

## SPECTROSCOPIC MONITORING OF ACTIVE GALACTIC NUCLEI FROM CTIO. II. IC 4329A, ESO 141–G55, ARAKELIAN 120, AND FAIRALL 9

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### ABSTRACT

The results of an intensive monitoring campaign on the Seyfert 1 galaxies IC 4329A and ESO 141–G55 are presented. Variability was detected in both continuum and broad emission line fluxes, and the cross-correlation analysis indicates that the most likely delay between the variations of the 6225 Å continuum and the response of the H $\beta$  and H $\alpha$  emission lines for IC 4329A is  $\sim 15$ –25 days. For ESO 141–G55, the time-series analysis was inconclusive, and we could not obtain a clear cross-correlation signal between the lines and continuum light curves. We also present new data obtained for AKN 120 and Fairall 9, consisting of two sets of optical spectra taken  $\sim 4$  months apart. Both objects underwent not only significant flux variability (by up to a factor of  $\sim 2$ ) in this interval but also strong H $\alpha$  and H $\beta$  profile variations.

*Subject headings:* galaxies: active — galaxies: individual (IC 4329A, ESO 141–G55, Arakelian 120, Fairall 9) — galaxies: Seyfert

### 1. INTRODUCTION

Continuum and emission-line variability is a well-known characteristic of Seyfert 1 and quasar nuclei (see Peterson 1988, 1993 for reviews). In the standard model for these active galactic nuclei (AGNs), the continuum from an unresolved central source ionizes the high-velocity gas of the surrounding broad-line region (BLR), thus producing the broad (up to a few times  $10^4$  km s $^{-1}$ ) component of the permitted emission lines. Fluctuations in the ionizing continuum will therefore appear in the emission-line fluxes delayed by an amount comparable to the light-travel time from the central source to the emission region. Simultaneous monitoring of the continuum and emission lines could, in principle, provide information about the structure, size, and kinematics of the BLR gas by using reverberation mapping techniques (Blandford & McKee 1982). Within the last few years, intensive monitoring campaigns have provided data with the necessary time resolution and coverage for quantitative time-series analysis (Clavel et al. 1991; Dietrich et al. 1993, 1994; Erkens et al. 1995; Jackson et al. 1992; Korista et al. 1995; Maoz et al. 1990, 1991; Peterson et al. 1991, 1992, 1993, 1994; Reichert et al. 1994; Salamanca et al. 1994; Stirpe et al. 1994a, 1994b; Wanders et al. 1993).

During the period 1991 December–1992 July, in parallel with the observations for the NGC 3783 AGN Watch campaign (Stirpe et al. 1994b), we carried out an intensive spectroscopic monitoring campaign at Cerro Tololo Inter-American Observatory (CTIO) on a few other Seyfert galaxies of different luminosities. The results for NGC 3227 have already been published (Winge et al. 1995, hereafter Paper I), and in this paper, we present the data and results for the monitoring of two southern AGNs, IC 4329A and

ESO 141–G55, as well as the less well sampled data obtained for the higher luminosity objects AKN 120 and Fairall 9.

The Seyfert 1 nucleus of IC 4329A was detected by Disney (1973) and presents an optical spectrum characterized by strong internal reddening [ $E(B-V) \approx 0.8$  mag; Marziani, Calvani, & Sulentic 1992; but see Winkler et al. 1992] and very broad permitted lines with double-peaked profiles (Pastoriza 1979; Wilson & Penston 1979). The host is a late-type lenticular galaxy, seen almost edge-on. A dust lane is visually evident along the disk, and there is evidence of interaction with a nearby companion, IC 4329, a giant elliptical galaxy (Unger et al. 1987; Giuricin, Mardirossian, & Mezzetti 1990). The optical light shows significant polarization oriented parallel to the dust lane (Martin et al. 1982), suggesting the presence of a magnetic field in the plane of the galaxy, but there also appears to be an additional polarized component, which can be associated with dust scattering in a torus surrounding the AGN (Wolstencroft et al. 1995) or with a nonthermal process like electron scattering or synchrotron emission (Brindle et al. 1990). The AGN in IC 4329A is an X-ray source (Cooke et al. 1978; Elvis et al. 1978; Delvaille, Geller, & Schnopper 1978; Zdziarski et al. 1994) with a conflicting history of variability detection (Marshall, Warwick, & Pounds 1981; Tennant & Mushotzky 1983; Petre et al. 1984; Fabian et al. 1993). Photometric and spectrophotometric studies in the optical spectrum evidence the presence of variability in the continuum (Hamuy & Maza 1987; Winkler et al. 1992) and in the broad emission lines (Morris & Ward 1988; Marziani et al. 1992; Winkler 1992).

The AGN in ESO 141–G55 is a bright but not very well studied source. It was identified as Seyfert 1 by Elvis et al. (1978) from the X-ray *Ariel 5* survey list of Cooke et al. (1978) and confirmed as such by Ward et al. (1978). High-resolution spectra of the Balmer lines (Rafanelli 1985; Stirpe 1990) show that the line profiles are asymmetric and that the Balmer decrement is a function of velocity, being greater at the wings than at the line core. There are inconclusive reports of variability in the X-ray bands (Marshall et al. 1981; Tennant & Mushotzky 1983), and optical and UV

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TABLE 1  
IC 4329A AND ESO 141–G55 OBSERVING LOGS

| JD<br>(2,440,000+) | UT Date<br>(1992) | IC 4329A |                 |          | ESO 141–G55 |                 |          |
|--------------------|-------------------|----------|-----------------|----------|-------------|-----------------|----------|
|                    |                   | Air Mass | Scaling Factors | Comments | Air Mass    | Scaling Factors | Comments |
| 8643 .....         | Jan 21            | 1.19     | 1.00            |          | ...         | ...             |          |
| 8647 .....         | Jan 25            | 1.06     | 1.34            |          | ...         | ...             |          |
| 8651 .....         | Jan 29            | 1.06     | 1.03            |          | ...         | ...             |          |
| 8656 .....         | Feb 3             | 1.02     | 0.92            |          | ...         | ...             |          |
| 8660 .....         | Feb 7             | 1.01     | 0.85            | Cirrus   | ...         | ...             |          |
| 8664 .....         | Feb 11            | 1.00     | 0.87            |          | ...         | ...             |          |
| 8668 .....         | Feb 15            | 1.01     | 1.33            | Clouds   | ...         | ...             |          |
| 8676 .....         | Feb 23            | 1.06     | 1.39            |          | ...         | ...             |          |
| 8677 .....         | Feb 24            | 1.01     | 1.04            |          | ...         | ...             |          |
| 8678 .....         | Feb 25            | 1.07     | 0.87            |          | ...         | ...             |          |
| 8704 .....         | Mar 22            | 1.18     | 1.14            |          | 1.46        | 0.78            |          |
| 8712 .....         | Mar 30            | 1.11     | 0.97            |          | 1.53        | 0.97            |          |
| 8716 .....         | Apr 3             | ...      | ...             |          | 1.40        | 1.33            |          |
| 8720 .....         | Apr 7             | 1.05     | 1.01            |          | 1.36        | 0.96            |          |
| 8724 .....         | Apr 11            | 1.09     | 0.93            |          | 1.53        | 0.93            |          |
| 8728 .....         | Apr 15            | 1.10     | 0.85            | Clouds   | 1.51        | 1.36            | Clouds   |
| 8732 .....         | Apr 19            | 1.06     | 1.01            |          | 1.67        | 0.66            | Cirrus   |
| 8736 .....         | Apr 23            | 1.06     | 0.87            |          | 1.48        | 0.96            |          |
| 8752 .....         | May 9             | 1.03     | 1.38            |          | 1.19        | 1.00            |          |
| 8764 .....         | May 21            | 1.02     | 1.04            |          | 1.17        | 0.83            | Cirrus   |
| 8772 .....         | May 29            | ...      | ...             |          | 1.27        | 2.14            | Cirrus   |
| 8776 .....         | Jun 2             | 1.03     | 0.88            |          | 1.18        | 0.90            |          |
| 8783 .....         | Jun 9             | ...      | ...             |          | 1.14        | 0.63            |          |
| 8794 .....         | Jun 20            | 1.34     | 0.90            |          | 1.15        | 1.03            |          |
| 8802 .....         | Jun 28            | ...      | ...             |          | 1.16        | 0.89            |          |
| 8804 .....         | Jun 30            | ...      | ...             |          | 1.14        | 0.59            |          |
| 8808 .....         | Jul 4             | 1.12     | 1.86            |          | 1.14        | 0.98            |          |
| 8810 .....         | Jul 6             | ...      | ...             |          | 1.14        | 1.48            |          |
| 8812 .....         | Jul 8             | ...      | ...             |          | 1.16        | 1.05            |          |
| 8814 .....         | Jul 10            | ...      | ...             |          | 1.15        | 0.81            | Clouds   |
| 8818 .....         | Jul 14            | 1.64     | 1.11            |          | ...         | ...             |          |
| 8822 .....         | Jul 18            | 1.26     | 1.03            |          | 1.14        | 0.93            |          |
| 8824 .....         | Jul 20            | 1.27     | 1.14            |          | 1.14        | 1.04            |          |
| 8826 .....         | Jul 22            | 1.42     | 1.78            |          | 1.15        | 1.23            | Cirrus   |
| 8830 .....         | Jul 26            | 1.34     | 0.89            |          | 1.14        | 0.97            |          |
| 8832 .....         | Jul 28            | 1.50     | 0.79            |          | 1.26        | 1.02            |          |

TABLE 2  
ARAKELIAN 120 AND FAIRALL 9 OBSERVING LOGS

| JD<br>(2,440,000+) | UT Date     | AKN 120  |                 |          | Fairall 9 |                 |          |
|--------------------|-------------|----------|-----------------|----------|-----------|-----------------|----------|
|                    |             | Air Mass | Scaling Factors | Comments | Air Mass  | Scaling Factors | Comments |
| 8607 .....         | 1991 Dec 16 | ...      | ...             | Clouds   | 1.18      | 0.82            | Clouds   |
| 8619 .....         | 1991 Dec 28 | 1.19     | 1.10            | Clouds   | 1.32      | 1.31            |          |
| 8623 .....         | 1992 Jan 1  | 1.16     | 0.78            |          | 1.35      | 1.12            |          |
| 8627 .....         | 1992 Jan 5  | 1.16     | 0.96            |          | 1.31      | 0.87            |          |
| 8631 .....         | 1992 Jan 9  | 1.16     | 0.64            | Cirrus   | 1.36      | 0.94            | Cirrus   |
| 8635 .....         | 1992 Jan 13 | 1.27     | 0.70            |          | 1.36      | 0.98            |          |
| 8643 .....         | 1992 Jan 21 | 1.15     | 0.87            |          | ...       | ...             |          |
| 8647 .....         | 1992 Jan 25 | 1.16     | 0.78            |          | ...       | ...             |          |
| 8651 .....         | 1992 Jan 29 | 1.16     | 0.66            |          | ...       | ...             |          |
| 8656 .....         | 1992 Feb 3  | 1.21     | 0.69            |          | ...       | ...             |          |
| 8660 .....         | 1992 Feb 7  | 1.19     | 1.04            |          | ...       | ...             |          |
| 8664 .....         | 1992 Feb 11 | 1.22     | 1.13            |          | ...       | ...             |          |
| 8668 .....         | 1992 Feb 15 | 1.26     | 1.09            |          | ...       | ...             |          |
| 8672 .....         | 1992 Feb 19 | 1.18     | 0.84            |          | ...       | ...             |          |
| 8676 .....         | 1992 Feb 23 | 1.19     | 0.75            |          | ...       | ...             |          |
| 8678 .....         | 1992 Feb 25 | 1.19     | 0.72            |          | ...       | ...             |          |
| 8808 .....         | 1992 Jul 4  | ...      | ...             |          | 1.15      | 0.92            |          |
| 8822 .....         | 1992 Jul 18 | ...      | ...             |          | 1.14      | 1.06            |          |
| 8824 .....         | 1992 Jul 20 | ...      | ...             |          | 1.16      | 1.05            |          |
| 8830 .....         | 1992 Jul 26 | 1.84     | 1.28            |          | 1.14      | 0.80            |          |
| 8832 .....         | 1992 Jul 28 | 1.77     | 0.92            |          | 1.14      | 0.96            |          |
| 8834 .....         | 1992 Jul 30 | 1.73     | 1.00            |          | 1.14      | 1.00            |          |

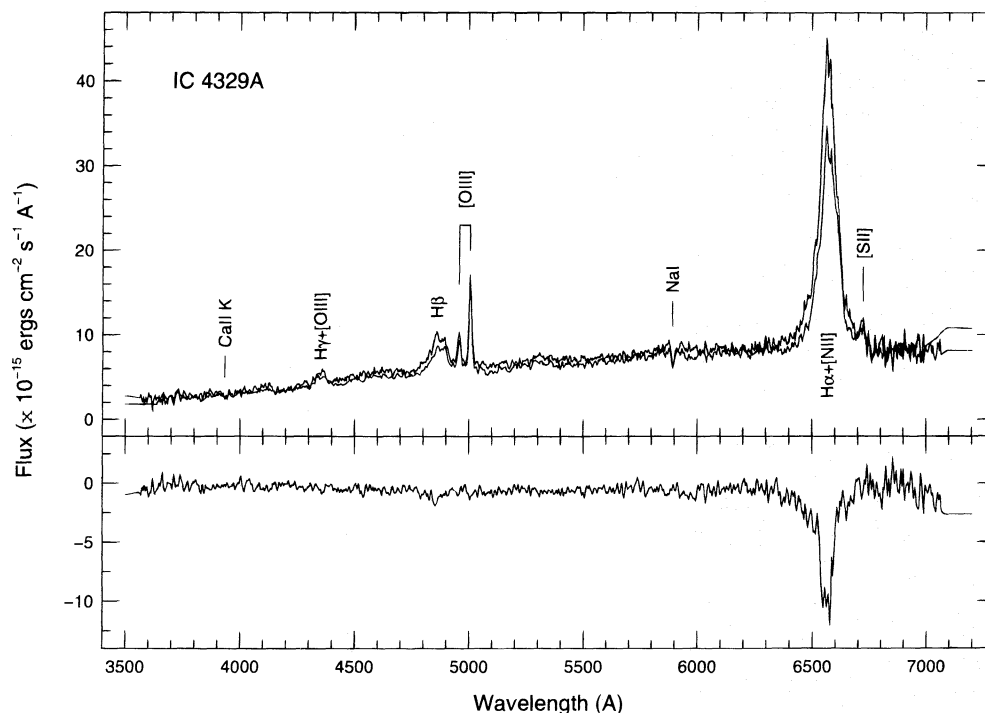


FIG. 1.—*Top*: Representative spectra of IC 4329A obtained during the monitoring: JD 2,448,643 (*upper spectrum*) and 2,448,736 (*lower spectrum*). *Bottom*: The difference spectrum.

variability has been reported by Chapman, Geller, & Huchra (1985), Morris & Ward (1988), Winkler et al. (1992), and Winkler (1992). Using data from the *IUE* archives, Koratkar & Gaskell (1991) analyzed the UV continuum and emission-line light curves using cross-correlation techniques and obtained lags of  $\sim 30$  and  $\sim 90$  lt-days between the variations of the UV continuum and the response of the  $\text{Ly}\alpha$  and C IV  $\lambda 1549$  lines, respectively.

The continuum and emission lines of AKN 120 have a widely discussed history of flux and line-profile variability (see Lyutyi 1976; Foltz et al. 1981; Kollatschny et al. 1981; Peterson et al. 1985; Alloin, Boisson, & Pelat 1988; Peterson, Korista, & Wagner 1989; Marziani et al. 1992). The broad-line profiles are complex, with double or even triple peaks of variable relative intensity (Korista 1992) and a strong red shoulder attributed to a blend of Fe II multi-

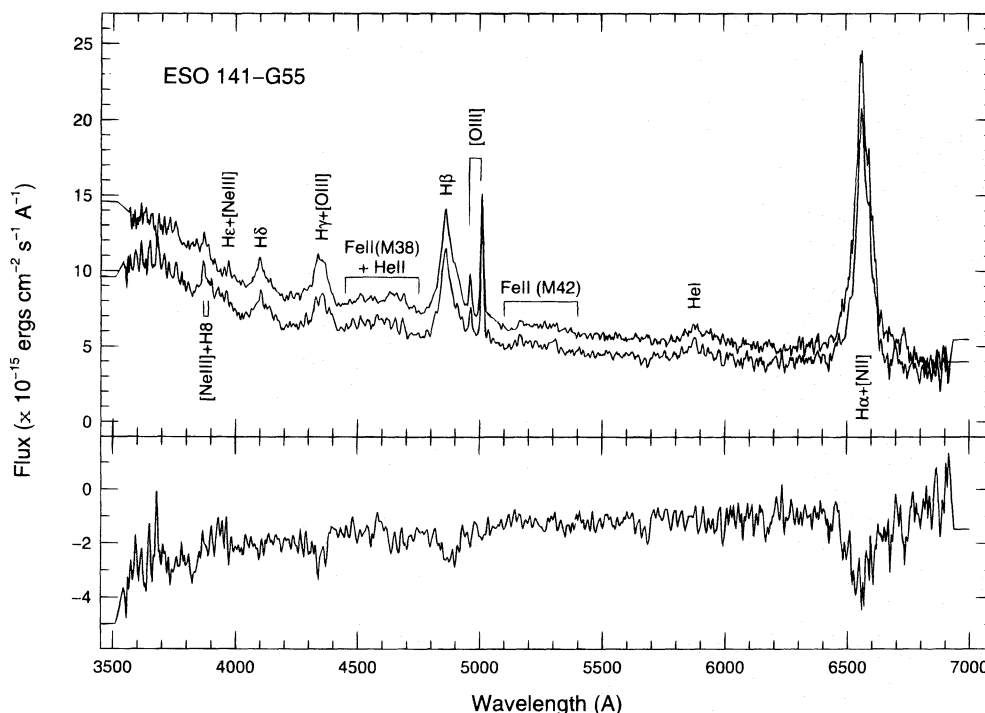


FIG. 2.—Same as Fig. 1, but for ESO 141-G55. *Top*: JD 2,448,716 (*upper spectrum*) and 2,448,732 (*lower spectrum*).

plets and a possibly “broad” component of the [O III] lines (Meyers & Peterson 1985). The response of the emission lines to the continuum variability has been studied in a systematic way for several years (see Peterson & Gaskell 1991 and references therein), but the results are not conclusive. The time delay derived from the optical continuum and H $\beta$  light curves indicates a BLR radius of  $\sim 40$  lt-days, much smaller than the size predicted by the ionization models. Koratkar & Gaskell (1991) obtained a similar value using the *IUE* database. A larger value for the emission-line region’s radius cannot, however, be dismissed, because of the nonuniformity of the data sampling and the irregularity of the variability behavior.

Fairall 9 has been known as a variable source since its identification as an AGN (Fairall 1977). The X-ray spectrum is variable in flux and shape (Morini et al. 1986). In the UV, this object shows a “saturation limit” in the relationship of C IV  $\lambda 1549$  with the continuum (Wamsteker & Colina 1986; Shields, Ferland, & Peterson 1995) that suggests the presence of an optically thin broad-line component. The time delay between the UV continuum variations and the emission lines’ response implies a BLR radius between 150 and 200 lt-days (Koratkar & Gaskell 1991). The UV and optical continua are found to vary in phase, but the near-infrared emission, which is emitted by dust warmed by the central continuum source, is delayed by  $\sim 400$  days (Clavel, Wamsteker, & Glass 1989; Lub & de Ruiter 1992; Barvainis 1992).

## 2. OBSERVATIONS

The data were obtained with the CTIO 1.0 m telescope and Cassegrain spectrograph plus “2D-FRUTTI” detector during the period 1991 December 16–1992 July 30. The instrumental setup was the same for all the observations, with a 5" slit oriented east-west and spectral coverage from 3500 to 7200 Å. The resolution is 8 Å, measured from the FWHM of the comparison lines. The two-dimensional spectrograms were reduced according to IRAF standard procedures, and one-dimensional spectra were extracted in a 10" window centered on the maximum of the continuum emission. The large slit width and extraction windows were employed to avoid, as much as possible, seeing and differential refraction effects. The spectra were flux-calibrated using the standard spectrophotometric stars from Stone & Baldwin (1983), which were observed with a 10" slit. The observing logs are presented in Tables 1 and 2, and Figures 1 and 2 show examples of the spectral variations observed for IC 4329A and ESO 141–G55, respectively, during this campaign.

## 3. ANALYSIS OF THE DATA

### 3.1. Relative Scaling of the Spectra

As is common in variability studies, relative flux calibration of the spectra has been accomplished by assuming that the flux in the narrow emission lines was constant over the duration of the monitoring. The absence of extended [O III] emission at levels that could cause aperture effects was verified from inspection of the original two-dimensional spectrograms. The spectra for each object studied here were internally calibrated using a variant of the method described by van Groningen & Wanders (1992). The program finds the optimum flux-scaling factor, wavelength shift, and convolution factor for each spectrum of a

data set (with respect to a reference spectrum) by varying these parameters until the residuals of one or more narrow lines in the difference between the two spectra are minimized. For all objects studied in this paper, the residuals of [O III]  $\lambda 5007$  were minimized. The reference spectra and [O III]  $\lambda 5007$  normalization fluxes are listed in Table 3. The accuracy of the internal calibration, as judged from the [O III]  $\lambda 5007$  residuals, is within 5% for all objects except AKN 120, for which the normalization procedure is not very stable as a result of the small equivalent width of [O III]  $\lambda 5007$  and the possibly variable underlying feature produced by Fe II multiplets and the red wing of H $\beta$ . In this case, the normalization of each spectrum was checked by integrating by hand the [O III]  $\lambda 5007$  flux above a local continuum defined by a smooth interpolation of the underlying line profile, and small adjustments (always less than 10%) were made to the flux scaling. Table 2 lists the final values of the scaling factors for this object.

Since all spectra were obtained with the same instrument and setup, the convolution factor has almost no effect on the results in this case. All data were corrected for Galactic reddening [IC 4329A,  $E(B-V) = 0.033$ ; ESO 141–G55,  $E(B-V) = 0.047$ ; AKN 120,  $E(B-V) = 0.093$ ; Fairall 9,  $E(B-V) = 0.0$ ; Burstein & Heiles 1984] and redshift, as measured by using the strongest narrow emission lines in each spectrum. Flux scales and integrated flux measurements, however, have not been transformed to the rest frames of the objects.

### 3.2. Derivation of the Light Curves

All the observed spectra are contaminated to some extent by the underlying stellar population, which has the effect of diluting the continuum variations through the presence of a constant component. For each of the objects studied in this paper, we assessed the contribution of starlight to the nuclear spectra by examining the diluted equivalent widths of stellar absorption features in a high signal-to-noise ratio (S/N) spectrum obtained by averaging the best individual observations (i.e., excluding the ones with lower S/N due to poor weather) of IC 4329A and ESO 141–G55 and the spectra of the two sets of data of AKN 120 and Fairall 9. The mean spectra clearly reveal the presence of the Ca II K  $\lambda 3933$  and Mg I + Mg II  $\lambda 5175$  absorption lines in IC 4329A and in the low state of Fairall 9, defined by the average of the JD 2,448,808–2,448,834 observations.

By measuring the equivalent width of an absorption feature that arises from the stellar population in the nuclear spectrum of an AGN and comparing it with the equivalent width of the same feature in a normal galaxy of similar morphological type and luminosity, or in the bulge of the AGN’s host galaxy, it is possible to evaluate the fraction of the continuum at the wavelength of the absorption lines in the AGN’s nuclear spectrum that arises from the underlying

TABLE 3  
REFERENCE SPECTRUM AND [O III]  $\lambda 5007$  NORMALIZATION FLUX

| Object          | JD<br>(2,440,000+) | UT<br>Date<br>(1992) | $F([\text{O III}] \lambda 5007)$<br>( $10^{-15}$ ergs cm $^{-2}$ s $^{-1}$ ) |
|-----------------|--------------------|----------------------|--|
| IC 4329A .....  | 8643               | Jan 21               | $186.5 \pm 22.5$   |
| ESO 141–G55...  | 8752               | May 9                | $139.2 \pm 9.7$  |
| AKN 120 .....   | 8834               | Jul 30               | $70.1 \pm 17.4$  |
| Fairall 9 ..... | 8834               | Jul 30               | $164.2 \pm 14.9$   |



TABLE 4

LINE AND CONTINUUM INTEGRATION WAVELENGTH WINDOWS

| Component                           | Wavelength Window (Å) | Interpolated Continuum Window (Å) |
|-------------------------------------|-----------------------|-----------------------------------|
| IC 4329A                            |                       |                                   |
| $F_{\lambda}(4210 \text{ Å})$ ..... | 4172–4248             | ...                               |
| $F_{\lambda}(6225 \text{ Å})$ ..... | 6150–6300             | ...                               |
| H $\beta$ .....                     | 4750–4930             | 4700–4750, 5080–5120              |
| H $\alpha$ .....                    | 6300–6790             | 6100–6300, 6800–6940              |
| ESO 141–G55                         |                       |                                   |
| $F_{\lambda}(4200 \text{ Å})$ ..... | 4180–4220             | ...                               |
| $F_{\lambda}(5110 \text{ Å})$ ..... | 5090–5130             | ...                               |
| $F_{\lambda}(6240 \text{ Å})$ ..... | 6200–6280             | ...                               |
| H $\gamma$ .....                    | 4280–4425             | 4180–4220, 4425–4465              |
| He II $\lambda 4686^a$ .....        | 4465–4725             | 4425–4465, 4725–4770              |
| H $\beta$ .....                     | 4770–4745             | 4725–4770, 5090–5130              |
| He I $\lambda 5876$ .....           | 5870–5980             | 5700–5780, 6000–6080              |
| H $\alpha$ .....                    | 6380–6800             | 6200–6280, 6800–6860              |
| AKN 120                             |                       |                                   |
| $F_{\lambda}(4200 \text{ Å})$ ..... | 4180–4220             | ...                               |
| $F_{\lambda}(5630 \text{ Å})$ ..... | 5580–5680             | ...                               |
| H $\gamma$ .....                    | 4265–4420             | 4180–4220, 4420–4460              |
| H $\beta$ .....                     | 4770–4930             | 4730–4770, 5080–5120              |
| H $\alpha$ .....                    | 6350–6700             | 6200–6280, 6740–6820              |
| Fairall 9                           |                       |                                   |
| $F_{\lambda}(4230 \text{ Å})$ ..... | 4200–4260             | ...                               |
| $F_{\lambda}(5630 \text{ Å})$ ..... | 5480–5580             | ...                               |
| H $\gamma$ .....                    | 4280–4420             | 4200–4260, 4420–4460              |
| He II $\lambda 4686^a$ .....        | 4460–4750             | 4420–4460, 4750–4780              |
| H $\beta$ .....                     | 4780–4930             | 4750–4780, 5080–5120              |
| H $\alpha$ .....                    | 6400–6700             | 6170–6270 <sup>b</sup>            |

<sup>a</sup> Includes a contribution from Fe II multiplets.

<sup>b</sup> Continuum taken to be a constant defined by the mean value inside the window.

galaxy (Salamanca et al. 1994; Paper I). By using the continuum energy distribution of the stellar population's spectrum, we can obtain an estimate of the contribution at other wavelengths.

For the objects studied here, we are however faced with the problem of identifying the correct template for the host galaxy. In IC 4329A, the morphological classification is uncertain as a result of the high inclination of the galaxy, while in Fairall 9, this uncertainty is a consequence of the brightness of the nucleus. If we suppose that the host galaxy of IC 4329A can be represented as a late-type lenticular (SA0+; de Vaucouleurs et al. 1991) and use the equivalent widths of the appropriate E/S0 template published by Bica (1988), the contribution from the underlying stellar population is  $\sim 20\%$  at 3933 Å (the Ca II K  $\lambda 3933$  absorption line;  $W_{\text{AGN}} = 3.0 \text{ Å}$ ), and  $\sim 35\%$  at 5175 Å (the Mg I + Mg II  $\lambda 5175$  band;  $W_{\text{AGN}} = 2.5 \text{ Å}$ ). For Fairall 9, Véron-Cetty, Woltjer, & Roy (1991) found that the colors and luminosity profile of the underlying galaxy are compatible with those of a luminous giant elliptical, and a comparison with the E1 template indicates a contribution of  $\sim 10\%$  from the stellar population to the nuclear continuum at 3933 Å in the mean spectrum corresponding to the JD 2,448,808–2,448,834 low state.

Since the actual spectral energy distribution of the host galaxy of IC 4329A is affected by the strong internal reddening and we do not know either the value of the

TABLE 5

MEASUREMENTS OF SPECTRA—IC 4329A<sup>a</sup>

| JD (2,440,000 +) | $F_{\lambda}(4210 \text{ Å})$ | $F_{\lambda}(6225 \text{ Å})$ | $F(\text{H}\beta)$ | $F(\text{H}\alpha)$ |
|------------------|-------------------------------|-------------------------------|--------------------|---------------------|
| 8643 .....       | $3.74 \pm 0.20$               | $8.82 \pm 0.47$               | $363.9 \pm 20.9$   | $3866.5 \pm 113.3$  |
| 8647 .....       | ...                           | ...                           | $338.8 \pm 22.7$   | $2751.5 \pm 150.4$  |
| 8651 .....       | $3.60 \pm 0.15$               | $8.05 \pm 0.64$               | $353.3 \pm 16.7$   | $2521.7 \pm 120.2$  |
| 8656 .....       | $3.41 \pm 0.15$               | $8.13 \pm 0.50$               | $311.7 \pm 11.0$   | $2805.5 \pm 96.9$   |
| 8660 .....       | $3.71 \pm 0.20$               | $8.47 \pm 0.33$               | $310.9 \pm 14.9$   | $3202.0 \pm 85.3$   |
| 8664 .....       | $4.05 \pm 0.16$               | $9.16 \pm 0.53$               | $324.4 \pm 12.1$   | $3125.0 \pm 136.2$  |
| 8668 .....       | $4.38 \pm 0.14$               | $9.01 \pm 0.61$               | $303.0 \pm 16.5$   | $3216.5 \pm 186.2$  |
| 8676 .....       | $4.09 \pm 0.26$               | $8.79 \pm 0.68$               | $319.6 \pm 11.6$   | ...                 |
| 8677 .....       | $4.11 \pm 0.30$               | $8.44 \pm 0.46$               | $331.2 \pm 23.3$   | $3208.2 \pm 116.8$  |
| 8678 .....       | ...                           | $8.99 \pm 0.57$               | $306.8 \pm 8.9$    | $2965.1 \pm 105.7$  |
| 8704 .....       | $3.91 \pm 0.30$               | $8.59 \pm 0.57$               | $288.4 \pm 21.2$   | $2904.8 \pm 120.3$  |
| 8712 .....       | $3.51 \pm 0.14$               | $8.55 \pm 0.37$               | $309.6 \pm 10.1$   | $3004.5 \pm 95.8$   |
| 8720 .....       | $3.54 \pm 0.17$               | $8.33 \pm 0.40$               | $308.8 \pm 13.2$   | $2915.1 \pm 92.1$   |
| 8724 .....       | $3.55 \pm 0.16$               | $8.66 \pm 0.48$               | $324.2 \pm 14.1$   | $3071.1 \pm 95.2$   |
| 8728 .....       | $4.54 \pm 0.38$               | ...                           | $367.5 \pm 39.4$   | ...                 |
| 8732 .....       | $4.37 \pm 0.16$               | $9.24 \pm 0.49$               | $318.2 \pm 30.1$   | $3181.4 \pm 130.4$  |
| 8736 .....       | $3.72 \pm 0.19$               | $8.54 \pm 0.52$               | $297.3 \pm 15.3$   | $2794.9 \pm 79.7$   |
| 8752 .....       | $4.44 \pm 0.17$               | $9.75 \pm 0.56$               | $326.9 \pm 16.0$   | $3210.0 \pm 125.9$  |
| 8764 .....       | $4.49 \pm 0.17$               | $10.13 \pm 0.57$              | $360.2 \pm 14.2$   | $3268.9 \pm 102.4$  |
| 8776 .....       | $3.78 \pm 0.14$               | $9.25 \pm 0.63$               | ...                | $3352.7 \pm 105.7$  |
| 8794 .....       | $3.41 \pm 0.13$               | $9.08 \pm 0.58$               | $332.7 \pm 13.9$   | $3396.5 \pm 112.0$  |
| 8808 .....       | $3.72 \pm 0.18$               | $9.77 \pm 0.50$               | $384.0 \pm 18.9$   | $3473.6 \pm 121.0$  |
| 8822 .....       | $3.72 \pm 0.22$               | $9.44 \pm 0.41$               | $366.8 \pm 17.4$   | $3422.3 \pm 92.7$   |
| 8824 .....       | $3.64 \pm 0.15$               | $9.09 \pm 0.48$               | $347.5 \pm 24.6$   | $3312.0 \pm 103.3$  |
| 8826 .....       | $3.99 \pm 0.19$               | $10.05 \pm 0.60$              | $370.6 \pm 27.5$   | $3640.8 \pm 132.6$  |
| 8830 .....       | $3.83 \pm 0.13$               | $9.43 \pm 0.38$               | $346.8 \pm 12.8$   | $3268.2 \pm 75.9$   |
| 8832 .....       | $3.72 \pm 0.20$               | $10.06 \pm 0.62$              | $340.3 \pm 18.2$   | $3420.3 \pm 140.9$  |

<sup>a</sup> Continuum fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ Å}^{-1}$  and line fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1}$ .

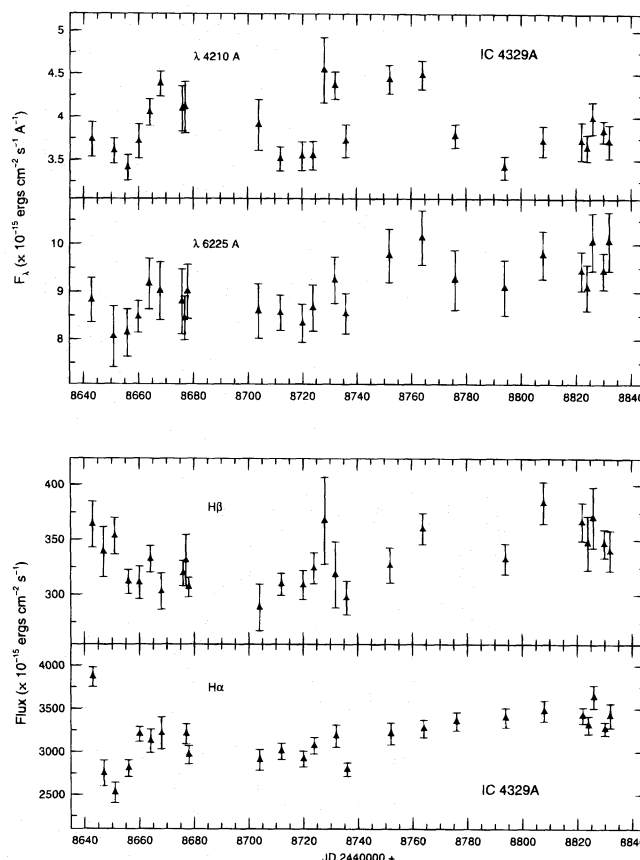


FIG. 3.—IC 4329A light curves. Top, 4210 and 6225 Å continua; bottom, H $\beta$  and H $\alpha$ .

TABLE 6  
MEASUREMENTS OF SPECTRA—ESO 141—G55<sup>a</sup>

| JD<br>(2,440,000+) | $F_{\lambda}(4200 \text{ \AA})$ | $F_{\lambda}(5510 \text{ \AA})$ | $F_{\lambda}(6240 \text{ \AA})$ | $F(\text{H}\gamma)$ | $F(\text{He II } \lambda 4686)^b$ | $F(\text{H}\beta)$ | $F(\text{He I } \lambda 5876)$ | $F(\text{H}\alpha)$ |
|--------------------|---------------------------------|---------------------------------|---------------------------------|---------------------|-----------------------------------|--------------------|--------------------------------|---------------------|
| 8704 .....         | 10.71 $\pm$ 0.17                | 7.68 $\pm$ 0.17                 | 5.51 $\pm$ 0.25                 | 217.2 $\pm$ 15.7    | 156.1 $\pm$ 32.9                  | 503.4 $\pm$ 18.0   | 127.0 $\pm$ 22.6               | 1690.9 $\pm$ 67.1   |
| 8712 .....         | 9.26 $\pm$ 0.13                 | 6.50 $\pm$ 0.14                 | 5.01 $\pm$ 0.30                 | 182.0 $\pm$ 9.2     | 180.6 $\pm$ 19.9                  | 500.7 $\pm$ 14.4   | 104.0 $\pm$ 20.6               | 1707.6 $\pm$ 62.1   |
| 8716 .....         | 8.50 $\pm$ 0.17                 | 6.44 $\pm$ 0.15                 | 4.93 $\pm$ 0.22                 | 209.3 $\pm$ 9.5     | 147.9 $\pm$ 19.0                  | 508.3 $\pm$ 15.4   | 119.8 $\pm$ 22.8               | 1860.0 $\pm$ 58.4   |
| 8720 .....         | 8.92 $\pm$ 0.31                 | 6.65 $\pm$ 0.14                 | 5.05 $\pm$ 0.30                 | 243.1 $\pm$ 15.0    | 171.7 $\pm$ 11.7                  | 522.5 $\pm$ 9.7    | 86.8 $\pm$ 17.7                | 1669.3 $\pm$ 87.7   |
| 8724 .....         | 7.96 $\pm$ 0.13                 | 6.35 $\pm$ 0.10                 | 4.92 $\pm$ 0.22                 | 224.6 $\pm$ 13.9    | 154.7 $\pm$ 24.8                  | 502.2 $\pm$ 10.2   | 113.5 $\pm$ 16.1               | 1759.7 $\pm$ 54.3   |
| 8728 .....         | 7.38 $\pm$ 0.34                 | 6.03 $\pm$ 0.65                 | 4.49 $\pm$ 0.65                 | 197.6 $\pm$ 18.3    | 115.1 $\pm$ 29.1                  | 473.4 $\pm$ 26.4   | 136.4 $\pm$ 50.2               | 1488.0 $\pm$ 130.4  |
| 8732 .....         | 7.17 $\pm$ 0.18                 | 5.71 $\pm$ 0.17                 | 4.57 $\pm$ 0.40                 | 171.4 $\pm$ 12.9    | 147.0 $\pm$ 19.0                  | 452.6 $\pm$ 12.5   | 97.6 $\pm$ 27.7                | 1524.6 $\pm$ 89.7   |
| 8736 .....         | 8.12 $\pm$ 0.17                 | 5.93 $\pm$ 0.15                 | 4.51 $\pm$ 0.27                 | 201.5 $\pm$ 13.5    | 195.1 $\pm$ 22.9                  | 518.1 $\pm$ 12.9   | 73.6 $\pm$ 19.0                | 1578.9 $\pm$ 58.5   |
| 8752 .....         | 7.28 $\pm$ 0.16                 | 5.57 $\pm$ 0.11                 | 4.33 $\pm$ 0.35                 | 178.4 $\pm$ 8.9     | 133.7 $\pm$ 14.4                  | 484.1 $\pm$ 11.0   | 68.7 $\pm$ 23.5                | 1737.2 $\pm$ 65.8   |
| 8764 .....         | 6.96 $\pm$ 0.36                 | 5.31 $\pm$ 0.13                 | 4.38 $\pm$ 0.26                 | 167.3 $\pm$ 22.2    | 119.2 $\pm$ 31.7                  | 444.6 $\pm$ 16.2   | 56.1 $\pm$ 29.1                | 1605.1 $\pm$ 74.0   |
| 8772 .....         | 7.52 $\pm$ 0.38                 | 5.75 $\pm$ 0.15                 | 4.42 $\pm$ 0.31                 | 223.7 $\pm$ 21.4    | 148.8 $\pm$ 29.2                  | 504.2 $\pm$ 16.9   | 115.4 $\pm$ 25.7               | 1760.7 $\pm$ 64.1   |
| 8776 .....         | 7.46 $\pm$ 0.22                 | 5.96 $\pm$ 0.17                 | 4.64 $\pm$ 0.23                 | 186.8 $\pm$ 14.7    | 146.5 $\pm$ 22.7                  | 465.4 $\pm$ 14.8   | 99.6 $\pm$ 19.0                | 1716.2 $\pm$ 48.0   |
| 8783 .....         | 7.18 $\pm$ 0.17                 | 5.82 $\pm$ 0.18                 | 4.90 $\pm$ 0.22                 | 184.9 $\pm$ 10.7    | 128.8 $\pm$ 13.5                  | 451.3 $\pm$ 11.6   | 82.1 $\pm$ 24.0                | 1878.0 $\pm$ 55.0   |
| 8794 .....         | 8.97 $\pm$ 0.25                 | 7.27 $\pm$ 0.22                 | ...                             | 194.1 $\pm$ 16.7    | 101.7 $\pm$ 33.0                  | 458.8 $\pm$ 22.4   | 114.2 $\pm$ 32.1               | ...                 |
| 8802 .....         | 8.07 $\pm$ 0.22                 | 6.01 $\pm$ 0.14                 | 4.61 $\pm$ 0.29                 | 163.0 $\pm$ 12.9    | 136.2 $\pm$ 21.5                  | 422.0 $\pm$ 14.5   | 78.3 $\pm$ 20.2                | 1704.5 $\pm$ 60.7   |
| 8804 .....         | 8.06 $\pm$ 0.26                 | 5.95 $\pm$ 0.26                 | ...                             | 191.7 $\pm$ 12.9    | 125.0 $\pm$ 13.9                  | 402.6 $\pm$ 16.6   | 81.0 $\pm$ 25.3                | ...                 |
| 8808 .....         | 7.80 $\pm$ 0.15                 | 6.00 $\pm$ 0.17                 | 4.50 $\pm$ 0.29                 | 166.1 $\pm$ 10.9    | 128.9 $\pm$ 23.2                  | 418.2 $\pm$ 16.3   | 68.1 $\pm$ 24.6                | 1699.0 $\pm$ 57.6   |
| 8810 .....         | 8.07 $\pm$ 0.22                 | 6.12 $\pm$ 0.22                 | 4.70 $\pm$ 0.30                 | 165.4 $\pm$ 13.2    | 134.2 $\pm$ 25.0                  | 404.7 $\pm$ 19.9   | 69.9 $\pm$ 25.5                | 1720.5 $\pm$ 64.2   |
| 8812 .....         | 6.85 $\pm$ 0.34                 | 5.00 $\pm$ 0.33                 | 3.98 $\pm$ 0.34                 | 144.4 $\pm$ 17.9    | 112.8 $\pm$ 27.7                  | 395.2 $\pm$ 26.2   | 44.2 $\pm$ 23.5                | 1601.3 $\pm$ 59.0   |
| 8822 .....         | 7.54 $\pm$ 0.37                 | 5.40 $\pm$ 0.20                 | 4.22 $\pm$ 0.33                 | 123.7 $\pm$ 17.8    | 138.7 $\pm$ 17.3                  | 368.2 $\pm$ 14.9   | 76.6 $\pm$ 18.2                | 1671.2 $\pm$ 69.4   |
| 8824 .....         | 7.65 $\pm$ 0.19                 | 5.84 $\pm$ 0.11                 | 4.56 $\pm$ 0.34                 | 144.4 $\pm$ 12.3    | 114.8 $\pm$ 23.6                  | 376.9 $\pm$ 14.3   | 73.7 $\pm$ 19.6                | 1748.3 $\pm$ 73.0   |
| 8826 .....         | 7.62 $\pm$ 0.29                 | 6.23 $\pm$ 0.23                 | ...                             | 172.3 $\pm$ 18.8    | 110.7 $\pm$ 34.6                  | 402.5 $\pm$ 23.2   | ...                            | ...                 |
| 8830 .....         | 7.60 $\pm$ 0.18                 | 6.10 $\pm$ 0.10                 | 4.74 $\pm$ 0.28                 | 177.1 $\pm$ 9.9     | 122.5 $\pm$ 12.7                  | 449.1 $\pm$ 8.7    | 100.2 $\pm$ 18.9               | 1973.6 $\pm$ 58.4   |
| 8832 .....         | 7.30 $\pm$ 0.29                 | 5.59 $\pm$ 0.12                 | 4.62 $\pm$ 0.21                 | 147.5 $\pm$ 13.5    | 109.3 $\pm$ 12.5                  | 446.0 $\pm$ 9.9    | 79.8 $\pm$ 29.6                | 1902.2 $\pm$ 58.5   |

<sup>a</sup> Continuum fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$  and line fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1}$ .

<sup>b</sup> Plus Fe II multiplets.

intrinsic color excess or whether a Galactic reddening law is actually valid in this galaxy (Brindle et al. 1990; Winkler et al. 1992), we decided against applying any kind of correction for the contamination of the stellar population in the light curves derived for this object. For Fairall 9, the underlying galaxy's contribution is small enough, and our observations too sparsely sampled (so no time-series analysis is possible), for this correction to be necessary.

As we are interested only in the variability of the continuum and emission lines, we opted to measure the features of interest in the simplest way. All emission lines were measured by interpolating a linear continuum, defined by two

windows on each side of the line, underneath the broad feature and integrating all flux above this continuum in a fixed interval. The errors were obtained by multiplying the rms of the continuum flux neighboring each line by the width of the line's integration interval. The continuum errors are just the rms flux inside the respective bands. Table 4 shows the continuum windows and line integration intervals for all objects. The H $\alpha$  line in Fairall 9 is located near the border of the spectrum, so it is impossible to define a red window for the continuum fitting; we assumed that this could be represented by the mean value inside the window at the blue side of the line. The flux measurements

TABLE 7  
MEASUREMENTS OF SPECTRA—ARAKELIAN 120<sup>a</sup>

| JD<br>(2,440,000+) | $F_{\lambda}(4200 \text{ \AA})$ | $F_{\lambda}(5630 \text{ \AA})$ | $F(\text{H}\gamma)$ | $F(\text{H}\beta)$ | $F(\text{H}\alpha)$ |
|--------------------|---------------------------------|---------------------------------|---------------------|--------------------|---------------------|
| 8619 .....         | ...                             | 6.02 $\pm$ 0.34                 | 119.6 $\pm$ 32.0    | 522.2 $\pm$ 22.8   | 1712.8 $\pm$ 136.2  |
| 8623 .....         | 10.38 $\pm$ 0.14                | 6.91 $\pm$ 0.15                 | 176.5 $\pm$ 11.1    | 585.0 $\pm$ 9.7    | 2185.9 $\pm$ 59.0   |
| 8627 .....         | 8.90 $\pm$ 0.18                 | 5.79 $\pm$ 0.24                 | 153.7 $\pm$ 11.1    | 471.1 $\pm$ 15.4   | 1819.5 $\pm$ 42.4   |
| 8631 .....         | 9.28 $\pm$ 0.21                 | 6.22 $\pm$ 0.20                 | 154.3 $\pm$ 13.6    | 513.6 $\pm$ 11.9   | 2116.5 $\pm$ 60.3   |
| 8635 .....         | 9.96 $\pm$ 0.23                 | 6.55 $\pm$ 0.22                 | 165.3 $\pm$ 15.4    | 536.1 $\pm$ 14.9   | 2128.9 $\pm$ 62.4   |
| 8643 .....         | 10.34 $\pm$ 0.22                | 7.01 $\pm$ 0.23                 | 183.4 $\pm$ 16.8    | 614.2 $\pm$ 16.2   | 2380.7 $\pm$ 46.1   |
| 8647 .....         | 10.39 $\pm$ 0.27                | 6.77 $\pm$ 0.20                 | 193.2 $\pm$ 16.4    | 659.6 $\pm$ 15.5   | 2172.0 $\pm$ 50.4   |
| 8651 .....         | 9.94 $\pm$ 0.28                 | 6.66 $\pm$ 0.21                 | 197.7 $\pm$ 19.2    | 625.7 $\pm$ 16.8   | 1984.1 $\pm$ 61.9   |
| 8656 .....         | 10.83 $\pm$ 0.24                | 7.28 $\pm$ 0.26                 | 211.1 $\pm$ 17.9    | 656.8 $\pm$ 9.1    | 2154.3 $\pm$ 71.8   |
| 8660 .....         | 9.85 $\pm$ 0.25                 | 6.96 $\pm$ 0.22                 | 211.1 $\pm$ 25.4    | 626.7 $\pm$ 12.9   | 2023.8 $\pm$ 50.2   |
| 8664 .....         | 9.28 $\pm$ 0.22                 | 6.13 $\pm$ 0.15                 | 173.2 $\pm$ 15.7    | 550.6 $\pm$ 13.6   | 1673.6 $\pm$ 37.8   |
| 8668 .....         | 10.80 $\pm$ 0.30                | 7.16 $\pm$ 0.24                 | 174.6 $\pm$ 10.9    | 643.3 $\pm$ 29.8   | 1967.0 $\pm$ 59.1   |
| 8672 .....         | 9.44 $\pm$ 0.14                 | 6.32 $\pm$ 0.26                 | 185.1 $\pm$ 16.0    | 573.4 $\pm$ 18.3   | 2080.0 $\pm$ 75.9   |
| 8676 .....         | 10.37 $\pm$ 0.33                | 6.86 $\pm$ 0.30                 | 242.9 $\pm$ 19.4    | 647.5 $\pm$ 16.4   | 2567.5 $\pm$ 54.1   |
| 8678 .....         | 9.90 $\pm$ 0.27                 | 7.02 $\pm$ 0.22                 | 210.8 $\pm$ 18.8    | 649.1 $\pm$ 18.4   | 2654.9 $\pm$ 85.5   |
| 8830 .....         | 9.97 $\pm$ 0.09                 | 7.08 $\pm$ 0.26                 | 212.8 $\pm$ 8.5     | 658.4 $\pm$ 21.7   | 2564.9 $\pm$ 56.1   |
| 8832 .....         | 9.56 $\pm$ 0.34                 | 7.17 $\pm$ 0.19                 | 209.7 $\pm$ 17.8    | 633.4 $\pm$ 13.9   | 2726.8 $\pm$ 70.4   |
| 8834 .....         | 10.45 $\pm$ 0.31                | 6.96 $\pm$ 0.23                 | 235.6 $\pm$ 23.9    | 667.1 $\pm$ 17.1   | 2341.2 $\pm$ 88.6   |

<sup>a</sup> Continuum fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$  and line fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1}$ .

TABLE 8  
MEASUREMENTS OF SPECTRA—FAIRALL 9<sup>a</sup>

| JD<br>(2,440,000 +) | $F_{\lambda}(4230 \text{ \AA})$ | $F_{\lambda}(5630 \text{ \AA})$ | $F(\text{H}\gamma)$ | $F(\text{He II } \lambda 4686)^b$ | $F(\text{H}\beta)$ | $F(\text{H}\alpha)$ |
|---------------------|---------------------------------|---------------------------------|---------------------|-----------------------------------|--------------------|---------------------|
| 8607 .....          | $6.87 \pm 0.26$                 | $4.93 \pm 0.28$                 | $96.2 \pm 19.3$     | $133.8 \pm 35.8$                  | $307.5 \pm 16.9$   | $1362.2 \pm 72.1$   |
| 8619 .....          | $6.87 \pm 0.17$                 | $4.30 \pm 0.19$                 | $135.7 \pm 12.0$    | $137.2 \pm 22.9$                  | $301.9 \pm 12.4$   | ...                 |
| 8623 .....          | $5.75 \pm 0.11$                 | $4.56 \pm 0.19$                 | $95.7 \pm 8.2$      | $127.5 \pm 16.9$                  | $311.1 \pm 6.9$    | $1007.2 \pm 20.9$   |
| 8627 .....          | $5.89 \pm 0.11$                 | $4.68 \pm 0.21$                 | $114.6 \pm 5.9$     | $152.1 \pm 10.0$                  | $317.4 \pm 7.2$    | $1108.2 \pm 37.7$   |
| 8631 .....          | $6.37 \pm 0.18$                 | $4.86 \pm 0.17$                 | $119.8 \pm 9.2$     | $170.1 \pm 11.6$                  | $343.0 \pm 5.5$    | $1131.6 \pm 18.7$   |
| 8635 .....          | $6.05 \pm 0.20$                 | $4.75 \pm 0.12$                 | $110.3 \pm 12.3$    | $137.0 \pm 17.7$                  | $326.5 \pm 7.1$    | $1106.3 \pm 40.6$   |
| 8639 .....          | $6.01 \pm 0.14$                 | $4.39 \pm 0.21$                 | $100.6 \pm 11.5$    | $106.3 \pm 20.0$                  | $294.2 \pm 6.9$    | ...                 |
| 8808 .....          | $3.85 \pm 0.14$                 | $3.55 \pm 0.20$                 | $108.0 \pm 7.6$     | $90.7 \pm 17.5$                   | $240.1 \pm 8.8$    | $1132.0 \pm 28.2$   |
| 8822 .....          | $4.21 \pm 0.20$                 | $4.03 \pm 0.27$                 | $108.3 \pm 15.2$    | $65.4 \pm 34.8$                   | ...                | ...                 |
| 8824 .....          | $3.56 \pm 0.13$                 | $3.60 \pm 0.26$                 | $102.2 \pm 8.0$     | $70.8 \pm 19.0$                   | $235.0 \pm 9.6$    | $1112.4 \pm 49.2$   |
| 8830 .....          | $3.60 \pm 0.13$                 | $3.31 \pm 0.16$                 | $92.5 \pm 7.3$      | $77.8 \pm 10.5$                   | $243.9 \pm 6.1$    | $1062.5 \pm 37.7$   |
| 8832 .....          | $3.80 \pm 0.10$                 | $3.53 \pm 0.22$                 | $93.0 \pm 8.4$      | $79.8 \pm 19.3$                   | $241.4 \pm 9.5$    | $1185.3 \pm 25.1$   |
| 8834 .....          | $3.96 \pm 0.24$                 | $3.44 \pm 0.20$                 | $93.6 \pm 14.6$     | $95.2 \pm 21.1$                   | $253.0 \pm 8.0$    | $1148.7 \pm 39.4$   |

<sup>a</sup> Continuum fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$  and line fluxes in units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1}$ .

<sup>b</sup> Plus Fe II multiplets.

are listed in Tables 5–8, and the light curves for the continua and emission lines measured in the IC 4329A and ESO 141–G55 spectra are shown in Figures 3, 4, and 5. The H $\gamma$  line in all objects is contaminated by the [O III]  $\lambda$  4363 emission line, and He II  $\lambda$  4686 is contaminated by Fe II multiplets. We have excluded from these tables the epochs in which the low S/N of the spectra (due to poor weather or full moon) or suspected calibration problems resulted in flux errors greater than 20%, except for the low-contrast features (He II  $\lambda$  4686 and He I  $\lambda$  5876), where we excluded only the measurements in which obvious problems of calibration could be detected.

#### 4. VARIABILITY ANALYSIS

##### 4.1. Variability Amplitude

The general characteristics of the database for each object studied here are summarized in Table 9. The parameters  $R_{\text{max}}$  and  $F_{\text{var}}$  are the ratios of the maximum to minimum flux observed and of the rms fluctuation amplitude to the

mean flux (corrected for the effect of the measurement errors), respectively (Clavel et al. 1991). In column (8), we present the reduced  $\chi^2$  for variability with respect to the mean and, in column (9), the probability of obtaining that result under the hypothesis of constant flux (no real variability). It can be seen that this hypothesis is strongly rejected in most cases [ $P(\text{null}) < 10^{-4}$ ], with the exception of He I  $\lambda$  5876 in ESO 141–G55 and most of the features inside each group of observations for Fairall 9. While our data indicate little variability in the continuum and emission lines of Fairall 9 on timescales of a few days to 1

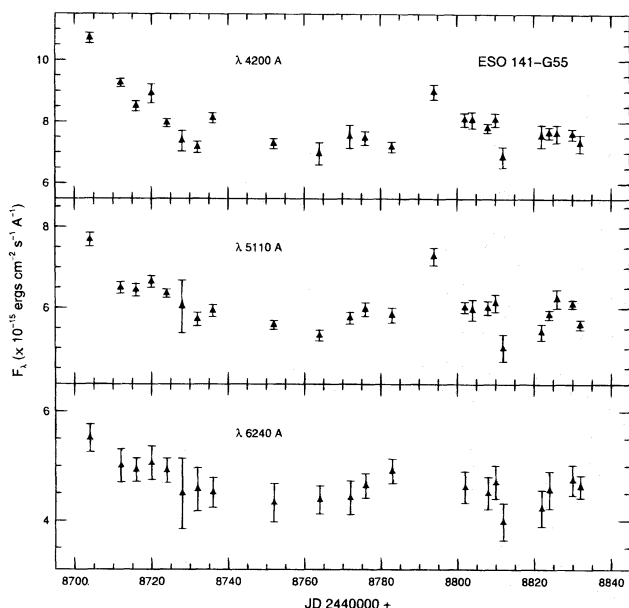


FIG. 4.—ESO 141–G55 continuum light curves: 4200, 5110, and 6240 Å continua (top to bottom).

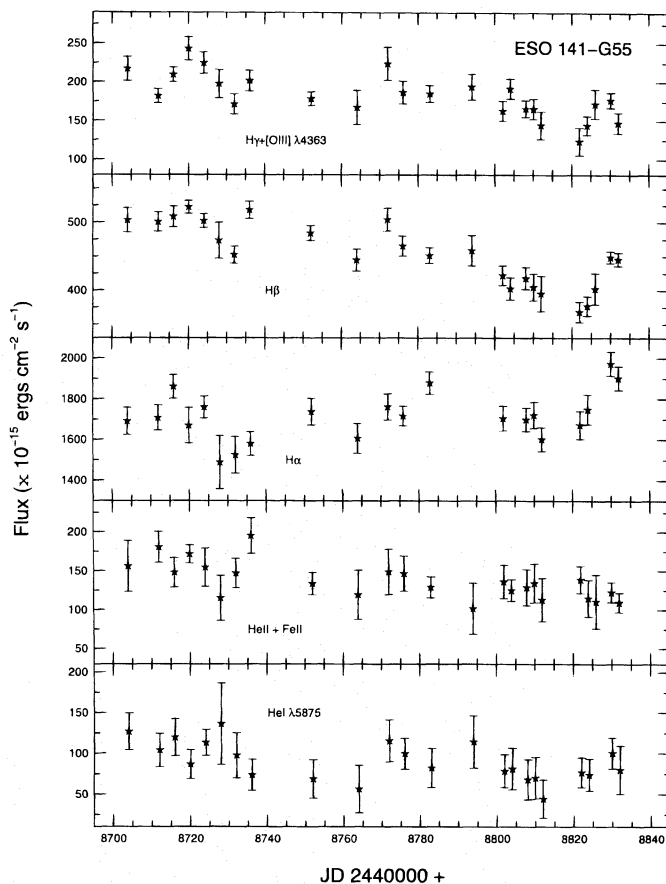


FIG. 5.—ESO 141–G55 broad emission line light curves: H $\gamma$  + [O III]  $\lambda$  4363, H $\beta$ , H $\alpha$ , He II  $\lambda$  4686 + Fe II, and He I  $\lambda$  5876 (top to bottom).

TABLE 9  
VARIABILITY PARAMETERS AND SAMPLING CHARACTERISTICS

| FEATURE<br>(1)                        | NUMBER OF<br>EPOCHS<br>(2) | SAMPLING INTERVAL (days) |               | MEAN<br>FLUX <sup>a</sup><br>(5) | $F_{\text{var}}$<br>(6) | $R_{\text{max}}$<br>(7) | $\chi^2_{\nu}$ <sup>b</sup><br>(8) | $P(\text{null})^c$<br>(9) |
|---------------------------------------|----------------------------|--------------------------|---------------|----------------------------------|-------------------------|-------------------------|------------------------------------|---------------------------|
|                                       |                            | Average<br>(3)           | Median<br>(4) |                                  |                         |                         |                                    |                           |
| IC 4329A                              |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4210 \text{ \AA})$ ..... | 25                         | 7.88                     | 4             | 3.88                             | 0.08                    | 1.33                    | 4.18                               | $<10^{-4}$                |
| $F_{\lambda}(6225 \text{ \AA})$ ..... | 25                         | 7.88                     | 4             | 9.03                             | 0.05                    | 1.26                    | 1.38                               | 0.9                       |
| H $\beta$ .....                       | 26                         | 7.56                     | 4             | 333.1                            | 0.08                    | 1.33                    | 2.46                               | $<10^{-4}$                |
| H $\alpha$ .....                      | 25                         | 7.88                     | 4             | 3172.0                           | 0.09                    | 1.53                    | 7.20                               | $<10^{-4}$                |
| ESO 141—G55                           |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4200 \text{ \AA})$ ..... | 24                         | 5.57                     | 4             | 7.92                             | 0.10                    | 1.56                    | 22.34                              | $<10^{-4}$                |
| $F_{\lambda}(5110 \text{ \AA})$ ..... | 24                         | 5.57                     | 4             | 6.05                             | 0.09                    | 1.54                    | 11.51                              | $<10^{-4}$                |
| $F_{\lambda}(6240 \text{ \AA})$ ..... | 21                         | 6.40                     | 4             | 4.65                             | 0.07                    | 1.38                    | 1.40                               | 0.9                       |
| H $\gamma$ .....                      | 24                         | 5.57                     | 4             | 182.4                            | 0.16                    | 1.97                    | 3.74                               | $<10^{-4}$                |
| He II $\lambda 4686^d$ .....          | 24                         | 5.33                     | 4             | 138.8                            | 0.18                    | 1.92                    | 1.51                               | 0.9                       |
| H $\beta$ .....                       | 24                         | 5.57                     | 4             | 453.1                            | 0.10                    | 1.42                    | 10.69                              | $<10^{-4}$                |
| He I $\lambda 5876$ .....             | 23                         | 5.82                     | 4             | 89.8                             | 0.26                    | 3.09                    | 0.91                               | $>0.5$                    |
| H $\alpha$ .....                      | 21                         | 6.40                     | 4             | 1714.1                           | 0.07                    | 1.33                    | 3.31                               | $<10^{-4}$                |
| AKN 120—JD 2,448,629 to 2,448,678     |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4200 \text{ \AA})$ ..... | 14                         | 4.23                     | 4             | 9.98                             | 0.05                    | 1.22                    | 8.27                               | $<10^{-4}$                |
| $F_{\lambda}(5630 \text{ \AA})$ ..... | 15                         | 4.21                     | 4             | 6.65                             | 0.06                    | 1.26                    | 4.06                               | $<10^{-4}$                |
| H $\gamma$ .....                      | 15                         | 4.21                     | 4             | 183.5                            | 0.16                    | 2.03                    | 2.47                               | 0.995                     |
| H $\beta$ .....                       | 15                         | 4.21                     | 4             | 591.7                            | 0.10                    | 1.40                    | 17.55                              | $<10^{-4}$                |
| H $\alpha$ .....                      | 15                         | 4.21                     | 4             | 2108.1                           | 0.13                    | 1.59                    | 25.08                              | $<10^{-4}$                |
| AKN 120—All Data                      |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4200 \text{ \AA})$ ..... | 17                         | ...                      | 4             | 9.98                             | 0.08                    | 1.34                    | 6.97                               | $<10^{-4}$                |
| $F_{\lambda}(5630 \text{ \AA})$ ..... | 18                         | ...                      | 4             | 6.72                             | 0.06                    | 1.26                    | 3.99                               | $<10^{-4}$                |
| H $\gamma$ .....                      | 18                         | ...                      | 4             | 189.5                            | 0.16                    | 2.03                    | 3.09                               | $<10^{-4}$                |
| H $\beta$ .....                       | 18                         | ...                      | 4             | 601.9                            | 0.10                    | 1.42                    | 16.30                              | $<10^{-4}$                |
| H $\alpha$ .....                      | 18                         | ...                      | 4             | 2180.8                           | 0.14                    | 1.63                    | 30.10                              | $<10^{-4}$                |
| Fairall 9—JD 2,448,607 to 2,448,639   |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4230 \text{ \AA})$ ..... | 7                          | ...                      | ...           | 6.26                             | 0.06                    | 1.19                    | 9.09                               | $<10^{-4}$                |
| $F_{\lambda}(5630 \text{ \AA})$ ..... | 7                          | ...                      | ...           | 4.64                             | 0.03                    | 1.15                    | 1.39                               | 0.75                      |
| H $\gamma$ .....                      | 7                          | ...                      | ...           | 110.4                            | 0.13                    | 1.42                    | 1.75                               | 0.75                      |
| He II $\lambda 4686^d$ .....          | 7                          | ...                      | ...           | 137.8                            | 0.14                    | 1.60                    | 2.12                               | 0.9                       |
| H $\beta$ .....                       | 7                          | ...                      | ...           | 314.5                            | 0.05                    | 1.17                    | 6.69                               | $<10^{-4}$                |
| H $\alpha$ .....                      | 5                          | ...                      | ...           | 1143.1                           | 0.12                    | 1.35                    | 13.38                              | $<10^{-4}$                |
| Fairall 9—JD 2,448,808 to 2,448,834   |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4230 \text{ \AA})$ ..... | 6                          | ...                      | ...           | 3.83                             | 0.04                    | 1.18                    | 2.37                               | 0.9                       |
| $F_{\lambda}(5630 \text{ \AA})$ ..... | 6                          | ...                      | ...           | 3.58                             | 0.04                    | 1.22                    | 1.27                               | 0.7                       |
| H $\gamma$ .....                      | 6                          | ...                      | ...           | 99.6                             | 0.08                    | 1.17                    | 0.68                               | $>0.5$                    |
| He II $\lambda 4686^d$ .....          | 6                          | ...                      | ...           | 80.0                             | 0.14                    | 1.46                    | 0.27                               | $>0.5$                    |
| H $\beta$ .....                       | 5                          | ...                      | ...           | 242.7                            | 0.03                    | 1.08                    | 0.61                               | $>0.5$                    |
| H $\alpha$ .....                      | 5                          | ...                      | ...           | 1128.2                           | 0.04                    | 1.12                    | 2.15                               | 0.9                       |
| Fairall 9—All Data                    |                            |                          |               |                                  |                         |                         |                                    |                           |
| $F_{\lambda}(4230 \text{ \AA})$ ..... | 13                         | ...                      | ...           | 5.14                             | 0.24                    | 1.93                    | 76.80                              | $<10^{-4}$                |
| $F_{\lambda}(5630 \text{ \AA})$ ..... | 13                         | ...                      | ...           | 4.15                             | 0.13                    | 1.48                    | 10.64                              | $<10^{-4}$                |
| H $\gamma$ .....                      | 13                         | ...                      | ...           | 105.4                            | 0.12                    | 1.47                    | 1.63                               | 0.9                       |
| He II $\lambda 4686^d$ .....          | 13                         | ...                      | ...           | 111.1                            | 0.31                    | 2.60                    | 5.70                               | $<10^{-4}$                |
| H $\beta$ .....                       | 12                         | ...                      | ...           | 284.6                            | 0.14                    | 1.46                    | 29.38                              | $<10^{-4}$                |
| H $\alpha$ .....                      | 10                         | ...                      | ...           | 1135.6                           | 0.08                    | 1.35                    | 6.30                               | $<10^{-4}$                |

<sup>a</sup> In units of  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1} \text{ \AA}^{-1}$  for the continua and  $10^{-15} \text{ ergs cm}^{-2} \text{ s}^{-1}$  for the lines.

<sup>b</sup> Reduced  $\chi^2$  for variability about the mean. Degrees of freedom are the number of epochs  $N - 1$  for each feature.

<sup>c</sup> Probability of obtaining the calculated value of  $\chi^2_{\nu}$  if no real variability is present.

<sup>d</sup> Plus Fe II multiplets.

month, the analysis of the complete set of observations shows that this object can vary by a factor of  $\sim 2$  in both continuum and broad lines over a few months. The same is not true for AKN 120, in which the variability on short timescales (up to 50 days) does not differ too much in ampli-

tude from the results for the complete data set, which includes observations taken 4 months apart. This behavior is consistent with the known variability history of this source (Peterson et al. 1989). Note also that the  $\chi^2$  test indicates that the variations observed in IC 4329A



[ $\log L(\text{H}\beta) \sim 41.49$ ; if corrected by  $E(B-V) = 0.8$ , this value rises to  $\log L(\text{H}\beta) \sim 41.96$ ] are of smaller amplitude than those in ESO 141–G55, a higher luminosity AGN [ $\log L(\text{H}\beta) \sim 42.21$ ]. This effect runs counter to the behavior usually observed, as in the standard-model AGN geometry the amplitude of the emission-line variations decreases with increasing luminosity as a consequence of the larger size of the BLR (Peterson 1994; Robinson 1994), and could be due to the limited temporal extension of the monitoring campaign.

#### 4.2. Time-Series Analysis

Under the assumptions of the standard reverberation scenario (see Peterson 1993), the time delay between the continuum and broad emission line variations can be interpreted as an estimate of the BLR's size. For irregularly sampled data, this delay can be obtained by use of the interpolation cross-correlation (CCF) technique (White & Peterson 1994), and we can use the centroid of the distribution as a measure of the responsivity-weighted radius of the emission region (Koratkar & Gaskell 1991). In this section, we present and discuss the analysis of the light curves derived for IC 4329A and ESO 141–G55.

The first step in analyzing any time series is to determine whether the sampling is adequate. This can be accomplished by comparing the width of the autocorrelation functions (ACFs) for the series of interest with that of the sampling-window autocorrelation function (SWACF), obtained by repeatedly sampling a white-noise spectrum in the same pattern as the real observations. The FWHM of the window ACFs indicates how much artificial correlation is introduced when the observed light curves are interpolated while calculating the CCFs. We adopted the same criterion as Gaskell & Peterson (1987), considering the data to be well sampled when the true (vs. observed) FWHM of

the light-curve ACF is at least 10% greater than the FWHM of the window ACF. If the ACFs are Gaussian, the observed FWHM ( $W_a$ ) will be the square root of the two quantities above added in quadrature. The sampling criterion for the observed ACFs is then  $W_a/W_s \gtrsim 1.35$ . The comparison between the distributions for the two objects studied are shown in Figures 6 and 7. The FWHMs of the line and continuum ACFs and the ratio  $W_a/W_s$  are shown in columns (3) and (4) of Table 10, respectively.

From these data it can be seen that the light curves are slightly undersampled for IC 4329A, especially the 4210 Å continuum and H $\alpha$ . Even for the cases in which the sampling was not adequate, an upper limit on the size of the emission region can be provided by the half-width at zero correlation (HWZC) of the line ACFs, as, assuming a simple spherical model, this will represent the larger coherence length of the variations, defined by the diameter of the emission region (Gaskell & Peterson 1987; Koratkar & Gaskell 1991). The results for the H $\beta$  and H $\alpha$  emission lines in IC 4329A are shown in column (5) of Table 10 and indicate an upper limit of  $\sim 30$  lt-days (0.03 pc) for the radius of the emission region.

For ESO 141–G55, all series satisfy the sampling criterion with the possible exception of H $\alpha$ , which, although formally within the limit above, resulted in an ACF with little power for delays longer than a few days (see Fig. 7). The shape of the He II  $\lambda 4686$  ACF similarly indicates that the correlated errors are more important in this light curve than in the case of H $\beta$ . Taking these facts into account, probably only the HWZC obtained from the H $\beta$  ACF can be regarded as somewhat representative of the scale length of the variations, resulting in a lower limit of  $\sim 30$  lt-days for the emission region.

The results of the cross-correlation analysis are summarized in columns (6)–(8) of Table 10. Here  $\Delta t_{\text{peak}}$  is the lag

TABLE 10  
VARIABILITY ANALYSIS

| First Series<br>(1)                         | Second Series<br>(2)          | FWHM<br>(days)<br>(3) | $W_a/W_s$<br>(4) | HWZI<br>(days)<br>(5) | $\Delta t_{\text{peak}}$<br>(days)<br>(6) | $\Delta t_{\text{cent}}$<br>(days)<br>(7) | $r_{\text{max}}$<br>(8) |
|---|-------------------------------|-----------------------|------------------|-----------------------|---|---|-------------------------|
| IC 4329A                                    |                               |                       |                  |                       |   |   |                         |
| $F_{\lambda}(4210 \text{ Å})$ ACF .....     | ...                           | 10.8                  | 1.6              | ...                   | ...                                       | ...                                       | ...                     |
| $F_{\lambda}(6625 \text{ Å})$ ACF .....     | ...                           | 23.9                  | 3.5              | ...                   | ...                                       | ...                                       | ...                     |
| H $\beta$ ACF .....                         | ...                           | 15.7                  | 2.3              | 60                    | ...                                       | ...                                       | ...                     |
| H $\alpha$ ACF .....                        | ...                           | 7.8                   | 1.2              | 60                    | ...                                       | ...                                       | ...                     |
| $F_{\lambda}(6625 \text{ Å})$ .....         | H $\beta$                     | 74.4                  | ...              | ...                   | 18  | 15.6                                      | 0.597                   |
| $F_{\lambda}(6625 \text{ Å})$ .....         | H $\alpha$                    | 76.1                  | ...              | ...                   | 23 <sup>a</sup>                           | 25.0 <sup>a</sup>                         | 0.620                   |
| SWACF <sup>b</sup> .....                    | ...                           | 6.8                   | ...              | ...                   | ...                                       | ...                                       | ...                     |
| ESO 141–G55                                 |                               |                       |                  |                       |   |   |                         |
| $F_{\lambda}(4200 \text{ Å})$ ACF .....     | ...                           | 18.1                  | 4.0              | ...                   | ...                                       | ...                                       | ...                     |
| $F_{\lambda}(5110 \text{ Å})$ ACF .....     | ...                           | 13.8                  | 3.1              | ...                   | ...                                       | ...                                       | ...                     |
| $F_{\lambda}(6240 \text{ Å})$ ACF .....     | ...                           | 18.7                  | 4.2              | ...                   | ...                                       | ...                                       | ...                     |
| H $\gamma$ ACF .....                        | ...                           | 12.7                  | 2.8              | 40                    | ...                                       | ...                                       | ...                     |
| He II $\lambda 4686$ ACF <sup>c</sup> ..... | ...                           | 11.1                  | 2.5              | 50                    | ...                                       | ...                                       | ...                     |
| H $\beta$ ACF .....                         | ...                           | 53.8                  | 12.0             | >60                   | ...                                       | ...                                       | ...                     |
| He I $\lambda 5876$ ACF .....               | ...                           | 11.3                  | 2.5              | ...                   | ...                                       | ...                                       | ...                     |
| H $\alpha$ ACF .....                        | ...                           | 9.8                   | 2.2              | ...                   | ...                                       | ...                                       | ...                     |
| $F_{\lambda}(4200 \text{ Å})$ .....         | $F_{\lambda}(5110 \text{ Å})$ | 18.4                  | ...              | ...                   | 0   | –0.6                                      | 0.903                   |
| $F_{\lambda}(4200 \text{ Å})$ .....         | $F_{\lambda}(6240 \text{ Å})$ | 27.4                  | ...              | ...                   | 0   | –1.6                                      | 0.811                   |
| SWACF <sup>d</sup> .....                    | ...                           | 4.5                   | ...              | ...                   | ...                                       | ...                                       | ...                     |

<sup>a</sup> Position and centroid of the second most significant peak of the CCF.

<sup>b</sup> Sampling-window ACF calculated for the 6625 Å continuum light curve.

<sup>c</sup> Plus Fe II multiplets.

<sup>d</sup> Sampling-window ACF calculated for the 4200 Å continuum light curve.

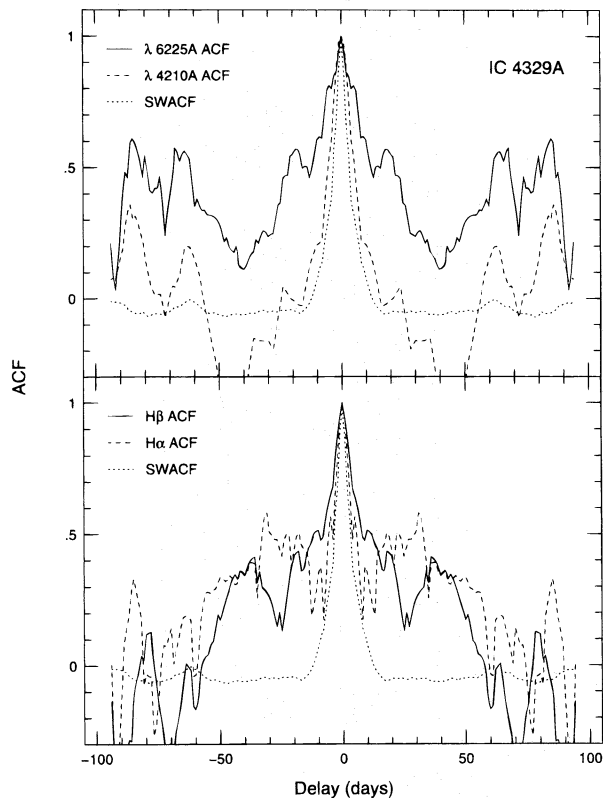


FIG. 6.—Autocorrelation functions for the continua and broad emission lines of IC 4329A. Top: 6225 Å (solid line), 4210 Å (dashed line), and 6225 Å sampling window (dotted line). Bottom: H $\beta$  (solid line), H $\alpha$  (dashed line), and H $\beta$  sampling window (dotted line).

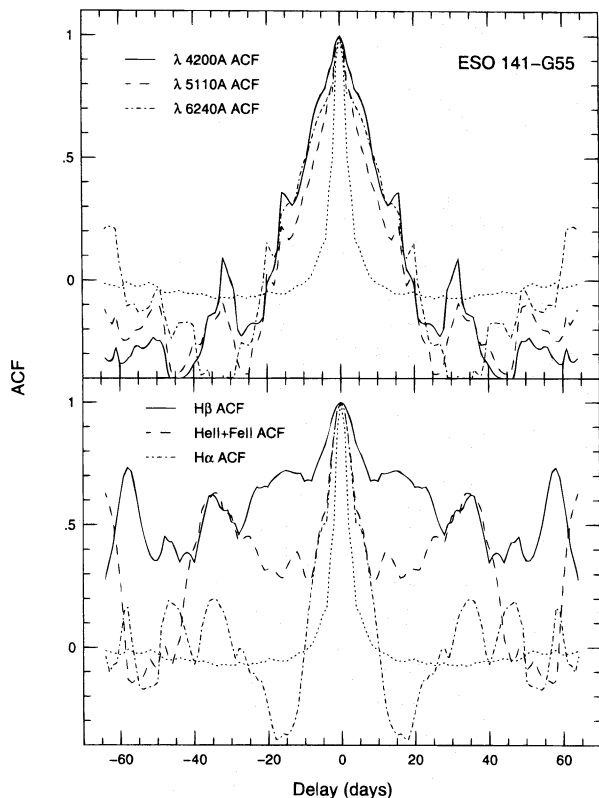


FIG. 7.—Same as Fig. 6, but for ESO 141-G55. Top: 4200 Å (solid line), 5110 Å (dashed line), and 6240 Å (dot-dashed line). Bottom: H $\beta$  (solid line), He II  $\lambda$ 4686 + Fe II (dashed line), and H $\alpha$  (dot-dashed line). The dotted line in both panels is the 4200 Å continuum sampling-window ACF.

at which the CCF reaches its maximum value,  $\Delta t_{\text{cent}}$  is the position of the CCF centroid, and  $r_{\text{max}}$  is the peak value. The CCFs between the H $\alpha$  and H $\beta$  emission lines and the 6225 Å continuum for IC 4329A are shown in Figure 8. Both curves are contaminated by correlated errors, as evidenced by the presence of a sharp peak at zero delay, but are clearly asymmetric in the direction of positive lags, which indicates the existence of a real correlation between the lines and the continuum light curves. Besides the zero-lag peak produced by the correlated errors, the H $\alpha$  CCF presents a highly significant maximum ( $P \approx 99.8\%$ ) at  $\Delta t_{\text{cent}} \sim 25$  lt-days. The H $\beta$  CCF also presents two maxima of about the same significance ( $P \approx 99.8\%$ ), located at  $\Delta t_{\text{cent}} \sim 15.6$  and 51.6 lt-days. This last value would be in contradiction with the maximum size derived from the HWZC of the line ACF, so we assume that the first peak represents the actual lag between the two time series and that the second is an alias. The cross-correlation between the two continua is completely dominated by the correlated errors, as could be expected from the small width of the 4210 Å ACF.

The significance of these results can be assessed by use of Monte Carlo simulations, following the method introduced by Gaskell & Peterson (1987) and Maoz & Netzer (1989), with the modifications described in Paper I. In short, the method consists of generating a model light curve by linearly interpolating to 1 day intervals and smoothing the observed continuum, which is then convolved with the transfer function for a thin spherical shell of radius  $R$  to obtain a synthetic line light curve. The two model time series are then resampled at the same number of points as the observed ones, to preserve the number of paired observations (nights when it was possible to measure both continuum and line fluxes from the same spectrum) and the distribution of intervals between the emission-line observations, and Gaussian-distributed random noise comparable to the observational errors is added to each point. The data sets are then cross-correlated to determine the location of the centroid of the CCF, setting a minimum confidence level based on the peak value of the CCF,  $\rho$ , as a condition for a given trial to be taken as successful and the result registered. The light curves are then resampled and the process repeated a large number of times for a given  $R$ . The result is a probability distribution for the possible values of the CCF centroid that can be obtained from the observed light curves, given the amplitude of the variations, the observational sampling and errors, and the assumed size and geometry of the BLR. For reasonably well defined lags, the width of the probability distribution can be regarded as an estimate of the error in the observed delay, while for less well sampled series, we can use the method to explore the probability space around the observed result allowed by the observational data.

The simulations were run for a series of model BLRs with radii between 1 and 60 lt-days, with the confidence level set to 99.8% ( $\rho = 0.544$  and 0.534 for  $N = 25$  and 26 points, respectively). For both series, if the BLR's radius  $R$  is 5 lt-days, the probability that a single set of observations will produce a 99.8% significant lag of greater than 30 days is  $\sim 0.18$ . On the other hand, if  $R = 40$  lt-days, a single experiment will produce a significant lag that is smaller than 10 days  $\sim 10\%$  of the time. The results are shown in Figure 9, in which the curves present, as a function of the size of the model BLR, (a) the probability that the samples will

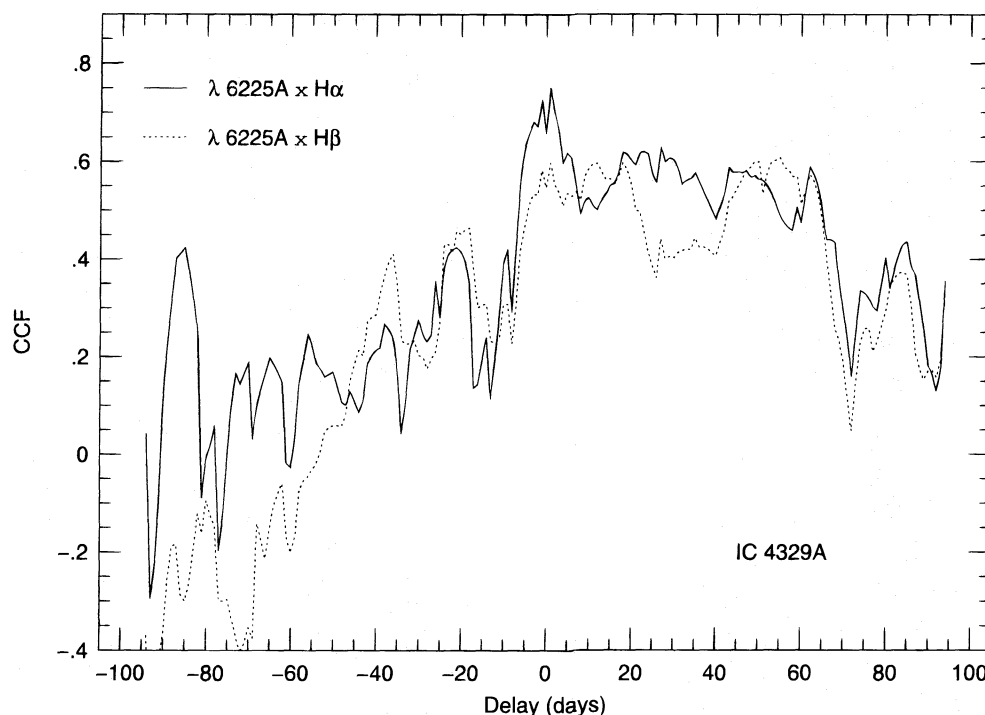


FIG. 8.—Cross-correlation between the 6225 Å continuum and the H $\alpha$  (solid line) and H $\beta$  (dotted line) emission lines of IC 4329A

produce a delay smaller than 30 days, consistent with the upper limit set by the line ACFs, and (b) a result within the interval 10 days  $< \tau_{LT} < 30$  days, so as to include the CCF lags obtained for both lines.

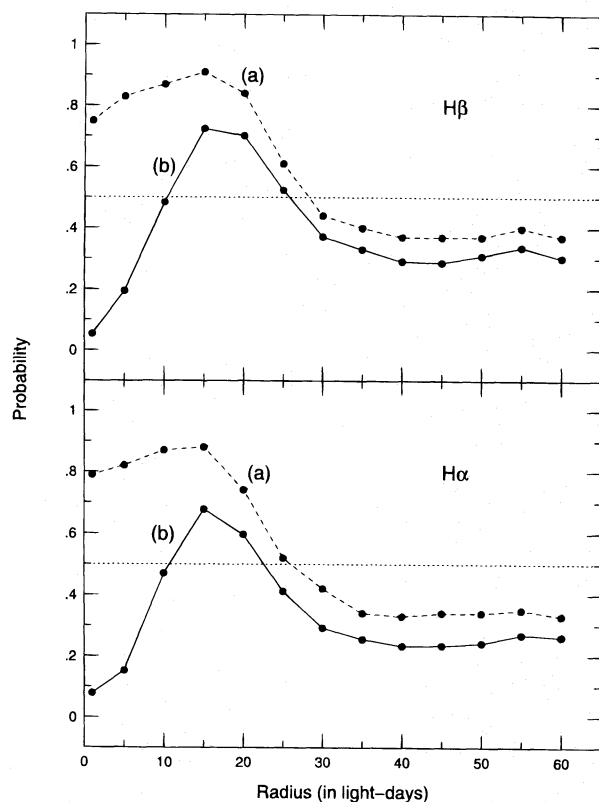


FIG. 9.—Results of the Monte Carlo simulations for H $\beta$  (top) and H $\alpha$  (bottom) of IC 4329A, as a function of the model BLR radius. The curves labeled “(a)” represent the probability that the observed samples will yield a delay smaller than 30 days, while the curves labeled “(b)” represent the probability of obtaining a CCF result within the interval 10 days  $< \tau_{LT} < 30$  days. The dotted line is the 50% probability level.

Curve *a* demonstrates that, if the BLR is indeed small ( $R \lesssim 25$  lt-days), 80% or more of the samples will lead to the observed result. It is worth noting that, even when the BLR’s radius is 40 lt-days or more, there is a  $\sim 40\%$  probability that the cross-correlations will yield a size determination smaller than 30 lt-days. This effect is due to the limited temporal coverage of the monitoring and the low amplitude of the observed variations. From curve *b*, we can see that the range of model BLR sizes that will result in a cross-correlation lag in the range 10–30 days at least at the 50% level is 11 lt-days  $\lesssim R \lesssim 25$  lt-days. This interval represents the most likely lag between the continuum and line variations, but other values within the range 0–60 lt-days cannot be ruled out with a high level of confidence based on the present data.

Figure 10 shows the 5110 and 6240 Å continua and the He II  $\lambda 4686$  and H $\beta$  emission lines versus the 4200 Å continuum CCFs for ESO 141–G55. The continuum CCFs peak at zero delay, indicating that the optical continuum in this object varies in phase within the resolution of our data ( $\sim 4$  days). As the amplitude of the variations increases for shorter wavelengths, this implies that the spectrum is bluer when the source is brighter, as has been observed for several other AGNs (Edelson, Krolik, & Pike 1990). The clearest correlation between the emission lines and the continuum occurs at zero lag and is of low significance (95% confidence level), being associated with the correlated errors, as the shape of the CCF does not differ significantly from that of the ACF. The CCFs rise at large delays, but the temporal extent of our campaign was not long enough to tell whether this is due to the presence of a real peak on the cross-correlation function located at a lag greater than 60 days.

### 4.3. Profile Variability

Although the large gaps in the temporal coverage preclude a similar time-series analysis for the AKN 120 and Fairall 9 data, it is interesting to point out the strong flux

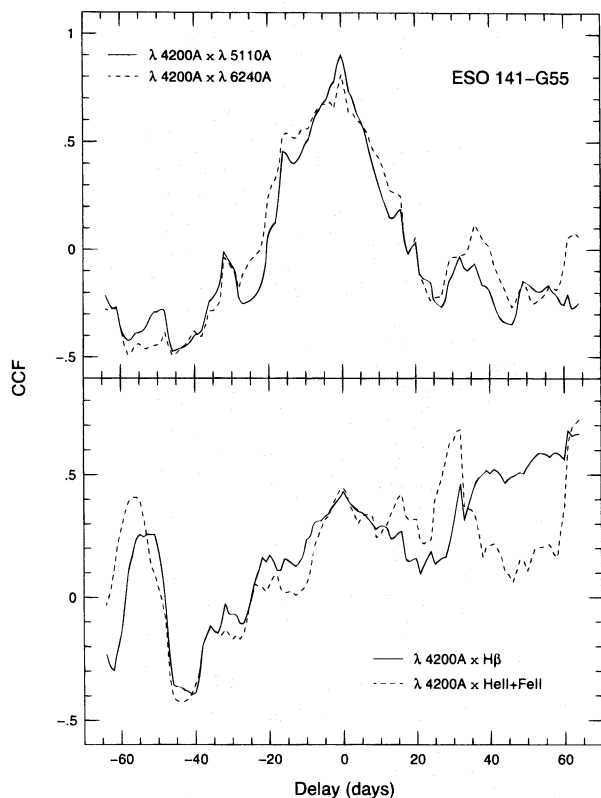


FIG. 10.—Cross-correlation between the 4200 Å continuum of ESO 141-G55 and the 5110 Å (solid line) and 6240 Å (dashed line) continua (top) and the H $\beta$  (solid line) and He II 14686 + Fe II (dashed line) emission lines (bottom).

and profile variations experienced by the main Balmer lines in these two objects during the period covered by our observations.

In Figure 11 are shown the mean spectra of the two sets

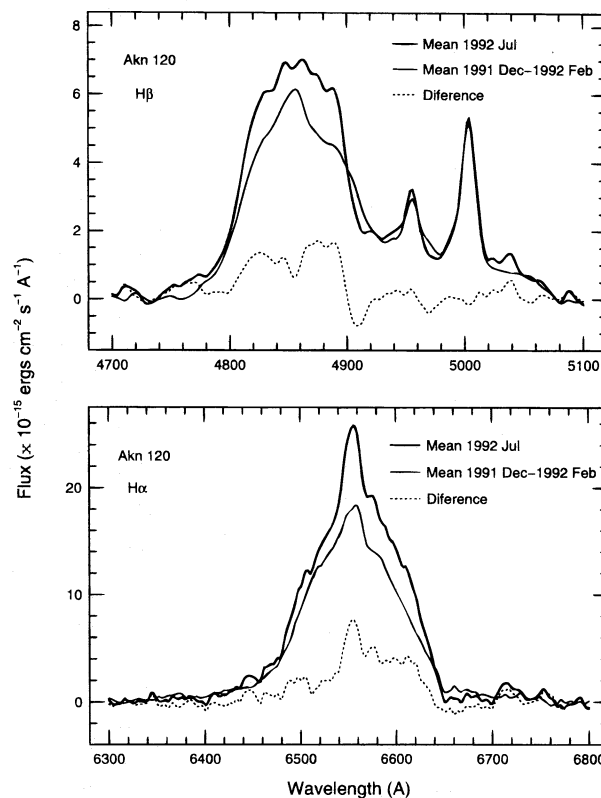


FIG. 12.—Broad-line profile variation between the mean spectra of AKN 120. Top, the H $\beta$  spectral region; bottom, the H $\alpha$  region. A linear continuum was subtracted from both spectra to highlight the profile variations (see § 4.3 for details).

of observations of AKN 120 (1991 December–1992 February, excluding JD 2,448,619 and 2,448,668, and 1992 July), as well as the difference between them. Note the strong flux variation in the Balmer lines (by factors of 1.4–2.0; see

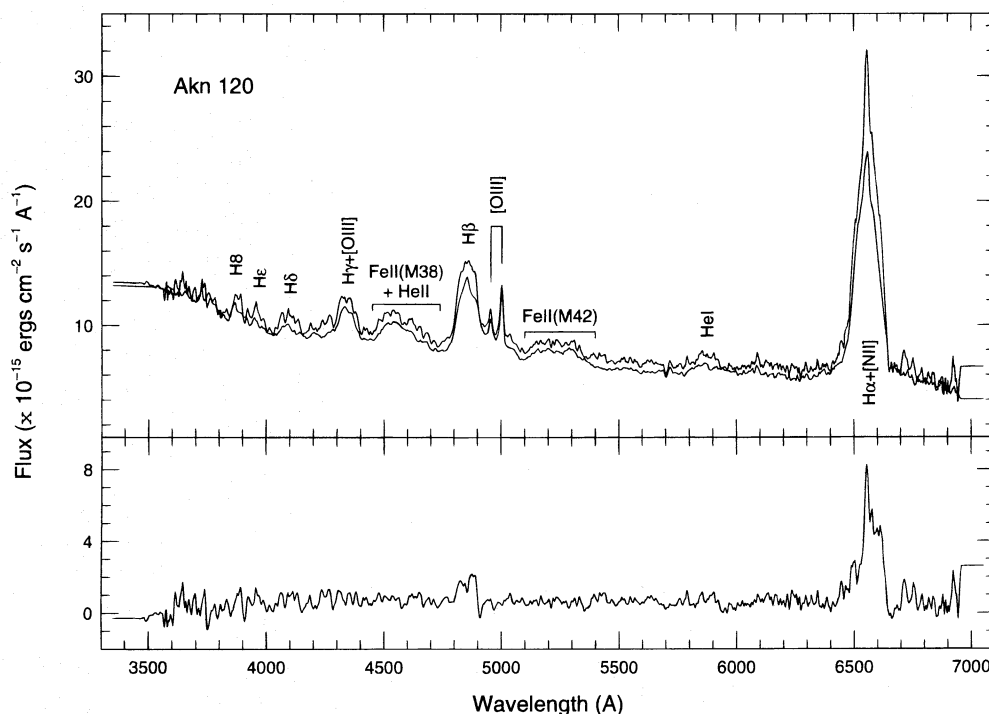


FIG. 11.—Top: AKN 120 mean spectra for 1991 December–1992 February (lower spectrum) and 1992 July (upper spectrum). Bottom: The difference spectrum.



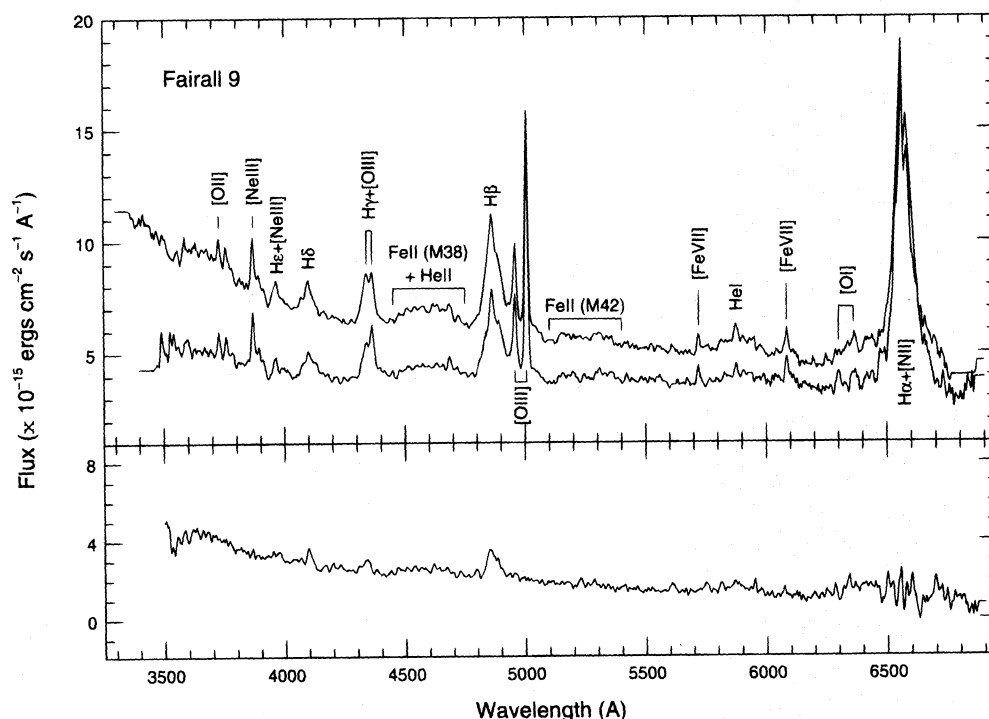
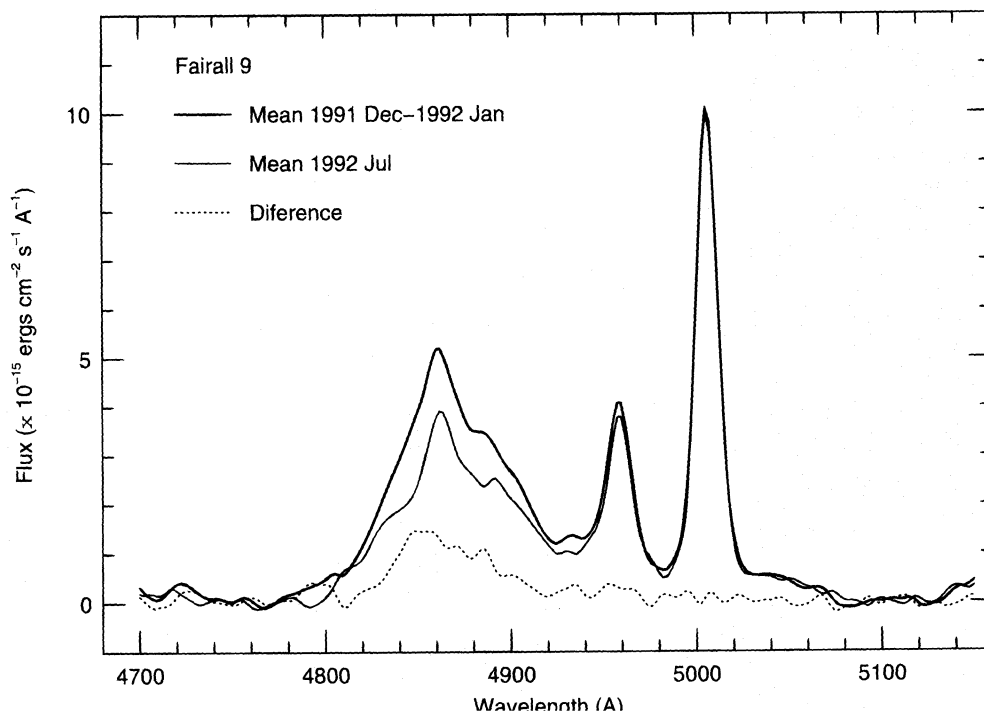


FIG. 13.—Same as Fig. 11, but for Fairall 9

Table 9) and the almost complete disappearance of the Fe II multiplets in the difference spectrum. To bring out the line-profile variations more clearly, we subtracted a local linear continuum, defined by the same windows presented in Table 4, interpolated under the line of interest in the two mean spectra. The results are shown in Figure 12 for H $\alpha$  and H $\beta$ . Note the sharp cut at the red wing in both lines and the very good subtraction of the [O III]  $\lambda$ 5007 lines in the H $\beta$  region.

Figure 13 shows the two mean spectra of Fairall 9 (1991 December–1992 January, excluding JD 2,448,619 and

2,448,639, and 1992 July, excluding JD 2,448,818 and 2,448,822), and their difference. In contrast to the case of AKN 120, both line and continuum levels were significantly lower in the second set of observations. As has been detected previously in other objects (Antonucci & Cohen 1983; Robinson 1994), there is a trend for the higher order Balmer lines to present larger amplitudes of variability. The decrease in flux between the two sets of observations corresponds to variations of 37%, 29%, 25%, 26%, and 8% in the fluxes of H $\epsilon$ , H $\delta$ , H $\gamma$ , H $\beta$ , and H $\alpha$ , respectively, in the December/January spectrum. Finally, in Figure 14, we



present the  $H\beta$  region in the two mean spectra, with a local continuum subtracted using the same procedure as for AKN 120, to show the profile variability. The line profile is smoother in this object than in AKN 120, and most of the changes were due to a decrease in the blue wing of the line.

### 5. CONCLUSIONS

We have presented the data from a campaign of optical spectroscopic monitoring of four southern active galaxies, IC 4329A, ESO 141–G55, AKN 120, and Fairall 9. Continuum and broad-line variability were detected in all objects, and the results of the campaign can be summarized as follows:

1. The mean contribution of the underlying stellar population to the nuclear spectrum of IC 4329A during the monitoring was  $\sim 20\%$  of the nuclear continuum at 3933 Å and 35% at 5175 Å. Assuming that the underlying galaxy of Fairall 9 is a giant elliptical, we conclude that the stellar population contributed with 10% or less of the nuclear continuum at 3933 Å when the source was in a “low” state of activity. For the two other objects studied, ESO 141–G55 and AKN 120, the stellar signatures were at the noise level, diluted by the AGN emission.

2. From the autocorrelation functions of the broad emission lines, we obtain an *upper* limit of  $\sim 30$  lt-days for the

size of the emission region of IC 4329A. The cross-correlation analysis between the continuum and the emission-line light curves of IC 4329A indicates that the most likely lag between the 6225 Å continuum variations and the response of  $H\alpha$  and  $H\beta$  lines is in the range 15–25 days. For ESO 141–G55, the continuum from  $\sim 4000$  to  $\sim 6500$  Å was found to vary in phase within the time resolution of our data.

3. Strong broad-line flux and profile variations were observed in both AKN 120 and Fairall 9 in timescales of  $\sim 4$  months. In Fairall 9, the amplitude of the flux variations was observed to increase for the higher order Balmer lines.

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