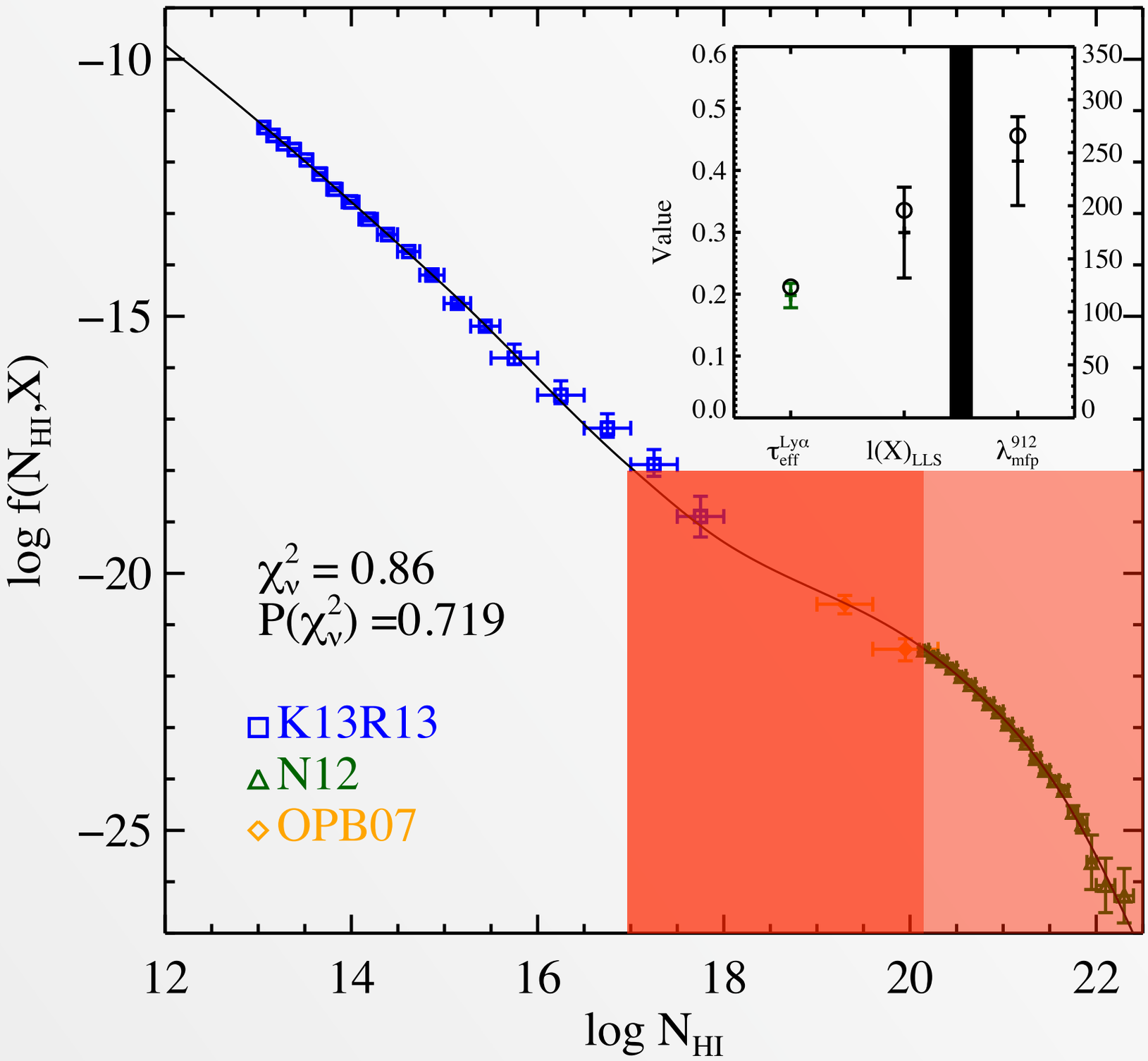
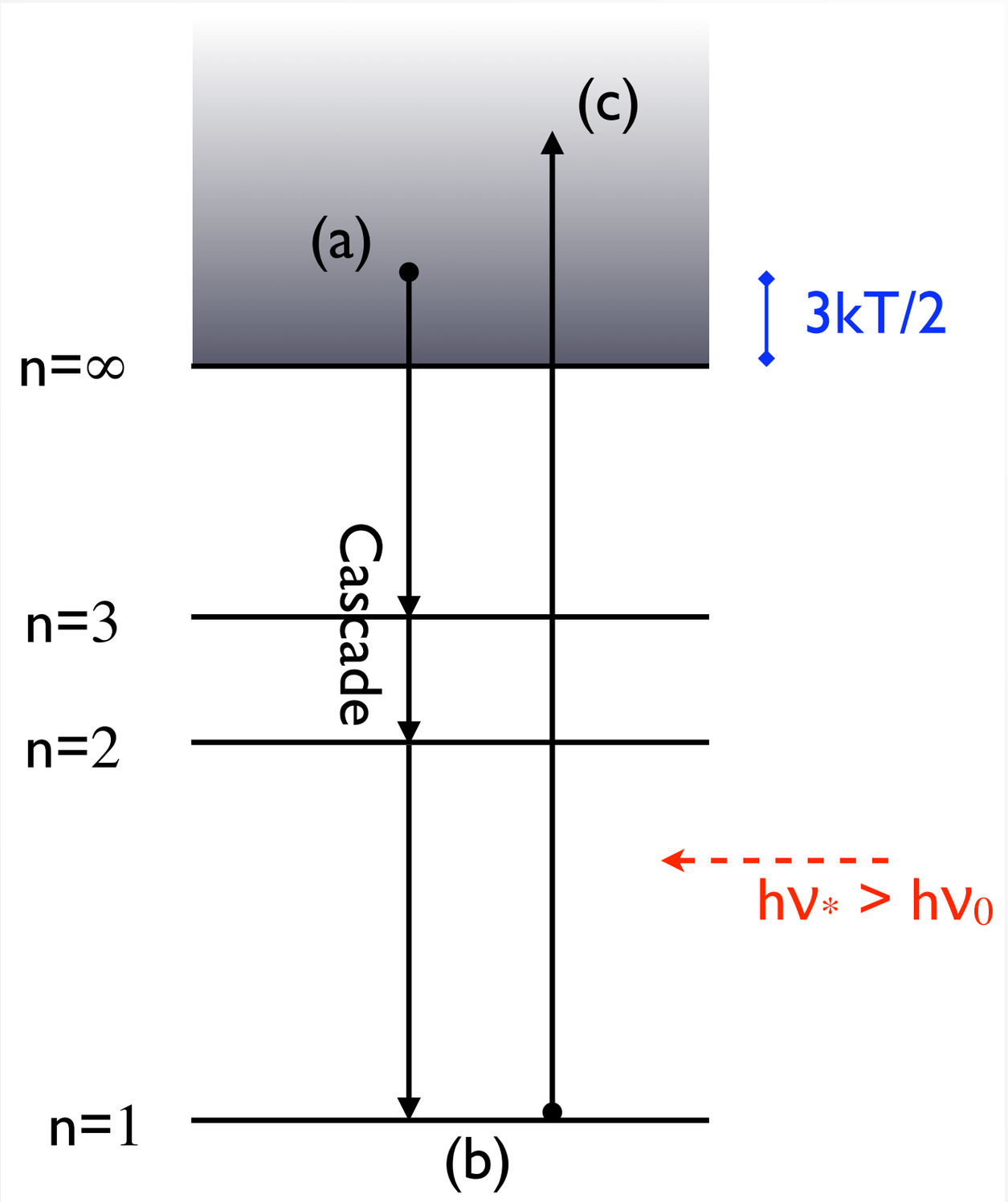
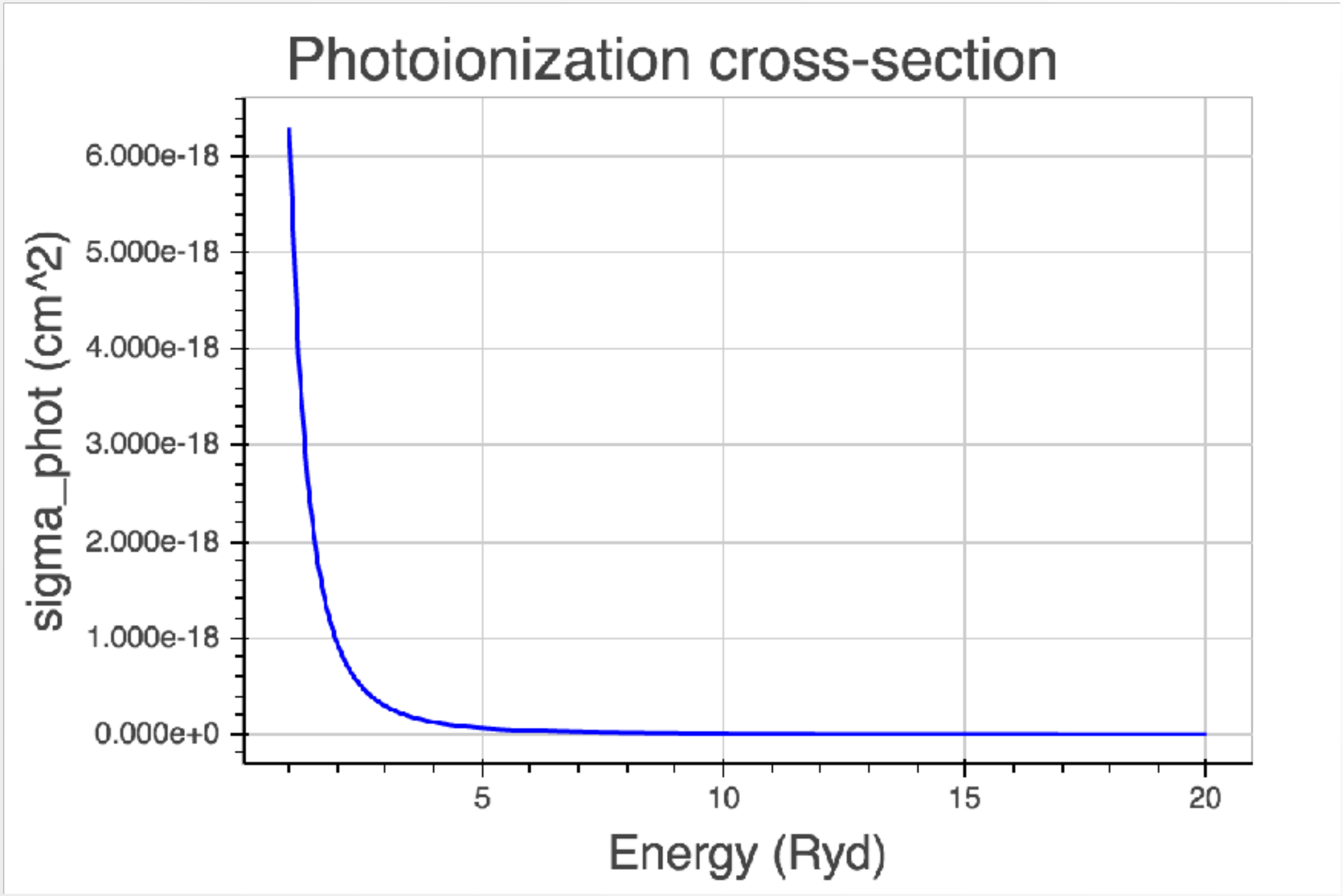
Introduction to Lyman Limit Systems



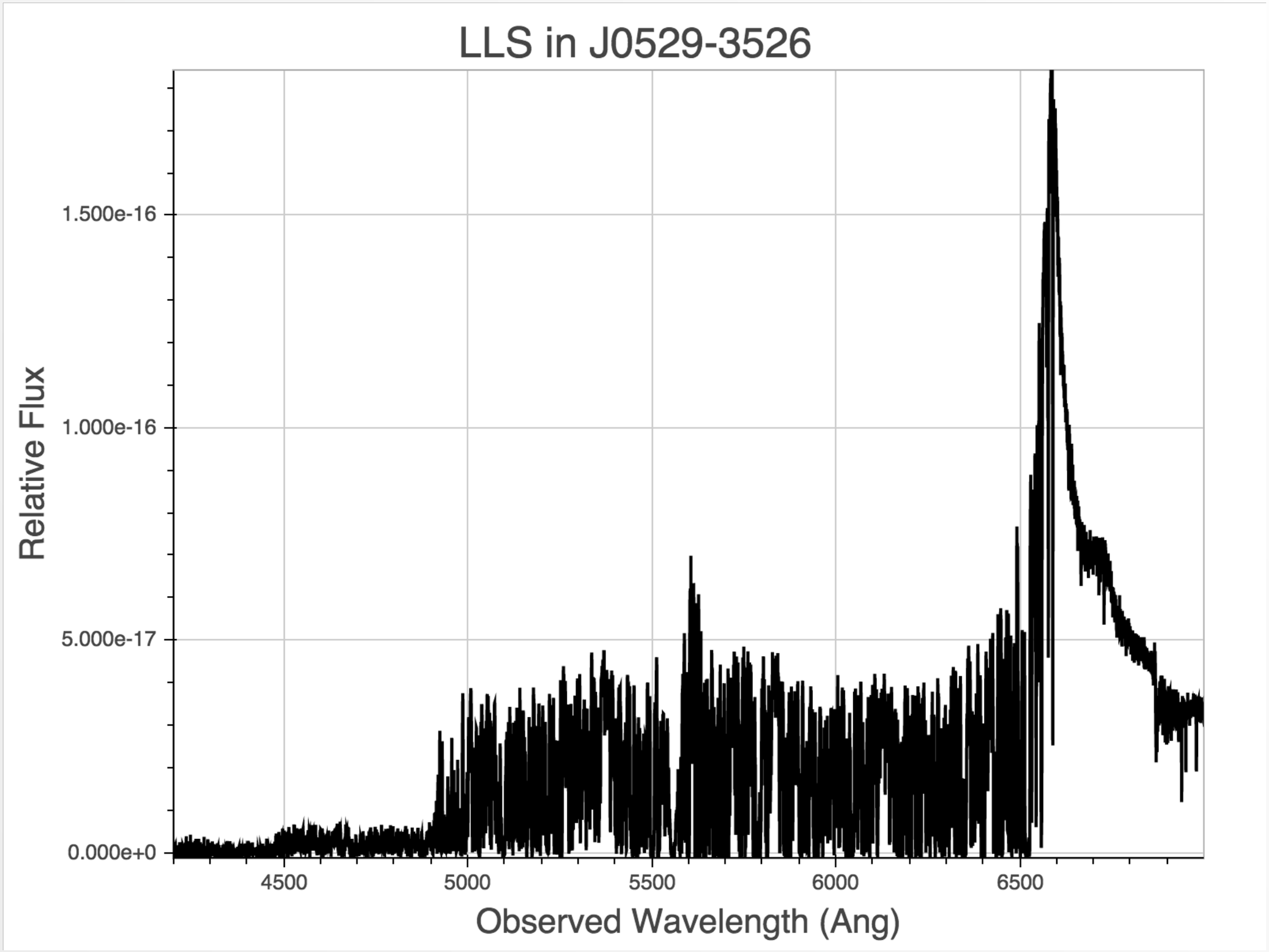
HI Continuum Opacity



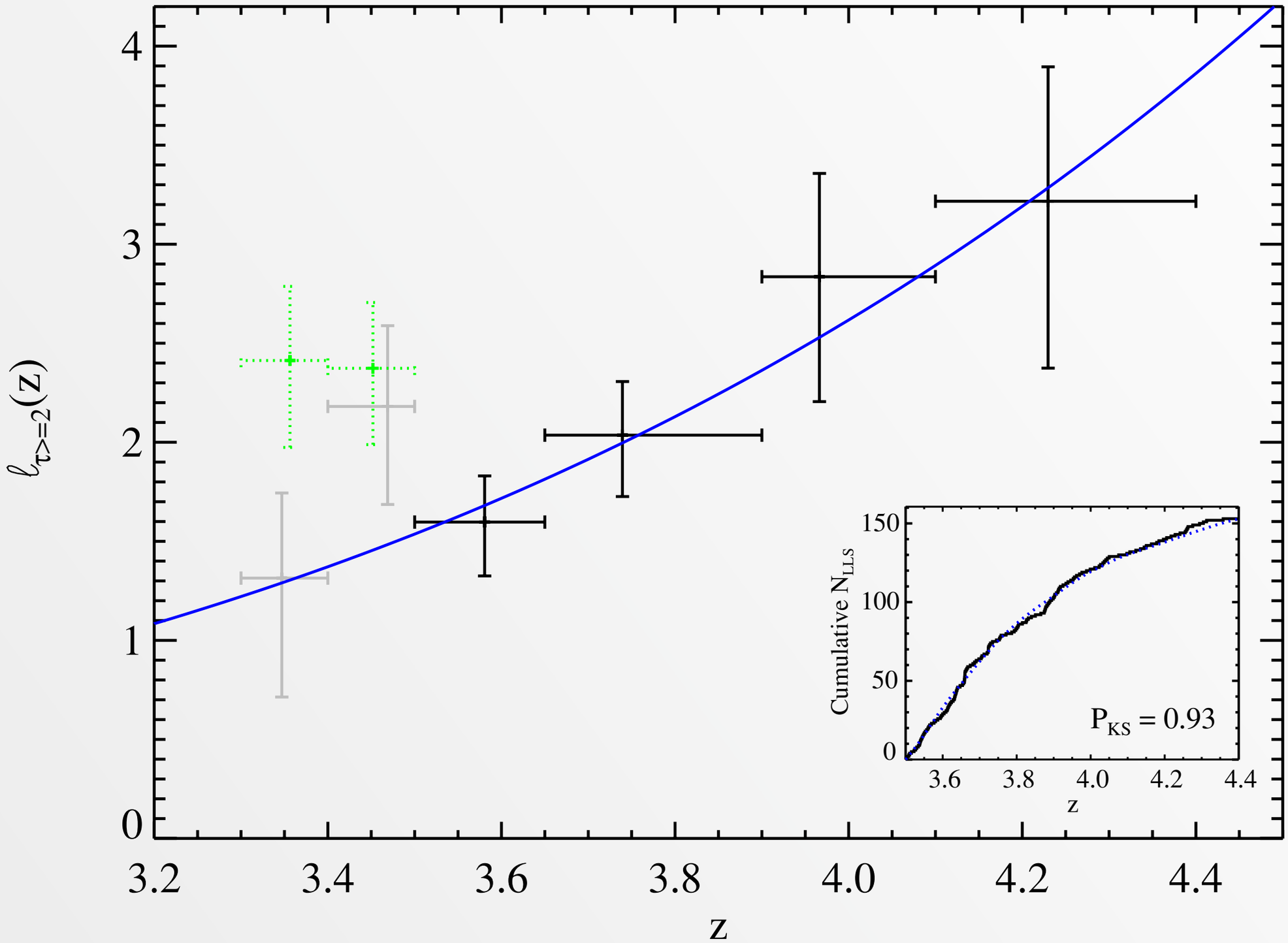
HI Continuum Opacity



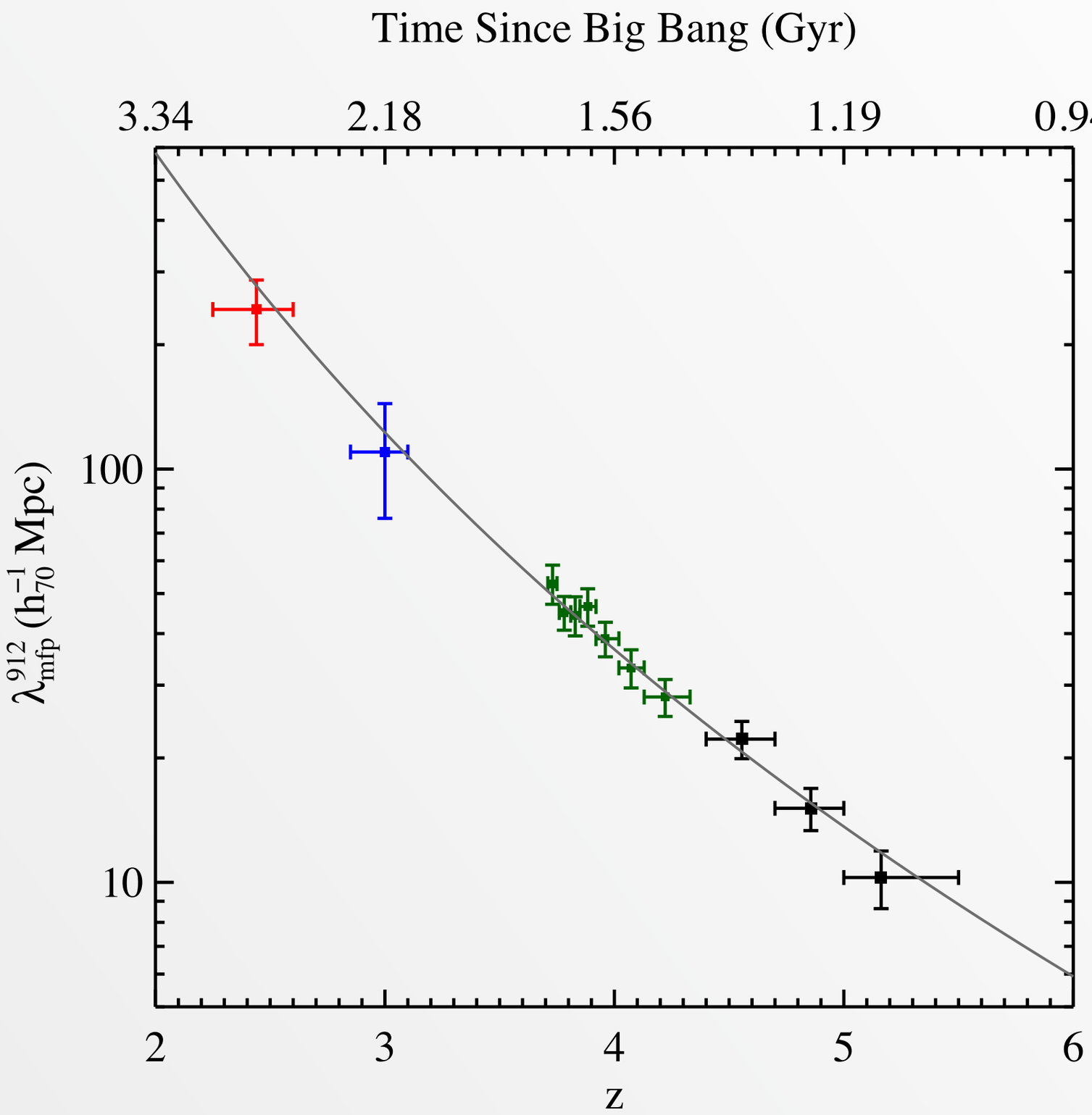
LLS


LLS in J0529-3526
Relative Flux
1.500e-16
1.000e-16
5.000e-17
0.000e+0
4500
5000
5500
6000
6500
Observed Wavelength (Ang)

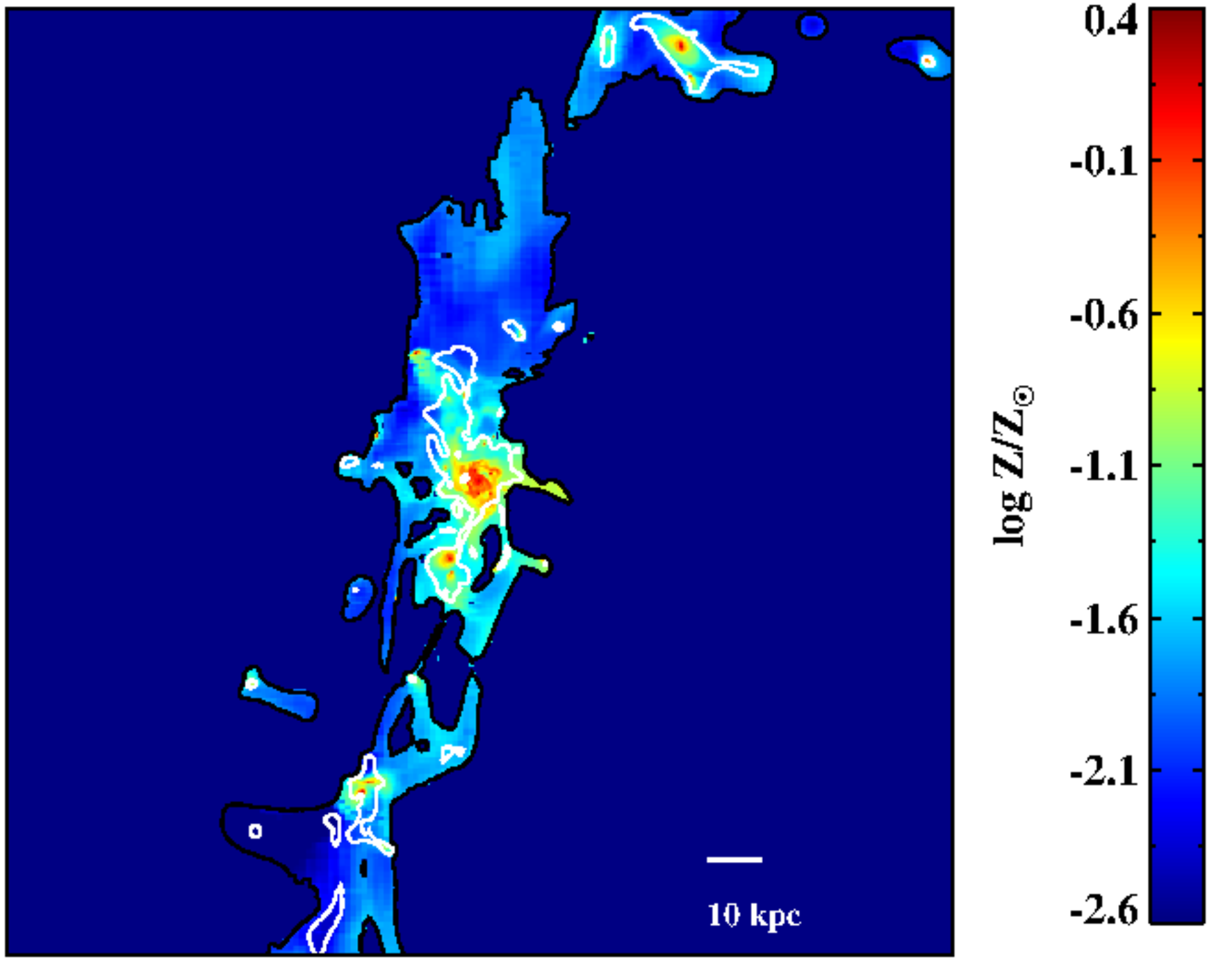
Incidence of Optically Thick Gas



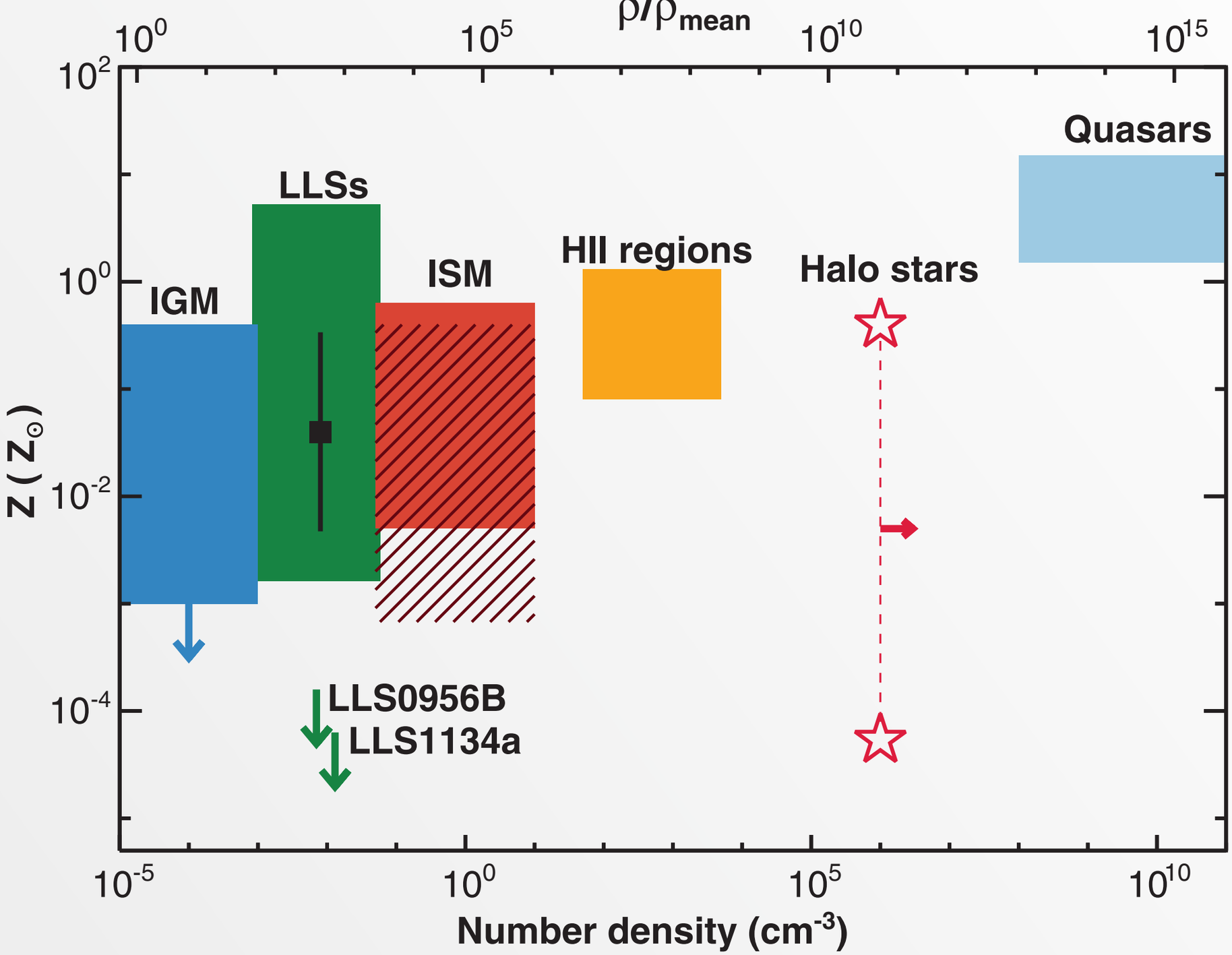
Cosmological Mean Free Path



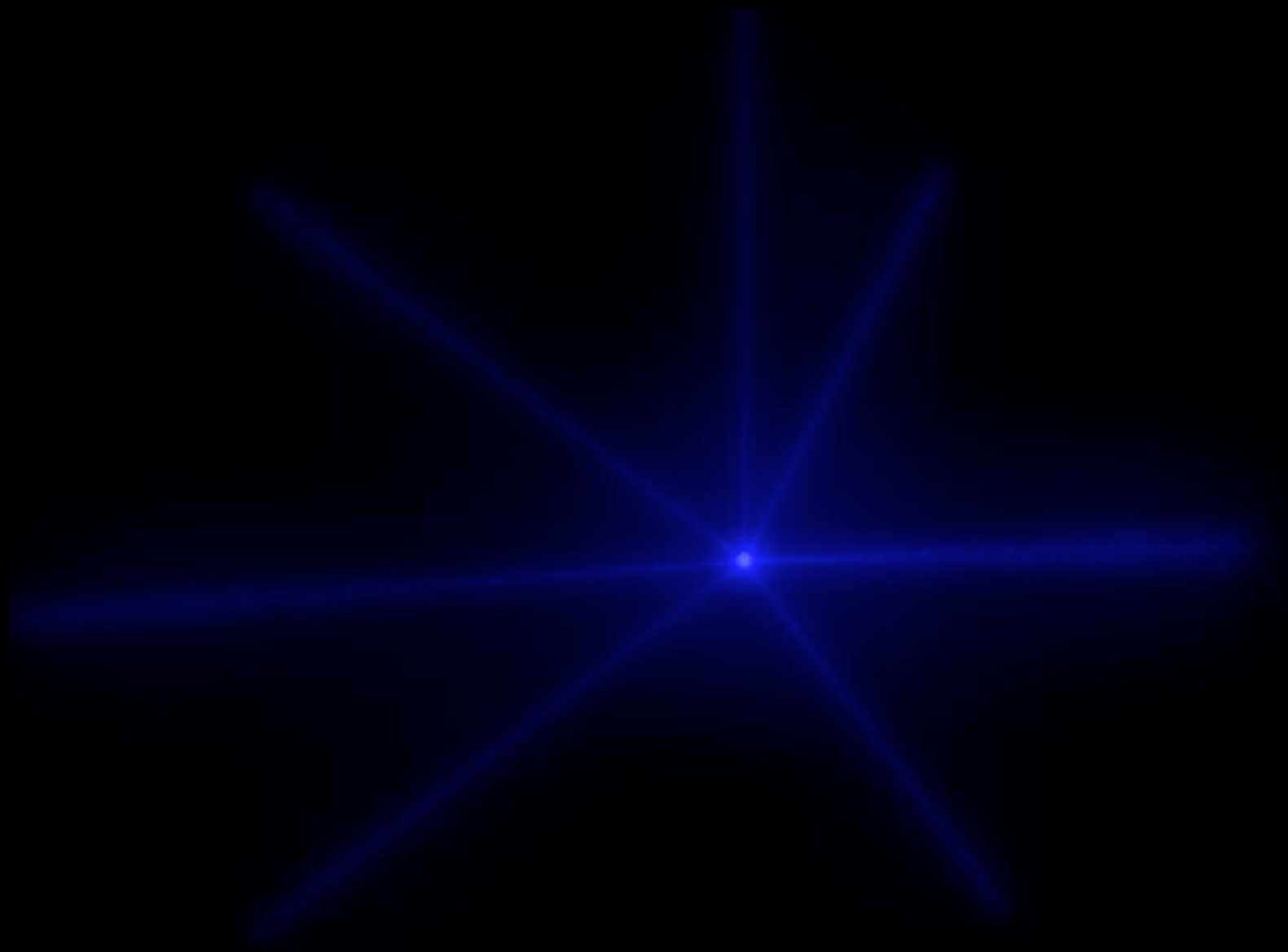
Connection to Circumgalactic Gas



Metal Enrichment

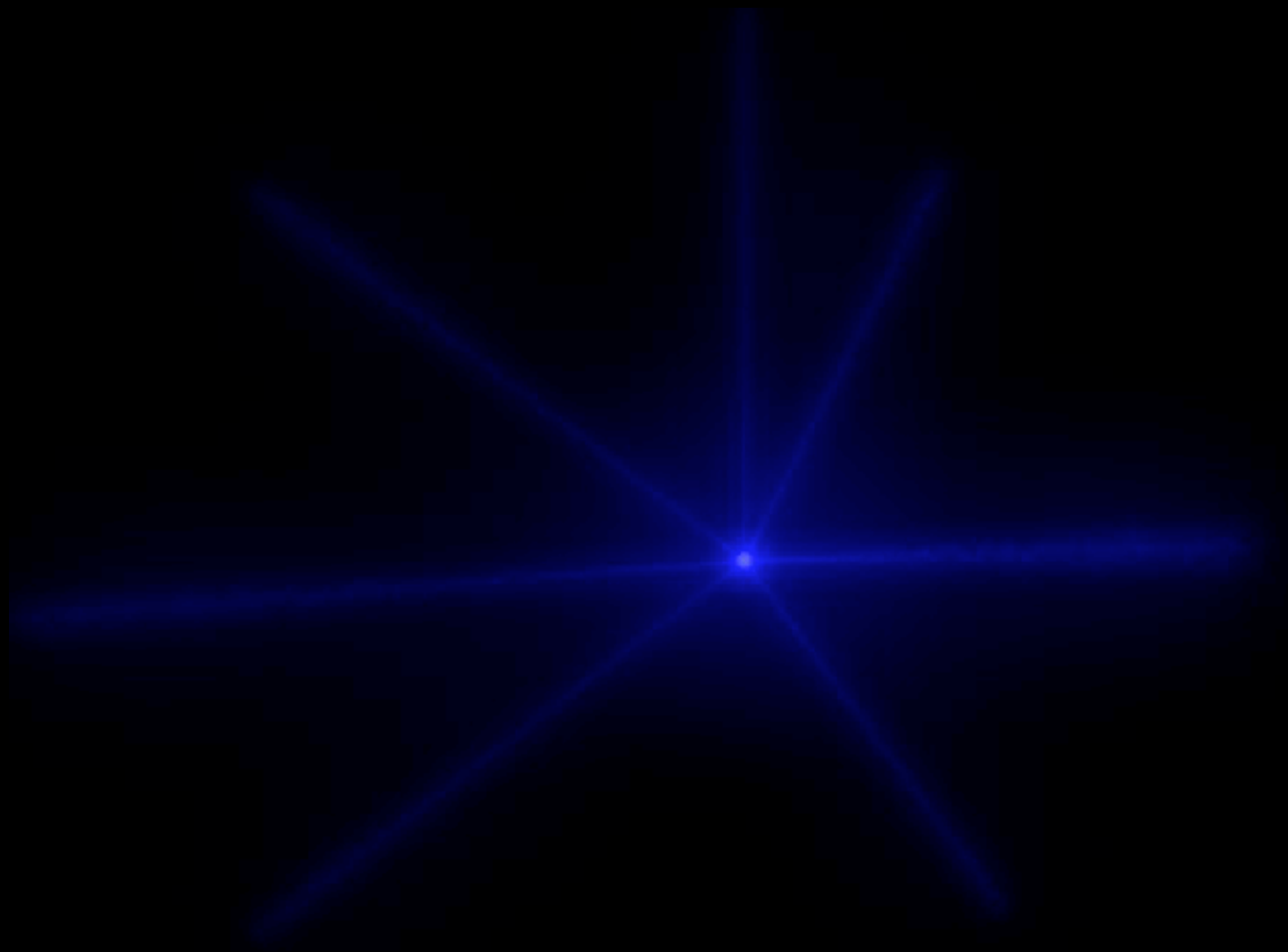


Viewing the Photons



QSO emits (blue) ionizing photons and lower energy ones (red) too

Viewing the Photons



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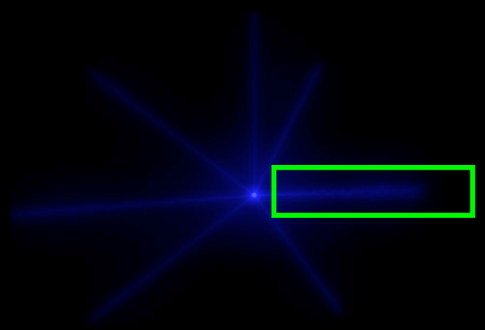

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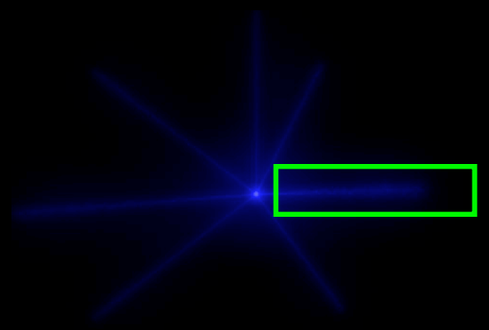
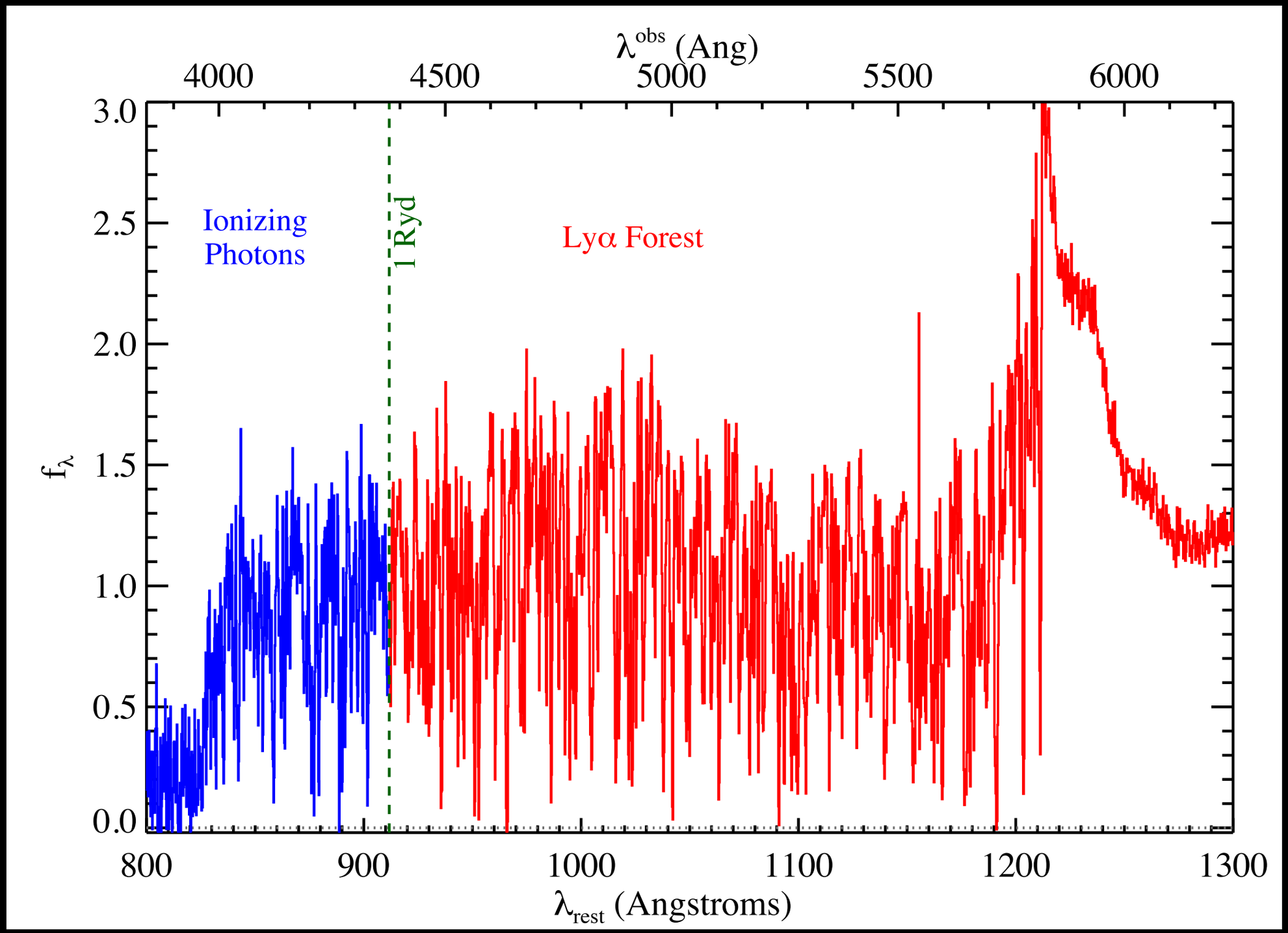
Viewing the Photons





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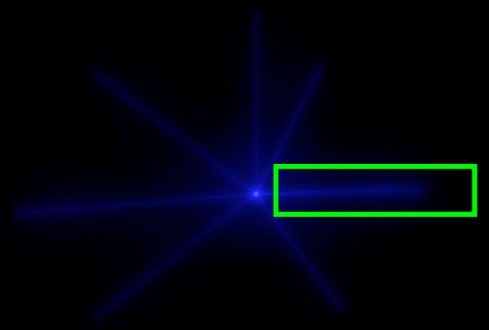
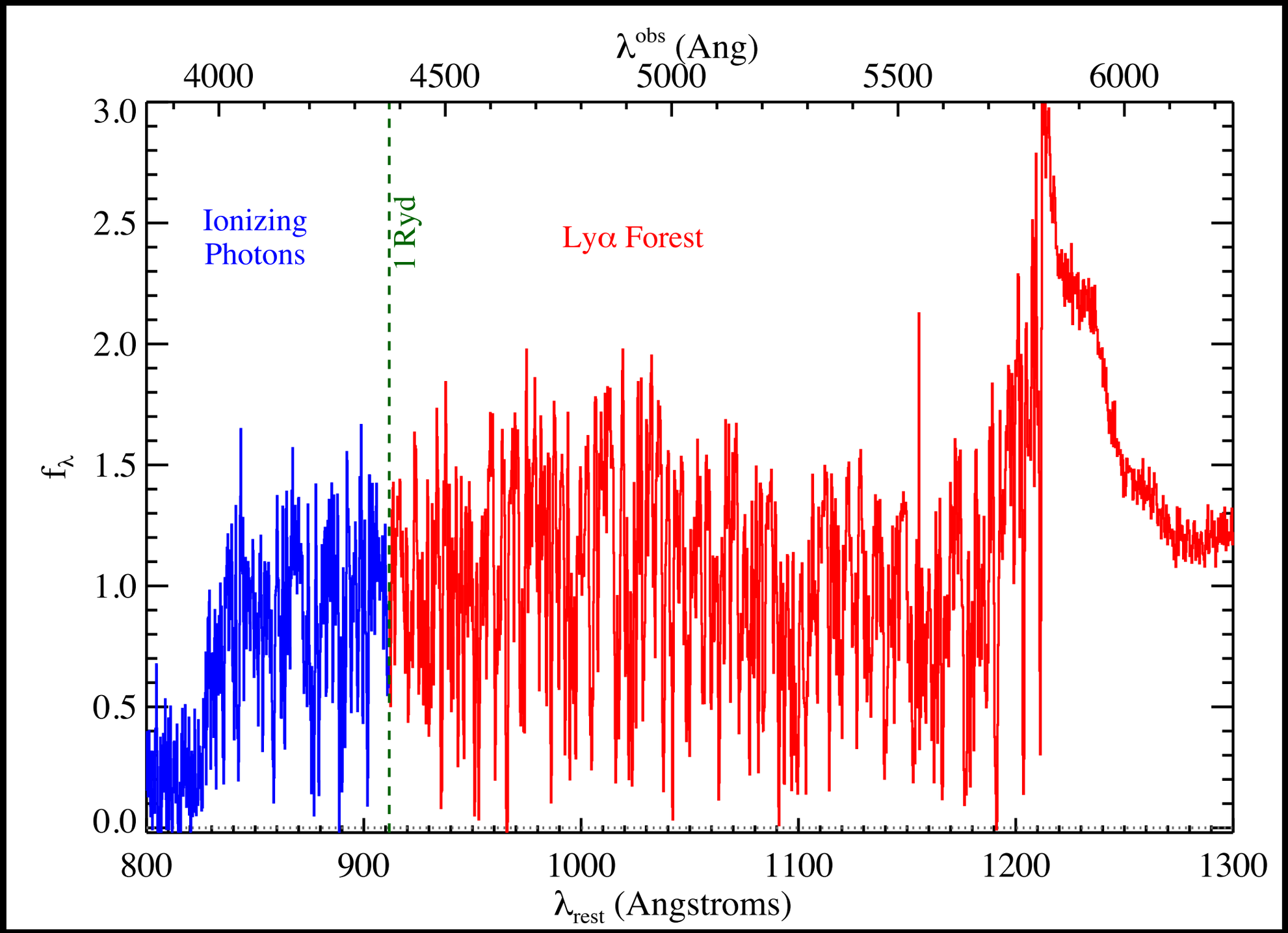
Viewing the Photons





When I view this spectrum, I visualize distance (not just energy)

Visualizing the Photons

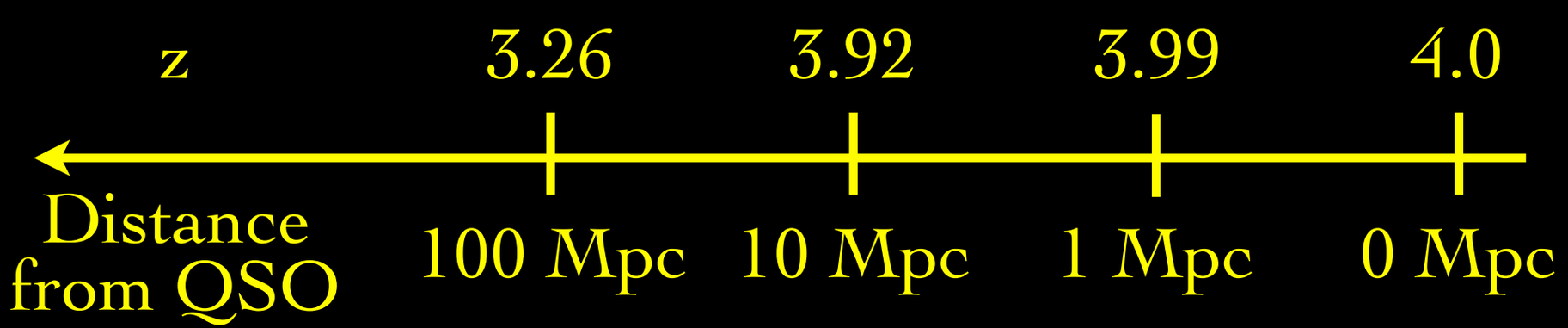
<1Ryd

>1Ryd

<1Ryd (λ_r = 1100A; λ^{obs} = 5500A)

Quasar

Photons redshift during the journey to Earth

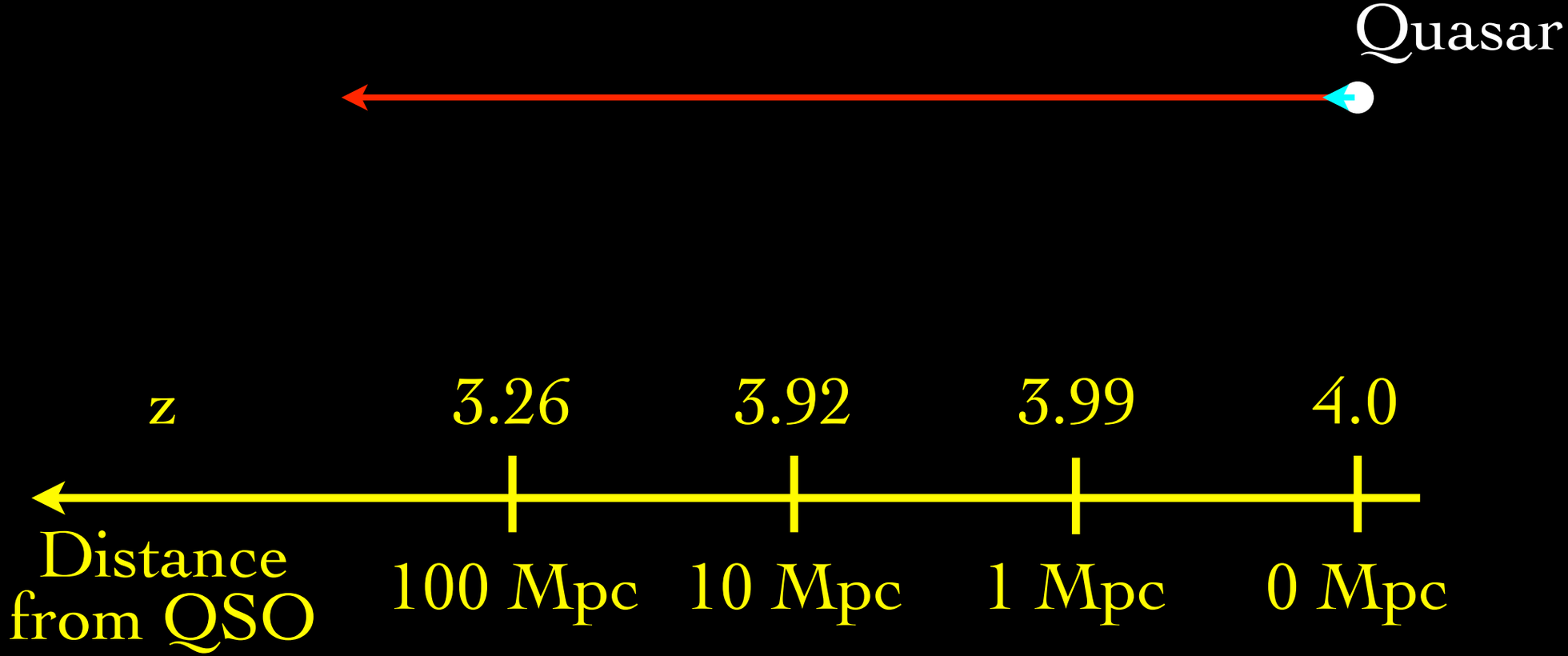


Visualizing the Photons

<1Ryd

>1Ryd

1Ryd (λ_r = 912A; λ^{obs} = 4560A)

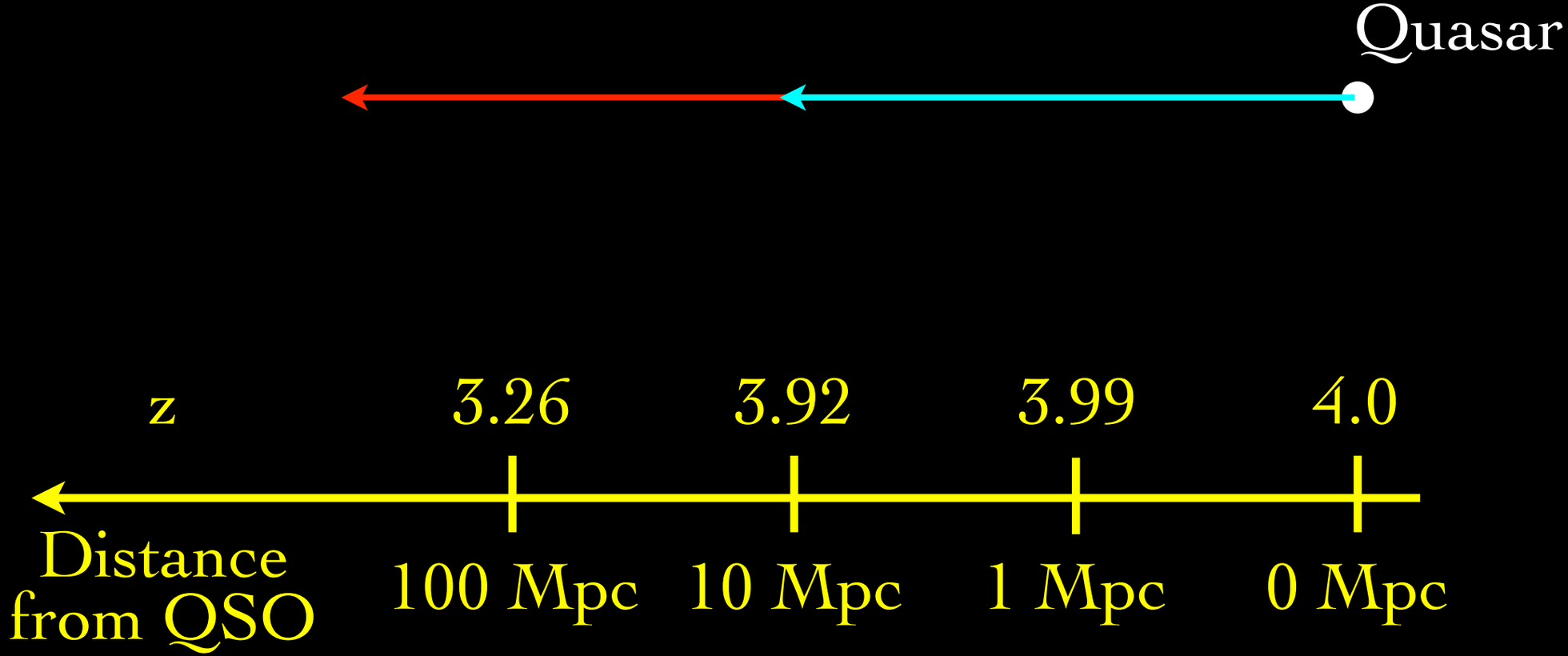


Visualizing the Photons

<1Ryd

>1Ryd

1.02 Ryd (λ_r = 897A; λ^{obs} = 4485A)

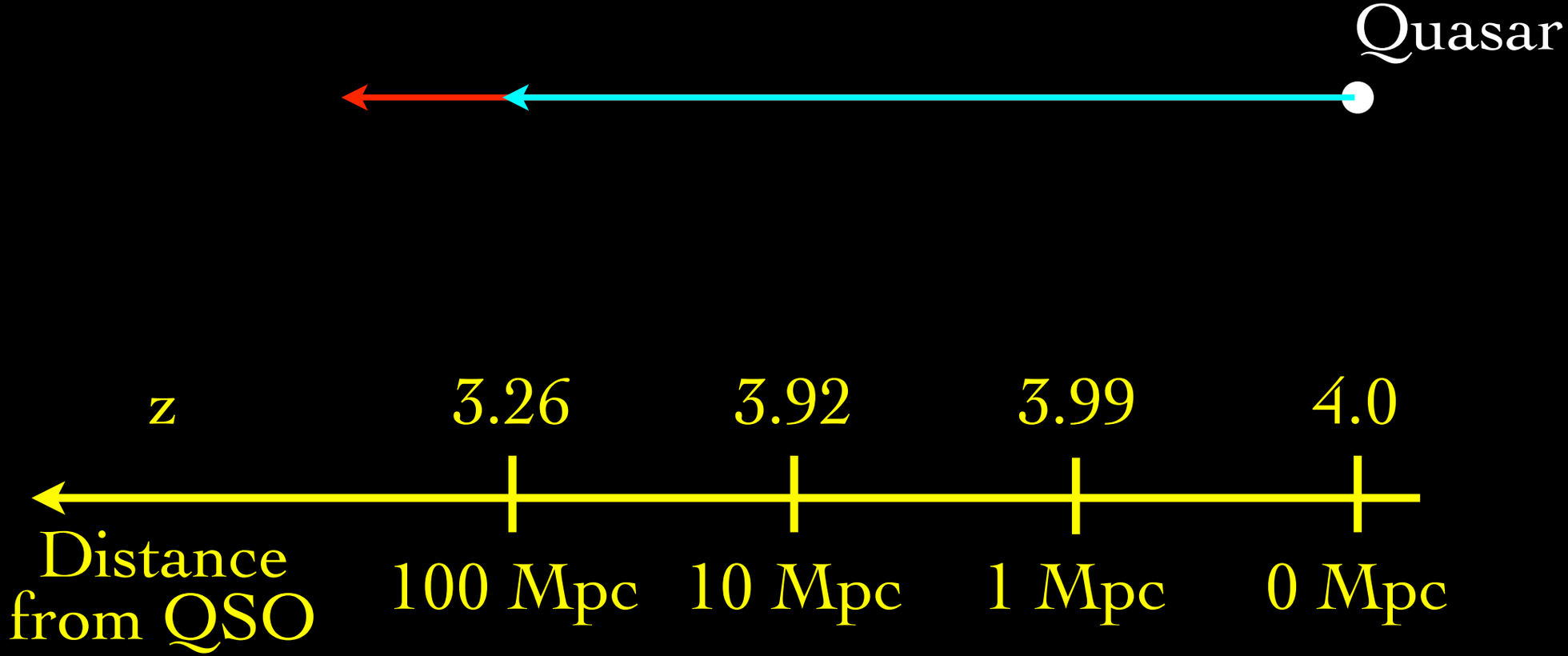


Visualizing the Photons

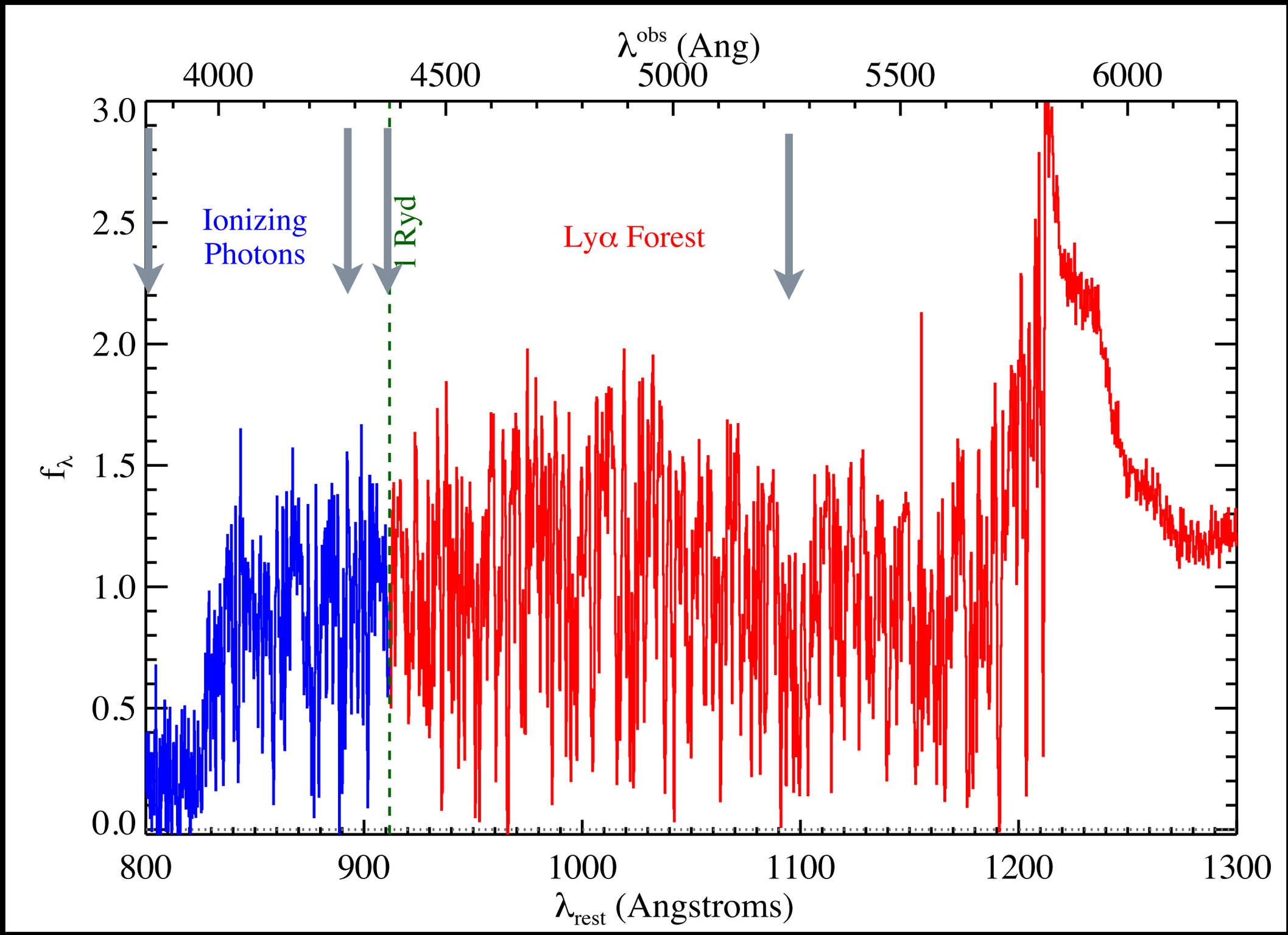
<1Ryd

>1Ryd

1.17 Ryd (λ_r = 776A; λ^{obs} = 3880A)



Viewing the Photons



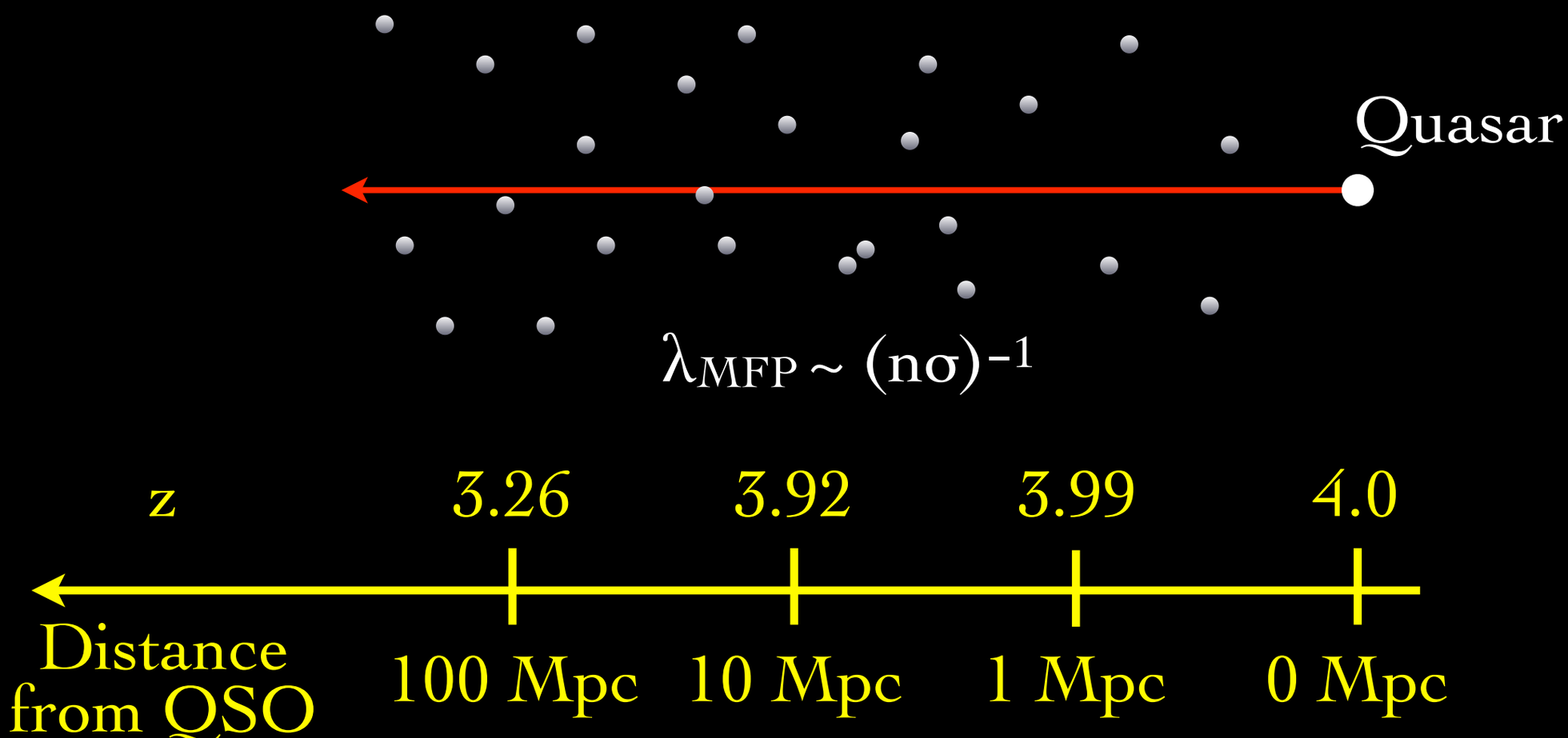
We have neglected the IGM in the discussion thus far.

Visualizing the Photons

<1Ryd

>1Ryd

<1Ryd (λ_r = 1100A; λ^{obs} = 5500A)

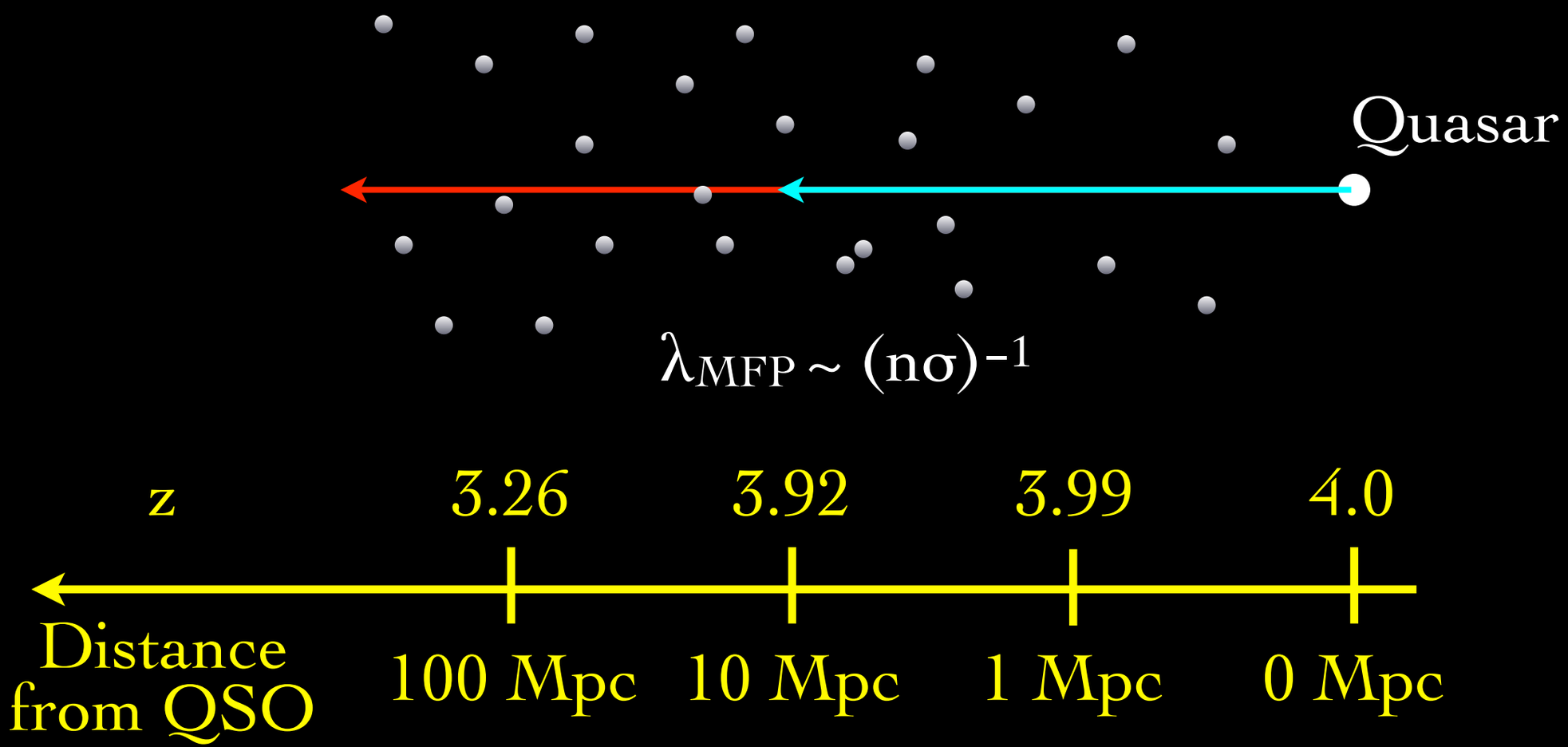


Visualizing the Photons

<1Ryd

>1Ryd

1.02 Ryd (λ_r = 897A; λ^{obs} = 4485A)

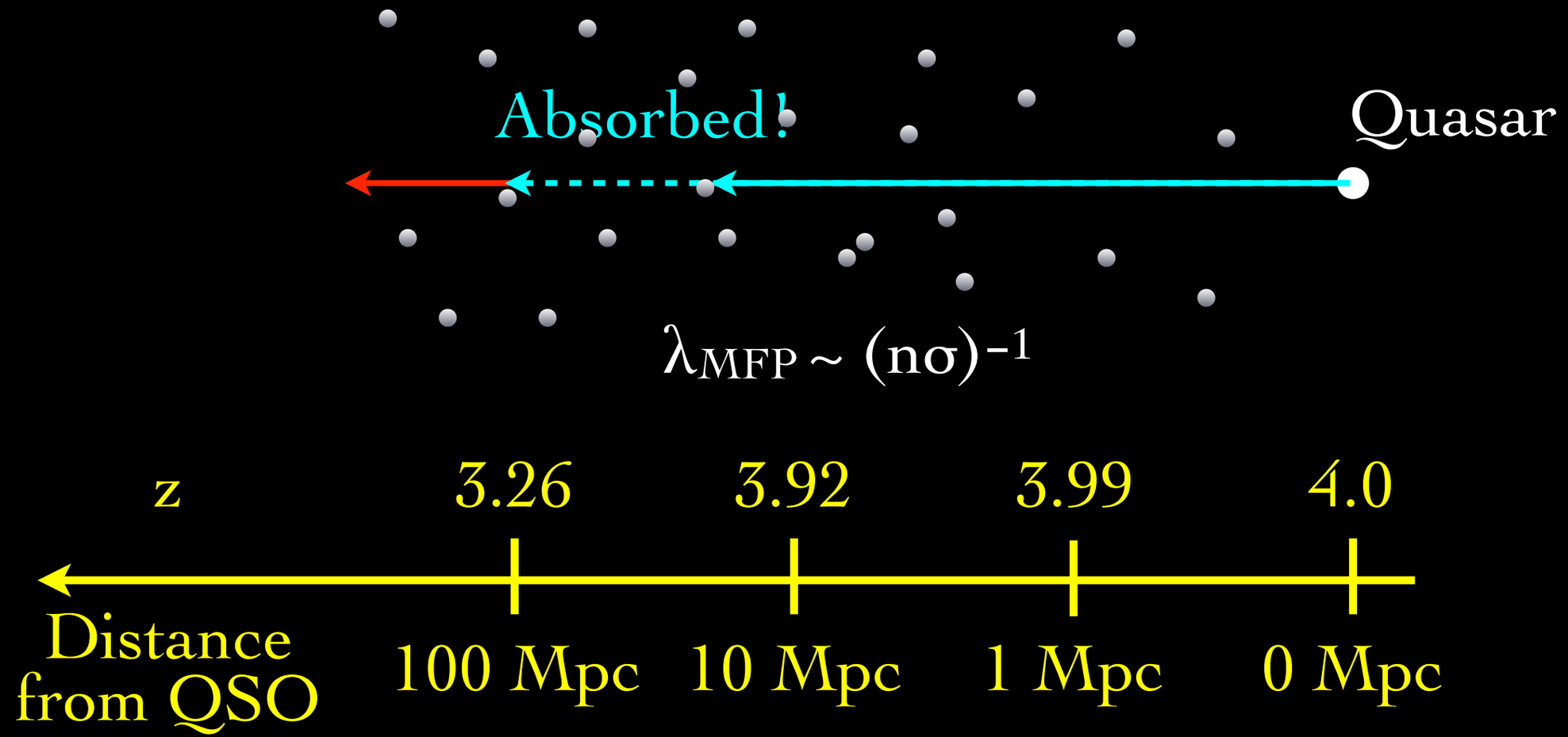


Visualizing the Photons

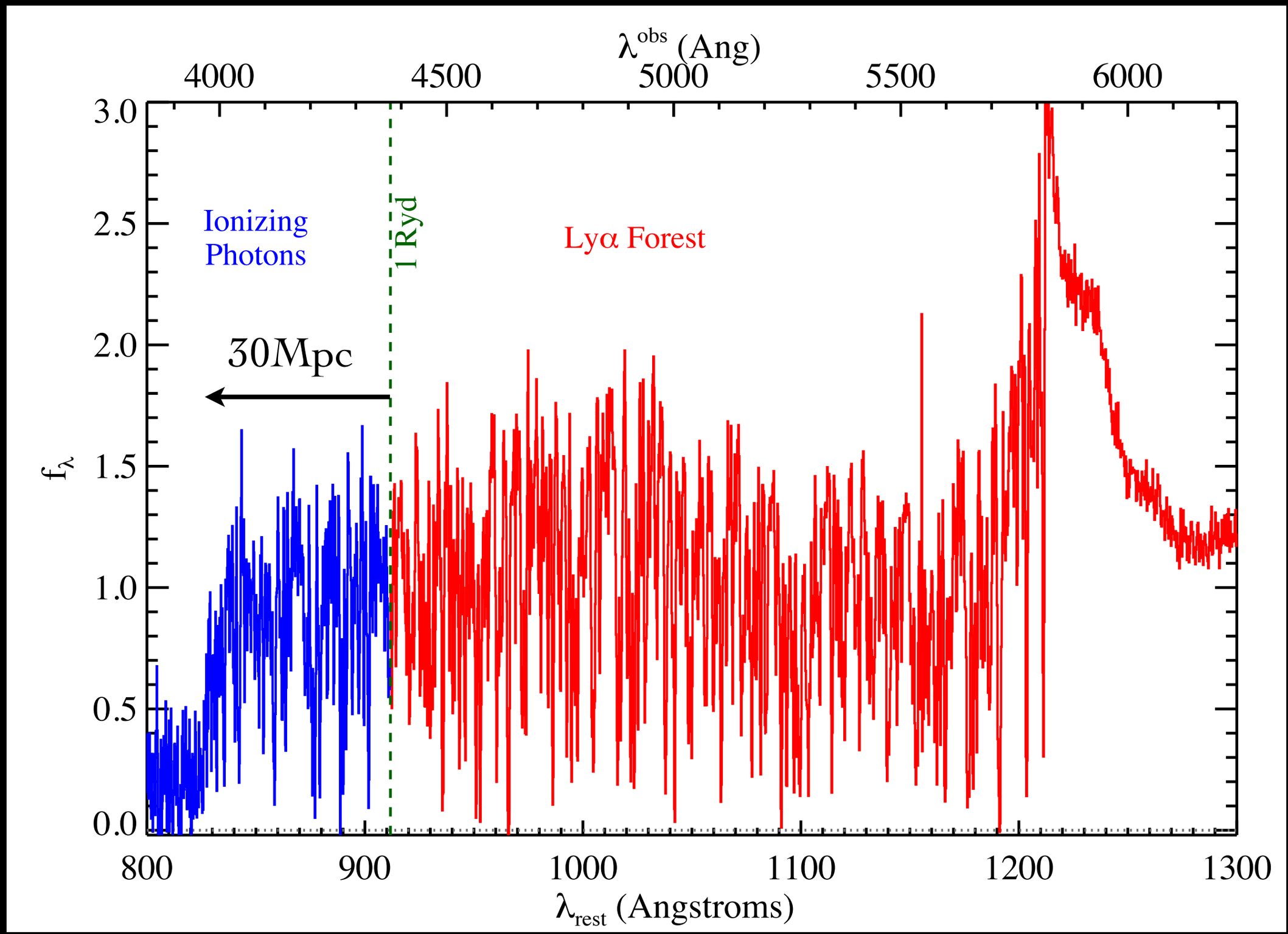
<1Ryd

>1Ryd

1.17 Ryd (λ_r = 776A; λ^{obs} = 3880A)

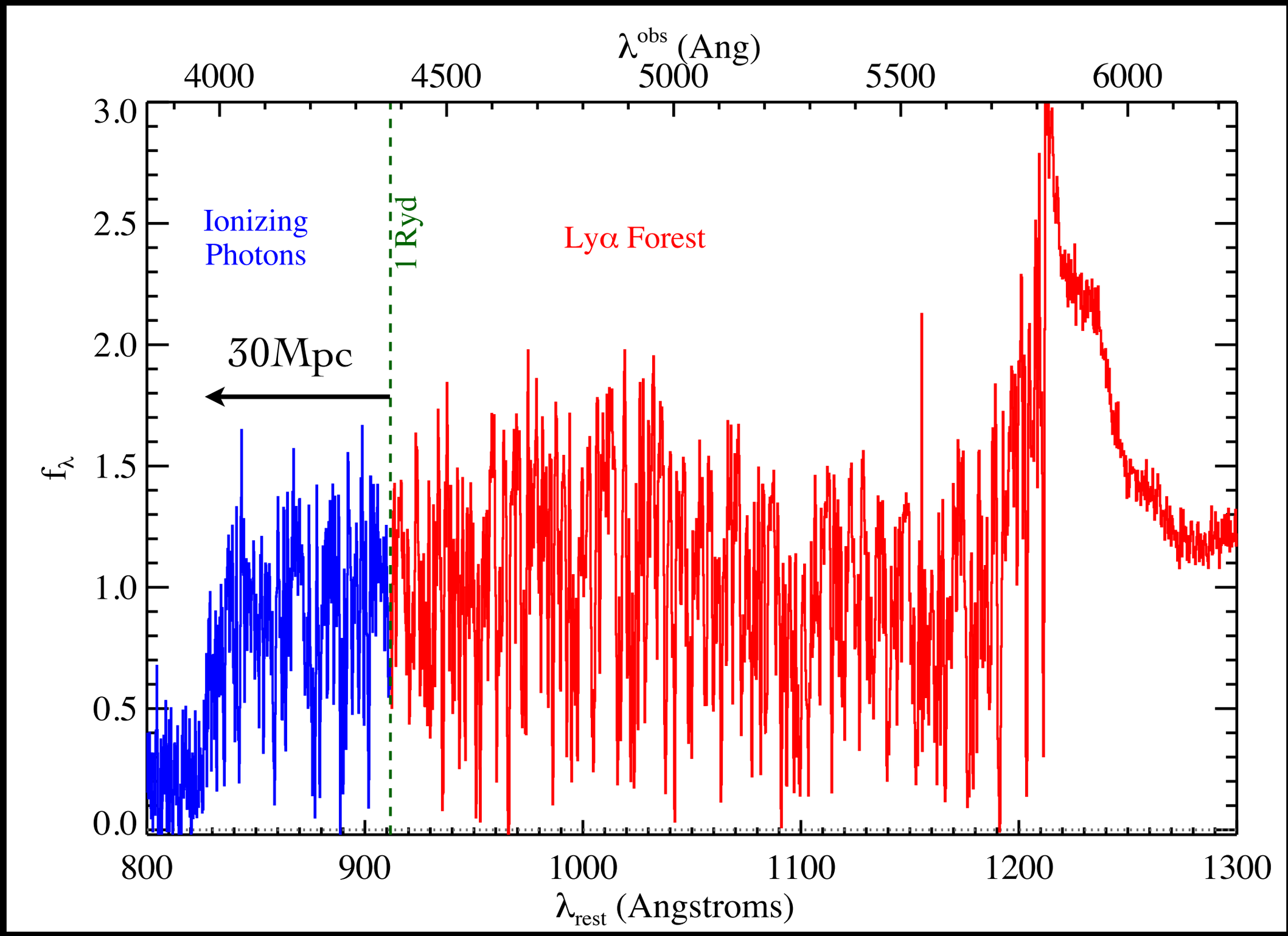


Viewing the Photons



A (partially) optically thick `cloud' lies ~30Mpc in front of this quasar.

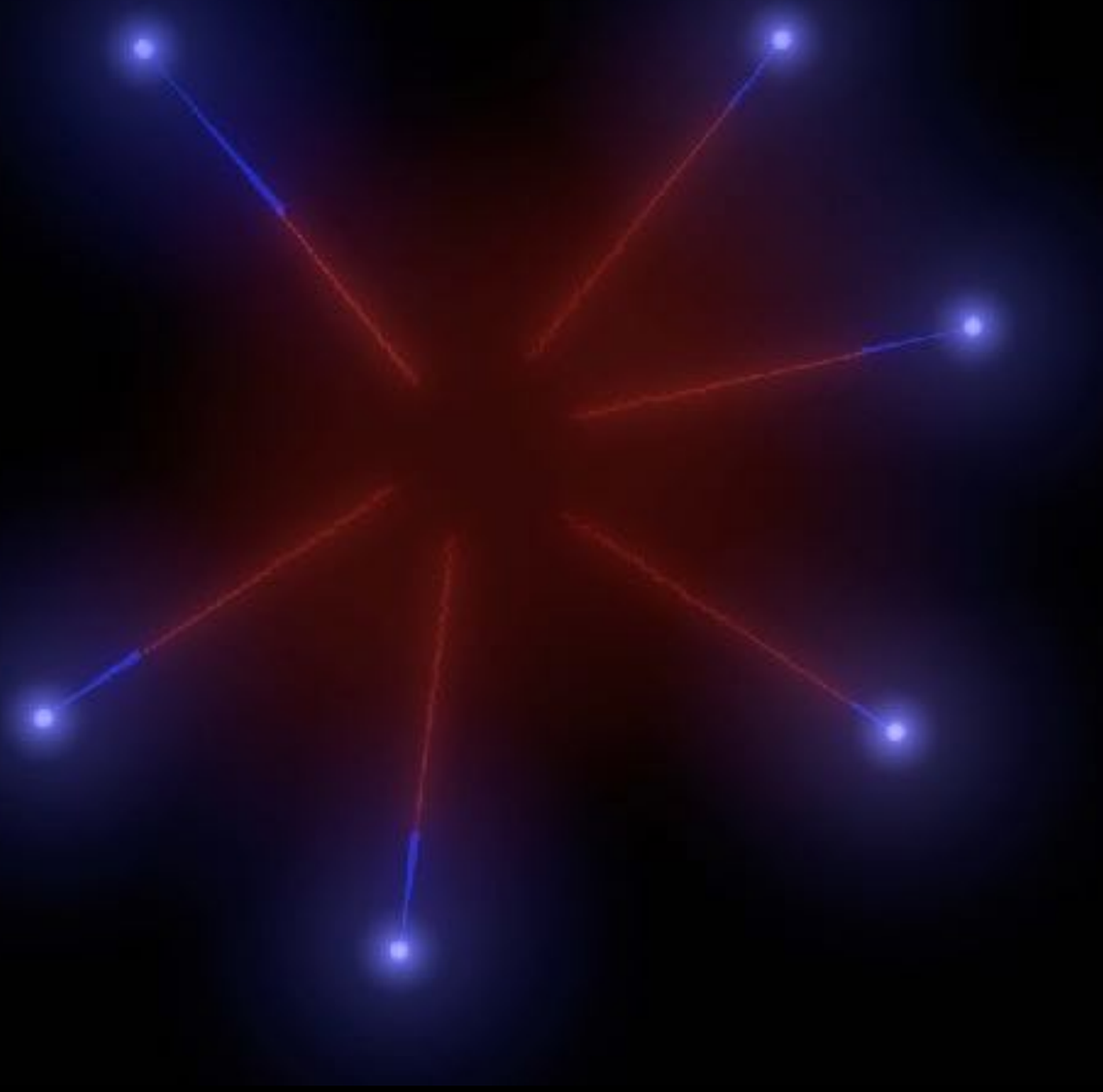
Viewing the Photons



We measured the absorption distance along one sightline, but the IGM is a stochastic medium.

Visualizing the Experiment

z=3 Universe



Spectra are too poor to measure individually.
Average (stack) the IGM spectra from a sample of quasars