EVIDENCE OF RELATIVISTIC BEAMING IN BL LAC-TYPE OBJECTS

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Multifrequency observations of a variable extragalactic object, when all acquired within the inferred variability time scale of the source, can provide clues to the source's energy mechanisms. A guest observer program with the International Ultraviolet Explorer satellite has provided the focus for such measurements of a few BL Lac-type and related objects at frequencies in the radio, mm, IR, visual and UV. Earlier-epoch X-ray measurements are included in subsequent model fitting. This paper summarizes some of the observations in this program. Synchrotron self-Compton (SSC) models are then applied to the data, leading to the conclusions that the objects are relativistically beamed and that radio emission, at least below a frequency of $\sim$20 GHz, is from a separate source region.

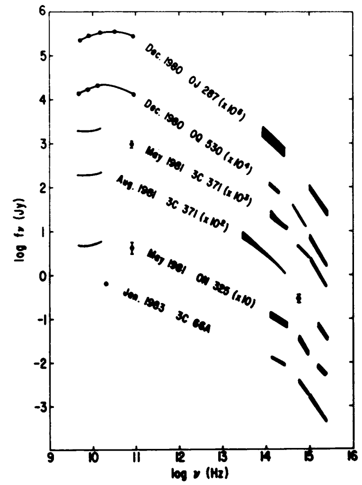

Figure 1. The "Simultaneous" multifrequency spectra display curvature between IR and UV frequencies.

The sources OJ 287, OQ 530, 3C 371, ON 325 and 3C 66A have been selected for their relatively low reddening. Only 3C 371 has a surrounding galaxy which is bright enough that it must be subtracted from the visual and IR data before the radiation of the central component can be studied (Sandage 1973). Contributors to the observational program include M. Aller, H. Aller, T. Balonek, F. Bruhweiler, F. Cordova, P. Hodge, B. Jones, W.H.-M. Ku, R. Leacock, K. Mason, K. Matthews, H.R. Miller, G. Neugebauer, A. Pica, J. Pollock, J. Puschell, J. Rodriguez-Espinosa, R. Rudy, M. Sitko, A.Smith, P. Smith, B.T. Soifer, W. Stein, J. Webb, W. Wisniewski and myself. The largest separation between same-epoch observations of a particular object has typically been that between the IR and the UV. For successive spectra of Figure 1, beginning with OJ 287, these separations were 1,1,8,12,8 and 9 days. Using published data, we infer that these should be within the time scales of any spectral-shape variability. For observa-

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tional details see Worrall et al. (1982;1983). Note that the objects all exhibit spectral curvature between IR and UV frequencies. Not shown in Figure 1 is the fact that previous-epoch Einstein Observatory X-ray measurements for OJ 287, 3C 371, On 325 and 3C 66A, and a HEAO-1 A-2 X-ray upper limit for OQ 530, lie above the visual to UV power-law extrapolations.

I have assumed that the core radiation is nonthermal and have applied SSC models to the data. The degree of relativistic beaming is determined by the value of $\delta=(1-\beta^2)^{\frac{1}{2}}/(1-\beta\cos\Theta)$, where β is the velocity in units of c and Θ is the angle of motion relative to the line of sight. The sources of no measured redshift, ON 325 and OQ 530, are conservatively assumed to have z=0.05. The observed IR-UV spectral curvature at ν_b is assumed to be due to electron energy losses. The first model assumes a homogeneous source in which the lifetime of electrons producing synchrotron radiation at frequencies $\lesssim\nu_b$ is at least as long as the light-crossing time of the source. Using the equations of Marscher et al. (1979) and Marscher (1983), the data of Figure 1, and previous-epoch X-ray measurements, it is found that all the sources require $\delta\gtrsim10$, and no radiation at frequencies less than $\sim$100 GHz is described by the model. A possibly more realistic model is presented by Königl (1981). The magnetic field and electron density decrease with increasing pathlength along the jet and electrons are continuously accelerated. Although precise values of δ are sensitive to spectra in the 10^{11}-10^{13} Hz band, where we have no observations, lower limits still suggest $\delta\gtrsim2$ for ON 325 and 3C 66A and $\delta\gtrsim10$ for the other sources. No radiation at frequencies less than $\sim$20 GHz is described by the model ($\sim$100 GHz for OQ 530 and 3C 371). This is a consequence of the measurement of ν_b in the IR-UV frequency band. The model may describe flat-spectrum <20 GHz radio emission from sources for which $\nu_b>2\times10^{15}$ Hz.

Assuming SSC emission, it is concluded that all of the five sources presented here are relativistically beamed and that radio emission, at least below a frequency of $\sim$20 GHz, is from a separate source region. Both the homogeneous and Königl SSC models could be constrained by better knowledge of the relationship between variability time scales at different frequencies. Spectral coverage between 10^{11} and 10^{13} Hz, with temporal monitoring, could tie down parameter fits. Simultaneous mm and X-ray monitoring could also be an important diagnostic, as could X-ray spectral measurements.

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