

# Detection of Ca II absorption triplet in a circumnuclear H II region of NGC 3310

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## SUMMARY

We have obtained long slit spectrophotometry across NGC 3310, a luminous galaxy with circumnuclear bursts of star formation, covering the spectral range from  $\lambda 3650$  to  $9700 \text{ \AA}$ . In one giant star-forming region, the near-IR Ca II absorption lines (a signature of young supergiants) was detected with a strength similar to that of the nuclear region. This is, to our knowledge, the first detection of the IR Ca II triplet in an extragalactic giant H II region and confirms theoretical predictions that, after some 4 Myr, red supergiants should appear in bursts of star formation.

## 1 INTRODUCTION

The Ca II triplet ( $\lambda\lambda 8498, 8542, 8662 \text{ \AA}$ ) is the most prominent absorption feature in the IR spectrum of late-type stars and normal galaxies. At metallicities higher than 0.5 solar it is very sensitive to luminosity – its strength increasing with decreasing stellar surface gravity – (Díaz, Terlevich & Terlevich 1989; DTT and references therein) and should be strong in a young star cluster containing some luminous red supergiants, since these stars dominate the near-IR light (e.g. NGC 2004, Bica & Alloin 1987). This should occur after about 4 Myr of evolution, according to Maeder & Meynet (1988) models. The cluster continuum in the region  $\lambda 3500\text{--}7000 \text{ \AA}$  on the other hand, should be highly featureless since the spectra of the OB stars dominating the light in the optical range show very weak absorption lines, which, for clusters younger than about 5 Myr, coincide with the emission from the ionized gas of the associated H II region (Kinman & Davidson 1981; Rayo, Peimbert & Torres-Peimbert 1982; Melnick, Moles & Terlevich 1985).

This type of spectral energy distribution has been proposed by Terlevich, Díaz & Terlevich (1990, TDT) to explain the fact that while the Mg I lines at  $\lambda 5175 \text{ \AA}$  are substantially diluted in the nuclei of Seyfert type 2 and some Seyfert type 1 galaxies, the Ca II triplet is observed at full strength. In this scenario, the nuclear activity is attributed to star formation and their associated processes (Terlevich & Melnick 1985; Terlevich, Melnick & Moles 1987; Terlevich & Melnick 1987, 1988).

To understand the properties of nuclear and extranuclear bursts of star formation, we engaged in a detailed study of nearby hot spot galaxies. NGC 3310 is a luminous Sb galaxy (Humason, Mayal & Sandage 1956) with a ring 1 kpc in

diameter of circumnuclear giant H II regions. The detection of the IR Ca II triplet in the nucleus and in one of the regions is reported here.

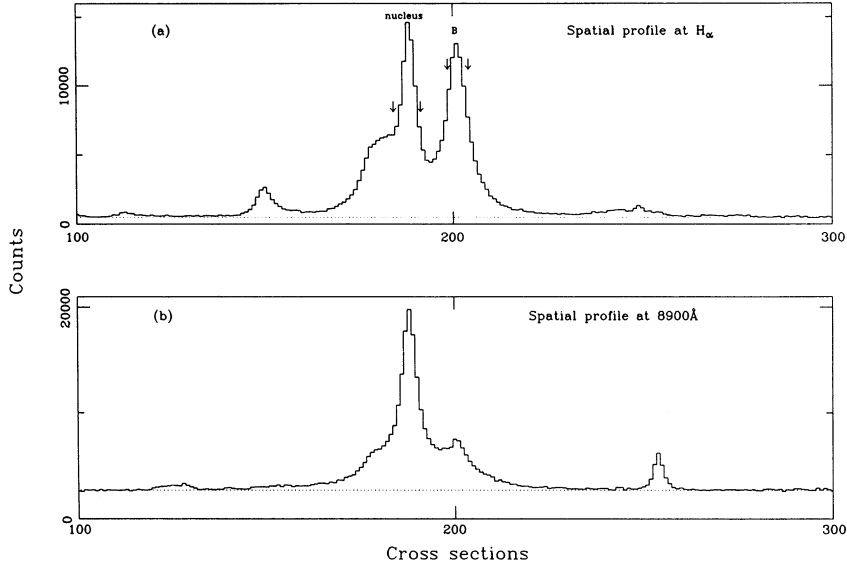
## 2 OBSERVATIONS AND REDUCTIONS

The observations were made in 1989 March 20/21 with the INT at the Roque de los Muchachos Observatory on the Spanish island of La Palma using the intermediate dispersion spectrograph (IDS), the 235-mm camera and a CCD detector with a blue coated GEC chip. Two different gratings were used (both with  $400 \text{ g mm}^{-1}$ ) to cover a total spectral range from  $\lambda 3650$  to  $7300 \text{ \AA}$  and from  $8400$  to  $9700 \text{ \AA}$ . The dispersion obtained is  $2.3 \text{ \AA}$  per pixel which, with the slit width used for the observations ( $1.5 \text{ arcsec}$ ), yielded a spectral resolution of about  $4 \text{ \AA}$ . The size of the CCD along the spatial direction is 400 pixel of  $0.7 \text{ arcsec}$  each. The slit was positioned over the nucleus of NGC 3310 at a PA  $347^\circ$ , including a bright knot at about  $10 \text{ arcsec}$  to the south.

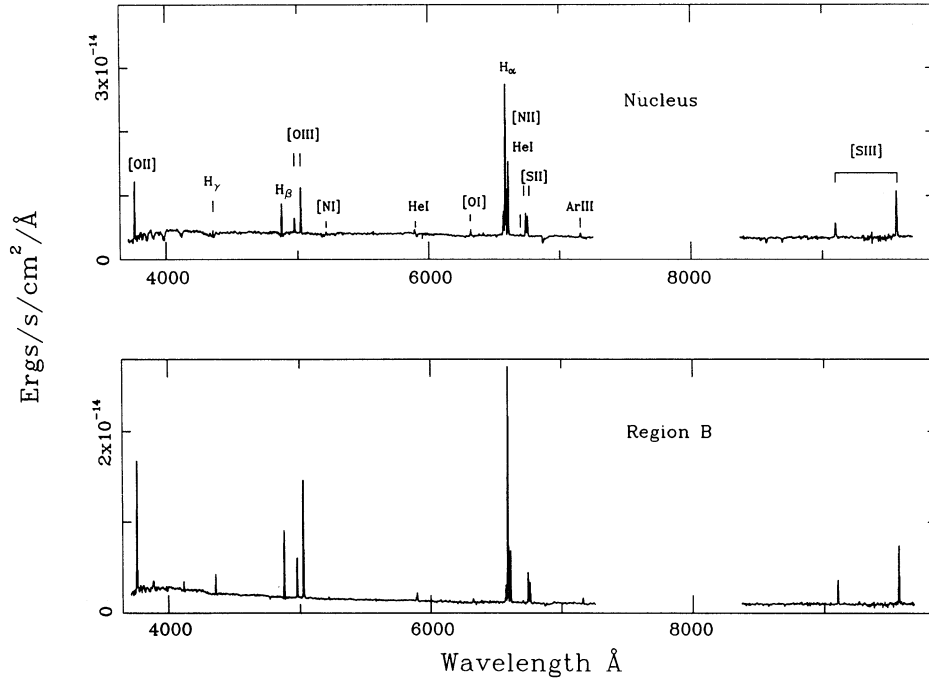
The reduction of the data was carried out at the Instituto de Astrofísica de Canarias and the Royal Greenwich Observatory using STARLINK software packages. The procedure includes the subtraction of a dark current bias and a preflash applied in order to avoid non-linearity effects at low illumination; removal of cosmic-ray hits due to the long exposure times involved (from 1300 to 1800 s); division by a flat field and wavelength calibration. The spectra were flux calibrated using as standards HD 140283 and HD 84937 (Oke & Gunn 1983).

## 3 RESULTS AND DISCUSSION

Fig. 1(a) shows a spatial profile in  $H_\alpha$ , where the arrows indicate the regions extracted to obtain one-dimensional



**Figure 1.** (a) Spatial profile of NGC 3310 in H $\alpha$ . The arrows indicate the cross-sections used to extract the nucleus and region B. (b) Spatial profile in the near IR continuum ( $\lambda$ 8850–8950 Å). The contribution of region B can be noted. The dotted lines show the background level in both figures

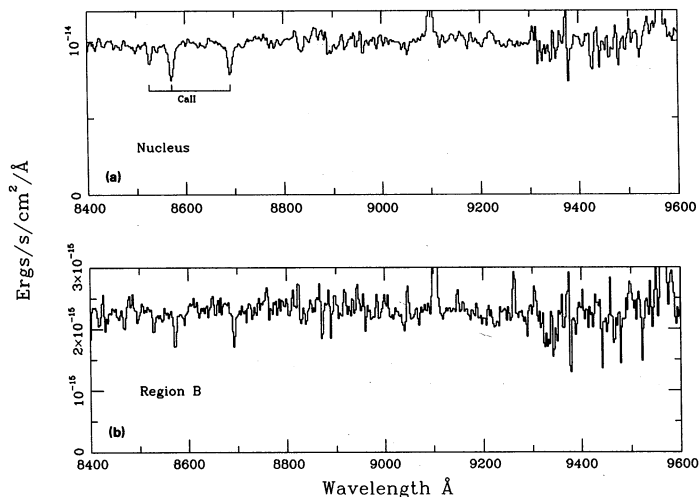


**Figure 2.** Joined spectra of the nucleus and region B from  $\lambda$ 3700 to 9700 Å in full scale as to see the emission lines.

spectra for the nucleus and one region that we have labelled B. The joined spectra of the starburst nucleus and of region B, a low-excitation H II region, are shown in Fig. 2.

The near-IR spectra of both regions are shown in Fig. 3. It is apparent from the figure that the Ca II triplet absorptions are comparable in region B and in the nucleus. Their strength [EW(Ca II)] has been measured following the method

described in TDT and was found to be  $6.2 \pm 0.8$  Å for the nucleus and  $7.0 \pm 1.2$  Å for region B. The internal velocity dispersion produces a broadening of the lines that affects the continuum level and the lines themselves. A correction for this effect as a function of the measured velocity dispersion for the instrumental configuration used is given in TDT. According to this expression, for the nuclear velocity disper-



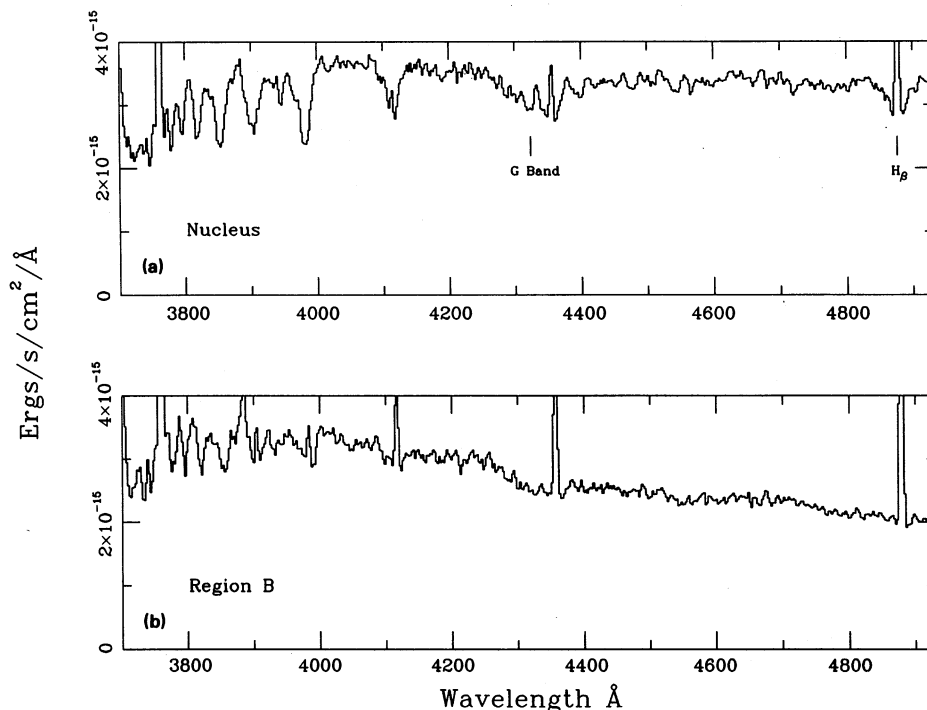
**Figure 3.** Near-IR spectra (a) nucleus, (b) region B. Strong emission lines are out of scale.

sion of NGC 3310 ( $110 \text{ km s}^{-1}$ ; TDT), the correction is at most  $0.2 \text{ Å}$ . The corrected value for  $\text{EW}(\text{Ca II})$  is therefore  $6.4 \text{ Å}$ . No correction is needed for the  $\text{H II}$  region.

The blue ( $\lambda 3700\text{--}5000 \text{ Å}$ ) and yellow ( $\lambda 4700\text{--}6000 \text{ Å}$ ) spectra of the two observed regions are shown in Figs 4 and 5. The two regions are strikingly different in these spectral regions; however, they look very similar in the near IR (Fig. 3). The nucleus shows relatively strong metal features characteristic of an old stellar population: G-band ( $\lambda \sim 4300 \text{ Å}$ ),  $\text{Mg I}$  ( $\lambda \sim 5175 \text{ Å}$ ),  $\text{Na I}$  ( $\lambda \sim 5890 \text{ Å}$ ),  $\text{Ca II}$  triplet etc. together with strong and wide Balmer absorption lines characteristic of a relatively old starburst. On the other hand, the only strong metal absorption features seen in region B are the near-IR  $\text{Ca II}$  lines. This leads to the conclu-

sion that while the IR  $\text{Ca II}$  triplet in the nucleus of NGC 3310 probably comes from the red giant population of the bulge, the  $\text{Ca II}$  features seen in region B originate in luminous young red supergiants already present in the star-forming region. This interpretation is strengthened by the fact that the lines in region B are narrower than expected if they originate in the bulge. Furthermore, the contribution of the bulge component at position B is at most 50 per cent as can be seen from Fig. 1(b).

This is, to our knowledge, the first direct detection of the presence of these young red stars in extragalactic gas-forming regions which, unlike NGC 2004 in Bica & Alloin (1986), have not yet lost their associated  $\text{H II}$  region and are therefore probably younger than 5–6 Myr (Dottori 1981;



**Figure 4.** Blue ( $\lambda 3700\text{--}5000 \text{ Å}$ ) spectra for (a) the nucleus and (b) region B. Strong emission lines are out of scale.

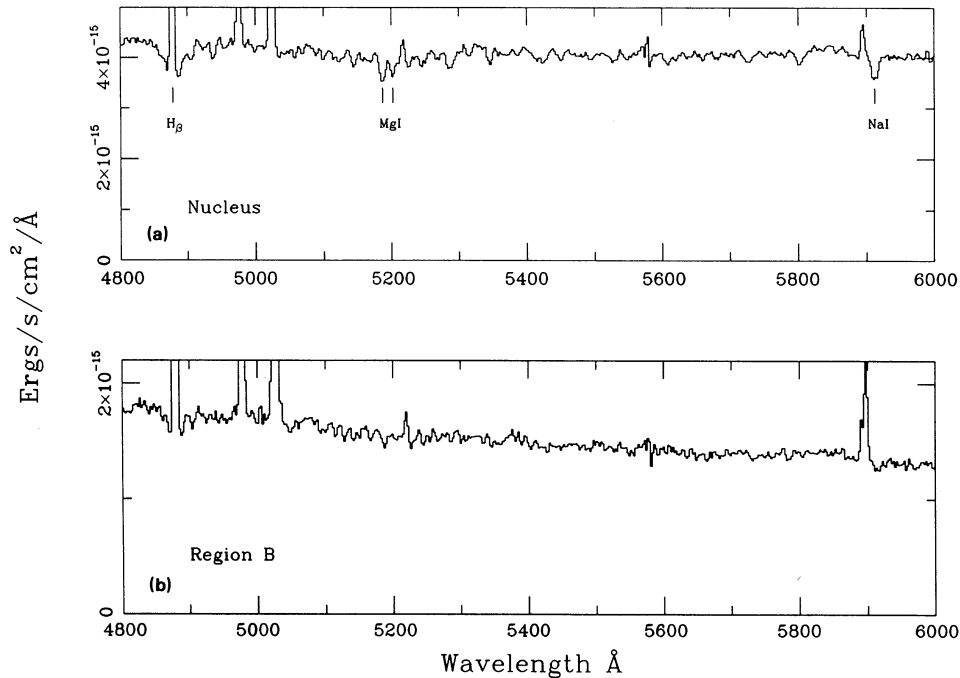


Figure 5. Yellow ( $\lambda$ 4800–6000 Å) spectra for (a) the nucleus and (b) region B. Strong emission lines are out of scale.

Copetti, Pastoriza & Dottori 1986). Our result confirms Campbell & Terlevich's (1984) theoretical predictions on the spectral energy distribution of very young star clusters.

We can suggest two reasons to explain why the Ca II triplet has not been detected before in giant H II regions. First, high signal-to-noise near-IR spectra have only recently become available with the advent of low-noise CCDs. Secondly, most of the work on these objects is devoted to the study of nebular abundances, and consequently strongly biased towards those systems with the strongest emission lines which are probably too young to host red supergiants.

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