Effects of Shielding on Metallicity Estimates in QSO Absorption Line Systems

Elizabeth S Klimek
NM Spacegrant Consortium
Student Colloquium
April 15, 2011

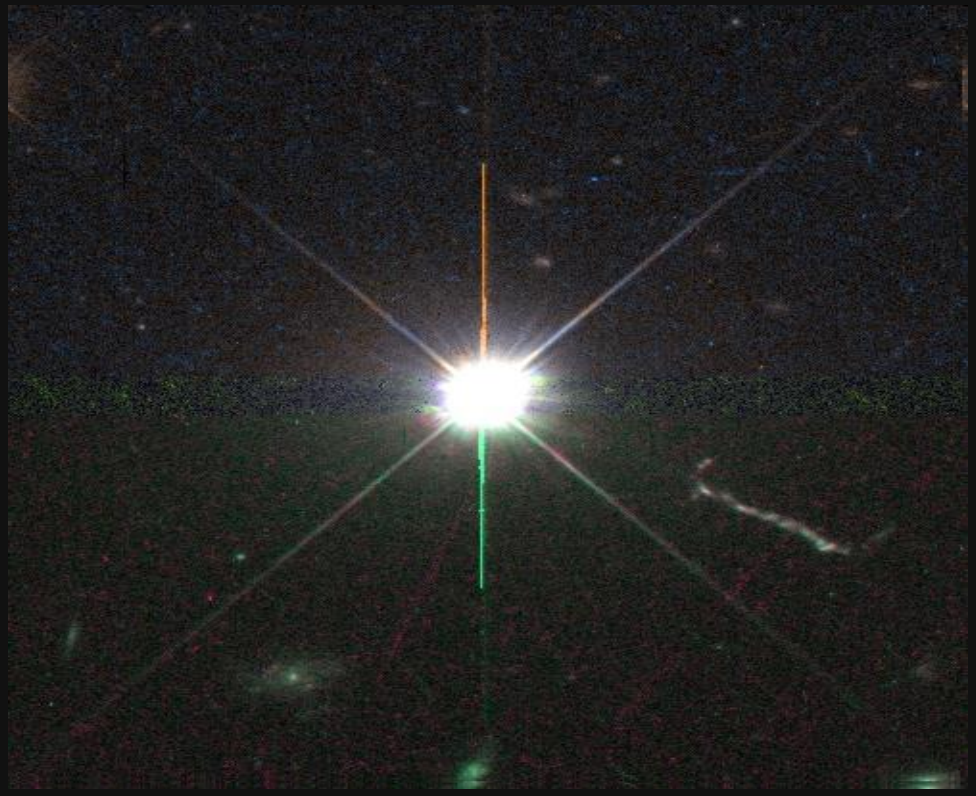
The Big Picture

What can the gas within, nearby, and between galaxies tell us about galaxy formation and evolution?

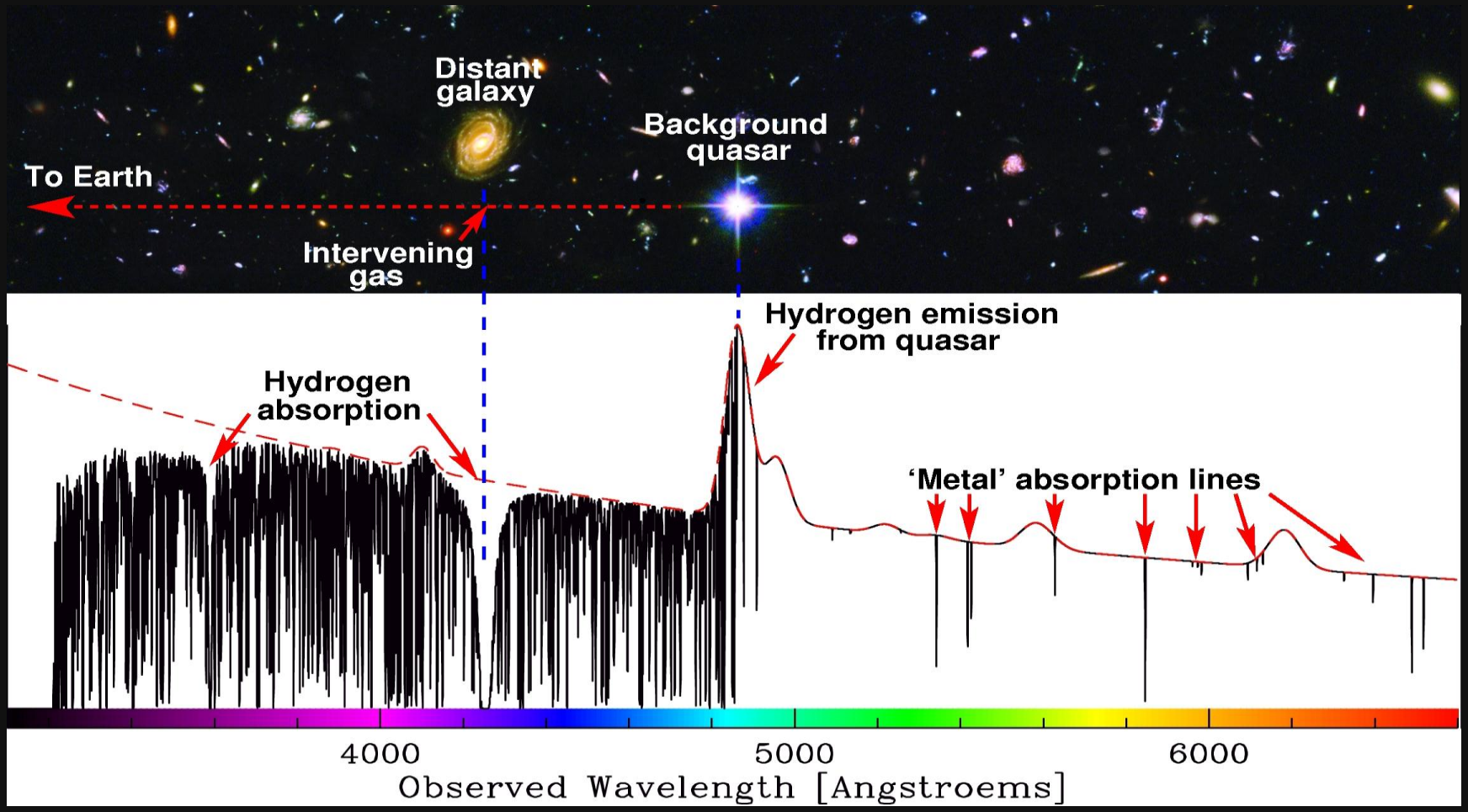
What methods can we use to study the gas, when most of it is so far away?

What is a QSO Absorption Line System (QAL)?

- QSO: a distant, extremely luminous object that can be used as a cosmic flashlight
- Absorption Line System: intervening material, such as a gas cloud, that absorbs background light
- Elements/ions within the material absorb the light
- In doing so, each ion leaves a signature, or fingerprint, in the form of an absorption line.
- The light that makes it through the material carries a record of the absorption signature, and you have a spectrum



Quasar spectrum shows metal absorption signatures from intervening material



Why QALs are Useful

- QALs are great for probing the metallicity content (composition) of gas in a wide variety of enivronments
  - Column density of a metal only depends on the number density of absorbers along line of sight
  - Independent of luminosity, morphology, etc…of the absorber
- Limited by specific sight lines to QSOs, but there are lots of these thanks to SDSS

Importance of QAL Metallicities

- Tells us about enrichment history of gas
  - How did the Universe build up metals over time?
- Metallicities might give a clue as to the relationship between absorbers and galaxies
  - For example, is there evidence that a system was in close proximity of vigorous star formation?
  - Is there a relationship between large neutral column systems and the mass the galaxy they are associated with? (e.g., Kulkarni et al. 2010)

Getting Metallicities from Absorption Spectra

- Absorption line measurements give column densities: number of ions per cm^2
- Column density (N) measured depends on:
  - number of absorbers (how much absorbing stuff there is)
  - number of ionizing photons (how strong your flashlight is)
- However, now we only know the column density of one particular ionization stage (i.e., MgII)
- We want to know how much of a particular element is present in the cloud (i.e, Mg/H)
- How do we do this?

Photoionization Modeling

- Computer modeling of the ionization conditions (i.e., density, temperature) present in gas
- Simulate what kinds of column densities would be measured and compare with observational data
- Model gives the column densities of other ionization stages of metal (i.e., MgI, MgII, MgIII, etc…)
- Now you know the column density of the metal
- Compare to hydrogen, and you have the metallicity (i.e., Mg/H)

Common Modeling Assumptions

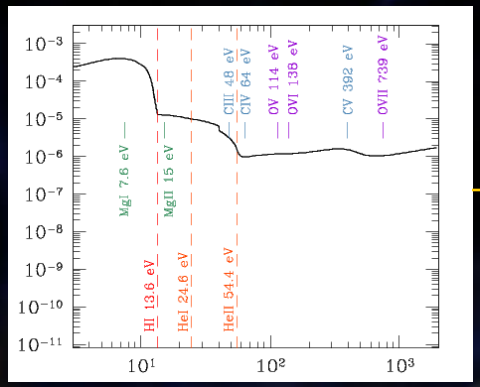
- Photoionization equilibrium
- Single phase (Milutinovic et al. 2010)
- Solar abundance pattern
- No depletion onto grains
- A particular ionizing continuum
  - Usually assumed to be Haardt-Madau UV background, which is the contribution from galaxies and quasars at a given redshift (Misawa et al. 2008)
  - Degree of ionization in a cloud depends critically on the shape of the ionizing continuum source—so environment is important

Environmental Effects: Shielding

- Shield cloud will modify the shape of the bare Haardt-Madau UV background
- How does shielding affect the column densities that we measure?
- This will affect the metallicity that we infer
- To date no one has investigated this before

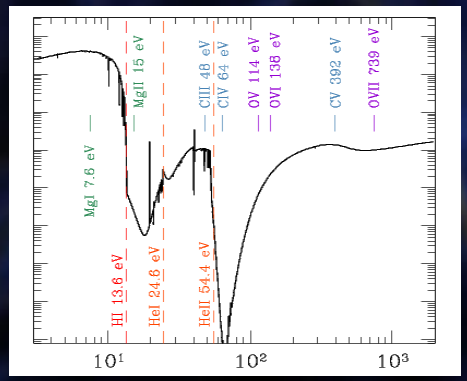
Simplest Case Scenario

- redshift = 1,
- solar abundance pattern,
- single phase



H&M bare UVB at z=1

shield cloud

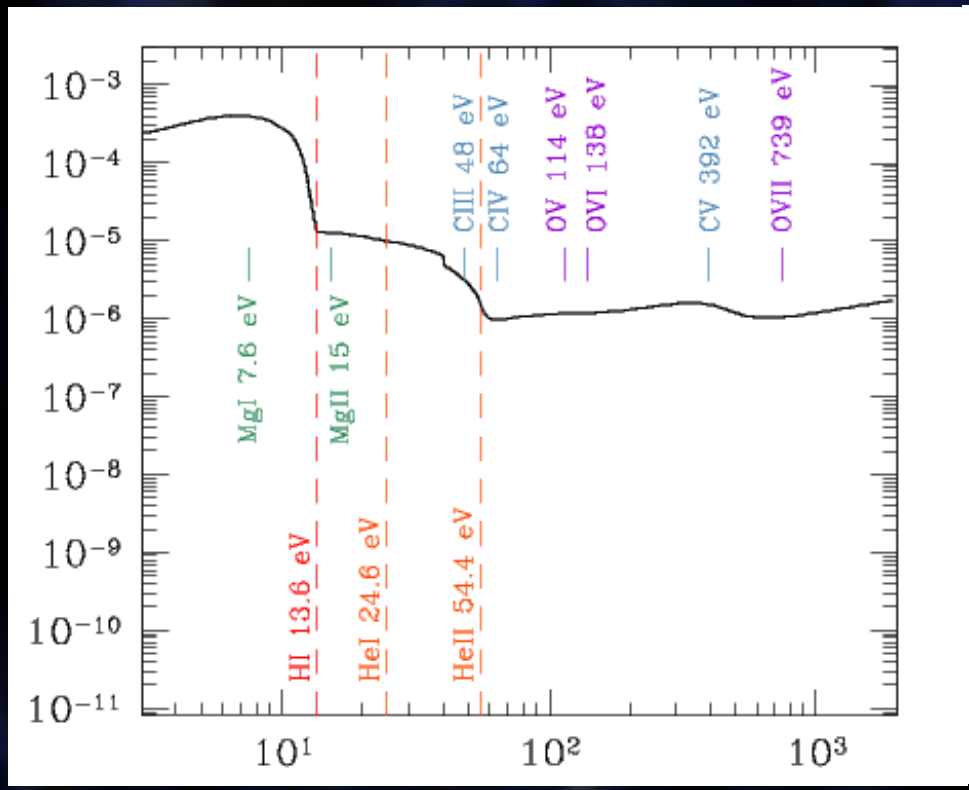


H&M shielded UVB at z=1

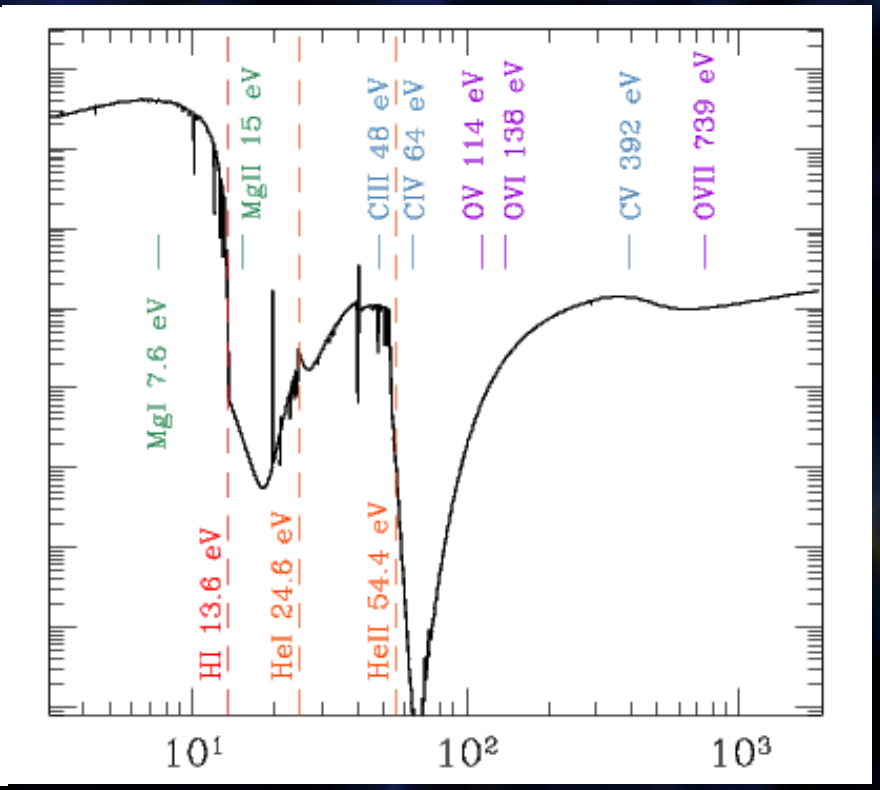
observed cloud

To Observer

Modified Incident Continuum

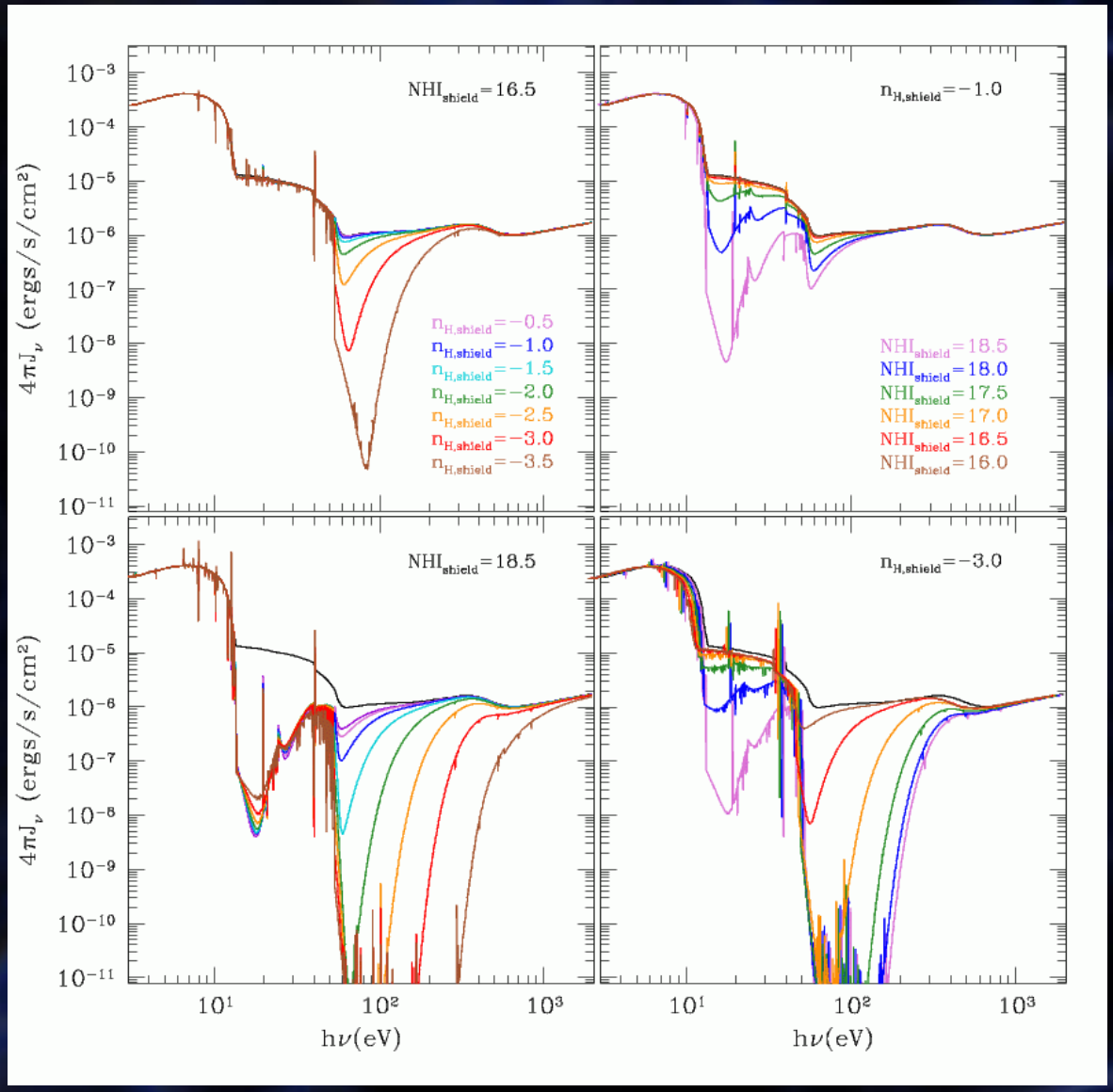


Incident Continuum

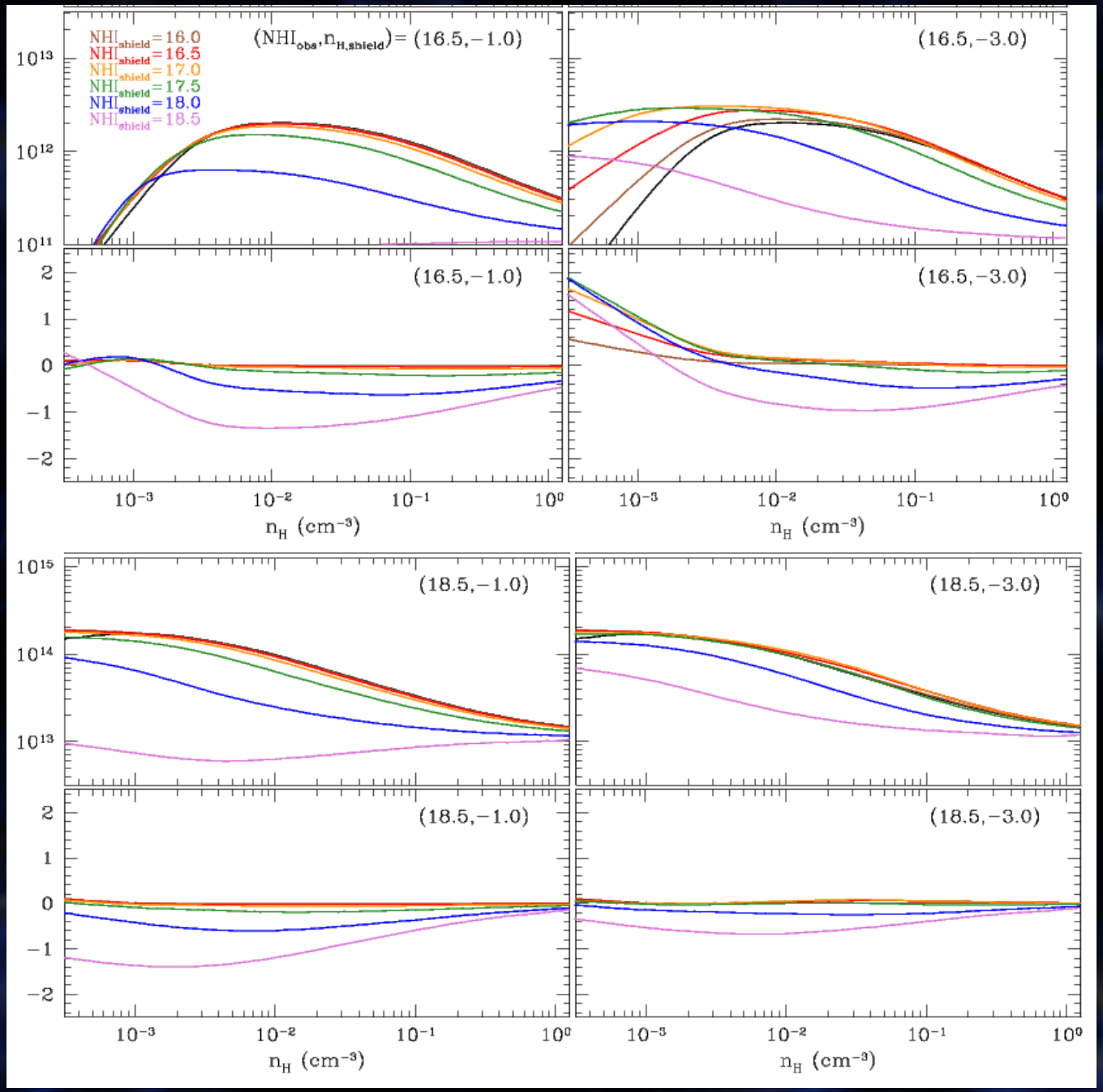


Transmitted Continuum

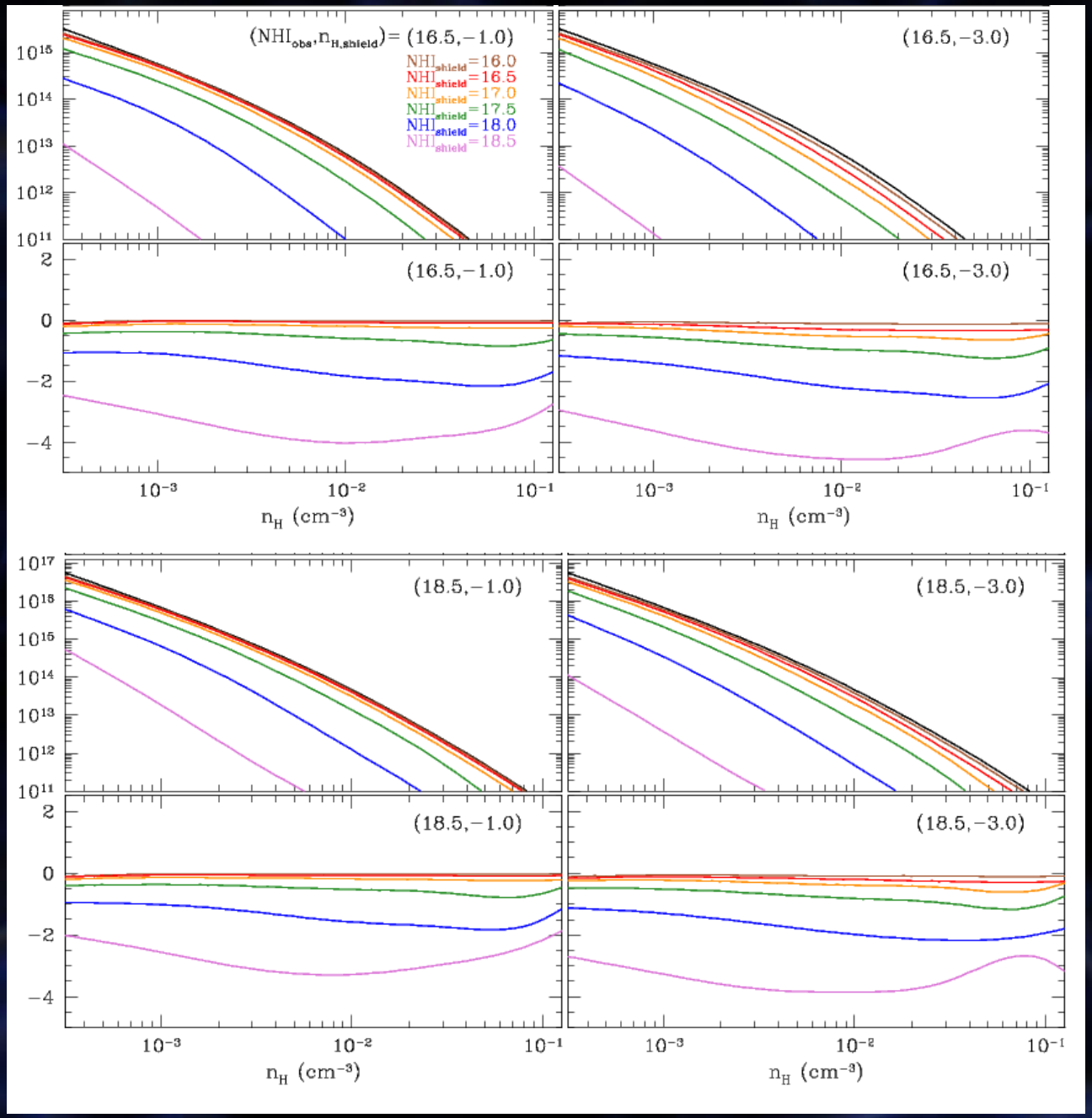
Modified Haardt-Madau Background



Mg II


NHI_shield=16.0
NHI_shield=16.5
NHI_shield=17.0
NHI_shield=17.5
NHI_shield=18.0
NHI_shield=18.5
(NHI_obs, n_H,shield)= (16.5,−1.0)
(16.5,−3.0)
(16.5,−1.0)
(16.5,−3.0)
(18.5,−1.0)
(18.5,−3.0)
(18.5,−1.0)
(18.5,−3.0)
n_H (cm⁻³)
n_H (cm⁻³)
n_H (cm⁻³)
n_H (cm⁻³)

C IV


(NHI_obs, n_H,shield) = (16.5, −1.0)
NHI_shield = 16.0
NHI_shield = 16.5
NHI_shield = 17.0
NHI_shield = 17.5
NHI_shield = 18.0
NHI_shield = 18.5
(16.5, −3.0)
(16.5, −1.0)
(16.5, −3.0)
(18.5, −1.0)
(18.5, −3.0)
(18.5, −1.0)
(18.5, −3.0)
n_H (cm⁻³)
n_H (cm⁻³)
n_H (cm⁻³)
n_H (cm⁻³)

What This Means

- In most cases, shielding effects will cause metallicity to be underestimated
- In practicality, there is no way to determine the amount of shielding for an absorber
- However, this work demonstrates that the (necessarily) simple assumption of a bare Haardt-Madau background made in photoionization modeling can lead to significantly incorrect metallicity determinations
- Observations of as many ionic species as possible can help constrain the ionization conditions in an absorber

Thank you