COMPARATIVE STUDY OF EXTRAGALACTIC RADIO SOURCES FROM "DOUBLE JET" MODELS

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It seems now important to consider bulk velocity gradients inside jets (Blandford, 1993; Biretta et al, 1995) and recent results from tomography technique suggest the presence of different components in radio sources (Rudnick, this symposium). A few jet models take explicitly into account two components with different bulk velocities (Smith, Raine, 1985; Baker et al, 1988; Sol et al, 1989; Achatz et al, 1990). A fast beam comes from the vicinity of the black hole while a slower collimated wind is emitted by the accretion disk. When stable, the two components can survive along the jet. If a fast instability develops at a distance D_c from core, the beam is destroyed over some relaxation length. Its energy and momentum are transmitted to the wind. Apparent change in the flow regime such as slowing down, decollimation, local bending or discontinuity in surface brightness is the expected observational signature of such critical zones on radio maps. The exact appearance of the zone depends on the parameters of the two flows and on their interaction regime.

Several plasma microinstabilities can grow in "double jets" and impose specific conditions to ensure stability:

(1) light e^+e^- beams with density ratio $n_b/n_0 \simeq 10^{-3}$ to 0.1.

(2) strong magnetic field along jet axis, $B > B_c = 3.2 \times 10^{-3} n_0^{1/2}$ in CGS units (i.e. plasma and cyclotron frequencies such that $\omega_p < \omega_c$, density $n_0 < 9.7 \times 10^4 B^2$, and Alfven velocity $v_A > 0.02c$) to avoid efficient generation of Langmuir waves.

(3) bulk Lorentz factor $\gamma < \gamma_A = \left(\frac{\omega_c}{\omega_p}\right)\left(\frac{m_p}{m_e}\right)^{1/2} = \left(\frac{m_p}{m_e}\right)\left(\frac{v_a}{c}\right)$ to avoid excitation of Alfven waves: $\gamma_A^{\min} \simeq 43$

(4) $\gamma < \gamma_W = \left(\frac{4v_a}{c}\right)\gamma_A$ to avoid whistler generation: $\gamma_W^{\min} \simeq 4$.

Application to fifty-six jets provides tests of the scenario and comparative studies of different types of sources. To qualitatively describe a source

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within two-component models, one needs to interpret some feature along the jet as a critical zone from its apparent morphology. To follow the quantitative approach, one needs some estimates of the magnetic field along the jet and at the critical zone to determine the wind density n_0 from (2).

For WATs, critical zones are identified with the so-called inner hot spots and for FRIs with the start of bright jets after the gaps. In FRIIs inner straight beams come out from nucleus and disappear at brighter knot or decline with small change in direction before entering radio lobes. We tentatively identified the end of these beams with the critical zone. Cross-sectional areas of the two components are deduced from the maps. From (1) to (4), we impose $n_b = 10^{-2} n_0$ and $\gamma = 4$. We first assume $v_0 = 0.02c$ for the wind velocity. Mass flux, net energy flux, and efficiency factor $\varepsilon = L_{\rm rad}/(K_b + K_0)$ for conversion of jet power into radio luminosity are then deduced.

	D_c kpc	B_c μG	$\dot{M}_b$ 10^{-5}M$_\odot$/yr	$\dot{M}_0$ M$_\odot$/yr	K_b 10^{42}erg/s	K_0	ε
$\langle$WAT$\rangle$	29.2	14.1	15.5	1.1	105	35.8	0.022
$\langle$FRI$\rangle$	2.9	14.3	0.1	0.007	0.7	0.2	0.12
$\langle$FRII$\rangle$	42.3	42.5	19.9	0.86	135	27.7	0.60
$\langle$FRI$_{CF}\rangle$	1.4	134.0	10.5	0.58	71.5	19.4	0.019

Our study shows that (i) critical zones can be identified in many jets, (ii) the scenario leads to quite realistic values for the $\dot{M}$, K and ε, (iii) different morphological types of sources define specific domains of parameters in $D_c - B_c$ and $K_0/K_f - \varepsilon$ diagrams, together with some continuity from one type of sources to another, (iv) cooling flows harbour smaller but more powerful sources, (v) to keep $\varepsilon < 1$ in all FRII requires $v_0 \simeq 0.06c$ in FRIIs and their inner beam can not lead alone to observed luminosities, (vi) ε is quite different for different types of sources. A Kolmogorov-Smirnov test shows that the distributions of ε are different at the 92% level for WATs and FRIIs. Acceleration of particles appears less efficient in inner hot spots of WATs than in terminal FRII hot spots.

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