# Exercises, Day 4

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Names: ______________________________________________

## 1 Luminosity distance and statistical distributions

Assume a distribution of the intrinsic brightness of astronomical objects of a certain class (e.g. galaxies) with a maximum and tails towards the higher and lower values. Assume that those objects are distributed evenly through space, and that their brightness does not evolve over time.

(a) If you look at the distribution of redshift $z$ vs. apparent magnitude $m$ only for the brightest objects of this class, what distribution (scatter plot) in the $z$-$m$ plane would you expect? Where are the other objects? What if the survey whose data you are using has a limiting magnitude?

(b) Where in the $z$ range would you expect the most significant scattering? Give at least one statistical reason and one reason related to proper motion.

(c) If you want to directly compare distributions of these objects in different redshift ranges by binning the apparent magnitude data to create a histogram, how should you select your bin sizes as a function of $z$?

## 2 Blackbody radiation in an expanding universe

(a) In thermal equilibriium, the number density $n_T(\nu)$ of photons in the frequency range $\nu$ to $\mathrm{d}\nu$ is given by the Planck formula

$$n_T(\nu)\,\mathrm{d}\nu = \frac{8\pi\nu^2}{\exp(h\nu/kT) - 1}\,\mathrm{d}\nu,$$

with $k$ the Boltzmann constant. Assuming that these blackbody photons travel freely through space, list all the different effects of cosmic expansion on the quantities involved. What is their combined effect?

(b) How is this linked with the Stefan-Boltzmann law and the scaling behaviour we have derived for the energy density of relativistic particles and radiation?