Cume #457

Welcome to the first cume of 2022 – Happy New Year! You will have received the corresponding paper, Peluso et al. (2021) 30 minutes prior to the receiving this exam. Herein, you will find questions on that paper and related topics.

There are 13 questions with 84 points possible. A score of 63 points or more will warrant an automatic pass.

As a reminder, references beyond this paper, notes, or communication (other than with me) are NOT permitted during this exam. You are permitted to use the basic functions of a calculator, i.e., not graphing or information stored prior to the exam.

Please make sure your writing is legible. As a general rule, I try to assign partial credit for good efforts, but I *cannot if the writing is illegible.* Also, please show all work and do attempt each problem, showing your thought process even if you can't solve it completely. Note that most questions have multiple parts, so make sure you answer the entire problem.

If anything needs clarification, please email me (jnb@nmsu.edu).

Possibly relevant information:

$M_{sun} = 1.988 \times 10^{30}$ kg
$G = 6.674 \times 10^{-11}$ m^3 / (kg s^2)
1 pc = 3.08×10^{16} m

1. (6pt) In two to three sentences (or one sentence and a drawing), describe the process of ram-pressure stripping and the environments where it is likely to happen.

2. (4pts) What are two of the observable morphological signatures of ram-pressure stripping?

3. (6pts) In two sentences, describe the hypothesized process by which ram-pressure stripping induces active galactic nuclei.

4. (4pts) The authors use emission-line diagnostics to identify regions in the AGN-dominated regions of the interstellar media (ISM) in their galaxy sample. Why might, e.g., the [NII]/Hα ratio be sensitive to AGN activity?

5. (10pts) Referring to the BPT diagram in Figure 1, sketch galaxy spectra that are representative of the four classes: star-forming, composite, Seyfert, and LINER. Note: the hard-to-see dashed bright green line differentiates between the Seyfert and LINER regions of the more general AGN class. Your drawings do not have to be perfectly to scale with respect to the line fluxes, but they should be self-consistent with one another; exaggeration of features is okay!

Hint #1: Make two sketches per galaxy where each 'zooms' in on either the region around the

[OIII] and Hβ lines or the region around the [NII] and Hα lines. Hint #2: First, draw your star-forming spectrum for reference, then draw the others relative to this.

6. (8pts) From Figure 2, what might you conclude about the relationship between AGN fraction and galaxy stellar mass? Why or why not do these histograms justify the mass selection criteria for the samples compared in this study?

Note: Questions 7 through 9 relate back to the following paragraph:
The 'classical' Gunn & Gott (1972) formulation of ram-pressure stripping takes the form $P_{ram} \approx \rho\,(\Delta v)^2$ where ρ is the density of the intracluster medium (ICM) through which the galaxy is moving and Δv is the difference between the galaxy velocity and local velocity of the gas. For simplicity, we assume that there no net bulk motions in the ICM around the galaxy and $\Delta v = v_{sat}$ where v_{sat} is the velocity of the galaxy.

7. (4pts) Using dimensional analysis, show that the expression above indeed yields the expected units of pressure.

8. (8pts) For simplicity, we could assume that the velocity of the galaxy is equal to the virial velocity of the galaxy cluster. Note that the virial theorem technically holds for average total kinetic and potential energies of systems. As an approximation, we will assume the individual galaxy motions satisfy the virial theorem as well.

a) Write down the virial theorem.
b) Now rewrite the virial theorem in terms of the mass of the satellite galaxy (M_{sat}), mass of the cluster (M_{clust}), virial radius of the cluster (R_{clust}), and velocity of the satellite galaxy (v_{sat}).
c) Show that v_{sat}, the virial velocity of the satellite galaxy, can be expressed as follows:

$$v_{sat} = \sqrt{\frac{GM_{clust}}{R_{clust}}}$$

9. (8pts) For the density of the cluster, assume that it follows the profile of an isothermal sphere, so $\rho \propto r^{-2}$. Calculate the timescale required for a galaxy moving at the virial velocity to experience a doubling in ram pressure on path starting from the cluster radius R_{clust}. Assume a cluster with $M_{clust} = 10^{14}\ M_{sun}$ and $R_{clust} = 1500$ kpc.

10. (4pts) Referring to Figure 3, what might one infer about the relationship between AGN activity and the degree of ram-pressure stripping as indicated by the Jstage (if anything)?

11. (6pts) Considering the information in Table 2, would you conclude that this relationship is or is not monotonic? Why or why not?

12. (10pts) You are at a conference where one of the authors of this paper is presenting the results. One proponent of AGN-driven quenching speaks up and says, "So you've shown that

AGN are more prominent where environmental interactions are taking place. This proves that even in dense environments like galaxy clusters, it's the AGN that quenches star formation. Ram-pressure activates the AGN, and the AGN either ejects the gas supply from the galaxy altogether or heats it up so that stars cannot form."

Critique this argument by drawing on your own knowledge and information from within the paper to assess the logic at play here. Do you agree or disagree?

13. (6pts) What is the primary observational difference between the 'LIT-RPS' sample and the 'GASP-RPS' and 'MaNGA-Ref' samples? What uncertainties might this introduce?