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ACTIVE GALACTIC NUCLEI: NARROW EMISSION LINE PROFILES

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RESUMEN. El perfil de emisión de la línea [OIII]5007 está calculado en base a los modelos compuestos que toman en consideración los efectos acoplados de fotoionización y choque en las condiciones físicas de la región de las líneas angostas de emisión del núcleo activo galáctico. Se comparan los resultados con los perfiles observados.

ABSTRACT. The emission profile of the [OIII]5007 line is calculated on basis of the composite models which take into account the coupled effects of photoionization and shock on the physical condition of the narrow emission line region of the active galactic nuclei. The results are compared to the observed profiles.

Key words: GALAXIES-ACTIVE — LINE-PROFILE

I. INTRODUCTION

In the last years some models for the narrow emission line region (NLR) of the active galactic nuclei (AGN) have been calculated taking into account the coupled effects of photoionization and shock (Contini, Aldrovandi 1983, 1986a; Aldrovandi, Contini 1984, 1985, Papers I to IV). The physical conditions of the gas are obtained assuming that the emitting clouds move radially through a dilute gas being reached by the ionizing radiation from a central source and by a shock front. Our previous results show that clouds of different velocities coexist in the NLR as suggested by high dispersion observations of the [OIII]5007 emission line (Pellat, Alloin 1982).

In this paper a comparison between the observed and theoretical [OIII] line profiles is presented for various AGN. The theoretical profile is obtained from the emission line intensities provided by the composite models and assuming a velocity distribution for the emitting clouds.

II. KINEMATIC LINE PROFILE

The composite models for the NLR of the AGN provide the emission line intensities of several ions. As the physical conditions of the emitting gas are obtained considering also the effect of a shock front, the theoretical line intensities depend on the cloud velocity. Considering that the broadening of a line is due to the Doppler shift resulting from the motion of the various clouds present in the NLR, a theoretical profile can be obtained from these models. Theoretical profiles calculated previously (Vrtilek 1985; Schiano 1986) consider the NLR as a single entity and the gas emissivity independent of the velocity.

Assuming the NLR composed by various emitting clouds with different velocities and reached by the ionizing radiation from the central source, the kinematic line profile is given by (Viegas-Aldrovandi, Contini 1986)

$$I_T(v) = (I(v)f(v) + \sum_i I(v\ )\ v/v_i f(v_i))g_R \ ,$$

where I(v) is the emission line intensity given by the composite models, f(v) is the velocity distribution of the emitting clouds and g_R is introduced in order to take the presence of dust in the NLR (leading to an asymmetric profile) into account in a simplified manner: $g_R = 1$ (symmetric profile) or $g_R \neq 1$ (blueward asymmetry). Previous calculations (Contini, Aldrovandi 1986a) indicated that the velocity distribution f(v) is a decreasing function of the cloud velocity. For the [OIII]5007 profile calculations, two types of distribution functions have been considered: (a) exponential function, characterized by the ratio, r, between the number of clouds with velocity 100km/s and 200km/s; (b) a step function, characterized by the ratio, r, between the number of the low velocity clouds (v<400km/s) and high velocity clouds (v≥400km/s).

Many theoretical profiles have been obtained, considering outward and inward motion of the emitting clouds. (Contini, Viegas-Aldrovandi 1986b, Paper V) with different values of r and g_R.

III. COMPARISON TO OBSERVATIONS

Observations of the [OIII]5007 line profile, presented for many objects (Heckman et al. 1984; Vrtilek, Carleton 1985; Whittle 1985), generally show an asymmetry, indicating the presence of dust in the NLR. As discussed in Paper V, considering the composite models a blueward or a redward asymmetry can appear depending on the relative importance of photoionization and shock in determining the physical conditions of the gas. As most of the observed profiles show a blueward asymmetry, the theoretical profiles considered have been calculated with $g_R<1$.

The fitting to observed profiles has been done on basis of the general shape of the line, the asymmetry and other parameters defined in the literature. Three types of theoretical profiles appear: (A) characteristic of emitting clouds reached by an ionizing radiation flux decreasing with the cloud velocity showing a high energy cutoff at 500eV; (B) the ionizing radiation reaches the clouds with the same intensity. Types (A) and (B) correspond to clouds with outward motion and a third type (I) to clouds with inward motion.

In Table 1, the results concerning the profiles observed by Heckman et al (1984) are presented. In the first two columns appear the name and the classification of the object as given by Heckman et al., in the third column the type of theoretical profile fitting to observed one is given, and in the last column the logarithm of the r value is listed. For all objects the line profile corresponds to outward motion of the emitting filaments, and, except for NGC1052, the velocity distribution is an exponential function. The results indicate that

TABLE 1. Comparison to observations (Heckman et al. 1984)

Object	Class	Model	log r	Object	Class	Model	log r
NGC 1052	QG	A	2.	0214+108	SQ	A	3.
NGC 4388	QG	A	2.	0602-319	SQ	A	2.
NCG 5506	QG	A	3.	0752+258	SQ	A	2.
MrK 486	QG	A	2.	0812+020	SQ	B	2.
3C 33	SG	A	2.	1103-006	SQ	B	2.
3C 109	SG	B	3.	1117-248	SQ	B	2.
3C 227	SG	B	2.	1223+252	SQ	B	2.
0211-479	SG	A	1.	1020-103	FQ	A	2.
0518-458	SG	A	2.	1302-102	FQ	A	2.
0521-365	SG	B	3.-2.	1116+215	QQ	A	2.
0634-206	SG	B	2.-3.	1151+117	QQ	A	2.
0921-213	SG	B	2.-3.	1202+281	QQ	A	2.-3.
3C 120	FG	A	3.	1229+204	QQ	A	2.
0111+021	FG	B	2.	1416-129	QQ	A	3.
3C 215	SQ	B	1.	1427+480	QQ	B	1.
0003+158	SQ	B	2.	1435-067	QQ	A	2.
0202-765	SQ	A	2.-3.	1613+658	QQ	A	3.

radio quiet objects (Q) are characterized by clouds reached by an ionizing radiation decreasing with the cloud velocity. It seems also that the ionizing flux is less screened for galaxies than for QSOS. The screening of the ionizing flux could be due to the presence of a broad line region, which is characteristic of almost all QSO's. No profile is type (I).

The results concerning the fitting to the line profiles given by Whittle (1985) are summarized in Table 2. In this table another column has been added giving the values of g_R (column 5). All the objects are galaxies and only NGC3281 has a theoretical profile type (I), i.e., corresponding to inward motion of the emitting clouds, and a step function for the velocity distribution. Narrow line objects have the observed profile fitted by type (A) theoretical profile, while the majority of the broad line galaxies by type (B) profile so that the screening of the ionizing radiation is not due to the BLR as suggest previously by the fitting to the [OIII] line profiles observed by Heckman et al. (1984).

TABLE 2. Comparison to observations (Whittle 1985)

Object	Type	Model	logr	g_R
NGC 2992	N/BLG	B	2	1/4
NGC 3081	NLG	A	3	1/8
NGC 3227	B/NLG	B	2	1/2
NGC 3281	NLG	I	1	1/2
NGC 3783	BLG	A	3-2	1/2-1/4
NGC 4507	NLG	A	3	1/4
NGC 4593	BLG	B	2	1/8
NGC 5135	NLG	B	2	1/8
NGC 5506	NLG	A	3	1/2
NGC 5548	BLG	B	2	1/2-1/4
NGC 5643	NLG	A	3	1/8
NGC 5728	NLG	A	3	1/2
NGC 6814	BLG	A	3	1/8
NGC 6890	NLG	A	3	1/2
NGC 7469	BLG	B	2	1/8
NGC 7582	NLG,T	A	3	<1/2
TOL 0109-383	NLG,T	A	2	<1/16
TOL 1028-301	NLG	A	3	1/8
TOL 1238-364	NLG	A	3	1/4
TOL 1351-375	N/BLG	A	2	1.
F9	BLG	B	2	1/2
F51	BLG	B	1	1/4
F 188	NLG	A	3	1/8
MKN 304	BLG	B	3	1/8
MKN 463	NLG	B	2	>1/2
MKN 509	BLG	B	2	>1/2
IC 4329 A	BLG	B	2	<1/2
IC 5063	NLG,R	A	2	1.
PKS 0349-27	NLG,R	B	2	1.
PKS 2152-69	BLG,L,R	B	1	<1.
3 C 33	NLG	B	2	1
3 C 445	B/NLG,R	A	3	1/8
PICTOR A	BLG,L.R	A	3	1/2
AKN 120	BLG	A	2	1/16
MGC-2-58-22	BLG	B	3	1
ESO 141-655	BLG	B	1	1-1/2

For all objects the best fitting was obtained using an exponential distribution function, except for NGC1052 (Table 1) and NGC3281 (Table 2) for which a step function has been used.

Finally the profile of other lines can be calculated by the same method presented in the previous section. At present, no observations of these lines are available. Since, for a given model, the line profiles depend on the ion, in the future, comparison of theoretical to observed profile for different ions could contribute to a better understanding of the narrow line region of the active galactic nuclei.

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DISCUSSION

DULTZIN: Es realmente muy importante extender esos modelos a la regiõn de lĩneas anchas. Yo creo que hay evidencia fuerte en favor de que algunas lĩneas de baja ionizaciõn (en mi trabajo afirmo que el Fe II õptico y el Si II) no pueden emitirse por fotoionizaciõn ni siquiera en nubes de muy alta densidad. Deben ser emitidas por regiones ionizadas colisionalmente.

ALDROVANDI: Faz parte dos projetos estender os modelos para a BLR, mas hâ um problema de tempo de computaçao, o programa serâ muito caro.

PEIMBERT: ¿Tus resultados sobre eyecciõn de materia en lugar de acreciõn estân en contradicciõn con la hipõtesis de que la fuente de energĩa se debe a acreciõn de materia por un hoyo negro central?

ALDROVANDI: O tamanho caracterĩstico da region das linhas de emissan estreitas ê muito maior que o do disco de acresçan. Aluie disso observam-se jatos radio soindo da region central.

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