Weak Lensing of The Faint Source Correlation Function

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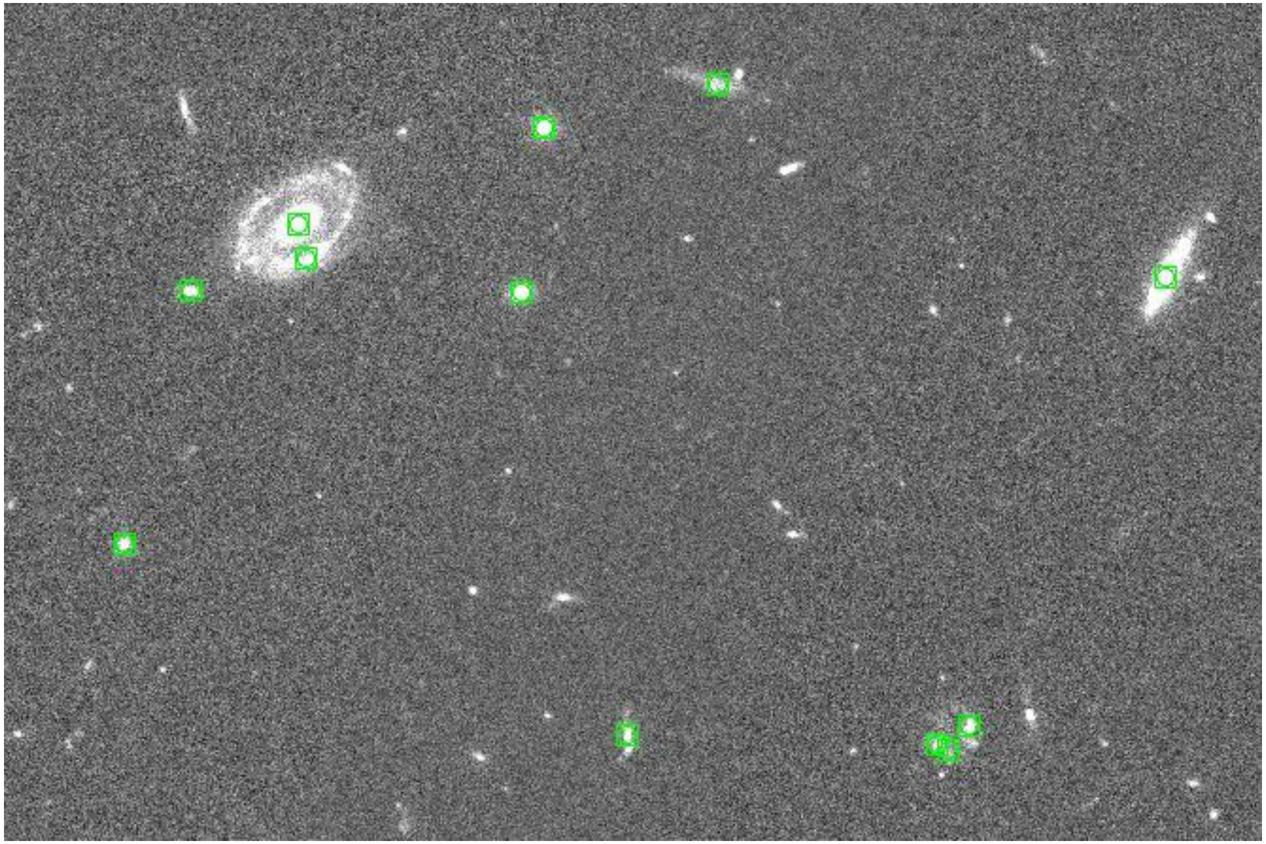
Overview

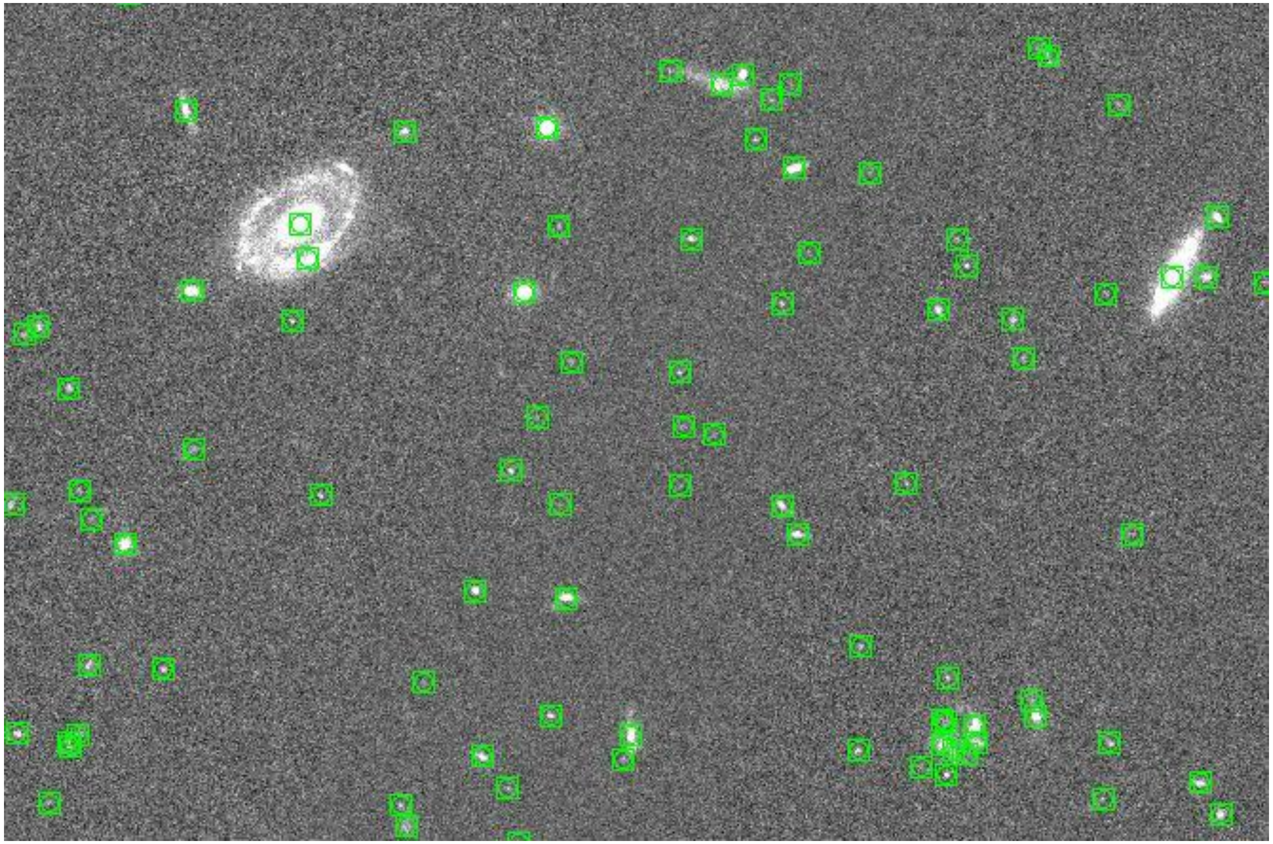
* Why care about faint sources and faint clusters?
* The angular correlation function until now
* Our improved measurement of the faint source angular correlation function (FSCF)
* A primer on weak lensing
* Weak lensing of the correlation function
* Future surveys

Bright Sources



The V < 25 sources (in HST GOODS) have well defined ellipticities, photometric redshifts accurate within $\sigma_z = 0.1$

All Sources



About 85% of sources in HST-GOODS have 25 < V < 27.5 and are too dim get spectral or shape information

Faint (V > 25) Sources

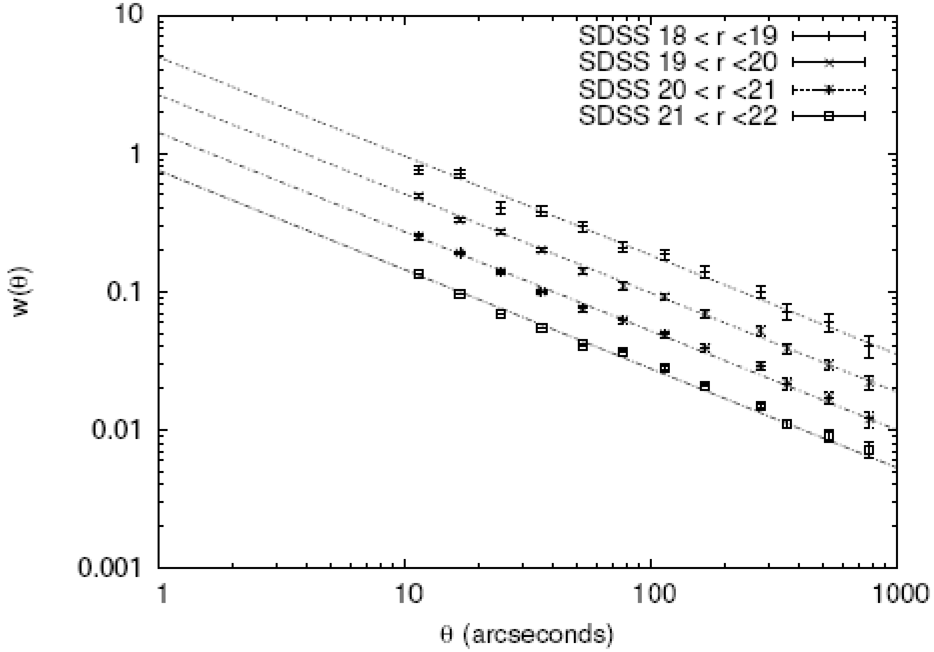
- * The faintest sources are blue, compact (d < 3 kpc) and bright (L/V greater than that of the Milky Way)
- * They are too dim to get spectra from, and photometric redshifts are uncalibrated (Coe et al. 2007)
- * Barely resolved (no morphology measurements)
- * Different authors have suggested that faint sources are at z < 1 (Babul & Rees) and z > 2.5 (He et al.)
- * There are at least 200 billion faint (V<29) sources about 10 times what we would expect from local galaxy counts
- * This suggests that they merged into modern galaxies
- * Measuring how their counts and clustering change with redshift would give us a history of galaxy assembly

The Angular Correlation Function, w(θ)

* The angular correlation function, w(θ), is defined as:

$$\left\langle \frac{dP(\theta_1)}{d\theta_1} \frac{dP(\theta_2)}{d\theta_2} \right\rangle = \sigma_0^2(1 + w(\theta))$$

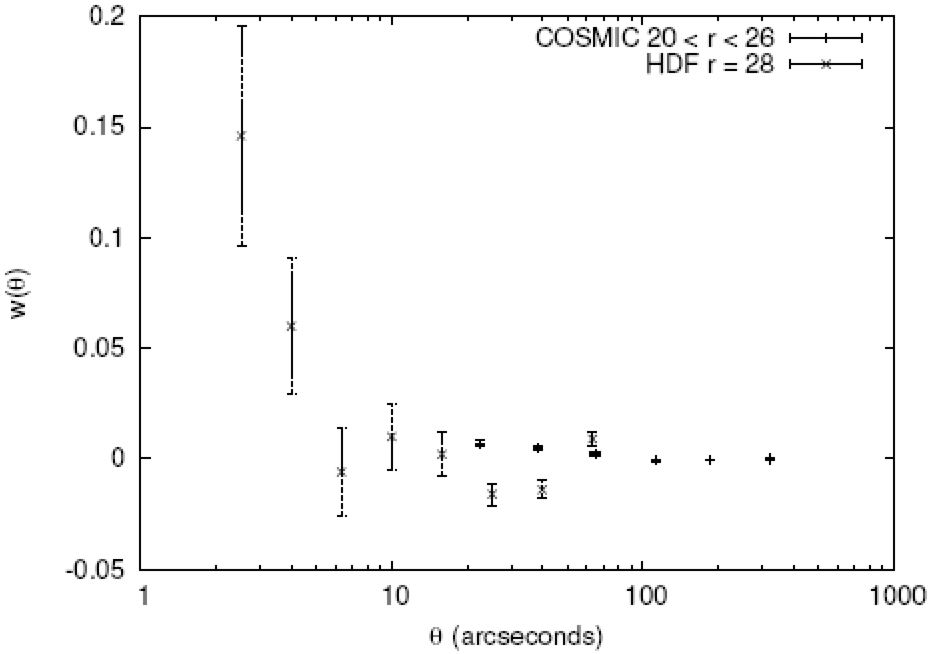
* It measures the excess probability of detecting a source at a distance θ from another source
* The bright source (r<22), large scale (θ > 10") w(θ) is consistent with: $w(\theta) = (\theta/\theta_0)^{-0.8}$, $\theta_0 = 10^{-0.4(r-21.5)}$



The Sloan Digital Sky Survey found that bright sources have power law w(θ) (Zehavi et al.)

The Faint Source Correlation Function (FSCF)

* w(θ) for r > 23 had not been well-measured
* Brainerd et al. measured a statistically insignificant w(θ) for r < 26, θ > 10" with COSMIC
* Villumsen et al. did a bit better in HDF r < 28 by going down to 3" resolution
* Both groups were limited by small sample size and their inability to study smaller scales

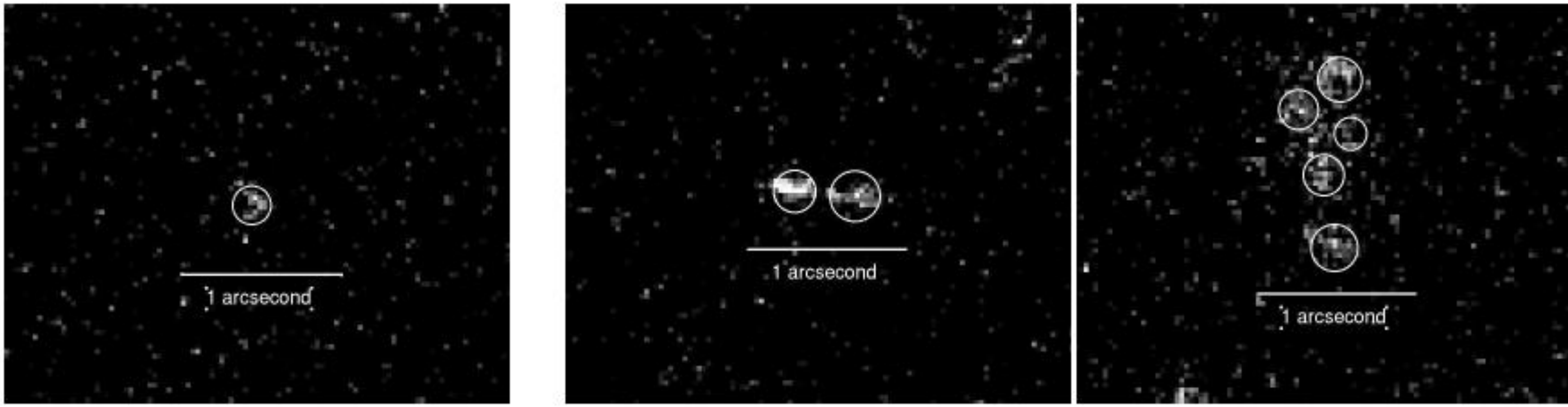


Brainerd et al. measured a w(θ) of a few hundredths and Villumsen et al. measured a w(θ) of a few tenths

How did we improve this measurement?

* The previous best data set was the Hubble Deep Field (HDF) which covered 15 arcmin^2 with r = 27 depth
* The Hubble Space Telescope produced two bigger datasets, The Great Observatories Origins Deep Survey (GOODS), is 20 times larger than HDF at the same depth, and the Ultra Deep Field (UDF) is about 1.5 magnitudes fainter, giving it exponentially more sources
* To push our effective resolution down, we simulated GOODS and UDF images and optimized our source extraction procedures to find close pairs (allowing one percent false detections)

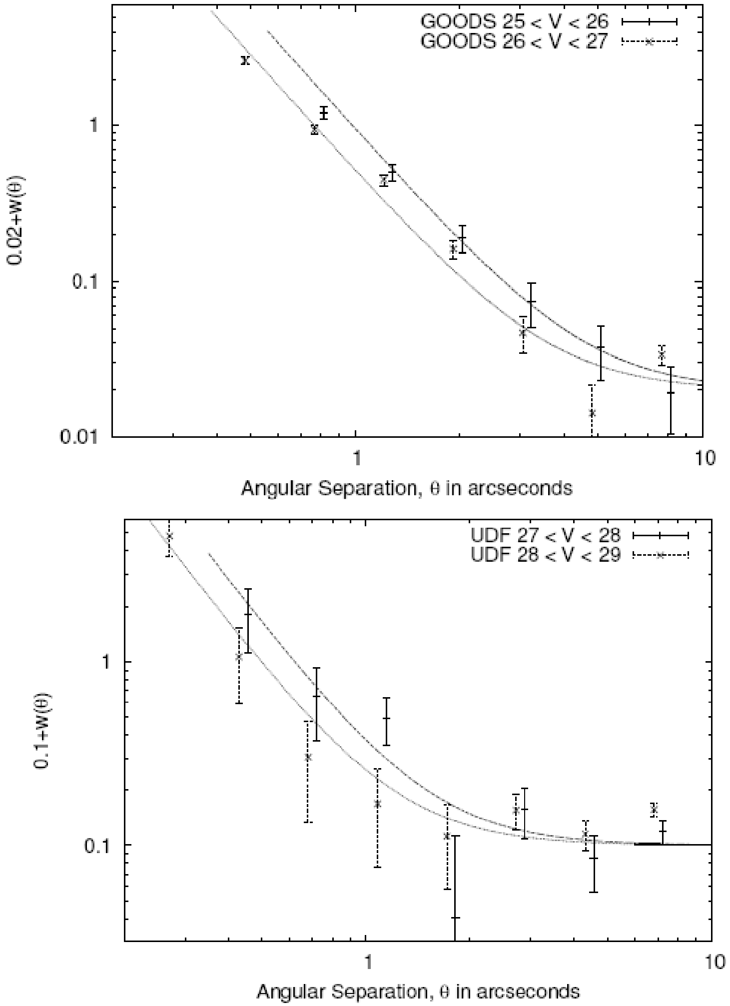
What did these improvements really do?



* Most catalogs tend to be very conservative so that every source in the catalog is real
* In a standard catalog, the last two images had1 and 2 sources respectively (in ours they are 2 and 5 as shown)
* Our catalogs best match the reality of simulations where we know what’s a source and what’s noise

Measuring the FSCF

* Morganson & Blandford made the first precise FSCF measurement in GOODS (top) and the UDF (bottom)
* We find:
  $w(\theta) = (\theta/\theta_0)^{-2.5}$,
  $\theta_0 = 10^{-0.1(V-25.8)}$
* This is much steeper than the cosmological $w(\theta)$
* They are different, because we are probing galactic physics like gas dynamics



Weak Gravitational Lensing

* Matter between us and sources "gravitationally lenses" the source image
* In strong lensing, a source gets multiply imaged (red)
* In weak lensing, a source is sheared by $\gamma = 0.1$ or so, and its ellipticity is altered
* We need many sources to make a statistically significant measurement
* $\gamma \propto D_{LS} D_L / D_S$

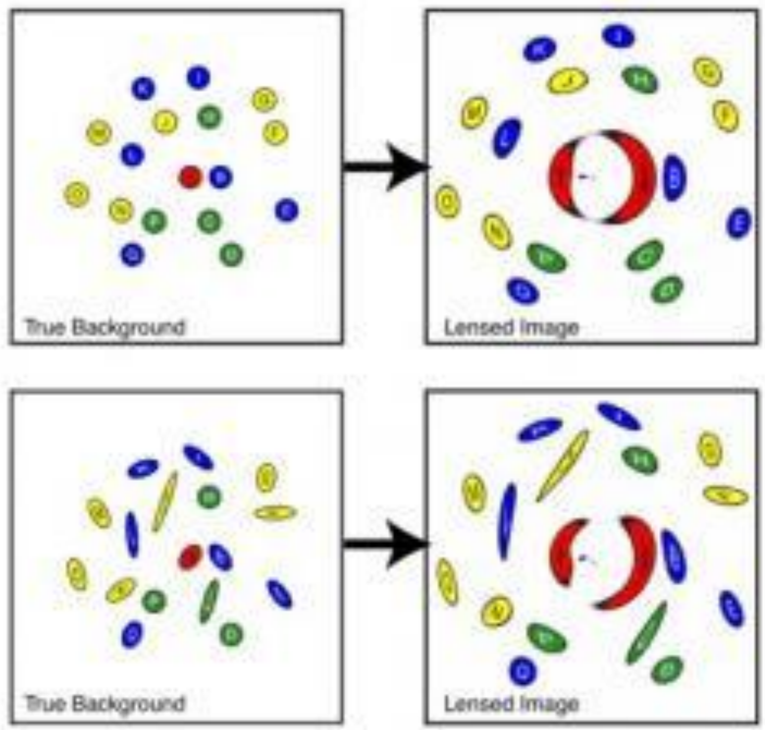


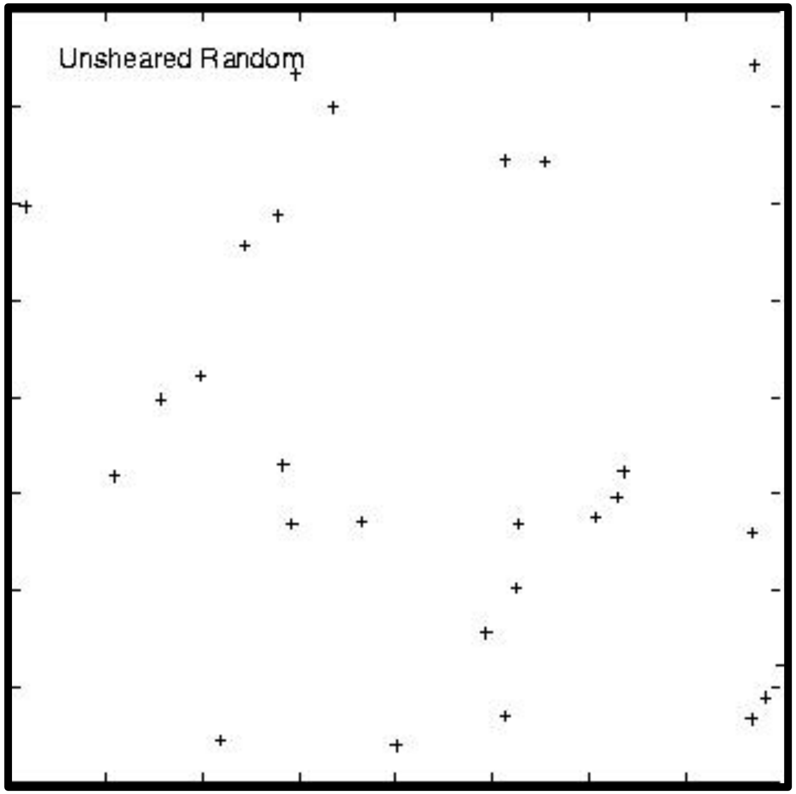
Image courtesy of Williamson et al.

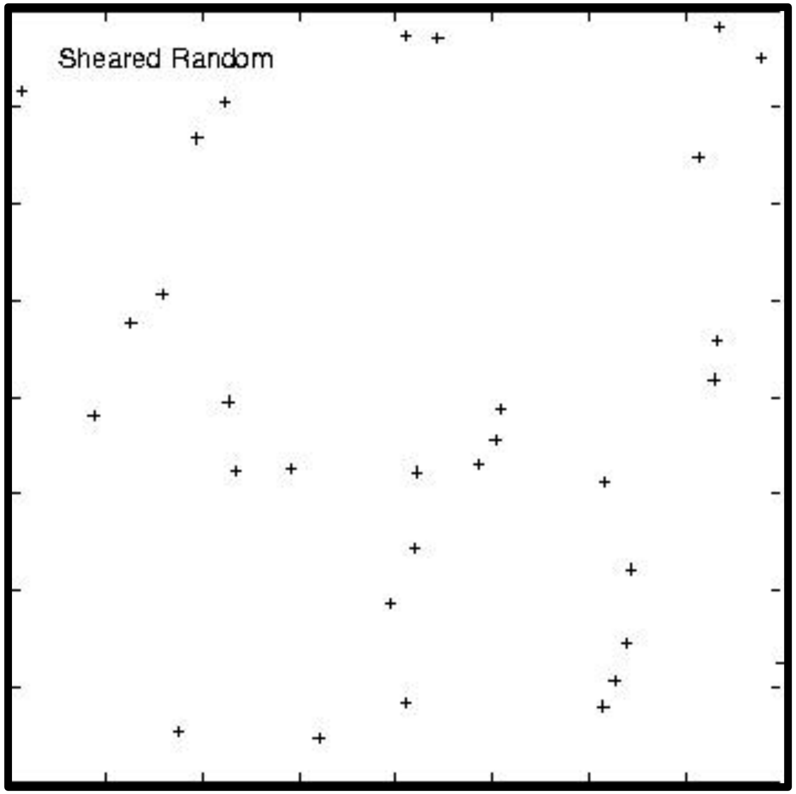
Cosmic Shear

* Cosmic structure on the degree scale distorts ellipticities by $\gamma = 0.01$ or so (Hoekstra & Jain)
* It takes thousands of sources to observe this effect
* But a degree scale dataset will have a roughly uniform shear, making the effect observable when one gets enough data (Blandford et al.)
* In the presence of uniform shear, $w(\theta)$ changes:
  – $w(\theta) = (\theta/\theta_0)^{-2.5}$, with no shear
  – $w(\theta, \Phi) = (\theta/\theta_0)^{-2.5}(1+2.5\,\gamma \cos(2\Phi))$, with shear

  Where Φ is the angle between the pair vector and the shear

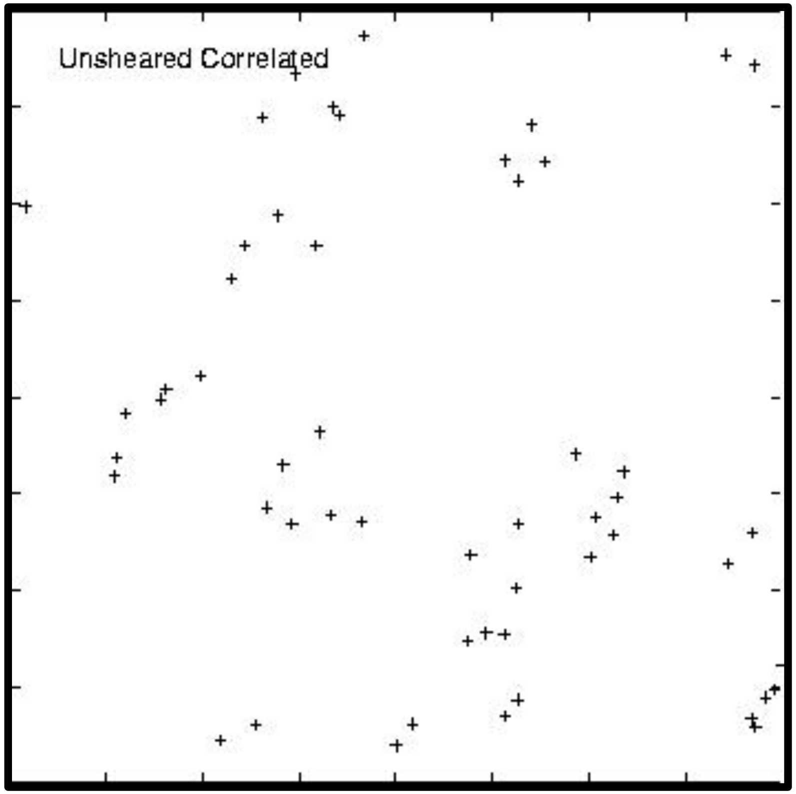
Shearing Uncorrelated Sources

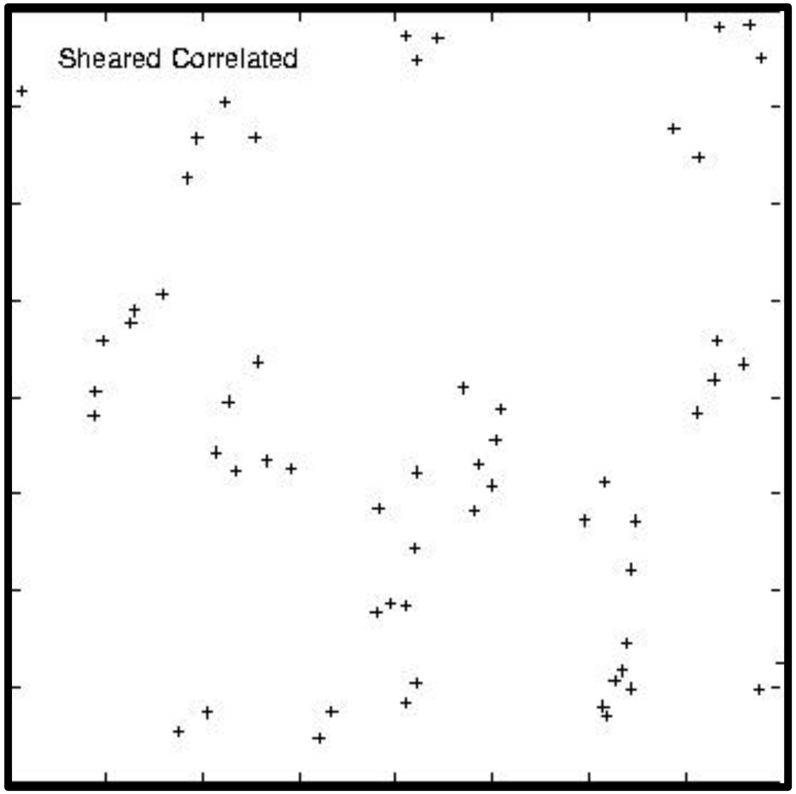




We start with a set of random, uncorrelated dots. When we shear the image by 20% there is no statistical difference. A uniform distribution is still uniform.

Shearing Clusters





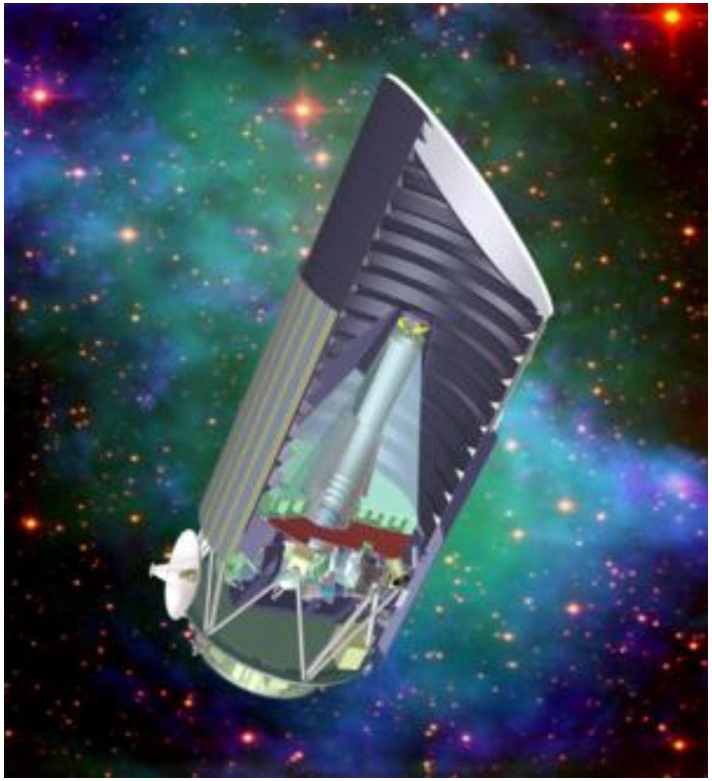
We start with a set of clustered dots. When we shear the image by 20% there is a measurable statistical difference. The clusters are elliptical and aligned with the shear.

FSCF Lensing by Cosmic Shear

* Cosmic shear is ideal for FSCF lensing, because both measurements require large patches of sky
* With1 deg^2 of 28^{th} magnitude, HST quality data, one can make a measurement of γ with statistical uncertainty of $\sigma_\gamma = 0.002$, about a fifth of the expected rms of γ
* Ellipticity surveys of brighter sources still provide a better measurement of cosmic shear
* We can measure the mass distribution with ellipticity lensing and use the distance-dependence of shear to find the distance to our faint sources
* The redshift distribution of these sources will tell us how galaxies went from many little dots to large modern structures

Large Area Projects

* LSST will cover 30,000 deg^2 to 27.5^{th} magnitude
* 1” resolution limits FSCF precision so that shear measurements are difficult
* SNAP will probe 1000 deg^2 to 28^{th} magnitude with 0.15” resolution and find10^9 sources
* Correlating ellipticity lensing and FSCF lensing, gives us percent level distance measurements to the faintest sources in the sky



SNAP provides the perfect tool to study the lensing of the FSCF (SNAP Collaboration)

Summary

* Faint sources do not give us much information individually, but with the right data, we can measure their clustering (correlation function)
* We recently showed that these sources cluster on the arcsecond (galactic) scale with a different power law than brighter sources display on cosmological scales
* With an enormous survey like SNAP, we will study the cosmic shear of this correlation function with a few percent level precision over a square degree
* Over 1000 deg^2, we will correlate the observed shear of these faint dots with that of the brighter ellipses to obtain distance measurements at the percent level

References

Babul, A. & Rees, M. J. MNRAS, 255, 346 (1992).

Blandford et al. MNRAS, (1991).

Brainerd, T. G. et al. MNRAS, 275, 781 (1995).

Coe, D. et al. AJ, 132, 926 (2006).

He, P. et al. Ap&SS, 274, 557 (2000).

Hoekstra, H. & Jain, B. ArXiv e-prints, 805 (2008).

Morganson, E. & Blandford, R. ArXiv e-prints, 805 (2008).

SNAP Collaboration. ArXiv e-prints (2005).

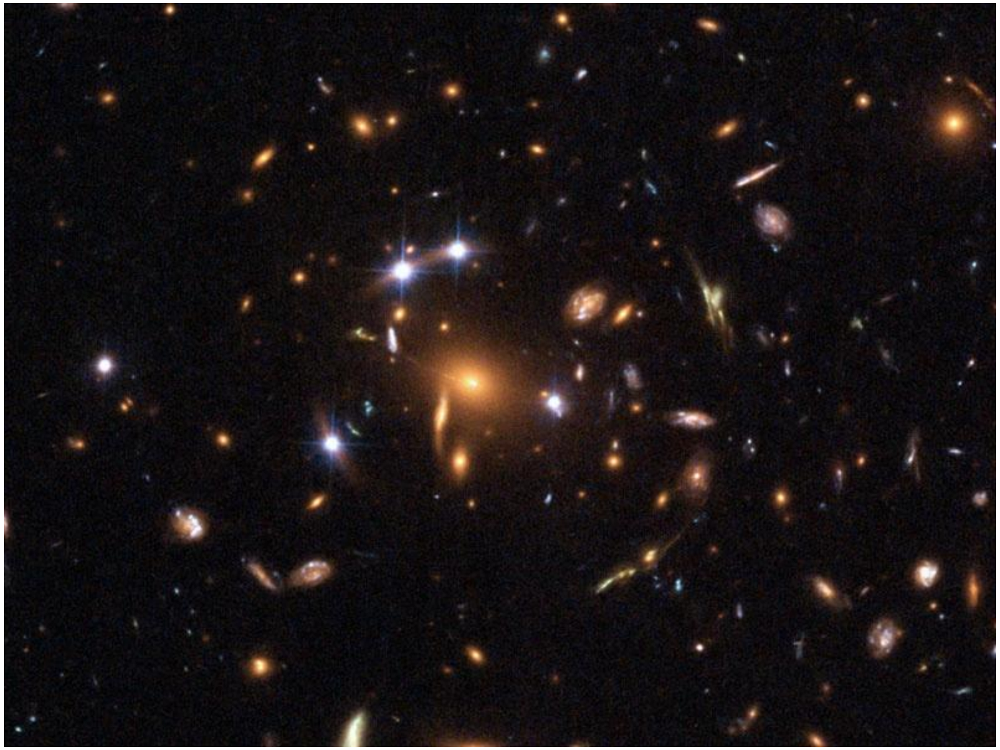
Villumsen, J. V. et al. ApJ, 481, 578 (1997).

Williamson, J. et al. JYI, 17, 7 (2008).

Zehavi, I. et al. ApJ, 571, 172 (2002).

FSCF Lensing By Clusters (Bonus Slide)

* It takes 10,000 sources to measure the FSCF well
* We need many more to measure lensing
* Even enormous lenses have only about 10,000 sources around them
* We could measure 100s of lenses to observe the effect



Even a large cluster lens like SDSS J1004+4112 only has a few thousand sources (courtesy of Astronomy Picture of the Day)