S0s - Formation and Mass

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Abstract

We present first results from a pair of complementary studies which aim to illuminate the formation and evolution of S0 galaxies. These studies examine the stellar populations, kinematics and masses of S0 galaxies in the nearby Universe.

Introduction

Several mechanisms may lead to the formation of an S0 galaxy including mergers or star formation truncation in Spirals. In order to study the relative importance of such mechanisms and to allow the accurate determination of the mass function of S0s we have undertaken two studies of S0 stellar populations and dynamics.

The first study makes use of extremely deep (~2 hours integration) Gemini/GMOS longslit spectroscopy along the major and minor axes of 20 local edge-on S0s (Fig 1.). These data are of sufficient quality to probe stellar populations and kinematics from stellar absorption lines beyond $2R_e$. The primary aim of this study is to examine gradients in stellar population parameters (age, metallicity and α-element enhancement) in S0 disks and bulges to place constraints on the possible formation mechanisms.

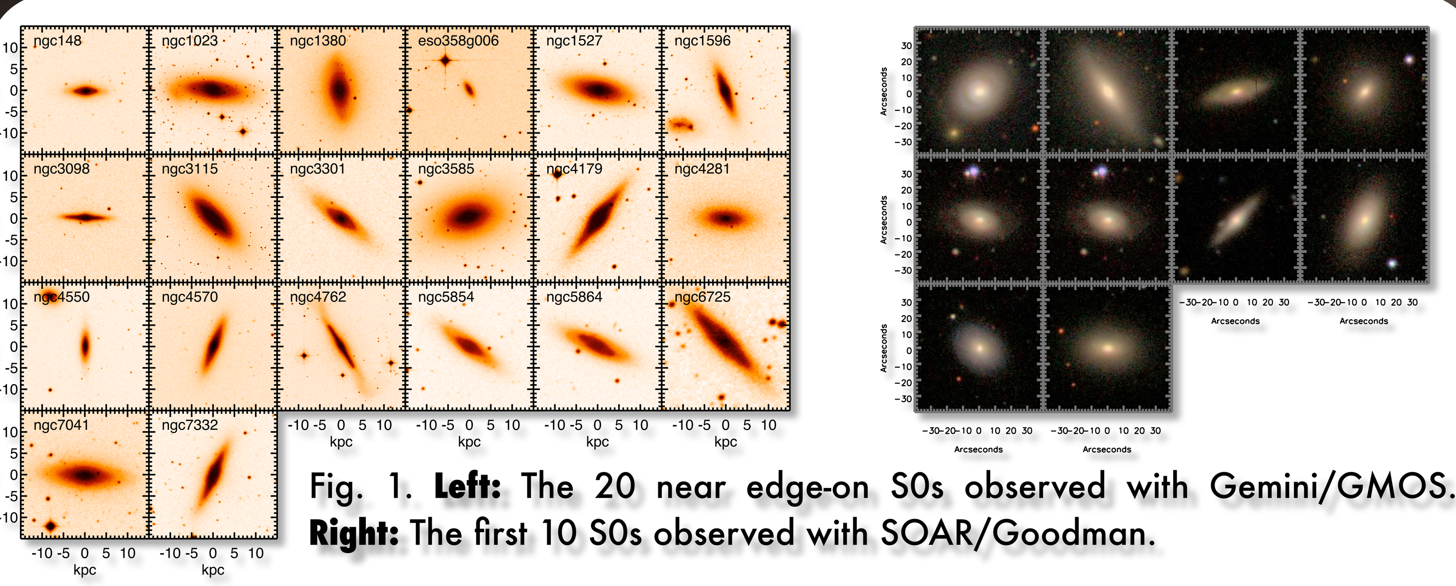

Fig. 1. **Left:** The 20 near edge-on S0s observed with Gemini/GMOS. **Right:** The first 10 S0s observed with SOAR/Goodman.

Our second project aims to resolve a major concern with comparative studies of Spiral and S0 galaxies, namely that kinematic mass estimates for each population must use different tracers, because S0s generally display little of the gas emission used to trace kinematics in Spirals. The usual solution to this problem has been to make use of stellar absorption line kinematics to measure S0 masses. This approach is not without risks as large (and uncertain) corrections must first be made for effects such as asymmetric drift. To reduce this uncertainty we are in the process of constructing an empirical calibration between velocity profiles derived from stars and trace gas revealed in deep SOAR spectroscopy. Our final sample will comprise 24 S0s selected to span the observed range of mass, bulge-to-disk ratio and environment. The determination of the masses of S0 galaxies is an important part of the larger RESOLVE survey (see poster by Sheila Kannappan) which aims to construct an accurate mass census of the local Universe.

Results - Gemini/GMOS

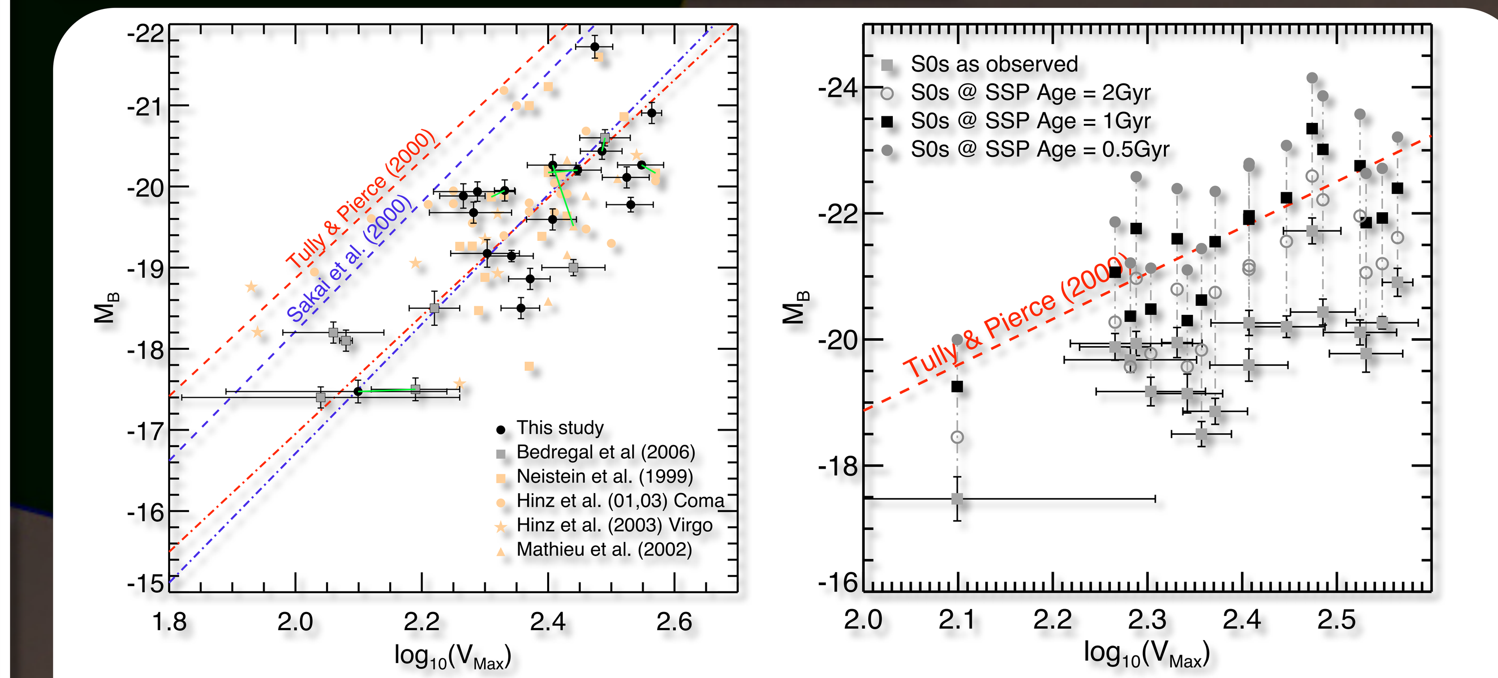

Fig. 2. **Left:** The Tully-Fisher relation for S0s examined in various studies. The red and blue dashed lines denote the Spiral TFR as measured by Tully & Pierce (2000) and Sakai et al. (2000). **Right:** Results of the simple disk fading model. Grey squares show the S0 galaxies examined here as currently observed. Filled black squares show the galaxies as they would appear assuming the disks of the galaxies had an SSP age of 1 Gyr, unfilled grey circles show the same but for SSP age of 2 Gyr, and the filled grey circles have SSP age 0.5 Gyr.

Applying the previously mentioned corrections for asymmetric drift etc. it is possible to construct an S0 Tully-Fisher relation for the S0s examined as part of our Gemini study (Fig. 2). It is found that the S0s are systematically offset from the Spiral TFR in the sense expected if these S0s represent faded Spirals.

The best fitting Single Stellar Population (SSP) models were determined for the central (bulge) and disk to determine age, [Z/H] and [α/Fe]. The S0 sample spans a wide range in both age and metallicity, but most interestingly the age of the bulge and disk components is found to correlate with the individual S0 offsets from the Spiral TF relation (Fig. 3.).

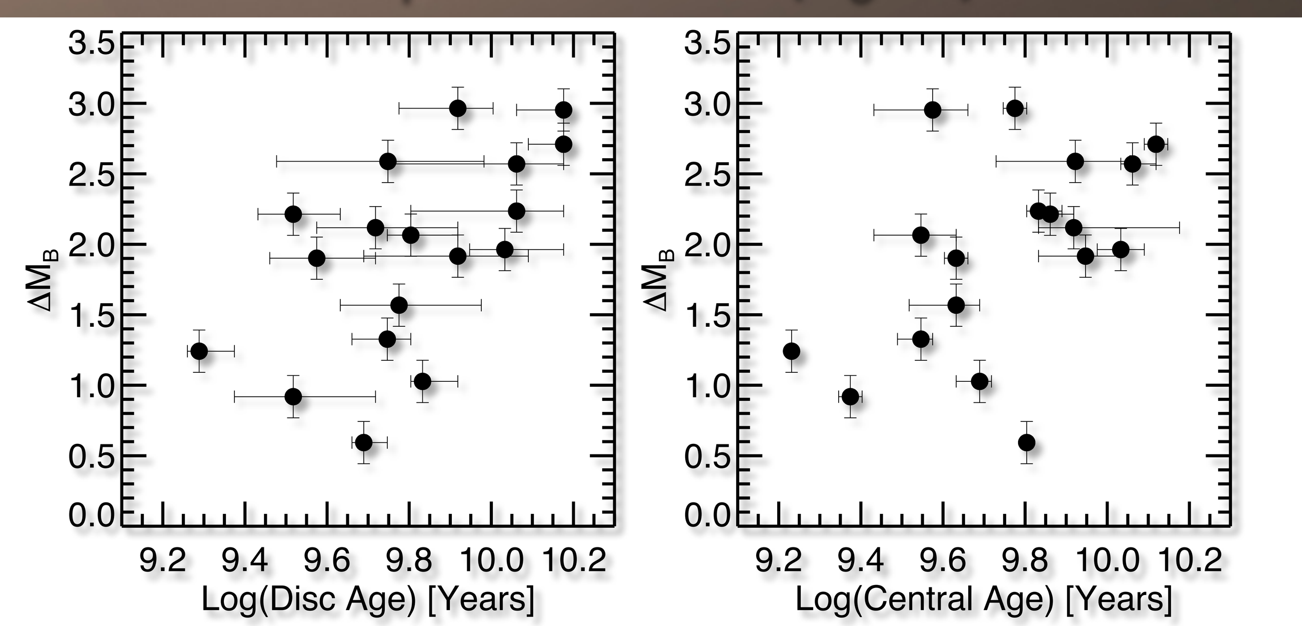

Fig. 3. **Left:** Offset from Spiral TFR vs. age of disk. **Right:** TFR offset vs. age of centre measured within $R_e/8$. The correlation between offset and disk age is significant at the 99.6% level. The offset - central age correlation is significant at the 95.5% level. Similar results were found by Bedregal et al. (2006) for their sample of 7 Fornax S0s.

We have simulated the location of our S0s on the TFR at earlier times (Fig. 2.). The observed stellar populations and bulge-to-disk ratios were combined with SSP models to estimate the luminosity of the S0s when their SSP ages were 0.5 - 2Gyr. All of our S0s are found to lie close to the Spiral TFR when their SSP age was ~1Gyr, an SSP age close to that determined for the thin disks of Spirals by Yoachim & Dalcanton (2008). This supports the picture in which most S0s are faded Spirals, and where the scatter in the S0 TFR is due to the different epochs at which each galaxy ceased star formation.

Results - SOAR/Goodman

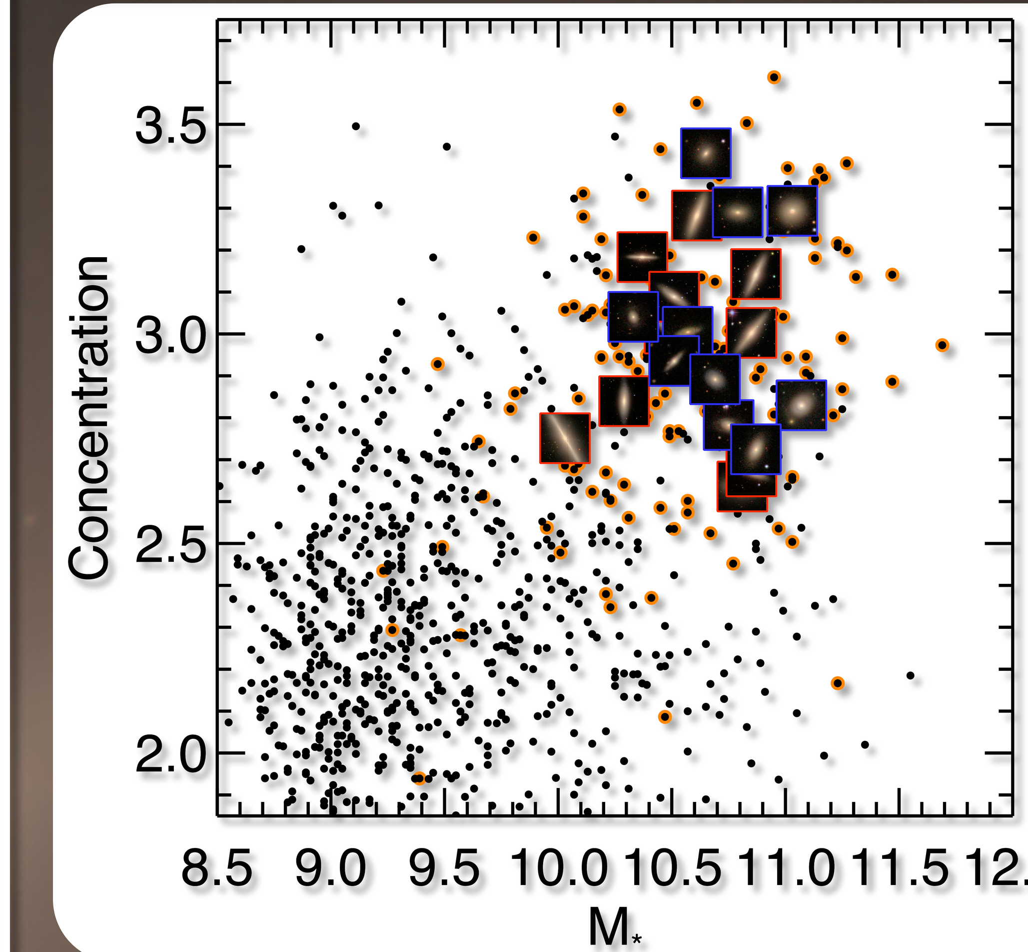

Fig. 4. The stellar mass and concentration value for all galaxies found in the RESOLVE spring region (black dots). Orange circles are all visually classified S0s. Images represent the position of all 10 galaxies observed with SOAR during 09A (blue squares) and for 10 of our GMOS galaxies which are covered by the SDSS (red squares). Observations in 09B with SOAR will extend to lower masses and concentrations.

Examination of the first 10 S0s observed as part of our SOAR/Goodman study has demonstrated that all 10 display measurable gas emission in their inner regions. 5 of the sample display gaseous rotation curves which extend to the flat portion of the rotation curve (See Fig. 5.), including one which is counter-rotating. Application of more sophisticated methods of analysing spectroscopy containing weak emission (i.e the GANDALF code (Sarzi et al. 2006)) will likely increase the fraction of galaxies for which gas and stellar rotation curves extend to sufficient radii to allow direct comparison in the region where the rotation curve becomes flat.

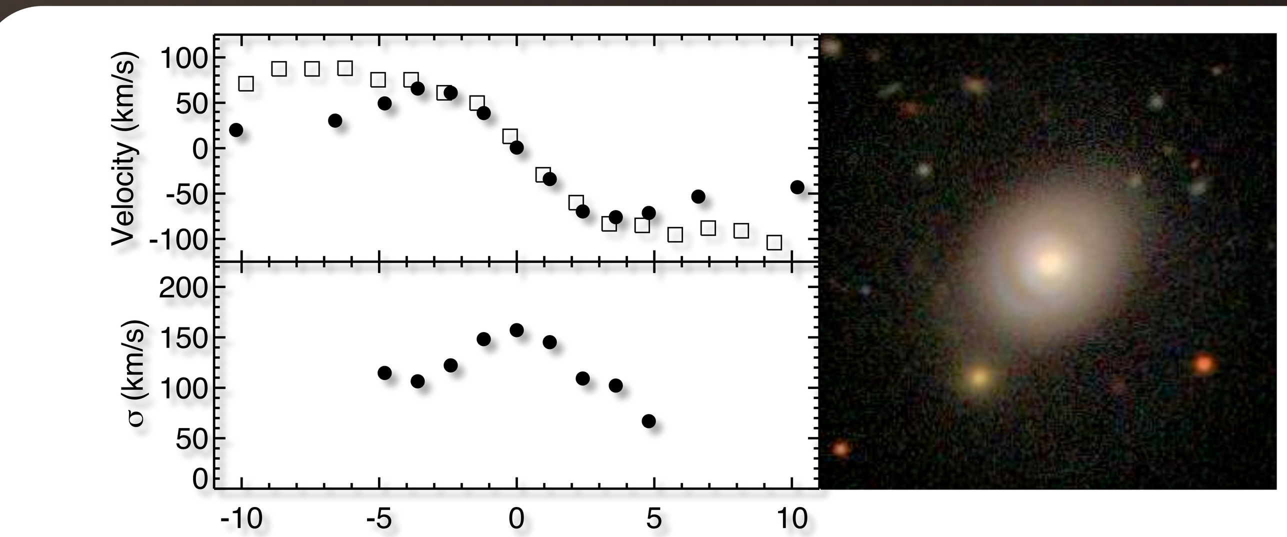

Fig. 5. Preliminary kinematics extracted from SOAR/Goodman spectroscopy. The black dots show absorption line kinematics, the open squares Hα rotation curve. The discrepancy between absorption and emission line rotation due to asymmetric drift is obvious.

When our final sample of 24 S0s is complete we will be well placed to construct an empirical relation between such observables as bulge-to-disk ratio, stellar velocity dispersion and stellar rotation curve and the total mass of these composite galaxies determined from cold gas rotation.

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GEMINI OBSERVATORY Based on observations obtained at the Gemini and SOAR observatories. SOAR TELESCOPE