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Understanding the Transformation of Spirals to Lenticulars

Evelyn Johnston

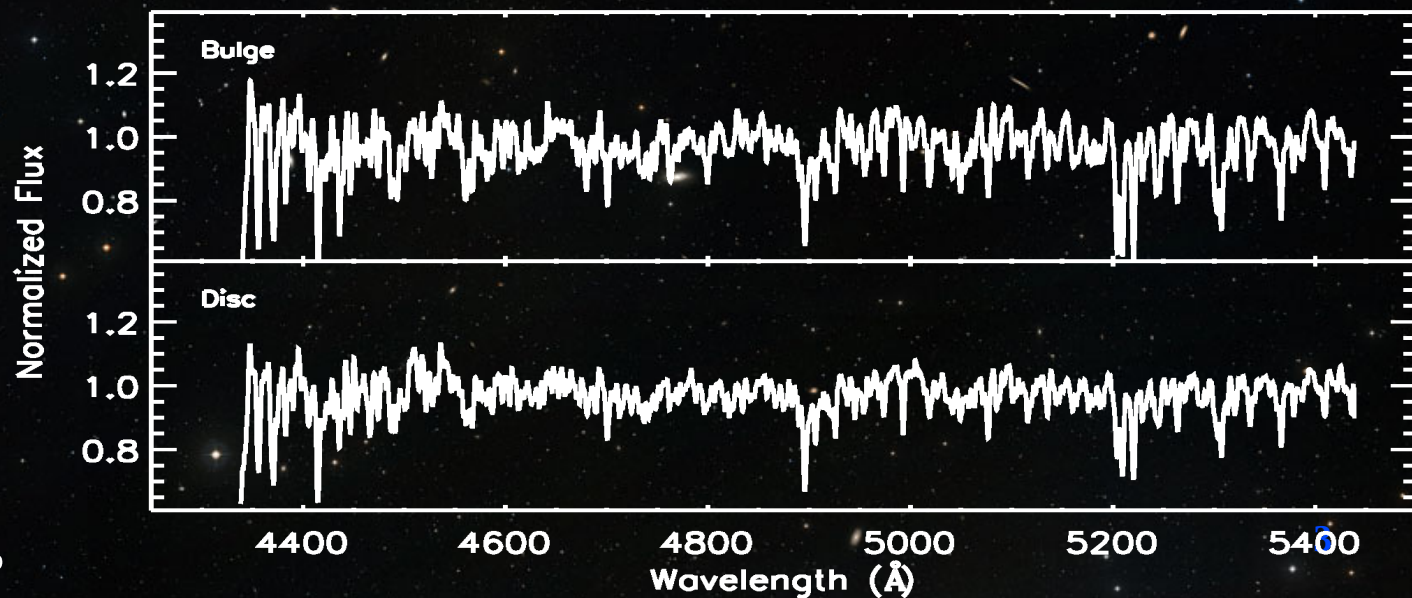
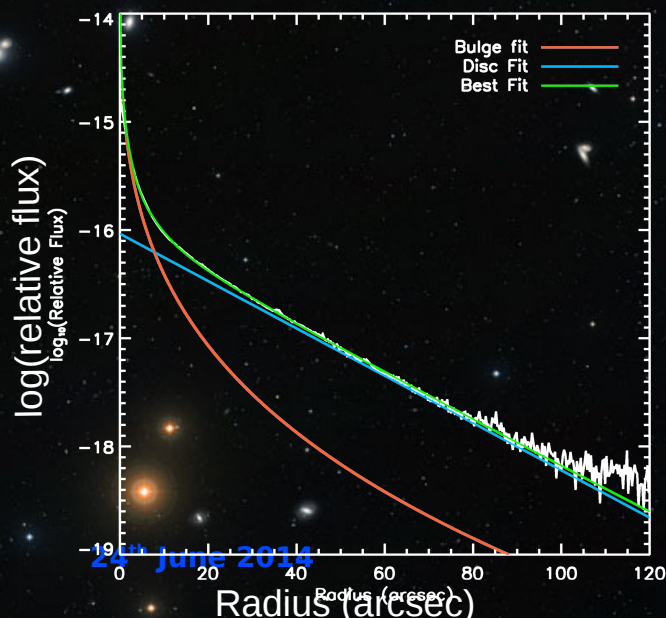
With A. Aragón-Salamanca, M. R. Merrifield
(Johnston, Aragón-Salamanca & Merrifield, 2014, MNRAS, 441, 333)

Transformation of Spirals to S0s

- To transform a spiral into an S0 you need to
 - Quench star formation in the disc
 - Increase bulge luminosity
- But the exact sequence of events leading to the transformation is still uncertain.
- Therefore, we need to study the independent star formation histories of the bulges and discs

Spectroscopic Bulge-Disc Decomposition

- Obtain a good quality long-slit spectrum of a galaxy
- Decompose light profile at each wavelength
- Integrate to get total light of bulge and disc for that wavelength bin
- Plot against wavelength to obtain high-quality spectra representing purely the bulge and disc light.



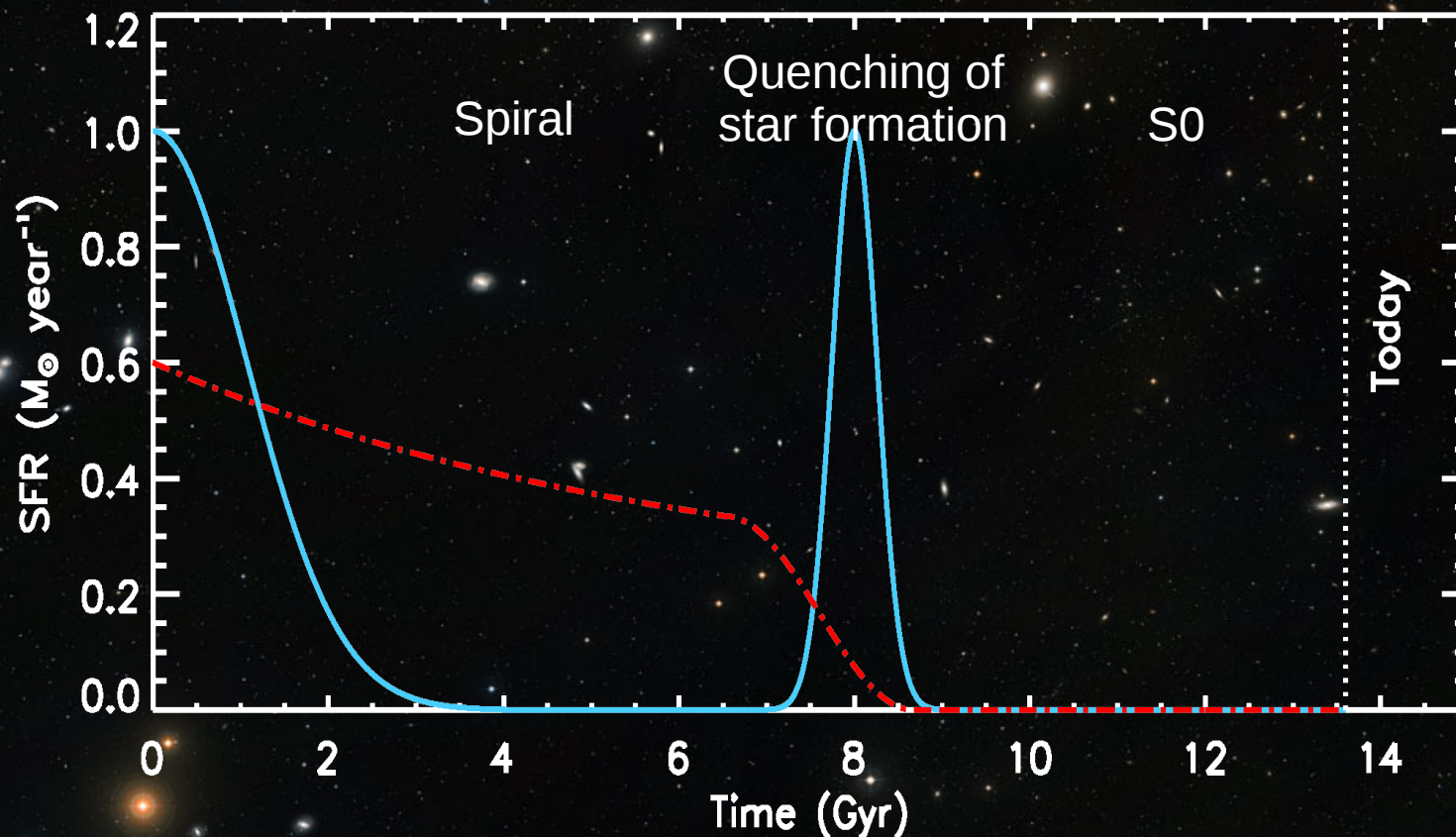
Transformation of Spirals to S0s

1. Disc undergoes continuous SF until quenching begins

2. During quenching, Fe-enriched gas is dumped in the central regions

3. Bulge undergoes a final SF event, using up the dumped disc gas and truncating all SF in the galaxy

4. After all SF has been quenched, the spiral galaxy transforms into an S0



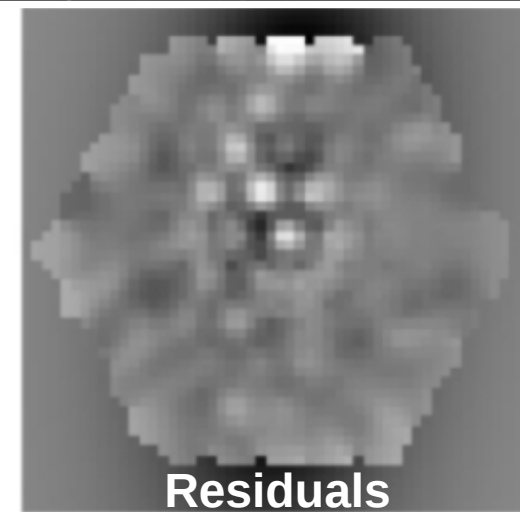
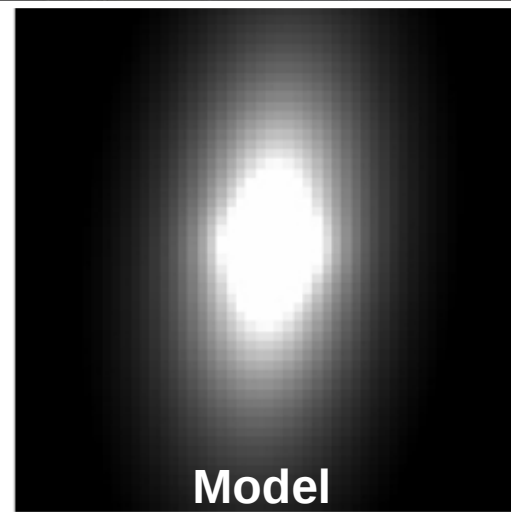
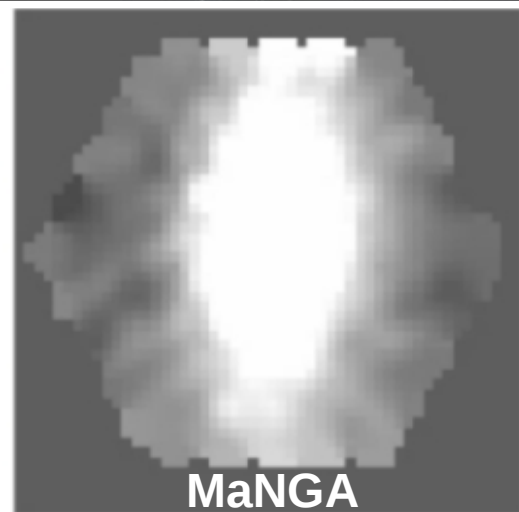
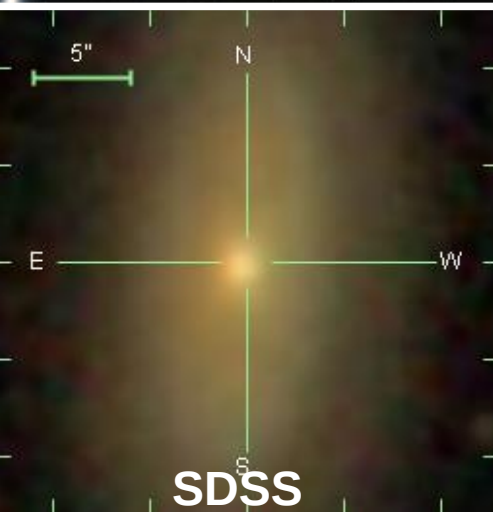
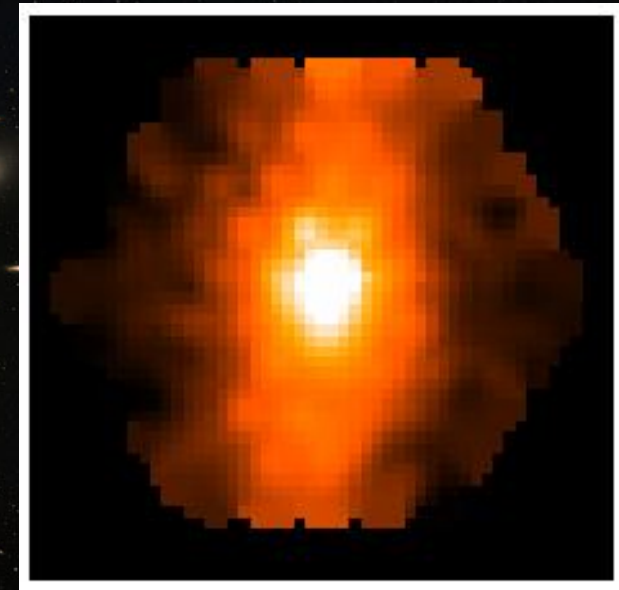
Note:

The following results are very preliminary and use many assumptions. They should be considered as a proof of concept only.

PRELIMINARY

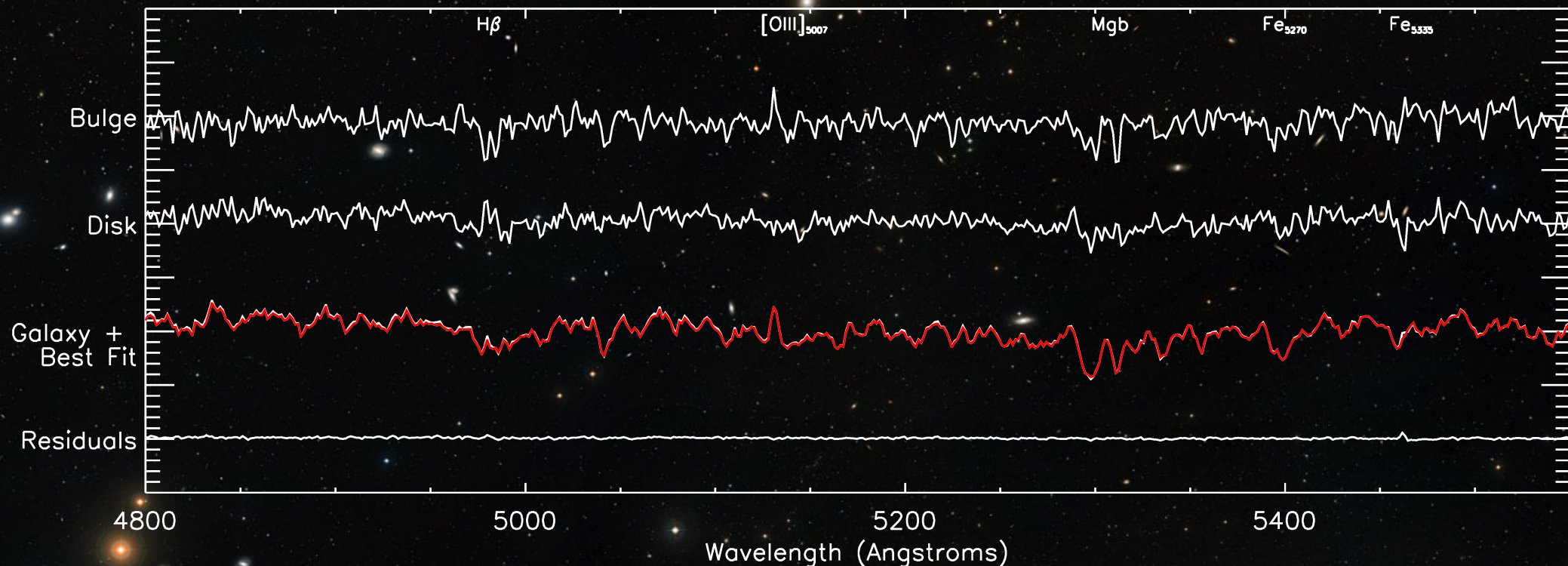
Steps to decompose IFU spectra

- Bin the data cube into a series of high S/N images, and decompose with GALFITM (Haeussler et al, 2013; Vike et al, 2013) to see how parameters vary with wavelength.
- Print off image slices at each wavelength from the IFU datacube, and decompose with GALFIT (Peng et al, 2002).



Steps to decompose IFU spectra

- Plot the integrated luminosity of each component against wavelength to get its one-dimensional decomposed spectrum.
- Use GALFIT to recreate images of subcomponents at each wavelength, and combine into data cubes for bulges and discs.



Come find me or my poster if you want to know more.



The transformation of spiral galaxies into lenticulars

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(Johnston, Aragón-Salamanca & Merrifield, 2014, MNRAS, 441, 323)



Introduction

Lenticular (S0) galaxies have long been considered a possible endpoint in the evolution of spiral galaxies since they share the same disc morphology but contain only older stellar populations. However, the exact sequence of events leading to the transformation is still uncertain.

Any theory proposed to explain the transformation of spirals to S0s must be able to account for both the truncation of star formation within the disc, and the increase in the luminosity of the bulge (Christie & Zaldarri, 2004). To better understand these two phenomena better and build up a sequence of events leading to the transformation of spirals to S0s, we must study the individual stellar populations, and thus the star-formation histories, of the bulges and discs independently.

Sample

The data set consists of long-slit Gemini/GMOS spectra of 21 Virgo Cluster S0s, with typical exposure times of ~3-3 hours. The galaxies were selected to have an inclination of greater than 40° to reduce contamination from misclassified spirals. The wavelength range was 4300 Å <math>< 5500 \text{ Å}</math>, with B-band magnitudes ranging from -22.3 to -17.3.

Spectroscopic bulge-disc decomposition

Spectroscopic bulge-disc decomposition (Johnston et al. 2012) was applied to the long-slit spectra to separate the stellar populations of their bulges and discs.

- The light profile of the galaxy along the major axis at each wavelength bin is fitted with 2-axis bulge and exponential disc profiles until a best fit is achieved, as shown in Fig. 1.
- The fit was repeated for each wavelength to get information on the size and luminosity of each component.
- The total luminosity of the bulge and disc as a function of wavelength is calculated by integration.
- One-dimensional spectra representing purely the bulge and disc light can then be created (see bottom of Fig. 1).

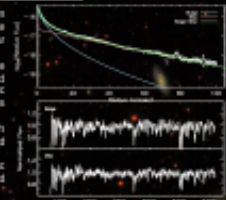


Figure 1: Top: An example of a long-slit spectrum fit to a typical light profile. Bottom: Examples of decomposed bulge and disc spectra.

Stellar populations of the bulges and discs

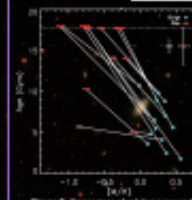


Figure 2: Comparison of relative ages and metallicities of bulges and discs.

Absorption line strengths were measured from the decomposed bulge and disc spectra, and estimates of the relative, light-weighted ages and metallicities of each component were measured from SSP models of Vazdekis et al. (2010). The results presented in Fig. 2 show that the bulges contain systematically younger and more metal rich stellar populations than the associated discs. This result suggests that the transformation triggered a final burst of star formation within the bulge region while the gas was gently stripped out of the disc.

Star-formation timescales

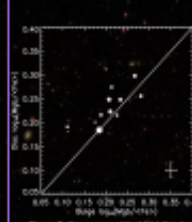


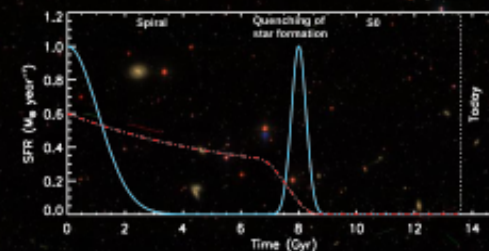
Figure 3: Comparison of the Mg/Fe ratio between the bulges and discs.

The most likely origin of the gas that fuelled the final star-formation activity in the bulge region is from the disc. To investigate this possibility, the star-formation timescales of each component were studied using the Mg/Fe ratio as a proxy of their stellar abundances. Short star-formation timescales possess large Mg/Fe ratios, while longer timescales are reflected by smaller ratios. Figure 3 shows that there is a clear correlation between the Mg/Fe ratios of the bulges and discs, indicating that their star-formation histories are connected. A small offset is also visible, such that the bulges show smaller Mg/Fe ratios than their surrounding discs. This offset could suggest that the bulge light is dominated by the light from a single star-formation event caused during the transformation into an S0, while the disc light represents the superposition of multiple stellar populations created during the lifetime of the progenitor spiral.

The sequence of events in the transformation of a spiral to an S0

1. The progenitor spiral galaxy starts out with an old bulge and ongoing star formation within the disc.

2. The gas is stripped out of the disc, quenching the star formation there over a short (~1 Gyr) timescale. While the disc gas is being stripped, spiral arms are channelled into the central regions of the galaxy.



3. The bulge undergoes a final star-formation event, using up the remaining disc gas and truncating all star formation in the galaxy.

4. With no more ongoing star formation, the galaxy fades into an S0.

IFU bulge-disc decomposition

In order to learn more about the star-formation histories of bulges and discs, we need information over the full radial structures of galaxies. Therefore, the next logical step for this study will be to apply the technique to IFU data cubes of galaxies. Initial tests have been carried out by decomposing image slices from the MANGA prototype data at each individual wavelength bin with GALFIT (Peng et al. 2012), an example of which is given in Fig. 4. By decomposing the spectra in this way, we 3-dimensional spectra for the bulge and disc light, such as those shown in Figure 4, can be created. Additionally, IFU data cubes for each component can also be produced, allowing more detailed structural studies of the stellar populations throughout the bulge and disc. Using such data, it will be possible to learn more about the star-formation histories of the bulges and discs, and thus how each are affected during morphological transformations.

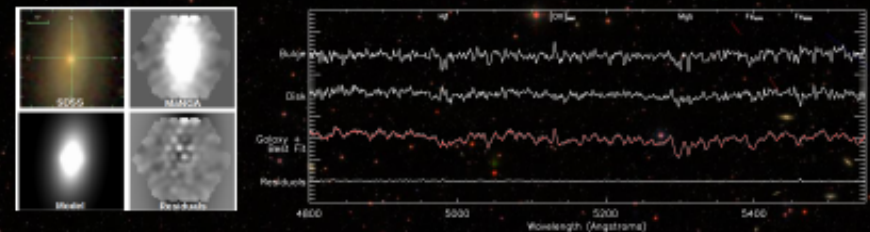


Figure 5: Left: An example decomposition of a galaxy from the MANGA prototype data set, showing the SEDs in image to the same scale. An example of a 3D data cube slice at 4300 Å, the best fit bulge plus disc model and the residuals after subtracting the model from the original. Right: Examples of the decomposed bulge and disc spectra from the MANGA data cubes, along with the fit to the original integrated spectrum (red) and the residuals.

1. <http://www.astrac.uk.ac.uk/manga.php>

References: Christie & Zaldarri, 2004, ApJ, 615, 252; Johnston et al. 2012, MNRAS, 422, 2582; Peng et al. 2012, ApJ, 744, 266; Vazdekis et al. 2010, MNRAS, 405, 1629

Background image from: SDSS DR7, Shegolev et al. 2006, ApJ, 640, 640