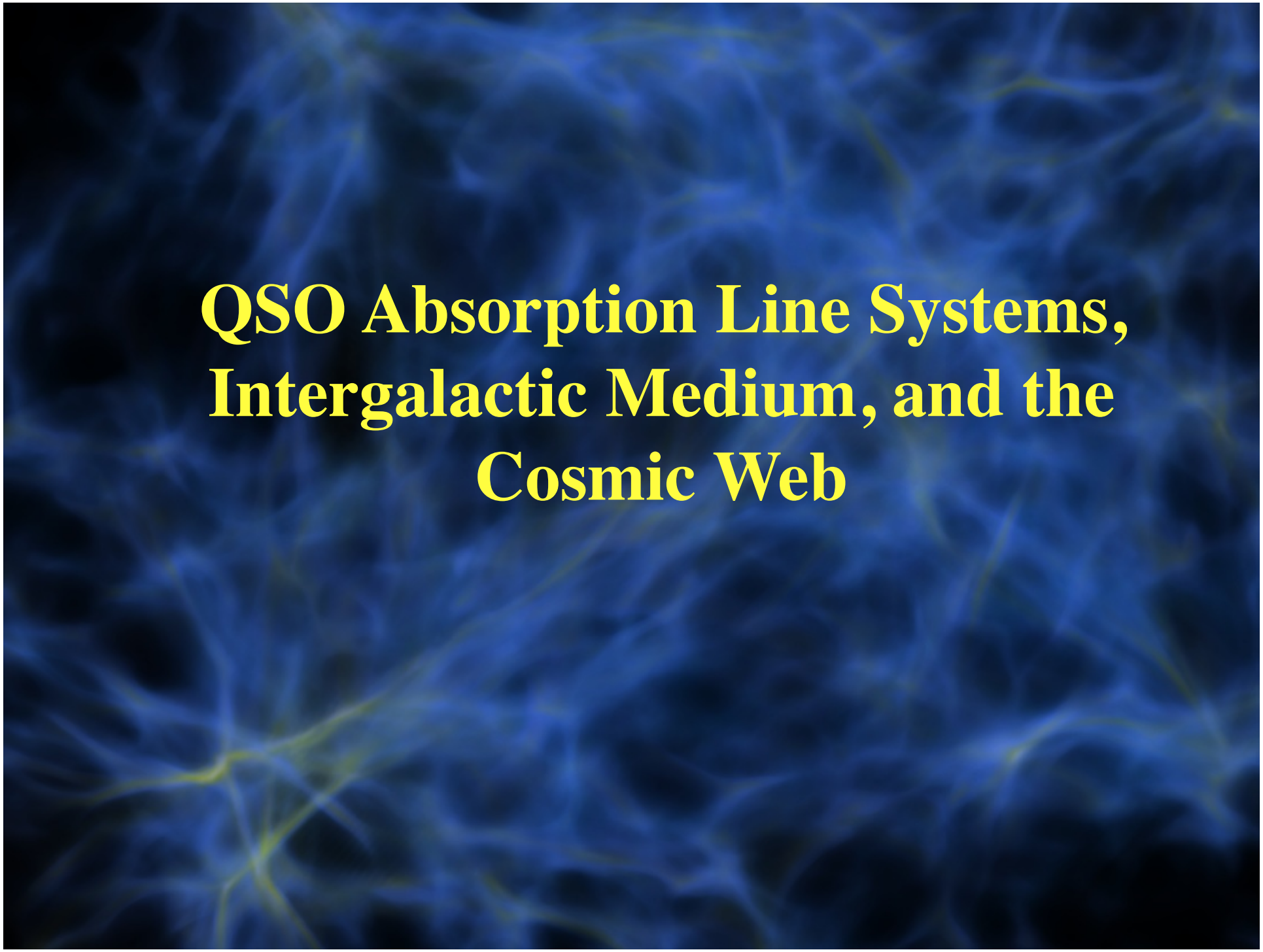
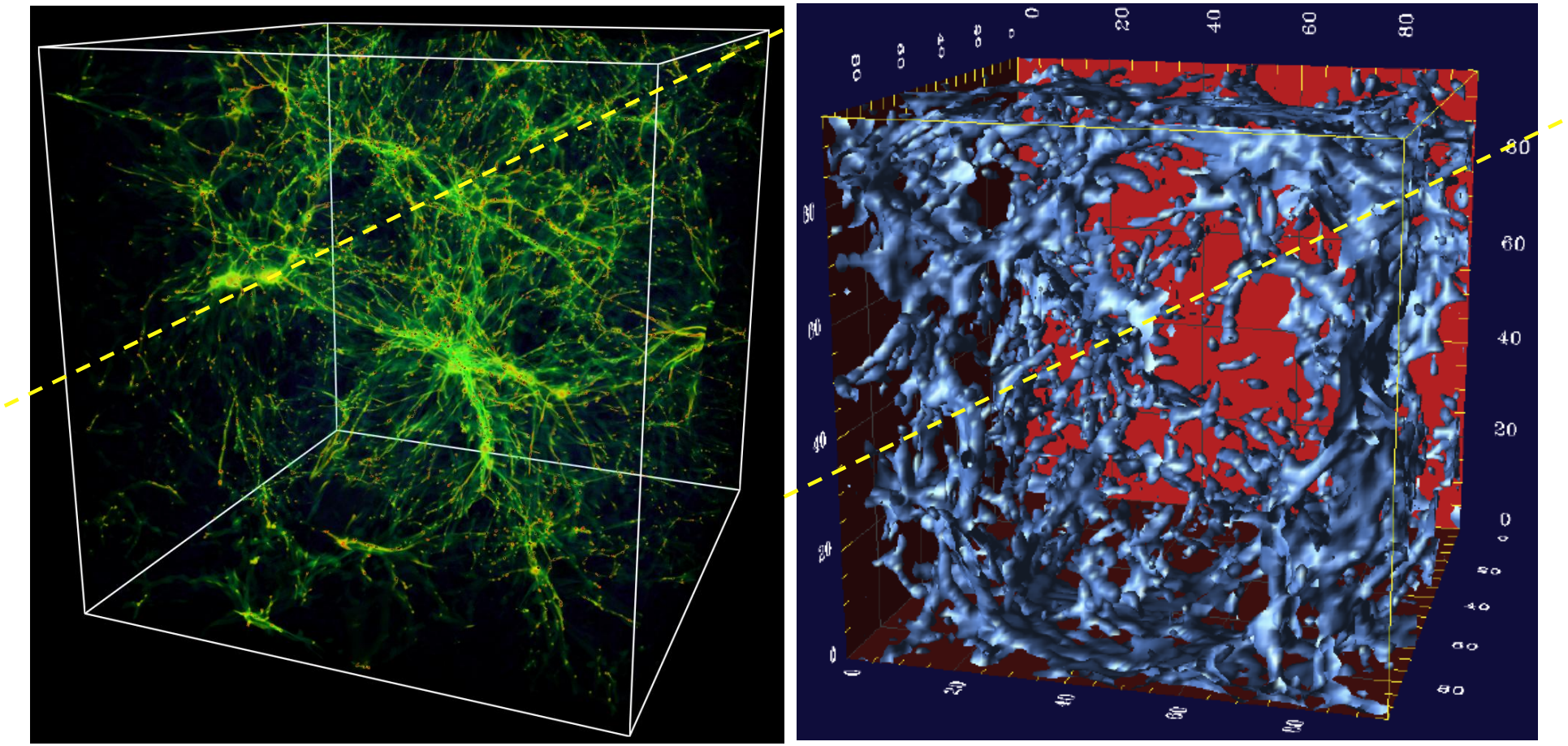

QSO Absorption Line Systems,
Intergalactic Medium, and the
Cosmic Web

Intergalactic Medium (IGM)

- Essentially, baryons between galaxies
- Its density evolution follows the LSS formation, and the potential wells defined by the DM, forming a web of filaments, the co-called **"Cosmic Web"**
- An important distinction is that this gas unaffiliated with galaxies samples the low-density regions, which are still in a linear regime
- Gas falls into galaxies, where it serves as a replenishment fuel for star formation
- Likewise, enriched gas is driven from galaxies through the radiatively and SN powered **galactic winds**, which chemically enriches the IGM
- Chemical evolution of galaxies and IGM thus track each other
- Star formation and AGN provide **ionizing flux** for the IGM

Cosmic Web: Numerical Simulations

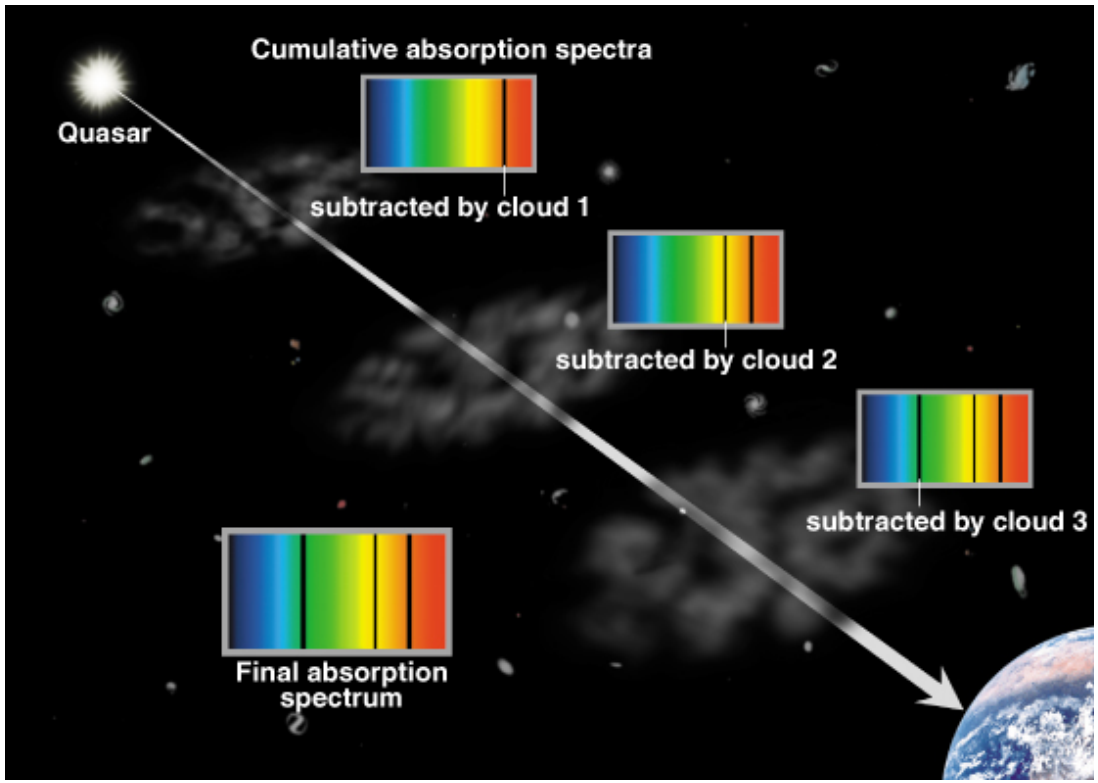
Our lines of sight towards some luminous background sources intersect a range of gas densities, condensed clouds, galaxies …



(from R. Cen)

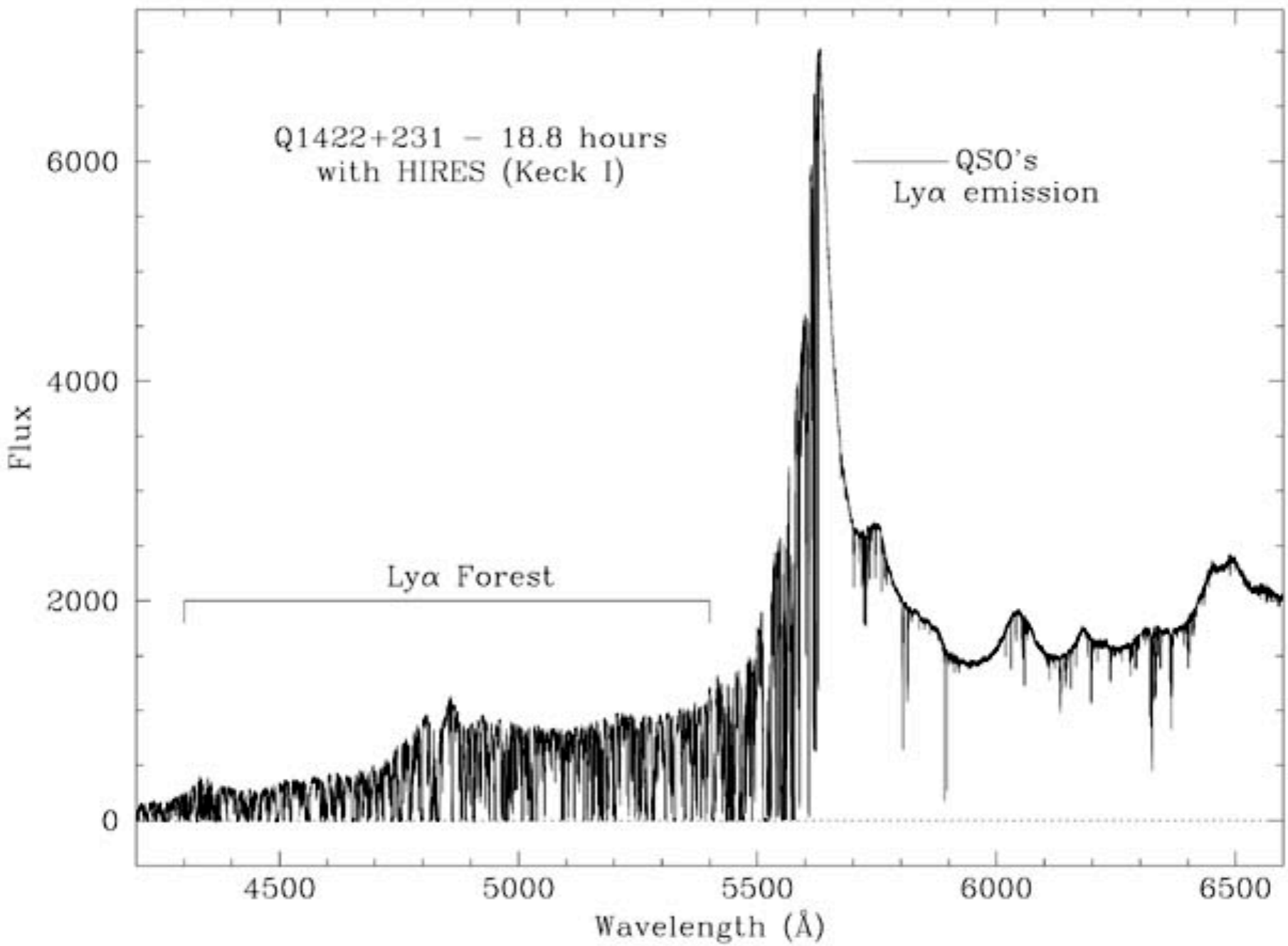
QSO Absorption Line Systems

- An alternative to searching for galaxies by their ***emission*** properties is to search for them by their ***absorption***
- Quasars are very luminous objects and have very blue colours which make them relatively easy to detect at high redshifts
- Nowadays, GRB afterglows provide a useful alternative
- Note that this has ***different selection effects*** than the traditional imaging surveys: not by luminosity or surface brightness, but by the cross section (size) and column density

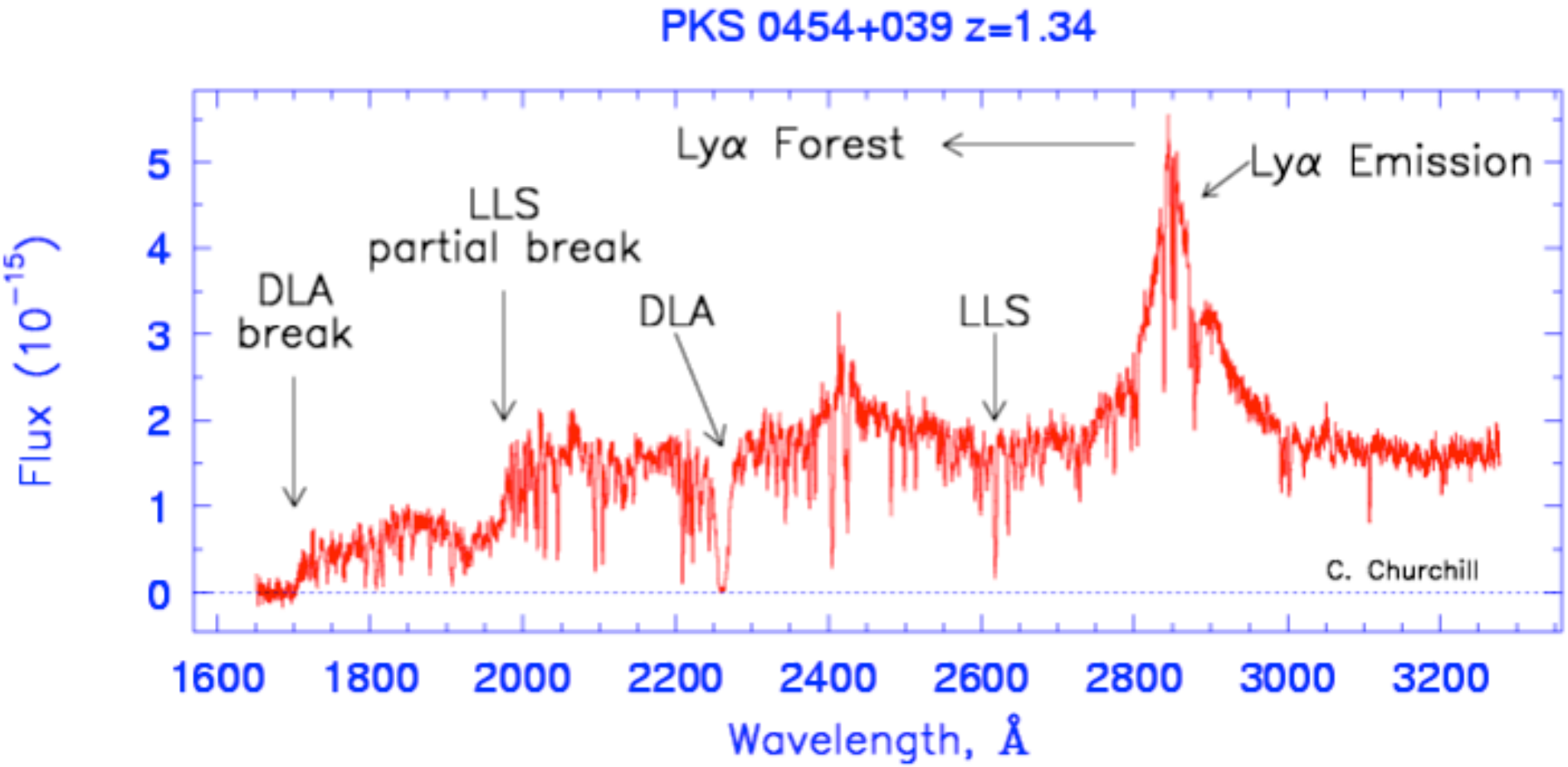


Types of QSO Absorption Lines

- Lyman alpha forest:
  - Numerous, weak lines from low-density hydrogen clouds
  - Lyman alpha clouds are proto-galactic clouds, with low density, they are not galaxies (but some may be proto-dwarfs)
- Lyman Limit Systems (LLS) and "Damped" Lyman alpha (DLA) absorption lines:
  - Rare, strong hydrogen absorption, high column densities
  - Coming from intervening galaxies
  - An intervening galaxies often produce both metal and damped Lyman alpha absorptions
- Helium equivalents are seen in the far UV part of the spectrum
- "Metal" absorption lines
  - Absorption lines from heavy elements, e.g., C, Si, Mg, Al, Fe
  - Most are from intervening galaxies


Q1422+231 – 18.8 hours
with HIRES (Keck I)
QSO's
Lyα emission
Lyα Forest
Flux
0
2000
4000
6000
4500
5000
5500
6000
6500
Wavelength (Å)

Types of QSO Absorption Systems



Types of QSO Absorption Systems

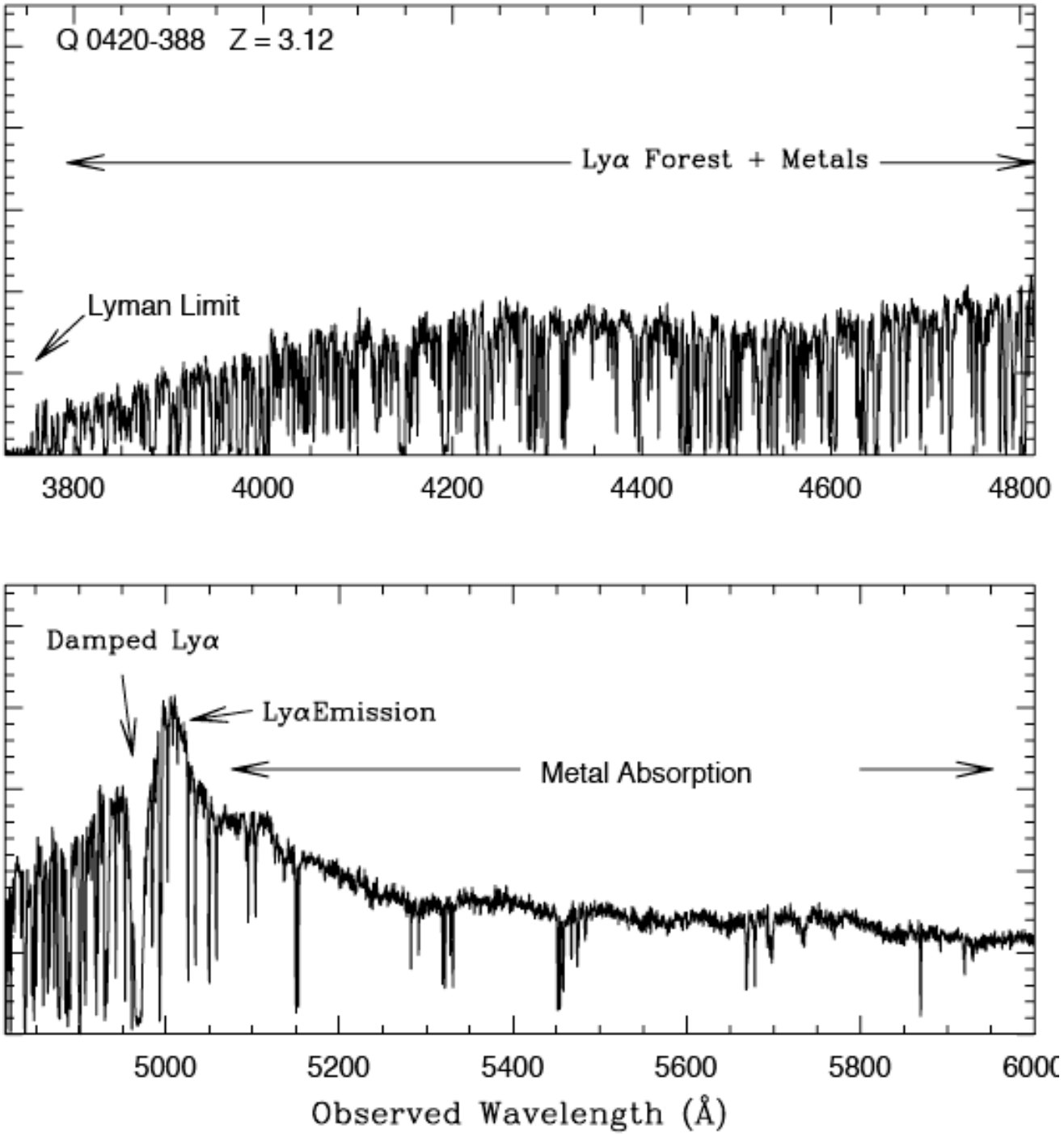


Table 1. A few strong atomic transitions

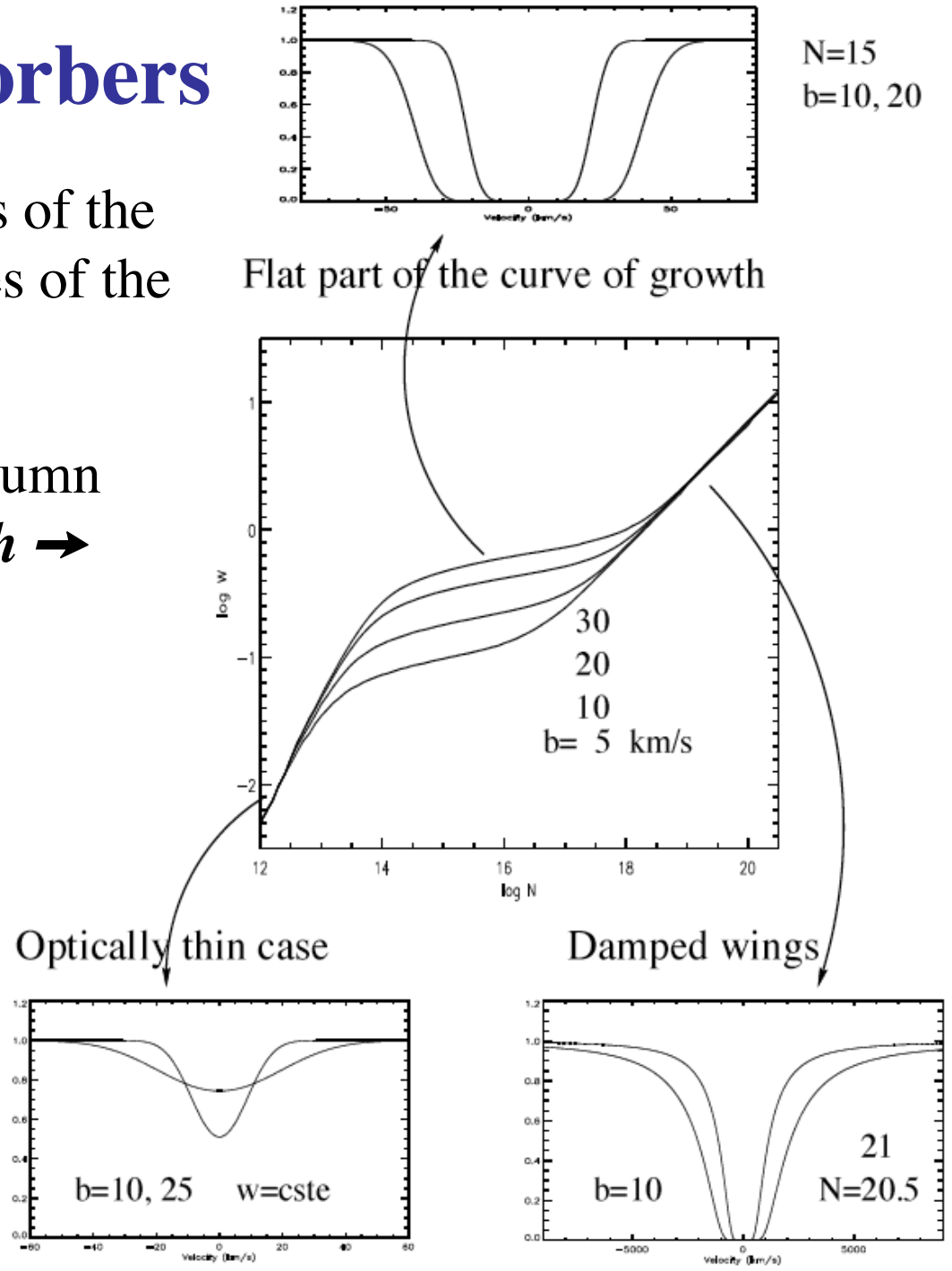
Ion	λ_o (Å)	f	$\log(\lambda_o f)$	$\log(\lambda_o^2 f)$
O VI	1031.927	0.130	2.128	5.141
O VI	1037.616	0.0648	1.828	4.844
H I	1215.670	0.4162	2.704	5.789
O I	1302.169	0.0486	1.801	4.916
C II	1334.532	0.118	2.197	5.323
Si IV	1393.755	0.528	2.867	6.011
Si IV	1402.770	0.262	2.565	5.712
C IV	1548.202	0.194	2.448	5.667
C IV	1550.774	0.097	2.177	5.368
Mg II	2796.352	0.592	3.219	6.666
Mg II	2803.531	0.295	2.918	6.365

Measuring the Absorbers

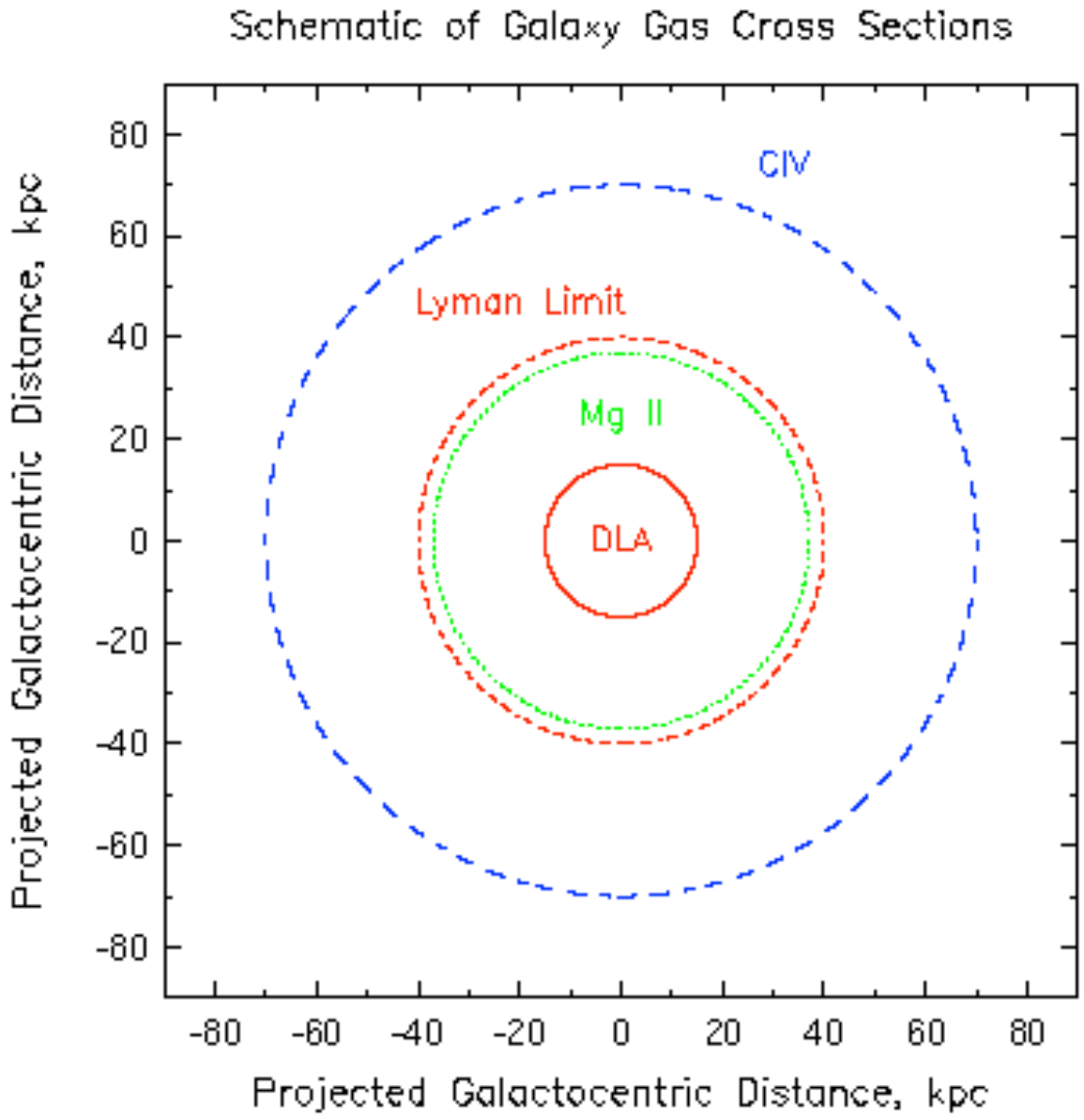
We measure equivalent widths of the lines, and in some cases shapes of the line profiles

They are connected to the column densities via ***curves of growth*** ➔

The shape of the line profile is also a function of the pressure, which causes a Doppler broadening, and also the global kinematics of the absorbing cloud



Absorber Cross Sections



Column density of neutral H is higher at smaller radii, so LLS and DLA absorbers are rare

Metals are ejected out to galactic coronae, and their column densities and ionization states depend on the radius


Next:
Hydrogen
Absorbers