Physics 224: Paper Discussion 1
Spring 2018

Stromgren 1939:

- I was wondering about the dilution factor - based on the equation, it seems to be a ratio of the star surface area to the surface area at s. So does it essentially scale the ionization at s from a given star of radius R? Seems like the inverse square law for the degree of ionization?
- A comment: The derivation is based on the Maxwell-Boltzmann statistics and Saha equation (i.e. LTE for the O stars). The validity of this assumption is discussed in section V. That hypothesis is confirmed by observations.
- Question 1: The HII region changes to HI abruptly. Any physical interpretations of the accelerated increase of HI? The interpretation in the paper isn't quite clear to me. "Once the proportion of neutral atoms begins to increase, the absorption of the ionizing radiation increases, leading to an accelerated increase of neutral atoms." Why is the change so abrupt?
- Question 2: Why did the authors estimate only after O5? How about the earlier O stars?
- Question 3: The authors assumed that the effective absorption coefficient is $2/3a_u$, but do we have a more sophisticated modification in the later work? If so, would the correction be large or significant?
- I'm a bit confused by their explanation of the abrupt change of the ionization fraction. He says "Once the proportion of neutral atoms begins to increase, the absorption of the ionizing radiation increases, leading to an accelerated increase of neutral atoms." What causes the initial increase in neutral atoms?
- Why didn't the author talk about the secondary ionization of hydrogen?
- Just to be clear, s_0 is a "sharp" boundary because as soon as light gets to the neutral H region, it gets absorbed instead of ionizing H? Is it purely based of number densities - as in s_0 encompasses the region where there's a higher number density of ionized H than that of neutral H? Does this mean that once the number density of neutral H is higher, it kicks itself into a cycle of absorbing more UV light with more neutral H atoms? Is this boundary still used today? I also thought Table 5 was interesting because it shows that the s_0 sphere drops by a factor of $\sim$100 over 1 spectral type letter.

- How is ionized hydrogen linked to Balmer or H-alpha emission? I thought those emissions would be more likely from hydrogen relaxing to the ground state, but I don't see the connection to the ionized fraction of hydrogen. Where does the uncertainty on the column depth and temperature come from? And is there large errors from just assuming that the radiation from stars is ionizing the Hydrogen and other metals, what about the UV background?

Werk et al. 2014:

- Basic question - when they say at the beginning of the introduction that baryons account for 17% of the gravitating mass in the universe, is "gravitating mass" meaning matter (baryonic and dark) and just excluding dark energy? Real question - this study seems to focus on low-ionization state metals. When they calculate the total mass of the photoionized CGM, their method uses only measured column densities of low-ionization state metal lines instead of both low- and intermediate-ionization. They say that their observations of low-ion transitions requires the gas be cool so does that mean that only the low-ionization state metals can't be ionized any more? Or is it also because of the recycled outflows that could be the primary source of the low ionization state metal lines so the cool CGM is mostly made up of low-ionization state material so then it's ok to assume that the total mass of the photoionized CGM can be modeled by just looking at the low-ion state metals? I think I found why they ignore highly ionized OVI, but this is high-ionization I thought and still does not address why there is no intermediate ionization state material considered.

- Is the galaxy halo missing baryon problem present for all galaxy types (spiral, elliptical, etc.)? They don't seem to mention which galaxy types were used in the study, are they assuming that different galaxy types have the same CGM profile, or is it implied that they are only looking at spiral galaxies? Couldn't a past merger affect the mass and composition of the CGM compared to a galaxy which has never had a merger? If so, did they only use galaxies which had not evidence of past mergers?

- Why is the virial radius important here? Can galaxies be measured with other types of radii?

- One comment: (Figure 12) Although the ionization fraction becomes larger for larger $R/R_{\rm vir}$, the total number density gets much smaller, so the electron density is lower for larger $R/R_{\rm vir}$. Question 1: (Figure 7) The upper limit of log NH seems to be around 20 for $R/R_{\rm vir}$ from 0.1 to 1.0. Do we have any interpretations for this? Is it because of the saturation of HI lines? Question

2: The modeling tool CLOUDY assumes that "gas is a uniform slab in thermal and ionization equilibrium.? It seems to be true in the paper, but do we have other cases such that this assumption is not applicable?

- I did not know that most of the baryonic content of the galaxy is not in the galaxy itself, but in the CGM instead. I figured there would be more in the stars+ISM, but I was wrong. We also briefly talked about this in Dusan's galaxy dynamics class today (Thursday). In the paper, they mentioned that H I has been observed out to 300 kpc from galactic centers, but their observations only went out to 160 kpc. It would be cool if they could come up with a way to either observe or extrapolate what the metal contents is out to 300 kpc too. It was also kind of funny that they tried to model the gas volume densities assuming hydrostatic equilibrium, but as you told us during the first week of class, nothing is in equilibrium out there, which was their conclusion.

- (Warning: very dumb question) Would there be a way to place an upper limit on the mass from saturation in the HI absorption lines? (e.g. simulate CGM and study the statistical properties of the HI absorption lines in spectra from random line of sights?)

- Is 160 kpc a general rule of CGM radius for the galaxy sizes they sample, or is this value originated from a different source?