A THEORETICAL MHD MODEL FOR EXTRAGALACTIC JETS AND ITS COMPARISON WITH THE OBSERVATIONS

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ABSTRACT. Two aspects of the MHD stationary equilibrium model developed by Chiuderi et al.(1989) to describe extragalactic jets are analyzed and compared with the observational constraints: the global energy flux convected by the cylindrical jet and the ranges of the equilibrium parameters allowed by the stability analysis. In particular, the results obtained from the *temporal* stability analysis are converted into a *spatial* point of view. In this context, it is easier to find essentially "stable" equilibrium configurations for shorter jets. In conclusion, the fundamental hypotheses of this model (like thermal confinement and substantial equipartition among the various forms of energy considered) are such that the model turns out to be suitable for the description of class I jets, associated with rather low-power radio sources.

Model Properties The model introduced by Chiuderi,Pietrini and Torricelli-Ciamponi [1] is intended to describe the structure of jets in a cylindrical geometry, requiring that relativistic particles do not give any consistent dynamical contribution, but only act as "tracers" of the underlying physical structure. Any observed z-dependence is fully ascribed to the relativistic component distribution ([1],[2]). This MHD model represents a large scale jet as a cylindrical structure where the thermal material, endowed with an outward flow velocity, supports electrical currents which originate a helical magnetic field. Return currents flow within the the jet, giving zero net current. The external confinement is given by the thermal pressure of the ambient medium. Different magnetic structures can be obtained, by varying a parameter A, which is a measure of the ratio B_ϕ/B_z. Previous investigations of the model were directed to the reproduction of the polarization patterns and intensity behaviour to compare model predictions with observations [3] and to the linear stability analysis of the stationary equilibrium configurations ([1],[2],[4],[5]).

As a following step, a critical discussion of model properties and obtained results has been carried on [2], taking into account the existence of two distinct classes of jets, corresponding to the two classes of radio sources FR I and II [6].

Energetics The aim of the analysis is to investigate whether the model is capable of describing both of these classes or, if not, for which one it is best suited. The energetics of the model is examined. A fundamental assumption is that of substantial "equipartition" among the various forms of energy (apart from that in relativistic particles, as specified above). With the chosen profiles for magnetic and velocity fields, the energy densities are evaluated by averaging them over the jet cross section. The equipartition hypothesis imposes restrictions on the values of the energy density ratios, which, in turn, define the ranges of equilibrium parameters that guarantee a substantial fulfilment of equipartition.

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Next, the energy flux along the jet F_j is evaluated as the sum of the kinetic energy flux, the enthalpy flux and the Poynting vector contribution, all integrated over the jet section. To define the descriptive capability of the jet model, an estimate of the "maximum" energy flux that can be carried along the jet (i.e. the maximum rate of energy replenishment for the large scale structure of the radio source) is derived by choosing for the speed parameter its maximum value in the "equipartition" range. Acceptable energy fluxes are predicted for FR I sources, with typical total luminosities around some 10^{41} ergs $\sec^{-1}$, while the possibility of an adequate description of very powerful (FR II) sources, with luminosity up to $10^{44} - 10^{45}$ ergs $\sec^{-1}$ is apparently excluded. This is in agreement with the thermal confinement characterization of the model and the need of rather high external pressure (to obtain physical equilibria), since FR I sources generally lie in rich clusters and are usually associated with the central, brightest galaxy [7], being thus presumably confined by the hot intergalactic medium. The model is thus best applied to FR I sources jets.

A Critical View of Stability Analysis Results The stability analysis of the predicted equilibrium configurations defines other constraints on the theoretical model. The "temporal" analysis gives a stability region in the parameter space, corresponding to equilibria essentially stable over the typical life-time ($\sim 10^8$ years) of extragalactic radio sources ([4], [5]). Stability is obtained for almost longitudinal $\mathbf{B}$ ($A \leq 0.6$). The results derived in [4] and [5] have been reinterpreted in the specific context of jets [2], including neglected effects, to test the possibility of enlarging the stable region. Thus, the finite length of jets and the possibility of a non-disruptive evolution of instabilities have been considered. In particular, converting the temporal results into a "spatial" point of view (obtaining growth-lengths l characterizing the growth in space of the perturbation, as it travels along the jet), the finite length of the jet, L, may be introduced by comparing it with l for the instabilities affecting an equilibrium configuration. When $L < l$, the jet may be considered basically stable, since the perturbations cannot grow to the non-linear, possibly disruptive, regime over the whole jet length. Progressively enlarging stability regions have been found with decreasing L [2]. Referring for details to [2], here can only be mentioned the possibility of neglecting the $m = -1$ mode (most restrictive for the stable region), as an internal kink mode, following Rosenbluth et al. [8], and that of the development of a quasi-stationary non-disruptive level of turbulence when the temporal growth-rates are small enough, as further possibilities of enlargement of the stable region. It turns out that only A values ≤ 2 are allowed as corresponding to basically stable magnetic structure; this is important in connection with model predictions on polarization patterns [3] which reproduce the majority of observed features with $A \leq 2$. There is, however, a number of very low power source jets that can be fitted only with $A \sim 4$, that is definitely out of the "stable" range defined. A possible way out for this problem may be the introduction of some z-dependence of the magnetic structure, which is considered in future work.

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