SURFACE PHOTOMETRY OF BARRED ACTIVE GALAXIES. WOLF-RAYET GALAXY NGC 6764

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I. Introduction

Towards the end of the 1970's it was realized that the properties of many of the nonSeyfert galaxies in the Markarian, Haro and Zwicky lists could be explained by the presence of large numbers of massive stars formed in recent bursts of strong star formation, in otherwise normal spiral or irregular galaxies (Huchra 1977; Larson & Tinsley 1978). Many of these galaxies showed signs of tidal disruption suggested that the excess star formation could be triggered by galaxy interactions.

Galaxies with nuclei that have large infrared (IR) luminosities, in most cases blue colours, very bright nuclear star clusters, strong but narrow emission line spectra, ultraviolet (UV) spectra showing absorption features typical of winds from massive stars, and nonthermal radio emission distributed over the same region as the IR emission, are all a part of a class of galaxies that came to be named "starburst" galaxies by the early 1980's. The prototypical member of this class is NGC 7714 (Weedman et al. 1981).

The work of Rieke et al. (1980) and Weedman et al. (1981) demonstrated that starburst models could quantitatively explain the observed radio, IR, optical, UV and Xray properties of these galaxies. Here we have to point the Xray properties of these galaxies were not well studied at that point, they could be attributed to much less Xray luminous galaxies than Seyfert galaxies or X ray selected Narrow Emission Line Galaxies (NELGs).

In a subset of starburst galaxies, often referred to as Wolf-Rayet (W-R) galaxies (Conti 1991), *broad stellar* emission lines (HeII λ4686Å among the strongest) in their optical spectrum testify to a population of W-R stars (Kunth & Sargent 1981, Kunth & Schild 1986). The very high ratio of W-R to O stars in W-R galaxies (Vacca & Conti 1992, Contini et al. 1995) is compatible with the models of stellar evolution computed by Maeder & Meynet (1994) provided that star formation occurs in *burst* mode on very short time scales, less than 10^6 years, and with a rather flat Initial Mass Function (IMF, Contini et al. 1995). The detailed study of this type of galaxies is of considerable importance for models of stellar evolution and of starbursts. Indeed, because W-R stars are the direct offsprings of the most massive O stars, and because their lifetime is at most 10^6 years, the presence of a very large number of such stars in a galaxy provides important constraints on several parameters characterizing starbursts, such as duration, intensity and age of the burst, and, most important, its IMF.

There is certainly a large number of W-R galaxies in the Universe since the first discovery by Allen et al. (1976), but only about 40 objects were reported in the catalog of Conti (1991).

NGC 6764 is a nearby (32 Mpc using H_o=75 km/s/Mpc) barred spiral galaxy (SBb), classified as a LINER galaxy on the basis of optical spectroscopy. NGC 6764 is unusual in that it displays a prominent 4660Å W-R emission feature in the nucleus (see **Fig.1b**). W-R emission features are rarely observed in galaxies, and the presence of the broad HeII λ4686Å feature is indicative of very recent massive star formation (Armus, Heckman & Miley 1988; Conti 1991). The study of such objects is essential for understanding the starburst phenomenon in galaxies. The first analysis of the starburst activity in NGC 6764 was presented by Eckart et al. (1991) and Eckart et al. (1996) and revealed a dense concentration of molecular gas and a very recent (at most a few times 10^7 years) starburst in the nucleus of NGC 6764. W-R galaxies therefore offer the unique possibility to study high-mass star formation (Maeder & Conti 1994). It is often unclear whether the W-R line emission is originating from a single isolated HII region or is associated with the nucleus of the parent galaxy itself. The study of W-R galaxies is therefore essential for understanding the starburst phenomenon in galaxies, as it offers the unique opportunity to analyze the stellar population at a well-defined evolutionary stage.

In **Fig.1** the R frame from the DSS is shown as well as the registrogram of the optical spectrum of the galaxy. The spectrum cleary demonstrates its W-R nature – see the broad W-R emission in the blue region of the spectrum, consisting of a blend of NIII λ4640Å, CIII λ4650Å, CIV λ4658Å and HeII λ4686Å emission lines, which is a spectral characteristic of the WN stars.

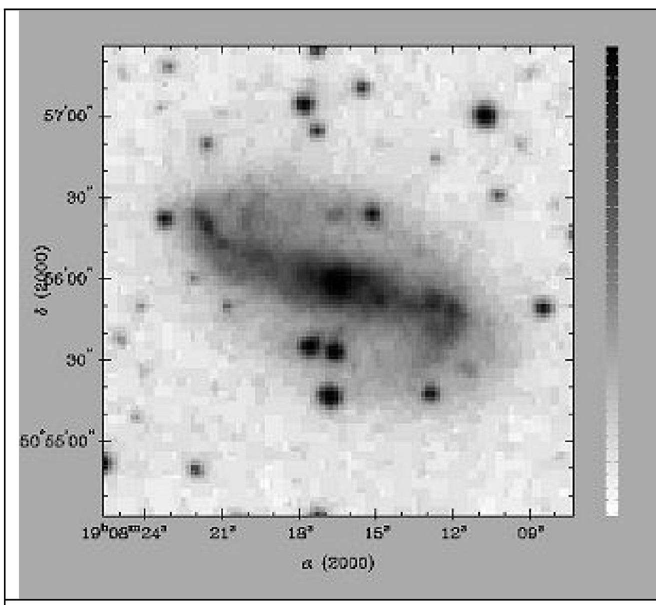

Fig.1a: A copy from DSS R plates of NGC 6764

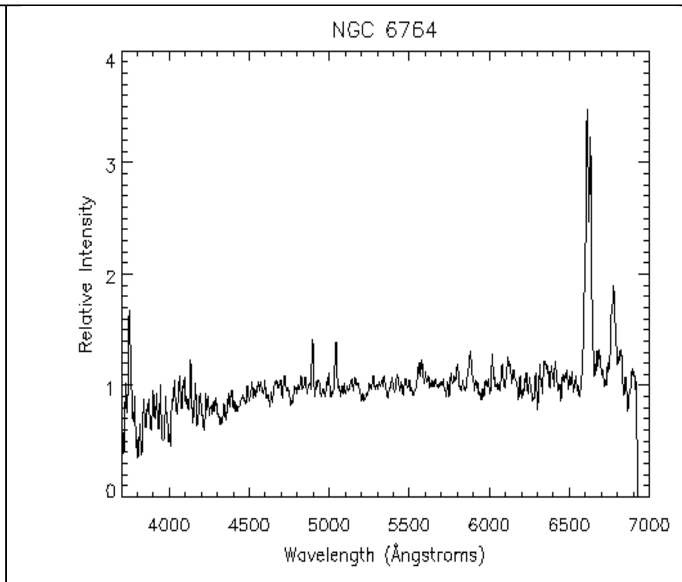

Fig.1b: A registrogram of the optical spectra of NGC 6764

The nature of the nuclear activity of NGC 6764 is not well established. Being originally classified as a Seyfert 2 galaxy by Rubin et al. (1975) and Koski (1978), Heckman (1980) included it in his list of LINERs on account of its large [OI]λ6300/[OIII]λ5007 ratio (0.3). On the other hand, Osterbrock & Cohen

(1982) noted the presence of emission features from W-R stars in the nucleus of NGC 6764. Considering these ratios and the diagnostic diagrams of Veilleux & Osterbrock (1987), one could imagine a starburst-like activity in the nucleus whereas the LINER activity originates from the circumnuclear region. We can thus interpret the LINER activity in NGC 6764 in terms of two ionization sources: *photoionization by young massive stars in the nucleus* (corroborated by the presence of W-R stars) and *excitation by shocks from supernovae in the circumnuclear region.*

II. Observation and data reduction

Here we present the results from the observation and analysis of NGC 6764 - now known as a W-R galaxy (Osterbrock & Cohen, 1982), Sy2-type galaxy (Rubin et al., 1975; Koski, 1978), LINER (Heckman, 1980; Veron-Cetty & Veron, 1993) and HII galaxy (Shuder & Osterbrock, 1981; Veillex & Osterbrock, 1987).

NGC 6764 was observed during the night of 14.07.1996 at the 2-m RCC telescope at Rozhen Observatory using standard Shott BVRI filters and ST-8 Peletier cooling CCD camera giving a field of view approx. 3 x 2 arcmin with resolution 0.23 "/px for the 2x2 binned frame. The gain factor is 2.3 e/ADU and RON is 6.5 ADU. Three 2-15 min frames were taken in each band. The frames were dark subtracted, flat fielded, cosmic events removed using the standard techniques and coadded to have higher signal to noise ratio.

The reduction of the frames was done using ESO MIDAS 96NOV software and the Richter's expansion of the SURFPHOT context (Lorenz et al., 1993). Fitting ellipses to the isophotes of the galaxy was done after Bender & Moelenhoff's (1987) method and the graphics and table representation - with the procedures of Vennik et al. (1996) and our own ones.

Tabl. 1 Basic data about the galaxy:

Coordinates (1950.0)	RA: 19h 07m 01.5 s Dec: +50º 51' 03"
Morphological type	SBbc
Apparent B magnitude	12.68
Distance (assumed H = 75 km/s/Mpc)	32. Mpc
Absolute B magnitude	-20.9
HI velocity	2416 km/s
Optical velocity	2412 km/s
Log M_{HI}	9.65 $M_{\odot}$
Log L_B	10.52 $L_{\odot}$
Log F_{ir}	10.23 $L_{\odot}$
Log (M_{HI}/L_B)	-0.87
Log (L_{Fir}/L_B)	-0.29

The photometric calibration was done using M92 standard stars (Christian et al., 1985) and the data of Doroshenko (1988) for the nuclear region.

III. Morphology

In **Fig.2** we present the distribution of light in the galaxy disk in VRI bands. All frames were aligned/shifted to the R image. The final frames were normalized via $\mathbf{I_{norm} = I_{image} / I_{sky} - 1}$.

The galaxy was checked for a box/peanut nucleus because of the shapes of the isophotes in the central 20” region (Luetticke, 1995, private communication) under the joint project between the Institute of Astronomy of the Ruhr-University, Bochum, Germany and the Institute of Astronomy of the Bulgarian Academy of Sciences. No clear X shape of the isophotes is visible.

In **Fig.3** V-R, R-I and V-I colour maps of the normalized NGC 6764 frames are presented. The left and right panels visualize different cut levels to better demonstrate the location of HII regions. These are the starburst regions and the regions, responsible for the W-R characteristics of the galaxy. The R-I colour is less informative, but theV-R and V-I colours clearly show the location of more than 100 HII regions.

IV. Analysing of surface brightness distribution

NGC 6764 is known as a barred spiral SBb galaxy with dust lanes. The multi-apperture photometry of the galaxy in BVRI system was carried out by Doroshenko (1988). Partially the morphology of the galaxy was studied in Ha and 4000-9000 Å band by Boer & Shulz (1990) and radio map of the galaxy was given by Wilson & Willis (1980). The starburst activity was studied, e.g. by Eckart et al. (1996).

Using Doroshenko’s (1988) (D88) data we evaluated the mean magnitudes and colours for different diaphragms for the period from 1978 to 1986; two outlying points were excluded. As Doroshenko pointed out, there was a long-term variation with a weak tendency for the nucleus of NGC 6764 (A = 14” and A = 27”.5) to become brighter (dV approx. 0.2 mag). The earlier data, published in Longo & de Vaucouleurs(1983) (L&V) used unpublished data between 1977 and 1982 and those of Dibai et al. (1981).

All these available data in UBVR bands are summarized in **Tab. 2,** where **A** stands for the apertute in arcsec, **Sxxx** are the standard errors and **N** – the number of observations.

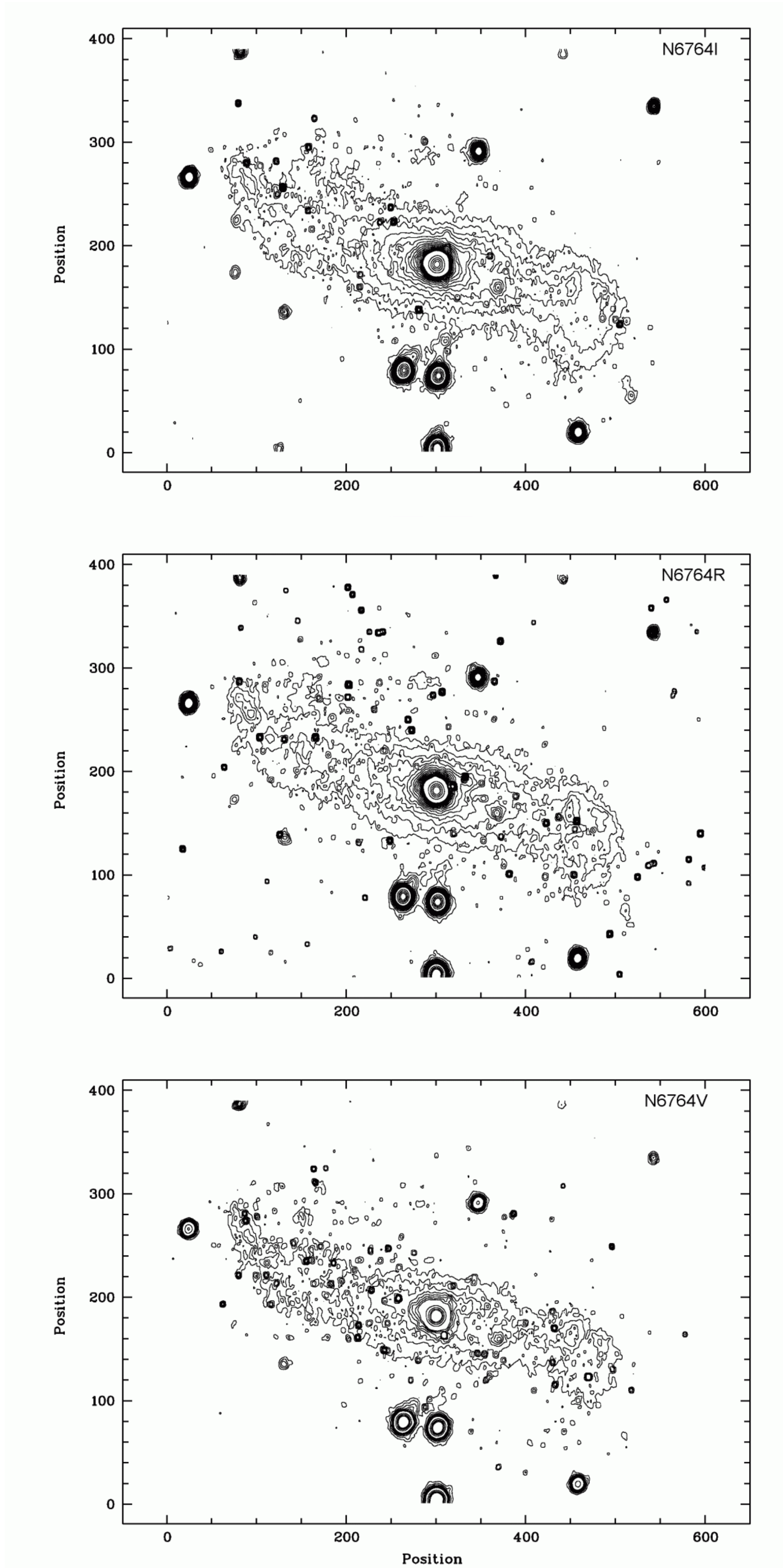

Fig.2: Isophotes in the V, R, and I bands of the galaxy NGC 6764. All frames were normalized first.

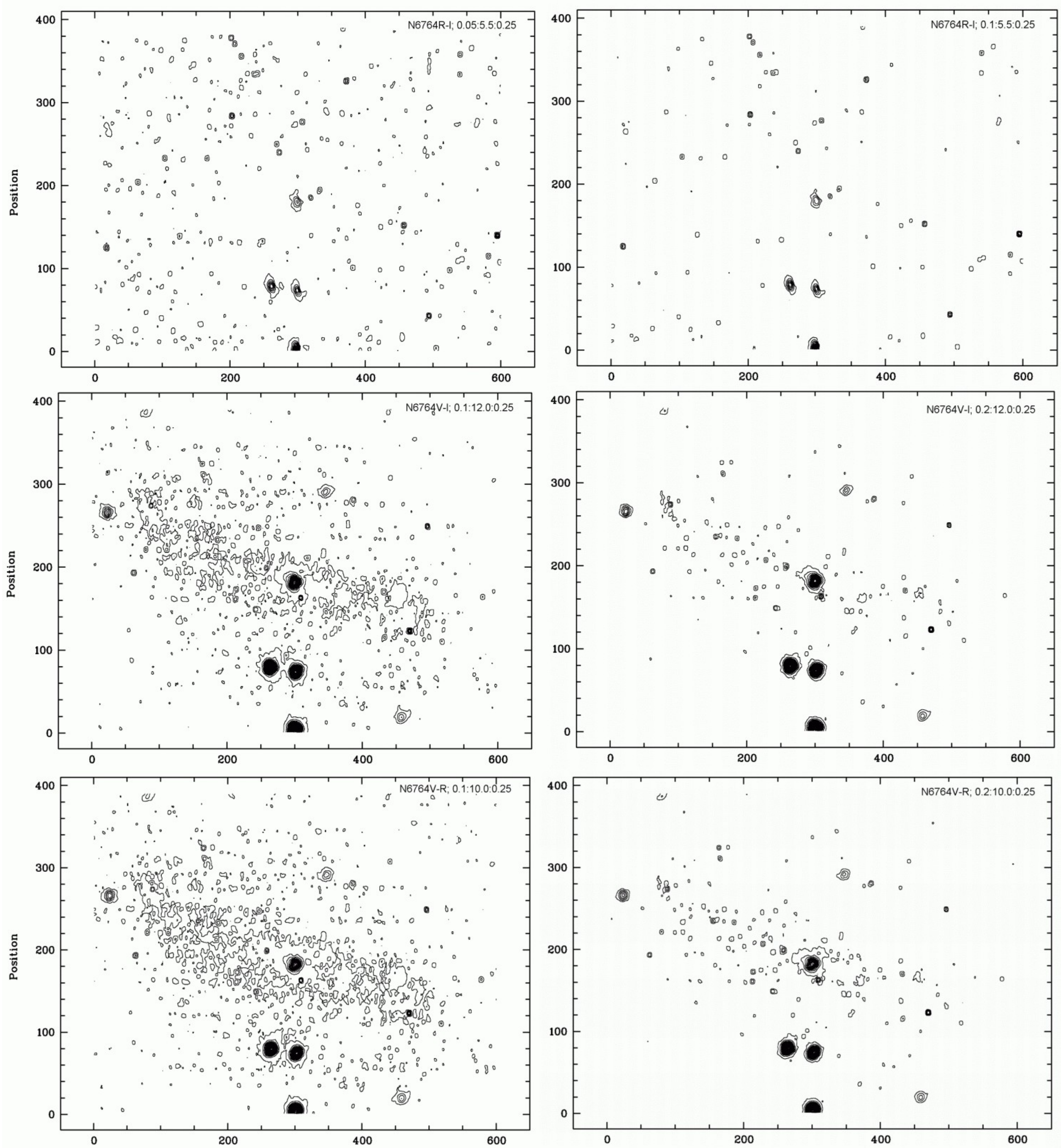

Fig.3: V-R, R-I and V-I colour maps of the normalized NGC 6764 frames.Left and Right panels visualize different cut levels to better demonstrate the location of HII regions.

Table 2:

A	V	Sv	N	B_V	Sb_v	N	U_B	Su_b	N	V_R	Sv_r	N	Src
7.2	15.16			0.43			-0.40						L&V
10.0	15.09	0.030	1	0.59	0.04	1	-0.07	0.12	1	1.14	0.08	1	D88
13.8	14.665	0.025	2	0.615	0.045	2	-0.24	0.04	2	1.75	0.085	2	D88
14.0	14.58	0.085	18	0.62	0.053	16	-0.317	0.109	11				D88
15.0	14.50	0.148	12	0.67	0.028	12	-0.268	0.027	8	1.07	0.019	8	D88
23.0	14.15	0.07	2	0.73	0.06	2	-0.125	0.025	2	1.06	0.02	2	D88
25.0	14.07	0.13	11	0.67	0.08	11	-0.213	0.083	7	1.005	0.051	4	D88
25.1	14.09			0.76			-0.14						L&V
27.5	13.98	0.084	35	0.73	0.065	32	-0.224	0.097	28				D88
34.6	13.72			0.72			-0.04						L&V
37.0	13.57			0.76			-0.09						L&V
70.7	12.82	0.03	1	0.83	0.03	1	-0.10	0.07	1				D88
73.8	12.77			0.74			0.07						L&V
111.7	12.33			0.70			0.08						L&V
134.3	12.27			0.70			0.06						L&V
137.4	12.23			0.74			0.02						L&V

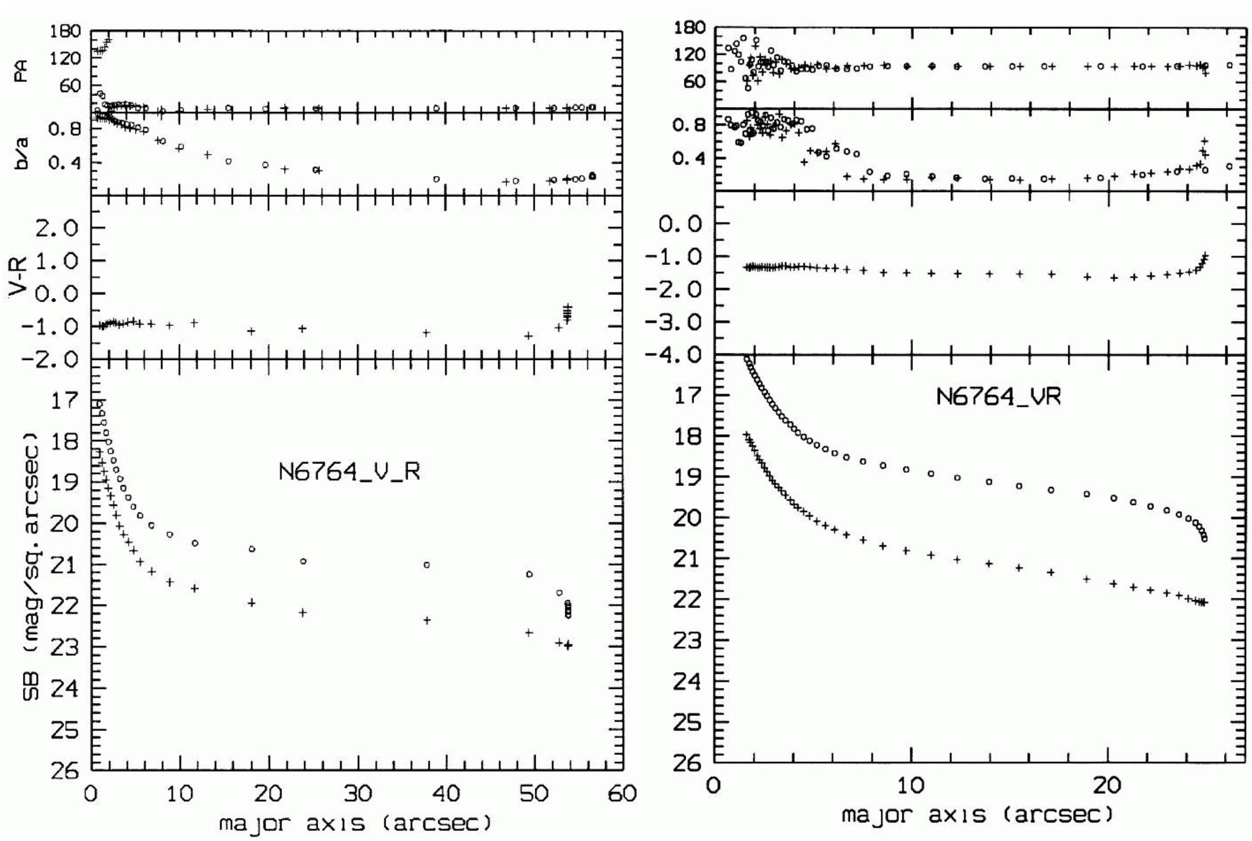

Fig. 4 Plots of the PA, b/a, colors V-R and SB for the disk (Fig.4a) and for the 20" nuclear region (Fig.4b).

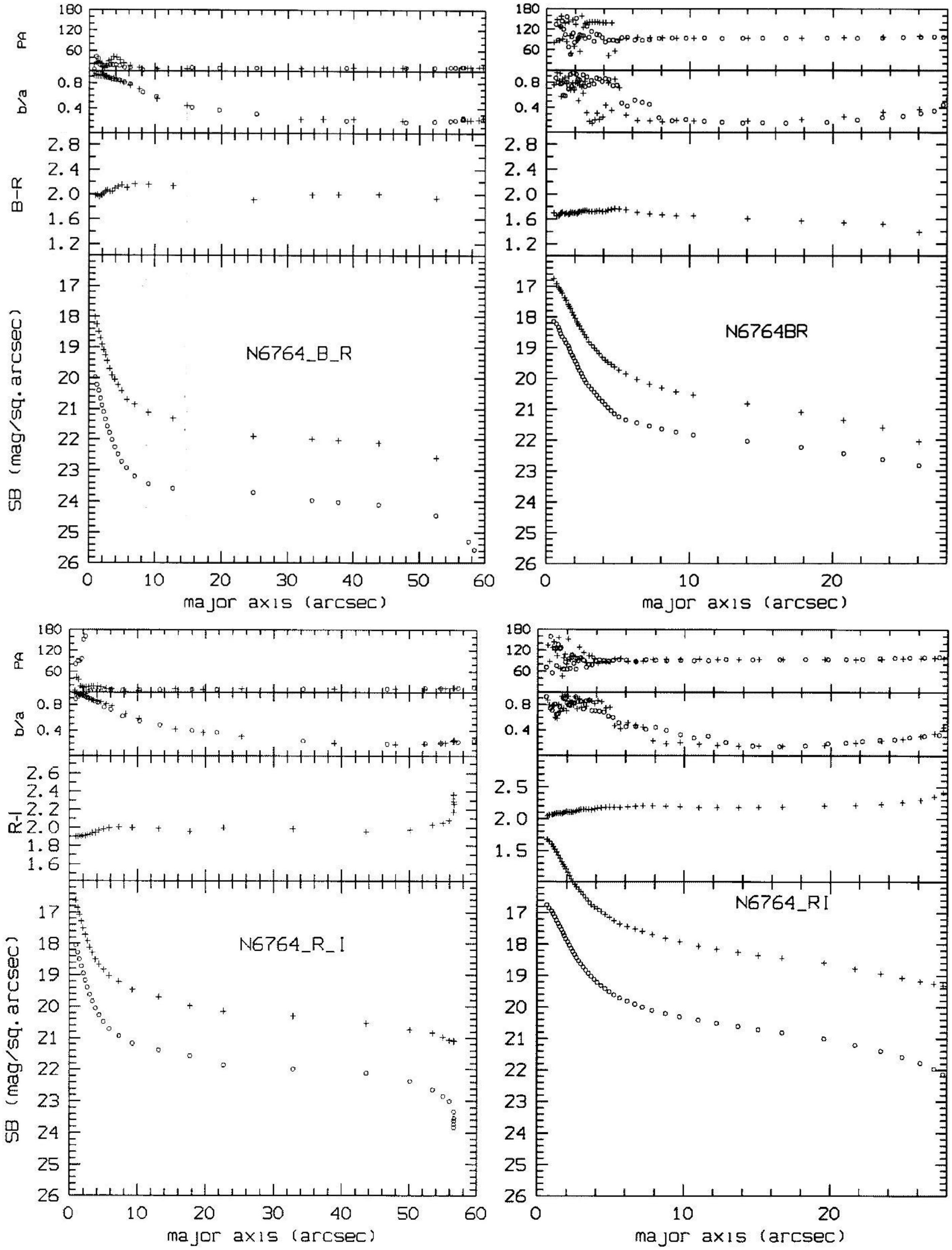

Fig. 5 Plots of the position angle (PA), axes ratio (b/a), colours B-R and R-I and surface brightness (SB) for the disk (Fig. 5a) and for the 20" nuclear region (Fig. 5b).

V. Conclusion

Surface photometry of the W-R galaxy NGC 6764 is presented, based on CCD frames from the 2-m RCC telescope of NAO Rozhen. As it was pointed from other authors, massive star formation could be an explanation of the emission lines in the optics. Infrared/Blue luminosity ratio is a secondary indicator for such scenario.

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