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MULTIFREQUENCY OBSERVATIONS OF THE BL LACERTAE OBJECTS OQ 530 AND ON 325

D. M. WORRALL[1] AND J. J. PUSCHELL[2]
Center for Astrophysics and Space Sciences, University of California, San Diego
F. C. BRUHWEILER[1]
Physics Department, Catholic University of America
M. L. SITKO AND W. A. STEIN
School of Physics and Astronomy, University of Minnesota
M. F. ALLER, H. D. ALLER, AND P. E. HODGE
Radio Astronomy Observatory, University of Michigan
R. J. RUDY
Steward Observatory, University of Arizona
H. R. MILLER
Department of Physics and Astronomy, Georgia State University
W. Z. WIŚNIEWSKI
Lunar and Planetary Laboratory, University of Arizona
F. A. CÓRDOVA
Los Alamos National Laboratory
AND
K. O. MASON
Mullard Space Science Laboratory, University College London
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ABSTRACT

We present spectral measurements of the two BL Lac objects OQ 530 and ON 325, from radio to ultraviolet frequencies. We infer from published data that the multifrequency measurements for each source have been made over a time interval which is short compared with the time scale for variability of the spectral shape. Both sources exhibit spectral curvature between infrared and ultraviolet frequencies. The sources differ from one another in optical variability behavior. The intensity and the spectral shape of OQ 530 vary, but in an uncorrelated manner. The spectral shape of ON 325, however, appears to remain constant during intensity variability. We have applied a nonthermal jet emission model to our data, incorporating both the spectral and time variability information. Relativistic beaming is required to successfully fit the data for OQ 530. The angular size of the jet is predicted to be less than 0.1 milli-arcsec at high radio frequencies. Emission at frequencies less than ~10 GHz is not described by the model, and must be produced externally to the jet. The model predicts that the source radiates at X-ray frequencies, with Compton radiation being dominant over synchrotron emission. The data for ON 325 do not require a highly relativistic jet, and the X-ray emission detected from the source may be dominated by synchrotron radiation.

Subject headings: BL Lacertae objects — infrared: sources — radiation mechanisms — radio sources: general — ultraviolet: general

I. INTRODUCTION

We have an ongoing program of multifrequency observations of BL Lac and related objects, directed at studying emission models for these sources. For each set of observations, we make all our measurements within a time interval which is short compared with the known variability time scales of the object. Previous results for OJ 287 and 3C 371 are reported by Worrall *et al.* (1982) and Worrall *et al.* (1984) (hereafter Paper I). In this paper we report results for the two objects OQ 530 (1418+546) and ON 325 (1215+303). Both have featureless optical spectra (Schmidt 1978; Strittmatter *et al.* 1972) and have been classified as BL Lac objects.

The observations of OQ 530 were made in 1980 mid-December, and those of ON 325 in 1981 late April and early May. In our model fitting we assume that our measurements of OQ 530 and ON 325 represent core flux densities. Galactic extinction is assumed to be negligible, since both sources are at high galactic latitude. For OQ 530 there is no reported detection of nebulosity. However, nebulosity to the south of ON 325 is apparent on the red Palomar Sky Survey print (Browne 1971). Weiler and Johnston (1980) also report resolving 20% of the 6 cm radio emission into a component of angular size 36″. No redshift is measured for ON 325 (or OQ 530), but this angular size converts to a galaxy-size diameter if the source is at fairly low redshift (e.g., 54 kpc for $z = 0.05$; $H_0 = 50$ km s^{-1} Mpc^{-1}, $q_0 = 0$). We know of no confirmation, such as a deep visual image, or evidence of galactic line emission similar to that reported for 3C 371 (see Paper I).

[1] Guest Observer with the *IUE* satellite.
[2] Now with Titan Systems, Inc.

TABLE 1

IUE Continuum Fits to $f_\nu(\mathrm{Jy}) = K\nu_{15}^{-\alpha}$

Source	Date (UT)		Camera[a]	α[b]	$K \times 10^3$ [c]
OQ 530	1980 Dec 13/14	1921–0923	SWP and LWR	1.83 ± 0.18	0.74 ± 0.02
ON 325	1981 May 2	0911–1550	SWP	0.99 ± 0.17	1.21 ± 0.03

Note.—ν_{15} is the frequency in units of 10^{15} Hz.

[a] Frequency ranges: SWP: $\nu \approx 1.54\text{–}2.50 \times 10^{15}$ Hz; $\lambda = 0.12\text{–}0.19$ μm. LWR: $\nu \approx 0.94\text{–}1.54 \times 10^{15}$ Hz; $\lambda = 0.19\text{–}0.32$ μm.

[b] 1 σ errors.

[c] 1 σ errors corresponding to best fit value of α.

II. OBSERVATIONS

a) International Ultraviolet Explorer Measurements

Low-resolution, large-aperture–mode observations (Boggess *et al.* 1978) were made as described in Table 1. No significant line features were detected from either object. The data reduction and power-law fitting procedures were identical to those described in Paper I. Separate spectral fits to the data from the SWP and LWR cameras for OQ 530 were in agreement. The spectral parameters in Table 1 were derived from a simultaneous fit to the data from both cameras. There have been no other ultraviolet measurements of OQ 530 or ON 325 as of 1983 June 30 with which to compare our data and study ultraviolet variability.

b) Visual and Infrared Measurements

The NASA/University of Arizona 1.5 m telescope on Mount Lemmon was used to obtain visual photometric observations of OQ 530. The source was measured at *UBVR* on 1980 December 16 (UT) and at *UBV* on December 17. The results on consecutive nights were in agreement to within the measuring errors of $\sim \pm 0.03$ mag. The December 16 values were $U = 15.43$ mag, $B = 16.07$ mag, $V = 15.49$ mag, and $R = 14.80$ mag. The magnitudes have been converted to flux densities using the calibration of Johnson (1966) and are shown in Figure 1*a*. The open circles representing the data are slightly larger than the errors.

Infrared observations of OQ 530 were made at 1.65 μm and 2.28 μm on 1980 December 15 (UT) using the University of Minnesota/University of California, San Diego, 1.5 m telescope on Mount Lemmon. The flux densities of 8.2 ± 0.7 mJy and 10.6 ± 0.9 mJy for 1.65 μm and 2.28 μm, respectively, are represented by filled squares in Figure 1*a*, which are of a size comparable with the measuring errors.

Previous studies of OQ 530 in infrared and visual wave bands revealed spectral curvature (O'Dell *et al.* 1978) and suggested that spectral-shape changes accompany flux variability (Puschell and Stein 1980). Using these published data and additional measurements of W. Z. W., we illustrate in Figure 2 that the spectral shape is not correlated with the visual flux density. The shortest variability time scale represented by these data is the $\sim 20\%$ flux-density increase (~ 0.25 mag) in 4 days between the Pushchell and Stein (1980) measurements of 1979 March 26 and the W. Z. W. measurements of 1979 March 30. The factor of 4 variability in the data of Figure 2 (i.e., $R = 0.5$–2) is small compared with the long-term behavior reported by Miller (1978), who found that between 1900 and 1977 the source slowly dimmed from 11.3 to 16.1 mag in the blue ($R \approx 80$–1). Miller also reports sporadic outbursts over time scales ≤ 1 yr, during which the flux density increased by factors of ~ 3–5, and one instance of a $\sim 67\%$ flux-density decline (~ 1.2 mag) and subsequent increase over an interval of 4 days.

Photometric *UBV* observations of ON 325 were made using the number 2, 0.9 m Kitt Peak National Observatory (KPNO) telescope with a 15".5 beam on 1981 May 5 (UT), 3 days after the *IUE* observations of this source. The observed magnitudes were $U = 15.05$ mag, $B = 15.56$ mag, and $V = 15.14$ mag. These measurements have been converted to flux densities using the calibration of Johnson (1966), and they are shown as solid squares in Figure 1*b*, where the symbols are slightly larger than the errors. The fine error sensor (FES) of the *IUE* measured a visual magnitude of 15.3 ± 0.16 ($\sim 2.9 \pm 0.4$ μJy) on May 2, immediately prior to the ultraviolet exposure (open triangle in Fig. 1*b*). This is in agreement with the May 5 measurement, within the rather large FES error.

Figure 1*b* also shows, as open squares, the infrared measurements of ON 325, taken on 1981 April 24, using the 3 m Shane telescope at the Lick Observatory with a 7".62 beam. The observations were obtained with a liquid-helium–cooled InSb detector through discrete bandpasses using a 15" chopper spacing. Flux densities at 1.05 μm, 1.25 μm, 1.65 μm, and 2.28 μm were 6.6 ± 1.0 mJy, 7.5 ± 1.1 mJy, 8.8 ± 1.3 mJy, and 10.9 ± 1.6 mJy, respectively.

In contrast to OQ 530, Figure 3 illustrates that the spectral shape of ON 325 has remained constant during time variability spanning a factor of 2.4 in intensity. There is a report of rapid variability (0.4 mag in ~ 3 hr) from Harvard plates of 1933 (Lucchetti and Usher 1971), but otherwise the source appears to be slightly less variable than OQ 530. The *B* magnitude since 1926 has ranged between ~ 14.3 and ~ 17 mag, with variations of ≥ 0.5 mag confined to time scales of a month or longer (Véron and Véron 1975; Schaefer 1980; Pica *et al.* 1980). The data of Figure 3 do show a small decrease of ~ 0.17 mag in 6 days between 1979 March 30 and April 5. Also, significant changes of a few percent in the polarization, but not the position angle, are reported over the time scale of a few days by Angel *et al.* (1978). The constancy of the optical spectral shape of ON 325 permits us to conclude with reasonable certainty that the curvature between the infrared and visual energy bands is real and is not a consequence of the 11 day gap between our infrared and visual measurements. A single power law through the visual and ultraviolet data provides an acceptable fit within the given errors.

c) Millimeter and Radio Measurements

The source OQ 530 was observed at 89.6 GHz on 1980 December 14, and ON 325 on 1981 April 20, using the National Radio Astronomy Observatory (NRAO) 11 m telescope on Kitt Peak. The observational method was identical to that described in Paper I. The measured flux densities were

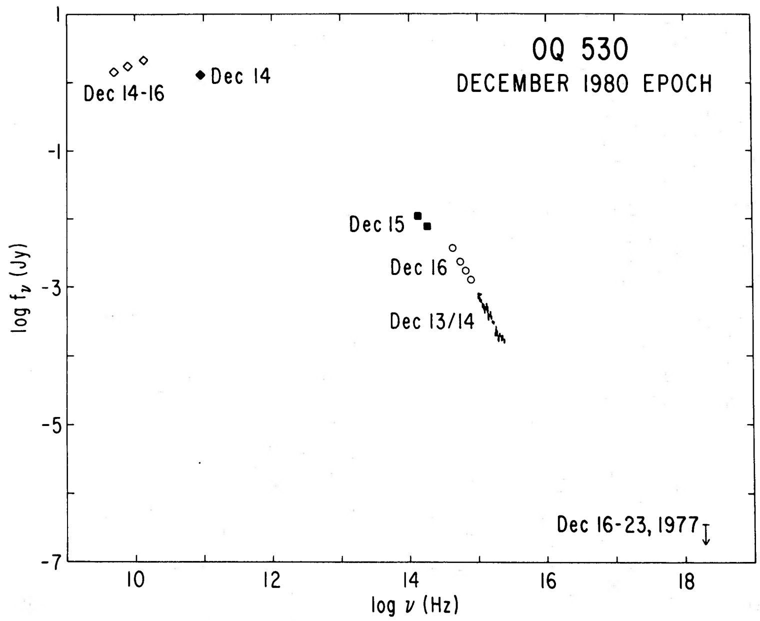

FIG. 1*a*

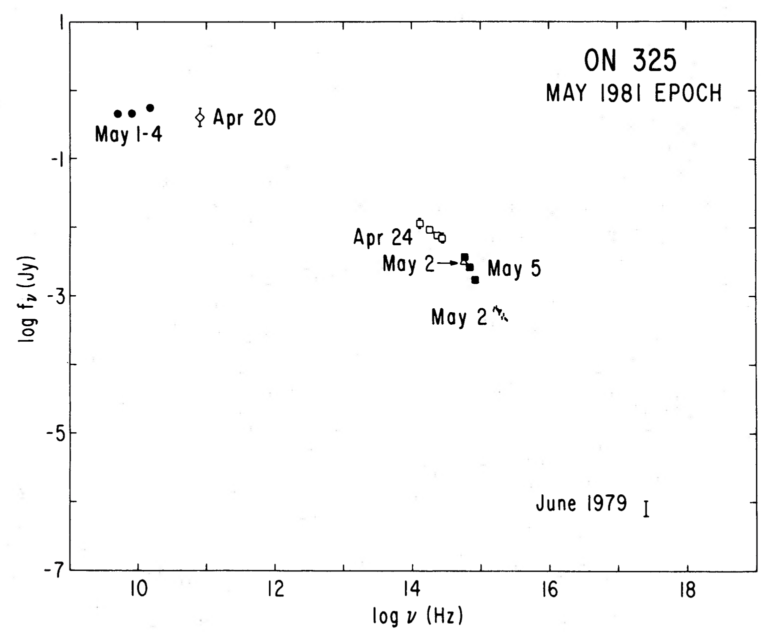

FIG. 1*b*

FIG. 1.—Measured flux densities of (*a*) OQ 530 and (*b*) ON 325

1.28 ± 0.14 Jy for OQ 530 and 0.41 ± 0.12 Jy for ON 325, as plotted in Figures 1*a* and 1*b*.

The University of Michigan 26 m (85 foot) paraboloid has monitored OQ 530 at 8 GHz since 1978 August and, more recently, also at 4.8 and 14.5 GHz (Aller, Aller, and Hodge 1981). There was a relatively large outburst in late 1979, and two smaller bursts, each lasting a few months, were superposed on the decay portion of this burst during 1980. In the first two bursts the 14.5 GHz flux showed a larger amplitude and peaked earlier than at 8 GHz, indicating the adiabatic cooling of an expanding source. During the less active period between late 1980 and early 1981, the small bursts had similar amplitudes at both frequencies, suggesting that new particle generation or reacceleration was important. Although the long-term coverage of ON 325 is more sparse, our data indicate that the degree of activity in this source is significantly less than in OQ 530. There is no strong evidence for variability at 4.8 and 8.0 GHz during the period 1980–1983; during 1980 the 14.5 GHz flux was near 0.7 Jy, but it has remained near 0.5 Jy since 1981 April. A low degree of activity in ON 325 was also reported by Wardle (1978), and Altschuler (1982) reports no variability from 6 months of monthly spaced observations at 2.3 GHz in

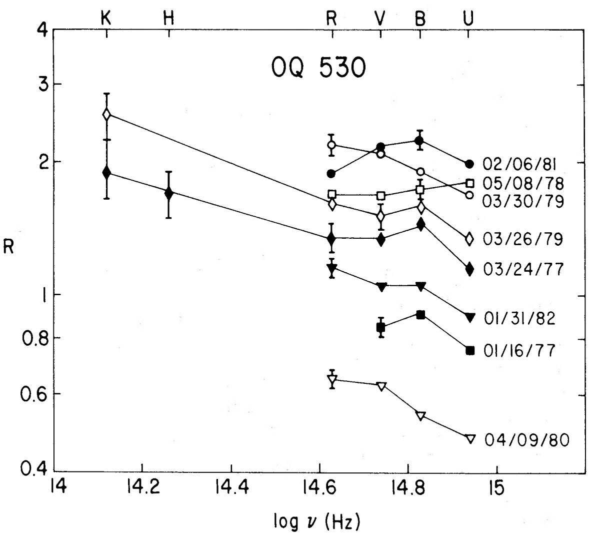

FIG. 2.—Spectral measurements of OQ 530. Each data point is the ratio of the measured flux density to that measured at U, B, V, or R 1980 December 16, or at H or K on 1980 December 15, as in Fig. 1a. Only one representative error bar is shown for each spectrum in the $UBVR$ colors. The lines are drawn to help the eye pick out each set of symbols. The data of 1977 January 16 and March 24 are from O'Dell *et al.* (1978); data of 1978 May 8 and 1979 March 26 are from Puschell and Stein (1980); other data were taken by W. Z. W. with the University of Arizona 1.5 m telescope on Mount Lemmon.

1979. The flux-density measurements of OQ 530 and ON 325 obtained near the epochs of the *IUE* observations are given in Table 2.

d) X-Ray Characteristics of the Sources

The object OQ 530 is not a reported X-ray source. It was not looked at with the *Einstein Observatory* telescope. Its nondetection with the MED and HED A-2 detectors of the *HEAO 1* satellite sets a 3 σ flux-density upper limit of $\sim$0.35 μJy at 8 keV ($\sim 1.9 \times 10^{18}$ Hz) for 1977 December 16–23, 3 yr prior to our multifrequency observations.

The object ON 325 was observed with the IPC of the *Einstein Observatory* twice, 11 and 23 months prior to our multifrequency observations (G. Kriss and C. Canizares, private communication). Although systematic uncertainties preclude the use of the IPC to determine the spectral parameters of point sources with any certainty, we find that the two observations are consistent with soft X-ray spectra ($\alpha \geq 1.5$). Most of the detected photons have energies less than 1 keV, and there is no evidence for a low-energy cutoff. No flux-density variation was measured between these two observations, which are consistent with 0.7–1.0 μJy at 1 keV. The flux-density range reflects the uncertainty in detector gain.

III. DISCUSSION

Relatively strong polarization, optical variability, and absence of line radiation are factors which traditionally support a synchrotron origin for the emission from BL Lac objects such as OQ 530 and ON 325. We will thus confine our model fitting to the synchrotron self-Compton (SSC) class of models. Such models assume a synchrotron origin for the radiation but do not neglect the Compton-scattered radiation which results from any small bright synchrotron source, and which may contribute significantly to the X-ray flux density.

Our SSC model applications to these sources assume that our spectral measurements represent core flux densities. In par-

TABLE 2

RADIO OBSERVATIONS

Date (UT) mo/day/yr	Frequency (GHz)	Flux, f (Jy)	σ_f
OQ 530			
12/01/80.........	8.0	1.53	0.07
12/05/80.........	8.0	1.58	0.05
12/08/80.........	4.8	1.15	0.16
12/10/80.........	8.0	1.60	0.04
12/12/80.........	14.5	2.75	0.37
12/13/80.........	4.8	1.50	0.03
12/14/80.........	8.0	1.86	0.08
12/15/80.........	8.0	1.73	0.02
12/16/80.........	8.0	1.82	0.02
12/17/80.........	4.8	1.54	0.28
12/18/80.........	14.5	1.86	0.05
12/20/80.........	8.0	1.73	0.05
12/24/80.........	8.0	1.79	0.14
12/27/80.........	4.8	1.57	0.06
ON 325			
4/20/81.........	14.5	0.40	0.06
4/30/81.........	8.0	0.50	0.04
5/01/81.........	4.8	0.47	0.01
5/02/81.........	8.0	0.44	0.05
5/03/81.........	14.5	0.52	0.04
5/05/81.........	14.5	0.50	0.04
5/06/81.........	8.0	0.55	0.04
5/07/81.........	8.0	0.54	0.04
5/08/81.........	4.8	0.47	0.03
5/10/81.........	8.0	0.49	0.04
5/13/81.........	14.5	0.52	0.03

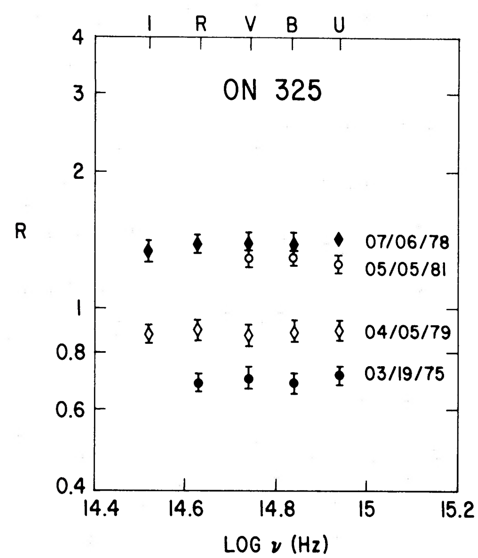

FIG. 3.—Spectral measurements of ON 325. Each data point is the ratio of the measured flux density to that of 1979 March 30. The data of 1981 May 5 are as in Fig. 1b; the data of 1975 March 19 are from Tapia, Craine, and Johnson (1976); the other data, including the measurements for 1979 March 30, were taken by W. Z. W. with the University of Arizona 1.5 m telescope on Mount Lemmon. Additional measurements of Strittmatter *et al.* (1972) and O'Dell, and Stein (1977) have larger errors but do not disagree in spectral shape with the data plotted. Data of W. Z. W. for 1981 March 14 are too close in value to those of 1978 July 6 to be plotted, but do not disagree in spectral shape. Data of Wing (1973) for 1972 March 6 are too close in value to those of 1979 April 5 to be plotted, but do not diagree in spectral shape.

ticular, it is assumed that the curvature in the infrared to ultraviolet spectrum of each source is a manifestation of electron energy losses. Such an assumption might be compromised if the sources were situated in nearby host elliptical galaxies similar to those reported for at least four BL Lac nuclei, including 3C 371 (see Weistrop *et al.* 1981). It might be possible that the host galaxy emission fully accounts for the curvature, leaving residual core emission of a single power-law index. We have tested this by placing an elliptical galaxy of the absolute magnitude of 3C 371 (Sandage 1973) at various redshifts, using the curve of growth of Sandage (1972) and the *K*-corrections of Whitford (1975). We find that, if ON 325 were at $z \approx 0.08$, the galaxy could produce contributions to our measured flux densities at *UBVJHK* of 13%, 32%, 57%, 55%, 59%, and 35%, respectively. The residual core radiation would then have a power law of spectral index $\alpha \approx 0.9$. However, our *IUE* data would be a discernible amount, $\sim$26%, below this power law, implying a discontinuity or break in the core spectrum. Furthermore, a relatively large galaxy contribution would make it fortuitous that the measured *UBVR* spectral index, a sum of that of galaxy and core, should remain so constant while only the core intensity varies (Fig. 3). The source OQ 530 is sufficiently steep in the optical and ultraviolet that a relatively strong galaxy contribution would be required here too, in order to steepen the infrared core and produce a single power law through the core infrared and optical. Again, a galaxy like 3C 371 must be at $z \approx 0.08$. However, again the core spectrum, while having $\alpha \approx 1.1$ between *K* and *V*, has discontinuities through *UB* and the ultraviolet. Thus, while there is a clear need for good imaging of ON 325 and OQ 530 (note especially the possible nebulosity around ON 325 mentioned in § I), our measurements give the smoothest spectral distribution for the core radiation in each source if the galaxy contribution is relatively weak—at least too weak to produce residual core emission which does not display spectral curvature.

Our discussion in Paper I of 3C 371, a source which has some similarities to OQ 530 and ON 325, considered two models. The first was a homogeneous model in which it was assumed that no electron reacceleration occurs in the source. In this model, the light crossing time for the source therefore cannot exceed the electron lifetime. This condition, together with spectral measurements and a condition that the Compton radiation should not exceed the measured X-ray flux density, enabled Worrall and Bruhweiler (1982) to show that OQ 530 and ON 325, along with 3C 371 and OJ 287, must have a Doppler factor $\delta = (1 - \beta^2)^{1/2}/(1 - \beta \cos \theta) > 1$. Here β is the bulk velocity in units of *c*, and θ is the angle of relativistic motion relative to the line of sight. This simple model has important limitations, however. It offers no explanation for the flat radio spectra measured in these sources. Rather, it assumes that the synchrotron component is self-absorbed at a frequency $\geq$100 GHz. Using the data of Figure 1, we find $\delta \geq 17$ and $\delta \geq 12$ for OQ 530 and ON 325, respectively. Neither source has a measured redshift, and the lower limits are derived by placing both sources at small redshift $z = 0.05$, and by allowing all the observed X-ray flux density (or upper limit to it in the case of OQ 530) to be Compton radiation. The latter assumption is questionable for ON 325 because of the suggestion of a relatively steep X-ray spectrum and the fairly good agreement of the X-ray flux density with the extrapolated visual/ultraviolet (synchrotron) spectrum.

Electron reacceleration is probably a more likely condition in sources such as OQ 530 and ON 325, and can allow smaller values of δ. A convenient formalism, also applied in Paper I, has been given by Königl (1981). The model describes a synchrotron spectrum of index α_1 ($f_\nu \sim \nu^{-\alpha}$) between frequencies ν_1 and ν_{12}; of index α_2 between ν_{12} and ν_{23}; and of index α_3 above ν_{23}. Typically, α_1 is flat, like the observed radio spectra of OQ 530 and ON 325. The physical ingredients of the model are a jet of opening angle Φ, viewed at an angle to the jet axis of $\theta > \Phi$. The observed synchrotron radiation comes from distances between r_m and r_u along the jet axis. Electrons of index $2\alpha_0 + 1$ are continuously reaccelerated along the jet on the time scale of the jet expansion time. Their density falls with distance as r^{-n}, and the magnetic field falls as r^{-m}. A relativistic Doppler factor, δ, is defined as above. If α_1, α_2, α_3, ν_{12}, ν_{23}, the redshift *z*, the normalization of the synchrotron component, and the Compton flux density at some frequency are known, an expression can be found which relates δ, θ, and Φ. The value of δ will be minimized if $\sin \theta = 1/\delta$ and Φ is as large as possible but less than θ. Values for r_m, r_u, and the magnetic field and electron density at any distance along the jet can also be found.

Unique determination of parameters in our applications of this model to OQ 530 and ON 325 is precluded by (*a*) uncertainties in the spectral parameters, (*b*) unknown redshifts, and (*c*) unknown Compton flux densities. Concerning (*a*), we assume that the well-defined spectral breaks in the infrared/visual band signify ν_{23}. Table 3 then shows results for three possible sets of values for the less well determined parameters α_1, ν_{12}, and α_2 for each source (see Fig. 1). Concerning (*b*), it is known from § II that the model will only be acceptable if it implies relatively rapid variability as seen by the observer, i.e., relatively small r_m/δ and r_u/δ. This is aided by placing the sources at low redshift, and we adopt $z = 0.05$ for our parameter evaluations. A larger *z* gives larger values for r_m/δ and r_u/δ, even though δ is itself increased. As an illustration, in example *c* for OQ 530 in Table 3, δ would be increased by a factor of 2.4, and r_m/δ and r_u/δ would be increased by factors of 4.3 if *z* were 0.5 rather than 0.05. Concerning (*c*), the ratio of Compton flux density to X-ray flux density, F_C/F_X, has been chosen to give a minimum value for δ. For OQ 530, this implies a choice of $F_C/F_X = 1$ for all three examples in Table 3. If F_C/F_X, is less than unity, the values of r_m/δ and r_u/δ are slightly reduced, but by only relatively small amounts relative to the increase in δ. As an illustration, if $F_C/F_X = 10^{-2}$, example c for OQ 530 gives a δ increased by a factor of 3.3, but r_m/δ and r_u/δ are only decreased by $\sim$14%. We therefore consider only $F_C/F_X = 1$ for this source. For ON 325, we find that examples b and c give $\delta = 1$ for $F_C/F_X = 1$. We can thus reduce F_C/F_X to the lowest value consistent with $\delta = 1$ in order to find the simultaneous minima of δ, r_m/δ, and r_u/δ. These parameters are presented in Table 3. Reducing F_C/F_X further causes a relatively rapid rise in δ, accompanied by an extremely slow decrease in r_m/δ and r_u/δ.

a) OQ 530

The values of α_0, *m*, and *n* depend only on α_1, α_2, and α_3. We see from Table 3 that, for OQ 530, *n* always falls far short of 2, the value corresponding to electron number conservation along the jet. The correct value of F_C/F_X is particularly uncertain for this source, since F_X is itself an upper limit. The assumption that the Compton radiation equals F_X, however, provides lower limits to δ, as too does the assumption that $z = 0.05$. The expected variability times of the flux densities at ν_{12} and ν_{23} are given in Table 3. These times correspond to cooling times of the electrons dominating emission at these

TABLE 3

SYNCHROTRON SELF-COMPTON JET MODEL FITS

A. INPUT PARAMETERS

Example	α_1	α_2	α_3	ν_{12} (GHz)	ν_{23} (GHz)	F_C/F_X
OQ 530						
Ex. a	0.3	0.95	1.83	2×10^3	3.2×10^5	1
Ex. b	0.0	0.95	1.83	7×10^2	3.2×10^5	1
Ex. c	0.0	0.7	1.83	1×10^2	3.2×10^5	1
ON 325						
Ex. a	0.35	0.6	1.3	4×10^3	3.5×10^5	1
Ex. b	0.0	0.6	1.3	2.5×10^2	3.5×10^5	2.5×10^{-1}
Ex. c	0.0	0.52	1.3	1×10^2	3.5×10^5	8.6×10^{-3}

B. OUTPUT PARAMETERS

Example	α_0	m	n	δ	r_m (pc)	r_u (pc)	ν_1 (GHz)	t_{var} at ν_{12}	t_{var} at ν_{23}
OQ 530									
Ex. a	0.77	1.56	0.71	20	5.9×10^{-3}	3.9×10^{-2}	300	8 hr	2.3 days
Ex. b	0.74	2.09	0.27	20	4.4×10^{-2}	1.8×10^{-1}	122	2.5 days	10 days
Ex. c	0.56	2.34	0.05	2.7	5.3×10^{-2}	2.6×10^{-1}	13.4	23 days	3.7 months
ON 325									
Ex. a	0.47	0.94	1.72	1.7	7.4×10^{-5}	1.7×10^{-2}	35	1.2 hr	12 days
Ex. b	0.38	1.30	1.61	1	4.3×10^{-3}	1.9×10^{-1}	4	>5 days	>225 days
Ex. c	0.34	1.31	1.61	1	8.9×10^{-3}	6.1×10^{-1}	1	>10.3 days	>2 yr

frequencies, and they are equivalent to the jet travel times to r_m and r_u, respectively, transformed into the observer's frame by dividing by δ. The variability time for ν_{23} is particularly interesting, since this occurs in an observed part of the spectrum. We see that, in order to have variability on the time scale of days, as in examples a and b in Table 3, the value of ν_1 is considerably larger than the lowest frequency of the observed flat radio spectrum, and δ is large (~ 20). A radio frequency as low as 13.4 GHz is produced if the jet dimensions are such as to give variability at ν_{23} on a time scale of months, and δ can be relatively small (~ 2.7). However, even lower frequency radio emission cannot be explained in this simple application of the Königl jet model. The value of ν_1 is smallest when ν_{23}/ν_{12} is a maximum. This is already the situation in example c of Table 3, since smaller ν_{12} is disallowed by the radio observations. The evaluation of ν_1 is independent of assumptions about z or F_C/F_X. The observed angular size of the jet at distance D and frequency ν_1 should be $r_u \sin\theta/D \approx r_u/\delta D$. For $z = 0.05$, the value for example c is 0.06 mas, and values are smaller for the other examples. Resolving a source this small at a frequency ≥ 100 GHz would be an ambitious experimental goal. Since observations suggest several variability time scales in the optical, it is possible that the physical properties of a jet are themselves time variable with each of the examples a–c, along with an array of others for which t_{var} may be larger, occurring at various times. In support of this, we note that our 4.8–90 GHz radio spectrum is not only brighter by a factor of ~ 2, but also less flat than the spectrum obtained previously by Owen, Porcas, and Neff (1978).

Our conclusion is thus that a relativistic jet of $\delta \geq 2.7$ would seem capable of producing the short time scale optical variability observed in OQ 530. Radio emission at frequencies below ~ 10 GHz must, however, be produced externally. This conclusion is similar to that reached for 3C 371 in Paper I.

b) *ON 325*

For ON 325, the values of n and m are closer to 2 and 1, respectively, than for OQ 530, i.e., the values which correspond to electron number conservation along the jet and equipartition of electron and magnetic field energy densities. We find that a Doppler factor of more than 1 is not always necessary. This depends on the values adopted for α_1, α_2, and ν_{12}. In examples b and c of Table 3, $\delta = 1$. In these cases we reduce F_C/F_X from unity to the lowest value still consistent with $\delta = 1$, in order to lower values for r_m/δ and r_u/δ. The steep X-ray spectrum and the measurement of an X-ray flux density which is roughly consistent with an extrapolation through the visual/ultraviolet flux density support an X-ray flux density predominantly of synchrotron origin. The nonrelativistic examples b and c can also produce radio emission to frequencies as low as 1 GHz. The predicted optical variability (at ν_{23}) is, however, relatively long. The values given for t_{var} for examples b and c are extreme lower limits because they have yet to be divided by a value of β, which is ill-determined but much smaller than unity. Although in § II we comment that ON 325 may be less variable than OQ 530, fluctuations over days, rather than months, may not be atypical. The jet would need to become relativistic for short times in order for this to happen. The predicted angular sizes for example b at 4 GHz and example c at 1 GHz are 0.13 mas and 0.4 mas, respectively. This may be consistent with the measurements of Weiler and Johnston (1980), where 75% of the 6 cm core emission of ON 325 was resolved into a component of 0.7 mas.

We conclude that the jet model appears successful in describing the emission from ON 325. Such a jet need not be highly relativistic during times when the emission is relatively constant. The X-ray flux density may then comprise mostly synchrotron radiation.

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H. D. Aller, M. F. Aller, and P. E. Hodge: 817 Dennison Bldg., Department of Astronomy, University of Michigan, Ann Arbor, MI 48109

F. C. Bruhweiler: Code 685, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

F. A. Córdova: Mail Stop 436, Los Alamos National Laboratory, Los Alamos, NM 87545

K. O. Mason: Mullard Space Science Laboratory, University College London, Holmbury-St.-Mary, Dorking, Surrey RH5 6NT, England, UK

H. R. Miller: Department of Physics and Astronomy, Georgia State University, Atlanta, GA 30303

J. J.Pushell: Titan Systems, Inc., La Jolla Gateway, 9191 Towne Centre Drive, Suite 500, San Diego, CA 92122

R. J. Rudy: University of Arizona, Steward Observatory, Tucson, AZ 85721

M. L. Sitko and W. A. Stein: School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455

W. Z. Wiśniewski: Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721

D. M. Worrall: Center for Astrophysics and Space Sciences, C-011, University of California at San Diego, La Jolla, CA 92093