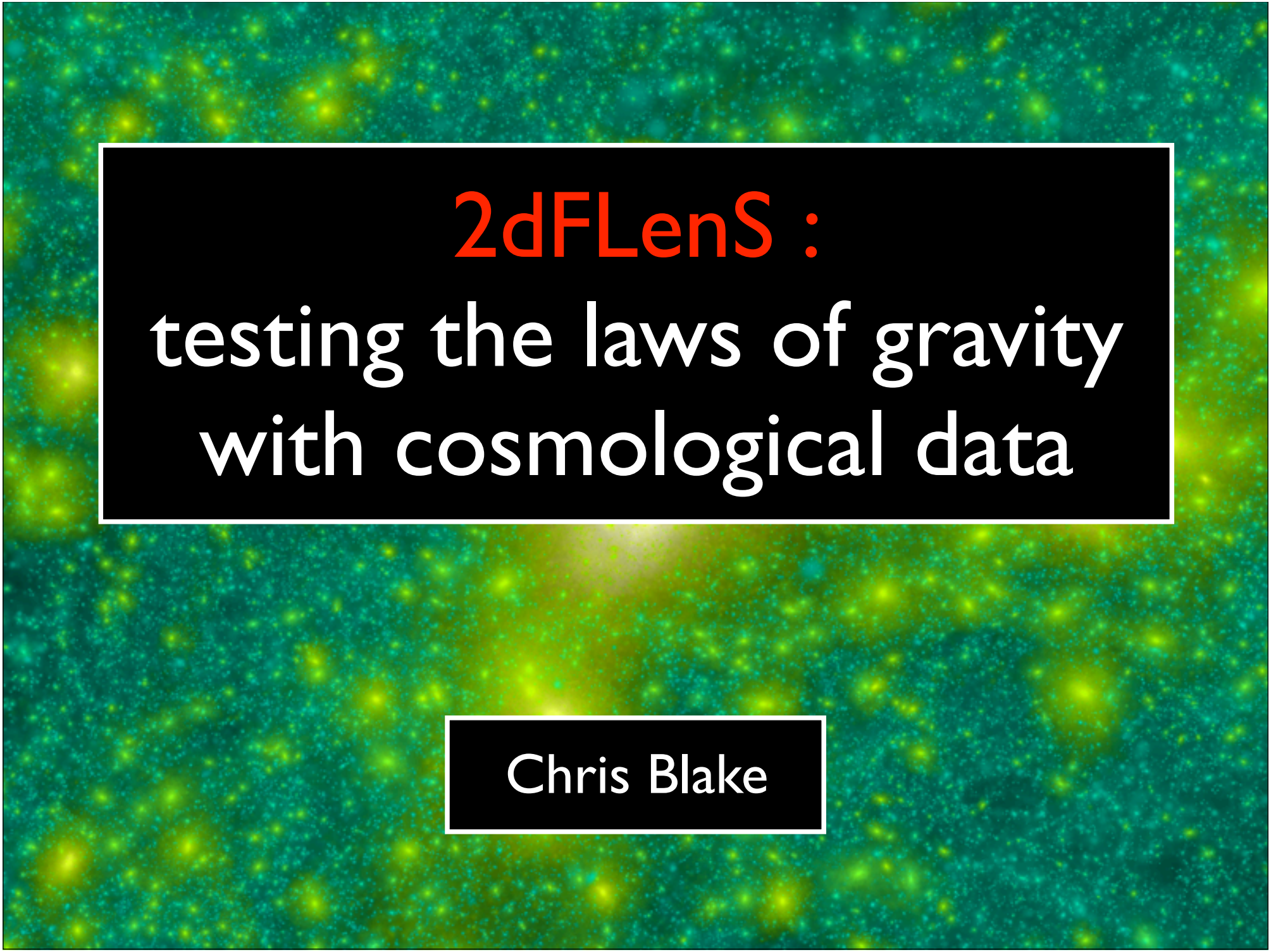
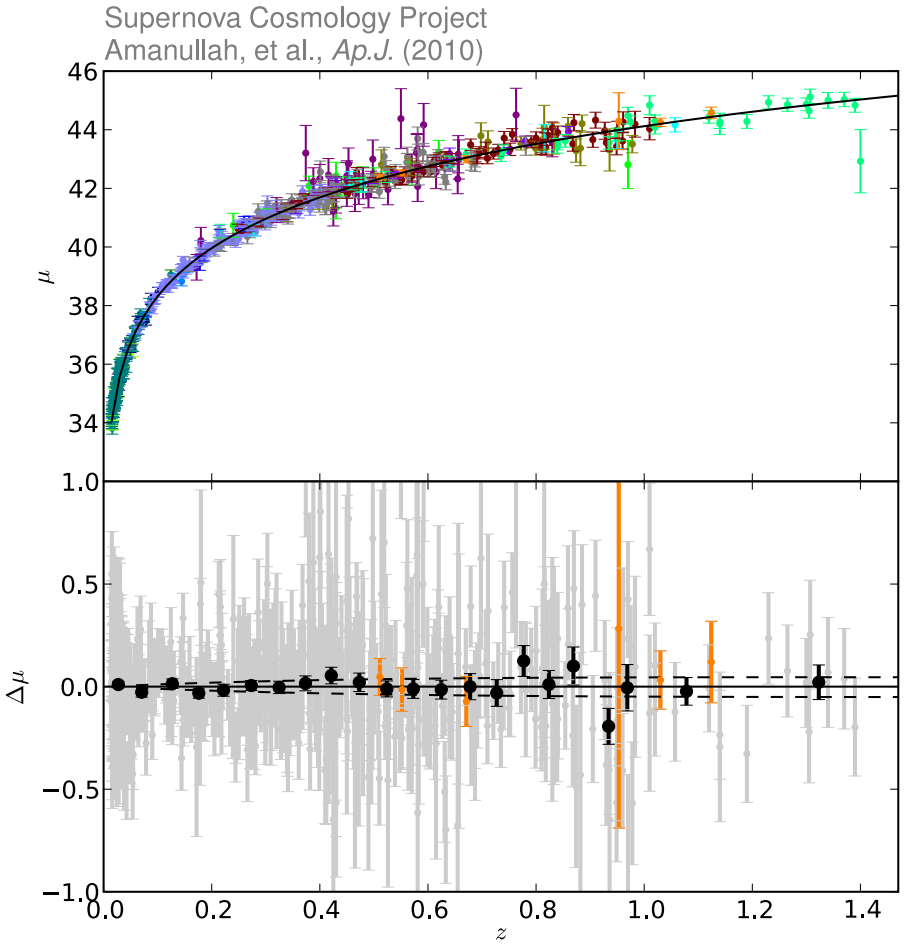
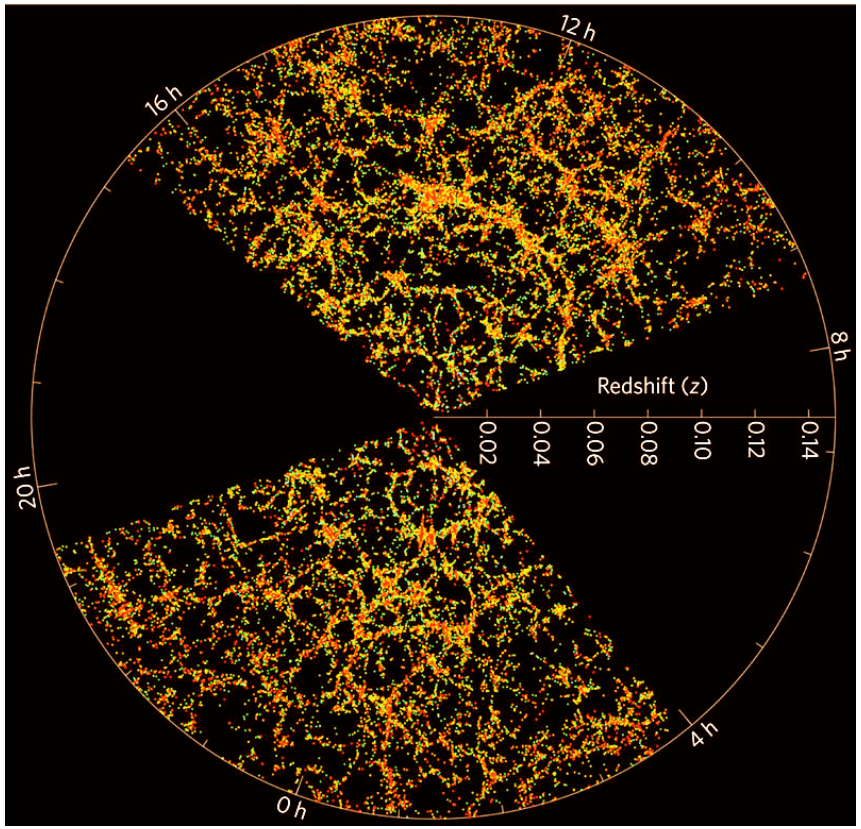

2dFLenS :
testing the laws of gravity
with cosmological data
Chris Blake

Probes of the cosmological model

How fast is the Universe expanding with time?

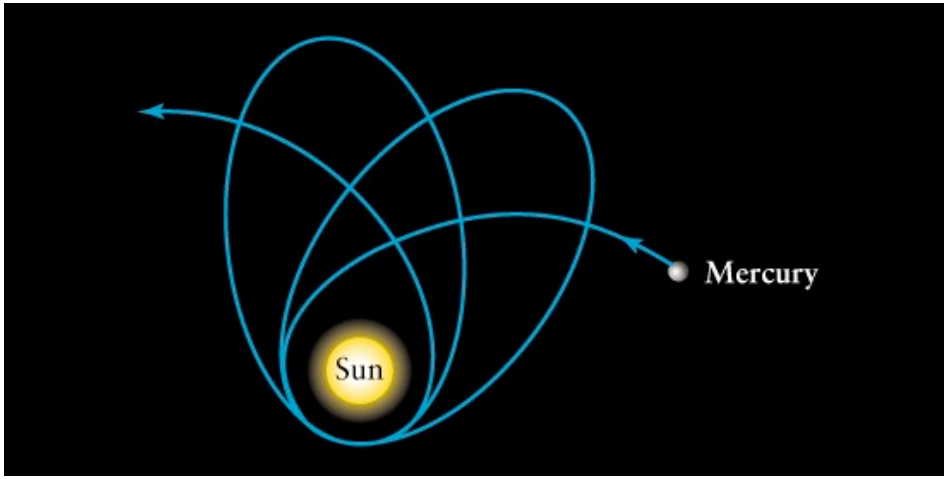
How fast are structures growing within it?

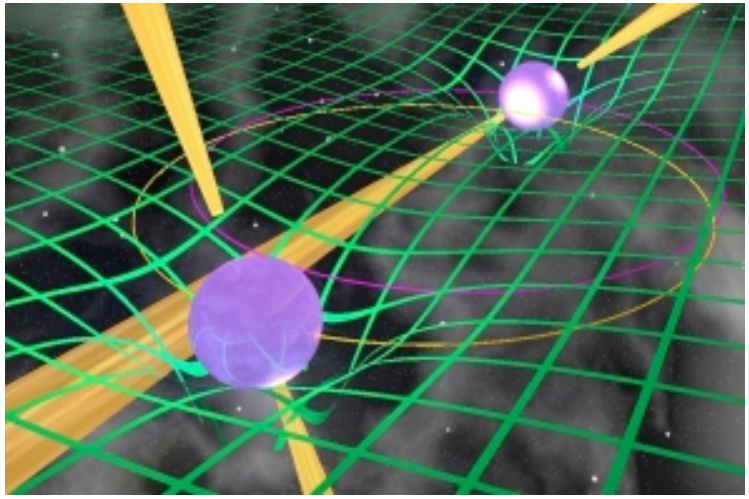


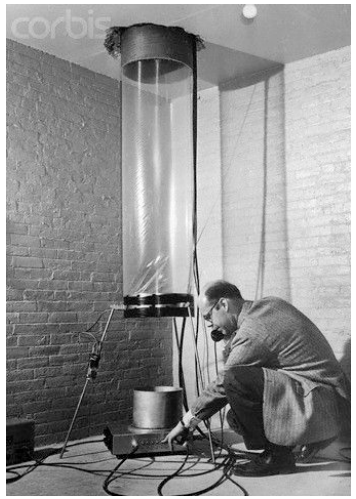


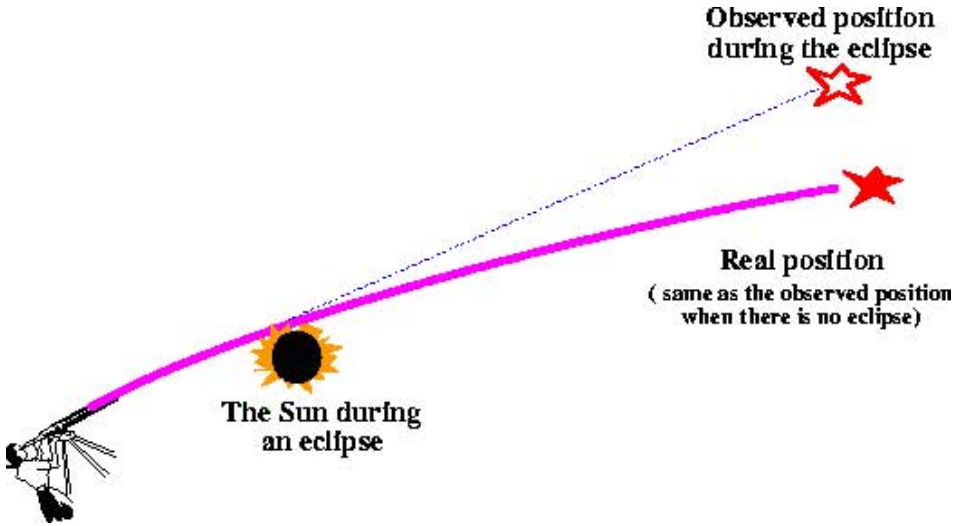
Tests of large-scale gravity

- Can tests of G.R. be extended to cosmic scales?
  And can that yield insight into dark energy?





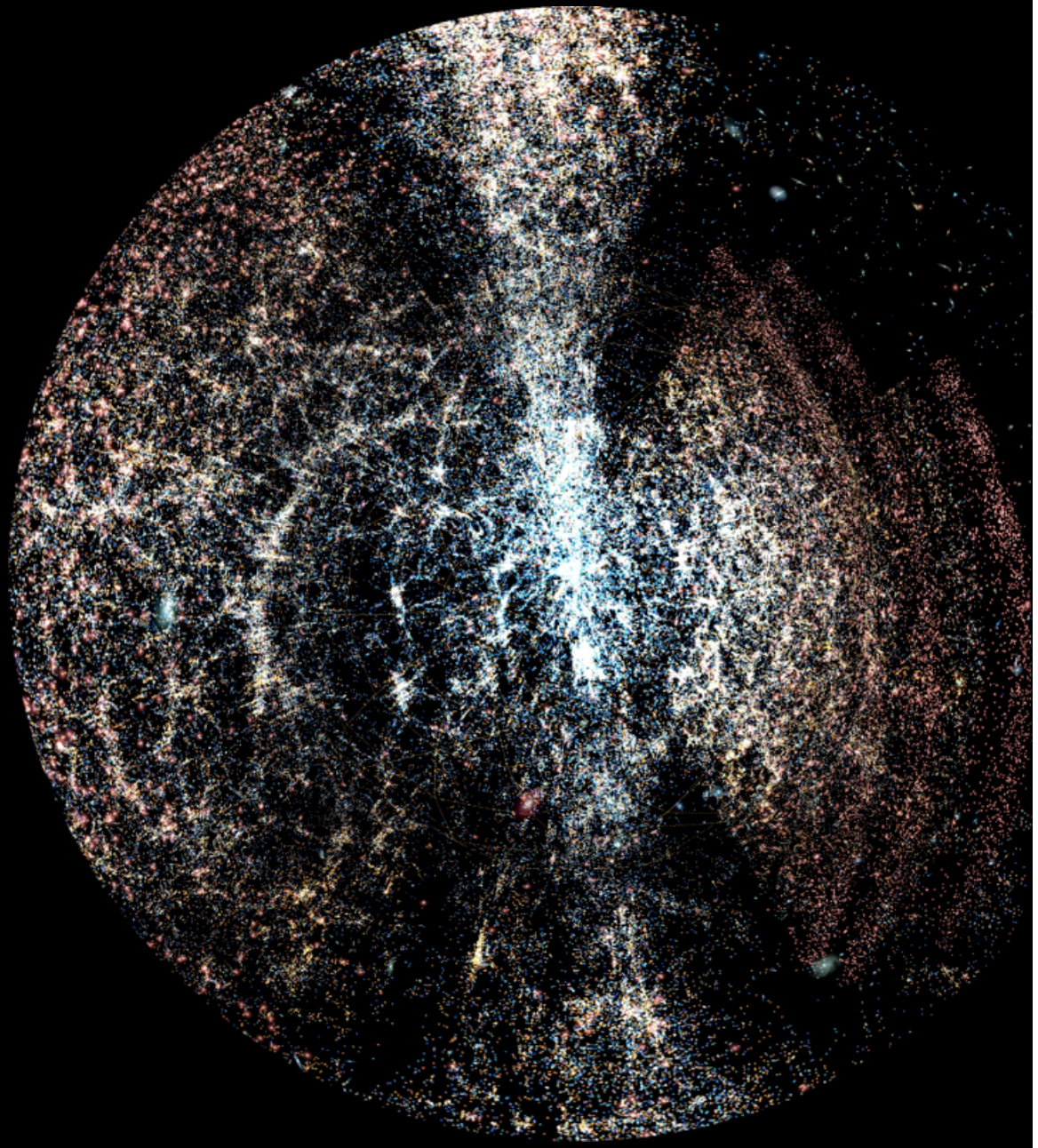




Tests of large-scale gravity

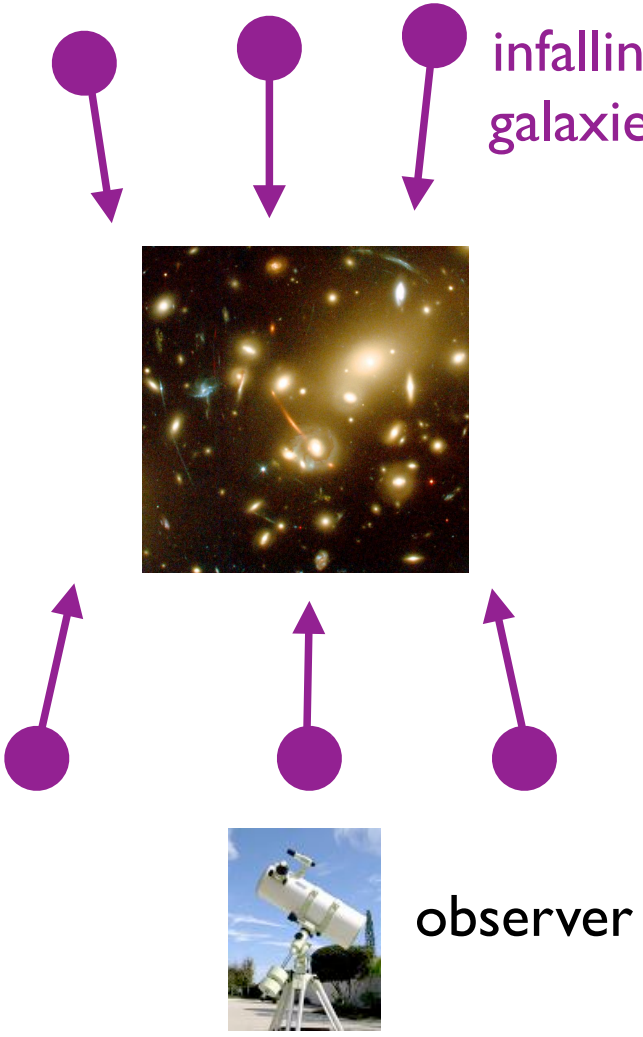
- The large-scale structure of the Universe creates a rich variety of observable signatures we can explore in the gravitational sector!

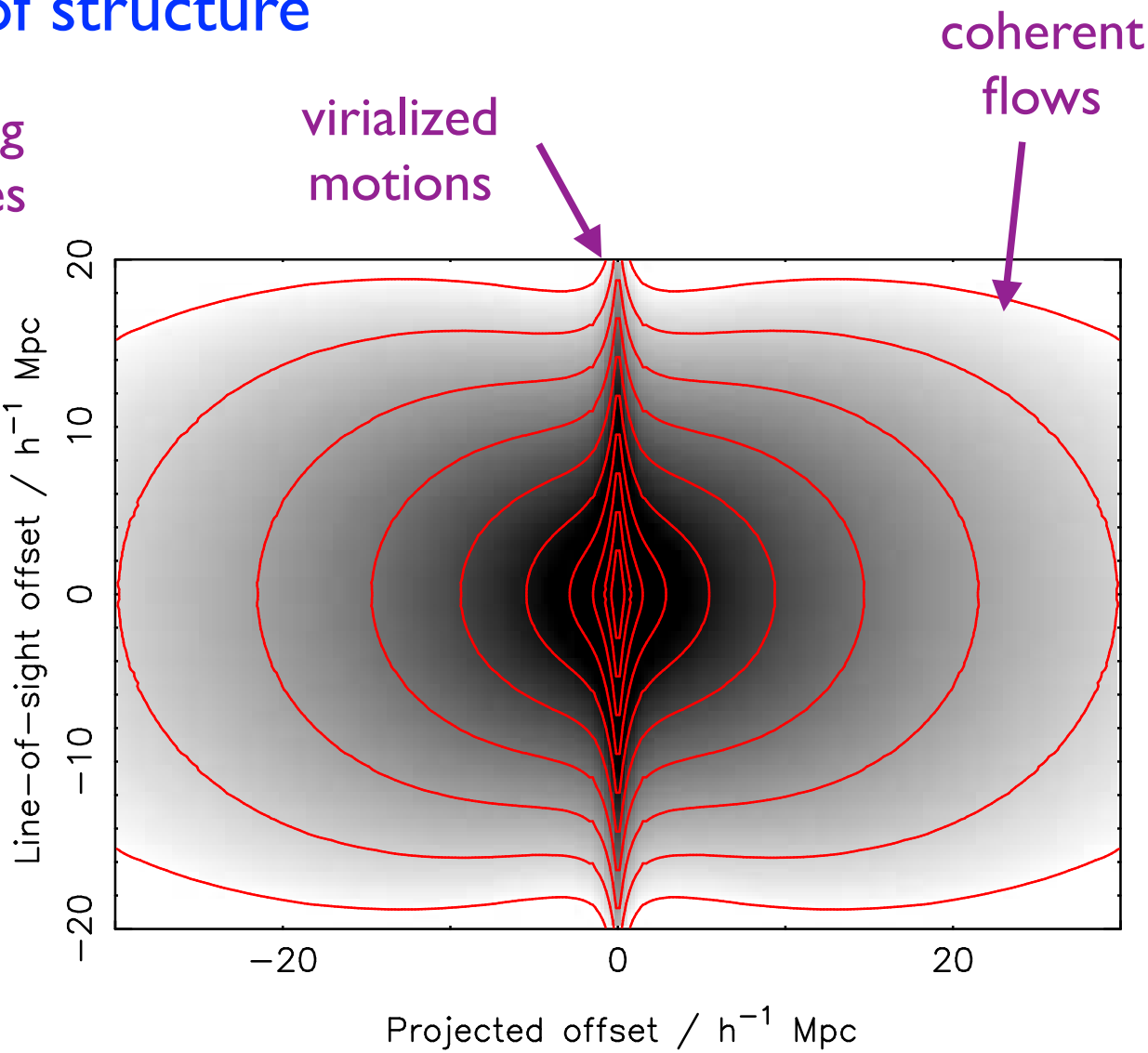
- Two of the most important are galaxy velocities and gravitational lensing



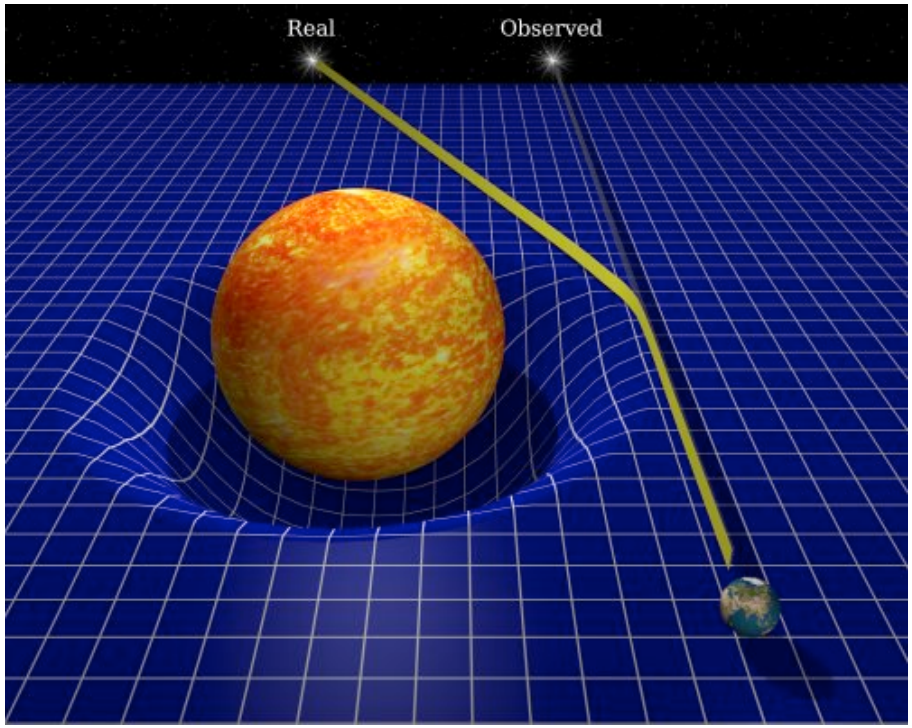
Galaxy velocities

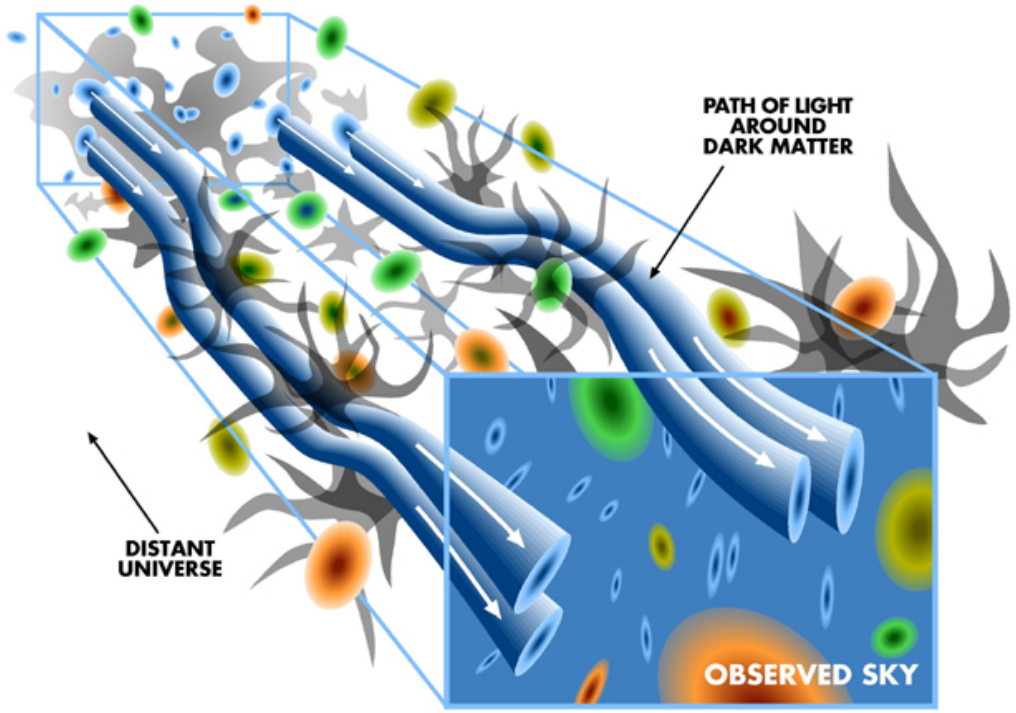
- RSD allow spectroscopic galaxy surveys to measure the growth rate of structure

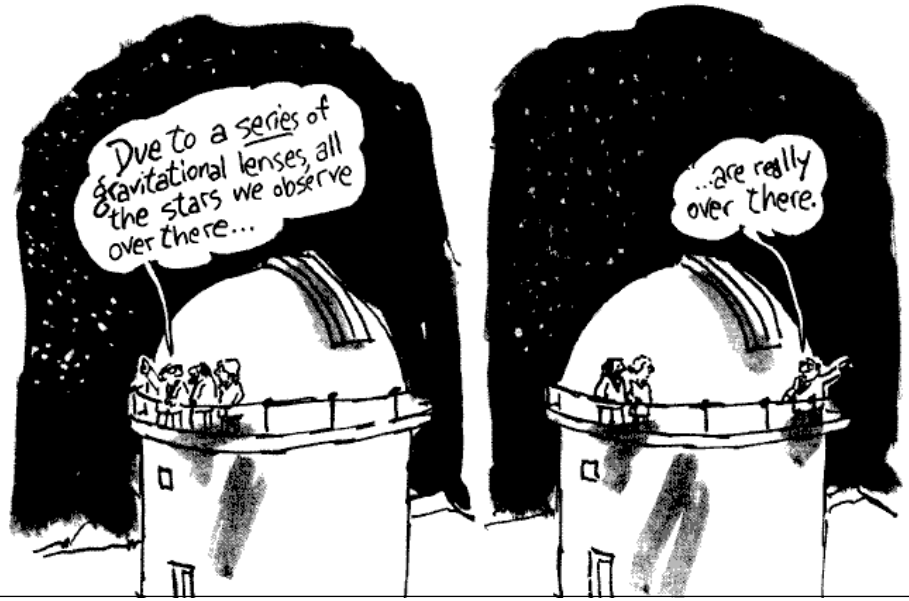


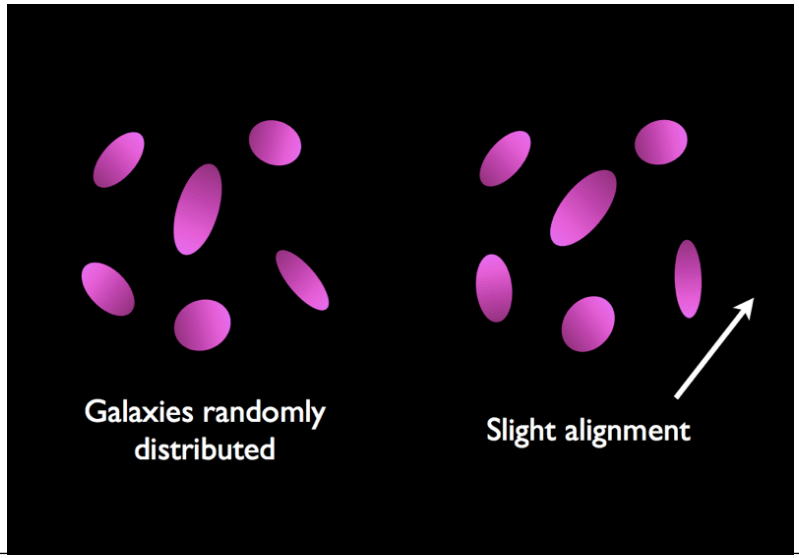


Gravitational lensing









Combining galaxy velocities and lensing

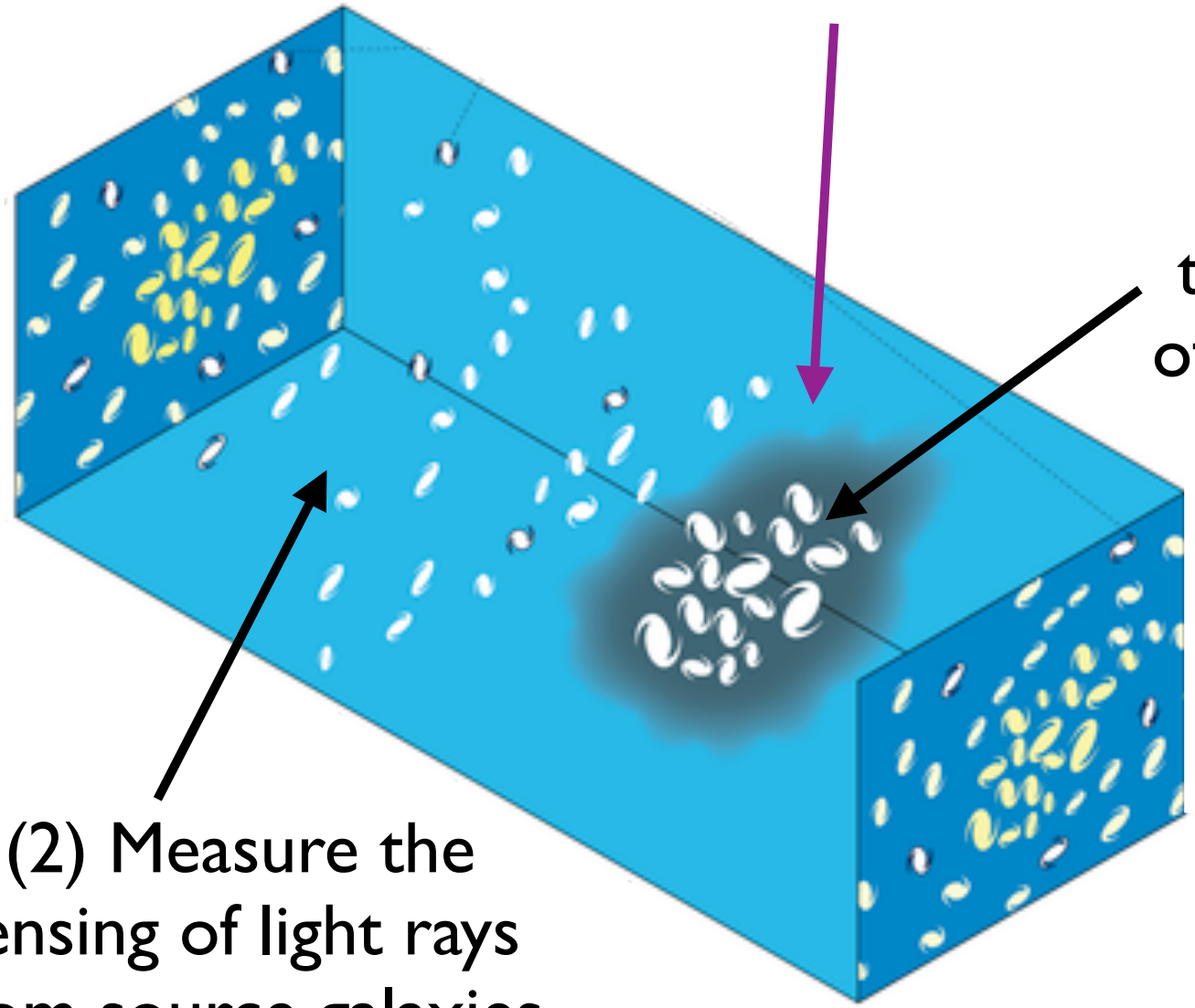
- Sensitive to theories of gravity in complementary ways
- General perturbations to FRW metric:

$$ds^2 = [1+2\psi(x,t)]\,dt^2 - a^2(t)\,[1-2\phi(x,t)]\,dx^2$$

- (ψ, ϕ) are metric gravitational potentials, identical in General Relativity but can differ in general theories
- Relativistic particles (e.g. light rays for lensing) collect equal contributions and are sensitive to $(\psi + \phi)$
- Non-relativistic particles (e.g. galaxies infalling into clusters) experience the Newtonian potential ψ

Combining galaxy velocities and lensing

- What gravitational force do these density ripples exert?

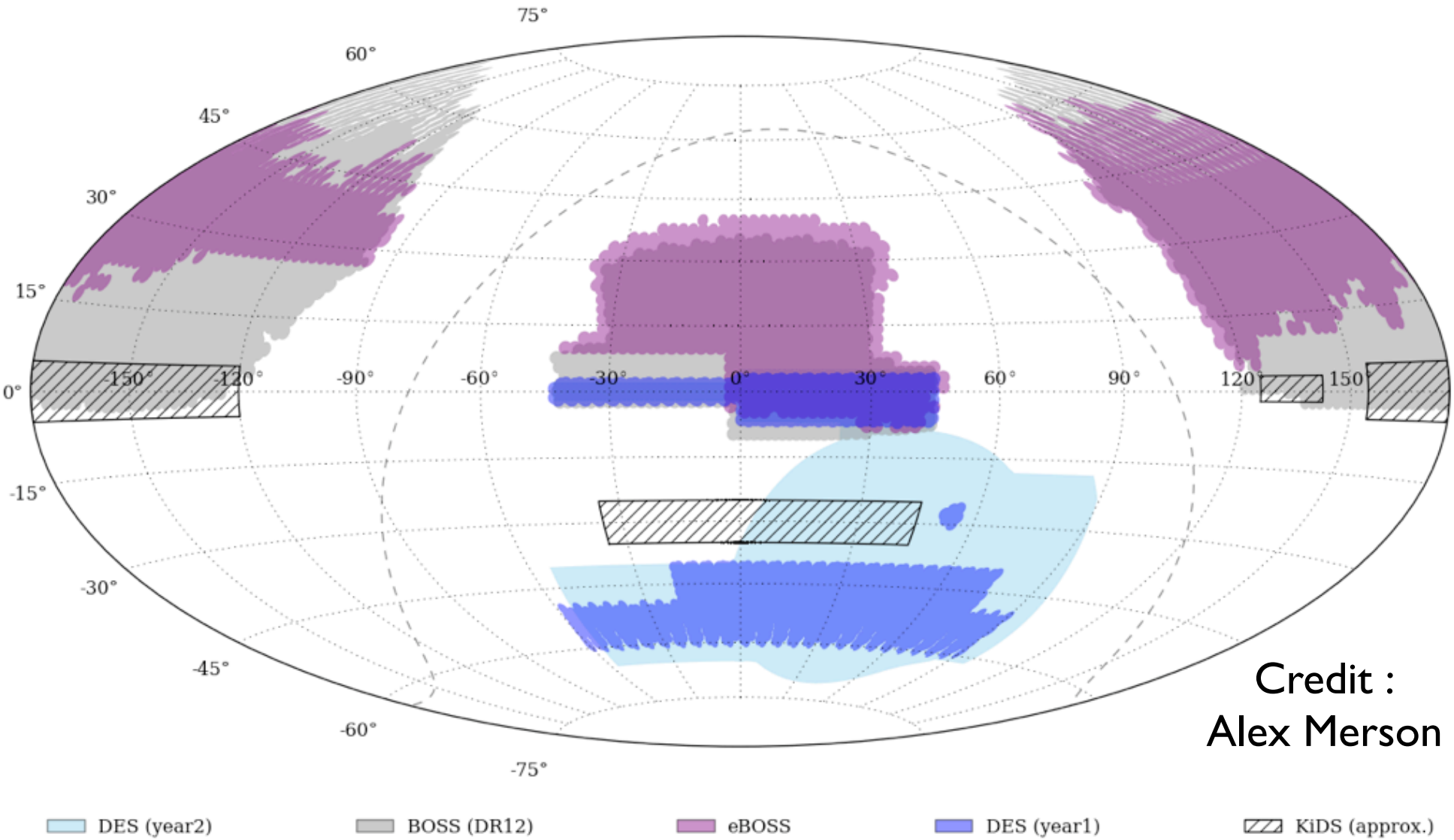


(1) Measure the velocities of lens galaxies

(2) Measure the lensing of light rays from source galaxies

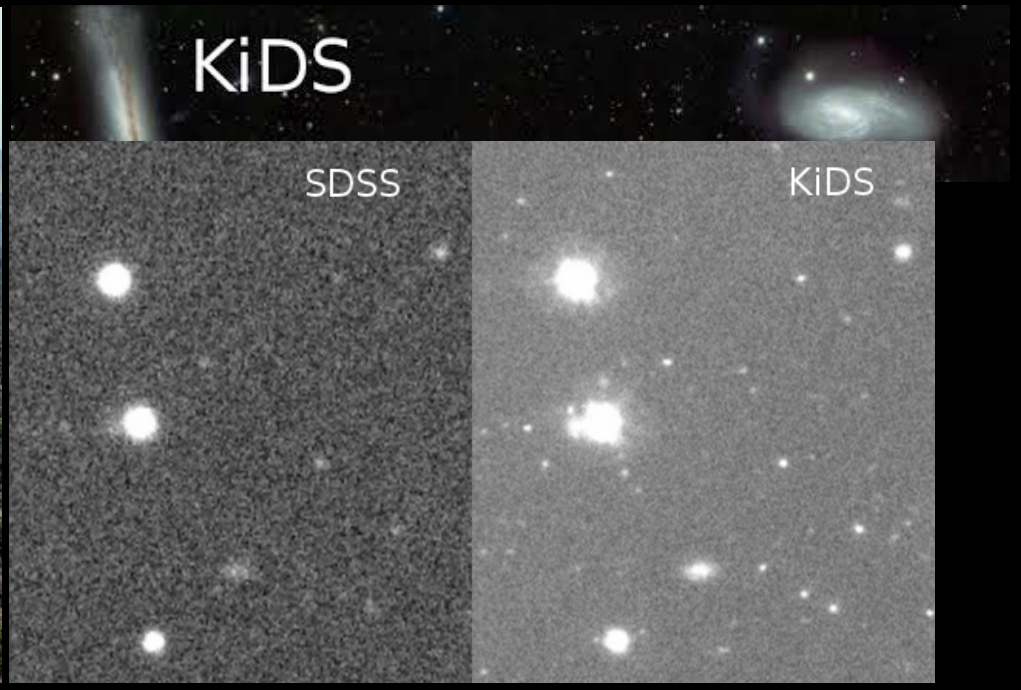
Combining galaxy velocities and lensing

- Mis-match of existing spectroscopy and deep imaging



Credit :
Alex Merson

2dF Lensing Survey (2dFLenS)

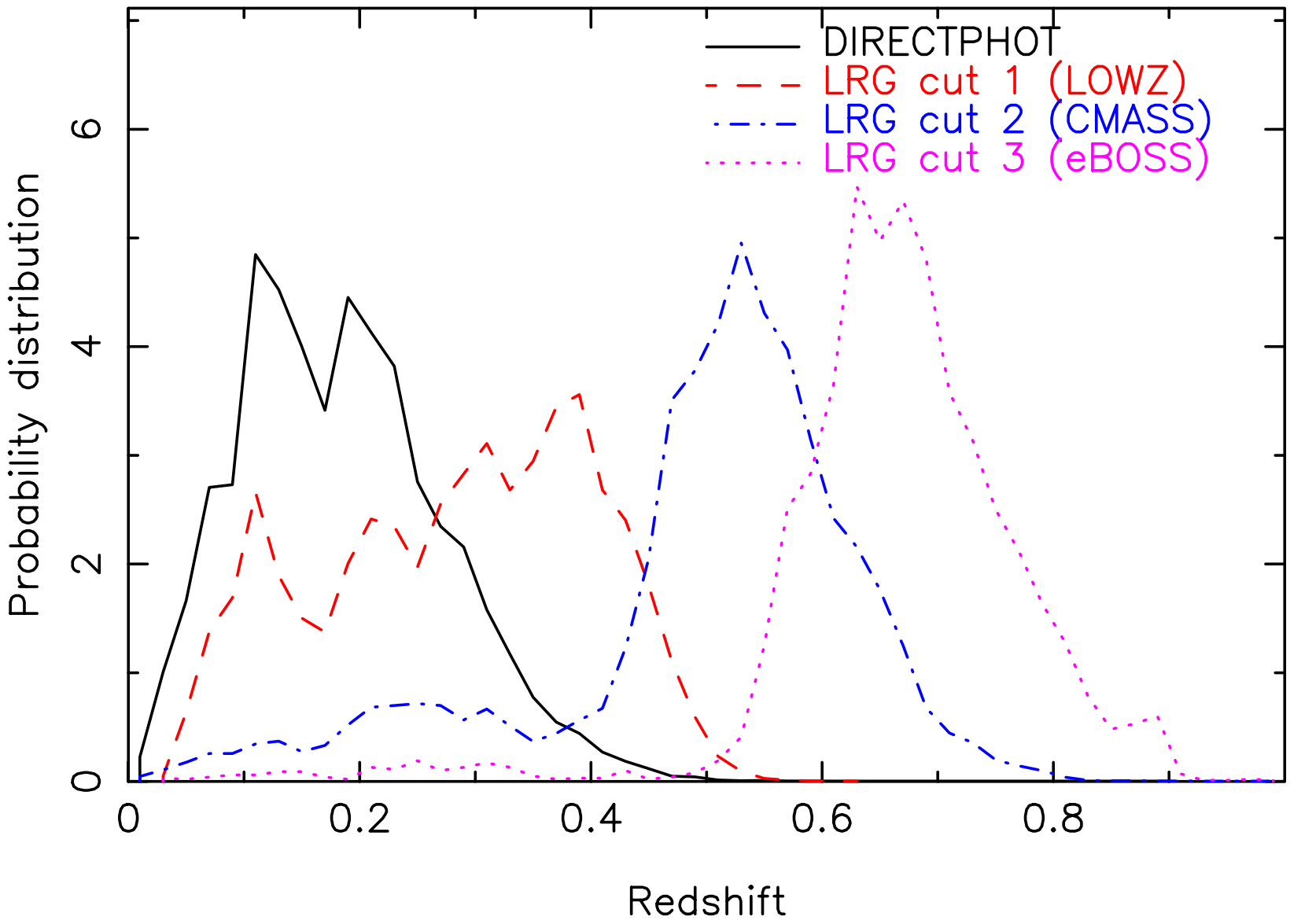


- 50 AAT nights granted (Sep 2014 to Jan 2016) for spectroscopic follow-up of southern lensing surveys
- Galaxy lens sample to test gravity by cross-correlating weak lensing distortions and galaxy velocities
- Perform photometric redshift calibration

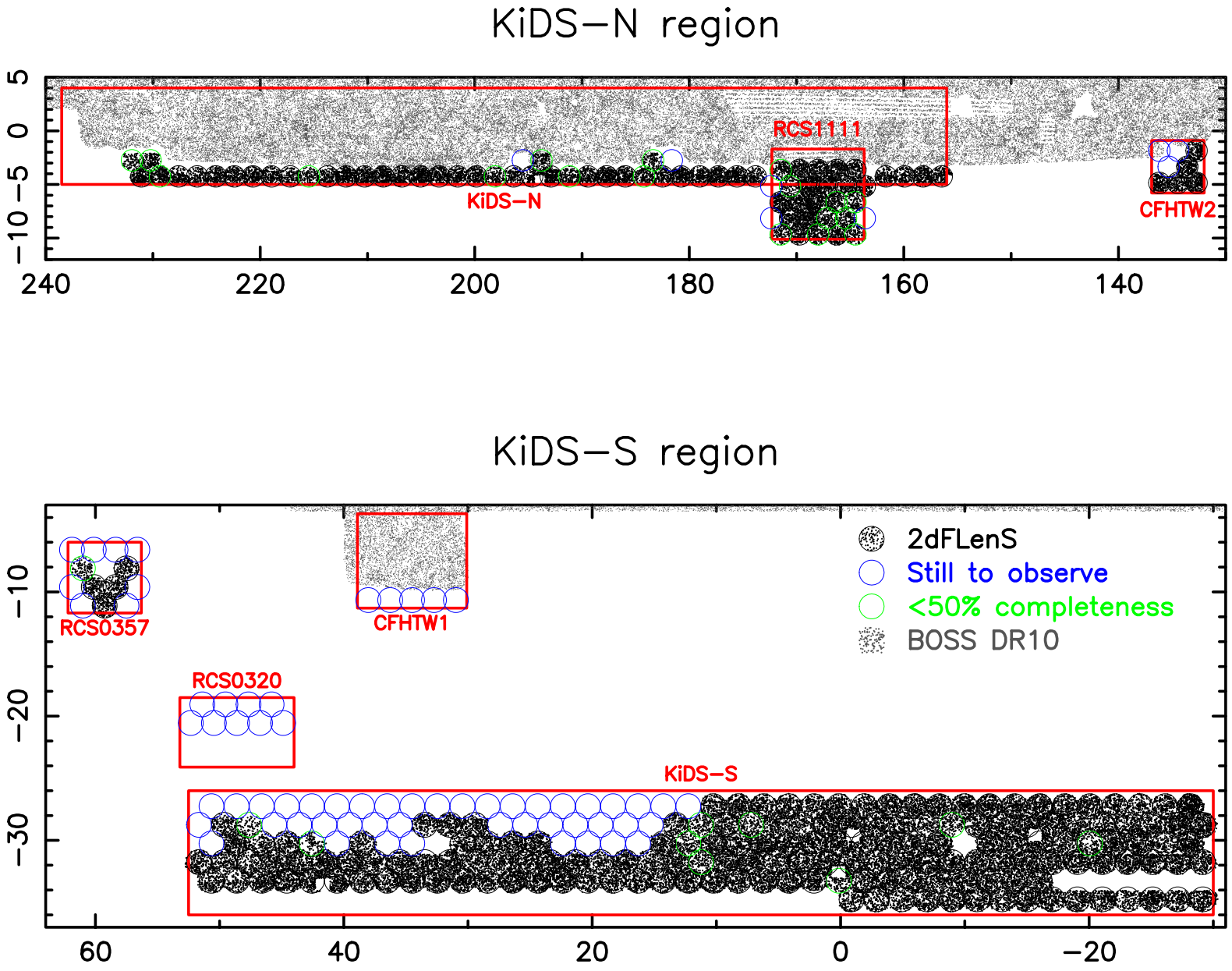
2dF Lensing Survey (2dFLenS)

- Cover ~1000 deg^2 in ~300 AAT pointings, producing ~80,000 redshifts
- KiDS imaging survey is still in progress so bright target selection is provided by VST-ATLAS data
- SDSS-inspired Luminous Red Galaxy samples $z < 1$ selected by colour cuts in ATLAS griz and WISE W1 (LOWZ, CMASS, eBOSS)
- Magnitude-limited complete sample $17 < r < 19.5$ for direct photometric redshift calibration of Skymapper
- Other "spare fibre" samples

Redshift distribution

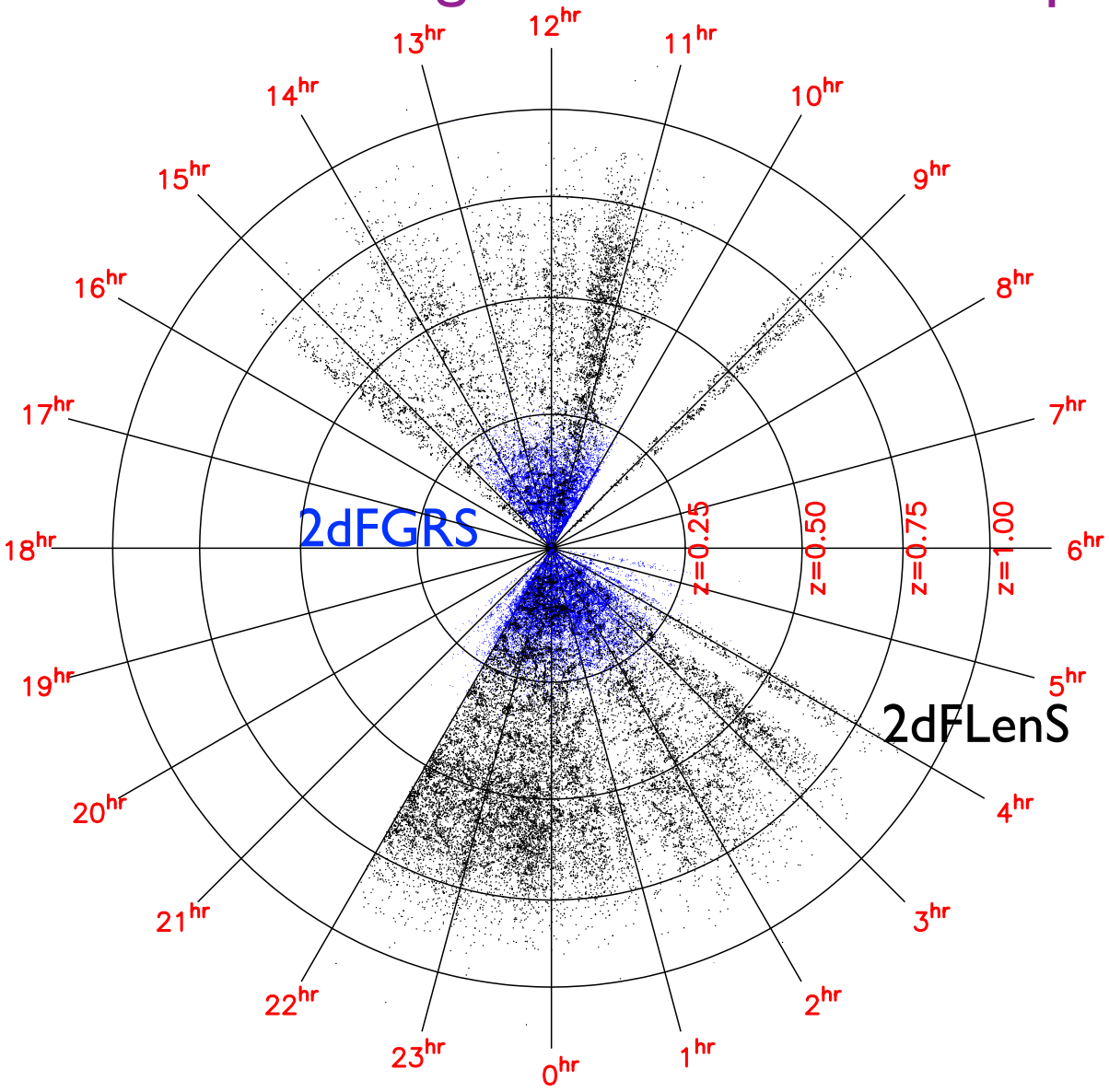


Survey progress : 41/50 nights

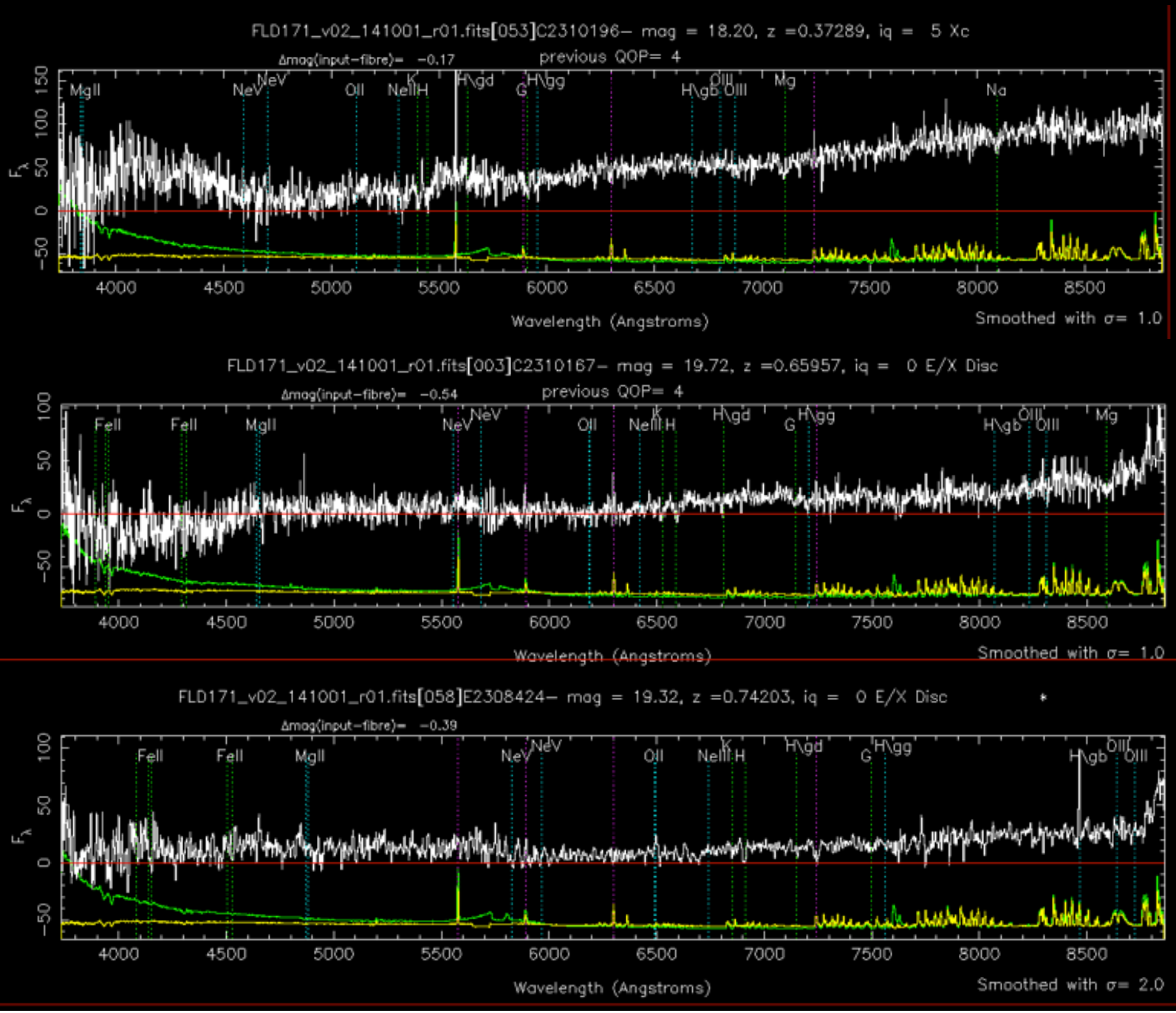


Cone plot

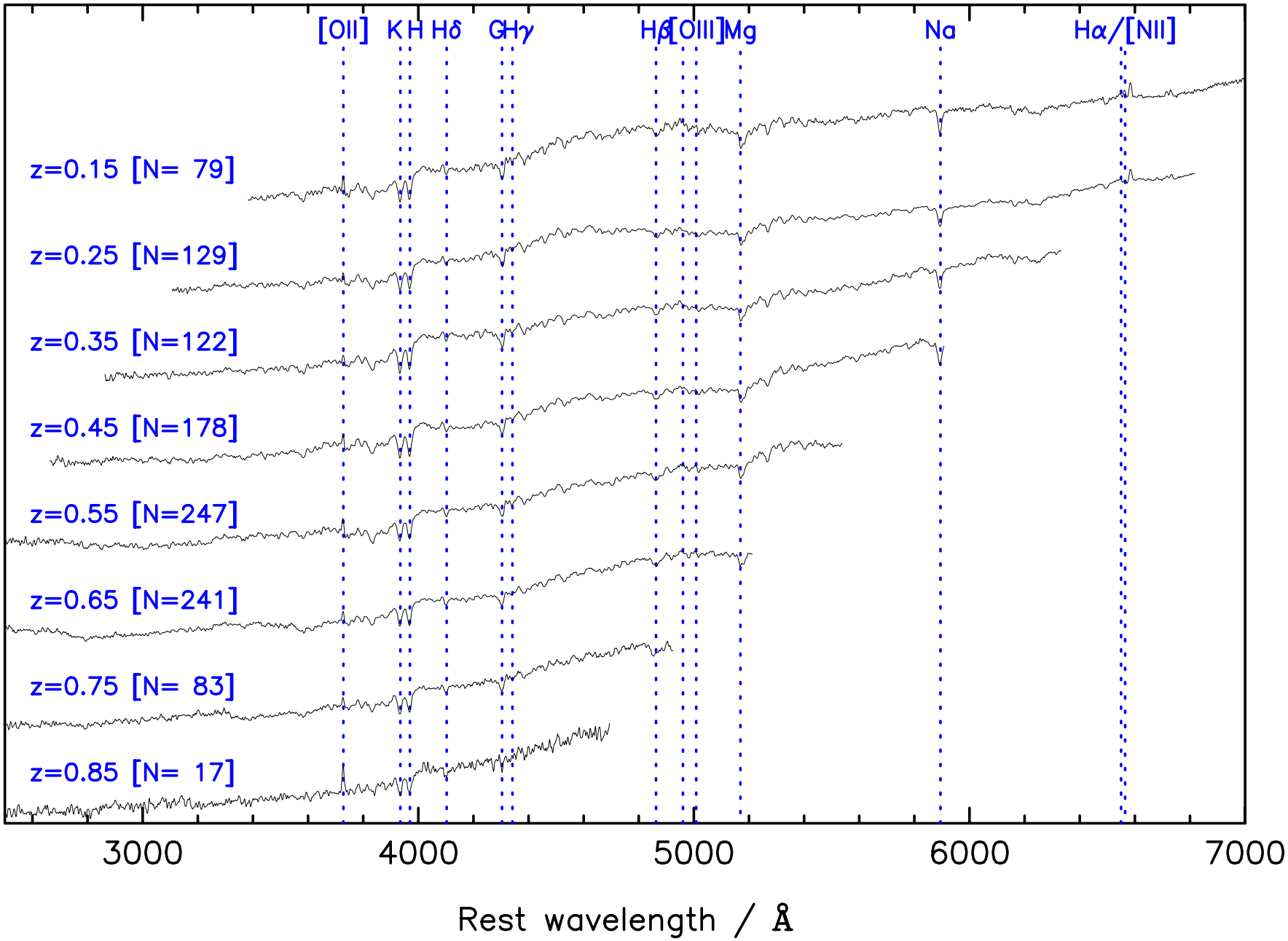
- So far we have 63,271 good redshifts in 254 pointings !



Example spectra

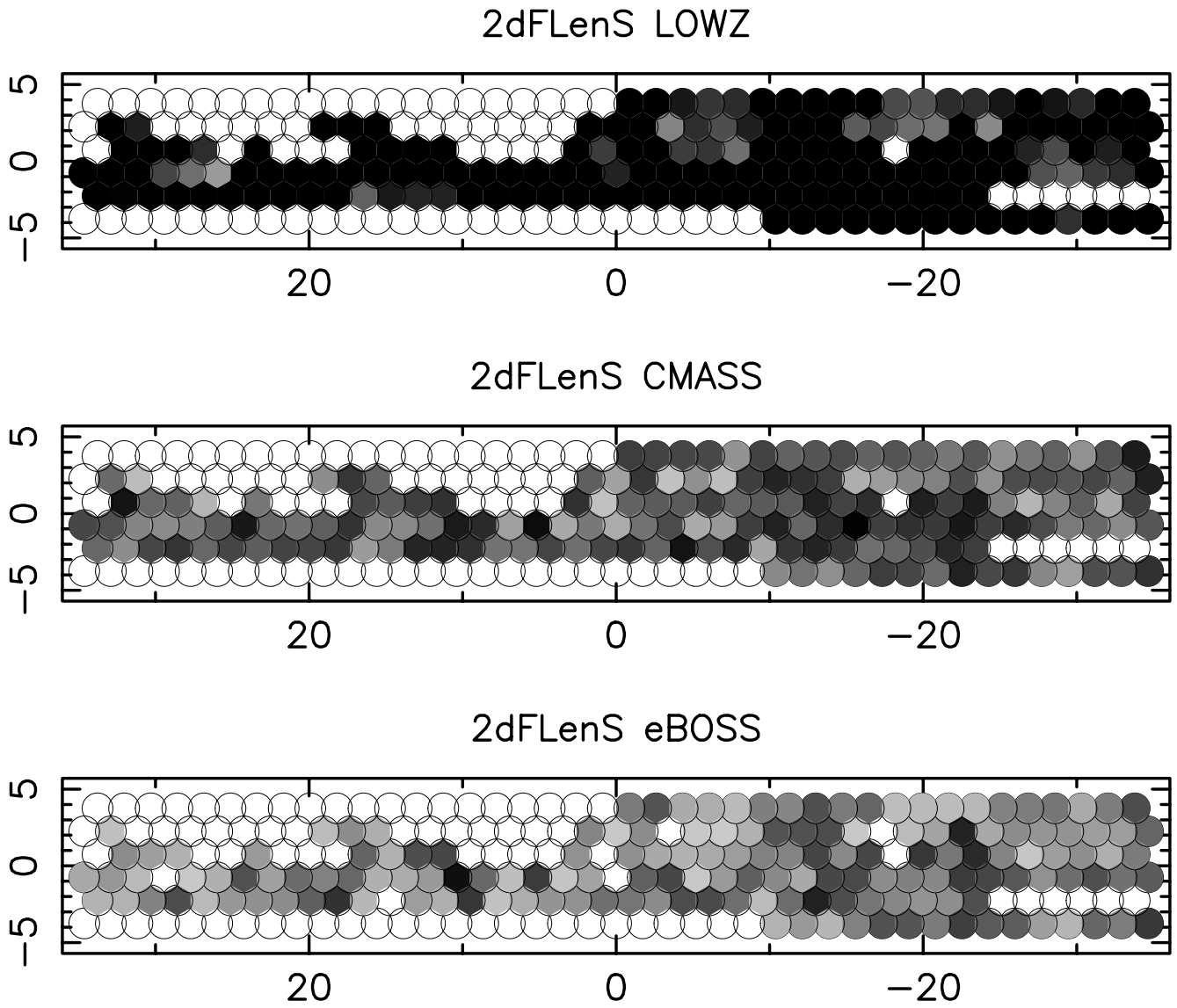


Example stacked spectra



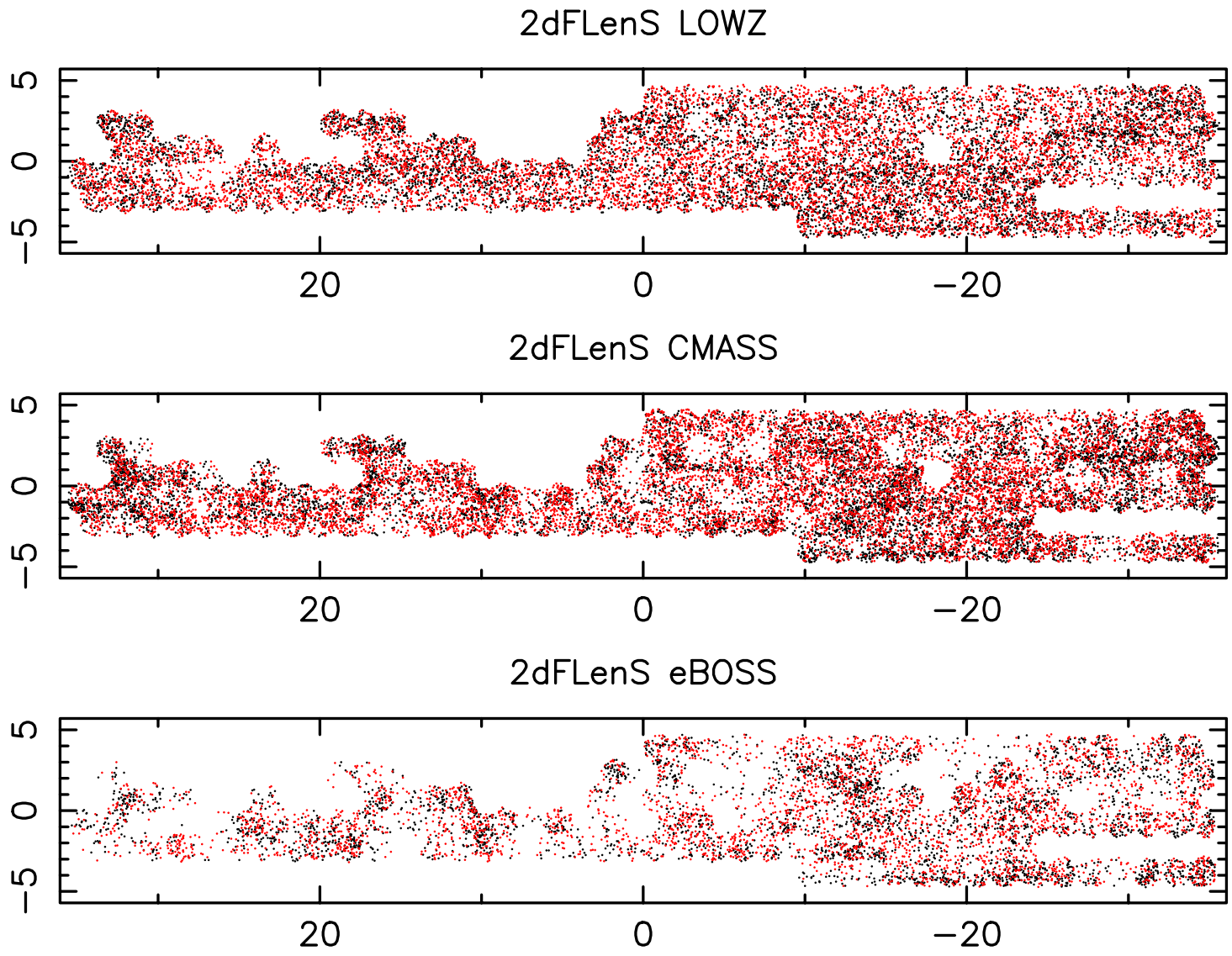
Selection function

- Redshift completeness per field



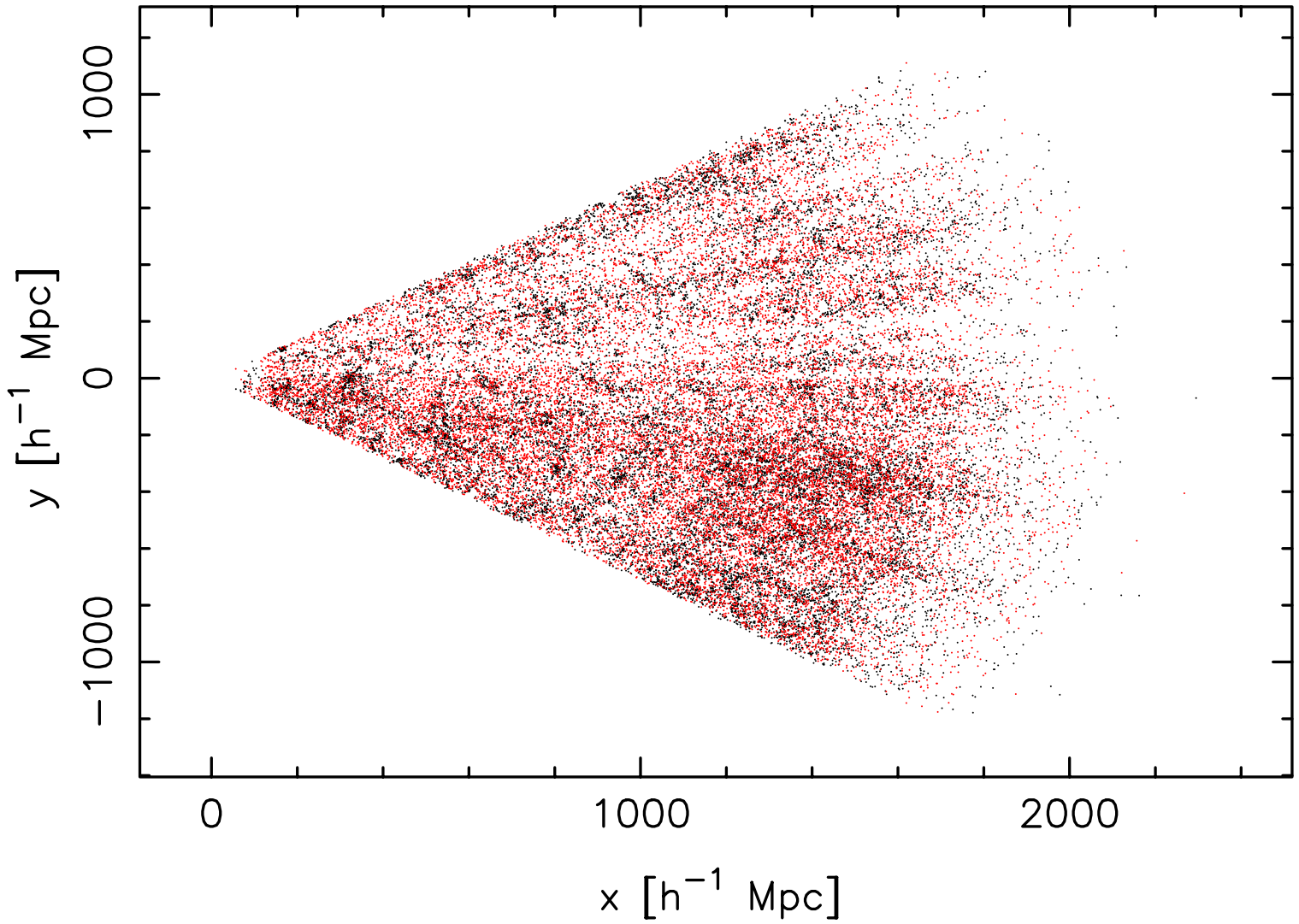
Selection function

- Data vs. random catalogues (angular)

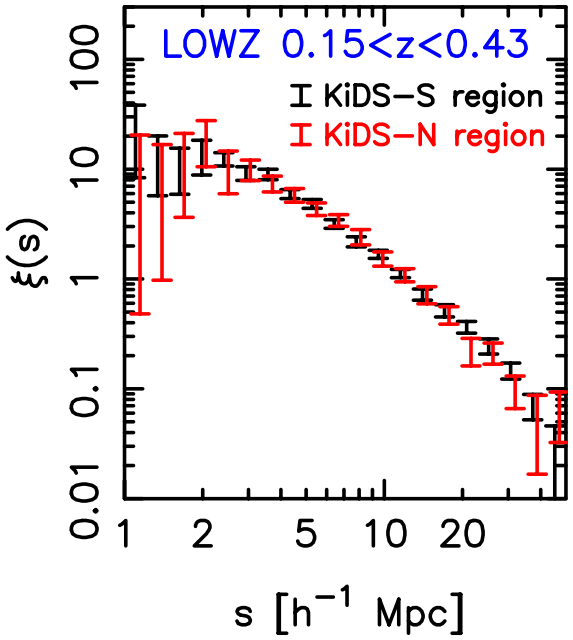


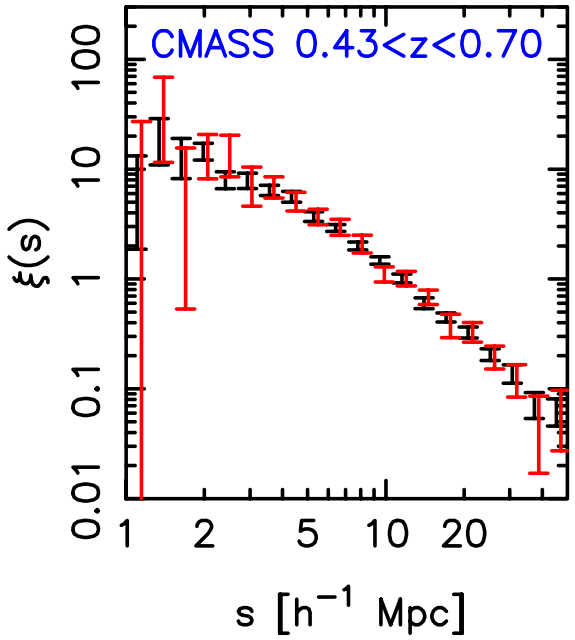
Selection function

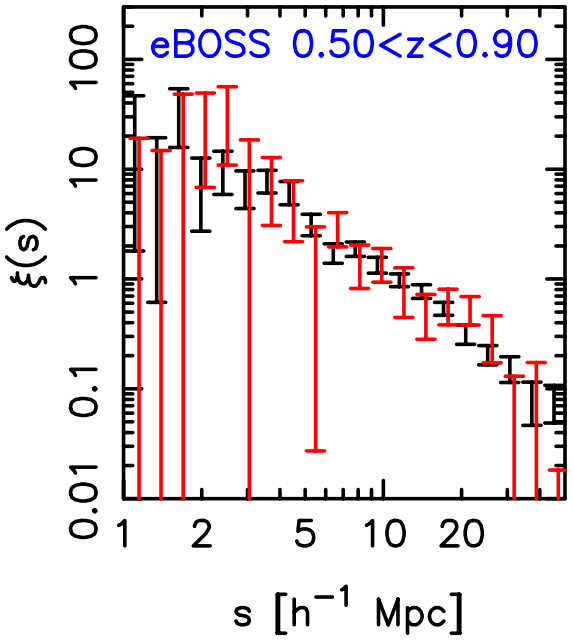
- Data vs. random catalogues (3D)

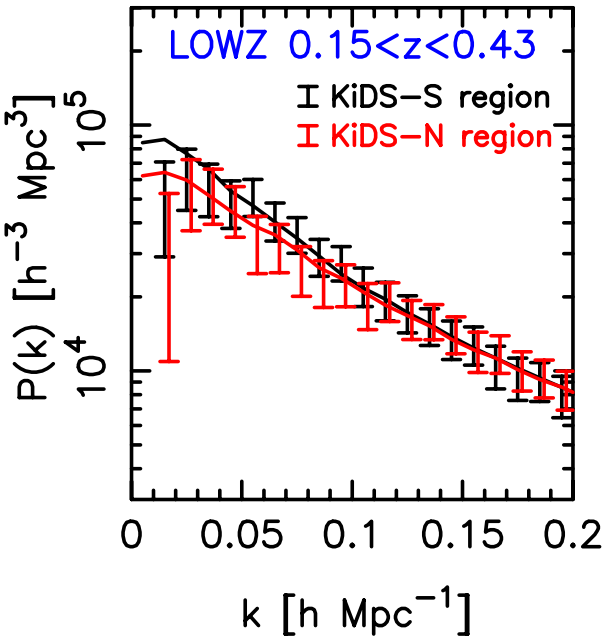


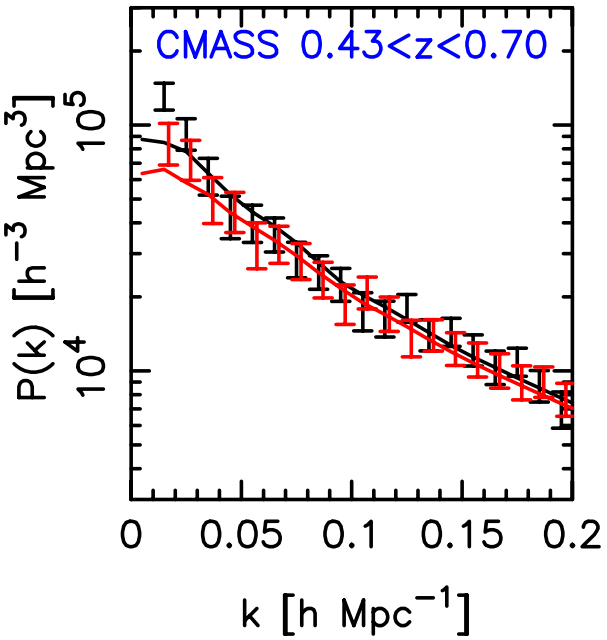
Clustering measurements

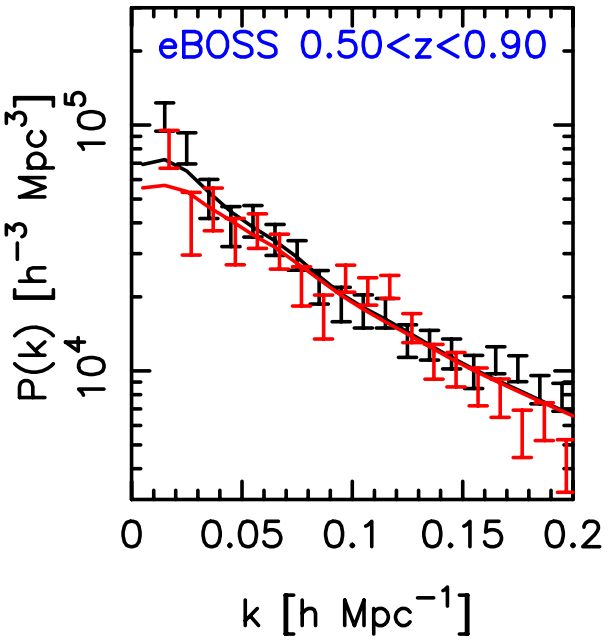






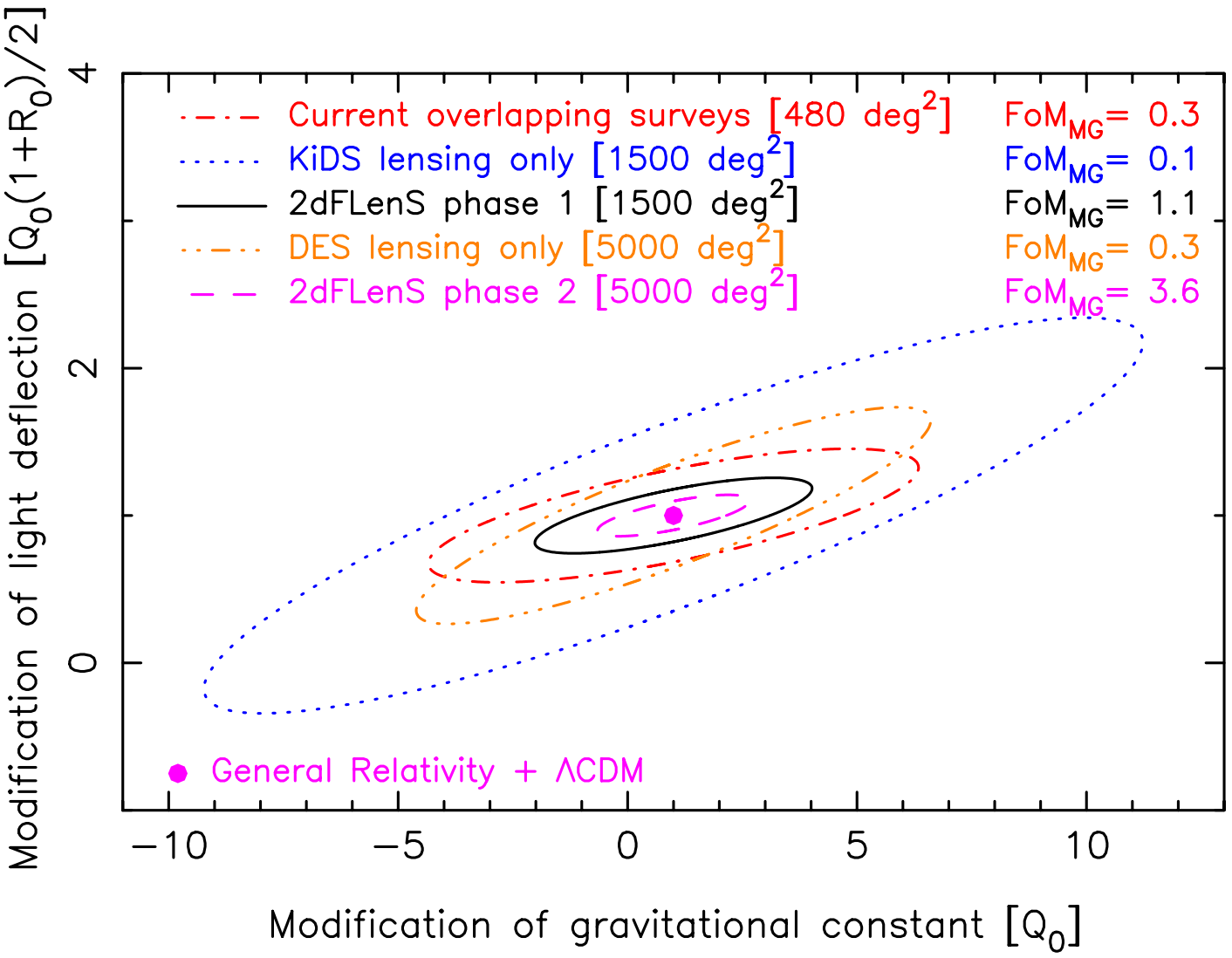






Tests of gravitational physics

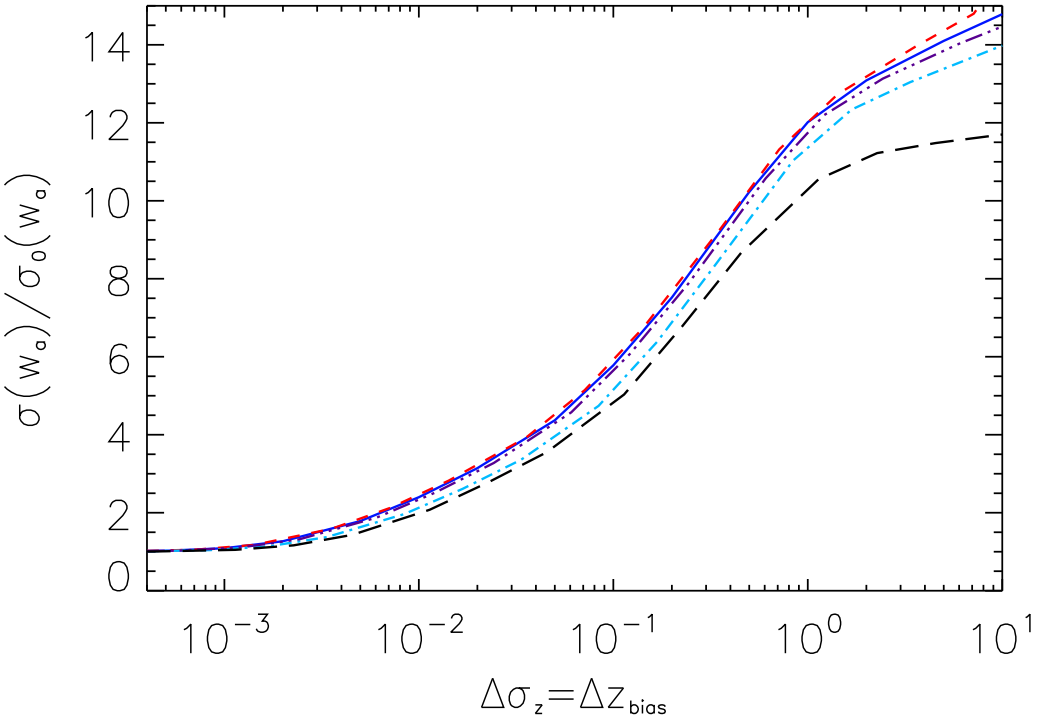
- Forecasts for final survey



Credit :
Donnacha Kirk

Photometric redshift calibration

- Photometric redshift errors are one of the leading systematics for weak lensing tomography
- Mean and width of redshift distributions in each photo-z bin must be known to accuracy ~ 10^{-3}



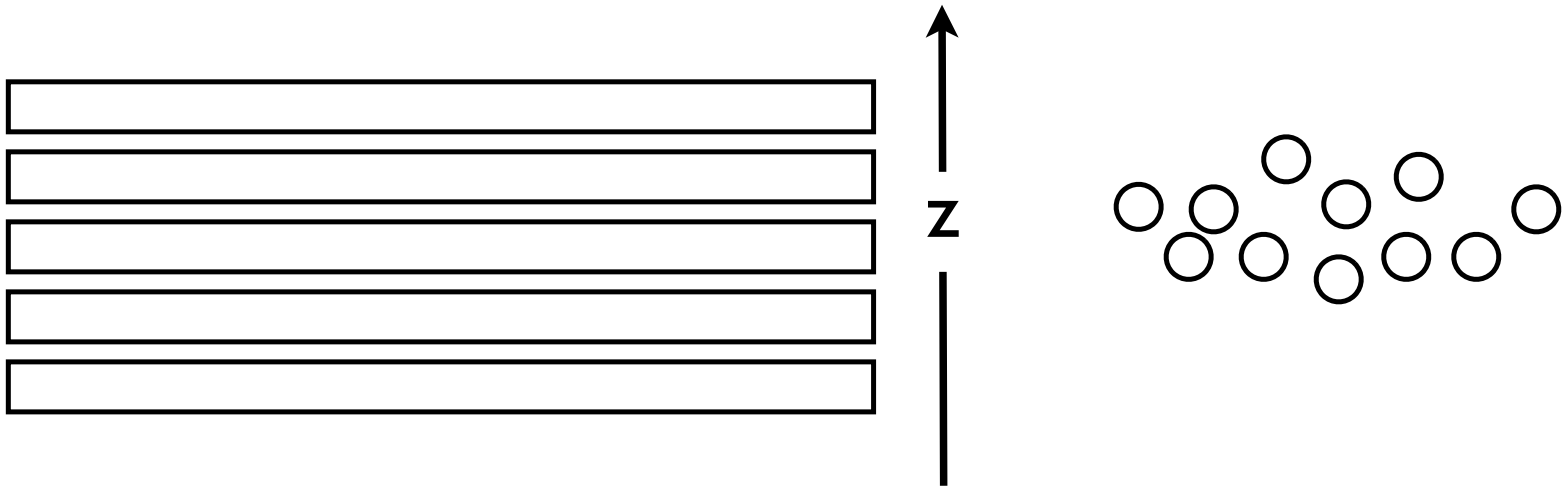
Credit :
Ma et al. (2005)

Photometric redshift calibration

- Photometric redshift errors are one of the leading systematics for weak lensing tomography
- Mean and width of redshift distributions in each photo-z bin must be known to accuracy ~ 10^{-3}
- Method (1) : spectroscopic training set [issues : sample variance, incompleteness of training set, outliers]
- Method (2) : photo-z/spec-z cross-correlations [issues : degeneracies with galaxy bias, cosmic magnification]
- Currently unsolved problem for current and future lensing surveys (DES, LSST, Euclid)

Photometric redshift calibration

- Photometric/spectroscopic surveys in same volume
- Divide spectroscopic survey into narrow redshift bins
- Measure angular cross-correlation function between the photometric survey and all the spec-z bins
- Relative amplitudes map out $N_{photometric}(z)$



Summary

- Apparent existence of dark energy motivates new tests of large-scale gravitational physics
- Two observable signatures are non-relativistic galaxy velocities and relativistic lensing of light
- Current mis-match in imaging/spectroscopic overlap
- 2dFLenS : a new AAT redshift survey to enhance the tests of gravity possible from lensing observations
- Will lead to future science with LSST and 4MOST