Available online at www.sciencedirect.com

SCIENCE DIRECT®

New Astronomy Reviews 49 (2005) 392–395

New Astronomy Reviews

www.elsevier.com/locate/newastrev

Weak lensing studies from space with GEMS

C. Heymans [a,*], M.L. Brown [b], M. Barden [a], J. Caldwell [c], B. Häußler [a], K. Jahnke [d], H.-W. Rix [a], S. Beckwith [c], E.F. Bell [a], A. Borch [a], S. Jogee [c], D.H. McIntosh [e], K. Meisenheimer [a], C. Peng [f], S. Sánchez [d], R. Somerville [c], A.N. Taylor [b], L. Wisotzki [d], C. Wolf [g]

[a] *Max-Planck-Institut für Astronomie, D-69117, Heidelberg, Germany*
[b] *University of Edinburgh, Edinburgh, EH9 3HJ, UK*
[c] *Space Telescope Science Institute, Baltimore MD, 21218, USA*
[d] *Astrophysikalisches Insitut Potsdam, D-14482 Potsdam, Germany*
[e] *University of Massachusetts, Amherst, MA 01003, USA*
[f] *University of Arizona, Tuscon AZ, 85721, USA*
[g] *University of Oxford, Oxford, OX1 3RH, UK*

Available online 26 September 2005

Abstract

The Galaxy Evolution from Morphology and SEDs (GEMS) survey is the largest contiguous field ever imaged in colour by HST with the Advanced Camera for Surveys (ACS), spanning some 900 square arcmins in the Chandra deep field south (CDFS). We discuss the power of the ACS for weak lensing studies and present preliminary results from our cosmic shear analysis of GEMS. Selecting a subset of GEMS galaxies which are resolved in deep ground-based R-band imaging of the CDFS from the COMBO-17 survey, we compare the cosmic shear signal determined from the ground and from space.

Contents

* Corresponding author.
E-mail address: heymans@mpia.de (C. Heymans).

1387-6473/$ - see front matter © 2005 Published by Elsevier B.V.
doi:10.1016/j.newar.2005.08.010

1. Introduction

Weak gravitational lensing by large scale structure shears images of background galaxies, inducing weak correlations in the observed ellipticities of galaxies, where the amplitude and angular dependence of these correlations are directly related to the nonlinear matter power spectrum $P_\delta(k)$ and the geometry of the Universe (see Bartelmann and Schneider, 2001 and references within). Following the success of the first generation of cosmic shear surveys several ground based surveys are currently underway that will image of the order of a hundred square degrees, providing exquisite data sets for future weak lensing analysis. These surveys will however be subject to atmospheric seeing which erases the weak lensing shear information from all galaxies smaller than the size of the seeing disk. This, in effect, limits the maximum depth of ground based weak lensing surveys and hence the sensitivity, leading to proposals for future deep wide-field space-based observations such as JDEM and DUNE.

With the installation of the ACS on HST, relatively wide-field space-based weak lensing studies are now feasible and in this conference proceeding we present the detection of weak gravitational lensing by large scale structure in F606W Galaxy Evolution from Morphology and SEDs (GEMS) data which has a resolved galaxy number density of ~100 galaxies per square arcmin (see Rix, 2004 for an overview of the GEMS survey).

2. The ACS PSF

The accuracy of any weak lensing analysis depends critically on the correction for the distorting point spread function (PSF) of the telescope and camera, characterised through images of stellar objects. As a result of the wide field of view of the ACS, the relative stability of the ACS PSF over time, and the observing strategy of GEMS, whereby all but three out of the 63 ACS images were taken in the space of 20 days, the PSF of the ACS in the time period of the GEMS observations is very well characterised.

We use the method of KSB+ (Kaiser et al., 1995; Luppino and Kaiser, 1997; Hoekstra et al., 1998) to invert the effects of the PSF smearing and shearing in order to recover an unbiased estimate of galaxy shear γ. Fig. 1 shows the variation in the measured KSB+ PSF correction vector p across the ACS field of view clearly revealing the anisotropy of the PSF distortion which is at the level of ~5%. We model p with a two-dimensional second order polynomial which we then use to correct all galaxy ellipticities in the GEMS mosaic. Owing to the non-Gaussian nature of the PSF, p changes as a function of galaxy size r_g and we therefore create models $p(r_\mathrm{g})$. Note that for the GOODS images (Giavalisco, 2004), which comprise the central 15 ACS tiles of the GEMS mosaic, we characterise a second set of PSF models using all stars imaged by GOODS, as the different dithering patterns of GOODS and GEMS impacts somewhat on the PSF. The right panel of Fig. 1 shows that the correlation between galaxy ellipticity and stellar ellipticity (upper panel) is successfully removed by the PSF correction (lower panel).

3. Analysis: the shear correlation function

We measure the mean shear correlation function $\langle \gamma_r^t \gamma_r^t \rangle_\theta$ and full statistical covariance matrix from the GEMS data using a modified jackknife method. With knowledge of the survey redshift distribution, the shear correlation function can be directly related to the nonlinear mass power spectrum P_δ, where the exact relationship can be found in Bartelmann and Schneider (2001). We estimate the median redshift z_m of the GEMS survey based on redshifts from the COMBO-17

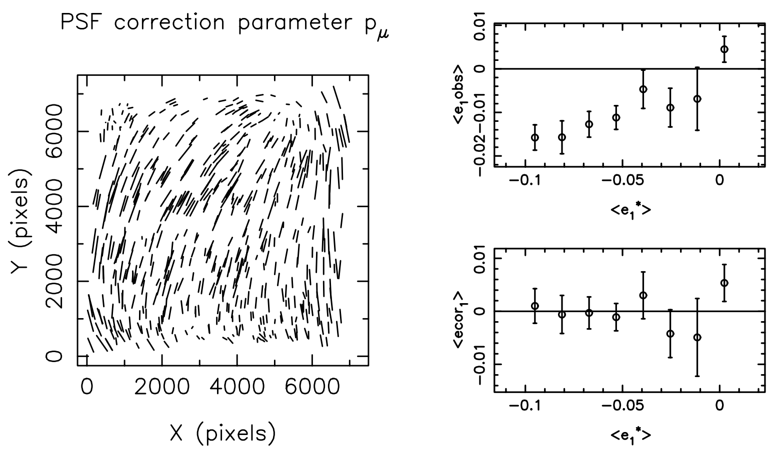

Fig. 1. The variation in the measured PSF correction vector p across the ACS field of view (left). Galaxy ellipticities are corrected for the PSF distortion such that the correlation between galaxy ellipticity and stellar ellipticity seen before PSF correction (upper right) is removed (lower right).

survey (Wolf, 2004) and VVDS survey (Le Fevre, 2004), finding $z_{\rm m} = 0.95 \pm 0.1$. Fig. 2 shows our preliminary measurement of the GEMS tangential and radial shear correlation functions with the theoretical model for a survey with $z_{\rm m} = 0.95$, calculated for a ΛCDM cosmology with the amplitude of the matter power spectrum $\sigma_8 = 0.85$ as found by WMAP (Spergel, 2003), over-plotted. Our results are consistent with this concordant model, although we do note that our error bars are statistical and do not include the uncertainty arising from cosmic variance. The CDFS is a factor of two under-dense in massive galaxies (Wolf, 2003) and we would therefore expect the measurement of σ_8 from this field to be lower than the Universal σ_8.

4. Comparison with COMBO-17 ground based data

COMBO-17 is a deep multi-colour survey spanning 1.25 square degrees in five separate regions, carried out with the WFI/ESO 2.2 m (Brown et al., 2003). The deep R-band COMBO-17 data in the CDFS allows us to compare the CDFS cosmic shear signal measured from space-based data and from ground-based data. We select a subsample of GEMS galaxies that are resolved in the

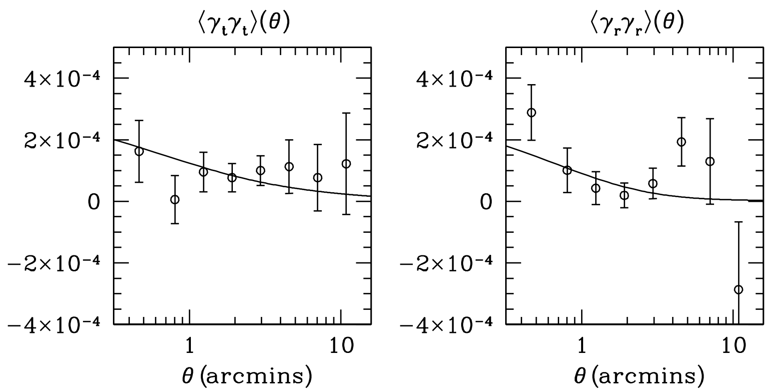

Fig. 2. The GEMS shear correlation function; $\langle \gamma_t \gamma_t \rangle_\theta$ (left) and $\langle \gamma_r \gamma_r \rangle_\theta$ (right). The correlation function prediction for a flat ΛCDM cosmology ($\Omega_{\rm m} = 0.3$, $\Omega_\Lambda = 0.7$) with $\sigma_8 = 0.85$ is over-plotted.

COMBO-17 data, finding good agreement between galaxy shear estimated from GEMS data and from COMBO-17 data. We calculate the shear correlation function for this galaxy subsample which although producing a very noisy result, reveals that the noise in the GEMS galaxy catalogue is less than that from the COMBO-17 catalogue, showing that the measurement of galaxy shear is improved with space-based imaging.

5. Conclusion

We have detected weak lensing by large scale structure in the GEMS survey, demonstrating the power of the ACS on HST for this type of study. The comparison of space-based GEMS data and ground-based COMBO-17 data has shown that galaxy shear is measured to a higher accuracy from space-based data and this evidence, combined with the threefold increase in resolved galaxy number density that comes with HST data, shows that space-based imaging is truly superior to ground-based imaging for weak lensing studies, supporting the drive towards large wide-field imaging surveys from space. A more detailed description of our GEMS weak lensing analysis can be found in Heymans et al. (2005), and our comparison with ground-based data can be found in Brown et al. (in preparation).

References

Bartelmann, M., Schneider, P., 2001. PhR 340, 291.
Brown, M., Taylor, A., Bacon, D., Gray, M., Dye, S., Meisenheimer, K., Wolf, C., 2003. MNRAS 341, 100.
Giavalisco, M.GOODS Collaboration, 2004. ApJ (Lett.) 600, L93–L98.
Heymans et al., 2005. MNRAS 361, 160.
Hoekstra, H., Franx, M., Kuijken, K., Squires, G., 1998. ApJ 504, 636.
Kaiser, N., Squires, G., Broadhurst, T., 1995. ApJ 449, 460–475.
Le Fevre, O., VVDS Team, 2004. A&A 428, 1043.
Luppino, G.A., Kaiser, N., 1997. ApJ 475, 20.
Rix, H.GEMS Collaboration, 2004. ApJ Suppl. 152, 163–173.
Spergel, D.WMAP Collaboration, 2003. ApJ Suppl. 148, 175–194.
Wolf, C.COMBO-17 Collaboration, 2004. A& A 421, 913.
Wolf, C.COMBO-17 Collaboration, 2003. A&A 401, 73.