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

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1. INTRODUCTION

Amongst the different types of cosmic structure within our universe, galaxies can be described as the most unique and diverse. With each containing countless numbers of stars and vast amounts of gas, dust, and dark matter [1], it would certainly be surprising if these various objects were found to not be connected in any way.

Through observational astronomy the internal structure of galaxies and the motions of their inner objects can be studied and understood. With approximately $(2.0^{+0.7}_{-0.6})$ $\times 10^{12}$ galaxies in the universe up to $z = 8$ which in principle could be observed [2], there is definitely not a lack of choice. What is important is how these objects are observed and how the collected data is later analysed.

It is additionally significant to understand what a galaxy generally is and how they can be defined and placed into different categories. Once an appreciation is built for the galactic classification, the intricacies of motions and inter-relationships can be explored further.

a. Galactic classification

As stated previously, a galaxy can be quite broadly defined as a collection of gas, dust, stars and dark matter. But if a large enough sample was observed then one would begin to see that they can be grouped and classified together.

The most general categorisation is called the *Hubble Sequence* or the *Hubble Tuning Fork* [1]. Galaxies can be roughly divided into ellipticals, spirals and irregulars (Fig. 1). With early Hubble type ellipticals along the horizontal handle, then the two prongs contain normal and barred spirals (later Hubble types), and irregulars as the third category. What can be seen from the Tuning Fork is a summarised view of the main galaxy types, however in reality there are more than the 11 named.

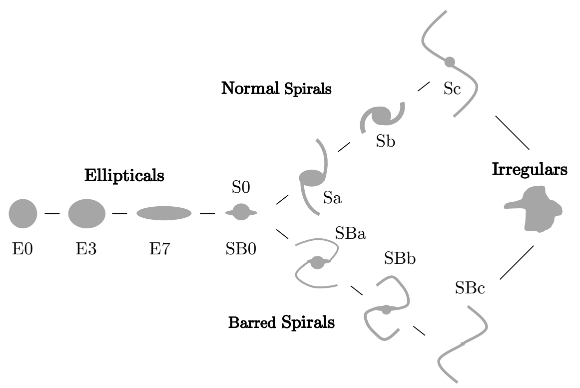


Figure 1: The Hubble Sequence displays the different morphologies of galaxies, they can be classified into three general groups: ellipticals, spirals, and irregulars. The former two can be broken up further, and from the diagram one can see an example pictogram and the respective classification name.
(*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 potential morphologies. So then, what does each grouping from the sequence actually represent?

Starting with the most broad, irregulars are objects which do not fall into the two main galaxy types (ellipticals and spirals). In 1926, Edwin Hubble produced two sub-categories for irregulars depending on if a particular galaxy could be seen to have structure, such as spiral arms [1]. If they did then they would be Irr I galaxies, and if they appeared to be extremely disorganised structures then Irr II. Generally, irregulars are not particularly large, their diameters typically range from 1 to 10 kpc, and they have an absolute B-band magnitude of -13 to -20.

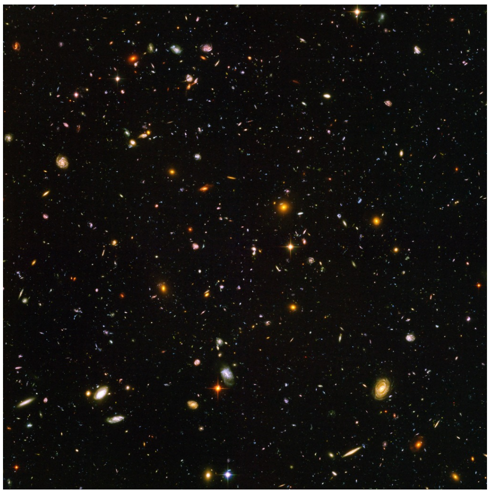
This classification has been performed by looking at the appearance of a galaxy, this can be extended to ellipticals and spirals, plus their component composition can be explored as well.

With ellipticals, they span from being virtually spherical (E0) to highly flattened (E7) collections of material and objects [3]. Through observations of their stellar objects, it can be seen that the majority of them are old and red-coloured. This may be attributed to the amount of gas which was used in the initial stages of galactic stellar formation. If a larger proportion was used up initially then current observations would should the current stellar-birthrate in ellipticals to be low [1]. This could additionally explain the lack of disks which can be otherwise seen in the spiral galaxies, if there is not enough material then the disk and arms features would not be able to form.

Exploring the second grouping of galaxies, spirals can be described as being composed of a central nucleus with 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) [3]. 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 [4]. As a result the density of the gas in the arms increase and certain regions

(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 [5].

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, 4].

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

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d. Project Aims

This paper discusses the study undertaken to understand the dynamics between

c. Data

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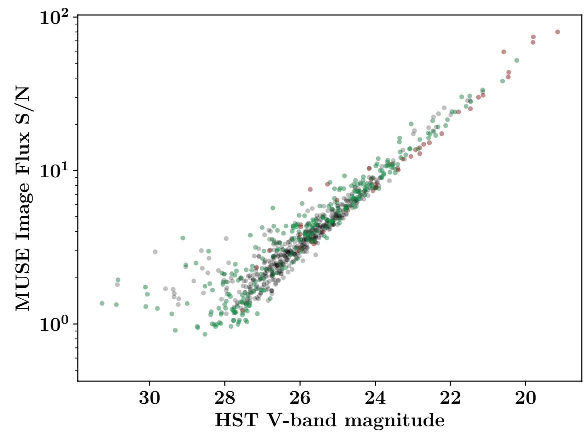
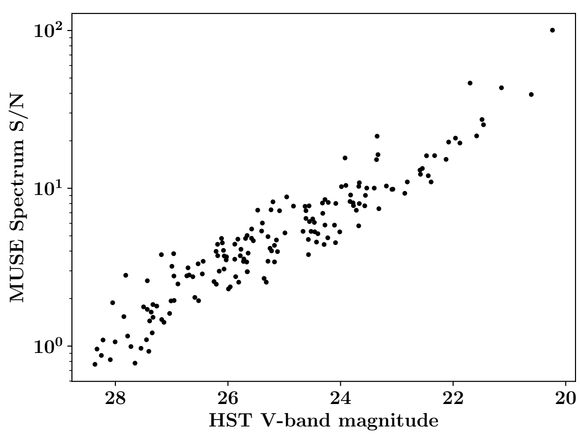
1. HUDF and MUSE

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



(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)

discussed.

2. ANALYSIS

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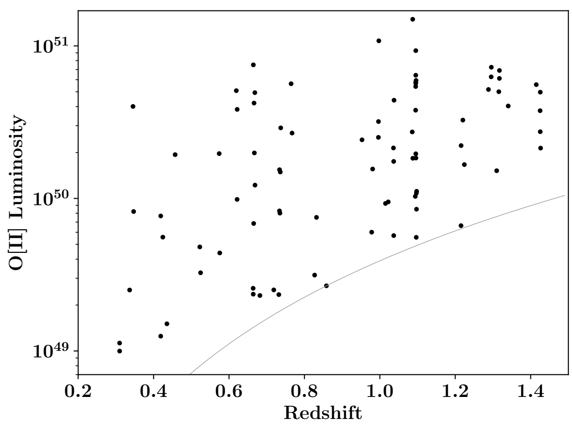

Figure 4: Graph showing the calculated luminosity for the O[II] doublet plotted against redshift. Data points are plotted as well as a model line representing the lower-limit of the flux from the sample. [???]a

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a. Cube extraction

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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.

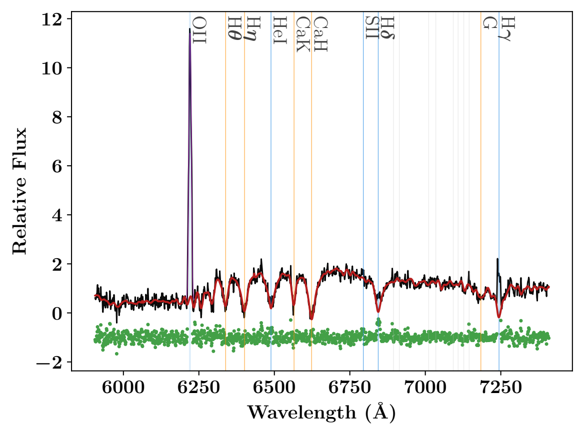

Figure 5: Fitting of a galaxy spectrum with pPXF.

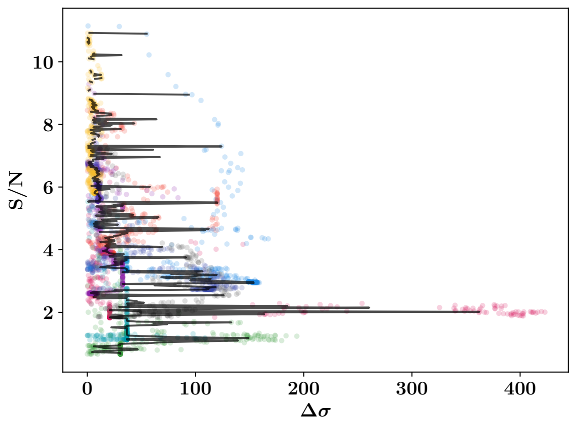

Figure 6: The signal-to-noise versus the fractional error of the σ line width of the pPXF curve fittings.

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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