The relation between stars and gas in distant galaxies

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Observing any galaxy in the universe will yield the fact that it contains stars and also gas. The dynamics of both can be explored by observing galaxies and collecting spectroscopic data.

Abstract abstract

Contents

1. INTRODUCTION

Amongst the different types of cosmic structure within our universe, galaxies can be described as the most unique and diverse. With an approximate [insert number here] galaxies in our universe, each of which containing countless numbers of stars, gas, dust, and dark matter [1], it would be difficult not to express the statement that the motions of these objects must be linked together in some galactic relationship.

Through observations of these galaxies, their structure and the motions of the objects within them can be studied to a great depth. As an example, if we took optical measurements of the stellar population, we could use that information to infer and estimate the potential age of the galaxy. We know that redder stars are older and bluer stars represent a younger set of objects [1]. Or if we wanted to know about the material composition or even the distance to a certain galaxy, we could split the collected light in a spectrograph to produce a spectrum. Values of redshift and the content of a galaxy can then be obtained by looking at the absorption and emission lines [1].

Gathering and processing this optical and spectroscopic information allows us to build a broad picture of the internal workings of a galaxy. To begin with however, we must consider galaxies in their generality, after which we will be able to explore the intricacies from the how a galaxy evolves from the early stages of being a gas cloud to the eventual relation of the stellar population to that gas.

a. Galactic classification

As we stated previously, a galaxy can be quite broadly defined as a collection of gas, dust, stars and dark matter. But if we were to observe a large enough sample then we would begin to see that the galaxies can be grouped and classified together.

This categorisation is called the *Hubble Sequence* or the *Hubble Tuning Fork* [1]. From Figure 1 we can see that galaxies can be divided into ellipticals, spirals and irregulars. With early Hubble type ellipticals along the horizontal handle, the two prongs containing normal and barred spirals (also known as the later Hubble types), and irregulars as the third category. What we see from the diagram is a summarised view of the main galaxy types, in reality there are more than the 11 named.

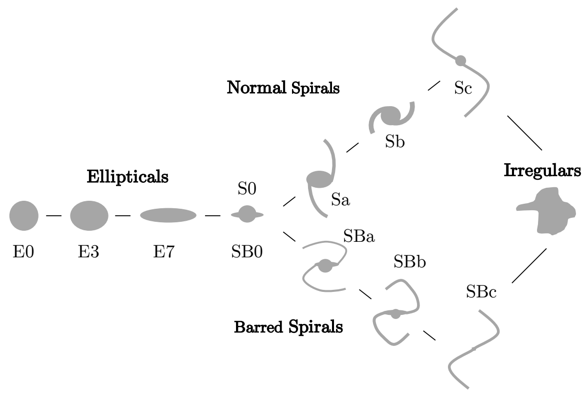

Figure 1: The Hubble Sequence, displaying the three general groups of galaxies: ellipticals, spirals, and irregulars, and the main galaxy types from each category. A pictogram and the classification name is shown for each of them. The sequence does not show the evolution of galaxies but their classification.
(*This diagram has been adapted from An Introduction to Modern Astrophysics* [1].)

The sequence itself does not show the evolution of the galaxies, rather it provides a way to view the different morphologies of them. We must ask ourselves then what each general grouping represents in relation to the make-up of the galaxy. Alongside the classification from appearance we can also explore the basic component composition.

Take ellipticals, we see from the Hubble Tuning Fork that they can be described as spherical-like distributions. In fact, they actually range from being virtually spherical (E0) to highly flattened (E7) collections of gas, dust, and dark matter [2]. Through observation of the stars within them, we find that the majority of them are the older, red coloured variety. This may be due to the fact that early on in the creation of ellipticals, a considerable proportion of the gas went into the formation of stars, thus viewing these galaxies now we find that their stars are predominantly older types [1] as new stars are not being born. This could also explain the lack of disks which can be otherwise seen in the spiral galaxies. With not enough material the disk and arms features would not form.

Comparatively, we can describe spiral galaxies as being composed of a central nucleus which has a surrounding disk of material. This disk then has denser regions which can coalesce and form the protruding arms which we can see around the main bulge [1]. The later type spirals (Sc and SBc) have arms which are more loosely wound than their earlier types (Sa and SBa) [2]. With more available gas and dust [1], we would assume that spirals in their various forms would have more opportunities to form new stars than ellipticals.

It is within the arms of spiral galaxies that we find the creation of new stars. It is within the spiral structure that we find the gravitational field which allows for angular momentum to be transported outwards. Older and less massive stars in the galaxy produce a gravitational field which eventually leads to the shocking of the interstellar gas [3]. As a result the density of the gas in the arms increase and certain regions then collapse to form new young, blue, and massive stars.

Spiral galaxies therefore have a mix of ages in relation to their stellar population. The arms in a spiral contain young stars whilst the central nucleus is similar to that of elliptical galaxies where the population of stars is composed of older types [1, 3].

Irregular galaxies have no noticeable symmetry and no obvious central nucleus, so they do not fall into either of the other two categories.

By knowing these general characteristics, as we continually to improve our observational instruments we can then view deeper into the Universe's past. This means the galactic objects are becoming more and more younger, this is a powerful way for us to build a picture of the evolutionary nature of galaxies and their structure.

b. Galactic and stellar formation

We introduced the concept that through optical measurements of the stars

c. Data

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1. HUDF and MUSE

To obtain spectroscopic information on the Hubble UDF objects, the Multi-Unit Spectroscopic Explorer or MUSE was employed. This instrument is

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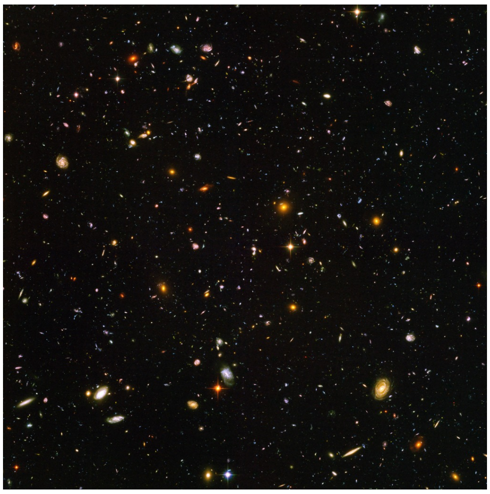
(a) MUSE HUDF



(b) HST HUDF

Figure 2: (a) A colour image created from the MUSE spectroscopic data of the HUDF. The wavelength range was split into three equal regions and then collapsed to create three bands (R, G, B). A final colour image was produced by combining these separate frames together. (b) The optical HUDF as captured by the Advanced Camera for Surveys instrument on the Hubble Space Telescope [4].

d. Project Aims

This paper discusses the study undertaken to understand the dynamics between the gas and stars in galaxies, data extraction is performed on the MUSE data cube, the sample is reduced, doublet fitting performed, applied the data set to a processing package pPXF.

In section 2, the experimental methods behind the data extraction and analysis are discussed.

2. ANALYSIS

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a. Cube extraction

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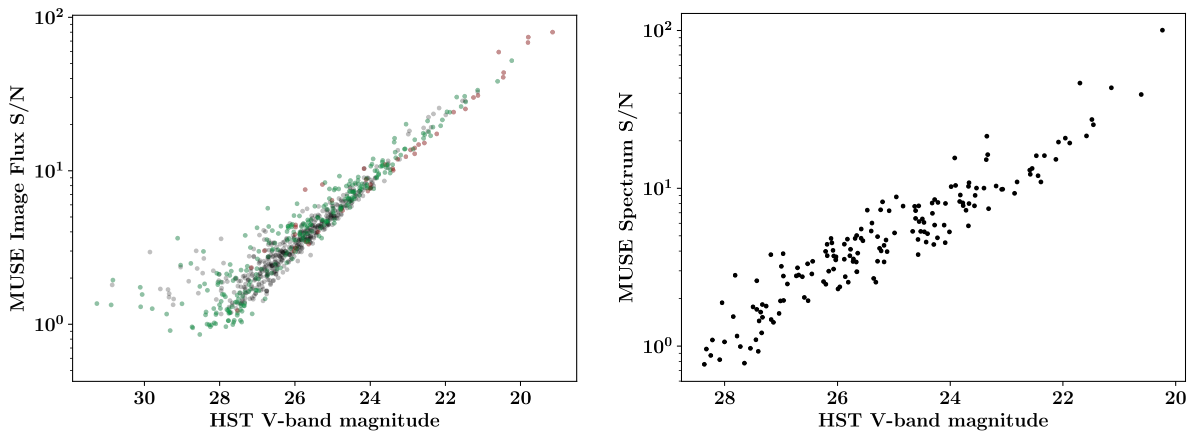

(a) Image S/N vs. V-band **(b)** Spectroscopic S/N vs. V-band

Figure 3: (a) The signal-to-noise of the image flux for every object in the MUSE collapsed image plotted against their respective V-band magnitudes from the HST catalogue. The red points represent those with redshifts $z < 0.3$, and the green points are a chosen sample of 300 points as defined by the sextractor probability that they are not stars. (b)

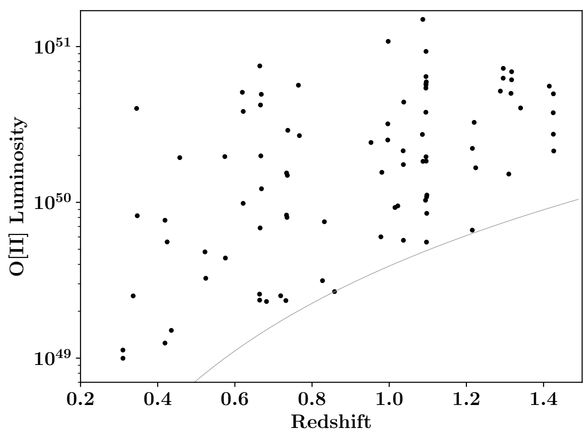

Figure 4: Graph showing the calculated luminosity for the O[II] doublet plotted against redshift. Data points are plotted as well as a model line representing the lower-limit of the flux from the sample. [???]a

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b. Line fittings and pPXF

After extracting the individual galactic objects from the main MUSE cube, the data had to be verified and then fitted using two different routines: (i) O[II] doublet fitting, and (ii) pPXF absorption line fitting.

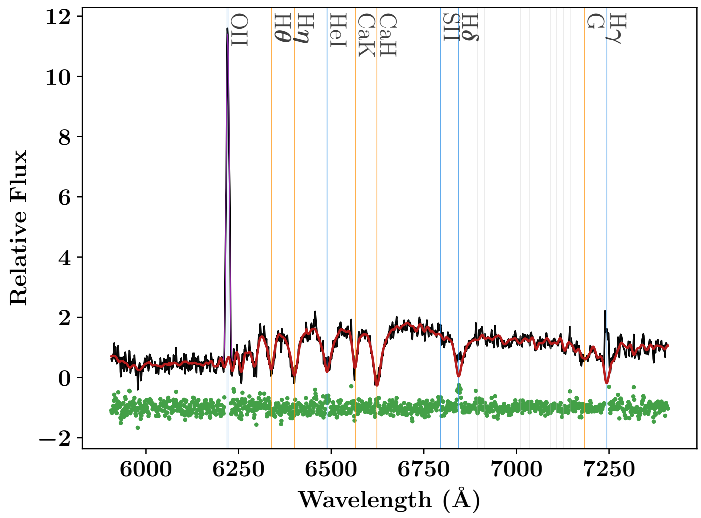

Figure 5: Fitting of a galaxy spectrum with pPXF.

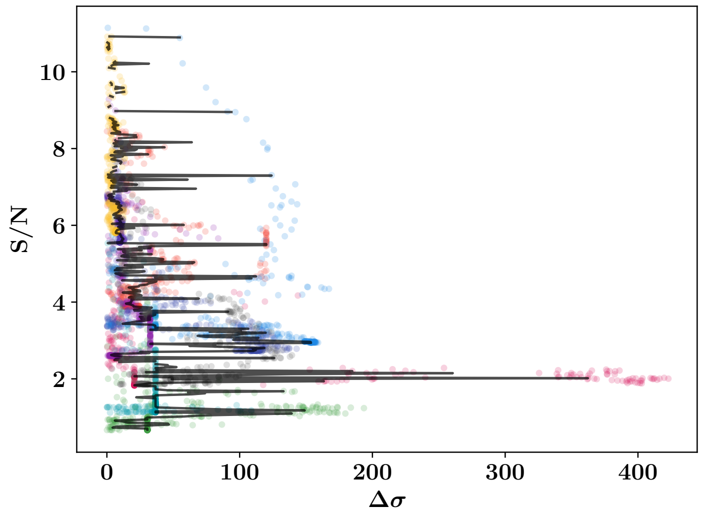

Figure 6: The signal-to-noise versus the fractional error of the σ line width of the pPXF curve fittings.

3. DISCUSSION

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4. CONCLUSIONS

In conclusion, through extensive data and statistical analysis it can be said that the dynamics of stars and gas in galaxies are ... (?)

Acknowledgments

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been experimentally grounded.

References

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