Ay 121: Homework 2

Due no later than midnight of October 14, 2024

[1] The Great Dipole in the Sky. While the Universe is isotropic. It is homogenous on scales larger than the Baryon Acoustic Oscillation scale of 150 Mpc. Locally, galaxies can be located in clusters, groups or occasionally voids. Galaxies experience "peculiar" velocities relative to the expansion of the Universe. For galaxies in clusters the peculiar velocity can be large, up to several thousand of km/s. For field galaxies it is typically several hundreds of km/s. These peculiar velocities can be measured by careful measurement of the brightness of the Cosmic Microwave Background radiation (CMB). This was first detected by ground-based telescopes and exquisitely measured by space-based missions (Figure 1).

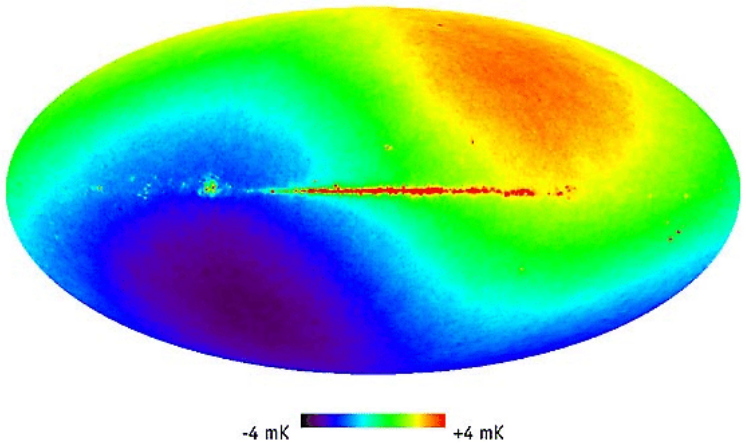

Figure 1: The brightness temperature map of the CMB in Galactic coordinates (from WMAP). The thin horizontal stripe is the Galactic plane which is teeming with HII regions and hence bright. At radio wavelengths, Planck formula is indistinguishable from Rayleigh-Jeans formula and so it is tradition to use $I_\nu/\nu^2 \propto T$ instead of I_ν. The resulting quantity is called "brightness temperature". The color coding is the excess or deficit wrt $T_0 = 2.7254 \pm 0.00057\,\mathrm{K}$.

a) From the data given in Figure 1 infer the peculiar velocity of the Sun wrt to CMB. [**5 points**]

b) Estimate the Earth's orbital velocity around the Sun. Has this been measured using CMB observations? [**5 points**]

[2] Problem 1.2 in Rybicki & Lightman. [**10 points**]

[3] Problem 1.4 in Rybicki & Lightman. [**15 points**]

[4] Problem 1.8 in Rybicki & Lightman. [**15 points**]

[5] Problem 1.9 in Rybicki & Lightman. [**15 points**]