THE ASTROPHYSICAL JOURNAL, 266:L1–L3, 1983 March 1

OPACITY EFFECTS AT RADIO WAVELENGTHS IN THE QUASAR 1308+326

C. P. O'DEA,[1,2] W. A. DENT,[1] AND T. J. BALONEK[1,3]
Received 1982 August 23; accepted 1982 October 26

ABSTRACT

We present 2.7 GHz flux density and linear polarization measurements of the BL Lacertae type quasi-stellar object 1308+326. Both the linear polarization and total flux density variations observed during 1977–1981 are consistent with a change in opacity of an incoherent synchrotron component.

Subject headings: BL Lacertae objects — polarization — quasars — radio sources: variable

I. INTRODUCTION

The BL Lacertae type quasi-stellar object 1308+326 has been the subject of much interest. This source is discussed in detail by Puschell *et al.* (1979) and Moore *et al.* (1980) who observed an optical-infrared outburst in early 1978 with a luminosity of $\sim 10^{48}$ ergs s^{-1} (assuming isotropic emission), making it one of the most luminous outbursts known in any quasar. During this outburst, changes in the optical polarization occurred on a time scale of 1 day. The polarization position angle was near 90° between 31.4 and 4.8 GHz, and the polarization decreased from ~ 6% at 31.4 GHz to ~ 2% at 2.7 GHz. The radio spectrum in early to mid-1978 was flat at centimeter wavelengths with a broad peak near 10 GHz. There is a steep spectral component at frequencies below 1 GHz. Ulvestad, Johnston, and Weiler (1982) have mapped this source with the VLA and find a steep spectrum secondary component located 11″ north (position angle 0°) of a compact core. This (0″.0005) core is elongated at a position angle of 10° (Weiler and Johnston 1980).

II. OBSERVATIONS AND RESULTS

The 2.7 GHz measurements of the total flux density and linear polarization of 1308+326 were made with the NRAO 300 foot (91 m) transit telescope. The source transits through 3 beams (two of which are polarization switched, with the third load switched) to give the Stokes parameters I, Q, and U. The details of the observing techniques and the reduction procedures are given by Kapitzky (1976). Observing sessions were typically of 1 week duration and were scheduled approximately every 4 months. Observations taken during this week period were combined to derive an average total flux density and polarization (in order to increase the signal-to-noise ratio). Sufficient signal-to-noise daily measurements are obtained only for strong or highly polarized sources. Thus our data are not sensitive to events occurring on time scales of less than 4 months.

From 1976.5 to 1978.9 the 2.7 GHz total flux density, S_T, increased nearly monotonically from 1.3 Jy to 2.3 Jy (Fig. 1). The flux density then remained roughly constant until early 1980 when a small (−0.3 Jy) decrease occurred. Initially the polarization position angle, χ, was constant at about 175° for a period of 2 years. Coincident with the optical outburst in 1978.4, the position angle began rotating, changing by about 70° over the following 2 years. It has remained constant at ~ 105° since 1980. The postrotation angle is roughly the same at all frequencies from 2.7 to 31.4 GHz. The polarized flux density, S_P, fluctuated during this time. It decreased from about 0.04 Jy in late 1976 to ~ 0.01 Jy in mid-1978 just preceding the onset of the position angle change. Simultaneous with the time of maximum total flux density (in early 1979), the polarized flux density jumped to 0.05 Jy, after which it decreased slowly to 0.03 Jy by early 1981.

The evolution of the radio spectrum is presented in Figure 2. The observations were obtained from our variable radio source programs at several frequencies ranging from 2.7 to 90 GHz and conducted at the Haystack Observatory and the NRAO. During the period of the polarization variations at 2.7 GHz, only minor total flux density variations occurred at centimeter wavelengths (Puschell *et al.* 1979; Balonek 1982). The spectrum in 1977.5 had a broad peak near 20 GHz. The frequency of the spectral maximum propagated in time to lower frequencies, peaking at 8.0 GHz by 1979.0. At this time, the spectrum appeared to have a sharper, more narrow peak due to a decline in the flux density at millimeter wavelengths. Between 1979.0 and 1981.1, the spectrum below 15.5 GHz fell as the first outburst

[1]Department of Physics and Astronomy, University of Massachusetts, Amherst.

[2]NRAO VLA Program. The National Radio Astronomy Observatory is operated by Associated Universities, Inc., under contract with the National Science Foundation.

[3]Department of Physics and Astronomy, University of New Mexico.

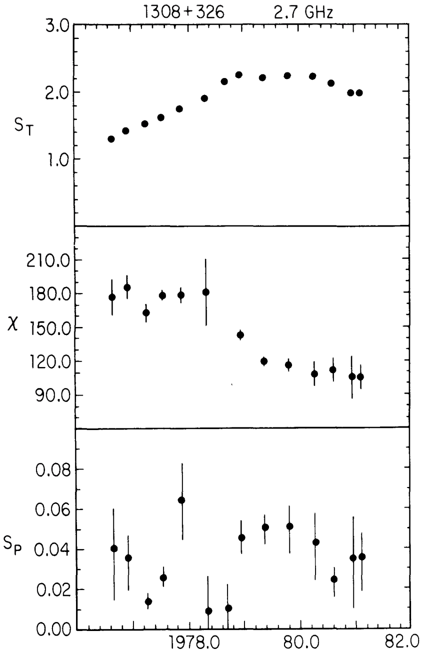

FIG. 1.—The 2.7 GHz total flux density, S_T, polarization position angle, χ, and polarized flux density, S_P, as a function of time.

decayed, and the spectrum above 15.5 GHz rose as a subsequent outburst began, flattening the total spectrum. The 70° position angle rotation occurred during the time when the first outburst was becoming transparent at 2.7 GHz.

III. DISCUSSION

The observed polarization variations are in good agreement with the predictions of the simple opacity model (Pacholczyk and Swihart 1967; Aller 1970; Takarada 1970; Pacholczyk 1977). The model assumes the existence of an initially opaque, homogeneous, incoherent synchrotron component with a power-law electron energy distribution. A rotation in position angle of 90° will occur near an opacity of ~ 0.5 as the component becomes transparent. The rotation is accompanied by a rapid decline in the percentage polarization to zero followed by a sudden increase as the opacity decreases further. Aller and Ledden (1978) observed polarization variations consistent with this scenario in OJ 287 in 1973. The polarization position angle was observed to rotate by ~ 100° at 8, 4.8, and 2.7 GHz.

In 1308 + 326, the observed position angle change is 70° instead of 90°, and the polarized flux density increased only slightly during the rotation. Thus, the data are not in perfect agreement with the homogeneous model, and some amount of inhomogeneity in the magnetic field and the existence of a constant polarized component seem necessary to account for the details of the minor deviations (e.g., a component with a polarized flux density of ~ 0.01 Jy and an orientation of ~ 180° is consistent with the variations).

The observed postrotation polarization position angles (90°–105°) imply a magnetic field orientation in the source of roughly 10°. This is in good agreement with the core elongation and with the alignment between the core and the secondary component. The coincidence of these orientations suggests that there is a physical relationship between these three structures.

Following the analysis outlined in Marscher *et al.* (1979) and using $\Delta S = 1$ Jy, $\Delta t = 2$ yr, $z = 0.996$ (Miller, French, and Hawley 1978), $H_0 = 75$ km s^{-1} Mpc^{-1}, and $q_0 = 0$, we obtain a brightness temperature of ~ 10^{13} K based on a size deduced from the variability time scale. Since the polarization variations suggest that the flux density changes are due to an outburst in an incoherent synchrotron source, the high brightness temperature in this outburst in 1308 + 326 is probably due to bulk relativistic motion of the emitting material with a relativistic Doppler factor, $\delta \geqslant 3$. If the optical-infrared emission originates from a region moving with bulk relativistic motion along the line of sight, the apparent outburst luminosity would be enhanced. Using the observed optical-infrared spectral index of -1.4 (Puschell *et al.* 1979), $\delta = 3$, and $\beta = 0.8$, the estimated 1978 outburst optical luminosity of ~ 10^{48} ergs s^{-1} would be decreased by a factor of ~ 50.

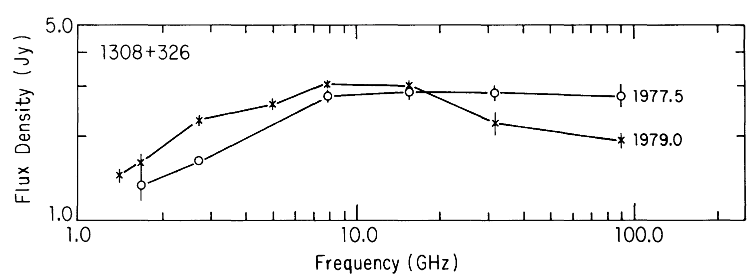

FIG. 2.—The evolution of the radio spectrum at 2 epochs. The data at 1.4 and 5.0 GHz are from Balonek (1982), and at 1.6 GHz from Webber, Yang, and Swenson (1980). The data points at 7.9 and 15.5 GHz were obtained with the Haystack Observatory 120 foot (37 m) antenna, and those at 31.4 and 89.6 GHz were obtained with the NRAO 36 foot (11 m) telescope at Kitt Peak.

We would like to thank W. Kinzel for his help in making the figures, and M. Hartman for his assistance with some of the data reduction. One of the authors (C. P. O.) would like to thank G. Void for helpful discussions. This research work was supported by a grant from the National Science Foundation. Radio Astronomy at the Haystack Observatory is also supported by the NSF. This is Contribution No. 536 from the Five College Astronomy Department.

REFERENCES

Aller, H. D. 1970, *Ap. J.*, **161**, 19.
Aller, H. D., and Ledden, J. E. 1978, in *Proceedings of the Pittsburgh Conference on BL Lac Objects*, ed. A. M. Wolfe (Pittsburgh: University of Pittsburgh), p. 53.
Balonek, T. J. 1982, Ph.D. thesis, University of Massachusetts, Amherst.
Kapitzky, J. E. 1976, Ph.D. thesis, University of Massachusetts, Amherst.
Marscher, A. P., Marshall, F. E., Mushotzky, R. F., Dent, W. A., Balonek, T. J., and Hartman, M. F. 1979, *Ap. J.*, **233**, 498.
Miller, J. S., French, H. B., and Hawley, S. A. 1978, in *Proceedings of the Pittsburgh Conference on BL Lac Objects*, ed. A. M. Wolfe (Pittsburgh: University of Pittsburgh), p. 176.
Moore, R. L., *et al.* 1980, *Ap. J.*, **235**, 717.
Pacholczyk, A. G. 1977, *Radio Galaxies* (New York: Pergamon), chap. 3.
Pacholczyk, A. G., and Swihart, T. L. 1967, *Ap. J.*, **150**, 647.
Puschell, J. J., Stein, W. A., Jones, T. W., Warner, J. W., Owen, F. N., Rudnick, L., Aller, H., and Hodge, P. 1979, *Ap. J. (Letters)*, **227**, L11.
Takarada, K. 1970, *Pub. Astr. Soc. Japan*, **22**, 551.
Ulvestad, J. S., Johnston, K. J., and Weiler, K. W. 1982, preprint.
Webber, J. C., Yang, K. S., and Swenson, G. W. 1980, *Astr. Ap.*, **85**, 1434.
Weiler, K. W., and Johnston, K. J. 1980, *M.N.R.A.S.*, **190**, 269.

T. J. BALONEK: Department of Physics and Astronomy, University of New Mexico, Albuquerque, NM 87131

W. A. DENT: Department of Physics and Astronomy, University of Massachusetts, Graduate Research Center, Tower B, Amherst, MA 01003

C. P. O'DEA: National Radio Astronomy Observatory, P. O. Box 0, Socorro, NM 87801