Observations of extended and counterrotating disks of ionized gas in S0 galaxies*

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Introduction

While many E/S0 galaxies have been found to show emission line spectra in their nuclear regions the question of the presence and nature of extended disks of ionized gas in these galaxies has been addressed only in recent years. Typically the ionized gas is detected in the inner region on a scale of $\sim$ 1 kpc (e.g. Phillips *et al.* 1986, Caldwell 1984).

Here we present evidence that the disks of ionized gas of at least some S0 galaxies are much more extended than previously believed. In addition, with the detection of the counterrotation of gas and stars in NGC 7007 we strengthen the basis for arguments that the source of gas in S0 galaxies is external.

Object selection and observations

Our original objective was to find high rotational velocities in bulge-dominated, early type disk galaxies. For that purpose we selected objects, that show morphological similarities to NGC 4594 or NGC 7814, by visually inspecting the ESO/SRC-J film copies and by using the remarks in Corwin *et al.* (1985) . Some of these objects are also in a sample of E/S0 galaxies studied by Phillips *et al.* (1986) and classified by Lauberts (1982) to be S0's. All of these originally selected galaxies show extended Hα and [NII] emission. However, as a comparison with the type parameter for these objects given by Corwin *et al.* shows, the classification of these objects is very uncertain. Therefore we have selected two additional groups: (1) galaxies with an S0 classification confirmed by Corwin *et al.* that were also observed by Phillips *et al.*, (2) a comparison group consisting of confirmed S0's which are not in the Phillips *et al.* sample.

The observations were obtained with the B&C Cassegrain spectrograph at the 2.2m telescope on La Silla during bright time between June 8 and June 18, 1987. The dispersion was 1.74Å/pixel. The ESO #5 RCA CCD was used and the integration time was 40 minutes for each spectrum. We have used position angles from Lauberts (1982) to align the slit with the major axis. After standard reduction the frames were rebinned to constant $\Delta\lambda$, and the night sky and the galaxy continuum were subtracted. Rotation curves were measured by fitting Gaussian profiles to the Hα [NII] emission lines.

The extent of the ionized gaseous disks

In Table 1 we summarize the characteristics of the observed S0 galaxies. Morphological types are given in columns (2) and (3). The diameter of the ionized gas d is given in arcsec in column (4) and in kpc in column (5), assuming H_0=75 km sec^{-1} Mpc^{-1}. The three different groups of objects discussed above are seperated by horizontal lines.

For most of the objects in Table 1 with detected emission lines, the extent of the gas is typically of the order of 10 kpc. This is significantly larger than most other known examples like NGC 4636 ($\sim$ 1 kpc), and NGC 5846 ($\sim$ 1.7 kpc) (Demoulin-Ulrich *et al.* 1984), NGC 5266 and NGC 3109

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* Based on observations collected during MPI time at the ESO/MPI 2.2m telescope, La Silla/Chile
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(~ 2kpc; Caldwell, 1984). Only the gaseous disk of the SB0 galaxy NGC 4546, where the gas is counterrotating, is extended over 8 kpc (Galetta, 1987).

This scalelength of ~10 kpc should be compared with the scalelength for the radio continuum emission in E/S0 galaxies which was recently determined to be of the same order of magnitude for eight galaxies studied by Wrobel and Heeschen (1988). The presence of radio continuum radiation is strong evidence for star formation processes in these galaxies. Recent star formation also could explain the ionization of the gaseous disks. However, for most of the galaxies in Table 1 the emission lines of the gaseous disks are more LINER like, with [NII] stronger than Hα for the whole range of distances from the nuclei. In four galaxies the ratio [NII]/Hα changes from >1 for the nuclear region to <1 for the extended disk. This might indicate that also the dominant excitation process changes from nuclear activity to processes related to star formation.

The high detection rate of extended gaseous disks in our sample is perhaps biased by object selection as we favoured galaxies with dust lanes. Therefore the relation between the presence of dust, star formation, and the properties of the ionized ISM can not be addressed.

Table 1: Summary of observations

Object (1)	$T_{Lauberts}$ (2)	T_{Corwin} (3)	d(") (4)	d(kpc) (5)	Remarks (6)
NGC 3573	-2	0	>89	>13	dust, [NII]/Hα changes*
NGC 5220	-2	1	101	27	dust, [NII]/Hα changes
NGC 5237	-2	0	50	0.3	dust, HII spectrum, no rotation
NGC 6848	-2	0.5	75	20	dust, [NII]/Hα changes
NGC 7123	-2	1	78	19	dust, small vel. gradient
ESO 13-G12	-2	-0.3	82	26	dust, small vel. gradient
IC 4704	-2	-3			dust, no detection
NGC 6771	-2	-2	71	19	dust
IC 4906	-2	-2.7	21	5	dust, [NII]/Hα changes
ESO 235-G42	-2	-1	15	5	dust
NGC 7007	-2	-2	30	6	dust, counterrotation
NGC 7014	-2	-3.0			dust, no detection
NGC 7049	-2	-3.7	47	7	dust
NGC 7070A	-2	-2	48	7	dust, [NII]/Hα changes
NGC 3203	-2	$S0_2$ $			no detection
ESO 506-G33	-2	-2	35	3	small vel. gradient
ESO 575-G59	-2	-0.7	28	8	dust

Notes: $ from RSA, * the [NII]/Hα changes from >1 for the the nuclear region to < 1 in the disk

The counterrotating disk of ionized gas in NGC 7007

While most of the galaxies in Table 1 show a rotating gaseous disk, in some cases the velocity gradient is so small, that we can not from just one spectrum establish that this is due to rotation. These cases are indicated in column (6) of Table 1. The case of NGC 7007 is especially remarkable. The continuum-subtracted spectrum of NGC 7007 (Figure 1) shows counterrotating gaseous and stellar components. This is the third S0 galaxy known to show counterrotation of gas and stars

(Bertola *et al.* 1988). The relatively large percentage of S0 galaxies with peculiar gas motions (polar rings or counterrotation) is indicative of an external origin of the gas.

Acknowledgments. RJD and AB are grateful to the director of the MPI für Astronomie for the generous allocation of observing time. This work has been partly supported by the Deutsche Forschungsgemeinschaft under De 385/1-1 and De 385/2-1 and the Lowell Observatory Research Fund.

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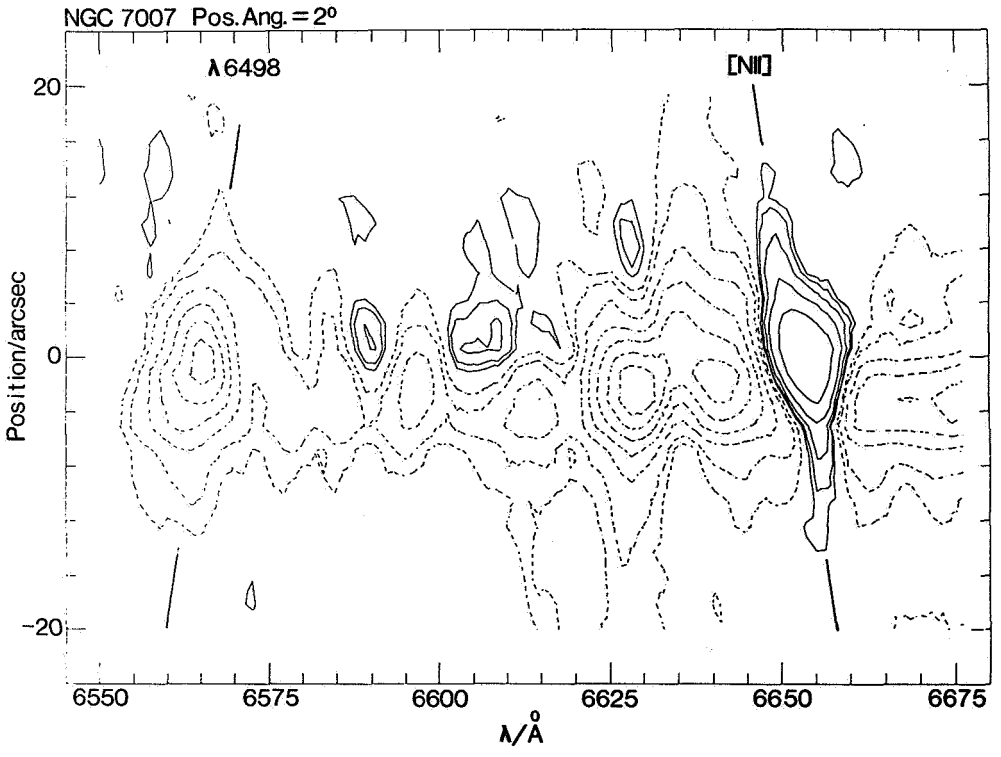

Fig. 1: The contour plot of the continuum-subtracted spectrogram of NGC 7007 shows the counterrotation of the ionized gas and the stellar component if, for example, the λ6583 [NII] line is compared with the metal blend at λ6498 or the underlying Hα absorption. Emission is indicated by continuous lines, absorption by dashed contours.