THE ASTROPHYSICAL JOURNAL, 307:486–496, 1986 August 15

SIMULTANEOUS *EXOSAT* AND *IUE* OBSERVATIONS OF FAIRALL 9: SHORT AND LONG TERM VARIABILITY[1]

M. MORINI AND L. SCARSI
Istituto di Fisica Cosmica ed Applicazioni dell'Informatica, Consiglio Nazionale delle Ricerche, Palermo
D. MOLTENI
Istituto di Fisica, Università di Palermo
M. SALVATI
Istituto di Astrofisica Spaziale, Consiglio Nazionale delle Ricerche, Frascati
G. C. PEROLA, L. PIRO,[2] AND G. SIMARI
Istituto Astronomico, Università di Roma
A. BOKSENBERG, M. V. PENSTON, AND M. A. J. SNIJDERS
Royal Greenwich Observatory
G. E. BROMAGE
Astrophysics Group, Rutherford and Appleton Laboratories
J. CLAVEL
IUE, Vilspa
A. ELVIUS
Stockholm Observatory
AND
M. H. ULRICH
European Southern Observatory
Received 1985 November 4; accepted 1986 January 30

ABSTRACT

Simultaneous observations of the Seyfert I galaxy Fairall 9 (F9) were performed with *EXOSAT* and *IUE* during 1983 October and 1984 October. A decrease in the flux of the source by more than a factor of 2 was observed at all wavelengths between the two epochs. Furthermore, in the X-ray (0.05–10 keV) band, variability of the order of 50% on a time scale of days was found during 1983 October. The shape of the spectrum varied together with the flux level both on short and on long time scales, the ratio between soft and hard X-rays counts being higher when the source was brighter. The complete X-ray light curve for the period 1971–1984 shows that during recent years F9 has faded not only in the UV—which was already known—but also in the X-ray band. The latter decreased more slowly than the former before 1983; then the decline rates in the two energy bands took on comparable large values.

Different interpretations of the spectral variability are possible, and three are discussed: the X-ray spectrum can be taken as due to a constant slope power law, with energy index $\alpha = 0.96 \pm 0.06$ and varying column density; alternatively, the changes can be interpreted as spectral index changes in a power law with constant absorption, $n_H = 2 \times 10^{20}$ cm^{-2}; finally, a multicomponent spectrum can be assumed, with a variable soft excess responsible for the soft X-ray variability. In the last case, the X-ray and UV spectra can be linked, under the assumption that the soft X-ray excess is the exponential tail of the UV, and a cutoff energy of 86 ± 15 eV can be determined.
Subject headings: galaxies: individual — galaxies: Seyfert — galaxies: X-rays — ultraviolet: spectra

I. INTRODUCTION

At the time of its discovery (Fairall 1977) the Seyfert I galaxy F9 (ESO 113–1G45) was one of the most powerful sources of its class. At a redshift $z = 0.0461$ (Weedman 1979), its optical luminosity ($M_v = -24.25 + 5 \log h_{100}$), H$\beta$ emission ($L_{H\beta} = 5.6 \times 10^{42} h_{100}^{-2}$ ergs s^{-1}; Steiner 1981), and X-ray luminosity ($L_{2-10\,\mathrm{keV}} = 7.8 \times 10^{43} h_{100}^{-2}$ ergs s^{-1}; McHardy *et al.* 1981) were typical of QSOs rather that Seyfert galaxies, so that it was considered as a Seyfert I–QSO transition object.

From 1978 onward F9 has been extensively monitored at UV and optical frequencies. In this period both the continuum and broad-line fluxes have decreased by nearly one order of magnitude (Wamsteker *et al.* 1984, 1985; Masegosa, Moles, and Penston 1986), while the fluxes of the [O III] lines remained approximately constant, so that the optical–UV spectrum of F9 appeared in 1984, at low signal to noise, like a typical Seyfert II spectrum (Kollatschny and Fricke 1985). At the time of writing, the source has brightened again in the UV region (Wamsteker, Gilmozzi, and Clavel 1985), suggesting that in 1984 it was at a minimum.

We have observed F9 simultaneously in the UV and X-ray regions with *IUE* and *EXOSAT*. In order to monitor its behavior on long as well as on short time scales, we grouped our observations into two campaigns separated by about a

[1] Based on observations with *EXOSAT* collected at the European Space Operation Centre in Darmstadt (ESA) and with *IUE* collected at the Villafranca Tracking Station (ESA).

[2] Now at Istituto di Tecnologie e Studio delle Radiazione Extraterrestri, Consiglio Nazionale delle Ricerche, Bologna.

TABLE 1

F9 X-RAY OBSERVATIONS

Date (1)	Observing Time (s) (2)	ME(1–10 keV)[a] (3)	ME(2–6 keV)[a] (4)	LE2 Lexan Filter[a] (5)	LE1 Lexan Filter[a] (6)	LE1 Al-Pa Filter[a] (7)	Lexan/Al-Pa (8)	ME/Lexan (9)
1983 Oct 9	15,900	1.313 ± 0.072	0.884 ± 0.044	0.0873 ± 0.0048	0.0768 ± 0.0066	0.0475 ± 0.0068	1.62 ± 0.27	11.5 ± 1.1
1983 Oct 11	12,100	1.549 ± 0.058	1.100 ± 0.035	0.1144 ± 0.0036	0.0882 ± 0.0055	0.0464 ± 0.0036	1.90 ± 0.19	12.5 ± 0.9
1983 Oct 13	28,100	1.475 ± 0.048	0.968 ± 0.030	0.0911 ± 0.0022	0.0611 ± 0.0029	0.0305 ± 0.0031	2.00 ± 0.22	15.8 ± 0.9
1983 Oct 15	16,200	1.228 ± 0.068	0.829 ± 0.040	0.0730 ± 0.0030	0.0517 ± 0.0034	0.0298 ± 0.0039	1.73 ± 0.25	16.0 ± 1.3
1983 Oct 17	14,800	1.201 ± 0.074	0.760 ± 0.044	0.0636 ± 0.0027	0.0467 ± 0.0029	0.0240 ± 0.0053	1.95 ± 0.45	16.3 ± 1.4
Mean 1983[b]		1.309 ± 0.027	0.932 ± 0.017	0.0839 ± 0.0013	0.0578 ± 0.0016	0.0348 ± 0.0018	1.85 ± 0.11	14.2 ± 1.8
1984 Oct 17	21,600	0.564 ± 0.043	0.394 ± 0.026	...	0.0194 ± 0.0018	0.0122 ± 0.0019	1.59 ± 0.29	20.3 ± 2.3
1984 Oct 19	12,500	0.492 ± 0.057	0.302 ± 0.034	...	0.0233 ± 0.0048	0.0067 ± 0.0050	3.48 ± 2.66	13.0 ± 3.0
1984 Oct 21	16,300	0.589 ± 0.047	0.353 ± 0.028	...	0.0172 ± 0.0034	0.0077 ± 0.0026	2.23 ± 0.88	20.5 ± 4.5
1984 Oct 23	12,300	0.408 ± 0.058	0.224 ± 0.035	...	0.0134 ± 0.0048	0.0079 ± 0.0030	1.70 ± 0.89	16.7 ± 6.5
1984 Oct 25	17,000	0.675 ± 0.050	0.452 ± 0.029	...	0.0177 ± 0.0025	0.0082 ± 0.0020	2.16 ± 0.61	25.5 ± 4.0
Mean 1984[b]		0.611 ± 0.031	0.420 ± 0.019	...	0.0185 ± 0.0012	0.0093 ± 0.0011	1.75 ± 0.24	22.7 ± 1.8

[a] Counts per second.

[b] The mean values refer to "quality 1" data as discussed in the text, namely: all data for the 1983 observations; Oct 17 and 25 data for the 1984 ME observations; all data for the 1984 LE observations.

year; they happened to be scheduled in 1983 October and 1984 October, i.e., on the steepest portion of the long-term light curve and near its minimum. Within each campaign, the individual observations were separated by intervals of a few days, as described in the following sections. In the X-ray band, we detected flux and spectral variations both on short and long time scales; in the UV only evidence for long-term variations was found.

Section II is devoted to the analysis and description of the X-ray data; in particular, we indicate how the spectral variability can be represented in different ways, all formally acceptable, Section III deals with the UV data, and with the determination of the broad-band spectral slope which includes optical information. In § IV we first discuss our results from the standpoint of the long-term behavior, complementing them with historical measurements; then, we elaborate on the physical consequences of the various hypotheses on the spectral variability. We present our conclusions in § V.

II. X-RAY DATA

We observed F9 with *EXOSAT* (see Taylor *et al.* 1981 for a complete description of the satellite and its instruments) in 1983 October and 1984 October. In each campaign, five exposures were spread over alternate days; the details are given in Table 1, columns (1) and (2). Simultaneous UV observations were performed with *IUE*, and are described in § III.

During the 1983 *EXOSAT* observations both low energy telescopes (LE) were working with the Channel Multiplier Array (CMA) detectors. One (LE2) operated for the entire length of time with the thin Lexan filter (the most sensitive one), while the other (LE1) was used with the thin Lexan and the Aluminum-Parylene filters, respectively, in the first and second halves of each observation. So, both temporal and spectral information were obtained for the low-energy (0.05–2 keV) X-ray range, the former from LE2 and the latter from the filter ratio in LE1. In 1984 only one low-energy instrument was available (LE1 + CMA); it was used with the same filters alternating in the same sequence.

The medium energy detector (ME) was always operated with half the total collecting area exposed to the source and with the other half offset in order to gauge the background level.

a) ME X-Ray Data

The ME spectra were obtained with the procedure described by Smith (1984). Each observation started with four argon and the corresponding four xenon detectors pointed at the source and the remaining $4 + 4$ detectors offset by $\sim 2°$; halfway during the observation, the offset counters were aligned, and the other ones were offset by the same amount in the same direction. The 16 elements provided 16 separate spectra once every 10 s. For each element, it was assumed that the background spectra in the aligned and, respectively, the offset position differ by a constant vector, determined from long blank field observations during the in-flight calibrations of the ME experiment. Hence, the count spectrum of a given element during the off-source half observation was corrected with the difference vector and subtracted from the count spectrum of the same element during the other, on-source, half observation. Background-subtracted spectra from corresponding counters in the two ME halves were then summed: this removes the systematic effects of slow background variations, provided they are correlated in the two halves of the ME experiment. The spectra from the inner and outer counters were summed together only if they were found mutually consistent; otherwise the spectrum due to the inner elements was rejected. The inner counters, indeed, are less shielded and more sensitive to background variability when it occurs. Rejection of the inner counter data was necessary for three out of 10 observations (1983 October 9, 13, and 15). Furthermore, in October 1984 the source was in a very low state, at ~ 0.25 millicrabs, close to the limiting sensitivity of the ME argon detectors. Three spectra obtained at this epoch (1984 October 19, 21, and 23) were very noisy, and the corresponding derived parameters will be reported for completeness but ignored in the discussion (they will be referred to as "quality 2" data). In spite of the subjectiveness of the criteria adopted in rejecting the bad-quality data, it turns out that there is exact correspondence between "quality 2" data and periods of high solar activity. The solar activity can be monitored by means of the "flares" induced in the LE + CMA background. If we define a flare as a situation in which the LE background is higher than 50 counts s^{-1}—about 50% above its nominal value—then we find that the flare time fraction was more than 30% both in the 1983 observations where only the outer counter spectra could be used, and in the 1984 observations, which produced "quality 2" data. In all the other cases, the flare time fraction was less than 2%.

Figure 1 shows the count-rate spectra obtained with the argon detectors in two observations, representative of the 1983 and 1984 data. No useful information was provided by the Xenon detectors. Table 1, columns (3) and (4), gives the count rates for all the observations in the nominal argon counter range (1–10 keV) and in the energy range which optimizes the signal-to-noise ratio (2–6 keV). All rates refer to the whole ME half: in the cases where the inner counters had to be ignored, the reported rates are twice the outer counter results.

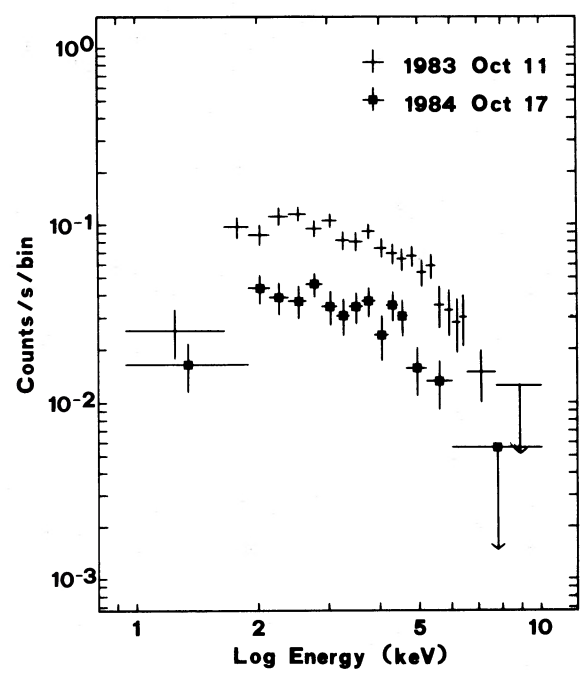

FIG. 1.—Count-rate spectra of F9 from the *EXOSAT* ME-Argon detectors, at the epochs 1983 October 11 and 1984 October 17.

b) *LE X-Ray Data*

Table 1, columns (5), (6), and (7), gives the count rates measured with the CMA detectors of the two LE telescopes in conjunction with the thin Lexan and Aluminum-Parylene filters. The number of photons detected in each observation was estimated by accumulating the full resolution image for the entire exposure time, counting the events less than 100″ from the source center, and assuming as background all the events between 100″ and 300″. This was chosen to pick up most of the photons falling in the wings of the point spread function (whose shape depends on the photon energy and therefore cannot be evaluated if the incident spectrum is not known), while determining the background (which in turn is not uniform in the field of view) sufficiently close to the source.

We find no evidence of temporal variability within individual observations: from the LE2 data of the 1983 campaign we obtain a 2 σ upper limit to linear variations of 20%–30% in 10,000 s. Spectral information in the low-energy range (<2 keV) is then provided by the thin Lexan, Aluminum-Parylene count ratio measured with LE1, under the assumption that the source is not varying. The data are shown in Table 1, column (8). The transmissions of the two filters have a ratio of ~ 1.35 for energies greater than 284 eV, the *K*-edge energy of carbon, and more than 5 for lower energies. The observed ratio is 1.85 ± 0.09 (1983 average), which is definitely greater than 1.35 and implies a soft spectrum with a significant flux of low-energy photons (<284 eV).

c) *X-Ray Spectral Variability*

The variability of F9 on various time scales is clear from Table 1 and the light curves of Figure 2, both in the LE (<2 keV) and ME (2–6 keV) spectral ranges. The decline of the source luminosity between 1983 and 1984 is apparent at all energies: the change is about a factor of 2.2 for the ME, and 3.5 for the LE, if one considers the average fluxes at both epochs. The different degree of variability in the two energy bands is also seen from the ratio of ME to LE1 counts (Table 1, col. [9]), which takes up significantly different values and points to spectral changes together with luminosity changes: the overall spectral shape seems to become flatter when the flux decreases.

Variability on time scales of days is shown by the 1983 light curves. A significant increase in the source luminosity was observed between 1983 October 9 and 11 in both the ME and LE ranges, followed by a monotonic decrease. As in the case of long-term variability, the short-term variability is also stronger in the LE than in the ME range; i.e., compare the ratio between the ME and LE1 counts, Table 1, column (9). Note, however, that the ratio ME/LE2 (not shown in Table 1) varies by a smaller amount as compared with ME/LE1: LE1 and LE2 have significantly different responses, namely, LE2 is more sensitive than LE1 between 1 and 2 keV, where the LE and ME ranges overlap, and less sensitive below 300 eV. Hence, the different behavior of the ratios indicates that only the very low energy range is responsible for the spectral modifications.

The process of deriving spectral parameters from our observations is complicated by the variability discussed above. As a first step, we have fitted the ME data alone with a power-law spectrum. No interstellar absorption has been considered at this point: it will be shown *a posteriori* that the column density suggested by the LE data ranges between 1 and 5×10^{20} cm^{-2}, with photoelectric absorption energies of the order of 200–300 eV, well below the ME threshold. Table 2, columns (2) and (3), reports the resulting values for the spectral indices and the integral fluxes in the 2–6 keV band. An acceptable value for the χ^2 is obtained for all the fits. Within the statistical accuracy of our data, the ME spectrum seems to retain its shape even when the intensity changes. All the 1983 spectra are consistent with a mean energy index $\alpha = 0.96 \pm 0.06$, which is to be compared with the mean index of the "quality 1" 1984 spectra, $\alpha = 1.05 \pm 0.16$.

Further information is contained in the LE data; this, however, is only in the form of wide-band, multifilter photometry, and any spectral parameter which depends primarily on the low-energy points, such as the absorbing column, inevitably attains a confidence level weaker than the ME parameters. Given the above difficulty, we note that the following.

1. If one assumes a single power law extending from LE to ME, and fits simultaneously to each observation both the spec-

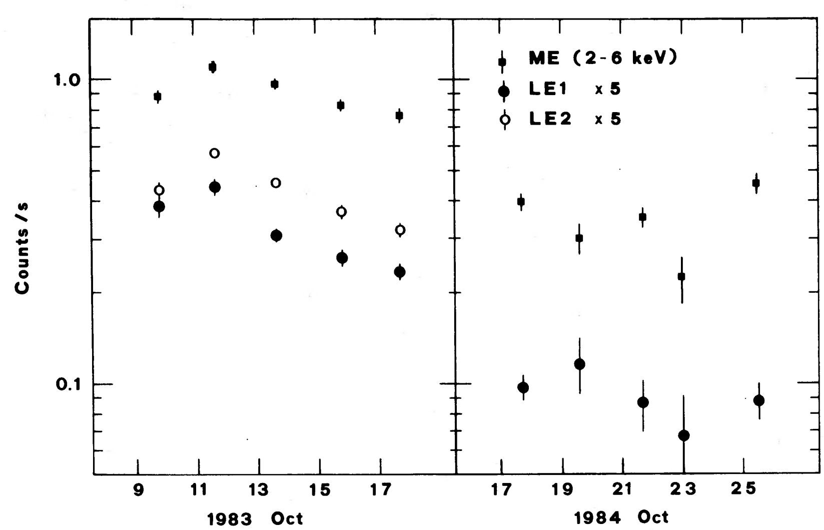

FIG. 2.—Count-rate light curves of F9 as a function of time during 1983 October 9–17 and 1984 October 17–25, for the ME-Argon detectors, 2–6 keV (*filled squares*), and for LE with thin Lexan filter (LE1, *filled dots*; LE2, *open circles*).

TABLE 2

X-Ray Spectral Parameters of F9

	ME Data		ME + LE Data		
Date (1)	Spectral Index[a] (2)	Flux[b] (3)	n_H[c] (4)	Spectral Index[d] (5)	LE Excess[e] (6)
1983 Oct 9..........	1.13 ± 0.16	1.06	1.69 ± 0.14	1.022 ± 0.028	0.0384 ± 0.0066
1983 Oct 11	0.93 ± 0.11	1.27	1.55 ± 0.08	1.037 ± 0.018	0.0423 ± 0.0055
1983 Oct 13	0.87 ± 0.10	1.15	2.00 ± 0.09	0.959 ± 0.016	0.0177 ± 0.0029
1983 Oct 15	1.09 ± 0.16	0.97	2.07 ± 0.14	0.960 ± 0.025	0.0155 ± 0.0034
1983 Oct 17	0.96 ± 0.19	0.93	2.45 ± 0.19	0.899 ± 0.028	0.0107 ± 0.0029
1984 Oct 17	1.14 ± 0.22	0.47	3.66 ± 0.46	0.791 ± 0.045	0.0025 ± 0.0018
1984 Oct 19[f].........	0.29 ± 0.36	0.36	1.91 ± 0.55	0.885 ± 0.112	0.0111 ± 0.0048
1984 Oct 21[f].........	0.64 ± 0.25	0.43	3.97 ± 0.99	0.725 ± 0.087	−0.0005 ± 0.0034
1984 Oct 23[f].........	0.18 ± 0.43	0.30	2.95 ± 1.19	0.788 ± 0.145	0.0009 ± 0.0048
1984 Oct 25	0.96 ± 0.22	0.54	5.48 ± 1.17	0.674 ± 0.060	−0.0037 ± 0.0025

Note.—Errors are 1 σ (68% probability for the confidence intervals).

[a] Energy spectral index α, $dF/dE = kE^{-\alpha}$.

[b] 2–6 keV flux in 10^{-11} ergs cm^{-2} s^{-1}.

[c] Absorbing column density in 10^{20} cm^{-2}, for a power-law spectrum with energy spectral index $\alpha = 0.96$ normalized to the ME data.

[d] Energy spectral index, for a power-law spectrum with $n_H = 4 \times 10^{20}$ cm^{-2}, normalized to the ME data.

[e] Soft excess flux in counts s^{-1} required to fit the LE data (LE1 + Lexan filter) in addition to a power-law spectrum with $\alpha = 0.96$, $n_H = 4 \times 10^{20}$ cm^{-2}, normalized to the ME data.

[f] "Quality 2" data (see note to Table 1) not considered in the discussion.

tral index and the column density, the statistical errors on the resulting values are too large to determine whether the spectral variations—certainly present—are due to the first parameter, or to the second, or to both.

2. If one of the two parameters is given an ad hoc, constant value, the other can be varied so as to fit the data. This is shown in Table 2, columns (4) and (5). Column (4) gives the fitting values of the absorption thickness, n_H when the spectral index is assumed equal to the 1983 ME average, $\alpha = 0.96$; during 1983 October, n_H appears to be anticorrelated with the integral ME flux, and ranges from 1.5 to 2.5 × 10^{20} cm^{-2}; even higher values are found for the "quality 1" 1984 observations, when the source was faintest. Column (5), on the other hand, gives the values of the spectral index which follow from the assumption $n_H = 2 \times 10^{20}$ cm^{-2}; obviously a correlation is found with the ME flux, analogous to the one already observed in n_H; this does not appear in the values listed in column (2), which were deduced for the same observations from the ME data alone, because of the larger errors due to the narrower bandpass.

3. Finally, a multicomponent spectrum could be assumed, where, for instance, the total absorption, and the slope of the ME component are constant, and the spectral variations are entirely due to an additional LE component. Table 2, column (6), indicates the additional flux (LE1 + thin Lexan filter) which would reside in this hypothetical soft excess; the spectral index for the former component is $\alpha = 0.96$, as above, and the absorption $n_H = 4 \times 10^{20}$ cm^{-2} in order to account for the hardness of the 1984 spectra.

We conclude with a quantitative estimate of the variability time scale. Let us assume that the 1983 October 11–17 light curves can be modeled with a law of the type $F = F_0 + F_1 \exp[-(t - t_0)/t_c]$, where the peak time, t_0, and the e-folding time, t_c, are the same for all the curves. A satisfactory fit is achieved with the parameters of Table 3: $t_c = 4.06 \pm 0.26$ days is obtained. The different ratios F_1/F_0 in the different spectral ranges provide an additional representation of the spectral variability of F9.

TABLE 3

Parameters of the X-Ray Variability: $F = F_0 + F_1 \exp[-(t - t_0)/t_c]$

Instrument	F_0 (counts s^{-1})	F_1 (counts s^{-1})
ME (2–6 keV)...............	0.676 ± 0.058	0.562 ± 0.112
LE2 + Lexan filter	0.0487 ± 0.0044	0.0860 ± 0.0098
LE1 + Lexan filter	0.0338 ± 0.0054	0.0630 ± 0.0133
LE1 + Al-Pa filter..........	0.0168 ± 0.0060	0.0356 ± 0.0115

Note.—In the equation, t_0 = 1983 Oct 10.5, $t_c = 4^d.06 \pm 0^d.26$.

III. UV DATA

At the time of the X-ray campaigns of 1983 October and 1984 October, we observed F9 repeatedly with *IUE* in order to monitor possible related variations in the UV band. The journal of the observations is given in Table 4. The raw spectra have been processed in the standard way for intensity and wavelength calibration and for wavelength rebinning.

Visual inspection of the *IUE* spectra and theoretical work on AGN line emission (e.g., Netzer and Wills 1983; Wills,

TABLE 4

UV Observations of F9 Simultaneous with *EXOSAT* Observations

Observation	Date	Time (s)	log ⟨F_0⟩
S21260.........	1983 Oct 9	3000	−25.863 ± 0.041
S21261.........	1983 Oct 10	6900	−25.863 ± 0.041
S21286.........	1983 Oct 13	7200	−25.873 ± 0.041
S21287.........	1983 Oct 13	5400	−25.796 ± 0.041
S24193.........	1984 Oct 17	2880	−26.664 ± 0.181
S24254.........	1984 Oct 21	5400	−26.262 ± 0.073
S24291.........	1984 Oct 25	7200	−26.238 ± 0.041
S24345.........	1984 Oct 29	5460	−26.297 ± 0.054

Note.—⟨F_0⟩ is the flux at 1400 Å (2.14×10^{15} Hz) in units of ergs cm^{-2} s^{-1} Hz^{-1}.

Netzer, and Wills 1985) indicate that good windows for the determination of the continuum level are found more easily in the short than in the long wavelength range: the latter, in fact, is contaminated by a pseudocontinuum due mainly to Fe II multiplets. We have chosen two windows (1370–1420 Å and 1500–1550 Å in the observer frame) on both sides of the Si IV + O IV] blend around 1400 Å (source frame). After smoothing with a 15 Å box, the local minima have been scaled to the same $\nu = 2.14 \times 10^{15}$ Hz and averaged geometrically; the scaling assumed a frequency spectral slope $\alpha = 0.5$ (arbitrary, but not crucial). From the dispersion of the spectral pixels fed into the algorithm one can compute the internal error of our results, less than $\sim 10\%$ in most cases; since 10% is the nominal repeatability limit of a medium quality *IUE* spectrum (Penston *et al.* 1981), we have attributed to each flux value either a 10% error or the internal error, depending on which is larger. Our assumption might seem too optimistic, especially for the most recent observations when F9 was in a very low state. Note, however, that the exposure times have been systematically increased when the source declined to obtain approximately constant exposure levels, and in those cases in which two exposures have been taken a few hours apart—see 1983 October 9 and 13—no difference in excess of 10% has been measured.

In the year between the two campaigns the UV flux diminished by a factor of 2.8 (average 1983 vs. average 1984); this is to be compared with 3.5 and 2.2 for the LE and the ME decreases, respectively. On a time scale of days the UV flux appears steady; in particular, no change is detected during the X-ray flare of 1983 October. Unfortunately, the only two measurements were at times symmetrically arranged with respect to the X-ray maximum, and a similar, undelayed UV variation cannot be excluded.

Other windows within the short wavelength range could perhaps be found—for instance, just blueward of the C III] feature—but they provide an insufficient baseline for a satisfactory determination of the continuum slope. The difficulties inherent in the long wavelength range have already been mentioned. One must thus resort to optical and near-infrared spectral data, well beyond the so-called 3000 Å bump, where several authors recognize the presence of the bare continuum (Malkan and Sargent 1982; Wamsteker *et al.* 1984). Multicolor photometry of F9 simultaneous with our 1983 October campaign has been kindly provided by P. A. Whitelock and J. W. Menzies of the SAAO; details of their observations are listed in Table 5. The measurements have been made through apertures large enough to include a conspicuous fraction of the galaxy, so that some contamination by starlight must be present. The optical measurements, however, are available with two values of the aperture (11″ and 16″, respectively), and a minimal correction can be applied on the hypothesis that the starlight distribution is uniform. The observed fluxes (or the extrapolations to zero aperture in the cases of *U*, *B*, and *V*) are plotted in the synthetic spectrum of Figure 3*a*. We note that the general shape delineated by the IR, optical, and UV data is concave upward, and any extension of the UV continuum must be looked for in the optical region. The *U*, *B*, and *V* observations are poorly suited for the purpose because their bandpasses transformed to the source frame include important emission features. Since *U* is affected by the Balmer continuum and *V* is affected by Hβ and the [O III] doublet, we restrict ourselves to *B*, which entails $\alpha \leq 0.76$.

Further progress can be made only by means of spectrophotometric data, and to this purpose we refer to the results of Wamsteker *et al.* (1984, 1985). In the original papers the optical and UV spectra are fitted with an elaborate photoionization model, but a more direct approach is also possible: the authors identify a good continuum gauge just redward of the Hβ + [O III] complex, at a rest wavelength of 5076 Å; they also fitted the time behavior of the flux density here with a 1000 day exponential decline:

$$\nu = 5.65 \times 10^{14}\ \text{Hz}\ ;$$
$$F_\nu = 4.70 \exp\left[(1983.0 - t)/2.74\right]\ \text{mJy}\ . \quad (1)$$

By combining the above expression with our UV results, we obtain $\alpha = 0.66 \pm 0.11$ and 1.12 ± 0.11 for 1983 and 1984, respectively. A similar behavior has been found also by Kollatschny and Fricke (1985), by fitting a power law to continuum windows completely within the optical band.

We stress that no correction for reddening has been applied up till now; since F9 is located at high galactic latitude, our

TABLE 5

OBSERVATIONS OF F9[a]

A. Infrared

Date	Magnitude *J*	*H*	*K*	*L*	Aperture
1983 Oct 11.94	12.29 ± 0.03	11.26 ± 0.03	10.17 ± 0.03	8.49 ± 0.05	12″
1983 Oct 12.87	12.25 ± 0.03	11.28 ± 0.03	10.18 ± 0.03	8.57 ± 0.06	12″
1983 Oct 13.90	12.30 ± 0.03	11.26 ± 0.03	10.13 ± 0.03	8.50 ± 0.09	12″

B. Optical

Date	Magnitude *U*	*B*	*V*	Aperture
1983 Oct 12.036	14.15 ± 0.02	14.87 ± 0.02	14.23 ± 0.02	16″
1983 Oct 12.045	14.34 ± 0.02	15.04 ± 0.02	14.39 ± 0.02	11″
1983 Oct 12.871	...	14.87 ± 0.02	14.26 ± 0.02	16″
1983 Oct 12.876	...	14.97 ± 0.02	14.42 ± 0.02	11″

[a] From Whitelock and Menzies 1983.

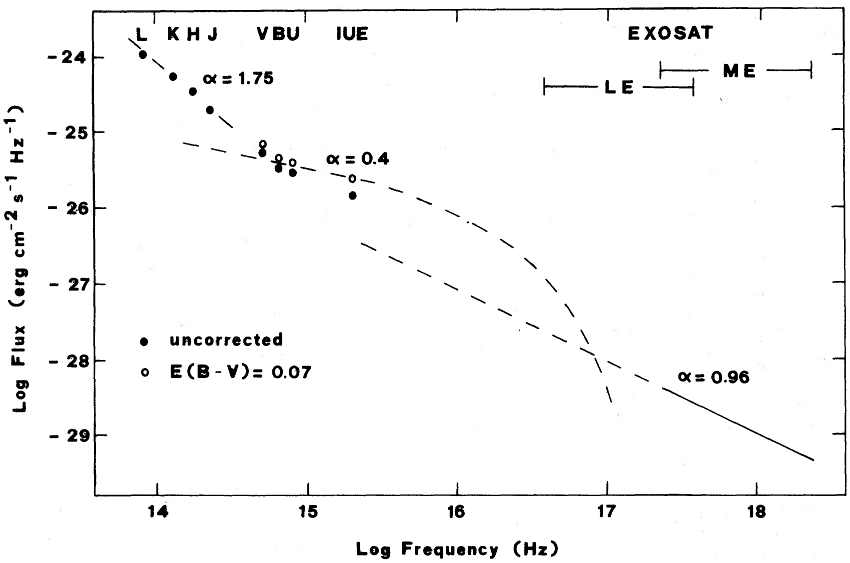

FIG. 3*a*.—Synthetic spectrum of F9 from infrared to X-rays on 1983 October 13. Data are (i) the best-fit power law with energy index $\alpha_X = 0.96$ between 1 and 10 keV, from the *EXOSAT* ME-Argon detectors; (ii) the observed *IUE* flux at 1400 Å; (iii) optical and infrared broad-band photometry, from Whitelock and Menzies 1983, SAAO. For the *IUE*, *U*, *B*, and *V* data both the observed fluxes (*filled dots*) and the fluxes corrected for $E(B-V) = 0.07$ (*open circles*) are shown. Note that the *U*, *B*, and *V* points are corrected also for the finite size of the collecting aperture as described in the text. Extrapolation of the 1–10 keV spectrum to lower energies, and the model UV spectrum with power-law energy index $\alpha_0 = 0.4$ and cutoff energy $E_0 = 86$ eV (see discussion in § IV*d*) are also shown.

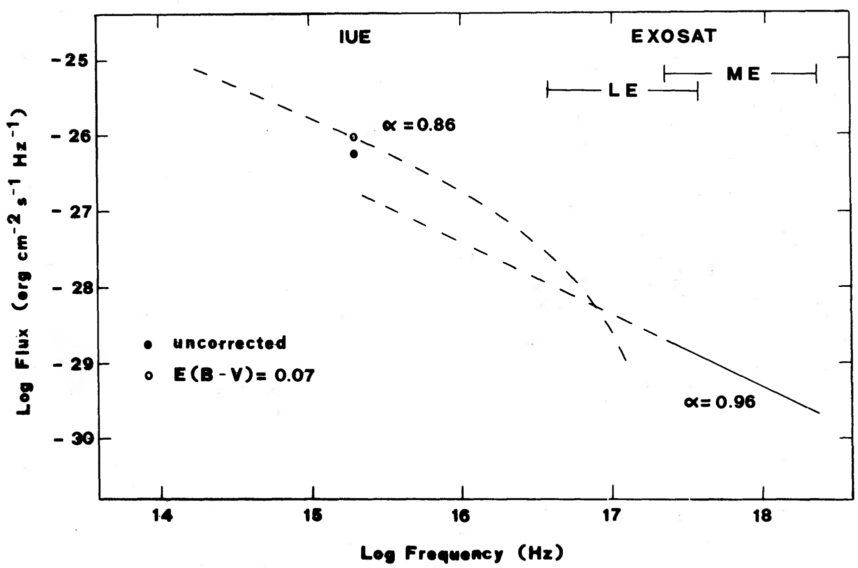

FIG. 3*b*.—Same as Fig. 3*a* for the 1984 October 25 data. The model UV spectrum is a power law with energy index $\alpha_0 = 0.86$ and cutoff energy $E_0 = 150$ eV corresponding to the 2 σ upper limit for E_0 derived from the LE *EXOSAT* data.

neglect is justified as a zeroth order approximation. In order to improve upon it, we relate the observed α to the intrinsic α_0 in accordance with the reddening law of Seaton (1979):

$$\alpha_0 = \alpha - 3.57E(B-V) . \quad (2)$$

Extrapolation of the reddening from low galactic latitudes with the cosecant law gives $E(B-V) = 0.1$ (Allen 1976; Wamsteker *et al.* 1982); alternatively, one can convert the radio limits on the H I column in front of F9, ($n_{\rm H\,I} < 10^{20}$ cm^{-2} in our Galaxy [Burstein and Heiles 1982] and $n_{\rm H\,I} = 9 \times 10^{19}$ cm^{-2} in the Magellanic Stream [Mathewson *et al.* 1974]) into a limit on $E(B-V)$, $E(B-V) < 0.04$, by means of the calibration of Bohlin, Savage, and Drake (1978):

$$E(B-V) = n_{\rm H}/(5.4 \times 10^{21}\ {\rm cm}^{-2}) . \quad (3)$$

Finally, a measure of the total column—as opposed to "galactic" column—can be derived from low-energy X-ray spectral data, if one adopts the approach described in the next section. There we infer $n_{\rm H} = 4 \times 10^{20}$ cm^{-2}, that is, according to equation (3), $E(B-V) = 0.07$.

IV. DISCUSSION

The spectral variability exhibited by F9 during our observations is very complex, and some aspects of the interpretation are necessarily ambiguous. Further insight can be gained by

TABLE 6

X-Ray Data[a]

Experiment	Date	2–10 keV Flux (ergs cm^{-2} s^{-1})	Reference
Uhuru (PST)	1970 Dec–1973 Mar	$5.04 \pm 1.2 \times 10^{-11}$	1
Ariel 5	1975 May–1977 Apr	$3.44 \pm 0.37 \times 10^{-11}$	2
HEAO 1 A-1	1977 Dec	$3.4 \pm 0.4 \times 10^{-11}$	3
HEAO 1 A-2	1977 Dec	$2.61 \pm 0.36 \times 10^{-11}$	4
HEAO 1 A-2	1978 Jun	$2.79 \pm 0.40 \times 10^{-11}$	4
HEAO 2 (SSS + MPC)	1979 May	$2.52 \pm 0.20 \times 10^{-11}$	5
HEAO 2 (SSS + MPC)	1979 Jul	$2.95 \pm 0.24 \times 10^{-11}$	5
EXOSAT	1983 Oct	$1.58 \pm 0.03 \times 10^{-11}$	6
EXOSAT	1984 Oct	$0.74 \pm 0.03 \times 10^{-11}$	6

References.—(1) Forman *et al.* 1978; (2) McHardy *et al.* 1981; (3) Wood *et al.* 1984; (4) Piccinotti *et al.* 1982; (5) Petre *et al.* (1984); (6) this work.

considering the entire history of the source and by comparing it with the general properties of the Seyfert galaxies and the current ideas about AGNs. In the following, we examine first the conclusions which can be drawn from the long-term behavior of the broad-band fluxes; then we elaborate on the physical consequences of the competing hypotheses made in the previous sections about the X-ray spectrum.

a) *Long-Term Variability*

In Table 6 we have collected the flux values of F9 as measured by previous X-ray satellites: *Uhuru* (Forman *et al.* 1978), *Ariel 5* (McHardy *et al.* 1981), *HEAO 1* A1 (Wood *et al.* 1984) and A2 (Piccinotti *et al.* 1982), and *Einstein* (Petre *et al.* 1984). When necessary, the original data have been scaled to the 2–10 keV band. The long-term X-ray light curve, including our own ME points, is shown in Figure 4.

We have also retrieved all the archival *IUE* observations of F9 and processed them according to the procedure of § III, in order to ensure a consistent definition of the continuum over the entire data base. Table 7 contains the journal of the observations used and the flux values; the 1978–1984 light curve is shown in Figure 4, together with the X-ray points. The most obvious feature of the long-term behavior at both wavelengths is a secular decline by large factors; in particular, the UV flux decreased by more than a factor of 20 in ~6 yr, with an average *e*-folding time of 893 ± 13 days. Both curves are better fitted if two exponential are used instead of just one: then at early times the X-ray flux is found to decrease more slowly than the UV, having a decay rate of 4650 ± 580 days versus 1448 ± 53; at recent times both rates become faster and take on comparable values (481 ± 39 days and 400 ± 21 for the X-ray and the UV data, respectively). Brief flarelike episodes could alter locally the general trend: one such case is the apparent increase in the UV flux between 1982 October 24 and November 8, where the significance of the variation is 3 σ, and the nominal *e*-folding time 50 days only. Furthermore, there is a suggestion that the X-ray break occurs later than the UV one, since the best-fit values are epoch 1983.50 ± 0.05 for the former, and 1982.51 ± 0.08 for the latter. The 4 year gap in the X-ray data makes it difficult to draw a firm conclusion about

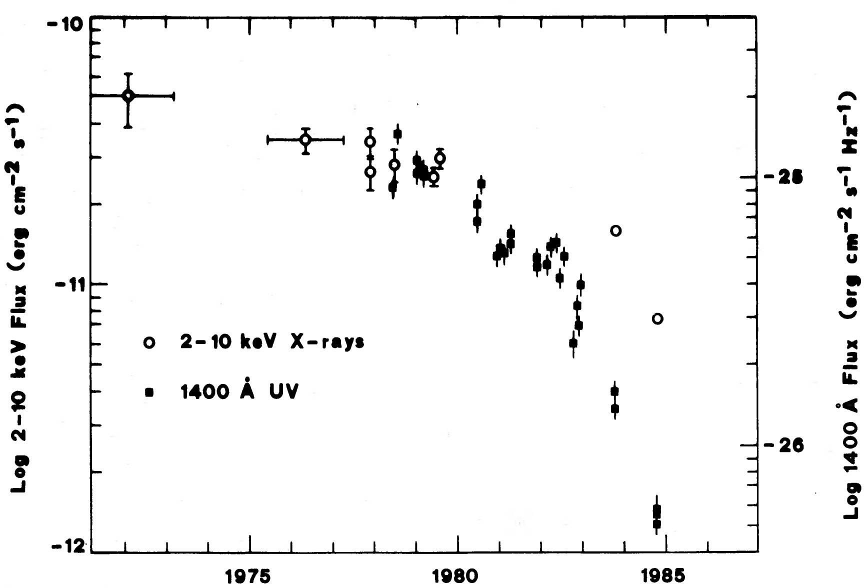

Fig. 4.—The 2–10 keV (*open circles*, left-side scale) and 1400 Å (*filled squares*, right-side scale) fluxes of F9 as a function of time in the period 1970–1984. X-ray data are from *Uhuru* (Forman *et al.* 1978), *Ariel 5* (McHardy *et al.* 1981), *HEAO* A1 (Wood *et al.* 1984) and A2 (Piccinotti *et al.* 1982), *Einstein* SSS and MPC (Petre *et al.* 1984), and *EXOSAT* (this work). All the *IUE* results are from this work.

TABLE 7

PREVIOUS UV OBSERVATIONS OF F9

Observation	Date	Time (s)	log $\langle F_0 \rangle$[a]
S1804	1978 Jun 18	7200	-25.034 ± 0.041
S1805	1978 Jun 18	2700	-25.035 ± 0.041
S2178	1978 Aug 2	2700	-24.831 ± 0.041
S2215	1978 Aug 5	7200	-24.836 ± 0.041
S3936	1979 Jan 18	2220	-24.936 ± 0.041
S3937	1979 Jan 18	2100	-24.979 ± 0.041
S4539	1979 Mar 8	2700	-24.965 ± 0.041
S4732	1979 Mar 23	1800	-24.985 ± 0.041
S9353	1980 Jun 23	2100	-25.103 ± 0.041
S9354	1980 Jun 23	1500	-25.166 ± 0.041
S9616	1980 Jul 28	1500	-25.036 ± 0.041
S10941	1981 Jan 1	1500	-25.293 ± 0.041
S13351	1981 Feb 23	8180	-25.243 ± 0.041
S13616	1981 Mar 30	2400	-25.264 ± 0.041
S14157	1981 Jun 2	5400	-25.217 ± 0.041
S14158	1981 Jun 2	3600	-25.247 ± 0.041
S15689	1981 Dec 9	3600	-25.307 ± 0.041
S15794	1981 Dec 18	2700	-25.302 ± 0.041
S15795	1981 Dec 18	1200	-25.330 ± 0.041
S15890	1981 Dec 27	1500	-25.339 ± 0.041
S16410	1982 Feb 22	2400	-25.310 ± 0.041
S16426	1982 Feb 25	2400	-25.336 ± 0.041
S16559	1982 Mar 17	3600	-25.260 ± 0.041
S16890	1982 May 5	7920	-25.250 ± 0.041
S17249	1982 Jun 17	4200	-25.383 ± 0.041
S17446	1982 Jul 19	8100	-25.294 ± 0.041
S17521	1982 Jul 30	3100	-25.306 ± 0.041
S18094	1982 Sep 24	2400	-25.613 ± 0.052
S18202	1982 Oct 4	2400	-25.474 ± 0.041
S18242	1982 Oct 8	2400	-25.541 ± 0.041
S18382	1982 Oct 24	2700	-25.532 ± 0.041
S18506	1982 Nov 8	3000	-25.402 ± 0.041

[a] $\langle F_0 \rangle$ is the flux at 1400 Å (2.14×10^{15} Hz) in units of ergs $cm^{-2}\,s^{-1}\,Hz^{-1}$.

the epoch of the X-ray break; nevertheless, the UV–X-ray lag and the usual assumption according to which the highest frequencies originate in the innermost regions point to a kind of "fading wave" propagating toward the center.

It may also be worthwhile to recall here that the optical–UV spectrum has become steeper from 1983 to 1984 (see § III for details); since at the same time the X-ray spectrum has become flatter, the overall behavior can be described as a decrease plus a "straightening" of the continuum; this amounts to a depression—not only in absolute, but also in relative sense—of the UV–XUV bump which was initially dominating.

b) Column Density Variations

The observed correlation between the X-ray spectrum and luminosity implies a physical link between the underlying mechanisms. This does not occur, for instance, if the low-energy X-ray spectral variability is interpreted as due to a variable coverage of the central source by moving absorbing clouds. A possible explanation is provided by Halpern's (1984) "warm absorber" model: here the increased luminosity increases the ionization of the absorbing material, which therefore becomes more transparent. In our particular case, we require an optical depth $\tau = 1$ at 250 eV, so that the absorption is supplied by He and, depending on the ionization structure, by H. Order of magnitude estimates can be obtained by considering hydrogen like atoms in a power-law radiation field $\propto \nu^{-1}$, $h\nu > 250$ eV. It is then possible to build up an absorber where He is partially ionized to He III and τ varies almost in proportion to L^{-1}; the H opacity is also high, and the radiation between the Lyman limit and 250 eV is suppressed, in accordance with our initial guess. The minimum variability time scale depends, in this scheme, on the ionization and recombination times for the absorbing medium along the line of sight, independently of the dimension r of the absorbing region. We find that they are shorter than the observed variability time if the plasma is dense ($n > 10^7$ cm^{-3}) and close to the center ($r < 1$ pc). The required screen is similar to Halpern's because of the dependence of the cutoff frequency on the incident flux; but—at variance with the latter—it does not become transparent below the frequency of interest. This fact, and the location coincident with the broad-line region, make it difficult to obtain a fully consistent picture: either the absorber is a large shell, so thin ($< 10^{14}$ cm $\ll r$) to be likely unstable, or it is very near to the nucleus, but then the broad-line clouds are outside the absorber and the ionization radiation reaching them is above 250 eV, which is hardly consistent with the analysis of the broad lines.

c) Spectral Slope Variations

Seyfert nuclei have been said to have a "universal" X-ray spectral slope (e.g., Mushotzky 1982; Rothschild *et al.* 1983), which apparently is not related to the mean luminosity for different objects, or the different luminosity states for a single object. But evidence to the contrary is just coming in: see for instance, the cases of NGC 4051 (Lawrence *et al.* 1985), 3C 120 (Halpern 1985), and NGC 4151 (Perola *et al.* 1986), where—as in our observations—spectral hardness and flux level are anticorrelated.

For the specific case of F9, though, the spectral variations are detected in the ratio ME/LE, and the ME data by themselves are compatible with a constant slope. Note that the average index in 1979, deduced from the *Einstein* (SSS and MPC) observations of Petre *et al.* (1984), is $\alpha = 0.93 \pm 0.08$, also compatible with our ME measurements of 1983 and 1984. Thus, all available data at $E > 1$ keV do not provide any evidence of spectral variability, either on short or on long time scales, while at the same time and in the same energy band the luminosity has varied by a factor of 4. If the hardness changes have been due to index changes in a single power law, these index changes have always fallen just short of being detected by the available medium energy experiments.

d) Soft Excess

Seyfert galaxies with clearly observed soft excesses are not numerous (E1615+061, Pravdo *et al.* 1981; Mrk 841, Arnaud *et al.* 1985). The flux of the UV continuum, however, generally lies above the extrapolation of the X-ray spectrum (see Fig. 3), and a turnup of the latter between 1 keV and 10 eV is required. We have available three sets of simultaneous, good-quality UV and X-ray data for F9 on 1983 October 9 and 13 (with practically identical results) and on 1984 October 25. In accordance with the previous discussion on the X-ray spectrum and short-term variability, we assume a constant absorption density $n_H = 4 \times 10^{20}$ cm^{-2}, corresponding to the average of the two useful 1984 observations. This includes contributions from our Galaxy, from the Magellanic Stream, and possibly further absorption within F9 itself. For consistency, we must now correct the UV data for the reddening using the total value of n_H; if indeed some absorption is contributed by the interstellar medium within F9, we are forced to assume that it has the same properties as in our Galaxy. From equations (2) and (3) we obtain $E(B-V) = 0.07$, and $\alpha_0 = 0.40 \pm 0.11$ and 0.86 ± 0.11 for the UV continua in 1983 October and 1984 October, respectively. We do not include here the uncertainty on α_0 deriving from the $E(B-V)$ correction, which is probably smaller than the uncertainty already considered in the determination of the observed slope α. A plausible model of the overall optical–UV–X-ray spectrum is given by a power law having energy index $\alpha_{UV} = \alpha_0$ and exponential cut off at energy E_0, $dF/dE = E^{-\alpha_{UV}} \exp(-E/E_0)$, plus a second power law having energy index $\alpha_X = 0.96$, and an absorbing column $n_H = 4 \times 10^{20}$ cm^{-2}; by fitting we obtain $E_0 = 86 \pm 15$ eV and $L_{XUV} = 8.1 \times 10^{44} h_{100}^{-2}$ ergs s^{-1} for the mean of the two 1983 October observations, and $E_0 < 150$ eV ($2\,\sigma$) in 1984 October. This spectra are plotted in Figure 3*a*–3*b*, together with 1983 October 13 and 1984 October 25 data. In the absence of complete UV coverage, the 1983 variability of the hardness ratio ME/LE could be attributed to a variation either of the normalization of the UV continuum or of the cutoff energy E_0. The simultaneous ME flare is shallower, in qualitative agreement with the long-term X-ray decline being less abrupt than the UV one; the flare could be due to inverse Compton scattering of the excess photons around E_0 but a quantitative agreement requires a careful tuning of the geometry and the scattering depth. The actual XUV spectrum could, of course, be more complicated. A limit to the luminosity in this band is given by a blackbody spectrum normalized to the excess flux observed in the low-energy X-rays and to the UV flux at the highest observed frequency; then, in 1983 October, a temperature $T = 17.9$ eV was obtained, with $L_{XUV} < 1.6 \times 10^{46} h_{100}^{-2}$ ergs s^{-1}. The UV bump in the spectra of Seyfert galaxies and QSOs was discussed by Malkan and Sargent (1982) in terms of blackbody emission, but at a considerably lower temperature. If a blackbody component were indeed present in the spectrum of F9, it would rather be analogous to the one discussed by Arnaud *et al.* (1985) in connection with Mrk 841; we stress, however, that, contrary to Mrk 841, in the case of F9 there is no evidence of a spectral turnup at the highest UV frequencies.

V. CONCLUSIONS

The most obvious outcome of our investigation is that on long time scales the X-ray flux of F9 varies in a manner qualitatively similar to the UV. From a quantitative point of view, it is noteworthy that the former "lags behind" the latter, with a substantially longer characteristic time; only at the lowest luminosities do the X-rays catch up with the UV and vary in proportion to it. At present, F9 is brightening again, and it will be important to know whether the same pattern is being repeated in order to pin down the geometry of the source.

On a time scale of days we have no evidence for UV variability, but the X-rays do vary both in flux and in spectral shape in such a way that lower states correspond to harder spectra. These changes lend themselves to various interpretations, which, although formally equivalent, have very different physical implications.

The idea of a soft excess with a characteristic energy E_0 lying in the XUV has a special attractiveness: indirect evidence was already available, from the spectral shape in the adjacent bands and from the analysis of the broad lines (e.g., Shuder 1981), but here for the first time we would have some quantitative information. A determination of E_0 is important in assessing the photoionization balance, which is again under debate within the so-called Fe II problem (Netzer 1985). The apparent correlation between soft excess and ME flux is not difficult to understand qualitatively, if the XUV photons are the targets in an inverse Compton process. Less obvious is the time behavior of the excess itself: the 1983 October event might have been just a jiggle in E_0; however, between 1983 October and 1984 October and the XUV bump practically disappeared. Interesting theoretical consequences can be drawn in either accretion or spinar scenarios; one can also hope to trace the relative variation of the ionizing flux in the retarded variation of the equivalent widths of the broad lines.

If instead we attribute the hardness changes to changes in the effective column density, anticorrelated with the luminosity, we must postulate a new "phase" in the circumnuclear matter. This "phase" would be characterized by a column density less than 10^{21} cm^{-2}, substantially less than the canonical broad-line cloud; one would like that its covering factor be close to 1, in order to produce effective X-ray absorption, but then one would invoke a special geometry, probably too complicated for the model to be viable.

Finally, the hardness changes could be intrinsic to the source, in which case we would have a powerful diagnostic of the radiation mechanism; for instance, the observed anticorrelation between hardness and luminosity would rule out the simplest versions of the thermal Comptonization model. It is embarassing, though, that the slope variations in the ME X-ray range have always been too small to be detected directly, even at times of very large flux variations.

We would like to thank R. Buccheri, A. Cavaliere, E. Massaro, and B. Sacco for discussions which led to the adopted strategy for the X-ray observations. We would also like to thank P. A. Whitelock and J. W. Menzies of SAAO for the optical and infrared data simultaneous to our X-ray and UV measurements, W. Wamsteker of the *IUE* Observatory for communication of results about the 1985 *IUE* observations of F9, and the *EXOSAT* Observatory staff for assistance during the X-ray observations and for discussion about the use of the *EXOSAT* calibration data.

REFERENCES

Allen, C. W. 1976, *Astrophysical Quantities* (London: Athlone Press).
Arnaud, K. A., *et al.* 1985, *M.N.R.A.S.*, **217**, 105.
Bohlin, R. C., Savage, B. D., and Drake, J. F. 1978, *Ap. J.*, **224**, 132.
Burstein, D., and Heiles, C. 1982, *A.J.*, **87**, 1165.
Fairall, A. P. 1977, *M.N.R.A.S.*, **180**, 391.
Forman, W., Jones, C., Cominsky, L., Julien, P., Murray, S., Peters, G., Tananbaum, H., and Giacconi, R. 1978, *Ap. J. Suppl.*, **38**, 357.
Halpern, J. P. 1984, *Ap. J.*, **281**, 90.
———. 1985, *Ap. J.*, **290**, 130.
Kollatschny, W., and Fricke, K. J. 1985, *Astr. Ap.*, **146**, L11.
Lawrence, A., Watson, M. G., Pounds, K. A., and Elvis, M. 1985, *M.N.R.A.S.*, **217**, 685.
Malkan, M. A., and Sargent, W. L. W. 1982, *Ap. J.*, **254**, 22.
Masegosa, J., Moles, M., and Penston, M. V. 1986, *M.N.R.A.S.*, **218**, 514.
Mathewson, D. S., Cleary, M. N., and Murray, J. D. 1974, *Ap. J.*, **190**, 291.
McHardy, I., Lawrence, A., Pye, J. P., and Pounds, K. A. 1981, *M.N.R.A.S.*, **197**, 893.
Mushotzky, R. F. 1982, *Ap. J.*, **256**, 92.
Netzer, H. 1985, *Ap. J.*, **289**, 451.
Netzer, H., and Wills, B. J. 1983, *Ap. J.*, **275**, 445.

Penston, M. V., *et al.* 1981, *M.N.R.A.S.*, **196**, 857.
Perola, G. C., *et al.* 1986, *Ap. J.*, **306**, 508.
Petre, R., Mushotzky, R. F., Krolik, J. H., and Holt, S. S. 1984, *Ap. J.*, **280**, 499.
Piccinotti, G., Mushotzky, R. F., Boldt, E. A., Holt, S. S., Marshall, F. E., Serlemitsos, P. J., and Shafer, R. A. 1982, *Ap. J.*, **253**, 485.
Pravdo, S. H., Nugent, J. J., Nousek, J. A., Jensen, K., Wilson, A. S., and Becker, R. A. 1981, *Ap. J.*, **251**, 501.
Rothschild, R. E., Mushotzky, R. F., Baity, W. A., Gruber, D. E., Matteson, J. L., and Peterson, L. E. 1983, *Ap. J.*, **269**, 423.
Seaton, M. J. 1979, *M.N.R.A.S.*, **187**, 73P.
Shuder, J. M. 1981, *Ap. J.*, **244**, 12.
Smith, A. 1984, *EXOSAT Express*, No. 5, 48.
Steiner, J. E. 1981, *Ap. J.*, **250**, 469.
Taylor, B. G., Andresen, R. D., Peacock, A., and Zobl, R. 1981, *Space Sci. Rev.*, **30**, 513.
Wamsteker, W., Benvenuti, P., Cacciari, C., Cassatella, A., Bianchi, L., Patriarchi, P., Blades, J., Danks, A. C. 1982, in *Advances in UV Astronomy*, ed. Y. Kondo, J. M. Mead, and R. D. Chapman (NASA CP-2238), p. 165.
Wamsteker, W., *et al.* 1984, in *Proc. 4th European IUE Conf.*, ed. E. Rolfe and B. Battrick (ESA SP-218), p. 97.
Wamsteker, W., Alloin, D., Pelat, D., and Gilmozzi, R. 1985, *Ap. J.* (*Letters*), **295**, L33.
Wamsteker, W., Gilmozzi, R., and Clavel, J. 1985, *IAU Circ.*, No. 4081.
Weedman, D. W. 1979, talk presented at Montreal IAU General Assembly.
Whitelock, P. A., and Menzies, J. W. 1983, unpublished observations.
Wills, B. J., Netzer, H., and Wills, D. 1985, *Ap. J.*, **288**, 94.
Wood, K. S., *et al.* 1984, *Ap. J. Suppl.*, **56**, 507.

A. Boksenberg, M. V. Penston, and M. A. J. Snijders: Royal Greenwich Observatory, Herstmonceux Castle, Hailsham, East Sussex BN27 1RP, England, UK

G. E. Bromage: Astrophysics Group, Rutherford and Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX, England, UK

J. Clavel: Villafranca Satellite Tracking Station, Apartado 54065, Madrid, Spain

A. Elvius: Stockholm Observatory, 13300 Saltsjobaden, Sweden

D. Molteni: Istituto di Fisica, Università di Palermo, via Archirafi 36, 90123 Palermo, Italy

M. Morini and L. Scarsi: Istituto di Fisica Cosmica ed Applicazioni dell'Informatica, CNR, via M. Stabile 172, 90139 Palermo, Italy

G. C. Perola and G. Simari: Istituto Astronomico, Università di Roma, via Lancisi 29, 00161 Roma, Italy

L. Piro: Istituto TESRE, CNR, via De' Castagnoli 1, 40126 Bologna, Italy

M. Salvati: Istituto di Astrofisica Spaziale, CNR, CP 67, 00044 Frascati, Italy

M. H. Ulrich: European Southern Observatory, 8046 Garching bei Munchen, West Germany