Cosmic shear analysis of archival HST/ACS data

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Outline

Data from the ACS archive

Pilot feasibility study: Schrabback et al. (2007): A&A 468

- **ACS Parallel Survey** (early): $0.16^{\circ 2}$ in i_{775}: 59 fields, inhomogeneous
- **GEMS+GOODS/CDFS**: $0.22^{\circ 2}$ in V_{606}: $28' \times 28'$ mosaic. Independent analysis by Heymans et al. (2005)

Processing the archive (work in progress)

- **A901/A902 Field (STAGES)**: $0.25^{\circ 2}$ in V_{606}: $30' \times 30'$ mosaic.
- **COSMOS**: $1.64^{\circ 2}$ in i_{814}: $77' \times 77'$ mosaic. Independent analysis by Massey et al. (2007)
- **Extended ACS Parallel Survey**: $1.22^{\circ 2}$ in V_{606}, r_{625}, i_{775}, or i_{814}: 440 fields, 69% parallel, 31% other ($z < 0.07$ or $z > 1.2$), $t_{\rm exp} \geq 1.2$ks. Joint forces with **HAGGLeS** $\Rightarrow$ **P. Marshall's talk on Wednesday**.

Data reduction

Use **MultiDrizzle** for cosmic ray rejection, distortion correction, coaddition

Our upgrades:

- Optimised sky subtraction (bias anomaly)
- **Robust shift refinement**
- **Improved bad pixel masks**:
  - Warm pixels
  - Variable bias structures
  - Residual in median image
- **Optimal weighting** of pixels and frames
- RMS map with proper treatment of noise correlations
- WCS correction
- **Efficient, partially automated masking over the Internet**

Shape measurement+PSF correction

- **Erben et al. (2001) KSB+ implementation**
  (Kaiser et al. 1995; Luppino & Kaiser 1997; Hoekstra et al. 1998)
- **Modifications for space-based data:**
  - Sub-pixel interpolation
  - Measure stellar quantities as function of r_g (Hoekstra et al. 1998; Heymans et al. 2005)
  - Integrate stellar images to $4.5 r^*_{\mathrm{FLUX}}$ (PSF wings)
- Tested on **STEP** simulations: ⇒ **Accuracy sufficient for ACS data**

STEP: Talk by K. Kuijken at 15:30

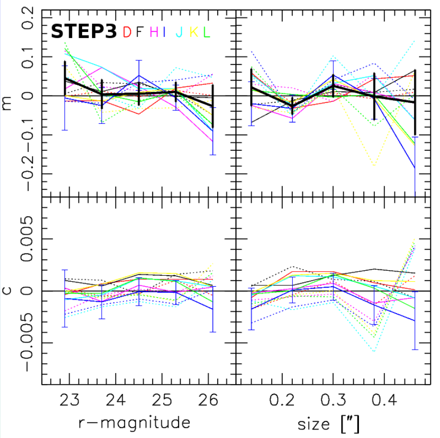


Figure: Calibration bias m and PSF residuals c in the TS analysis of the ACS **STEP3** (spaceSTEP) image simulations. Simulations by W. High, R. Massey, and J. Rhodes.

PSF anisotropy: size dependence

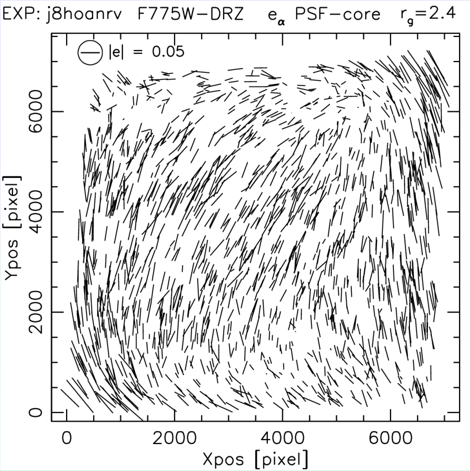


Figure: PSF core for the field j8hoanrv.

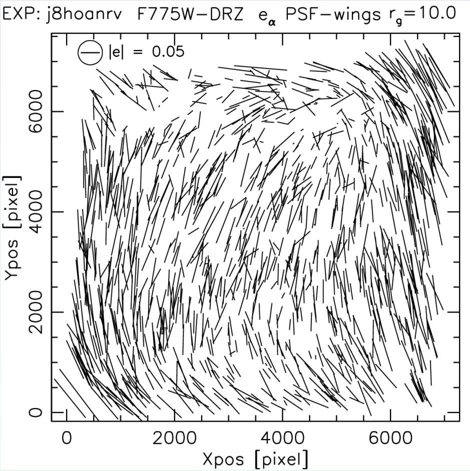
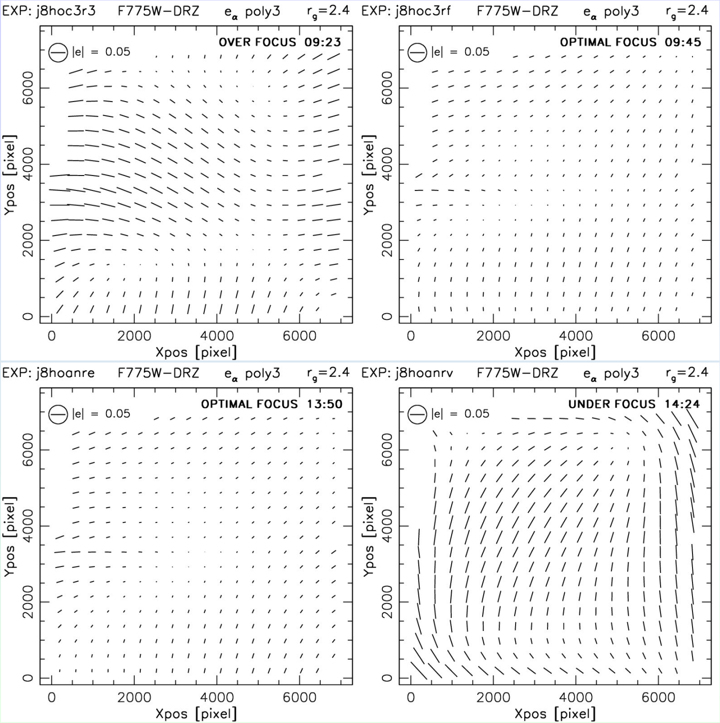


Figure: PSF wings for the field j8hoanrv.



EXP: j8hoc3r3 F775W−DRZ e_α poly3 r_g=2.4
OVER FOCUS 09:23
|e| = 0.05
EXP: j8hoc3rf F775W−DRZ e_α poly3 r_g=2.4
OPTIMAL FOCUS 09:45
|e| = 0.05
EXP: j8hoanre F775W−DRZ e_α poly3 r_g=2.4
OPTIMAL FOCUS 13:50
|e| = 0.05
EXP: j8hoanrv F775W−DRZ e_α poly3 r_g=2.4
UNDER FOCUS 14:24
|e| = 0.05
Ypos [pixel]
Xpos [pixel]
0
2000
4000
6000

PSF correction scheme

- Few stars in galaxy fields (≈ 10) $\Rightarrow$ No polynomial interpolation + time variations $\Rightarrow$ New interpolation scheme
- **Stellar field PSF models** densely cover the parameter space of PSF variation (mainly 1D: focus)
- Find **best-fitting stellar field model** for stars in galaxy fields
- **Clue:** Determine correction for **each exposure** in **undrizzled** frames $\Rightarrow$ **Optimal time-dependence and minimal noise**
- Compute combined model according to dither pattern
- Tests with stellar fields: 10 stars per galaxy field are enough to reduce spurious PSF anisotropy contribution to $\langle\gamma\gamma\rangle$ to $\lesssim 2 \times 10^{-6}$

Pilot study: Average corrected galaxy ellipticity

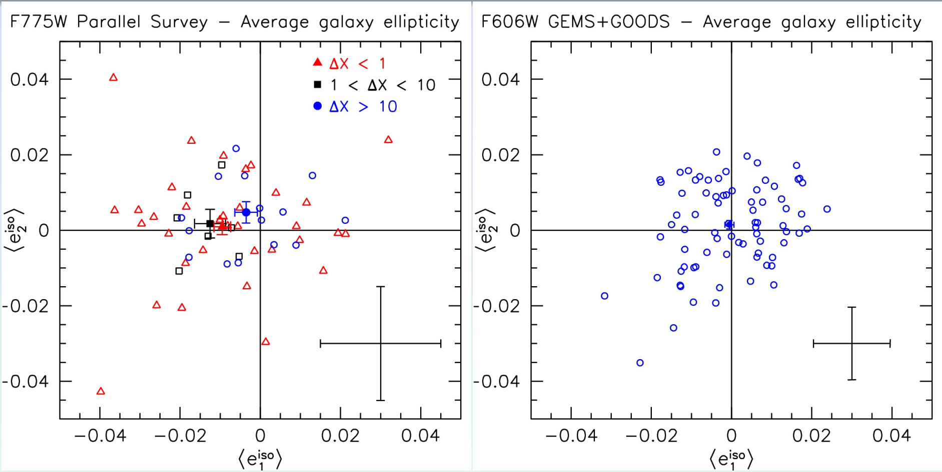


Figure: Average corrected galaxy ellipticity: For the parallel data the sample was split according to the maximal X−shift between the exposures [sub-pixels].

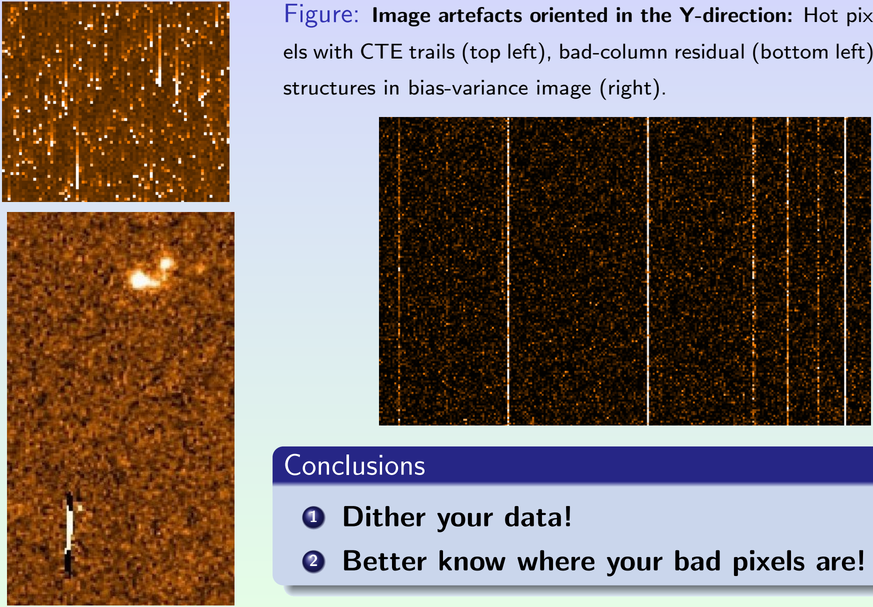


Figure: **Image artefacts oriented in the Y-direction:** Hot pixels with CTE trails (top left), bad-column residual (bottom left), structures in bias-variance image (right).

Conclusions

1. **Dither your data!**
2. **Better know where your bad pixels are!**

Pilot study: E/B-mode decomposition ξ_E,ξ_B

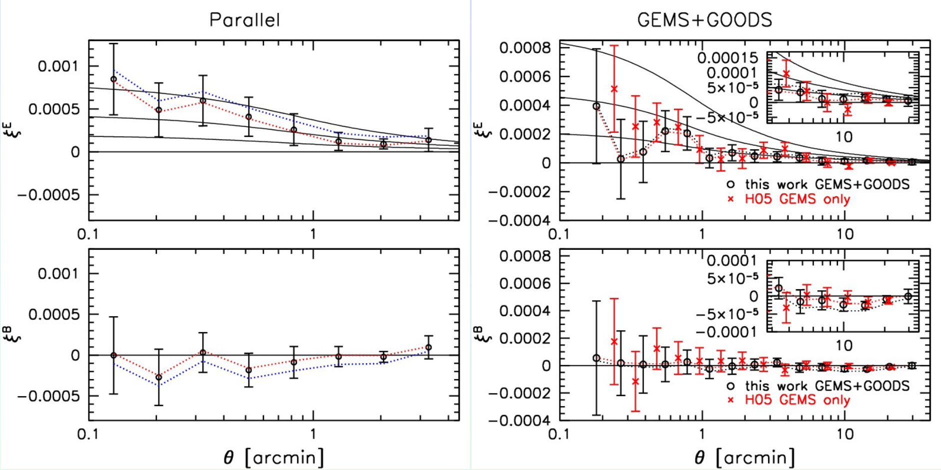
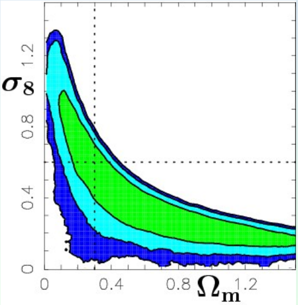


Figure: E/B-Mode decomposition of $\xi_\pm$ according to Crittenden et al. (2002) for $\sigma_8 = 0.7$. Curves: ΛCDM predictions for $\sigma_8 = (0.6, 0.8, 1.0)$, $z_\mathrm{m} = 1.35/1.46$ (l/r).

Cosmological parameter estimation from GEMS/GOODS

- **Redshift distribution** from the GOODS-MUSIC sample (Grazian et al. 2006): $z_{\rm m} = 1.46 \pm 0.12$
- **Monte Carlo Markov Chain** (MCMC) with $\xi_\pm$ in 14 log-bins, $N = 96/[']^2$
- **ΛCDM** with $\Omega_{\rm m}, \Omega_\Lambda \in [0, 1.5]$; $(w, \Omega_{\rm b}, n_{\rm s}) = (-1, 0.042, 0.95)$; Smith et al. (2003)
- **Covariances** from 2000 **Gaussian shear field realizations**



Result: σ_8 for $\Omega_{\rm m} = 0.3$

$\boldsymbol{\sigma_8 = 0.52^{+0.11}_{-0.15}}$ (stat. 68% conf.).

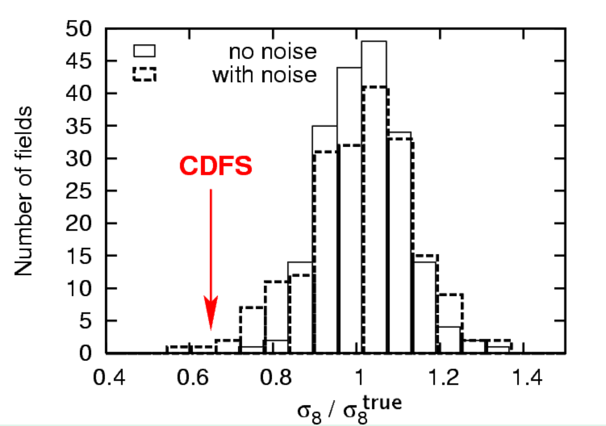
H05 result: $\sigma_8(\Omega_{\rm m}/0.3)^{0.65} = 0.68 \pm 0.13$
Use H05 $z_{\rm m}(m_{606})$ relation: $\sigma_8 = 0.62^{+0.12}_{-0.16}$

Interpretation: local under-density of foreground structures in the CDFS.

Phleps et al. (2006): red galaxy deficiency

Strong non-Gaussian contribution to cosmic variance (see Kilbinger & Schneider 2005; Semboloni et al. 2006)

How peculiar is the CDFS? Compare to ray-tracing...



Conclusion

No representative cosmology from the CDFS!

Figure: **Ray-tracing through the GIF-Simulations**: Histogramm of σ_8-estimates from GEMS-like fields. $\Omega_\Lambda = 0.7$, $\Omega_{\rm m} = 0.3$, $\sigma_8 = 0.9$, $L = 141.3$ Mpc/h, 200 ray-tracing realisations (Hartlap et al. in prep.).

The A901/A902 super-cluster field

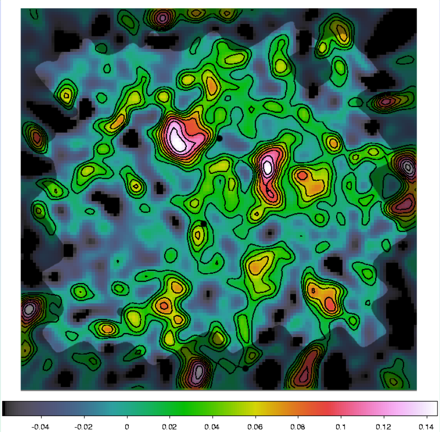


Figure: κ-**Reconstruction of the A901/A902 field.**

If representative: $\sigma_8 \approx 1.2 - 1.3$

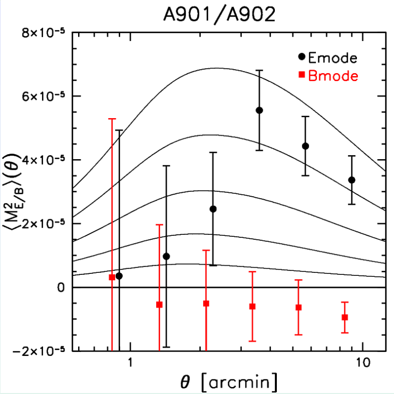
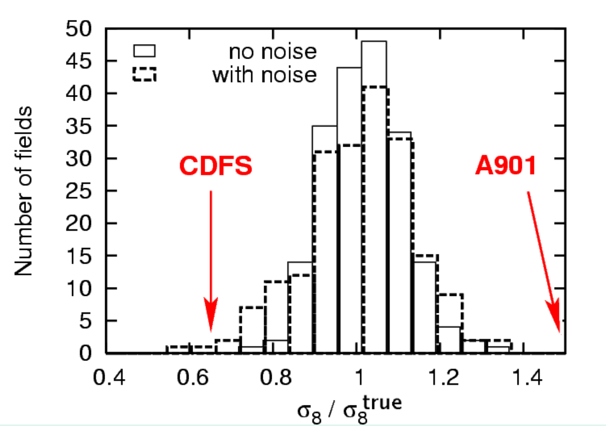


Figure: $\langle M_{\rm ap}^2 \rangle$ E/B-mode decomposition for the A901/A902 field. Error-bars: statistical without cosmic variance. ΛCDM predictions for $z_{\rm m} = 1.25$ and $\sigma_8 = (0.6, ..., 1.4)$.

And how peculiar is that?



Conclusion

No representative cosmology from the A901/A902 field either!

Figure: **Ray-tracing through the GIF-Simulations**: Histogramm of σ_8-estimates from GEMS-like fields. $\Omega_\Lambda = 0.7$, $\Omega_{\rm m} = 0.3$, $\sigma_8 = 0.9$, $L = 141.3$ Mpc/h, 200 ray-tracing realisations (Hartlap et al. in prep.).

COSMOS E/B-mode decomposition: $\xi_{\rm E,B}$

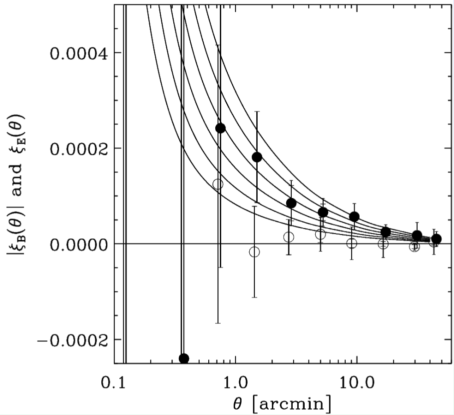


Figure: **Massey et al. (2007) analysis**: Outer error-bars include cosmic variance.

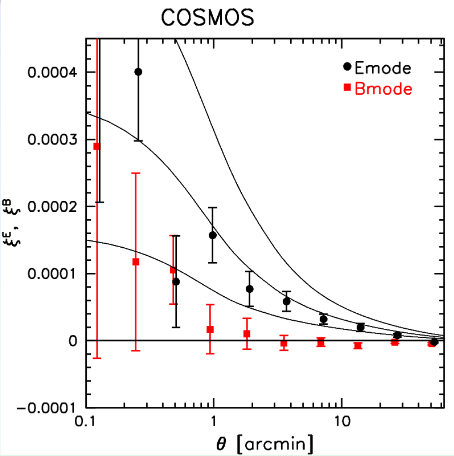
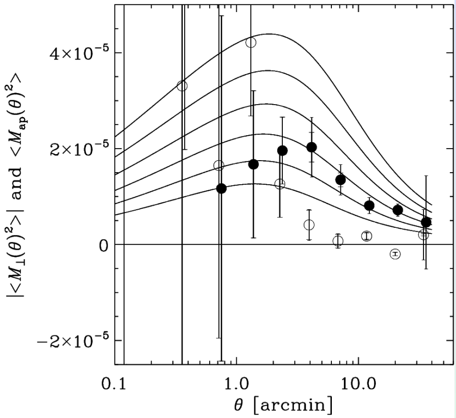


Figure: **Schrabback et al. analysis**: Statistical error-bars without cosmic variance.

COSMOS E/B-mode decomposition: $\langle M_{ap}^2 \rangle_{E,B}$



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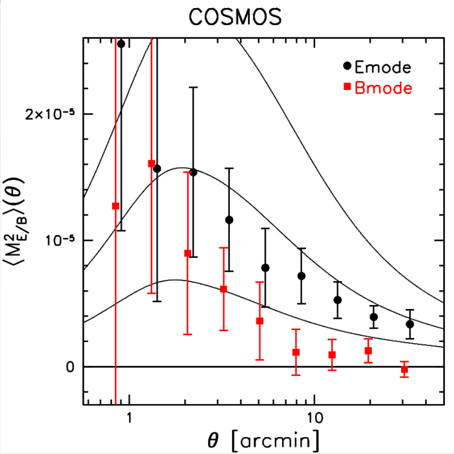

Figure: **Schrabback et al. analysis**: Statistical error-bars without cosmic variance.

COSMOS dark matter map

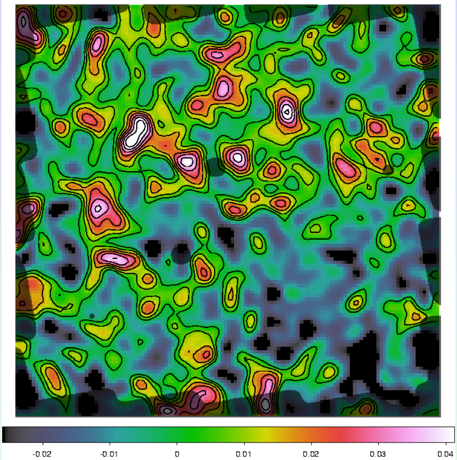

Figure: κ-**Reconstruction of the COSMOS field**.

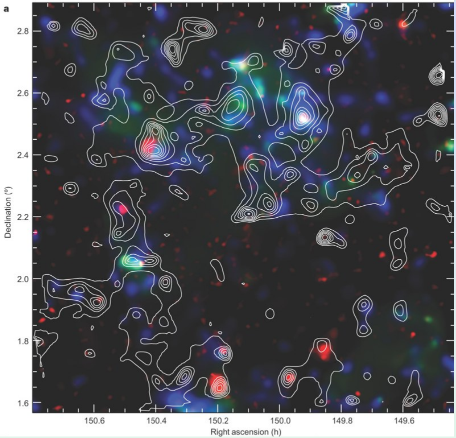

Figure: κ-**Reconstruction of the COSMOS field** and baryonic tracers from **Massey et al. (2007), Nature 445**.

Conclusions

- The ACS PSF varies between subsequent exposures, which is properly taken into account in our PSF correction scheme.
- Good dithering is highly recommended for HST weak lensing studies.
- The CDFS is exceptionally under-dense.
- The TS and CH weak lensing pipelines yield consistent shear estimates.
- We recover the Massey et al. (2007) COSMOS κ-maps with good consistency.
- In the COSMOS data we detect a small scale B-mode with $\langle M_{ap}^2 \rangle$, similar to Massey et al. (2007), with yet unidentified origin.

Outlook

- Perform Ray-tracing comparison with larger volume.
- Verify the (non-)existence of filaments in the A901/A902 field.
- COSMOS: Track down the origin of the small-scale B-mode; determine cosmological parameters; check if significant dark mass peaks exist.
- Process and analyse the Extended ACS Parallel Survey.