Introduction

Galaxies are fundamental structures in the universe, yet after centuries of study, several unresolved questions remain about their formation. To understand how galaxies evolve, previous studies have investigated the relationships between global galactic properties such as stellar mass, metallicity, and star formation rate (e.g. Madau & Dickinson 2014, de los Reyes et al. 2015). My internship at the Space Telescope Science Institute (STScI) with Drs. Janice Lee and Chun Ly focused on studying these galactic properties at redshift $z \approx 0.8$, when the universe was about half its current age.

As I discovered at STScI, one of the main challenges of these galaxy evolution studies is the natural bias resulting from sample selection. More luminous galaxies, which tend to be more massive galaxies, are inherently more likely to be seen than dimmer (less massive) galaxies at the same distance. Therefore galaxy surveys often represent a sample biased towards higher masses. Since low- and high-mass galaxies may evolve differently, it can be difficult to investigate hypotheses about galaxy evolution without a statistically complete sample. To that end, I propose a two-phase spectroscopic study of low-mass galaxies, often called dwarf galaxies, at low redshifts ($z < 1$).

Background

This study would supplement current studies of two important galaxy property relations: (1) the star formation history (SFH) of the universe, and (2) the relationship between stellar mass, metallicity, and star formation rate. Increasing the scope and sample size of current dwarf galaxy surveys will help constrain the low-mass end of both relations.

The star formation rate is the amount of stellar mass produced per time in a galaxy. The SFH of the universe, then, is the evolution of the average star formation rate per unit volume of the universe, which approximates the SFH of individual galaxies. Previous work showed that average star formation rates peak around redshift $z \approx 1.9$—that is, around 10 billion years ago—then decline at lower redshifts (Madau & Dickinson 2014).

A third property called metallicity helps us understand how galaxies interact with their environments. Metallicity indicates the abundance of gas-phase elements heavier than helium in a galaxy. A balance of different interaction mechanisms is thought to drive the relative amounts of metals in a galaxy: inflows of metal-poor gas dilute the metal content of galaxies, while enriched gas outflows expel metals from galaxies. Understanding the relative contributions of these mechanisms requires understanding how metallicity relates to other galactic properties—for instance, the relation between metallicity, stellar mass, and star formation rate (Mannucci et al. 2010, de los Reyes et al. 2015).

Study Description

My proposed study is unique because it focuses on a redshift region that has often been ignored by dwarf galaxy surveys. Previous non-local surveys have largely targeted intermediate-redshift galaxies at $z > 1$ (e.g. CANDELS; see van der Wel et al. 2011).

Over the next 2-3 years, the first phase of this study will use existing data to choose previously-studied sky fields with relatively low amounts of dust. Working with astronomers from STScI, I will then begin ground-based surveys in the selected fields, using narrowband filters to measure the flux of the Balmer Hα emission line. This is a well-documented tracer for star formation (Kennicutt 1997), and measuring it will allow us to begin preliminary work on the SFH and to select star-forming dwarf galaxies for follow-up observation.

In the long-term, I will again collaborate with astronomers from STScI to request observation time with the James Webb Space Telescope (JWST), which will become operational in 2018, to collect spectral data on the selected galaxies. JWST's multiobject spectrograph called NIRSpec will have a limiting line flux smaller than that of many current ground-based spectrographs (Gardner et al. 2006). JWST should therefore be able to obtain spectra for galaxies less luminous than those currently included in most surveys. Stellar masses could be estimated from NIRSpec spectra with theoretical models that fit galaxies to spectral energy distributions. The spectra could also provide the fluxes of certain rest-frame optical emission lines ([OII], [OIII], Hβ) that can be used to calculate metallicities (Kewley & Ellison 2008).

Outreach Component

Inspired by my previous science outreach at the North Carolina Museum of Natural Sciences, my goal is to show what "real" science looks like. When I first began research, I thought that science was a linear process from point A to point B. Every time I ran into a problem with my research, I thought I must be doing something wrong, and I almost left physics as a result. It is therefore incredibly important to me to show the general public—especially budding scientists—that science is not simply a linear progression, but an often messy endeavor of trying new ideas and learning how to work around unexpected failures.

Throughout this proposed project, I will maintain a weekly video blog on Youtube and a site on the popular social media site Tumblr. My posts will regularly document the daily trials and successes of research and graduate student life. I hope that this will help me be a role model for students, particularly ones who may not have direct access to mentors or resources.

Conclusion

My research at STScI involved using Hα data from a narrowband survey (de los Reyes et al. 2015). As a result, I have experience in dealing with many of the challenges inherent in working with galaxy observations in the redshift range $z < 1$, such as correcting for dust attenuation and contamination of the Hα emission line by other emission lines. Furthermore, I plan to pursue graduate study across the street from STScI at Johns Hopkins University, facilitating my collaboration with astronomers at STScI.

I look forward to using these skills to help understand how galaxies—the "basic building blocks of the universe" (Gardner et al. 2006)—evolved to their present-day form.

References

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