The magnitude dependent calibration bias in the TS KSB+ analysis of STEP1-3

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Outline

KSB+ on one slide

Ellipticity from weighted 2nd-order brightness moments

$$e = e_1 + \mathrm{i}e_2 = \frac{Q_{11} - Q_{22} + 2\mathrm{i}Q_{12}}{Q_{11} + Q_{22}} \quad .$$

$$Q_{ij} = \int \mathrm{d}^2\theta \, W_{r_g}(\theta^2)\theta_i\theta_j I(\boldsymbol{\theta}) \, , \quad i,j \in \{1,2\} \quad ,$$

with coordinates such that $\int \mathrm{d}^2\theta \, W_{r_g}(\theta^2)\boldsymbol{\theta} I(\boldsymbol{\theta}) = 0 \quad .$

PSF correction with *shear* and *smear polarisability* tensors

$$e - e^{\mathrm{s}} = P_g g + P_{\mathrm{sm}} q^* \quad ,$$

$$P_g = P_{\mathrm{sh}} - (P^*_{\mathrm{sm}})^{-1} P^*_{\mathrm{sh}} P_{\mathrm{sm}} \quad ,$$

from stars: $P^*_{\mathrm{sh}} \, , \quad P^*_{\mathrm{sm}} \, , \quad q^* = (P^*_{\mathrm{sm}})^{-1} e^* \quad .$

Kaiser, Squires, & Broadhurst (1995), Luppino & Kaiser (1997), Hoekstra et al. (1998)

Limitations

- KSB assumes that the PSF can be described as a convolution of an isotropic (nearly Gaussian) part with a "small" anisotropy kernel
- Ill defined for realistic PSF types (Kaiser 2000)
- Pixelization is not taken into account
- Non-linear operations on noisy quantities (inversion of P_g)

A zoo of KSB+ implementations

Possible differences between KSB+ implementations

- Object detection (SExtractor, hfindpeaks)
- Choice of scale r_g (SExtractor, hfindpeaks), $r_g = X \cdot \mathrm{FLUX\_RADIUS}$
- Transformation of KSB integrals into sums over pixels (interpolation)
- Inversion of P_g, $(P^*_{\mathrm{sm}})^{-1} P^*_{\mathrm{sh}}$
- Fitting of q^*, P^*_{sh}, P^*_{sm} as a function of position, r_g
- Fitting of P_g as a function of mag, r_{h}, $|e|$, ...
- Applied cuts / weighting

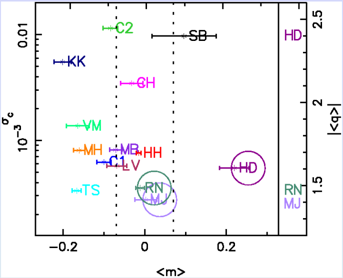
Our implementation of KSB+

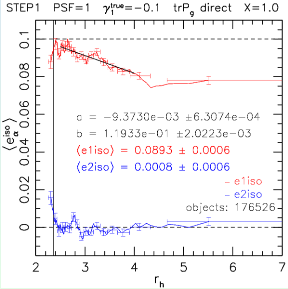
- Object detection with **SExtractor** (Bertin & Arnouts 1996)
- Shape measurements with the **Erben et al. (2001) KSB+ implementation + modifications**
  - Linear interpolation across sub-pixel
  - $r_g = 1.0 \times \texttt{FLUX\_RADIUS}$
  - **Measure all stellar quantities as function of $\mathbf{r_g}$** (Hoekstra et al. 1998; Heymans et al. 2005)
  - Use trace for $(P_g)^{-1}$, $(P^*_{\rm sm})^{-1}P^*_{\rm sh}$, no P_g-fitting

Conclusions from STEP1

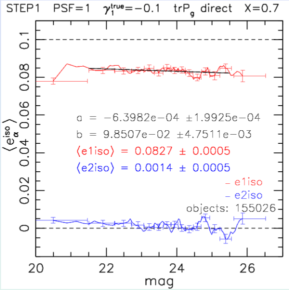
- **Selection bias** due to cuts: $r_{\rm h} > 1.2 \cdot r^*_{\rm h}$, $|\gamma| < 0.8$
- Applied **weighting scheme** not adequate for constant shear
- Both corrected $\Rightarrow -9\%$ bias
- Probably **due to approximation of P_g^{-1} as** $2/{\rm tr}P_g$: Full tensor: $m = +1.4\%$ for $|\gamma| < 1.4$, $m = +5.6\%$ for $|\gamma| < 2.0$, very noisy. Instead: $1/0.91$ shear calibration factor
- Value quite stable between PSFs, but depends on interpolation, r_g-factor X

Heymans et al. 2006

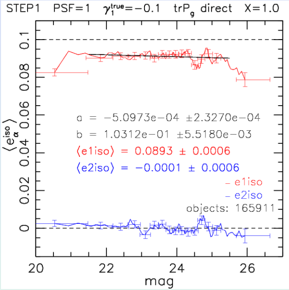




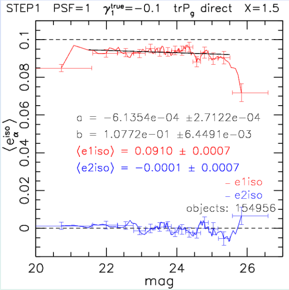
Dependence weak on magnitude, strong on X



X = 0.7



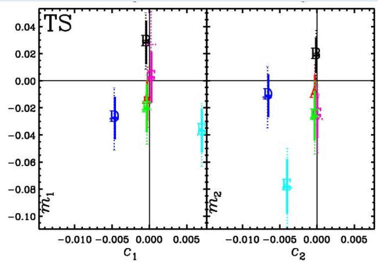
X = 1.0

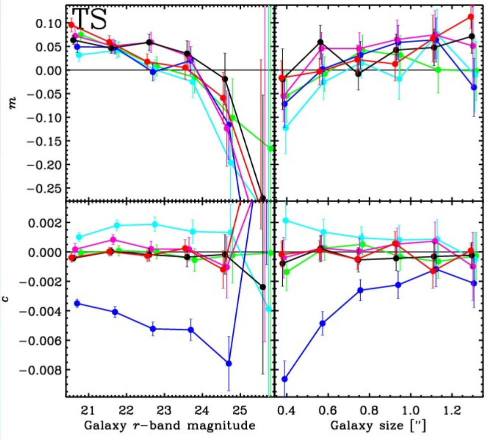


X = 1.5

Original performance on STEP2

- Confirmed calibration factor except PSF D,E
- 20 – 30% under-estimation at faint end
- Same selection as for “corrected” STEP1, but neglected noise correlation





Massey et al. 2007

The STEP2 noise correlation

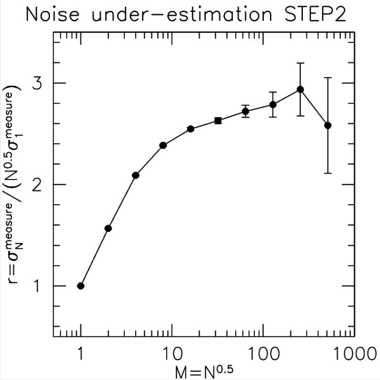
For uncorrelated noise:

$$\sigma_N = \sqrt{N}\sigma_1$$

Correlation leads to an under-estimation of σ_1, but σ_N remains unaffected for areas much larger than the drizzle kernel.

$$r = \frac{\sigma_N^{\mathrm{measure}}}{\sqrt{N}\sigma_1^{\mathrm{measure}}} \sim 2.8 \quad \mathrm{for} \quad N \to \infty$$

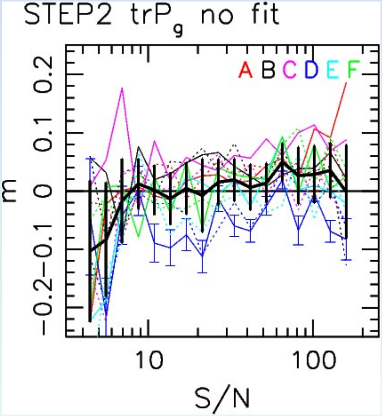
$\Rightarrow$ **S/N is over-estimated from σ_1 by a factor 2.8!**



$$\mathrm{S/N} = \frac{\int \mathrm{d}^2\theta\, W_{r_\mathrm{g}}(|\boldsymbol{\theta}|)\, I(\boldsymbol{\theta})}{\sigma_1 \sqrt{\int \mathrm{d}^2\theta\, W_{r_\mathrm{g}}^2(|\boldsymbol{\theta}|)}}$$

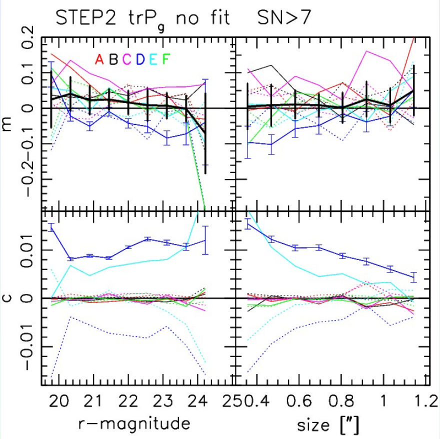
The STEP2 noise correlation

- Cut in original analysis $\mathrm{S/N} > 4$ corresponds to $\mathrm{S/N}^{\mathrm{true}} > 1.4$
- Deterioration occurs for $\mathrm{S/N} < 7$ or $\mathrm{S/N}^{\mathrm{true}} < 2.5$
- Consistent with STEP1: No strong bias down to $\mathrm{S/N}^{\mathrm{true}} = 3.0$

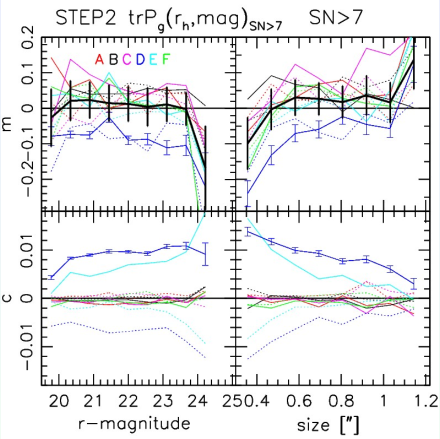


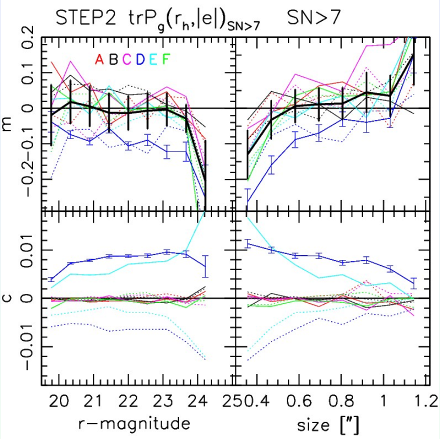
A proper signal-to-noise cut excludes the strongly biased faint galaxies

- $\mathrm{S/N} > 7$ or $\mathrm{S/N}^{\mathrm{true}} > 2.5$
- Rejects $\sim 30\%$ of the galaxies, but still lower true S/N cut than in STEP1!
- Adapted calibration: $1/0.93$
- Remaining bias variation: $\sim +4\%$ to -5%
- Fitting of $\mathrm{Tr}P^g/2$ $(r_\mathrm{h}, \mathrm{mag})$ or $\mathrm{Tr}P^g/2$ $(r_\mathrm{h}, |e|)$ does not improve remaining variation considerably

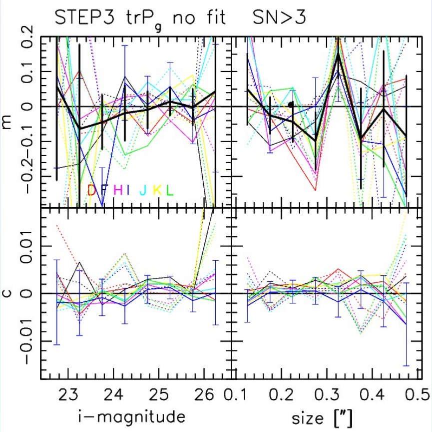


Fitting $\mathrm{TrP^g}/2(\mathrm{r_h}, \mathrm{mag})$ and $\mathrm{TrP^g}/2(\mathrm{r_h}, |\mathrm{e}|)$

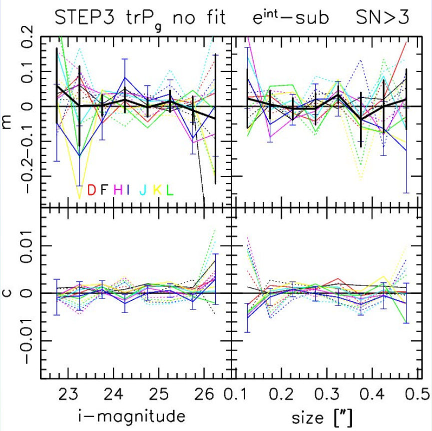




STEP3: ACS-type images

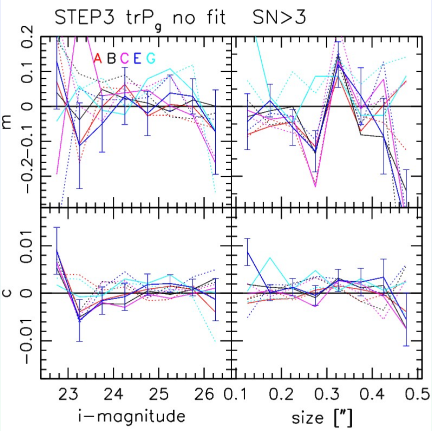


Normal: $\sigma_m = 1.5\% - 3.7\%$

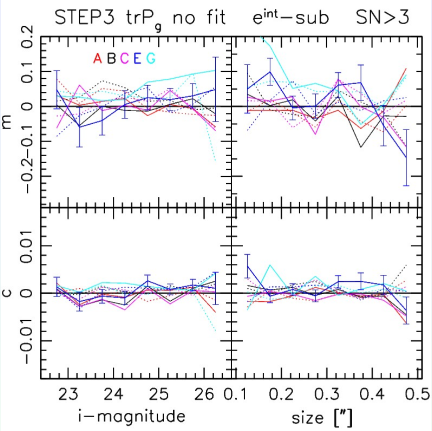


After subtraction of intrinsic ellipticity: $\sigma_m = 1.0\% - 2.2\%$

STEP3: SNAP-type images

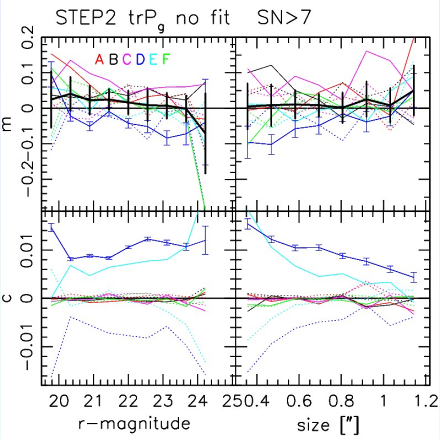


Normal

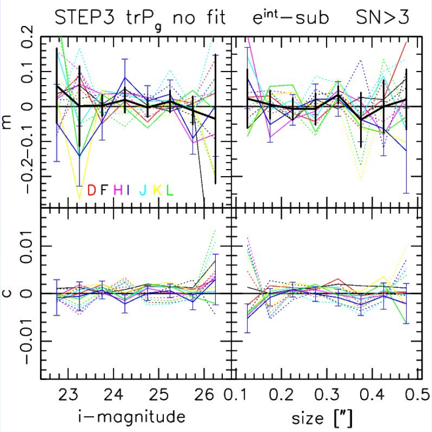


After subtraction of intrinsic ellipticity

Comparing STEP2 and STEP3



STEP2

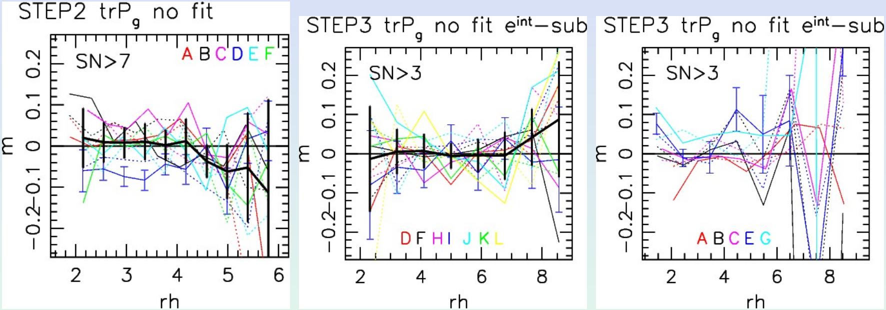


STEP3 ACS-type

Comparing STEP2 and STEP3

- Calibration $1/0.93$ OK for STEP2 and STEP3
- STEP3 more stable, both calibration (scatter 2% between ACS+SNAP image sets) and PSF anisotropy residuals, but $e^* = 11\%$ versus $e^* = 2.5\%$
- Overlap small $23 \lesssim m \lesssim 24.5$, $0\overset{''}{.}35 \lesssim s \lesssim 0\overset{''}{.}5$
- Is this sufficient to show: We can do better from space?

In contrast to STEP1 no strong dependence on half-light radius in STEP2 or STEP3



Peculiarity of the SKYMAKER simulations?

Conclusions

- With careful selection our KSB+ implementation yields an average bias $\sim -7\%$ (STEP2-3) to $\sim -9\%$ (STEP1).
- The bias is quite stable justifying the use of a calibration factor.
- The bias seems to increase for highly elliptical PSFs.
- Probably the trace-inversion of P_g is a major reason for the bias.
- Additionally, X and the use of the interpolation modify the bias.
- The strong bias seen for the faint galaxies in STEP2 originates from improper $\mathrm{S/N}$ cuts as a result of the noise correlations.
- If corrected, the bias ranges from $\sim +4\%$ to -5%.
- The performance on the STEP3 simulations is more stable with 2% scatter between the image sets and weak magnitude/size dependence, but PSF ellipticities are smaller.
- The overlap in mag-size-space is small between STEP2 and STEP3