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Origins And Evolution Of Galactic Type Diversity

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Abstract

A study is presented into the origins of galactic type diversity and galaxy evolution through investigating the relationship between representative galaxy color index u-v and redshifts. A sample of 385,075 galaxies with redshifts 0.2<z<3.5 through absorption filters U and V, as provided by the COSMOS Deep-Sky Survey Public Database, is analyzed. After identifying and removing effects of redshifts on spectra, an approximation of the Friedmann Equation is used to determine galaxy distance, which is then applied to compare samples by absolute magnitude. It is concluded that galaxy type diversity in relation to star formation rates originates at approximately z=2, or 6.3 billion years after the Big Bang.

***Keywords*:** galaxy, color index, redshift, absorption, star formation, Big Bang

I. INTRODUCTION

This study is an investigation into the birth of galactic type diversity with respect to rates of star formation, as well as how their evolutionary patterns change over time. Data from the COSMOS DR12 Public Database, a cosmic wide-field survey consisting mostly of galaxies with values of z, or redshift (a measure of the relative recession velocity of the galaxy) between 0.2 and 3.5, was used to explore the origins of galactic type diversity, as well as how galactic evolution patterns changed over time. Galaxies with a redshift of 0.2<z<3.5 were surveyed, and conclusive data at 0.2<z<3.0, for galaxies with ages ranging from of 0.7 Gy to 11.6 Gy ago, was selected: a large percentage of the currently theorized age of the universe. The primary aim of this study is to investigate the relationship between galactic color and redshift, and thus determine a quantitative value for the time frame of the beginning of galactic diversity.

II. METHODS

The primary method of evaluating a galaxy's rate of star formation used in this study was the analysis of galactic color indices; ratios between detected radiation of different frequencies emitted from the specified galaxy. Due to younger stars emitting shorter-wave radiation (and thus appearing on the blue side of the visible spectrum), one can proceed on the assumption that, in general, galaxies that emit shorter-wave radiation than average have a faster rate of star formation, and galaxies that emit longer-wave radiation than average have a slower rate of star formation. By observing the spectra of a large sample size of galaxies through a range of z values (which represent the primary timescale in this survey), one can observe the change in star-formation rates of galaxies over time.

Data Selection

The COSMOS DR12 contains a total of 385,075 samples, each an individual galaxy, cluster or major nebula[1]. After eliminating all error values (indicated by a 99 in the database), 382,747 samples remain. Out of those, a filter between 0.2<z<3.5 was set, and all samples outside that range were rejected. Before z=0.2, there is a pronounced lack of large, bright galaxies, and after z=3.5 extinction becomes a major issue, preventing good-quality analysis.

Redshift Averaging

To enable the detection of general trends, the samples were divided into specified redshift intervals, and the redshifts and magnitudes within intervals were averaged in order to produce one data point per interval per magnitude. The size of the chosen intervals depended on the constraints of the data set and the analysis. As this averaging of intervals of samples prevents the observation of the distribution of points within an interval, this method was only used when insight concerning distribution is irrelevant or insignificant.

Determining Object Color

While there are multiple methods of determining the relative color of a luminous celestial object, two particular methods were used in this study. The color index u-v is the difference between the magnitudes for the u-band and the v-band, at wavelengths 3650Å and 5510Å respectively. Due to magnitude having an inverse relationship with apparent brightness, a higher u-v suggests the emission of longer wavelengths, while a lower u-v value suggests the emission of shorter wavelengths. The second color index b-v is calculated in a similar manner, with the b-band having a wavelength of 4450Å. The u-v color index is used very commonly in astronomy, and b-v serves as a complement to observe trends with varying redshifts.

Figure 1 shows the results of these analyses. However, here the effect of redshift has not been taken into account, so the increase in b-r and v-r color

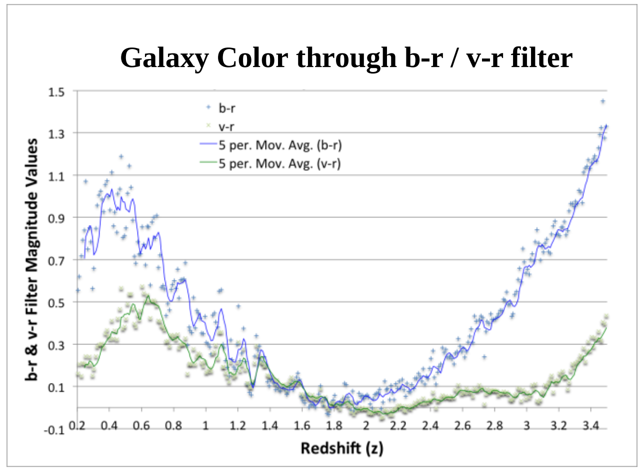

Figure 1. Measurement of Galaxy Color through Observed b-r / v-r Filter Magnitude Values of Galaxies (0.2<z<3.5) with respect to Redshift.

indexes with increasing redshift can be assumed to not be a feature of the original galaxies, but an effect of the increase in redshift. Thus, the observed wavelengths must be "shifted back" into the desired passbands.

The formula used for the interpolation of redshift based on two data points representing two accurately known thresholds of passband boundaries (assuming linear correlation) is shown below.

$$y = y_1 - \frac{x_1 - x}{x_1 - x_2} * (y_1 - y_2) \quad (1)$$

Where y indicates the redshift-reduced magnitude, x indicates the measured wavelength of the passband, x_1 indicates the lower boundary wavelength, x_2 indicates the higher boundary wavelength, y_1 indicates the magnitude that correlates to the lower wavelength, and y_2 indicates the magnitude that correlates to the higher wavelength. The x value is calculated using the redshift equation.

$$x = x_0(z + 1) \quad (2)$$

Where x_0 represents the original theoretical wavelength: in this case, the u-band.

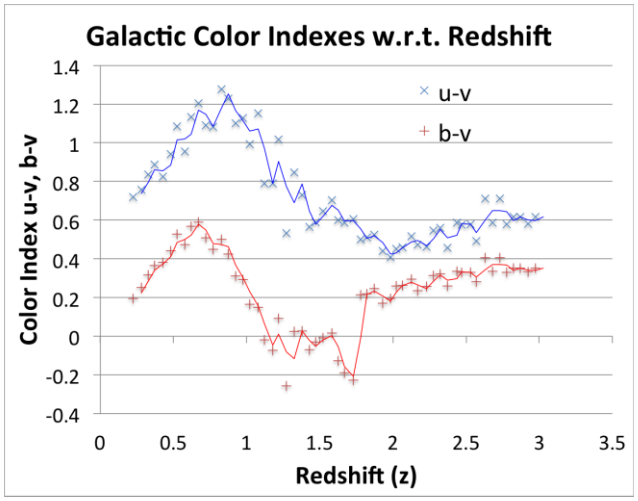

Figure 2. Galactic Color Indexes as a function of redshift, with the effect of redshift removed.

The data sample, corrected for the effect of redshift, is shown in figure 2. Comparing figure 2 with figure 1, one can observe that the effect from the redshift at higher values of z has been removed. While the b-v graph shows some peculiarities compared to the standard u-v, namely the unexpectedly low values between $1.5<z<2$ and the unexpectedly high values between $2<z<3$, the u-v color index shows a consistent pattern with galactic color.

Distance-Brightness Bias

At closer ranges, properties of darker galaxies will affect the average, as darker, smaller galaxies tend to have a blue tint. The sudden drop in redness with $z<0.6$ in Fig.1 is a reflection of this. To make sure that equally bright galaxies (and thus similar galaxies) are being surveyed, a criteria for the absolute brightness of a galaxy was created.

There are two known methods of determining the distance to an object from redshift alone. Firstly, the Hubble Equation and an equation for redshift may be used in conjunction. While this approach is acceptable in most cases, using a linear relationship between recession velocity and distance is not applicable for large distances, such as $z>1$. This is because the Hubble equation assumes an Einstein-de Sitter universe: where no cosmological constant exists, and the universe is thought to be perfectly flat. It is known today that this is an incorrect assumption; and that the universe is slightly curved.

Several astrophysical density parameters govern predictions on universe evolution, most commonly represented as Ω_m and Ω_A. Both parameters are drawn from the Friedmann Equations,[2] and must have a sum of 1. While various models have been tested on various combinations of Ω_m and Ω_A, the most commonly accepted model of the universe retains a parameter set of $\Omega_m = 0.3$, and $\Omega_A = 0.7$, which will be assumed in this study. An online calculator[3] was used to find values for d, the distance to a galaxy, for every 0.05 z. Finally, the absolute magnitude, M, of an object, was calculated for each passband using:

$$M = m - 2.5log_{10}\frac{d^2}{10^2} \qquad (3)$$

where m is the observed magnitude, and d is the distance to the galaxy.

As shown in figure 3, an interesting trend can be noticed within the brightness distribution for galaxies at different distances. At closer distances, the number of darker galaxies is greater, while only very bright galaxies at $-21<$ M can be found at large redshifts. This will cause a distortion in the data produced, due to the aforementioned correlation between brightness and galactic color. Thus, criteria for galaxy brightness were created in order to more accurately observe galaxy evolution. To record trends over the largest redshift range possible, two criteria were selected; for darker galaxies, with $-19<M<-21$ over $0.2<z<1.5$, and for brighter galaxies, with $-21<M<-23$ over $0.6<z<3.0$. These two datasets were processed separately. Galaxies in the range $3.0<z<3.5$ were not included due to lack of data, as shown in figure 2.

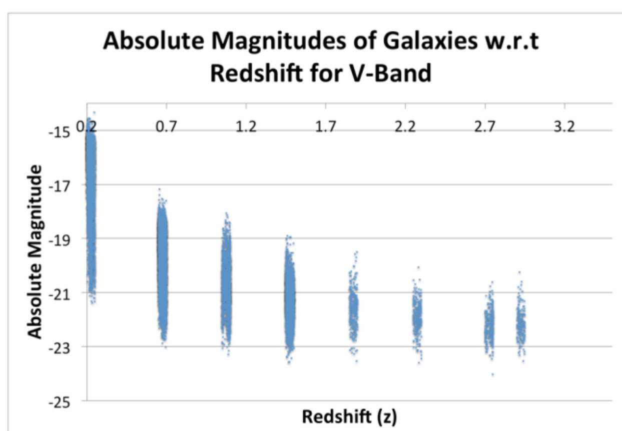

Figure 3. Absolute Magnitude Distribution of Galaxies for the V-Band over redshifts $0.2<z<3.5$

III. RESULTS AND DISCUSSION

Figure 4 shows an imprecise but consistent distribution of galaxies between $2.1<z<3.0$, mostly blue on the spectrum. The cause of this imprecise distribution is unknown, but a prominent candidate is the effect of extinction; galactic and intergalactic dust blocking the shorter wavelength light, which explains why some galaxies in that area are prominently red. However, the effect of extinction seems to decrease to negligible amounts near z=2.1. Due to this, this study will treat the area $2.1<z<3.0$ as a constant, horizontal trend.

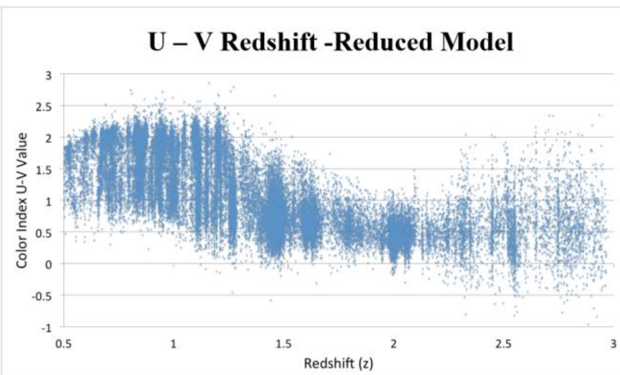

Figure 4. Redshift-Reduced model of absolute magnitude galactic color index (U-V) distribution across Redshifts $0.5<z<3.0$

At around z=2.0 (6.3 Gy after the Big Bang), the maximum boundary of the distribution starts increasing, while the minimum boundary stays temporarily stationary. This suggests the appearance of galaxies that have slowing star formation rates, coexisting with galaxies that continue to retain a high star formation rates; namely, the diversion point towards the existence of star-forming and passive galaxies. The cause of this divergence cannot be determined from this analysis.

For galaxies closer than z=1.2~1.3, the minimum boundary also starts increasing, signifying the disappearance of galaxies with high star-formation rates for closer galaxies. The maximum boundary becomes relatively constant for galaxies closer than z=1.2~1.3, while the minimum boundary does the same at around z=0.9. This suggests a lower limit to the rate of star formation of galaxies. Furthermore, the distribution range at $0.2<z<0.9$ is much larger than $z>2$, suggesting that multiple types of galaxies with varying rates of star formation exist.

One must take care not to ignore the presence of extinction when reflecting on the accuracy of these conclusions. Extinction, the scattering of radiation by cosmic dust, can make very distant objects appear red even when not considering redshift. Observing the very loose distribution of data points beyond z=2.3, one should regard the values at around z=3 to be the general limit of the methodology used in this study.

IV. CONCLUSION

Color index seems to have little significant variation with redshift until z=2, where divergence of star-forming and passive galaxies occurs, indicating the origin of galactic type diversity at 6.3 Gy after the Big Bang. The variation in galactic star formation rates for $0.5<z<0.9$ suggests a fundamental difference in galactic properties that prevents galaxies in this range from emitting wavelengths below the limit.

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