Reading Exercise
Based on the review article
The First Galaxies
by Broom & Yoshida, 2011

March 21, 2018

The aim of this exercise is for you conduct self-directed study to gain insights into related material *beyond* the core material of the course. You are required to read a review article about the formation of the first galaxies soon after the Big Bang and answer the questions that follow. In doing so, you will consider early galaxy formation in more detail that will be covered in the lectures.

The paper you are required to read is *The First Galaxies* by Broom & Yoshida, 2011, ARAA, 49:373-407. It is available on course's MOLE page, as I am unable to make it world-viewable on GitHub due to copyright.

Some of the questions will require to do a small amount of reading beyond the main review article. The numbers in brackets are meant as a guide to the number of marks that can be obtained from each question.

1. The first paragraph of the Introduction refers to the "cosmic dark ages". Describe what is meant by this term. (1)

2. The review article refers a lot to "Population III" (Pop III) stars. What is the accepted definition of Population III stars, and how do they differ from Population II and Population I stars? (2)

3. What is meant by the term "stellar feedback" in the context of the review article. What are the two main forms of stellar feedback that the review article refers to? (4)

4. Provide an account of how the first stars affect further subsequent star-formation (3).

5. When discussing Black Holes (BHs) in the Introduction, the article states "such massive BHs would likely have influenced the structure and evolution of the first galaxies". Briefly explain *how* early BHs are thought to influence the first galaxies. You may wish to refer to the cited article, which is freely available on arXiv. (3)

6. What is meant by "top-heavy" and "bottom-heavy" in the context of star-formation? (2)

7. Why does a model in which the "halos that host the formation of the first Pop III stars coincide with the first galaxies" involve the implicit assumption that the initial mass function was not very different from today? (2)

8. Summarise the challenges in forming the first galaxies associated with the assumption that Pop III were predominantly massive. (4)

9. Throughout, the review article refers to a virial temperature of 10^4 K. What is the significance of this temperature? (2)

10. Considering Fig. 1 and its caption, why are the first galaxies unlikely to contain Pop III stars? (2)

11. What is the argument that the review provides for the possible need for mini-Quasars as early sources of re-ionising photons? (1)

12. According to Section 4.1.1, how does the formation of the first galaxies depend on the assumed cosmological parameters? (1)

13. Provide an account of the problems associated with forming a *supermassive* black hole from a Pop III seed. (3)

14. By editing the Python notebook associated with Lecture 7 to generate the relevant plot, show that the approximation $d_L \sim 100[(1+z)/10]$ given in Section 6.2 is reasonable (you should include your plot in your answer) (3).

15. Explain why Lyman-α from galaxies at $z > 10$ would be severely attenuated if the bulk of the Universe was neutral at high redshifts? (2)