The transformation of spiral galaxies into lenticulars

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Introduction

Lenticular (S0) galaxies have long been considered a possible endpoint in the evolution of spiral galaxies since they share the same discy 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 (Christlein & Zabludoff, 2004). In order 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~~2-3 hours. The galaxies were selected to have an inclination of greater than 40° to reduce contamination from misclassified ellipticals. The wavelength range was 4300 < λ < 5500 Å, 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 Sersic bulge and exponential disc profiles until a best fit is achieved, as shown in Fig. 1.
- The fit was repeated at 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).

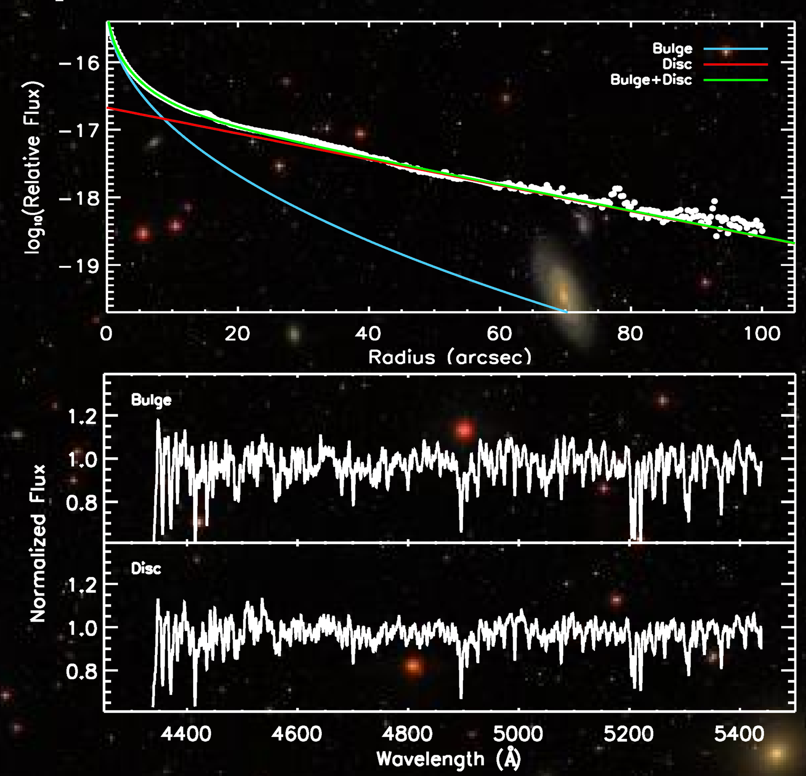


Figure 1: *Top*- an example of a bulge-plus-disc fit to a spectral light profile. *Bottom*- examples of decomposed bulge and disc spectra.

Stellar populations of the bulges and discs

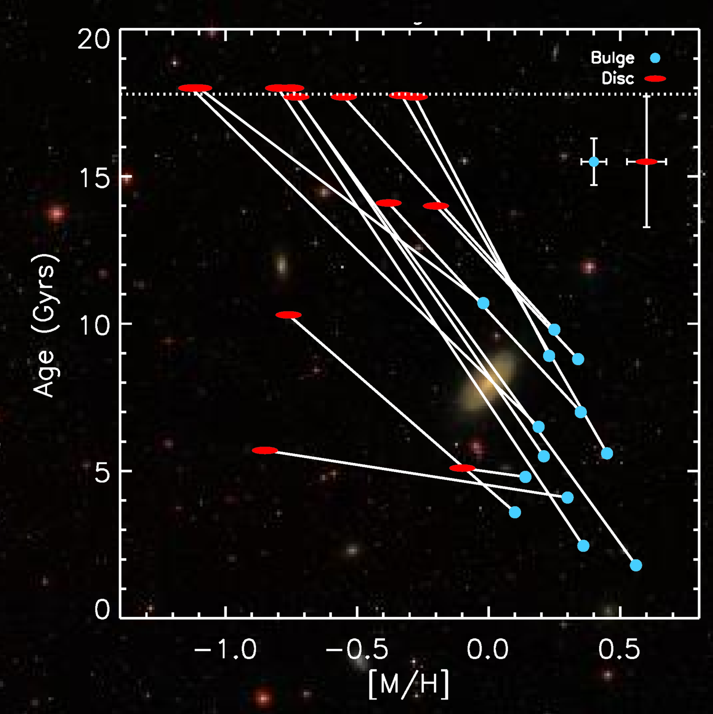


Figure 2: Comparison of relative ages and metallicities of bulges and discs.

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

The most likely origin of the gas hat 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 was studied using the Mg/Fe ratio as a proxy of their α-element abundances. Short star formation timescales present 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 created 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.

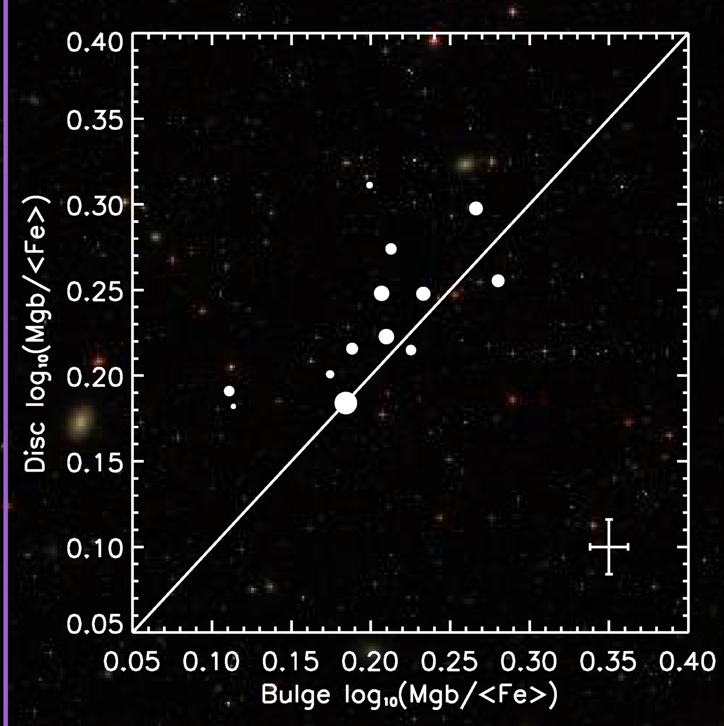
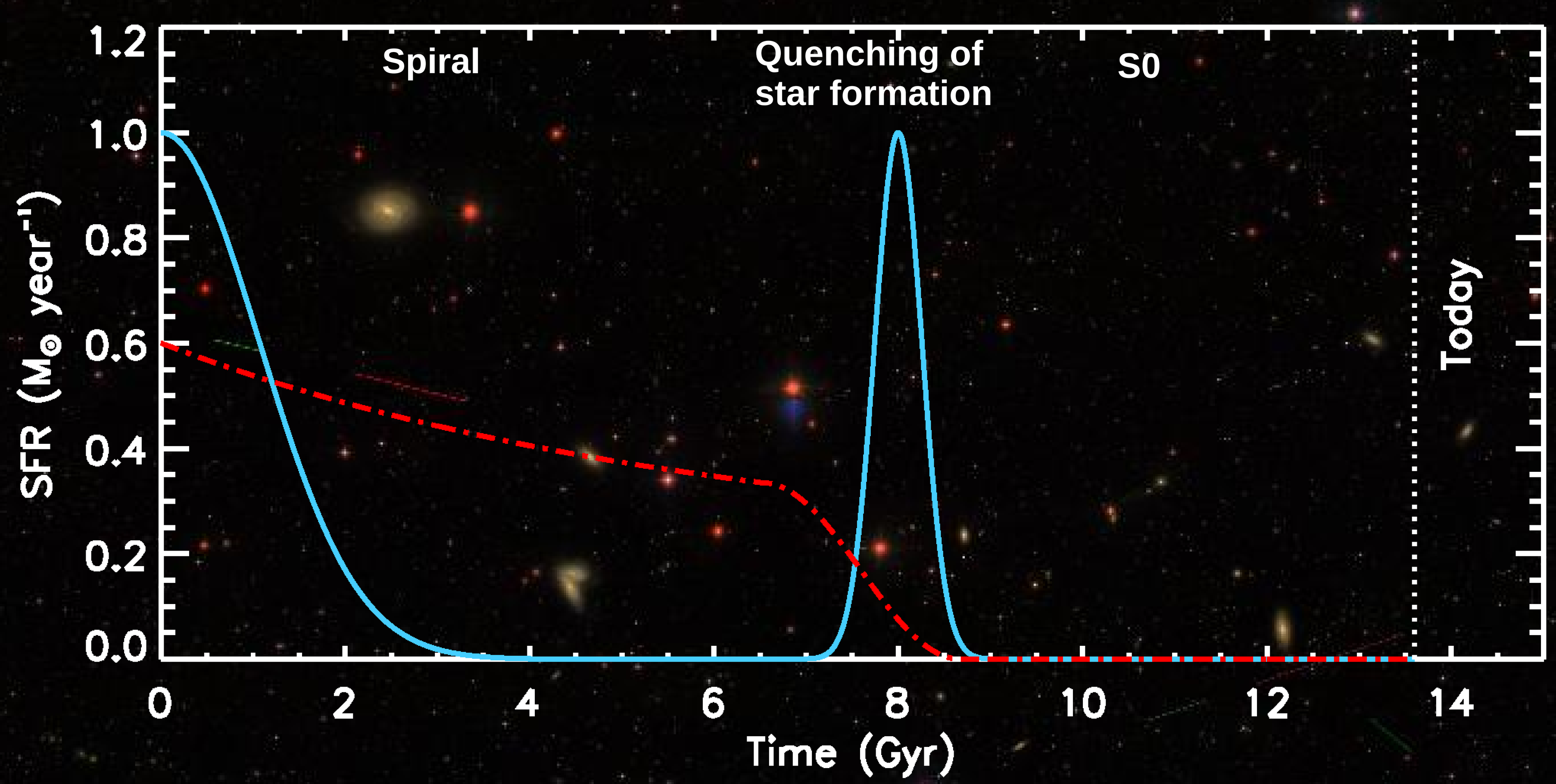


Figure 3: Comparison of the Mgb/<Fe> line ratios measured from the decomposed bulge and disc spectra.

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 (~1Gyr) timescale. While the disc gas is being stripped, small amounts 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[1] prototype data at each individual wavelength bin with GALFIT (Peng et al, 2002), an example of which is given in Fig. 4. By decomposing the spectra in this way, two 1-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.

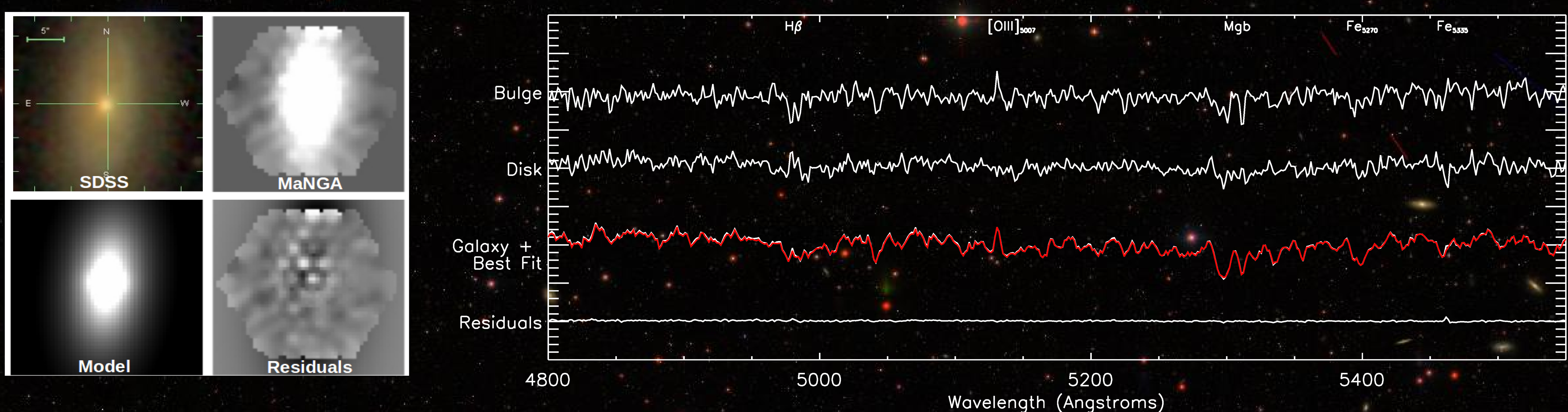


Figure 4: *Left*- an example decomposition of a galaxy from the MaNGA prototype data set, showing the SDSS image to the same scale, an example of a MaNGA image slice at ~5000Å, the best fit bulge-plus-disc model and the residuals after subtracting the model from the original. *Right*- examples of the decomposed bulges and disc spectra from the MaNGA data cube, along with the fit to the original integrated spectrum (red) and the residuals.

1: https://www.sdss3.org/future/manga.php

References: **Christlein & Zabludoff, 2004**, ApJ, 616, 192; **Johnston et al, 2012**, MNRAS, 422, 2590; **Peng et al, 2002**, AJ, 124, 266; **Vazdekis et al, 2010**, MNRAS, 404, 1639