ASTR 541 - Interstellar Medium

Problem Set 0 TOM WAGG

October 30, 2022

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,

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

to find that the mass density of baryonic matter is

$$\rho_B \approx 4 \times 10^{-28}\,\mathrm{kg\,m^{-3}}. \tag{2}$$

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

$$\rho = \mathcal{L}_B f_B \left\langle M/L_B \right\rangle, \tag{3}$$

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 $\mathrm{M_\odot/\,L_\odot}$) for each of these are $(0.385, 6.5)$ and $(0.582, 1.5)$ respectively. Summing these gives that the total mass density is

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

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

$$\mathcal{L}_B \approx 2 \times 10^8\,\mathrm{L_\odot\,Mpc^{-3}} \tag{5}$$

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

$$\rho_{\rm stars} \approx 6.8 \times 10^8\,\mathrm{M_\odot\,Mpc^{-3}} \tag{6}$$

We can now compare ρ_B and $\rho_{\rm stars}$ and note that

$$\boxed{\frac{\rho_{\rm stars}}{\rho_B} \approx 11\%} \tag{7}$$

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