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ABSTRACT

A sample consisting primarily of radio bright quasars has been observed in X-rays with the Einstein Observatory for times ranging from 1500 to 5000 seconds. Detected sources have luminosities ranging from 0.2 to 41.0 x 10^{45} ergs s^{-1} in the 0.5 to 4.5 kev band. Three of the 14 objects which have been reobserved show flux increases greater than a factor of 2 on a time scale greater than six months. No variability was detected during the individual observations. The optical and X-ray luminosities are correlated, which suggests a common origin. However, the relationship ($L_x \sim L_{op}^{.89\pm.15}$) found for historic radio variables may be significantly different than that reported for other radio bright sources. Some of the observed X-ray fluxes are substantially below the predicted self-Compton flux, assuming incoherent synchrotron emission and using VLBI results to constrain the size of the emission region, suggesting relativistic expansion in these sources. Normal CIV emission in two of the sources with an overpredicted Compton component suggests that although they, like BL Lac objects, have highly relativistic material apparently moving at small angle to the line of sight, they have a smaller fraction of the continuum component in the beam.

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I. INTRODUCTION

Previous X-ray surveys of quasi-stellar objects (Tananbaum et al. 1979; Ku, Helfand, and Lucy 1980; Zamorani et al. 1981) have been made in order to determine the radiation mechanisms responsible for the extreme brightness in X-rays as well as in other wavelength regimes. A wide range in the X-ray luminosity was found, and a weak correlation was seen between brightness in radio and X-ray. This correlation was tested (Owen et al. 1981) by X-ray observations of a sample of BL Lac objects and quasars showing strong emission at millimeter wavelengths. As expected, a large number of X-ray detections were made and this was interpreted to support the synchrotron self-Compton model. In this model, the photons resulting from the gyration of electrons in a magnetic field upscatter off of the same population of electrons and eventually emerge as X-radiation. However, calculations of the Compton luminosity for quasars (Burbidge, Jones, and O´Dell 1974) and BL Lac objects (Madejski and Schwartz 1983; Urry and Mushotzky 1982), showed that the observed X-ray emission was significantly less than expected. In both cases, it was argued that relativistic bulk motion toward the observer resulted in beaming of the radiation and thus an overestimate of the true luminosity of the source.

In designing our survey, we hoped to test further the jet hypothesis for quasars by observing those bright in radio emission, reasoning that if the primary difference between radio bright and radio weak is due to alignment of a jet with the observers line of sight (Scheuer and Readhead 1979), then the over-estimation of the Compton luminosity should be found for a significant number of these radio bright objects. In addition, if the synchrotron self-Compton mechanism were actually at work, then self consistency of this model would require that the objects most variable in radio would be the most likely to show variability in X-rays. Thus, the members of the present sample were chosen from a compilation of bursting radio sources and those showing flux variations at low frequencies (Marscher et al. 1979).

II. OBSERVATIONS

The Imaging Proportional Counter (IPC) on the Einstein Observatory (Giacconi et al. 1979) was used to observe the sample in X-rays. This detector, which has a field of view of about one square degree and a spatial resolution of about 1 arcmin, is most sensitive in the .5 to 3 kev energy band. Table 1 contains the count rates observed in this energy band.

The sources observed were chosen primarily because of their historic radio variability. Observation lengths range from 1500 to 5000 seconds. In addition, 14 objects were reobserved six months or one year later. Since the IPC records photon arrival times, we were able to search for variability over a wide range of timescales.

The sample consists of 24 quasars, 2 radio galaxies and 9 unidentified variable radio sources. The redshift is known for 18 sources and ranges from .059 to 2.286. The redshifts were obtained from Kuhr et al. (1981). Identification of the radio sources as a quasar or a radio galaxy for objects without measured redshift is also from Kuhr et al.

We found that 77% of the objects were detected as X-ray sources. This detection rate is comparable to the combined surveys of Zamorani et al. (1981) and Ku, Helfand, and Lucy (1980). Kembhavi and Fabian (1981) report that the combined surveys show 82% of the radio loud quasars were detected as opposed to 22% of the radio quiet (all others). We use the definition of radio loud given by Zamorani et al. $\alpha_{ro} > 0.35$ where $\alpha_{ro} = -\log[L_r/L_o]/\log[\nu_r/\nu_o])$. All of the members of the present sample are radio loud and the detection rate is similarly high. The radio luminosities used to calculate the radio to optical spectral index utilize nearly simultaneous (to the X-ray observation) radio fluxes at 8 GHz provided by M. Aller of the University of Michigan.

The X-ray luminosity in the 0.5 to 4.5 kev band, at the source, is calculated (Table 2) for the objects with known redshift. The procedure for the luminosity calculation is that given in Tananbaum et al. (1979). We assume a hydrogen column density of 3×10^{20} cm^{-2}, and a power-law spectrum with energy spectral index of 0.5. Because of the difficulties in getting good spectral fits from the IPC, the hardness ratio (defined as (counts in 1.2 - 3.0 kev band)/(counts in 0.5 - 1.2 kev band)) is used to indicate the approximate slope of the power law. The average hardness ratio for detected sources is consistent with a spectral index of 0.4 or 0.5 (Zamorani et al. 1981) but in general for these weak detections it is not well determined. More importantly though, the distribution of the hardness ratio is consistent, within random counting errors, with that found for other quasars with a wider range in radio luminosity.

We have assumed a 30% uncertainty in the luminosity, due to uncertainties in the IPC gain and possible differences in the spectrum from the assumed $\alpha = 0.5$, in addition to the statistical error.

For sources not detected, upper limits are given. The upper limits are 3 sigma above the actual flux at the object's position. The X-ray luminosities range from 2×10^{44} to 4×10^{46} ergs s^{-1}.

Optical luminosities are calculated based on magnitudes which are not measured simultaneously with the X-ray and radio observations. This will introduce an uncertainty into the optical luminosity for the quasars which are most variable, such as NRAO 530. Based on non-simultaneous optical coverage of a few of our sources (discussion section of this paper), there is reason to believe that this uncertainty is significant. A parameter which is often used to characterize the relative brightness in the optical and X-radiation is the optical to X-ray spectral index (α_{ox} = $-\log[L_x(2kev)/L_o(2500Å)]/2.608$). For the 13 detected quasars in this sample with known redshift, the average α_{ox} is 1.29 with a standard deviation of .14; the undetected objects typically have a larger α_{ox}. Comparison to other extragalactic X-ray sources (see Figure 1) shows that this value of α_{ox} is similar to that previously found for radio bright quasars (Zamorani et al. 1981), and nearby radio bright objects such as N-galaxies and Bl Lacs (Ku, Helfand, and Lucy).

III. Discussion

(A) Synchrotron-Self Compton Model

We assume incoherent synchrotron self-Compton for our sources and calculate the Compton luminosity (Marscher 1983). The distribution of electrons is assumed to be isotropic and given by a power law with spectral index 2.0. The Compton flux is not very sensitive to the spectral index. For example, in the case of DA406, an electron spectral index of 1.5 would decrease the flux roughly by a factor of 2 while an electron spectral index of 2.5 would increase the flux by a factor of 2. In the most interesting cases, such as DA406, 0400+25, OR103, and 0738+31, the uncertainty in the predicted flux is insignificant compared to the disagreement with the observed flux. The flux (ergs cm^{-2} sec^{-1}) in the .5 to 4.5 kev band is given by equation (A) for photon spectral index 1.5.

$$F(.5 - 4.5\ kev) \approx 5.8 \times 10^{-10} \ln\left(\frac{\nu_2}{\nu_m}\right) S_m{}^5 \theta^{-8} \nu_m{}^{-6.5} (1 + Z)^5 \delta^{-5} \qquad (A)$$

ν_m is the turnover frequency, assumed due to self-absorption, in GHz

S_m is the flux at ν_m, obtained by extrapolation of the transparent part of the spectrum back to the turnover frequency, in Janskys

θ is the angular diameter of the emitting region in milliarcsec

δ is the Doppler factor necessary to reduce the flux down to observed limits

$$= [\Gamma(1 - \beta\cos\theta)]^{-1} \text{ where } \beta = v/c, \quad \Gamma = (1 - \beta^2)^{-1/2}$$

To measure ν_m and S_m accurately for variable radio sources, it is preferable to use simultaneous radio fluxes at a number of frequencies, typically ranging from 1 to 100 GHz; the primary constraint being that the turnover in the spectrum is visible. We use spectra published by Owen, Spangler, and Cotton (1980) and Owen et al. (1978), for 7 of 9 objects in table 3. For two sources we use the spectra in Kuhr et al. (1981). The self-Compton flux is most sensitive to the angular size of the emitting region. We use VLBI fringe visibilities (Figure 2) and following Marscher (1983), assume a spherical source to calculate an upper limit on the size of the emitting region. The calculated sizes are upper limits for two reasons. The resolution, given by the inverse of the separation of the interferometer elements, is on the order of 1 mas. This is also the typical source extent. Radio maps which partially resolve the compact cores of two quasars, NRAO 530 and NRAO 140 (Marscher and Broderick 1981), show two compact components which are tenths of a milliarcsec in diameter, separated by 1-2 mas. It may be that the fringe visibilities used here do not resolve these two components, which could be present in many quasars. Also, there may be multiple, discrete components of varying optical depth with the X-rays originating in an unresolved component (or one that is obscured by more diffuse emission) in close proximity to the "central machine". The spectrum resulting from this "onion-skin" model is usually flat (the opaque section of the spectrum of one layer is overlayed by the transparent part of the next outer layer).

No turnover is visible in the flat radio spectrum observed (in the sense that the "classic" opaque spectrum is not observed) for CTA26, 1739+52, NRAO 530, 4C31.63, and DA393. However, the spectra of DA393 and 1739+52 flatten out at low frequencies. Such spectra can be produced by multiple synchrotron components with different turnover frequencies. For these 2 sources, we choose the frequency at which the spectrum begins to flatten. We have used the largest turnover frequency for which equation A is valid assuming ν_2 is 300GHz, for the remaining 3 sources (Marscher 1983). Smaller values of the turnover frequency would require larger Doppler factors. The source DA 406 has a radio spectral index of 0.23. The lowest observed frequency, at which no turnover is seen, is used as an upper limit for the turnover frequency. An incorrect choice of this parameter may account for the extremely large predicted Compton luminosity.

Ennis et. al (1982) found that extrapolation of the radio spectrum predicts the flux at 1mm accurately for radio bright quasars. Though the number of sources in his sample is small, if this result extends to all radio bright quasars, then 300Ghz can be used as a lower limit to the break in the synchrotron spectrum (ν_2) used in equation (A).

For 5 of the quasars in Table 3, a Compton flux is predicted which is significantly greater than the observed level. In the case of 1739+52 the observed flux is lower than the predicted flux by a factor of 491, for 0738+31 the observed flux is lower than that predicted by a factor of $2.6\text{x}10^5$, for OR103 it is lower by $3.4\text{x}10^3$, for 0400+25 it is lower by a factor of $1.9\text{x}10^6$, and the most severe case, DA406, the Compton flux exceeds observation by 10^{11}. The predicted flux is a lower limit; if the emitting region is smaller, then the descrepancy would be even greater. The predicted flux can be reconciled with the observed flux if the emitting region is approaching us at a highly relativistic velocity (as in a jet at small angle to the line of sight). The Doppler factor is given in Table 3 which reduces the predicted X-ray flux to what we observe. Figure 3 shows the acceptable combinations of jet velocity and viewing angle for these four sources.

The range of δ inferred for these objects is quite similar to that seen in BL Lac objects (Madejski and Schwartz, 1983) which have $.35 < \delta < 30$ and typically in the range 2 to 6, while we have $\delta_{av} = 5.8$ (excluding DA406).

Using the VLBI to measure the source size used in this calculation is an improvement over the size derived from light travel time arguments used to infer an upper limit from the variability since the VLBI data remove the dependence on the Hubble constant. The predicted Compton flux varies as the eighth power of the size (for $\alpha = 0.5$), so an uncertainty of 2 would lead to an error of 256 in the flux. This is, of course, not critical for the most extreme cases such as 0400+25. However, to observe (albeit indirectly) a wide distribution of jet angles would require distance independent sizes. It is also interesting to note that a wide range, $> 10^{12}$, of X-ray fluxes, is predicted by this model in the absence of beaming.

(B) Jets and Emission Lines

In BL Lac objects, the presence of jets and the lack of strong line emission suggests a simple connection (Blandford and Rees 1978). Consider a model for the optical emission line region in which a power law continuum source ionizes a surrounding spherical distribution of clouds. If the continuum source is expanding in a relativistic jet, then the continuum energy is beamed into a small angle ($\theta \sim 1/\delta$). A small volume (compared to isotropic irradiation of the clouds) of the clouds is then photoionized. The emission lines would then be lost in the continuum or be very weak, depending on the bulk velocity. However, this cannot account for quasars such as DA406 (1611+34) and 0400+25 which show evidence for jets (this paper) and also have CIV equivalent widths (Wampler et al. 1983) similar to other quasars (for their optical luminosity). It may be that only a fraction of the continuum is actually beamed and that the remainder irradiates the surrounding clouds in a spherically symmetric fashion (Perola 1984). Under this hypothesis, objects such as DA406 and 0400+25 have only a small fraction of their continuum beamed so that most of the power law continuum contributes to photoionization of the emission line region giving similar equivalent widths to unbeamed objects. Part of the observed X-ray flux probably comes from the unbeamed component; thus δ is truly underestimated. This is clear from the fact that the ratio of X-ray to optical luminosity is normal for DA406 and 0400+25 ; one would not call them unusual unless one had VLBI data. The fraction of the power law component which is in the jet then is a free parameter which in the case of BL Lacs is large enough to drown the emission lines in the continuum or in the case of DA406 it is small enough to give normal lines. However, self consistency of this scenario requires that the fraction of the the core moving relativistically not be too small. The Compton problem for variable radio bright sources follows from the fact that we are observing a region of small angular extent, presumably a jet: thus the observed radio flux from the jet must dominate the flux from the unbeamed component.

(C) Optical and X-ray Correlation

An earlier survey of radio selected Quasars (Zamorani et al 1981), found that the ratio of X-ray to optical flux varied by a factor of > 300, but that the fluxes were weakly correlated (correlation coefficient, r = .45).

We applied a least squares fit to the optical and X-ray monochromatic luminosities, using flux levels at the sources position in the case of non-detections. The distribution and best fit line is given in Figure 4. The correlation coefficient is .92. However, the reduced chi-square is 4.2, implying that the linear fit is not a good model.

By adding an uncertainty into the X-ray luminosity, equal to some percent of the luminosity, a good fit can be achieved. An 80% systematic error is necessary to give a good fit. This means that the optical luminosity predicts the X-ray luminosity to within 80%. This would be a surprisingly good correlation if the dominant mechanism for the X-rays were Compton emission (without beaming), since the range in physical parameters from source to source would lead to a wide distribution in Compton luminosities. The most obvious explanation is that for radio bright quasars, the alignment of a jet at small angle to the observer reduces the contribution of the Compton process to the X-ray emission so that it is not the dominant part of the X-rays. The close correlation between the optical and X-ray luminosities is probably due to their having a common production mechanism: synchrotron radiation (Ku, Helfand, and Lucy 1980).

One of the possible explanations for the fact that the systematic uncertainty is as large as 80% is that these objects vary optically in a component which is not correlated with the X-ray emission. Malkan and Sargent (1982) have found that the continuum in the UV around 2500A is well fitted by a power law plus blackbody and the Balmer continuum. They also find that the non-thermal, power law component accurately predicts the 2 kev X-ray flux. The thermal component is believed to be highly variable, though this decreases for more luminous quasars (Malkan 1983). Furthermore, the ratio of blackbody to non-thermal flux is found to increase with luminosity. So, the thermal flux would be different for objects of different luminosity and may also vary in time.

Optical data, provided by J. Pollock, of the University of Florida, for some of our sources shows a wide range in optical variability. For example, CTA 26 brightened by a factor of 2.5 in 3 weeks, OT 081 dimmed by 4.5 times in one year, and the optically violent variable NRAO 530 brightened by a factor of 4 within 2 months. Six sources were reobserved in X-rays after 6 months and 8 after 1 year. A variation of greater than a factor of 2 in the count rate is seen in 3 of the 6 objects reobserved in 6 months. None of the 8 objects reobserved after 1 year varied by more than 50%, and none of the entire sample is variable over the length of a single observation, typically 1 hour. Though the optical and X-ray observations are not simultaneous, it appears that the X-rays are probably not characterized by flux variations comparable in magnitude to the optical flux variations over similar timescales. This could be understood if the non-thermal, optical and the X-ray component are highly correlated while the blackbody component is not correlated to the X-ray and suffers large flux variations. The radio data do not show flux changes greater than 50% for those sources with multiple X-ray observations. However, because of the combined systematic errors in the IPC and random errors for sources with few counts, we can not rule out that the radio and X-ray are both variable. Zamorani (1983) found that quasars typically varied in flux by less than a factor of 2 in six months. Madejeski and Schwartz (1983) found that 11 out of 16 BL Lacs were variable by more than a factor of 2. There is a weak indication that the quasars reported here may be more similar to BL Lacs in their characteristic X-ray variability.

There are other variables which may reduce the L_x and L_{op} correlation such as an L_x dependence on L_r (Owen et al 1980, Tananbaum et al. 1982), a possible weak dependence of L_x/L_{op} on redshift and a dependence of L_x/L_{op} on L_{op} (Reichert et al. 1982).

The best fit relationship for our sample is $L_x \sim L_{op}^{.89\pm.15}$. This is 2 sigma different from the correlation ($L_x \sim L_{op}^{.47\pm.15}$) reported by Tananbaum et al. (1982) for the 3CR sample. We applied the least squares analysis to the 3CR sample and found that a good fit, $L_x \sim L_{op}^{.51\pm.11}$, is obtained for a systematic uncertainty of 100%. This aggrees with the correlation found by Tananbaum et al.. The distribution in α_{ro} indicates that the 3CR sample is similar to our sample in radio brightness. The apparent difference with the 3CR sample may be related to the fact that the sample reported here was chosen for historic radio variability. In this respect, our sample is similar to that of Owen et al. We applied the same linear regression analysis to the 12 sources in his sample with known redshift. Very good agreement with our result is found ($L_x \sim L_{op}^{.86\pm.14}$). This suggests that the relationship between L_x and L_{op} is not unique for radio bright quasars and that variable radio sources may be significantly different than those found in the 3CR sample. An explanation suggested by Tananbaum et al. is that the 3CR sources show more of an extended component with steep spectrum and the variable sources emphasize the nuclear, flat spectrum component (a source of greater X-ray production). This nuclear region is probably a mixture of jet and isotropic radiation though the lack of short term variability in the X-ray band may indicate that the X-ray emission from the jet is dominated by the isotropic radiator. The relationship we find then indicates that for a given optical luminosity, the variable sources have a higher X-ray luminosity. This is qualitatively consistent with the idea that the relative importance of the nuclear and extended components is different in the two samples.

IV SUMMARY

The apparent relationship between the optical and the X-ray luminosities suggests a common origin. From the comparison of the calculated Compton luminosity and the observed levels, we find that the Compton component is suppressed in at least some of the strong radio quasars, perhaps due to near alignment of a jet.

If one accepts that a beamed continuum can account for the lack of strong emission lines in BL Lacs, then the presence of normal CIV emission in quasars with highly relativistic jets aligned nearly along the line of sight, suggests that the fraction of the continuum component which is beamed varies amongst these sources and that BL Lac type objects may be quasars in which such a large fraction of the power law continuum is beamed that the emission lines are lost. The other extreme, in which a small fraction of the continuum is in the jet, would be quasars such as 1611+34 and 0400+25.

We find that the dependence of X-ray luminosity on optical luminosity may be significantly different for radio sources which show variability in their radio emission.

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FIGURE CAPTIONS

Figure 1: The histogram is for the sample reported in this paper. The average value for this sample (μ) is given with the error bar. The distribution of mean X-ray to optical spectral index is also given for active galaxies. α_{ox} for Seyferts is from Kriss et al. (1980).

Figure 2: VLBI observations are shown with the calculated angular size, assuming a spherical source.

Figure 3: Contours of δ are shown for β v/c vs. θ (angle between jet and observer).

Figure 4: X-ray luminosity vs. optical luminosity and the best fit line.

TABLE 1

OBSERVATIONS OF VARIABLE RADIO BRIGHT SOURCES

OBJECT	OTHER NAME	(.5 - 3.0 keV) CNTS(1000 S)$^{-1}$	σ	DATE OBSERVED	ID
0116+31		<4.7		207-80	RGAL
0202+149		7.8	2.2	217-80	-
		8.[a]	4.	203-79	
0224+671	4C 67.05	32.5	5.7	72-80	-
		78.4	13.1	232-80	
0237+04		13.1	2.9	217-80	-
0336-019	CTA 26	11.8	1.9	218-80	QSO
		16.[a]	4.	226-79	
0400+25		< 3.9		38-81	QSO
		1.4[c]		52-80	
0454-234		19.4	4.2	65-80	QSO
0458-02		20.5	4.7	63-80	QSO
0528+13		21.8	4.5	84-80	QSO
0605-085		30.2	4.5	80-80	QSO
		34.5	4.8	300-80	
0607-15		11.0	3.1	65-80	QSO
		31.5	5.0	278-80	
0632+19		<8.6		91-80	-
		<5.0			
0723-008		42.5	5.2	281-80	QSO
		34.[a]	6.	278-79	
0738+31		21.0	4.6	114-80	QSO

		24.5[c]	5.0	299-80	
0834-20		19.2	3.0		
		28.4	5.8	98-81	
1117+14		<15.		346-80	QSO
1127-14		47.4	6.0	1-80	QSO
		41.3	6.1	4-81	
1335-12		126.4	12.7	196-80	-
1354-15		18.3	3.8	216-80	QSO
1358+62		<10.7		1-80	RGAL
1422+202		<4.0		190-80	QSO
		18.[b]	4.	20-80	
1502+10	OR 103	<7.5		220-80	QSO
1504-167		32.6	6.1	41-80	QSO
		21.7	4.7	211-80	
1548+05		19.8	4.4	239-80	QSO
1555+001	DA 393	<7.3		41-80	QSO
1611+34	DA 406	12.5	3.1	228-80	QSO
		20.2	3.4	10-81	
1730-13	NRAO 530	29.2	2.8	76-81	QSO
1739+522		23.1	4.1	99-80	QSO
1749+096	OT 081	29.3	5.3	260-80	-
1823+56		39.5	5.8	98-80	QSO
1908-20	OV -213	64.4	7.8	97-80	-
2033+18		<4.9		123-80	-
		<8.0		108-81	
2148+14		2.8	1.5	162-80	-

2201+31	4C 31.63	93.0	7.8	167-80	QSO
2230+11	CTA 102	118.3	22.9	356-80	QSO
		65.[b]	5.	328-79	

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[a] Owen et al. (1981)

[b] Zamorani et al. (1981)

[c] Ledden and O´Dell (1983)

TABLE 2

RADIO, OPTICAL, AND X-RAY PROPERTIES OF RADIO SOURCES

OBJECTS	Z	L_x(.5-4.5 kev) x 10^{45} ergs s^{-1}	α_{ox}	α_{ro}
0116+31	0.059	<.0058	>1.70	.48
0237+04	.978	3.20 ± .70	1.30	.68
0336-019	.852	2.68 ± .43	1.29	.84
0400+25	2.109	<5.70	>1.71	.71
		<1.25	>1.96	
0458-02	2.286	15.6 ± 3.6	1.48	.70
0607-15	.324	.34 ± .10	1.36	.67
		.94 ± .15	1.20	
0723-00	.1280	.19 ± .02	1.00	.70
0738+31	.630	2.08 ± .46	1.45	.66
		2.43 ± .31	1.42	
1127-14	1.187	12.73 ± 1.65	1.41	.72
		13.74 ± 2.06	1.40	
1422+20	.871	<1.42	>1.42	.64
1502+10	1.833	<7.84	>1.52	.55
1504-167	.876	5.63 ± 1.07	1.18	.83
		4.08 ± .90	1.23	
1555+01	1.770	<6.04	>1.35	.83
1611+34	1.401	6.96 ± 1.74	1.45	.75
		10.84 ± 1.84	1.31	
1730-13	.908	5.60 ± .56	1.33	.65
1739+522	1.375	14.19 ± 2.55	1.22	.78
2201+31	.297	2.62 ± .21	1.37	.57
2230+11	1.037	41.05 ± 1.72	1.08	.78

PREDICTED INVERSE COMPTON FLUX IN 0.5-4.5 keV BAND

OBJECT	Z	ν_m (GHz)	S_m (JANSKYS)	θ (MAS)*	F_{PRED} (10^{-13} ergs cm^{-2} sec^{-1})	F_{OBS}	δ**
CTA 26	.852	5.0	2.8	1.4	80	3.9	1.8
DA406	1.401	0.4	3.3	1.0	3.9E11	3.2	160
NRAO 530	0.908	10.0	5.8	1.7	8.7	6.9	1.1
4C 31.63	0.297	3.0	3.0	1.1	4.3E3	49	2.4
DA 393	1.770	10.2	2.4	.92	69.8	<1.1	2.3
0400 + 25	2.109	1.5	1.6	1.3	1.0E6	$<.58$	18
OR 103	1.833	5.0	2.2	.97	4.1E3	<1.2	5.1
0738 + 31	0.630	2.0	2.3	.80	1.7E6	6.6	12
1739 + 52	1.375	2.0	1.2	1.5	2.7E3	5.5	3.5

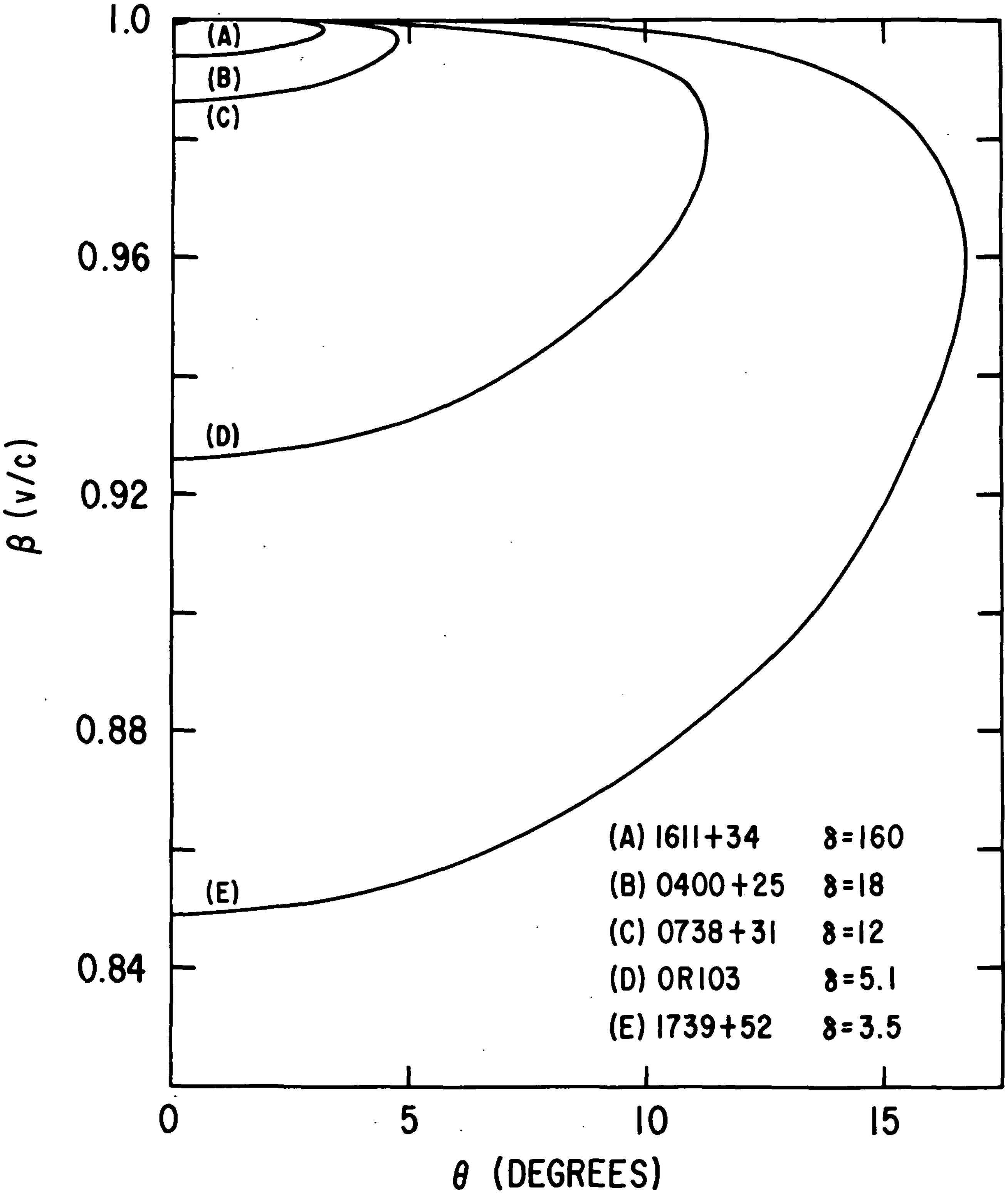
*UPPER LIMIT
**LOWER LIMIT

ANGULAR SIZE OF COMPACT RADIO SOURCE

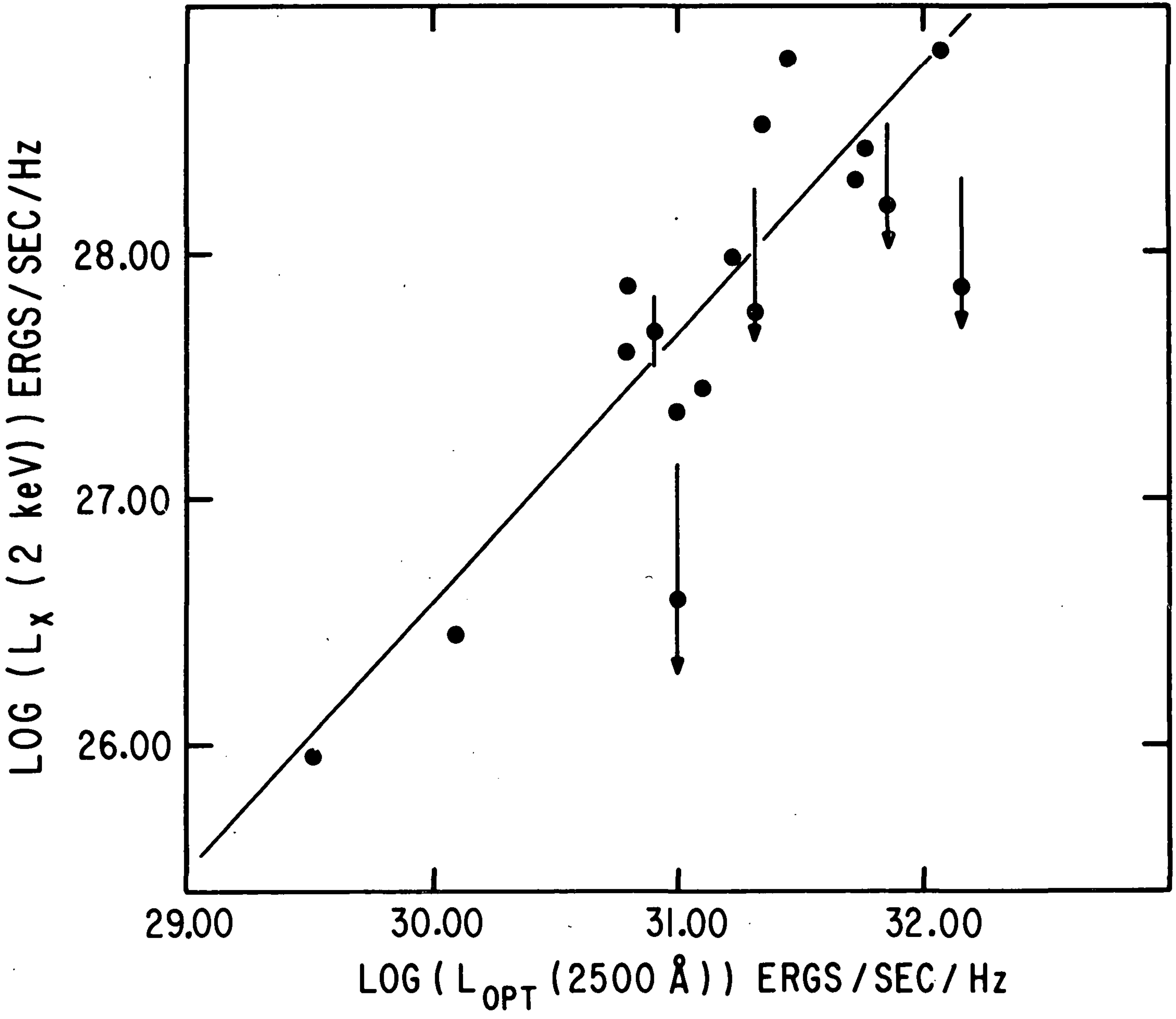
SOURCE	λ(CM)	BASELINE ($10^6\lambda$)	VISIBILITY	SIZE (MAS)
(1)CTA26	3.8	100	.6	1.4
(1)DA406	3.8	100	.4	1.0
(3)NRA0530	6	55	.5	1.7
(5)4C31.63	2.8	150	.5	1.1
(2)DA393	13	70	.91	.92
(4)0400+25	13	80	.36	1.3
(6)OR103	3.8	100	.63	.97
(5)0738+31	2.8	150	.3	.80
(5)1739+52	3.8	100	.5	1.5

(1)COHEN et al. (1971)
(2)KELLERMANN et al. (1970)
(3)KELLERMANN et al. (1971)
(4)PRESTON R.A., et al. (1983)
(5)SCHAFFER D., (1983)
(6)WITTLES et al. (1975)

VELOCITY OF EMITTING REGION vs. ANGLE TO OBSERVER



X-RAY LUMINOSITY AND OPTICAL LUMINOSITY



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16. Abstract

A sample consisting primarily of radio bright quasars has been observed in X-rays with the Einstein Observatory for times ranging from 1500 to 5000 seconds. Detected sources have luminosities ranging from 0.2 to 41.0 x 10^{45} ergs s^{-1} in the 0.5 to 4.5 keV band. Three of the 14 objects which have been reobserved show flux increases greater than a factor of 2 on a time scale greater than six months. No variability was detected during the individual observations. The optical and X-ray luminosities are correlated, which suggests a common origin. However, the relationship ($L_x \sim L_{op}^{.89\pm.15}$) found for historic radio variables may be significantly different than that reported for other radio bright sources. Some of the observed X-ray fluxes are substantially below the predicted self-Compton flux, assuming incoherent synchrotron emission and using VLBI results to constrain the size of the emission region, suggesting relativistic expansion in these sources. Normal CIV emission in two of the sources with an overpredicted Compton component suggests that although they, like BL Lac objects, have highly relativistic material apparently moving at small angle to the line of sight, they have a smaller fraction of the continuum component in the beam.

17. Key Words (Selected by Author(s))

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