Are More Distant Galaxies Hotter?

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1. Introduction

The stellar mass function is assumed to be constant through time. If it is constant, then the flux contribution to H II regions from hot, high mass stars would remain uniform with redshift. If this contribution has changed, then the mean H II region temperature would change with increasing redshift. To quantify how mean stellar temperature may have evolved with time, we mapped the temperature of H II regions to a redshift of about $z = 0.7$ using SDSS spectral data.

2. Methods

Our database consists of the spectra of over 22,000 galaxies from SDSS having redshift ranging from $0 < z < 0.7$. These galaxies were identified as having [O III] emission by the MPA-JHU group (http://www.sdss.org/dr12/sprectro/galaxy_mpajhu/). A file containing a list of these galaxies is presented in DR12 (Alam et al. 2015, https://www.sdss.org/dr12/spectro/spectro_access/) but is based on data from DR8 (Aihara et al. 2011). To ensure uniformity in the equivalent width data, we wrote our own Python script to calculate equivalent widths for the emission lines of interest within each spectrum. We used the ratio of the [O III] equivalent widths (λ4959+λ5007)/λ4363 as a tracer of temperature (Osterbrock 1989). Because the λ4363 emission line is weak, closer objects with better spectral S/N will measure down to lower temperatures than more distant data. To prevent this effect from biasing the data to lower temperatures, we removed all samples with z less than 0.002 and λ4363 equivalent width less than 5.0, leaving about about 1000 spectra. The ratio of (λ4959+λ5007)/λ4363 for each object was then plotted against redshift. We then binned these data in increments of $\Delta z = 0.1$. Within each bin we rejected the highest 10% and the lowest 10% of the ratios and averaged the remainder. The results are shown in Figure 1.

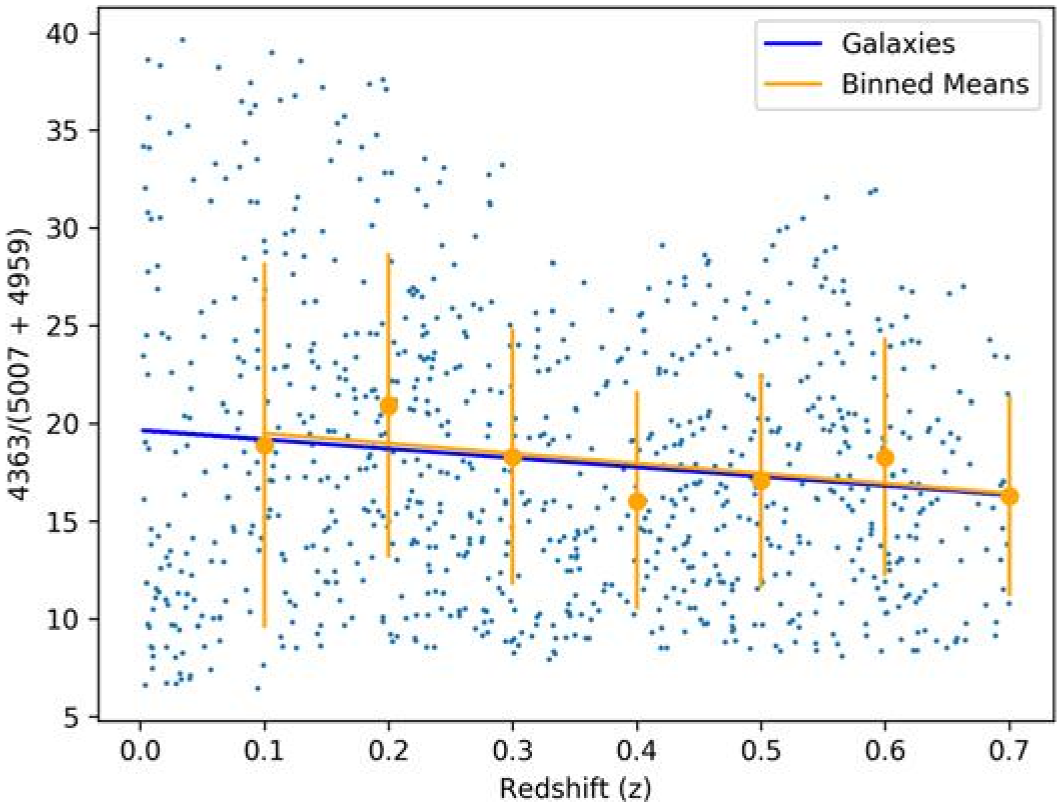

Figure 1. The ratio of the sum of the 5007 and 4959 lines to the 4363 lines plotted against the redshift. Lower ratios indicate higher temperature. Blue dots are individual galaxies. Orange dots are the average value for each $\Delta z = 0.1$ bin. Linear fits to both the individual and binned data are shown and are essentially the same. The slope in the fits is attributed to a bias against detecting the [O III]λ4363 line at higher redshifts. This is supported by the fact that the bound on the highest temperature objects is essentially constant with z.

3. Results

In Figure 1, the blue data points represent individual galaxies and the orange points represent the mean of each of each bin. The blue and orange lines are the best fit lines of the blue and orange points, respectively. As shown, there is a trend with redshift, but it is well within the error bounds and is likely an observational bias. Evidence for this bias includes the fact that the hot temperature bound in the blue dots stays constant with z, but the low temperature bound increases at lower redshift. This trend is consistent with weak λ4363 lines being harder to detect at higher redshift. In fact, since signal is proportional to $1/r^2$ and error is proportional to $\sqrt{\text{signal}}$, error is proportional to $1/r$. We would therefore expect to see a linear bias with distance, and we believe that is what we are seeing.

4. Discussion

We conclude that the temperature of H II regions within their host galaxies has not varied with redshift since a redshift of 0.7. Or in other words, according to ΛCDM models with H_o = 67.8 km s^{-1} Mpc^{-1}, Ω_M = 0.308, and Ω_Λ = 0.692, (Ade et al. 2016) temperature has not varied since the universe was 7.35 Gyr old (Wright 2006, http://www.astro.ucla.edu/wright/CosmoCalc.html). We had wondered if the numbers of hot O and B stars, as a fraction of stellar population, was higher in the past. Our data are consistent with their numbers being the same and the hot end of the stellar luminosity function not evolving since a redshift of 0.7.

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