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THE LATE TYPE SPIRAL GALAXY NGC 7793. I. ABUNDANCES OF HII REGIONS

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ABSTRACT

Four HII regions of the Sd galaxy NGC 7793 were observed using AAT/IPCS. From these spectra we determined abundances of the elements using observed emission lines and electron temperatures. The calculated abundances show that this galaxy does not show any significant radial abundance gradient. The mean oxygen abundance is very much like the Orion nebulae and the nitrogen abundance is similar to the late type barred spiral galaxy NGC 1313.

I. INTRODUCTION

NGC 7793 is the fifth brightest galaxy in Sculptor group. It belongs to the pure disk galaxies which show no apparent bulge and in which the bulge contributes very little(2~3%) to the total luminosity. The rotation curve of this galaxy shows the normal circular motion, which has a much slower rise and reaches a smaller maximum rotation velocity(75km/s) close to the optical radius.

The morphological appearance of NGC 7793 is more or less diffuse and it exhibits a very chaotic and ill-defined multiple spiral arms pattern, in contrast to the well-defined and symmetric two arms pattern of earlier type systems. The corrected face-on colours are $(B-V)_0=0.46$, $(U-B)_0=-0.15$ (de Vaucouleurs and Davoust 1980), which implies an important star formation activity. In fact NGC 7793 has a large number of bright HII regions (more than 300 HII regions) and young star association.

One important features of the pure disk galaxies like NGC 7793, that comes from abundance studies (Pagel et al. 1979), is their nitrogen deficiency which shows in their very small [NII]/[SII] line ratio (typically one-fourth of the value seen in a normal HII region). If nitrogen is a secondary product of nucleosynthesis(sulphur is primary), those observations imply that star formation proceeds more slowly or started later in those systems than in earlier types. On the other hand, if a substantial component of nitrogen is a primary product whose yield depends on the age and/or initial mass function(Edmunds and Pagel 1978), the interpretation of this result is not as straightforward.

Often HII regions in spiral galaxies show a radial abundance gradient in oxygen like M83 (Dufour et al. 1980), M101 (Shields and Searle 1978), M 33 (Smith 1975) and NGC 300 (Pagel et al. 1979, paper 1) by a factor of 10 between inner and outer region. On the other hand, investigation of the Magellanic Clouds (Pagel et al. 1978), NGC 1313 and 6822 (Pagel et. al. 1980), NGC 1365 (Pagel et al. 1979) shows only a marginal or none in O/H radial gradient.

The main purpose of this paper is the study of four HII regions in the late type spiral galaxy NGC 7793. From this study we want to see if we can find a correlation between the presence or absence of an abundance gradient in a galaxy and its other characteristics. Relevant properties

Table 1. Properties of NGC 7793.

R.A. (1950)(1)	$23^h55^m.26$
Dec. (1950)(1)	$-32°52'.1$
BGC rev type(1)	SAS 8
Other type(1)	Sdm
D_o, arc min(1)	$8'.7$
V_o, Kms^{-1}(1)	214
Distance, Mpc(2)	2.5
Linear scale of 1 arc min, kpc(2)	0.91
Inclination(2)	53°
Position angle of nodes(2)	97°

(1) de Vaucouleurs et al. 1976 (BGC)
(2) de Vaucouleurs and Davoust, 1980.

Table 2. Corrected Line Intensities Log I_c in NGC 7793.

	Ident	$f(\lambda)$	H5(1)	H29(2)	H23(3)	W11(4)
3727	[OII]	.32	2.74	2.76	2.62	2.47
3798	H10	.29	0.44	0.27	1.03	0.90
3835	H9	.28	1.01	0.55	0.85	0.46
3869	[NeIII]	.27	0.68	0.63	0.99	1.09
3889	H8	.27	1.16	1.18	0.25	0.42
3967	[NeIII]	.24	0.74	0.95	0.88	0.90
4026	HeI	.23		0.05	−0.66	−0.02
4068+76	[SII]	.21	0.68	−0.03	1.07	1.03
			0.47	0.78	0.28	0.03
4102	H_δ	.20	1.38	1.29	1.42	1.47
4340	H_γ	.14	1.64	1.66	1.64	1.64
4363	[OIII]	.13	0.47	0.27	1.06	0.93
4472	HeI	.11	0.62	0.68	0.27	
4686	HeII	.05	0.45	0.50	0.83	0.88
4861	H_β	.00	2.00	2.00	2.00	2.00
4959	[OIII]	−.20	1.33	1.73	1.96	2.03
5007	[OIII]	−.03	1.81	2.18	2.40	2.46
5198	NI	−.08	0.63	0.51	0.95	1.07
5518	[ClIII]	−.14	−0.42	0.49	0.73	0.70
5538	[ClIII]	−.15	0.69	−0.38	0.57	0.63
5755	[NII]	−.19		0.54		
5876	HeI	−.21	1.10	0.99	1.10	0.89
6300	OI	−.29	1.65	1.63	2.00	1.70
6311	[SIII]	−.29	0.12		1.03	1.01
6363	OI	−.30	1.14	1.06	1.49	1.06
6548	[NII]	−.33	1.22	1.15	0.98	0.95
6563	H_α	−.34	2.34	2.41	2.37	2.46
6584	[NII]	−.34	1.57	1.56	0.80	1.00
6678	HeI	−.36	0.12	0.41	0.15	0.58
6717	[SII]	−.37	1.30	1.17	1.09	0.94
6731	[SII]	−.37	1.30	0.95	1.07	1.20
7065	HeI	−.40	—	—	—	—
7136	[ArIII]	−.41	—	0.46	—	—
7320	[OII]	−.44	—	—	—	—
7330	[OII]	−.44	—	—	—	—

$\log I_c = \log I_o + Cf(\lambda)$
$I_o = I(\lambda)/I(H_\beta) \times 100$

(1) $C=1.38$
(2) $C=1.42$
(3) $C=1.27$
(4) $C=0.93$
were applied.

of this galaxy are listed in Table 1.

II. OBSERVATION AND REDUCTION

Observation was carried out using the Anglo-Australian Telescope with the RGO Cassegrain spectrograph and UCL Image Photon Counting System (Boksenberg and Burgess 1973) and reduced using standard programs at AAO as described in paper I. Figure 1 shows the summed spectrum of H 5 region in NGC 7793. Reddening-corrected line intensities are given in Table 2. The HII regions in this system that

Table 3. HII regions observed

	$\rho^{(1)}$ (arc sec)	ρ/ρ_0	$R^{(2)}$ (kpc)
H5	174	0.68	2.6
H29	143	0.56	2.2
H23	72	0.28	1.1
W11	317	1.24	4.8

(1) Angular distance from nucleus, corrected for projection.
(2) Calculated radial distance using a distance scale in Table 1.

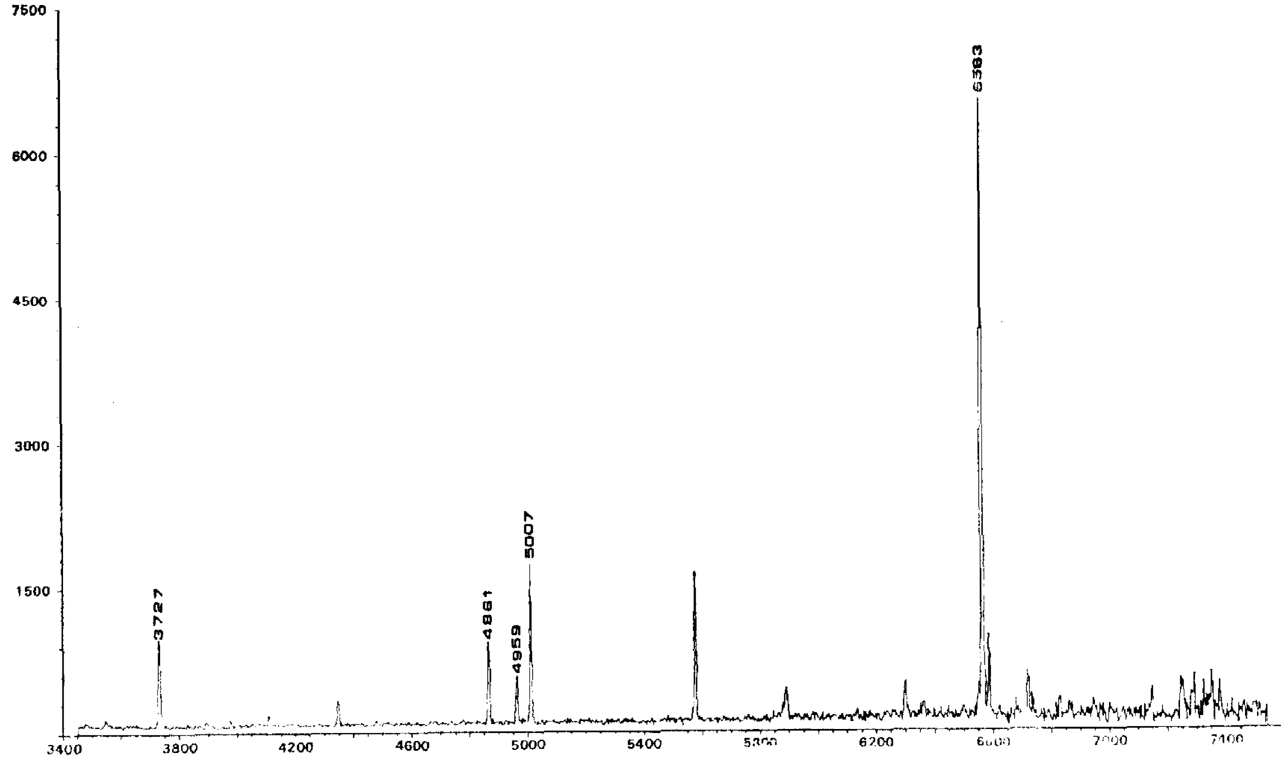

Fig 1. Summed spectrum of NGC 7793, region H5.

we have observed, come from the catalogue by Hodge (1969) and denoted as H. Properties of observed HII regions are listed in Table 3.

III. ABUNDANCE ANALYSIS

There are basically two ways of estimating abundances in HII regions. One is semi-empirical method which depends on the observation of weak temperature-sensitive lines and the other is model-fitting which can be carried out without such observations, provided that the model is known to be realistic. In our observation temperature discriminating lines (for example [OIII] 4363 and [OII] 7325) have been observed in a few cases and even with the large errors, we therefore use a semi-empirical procedure of model fitting.

The basic datum needed for abundance analysis is the electron temperature. Densities are not important in the present context, since the [SII] red line ratio is invariably at the low density limit (i.e. $X=10^{-4}nt^{-1/2}\leq 10^{-2}$ where n is the electron density in cm^{-3} and t is the electron temperature in unit of 10^4 °K). In the case of typical low abundance HII regions, temperature is easily determined from [OIII] 4363/5007, but with increasing oxygen abundance the temperature goes down because of enhanced cooling and softening of the radiation field which also cut down [OIII]; both factors conspire to make [OIII] 4363 disappear very rapidly with increasing abundance.

The choice among the wide range of possible models is limited by the fact that extragalactic HII regions do not depart much from a one-parameter sequence. However, if we can not applied directly to the model, we approach the domain where empirical abundances are available from the work of Shields and Searle (1978) and Smith (1975), so that it should be possible to estimate the oxygen abundance by an interpolation method on either [OIII] or [OIII]/[OII], having done this, we can deduce the unobserved electron temperature and hence obtained abundances of nitrogen and neon by conventional method.

In Figuge 7 in paper I, we have combined theoretical and empirical data to study relationship between oxygen abundance and [OII]+[OIII] intensities. In that figure we had drawn an adopted curve arbitrarily, but fortunately the slope of the curve in the low excitation domain are flat that the errors due to the arbitrariness are unlikely to exceed ±0.1 dex, and the credibility of the two low excitation models checked by some previous observational criteria (paper I) gave the excellent agreement. However, we assumed the probable error of our oxygen abundances will be ± 0.15 dex.

The electron temperature was deduced from the combined observed and predicted model in Figure 8 in paper I. The observations and models define a tight relationship, and our arbitrary curve can be expected to give electron temperatures good enough to determine N/O and Ne/O, which are not extremely sensitive to temperature. As we assumed zero temperature fluctuations throughout, we neglected local temperature fluctuations.

The other abundances like O/S, O/Ar, O/Cl are calculated as the same method as in paper I. All calculated abundances with the radial distances and electron temperatures for each observed regions are listed in Table 4.

The oxygen abundances found in Table 4 agree satisfactorily (within 0.16 dex and usually less) between the model fitting and electron temperature's method. Stasinska's prediction (1978) that the fraction of Ne^{++} is only half that of O^{++} would lead to a surprisingly high neon abundance in most of the HII regions we have observed, and so we prefer to adopt the conventional ionization correction scheme $Ne/O = Ne^{++}/O^{++}$, as well as N^{+}/O^{+} which Stasinska (1978) confirms.

Table 4. Electron temperatures and abundances in the HII regions of NGC 7793.

	H5	H29	H23	W11
ρ/ρ_0	0.68	0.56	0.28	1.24
[OII]+[OIII]/H_β	6.34	6.17	7.73	6.97
⟨t⟩	0.88	0.86	0.98	0.92
12+log O^{++}/H^{+}	7.52	7.95	7.93	8.09
12+log O^{+}/H^{+}	8.58	8.47	8.23	8.20
12+log O/H	8.62	8.59	8.41	8.45
log O^{+}/N^{+}	1.54	1.49	1.86	1.68
log O^{+}/S^{+}	2.34	2.48	2.36	2.24
log O^{+}/S^{++}	1.80	1.49	0.78	0.63
log O/S	1.69	1.45	0.77	0.63
log O^{++}/Ne^{++}	0.63	1.10	0.95	0.89
log O^{++}/Ar^{++}	1.94			
log O^{+}/Cl^{++}	3.15	3.75	2.72	2.59
$O^{++}/O^{+}+O^{++}$	0.14	0.35	0.46	0.58

IV. DISCUSSIONS

Radial abundances of HII regions in NGC 7793 from Table 4 are displayed in Figures 2a and 2b. From these figures we can say that the radial abundance gradient is not present unlike in M101 and NGC 300. Even NGC 7793 has a normal circular motion and is classified as a late type spiral galaxy, the radial abundance gradient was not shown there. In paper I we assumed that the radial gradient of HII regions is correlated with the overall circular motion. For

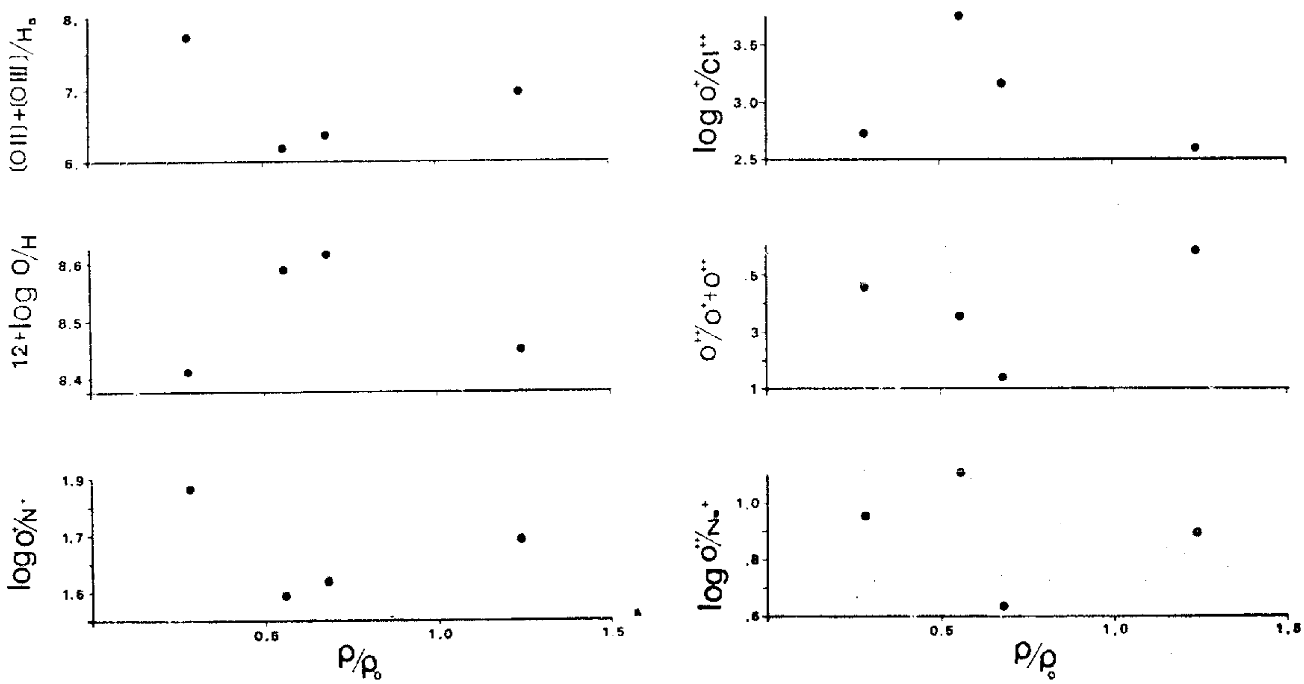

Fig 2a and 2b. Various abundances plotted against normalised radial distance.

example the abundance gradient in spiral galaxies may be suppressed by large scale non-circular motion, so we can not detect the gradient. For the late spiral galaxies with normal circular motion, there will be an abundance gradient. The present result of NGC 7793 makes us puzzle to give any convinced assumption for this radial abundance gradient in late type spiral galaxies.

Assuming the same principle to apply to He 5876 as in paper I, we find a helium abundance relative to hydrogen, Y=0.083 in NGC 7793, with an observational error of ± 20 percent. This value agrees well with the mean helium abundance of HII regions in spiral galaxies. The mean oxygen, nitrogen and sulphur abundance of NGC 7793 are [O/H]=0.39, [N/O] $=-0.71$, [S/O]=0.36. These mean values indicate that oxygen abundance of NGC 7793 is the similar value with the late type spiral galaxy NGC 300, while nitrogen abundance is close to NGC 6822.

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