THE ASTROPHYSICAL JOURNAL, 353:416–418, 1990 April 20

THE EMPIRICAL DIFFERENCE BETWEEN RADIO-LOUD AND RADIO-QUIET QUASARS

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Received 1989 July 5; accepted 1989 October 19

ABSTRACT

Lobe-dominant radio quasars and radio-quiet quasars have very similar spectral energy distributions in the infrared through ultraviolet spectral regions. The former class show flat-spectrum radio synchrotron cores as well. Are the radio cores the self-absorbed tails of nonthermal infrared sources, or are they separate components with properties expected for misdirected relativistic jets? Morphologically, do the spectra peak in the millimeter region as expected under the first hypothesis, or do they show deep minima there as expected under the second? Centimeter, infrared, and new millimeter observations show that the second hypothesis is correct for all six known *IRAS*–detected lobe-dominant quasars.

Subject headings: quasars — radio sources: spectra

I. INTRODUCTION

What is the empirical difference between normal lobe-dominant radio-quasar (LDQ) cores and radio-quiet quasars (RQQs)? The two classes have similar UV–optical–IR spectral energy distributions. The RQQs have spectral cutoffs in the submillimeter region. Do the LDQs simply have lower turnover frequencies? Alternatively, do they contain normal RQQs complete with submillimeter cutoffs, but also a morphologically unrelated radio source?

If the former hypothesis is correct, then the infrared emission is nonthermal, being just the optically thin tail of the synchrotron core observed in the radio, and the difference between these two types of quasars must be explained in terms of synchrotron or other absorption processes. If the latter hypothesis is correct, the infrared is more likely to be thermal, and the "unified scheme (US)" for radio sources receives support. The US identifies LDQs as misdirected blazars. The blazars have rado core turnover wavelengths in the ~1.5 mm region (Impey and Neugebauer 1988). Because of the Doppler shift of jet radiation and the aspect dependence of optical depth in jetlike sources, turnover wavelengths for LDQ cores are expected to be at least a few times larger. In that case the infrared sources cannot be the optically thin tails of the radio cores.

Six LDQs have been detected by the *IRAS* satellite and are reported in Neugebauer *et al.* (1986). The properties of these objects, and related data in the literature, are discussed in Antonucci and Barvainis (1988, hereafter Paper I). In that paper, we showed that for three objects, the radio core spectra *underpredict* the infrared fluxes. Therefore a spectral inflection in between the two and separate radio and infrared components were indicated. We felt that it was necessary to test the generalizability and robustness of this result for two reasons. First, for the remaining three objects, our data were inconclusive. Second, *IRAS* LDQs might have some additional thermal IR emission, by an obvious selection effect. We wanted to be sure that the minima between the radio and infrared bands are very deep, so that our conclusion applies to all significant components of the infrared emission. We have, therefore, observed all six objects at 1.3 mm with the IRAM telescope.

II. OBSERVATIONS

The radio and infrared data are described in Paper I. The new millimeter observations were carried out with the 30 m IRAM dish at Pico Veleta from 1989 March 4 to 5. We used the bolometer developed at the MPIFR (Krügel *et al.* 1988). Sky conditions were good, with a zenith transmission of 0.8 at 230 GHz. Some wind, however, near the end of the observing run resulted in a larger scatter among subscans. The flux calibration was performed through observations of the planet Mars within an accuracy of ~10%. We quote flux errors based on the scatter in the subscans added to this scaling error in quadrature.

III. RESULTS AND CONCLUSIONS

Figure 1*a*–1*f* and Table 1 show the spectral energy distributions of all six LDQs. The figures and table are very similar to those in Paper I, except that the crucial 1.3 mm point has been added. In every case the spectral energy distributions have gigantic holes in the millimeter region. We conclude that *LDQs contain normal RQQs and also unrelated sources of radio emission*. This strong qualitative conclusion for all objects cannot be the result of variability, but the nonsimultaneity of the observations could have affected the exact spectral shapes.

According to the Unified Scheme, the radio cores of LDQs are simply misdirected jets which are intrinsically the same as those of the blazars (Blandford and Königl 1979; Orr and Browne 1982; Antonucci and Ulvestad 1985). Because the Doppler factors (and also the synchrotron optical depths) are aspect dependent, substantially lower turnover frequencies are expected for LDQs, and that is what we see. Other interpretations of the LDQ core spectra are possible, but this one is supported by the relatively slow, but still superluminal proper motions detected in several LDQs. (Hough and Readhead 1987, and references therein).

TABLE 1

FLUX MEASUREMENTS

Source	6 cm	2 cm	1.3 cm	1.3 mm	100 μm	60 μm	25 μm	12 μm
0410+110/3C 109	234.5	198	158.2	30 ± 4.2	<564	261 ± 24	178 ± 29	68 ± 16
B2 704+384	73.0	69.0	64.7	7.0 ± 1.6	<101	62 ± 11	40 ± 13	<22
0836+195/4C 19.31	74.2	42	45.8	2.5 ± 1.4	<158	59 ± 20	<124	<57
PKS 0837−120	181	221	199.2	55.0 ± 6.3	94 ± 45	69 ± 15	49 ± 16	32 ± 11
1100+772/3C 249.1	78 ± 10	78	68.6	4.2 ± 1.8	<85	61 ± 9	45 ± 6	17 ± 5
1704+608/3C 351	17.7	8.2	4.8 ± 0.8	<6.0	<299	183 ± 9	125 ± 5	46 ± 5

NOTES.—*IRAS* fluxes from Neugebauer *et al.* 1986; radio flux errors estimated at 10% at 1.3 cm, and 5% at 2 cm and 6 cm, unless indicated otherwise. The 3C 249.1 6 cm measurement is slightly affected by confusion with extended emission. 3C 109 has sometimes been called a broad-line N-type radio galaxy. Quoted limits are 3 σ.

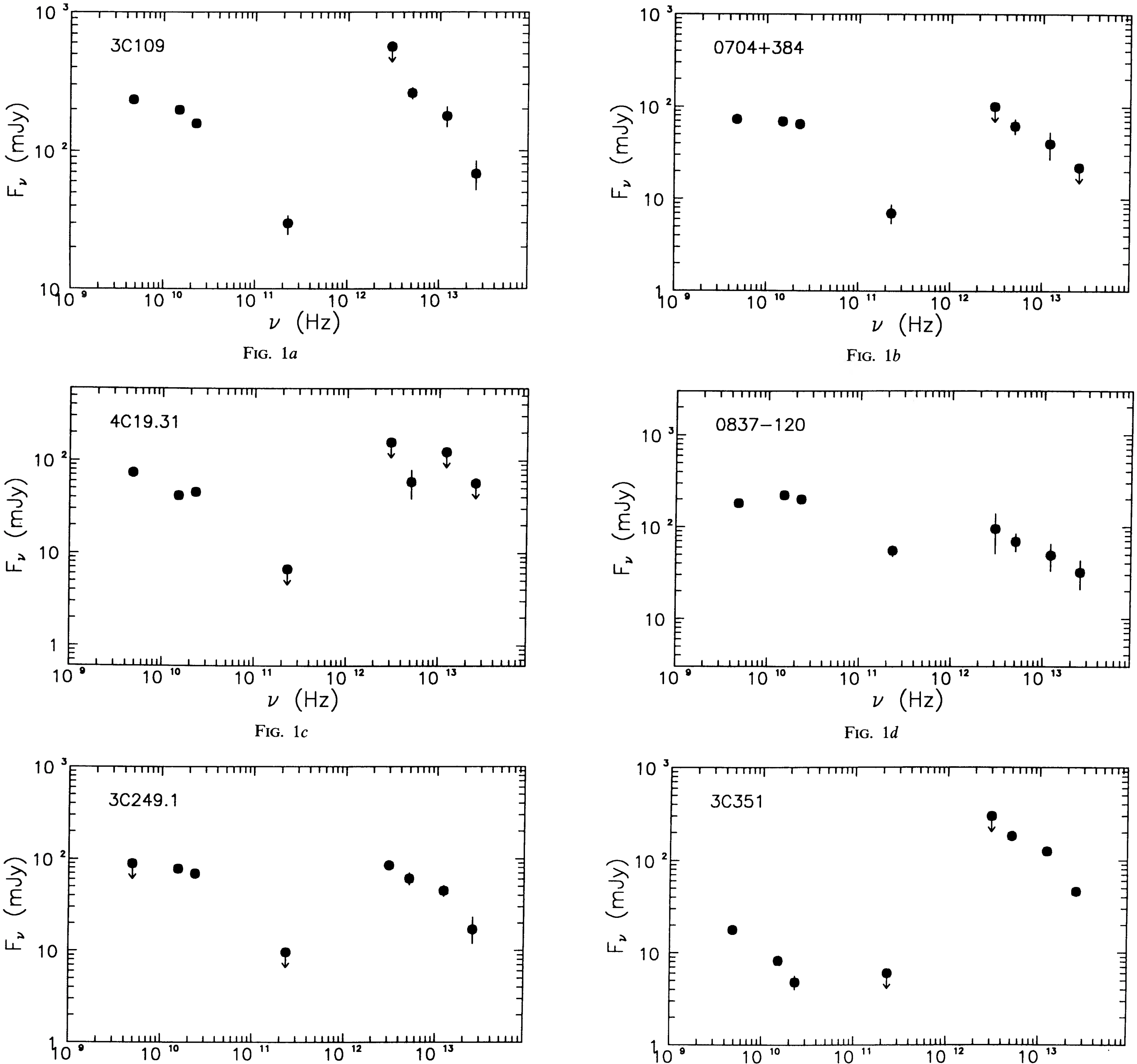

FIG. 1*a*

FIG. 1*b*

FIG. 1*c*

FIG. 1*d*

FIG. 1*e*

FIG. 1*f*

FIG. 1.—Spectra of the cores of lobe-dominant quasars in the radio, millimeter, and infrared regions. The data and their errors are presented in Table 1. Where error bars are not visible, they are smaller than the plotted points. Plotted limits are 3 σ, except for the 4C 19.31 and 3C 249.1 millimeter points, where we added 3 σ to the approximately $+2\ \sigma$ measured fluxes.

With more complete data on more quasars, it will be possible to correlate core dominance with turnover frequency. However, Barthel (1989) and Antonucci (1984, 1989) argue that such studies may still show a deficit of quasars very close to the sky plane. These papers give statistical and spectropolarimetric arguments that some such objects are actually classified as narrow-line radio galaxies.

Finally, regarding the infrared emission, our result somewhat strengthens the case for a thermal mechanism. This is consistent with the recent detection of strong CO emission (Barvainis, Alloin, and Antonucci 1989; Sanders *et al.* 1988; Alloin, Barvainis, and Antonucci 1990 and very steep submillimeter cutoffs (Chini, Kreysa, and Biermann 1989; Barvainis and Antonucci 1989) in some RQQs. Also, several recent papers have argued for thermal emission based on infrared spectral energy distributions, e.g., Barvainis (1987, 1990), Sanders *et al.* (1989); Lawrence (1990).

We would like to thank Hans Steppe for his careful service observing and reduction.

REFERENCES

Alloin, D., Antonucci, R., and Barvainis, R. 1990, in preparation.
Antonucci, R. 1984, *Ap. J.*, **278**, 299.
———. 1989, in *Proc. 14th Texas Symposium on Relativistic Astrophysics* (New York: New York Academy of Sciences), in press.
Antonucci, R., and Barvainis, R. 1988, *Ap. J. (Letters)*, **325**, L21 (Paper I).
Antonucci, R., and Ulvestad, J. 1985, *Ap. J.*, **294**, 158.
Barthel, P. 1989, *Ap. J.*, **336**, 606.
Barvainis, R. 1987, *Ap. J.*, **320**, 537.
———. 1990, in press.
Barvainis, R., Alloin, D., and Antonucci, R. 1989, *Ap. J. (Letters)*, **337**, L69.
Barvainis, R., and Antonucci, R. 1989, *Ap. J. Suppl.*, **70**, 257.
Blandford, R. D., and Königl, A. 1979, *Ap. J.*, **232**, 34.
Chini, R., Kreysa, E., and Biermann, P. L. 1989, *Astr. Ap.*, **219**, 87.
Hough, D. H., and Readhead, A. C. S. 1987, *Ap. J. (Letters)*, **321**, L11.
Impey, C. D., and Neugebauer, G. 1989, *A.J.*, **95**, 307.
Krügel, E., Chini, R., Dreysa, E., and Sherwood, W. 1988, *Astr. Ap.*, **190**, 47.
Lawrence, A. 1990, *IAU Symposium 134, Active Galactic Nuclei*, ed. J. Miller and D. Osterbrock, in press.
Neugebauer, G., Miley, G. D., Soifer, B. T., and Clegg, P. E. 1986, *Ap. J.*, **308**, 815.
Orr, M. J. L., and Browne, I. W. A. 1982, *M.N.R.A.S.*, **200**, 1067.
Sanders, D. B., Phinney, E. S., Neugebauer, G., Soifer, B. T., and Matthews, K. 1989, *Ap. J.*, **347**, 29.
Sanders, D. B., Scoville, N. Z., and Soifer, B. T. 1988, *Ap. J. (Letters)*, **335**, L1.

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