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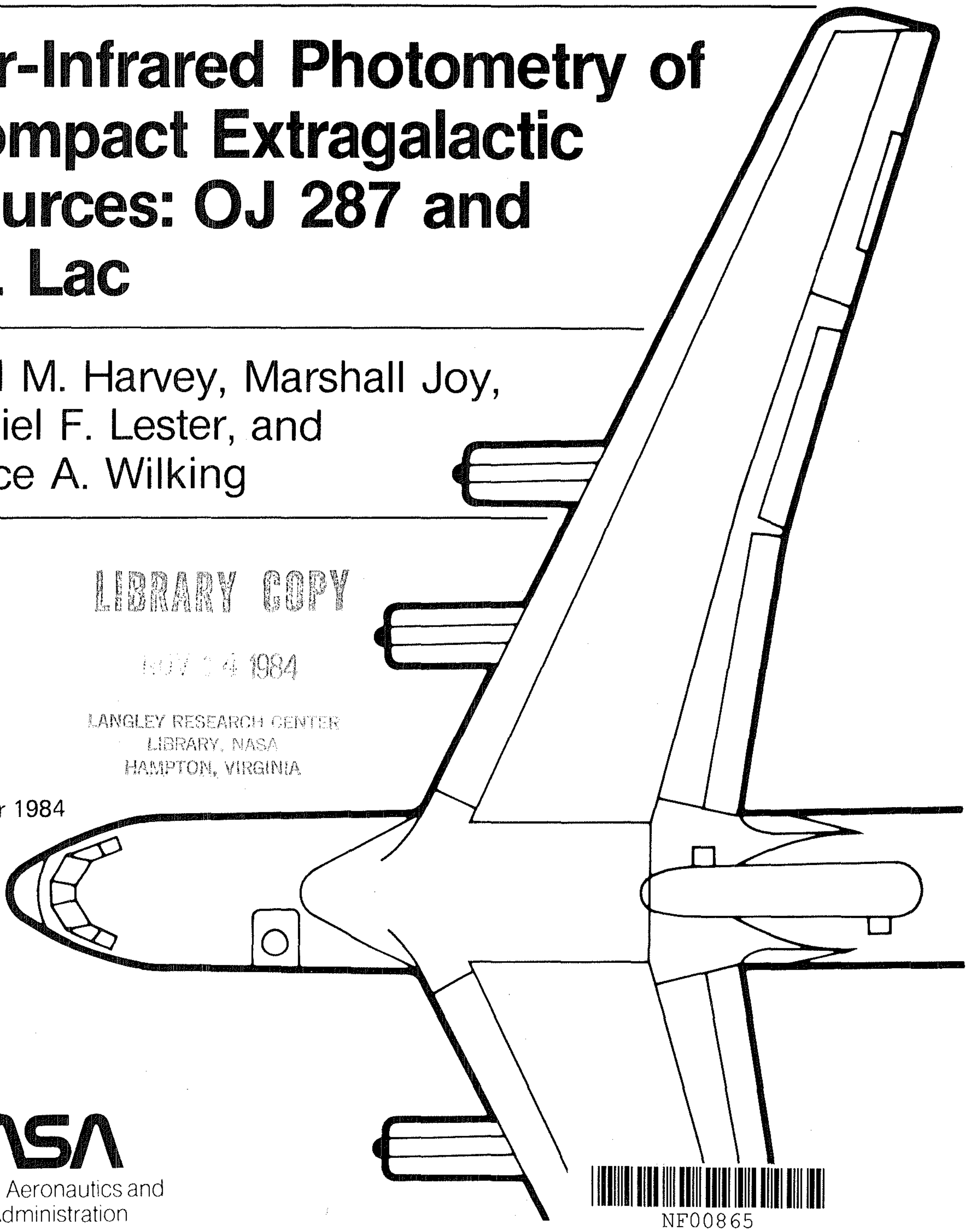

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Far-Infrared Photometry of Compact Extragalactic Sources: OJ 287 and BL Lac

by

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Abstract

We have detected the 50 and 100 μm emission of OJ 287 and obtained upper limits for BL Lac. These first measurements of two BL Lac objects in the far-infrared show them to be similar to the few quasars previously observed in the far-infrared. In particular there is no evidence for significant dust emission, and the $\lambda \sim 100$ μm flux density fits on a smooth line joining the near-infrared and millimeter continuum fluxes. We briefly discuss the implications of the results for models of the sources.

I. Introduction

The spectral region between 10 μm and 1 mm contains information critical to our understanding of quasar emission processes. In many models (see e.g. Marscher 1980b; Königl 1981) this wavelength range reflects the structure in the inner parts of the emission region of quasars. This spectral region also appears to contain a large fraction of the total luminosity of many quasars based on interpolations and extrapolations of observed energy distributions. To date only a handful of quasars have been observed at $\lambda \sim 100$ μm (Harvey, Wilking, and Joy 1982; Clegg et al. 1983; Neugebauer et al. 1984), although the IRAS survey will soon be providing a larger body of data on fluxes of many quasars within a narrow range of epochs. We report here on initial observations of two optically violently variable (OVV) quasars, OJ 287 and BL Lac, as part of a program to study their long-term variability.

II. Observations

Our observations were made using NASA's Kuiper Airborne Observatory in 1983 Oct/Nov. The observations of OJ 287 represent two nights of data, 28 Oct. and 1 Nov. 1983, totalling 3400 sec integration time, while BL Lac was observed for 2600 sec on 29 Oct. 1983. The observations were made with the 6-channel photometer described by Wilking et al. (1984). The KAO chopper throw was set at 1' so that one detector at each wavelength was always looking at the source while beam-switching. We observed each object simultaneously at 47 and 95 μm effective wavelengths with beam sizes of 28 and 40 arcsec respectively. The observations were calibrated relative to S140 and IRC+10420 (Harvey, Wilking and Joy 1984). The absolute calibration is believed accurate to ±20%. The 1σ statistical uncertainties of the measurements along with the measured flux densities are listed in Table 1.

III. Discussion

A. Results

Figure 1 shows our measured fluxes or upper limits plotted relative to measurements at other wavelengths summarized by Jones et al (1981). Since both OJ 287 and BL Lac are variable at optical and radio wavelengths, the details of these energy distributions are uncertain to a factor of ~2 . Unpublished observations (Glassgold and Bregman, priv. comm.), however, suggest that at the time of our observations BL Lac was in a relatively low state of power output while OJ 287 was slowly receding from a burst which peaked in early 1983. We have, therefore, attempted to plot fluxes in Figure 1 which were measured at similar levels of activity in the past.

Two obvious conclusions may be drawn from Figure 1. Following the discussion of Harvey, Wilking and Joy (1982) for 3C 345, it is clear that thermal dust emission cannot contribute significantly to the total far-infrared luminosity of OJ 287 and BL Lac because of the very broad and smooth energy distribution from infrared to millimeter wavelengths. Like 3C 345, it is also clear for OJ 287 that the far-IR spectral region contains a large fraction of its total luminosity, since νF_ν peaks at $\lambda \sim 100\mu m$. The total integrated luminosity of OJ 287 at the time of our observations was $L \sim 7 \times 10^{12} L_\odot$ for $z = 0.306$ (Miller, French, and Hawley 1978) assuming the fluxes plotted in Figure 1.

B. Implications for Quasar Models

Ennis, Neugebauer and Werner (1982, hereafter ENW) have shown that many BL Lac objects and OVV quasars have similar energy distributions in the sense that the ratio of millimeter to near-IR flux density is relatively constant. For this class of objects there is a growing body of evidence which suggests, in fact, that the entire optical-through-radio energy distribution may be due to a single emission mechanism (e.g. ENW; Harvey, Wilking and Joy 1982). Like many other BL Lac objects, OJ 287 and BL Lac exhibit relatively flat (in F_ν) spectra at radio through millimeter wavelengths. At shorter wavelengths their spectra turn down in F_ν (or flatten in νF_ν). In most models the point where the spectrum turns over in F_ν is set by the frequency where $\tau_{synch} \sim 1$ in the inner part of the source at a radius where the density gradient changes rapidly (Marscher 1980a,b; ENW; Kellermann and Pauliny-Toth 1981; Königl 1981). In order to account for apparent super-relativistic motions and for the lack of evidence for a second turnover in the near-infrared due to electron energy losses (Landau et al. 1983), it is attractive to explain the optical- through-radio continuum as the emission from a relativistic jet which is beamed nearly along our line-of-sight (e.g. Blandford and Königl 1979; Marscher 1980b). In Marscher's model, for instance, the sub-millimeter turnover frequency is identified with the synchrotron self-absorption cutoff-frequency at the point R^+ where the bulk acceleration stops and the particles begin to expand freely.

Our observations place improved limits on the turnover frequency for OJ 287 and BL Lac. From the energy distribution shown in Figure 1, this frequency must lie within roughly an octave of 3×10^{12} Hz or 100 μm, since the flux densities are significantly lower at 100 μm than at 1 mm. To the order of accuracy warranted by the models at this point, this implies R^+ is similar to that derived by Marscher (1980b) for 3C 345, i.e. 10^1-10^2 pc, assuming Lorentz factors of a few to 10.

Some of the most important observations to test and limit models for quasars will be to study the variability of these objects as a function of wavelength. As shown by the measurements reported here, the photometric sensitivity on the KAO is now high enough that it is practical to perform such a study of OVV quasar variability. Therefore we will be obtaining regular measurements of these and other similar objects in the future to compare with data at longer and shorter wavelengths.

We thank the entire staff of the Kuiper Airborne Observatory for their continued dedication which made these observations possible. This research was supported by NASA grant NAG 2-67.

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Table 1

Observed Flux Densities (Jy)

	50 μm	100 μm
OJ 287	0.62 ± 0.23	1.53 ± 0.31
BL Lac	0.18 ± 0.25	0.40 ± 0.32

Figure Caption

Figure 1 - The optical-through-radio energy distributions of OJ 287 and BL Lac. The points from this study are at 3 and 6 x 10^{12} Hz. The other data are taken from Jones *et al.*(1981). The OJ 287 data are from an epoch when the source was roughly a factor of two brighter than in its quiescent state while the BL Lac fluxes are from an epoch when it was in its quiescent state. The energy distribution is given in terms of νF_ν which shows energy per octave.

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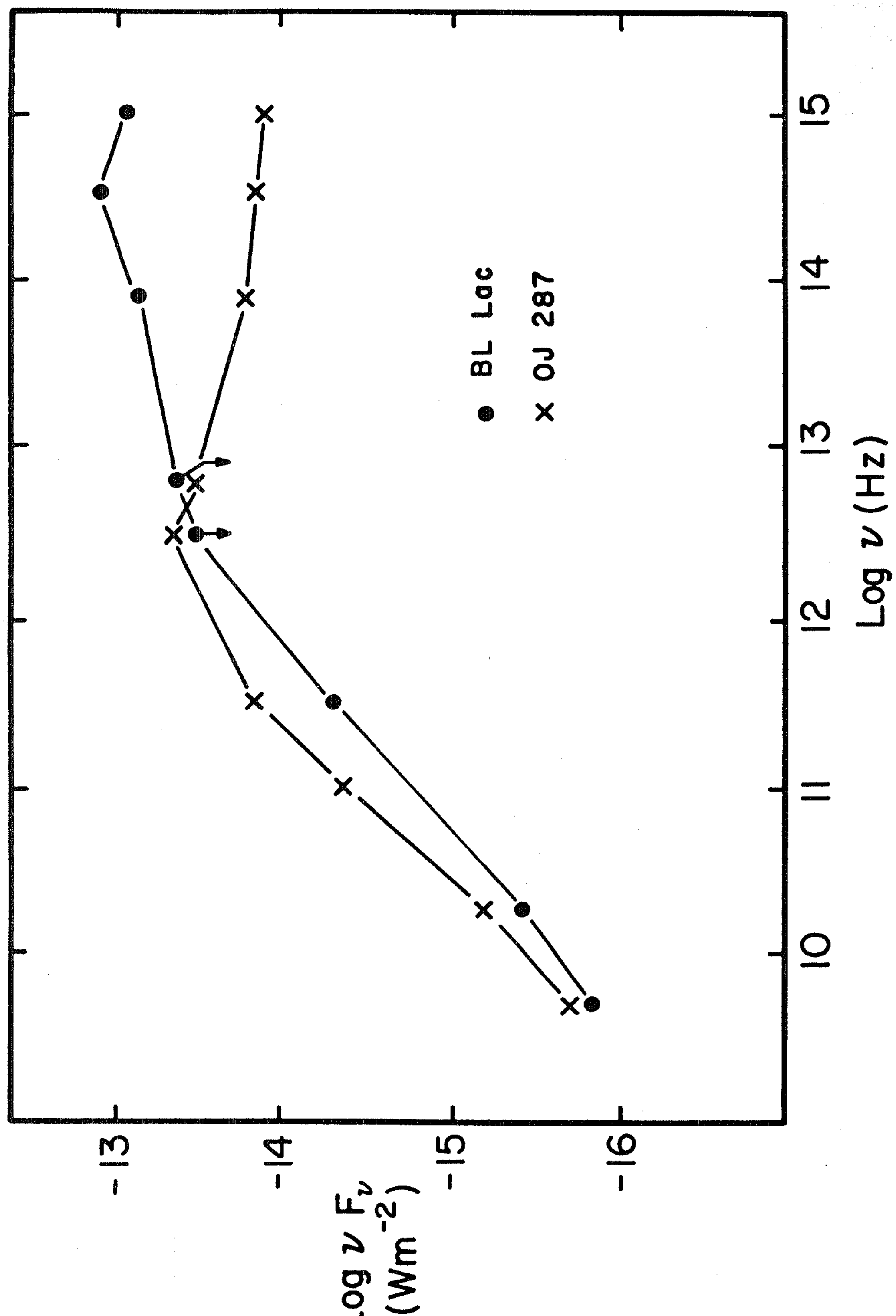
BL Lac
OJ 287
-13
-14
-15
-16
Log ν F_ν (Wm^-2)
10
11
12
13
14
15
Log ν (Hz)

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