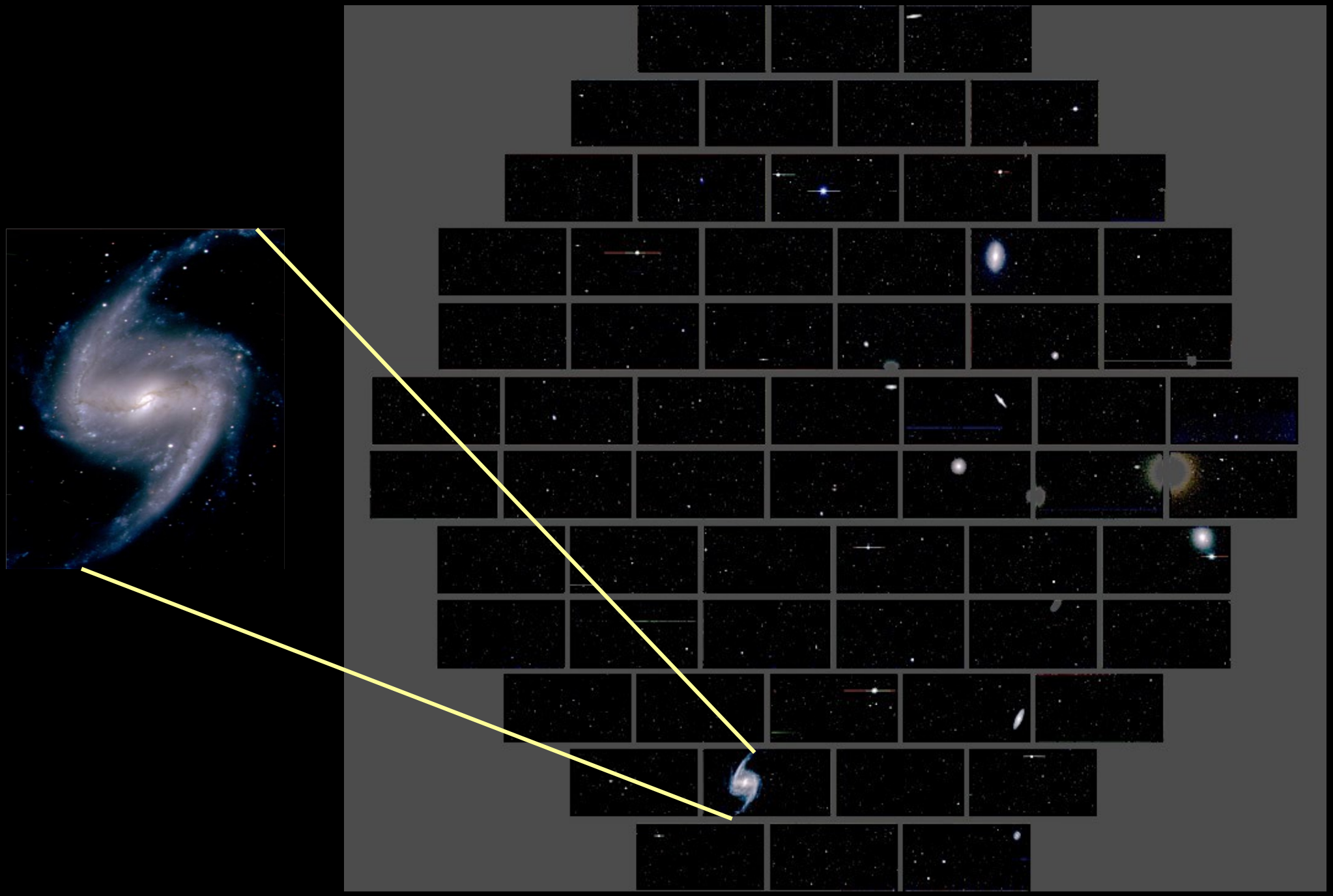
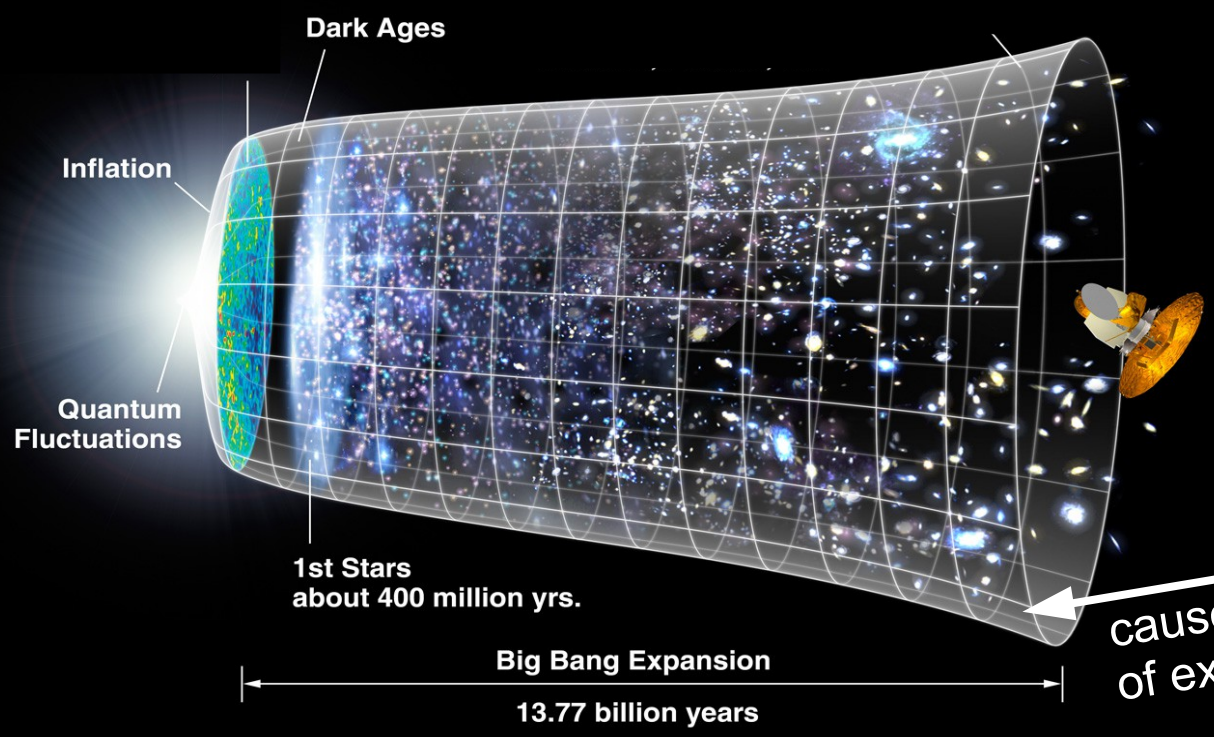


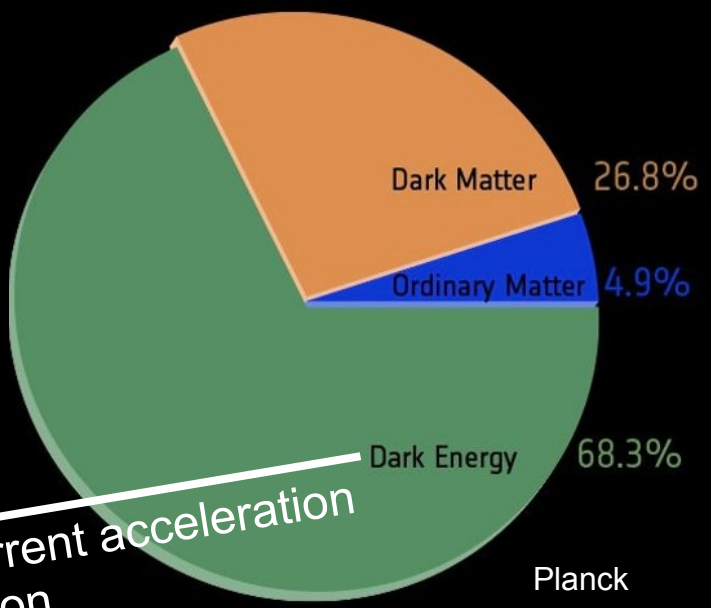
image from the Dark Energy Survey

Cosmic expansion

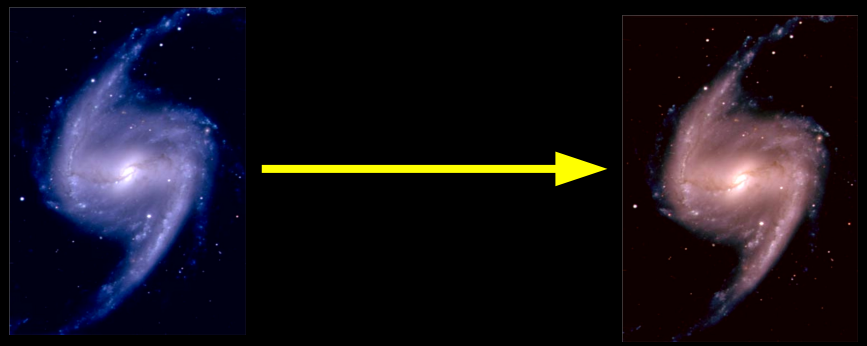


NASA/WMAP Science Team

causes current acceleration of expansion



Planck

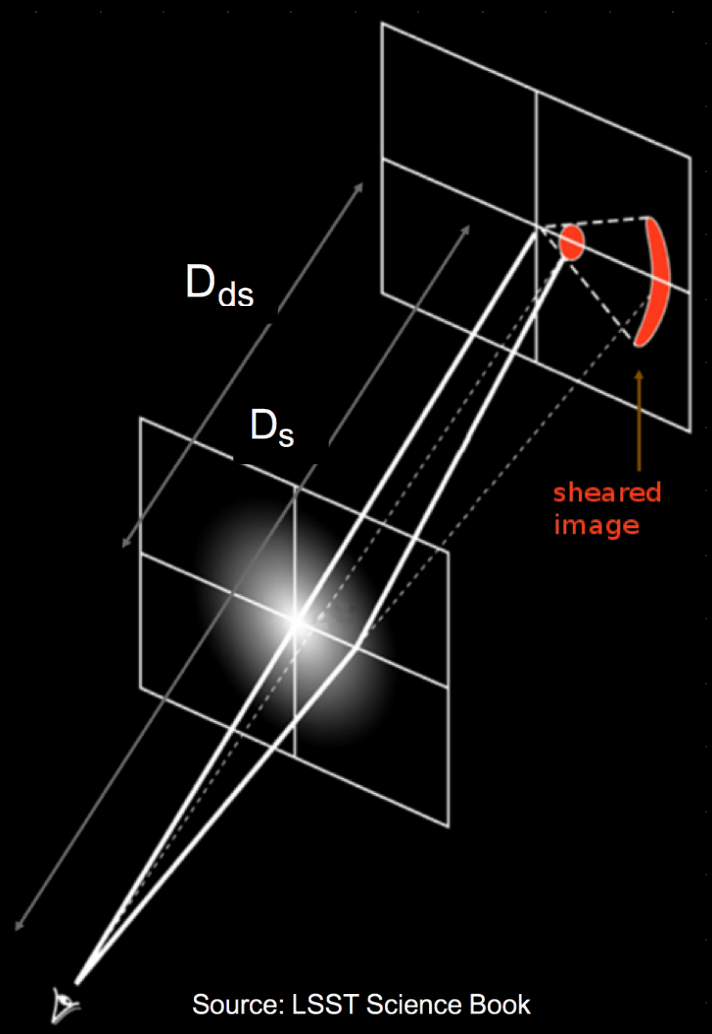


Gravitational lensing

- When our photon passes massive structures, it feels gravity and its path gets bent
- This causes **shifting**, and **magnification**, and **shearing** of the galaxy image and, in extreme cases, **multiple images**

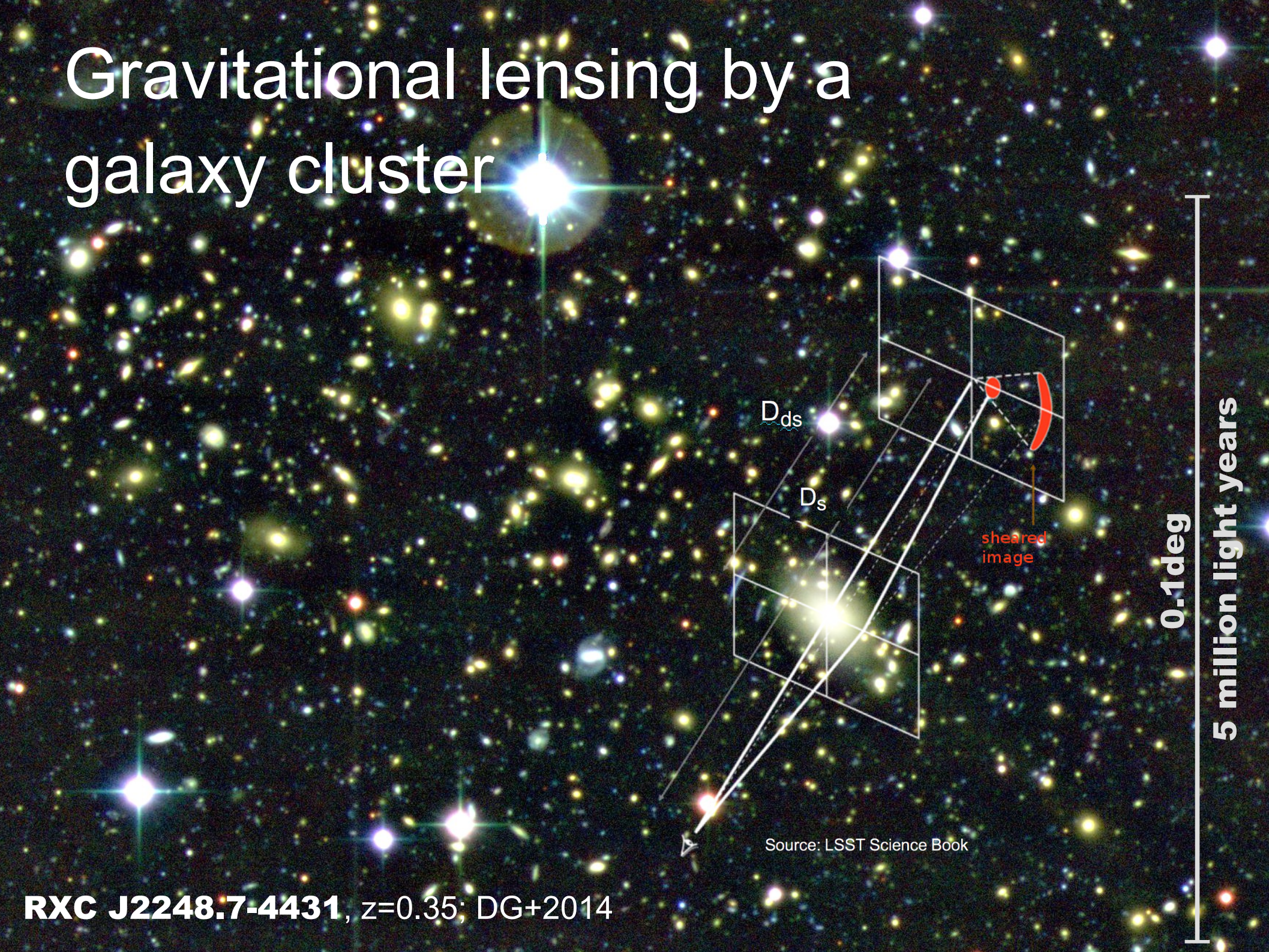
$$\gamma_t(\theta) = \langle \kappa(\theta') \rangle_{\theta' < \theta} - \kappa(\theta)$$

$$\kappa = \Sigma / \left[\frac{c^2}{4\pi G} \frac{D_\mathrm{s}}{D_\mathrm{d} D_\mathrm{ds}} \right]$$



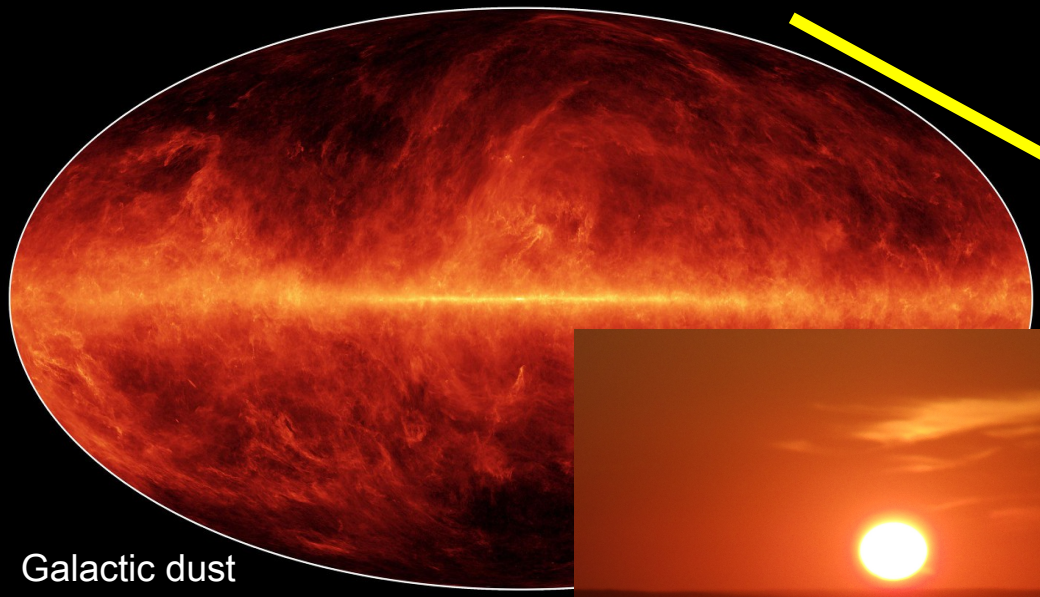
Source: LSST Science Book

Gravitational lensing by a galaxy cluster

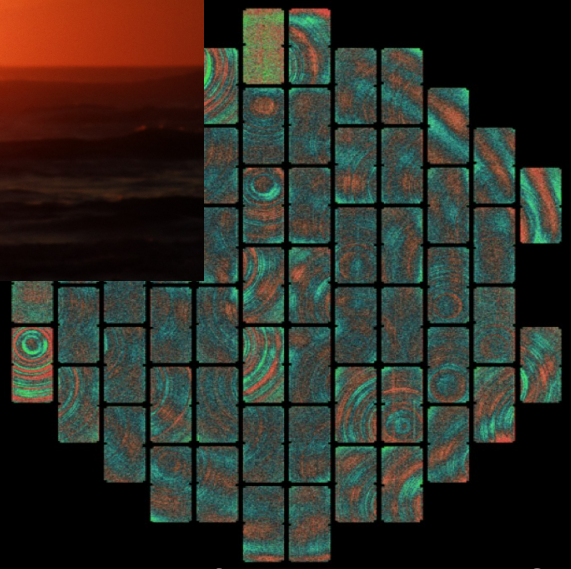


RXC J2248.7-4431, *z*=0.35; DG+2014

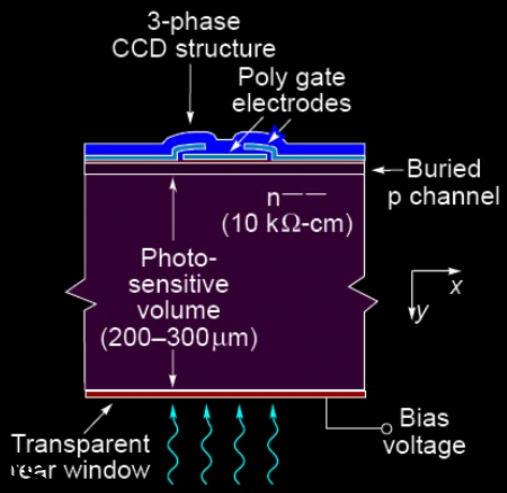
Galaxy, atmosphere, telescope optics, and CCD



Galactic dust
source: Planck

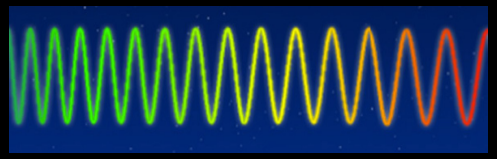


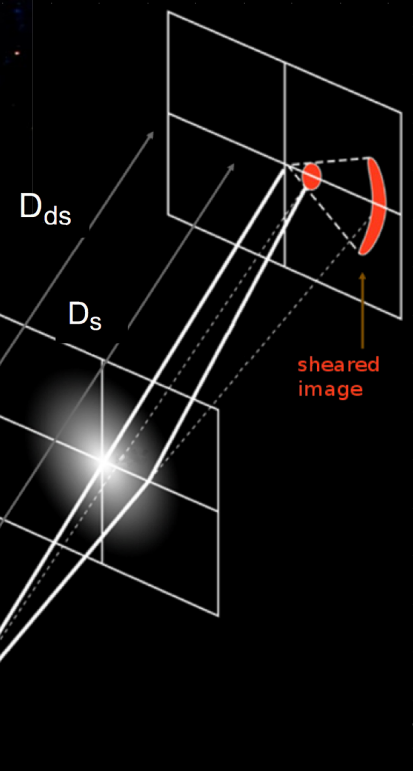
Size residual of star images in DES
source: Chris Davis / Sarah Bridle

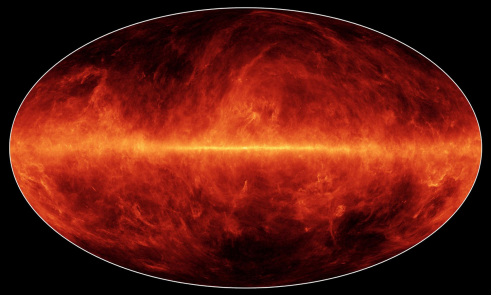


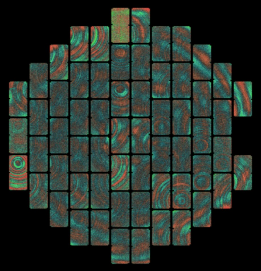
Source: Estrada+2011

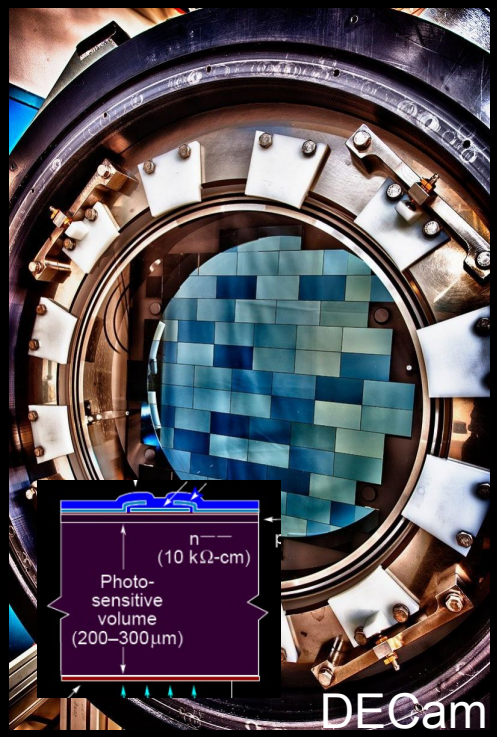
Weak lensing by galaxy clusters: from Pixels to Cosmology









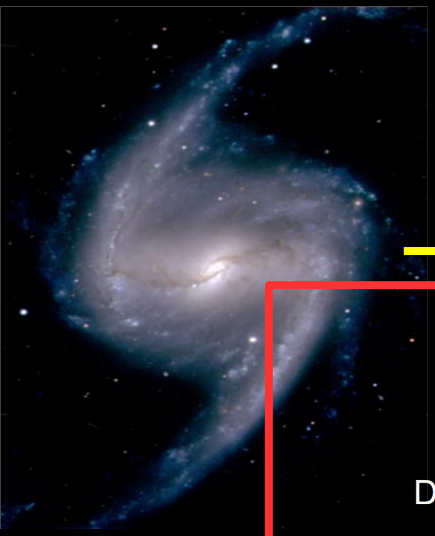


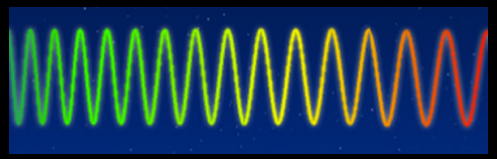
Daniel Gruen, SLAC / Thesis at LMU Munich

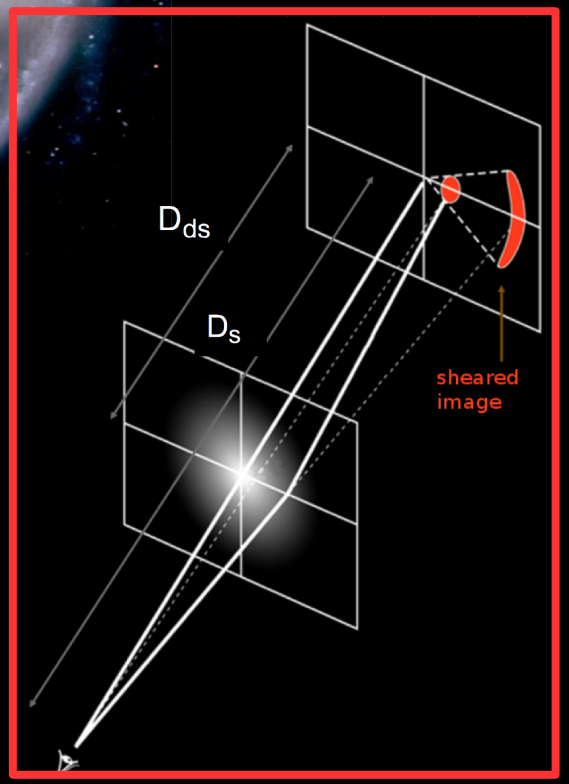
URA Thesis Award Talk

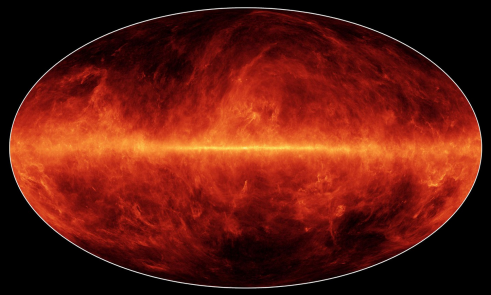
June 15, 2016

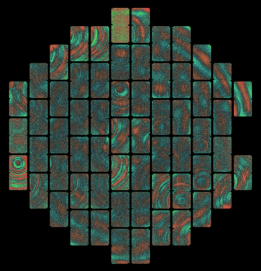
Weak lensing by galaxy clusters: from Pixels to Cosmology

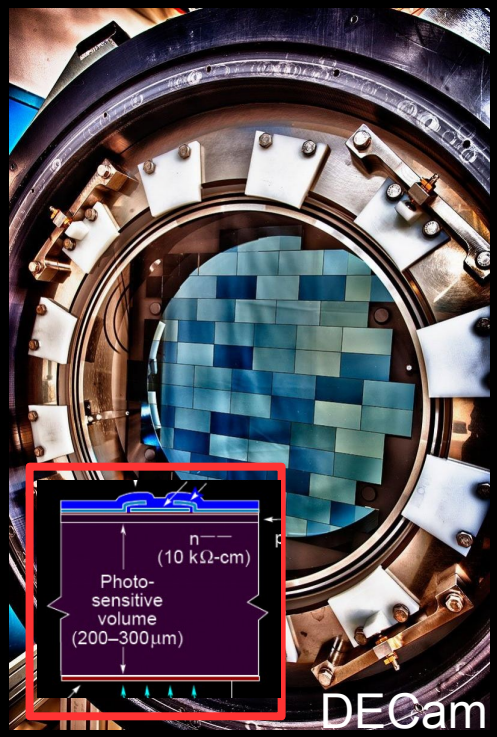






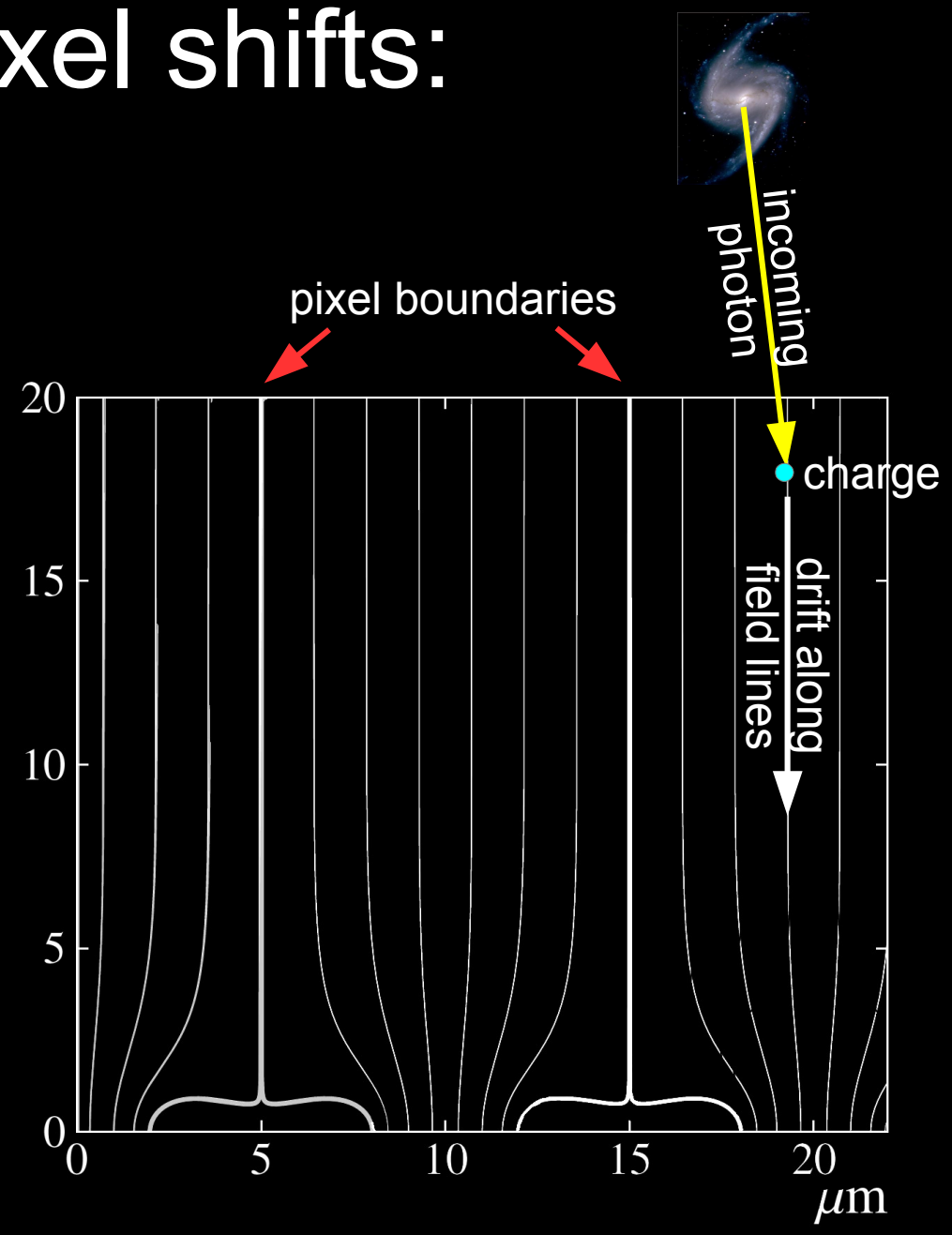






Charge-induced pixel shifts: CCD Physics

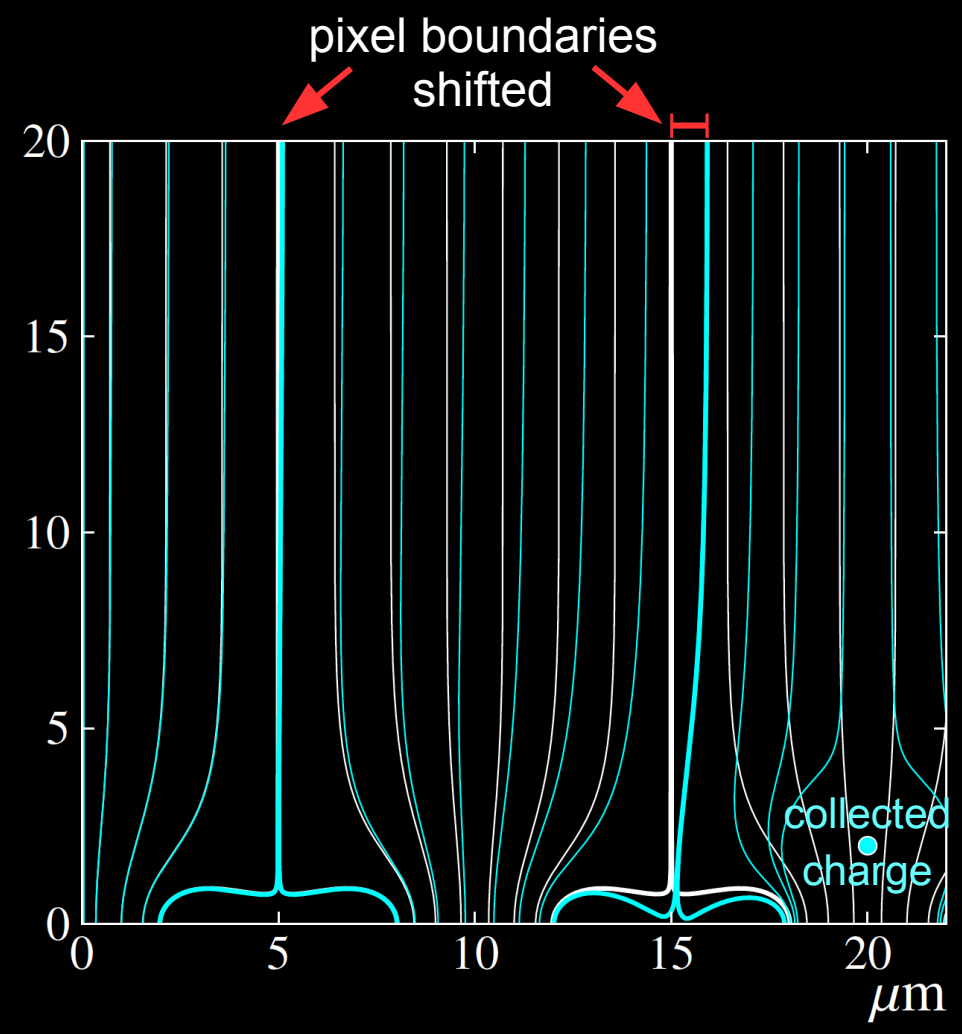
- Photons convert to charge pairs in CCD silicon
- Charges drift along field lines to where they are collected



Source: Guyonnet+2015

Charge-induced pixel shifts: CCD Physics

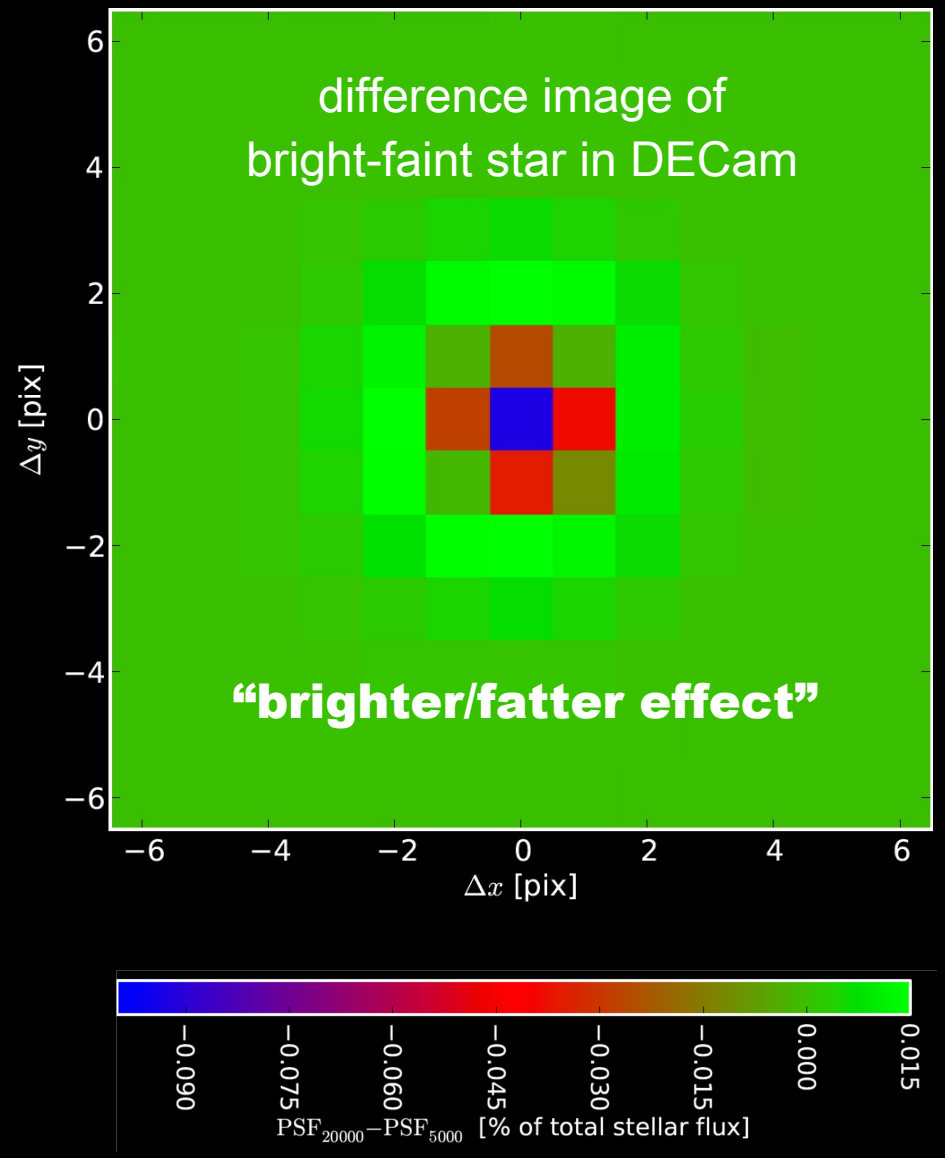
- Photons convert to charge pairs in CCD silicon
- Charges drift along field lines to where they are collected
- Accumulating charge changes field lines
- Pixels with large count “shrink” compared to their neighbors



Source: Guyonnet+2015

Charge-induced pixel shifts: Effect on stars

- Photons convert to charge pairs in CCD silicon
- Charges drift along field lines to where they are collected
- Accumulating charge changes field lines
- Pixels with large count “shrink” compared to their neighbors
- Bright stars look wider than faint stars (and than actual point-spread function)
- *Problem for weak lensing!*



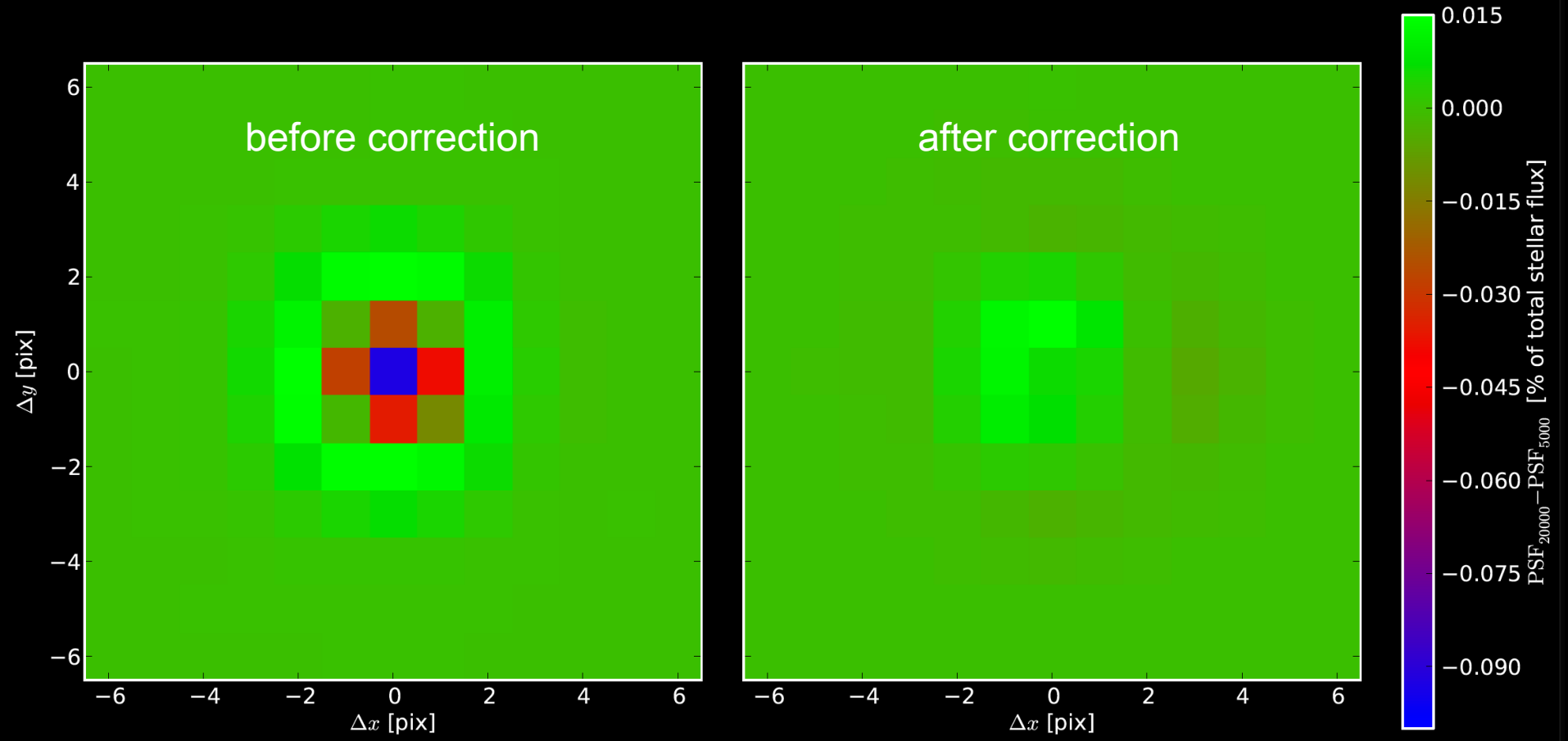
Source: DG+2015

Charge-induced pixel shifts: Correction

- We constrain a model of how far pixel borders shift based on the correlation of Poisson noise in flat field images …

Charge-induced pixel shifts: Correction

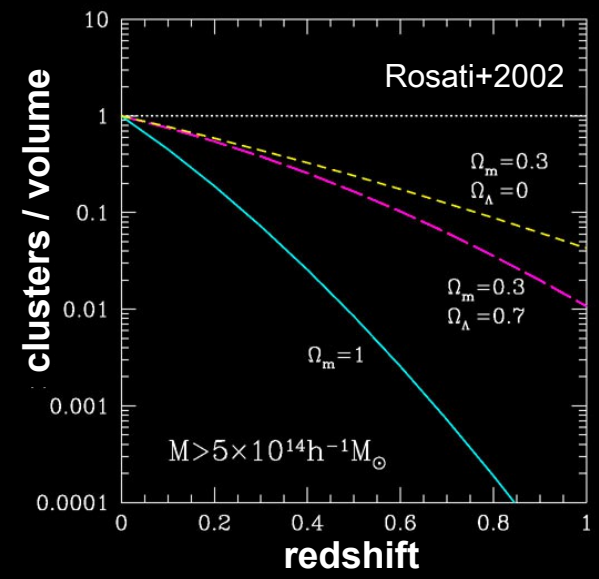
- We constrain a model of how far pixel borders shift based on the correlation of Poisson noise in flat field images …



- … and correct DECam images at the level required for DES

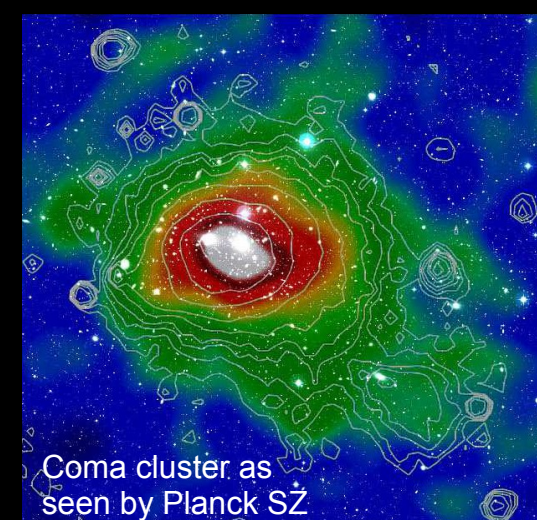
How to constrain cosmology by counting clusters of galaxies

- How many clusters form depends on
  - matter density (# increases at all masses)
  - matter clumpiness (# increases at high mass)
  - and dark energy (time of formation)



- There are effective ways of detecting clusters and measuring their *relative* masses...
  - # of galaxies (e.g. from DES photometry)
  - hot cluster gas (SPT/Planck-SZ / X-ray)

… but *absolute* mass calibration is best done with lensing (DES)

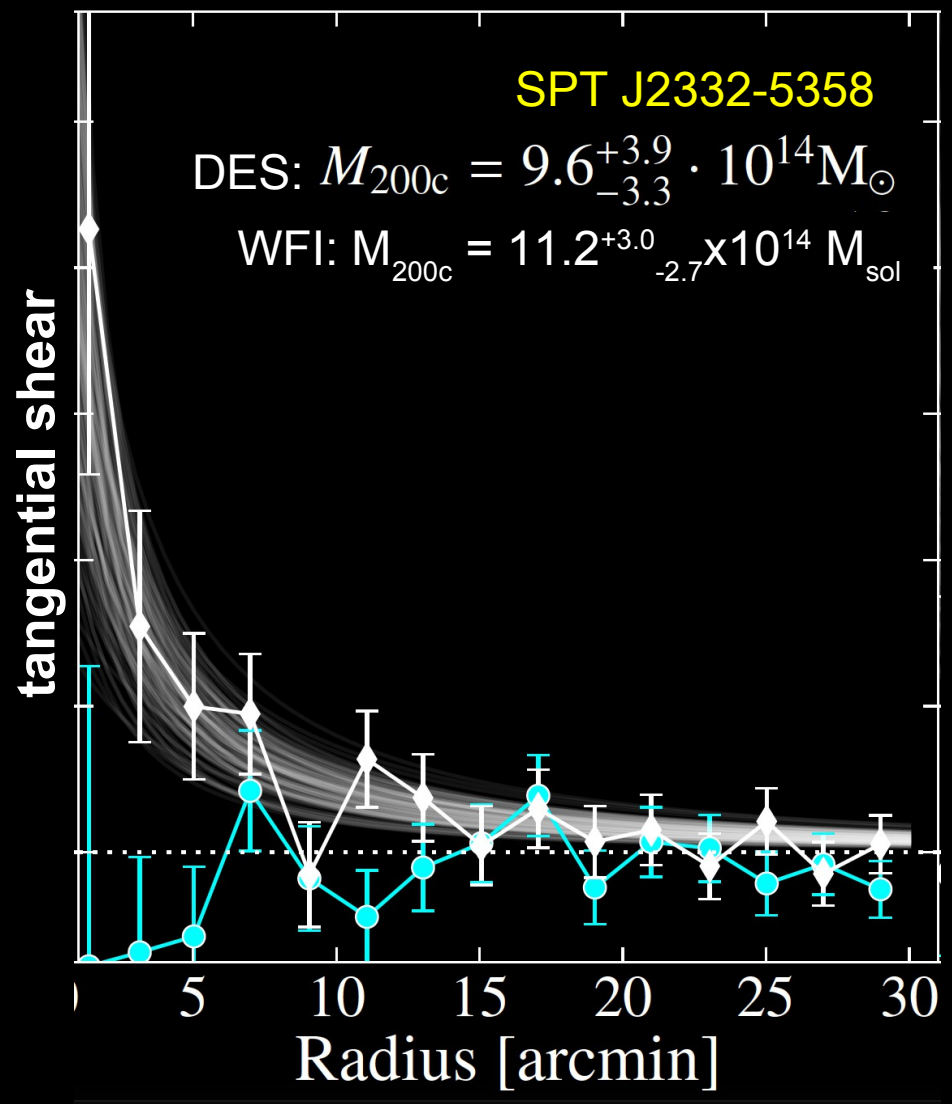


WFI **S**Z **C**luster of Galax**y** (WISCy) sample

From images to lensing mass

- Measure PSF-corrected shapes of background galaxies
- Run likelihood

  p(shear|mass, nuisance)

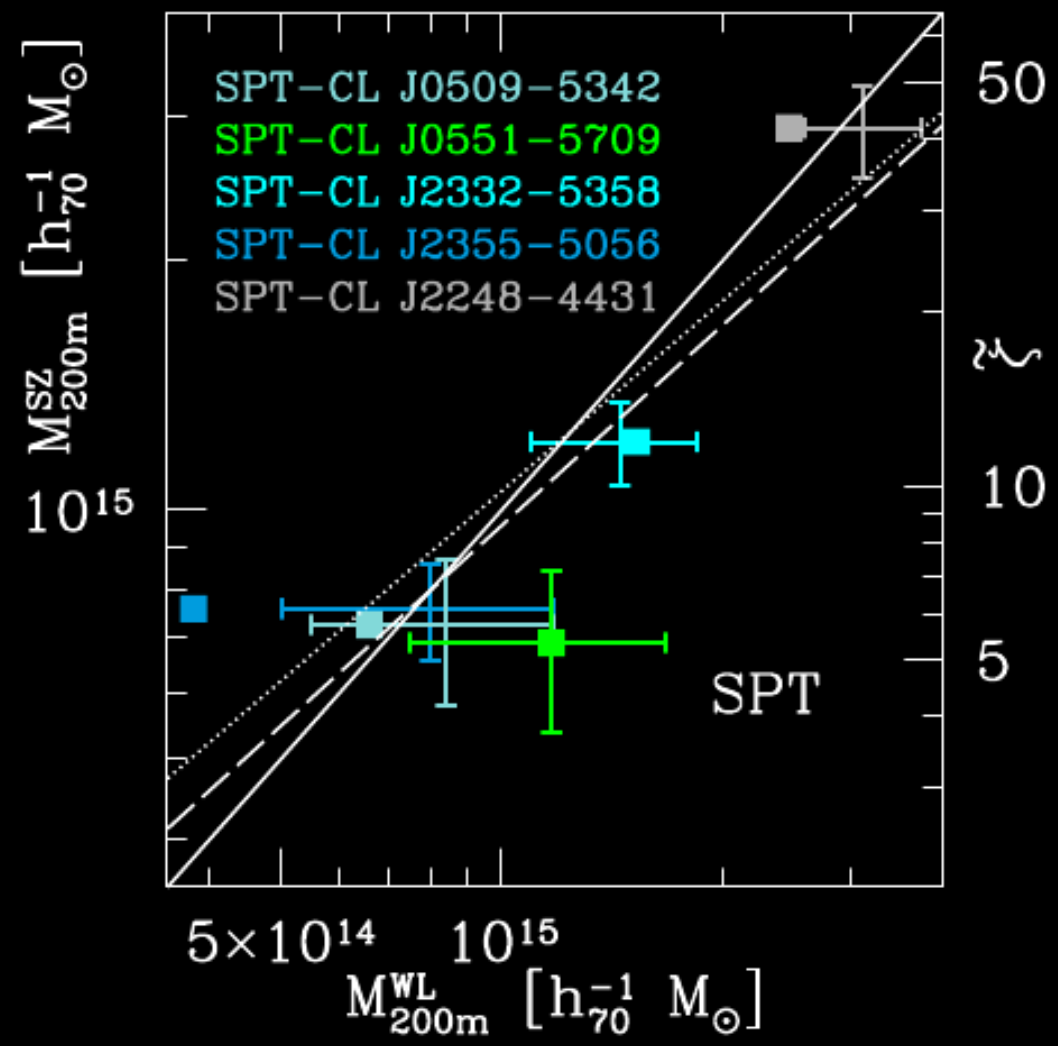


Source: Melchior, …, DG+2015

SPT SZ vs. weak lensing

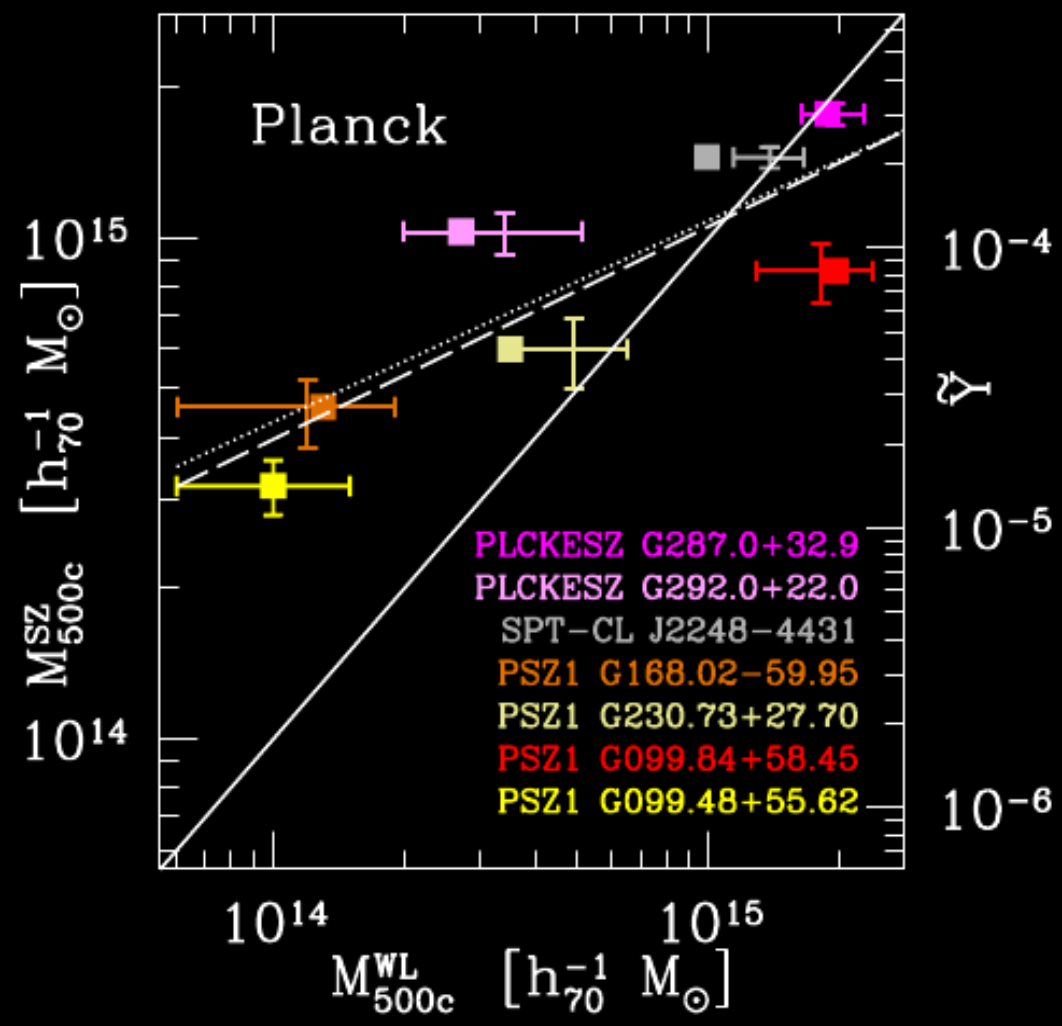
- SPT uses mass-significance relation
- Consistent within 68% confidence with other MOR results

e.g. Vanderlinde+2011, from mock survey;
Benson+2013, SZ+X-ray+CMB cosmology



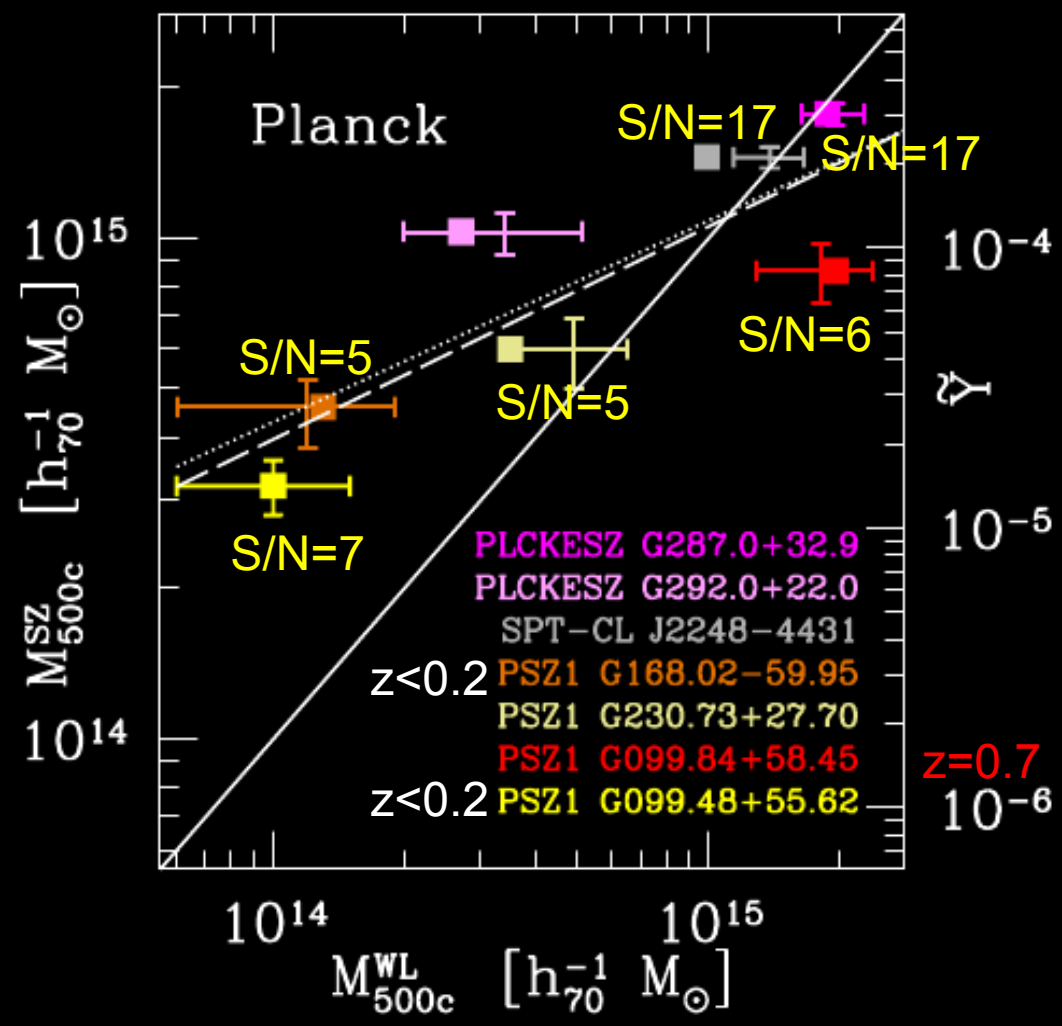
Planck SZ vs. weak lensing

- At face value, Planck MOR excluded at 3σ

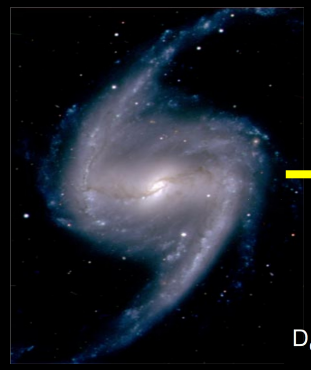


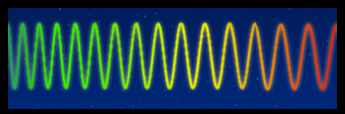
Planck SZ vs. weak lensing

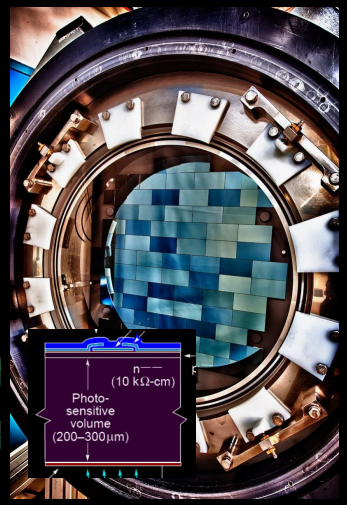
- At face value, Planck MOR excluded at 3σ
- Could this be...?
  - shallower MOR slope
  - redshift / size effect
  - noise (bias)
- DES Y1 data has >100 Planck clusters!

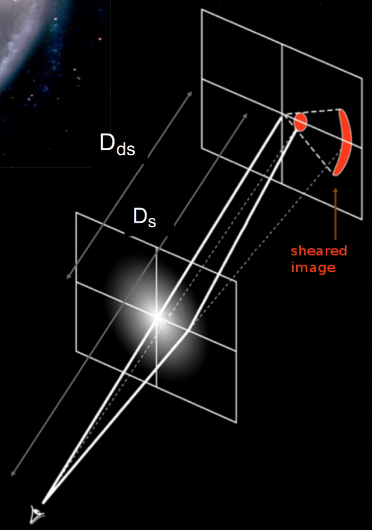


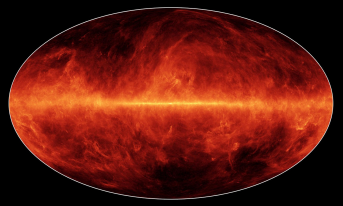
Summary

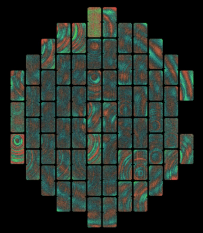












- Weak lensing studies require an understanding of physics from pixels to cosmology
- Methods and analysis techniques are in place (but will require improvements)
- The Dark Energy Survey is about to make groundbreaking weak lensing measurements

Thanks to:

… my supervisors, Stella Seitz and Ralf Bender

… the DES collaboration and collaborators

… URA