ASTRO190 HOMEWORK #4, DUE Feb 20.

This short homework covers the reading material in Chapter 4 and recent lecture notes. As always, the content, conciseness and clarity of your answers matter. More difficult questions will be graded with a lighter touch. Contact me (543-7683; balick@uw.edu) if you are stymied.

Quick Review: Work in the new field of quantum mechanics in the 1930s made it possible for Hans Bethe to solve the riddle of the energy process that makes all stars shine, i.e., how the energy that the production of a helium nucleus releases. This implies that cosmic helium should have been steadily produced in stars over cosmic time as stars age. At about the same time observers were finding that the ratio of the relative abundances of helium and hydrogen (called the He/H ratio) was about 10% in all stars, both young and old. George Gamow, a Russian cosmologist and theoretical nuclear physicist, recognized that the universal nature of the He/H ratio in stars required a new and novel explanation. He and his student Ralph Alpher created "nuclear astrophysics" that provided an explanation of the universality of the He/H ratio and gave us the first means to glimpse cosmic events that preceded the formation of familiar galaxies.

1. What explanation did Gamov and Alpher offer in order to explain the universality of the He/H ratio in stars?
2. What current observations suggest that it very **un**likely that elements heavier than helium in today's universe were created in much the same way and at about the same time as helium? *(hint: consider the abundances of metals in the oldest stars)*
3. What is the accepted mechanism for producing elements more massive than helium in the present universe (such as oxygen and gold)?
4. How does nuclear astrophysics explain how elements beyond helium in the periodic table are far less abundant than helium? (a somewhat difficult question!)

As a result of their work on cosmic helium Gamow and Alpher predicted that "fossil" cosmic microwave background ("CMB") radiation should be detectable as technology improved. Arno Penzias and Robert Wilson of Bell Labs accidentally discovered it in 1964. This discovery did more than confirm the earlier work of Gamow and Alpher. It opened vast new opportunities for more sophisticated observations of the CMB and improvements in nuclear astrophysics to reveal the state of the Universe as one second of cosmic history had elapsed.

Cosmic insights emerged over and over again for the next 30 years as new but very puzzling studies of cosmic expansion patterns (chapters 2 and 3) emerged (chapter 5). Dark matter was unexpectedly discovered in the 1970s and 80s (chapter 6). Then all hell broke loose (chapter 7).

5. Why did the detection of "noise" from the CMB frustrate Penzias and Wilson?
6. How was the cosmological value this newly detected "noise" first recognized after its discovery?
7. Why do we describe the spectrum of the CMB as a "2.73K blackbody"?
8. Physics argues that the actual temperature of the Universe must have been ≈3000K where the CMB radiation that we see today originated. Its current observed temperature about 1000x smaller? Why? (look thru Ch 4)
9. Ripples in the CMB are tiny (contrast* 100,001 : 100,000, or 1 part in 10^{-5}). Today the contrast of all matter exceeds 1,000,000 : 1. What caused this enormous change in contrast since the CMB was emitted?
10. Why do we say that the ripples in the CMB are "finely tuned"? (see pages 146 and beyond)

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* "Contrast "is the approximate ratio of maximum to minimum density.