Stellar Populations as Building Blocks of Galaxies
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IC 4200: an early-type galaxy formed via a major merger.

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Abstract. Recent observations have revealed a class of unusually HI-rich early-type galaxies. By combining observations of their morphology, stellar populations and neutral hydrogen we aim to understand how these galaxies fit into the hierarchical formation paradigm. Here we present the result of our radio and optical observations of a test case galaxy, the E/S0 IC 4200.

Keywords. galaxies evolution, elliptical and lenticular, stellar content

1. Introduction

Observations during the last decades have shown that, despite forming a fairly regular family of objects, early-type galaxies host frequent peculiarities: among these, HI-gas surrounding the stellar body. Such gas is often interpreted as the result of recent accretion of a gas-rich satellite galaxy. Supporting this view, the HI content of E/S0's does not correlate with their optical properties. However, recent observations have found galaxies with extremely massive, extended and quite regular HI structures, difficult to explain in terms of satellite accretion. Barnes (2002, B02) showed that such extended gas disks could form during the merger of gas-rich galaxies as a result of the re-accretion of high-angular-momentum gas. On the other hand, Keres *et al.* (2005, K05) showed that IGM gas is partially accreted around galaxies via a cold mode which could result in atomic-gas structures. Which of these two processes is dominant in the formation of HI-rich E/S0's?

If mergers are responsible for the formation of the observed gas systems, other signatures of the recent formation event should be found in the stellar body of the host galaxies; for example, intermediate-age stellar populations and morphological fine structure. In order to test this idea we have started an observational project aimed to study the HI gas content, stellar populations and optical morphology of HI-rich early-type galaxies. Here we summarise our study of the test case galaxy IC 4200, a S0 at z=0.013 and with L_B=5.30×10^{10}L$_\odot$, presented in details in Serra *et al.* (2006).

2. Radio and Optical Observations

We characterise IC 4200 HI-gas properties with 21 cm, interferometric ATCA observations. We find a 90-deg-warped HI disk of 8.5×10^9 M$_\odot$ extended out to 60 kpc from the centre of the galaxy (Fig.1). The gas of the disk is very dilute and as a result no large-scale, detectable star formation is expected. The morphology and velocity field of the HI are fairly regular and symmetric around the centre. Assuming the rotational velocity of 340 km/s that we find from modelling the HI disk, the gas must have been in place for at least 1-2 Gyr in order to settle into the observed configuration.

We study the stellar phase of IC 4200 by means of long-slit optical spectra and V- and R-band imaging obtained with ESO/NTT/EMMI. We detect ubiquitous ionised gas

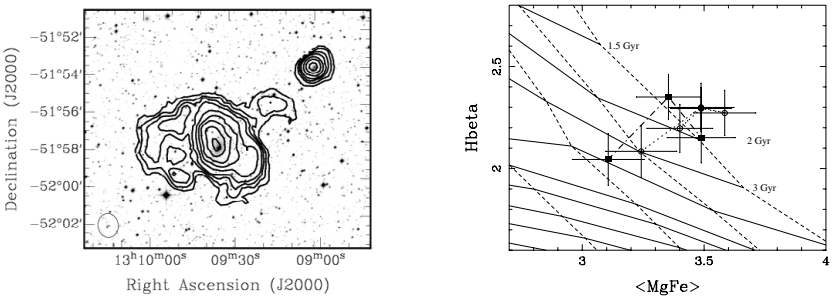

Figure 1. *Left:* Total HI contours over an optical image of IC4200; contours levels are (0.2, 0.4, 0.6, 0.8, 1.2, 1.6, 2.0, 2.6, 3.2)×10^{20} cm^{-2}. *Right:* IC 4200 line indices [MgFe] and Hβ along the major (filled squares) and minor (empty squares) axis plotted over Worthey (1994) model grids.

within 1 r_e, with ionisation typical of LINER's. In the central region the ionised gas counter-rotates with respect to the stars, consistently with the larger-scale kinematics of the HI disk, suggesting that ionised and atomic gas might share a common history. We analyse the stellar populations by measuring Lick/IDS absorption-line-strength indices at different distances from the centre, and comparing them to Worthey (1994) models extended to non-solar abundance ratios (Trager *et al.* 2000). We find SSP-equivalent ages of $\sim$ 2 Gyr in the centre of the galaxy and higher further out (Fig.1). Finally, by subtracting the best-fitting Sersic (+ disk) model to the V- and R-band images we reveal stellar shells around the stellar body.

3. Discussion

Scaling B02 results to the stellar mass of IC 4200 we find that two Milky Ways with twice the HI abundance of our Galaxy can produce, within 1 Gyr from the merger, a warped HI-disk of the observed mass and size. Within this picture, the kinematics and morphology of the HI imply that the merger occurred more than 1-2 Gyr ago. Consistently with this conclusion, the stellar age can be explained if a burst of star formation (which could be due to the merger) occurred less than 2-3 Gyr ago. The presence of shells can also be explained by a merger. All our observational results are therefore consistent with IC 4200 having formed via a major merger 1-3 Gyr ago. On the other hand, it is possible that the observed HI disk formed via cold accretion from the IGM (K05). However, in this case, 90% of the mass accretion would have occurred before z=1. It is not clear how this could match the indications coming from the age of the stellar populations. Furthermore, IGM accretion fails to explain the formation of shells.

The discussion above strongly suggest that IC 4200 formed via a major merger 1-3 Gyr ago. However, it is unlikely that IC 4200 will further evolve into a typical E/S0. The observed low-density HI disk might stay intact for very long times, or continuing gas in-fall might eventually lead to star formation turning IC 4200 into a spiral. It seems therefore that mergers can lead to a wider range of morphologies than just regular early-type galaxies.

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