Spectral Analysis of Young, Far-UV Galaxies

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Can We Understand The Early Universe?

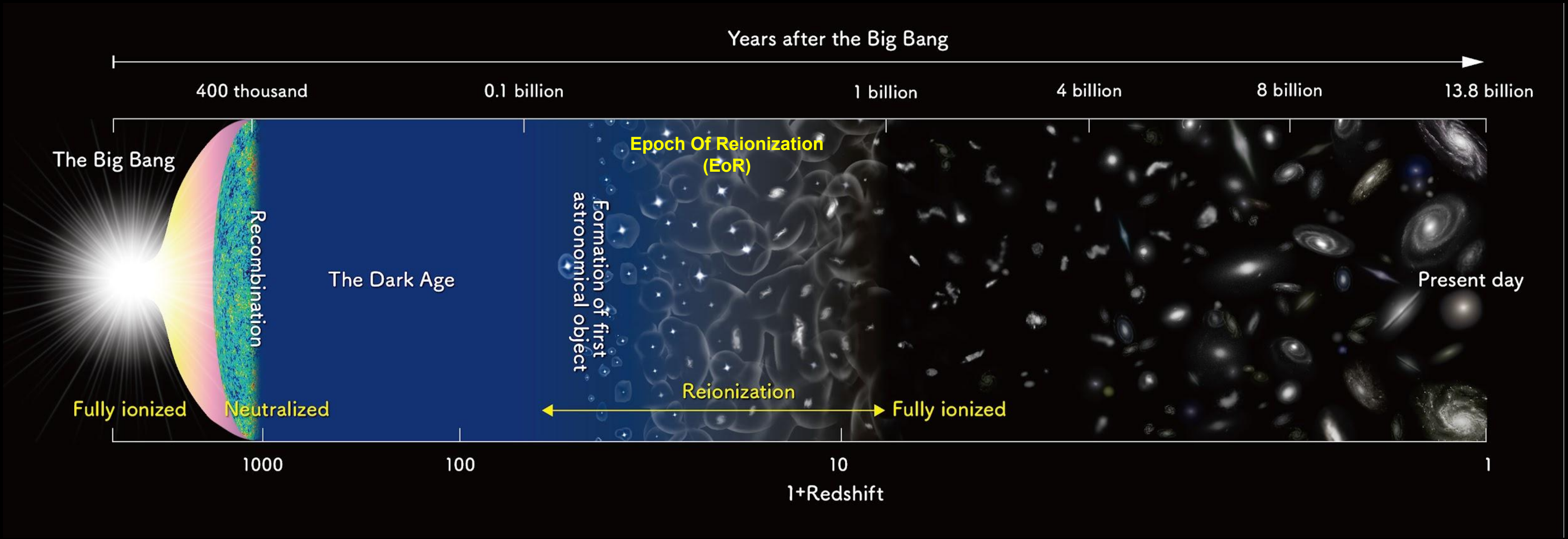


Image Credit: NAOJ

Where does the data come from?

Cosmic Origins Spectrograph aboard the Hubble Space Telescope

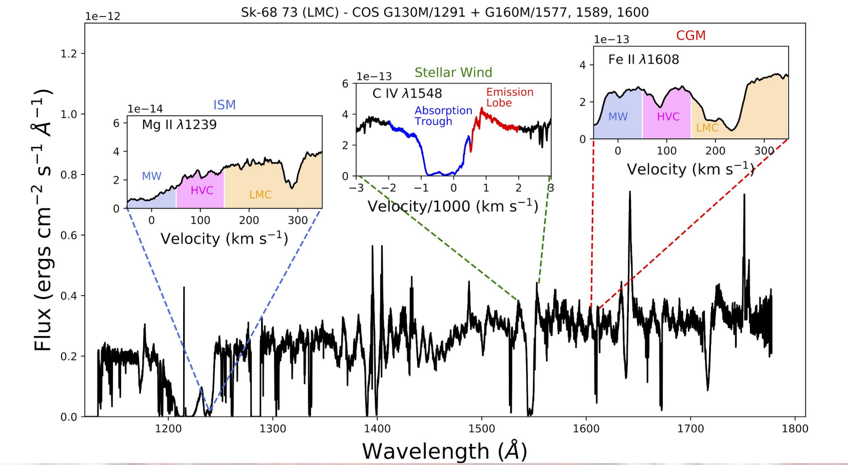


Image Credit: STSCI

Image Credit: NASA

Physics of Spectroscopy: Atomic Transitions

Hydrogen Transition Diagram

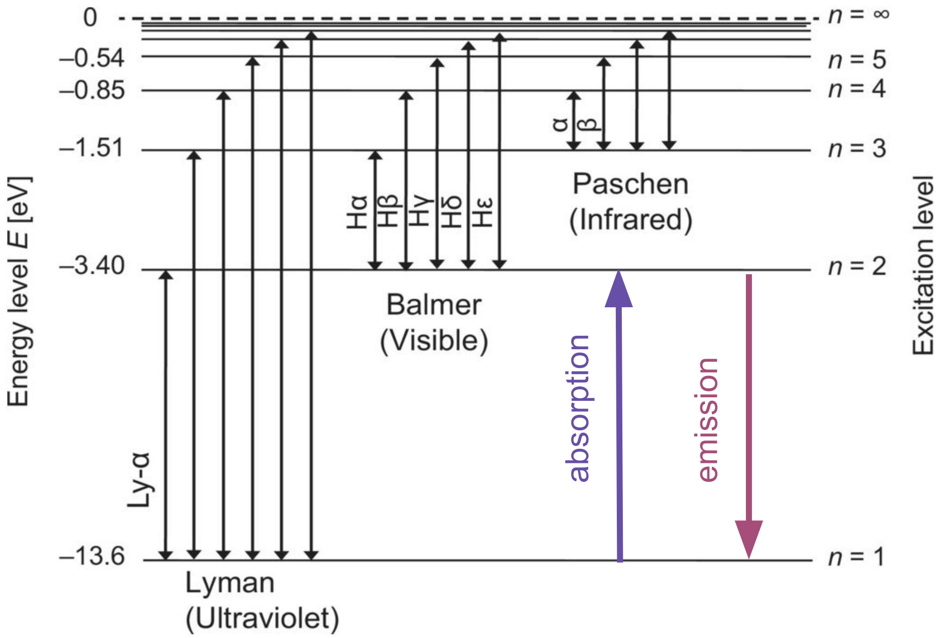


Image Credit: Cambridge University Press

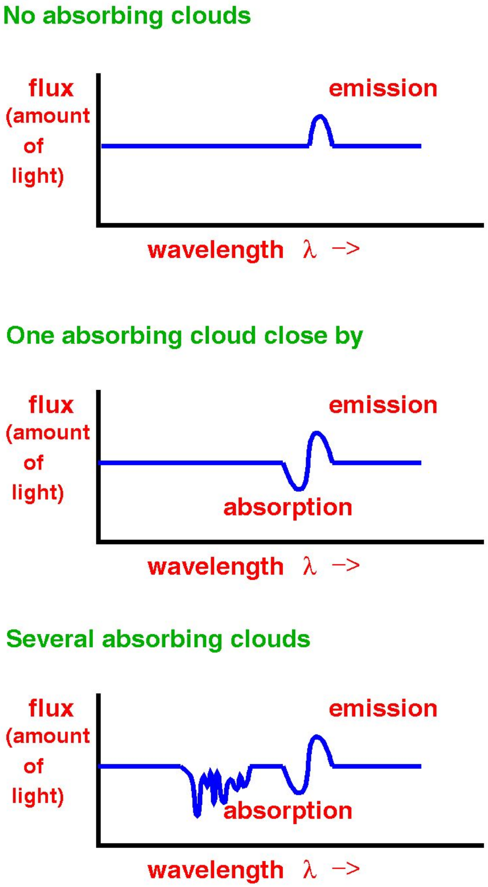
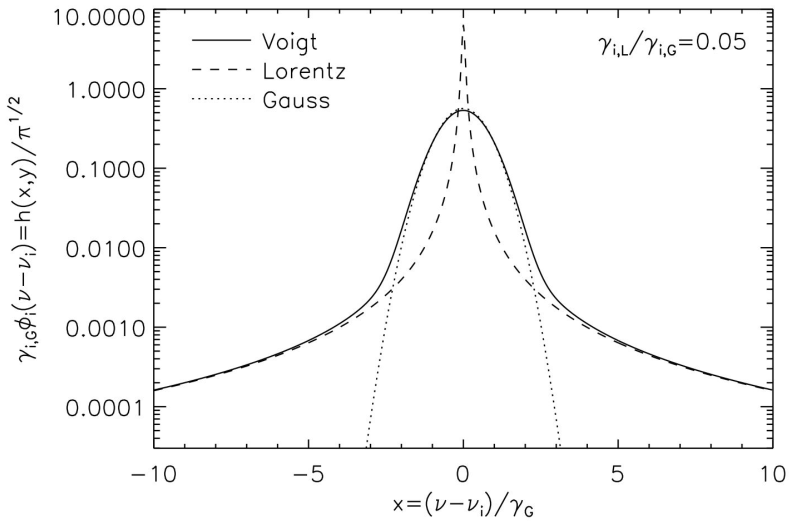


Image Credit: https://w.astro.berkeley.edu/~jcohn/lya.html

Physics Of Spectroscopy: Line Profiles



Lorentz profile - Natural Broadening and Collisional Broadening

$$\phi_{i,\mathrm{L}}(\nu) = \frac{1}{\pi}\frac{\gamma_{i,\mathrm{L}}}{(\nu-\nu_i)^2+\gamma_{i,\mathrm{L}}^2} \quad \text{with} \quad \gamma_{i,\mathrm{L}} = \gamma_{i,\mathrm{coll}} + \gamma_{i,\mathrm{nat}}$$

Gaussian profile -Doppler Broadening

$$\phi_{i,\mathrm{G}}(\nu) = \frac{1}{\sqrt{\pi}\,\gamma_{i,\mathrm{G}}}\exp\left(-\frac{(\nu-\nu_i)^2}{\gamma_{i,\mathrm{G}}}\right) \quad \text{with} \quad \gamma_{i,\mathrm{G}} = \sqrt{\gamma_{i,\mathrm{th}}^2 + \gamma_{i,\mathrm{turb}}^2}$$

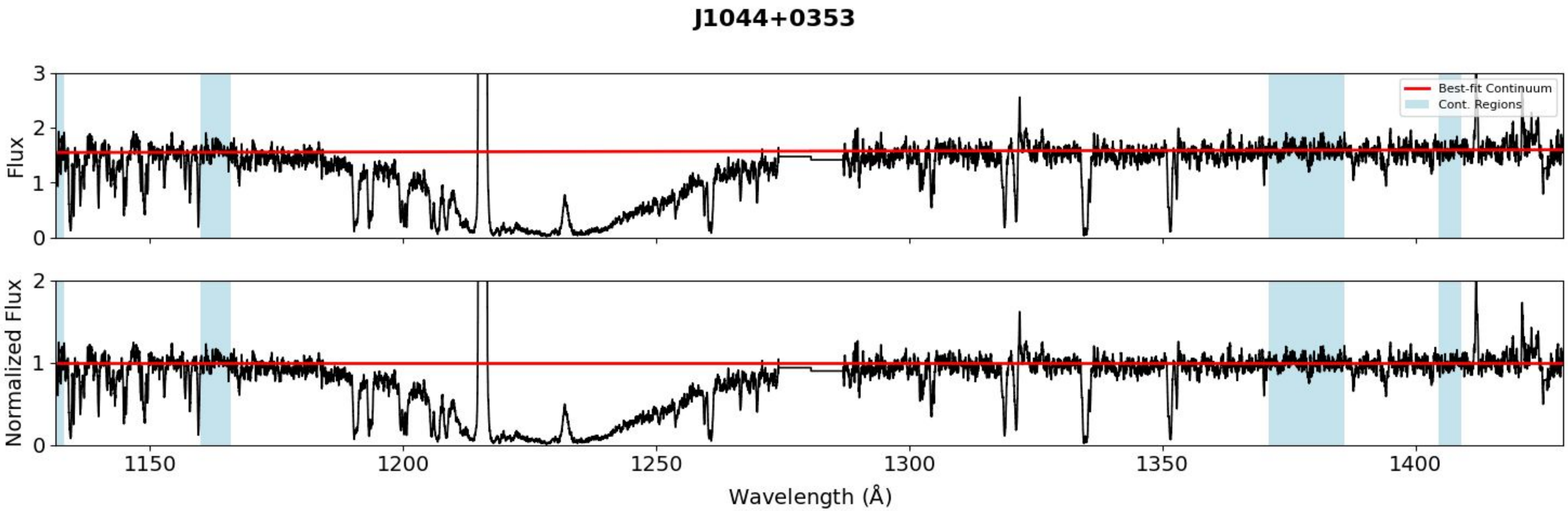
Doppler Parameter: $b = \sqrt{2}\sigma$

Voigt Profile:

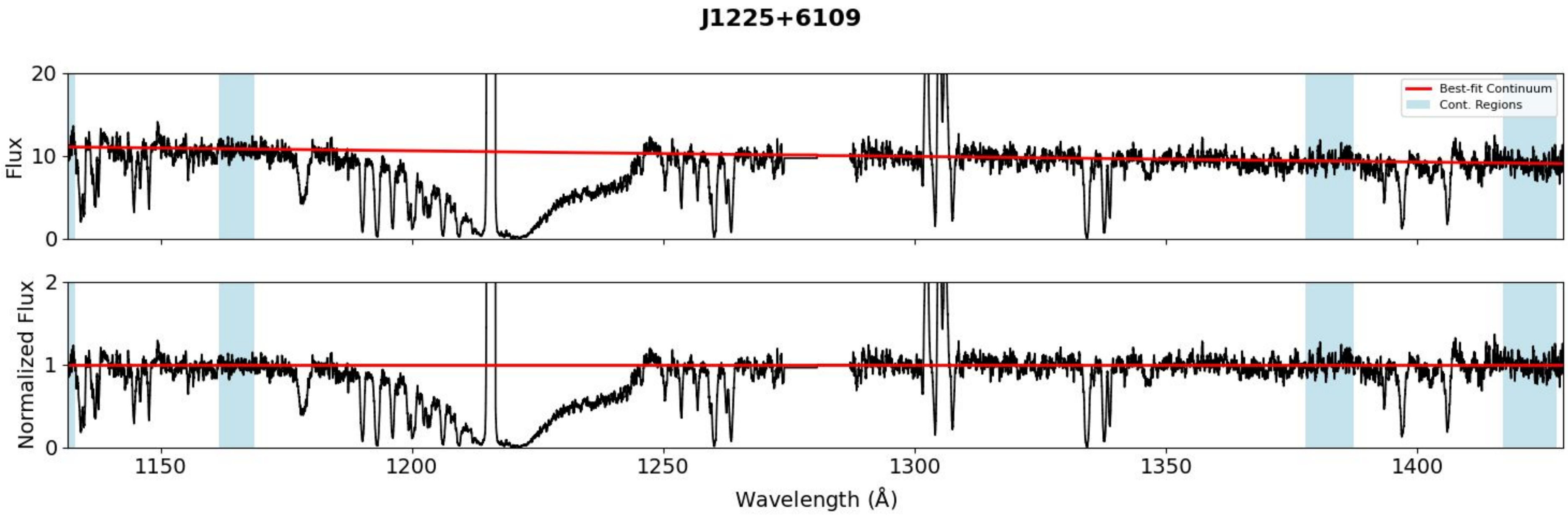
$$\phi_i(\nu) = \int_0^\infty \phi_{i,\mathrm{G}}(\nu')\phi_{i,\mathrm{L}}(\nu_i+\nu-\nu')d\nu'$$

Image Credit: C.P. Dullemond, Ch. 7: Line Radiative Transfer Lecture Notes

Methods: Normalize Flux For Measurement



Methods: Normalize Flux For Measurement

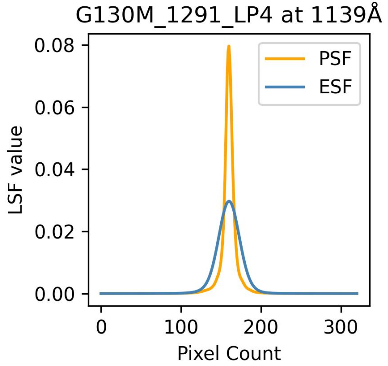


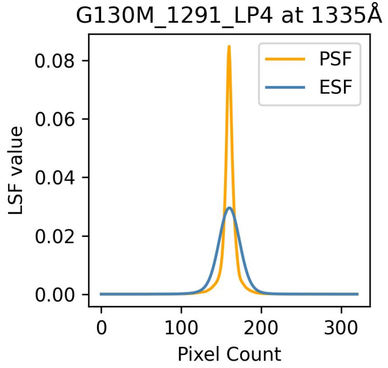
Methods: Line Spread Functions

-point source vs. extended source (PSF vs. ESF)

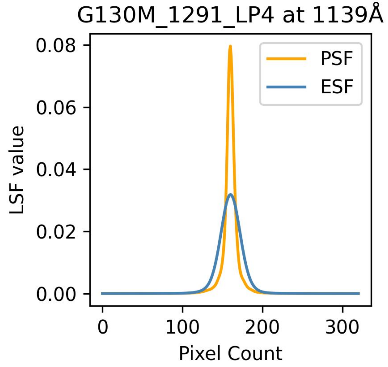
-different shapes for specific wavelengths, lifetime positions

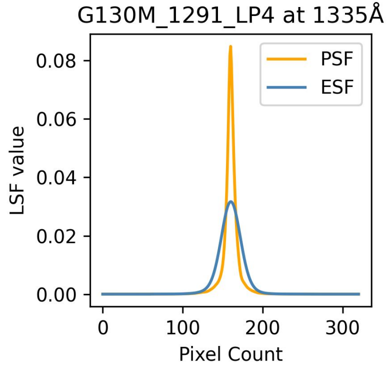
J1225+6109



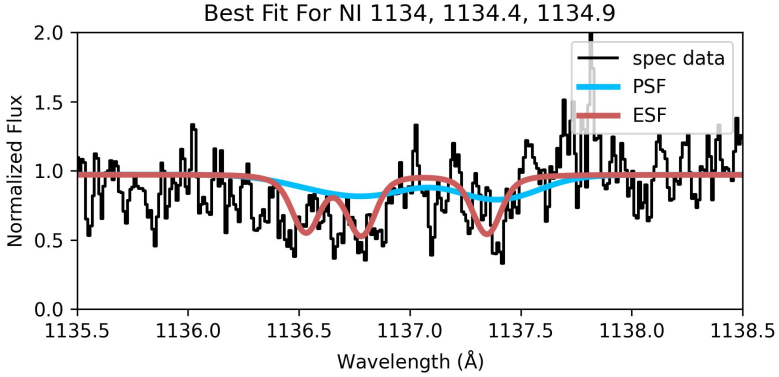


J1150+1501

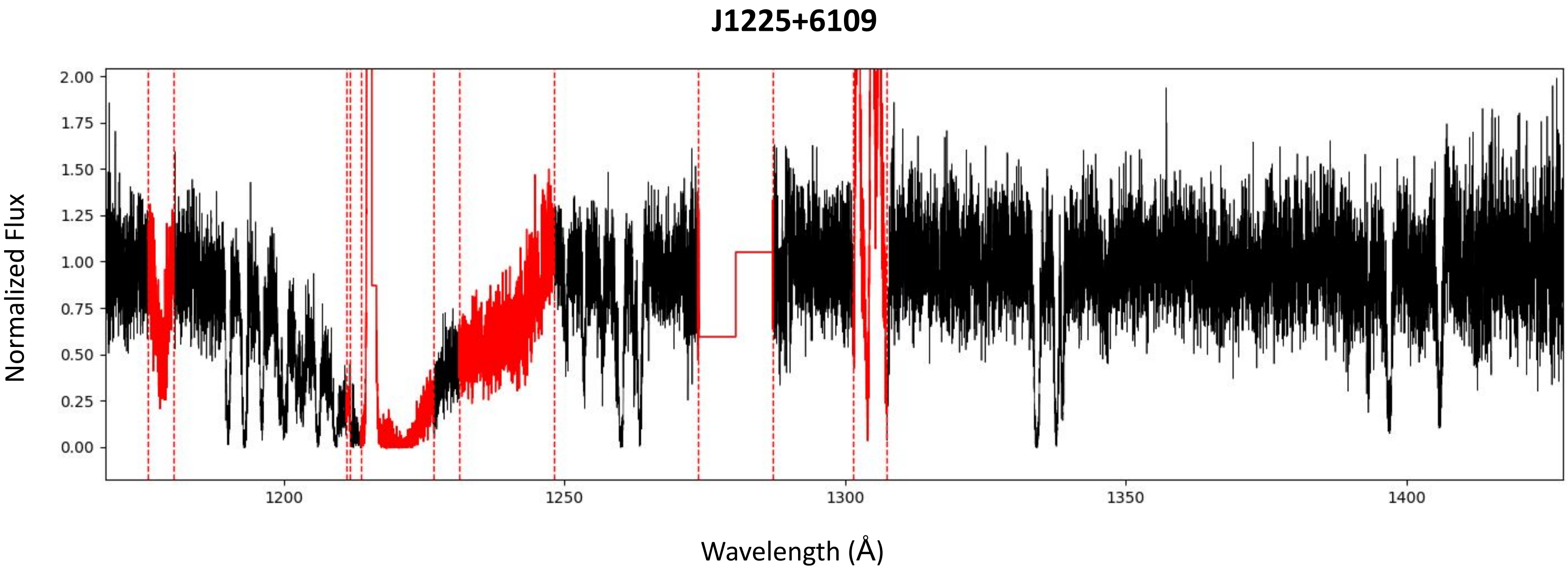




J1444+4237



Methods: Masking areas from the fit, stellar profiles and any emission



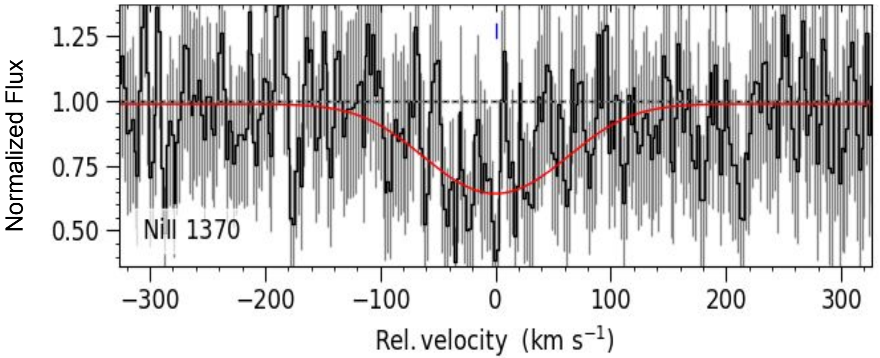
-geocoronal emission is not important to our goals

-PCygni abs+emis profile shapes, NV region

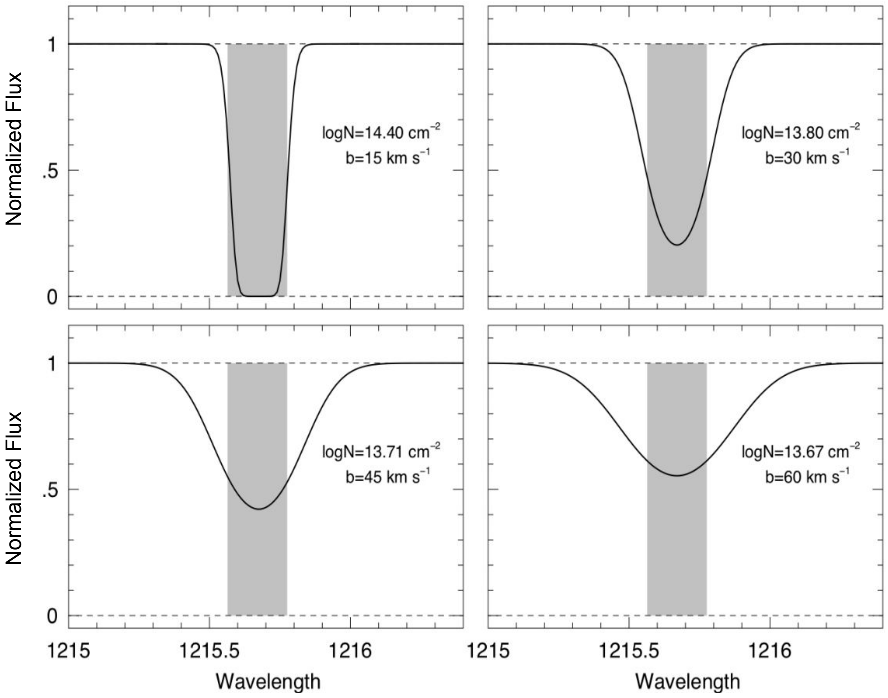
-extend mask out to +2000 km/s from Lyα because of red emission

Methods: Inputs for Velocity/Redshift, b-parameter, Column Density

J1044+0353 NiII 1370



$$\frac{(\lambda - \lambda_o)}{\lambda_o} = \frac{v}{c}$$

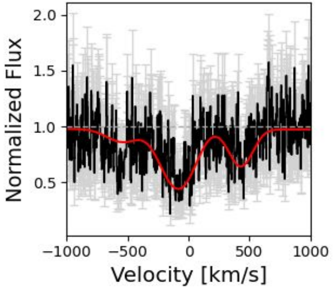


Column density is derived from area under curve-> half-width of absorption line

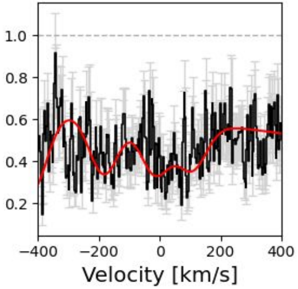
Image Credit: M. Pettini: Intro to Cosmology — Lec. 12

Results: Fitted absorption lines and Damped Lyα Absorption

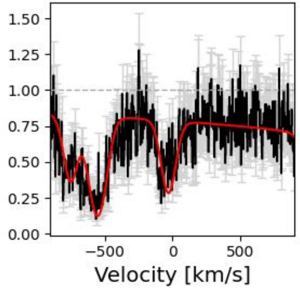
FeII 1142, **FeII 1143**, FeII 1144



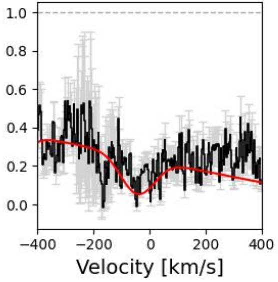
NI 1199, **NI 1200**, NI 1200.7



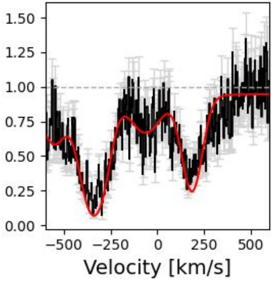
SiII 1193



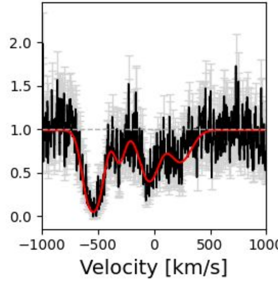
SiIII 1206

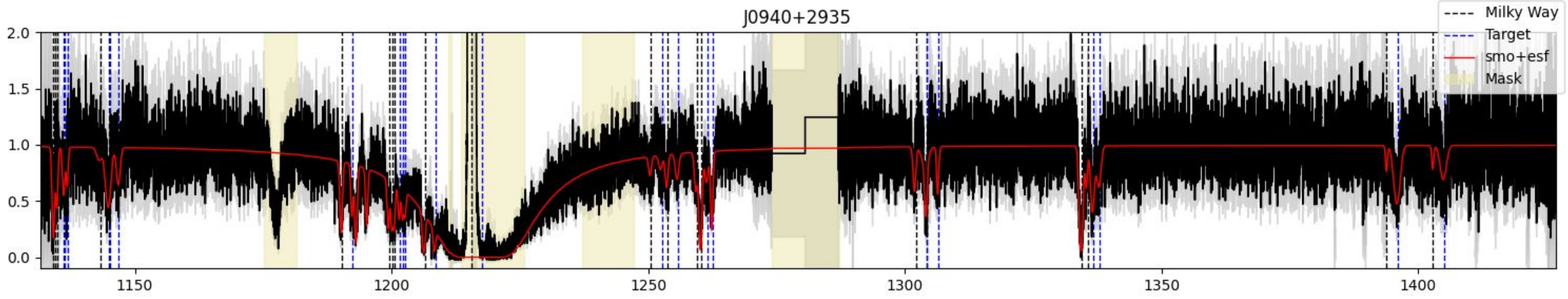


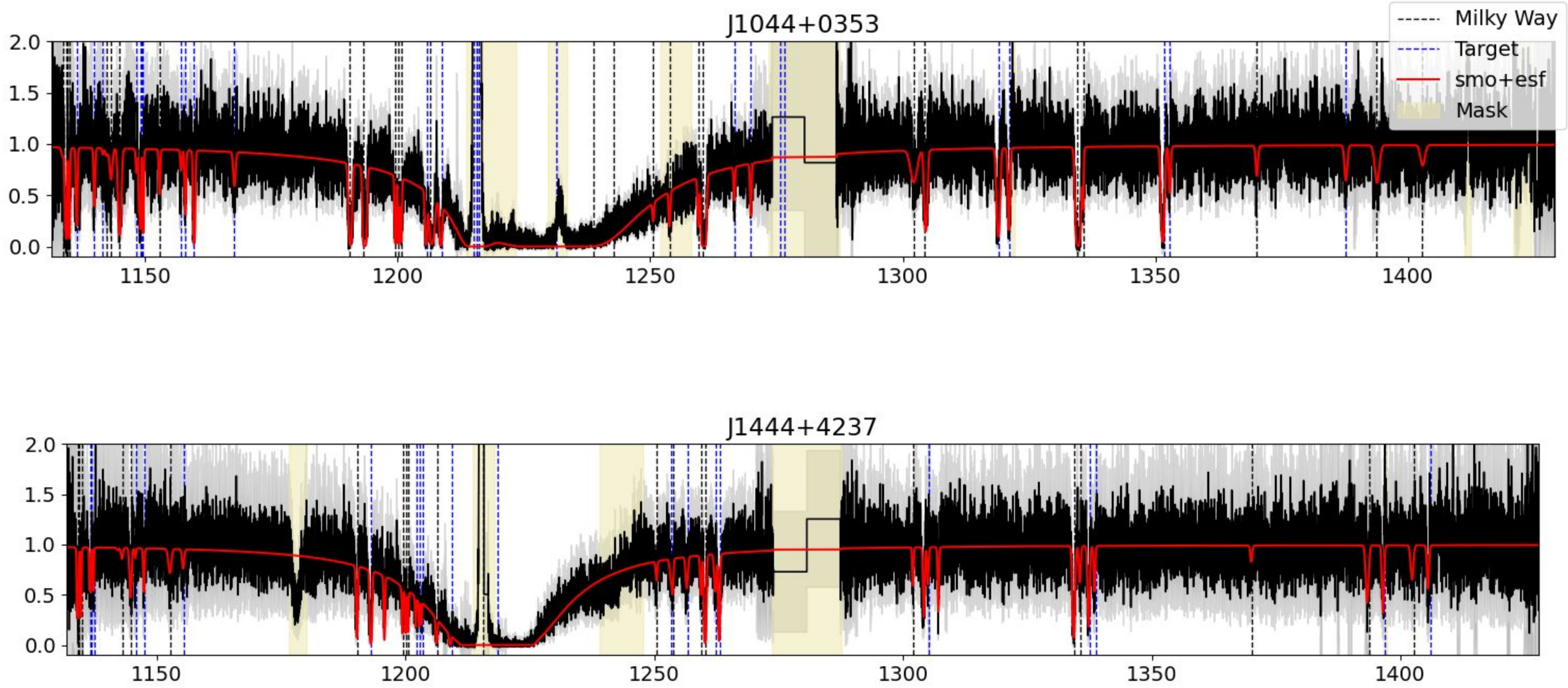
SII 1255, **SII 1259**, SiII 1260



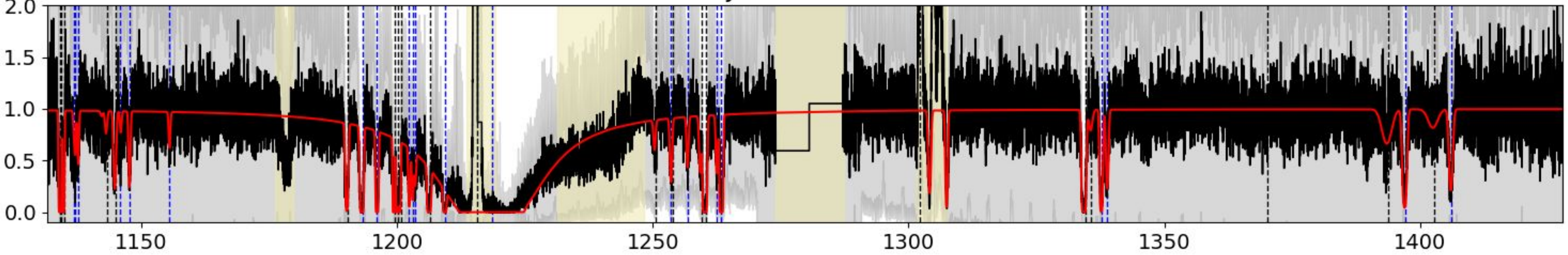
CII 1334, CII* 1335



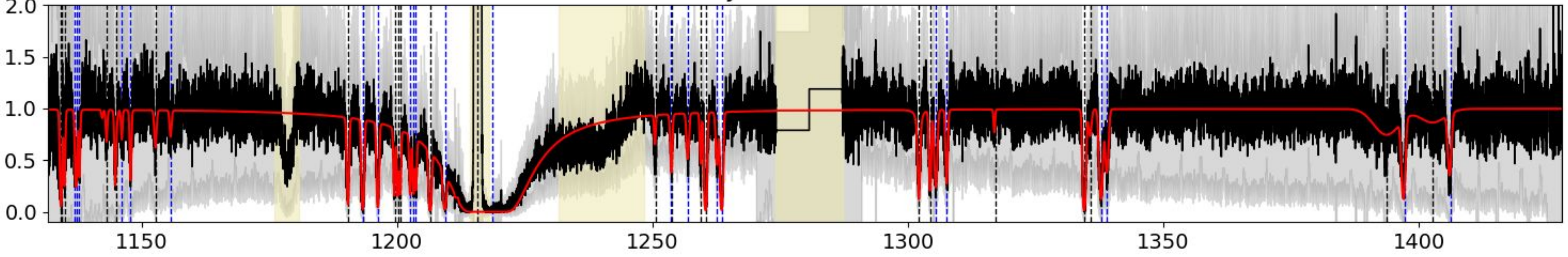


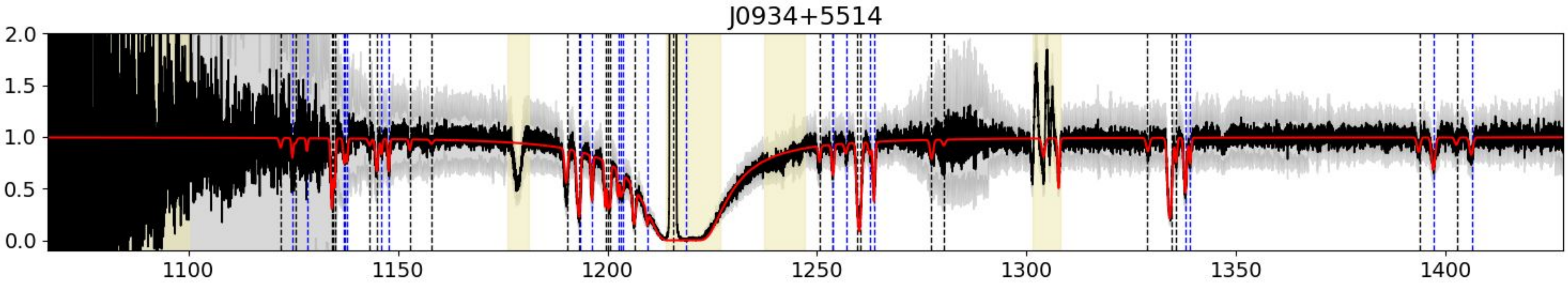

J1044+0353
Milky Way
Target
smo+esf
Mask
2.0
1.5
1.0
0.5
0.0
1150
1200
1250
1300
1350
1400
J1444+4237
2.0
1.5
1.0
0.5
0.0
1150
1200
1250
1300
1350
1400

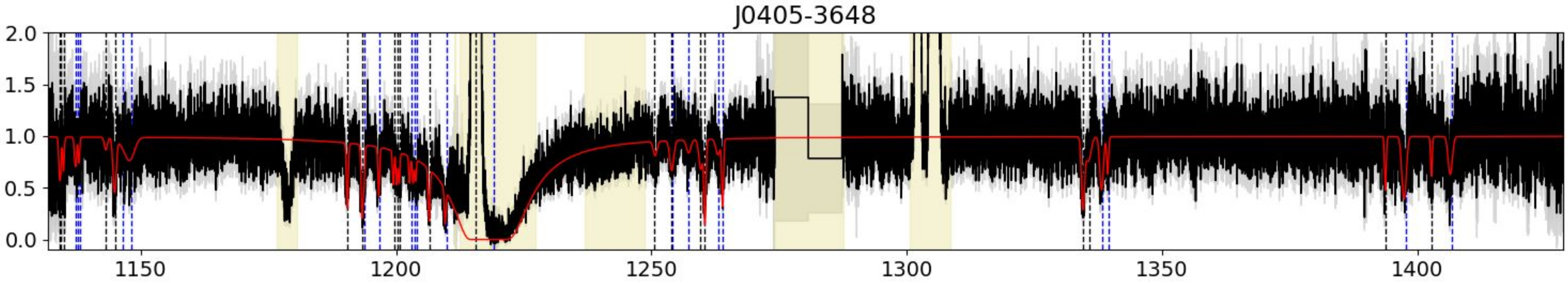
J1225+6109



J1150+1501



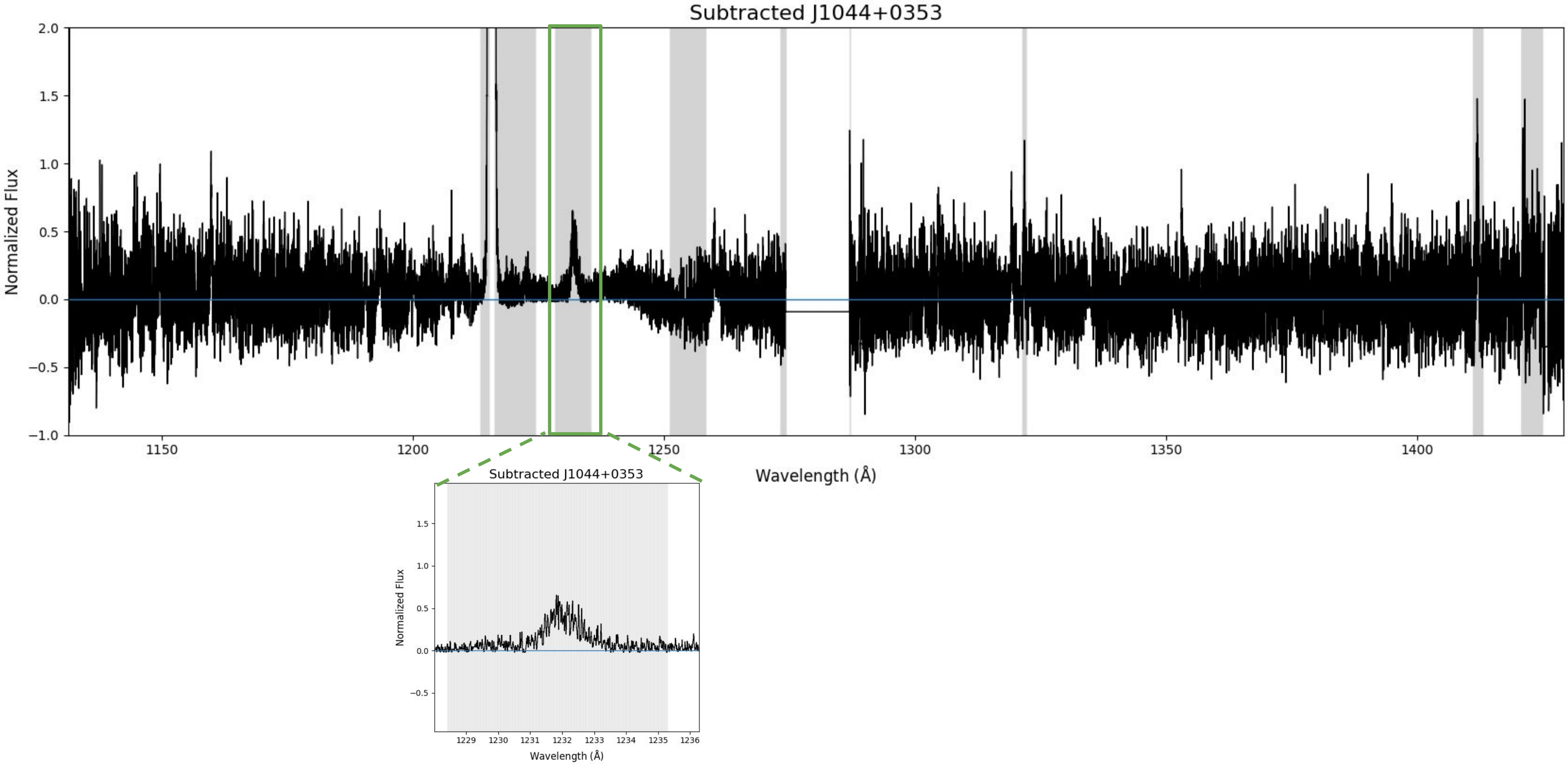

J0934+5514
2.0
1.5
1.0
0.5
0.0
1100
1150
1200
1250
1300
1350
1400


J0405-3648
2.0
1.5
1.0
0.5
0.0
1150
1200
1250
1300
1350
1400

Importance of Calculating HI and Metal Column Densities

- abundances in interstellar medium (ISM) of active star-forming galaxies typically determined by optical and near-infrared emission line spectroscopy of HII regions, used ratio of O/H in HII regions
- large reservoir of HI regions amounts to 90-95% of Baryonic matter- all visible matter within these types of galaxies
    - which means we study abundances in neutral ISM to understand the actual metal content of these galaxies (James et.al 2019), further constrains neutral gas properties
- Obtaining the LyA emission profile, which we use to fit the outflowing shell model

Results: Remove damping wings to isolate extreme galaxy’s Lyα emission



Results: Galaxy Lyα Column Density vs. redshift

Galaxy	Redshift	N(HI)
J0940+2935	0.001675	21.412 ± 0.003
J1444+4237	0.002300	21.629 ± 0.003
J1225+6109	0.002341	21.428 ± 0.008
J1150+1501	0.002448	21.11 ± 0.005
J0934+5514	0.002500	21.292 ± 0.001
J0405+3648	0.002800	21.035 ± 0.009
J1044+0353	0.01287	21.952 ± 0.006

Column Densities can tell us about star formation in a galaxy

- analyzed HI, FeII, PII, CI, NI, SiII, SiIII, SII, OI, NiII, CII, CII*, SiIV absorption lines in these low-redshift galaxies
- heavier elements come from *stellar nucleosynthesis*
- insights into star populations of the galaxy

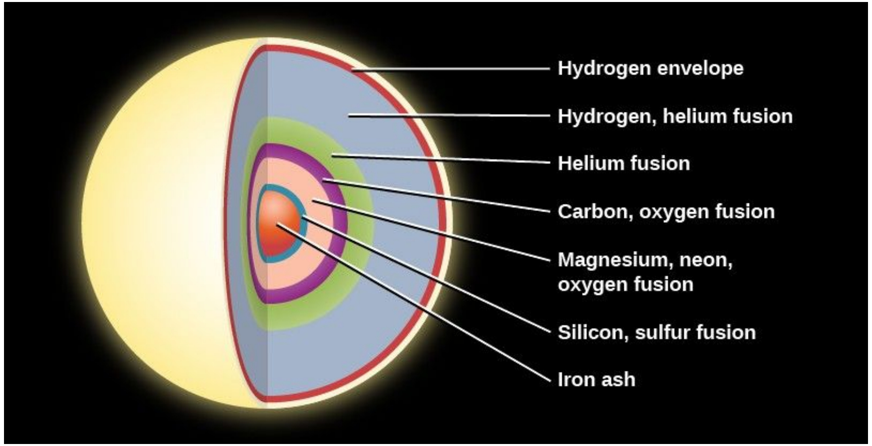
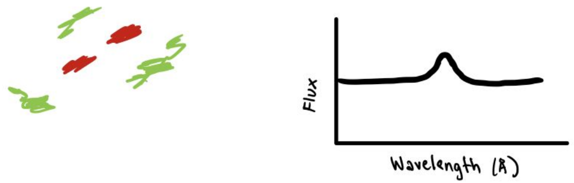
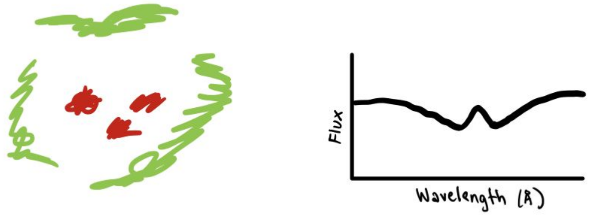


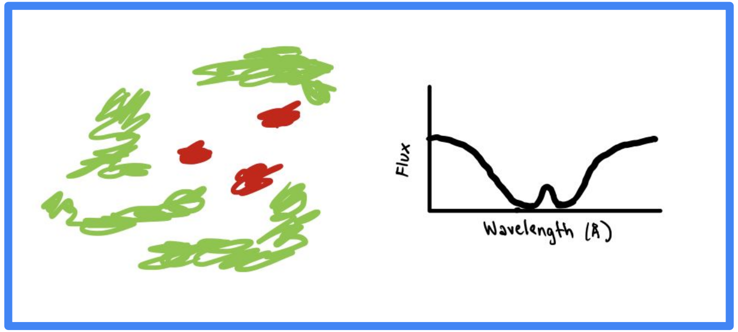
Image Credit: https://courses.lumenlearning.com/astronomy/chapter/the-evolution-of-more-massive-stars/

Subset Of Galaxies Special Because of DLA

- HII gas is extremely hot, ionized; HI gas is cool, neutral
- deeper the HI trough→ higher amount of neutral gas
- ⅓ of sample have this rare feature of damped trough with Lyα emission, *my focus*
- prototypes for galaxies at EoR







Further Work

-work through the larger sample

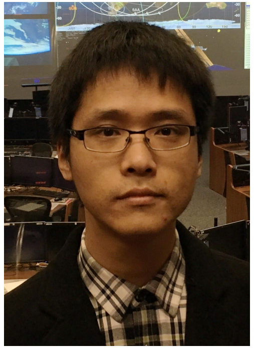
-with these multi-component absorption line fits, test overall correlations with galaxy properties

-probe Lyman alpha emission

Acknowledgements

Dr. Crystal Martin - UC at Santa Barbara

Dr. Nimisha Kumari - Space Telescope Science Institute



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