PARTICLE ACCELERATION IN RADIO SOURCES WITH INTERNAL TURBULENCE

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Many extended radio sources seem to need in situ regeneration of the relativistic electrons. MHD turbulence generated by surface instabilities has been suggested as the reacceleration mechanism. However, Eilek (1981) has shown that short wavelength MHD waves, which are the most effective particle accelerators, are strongly damped in radio sources. This results in the turbulent region being confined to a thin layer on the edge of the source, so that particles accelerated here must propagate into the radio source if this reacceleration mechanism is to account for the internal synchrotron luminosity. Most likely the particles diffuse across tangled field lines; using numerical modelling of the turbulence, Eilek showed that the particles propagate only a small distance (10 pc - 1 kpc) in from the edge. This predicts that larger sources should appear limb brightened; but such limb brightening is rare. If short wavelength MHD waves are indeed the source of reacceleration, they must be generated internally.

In this paper we propose an attractive alternative: that the flowing plasma displays vortical hydrodynamic turbulence, and that this turbulence drives MHD waves throughout a large portion of the source. Fluid turbulence will generate MHD waves, in a process akin to the Lighthill radiation of sound waves (Kato, 1968). Henriksen, Bridle and Chan (1981) have shown that this process can account for the surface brightness distribution of some radio jets, if all of the Lighthill energy goes directly into the radiating relativistic particles. But a more detailed investigation of the microphysics is needed. Are the strength and spectrum of the MHD waves generated in this process sufficient to reaccelerate the particles in the face of synchrotron and expansion losses? What effect does this reacceleration have on the particle spectrum? In this paper we discuss these questions generally; a fuller presentation and numerical modelling will appear elsewhere (Eilek and Henriksen, 1982).

The energy balance at wave number k is

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$$\frac{dW(k)}{dt} = P(k) - \sum_i \gamma_i(k)W(k) \qquad (1)$$

If W(k) is the energy density in MHD waves, P(k) is the driving function, and $\gamma_i(k)$ is the damping rate due to the i'th dissipation process. When the Lighthill driving is energetically small, the fluid turbulence is Kolmogorov and the driving function for Alfven waves can be shown to obey $P(k) \propto k^{-3/2}$. For times short compared to the particle response time, we set dW(k)/dt = 0 and solve (1) for W(k). With Alfven waves, the dominant damping is usually cyclotron resonant acceleration of the relativistic electrons. If the electron momentum distribution is $f(p) \propto p^{-s}$, Kolmogorov/Lighthill driving results in an Alfven wave spectrum,

$$W_A(k) \propto k^{-(s - 3/2)}. \qquad (2)$$

Once W(k) is known quantitatively, the particle acceleration rate can be found by integrating over the wavenumber spectrum. Eilek and Henriksen (1982) show that self consistent models of radio sources can be found with enough energy in the high-k waves to offset particle energy losses.

But what of the particle distribution? The acceleration time

$$t_A(p) \propto p^{-(s - 7/2)}; \qquad (3)$$

but the synchrotron lifetime

$$t_{sy}(p) \propto p^{-1}. \qquad (4)$$

Thus, an arbitrary electron distribution will tend to evolve towards a power law with s = 4.5. The synchrotron spectral index predicted is then $\alpha = (s - 3)/2 \sim 0.7$, which agrees with the observed trend in radio sources.

REFERENCES

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