Topics: Very early universe: flatness and horizon problems and how inflation solves them (with more cosmological constant-like weirdness)

Reading:

- Read section 4 of Ch. 24 (pp. 568-73) of Ryden and Peterson.

Summary of work to submit:

- Nothing to hand in for Thursday's class.

Overview:

So, we have our picture of the universe - the concordance model with $H_\mathrm{o} = 72$ or so. We see a vastly redshifted radiation background filling the sky from the time of recombination ($t \approx 400,000$ years), indicating a hot, dense early universe. Going back to just a few minutes after the big bang, we see protons combine with neutrons and form some helium and deuterium and a tiny bit of lithium, with about three quarters of the mass remaining regular hydrogen. There are two mysteries (at least!) that can't be explained in this standard model – the flatness of the universe's geometry (remember, only one particular value of all possible energy densities leads to this exact geometry) and the horizon problem (how does the CMB "know" to be the same temperature in all parts of the sky?). Turns out an early, very brief era of exponential growth (like what is seen from the cosmological constant, but much shorter in duration and much stronger) flattens out the universe and also allows for causal contact at ridiculously early times among all parts of the observable universe.

Commentary on the reading, viewing, and other preparation:

Do you think of flatness as a problem? Nature likes symmetry and stuff like that... But it is true, if the universe is very close to flat but not exactly flat, now, then in the past it was much, much closer. See how that's calculated? Back to solving the Friedmann equation when one component dominates in order to get eq. 24.61.

An exponential expansion will take any finite radius of curvature for a non-flat universe and inflate it up to something huge. And a sphere, for instance, that's huge, is locally very flat.

The horizon problem is about causality (in a Physics 5, special relativity sense) – if light can't travel between two points in the age of the universe then how can they have conditions that have come into equilibrium with each other? Note that the exponential, huge expansion solves this. Of course...the expansion is faster than the speed of light, by a lot.

Note the importance of the horizon distance on p. 572.

What *caused* inflation? The textbook presents a very brief outline – some field (like an electromagnetic field - so a force would've been associated with it) that has a zero-energy ground state (so not relevant today) but early in the universe had a much higher local-minimum state that quickly transitioned to the ground state. The book emphasizes, quantitatively, how bizarre and exotic the early universe was, with such incredibly high energies and densities. And also that we don't have a theory to analyze it because the very early universe is one place where quantum effects and strong gravitational effects exist. And we haven't been able to combine those two theories yet.

A lot of modern cosmology involves looking for faint clues of inflation imprinted on the CMB (e.g. gravity waves in the early universe).