NEW SOUTHERN GALAXIES WITH ACTIVE NUCLEI

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ABSTRACT

In this paper we present a list of active-galactic-nuclei candidates, identified from optical spectra taken as part of an ongoing redshift survey of southern galaxies. Using standard diagnostics, several new Seyferts and LINERs have been identified among the emission-line galaxies observed.

I. INTRODUCTION

Over the past few years, we have been carrying out a large-scale redshift survey of the southern skies (da Costa *et al.* 1984) and have accumulated over 1200 spectra of the nuclear region of galaxies. While the vast majority of our data are in the southern galactic cap ($b \leqslant -30°$), we have also observed galaxies near the Centaurus cluster as part of an investigation of the Centaurus-Hydra supercluster (da Costa *et al.* 1986). The ultimate goal of our survey is to complete a wide-angle redshift survey of the southern hemisphere down to the same magnitude limit ($m_B = 14.5$) and radial-velocity accuracy of the CfA Redshift Survey. Unfortunately, because the photometric data in the south are sparse, galaxies were primarily selected from a diameter-limited sample drawn from the ESO/Uppsala Catalog (Lauberts 1982), and our magnitude limit is probably fainter than 14.5. We should mention that our sky coverage is not uniform, with most of our observations being north of $\delta = -50°$, because the southern survey effort has been shared with other observers using the Las Campanas Observatory and the South African Astronomical Observatory.

Since our effort is near completion, we have examined the spectra of the emission-line galaxies observed at the Observatório Nacional (ON) in order to identify nonstellar nuclear activity and generate a list of active-galactic-nuclei (AGN) candidates. Our intention has not been to produce a statistically complete sample of active galaxies but simply to provide other observers with a preliminary list of potentially interesting objects for future and more thorough work.

II. OBSERVATIONS

The observations for the redshift survey are made utilizing a Cassegrain spectrograph and a photon-counting Reticon detector on the 60 in. telescope of the ON. The observations reported here were made through a pair of 3×12 arcsec entrance apertures separated by 30 arcsec on the sky for simultaneous object and sky exposures. Most observations were made using a 900 line/mm grating, giving a dispersion of ~ 100 Å/mm with a typical resolution of 6 Å (FWHM). The wavelength coverage is from about λ 4700 to λ 7100. This spectral range includes the emission lines of Hβ, [O III] $\lambda\lambda$ 4959, 5007, [O I] λ 6300, and the Hα-[N II]-[S II] complex of lines.

In general, our spectra have a relatively low signal-to-noise ratio, similar to the data used by Huchra, Wyatt, and Davis (1982), since our primary goal was to obtain redshifts for a large number of galaxies. Nevertheless, for a substantial number of objects the spectra are of sufficient quality to allow the detection of possible nuclear activity. Time constraints and lack of photometric sky conditions during most of the observing periods have prevented us from systematically observing photometric standard stars and thus we have not been able to convert our spectra into flux units.

III. RESULTS

Visual inspection of the available emission-line spectra reveals a great variety of spectral properties. We have examined each spectrum and tentatively classified them as H II regions or AGN, essentially following the method developed by Baldwin, Phillips, and Terlevich (1981). According to this method, conventional H II region emission can be distinguished from that associated with Seyfert-like activity or low-ionization nuclear-emission regions (LINERs, Heckman 1980) simply on the basis of the emission-line ratios [N II] λ 6583/Hα and [O III] λ 5007/Hβ. The exact boundary separating the different classes is uncertain but, in general, it is assumed that objects with λ 5007/H$\beta > 3$ and λ 6583/H$\alpha > 0.7$ are Seyferts, objects with λ 5007/H$\beta < 3$ and λ 6583/H$\alpha > 0.7$ are LINERs, and the remainder are nuclear H II regions (e.g., Shuder and Osterbrock 1981; Keel *et al.* 1985; Bushouse 1986). In addition, galaxies without detected λ 5007 were classified as LINERs if [N II] λ 6583/H$\alpha > 0.7$ (Keel *et al.* 1985). Whenever possible, the aforementioned line ratios were estimated using the ratios of the corresponding equivalent widths. This is a satisfactory approximation, at least for the contiguous lines of Hα and [N II], except in objects where Hα is blended with the λ 6583 line. The λ 5007/Hβ ratio is less well determined because Hβ, although visible, is usually too weak for a reliable determination of its equivalent width. The estimate of this ratio based on the equivalent widths is also more sensitive to the intrinsic variation of the underlying continuum. However, in most cases the apparent relative prominence of these two lines is sufficient to unambiguously distinguish between the Seyfert and LINER domains.

Our classification must also be considered as preliminary, especially for the weak-emission galaxies, because we have not corrected the spectra for underlying stellar absorption, interstellar reddening, and blending of lines. Our approximate equivalent-width cutoff is estimated to be about 3 Å in λ 6583. As is usually the case, there are several borderline objects, not only due to limitations of our data but also because AGN may form a continuous sequence ranging from LINERs to Seyferts.

Table I gives the identification, coordinates, and morphological type (Lauberts 1982; Vorontsov-Velyaminov and Arkhipova 1968), measured heliocentric radial velocity, and proposed emission type for the galaxies showing evidence of nonstellar nuclear activity. The different symbols used to identify the type of emission stand for: Seyferts (S);

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TABLE I. AGN candidates.

Galaxy	R. A. (1950)	Dec. (1950)	Morphological type	V (km/s)	Emission type	EW (Å) [O III]	EW (Å) Hα
ESO 538-G25	00^{h}08^{m}4	−21°21′	S0	7783	S	12.4	—
ESO 194-G4	00^{h}17^{m}2	−51°33′	S0a	6603	L	—	4.9
NGC 235	00^{h}40^{m}4	−23°49′	S0	6692	S	27.8	9.8
ESO 540-G17	00^{h}41^{m}9	−17°37′	Sa?	9305	S	6.0	6.0
ESO 411-G29	00^{h}52^{m}5	−32°18′	S0a	9622	L/S	—	—
NGC 334	00^{h}56^{m}5	−35°23′	Sb	9220	L	0.9	4.2
IC 1657	01^{h}11^{m}8	−32°55′	Sb	3564	S/L	5.6	8.4
ESO 244-G17	01^{h}18^{m}1	−44°23′	SB(r)a	7059	S	23.5	9.8
ESO 353-G9	01^{h}29^{m}6	−33°23′	S(r)a	4970	S	9.7	9.5
NGC 619	01^{h}32^{m}6	−36°45′	SBb	8522	L?	—	—
ESO 353-G38	01^{h}41^{m}4	−33°57′	Double?	8884	S	—	—
ESO 354-G4	01^{h}49^{m}5	−36°26′	Sa	10046	S	12.5	—
IC 1816	02^{h}29^{m}8	−36°53′	Sa–b	5215	S	19.8	—
ESO 416-G9	02^{h}40^{m}2	−30°32′	S0a	6518	L?	—	—
IC 1859	02^{h}47^{m}0	−31°23′	Sc	6006	S?	—	8.2
ESO 299-G20	02^{h}47^{m}6	−38°59′	Sa	5008	S	4.2	3.2
ESO 417-G6	02^{h}54^{m}3	−32°23′	S0	4901	S	29.5	—
IC 1904	03^{h}12^{m}9	−30°54′	Sa–b	4660	L/S	6.3	18.0
ESO 481-G17	03^{h}14^{m}9	−23°03′	S(r)a	3943	L	—	3.6
NGC 1301	03^{h}18^{m}3	−18°54′	Sc	4023	L	—	8.0
NGC 1326	03^{h}22^{m}0	−36°38′	S(r)0a	1352	L	—	6.3
ESO 549-G36	03^{h}52^{m}9	−17°37′	Sb	8501	S	3.2	—
ESO 549-G40	03^{h}54^{m}9	−18°55′	Sb–c	7608	L	—	3.6
ESO 15-G5	04^{h}02^{m}1	−81°12′	Sa–b	4831	L?	—	—
ESO 552-G4	04^{h}45^{m}3	−17°41′	S0a	9021	L	—	—
ESO 485-G16	04^{h}46^{m}8	−23°49′	Sa	8144	L	—	—
ESO 552-G45	04^{h}57^{m}8	−17°32′	Sa	6575	L?	—	—
ESO 362-G8	05^{h}09^{m}3	−34°27′	S0a	4802	S	9.3	—
ESO 553-G18	05^{h}09^{m}3	−22°18′	S0	9927	L?	—	3.6
ESO 362-G18	05^{h}17^{m}7	−32°42′	Sa	3790	S	32.3	—
ESO 253-G8	05^{h}29^{m}1	−45°09′	S0	10621	S	3.1	—
ESO 438-G20	11^{h}16^{m}4	−29°09′	Sb	9081	L	—	7.0
ESO 439-G18	11^{h}35^{m}5	−32°03′	S(r)b	8887	L	—	3.2
NGC 4696	12^{h}46^{m}1	−41°02′	S0	3008	L	—	2.9
ESO 443-G17	12^{h}55^{m}0	−29°30′	SB(r:)0a	3085	L	—	25.6
ESO 443-G29	12^{h}58^{m}6	−32°08′	Sc	9414	L	—	7.0
NGC 4903	12^{h}58^{m}6	−30°40′	SBc	4974	L	—	19.2
ESO 443-G41	13^{h}00^{m}6	−31°58′	Sb	4863	L	—	—
IC 4214	13^{h}14^{m}9	−31°50′	SB(r)0(r)	2297	L	0.7	2.6
NGC 5101	13^{h}19^{m}0	−27°10′	SB(r)0a	1848	L	—	1.1
IC 4253	13^{h}24^{m}8	−27°37′	Sb	10197	S	5.3	—
IC 4290	13^{h}32^{m}5	−27°46′	SB(r)a	4869	L?	—	4.6
NGC 5298	13^{h}45^{m}7	−30°11′	Sb	4420	L	—	—
ESO 445-G51	13^{h}46^{m}5	−27°57′	Sa	4995	L/S	2.9	7.7
NGC 5393	13^{h}57^{m}7	−28°38′	Sa	6019	L	—	—
ESO 510-G46	13^{h}59^{m}1	−25°18′	Sa	6389	S	8.6	—
IC 4374	14^{h}04^{m}6	−26°47′	S0	6534	L	—	1.6
NGC 6860	20^{h}04^{m}5	−61°15′	Sa	4479	S	20.1	—
ESO 462-G9	20^{h}18^{m}7	−31°27′	Sa	5796	S?	17.0	23.1
IC 5064	20^{h}48^{m}8	−57°25′	Sa	3377	S	8.1	8.4
ESO 286-G18	20^{h}54^{m}5	−43°34′	Sb	9162	L?	—	—
ESO 530-G42	21^{h}20^{m}2	−22°43′	S0	9674	L?	—	10.7
ESO 530-G47	21^{h}24^{m}2	−23°13′	Sa	9762	S?	32.3	31.1
ESO 404-G15	21^{h}57^{m}5	−33°37′	Sa	4480	L	—	6.6
IC 1417	21^{h}57^{m}6	−13°22′		5446	S	7.8	—
ESO 532-G12	21^{h}59^{m}1	−22°44′	S0(r)	5330	L	—	6.2
IC 5169	22^{h}07^{m}2	−36°20′	S(r)0(a)	3028	S	8.0	20.0
IC 1439	22^{h}13^{m}9	−21°44′	S(r:)a	9649	L?	—	5.2
IC 5212	22^{h}20^{m}6	−38°17′	S0a	8320	L?	—	—
NGC 7279	22^{h}24^{m}3	−35°24′	Sc	9097	L	—	21.5
NGC 7378	22^{h}45^{m}3	−12°05′		2580	S	24.1	8.9
ESO 291-G9	23^{h}11^{m}2	−43°00′	S0	16923	L	—	—
IC 1495	23^{h}28^{m}2	−13°47′		6392	S	20.7	8.6
ESO 292-G9	23^{h}37^{m}7	−44°48′	Sb	15462	S	12.7	11.3
NGC 7733	23^{h}39^{m}8	−66°14′	SB...	10198	S	16.4	23.5
NGC 7734	23^{h}39^{m}9	−66°13′	Sa–b	10624	S/L	—	4.6
ESO 349-G9	23^{h}54^{m}4	−34°57′	Sb	12641	L	—	10.5
ESO 349-G10	23^{h}54^{m}4	−35°02′	S0	14696	L?	—	—

LINERs (L); borderline cases between different classes of active galaxies (S/L, L/S) and between AGN and normal H II emission regions (S?, L?). Finally, in the last two columns we also give the estimated equivalent widths of the lines [O III] λ 5007 and Hα, whenever available from our analysis routine. This information is included as a guide for future observations. We note that several well-known southern active galaxies have also been observed and were classified following the same procedure adopted here. Comparison of our classification of these galaxies with that available in the literature shows good agreement, giving support to our criteria. A search through the recent literature and the catalog compiled by Véron-Cetty and Véron (1985) reveals that the 68 objects listed in Table I, including 29 Seyferts and 39 LINERs, are new identifications. Typical examples of spectra of the different classes of objects considered here are shown in Fig. 1.

Out of the 29 objects in the Seyfert class, there are five which show broad Hα emission, typical of Seyfert 1 galaxies. The raw spectra for these galaxies are plotted in Fig. 2, together with the spectrum of the well-known Seyfert 1 galaxy NGC 7213 (e.g., Filippenko and Halpern 1984).

IV. DISCUSSION

From over 1200 available galaxy spectra in the southern hemisphere, we have found that about 650 are emission-line galaxies. While a large fraction show spectral features typical of nuclear H II regions, several objects satisfy the criteria often used to identify nonstellar nuclear activity. Although we have not attempted to subclassify the Seyferts, the five galaxies identified as Seyfert 1 seem to have Hα emission over a velocity range in excess of 3000 km s^{-1}. An outstanding example is the broad Balmer component exhibited by the galaxy ESO 354-G4. In the case of IC 1816 the detection of strong emission in the forbidden lines of [Fe VII] λ 6087 and [Fe X] λ 6374 has also been used as additional evidence in favor of assigning it as a Type 1 Seyfert. Both spectra are shown in Fig. 3 in the domain $\lambda\lambda$ 6300–7000 Å. Two other Type 1 candidates are the galaxies IC 4253 and ESO 244-G17, but a more secure classification depends on the confirmation of the existence of a broad Hα component, difficult to detect because of the underlying stellar continuum.

We have also discovered 39 galaxies exhibiting LINER-like spectra, the great majority occurring in early-type galaxies, as expected from previous work (e.g., Heckman 1980; Keel 1983). We note that the identification of LINERs is more difficult since in general the emission lines are weak in these objects. It is interesting that in addition to the objects listed in Table I a substantial fraction of the weak-emission galaxies observed have [N II] λ 6583 stronger than Hα, suggesting that they could also be classified as LINERs. However, since the Hα emission may be strongly affected by the underlying continuum we have not attempted to classify these more extreme cases. Also worth mentioning is the fact that several LINERs show some evidence of a weak Hα broad component, similar to the findings of Filippenko and Sargent (1985). Unfortunately, our spectra are not adequate to search for such weak features in the line profiles.

The objects compiled in the present work form a useful

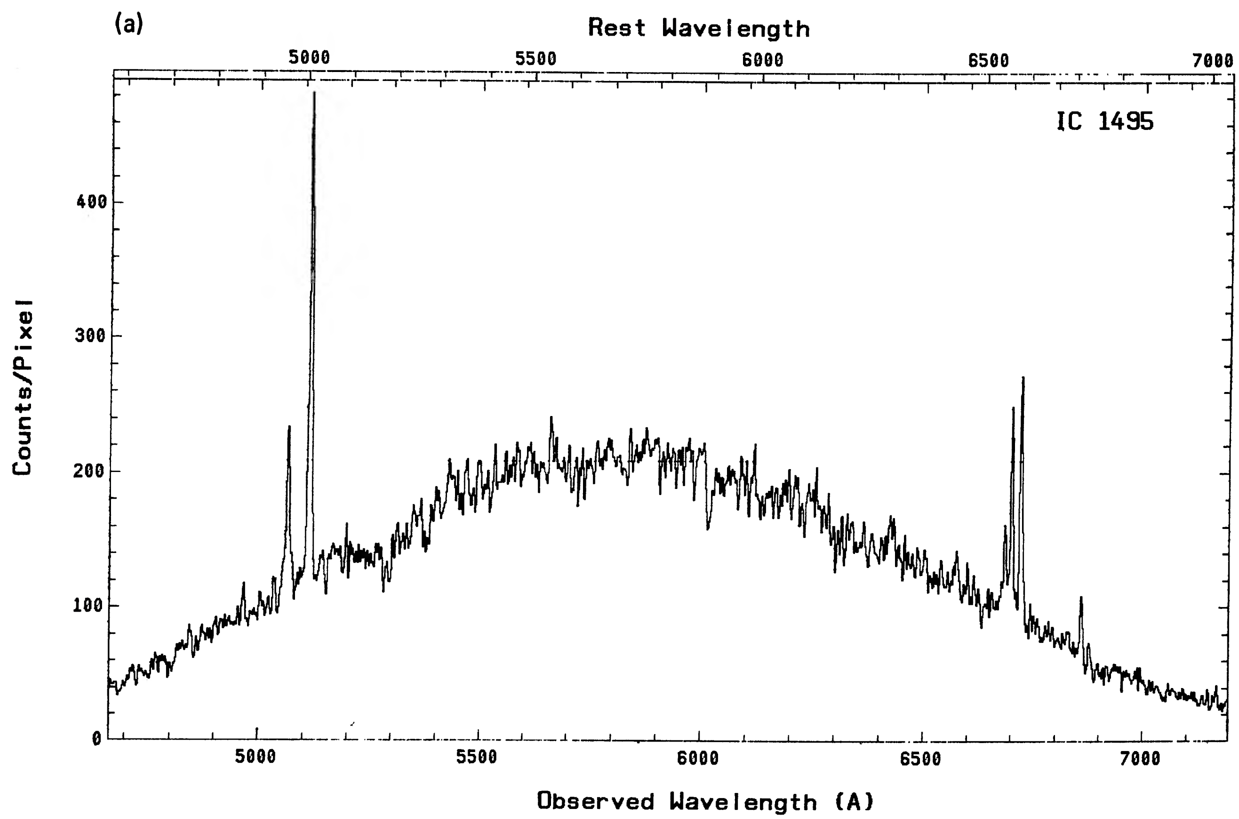
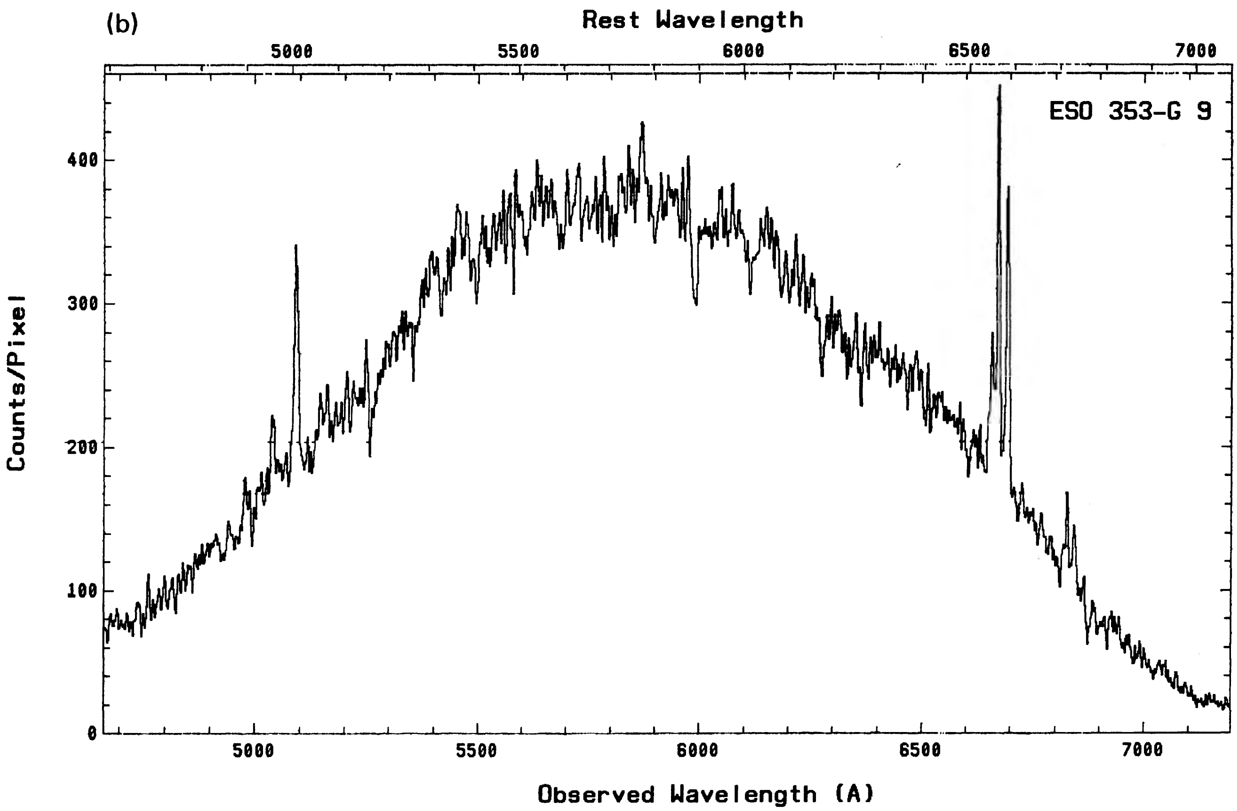


FIG. 1. Spectra of eight galaxies showing examples of the different classes of objects. The following cases are plotted: Seyferts (a,b); LINERs (c,d); borderline cases S/L (e), L/S (f), S? (g), and L? (h).



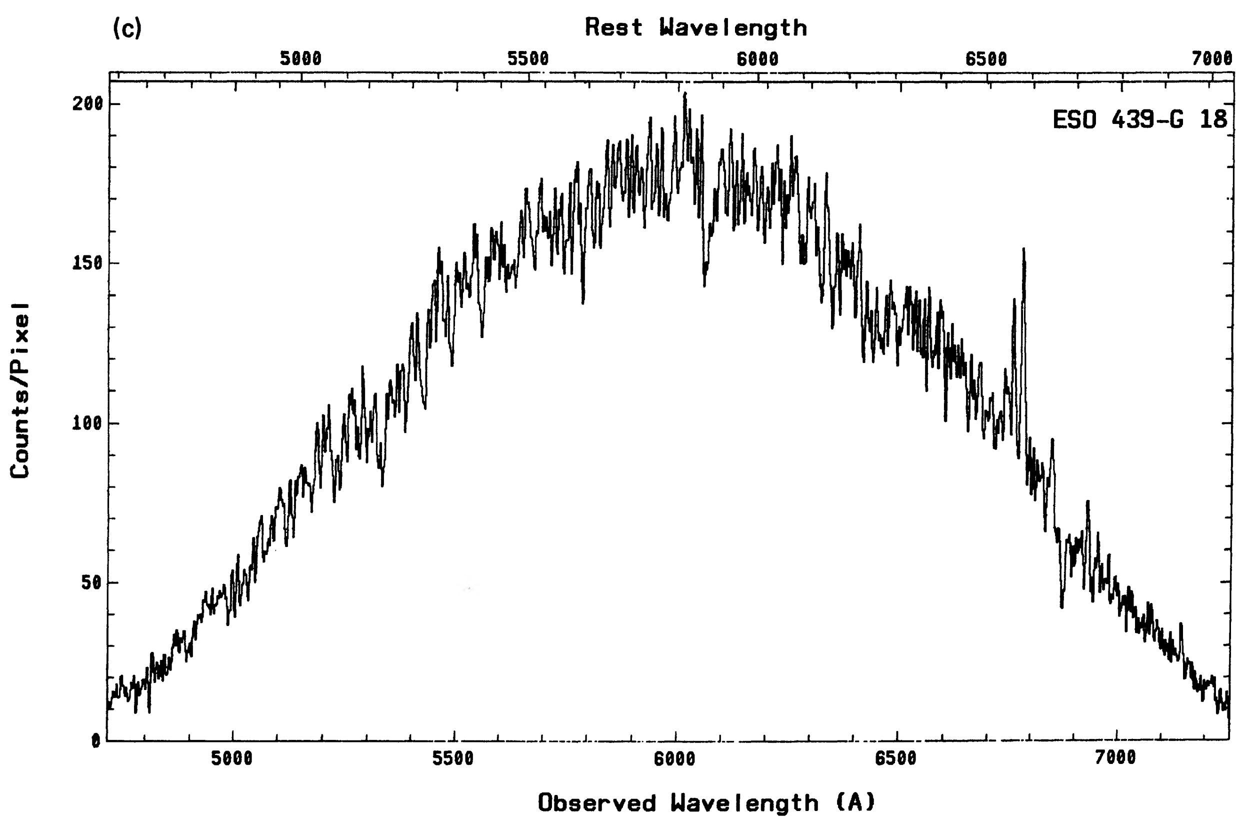
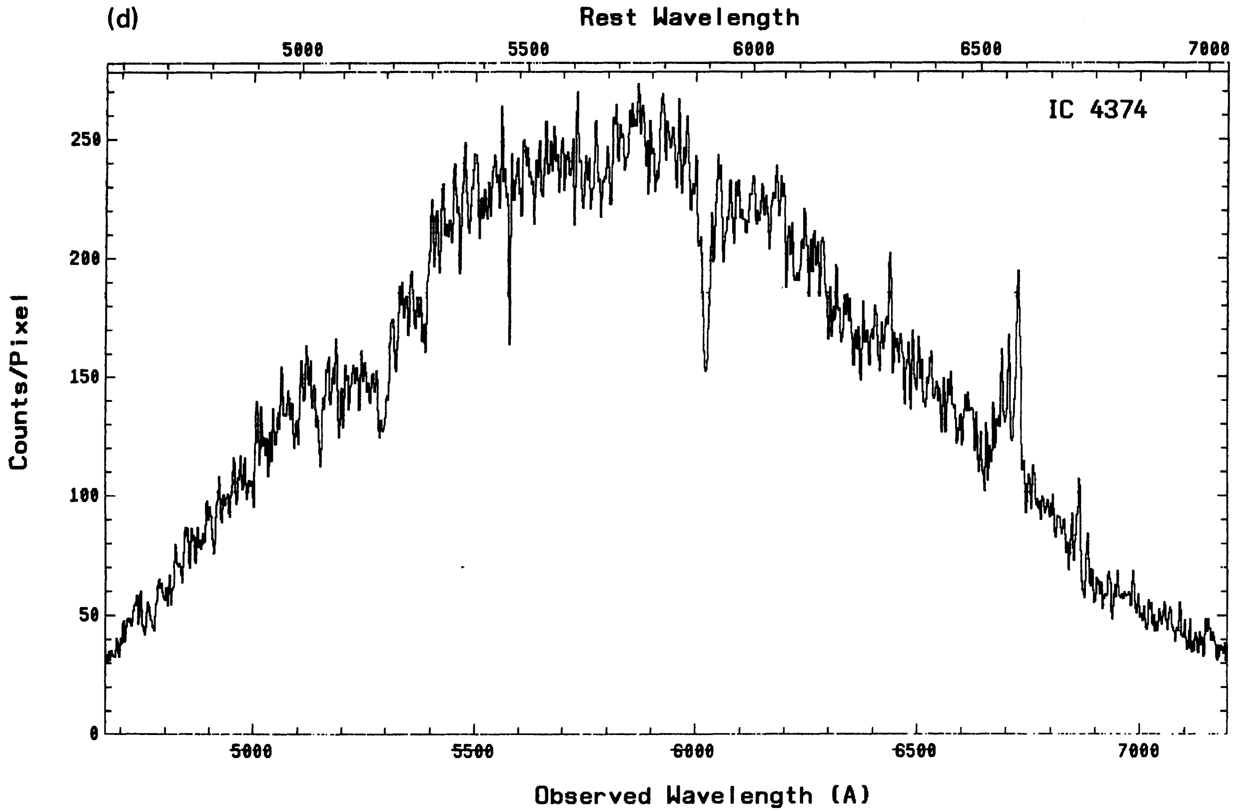
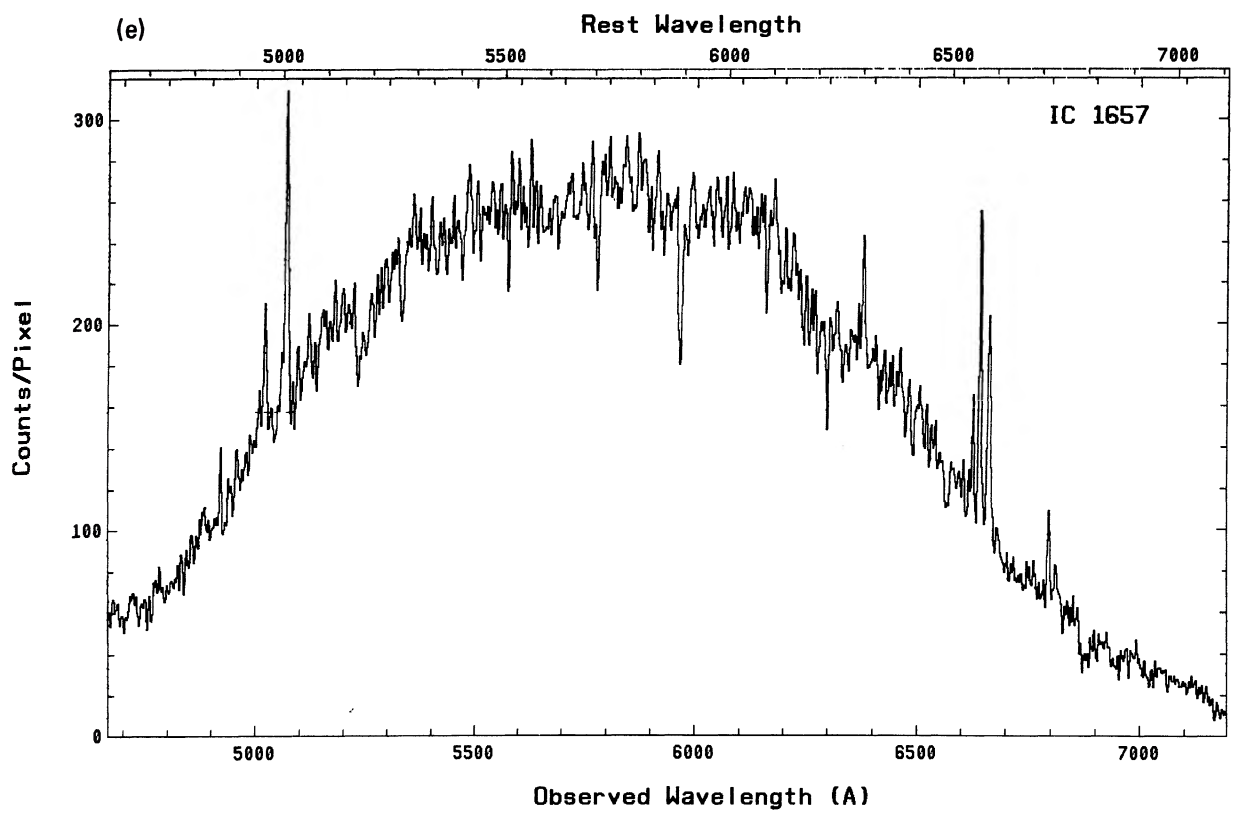


FIG. 1. (continued)





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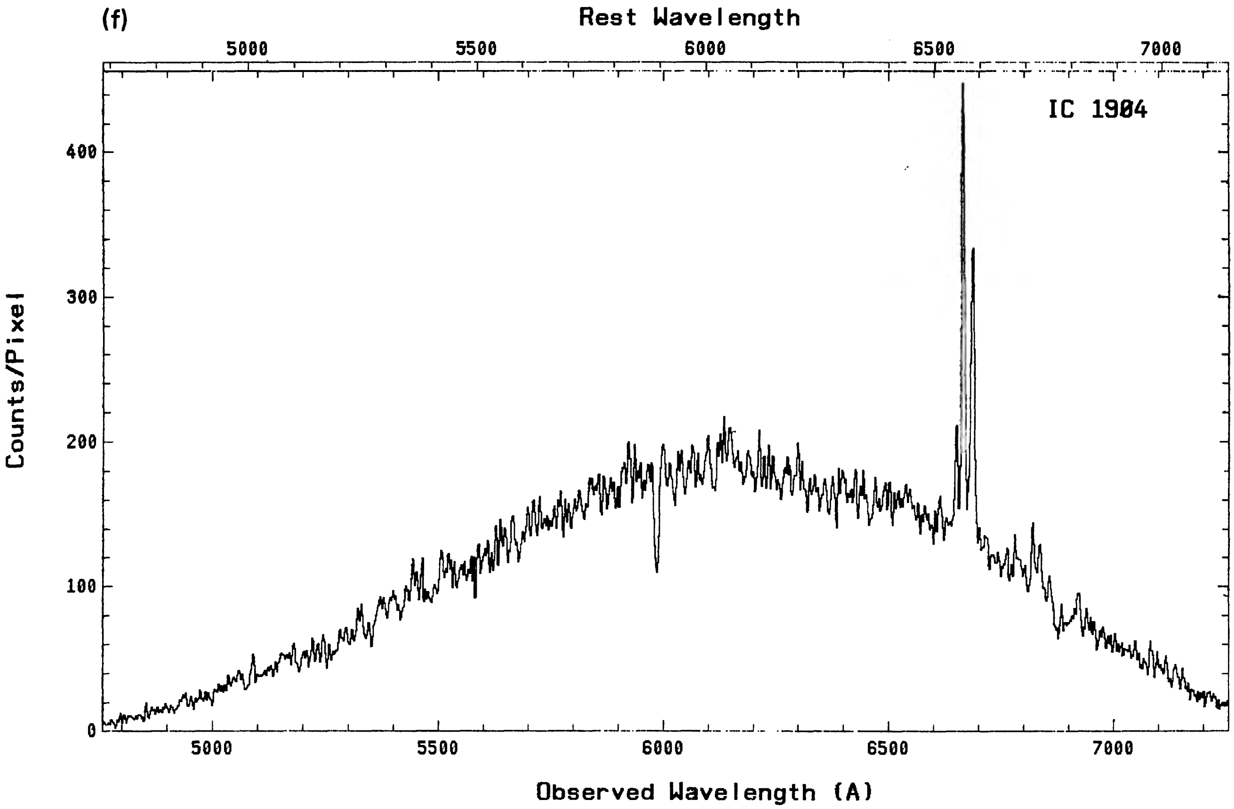


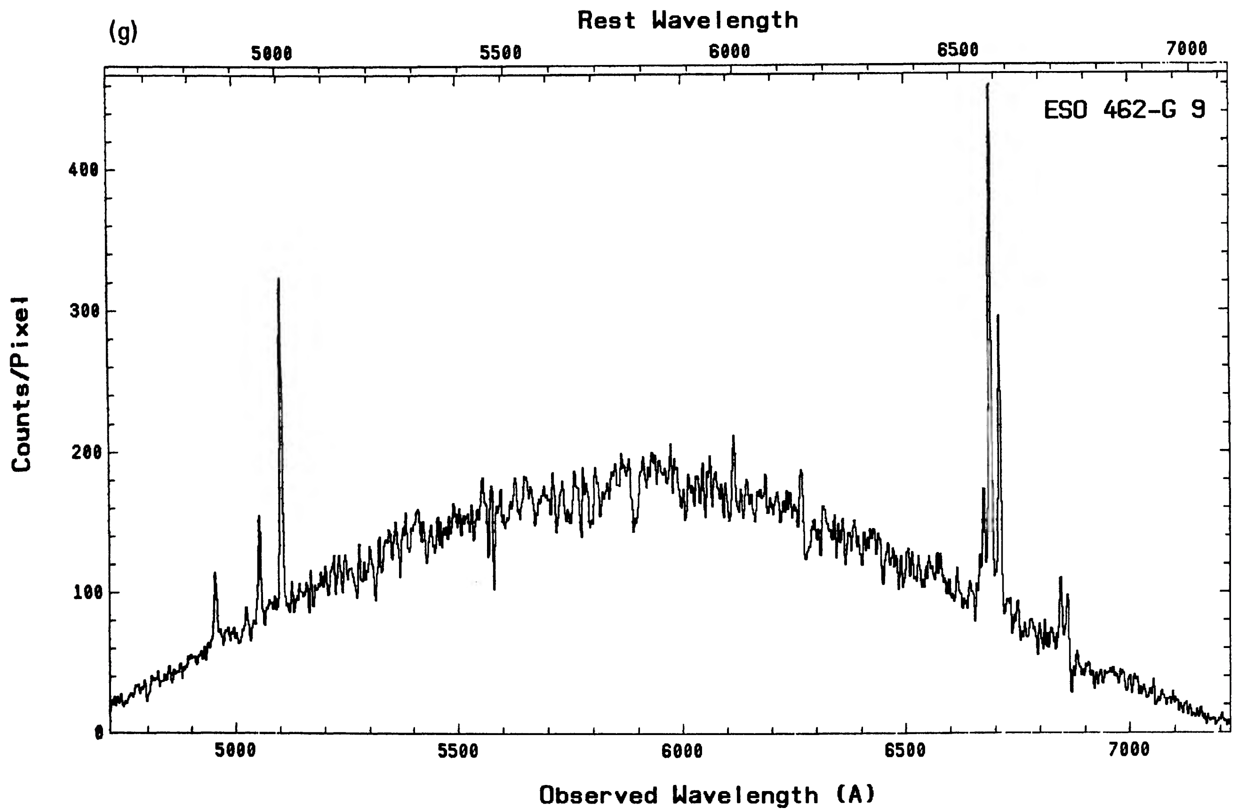


FIG. 1. (continued)

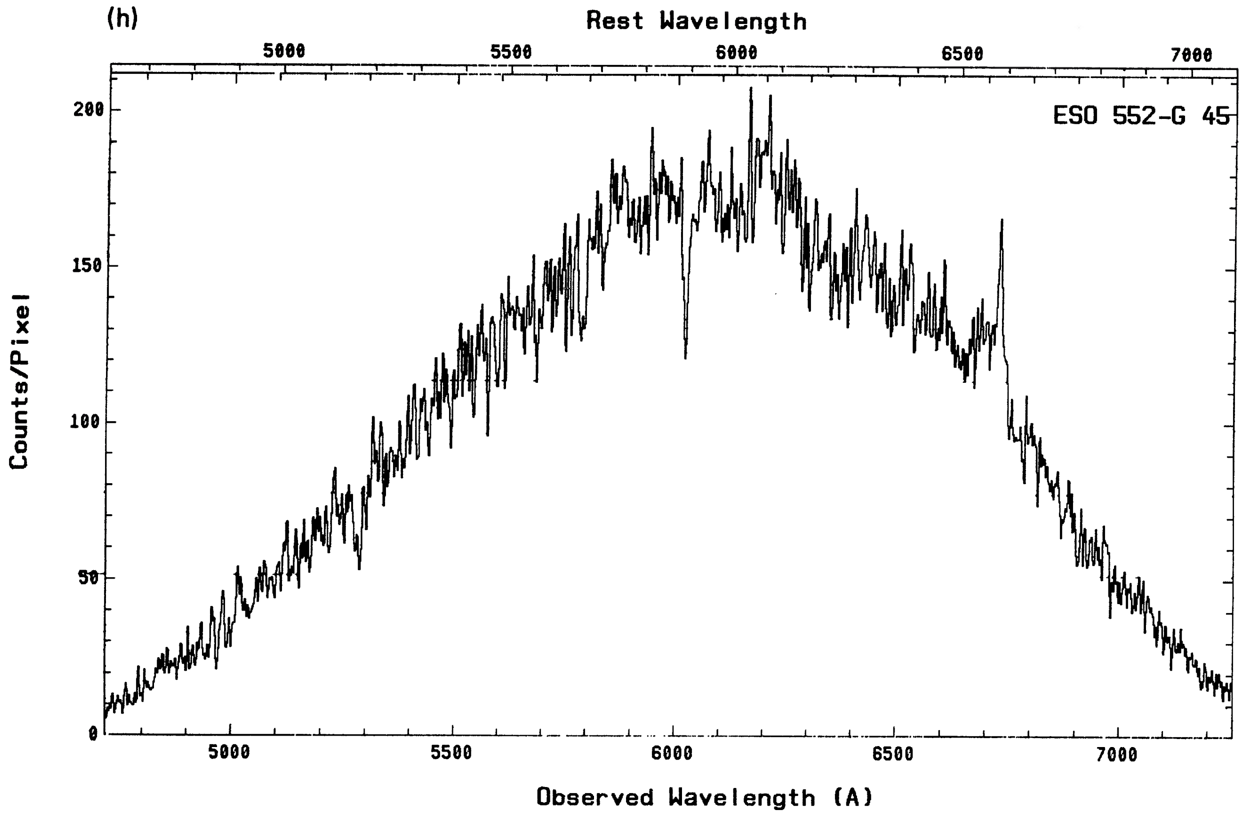


FIG. 1. (continued)

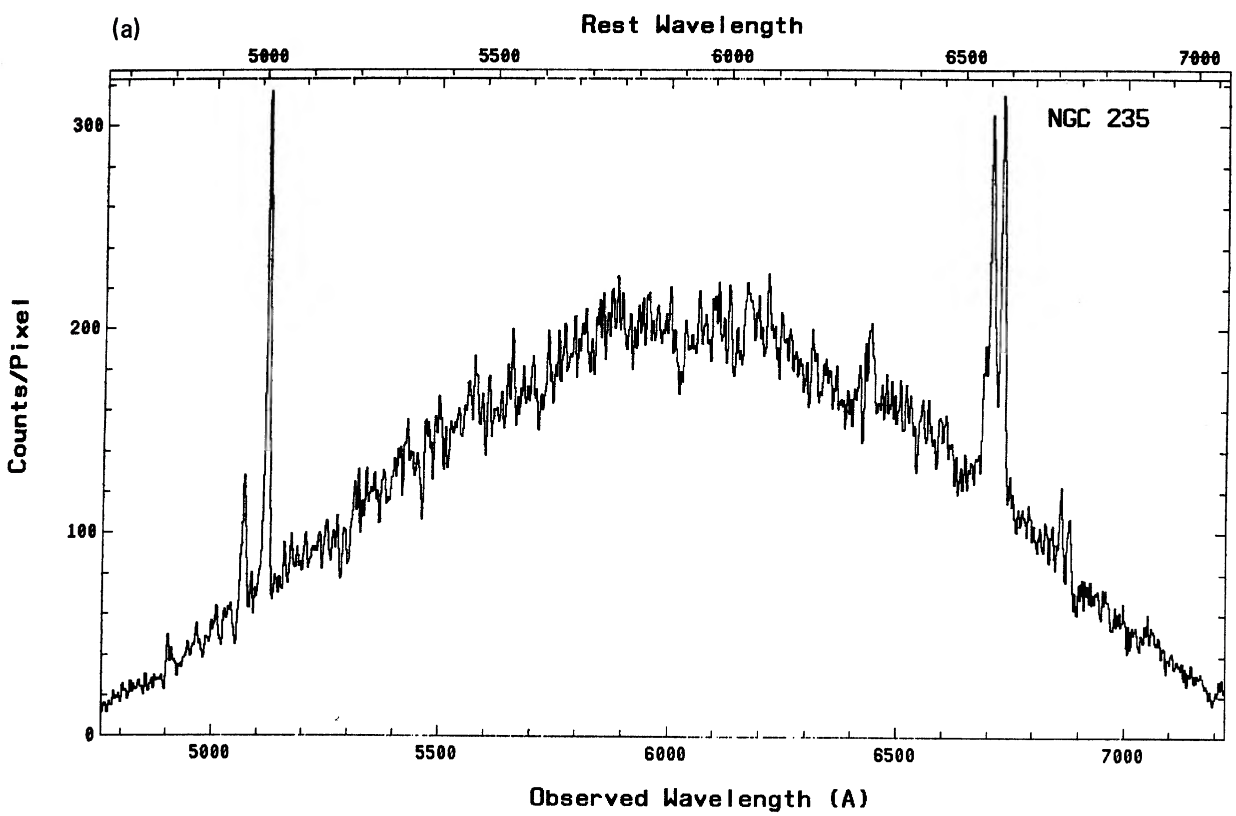
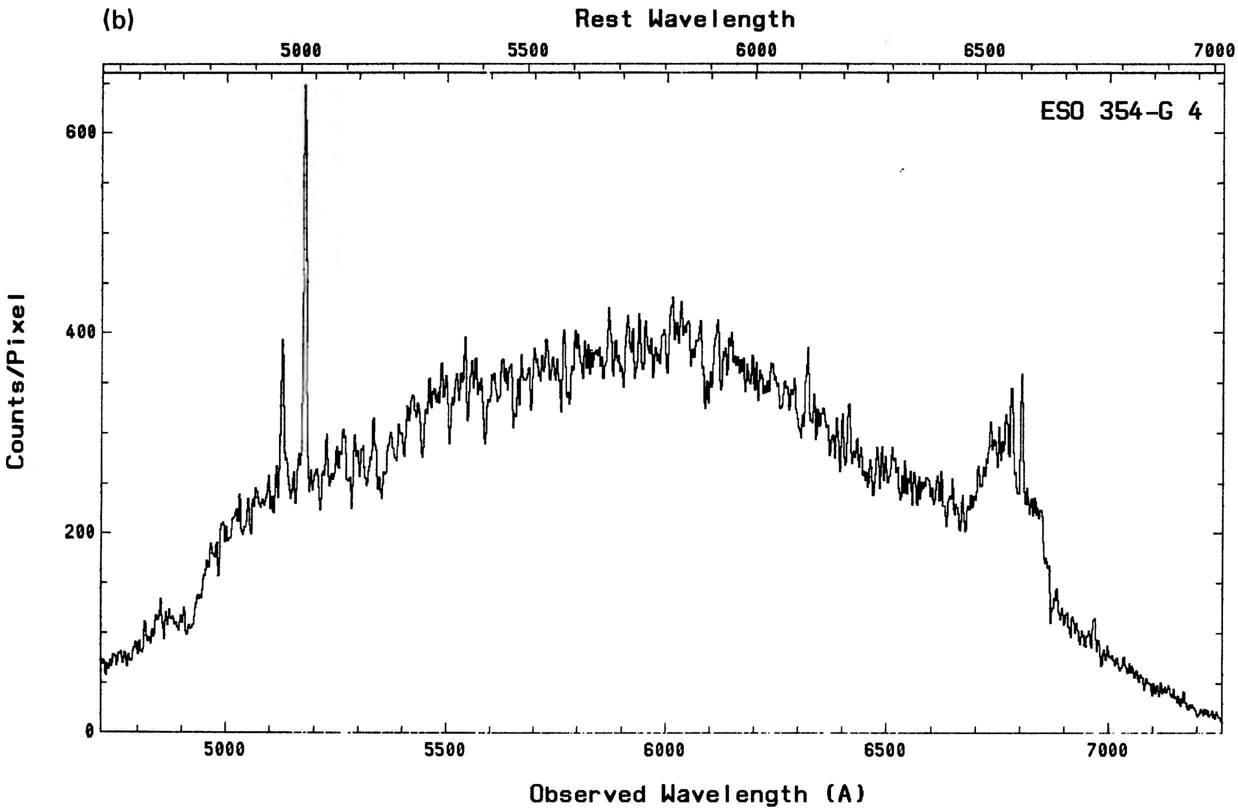


FIG. 2. Observed spectra of the five new Seyfert 1 galaxies (a–e). As a comparison we also show the spectrum of the well-known Seyfert 1 galaxy NGC 7213(f).



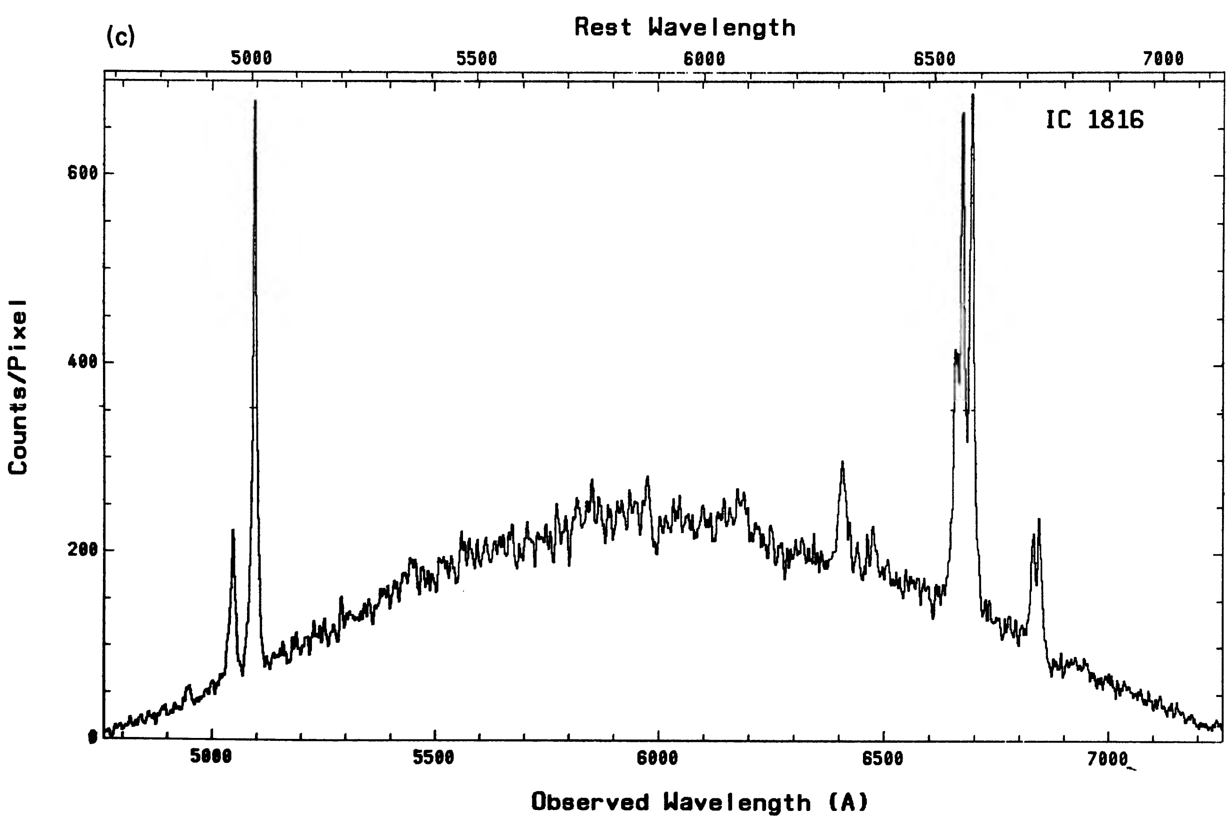
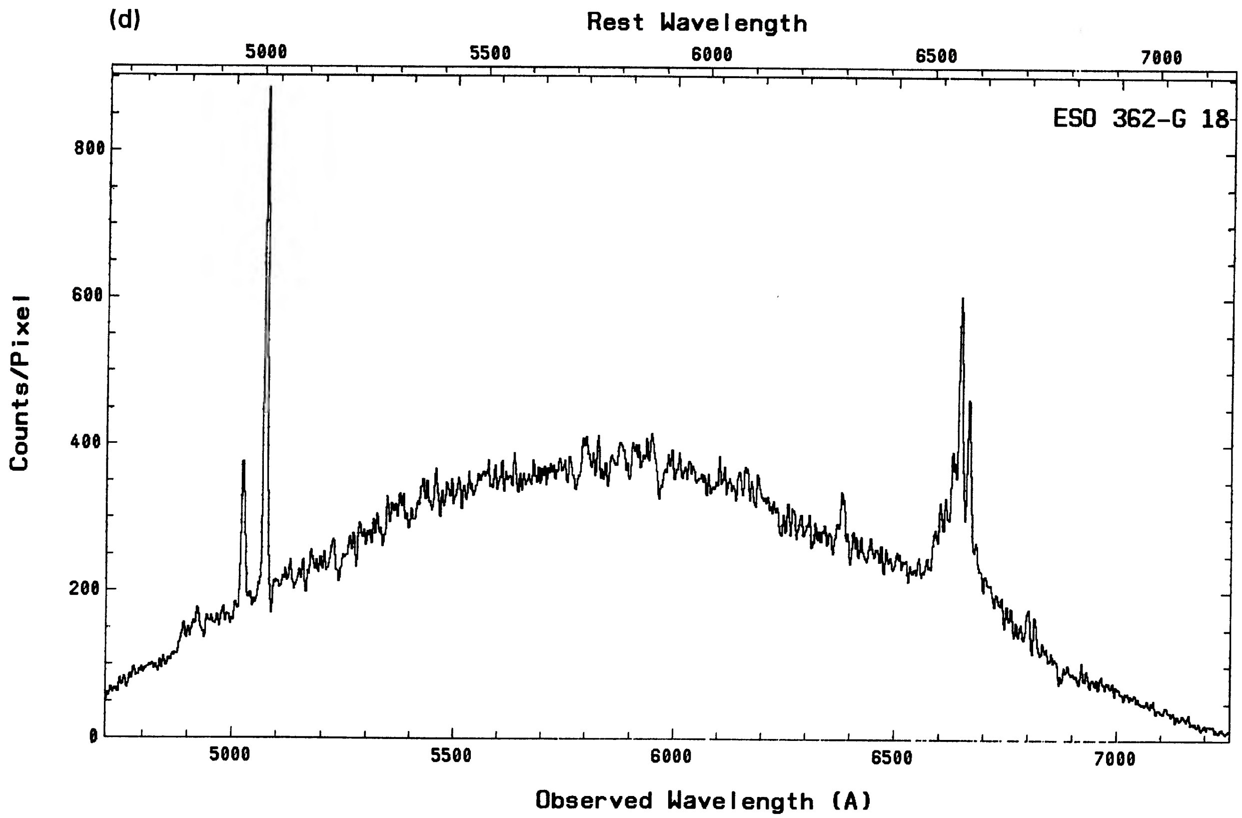


FIG. 2. (continued)



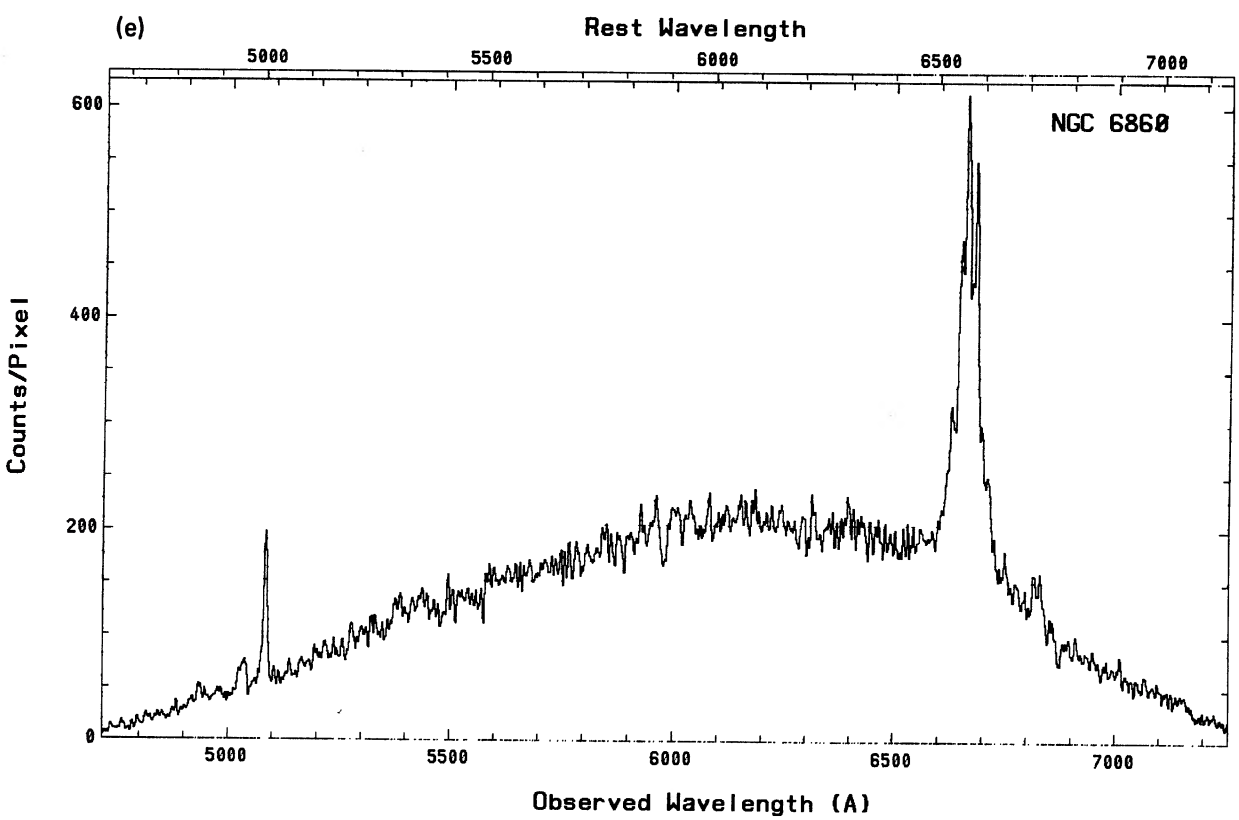
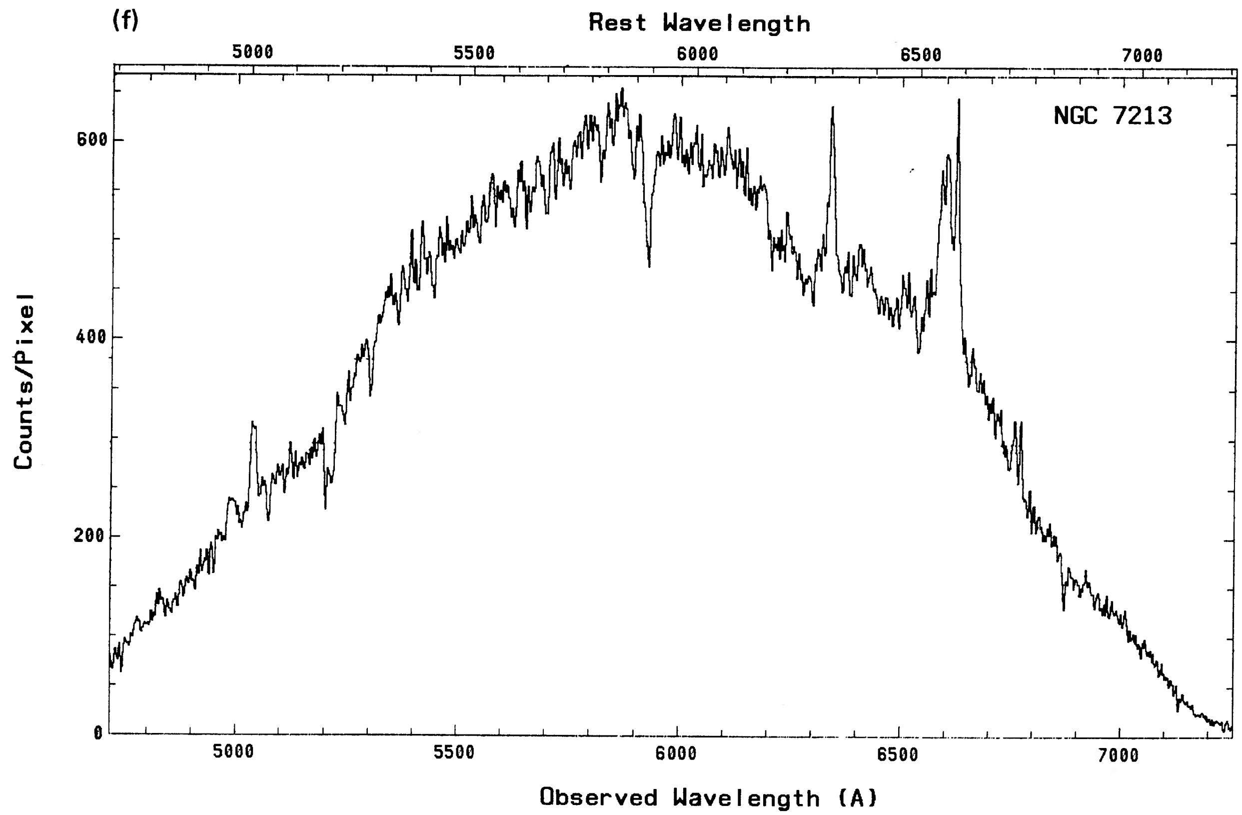


FIG. 2. (continued)



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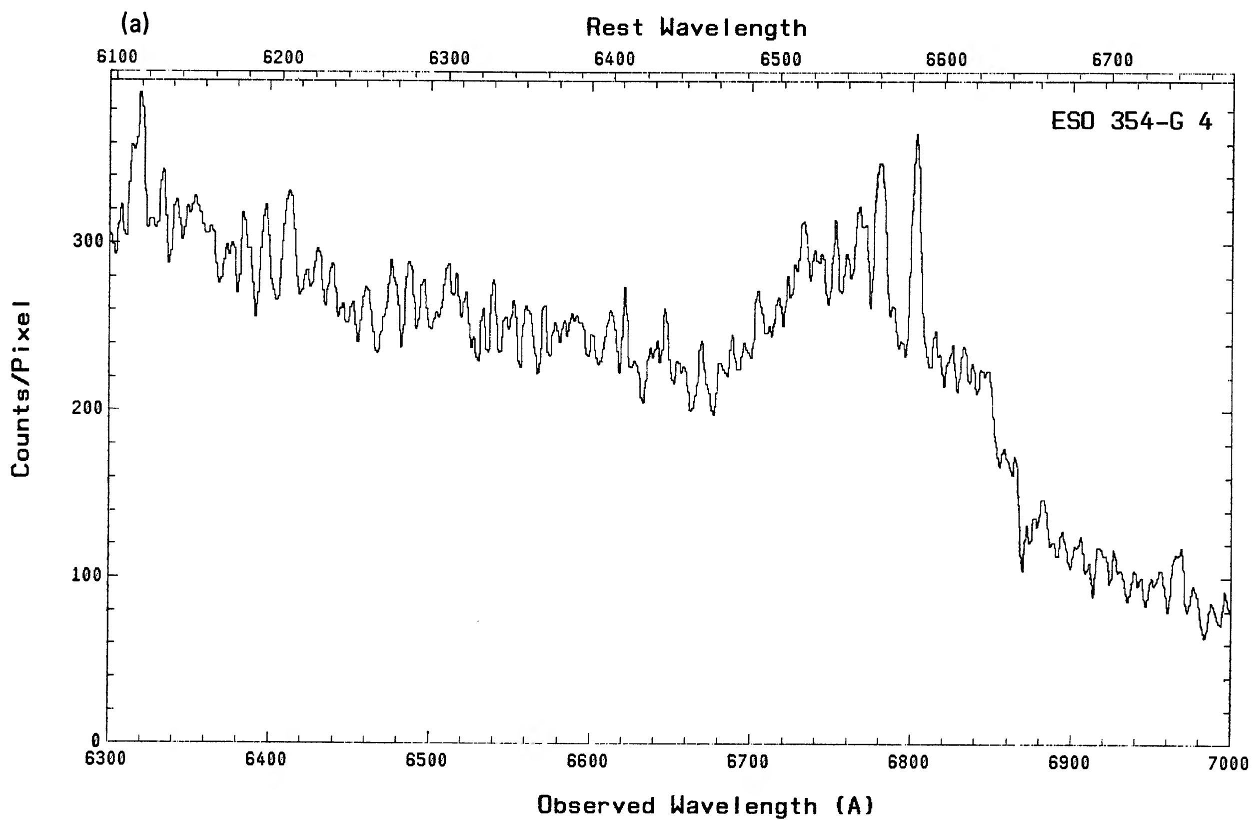

FIG. 3. Smoothed spectra of the Seyfert 1 galaxies ESO 354-G4 (a) and IC 1816 (b) in the interval $\lambda\lambda$ 6300–7000 Å. Despite the low signal-to-noise ratio, the presence of a broad Hα component is clearly detected in case (a). The galaxy IC 1816 shows a wide range of ionization exhibiting relatively strong [O I] $\lambda\lambda$ 6300, 6364 and [Fe X] λ 6374 lines.

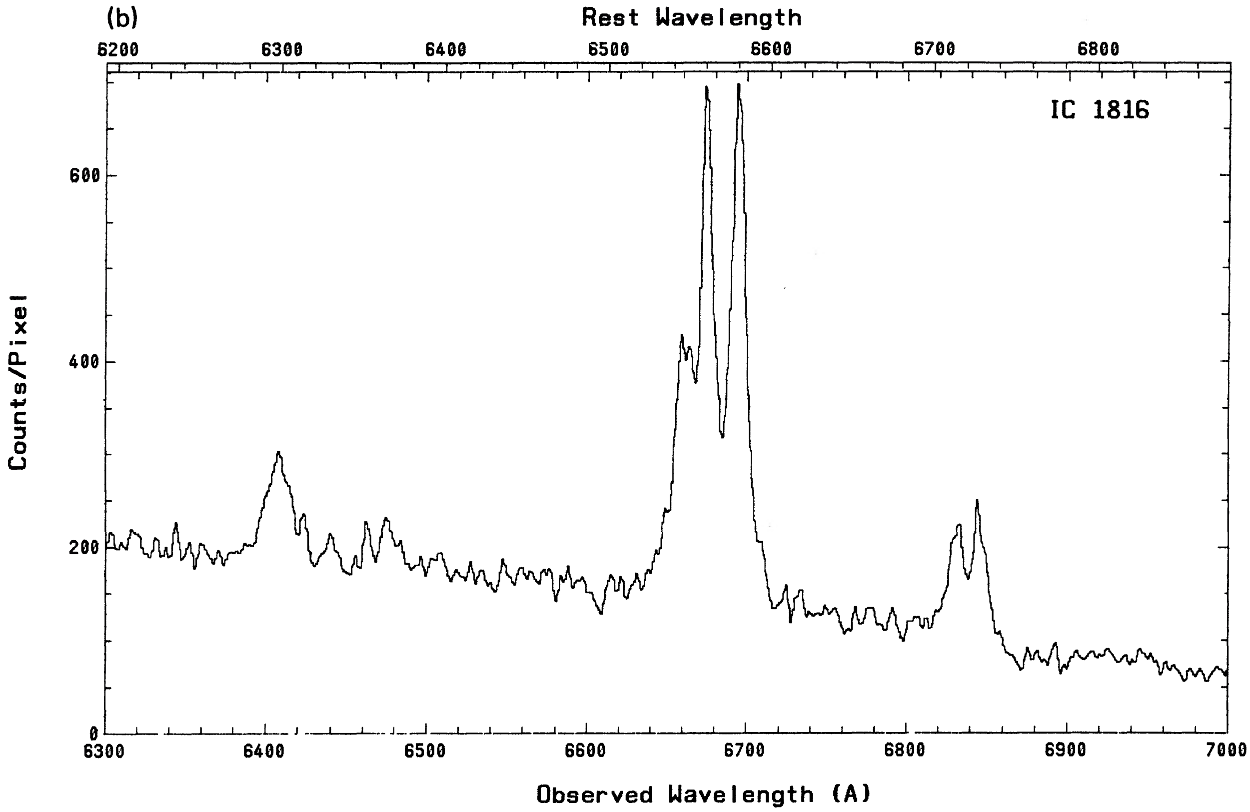

FIG. 3. (continued)

preliminary sample for follow-up spectrophotometric work on active galaxies. Further work on these objects may eventually contribute in the generation of a statistically complete sample which could be used to determine the nature and number density of nearby galaxies with nonstellar activity. It is particularly important to gain a better understanding of the relationship between the different classes of AGN, the frequency of mild activity in otherwise "normal" galaxies, and the physical processes which lead to the observed range of activity.

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