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Cosmic Shear with the Advanced Camera for Surveys

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In these proceedings we present a cosmic shear analysis of data from the HST/ACS Parallel Cosmic Shear Survey. Due to its relatively large field-of-view in combination with space-based resolution, ACS provides excellent conditions to measure cosmic shear on small and intermediate angular scales. We used 54 deep ACS/WFC images with an average galaxy number density of ~ 85 per square arcminute for the cosmic shear analysis. We thoroughly investigated the effect of the HST/ACS point spread function (psf) on the shear measurement. To account for the low number of stars present in many fields at high galactic latitudes, we developed a new method for the psf anisotropy correction using a superposition of template patterns. Our preliminary cosmic shear results are consistent with ΛCDM predictions with $\sigma_8 = 0.8$. We still find indications for a remaining contamination of our data with systematic effects. Once these remaining systematics are properly understood and corrected, it will be possible to measure cosmic shear at small scales with the ACS Parallel Cosmic Shear Survey with unprecedented precision.

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1. Introduction

The light of distant galaxies is continuously deflected while traveling through the gravitational potential of the large-scale matter distribution in the universe. This weak gravitational lensing effect of the large-scale structure itself is termed cosmic shear. The resulting distortion of the galaxy shapes is only of the order of 1% and thus cannot be measured from a single galaxy. However, a coherent distortion can be measured statistically from an ensemble of background galaxies. Such a cosmic shear analysis provides a powerful tool to probe the growth of structure on different scales, and thus to place constraints on cosmological parameters.

Ground-based cosmic shear surveys are strongly affected by atmospheric seeing, which dilutes the shear signal for galaxies of similar size as the seeing disk. This strongly limits the number density of usable background galaxies in ground-based surveys. Space-based cosmic shear data on the other hand yield number densities higher by a factor of two and more. Cosmic shear has previously been detected with HST/WFPC2 (Rhodes et al. 2001, Refregier et al. 2002, Casertano et al. 2003) and HST/STIS (Hämmerle et al. 2002, Miralles et al. 2003, Rhodes et al. 2004). These cosmic shear studies were however limited by the relatively small size of the investigated surveys. The recently installed Advanced Camera for Surveys (ACS) combines a large field-of-view ($3.'3 \times 3.'3$) and increased sensitivity with a good sampling of the psf ($0.''05$ per pixel), making it better suited for weak lensing studies than any previous HST camera. In these proceedings we present results of a pilot study to estimate the feasibility of a precision measurement of cosmic shear at small angular scales with ACS.

2. Data and data analysis

For a first pilot study we analyzed pure parallel ACS/WFC i–band data from the ACS Cosmic Shear Survey (PI: J. Rhodes). We used 54 high galactic latitude galaxy fields for the cosmic shear analysis and 63 star fields for the investigation of the ACS psf. Catalogs were created using *SExtractor* (Bertin & Arnouts 1996). For shape measurements and correction for psf effects we applied the KSB formalism (Kaiser et al. 1995) as implemented in Erben et al. (2001).

Precision measurements of cosmic shear require accurate knowledge of the image psf and the capability to correct for systematic effects induced by it. On the one hand the isotropic blurring of the psf dilutes the shear signal. Additionally uncorrected anisotropic components of the psf can mimic a false shear signal. Due to the small field-of-view of HST cameras, at most a few stars per camera chip can be used for a psf analysis in typical high galactic latitude fields. Since the instrumental psf usually varies across the field-of-view, a full correction can not be derived from the stars present in each galaxy field. Past studies solved this problem by deriving corrections from stellar fields and applying them under the assumption of temporal stability.

From the analysis of 63 stellar fields we found that the ACS psf shows a significant anisotropic component, which varies across the field-of-view and also shows time variations within hours. These can be accounted to telescope 'breathing', as the HST goes into and out of the sunlight in its 90 minute orbit. Here however only a few typical anisotropy patterns occur mainly depending on the focus position. To account for these time variations, we made use of the fact, that for the ACS field-of-view, even at high galactic latitudes, at least 10-15 stars are present in each image. To derive a correction for each galaxy field, we fitted the anisotropic component of the psf of the stars

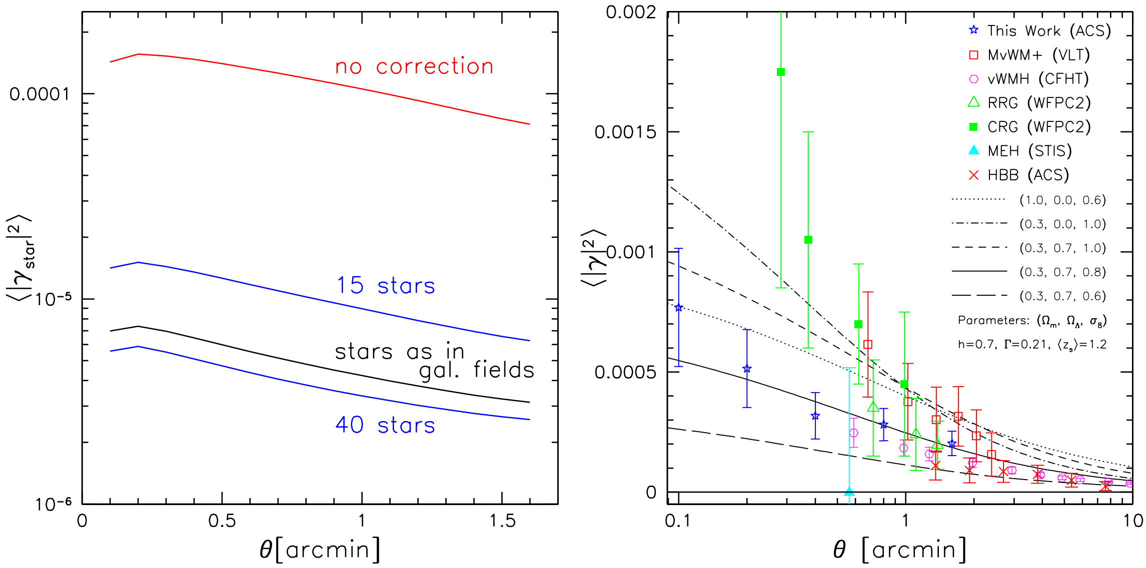

Figure 1: Left: Estimate of the remaining systematic shear variance after anisotropy correction depending on the number of stars, which can be used to determine the correction. **Right:** Comparison of the estimated top–hat shear variance as a function of the circular aperture radius θ with deep measurements from other groups and theoretical predictions corresponding to a redshift distribution as given by Brainerd et al. (1996) with a mean source redshift of $\langle z_s \rangle = 1.2$.

present with a superposition of template patterns. We used the anisotropy patterns of three typical star fields as templates, which were selected by applying the method to the entirety of all star fields. We tested this method by applied it to randomly chosen subsets of stars in stellar fields. For each star field we determined the correction from the chosen subset, but applied it to the entirety of stars. Talking into account that larger galaxies are less affected by psf effects than stars, we calculated the expected systematic shear variance from the corrected stellar ellipticities, which yields a reduction of the systematic signal by more than one order of magnitude (see left panel of Fig. 1).

3. Preliminary cosmic shear results

We used 54 fields at high galactic latitudes containing on average ~ 85 galaxies per square arcminute with a median i-band AB magnitude of 25.8 mag for the cosmic shear analysis. The estimated shear variance is compared to the results from other groups[1] and theoretical predictions in the right panel of Fig. 1. Due to the extremly high number density of background galaxies we were able to extend existing cosmic shear measurements to very small scales $0\farcm1 \le \theta \le 0\farcm2$, for which the nonlinear evolution of structure growth is extremely important. Assuming a median source redshift of $\langle z_s \rangle = 1.2$ and a standard ΛCDM cosmology, our results are consistent with an amplitude of the matter power spectrum $\sigma_8 = 0.8$. However, an E-/B-mode decomposition for the aperture mass dispersion (Schneider et al. 1998) yielded a significant B-mode in the data, which is not expected from pure lensing and thus indicates the presence of further systematic effects. Therefore our results have to be interpreted carefully. Also Heymans et al. (2004), who measured

[1] The results measured with a square aperture are plotted at the radius of a circular field with the same area. For the errorbars of the data from van Waerbeke et al. (2004) the statistical errors and the B-mode are added in squares. From the Heymans et al. (2004) results only the B-mode free scales are plotted.

cosmic shear in the ACS GEMS survey, detected a significant B-mode at small scales, which the authors account to a possible remaining psf anisotropy.

4. Conclusions

The ACS psf is temporally variable. We developed a new fitting strategy to account for this time variation using a superposition of templates. Our preliminary cosmic shear results are consistent with the results of most other groups and theoretical predictions for a standard ΛCDM cosmology with $\sigma_8 = 0.8$. However they have to be interpreted carefully since we detected indications for the presence of remaining systematic effects. We are currently carrying out a more detailed study to identify their origin. Once these systematics are understood and properly corrected for, we will be able to measure cosmic shear at small scales with unprecedented precision using the four times larger complete ACS Parallel Cosmic Shear Survey (in total about 0.7 square degrees).

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