TURBULENT CASCADE IN VLBI JETS

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ABSTRACT

In the framework of continuous beam from small (VLBI region) to large scales (VLA region), we deduce some typical quantities of VLBI-jets like maximum luminosity and time-scales of formation of turbulence in the hypothesis of turbulent cascade triggered by relativistic Kelvin-Helmholtz instabilities.

I. Relativistic Kelvin-Helmholtz instabilities

The MHD instabilities of a cylindrical jet have been studied in detail, see Ferrari et al. (1981); the envelope of reflecting modes can drive a strong hydrodynamic turbulence on wavelengths smaller than the radius, R_J, of the jet. Thus we will adopt a relativistic growth rate γ_p, and sound velocity C_s, $= C / \sqrt{3}$ (C = light velocity):

1) $\gamma_p \simeq \frac{C_s}{R_J \gamma_L}$ with scale of production $\lambda_p \simeq 0.5\ R_J$

where γ_L is the Lorentz factor of the relativistic bulk motion (this approximation is good only for $\gamma_L < 10$).

II. Determination of luminosity

We assume that a fraction close to unity of the sonic perturbations, produced on large scales by Kelvin-Helmholtz instabilities supplies smaller scale turbulence. We model the transfer of turbulent energy spectrum in terms of the wavenumber k (Pelletier and Zaninetti (1983)) with the hypothesis of Kraichnan cascade in which the turbulent energy spectrum $W(k) \propto k^{-3/2}$; this happens if $C_S < 5\ V_A$ (V_A = Alfven velocity).

R. Fanti et al. (eds.), VLBI and Compact Radio Sources, 231–232.

The power density supplied to the cascade is:

$$2)\quad Q \simeq \frac{C_s^2}{V_A R_J \gamma_L} W_M$$

where W_M is the density of magnetic energy. We thus obtain the maximum contribution to the total luminosity, in terms of the main parameters of the VLBI jet: D_J = length (D_1 = 1pc units), B = magnetic field of equipartition ($B_{-2} = 10^{-2}$ gauss units) and n = density ($n_{+2} = 10^{+2}$ part/cm^3):

$$3)\quad L \simeq 5.6\ 10^{39} \left(\frac{R_j}{D_J}\right) (B_{-2})^3 (n_{+2})^{-\frac{1}{2}} (D_{+1})^2 \left(\frac{\beta}{\gamma_L}\right) \text{ ergs/sec}$$

where β is the ratio between total kinetic and magnetic pressure. This maximum luminosity is in agreement with the total luminosities of VLBI jets as given by Preuss (1983).

III. Time scale of formation of the turbulence

The time, τ , required for a perturbation of size $< R_J$ to reach the dissipation range is of the order of $\approx \gamma_L R_J/C_S$. This time could be related to the time scale of variability of VLBI jets that are greater than a month. Setting $C_s = C/\sqrt{3}$ we obtain:

$$4)\quad \tau \simeq 70\,\gamma_L \left(\frac{R_j}{D_J}\right) (D_{+1}) \text{ months}$$

References

Ferrari, A., Trussoni, E., Zaninetti, L.: 1981, M.N.R.A.S. 196, 1051

Pelletier, G., Zaninetti, L.: 1983, submitted to Astron. Astrophys.

Preuss, E.: 1983, Workshop on Astrophysical Jets, Reidel, Dordrecht