Homework 9

Due April 12th

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1. *Estimate* in centimeters the size of the universe visible today at the time the CMB radiation last interacted with matter at a temperature of approximately 3000 K.

2. Assuming the CMB is 2.73K today, $H_0 = 72$ km/(Mpc s), and 70% of the energy density budget of the universe today is dark energy, how old is our sad, flat universe?

3. (a) Show in the context of the FRW models that if the combination $\rho+3p$ is always positive, then there will be a big bang singularity sometime in the past.

   (b) *De Sitter Space.* Solve the Friedmann equation for the scale factor as a function of time for closed FRW models that have only vacuum energy. Do these models have an initial big bang singularity?