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ABSOLUTE SPECTROPHOTOMETRY OF SEYFERT GALAXIES. (Research Note)

D. Dultzin-Hacyan and M.A. Herrera
Instituto de Astronomía
Universidad Nacional Autónoma de México

N. Núñez
Facultad de Ciencias
Universidad Nacional Autónoma de México

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RESUMEN

Se reportan los resultados de espectrofotometría absoluta para cuatro galaxias Seyfert. Se dan intensidades y anchos equivalentes de algunas líneas no reportadas previamente en la literatura. Se analizan las peculiaridades de cada objeto, tanto en el continuo como en las líneas de emisión, luego de comparar con observaciones anteriores. El comportamiento de Hβ en 3C120 es muy peculiar.

ABSTRACT

The results of absolute spectrophotometry for four Seyfert galaxies are reported. Absolute intensities and equivalent widths are given for several lines not reported before in the literature. Comments on each object's continuum and line spectra are given after comparison with previous observations. The behaviour of Hβ in 3C120 is very peculiar.

Key words: GALAXIES-SEYFERT — SPECTROPHOTOMETRY

I. INTRODUCTION

The recent theoretical studies of Capriotti, Foltz, and Peterson (1982); Blandford and McKee (1982); and Antokhin and Bochkarev (1984) emphasize the importance of the study of the temporal behaviour of the broad-line profiles in Seyfert 1 galaxies as a diagnostic of the structure and dynamics of the broad-line emitting gas.

Although optical-wavelength continuum variability of Seyfert galaxy nuclei has been recognized for at least 15 years (Pacholczyk and Weymann 1968) only within the past few years has it become clear that the broad emission line spectra of Seyfert 1 galaxies change in response to changes in the continuum flux. Consequently, systematic monitoring of the continuum flux and line profiles is potentially a valuable diagnostic of conditions within the Broad Line Region (BLR).

It is important that such observations be carried out in a consistent fashion: with the same instruments and under similar observing conditions. A few galaxies have been observed in this way (see e.g. Alloin *et al.* 1985). Unfortunately, this is not always possible, and the 'second best' alternative is to compare one's observations with those found in the literature, provided that due attention is paid to the effects of different observational conditions (see e.g. Peterson *et al.* 1982, 1984).

II. OBSERVATIONS

The observations were carried out during two seasons: August 1981 and October 1982 with the 2.1-m telescope of the Observatorio Astronómico Nacional at San Pedro Mártir, Baja California, using a low dispersion Boller and Chivens spectrograph coupled with the Optical Multichannel Analyzer described by Firmani and Ruiz (1981), consisting of a WL30677 Westinghouse image intensifier described by Ruiz (1974) and a SIT intensified camera described by Solar (1977).

The spectra were taken with a 200 line mm^{-1} grating giving a resolution of about 8 A channel^{-1} in the first order (5300 – 8300 A) and about 4 A in the second order (3800–5500 A). Wide entrance slits (1.5 X 16.5 and 3.5 X 16.5 arcsec) were used to obtain the spectra and a second slit 7 arcsec East was used alternatively for sky subtraction. Spectrophotometric standards from Stone (1977) were observed on the same nights for calibration. The journal of observation is given in Table 1.

To link the emission-line intensities to the continuum, the observed equivalent widths are given. In all cases, the continuum level has been fitted by eye, this being one of the sources of error in the measurement of emission-line intensities. The other sources of error

TABLE 1

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Object	Date of Observation	Wavelength Range (A)	Resolution (A/channel)	Slit (arcsec)
II Zw 136	08/08/81	3800 – 5500	4.2	1.5 X 16.5
II Zw 136	13/08/81	5300 – 8300	8.3	1.5 X 16.5
NGC 985	14/10/82	4050 – 5950	4.2	3.5 X 16.5
Mkn 609	15/10/82	4400 – 5650	4.2	3.5 X 16.5
3C 120	15/10/8?	4030 – 5550	4.2	3.5 X 16.5

(related to the first one) are the uncertainties in the estimation of the width of the broad wings, and of the degree of blending due to nearby lines. The errors given in Table 2 are estimated on the basis of extreme combinations of these three sources of error.

In what follows we shall analyze each object separately.

III. DISCUSSION AND RESULTS

a) *II Zw 136*

The spectrum of this typical Sy 1 galaxy was taken in two parts (Figure 1), the resolution is given in Table 1. Table 2 lists the values for line intensities and equivalent widths. Table 3 shows a comparison of width (FWHI and FWZI) measurements. From Table 3 and the comparison with previous determinations of the intensity in Hβ (Osterbrock 1977; Grandi 1981) we conclude that, within the error limits, the emission lines have not varied for this galaxy, at least over the time scale considered. The Balmer decrement is particularly smooth for this object.

b) *NGC 985*

This is one of the few ring galaxies known to have Seyfert characteristics. Line intensities and equivalent widths are given in Table 2. The spectrum is shown in Figure 2.

De Vaucouleurs and de Vaucouleurs (1985) classified this galaxy as Sy1. From Figure 2 one can clearly see a

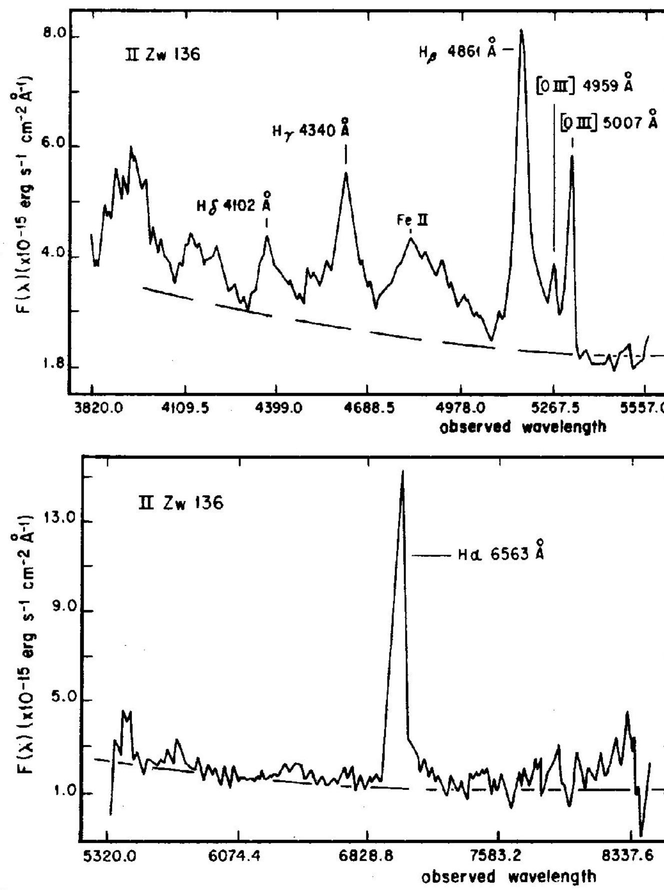

Fig. 1. Observed spectrum of II Zw 136 (*a*: blue, *b*: red).

TABLE 2

OBSERVED INTENSITIES AND EQUIVALENT WIDTHS[a]

			Hδ		Hγ		Hβ		[O III] 4959		[O III] 5007		Hα	
Object	z	m_V	I_0	W_0	I_0	W_0	I_0	W_0	I_0	W_0	I_0	W_0	I_0	W_0
II Zw 136	0.062	14.3	9 ± 3	30 ± 7	23 ± 4	85 ± 9	36 ± 3	156 ± 8	6 ± 0.3	25 ± 1	17 ± 0.5	50 ± 2	101 ± 3	565 ± 20
NGC 985	0.043	14.5	–	–	11 ± 2	38 ± 7	23 ± 5	81 ± 18	10 ± 2	36 ± 7	32 ± 1	73 ± 4	–	–
Mkn 609	0.032	14.5	–	–	–	–	2.2 ± 0.9	11 ± 4	2.3 ± 0.7	13 ± 2	7.1 ± 0.2	35 ± 1	–	–
3C 120	0.033	14.2	–	–	–	–	27 ± 4	90 ± 8	7 ± 1	30 ± 5	20 ± 2	83 ± 11	–	–

a. Observed intensities are given in units of 10^{-14} erg cm^{-2} s^{-1}. Observed equivalent widths in A.

TABLE 3

FULL WIDTHS AT HALF MAXIMUM AND ZERO INTENSITY FOR II Zw 136 (km s^{-1})

	Hα		Hβ	
	(1)	(2)	(1)	(2)
FWHM	2700 ± 200	2200 ± 300	2238 ± 300	2300 ± 400
FWZI	8571 ± 800	10100 ± 1000	11192 ± 1500	11400 ± 1900

1, This work.
2. Osterbrock (1977).

narrow component in Hβ, and the ratio [OIII]/Hβ does not correspond to a typical Sy1 galaxy. We believe that the type is certainly intermediate between Seyfert 1 and 2.

We have found a value of $\alpha_{opt} = -1.7 \pm 0.2$ for the spectral index of a power law continuum energy distribution in the wavelength range observed.

c) *Mkn 609*

This galaxy was first classified as a Sy1 by Weedman (1976) based only on morphological criteria. When the first high resolution spectra were obtained, Osterbrock (1978) classified it as intermediate type, Sy1.8. The superposition of a narrow component on broad wings in Hβ can be seen in our spectrum (Figure 3). Table 2 shows the intensities and equivalent widths for Hβ and [OIII]: these are the first absolute flux values reported for this galaxy.

d) *3C 120*

This is a luminous Sy 1 galaxy (often included in QSOs lists as well; z = 0.033), with a compact radio core. The morphology is most likely spiral (Arp 1975). 3C 120 is highly variable at all wavelengths in which data have been collected. The optical nucleus is variable by almost two magnitudes on time-scales of years, with smaller changes occurring in days (Lyutyi 1979; Pollack *et al.* 1979). Similar behaviour is seen in the infrared (Rieke and Lebofsky 1979), in radio flux at different frequencies (Epstein *et al.* 1982 and references therein) and in X-rays (Halpern 1985). Perhaps the most interesting observational results are the *VLBI* maps of Walker *et al.* (1982, 1984) which show structural variations indicative of multiple ejection at apparent superluminal velocities. It is also well known that the line spectrum is highly variable, see. e.g. Oke, Readhead, and Sargent (1980).

The comparison of observations performed with different apertures, detectors, etc. is not the ideal approach to the study of variability, and thus, since the variability of line intensities is so well established for this galaxy,

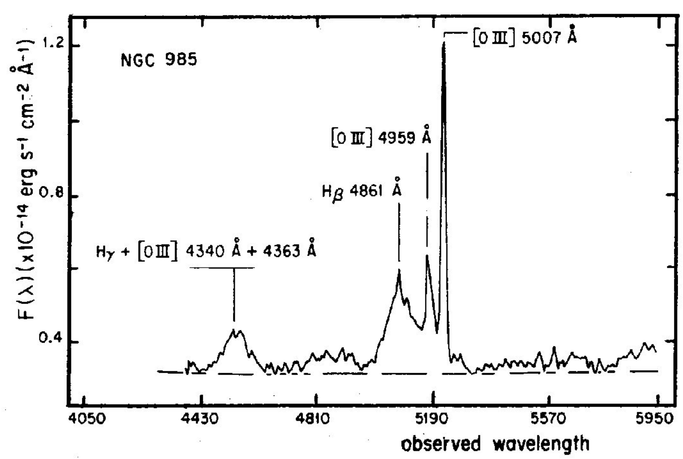

Fig. 2. Observed spectrum of NGC 985.

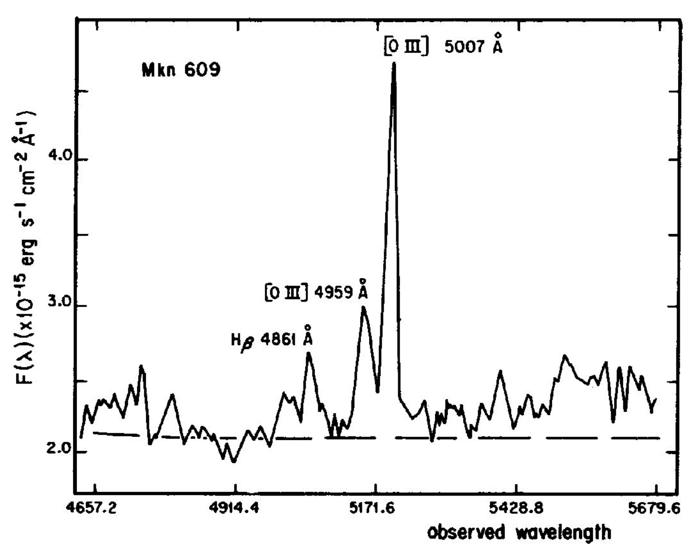

Fig. 3. Observed spectrum of Mkn 609.

we do not compare our values for intensities and equivalent widths (Table 2) with previous determinations.

The study of profile variation, has unfortunately been handicapped by the lack of high resolution spectra. Although good profiles have not been published, evidence for variability of the Hβ profile can be inferred from Table 4, in which we compare measurements of FWZI and FWHM of Hβ by different authors (this work included). The type of variability deduced from Table 4 (a broadening of the upper part of the line) has not been found before. Since this effect refers to a broadening at half maximum, no continuum fitting effects can be important to bias the measurements.

TABLE 4

FULL WIDTHS OF Hβ AT HALF MAXIMUM AND ZERO INTENSITY FOR 3C 120 (km s^{-1})

	(1)	(2)	(3)
FWHM	2000	1200	3046 ± 200
FWZI	–	10000	9691 ± 700

1. Shields *et al.* (1972).
2. Oke and Zimmerman (1979).
3. This work.

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Deborah Dultzin-Hacyan and Miguel A. Herrera: Instituto de Astronomía, UNAM, Apartado Postal 70-264, 04510 México, D.F., México.
Noemí Núñez: Laboratorio de Física General, Departamento de Física, Facultad de Ciencias, UNAM, 04510 México, D.F., México.