DES WL Algorithms

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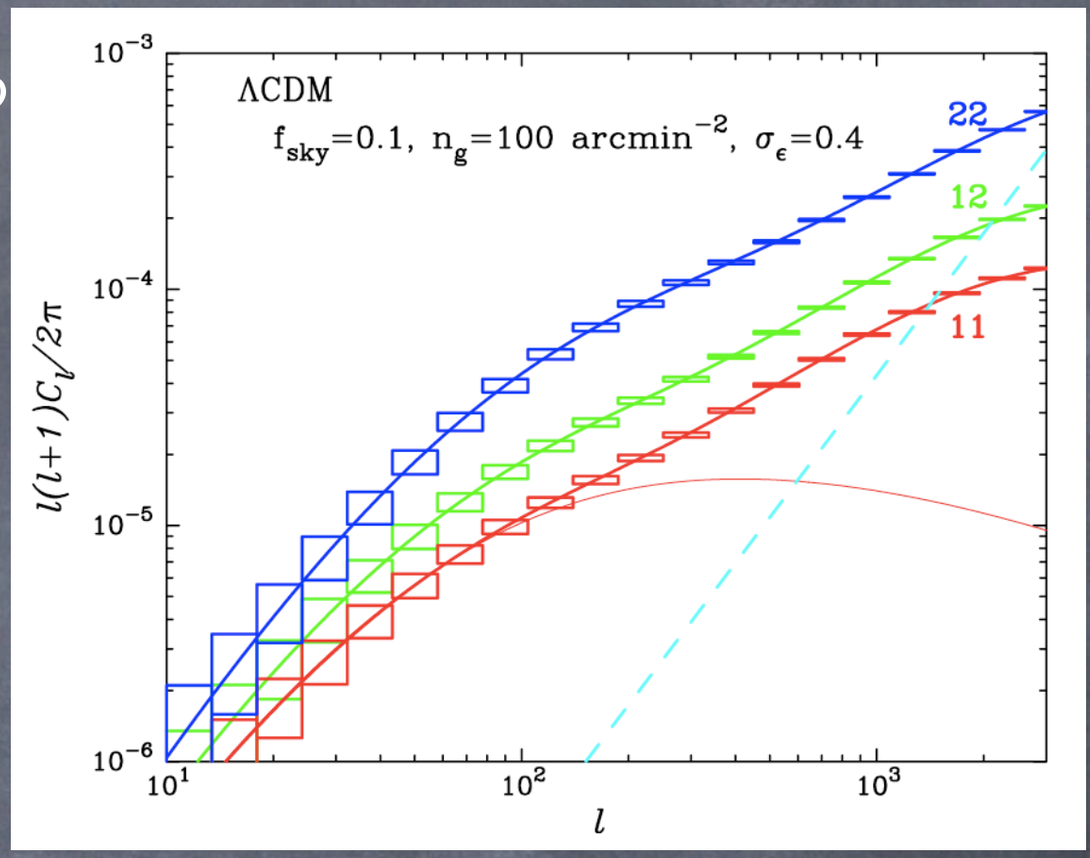
(actual work done by M. Jarvis & E. Sheldon)

WL processing steps

- Calibration of ADU into surface brightness scale (instrumental signature removal)
- Astrometric calibration
- Bad pixel identification
- PSF characterization
- Shape target galaxy selection (from stacks)
- Shape measurement from pixel data
- Shear statistics from shape catalogs

WL Requirements

- Systematic errors should be subdominant to statistical errors on cosmology
- Simple case: power spectrum measurement.
- In sample-variance limited regime, error on power spectrum is P$\sqrt{}$(2/#modes)
- Sample-variance dominated to $l \approx 10^{2.5-3}$, number of modes is $f_{sky} l^2 \approx 10^{4-5}$,
  - so shear **calibration** errors should be well below 1 part in 300
  - This is spec for knowledge of PSF size!
- Shear variance (per ln l) is $\Delta^2 \approx 10^{-4.5}$
- Stat. error on power spectrum: $\approx 10^{-7}$
  - so RMS spurious shear should be $<10^{-3.5}$
  - This is spec for knowledge of PSF shape!
- Tomography, etc. make this more complex.



Astrometric calibration

- Use DES facility, but will be most demanding user
- Mis-registrations have effect of broadening PSF in stacks or multi-fit analyses
- Req. is to grow second moments by <0.0003
- Quadrature formula says RMS mis-registration of 0.02*PSF size, or 20 mas, will eat entire sys. error budget. So want ~10 mas, or 0.05 pixel RMS, on 20 arcmin scales.
- Absolute astrometric accuracy not relevant.

PSF characterization

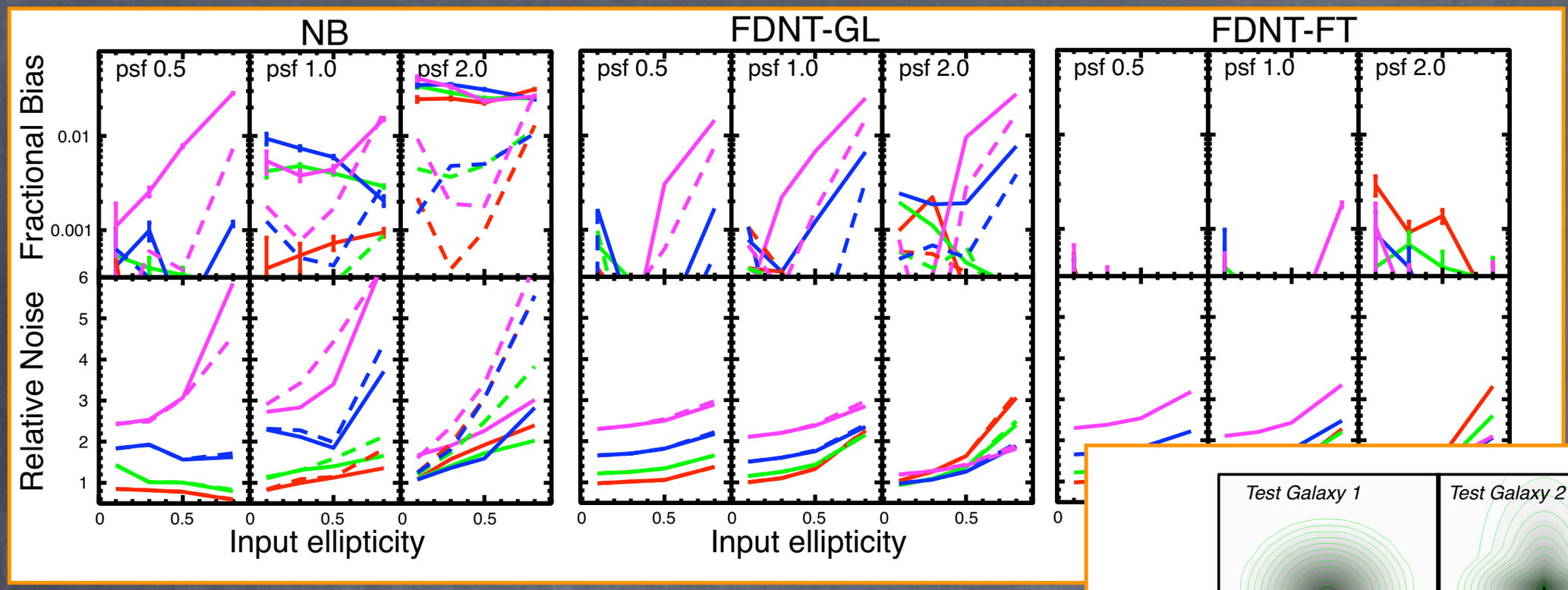
- Aim for <0.0003 ellipticity RMS errors and <0.001 size errors, when avg'ed on 20 arcmin scales.
- Algorithmic steps:
  1. Identify stars (Jarvis algorithm in mag-size plots)
  2. Decompose stars into some basis set (shapelets; Fourier modes?, pixelized basis?)
  3. PCA to reduce dimensionality of basis set
  4. Spatial interpolation function per basis element (quadratic polynomial per CCD?), with outlier rejection (e.g. binaries!)
  5. Validate on reserved stars
- Advanced: color dependence, should be static
- Advanced: incorporate wavefront sensor info and/or interpolate WFE, not PSF.

Target selection

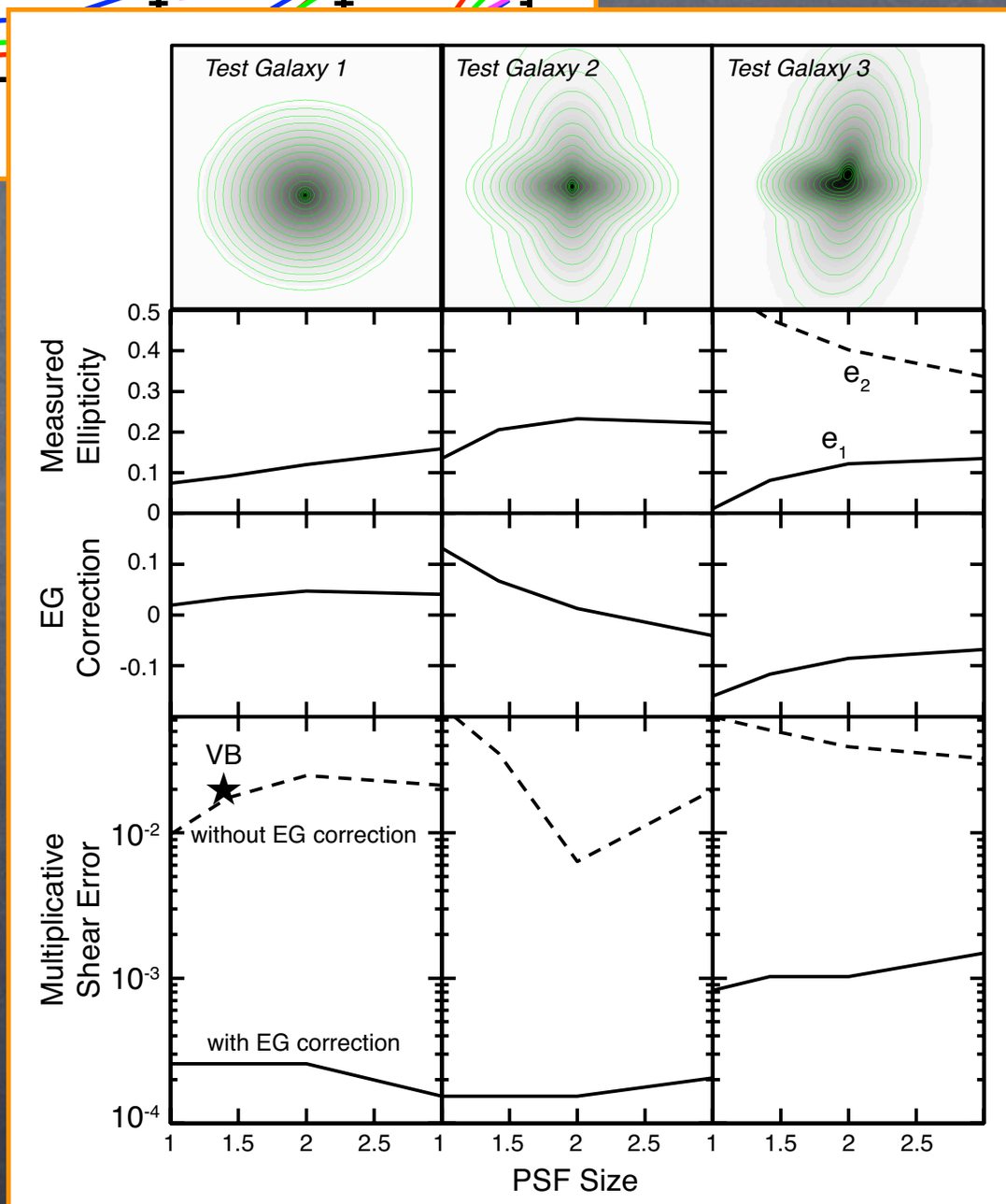
- Simple size/mag cuts?
- Will need to eliminate close pairs that have been split or will have sufficient isophote overlap to invalidate shape measurements.
- Should only affect shear measurements at scales of <10 arcsec, where there is no cosmological information
- Note SDSS problem with galaxies inside diffuse light of BCGs.

Shape measurement

- Where the magic happens!
- WLWG approach is to have multiple algorithms operative.
  - Simplest: moments of pixel distributions with circular Gaussian weight (Kaiser/Squires/Broadhurst). Works only on stacks, no rigorous underpinning.
  - SDSS heritage: "adaptive moments", moments with matched elliptical weights (Bernstein/Jarvis, Sheldon, Hirata et al)
  - Model-fitting: Gauss-Laguerre decomp (Bernstein/Jarvis, "shapelets"), multiple-Gaussian (Bridle)
  - Newest: Fourier-domain moments (Bernstein 2010)
- Only algorithmic challenges here is for methods requiring iterative solutions - find the ellipticity & centroid where certain quantities are nulled. Convergence is hard at low S/N



Performance of new "FDNT" shape measurements on well-behaved galaxies (above) and "ellipticity gradient" galaxies (right) (Bernstein 2010)



Shear statistics

- Go from shape catalog to cosmologically interesting quantities
- Shear (cross-) power spectra
  - Typically not computationally difficult; however E/B decomposition is not trivial and will require masking information
  - The greater challenge is in getting proper "responsivity" i.e. shear calibration out of shape catalog - will want limited area of survey with extra-high S/N, supernova fields would be perfect for this.
- Cluster finding: looking for peaks in shear field
- High-order statistics: shear bispectrum or 3-pt function
  - Can get computationally difficult but workable algorithms exist.