A SHOCK MODEL FOR QUASARS AND ACTIVE GALACTIC NUCLEI *

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ABSTRACT. First order Fermi acceleration is an efficient mechanism to produce relativistic particles in strong astrophysical shocks. We have developed a model using this theory to explain the non-thermal emission from non-relativistic jets in Quasars and AGNs. Fluid dynamical simulations of cosmic jets predict shock formation in them at quasi-periodic intervals. This is also suggested by observations of jets. We identify the shocks as the sites of reacceleration of the energetic particles required to explain the non-thermal emission of the jets. In order to facilitate the comparison with observations, we have done numerical simulations of the expected observational properties at high and low spatial resolution.

1. THE MODEL

The basic assumption of our model is to consider jet knots, and compact radio sources, planar shock waves of circular cross section with magnetic field parallel to the flow and constant diffusion coefficients upstream and downstream of the shock. Radiation losses are important in extragalactic jets and in compact nuclei for high energy electrons. Typical lifetimes for the electrons emitting at optical and higher frequencies are much lower than the light travel time from the nucleus. Therefore, cut-offs in the electron distribution function and in the corresponding synchrotron spectrum are expected (Webb, Drury and Biermann, 1984). Strong spectral steepening is actually observed in some sources (Rieke et al., 1982). The first solution of the cosmic ray transport equation in shocks is not strictly valid in this type of astrophysical shocks since it does not consider energetic losses. The solution in the presence of strong synchrotron and inverse Compton losses has been obtained by Webb, Drury and Biermann (1984), hereafter WDB, Schlickeiser (1984) and Bregman (1985).

The electron energy distribution as a function of distance to the shock was obtained numerically (following the solution of WDB) and used to calculate the synchrotron emission and absorption coefficients in all

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Stokes parameters for different frequencies. The synchrotron radiation transfer equations were solved to obtain the expected observational properties.

2. RESULTS

The main results of our simulations for a flow direction perpendicular to the line of sight are: 1) the local synchrotron spectrum is a power-law with a cut-off at high frequencies (the spectral index at low frequencies is the same as the one obtained in the absence of losses), 2) the cut-off frequency decreases with distance to the shock, 3) the upstream emission is negligible whereas downstream the size of the emitting region decreases with increasing frequency, 4) there is a sharp edge at the position of the shock front, 5) the spectrum steepens, and the degree of linear polarization increases, with distance to the shock, and 6) a flip in the linear polarization position angle is expected for sources which are optically thick near the shock front and become optically thin with increasing distance to the shock. When finite observing resolution as well as projection effects are considered the results of our simulations resemble the general core-jet morphology of compact radio sources.

For shocks with compression ratio higher than 4 the results are slightly different due to the pile-up in the electron distribution function below the cut-off momentum. The main difference is that the position of the surface brightness maximum at low frequencies does not coincide with the shock front but is displaced downstream of it. This can contribute to the wavelength dependence of the position of the maximum observed in the Quasars 1038+528 A,B (Marcaide et al., 1985)

The overall continuum properties of unresolved sources such as BL Lacs and red Quasars were obtained from the electron energy distribution integrated over the whole shock wave region. The integrated spectral index is,below the shock front cut-off frequency, steeper by 0.5 than the local one.

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