
Overview:

This Cume is based on the paper “An Ancient Massive Quiescent Galaxy Found in a Gas-rich $z \sim 3$ Group” by Kalita et al. 2021.

The exam contains 9 questions, worth 68 total points. The anticipated passing grade is 75%.

Additional Instructions:

- Please start each question on a new page and write legibly.
- Aim to answer questions completely but **concisely**, generally in a few statements.
- Be careful with your time management. Do not spend too much time on any one question. I recommend that you try to get through all the questions within ~ 90 minutes, and then use the remaining ~ 30 minutes to go back and complete any parts you skipped.
- Calculators may be used for calculations, but you may not use any other outside resources (i.e., no stored equations, notes, books, internet access, etc.).
- If at any point you aren’t able to remember or calculate a specific value, just introduce a variable or state your assumption and proceed with the rest of the question.
- At the end of the exam, put your responses in question order and either hand them in directly or upload them to Canvas.

Useful Information:

- The AB magnitude zeropoint is -48.6.

MORPHOLOGY

1. (6 points) The authors use morphological model fitting to obtain a Sérsic index of $n \sim 2$ for Galaxy-D (Section 4.1), which they suggest indicates the galaxy contains both a disk component and a significant bulge component.
 - (a) What is a Sérsic index?
 - (b) How could the authors have modified their approach to quantify the relative contribution of these two components, assuming sufficient signal-to-noise and high enough spatial resolution?
2. (8 points) In Section 4.1, the authors use matched aperture photometry to derive isophotal fluxes in several HST/WFC3 filters (F606W, F814W, F125W, F160W), and then scale those measurements up using the results from model fitting in the F160W image.
 - (a) What are isophotal versus model fluxes?
 - (b) What assumption are the authors making in doing this scaling?

MAGNITUDES AND DISTANCES

3. (8 points) Using the information provided in Section 4.1 (second paragraph), what is the angular diameter distance to this galaxy (in Mpc)?
4. (10 points) Based on Figure 3 (top left), what is the AB magnitude of Galaxy-D at $\lambda_{obs} = 2 \mu\text{m}$?

STELLAR POPULATION AGE

5. (8 points) According to the authors, the variable t_{50} signifies the time elapsed between the epoch of “half-mass formation” and the time of observation (Section 4.3). They report a best-fit value of $t_{50} = 1.6$ Gyr.
 - (a) To visualize this, make a sketch of Figure 4 (right panel) with just the best-fit $\tau = 0.2$ Gyr curve, and indicate on this figure what time t_{50} refers to.
 - (b) Use your sketch to argue that the reported value of $t_{50} = 1.6$ Gyr is indeed the epoch of “half-mass formation.”
6. (6 points) In Section 4.3 (second paragraph), the authors describe how their derived t_{50} varies with different assumed metallicities. Name and describe the well-known degeneracy that is responsible for the trends they report, and explain why this degeneracy occurs generally.

RARITY AND ENVIRONMENT

7. (10 points) The authors estimate the probability of a chance alignment of Galaxy-D and the center of the galaxy group in Section 4.4. Taking their estimate of 2–20 galaxies like Galaxy-D within the 2 square degree COSMOS survey area, recreate this calculation to show why the authors claim the probability is vanishingly small.
8. (6 points) In Figure 5, Galaxy-D appears to be one of the only galaxies at its redshift and relatively old age. In Section 5.1, the authors describe three possibilities for why this might be. Choose one possibility and explain how it would lead to there being very few galaxies near Galaxy-D in Figure 5. (Make sure to describe where else a galaxy would end up in Figure 5 as a result of your chosen scenario.)
9. (6 points) Given that Galaxy-D is relatively old for $z \sim 3$, what is surprising about the presence of a large Lyman-alpha ($\text{Ly}\alpha$) nebula surrounding the galaxy group (Figure 1)?