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

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With:

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HST Calibration Workshop

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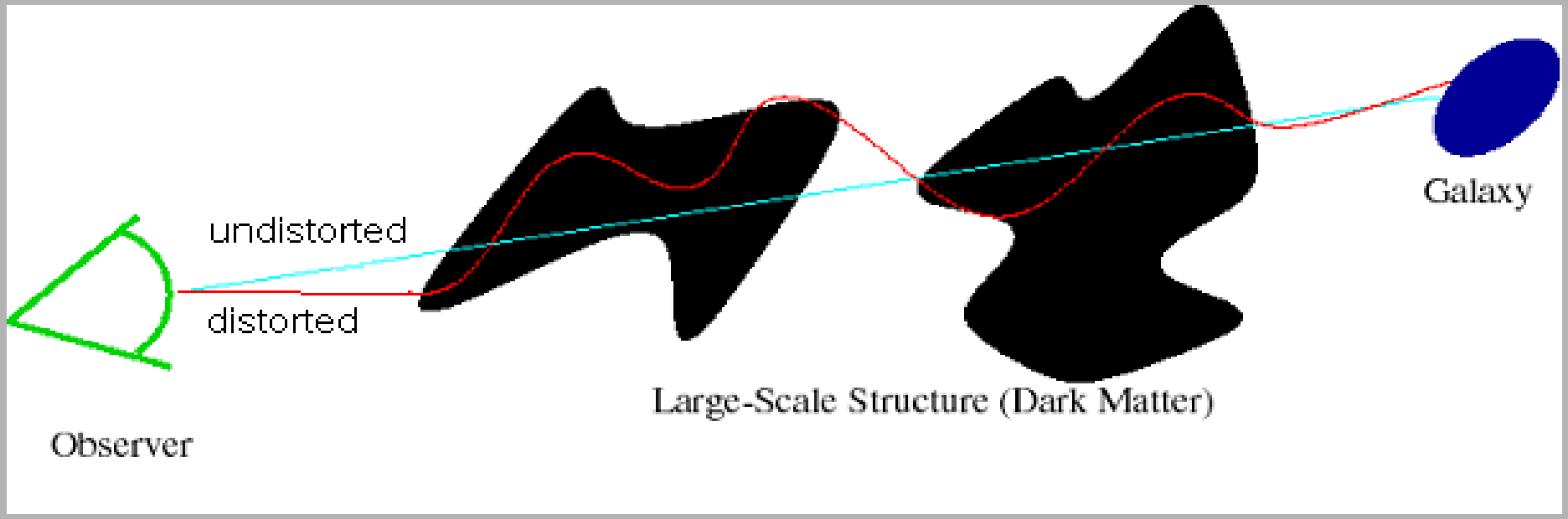
Motivation :Weak Lensing



- 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

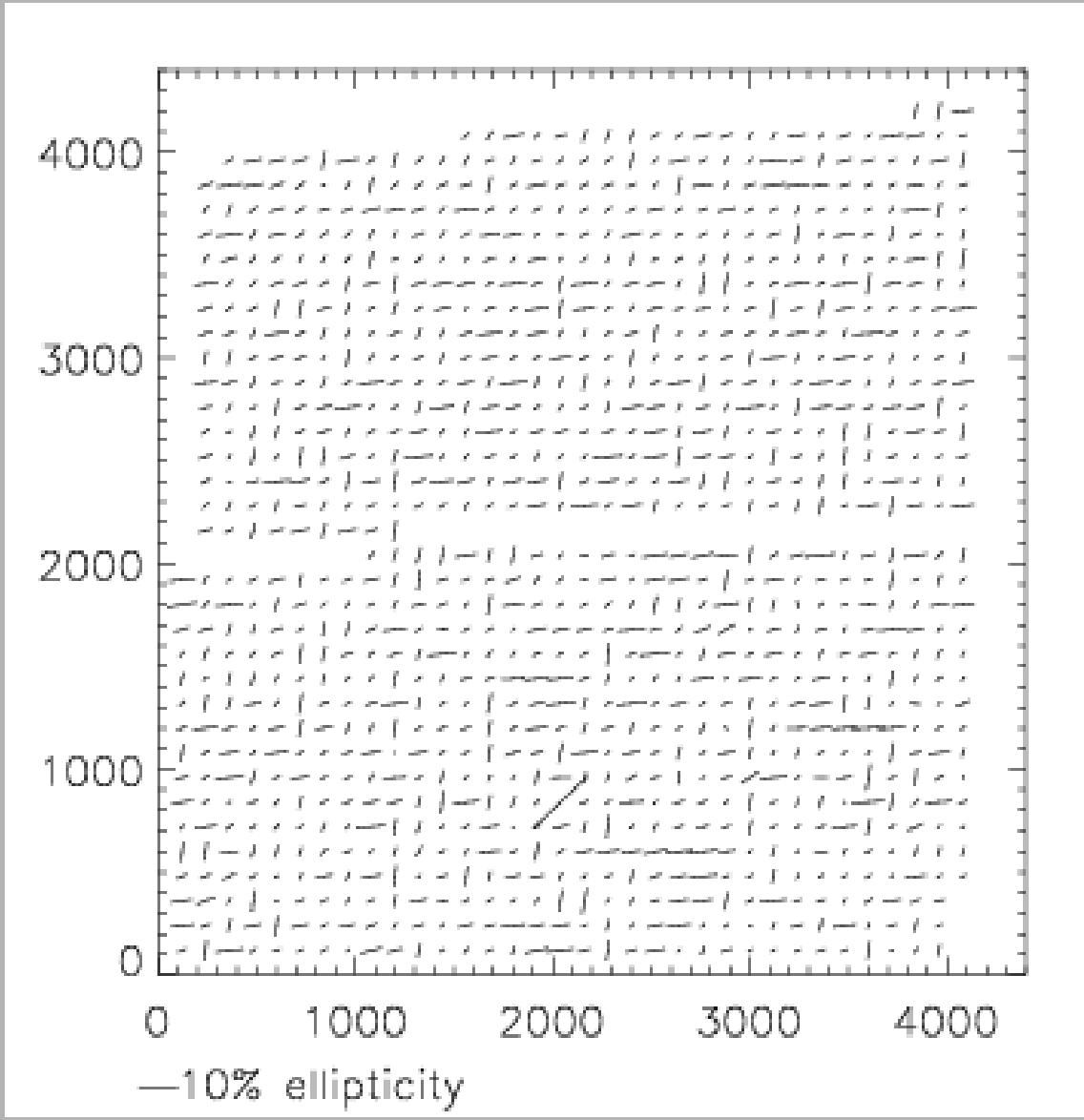
TinyTim

- **TinyTim Version 6.3 written by John Krist (http://www.stsci.edu/software/tinytim/tinytim.html)**
- **Creates a PSF anywhere on the ACS chip with any filter and spectrum**
- **Can be highly oversampled**
- **Includes diffraction, distortion and charge disffusion**
- **Produces stars as we see in raw (distorted) ACS images**

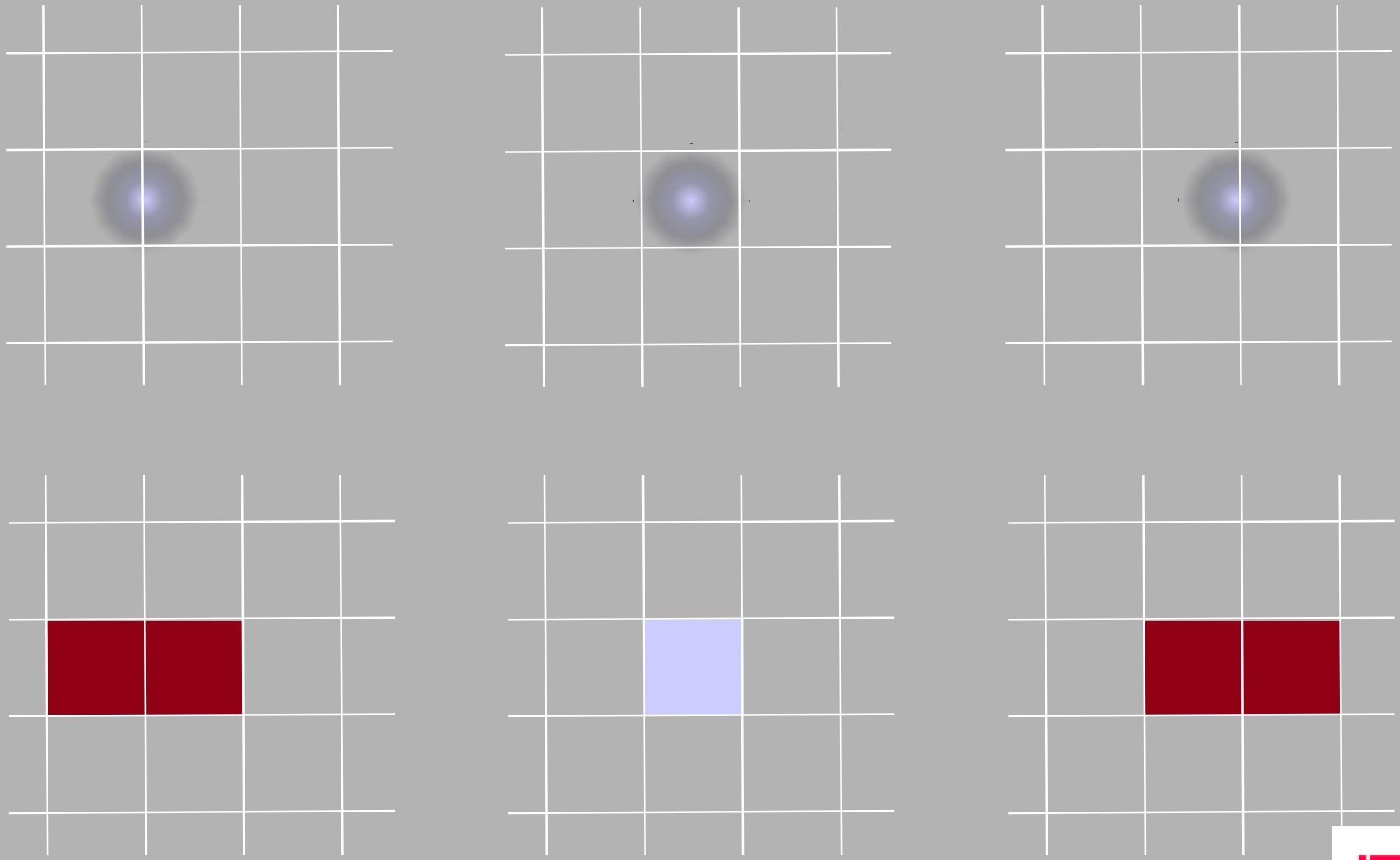
How We Use TT

- **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

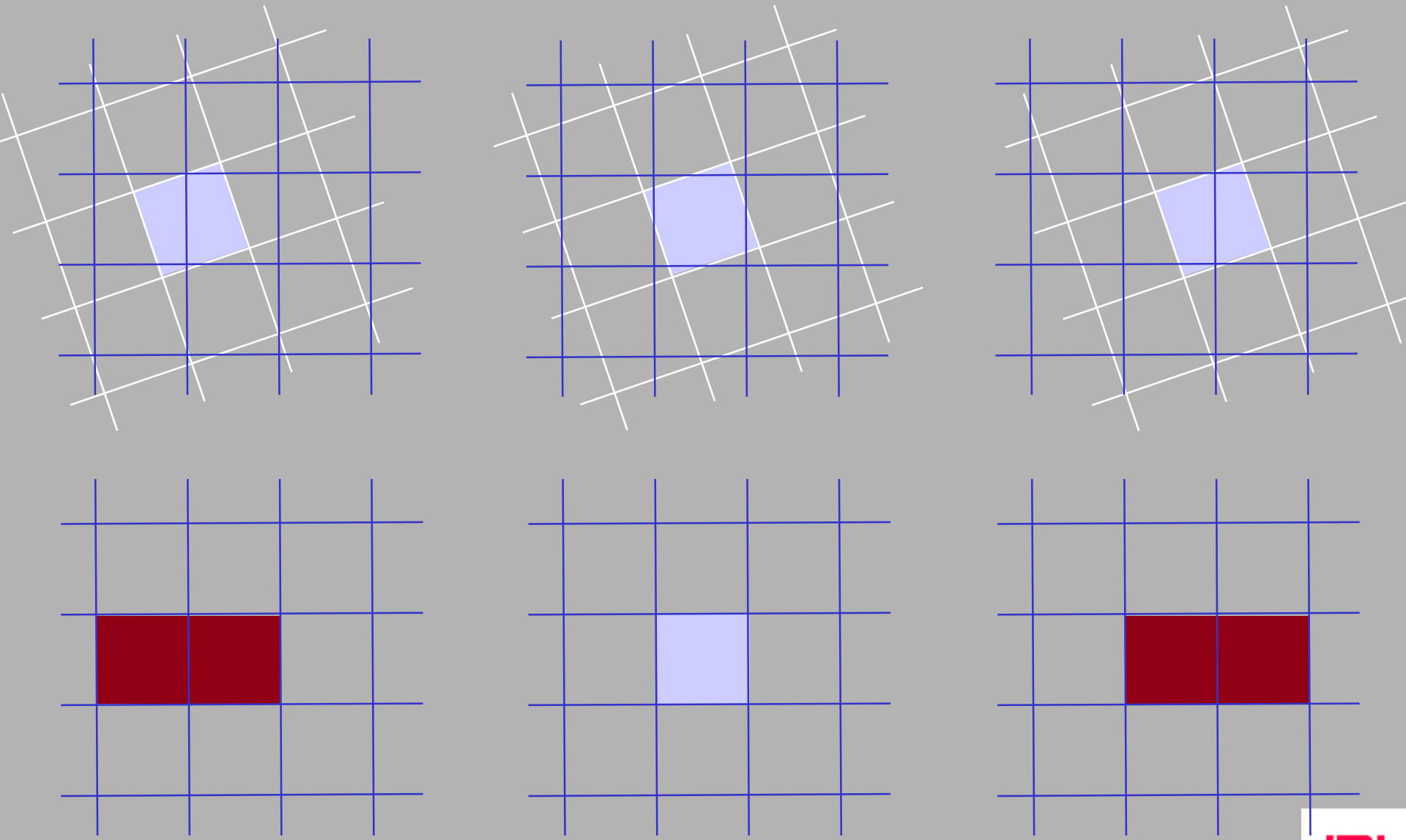


“Aliasing” from pixellization



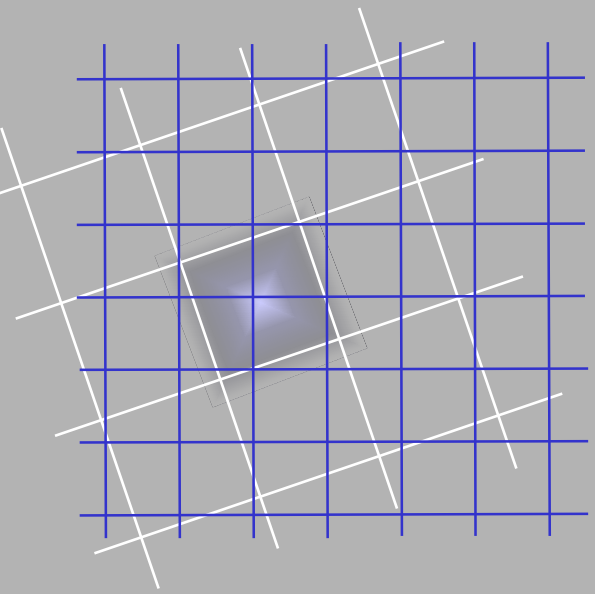
Unfortunately, a star’s sub-pixel position affects its observed shape.

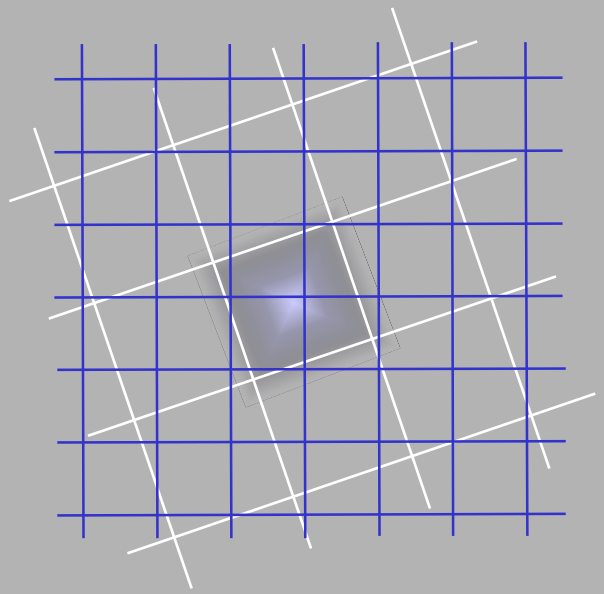
“Aliasing” from second Pixellization

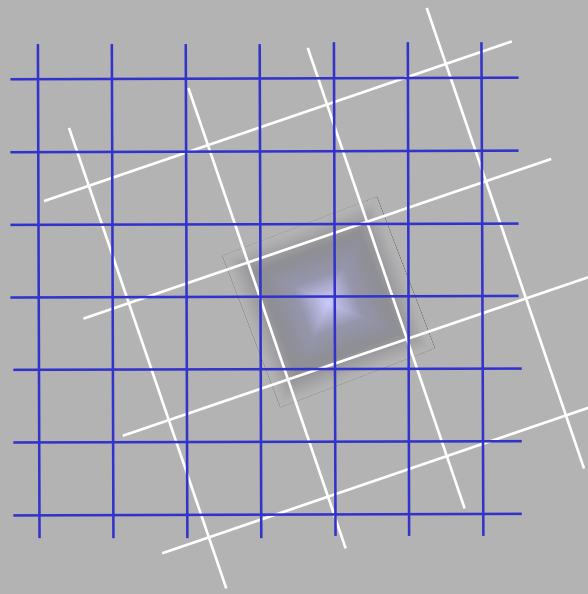


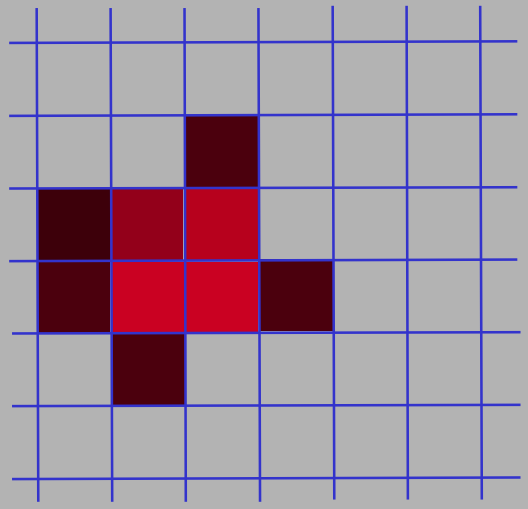
Then it happens again during DRIZZLE! This at least must be avoidable…

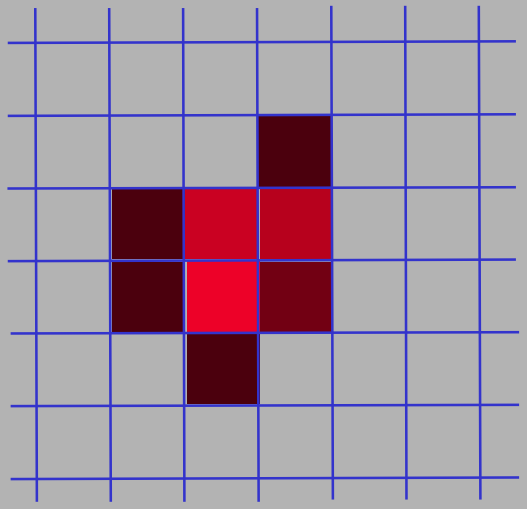
Adjust Pixel scale & DRIZZLE kernel

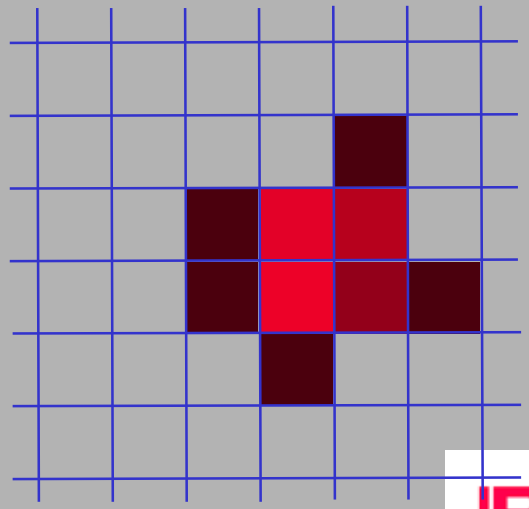








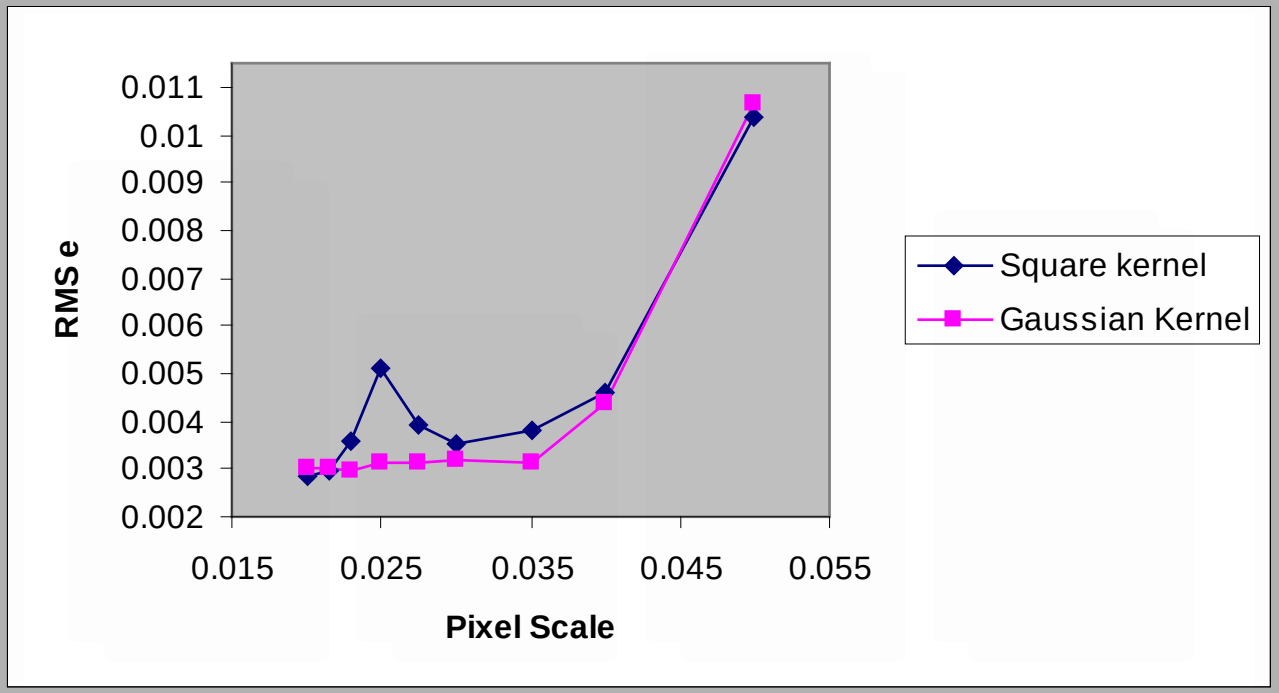




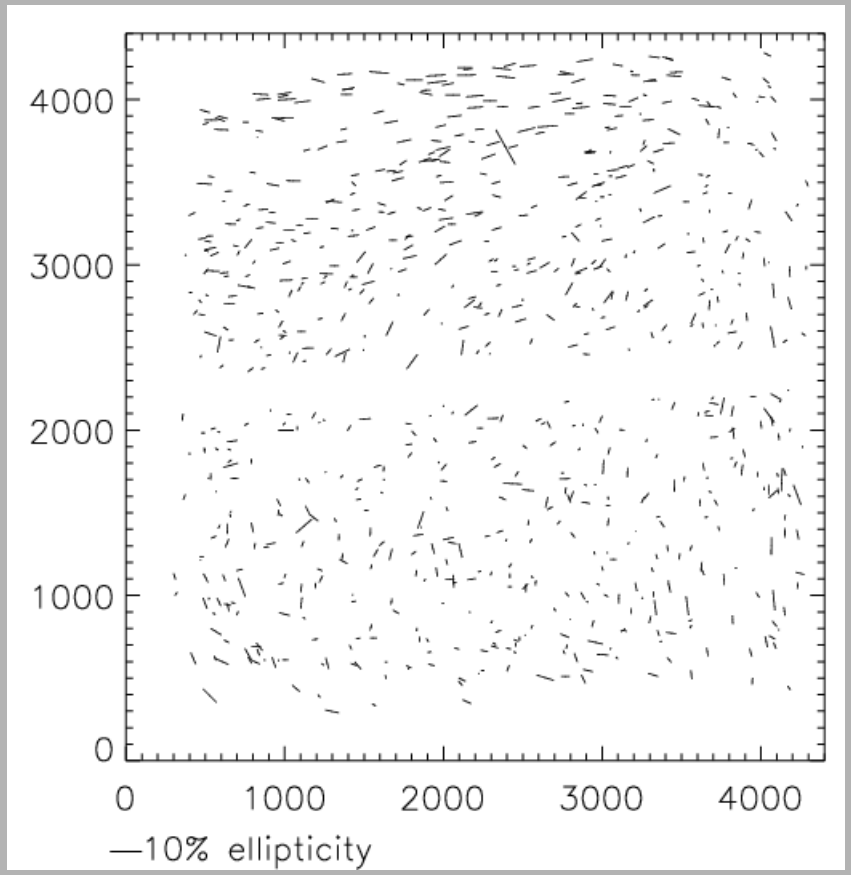
…it is!

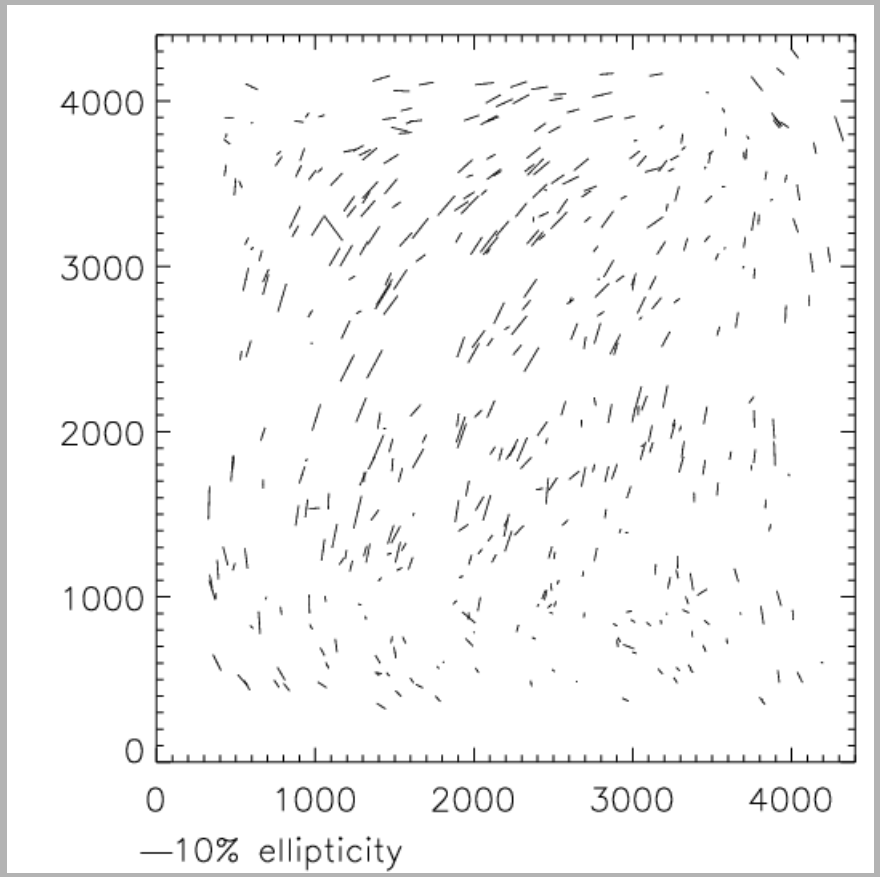
Recommended Multidrizzle Parameters

- 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



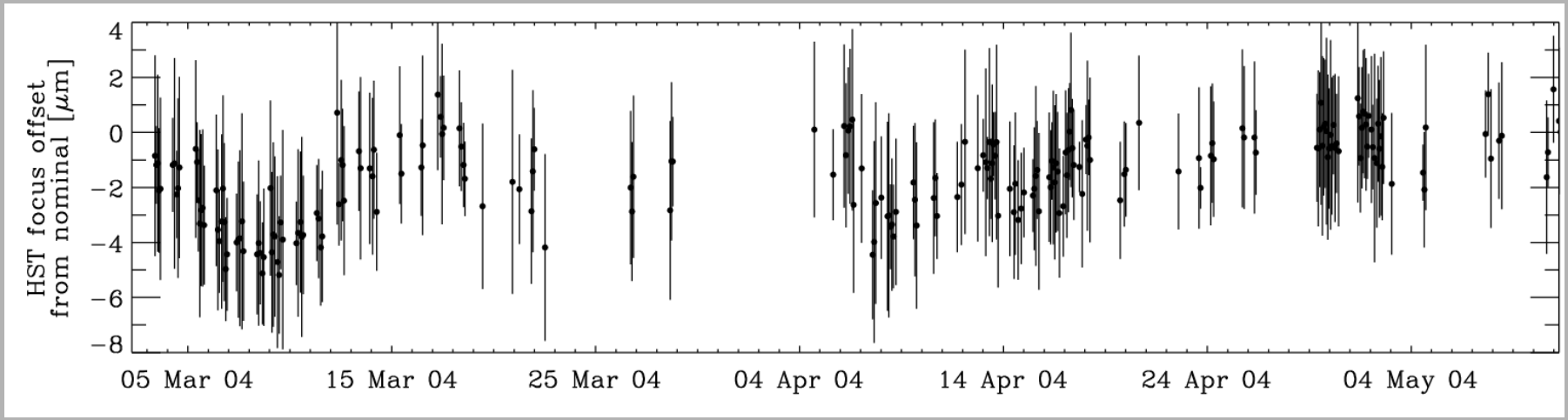
The PSF Problem





The PSF pattern is time dependent

Periodic Focus Variation



- COSMOS data
- ~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

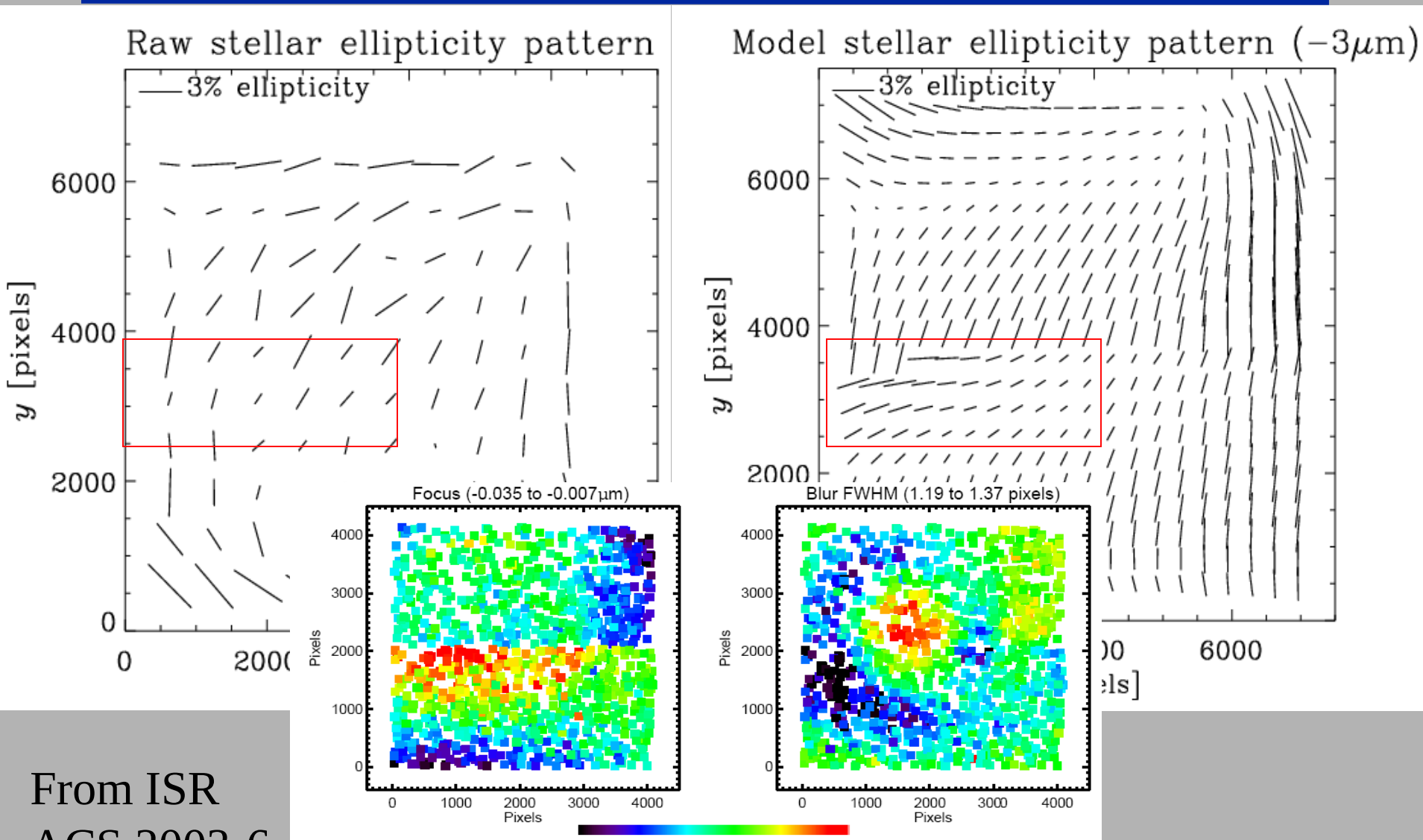
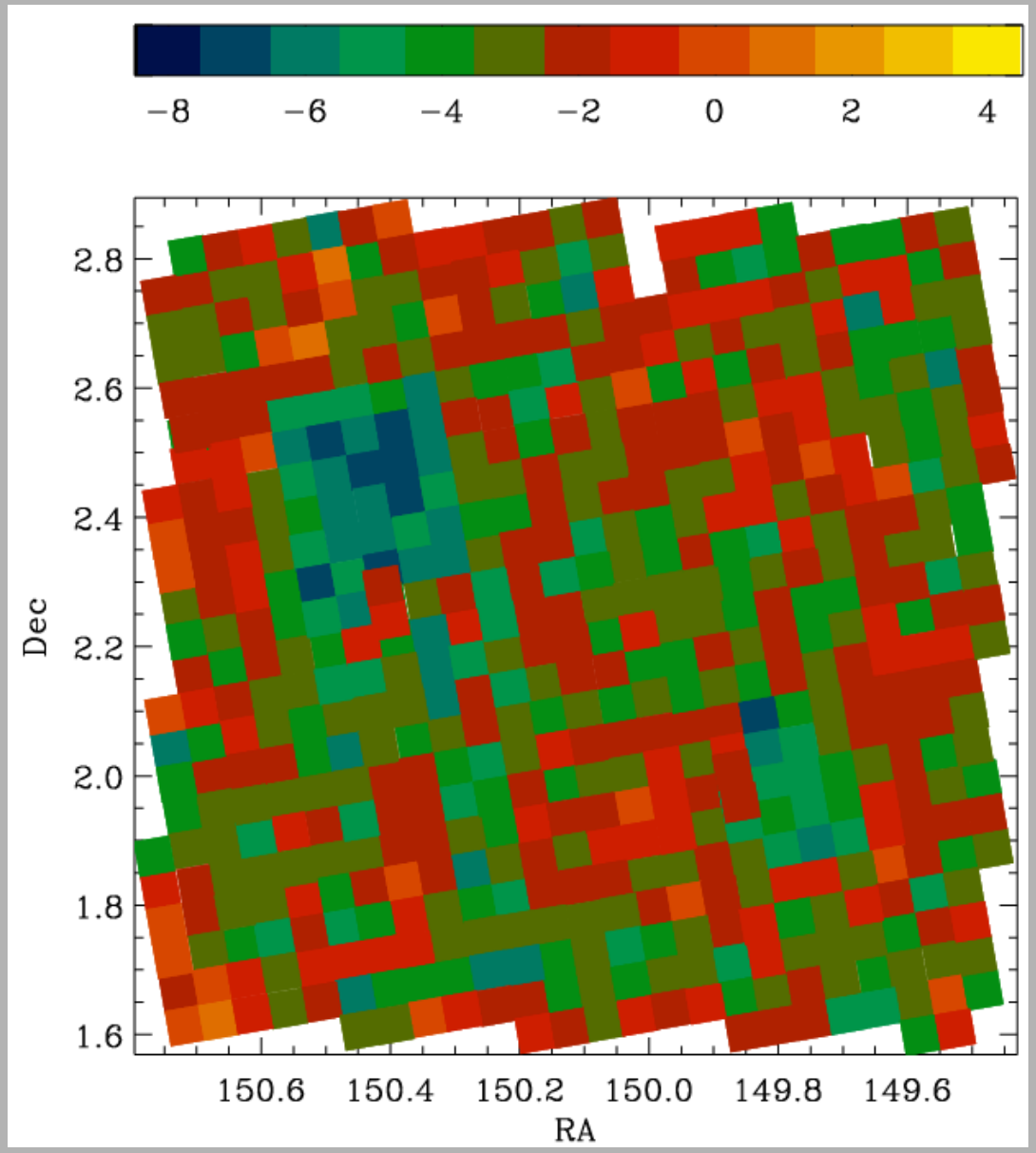


Figure 2: ACS/WFC focus wavefront error variations and charge diffusion blur widths derived from phase retrieval measurements of the F550M image.

From ISR
ACS 2003-6

Focus Values in COSMOS



Focus values cluster!

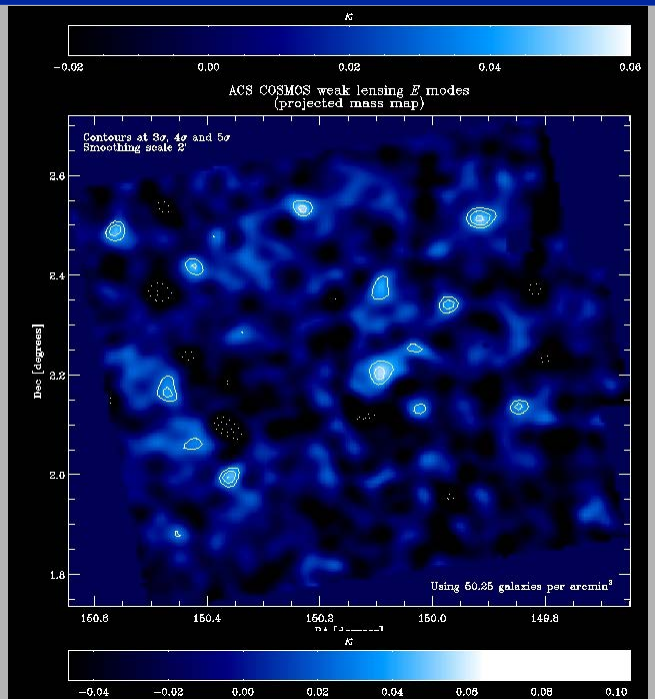
COSMOS Results

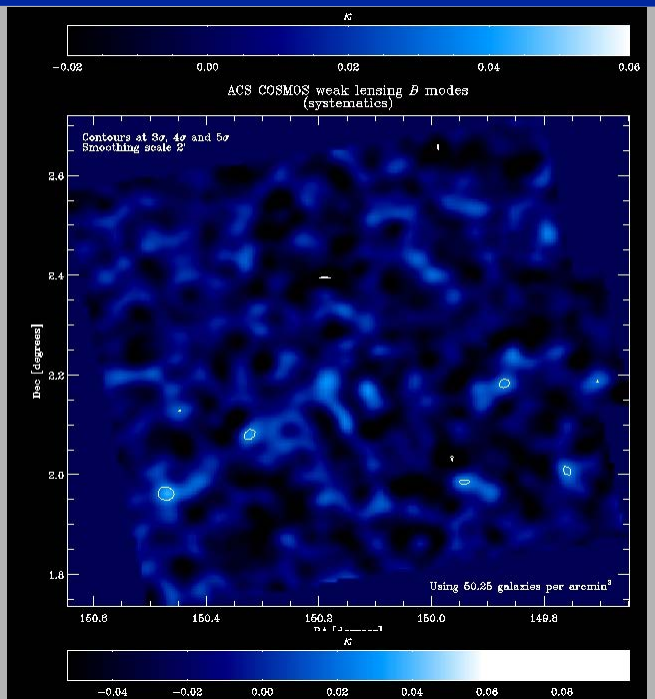
E modes

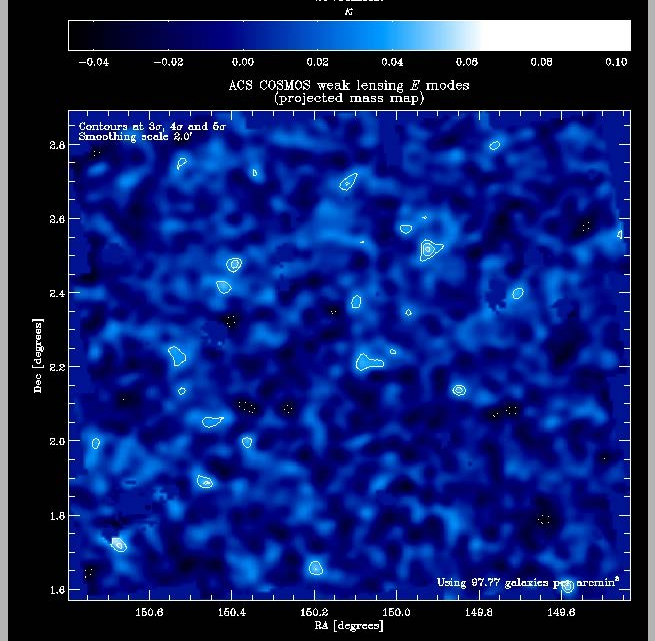
Before TT

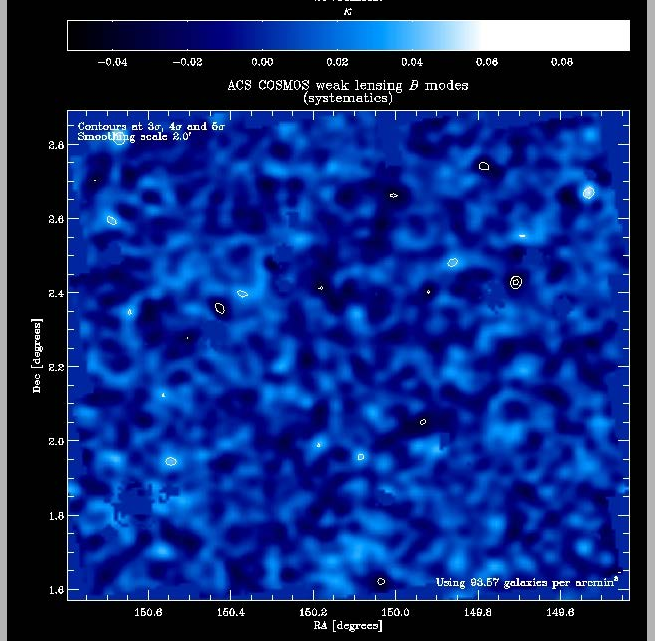
After TT

B modes









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**