Cosmic Shear with Keck: Systematic Effects

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Abstract. Cosmic shear probes the distribution of dark matter via gravitational lensing of distant, background galaxies. We describe our cosmic shear survey consisting of deep blank fields observed with the Keck II telescope. We have found biases in the standard weak lensing analysis, which are enhanced by the elongated geometry of the Keck fields. We show how these biases can be diagnosed and corrected by masking edges and chip defects.

Images of background galaxies become weakly distorted by gravitational lensing as light travels through intervening large-scale structure to the observer. These distortions provide a direct measurement of the mass distribution in the universe, without assumptions about the nature, state or luminosity of the dark matter.

This “cosmic shear” effect is small, with the axis ratio of a typical galaxy being elongated by only about 1%. However, adjacent lines of sight have passed through the same large-scale structures and close (∼1’) pairs of background galaxies receive coherent distortions. After removing systematic shape measurement biases, we may average over many galaxy pairs to detect this signal. We present a survey covering 0.6 square degrees to $R \sim 26$, scattered randomly around the sky in 173 pointings of the Echelle Spectrograph and Imager on Keck II. After cuts, our final catalogue contains 63,000 galaxies.

Shear Measurement and Elimination of Systematic Biases

Measurement of such a small effect demands careful data reduction and elimination of systematic errors. Bias subtraction and flat fielding were optimised using the background level and the overscan regions at the edge of individual exposures. Three slightly dithered exposures were then astrometrically realigned and co-added to produce each survey field. As a by-product, this allowed the monitoring of instrumental distortion at different telescope positions. Keck proves ideal for cosmic shear, with negligible <0.3% internal distortions even at the edges of the $2' \times 8'$ field of view. The PSF shape was measured from stars across each reduced field. The isotropic and anisotropic contributions of the PSF to galaxy shapes was then corrected using the $KSB$ method (Kaiser, Squires, & Broadhurst 1995), which is well tested and calibrated (Bacon et al. 2001; Erben et al. 2001).
Overall, we find $\langle \gamma_1 \rangle = -0.02\% \pm 0.16$ and $\langle \gamma_2 \rangle = -0.29\% \pm 0.16$.

However, the long-thin geometry of the ESI field enhanced two unforeseen biases in this standard reduction procedure. Firstly, the PSF interpolation in the short $x$ direction was often overfit by KSB's simple polynomial fitting. The divergent PSF model overcompensated for the true smearing and spuriously elongated in the $y$ direction galaxies near to the sides. This effect revealed itself as a residual shear offset (similar to that in CFHT data of van Waerbeke et al. 2001) and in the final shear correlation functions as a $\sim 1.1\%$ shear excess in pair separations around 2', the width of the chip. A more adaptive algorithm was written, which found the smallest degree polynomial possible for a significant fit and which could be monitored to remove any anomalous stars by hand.

Edge effects (including not only the boundaries of the CCD but also chip defects and saturated stars) were also of concern for such a narrow field of view. Galaxies near an edge on any one of the three dithered exposures are cut in half and appear aligned to that boundary. Even if not exactly on the boundary, the flat fielding was poorer near edges (\sim 10^{-4} gradient) and image co-addition failed because of differing background levels in the dithers. If strips of galaxies are not excluded from the final catalogue, the overall mean shear increases by $\sim 2\%$ or $\sim 1\%$ respectively. With masking and PSF fitting as described, this offset disappears. Figure 1, a useful diagnostic tool, shows our final results.

Conclusions

Two previously unforeseen biases in the standard weak lensing procedure, enhanced by the elongated Keck field geometry, were isolated and removed by CCD masking. Further treatment of systematics, results, and their cosmological implications will be presented in a forthcoming paper (Bacon et al. 2002, in preparation).

References

Bacon, D., Refregier, A., Clowe, D., & Ellis, R. 2001, MNRAS, 325, 1065
Erben, T. et al. 2001, A&A, 366, 717
Kaiser, N., Squires, G., & Broadhurst, T. 1995, ApJ, 449, 460
van Waerbeke, L. et al., 2001 A&A, 358, 30