Spurious shear from tree-rings on LSST CCD

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Charge-COupled Device(CCD) detectors in observational instruments are composed of a silicon layer, which changes photons from astronomical objects into electrons. The electron signal is amplified and contains information about the objects. Impurity gradients in the silicon that originate when it is grown produce transverse electric fields that bend the electron path. The bending creates flux modulation, position displacement and shape distortion of objects. The tree-ring effect is caused by circularly symmetric impurity gradients in the silicon wafer., which induce flux modulation, position displacement, and shape distortion of the observed astronomical objects. The tree-ring effect in some recent observational instruments (DES[a) , HSC[b)) are smaller than the pixel scale, inducing small changes in object images. Future high precision cosmology by the LSST[c) needs high precision measurement of astronomical objects. One of the methods for studying cosmology is the measurement of weak lensing shear (Schneider et al., 2006[1)]), which changes the shape of the image of objects from a large scale structure (cosmic shear). Statistics of the cosmic shear depend on the cosmological parameters, which characterize the initial state and future of the Universe. However, the tree-ring effect causes systematic error in the measurement because it changes the shape of images (Plazas et al., 2014[2)]). We studied the impact of the tree-ring effect on the LSST test CCDs for high-precision cosmology.

We are the first to quantify the tree-ring effect on the LSST prototype sensors. We used flat images that contain data taken with uniform illumination where concentric flux modulation (tree rings) can be observed. We found the center of the tree-ring effect near the corner of the CCD (Fig. 1) and measured teh one-dimensional profile by averaging by angle (blackline in Fig. 2). If the flux modulation or position displacement are concentric, shape distortion(spurious shear) can be obtained (Okura et al in preparation) as

$$\gamma^{TR}_{rad}(r) \approx -\frac{1}{2}f(r), \tag{1}$$

where $f(r)$ and $\gamma^{TR}_{rad}(r)$ are the profiles of flux modulation and spurious shear, respectively. We show the measured spurious shear in Figure 2, and the blue line indicates the measured spurious shear. As typical scale of the spurious shear is 0.005%, it is much smaller than the cosmic shear which has typical scale of approximately 1-2 %.

Next, we calculated the two-point correlation of the spurious shear because, in cosmological analysis, we calculate the two-point correlation of the cosmic shear for obtaining the statistics of the cosmic shear. Figure 3 shows the two-point correlation of the spurious shear in the field of view of LSST (189 CCDs, 60000 × 60000 pixels) with a sampleing scale of 50 pixels. The typical scale of the correlation is approximately 10^{-13}, which is much smaller than the two-point correlation of the cosmic shear(10^{-6}). Therefore, the tree-ring effect on the LSST CCDs will not degrade the constraining of the cosmological parameters.

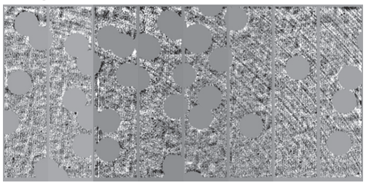

Fig. 1. Tree-ring pattern on the LSST CCD

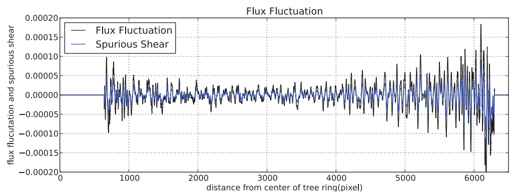

Fig. 2. One-dimensional profile of the flux modulation (black) and spurious shear (blue) caused by the tree-ring effect on the LSST CCD.

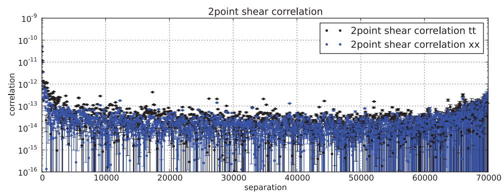

Fig. 3. Absolute values of two-point spurious shear correlation caused by the tree-ring effect on the FOV of the LSST CCD. Black points indicate parallel correlation, and blue points indicate cross correlation with 50-pixels sampling. Non-absolute values oscillated about zero.

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a) http://www.darkenergysurvey.org
b) http://www.naoj.org/Projects/HSC/HSCProject.html
c) http://www.lsst.org

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