

Spectroscopic studies with large surveys

Brice Ménard

Johns Hopkins University
Kavli IPMU, Tokyo University

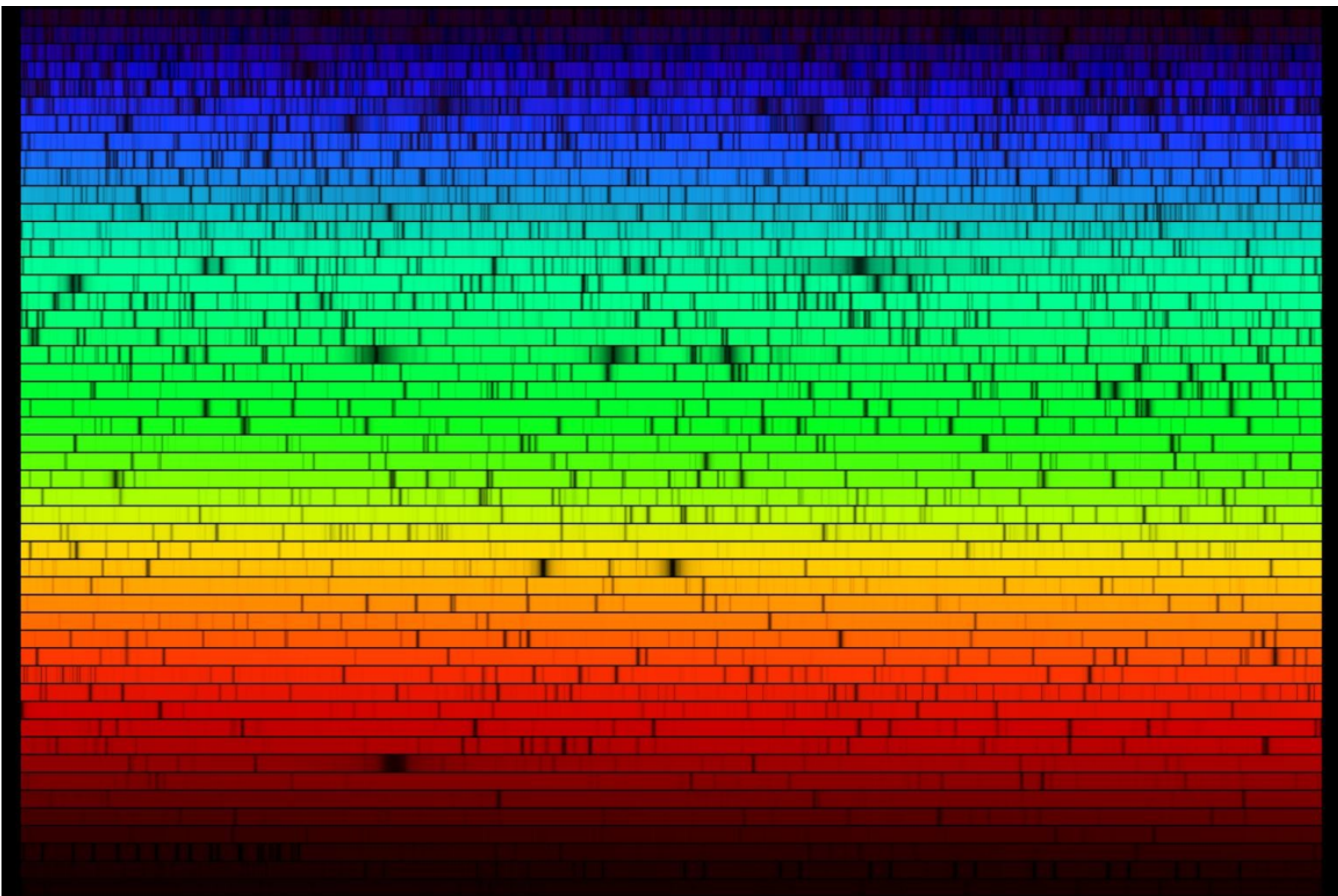
Guangtun Zhu

Johns Hopkins University



Zu Fraunhofer's Abh. — Denkschr. 1814—15.

Fraunhofer (1814)



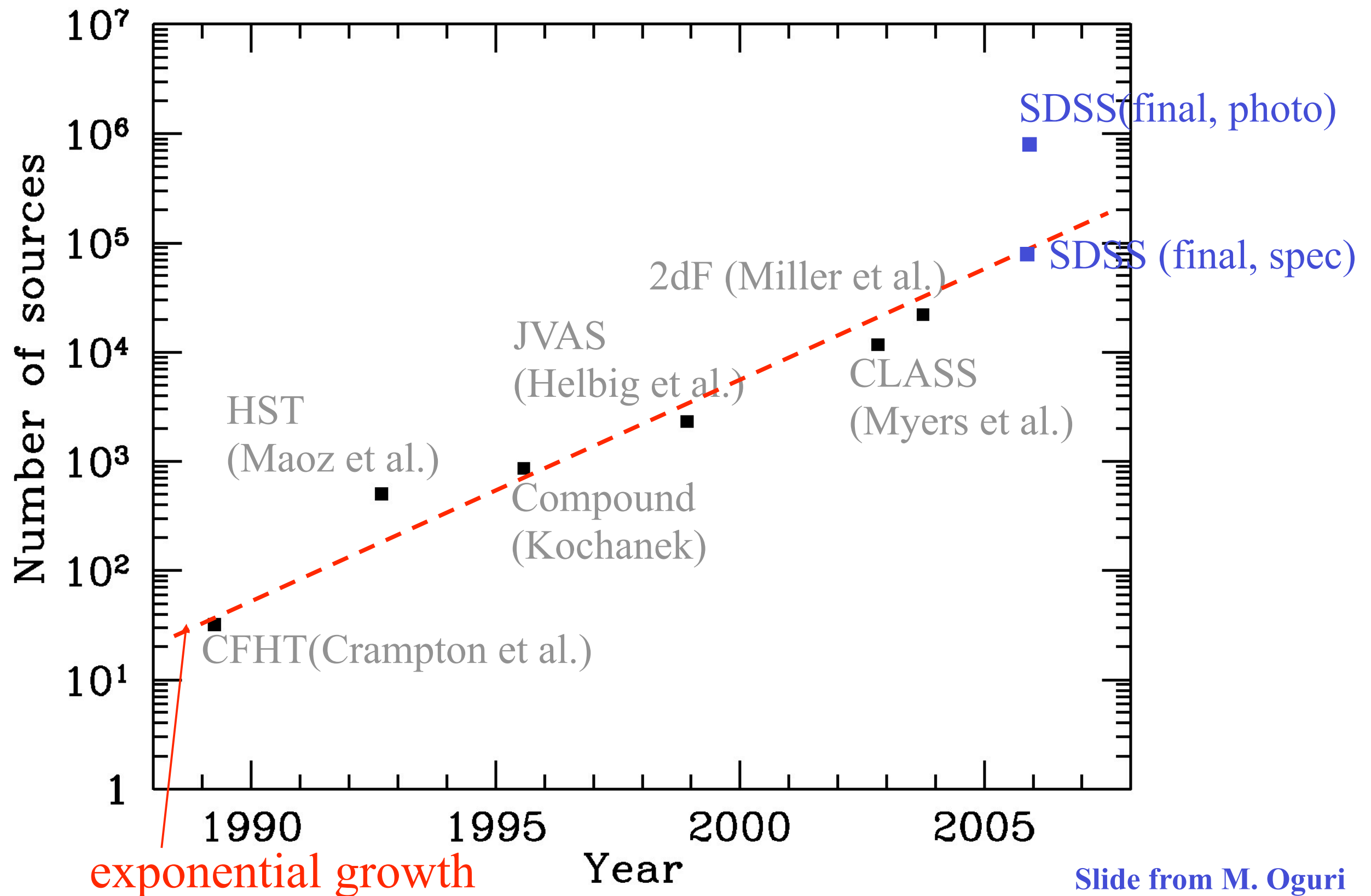
The optical spectrum of the Sun

Spectroscopy

Spectroscopic area	Total	9380 sq. deg.																																					
	Legacy	8032 sq. deg.																																					
	SEGUE	1348 sq. deg.																																					
Wavelength coverage	3800-9200Å																																						
Resolution	1800-2200																																						
Signal-to-noise	>4 per pixel at $g=20.2$																																						
Redshift accuracy	30 km/sec rms for main galaxy sample (from repeat observations)																																						
RV accuracy (systematics, for stars)	1.8 km/s systematics (SEGUE plate-to-plate wavelength solutions)																																						
RV accuracy (total errors, for stars S/N per pixel = 27)	5.5 km/s rms (SEGUE matched plate comparisons, near $g=18$ th mag)																																						
Target magnitude limits for main samples	Galaxies: Petrosian $r < 17.77$ Quasars: PSF $i < 19.1$ (20.2 for objects likely at $z > 2.3$)																																						
Spectroscopic catalog	<table><tr><th>Class</th><th>N(total)</th><th>N(main)</th><th>N(SEGUE)</th></tr><tr><td>All</td><td>1,640,960</td><td>1,374,080</td><td>266,880</td></tr><tr><td>Galaxies</td><td>929,555</td><td>928,567</td><td>988</td></tr><tr><td>Quasars ($z < 2.3$)</td><td>104,740</td><td>103,121</td><td>1,619</td></tr><tr><td>Quasars ($z \geq 2.3$)</td><td>16,633</td><td>15,411</td><td>1,222</td></tr><tr><td>M stars and later</td><td>84,047</td><td>76,125</td><td>7,922</td></tr><tr><td>Other stars</td><td>380,214</td><td>150,748</td><td>229,466</td></tr><tr><td>Sky spectra</td><td>97,398</td><td>75,209</td><td>22,189</td></tr><tr><td>Unknown</td><td>28,383</td><td>24,767</td><td>3,616</td></tr></table>			Class	N(total)	N(main)	N(SEGUE)	All	1,640,960	1,374,080	266,880	Galaxies	929,555	928,567	988	Quasars ($z < 2.3$)	104,740	103,121	1,619	Quasars ($z \geq 2.3$)	16,633	15,411	1,222	M stars and later	84,047	76,125	7,922	Other stars	380,214	150,748	229,466	Sky spectra	97,398	75,209	22,189	Unknown	28,383	24,767	3,616
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640 spectra are observed simultaneously on one <i>plate</i> . There are:																																							
<ul style="list-style-type: none">• 1802 Legacy ("main-survey") plates,•• 86 repeat observations ("extra plates") of 77 distinct Legacy plates,• 676 observations of 660 distinct special plates, including• 410 observations of 212 distinct special plates taken under SEGUE.																																							
Data volume	exposures and calibrated spectra ("2d")		3.3 TB																																				
	spectra, redshifts, line measurements ("1d")		450 GB																																				

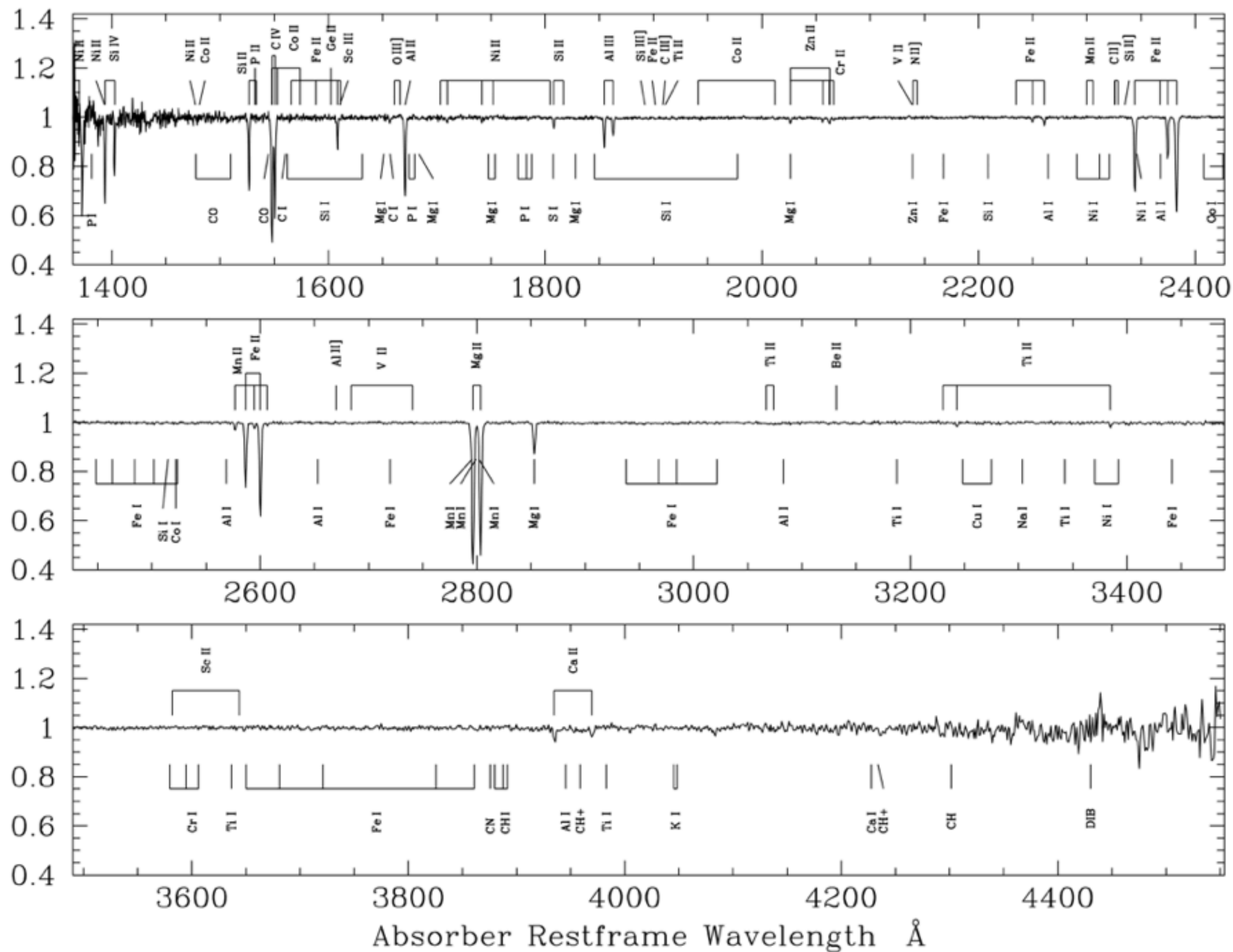


Number of quasars as a function of time

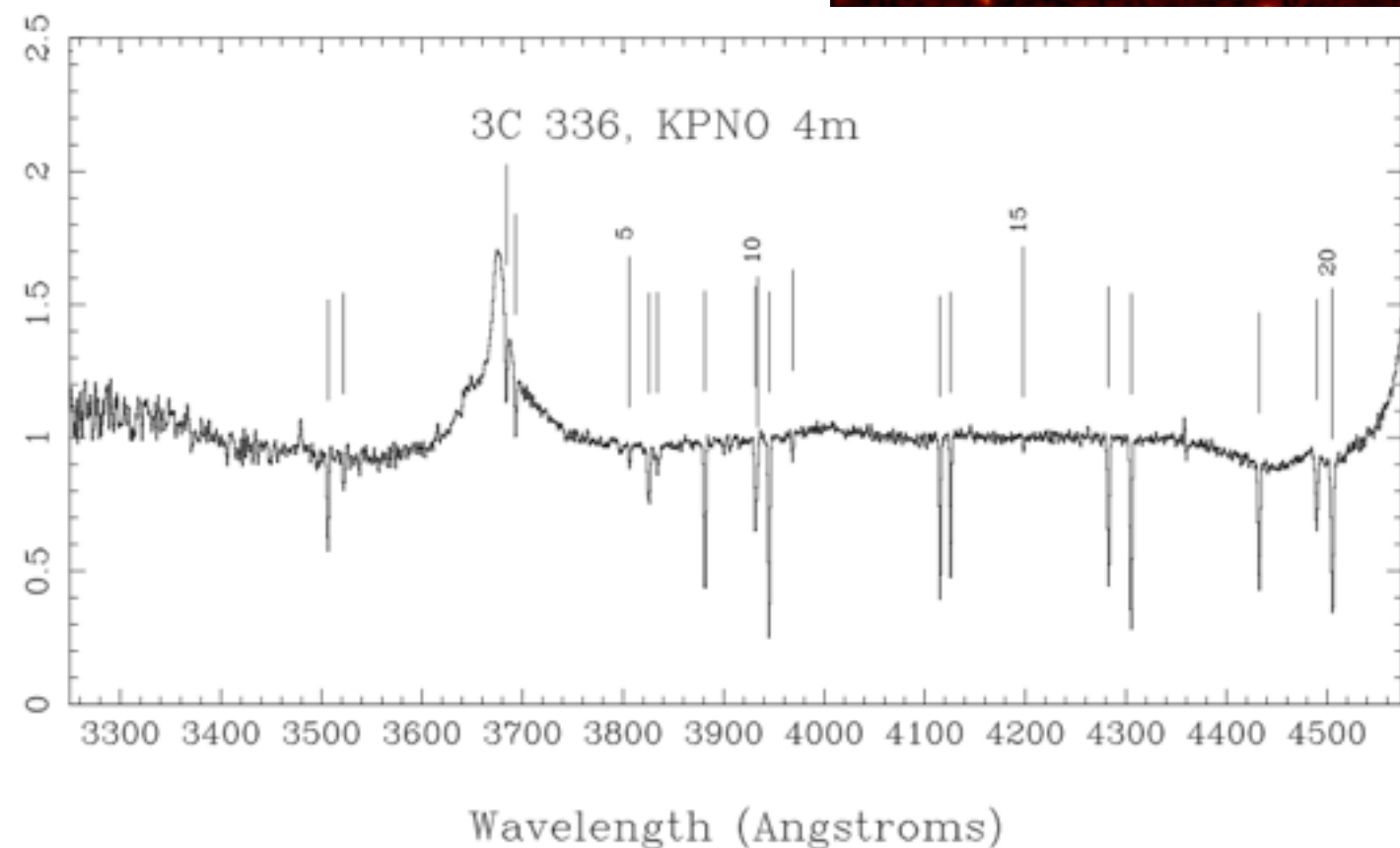
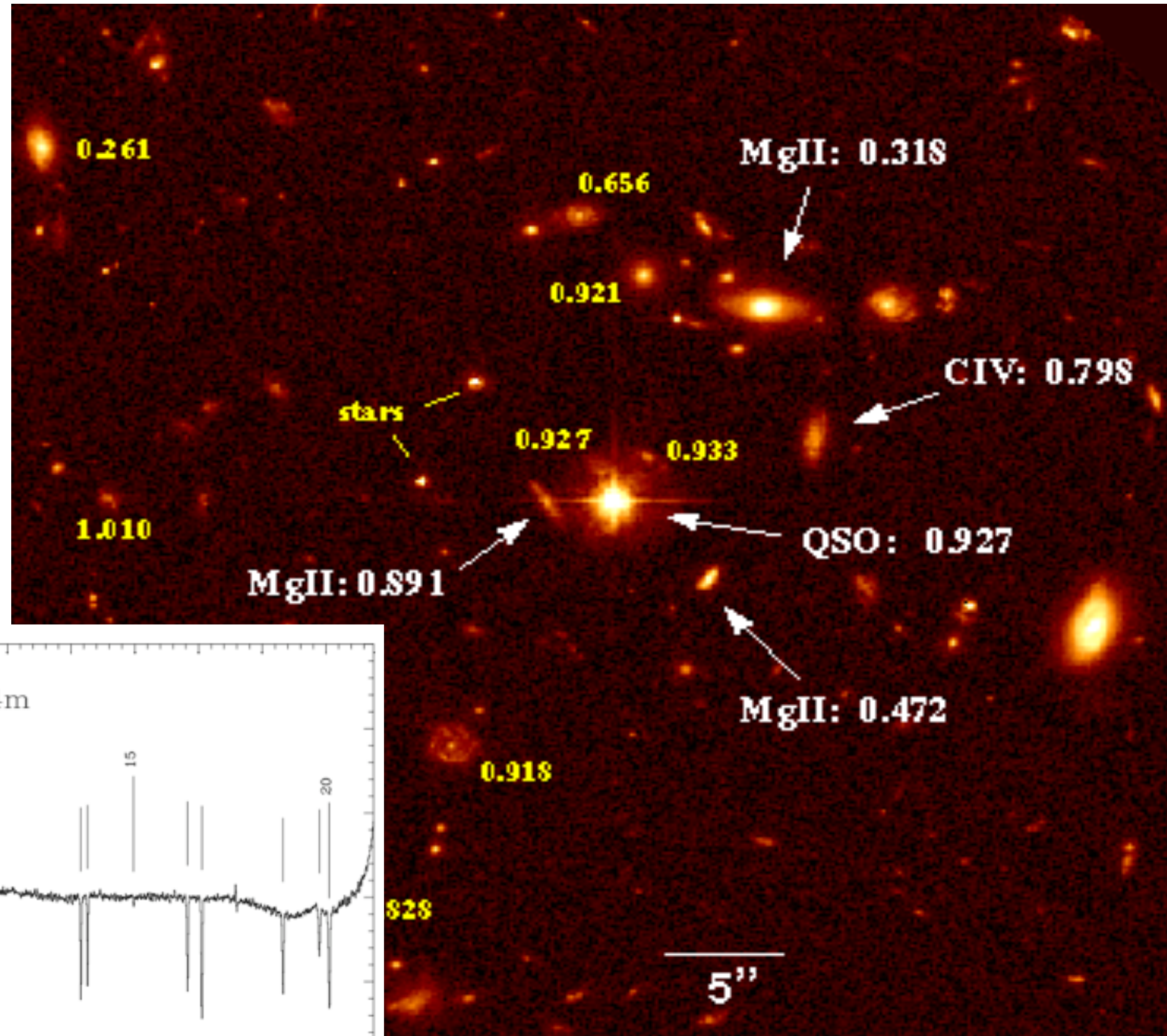


mean absorption spectrum

York et al. (2005)

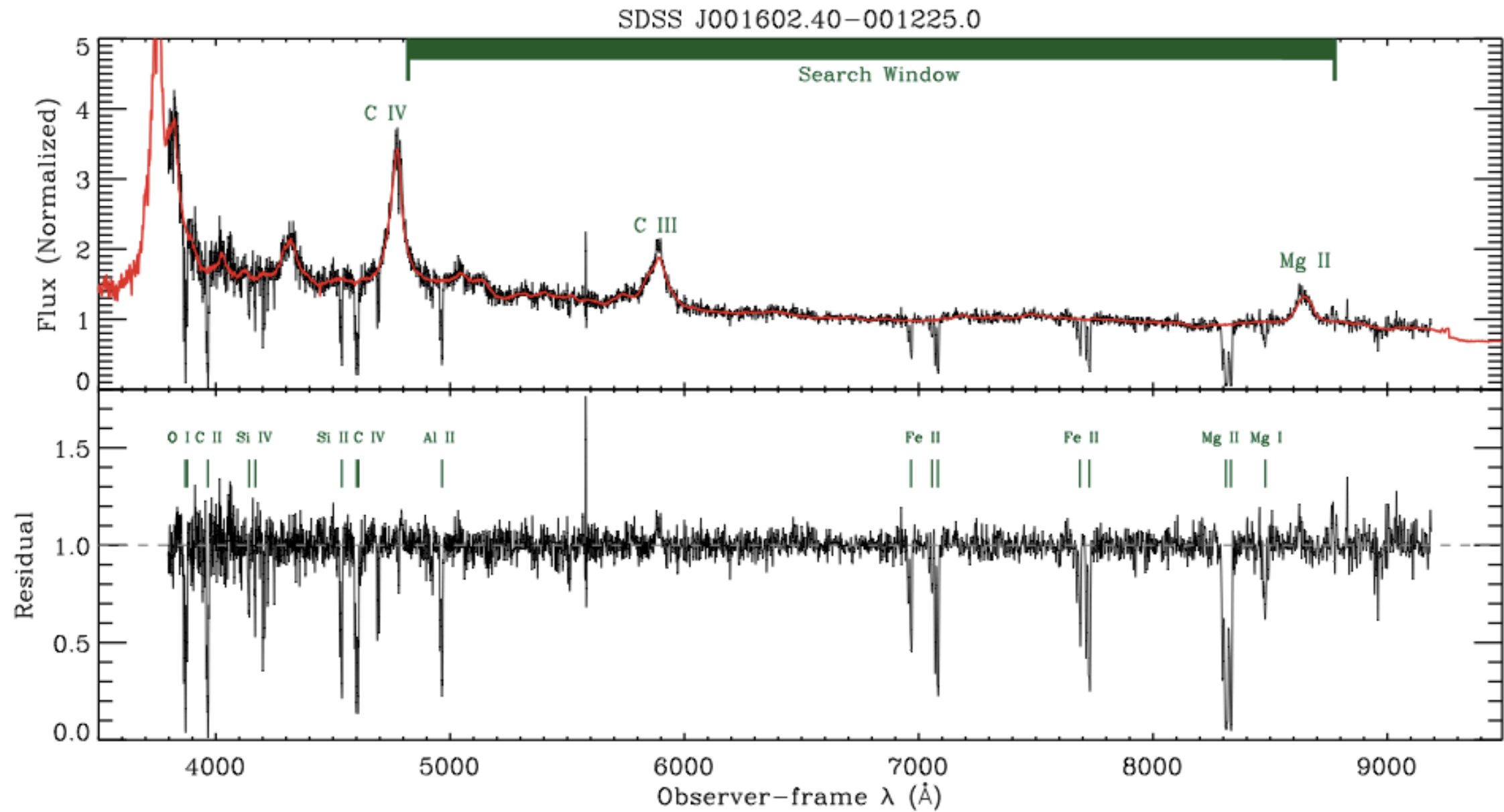


Galaxies and gaseous halos

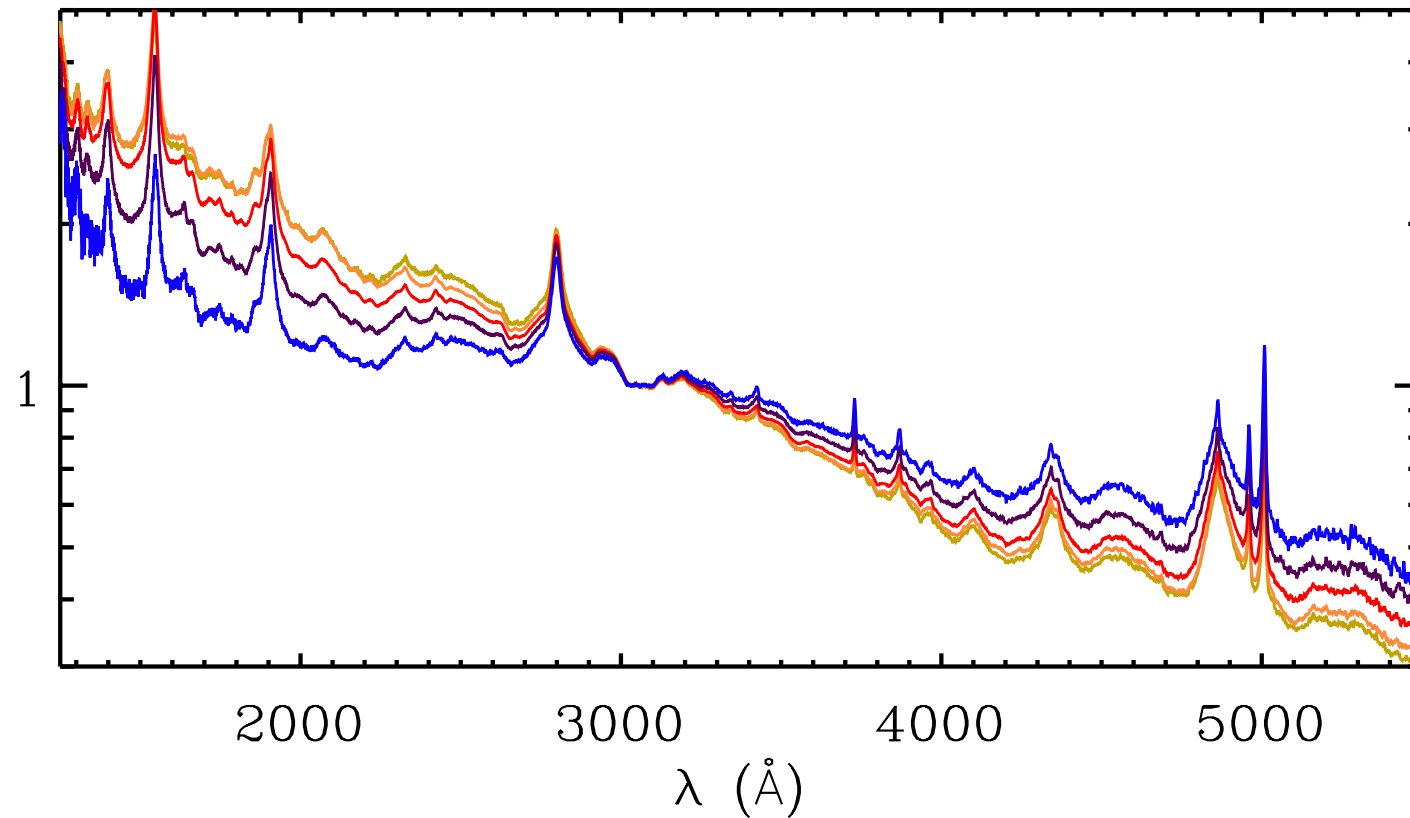


Steidel et al.

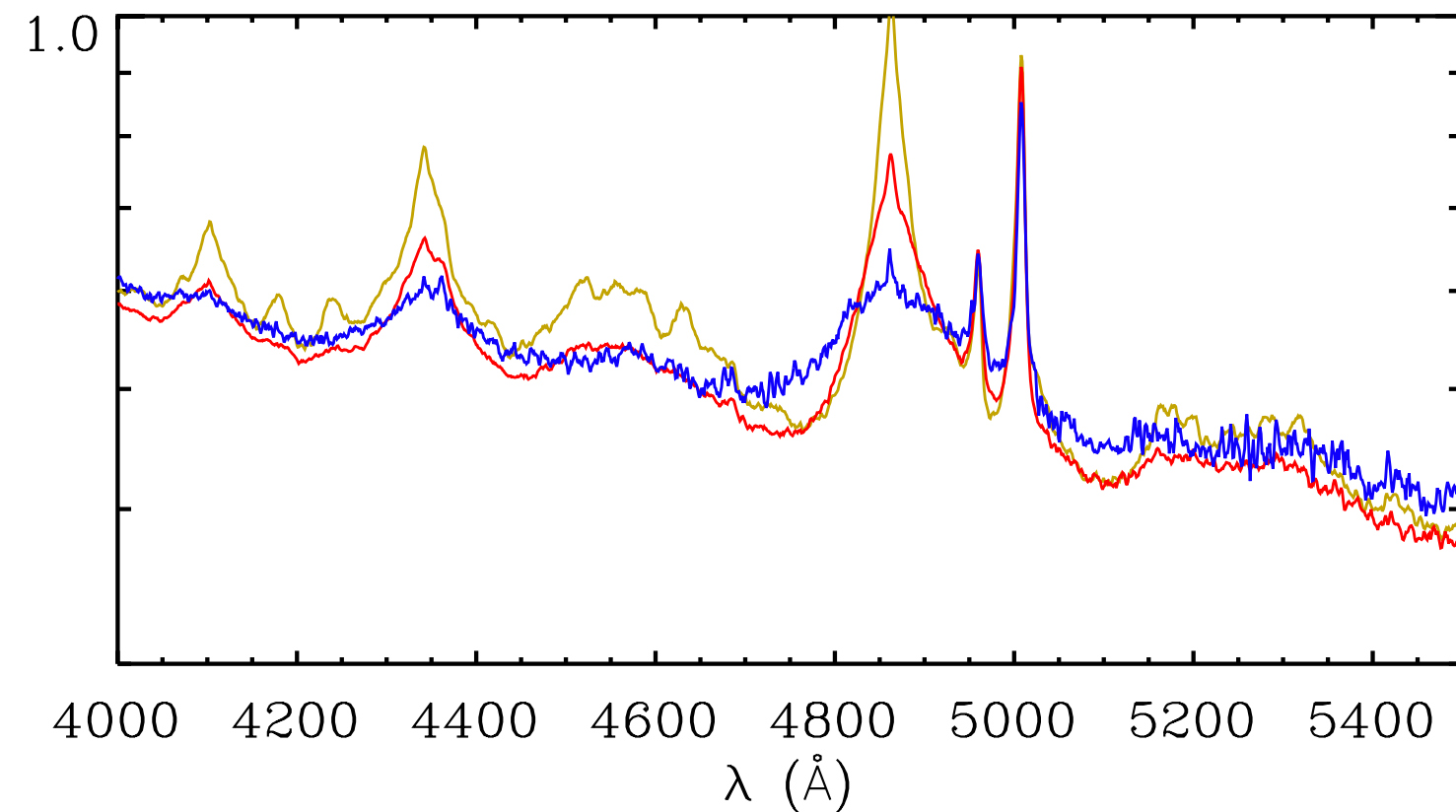
Detecting absorption lines



The diversity of quasar spectra



- Luminosity
- Slope
- Line Strength/Width
- Line Ratio



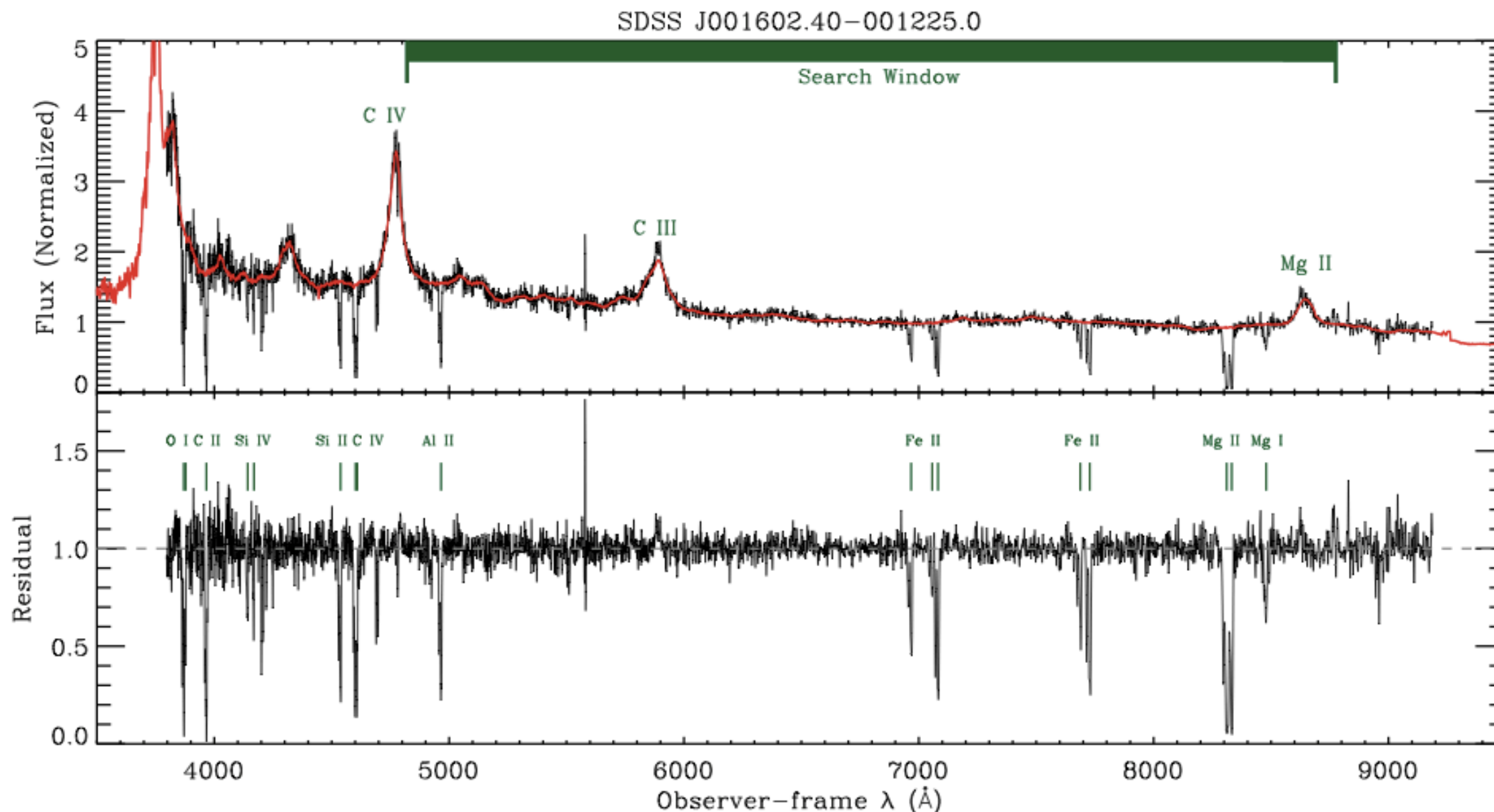
- In addition:**
- sky emission lines
 - Galactic absorption lines
 - Extragalactic absorbers

The JHU-SDSS absorber catalog

Zhu & Ménard (2013)

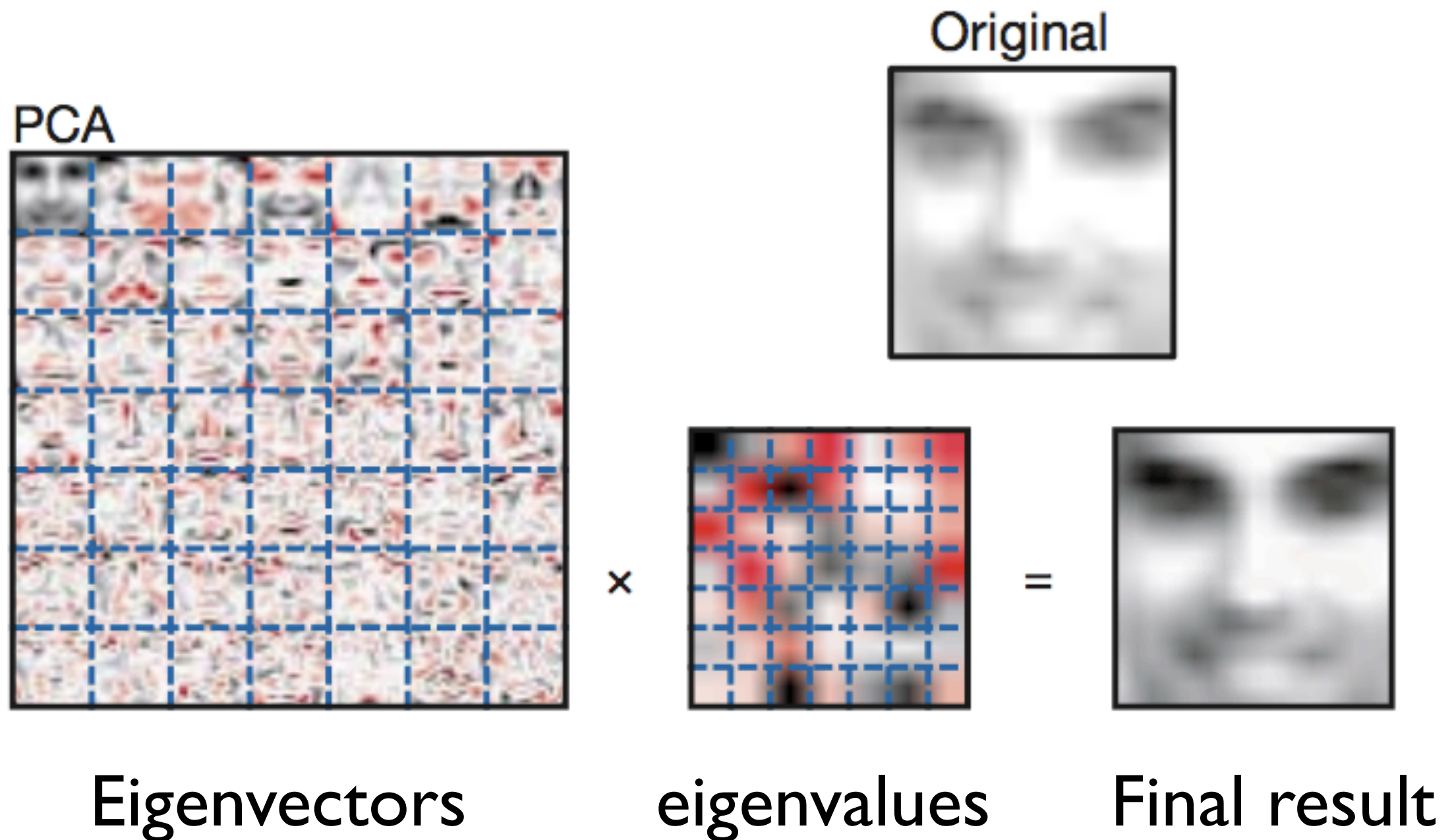
Fully automatic continuum estimate which can deal with:

- QSO emission lines
- Sky emission lines
- low S/N, missing data
- intervening absorbers



Method

- Principal Component Analysis

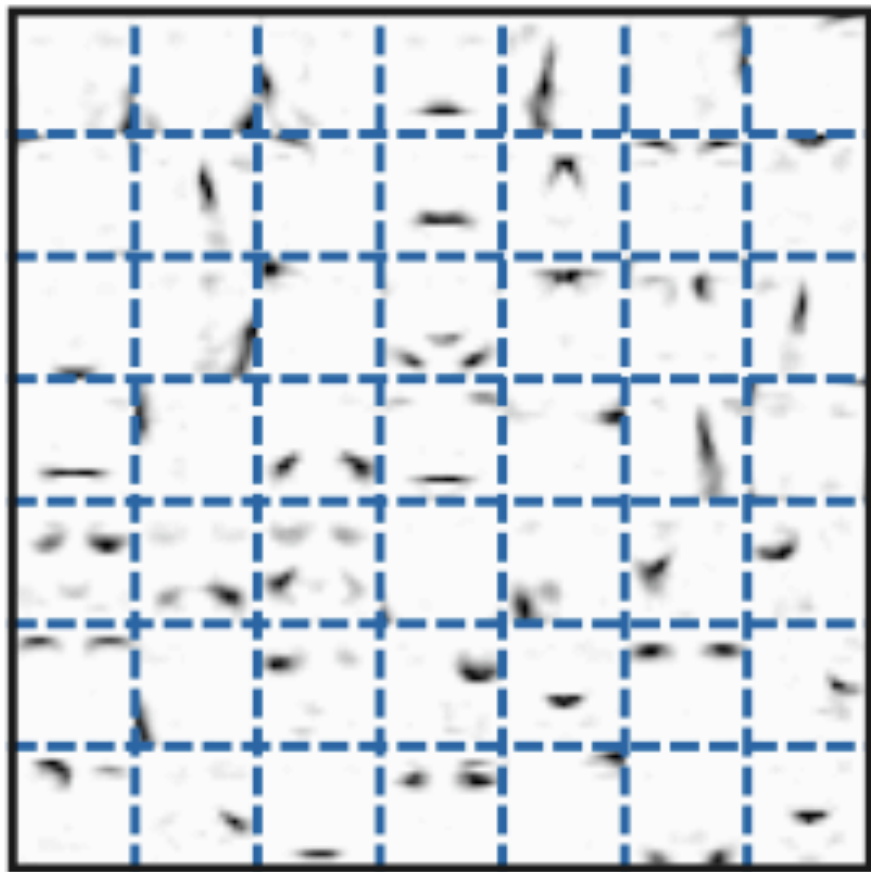


Method

- Non-negative Matrix Factorization (NMF)

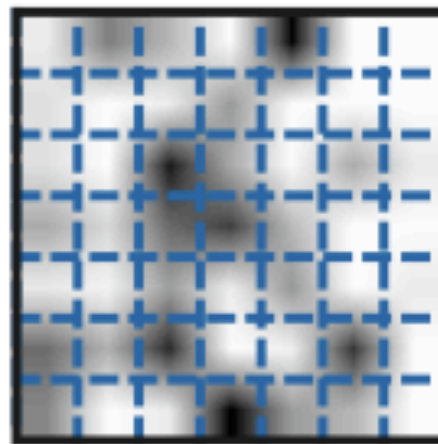
Lee & Seung (1999)

NMF



Eigenvectors

×



eigenvalues

=

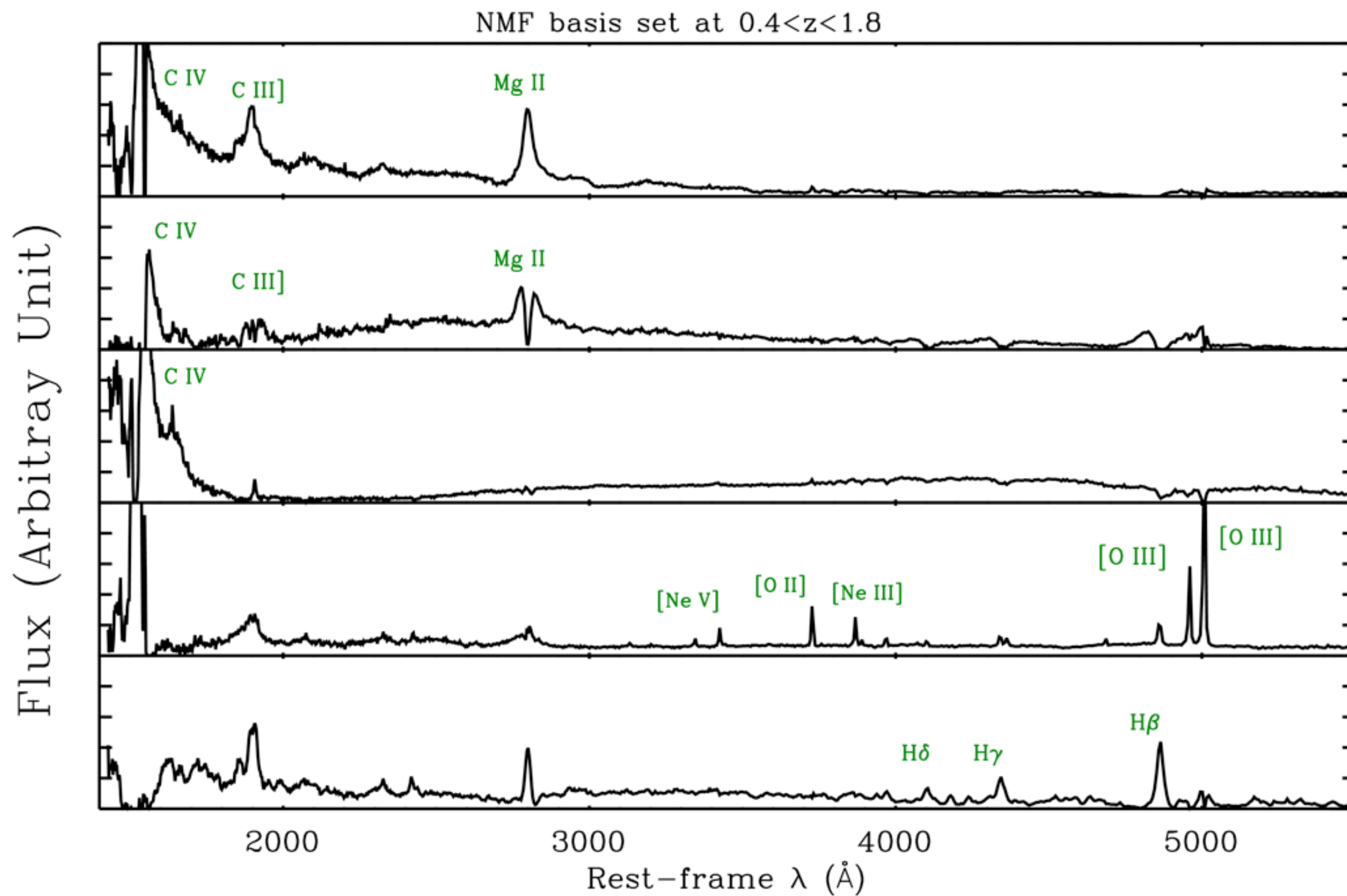


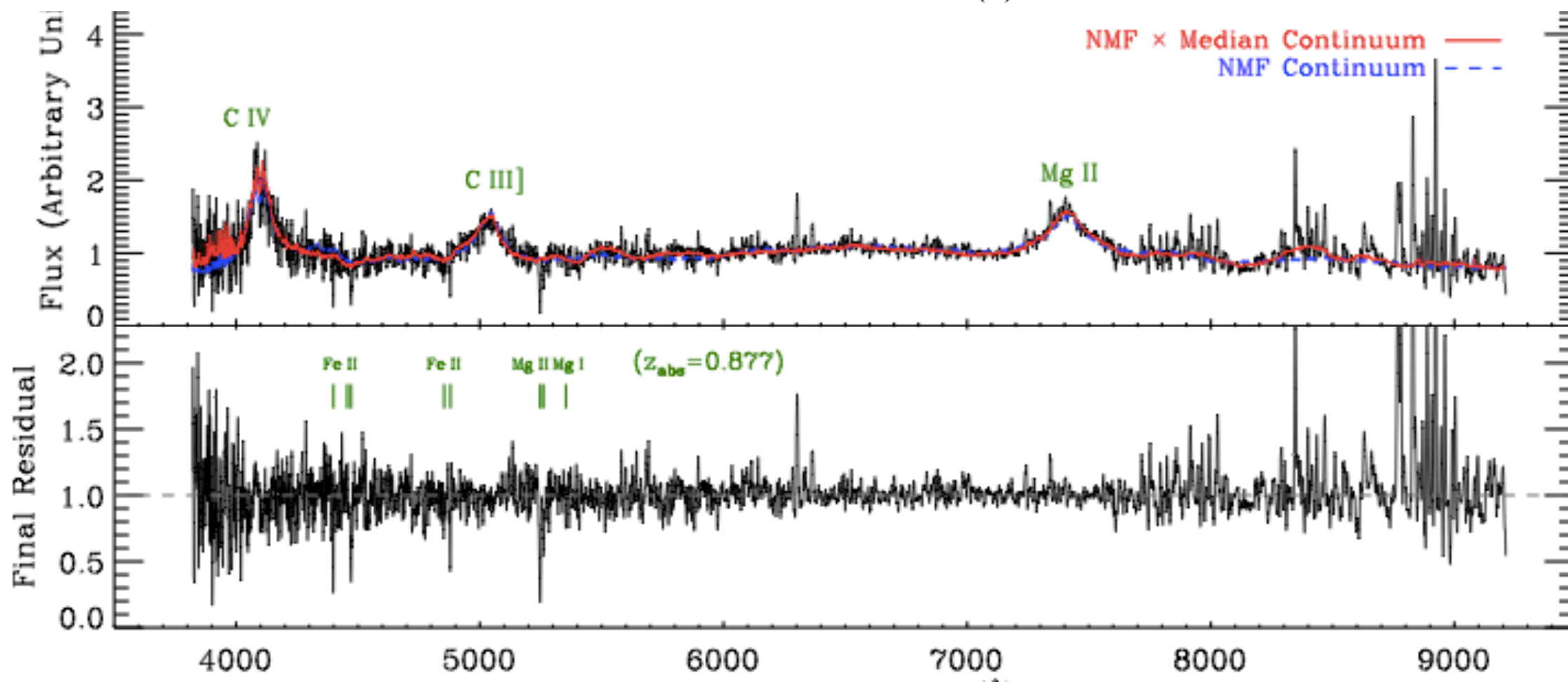
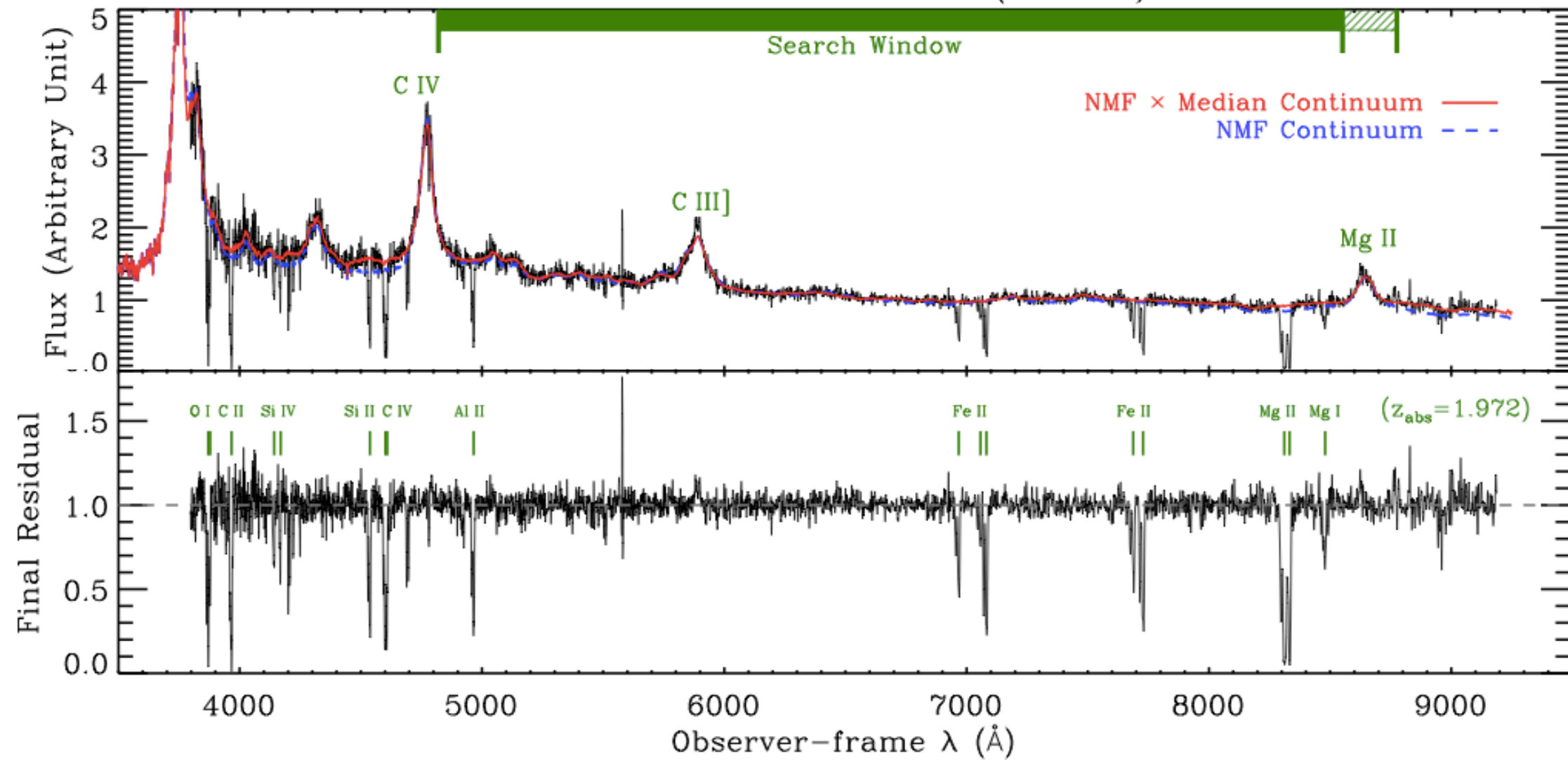
Final result

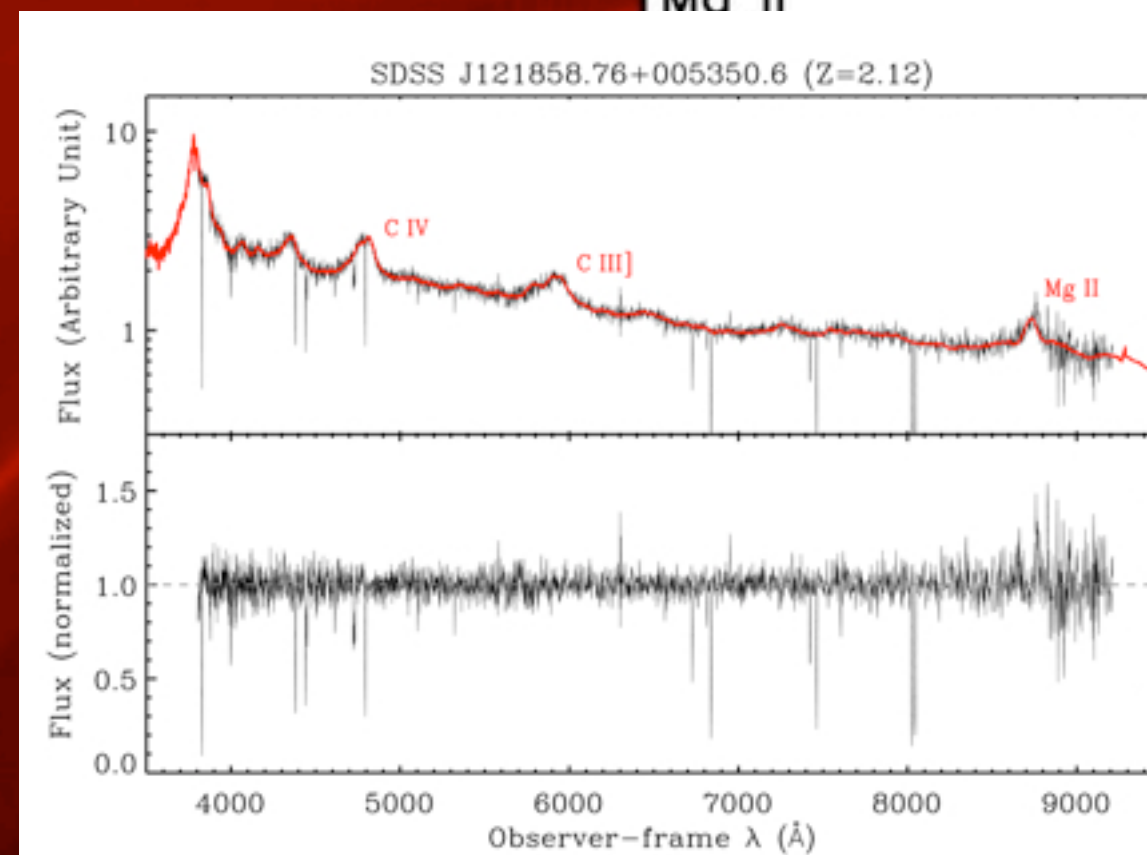
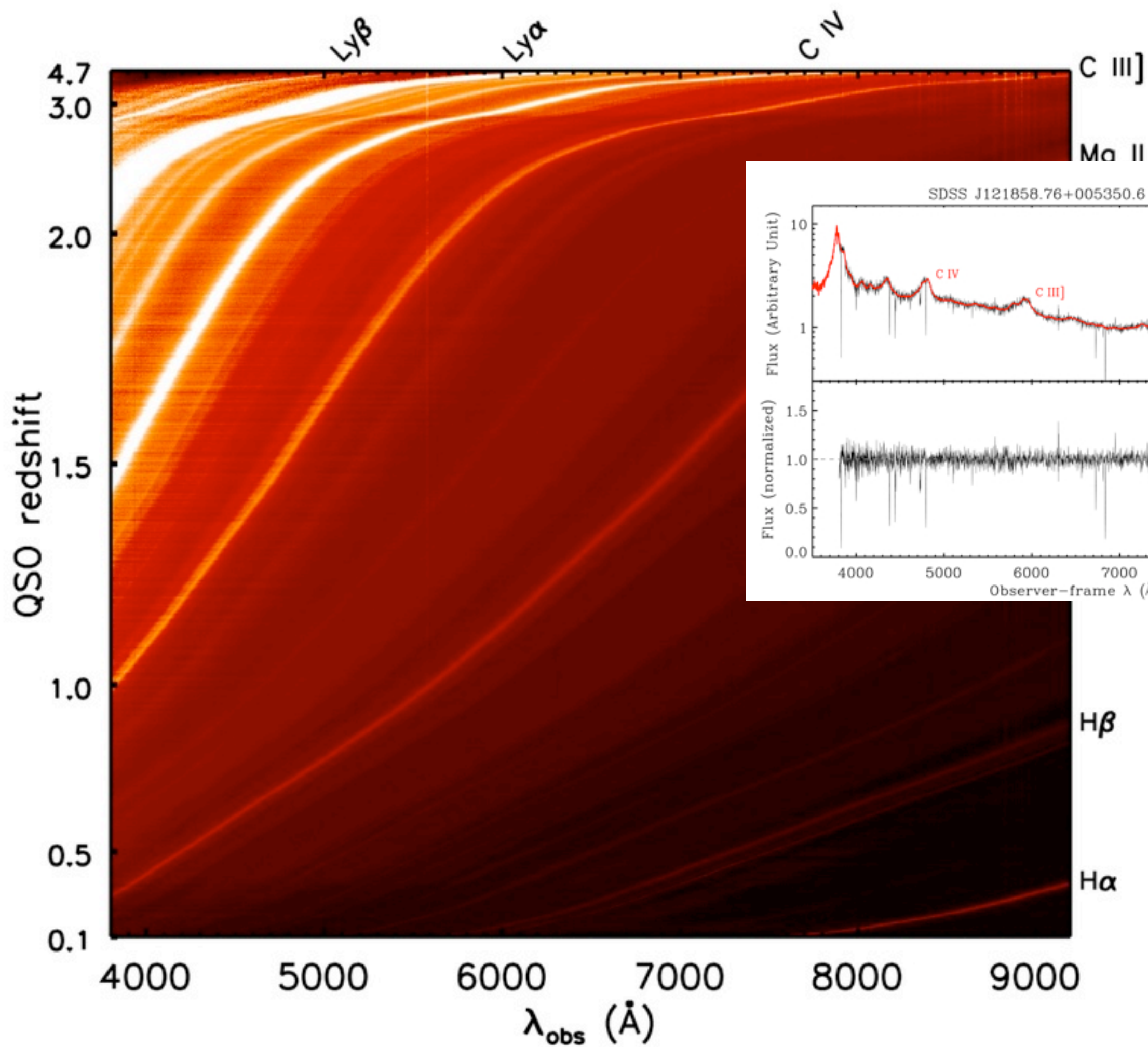
Original

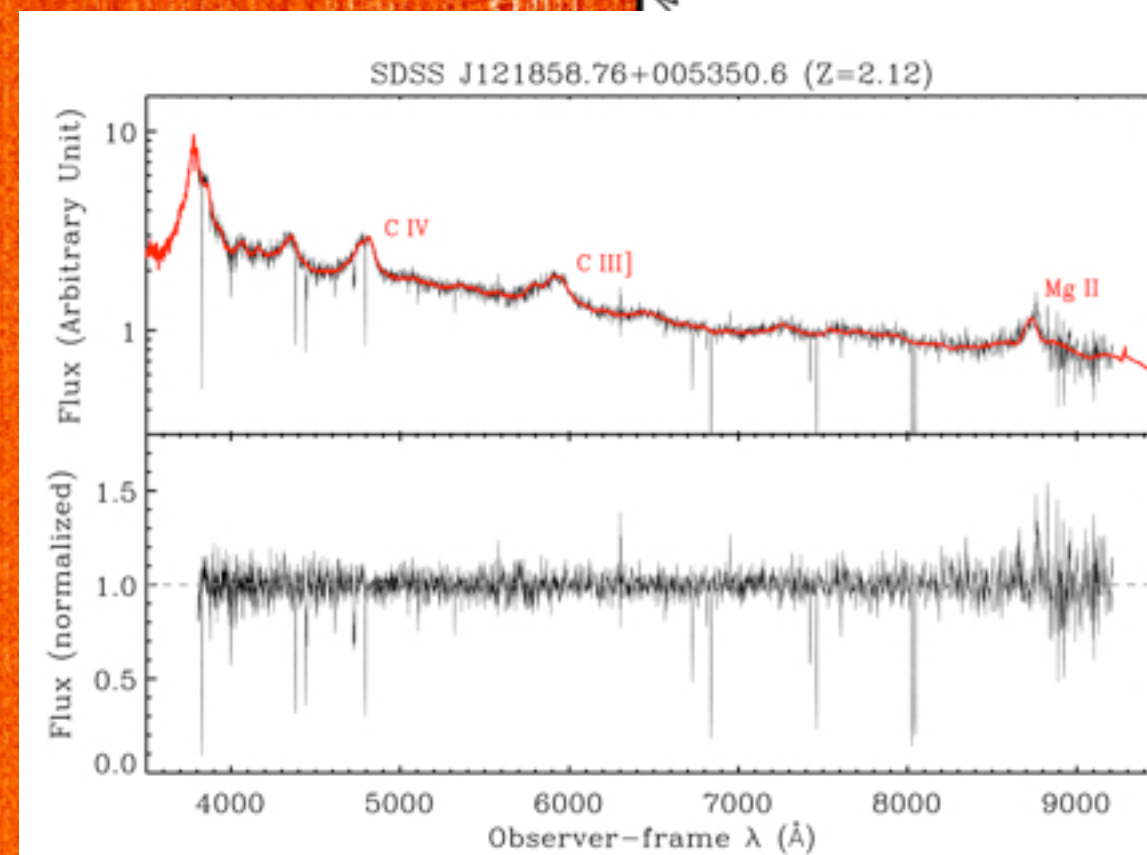
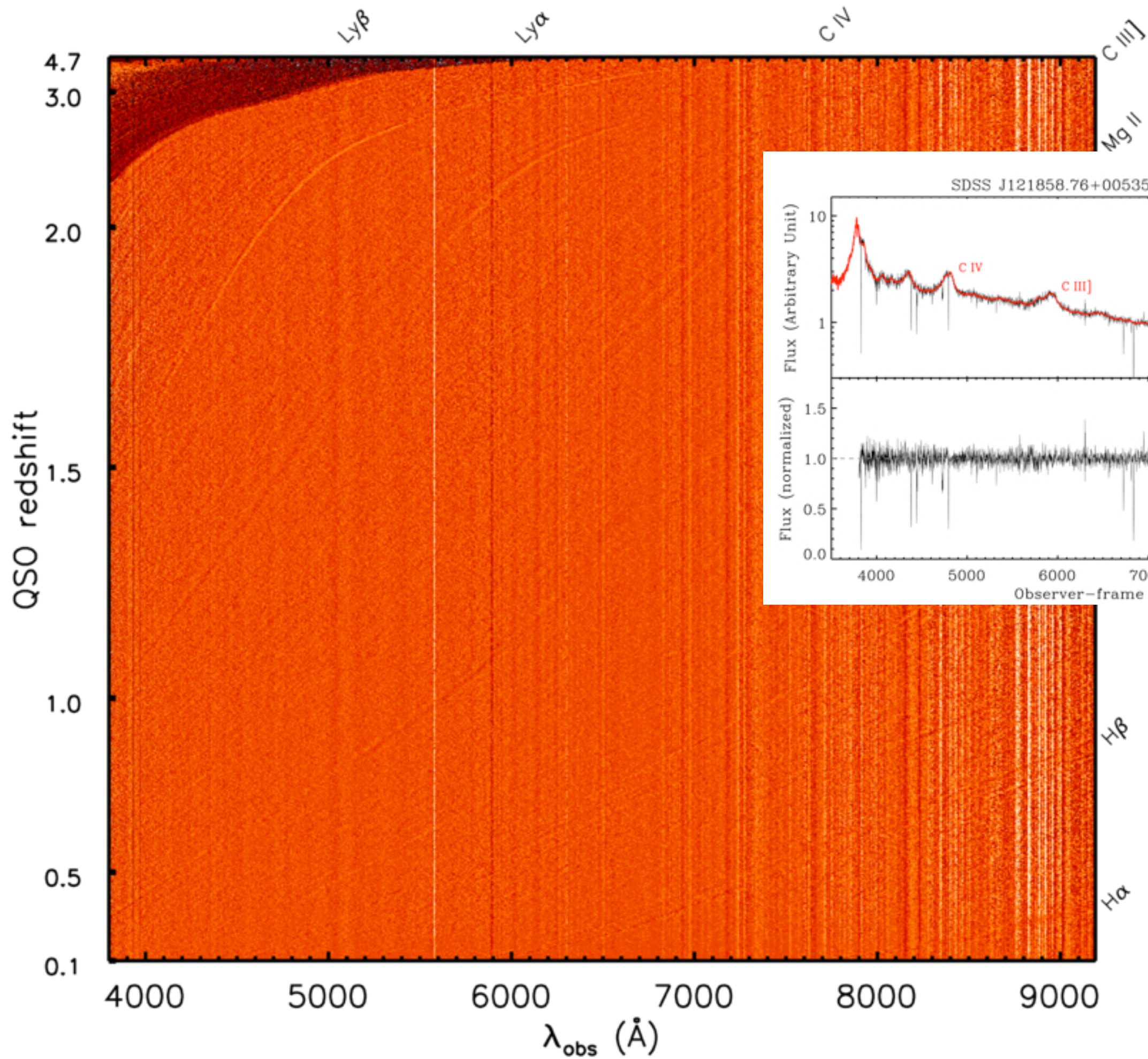


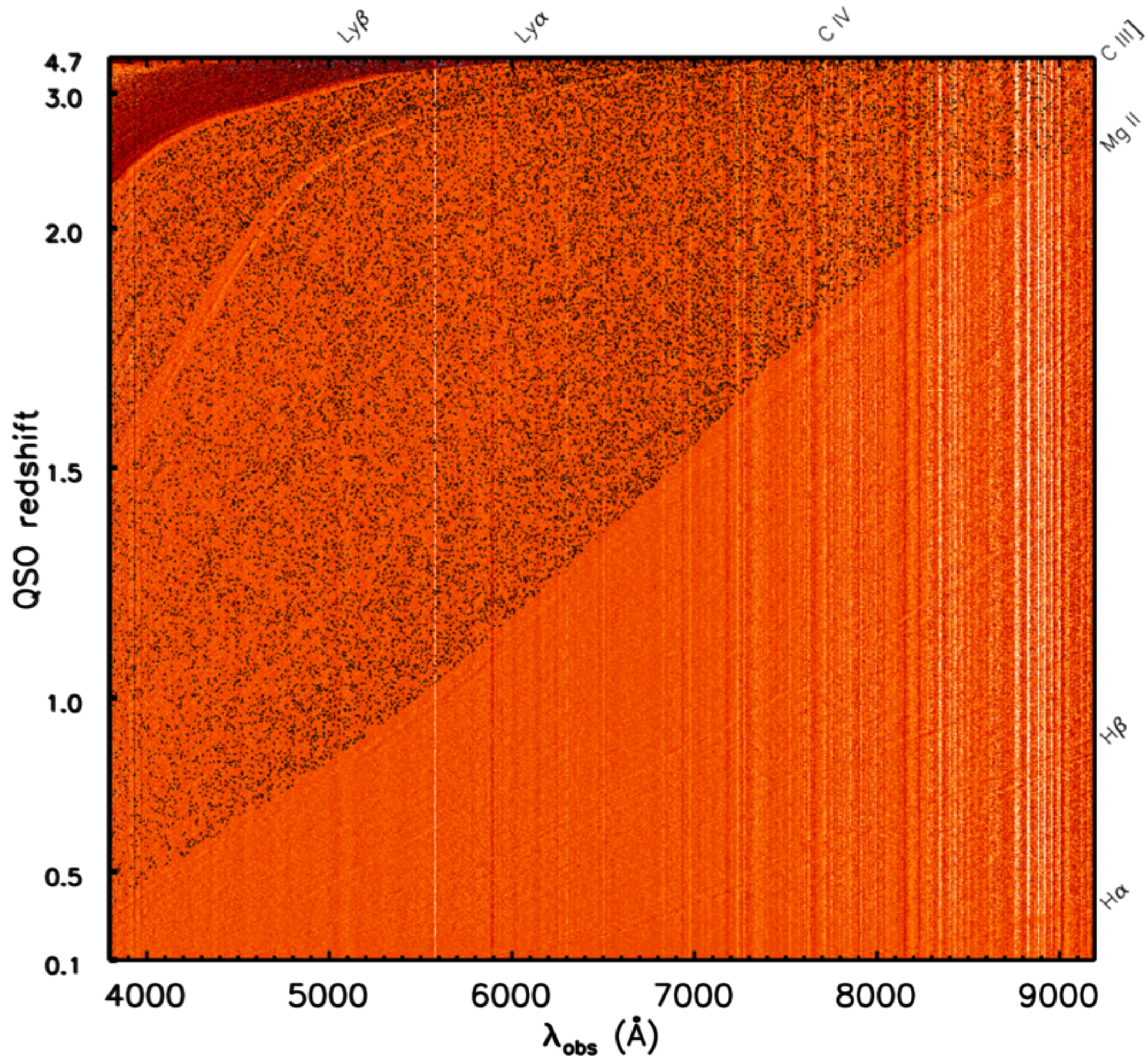
5 Eigenspectra out of 12 in the Basis Set

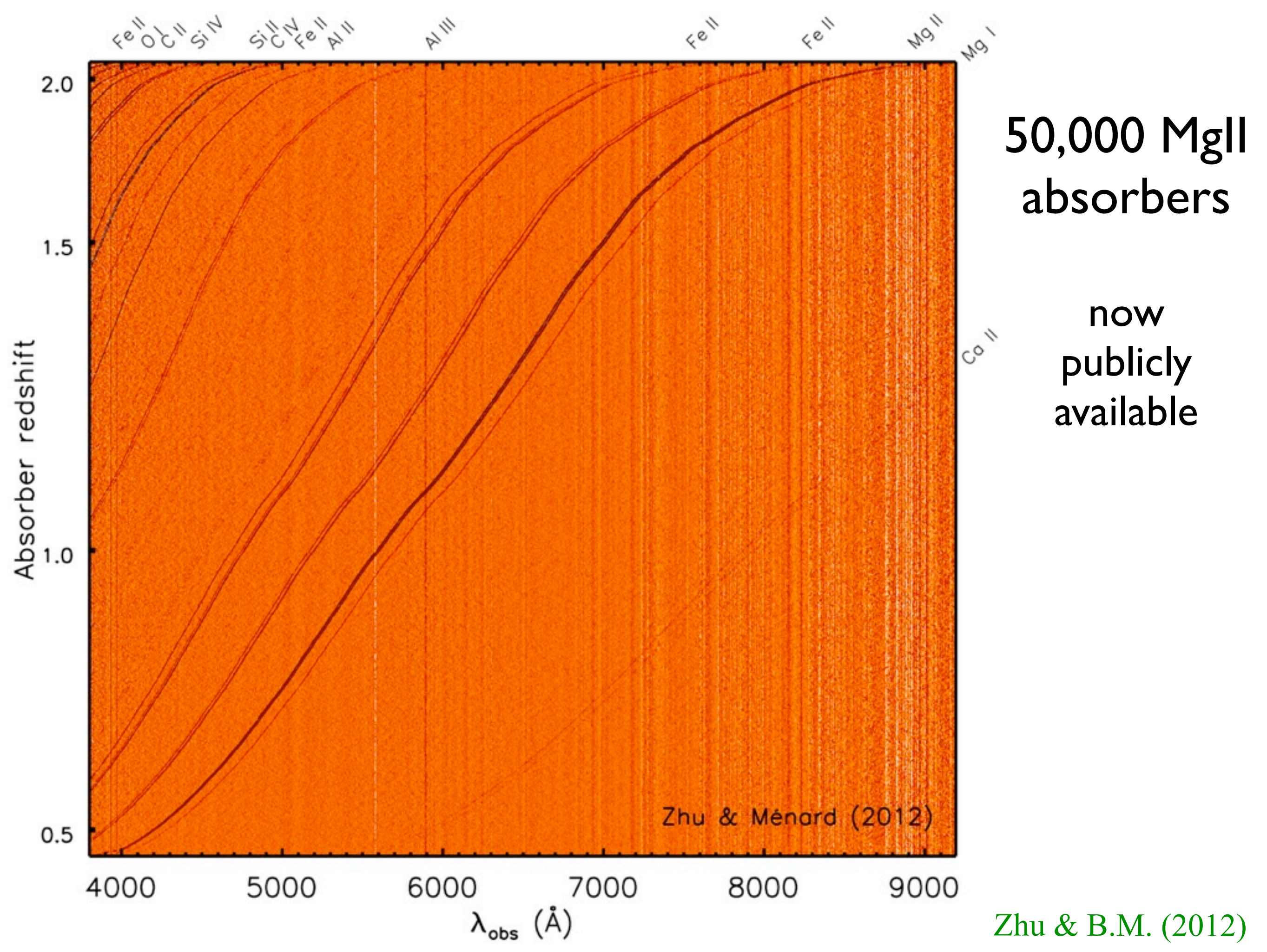






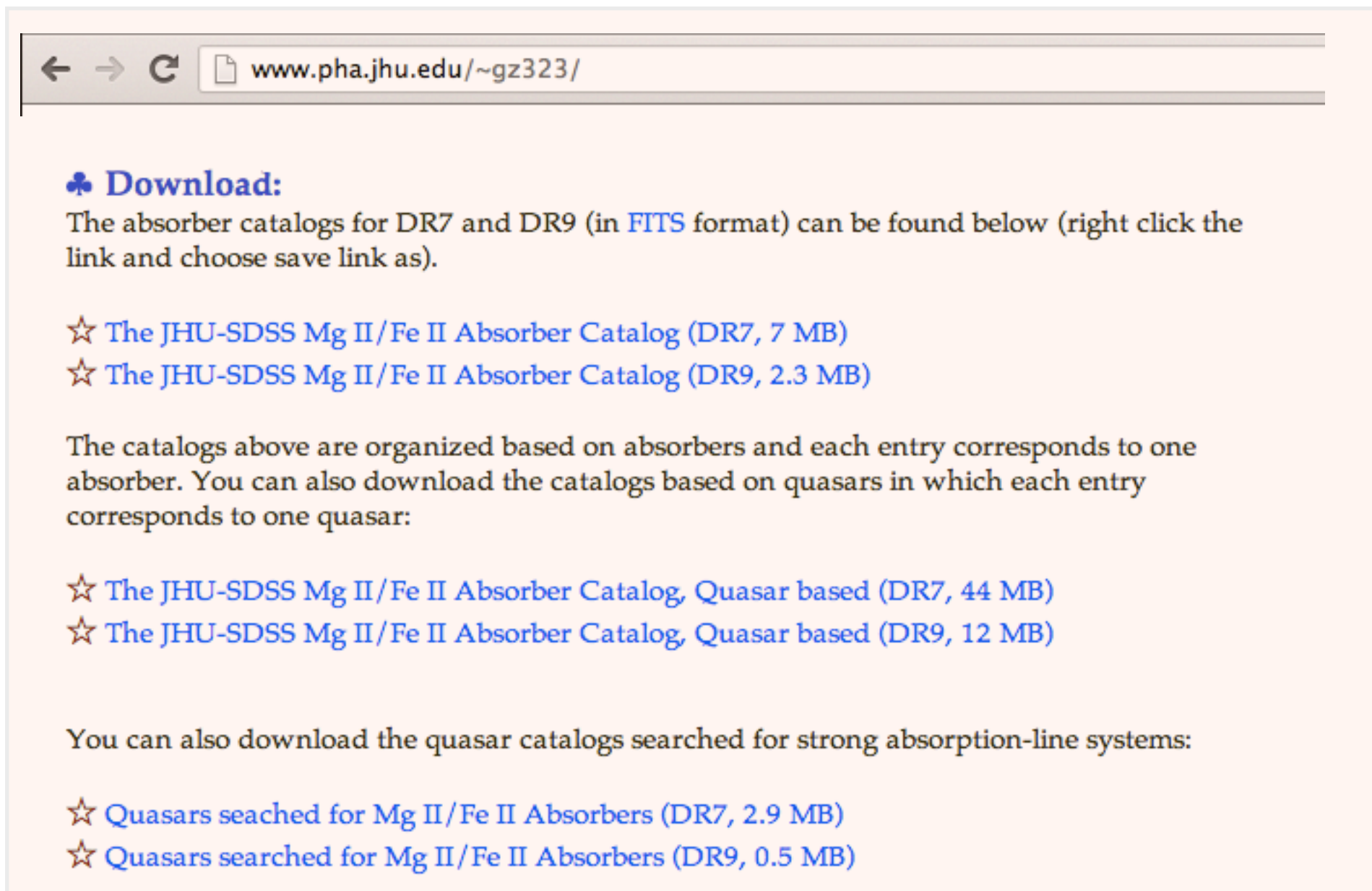






The SDSS-JHU absorber catalog

- catalog publicly available
- 50,000 MgII, Mgl & FeII absorbers ($0.4 < z < 2.5$)
- DR11 update coming up (70,000 systems)



The screenshot shows a web browser window with the address bar displaying `www.pha.jhu.edu/~gz323/`. The page content includes a "Download:" section with a blue club icon. It provides instructions on how to download the absorber catalogs for DR7 and DR9 in FITS format. There are two main sections of links, each preceded by a star icon. The first section lists the catalogs based on absorbers, and the second section lists the catalogs based on quasars. Each link specifies the data release (DR7 or DR9) and the file size in MB.

♣ Download:
The absorber catalogs for DR7 and DR9 (in [FITS](#) format) can be found below (right click the link and choose save link as).

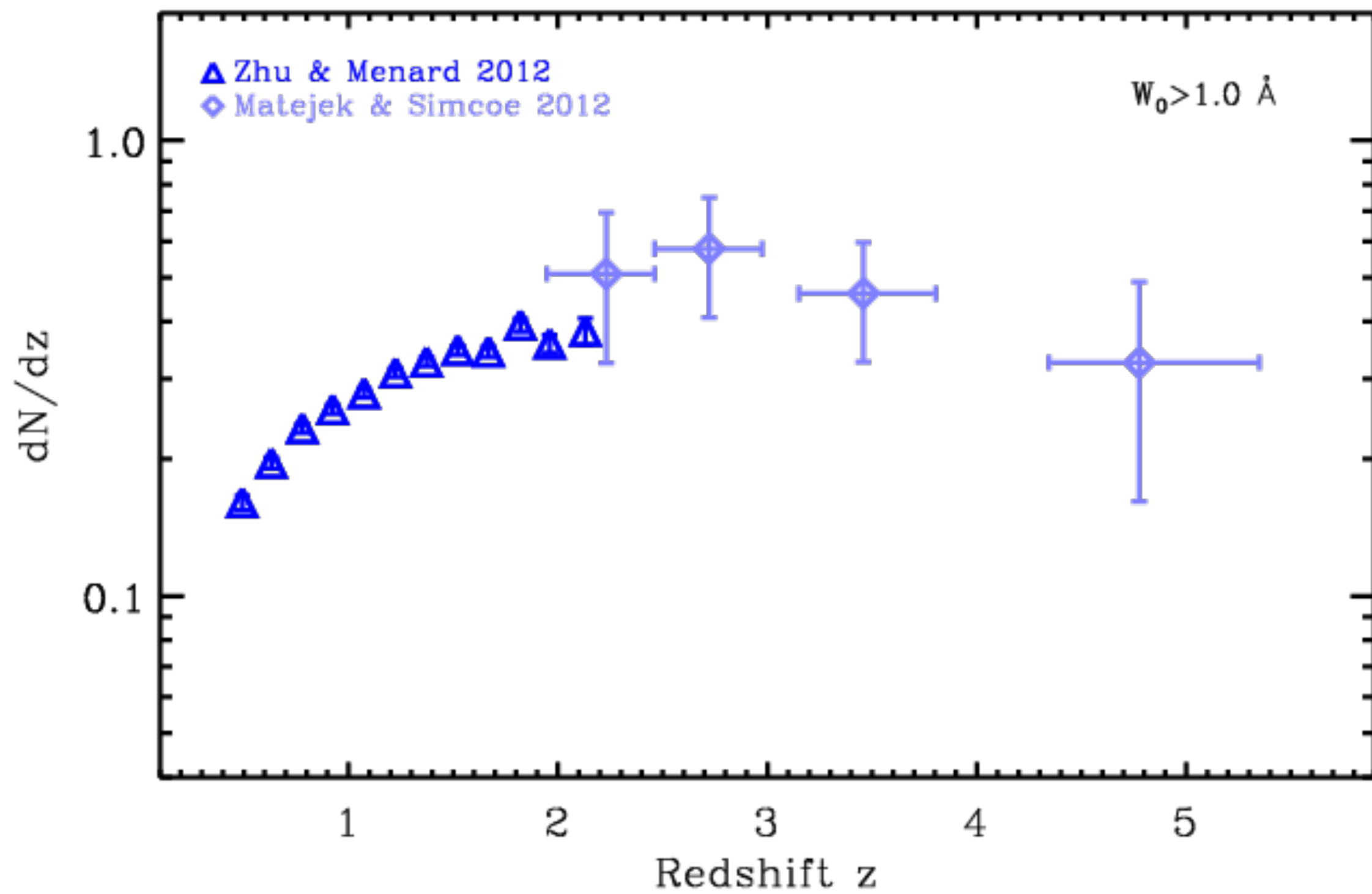
☆ [The JHU-SDSS Mg II/Fe II Absorber Catalog \(DR7, 7 MB\)](#)
☆ [The JHU-SDSS Mg II/Fe II Absorber Catalog \(DR9, 2.3 MB\)](#)

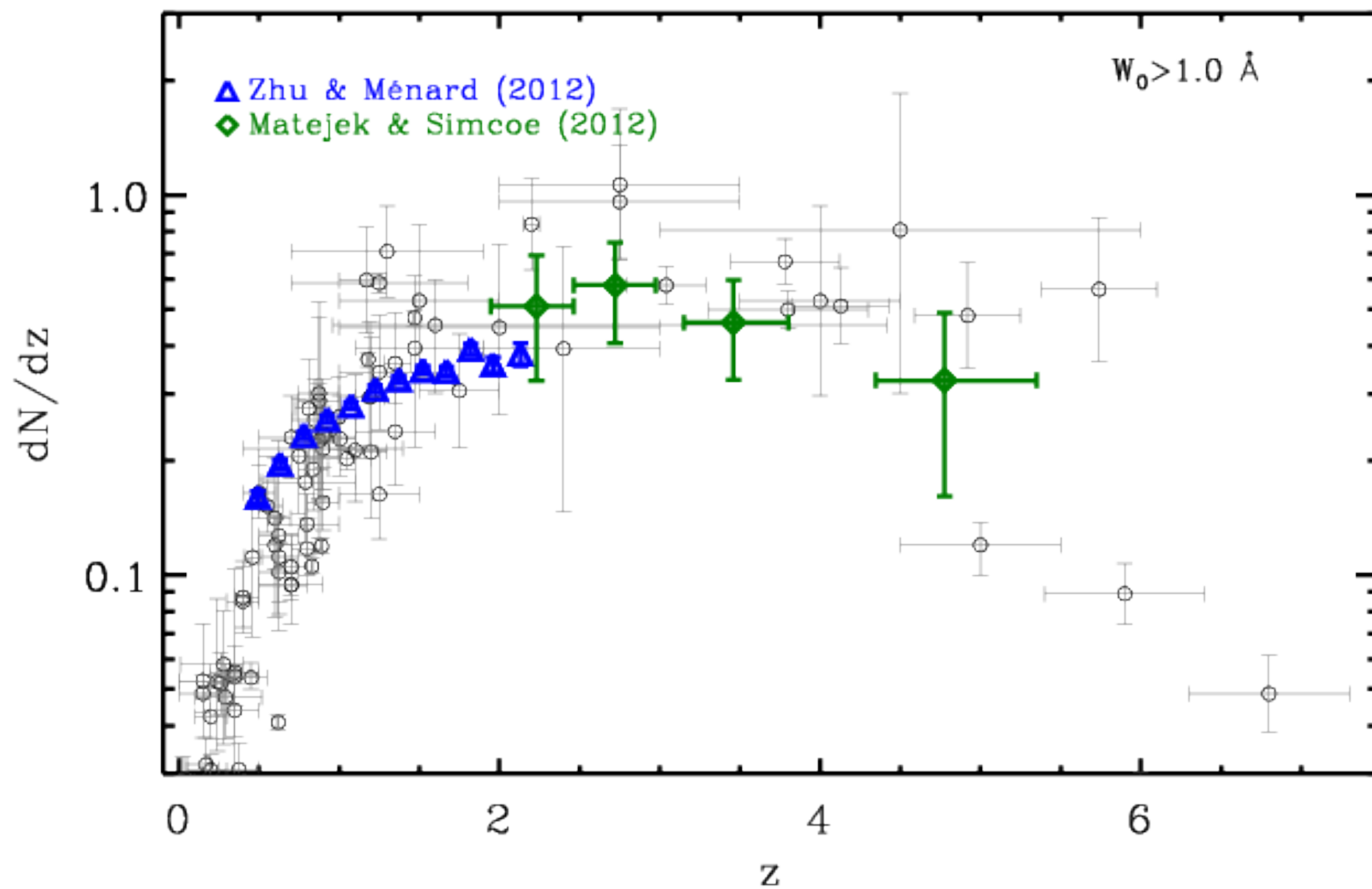
The catalogs above are organized based on absorbers and each entry corresponds to one absorber. You can also download the catalogs based on quasars in which each entry corresponds to one quasar:

☆ [The JHU-SDSS Mg II/Fe II Absorber Catalog, Quasar based \(DR7, 44 MB\)](#)
☆ [The JHU-SDSS Mg II/Fe II Absorber Catalog, Quasar based \(DR9, 12 MB\)](#)

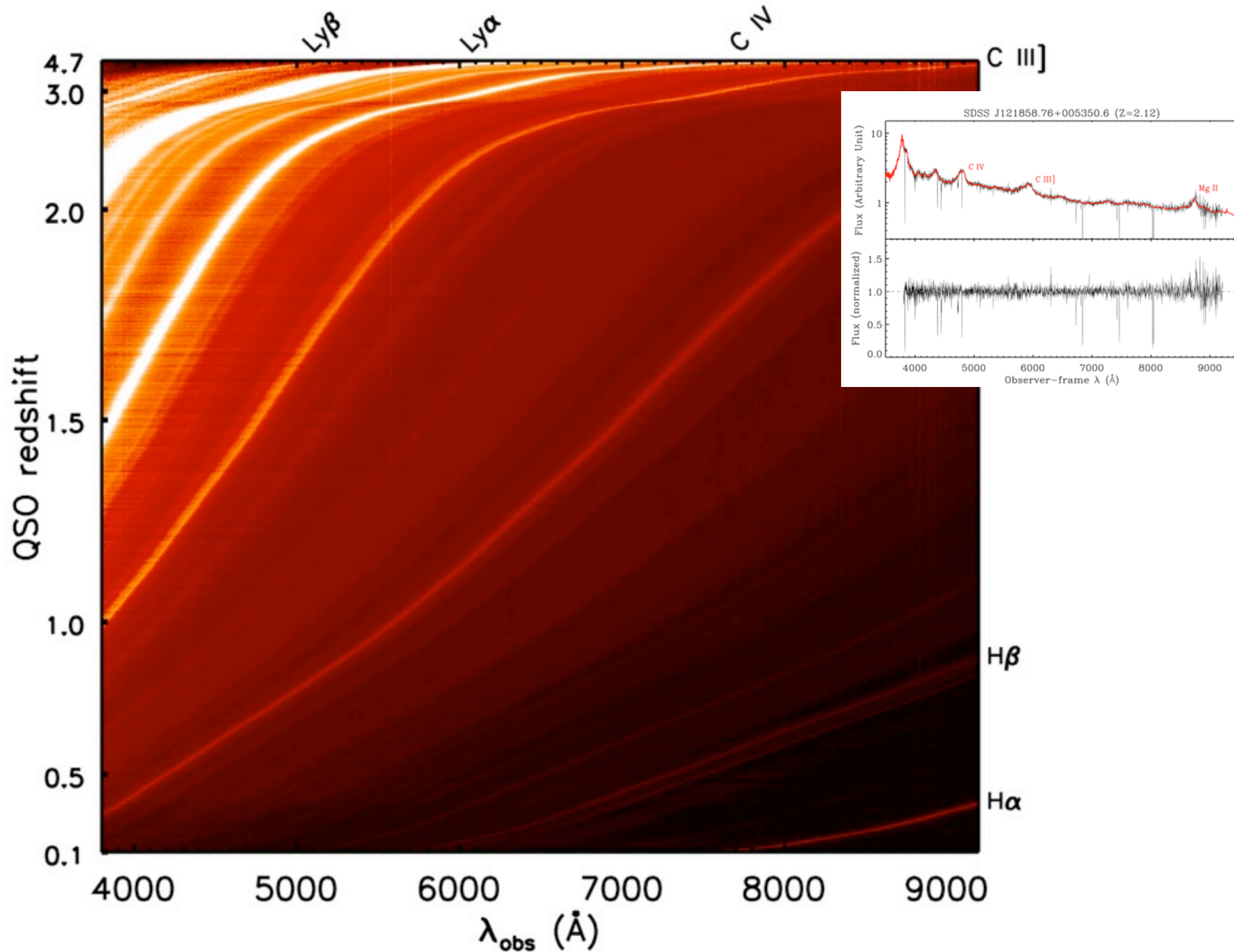
You can also download the quasar catalogs searched for strong absorption-line systems:

☆ [Quasars searched for Mg II/Fe II Absorbers \(DR7, 2.9 MB\)](#)
☆ [Quasars searched for Mg II/Fe II Absorbers \(DR9, 0.5 MB\)](#)





200,000 quasars from SDSS 1-3

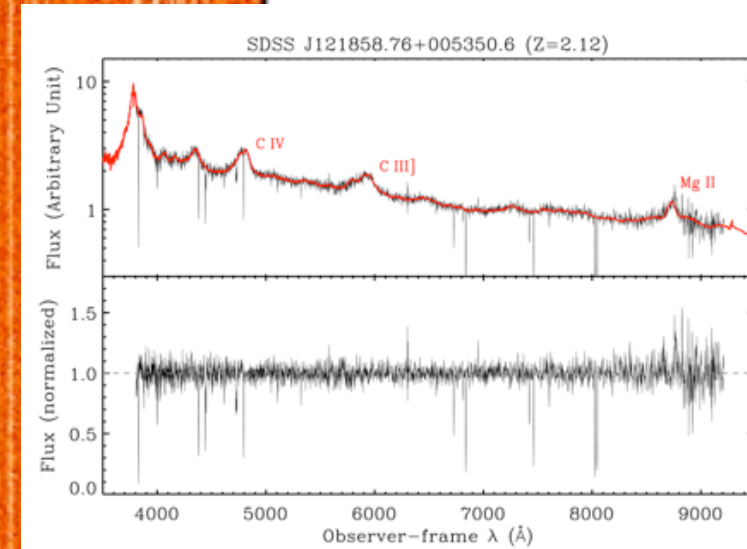
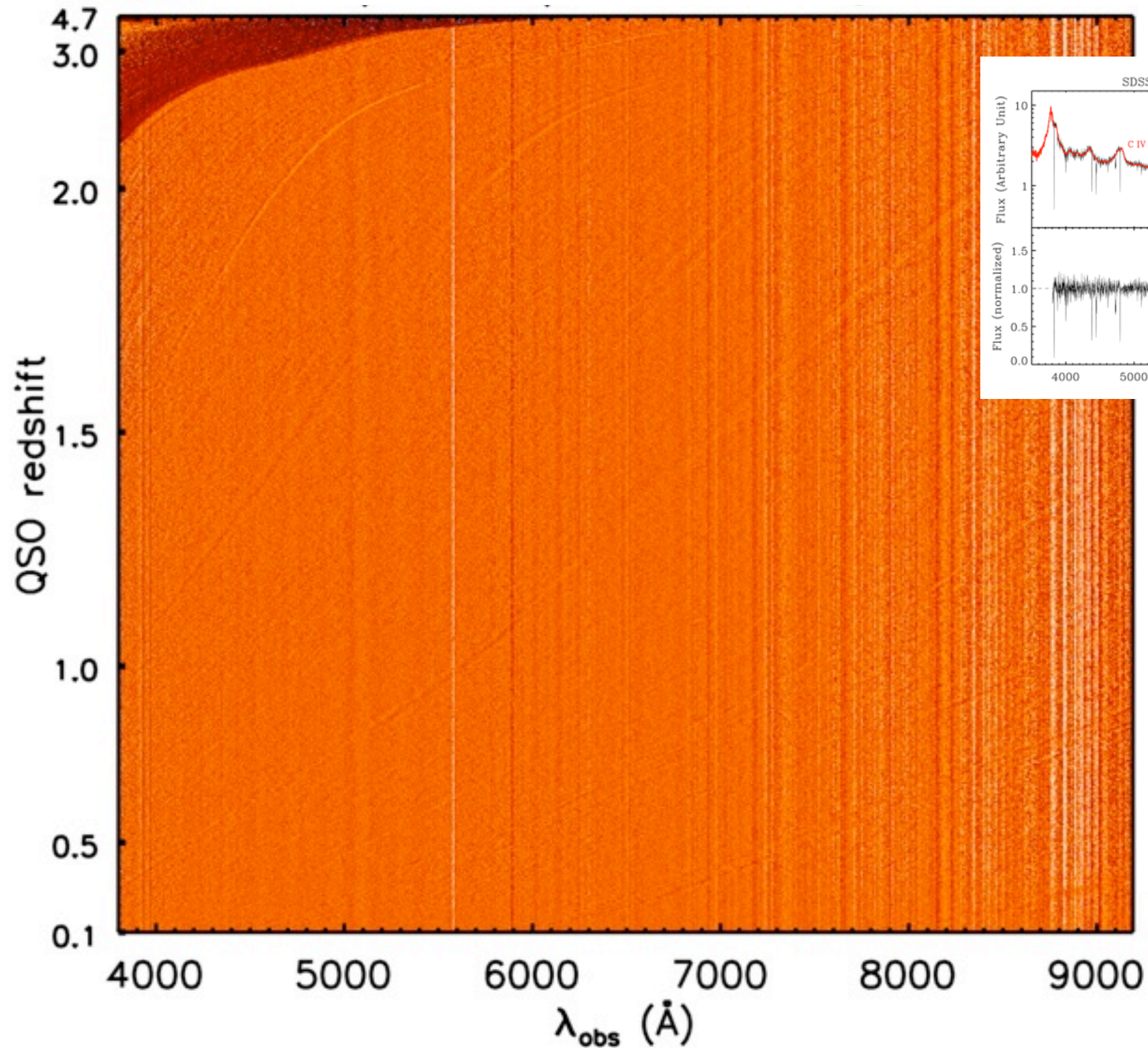


600 million
pixels

$$\langle \delta F_{\lambda}(\theta) \cdot \delta_g(\theta + \phi) \rangle$$

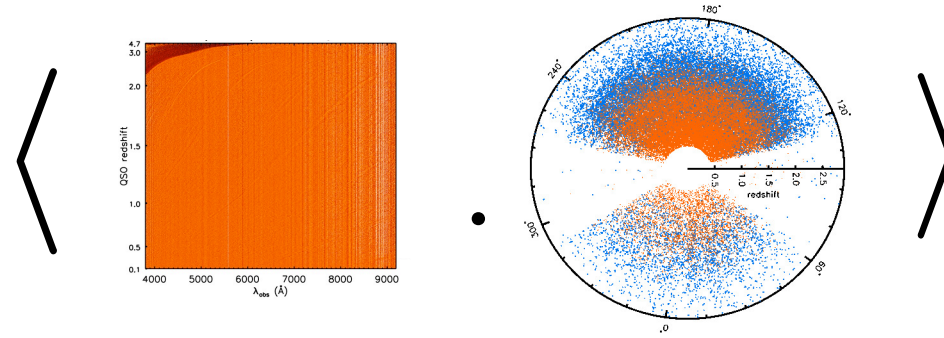
Gas

Galaxy



$$\langle \delta F_{\lambda}(r_p) \cdot \delta_g \rangle$$

Call absorption
in quasar spectra



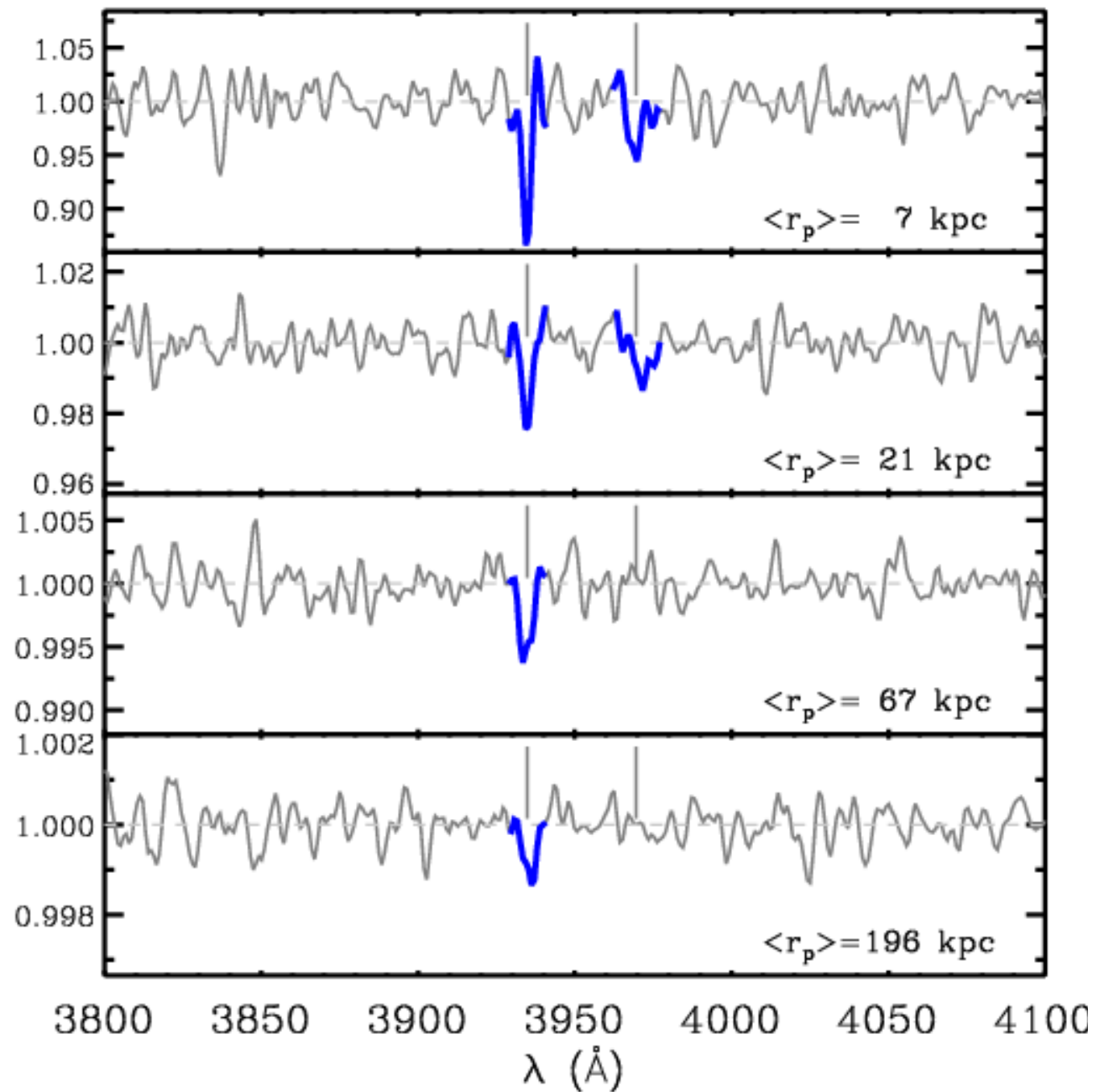
SDSS galaxies
at $z \sim 0.1$

Absorption
Strength

10^{-2}

Normalized Flux

10^{-3}

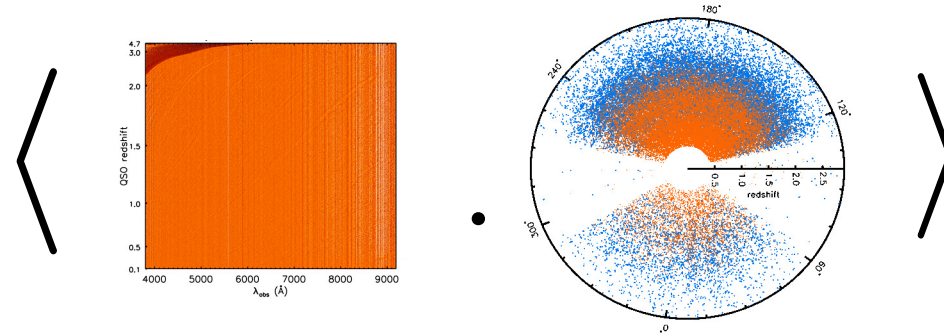


Previous
detections

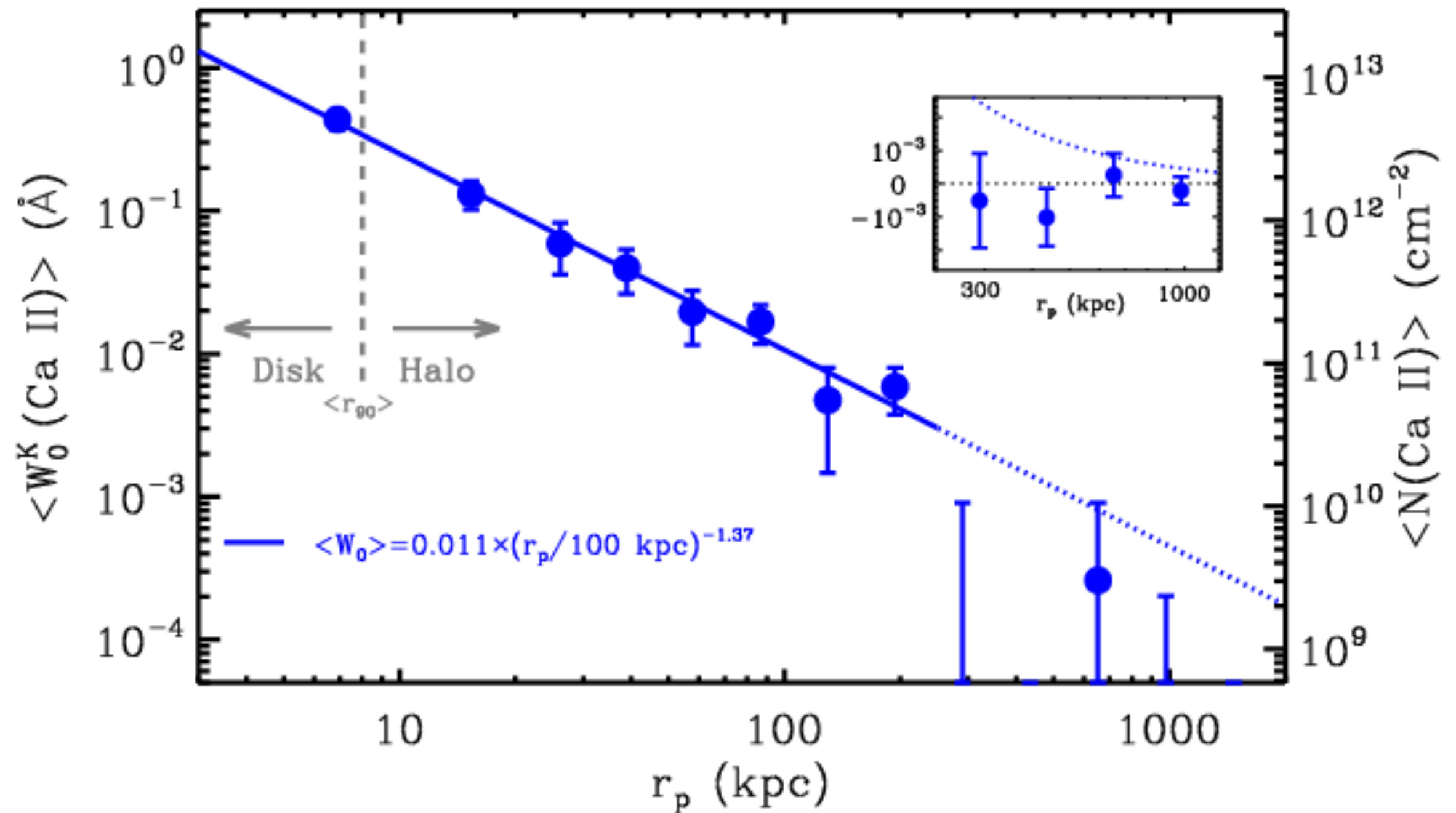
Unexplored

$$\langle \delta F_{\lambda}(r_p) \cdot \delta_g \rangle$$

Call absorption
in quasar spectra

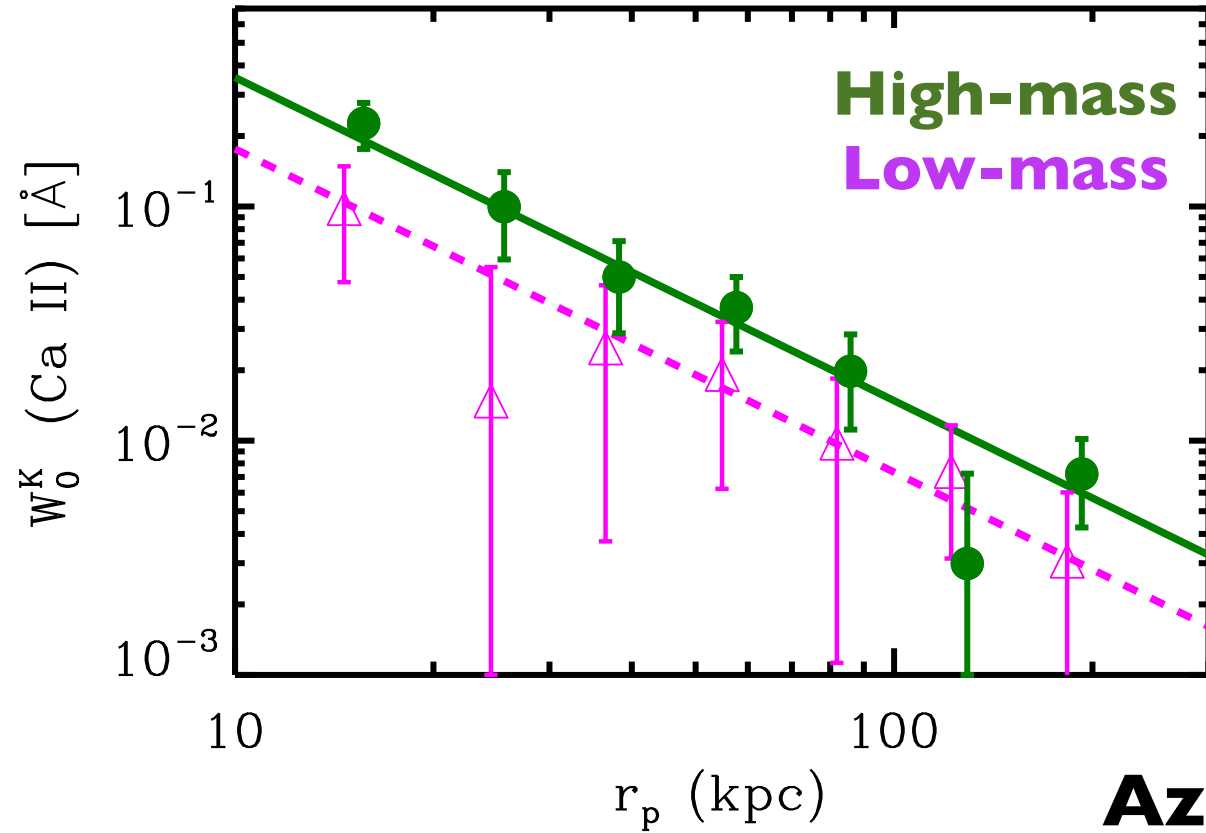


SDSS galaxies
at $z \sim 0.1$

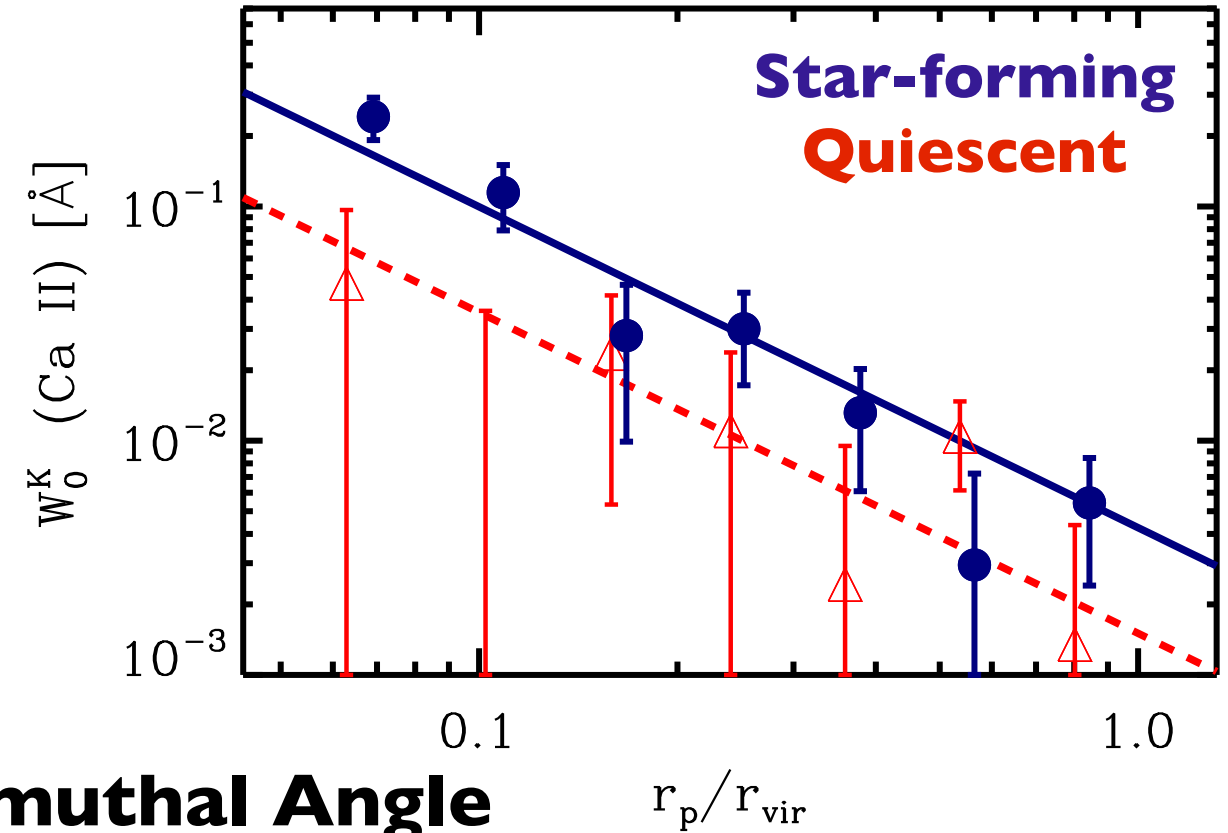


Gas halo as a function of galaxy properties

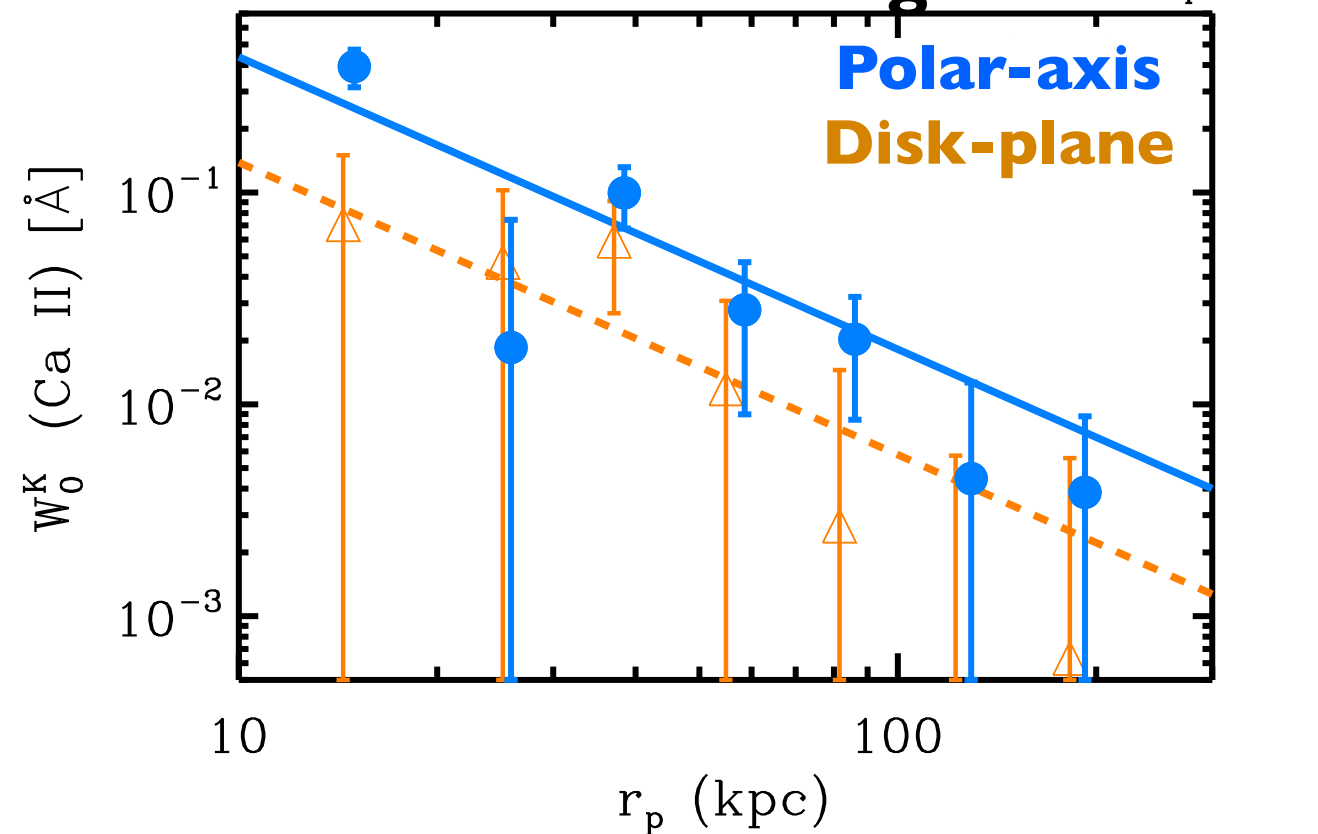
Stellar Mass



Star Formation Rate



Azimuthal Angle

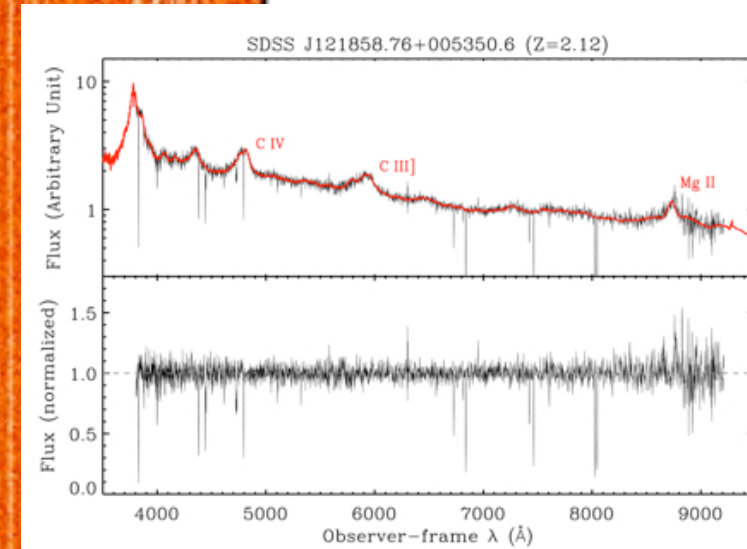
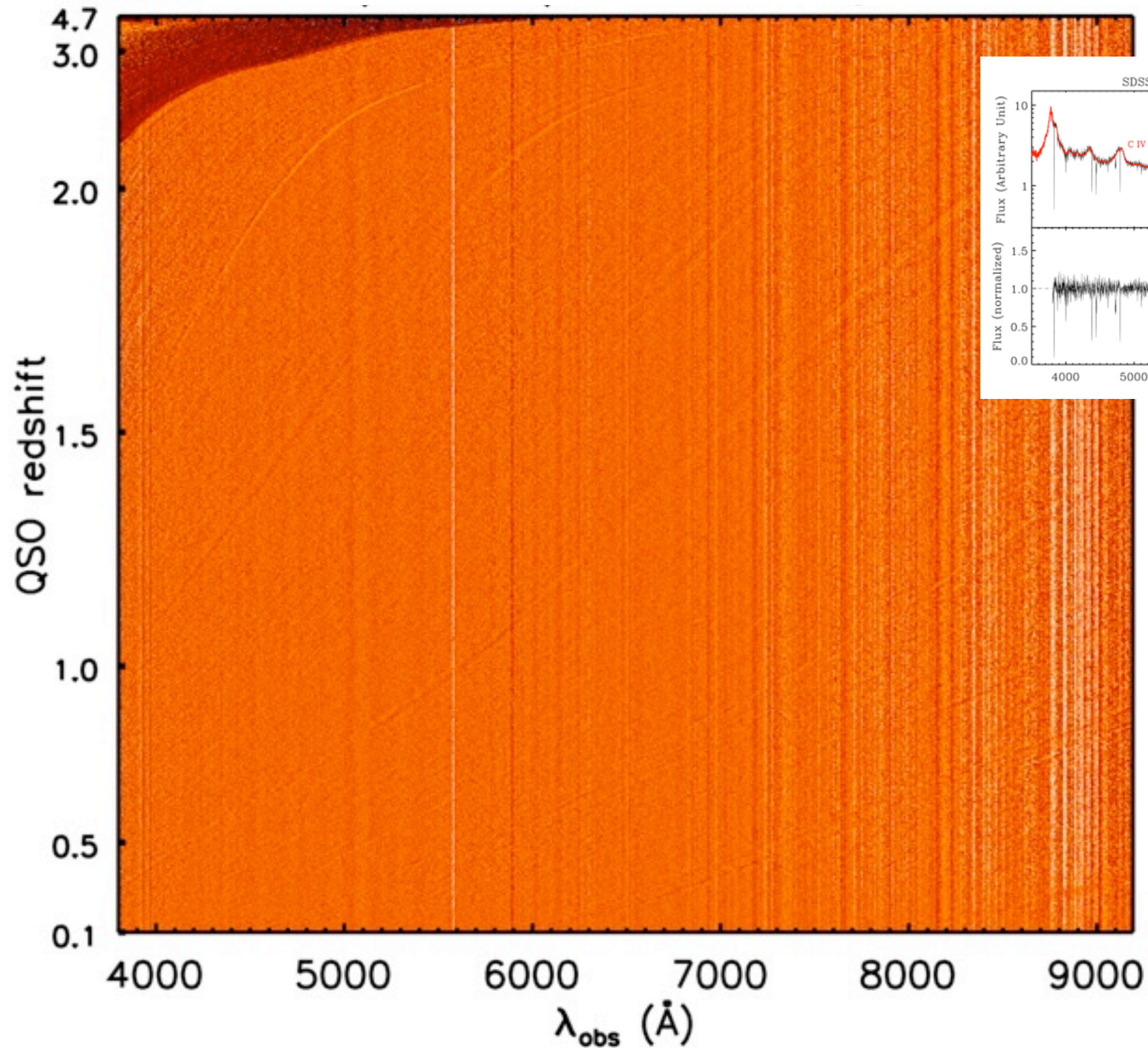


600 million
pixels

$$\langle \delta F_{\lambda}(\theta) \cdot \delta_g(\theta + \phi) \rangle$$

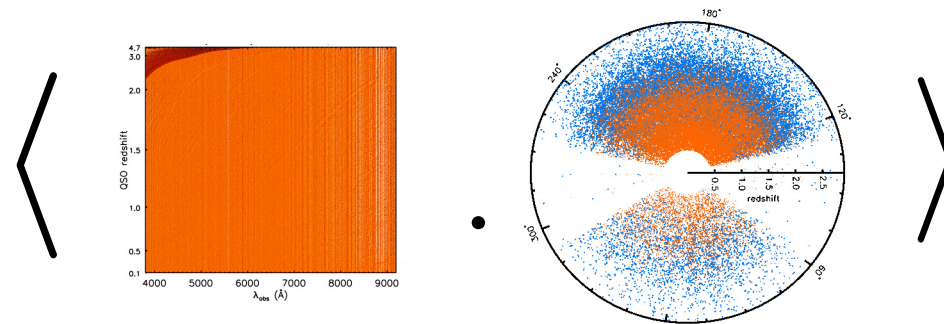
Gas

Galaxy



$$\langle \delta F_{\lambda}(r_p) \cdot \delta_g \rangle$$

Mg II absorption
in quasar spectra



SDSS LRGs
at $z \sim 0.5$

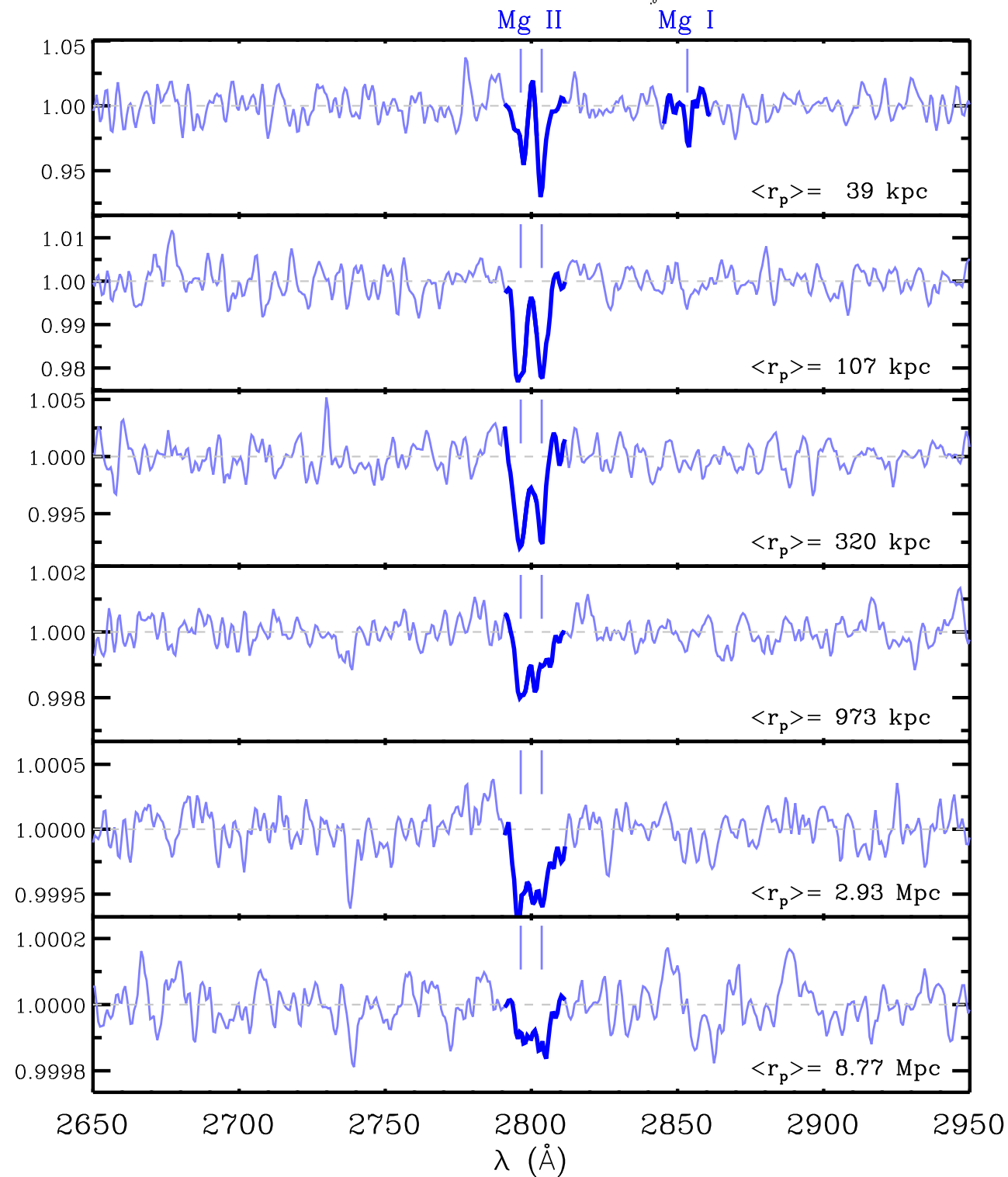
Absorption
Strength

10^{-2}

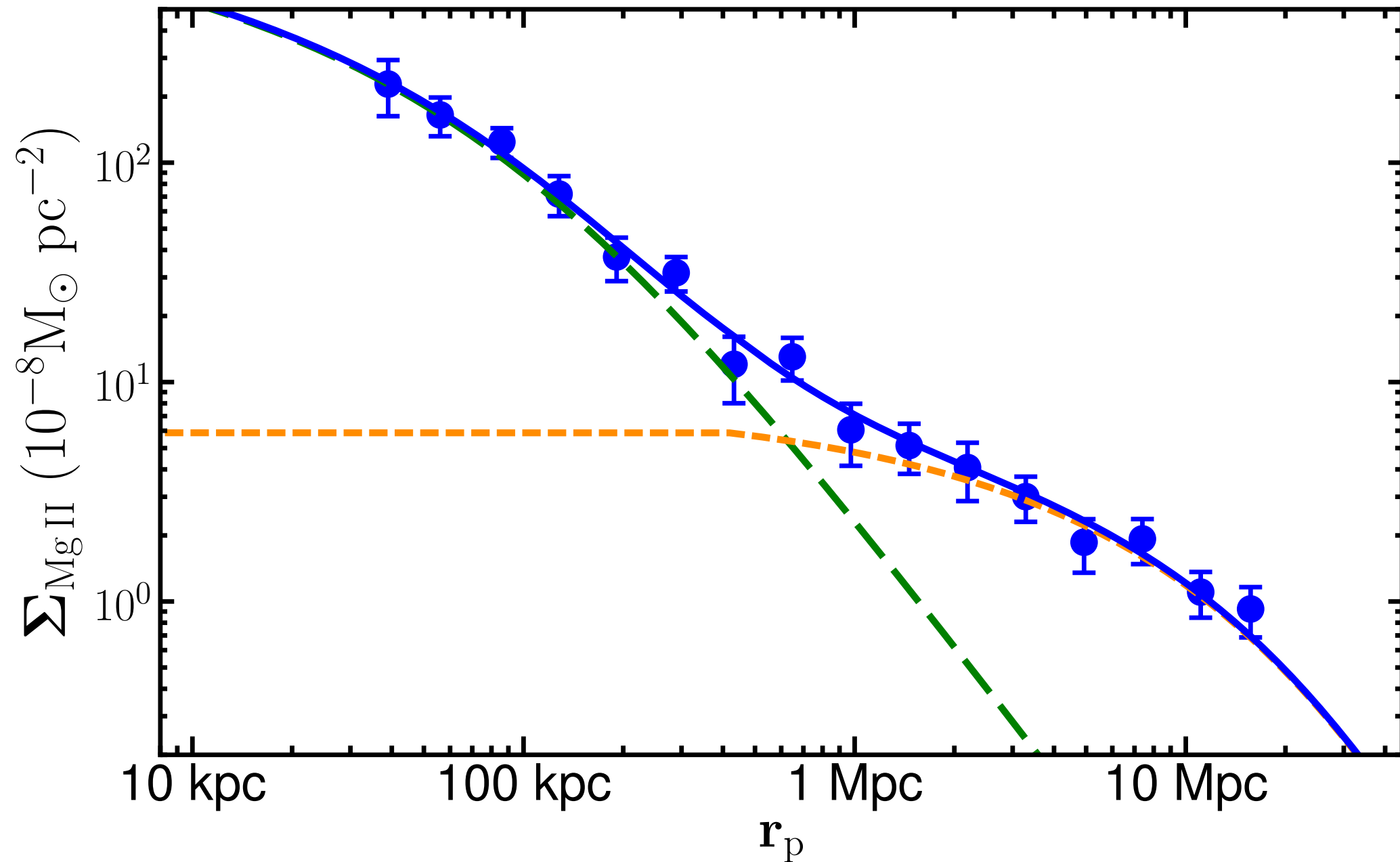
10^{-3}

10^{-4}

Normalized Flux

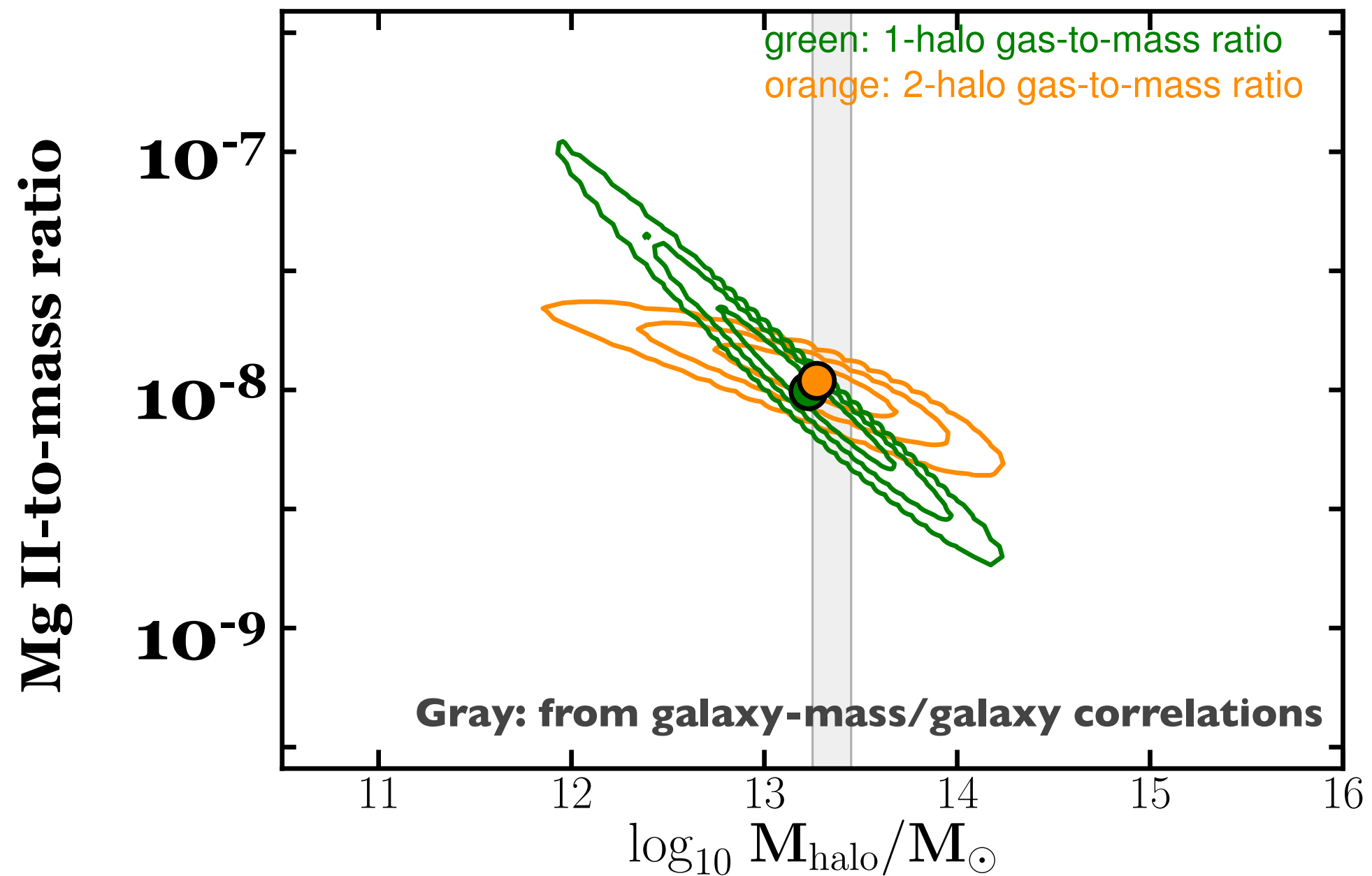


The halo model for gas



- 1-halo term: NFW profile (dark matter) \times gas-to-mass ratio
- 2-halo term: halo-mass correlation \times \langle gas-to-mass ratio \rangle

The halo model for gas



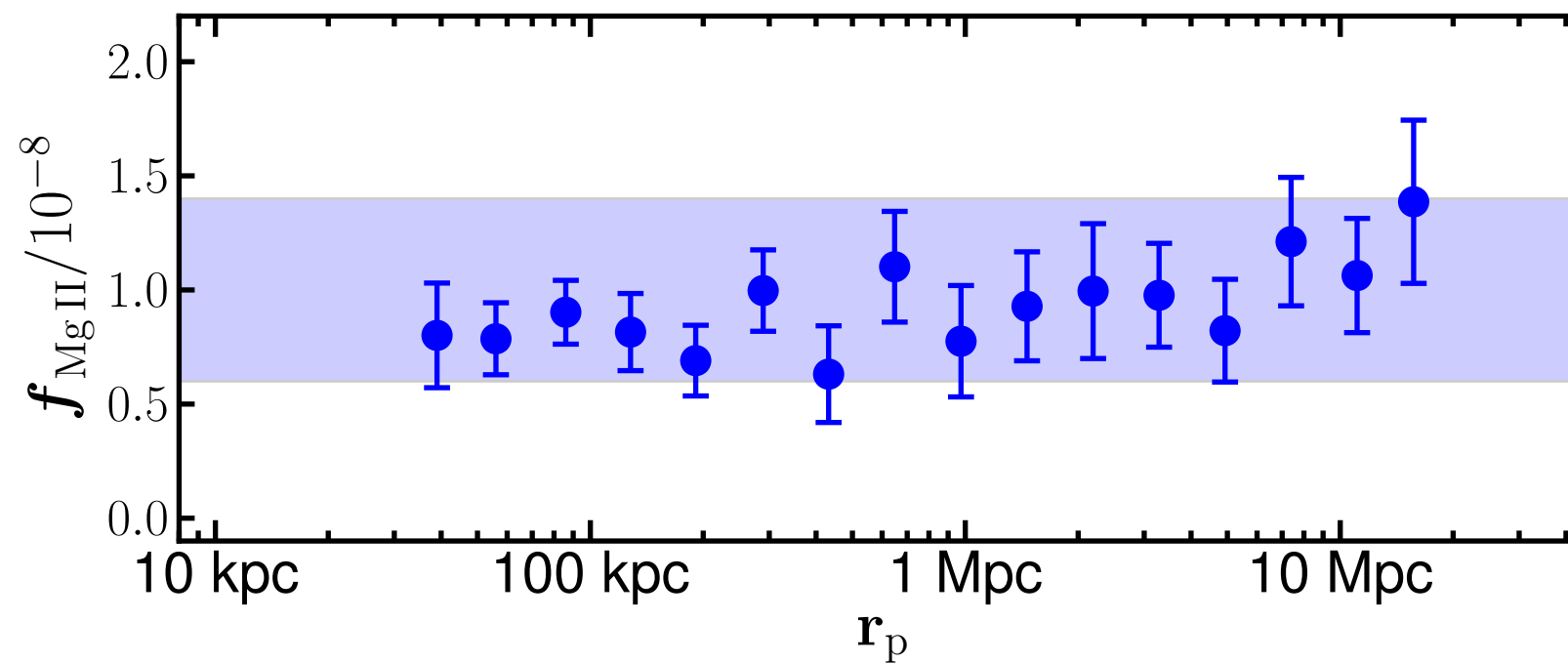
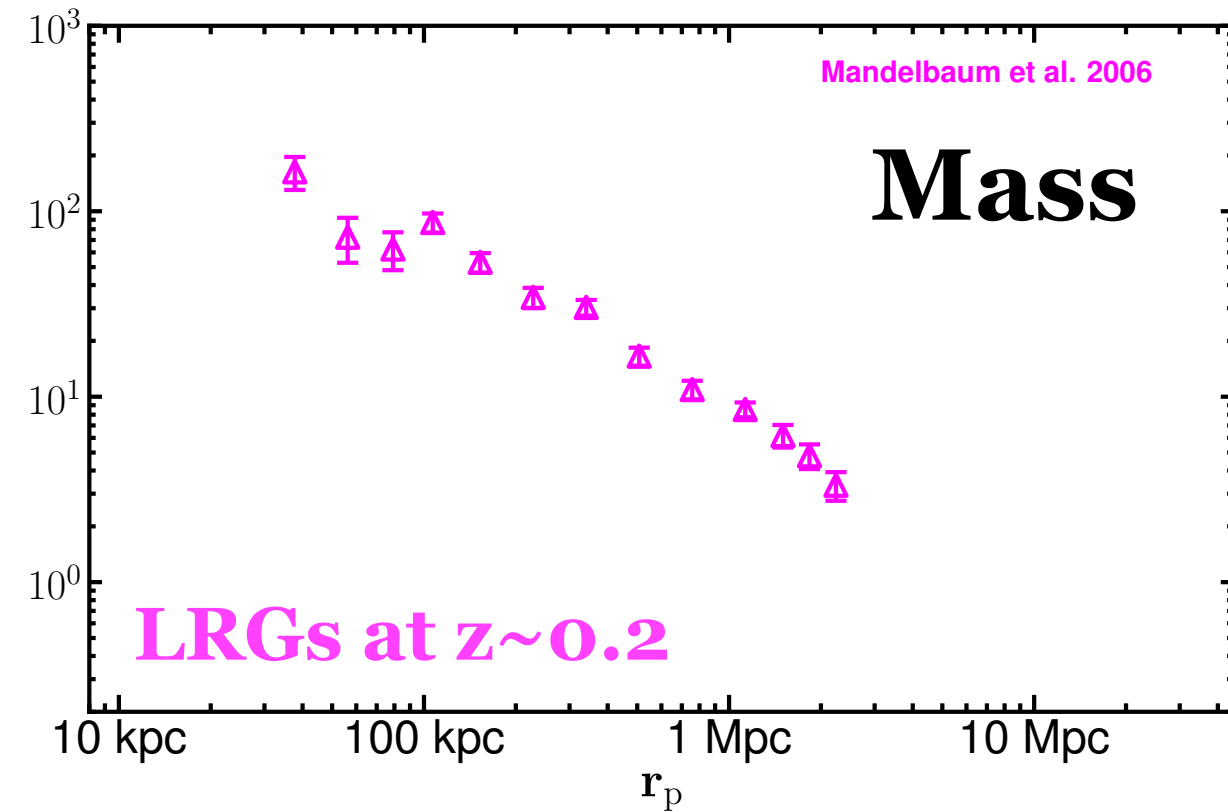
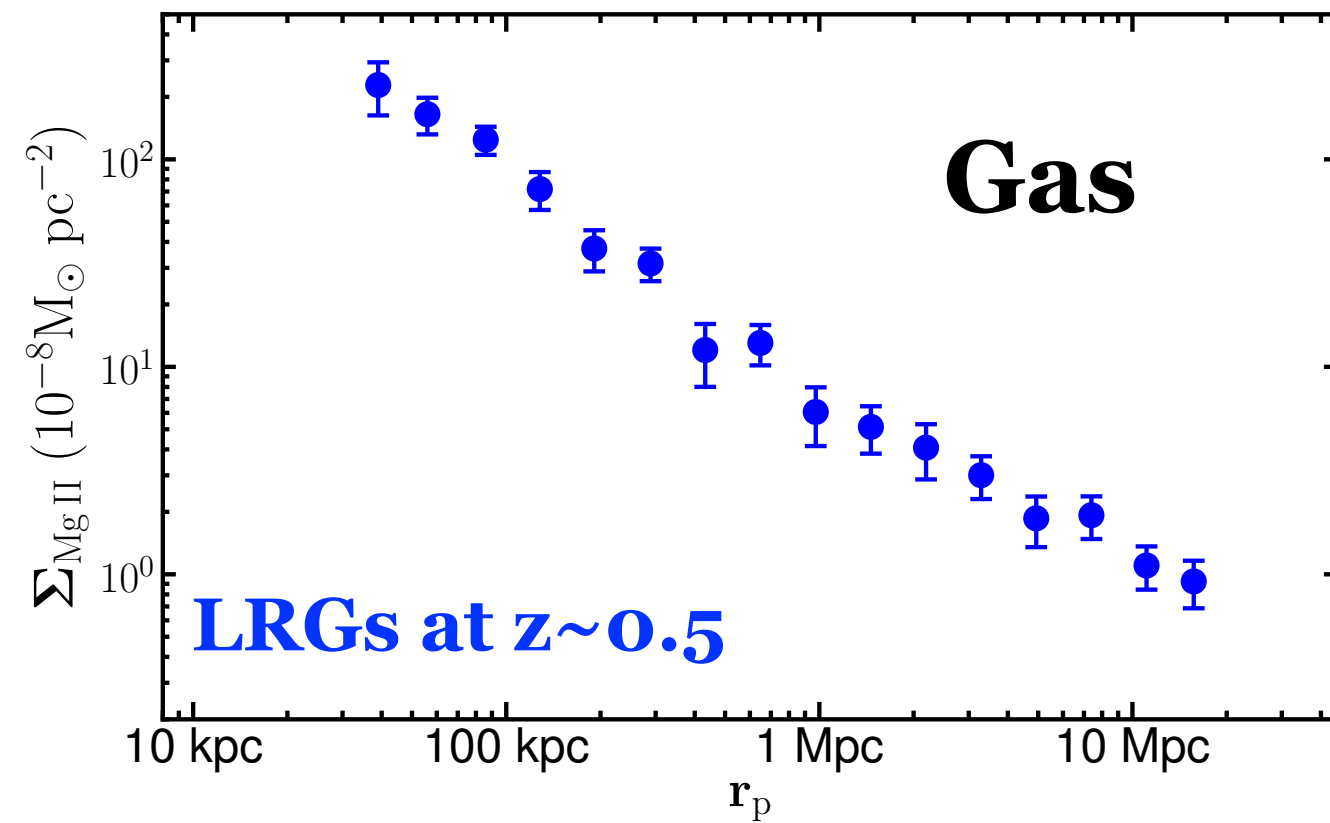
3 parameters:

halo mass M_{halo}

1-halo gas-to-mass ratio f^{1h}

2-halo gas-to-mass ratio f^{2h}

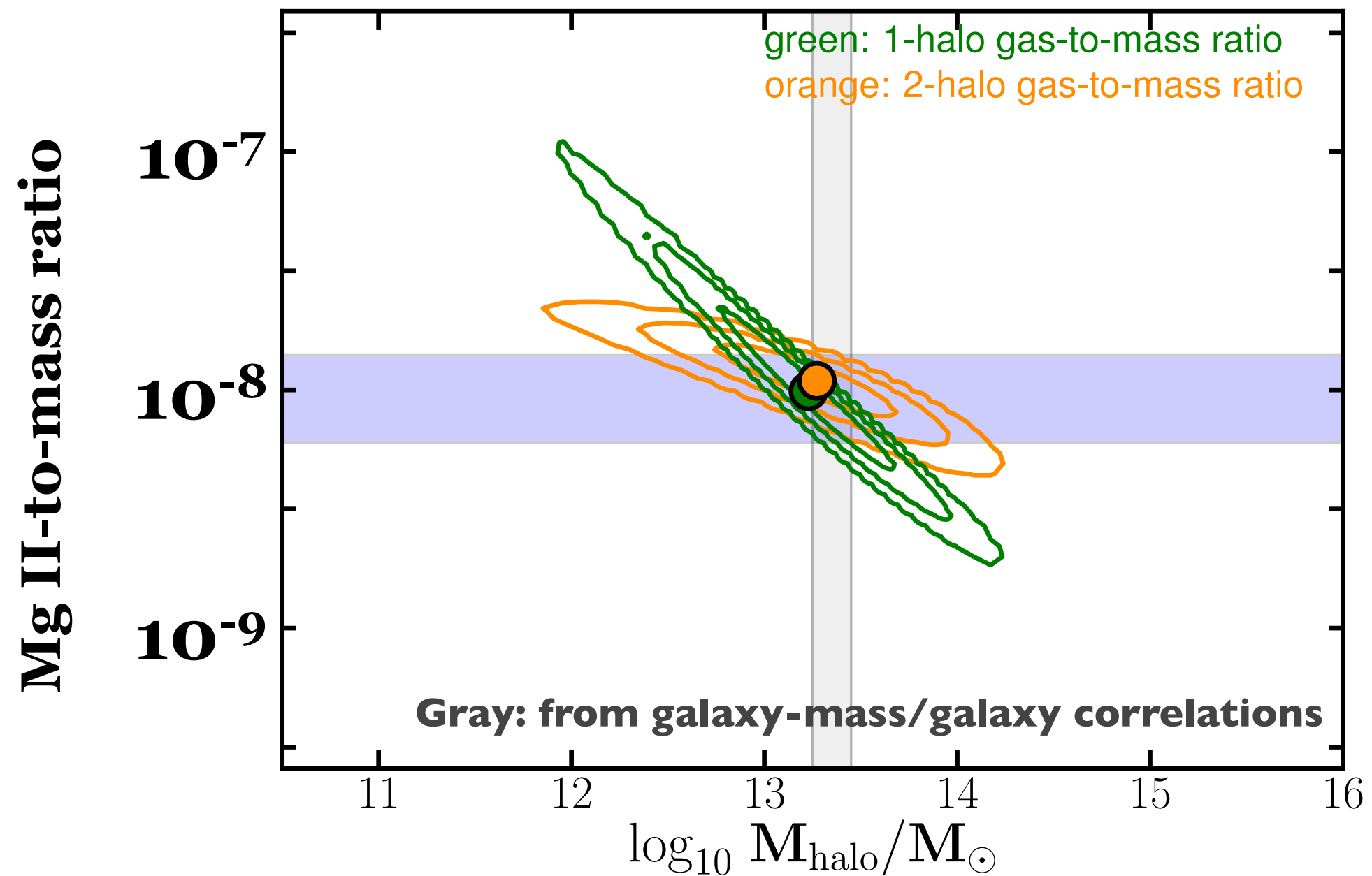
Combining the Galaxy-Gas/Mass Correlations



Gas

Mass

The halo model for gas



3 parameters:

halo mass M_{halo}

1-halo gas-to-mass ratio f^{1h}

2-halo gas-to-mass ratio f^{2h}

$$\langle \delta F_\lambda (r_p) \cdot \delta_g \rangle$$

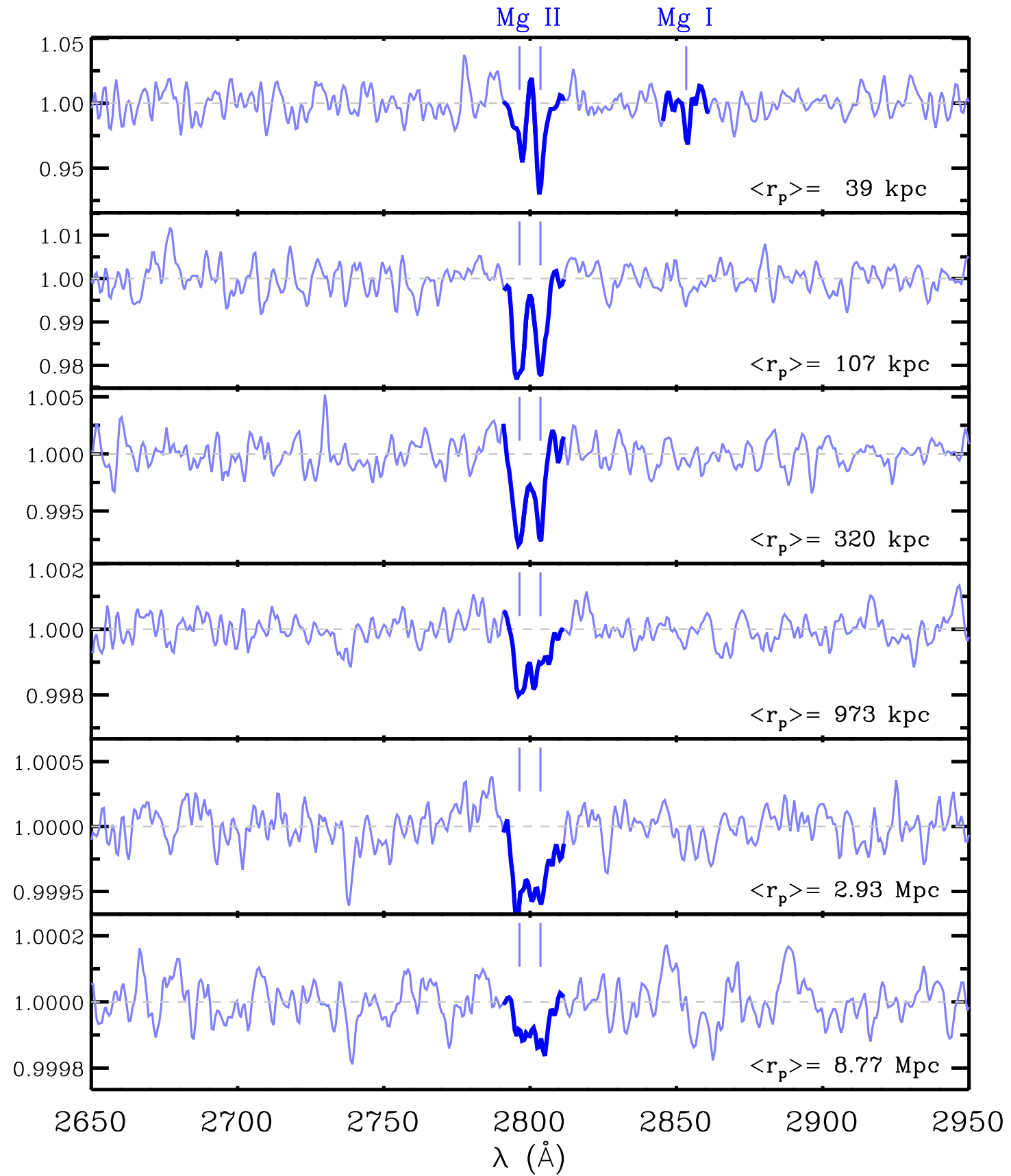
**Absorption
Strength**

10^{-2}

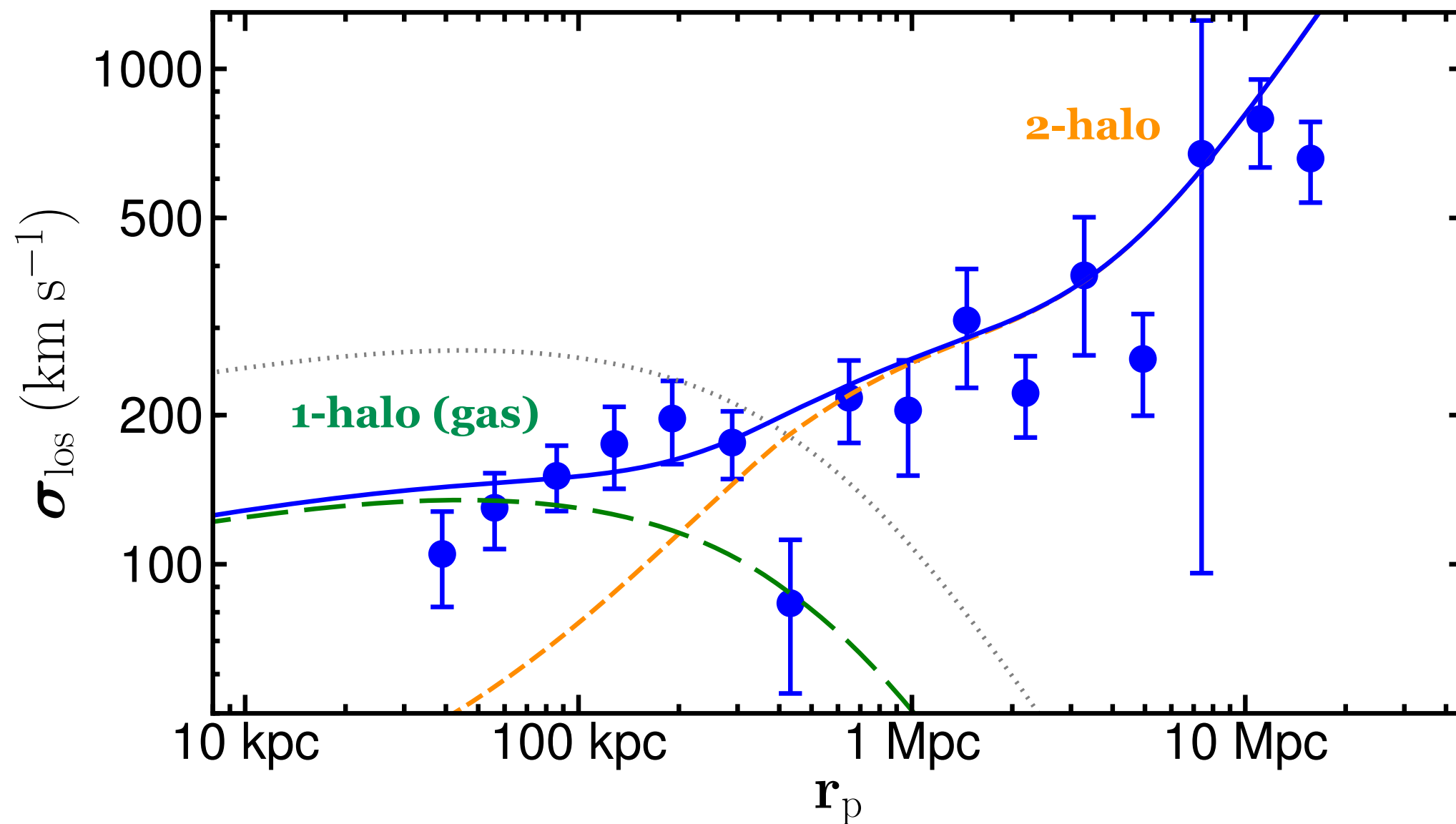
10^{-3}

10^{-4}

Normalized Flux



Dynamical information



-- 1-halo term for gas clouds

-- 2-halo term: halo-halo motion + virial motion in nearby halos

Galaxy-X Correlations: $\langle \delta_g \cdot \delta_X \rangle$

