

Ay 21 – Winter 2008 – Homework #4

Distributed on Feb. 15, due by 1 pm on Friday, Feb. 22

(Return to the Prof., one of the TAs, or to the Astronomy office, 211 Robinson)

As usual, the honor system applies: You can discuss the problems among yourselves, how to go about them, but not derive the solutions jointly – everyone should work out their own solutions.

Problem 1 [30 points total]:

Consider a positive density fluctuation in the early universe, which is just bound, and thus it separates from the Hubble expansion, collapses and sheds excess kinetic energy, and virializes.

- What is the change in its total energy? In its mean radius? Mean density? [12 points]
- Assuming that this happens in an Einstein – de Sitter universe, what is the final density contrast between the collapsed object and its surroundings? [18 points]

Problem 2 [14 points total, 7 each]:

- A cluster of galaxies is observed at a redshift $cz = 5000$ km/s. You are using a distance indicator whose zero-point which may vary by up to 20% in different environments. What is the expected magnitude of a spurious peculiar velocity you may measure for this cluster?
- You are surveying the volume out to $cz = 3000$ km/s. Assume that the typical peculiar velocities are of the order of 500 km/s. What precision of distance measurements do you need in order to have the peculiar velocities (not distances!) measured with a typical accuracy of 10% or better? How likely do you think this is, and why?

Problem 3 [20 points total, 5 each]:

Consider a cluster of galaxies with a radial velocity dispersion $\sigma = 1500$ km s⁻¹, and the mean radius $\langle R \rangle = 1.5$ Mpc. It contains approx. 500 galaxies, with a mean luminosity $\langle L \rangle = 10^{10} L_{\odot}$.

- What is the estimated mass of the cluster?
- What is the mass-to-light ratio, in Solar units?
- What is the temperature of the intra-cluster gas (assume a pure hydrogen)?
- What is the typical energy and wavelength of emitted photons (explain)?

Problem 4 [36 points total, 6 each]:

Define briefly (and be quantitative if you can) the following terms:

- Primordial density fluctuation spectrum
- Free-fall time
- Clusters of galaxies
- Superclusters, voids, and filaments
- Hierarchical clustering (or structure formation)
- Peculiar velocity field