Problem Set Recovery, *Optional*, Due Thurs. 4/27

If you decide to complete this *optional* assignment, I will use your score on this assignment to replace the lowest score that you got on any of Problem Sets 1-6 (including a zero if you didn't turn one in). I expect this assignment to take the same amount of time as one of the harder problem sets, i.e., 6-8 hours.

Baryon Acoustic Oscillations, BOSS, and Cosmology

Background: Look through "Some slides on Baryon Acoustic Oscillations (BAO)" below the "Friedmann-Robertson-Walker Metric" lecture notes on the course web page. Re-read the solution to Problem Set 3. Read §11.6 of the textbook.

Download the paper "Cosmological implications of baryon acoustic oscillations" by E. Aubourg et al., which you can find at
`https://arxiv.org/pdf/1411.1074.pdf`.
(The journal reference is Physical Review D, vol. 92, p. 123516, 2015.)

Read Sections I, II, IV, V, and VIII of this paper. You won't be able to understand all of it, but with the background you have from this course you should be able to follow the main points.

Answer the following questions.

(1) What were the defining goals of the Baryon Oscillation Spectroscopic Survey, and what observations did it do to achieve them? (§I)

(2) What was the fractional uncertainty of the BOSS distance measurements at $z = 0.32$, 0.57, and 2.34? (§II.B)

(3) How did BOSS measure both the angular diameter distance $D_M(z)$ and the expansion rate $H(z)$ [or the equivalent $D_H(z) = c/H(z)$] at $z = 0.57$? (§II.B)

(4) In this paper, what are the three key quantities extracted from CMB observations? (§II.C)

(5) At several points (e.g., §II.D, §IV) the paper emphasizes that the BAO method measures *absolute* distances, while the supernova method measures *relative* distances. What does this mean?

(6) How does the paper combine BAO and supernova distances to make an "inverse distance ladder" measurement of the Hubble constant H_0? Why is this described as an "inverse distance ladder"?

(7) Does the result of this measurement agree with direct distance-ladder measurements of the Hubble constant using Cepheid calibration of Type Ia supernovae? (§IV)

(8) What is the relation between the parameter Ω_k and the quantity we have referred to as Ω_0? What values of Ω_k correspond to $k = +1$, 0, or -1? (§II.A)

(9) What does the paper conclude about curvature of space assuming that dark energy is described by a cosmological constant? Are supernova data important to this conclusion, or just BAO and CMB? (§V, esp. Fig. 8 and Table IV)

(10) What does the paper conclude about the dark energy equation of state parameter w, assuming a flat universe? Are supernova data important to this conclusion, or just BAO and CMB? (§V, esp. Fig. 8 and Table IV)

(11) What conclusion does the paper draw about the agreement or disagreement of BAO measurements with predictions of the ΛCDM cosmological model? (§V, §VIII)

(12) What are two things that surprised you and/or puzzled you about this paper?

Questions 2, 4, 7, and 8 are worth five points, and the others are worth 10 points. Grading will be based on the clarity and accuracy of your answers. For most questions, 3-5 sentences should be enough; for some questions 1-2 sentences may suffice.