The Peculiar Galaxy NGC 7332

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Abstract. We present a detailed study of the edge-on S0 galaxy NGC 7332. We show that this object lies significantly below the fundamental plane of early-type galaxies. To understand this behaviour, we have carried out observations with the Integral Field Spectrograph SAURON, which give us a detailed view of the internal kinematics and gas and stars in this galaxy.

1. Introduction

NGC 7332 is an ordinary-looking galaxy that is peculiar in many aspects. A detailed study of its kinematics of gas, stars and its surface photometry has shown that it is a Rosetta stone that can teach us what the components are that galaxies consist of, and how they form.

The galaxy is a highly inclined S0 located close to the spiral galaxy NGC 7339 at 5.2′ with a similar systemic velocity. Previous papers on this galaxy include those by Fisher, Illingworth, & Franx (1994) and Plana & Boulesteix (1996). While the main results of Fisher et al. include the B/D decomposition of the galaxy, as well as an analysis of its stellar and gaseous kinematics, Plana & Boulesteix focus exclusively on determining the gas morphology of the galaxy from Hα emission maps. Fisher et al. show that the galaxy has kinematics fairly typical of a stellar disk, with a counter-rotating and a fainter co-rotating gas disk. An extension of this result was found by Plana & Boulesteix who not only mapped the distribution of the 2 gaseous components, but also modelled them, finding different inclination angles for each component. Broad band colours (Balcells & Peletier 1994) show that the colours of NGC 7332 (B − R = 1.4) are somewhat bluer than colours of elliptical galaxies of the same luminosity. This is confirmed by a spectral analysis showing that the galaxy has a luminosity weighted age of about 6 Gyr (Vazdekis & Arimoto 1999).

Here we present 2 studies aimed at understanding the difference between NGC 7332 and ordinary red S0 galaxies. First we present a new study of the position of this galaxy on the fundamental plane (FP) of early-type galaxies (for
details see Falcón-Barroso et al. 2002). We show that NGC 7332 lies below the relation, and that the displacement cannot be explained by uncertainties in our measurements. Second, we show new 2D maps of the stellar and the gaseous kinematics in the [OIII] 5007 Å line obtained with SAURON.

2. **NGC 7332 on the Fundamental Plane of Early-type galaxies**

We have studied the position of 19 galactic bulges (the sample of Peletier et al. 1999) on the FP in both B and K, with the aim of finding out whether bulges are formed in the same way as ellipticals. We find that bulges are slightly shifted with respect to the FP defined by ellipticals. This is explained easily by the fact that the sample consists of galaxies with inclination $> 50^\circ$, together with the contribution of the rotating disk, which causes the velocity dispersion of a bulge to be slightly lower than an elliptical of the same mass. NGC 7332, however, lies significantly further below the FP. Not only is this the case in the B-band, where such a deviation can be explained if the galaxy is much younger than other bulges, but also in K, where young stellar populations cannot cause such a deviation. At this stage of our analysis we do not have a satisfactory reason why this galaxy is departing so strongly from the FP relation. NGC 7332 is the only S0 galaxy that we know which deviates so strongly, without being obviously interacting (see e.g. Schweizer & Seitzer 1992). Another peculiarity of this galaxy is that the stellar colours in this galaxy are so homogeneous, with only a very small blueing towards the outer parts (Balcells & Peletier 1994; Fisher et al. 1994).

In Fig. 1 we show the location of our sample of bulges on the FP of early-type galaxies as defined by Jørgensen, Franx & Kjærgaard 1996 (in the B-band, top panel) and Pahre et al. 1998 (in K-band, bottom panel). We have marked NGC 7332 with an open circle.

3. **Stellar Kinematics**

NGC 7332’s kinematics reveals a smooth uniform stellar velocity field rotating along the minor axis of the galaxy (Fig. 2). The velocity field appears consistent with cylindrical rotation, although this result will have to be confirmed with some detailed modeling. The velocity dispersion map shows a dip along the major axis of the galaxy (Fig. 3). This is usually the case when a galaxy has an inner disk. Indeed, for NGC 7332 such an inner disk in the first ± 5 arcsec has been discovered by Seifert & Scorza (1996). The higher order moments Gauss-Hermite moments ($h_3$, $h_4$, van der Marel & Franx 1993) seem to be regular, which means that it is unlikely that the galaxy harbours multiple stellar disks, like e.g. in NGC 4550 (Rubin et al. 1992).

4. **Measurement of the emission lines**

In order to obtain the kinematics of the gas, we need to separate emission from absorption lines. To do this we used a small variation to a more sophisticated technique (see de Zeeuw et al. 2002) and subtracted the stellar spectrum by
fitting the observed stellar energy distribution outside the region of the emission lines with synthetic templates from the models of Vazdekis (1999) for composite single age/metallicity models of various ages and metallicities.

This procedure can be summarize in a few steps:

- We first derive the stellar kinematics ($\gamma, V, \sigma$) using the method of van der Marel & Franx (1993) with a single stellar population (SSP) model as template.
- Second, we build a library of models with different ages and metallicities (SSP models from Vazdekis 1999).
- We convolve the spectra of the library with the LOSVDs obtained in step 1.
- We then fit a linear combination of these SSP models to the galaxy spectrum.
- Finally we subtract the fitted spectrum from the observed SED to obtain a pure emission-line spectrum.

Using this method it is possible to recover faint emission line profiles, as seen at the NI doublet at 5199 Å ($\log \lambda \approx 3.718$) in Figures (8 & 9).

5. Counter-rotating gas in NGC 7332

This is without doubt the most unusual feature in NGC 7332. A close inspection of the [OIII] (5007 Å) gas emission lines shows a primary, counter-rotating gas disk (Figs. 4 & 5) and a much fainter secondary component (Figs. 6 & 7) corotating with respect to the stellar component. This double component has been detected also by Plana & Boulesteix (1996) from H$\alpha$ observations. In general, both Plana and we find the same spatial distribution of the second component. The spatial distribution of the emission in [OIII], however, is not the same as that of H$\alpha$. While we find very little OIII emission in the center of the galaxy, Plana & Boulesteix find a considerable amount of H$\alpha$. Trying to understand why this is the case, we have analysed long-slit data, in the H$\alpha$ region, from the ING (Isaac Newton Group) archive. These data, obtained in June 1994 by Merrifield & Kuijken, reveal that H$\alpha$ in the center is weak contrary to the results of Plana & Boulesteix. This is confirmed by the fact that H$\beta$ in our SAURON data is weak as well, casting doubt upon the results of Plana & Boulesteix. Further analysis about this subject is due to appear in a forthcoming paper.

6. Conclusions

- NGC 7332 is an unusual object.
- As yet it is a miracle why this galaxy lies so far away from the fundamental plane of early-type galaxies
- Its stellar kinematics is not peculiar at all.
• The existence of two gaseous components coexisting with opposite angular momentum leaves the hypothesis open of a recent merger scenario in NGC 7332.

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Figure 1. NGC 7332 on the fundamental plane of early-type galaxies.
Figure 2. Stellar velocity map of NGC 7332.

Figure 3. Stellar velocity dispersion map of NGC 7332.
Figure 4. Intensity of the main gas component in (OIII $[5007 \text{ Å}]$).

Figure 5. Velocity of the main gas component in (OIII $[5007 \text{ Å}]$).
Figure 6. Intensity of the secondary gas component in $(\text{OIII} [5007 \text{ Å}])$.

Figure 7. Velocity of the secondary gas component in $(\text{OIII} [5007 \text{ Å}])$. 
Figure 8. Synthetic stellar population models (dashed line) together with the central galaxy spectrum of NGC 7332 (solid line).

Figure 9. Residuals to the fit of Figure 8.