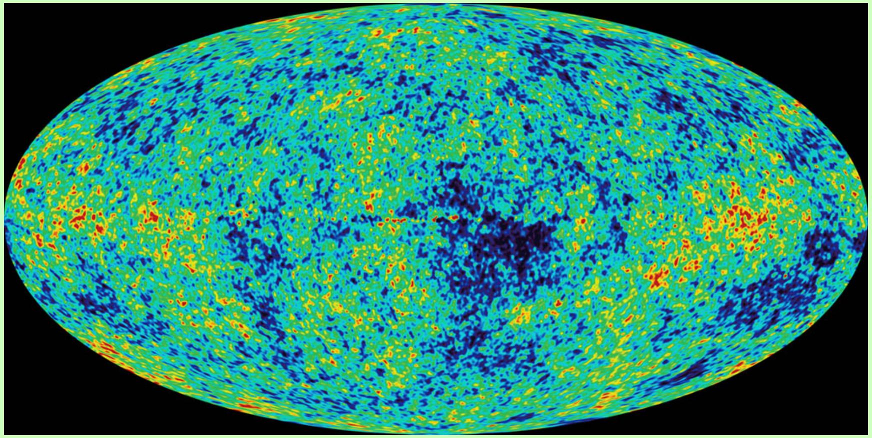
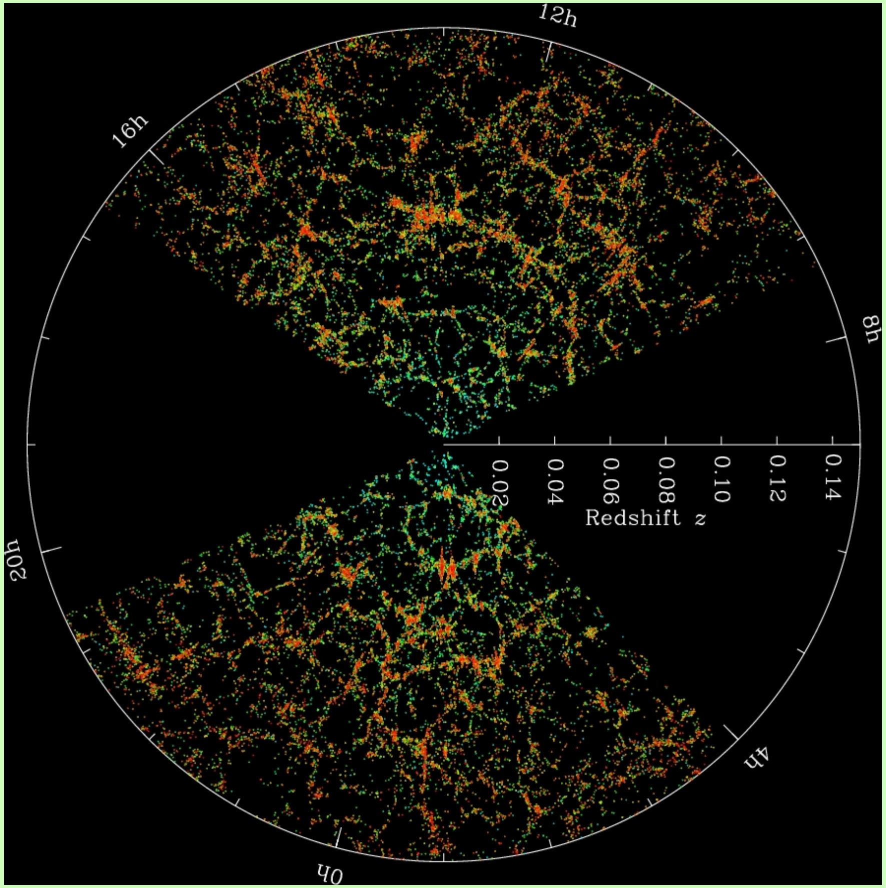
Probes of the Mass Density Field



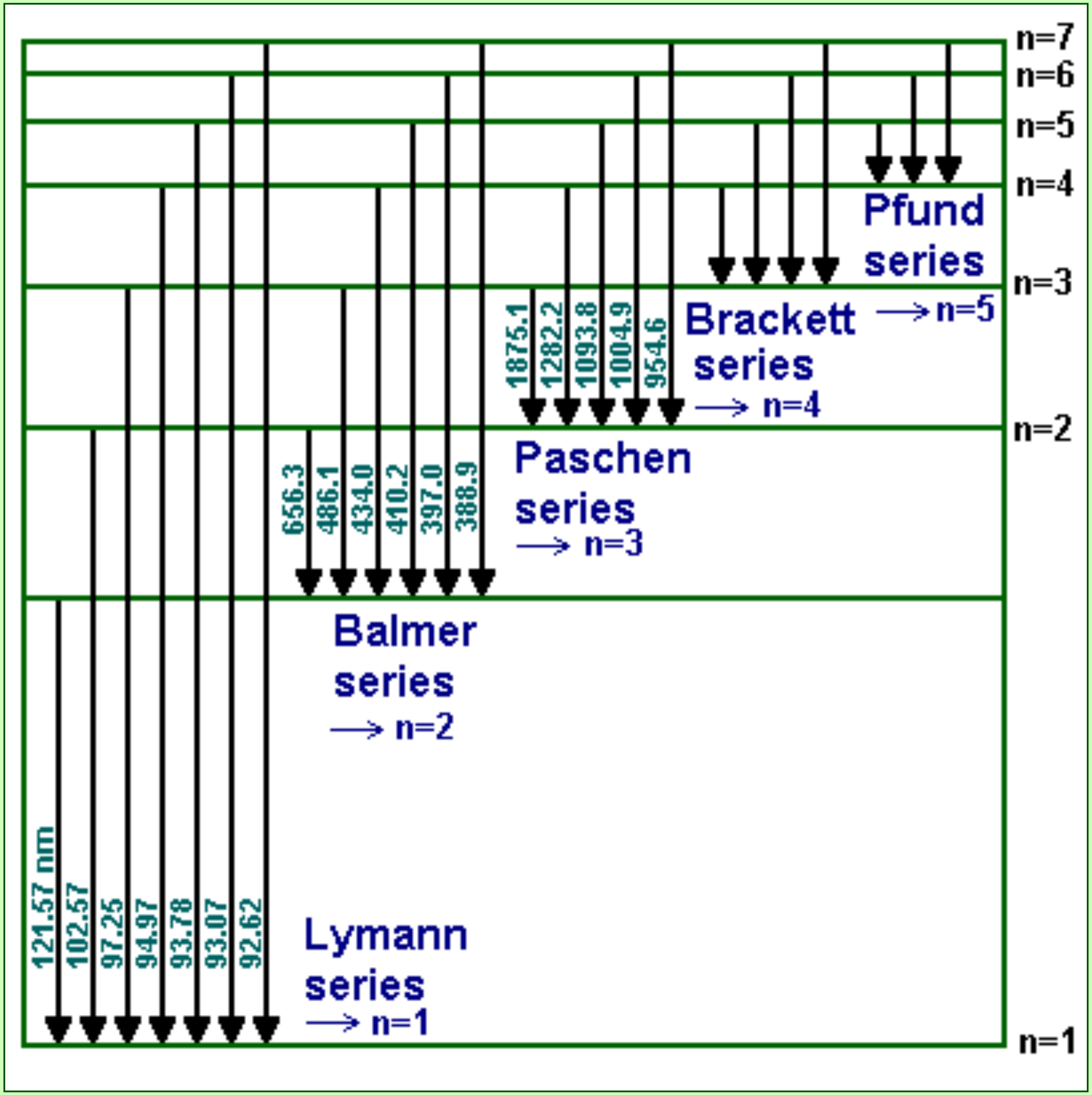
z~1000



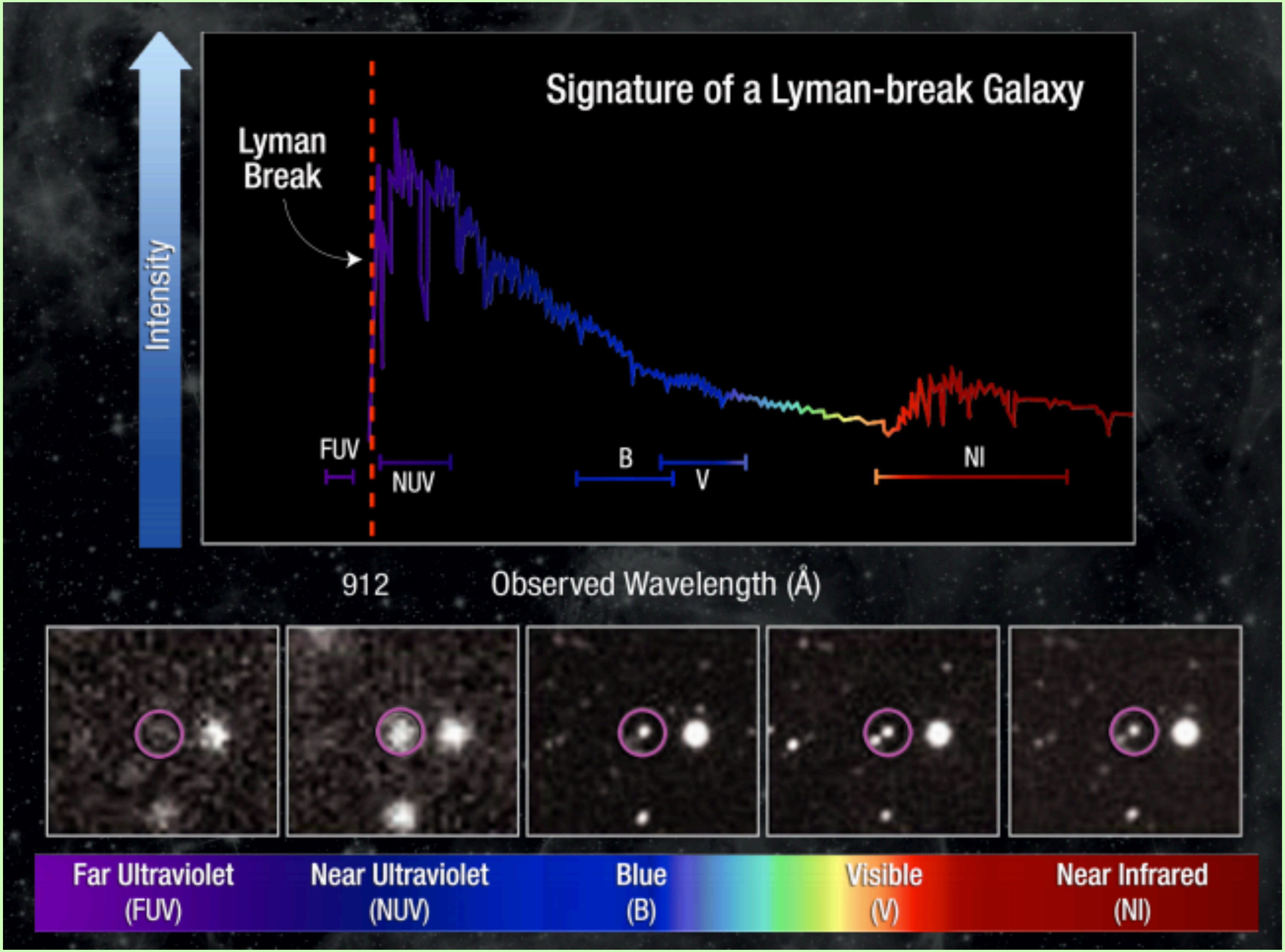
z~0-1

What about intermediate redshifts?

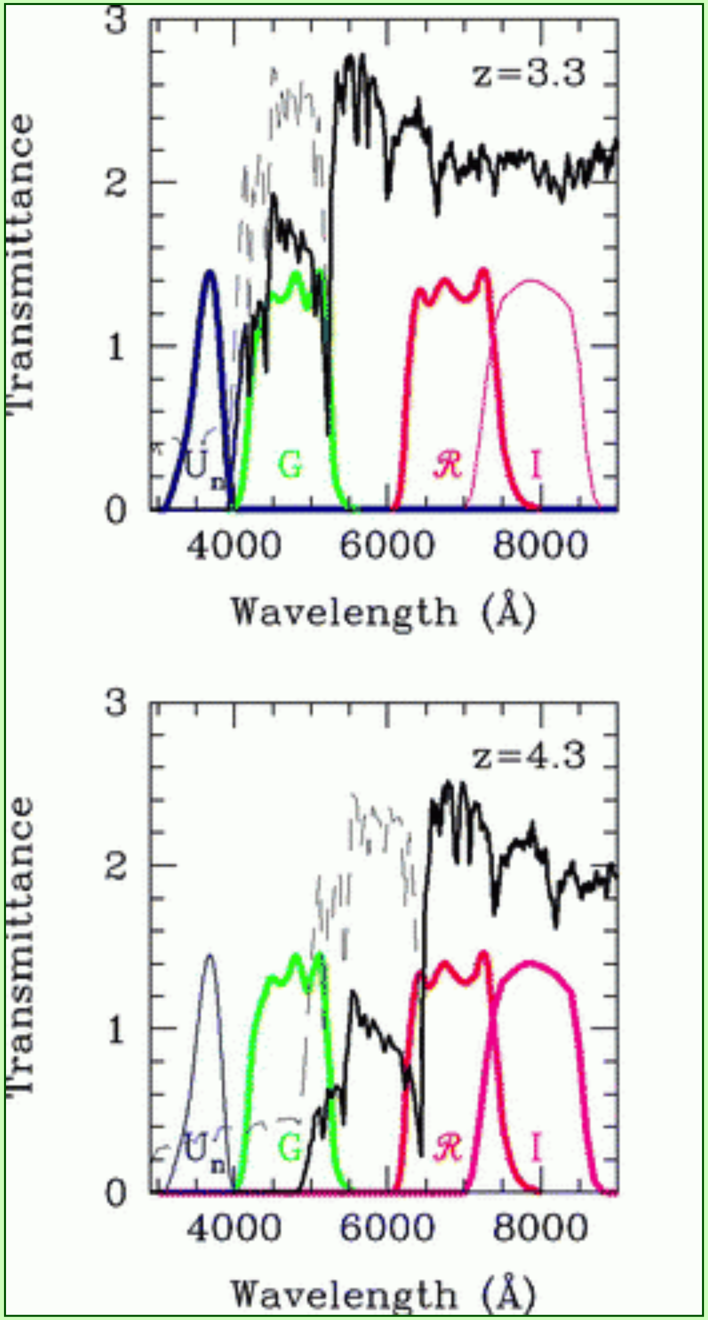
Lyman Break Galaxies



Lyman Break Galaxies

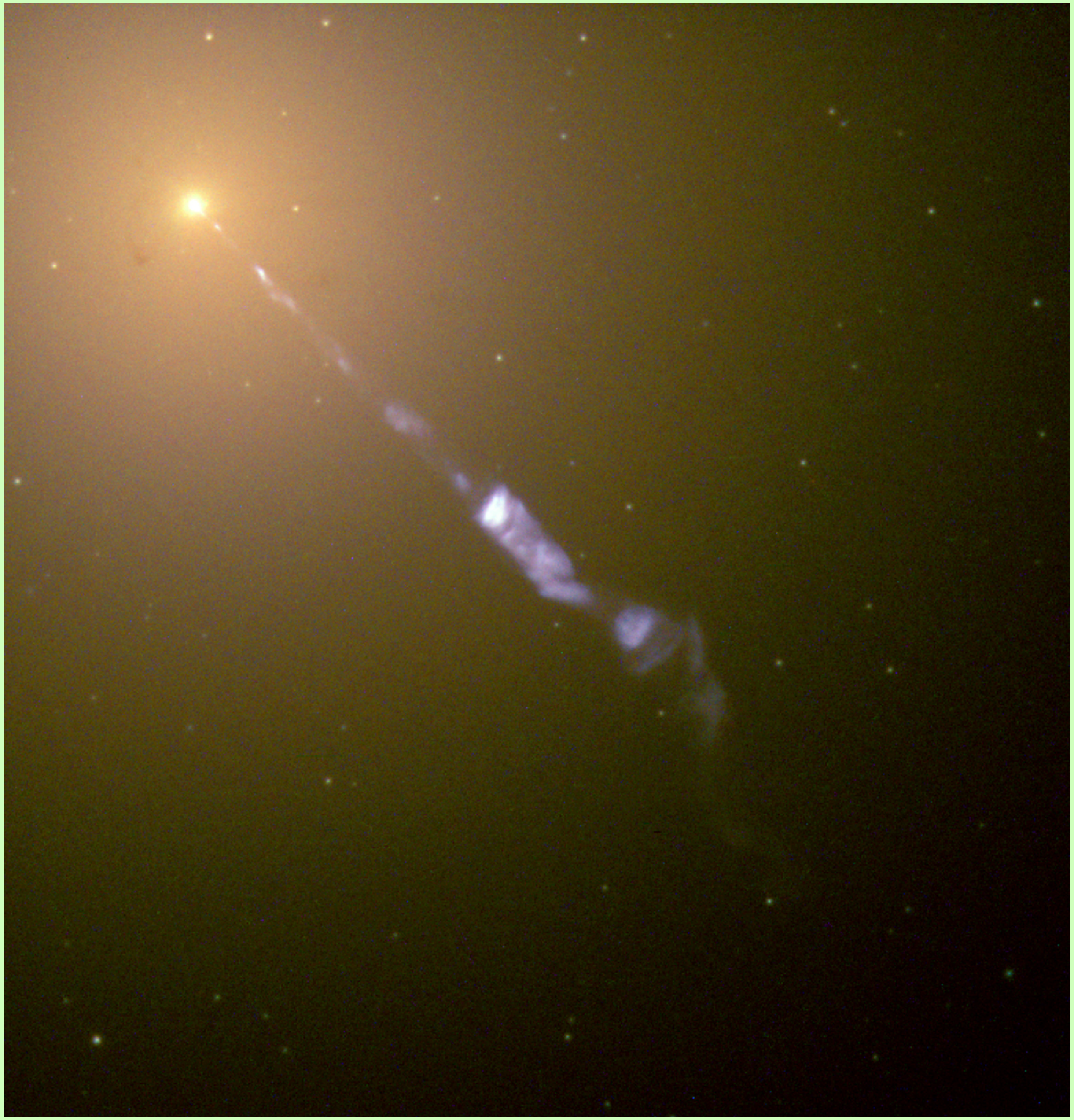


Lyman Break Galaxies



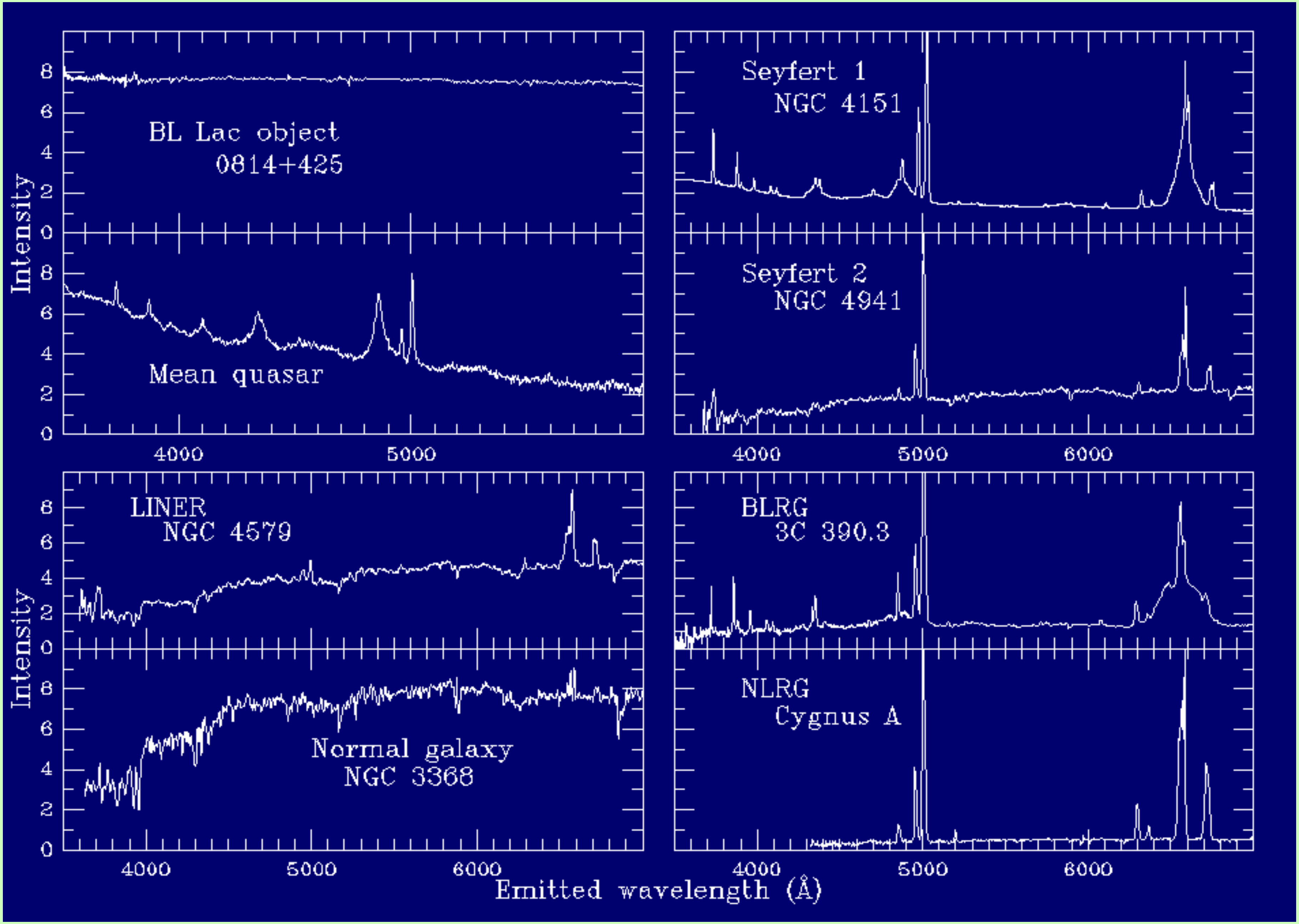
$$\lambda_{\min} = 912(1+z)$$

Quasars



Active Galactic Nuclei

AGN - Types



BL Lac object
0814+425
Seyfert 1
NGC 4151
Mean quasar
Seyfert 2
NGC 4941
LINER
NGC 4579
BLRG
3C 390.3
Normal galaxy
NGC 3368
NLRG
Cygnus A
Intensity
Emitted wavelength (Å)
4000
5000
6000
0
2
4
6
8

AGN - Types

Differences between active galaxy types and normal galaxies.

Galaxy Type	Active Nuclei	Emission Lines		X-rays	Excess of		Strong Radio	Jets	Variable	Radio loud
		Narrow	Broad		UV	Far-IR				
Normal	no	weak	none	weak	none	none	none	none	no	no
Starburst	no	yes	no	some	no	yes	some	no	no	no
Seyfert I	yes	yes	yes	some	some	yes	few	no	yes	no
Seyfert II	yes	yes	no	some	some	yes	few	yes	yes	no
Quasar	yes	yes	yes	some	yes	yes	some	some	yes	10%
Blazar	yes	no	some	yes	yes	no	yes	yes	yes	yes
BL Lac	yes	no	none/faint	yes	yes	no	yes	yes	yes	yes
OVV	yes	no	stronger than BL Lac	yes	yes	no	yes	yes	yes	yes
Radio galaxy	yes	some	some	some	some	yes	yes	yes	yes	yes

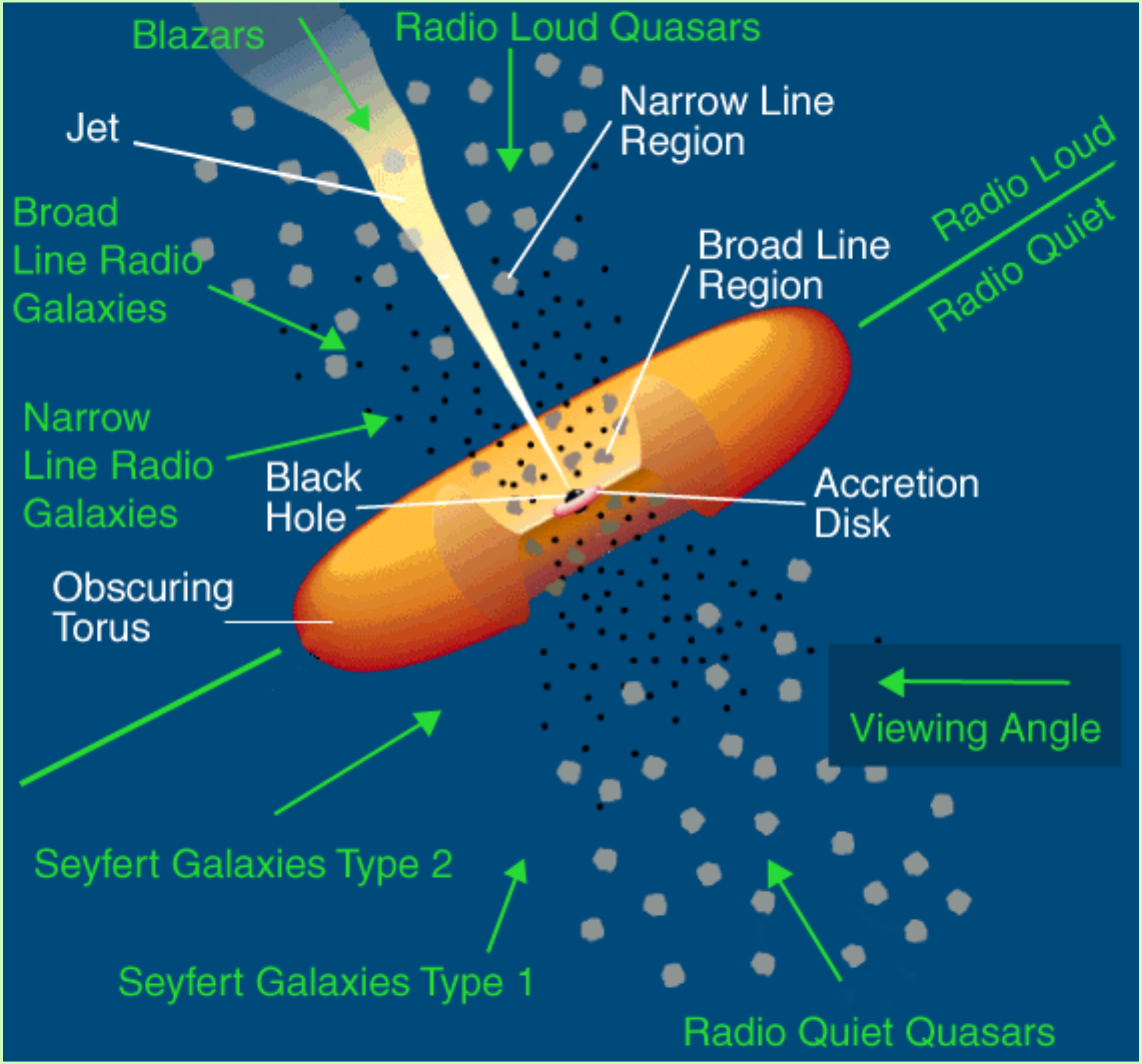
AGN – Unified Model

Hypothesis

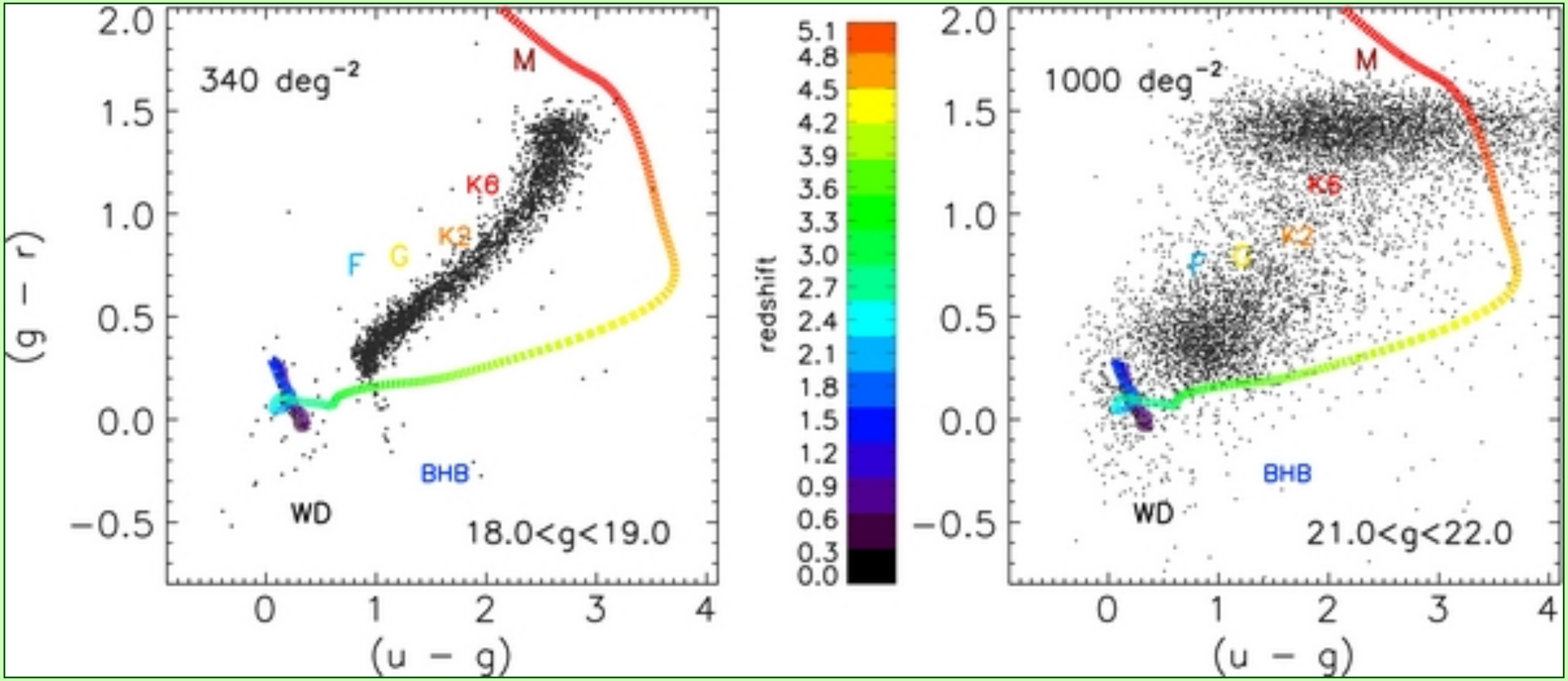
All active galactic nuclei are supermassive black holes at the centers of galaxies being fed by an accretion disk. Different types are just differences in:

- Black hole mass
- Accretion rate
- Type of galaxy
- Viewing angle

AGN – Unified Model

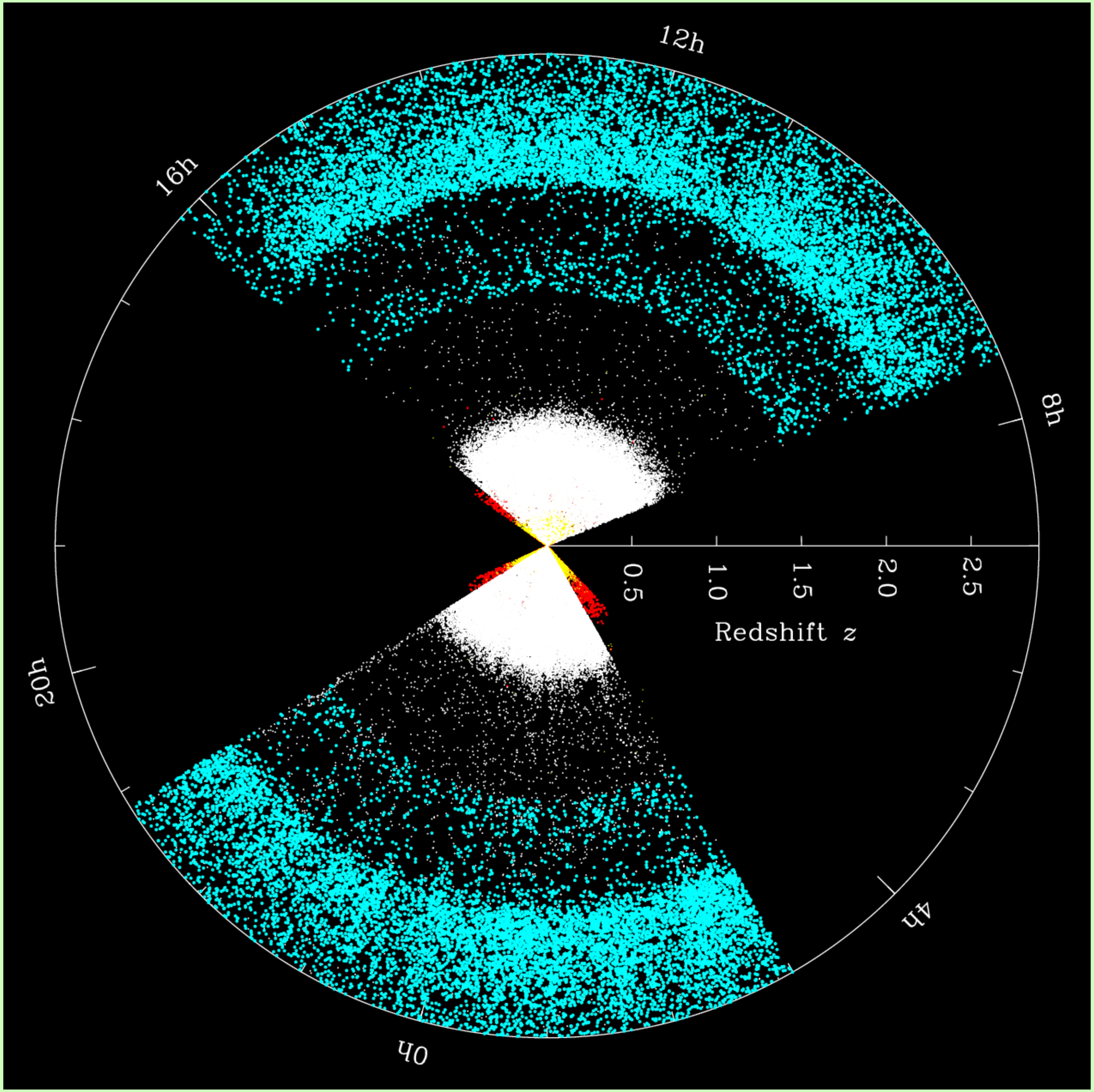


Quasars

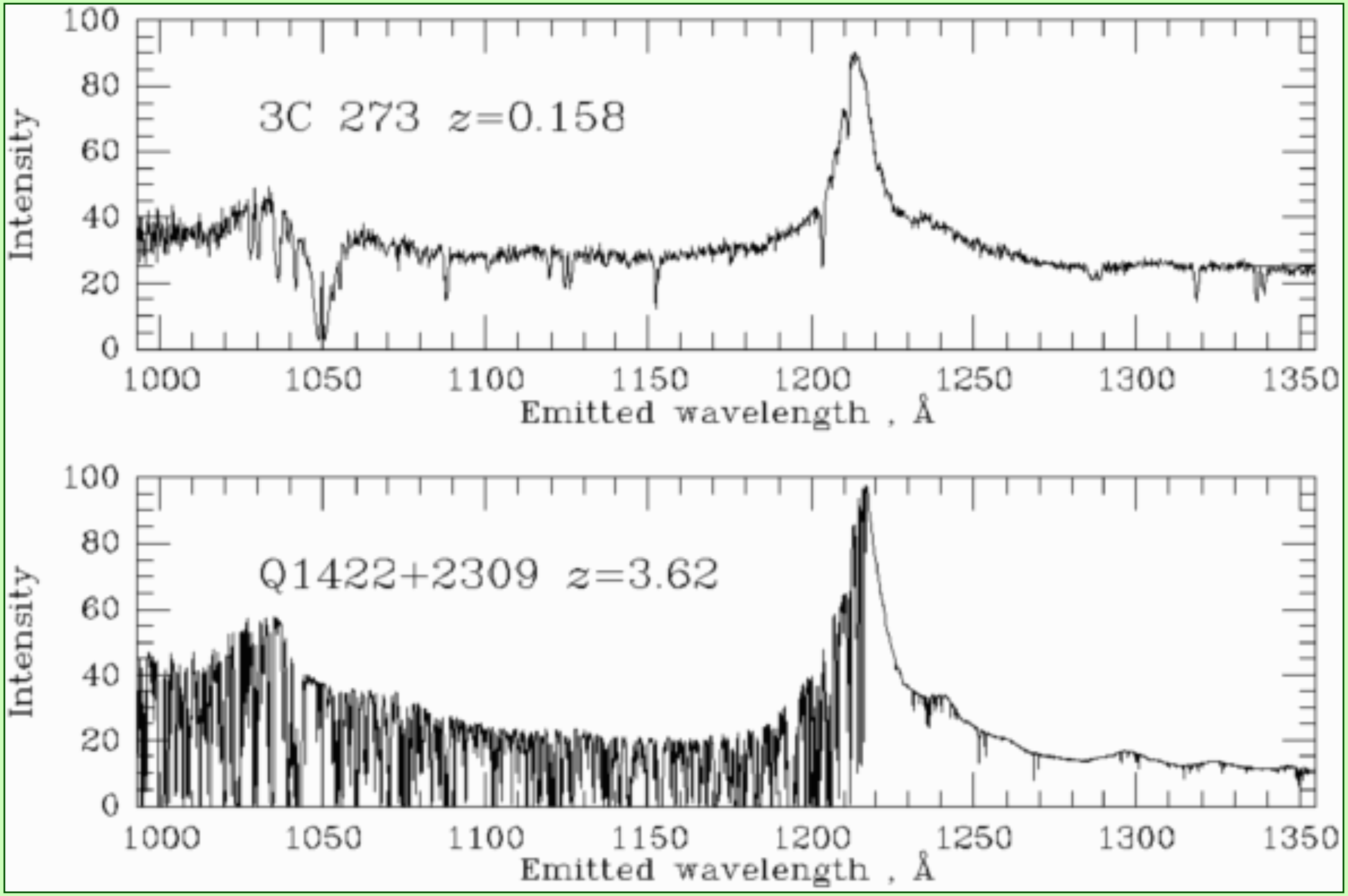


Ross et al. (2012)

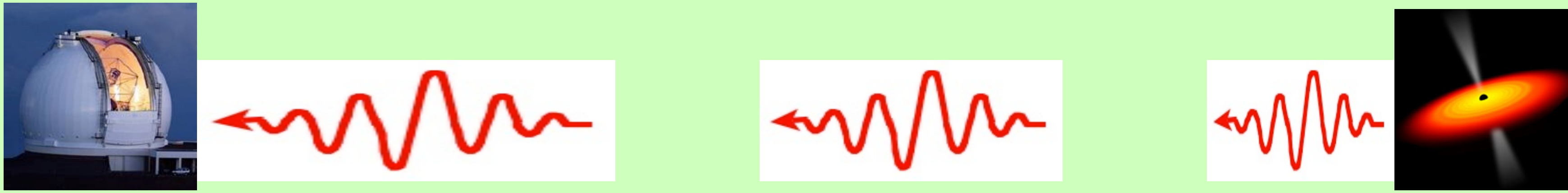
Quasars



The Lyman alpha Forest



The Lyman alpha Forest



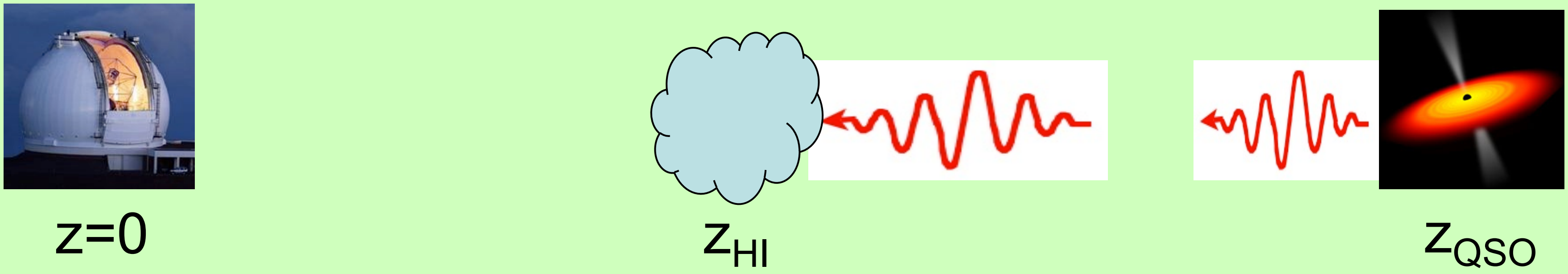
z=0 z_{QSO}

Emission wavelength: λ_e

$$\frac{\lambda_o}{\lambda_e} = \frac{1+z_e}{1+z_o}$$

Observation wavelength: $\lambda_o = \lambda_e\left(1+z_e\right)$

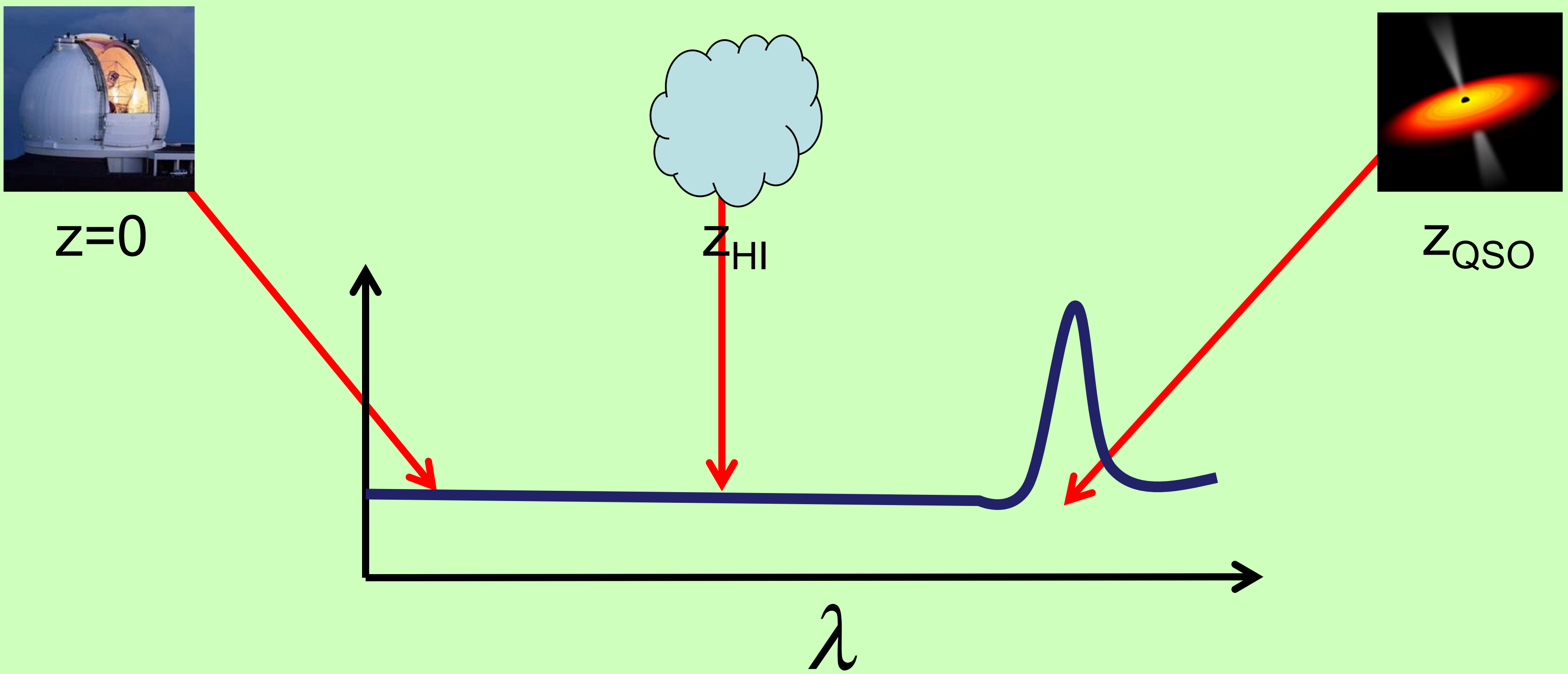
The Lyman alpha Forest



- A Lyman-α photon (1216 Å) emitted by the quasar has a longer wavelength by the time it encounters the HI cloud and so it will not be absorbed.

- The shorter wavelength photon emitted by the quasar that has stretched to 1216 Å by the time it encounters the HI cloud can be absorbed.

The Lyman alpha Forest



- In the emitted frame of the quasar, the Ly-α forest lies between the wavelengths of 1216/(1+z) and 1216 Å

- In the observed frame, the Ly-α forest lies between the wavelengths of 1216 and 1216(1+z) Å

The Lyman alpha Forest

The BOSS spectrograph covers the range 3600-10,400 Å

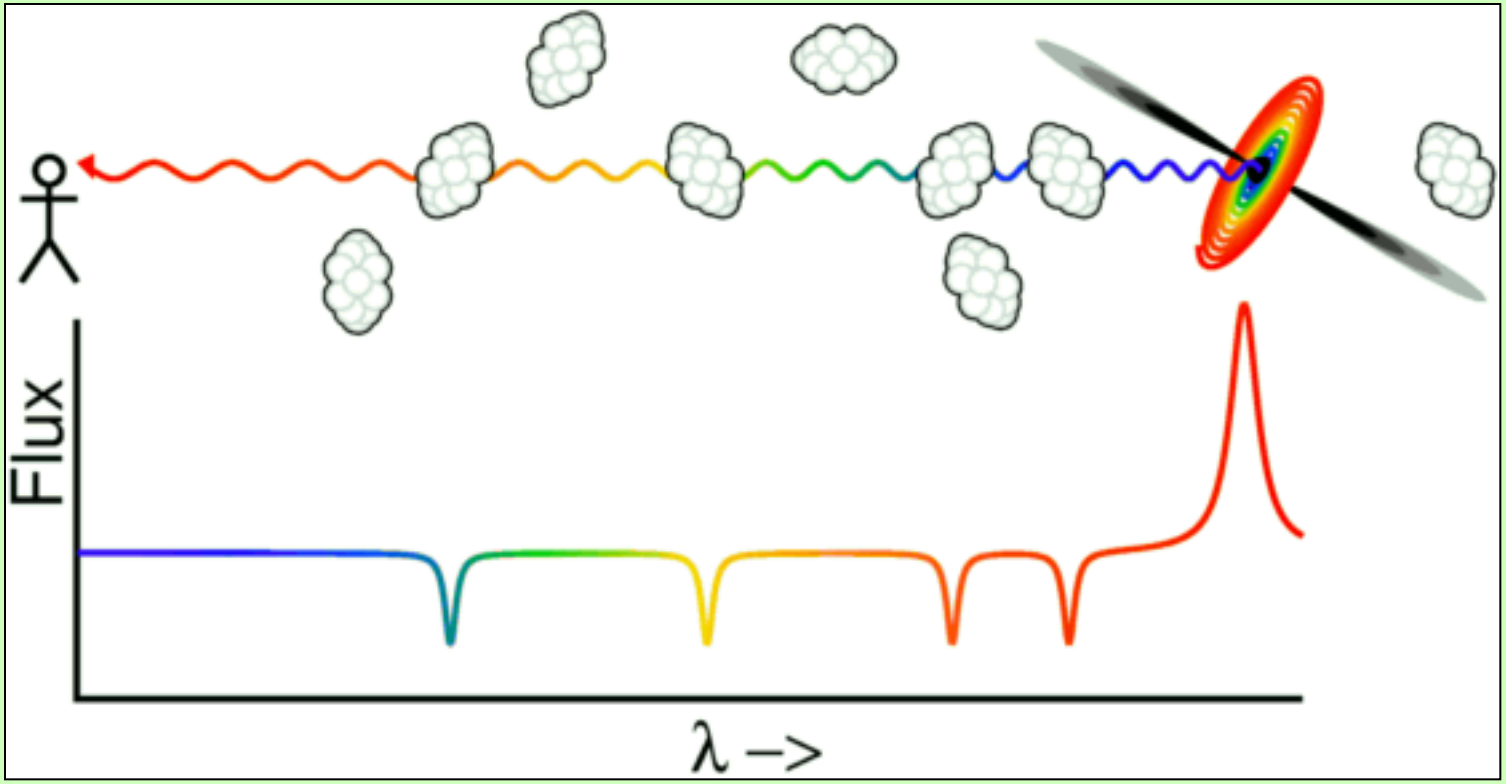
- The closest gas cloud that it can probe is at

$$\lambda_o = \lambda_e (1+z) \rightarrow z = \frac{\lambda_o}{\lambda_e} - 1 = \frac{3600}{1216} - 1 \rightarrow z = 1.96$$

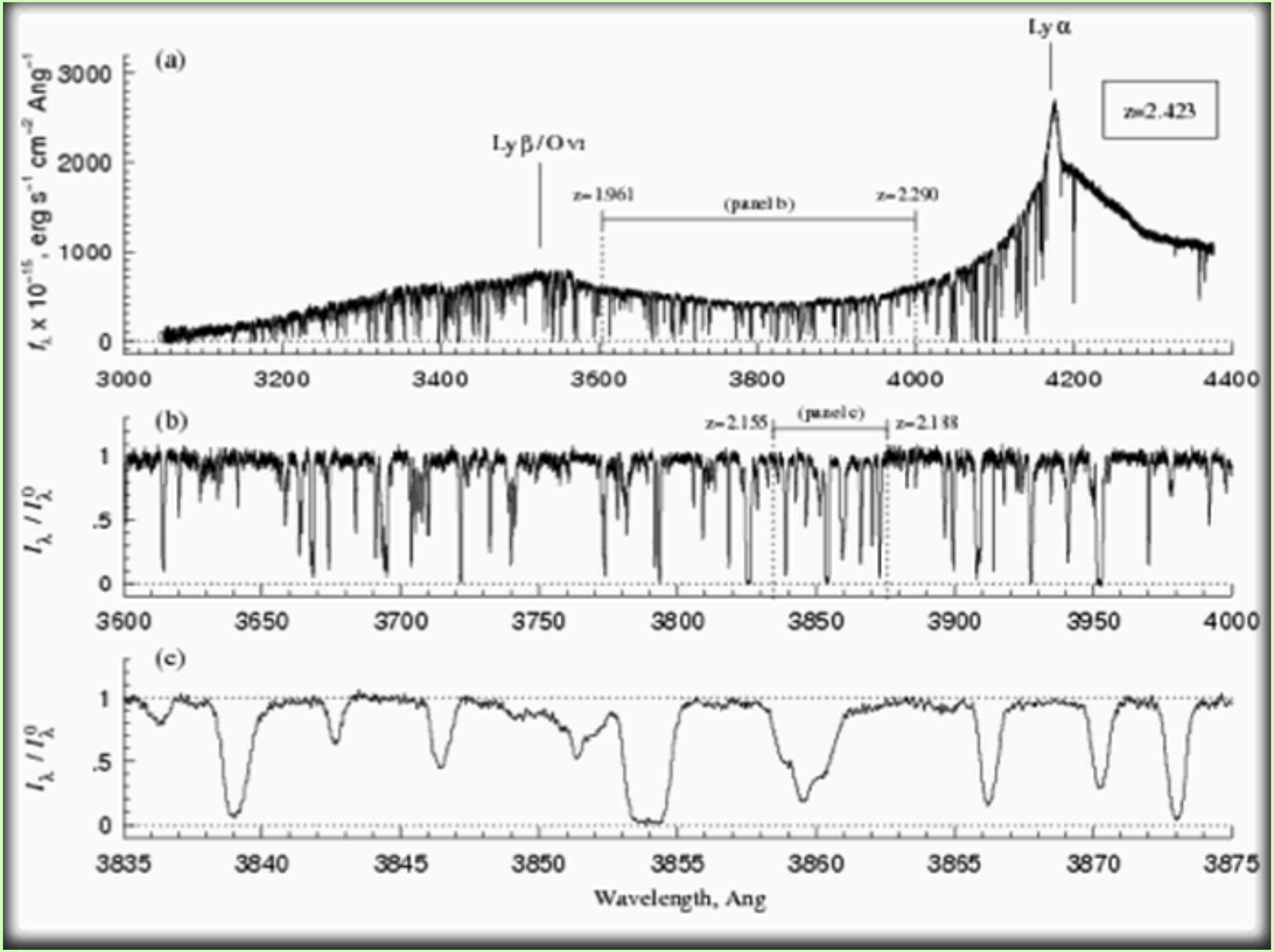
- The farthest gas cloud that it can probe is at

$$z = \frac{10,400}{1216} - 1 \rightarrow z = 7.55$$

The Lyman alpha Forest



The Lyman alpha Forest



The Lyman alpha Forest