

Cume #452

72 Points Possible; 50 Points is Guaranteed Pass

Administered May 1, 2021

The unchanging circumgalactic medium over the past 11 billion years

Hsiao-Wen Chen 2012, MNRAS, 1238-1244 (6 pages)

Be sure your solutions in your uploaded document presents in portrait mode. You may use a calculator, but no programmed formulae. Clearly start each question (by number) in the exact order the questions appear. The approximate wavelengths of some important quasar absorption lines and quasar emission lines are $\text{Ly}\beta = 1025 \text{ \AA}$; $\text{OVI} = 1031 \text{ \AA}$; $\text{Ly}\alpha = 1215 \text{ \AA}$; $\text{CIV} = 1548, 1550$, blended average = $1549 \text{ \AA}$; $\text{MgII} = 2796, 2803$. blended average = $2800 \text{ \AA}$;

1. [12 pts] (Comprehension: why, how, what) Write a very brief overview of this paper. Clearly separate your responses into the following well-defined categories– I am testing that you can parse and articulate the author’s (a) motivations, (b) observations, (c) analysis, and (d) results.
 - (a) [3 pts] In three sentences maximum, describe the big picture broader astronomical context motivating this work.
 - (b) [3 pts] In three sentences maximum, describe the data employed and the observations.
 - (c) [3 pts] In three sentences maximum, describe the scientific analysis performed (do not describe results or findings here).
 - (d) [3 pts] In three sentences maximum, describe the *new* most important conclusion(s), i.e., central to the larger picture addressed by the paper, i.e., your “walk away” result(s).
2. [13 pts] (Knowledge: what you know) Let’s consider the main observational technique applied in this paper.
 - (a) [7 pts] Succinctly describe the method known as “quasar absorption lines” as if you were explaining it to a graduate student for their very first time. Draw your student a simple diagram showing the spatial relationship between the quasar, the observer, and the object being studied. Also show the light path from the quasar to the observer (called the “line of sight”). Clearly label each of these parts. In your diagram, mark an “X” where the absorption being studied is coming from (and label this point). (Challenge: Try to keep your explanation to three sentence max!)
 - (b) [6 pts] Chen frequently mentions the “covering factor” or “covering fraction.” What is the covering fraction? In a quasar absorption line experiment, how is the covering fraction calculated in practice from the observations?
3. [19 pts] (Application: apply what you know) Now *that* is a Quasar Spectrum!
 - (a) [10 pts] Consider a redshift $z = 2.5$ quasar. Assume there is no intervening material between the observer and the quasar. As accurately as possible, draw the “typical” spectrum of this object over the wavelength range $3000 \text{ \AA}$ to $1 \mu\text{m}$. Label all features that you include in your spectrum.
 - (b) [9 pts] Now, consider how the spectrum is modified when intervening material is present. For this part, superimpose the following features on your quasar spectrum from part (a).
 - (i, 4 pts) Consider the IGM and the resulting $\text{Ly}\alpha$ forest absorption. Draw in the $\text{Ly}\alpha$ forest in your quasar spectrum and label the wavelength region over which we can/would observed the $\text{Ly}\alpha$ forest lines from intervening intergalactic medium clouds
 - (ii, 5 pts) Consider a $z = 2$ intervening galaxy with a CGM that gives rise to CIV , MgII , and damped $\text{Ly}\alpha$ absorption. Accurately draw in these absorption lines in your quasar spectrum and label each.

4. [12 pts] (Synthesis: putting it together) Chen briefly describes a variation of the quasar absorption line technique that was applied for the Keck Baryon Structure Survey (KBSS) of Steidel et al. (2010) and for the survey by Bordoloi et al. (2011).
- (a) [3 pts] Succinctly describe (3 sentences maximum) this method (or experiment) as if you were explaining it to a graduate student for their very first time.
 - (b) [3 pts] Explain why people invented this method, i.e., what its advantages are over the standard quasar absorption line method.
 - (c) [4 pts] Provide two caveats, or short comings, of this method as compared to the standard quasar absorption line method. Also, provide the reason why each is a short coming.
 - (d) [2 pts] In what way (or how) could Chen's decision to combine data from this method and data from the standard quasar absorption line method make their conclusions less robust.
5. [9 pts] (Analysis: what you think) A complex multi-component absorption profile encodes the physical conditions of the gas in great detail. Some changes in these properties would increase the absorption profile equivalent width (or "absorption strength"), while others would decrease it. This is because some physics governs the column density, which governs the depths of the components in the absorption profile, while other physics governs the number of components, their separations, and their individual width.
- (a) [3 pts] List (just list) at least three physical properties that might vary from galaxy to galaxy (of similar mass) and/or might evolve as a function of redshift that can, in principle, either increase or decrease the absorption strength of a CGM absorption line.
 - (b) [6 pts] For each property you listed above, briefly explain both how and why it can affect the measured value of the equivalent width. That is, provide statements like "If X increased, then the equivalent width would decrease because [insert reason]" or "If X increased, then the equivalent width would increase because [insert reason]"
6. [7 pts] (Evaluation: what you assess) As good scientists, we must think through and challenge Chen's statement that "the spatial extent and mean absorption strength of the CGM in halos of comparable mass have changed little since $z \sim 2$ " to see if it holds true in our own minds.
- (a) [3 pts] Given what we have discussed in Problem 5, should we interpret this statement to imply that the CGM of galaxies of comparable mass are truly physically similar at a given cosmic epoch or as a function of redshift? Explain.
 - (b) [2 pts] Suggest at least one scenario in which two distinct physical properties of galaxies of similar mass at the same redshift could differ such that they "cancel each other out" and the resulting absorption strength is substantially unchanged.
 - (c) [2pts] Suggest at least one scenario in which two distinct physical properties of galaxies of similar mass could evolve with redshift in such a way that they 'cancel each other out' and the resulting absorption strength is substantially unchanged.