Prediction of Observing Conditions for DES Exposure Scheduling

Dark Energy Survey techniques and surveys

The DES will measure dark energy equation of state parameters using four methods, requiring data from two surveys.

**NARROW-FIELD**
The narrow field survey will consist of observations of a small number of fields using regular cadence.

**TYPE Ia supernovae**
Because the SN Ia technique relies on supernovae to serve as a yardstick for distance, the narrow field survey will be observed at the same rate as the wide field survey in order to provide a calibrating standard.

**WIDE-FIELD**
The wide field survey will consist of normal observations of a very large area on the sky in each filter.

**BARYON ACOUSTIC OSCILLATIONS**
The weak gravitational lensing technique depends upon weak-lensing measurements of large numbers of galaxies. The wide field survey is therefore sensitive to seeing conditions.

ObsTac requires an estimate of the seeing to determine whether to observe the narrow or wide-field survey, and an estimate of the sky brightness to determine which pointings and filters are observable.

Sky brightness

**REFERENCE SKY BRIGHTNESS DATA**
The Sloan Digital Sky Survey (SDSS) photometric point (PT) is a 16" telescope used to monitor extinction and calibrate standard stars for the SDSS. The PT collected more sky exposure of a sequence each of the 5 SDSS filters from 1999 to 2001, over a range of seeing and conditions. These exposures form the reference data for the sky brightness model outlined here.

**AIRGLOW**
This model estimates airglow using the thin spherical shell model of van Rhijn (1981). In this model, the source function of the airglow depends on the scattering function, which is a function of the angle between the moon and the line of sight. The effective extinction in the airglow is a function of the distance of the moon and the line of sight.

**SCATTERING OF MOONLIGHT**
Moonlight scattered off atmospheric gases is advected in the atmosphere of the moon at a rate of 20,000 km per hour. The effective extinction in the airglow is a function of the distance of the moon and the line of sight. The lunar brightness is the difference between the combined single-wavelength moonlight model and the measured PT sky brightness.

**OTHER SOURCES OF SKY BRIGHTNESS**
There is an additional source of sky brightness, including light pollution, unregistered astronomical sources, medical light pollution, and polar auroras. These are not modeled explicitly. Instead, the effects from the best fit model of airglow and scattered moonlight are fit to a low order function of altitude, azimuth, time, latitude, and time of year.

**MODEL OFFSETS AS AN AUTO-REGRESSIVE TIME SERIES**
Even after the trend and systematic parameters have been subtracted, residuals remain. These residuals are strongly correlated in time, suggesting that a good estimate of the offset from the model is the largest factor in the offset from the model in the past year. An autoregressive model, for which the offset is the weighted mean of the global mean and a number of previous time steps, is one way of modeling such a system. For this model, the mean offset is the result of a linear combination of the previous two time steps plus a noise term. To model the offset, for example, 100,000 samples were taken for the offset:

\[
\Delta t = 0.10 \Delta t_{\text{meas}} + 0.11 \Delta t_{\text{meas}} + 0.01 \Delta t_{\text{meas}} + 0.01 \Delta t_{\text{meas}} + \eta
\]

where \( \eta \) is normally distributed with an amplitude of 0.01. The mean offset is then used to provide an estimate of the offset for future predictions.

**SEENING DISTRIBUTION**
The distribution of seeing is determined from data on the seeing distribution. The best fit model of seeing distribution is then used to provide a reasonable match. From the best fit, a distribution function that transforms the measured distribution of seeing values into a normal distribution of values \( x \).

**SEENING VARIATIONS AS AN AUTO-REGRESSIVE TIME SERIES**
For the transformed values, a good auto-regressive function is:

\[
\Delta x = 0.10 \Delta x_{\text{in}} + 0.03 \Delta x_{\text{in}} + 0.01 \Delta x_{\text{in}} + 0.02 \Delta x_{\text{in}} + \xi
\]

where \( \xi \) is normally distributed with a standard deviation of 0.01. The value \( x \) value is then used to provide a reasonable match. From the best fit, a distribution function that transforms the measured distribution of seeing values into a normal distribution is then used to provide a reasonable match.

Future work

The models are being implemented into ObsTac, where they will be used for two purposes. First, they will be used to determine the selection of the observation as described above. Second, they serve as the models in the simulation of the survey that we use to optimize survey strategy.