Modeling and Correcting the Time-Dependent ACS PSF for Weak Lensing

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Motivation: Weak Lensing

- Statistical measurement on many galaxies
- Lensing induced ellipticities 1-2%
- Telescope Point Spread Function (PSF) is the primary systematic concern—it changes shape (e)!
Two Main Problems

1. Aliasing of the PSF during distortion correction re-pixellization (Multidrizzle)

2. Time variation of PSF due to thermally induced focus changes
Data Sets

- Cosmos 2 Square degree field
  - Taken cycles 12-13
  - 590 orbits of F814

- ACS Parallels
  - Taken cycles 11-13
  - 500 fields of F775W

- Stellar Fields (globular clusters)
  - Taken cycles 11-13
  - A few fields in F775W and F814W

Not enough stars per field to model PSF

Not take often enough to account for time variation
TinyTim

- TinyTim Version 6.3 written by John Krist
- Creates a PSF anywhere on the ACS chip with any filter and spectrum
- Can be highly oversampled
- Includes diffraction, distortion and charge diffusion
- Produces stars as we see in raw (distorted) ACS images
How We Use TT

• We use F814W filter, and single wavelength 800nm

• We modify the code to measure the effects of multidrizzle

• We created a version of multidrizzle that only adds distortion across the field

• We modify the code to produce undistorted (post multidrizzle) stars

• We manually add charge diffusion as a convolution with a distorted kernel

• We avoid the complications of multidrizzle on our model stars
Aliasing From Multidrizzle

-10% ellipticity
“Aliasing” from pixellization

Unfortunately, a star’s sub-pixel position affects its observed shape.
“Aliasing” from second Pixellization

Then it happens again during DRIZZLE! This at least must be avoidable…
Adjust Pixel scale & DRIZZLE kernel

…it is!
Recommended Multidrizzle Parameters

- Created TinyTim models with same diffraction everywhere, only distortion is different
- Run through multidrizzle w/ various parameters
- Large improvement going from 0.05 to 0.03 arcsecond pixels
- Gaussian kernel has lower RMS(e) and is more stable

![Graph showing RMS e vs Pixel Scale]
The PSF Problem

The PSF pattern is time dependent
Periodic Focus Variation

- COSMOS data
- \( \sim 20 \) day time scale
- Determined by fitting to TinyTim models
Our Solution

• Not enough stars → Make our own!
• Use TinyTim PSF modeling software
• Create stars without geometric distortion (but with diffraction and other PSF effects)
• Required modification of TinyTim program

• Create dense stellar grids (up to 50x50 across field)
• Create at range of focus positions (-10 to +5 μm)
• Use stars in each COSMOS field (~10 to 20) to pick the best focus value
• Use the template at that focus value to perform correction
• Eliminates need for interpolation between stars
TinyTim - The PSF Solution

From ISR
ACS 2003-6

Figure 2: ACS/WFC focus wavefront error variations and charge diffusion blur widths derived from phase retrieval measurements of the F550M image.
Focus Values in COSMOS

Focus values cluster!
COSMOS Results

Before TT

E modes

B modes

After TT
Remaining Work and Conclusions

- Still some work to be done
  - mapping chip height variations with globular clusters
  - TinyTim stars still slightly too small (diffusion convolution?)
  - What effect does CTE have on the PSF?
  - Compare to other methods (e.g. principle component analysis; see Jarvis and Jain astro-ph/0412234)

- Method greatly reduces PSF systematics

- Can easily be extended to other filters

- Useful for more than weak lensing