Modeling the Focus and Alignment Systems on the Dark Energy Camera

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The Dark Energy Survey (DES) will image approximately 300 million galaxies in the southern skies using the 4-meter Blanco Telescope in Chile over five years. The primary science goal of the survey is to measure the equation of state parameter, w, for dark energy, the mysterious essence causing the expansion of the universe to accelerate. Among the many technologies required to achieve this goal are the focus and alignment systems on the 2-ton Dark Energy Camera (DECam) contained within the telescope. An effort is underway to create a system that corrects the focus and alignment of the camera after every other image, which are taken at a rate of once per 17 seconds. Dedicated to this task are 12 2k×2k pixel CCDs located on the periphery of the focal plane, set out of focus above and below the plane by 1.5 mm. The distortion of stars imaged on these CCDs will be used to determine the amount by which the alignment and focus of the camera need to be corrected. An algorithm under development will be able to extract the focus and alignment from these images. The primary goal of this project is to test the reliability of this algorithm using a model of the Blanco Telescope and DECam made with optical modeling software.

A model of the Blanco Telescope and DECam was previously made with the optics simulation software *Zemax*. Using the model, the Point Spread Function (PSF) of the system will be extracted for a variety of realistic camera tilts, decenters, and focuses. The PSF is the image observed from a point source, which for all purposes a star is. Using *Python* code, atmospheric effects at the telescope site, pixilation from the CCDs, and noise will be added to the PSF to create a library of realistic images that the camera could encounter.

A nonlinear fitting routine, also written in *Python*, will then be applied to the manufactured images. The routine will return the set of associated tilts, decenters, and focuses along with confidence intervals and other statistical data. The hope is that the parameters originally input into the model in *Zemax* will fall comfortably within the statistical parameter ranges provided by the fit, thereby confirming the reliability of the algorithm. Possible systematic errors in the parameters will be investigated to determine a root cause. Alterations to the fitting routine and model in *Zemax* will almost certainly be encountered, many of which will be made to make the model as realistic as possible. Examples include vignetting due to the cylinder and supports surrounding the camera, atmospheric seeing variability, level of random noise, and star magnitude.

The work completed should provide a thorough test of the fitting algorithm in the sort of conditions the telescope will face. The focus and alignment systems developed will be valuable in reducing systematic errors due to focus, which will increase the sensitivity of galactic weak gravitational lensing measurements used to probe dark energy.