8.902 Fall 2023 - Problem Set # 4

Due Tuesday, October 31 🎃

Unless otherwise stated, assume $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$, and $H_0 = 71$ km/s/Mpc. Some problems will require you to perform numerical integration.

1 Relative Redshifts and Line-of-Sight Distances

Suppose a quasar shows two absorption lines due to Si^{++} (rest wavelength 1206 Å) from galaxies along the line of sight between Earth and the quasar. The lines are observed at wavelengths 4711 and 4836 Å. Calculate:

A) The distance between the two galaxies in comoving Mpc (assume both are moving with the Hubble flow)

B) The redshift which an observer on the lower redshift galaxy would have measured for the higher one at the time the lower redshift galaxy absorbed the light from the quasar

C) Show that for small redshift distances, the answers to A) and B) can be simply related to the Hubble constant $H(z)$ at the earlier epoch, and give a simple expression for H(z). Compute an approximate answer to A) using this expression and the result of B).

2 The Size of Extended Baryonic Halos from Absorption Statistics

If objects distributed at random in the Universe have a constant comoving number density n and a constant cross-section σ for absorbing light from a distance quasar:

A) How many absorbers per unit redshift $\frac{dN}{dz}$ does one expect along an average line-of-sight? Does $\frac{dN}{dz}$ increase or decrease with z?

B) Quasar heavy-element absorption systems at $z \sim 1.5 - 2.5$ have $\frac{dN}{dz} \sim 2$. They are believed to be associated with typical bright ($L^\star$) galaxies, whose comoving number density is $n \sim 0.001$ per cubic Mpc. Determine the cross-section σ required of each galaxy to produce the metal line absorption systems seen at $z \sim 2$.

3 Baby Pictures

Compute the following quantities:

A) The angular size subtended at the recombination surface by a spherical region containing the mass of a galaxy.

B) The angular size subtended at the recombination surface by a region of diameter 200 comoving Mpc (the largest scale on which there is structure in the Universe today).

C) The total mass within the horizon at recombination. The horizon here is referring to the proper distance from the beginning of the universe to z.

D) The total mass within the horizon when the Universe first become matter dominated.

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