

# ASTR 541 - Interstellar Medium

Problem Set 0

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For reference, if you'd ever like to see the code that I've used to get my answers to these, [here's a link to my GitHub repo!](#) (#astropy.units for life)

## 1. Introduction to (Baryonic) Accounting

*The general aim of this problem is to prove that the majority of baryonic matter does not lie in stars in galaxy or galaxies in clusters in a back-of-the-envelope calculation*

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This answer heavily follows the solution laid out by [the paper that is the linked](#) in the question. To begin, we are given that  $\Omega_B = 0.0455$  at  $z = 0$ . We can multiply this by the critical density,

$$\rho_c = \frac{3H_0^2}{8\pi G} \approx 9 \times 10^{-27} \text{ kg m}^{-3}, \quad (1)$$

to find that the mass density of baryonic matter is

$$\rho_B \approx 4 \times 10^{-28} \text{ kg m}^{-3}. \quad (2)$$

Next we can calculate the mass density of stars and galaxies and compare it to this value. We can consider that most luminosity is coming from either a spheroid or a disk component and write that the density for each is

$$\rho = \mathcal{L}_B f_B \langle M/L_B \rangle, \quad (3)$$

where  $\mathcal{L}_B$  is the mean luminosity density,  $f_B$  is the fraction of light produced by this component and  $\langle M/L_B \rangle$  is the mean mass-to-light ratio for this component.

Let's assume that the only two components are spheroids and discs. The paper gives us that the fractions and mass-to-light ratios (in  $M_\odot/L_\odot$ ) for each of these are (0.385, 6.5) and (0.582, 1.5) respectively. Summing these gives that the total mass density is

$$\rho = \mathcal{L}_B (0.385 \cdot 6.5 + 0.582 \cdot 1.5) M_\odot/L_\odot \approx 3.4 \mathcal{L}_B M_\odot/L_\odot, \quad (4)$$

From the paper we have that the mean luminosity density is approximately (assuming  $h \approx 1$ )

$$\mathcal{L}_B \approx 2 \times 10^8 L_\odot \text{ Mpc}^{-3} \quad (5)$$

Plugging this back in we get that the mass density of stars is

$$\rho_{\text{stars}} \approx 6.8 \times 10^8 M_\odot \text{ Mpc}^{-3} \quad (6)$$

We can now compare  $\rho_B$  and  $\rho_{\text{stars}}$  and note that

$$\boxed{\frac{\rho_{\text{stars}}}{\rho_B} \approx 11\%} \quad (7)$$

So from our back-of-the-envelope estimate we find that stars represent a small fraction of the baryonic matter within the Universe!!