Cume #469
80 Points Possible
64 Points is Guaranteed Pass, but passes with lower scores are possible
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The Study of Circumgalactic Medium with Quasar Pairs
Chen, Zhi-Fe, et al. 2023, arXiv:2302.12942v1 (12 pages)

Be sure your solutions in your uploaded document presents in portrait mode. For Canvas uploads, submit a single document with your answers in exact problem order with the start (problem number) and end/solution of each problem clearly marked. You may use a calculator, but no other resources. HELPFUL COMMENT: before answering any problems, be sure to familiarize yourself with the full exam so that you can obtain some insight on how to partition your time management between problems. For any hand drawn diagrams, be sure to provide axes scales and labels very clearly. Please be sure your plots are also in portrait mode. At your discretion, where you think it will help guide my eye while grading, please box answers.

1. **[22 pts]** Let's consider some of the main bits of background knowledge on which this paper is founded.

   (a) [5 pts] Mg II $\lambda\lambda 2796, 2803$ absorption is a fine-structure doublet. (i) What is a fine-structure doublet and (ii) what atomic physics is responsible for the fine doublet structure of the energy levels involved in the $\lambda\lambda 2796, 2803$ transitions?

   (b) [5 pts] In a quasar spectrum, you observe what looks to you like it could be doublet absorption at the wavelengths, 4865 Å and 4877 Å. You hope to identify it as redshifted Mg II $\lambda\lambda 2796, 2803$ absorption. Verify (prove to yourself- and me) that you are indeed correct that both transitions reside at observed wavelengths that correspond to redshifted Mg II $\lambda\lambda 2796, 2803$ and provide the redshift of the absorption.

   (c) [6 pts] At one point (page 5, top of column 1), the authors mention emission from [O III] and C III]. (i) What does the "[X]" brackets around the O III mean. i.e., what do we call this kind of transition and what physics sets it apart from transitions that do not have "[]" around them? (ii) What does the single "X]" bracket around the C III mean. i.e., what do we call this kind of transition and what sets it apart from transitions that do not have "[X]" or "X]" around them?

   (d) [6 pts] At the very end of Section 3, the authors describe how they measure the Mg II absorption line equivalent widths. (i) Write down the *general* integral equation defining the equivalent width in terms of the observed flux and estimated continuum flux. Define all variables. (ii) Why is it that the authors measure only equivalent widths, and don't attempt to measure column densities? (HINT: as part of your answer, it may be worth considering the behavior of the curve of growth in your explanation).

2. **[20 pts]** Let's consider the experiment that has been conducted in this paper. Examining Figure 3 (page 7), we see that we are being shown the Mg II $\lambda\lambda 2796, 2803$ absorption (or lack of absorption) in the spectra of the foreground and the background quasars, Q_F and Q_B, for two different QSO-pairs We want to further visualize these two examples, so we are going to make a sketch.

   (a) [12 pts] For the quasars in the upper panels (the J2311 pair), draw a redshift axis from $z = 0$ to $z(Q_B)$, where the observer is located at $z = 0$ to the left. Let the vertical axis be the transverse separation. Place Q_F and Q_B in the proper location on your diagram. Now, on your diagram, draw in the CGM for both quasars (you can assume surrounding spheres). Now, on your diagram, draw in the location of where the featured Mg II absorption arises. Be sure to clearly label everything on your diagram.

(b) [4 pts] Now consider the quasars in the lower panels (the J0843 pair). In which quasar's CGM is the absorption arising, Q_F or Q_B? State why you make this conclusion.

(c) [4 pts] Throughout the paper, the authors use the terms "TRA" absorbers and "LOS" absorbers. Which of these is being illustrated for the J2311 pair? Which of these is being illustrated for the J0843 pair?

3. **[14 pts]** In Section 3, the authors define their absorber samples. Let's examine the issues and ambiguities of surrounding "intervening" versus "associated" absorbers.

   (a) [4 pts] First, let's define these two types of absorbers. (i) What is an intervening absorber?. (ii) What an associated absorber?

   (b) [6 pts] In low resolution spectra, where the absorption lines are unresolved, it is nearly impossible to directly ascertain whether an absorber is intervening or associated. (i) So, what method(s) do astronomers use to decide whether to identify an absorber as an intervening absorber or an associated absorber? (ii) What exact criteria do the authors employ for this study for each type?

   (c) [4 pts] In terms of "TRA" absorbers and "LOS" absorbers in this paper, which type corresponds to intervening absorbers and which correspond to associated absorbers?

4. **[14 pts]** Let's considers some of the findings in this work. There are two levels to this. The first is "what is the *qualitative* result?". The second is "what are the astrophysical inferences?". What we are not interested in here, are "quantitative factoids," i.e., "this has this value and that has that value", because facts are not interpretation, facts are *information*. We want to focus on the meaning of the facts of the findings. Keep your answers high level; resist repeating details from the text of the paper; summarize the qualitative take away.

   (a) [4 pts] (i) Explain what Figures 4 is *qualitatively* showing us. It is described and discussed in the latter half of Section 5. (ii) What do the authors conclude in regard to these results? (iii) In you opinion did they draw an appropriate conclusion? Why or why not?

   (b) [4 pts] Explain what Figure 6 is *qualitatively* showing us. It is described and discussed in the latter part of Section 4, starting on page 7.

   (c) [6 pts] (i) Explain what Figure 7 is *qualitatively* showing us. It is described and discussed in the latter part of Section 6, starting at the very bottom of page 10. (ii) What is the interpretation of the authors?

5. **[10 pts]** Finally, let's consider the overall roadmap and general experiment conducted for this paper, including the motivations, the observations, the analysis, and the results. Please read all the questions before answering any of the parts. Note, each of these components is being asked about separately; in addition to evaluating your explanation of the components of this paper, to a large degree, part of the grading of this question is to assess how well you can properly partition the work into its component parts.

   (a) [2 pts] In one sentences (yes one!), state what this paper is about.

   (b) [2 pts] In no more than three sentences, describe the astronomical context (big picture) motivating this work.

   (c) [2 pts] In no more than three sentences, describe the observational data employed and their suitability to the experiment.

   (d) [2 pts] In no more than three sentences, describe the experiment and the scientific analysis performed (do not describe results or findings here).

   (e) [2 pts] In no more than three sentences, 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).