1. INTRODUCTION

High resolution observations by the Einstein Observatory have allowed the detection of X-ray emission from galactic jets (Feigelson et al. 1981, Schreier 1981). Bright knots coincident with radio and/or optical features have been identified in Cen A (X-ray luminosity \( L_x \approx 10^{40} \text{ erg s}^{-1} \), distance \( D \approx 5 \text{ Mpc} \), knot size \( d \approx 0.4 \text{ kpc} \)) and M 87 (\( L_x \approx L_{\text{opt}} \approx 10^{41} \text{ erg s}^{-1} \), \( D \approx 15 \text{ Mpc} \), \( d \approx 50 \text{ pc} \)); significant emission is associated with jet-like structures in 3 C 273 and NGC 315 also (Feigelson and Schreier 1980). The most interesting results in connection with theoretical models for galactic jets are the following.

(1) The X-ray flux from the M87 jet fits a power-law spectrum extending from optical frequencies; this suggests a common synchrotron origin, imposing quantitative requirements on relativistic electron acceleration rates inside the knots. Although lack of optical data does not allow definite conclusions for Cen A, the similarity for spectral features at radio and X-ray frequencies suggests a synchrotron origin for its knots also.

(2) Standard equipartition arguments applied to magnetic, relativistic and thermal components inside the knots and the surrounding X-ray halo indicate that knots are not pressure confined. Such arguments might not apply to an initial propagation stage of the beam leading to the extended radio structure. However the presence itself of knots and wiggles, their regular spacing and very slight variations in (radio) sizes with distance from the parent nucleus require a proper interpretation in terms of intrinsic effects.

The purpose of this contribution is to investigate the above points in an attempt to correlate morphologies and radiation mechanisms at high frequencies.

2. MORPHOLOGY

The models proposed for interpreting the bright knots in the jet of M87 (and Cen A) so far referring to radio and optical observations - are based on either one of these two scenarios, having the common starting point that the parent nucleus emits a continuous beam of supersonic (eventually relativistic) particles.

(1) The knots are connected with clouds of cool, dense gas periodically ejected by the nucleus and entrained in the supersonic fluid flow (Blandford and Konigl 1978). The interaction of these two components generates shocks, which in principle can accelerate high-energy electrons in situ and support synchrotron emission. In a slightly different version no clouds are invoked; shocks develop from local pressure enhancements along the jet due to periodical variations of the flow velocity produced by irregularities in the central power engine (Rees 1978). As we shall discuss below, this type of model may have difficulties in explaining the high-frequency part of the spectrum.
In a different scheme, bright knots would indicate the nonlinear development (shocks, collective dissipations, radiative losses, etc.) of large scale MHD Kelvin-Helmholtz instabilities in the fluid flow interacting with the external medium (Ferrari et al. 1978, 1979, 1980; Hardee 1979; Benford et al. 1980, Benford 1981). Saturation of these perturbations provides an underlying structure for the radiation distribution; in addition short wavelength MHD perturbations, excited via a cascade process from long wavelength perturbations, could drive local stochastic acceleration of high-energy electrons for synchrotron emission. This scheme appears adequate in interpreting extended radio sources; however, in the present context; it might be hampered by the fact that the jets of Cen A and M87 do not appear to be pressure confined; consequently the above MHD instabilities might be quenched. Alternatively an increase of the magnetic field for better confinement (not unlikely in jets close to the parent nucleus) would immediately damp any instability and halt the whole process (Ferrari et al. 1980).

In this contribution we want to put forward a third physical model, especially designed for the first stages of development of a galactic beam. If supersonic (relativistic) jets originate from electrodynamic processes driven by accretion inflows into galactic nuclei, they are quite likely to carry currents.

A small charge separation

\[ \rho = \frac{n^+ - n^-}{n^+ + n^-} \approx 5.3 \times 10^{-15} \left( \frac{c}{v} \right) \frac{1}{n} \frac{B_{\perp}}{d_{pc}} \]

is sufficient to induce a magnetic field of the order of the equipartition fields (\( v \approx \) current velocity \( \sim \) beam velocity, \( n = \) beam particle density, \( B_{\perp} = B/10^{-4} \) G, \( d_{pc} = \) current sheet depth in parsecs). Then, when a jet emerges along the rotation and magnetic axis of the galactic nucleus, it will be characterized by a longitudinal magnetic field \( B_z \) plus an azimuthal component \( B_{\theta} \) due to the longitudinal current. Such a configuration is consistent with radio polarization data and is reproduced in laboratory experiments; Rutherford (1980) discusses how helicoidal perturbations (kinks) develop "magnetic islands" on critical surfaces around the beam axis. In fact, as the azimuthal component \( B_{\theta} \) decreases away from the axis, the pitch angle of (unperturbed) magnetic lines, \( \tan \theta_p = B_{\theta}/B_z \), decreases outwards: there will be a singular cylindrical surface where the pitch of the lines matches the pitch of the perturbations; here the magnetic topology is altered and a helicoidally shaped shear is formed. Modes with different azimuthal number (exp \( i(-\omega t + k_z + m \theta) \)) give rise to different critical surfaces, larger numbers corresponding to inner surfaces, \( m = B_{\theta}/B_z \). Sheared magnetic structures are unstable to resistive tearing instabilities, in collisionless regime also (Coppi et al. 1979); magnetic islands form along the shear, separated by neutral \( X \)-points at which dissipation of magnetic energy occurs via collective processes. It is difficult to evaluate which physical processes may lead to saturations of the island linear growth. They necessarily involve contribution to dissipation processes from anomalous resistivity (Coppi et al. 1979). One may envisage on the basis of laboratory experiments (Rutherford 1980), that a disruptive instability develops which drives a nonlinear coupling of tearing modes. As suggested by Coppi and Ferrari (1981), we use for the typical time scale of the nonlinear evolution the hydromagnetic time \( \tau_H = d/v_A \), where \( d \) is the size of the reconnection region; this can be written

\[ \tau_H = 4.4 \times 10^3 \left( \frac{d_{pc}}{B_{\perp}} \right)^{1/2} \text{ yrs.} \]