Interloper Bias in Emission Line Surveys

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Interloper Bias

Emission Line Survey
(1) Take a spectrum.
(2) Identify a line.
(3) Get the redshift.

$$\lambda_{\rm obs} = \lambda_{\rm rest}(1+z)$$

- Interlopers - misidentified emission lines
- For example, the lines OII (0.373μm) at z = 2 and Hα (0.656μm) at z = 0.7 have the same observed wavelength ($\lambda_{\rm obs}$ = 1.12μm).
- Relevant for the big upcoming LSS surveys!

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$$P_t(f|\mathbf{k}, z_{\rm true}) = (1-f)^2 P_{\rm true}(\mathbf{k}, z_{\rm true}) + f^2\gamma^3 P_{\rm int}(\vec{\gamma}\circ\mathbf{k}, z_{\rm int})$$

interloper fraction pixel distortion

$$f = \frac{n_{\rm int}}{n_{\rm true} + n_{\rm int}}$$

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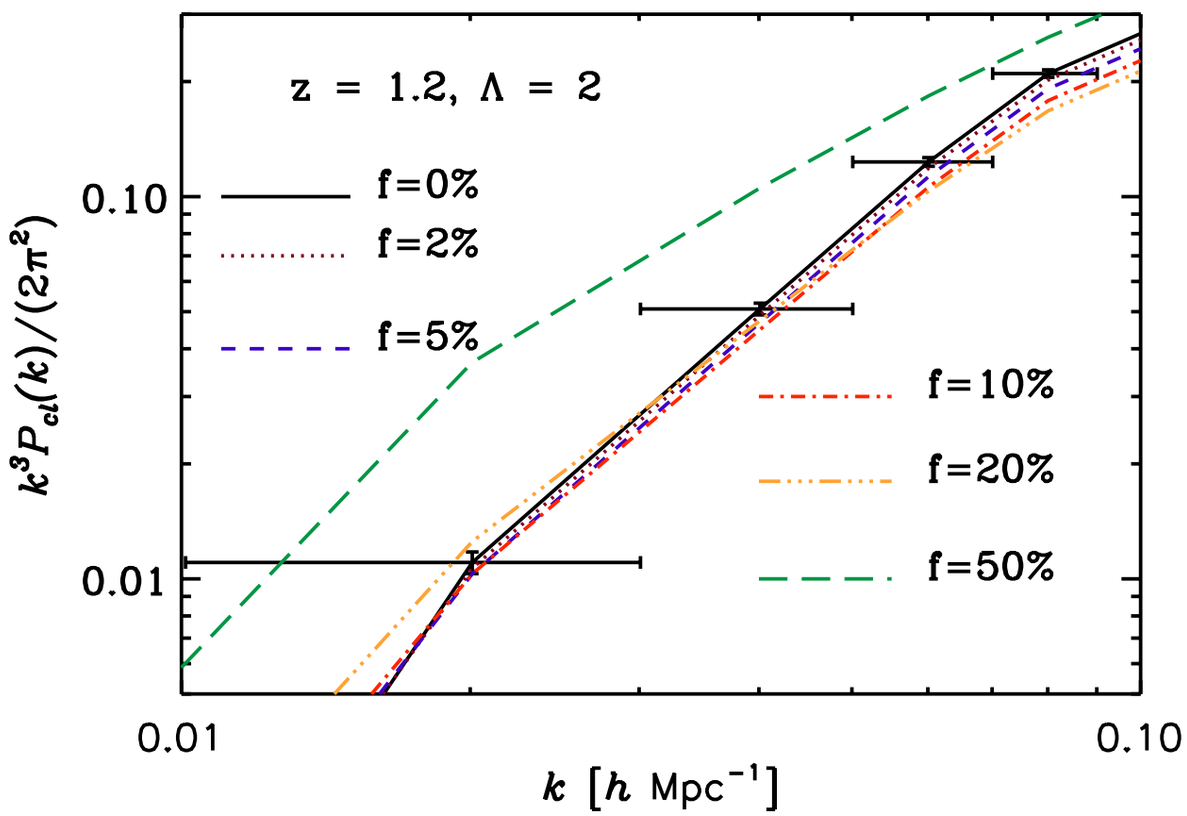
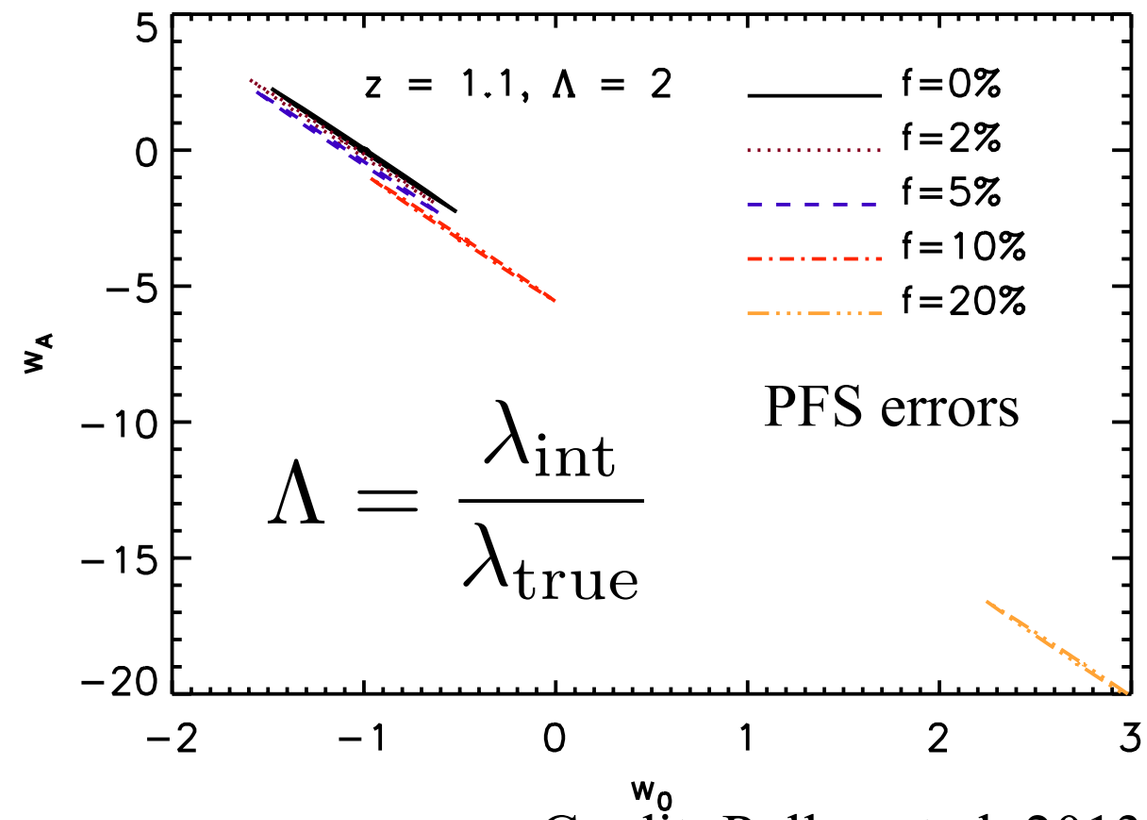
PFS Interloper Bias





Credit: Pullen et al. 2013

- $f > 2\%$ would shift PFS P(k) estimates by 3-sigma!
- $f > 10\%$ would catastrophically bias dark energy estimates.

Finding Interlopers

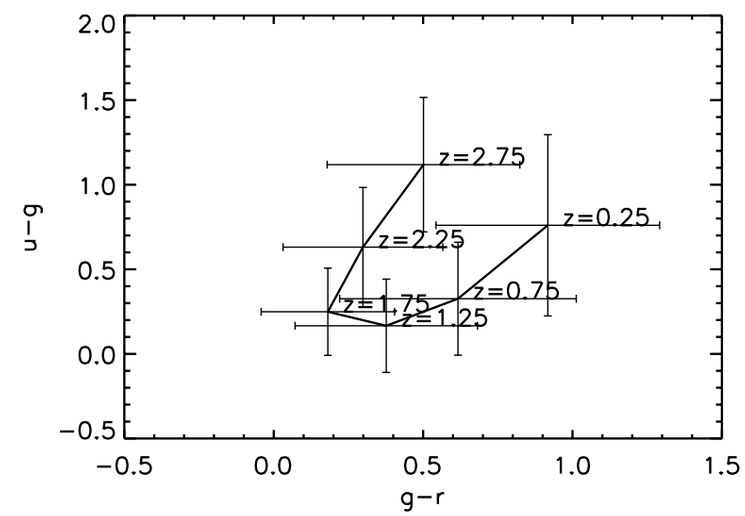
Secondary Line Identification (SLI)

$$\frac{\lambda_X^{\rm obs}}{\lambda_Y^{\rm obs}} = \frac{\lambda_X(1+z)}{\lambda_Y(1+z)} = \frac{\lambda_X}{\lambda_Y}$$

(z-independent)

Two lines can be identified by their wavelength ratio.

Photometric Redshifts

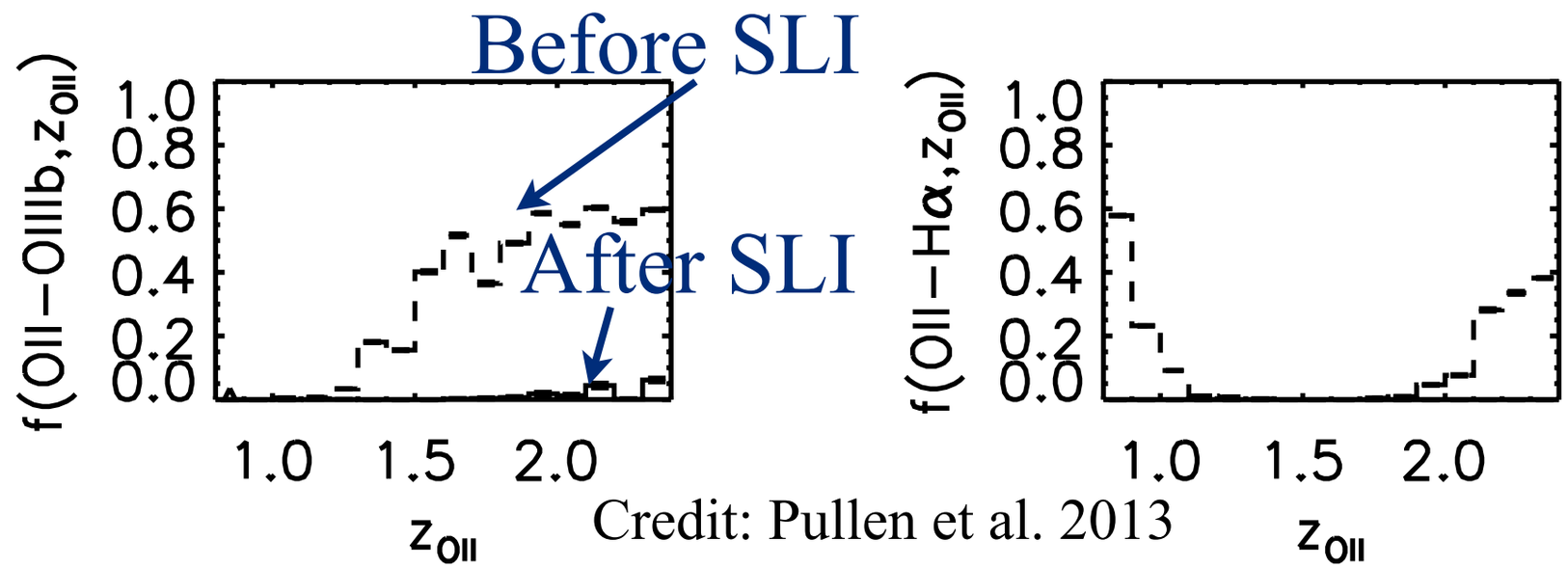


Interlopers have colors that appear at the wrong redshift.

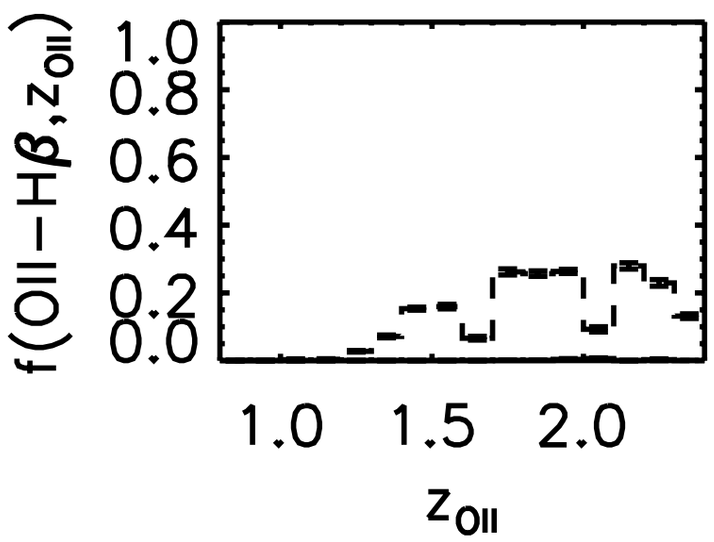
We test these methods for the PFS OII survey and the WFIRST Hα and OIII surveys.

Kirby et al. 2007

PFS Mock



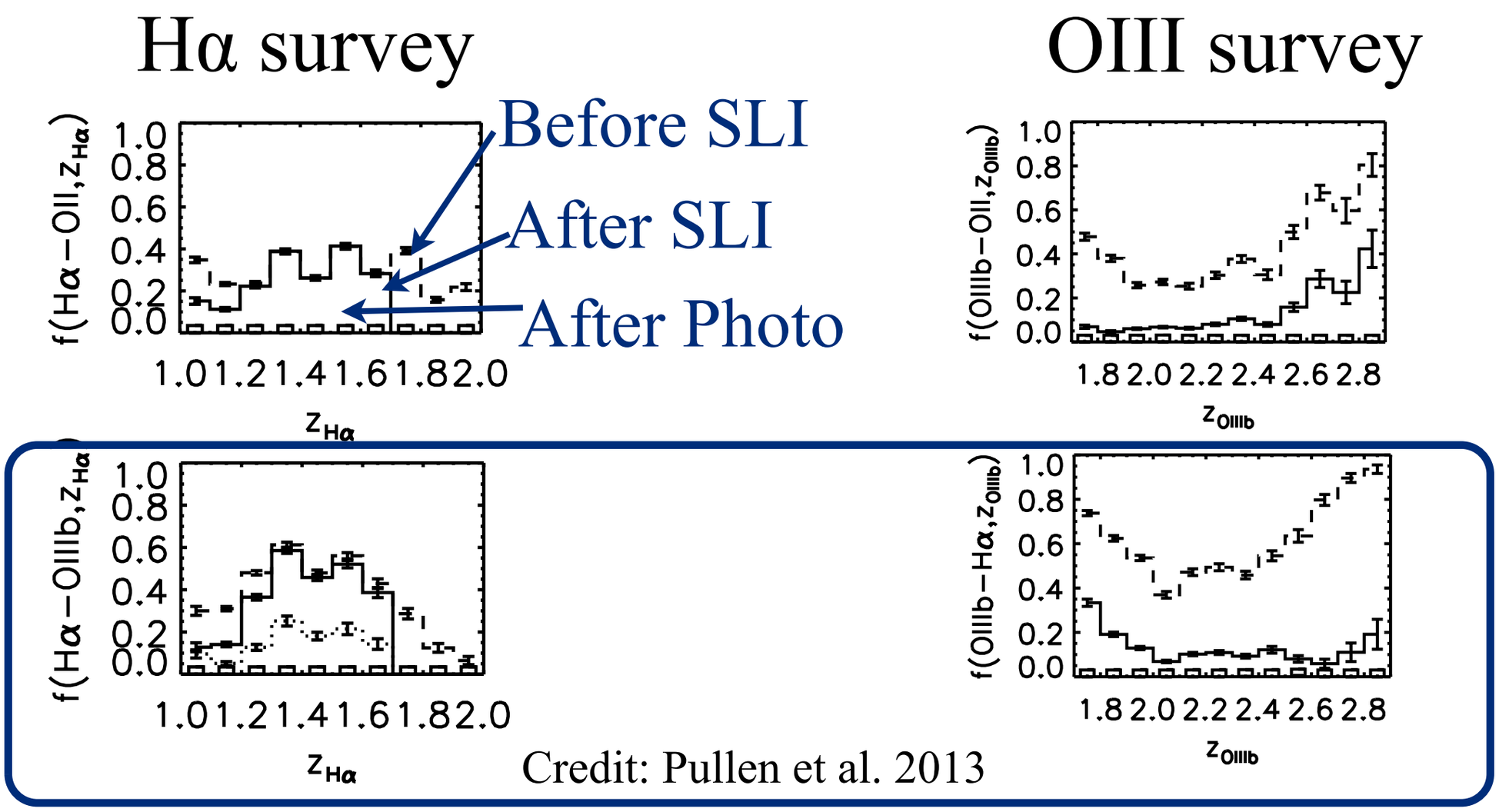
Credit: Pullen et al. 2013



Line	Secondary (OII survey)
Hβ	Hα,OII
OIII	OII
Hα	OII,OIII

OIII (0.501μm) is close to 10%, but eliminated when matched with OIII doublet partner (0.496μm).

WFIRST Mock

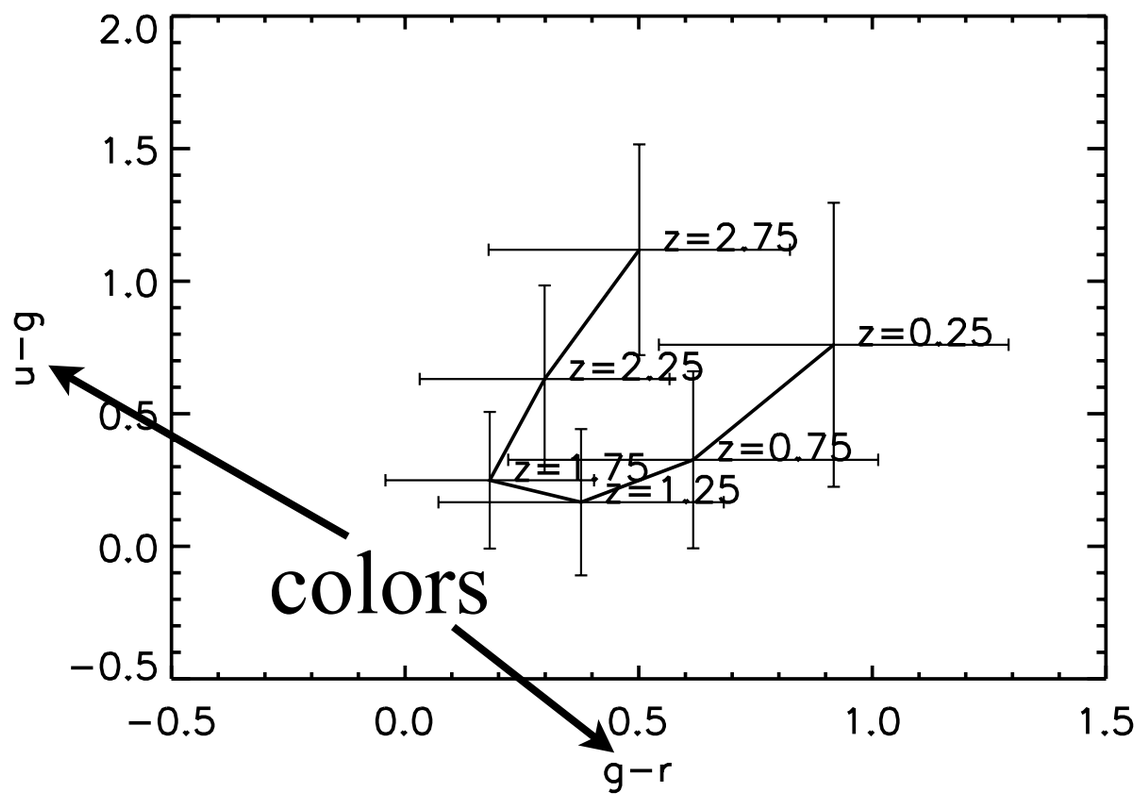


- OII interlopers are found using WFIRST/LSST photometry.
- Hα/OIII surveys contaminate each other, ***but small z-bin photometric cuts can separate the samples.***

Summary

- Emission line surveys are limited by the ability to remove interloping galaxies from different redshifts.
- A 2% interloper fraction will significantly shift power spectrum measurements.
- Secondary lines identification and targeted photometric cuts can reduce interloper rates for PFS and WFIRST to less than 1%.
- Interloper rates and identification methods need to be tested for other upcoming and future emission line surveys.

Photometric Redshifts



- Colors from apparent magnitudes vary with redshift, allowing redshifts to be estimated fast.
- Redshift errors are large (~ 0.1).

Distortion Vector

$$\gamma_\perp = \frac{D(z_{\rm SELG})}{D(z_{\rm Int})} \qquad \gamma_\parallel = \frac{(1+z_{\rm SELG})/H(z_{\rm SELG})}{(1+z_{\rm Int})/H(z_{\rm Int})}$$

$$\lambda_{\rm int} > \lambda_{\rm true} \Longrightarrow \gamma_\perp > 1$$

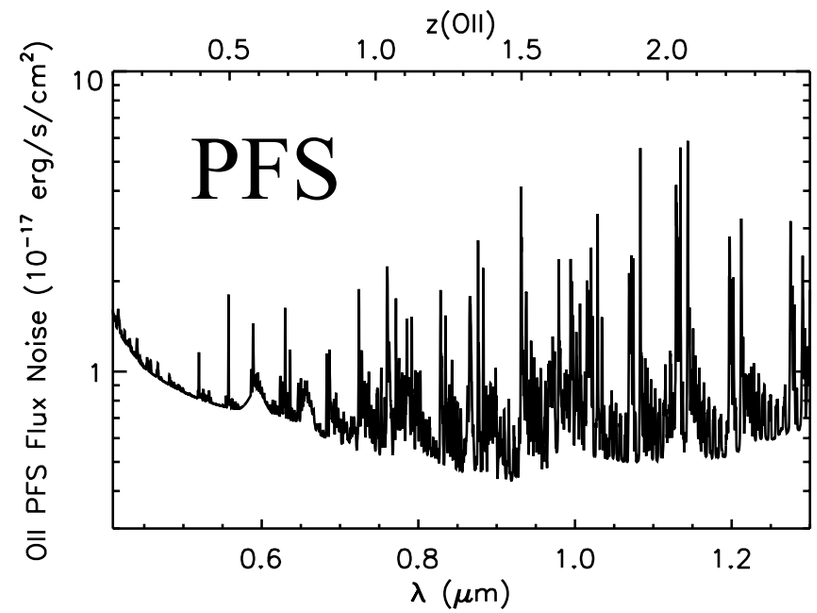
$$\lambda_{\rm int} > \lambda_{\rm true} \,\&\, z_{\rm true} < z_\Lambda \Longrightarrow \gamma_\parallel > 1$$

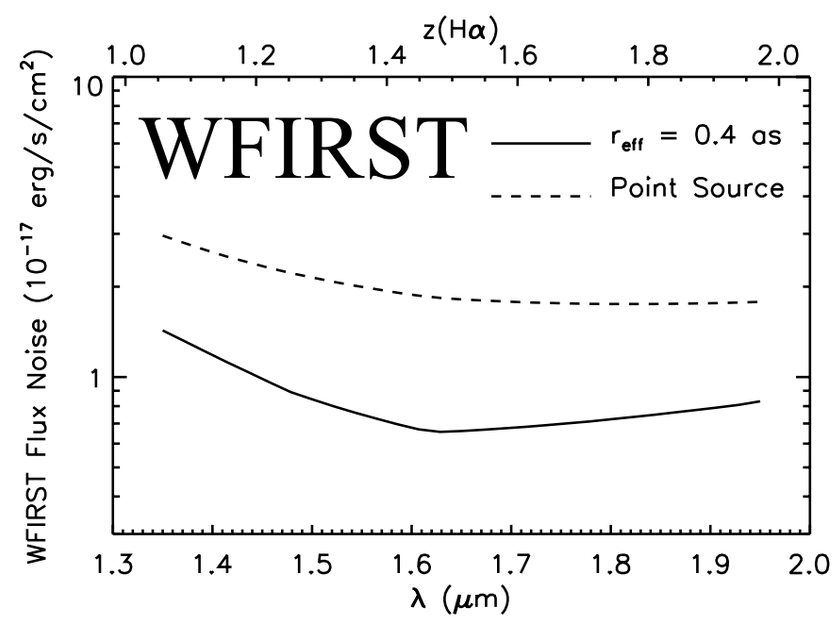
$$\lambda_{\rm int} > \lambda_{\rm true} \,\&\, z_{\rm true} > z_\Lambda \Longrightarrow \gamma_\parallel < 1$$

$$1 + z_\Lambda = \sqrt[3]{\frac{1-\Omega_m}{\Omega_m}\Lambda(\Lambda+1)} \quad \text{for Flat } \Lambda\text{CDM universe}$$

Mock Survey

- We use the COSMOS mock catalog to predict interloper rates.
- We mock the PFS OII survey and the WFIRST Hα and OIII surveys.
- For each potential interloper, we find secondary lines that help identify them.
- We find how many interlopers cannot be identified.





PFS - Prime Focus Spectrograph

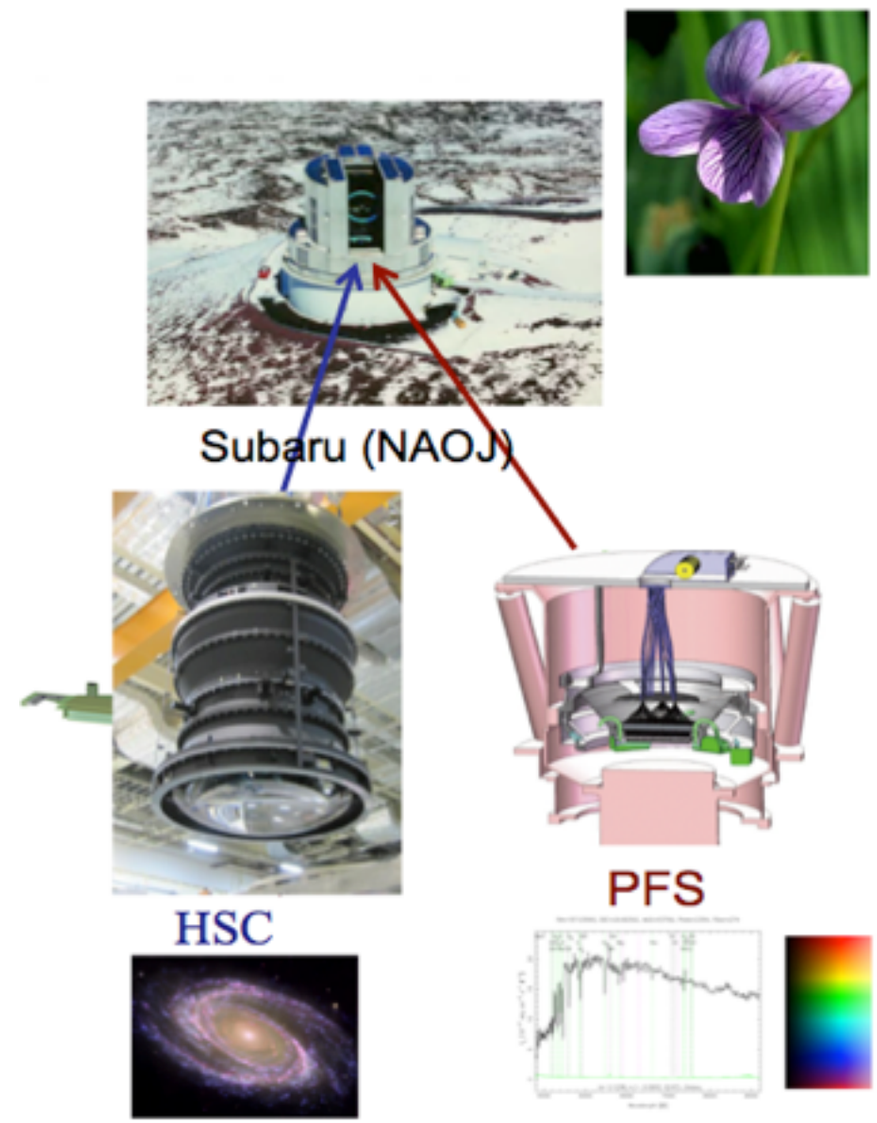
Jouvel et al. 2009, Ellis et al. 2012, Spergel et al. 2013

SuMIRe

- SuMIRe: Suburu Measurements of Images and Redshifts

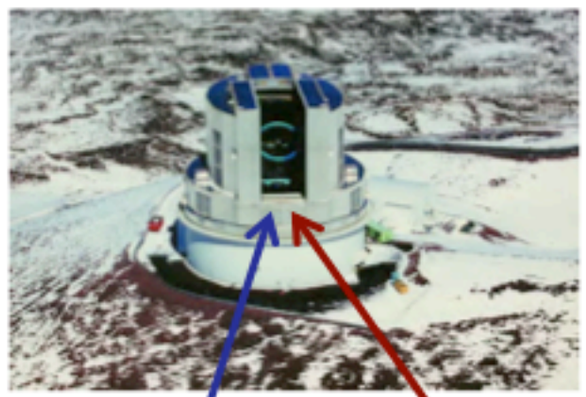
- Imager: Hyper Suprime-Cam (HSC)]; Spectrograph: Prime Focus Spectrograph (PFS)

- PFS: 2 million OII emitters over 1500 deg^2 within the redshift range $0.8 < z < 2.4$.



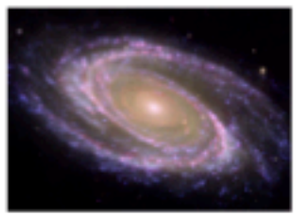
SuMIRe: Subaru Measurement of Images and Redshifts

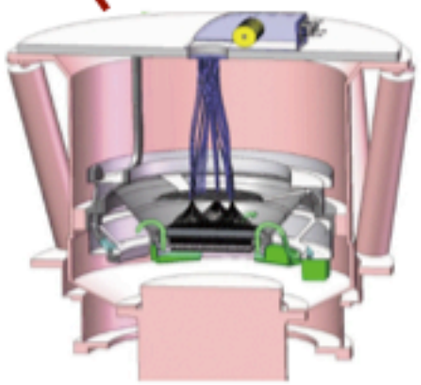
- Goal: to observe a wide-field camera (Hyper Suprime-Cam (HSC)) and wide-field multi-object spectrograph (Prime Focus Spectrograph (PFS)) for the Subaru Telescope (8.2m).



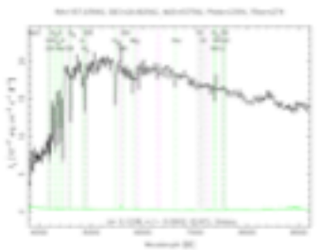
Subaru (NAOJ)

HSC





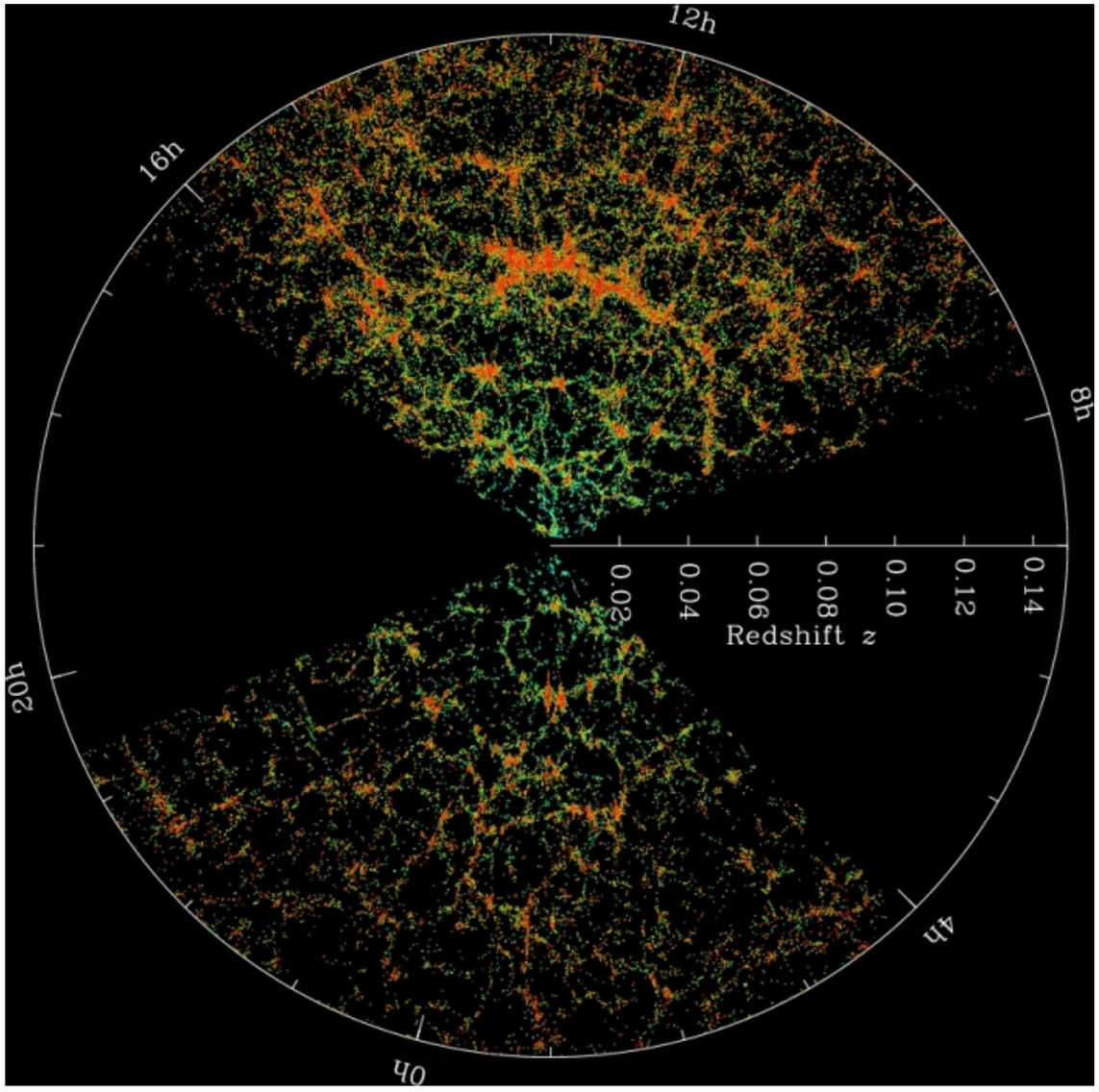
PFS



- HSC baseline design:
  - Wide FoV: 1.5° in diameter, i.e., 10×Suprime-Cam
  - Deep multi-band imaging (grizy; i~26, y~24)
  - Wide 1500 sq. deg. survey

- PFS baseline design:
  - The same optics as HSC
  - Use HSC for target selection
  - 2400 fibers
  - 380-1300 nm wavelength coverage
  - Wide 1500 sq. deg. Survey
  - ~2×10^6 in the cosmology survey
  - R~2000,3000,5000 (blue,red,NIR)

LSS Surveys

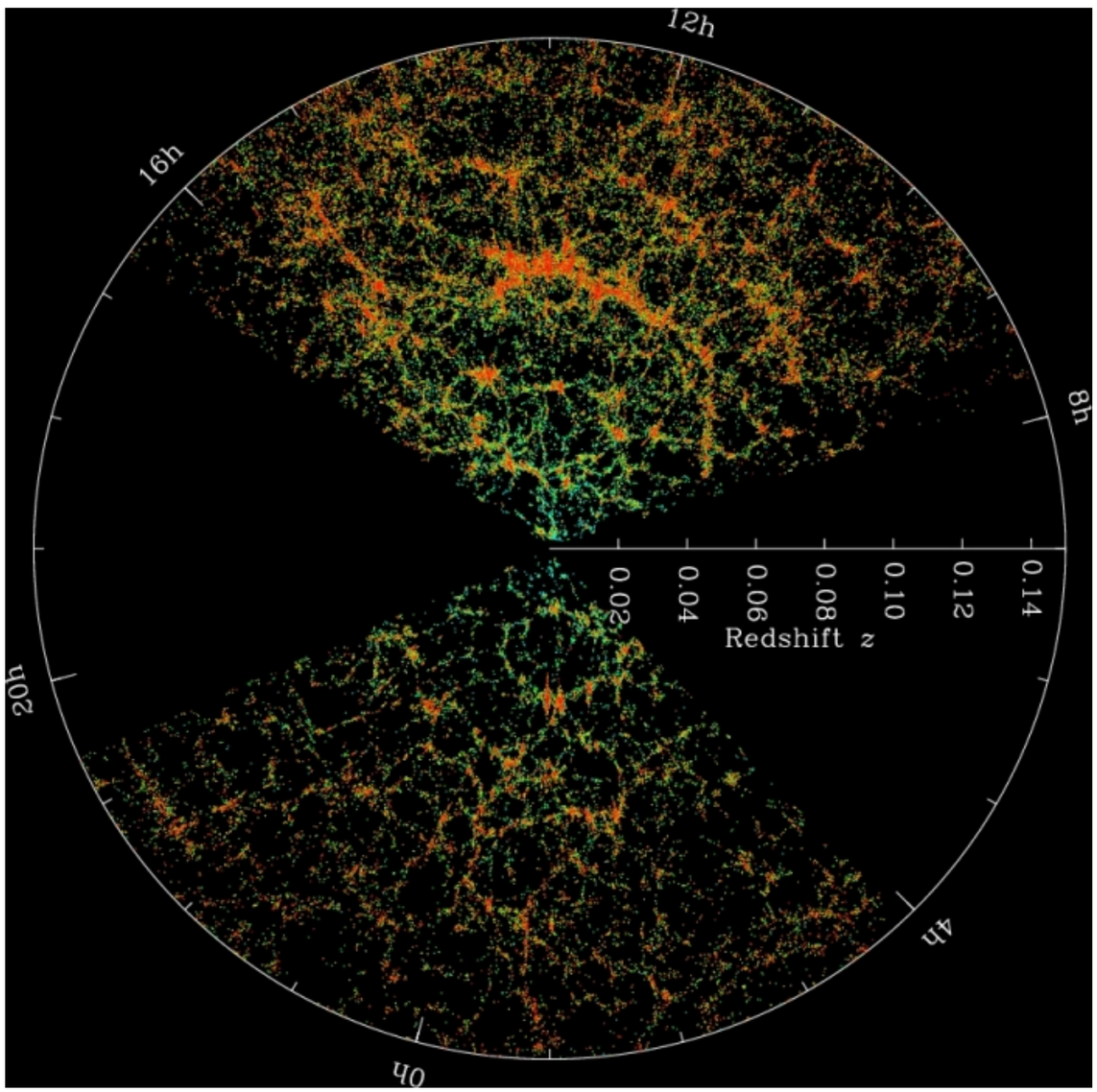


Credit: SDSS

SDSS - Sloan Digital Sky Survey

- A catalog of galaxies, quasars, etc. within a given distance/area interval.
- Traces large-scale structure (LSS) back in time.
- Carries an imprint from very early structure.

LSS Surveys



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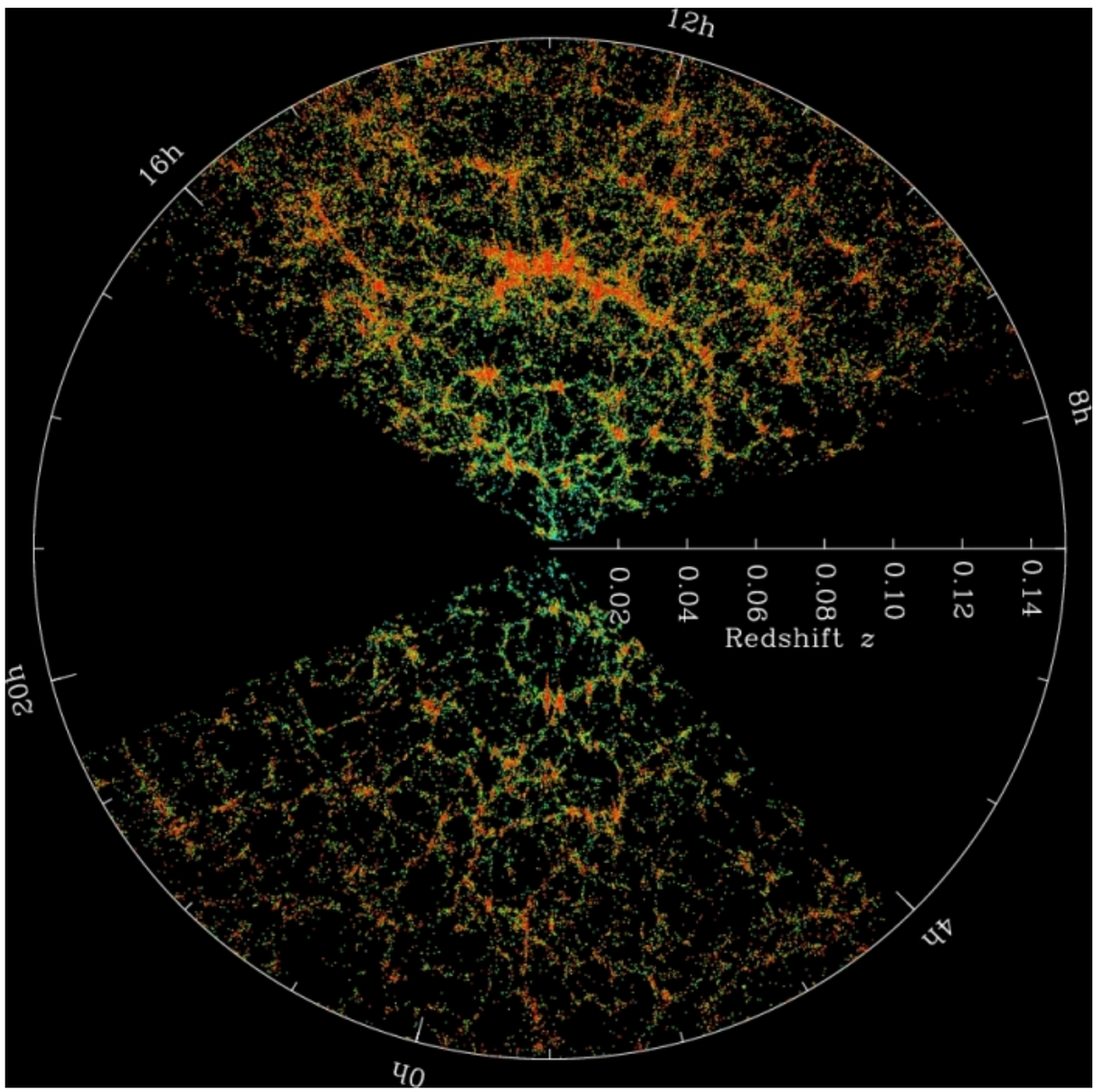

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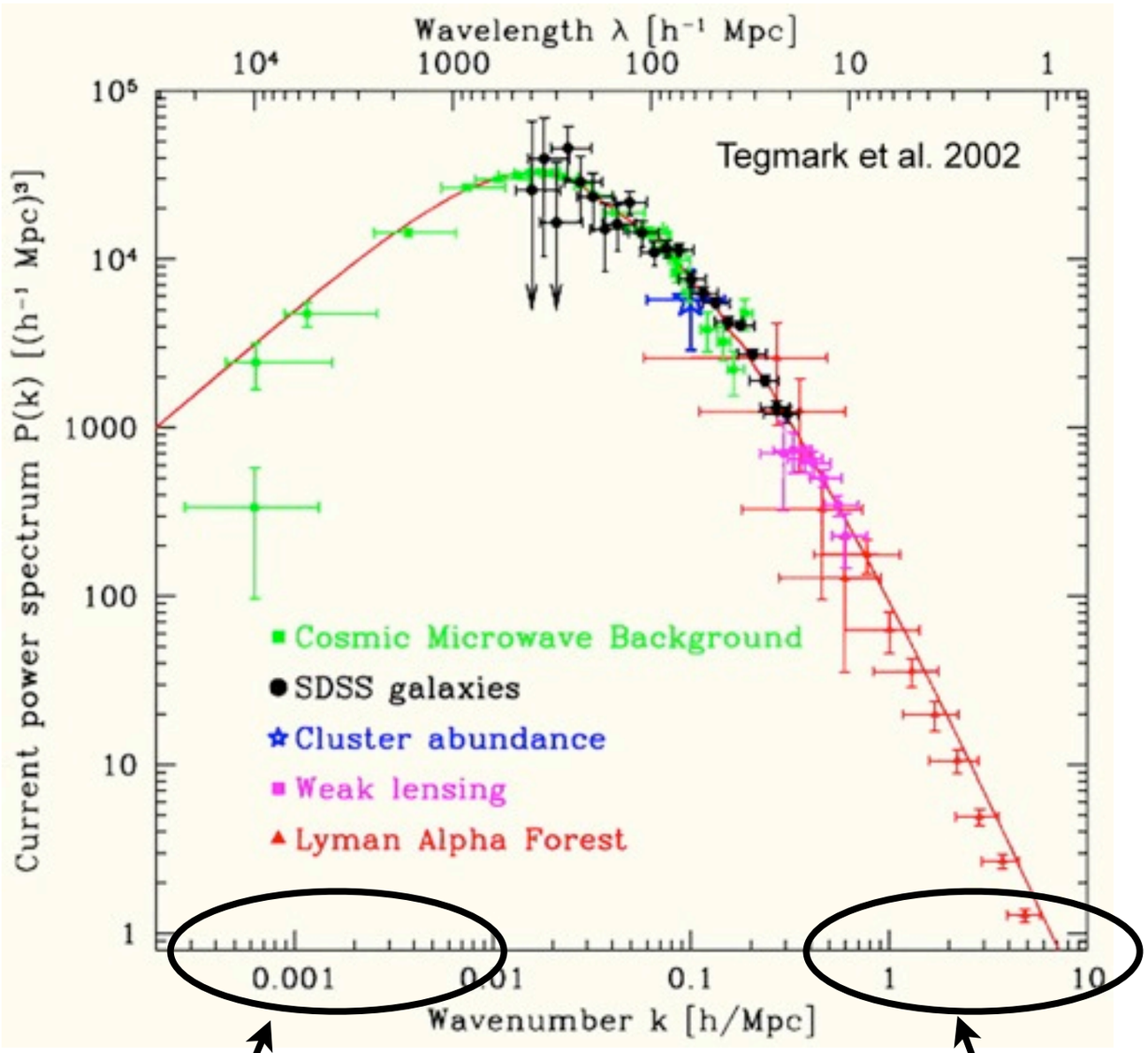
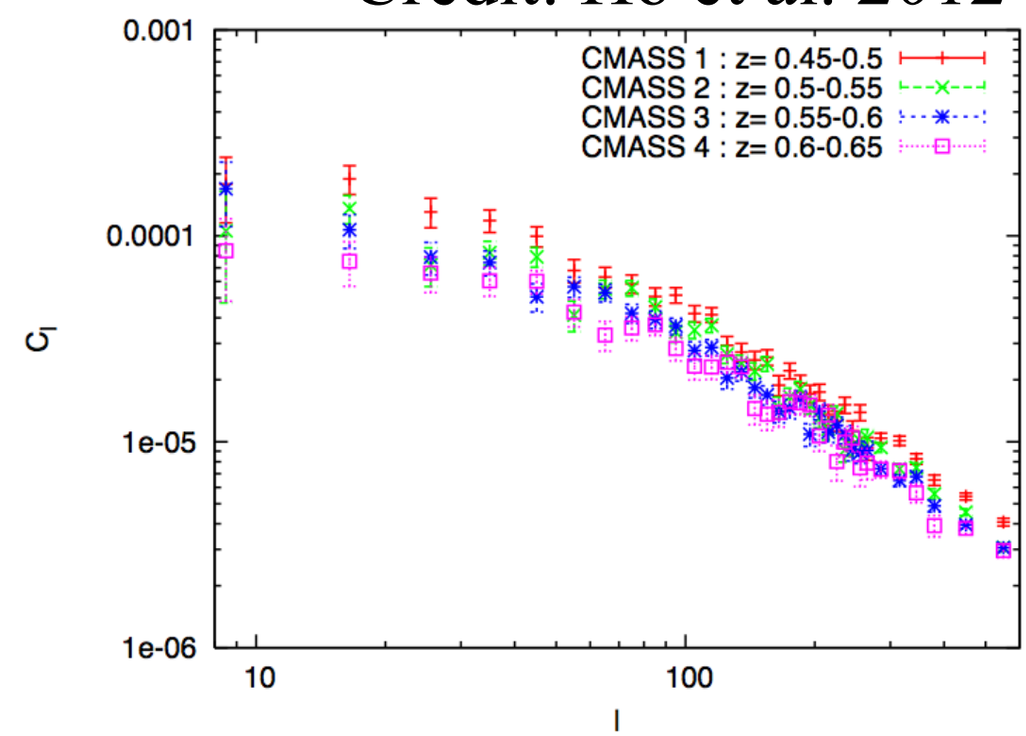
  Inflation

Power Spectrum



Credit: Ho et al. 2012



C_ℓ - angular power spectrum

= radial projection of $P(k)$

larger scales

smaller scales