# SAURON observations of Sa bulges: the formation of a kinematically decoupled core in NGC 5953

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**Summary.** We present results from our ongoing effort to understand the nature and evolution of nearby galaxies using the SAURON integral-field spectrograph. In this proceeding we focus on the study of the particular case formed by the interacting galaxies NGC 5953 and NGC 5954. We present stellar and gas kinematics of the central regions of NGC 5953. We use a simple procedure to determine the age of the stellar populations in the central regions and argue that we may be witnessing the formation of a kinematically decoupled component (hereafter KDC) from cold gas being acquired during the ongoing interaction with NGC 5954.

## 1 Interacting galaxies and the formation of KDCs

The interaction between galaxies lies at the heart of the current lore of hierarchical formation models. While most of the recent numerical simulations are able to make predictions about how such interactions affect the outer regions of galaxies (e.g. Combes et al. 1995; Moore et al. 1999), it is only in the last years that they have started to achieve sufficient resolution to provide clues of their effects on the inner regions of galaxies (e.g. Naab & Burkert 2001). Signatures of counter-rotation in either the stellar or gas components of galaxies have often been used to argue for the external origin of material and therefore interaction between galaxies (e.g. Bertola et al. 1988). In merger remnants, direct evidence for past interactions is the presence of a KDC in the inner regions of the galaxy.

One of the major goals of the SAURON survey is to study the structural and kinematical properties of such KDCs, as well as their frequency. Using

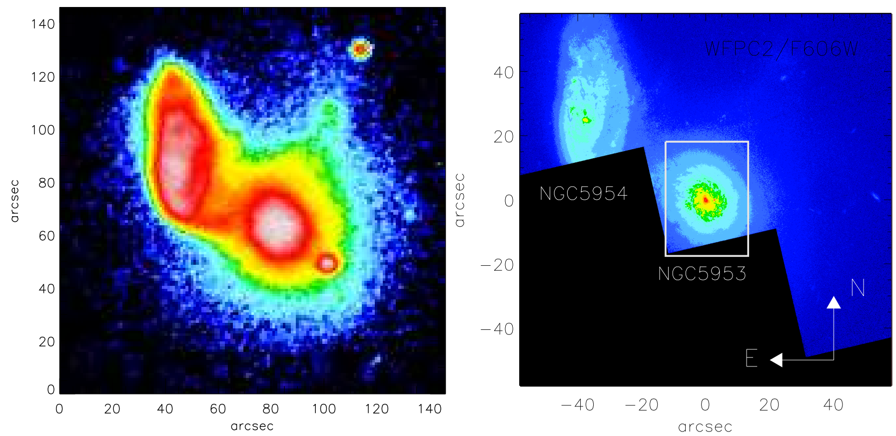


**Fig. 1.** The interacting pair formed by NGC 5953 and NGC 5954. Left: *B*-band DSS image (logarithmically scaled) showing the bridge of material between the two galaxies. Right: High spatial resolution HST/WFPC2-F606W image. Overlaid on NGC 5953 is the SAURON field-of-view covering the inner 4×3 kpc of the galaxy.

that information, it is possible to step back in time and infer the conditions that led to the final configuration of the merger remnant. Previous papers in the SAURON series, concentrated on E and S0 galaxies, have shown that KDCs are common in early-type galaxies (e.g. de Zeeuw et al. 2002; Emsellem et al. 2004). In general these are old KDCs that are thought to have formed early in the evolution of the host galaxies (Kuntschner et al. 2006). By zooming in onto the nuclear regions, however, one discovers that there is also a large fraction of young decoupled components in the centres (see Mcdermid et al., these proceedings).

Among the 24 Sa spiral bulges in the SAURON survey, we were able to detect kinematically decoupled components in up to 50% of the galaxies, most of them aligned with the galaxies photometric major axis, and likely the end result of secular evolutionary processes (e.g. Wozniak et al. 2003). Only two cases display strongly misaligned or counter-rotating KDCs (i.e. NGC 4698 and NGC 5953, see Falcón-Barroso et al. 2006). NGC 4698 is a well studied galaxy, where the KDC may be the result of an intermediate-size merger (Bertola et al. 1999). The case of NGC 5953 is particularly interesting in the survey because it is the only example where we are witnessing an interaction that is currently taking place (see Figure 1), rather than observe the end product of a past merger.

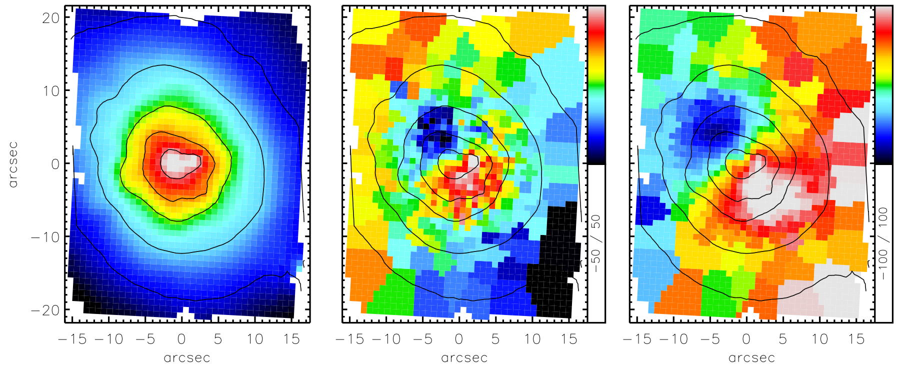


**Fig. 2.** Kinematics of NGC 5953. From left to right: i) `SAURON` reconstructed intensity, ii) stellar velocity, iii) H$\beta$ ionised-gas velocity. Levels for the kinematics are indicated in a box on the right-hand side of each map, and are expressed in km s$^{-1}$.

## 2 The interacting galaxy NGC 5953

The system formed by the interacting pair NGC 5953/NGC 5954 has been extensively studied in the past. Most of the work has focused on the active nature of NGC 5953's nucleus (Jenkins 1984; Reshetnikov 1993; Gonzalez Delgado & Perez 1996). Rampazzo et al. (1995) combined broad-band imaging and long-slit spectroscopy to produce a detailed photometric and kinematic analysis of the interaction between the two galaxies. More recent results make use of a Fabry-Pérot spectrograph to map the two-dimensional gas kinematics using the [N II] emission line (Hernández et al. 2003; see also Fuentes-Carrera et al. in these proceedings).

In Figure 2, we present the reconstructed intensity map and the stellar and gas kinematics of the central regions of NGC 5953. The `SAURON` observations reveal the presence of a kinematically decoupled component in the central regions, where the stars are counter-rotating with respect to the bulk of the galaxy. The ionised-gas velocity map of the central component is consistent with that of the stars in the inner parts, and it is in good agreement with that of Hernández et al. (2003). While the kinematic major axis of the stellar component (both the inner and outer parts) appears to be aligned with respect to the photometric major axis of the galaxy, the kinematics of the ionised-gas in the outer parts shows signs of non-axisymmetry.

In addition to the stellar and the gas kinematics, we have also determined the [O III]/H$\beta$ ratio over the `SAURON` field-of-view. This ratio is a good indicator of young metal-rich stellar populations where star formation is very intense (Kauffmann et al. 2003). In Figure 3 (left panel) the ratio map exhibits very low values at the location of the kinematically decoupled component and high values in the very centre of the galaxy. These results are similar to those of

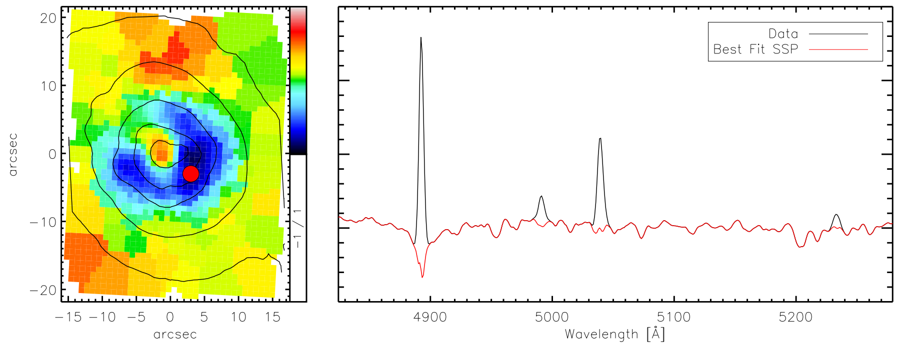


**Fig. 3.** A young KDC in NGC 5953. From left to right: i) SAURON [O III]/H$\beta$ ratio map (in logarithmic scale), ii) SAURON spectrum (black solid line) at the location marked in the left panel (red dot), with the best single stellar population model (t=3 Gyr) overlaid (red solid line).

Yoshida et al. (1993) in the inner regions (i.e. [O III]/H$\beta$=0.14-0.41) and are consistent with a star-forming region surrounding an active galactic nucleus.

## 3 A recently formed KDC in NGC 5953

Despite the fact that the gas and stars in the inner parts of the galaxy appear to be kinematically decoupled from the main body and despite the extremely low [O III]/H$\beta$ ratio in the same location, there is no direct proof that both the star-forming gas and stellar decoupled component are related, although this is likely. To establish this link, we need to estimate the age of the stars in that region and determine whether it is indeed consistent with a young stellar population.

Here we follow the simple procedure outlined in Vazdekis (1999) to measure the age of the underlying stellar population. Briefly, the idea is to find the single stellar population (SSP) model from a library of model templates that best matches the overall spectrum in the kinematically decoupled region. Figure 3 (right panel) shows the result of this experiment. The best-fit SSP model has an age of $\sim$3 Gyr. By making the simple assumption that the galaxy is made by two populations (i.e. young and old), then the luminosity-weighted age of 3 Gyr measured here sets an upper limit to the age of the young population. The true age of this population is however difficult to assess given that different fractions of young stars on top of an old population can lead to the same luminosity-weighted age. Nevertheless, given the quality of the fit, it seems certain that young stars are present at the location of the KDC.

The combination of these different observations suggests that at least part of the gas in NGC 5953 was acquired from the nearby interacting galaxy NGC 5954, settled to the disk plane with a direction of rotation opposite to that of the stars in the main disk, and itself started to form stars. The kinematic and population information set strong constraints on the formation timescale of the KDC we observe in this galaxy, and suggest that we are indeed witnessing the early stage of its formation.

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