 11
Wed. Nov. 16
Fri. Nov. 18
Wed. Nov. 23: NO CLASS (Thanksgiving break)
Fri. Nov. 25: NO CLASS (Thanksgiving break)
Wed. Nov. 30: NO CLASS
Fri. Dec. 2: NO CLASS
Wed. Dec. 7: Oral reports

- **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

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

- Supernovae
  - Type Ia Supernovae as Calibrated Candles
  - Light-curve fitting methods
  - Dust extinction and other systematics
  - Past results and expectations from DES

- Clusters:
  - Counting Clusters: probing geometry and growth
  - Cluster observables
  - Mass-observable relation, self-calibration, systematics
  - Optical cluster-finding methods

- Gravitational Lensing:
  - Gravitational Lensing and Shear
  - Cosmic Shear and Galaxy-galaxy lensing as probes of geometry and growth
  - Shear systematics
  - Strong Lensing: Arcs and Multiply-imaged QSOs
  - Strong Lensing Time Delays and Cosmology

- Large-scale structure:
  - Baryon Acoustic Oscillations
  - Galaxy Angular Clustering
  - Cross-correlation with CMB Lensing

- Photometric Redshifts:
  - Photo-z methods: template; empirical approaches
  - Methods applied to DES
  - Photo-z errors and systematics
  - Angular cross-correlations and $N(z)$

- Dark Energy Constraints from DES:
  - Combining multiple probes

- **The Dark Energy Survey:**

- Overview of DES:
  - Translating DE probes into survey parameters: area, depth, filters
  - The Dark Energy Camera
  - Survey Strategy and its optimization
  - CCDs and DECam
  - DECam optics and optical design

- DES data:
  - The DES Data Management System: turning raw into reduced images and creating catalogs of stars and galaxies
  - Technical issues: co-addition, difference imaging, object detection, photometry, star-galaxy separation, deblending, calibration
  - DES Data
  - Databases, catalogs: SVA1, SVA1-Gold, Y1A1, Science Portal, etc

Useful References

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

Frieman, Lectures on Dark Energy and Cosmic Acceleration, AIP Conf. Series, Vol. 1057, pp. 87-124 (2008); arXiv:0904.1832
Frieman, Turner, and Huterer, ARAA, 46, 385 (2008); arXiv:0803.0982: general review
Weinberg, etal, "Observational Probes of Cosmic Acceleration", Physics Reports; arXiv:1201.2434
Bernstein, etal., "Supernova Simulations and Strategies for DES", ApJ; arXiv:1111.1969
The Dark Energy Survey, astro-ph/0510346
DES Science Proposal (2007)
DES science papers published and in preparation
Dark Energy Survey Overview Paper (draft in preparation)