Rev. Mexicana Astron. Astrof., 21, 152-154 (1990

THE MAGNETIZATION OF THE INTERGALACTIC MEDIUM BY EXTRAGALACTIC JETS

L.C. Jafelice[1,2] and R. Opher[2]

1. Faculdade de Ciências Matemáticas e Físicas da Pontíficia Universidade Católica de São Paulo.

2. Instituto Astronômico e Geofísico da USP, Brazil.

RESUMEN. Estudios observacionales indican evidencia para la magnetización del medio intra-cúmulo para algunos cúmulos de galaxias, mientras todavía es una pregunta abierta si el medio inter-cúmulos está penetrado por campos magneticos. El origen de la magnetización de medios intra-cúmulo o inter-cúmulos todavía no está resuelto. Las teorías propuestas hasta ahora, así como sus limitaciones son brevemente discutidas. Proponemos una teoría alternativa basada en el fenómeno común observado de los chorros extragalácticos (CE). Consideramos la evolución temporal de un CE transportador de corriente y la corriente de retorno asociada cerrando el circuito. Para el camino de retorno la fuerza de Lorentz es expansiva. Suponemos que tal expansión ocurre a la velocidade de Alfvén local y calculamos numéricamente la distancia radial desde él eje del chorro a la cual el circuito de retorño alcanza. Los cálculos son hechos para valores observados de parámetros para las fuentes extragalácticas Cygnus A, NGC 6251, 3C465 y M84. Los resultados obtenidos pueden explicar varias características magnéticas observadas en esas fuentes. La posible importancia de generaciones anteriores de CE en la magnetización en gran escala del medio intergaláctico es discutida también.

ABSTRACT. Observational studies indicate evidence for the magnetization of the intracluster medium for some clusters of galaxies, whereas it is still an open question if the intercluster medium is permeated by magnetic fields. The origin of the intracluster media magnetization is not solved yet. Existing theories proposed up to now, and their limitations, are briefly discussed. We propose an alternative theory based on the observed common phenomenon of extragalactic jets (EJ). We consider the time evolution of a current carrying EJ, and the associated return current closing the circuit. For the return path, the Lorentz force is expansive. We assume that such an expansion occurs at the local Alfvén velocity and calculated numerically the radial distance from the jet axis which the return circuit reaches. Calculations are made for parameter values observed for the extragalactic sources Cygnus A, NGC 6251, 3C465 and M84. The results obtained can explain several magnetic features observed in these sources. The possible importance of previous generations of EJ in the large scale magnetization of the intergalactic medium is also discussed.

Key words: GALAXIES-JETS — HYDROMAGNETICS

I. INTRODUCTION

In the present work we study the magnetization of the intergalactic medium due to agnetic fields generated by extragalactic jets (EJ) from galactic nuclei. Although such a rocess has been mentioned in a generic form (e.g., Dreher et al. (1987); Rees (1987)), it as not been discussed in detail nor its implications have been analyzed.

I. THE MODEL

We analyze a current carrying EJ and the corresponding return current (J_{ret}) closing he circuit. The Lorentz force ($\vec{F}_L$) for the return path is expansive. We assume that the xpansion occurs at the local Alfvén velocity $V_A(r,h)$ and calculate numerically the radial istance (r_e) from the jet axis which the return circuit reaches due to this expansion (where he cylindrical radial coordinate is r, and h is the jet height). We have for the time interval τ) taken by the circuit to expand (radially):

$$\tau = \int_{r_i}^{r_e} dr/V_A(r,h) \qquad (1)$$

here r_i is of the order of the jet radius. We use the external density profiles inferred from -ray data to evaluate $V_A(r,h)$.

II. APPLICATIONS

The calculations are made for parameter values of several sources (as mentioned in he abstract). Here, because of the lack of space, we discuss briefly just the case of Cygnus . [A fuller discussion will be published elsewhere (Jafelice and Opher 1989)].

It has been observed by Dreher et al. (1987) that intracluster magnetic fields are ound around Cygnus A, which are ordered on scales ∿20-30 kpc, with intensities ∿ 2-10 μG.

We assume regular previous active (i.e., jet-current generation) periods, $_{act} \sim f\tau_{inact}$ ($\tau_{inact} \equiv$ inactive period), and that $\tau_{act} \sim \tau_j$, the present jet age (taken s ∿ 6 x 10^6 years). Jet current generation has recently been discussed by Jafelice et al. 1989) (for a more detailed discussion see also Jafelice et al. 1990). We studied f = 1; 0^{-1} and 10^{-2}. The above mentioned observations are found to be best fitted with f = 10^{-1}. e have $r_e \sim 16$ kpc and a mean azimuthal field $B_\phi \sim 3$ μ G is obtained at this distance from he jet axis.

The calculated r_e and B_ϕ are in good agreement with observations. The proposed rocess, moreover, can give rise to the unusual magnetic field geometries which seems to be eeded to explain observed large-scale rotation measure gradients in the lobes of Cygnus A Dreher et al. (1987)).

Consider the case of a galaxy which has two consecutive active periods separated y, e.g., $\tau_{inact} \sim 10\ \tau_j$, in the hypothetical situation where the parent galaxy has completed early $\lesssim$ 1/4 of its rotation period (through an axis perpendicular to the plane defined by he two generations of jets) when the second active period begins, with the associated jet-urrent generation taking place. Assume further that the energetics and electric current alues are similar in the two active periods, and that the parent galaxy has not moved too uch apart from one active period to the consecutive one which is not a stringent condition or galaxies sitting in the potential well of a cluster of galaxies. Such a scenario could ccount for the very special magnetic field geometry which is needed to explain some puzzling agnetic field features observed with some extragalactic radio sources and which are, up to ow, impossible to explain.

The above described scenario can explain, for example: 1) the large scale rotation easure gradients observed in the lobes of Cyg A mentioned above, and also such gradients bserved in the lobes of M84 (Laing and Bridle 1987); 2) the intergalactic magnetic field tructure needed to explain the bends observed in the jets in 3C465, the calculations of which ndicate that the magnetic force ($\vec{J} \times \vec{B}$) is the probable cause for the bending (Eilek et al. 984). [The present model is able to explain not just the intergalactic magnetic field eometry to account for the bending, when opposite jets bend to the same side, but also order f magnitude estimates indicate that the model can explain this phenomenon quantitatively Jafelice and Opher 1989)]. Similarly, the model can explain the slight bending, also to the ame side, of both jets in M84 (Laing and Bridle 1987) ; 3) the correlation among several eatures observed to exist at two locations in the jet in NGC 6251 (Perley et al. 1984) namely: diminishing rate of the jet lateral expansion; the existence of a strong transversal rotation easure gradient; the occurrence of knots; and the indication of a magnetoionic "sheath" ∿ 2.5 - 5 kpc) about the jet. [These are the dimensions of a magnetic cocoon which we obtain for this source following the procedure summarized in section II above, in particular, if the jet velocity is relativistic (which is still an open question, Perley 1989)] . Further detailed discussions of these and other applications of the present model are made in Jafelice and Opher (1989).

The authors would like to thank the Brazilian agencies CEPE/PUCSP and FAPESP (L.C.J. and CNPq (R.O.) for support.

REFERENCES

Dreher, J.W., Carilli, C.L., and Perley, R.A. 1987, Ap. J., 316, 611.
Eilek, J.A., Burns, J.O., O'Dea, C.P., and Owen, F.N. 1984, Ap. J., 278, 37.
Jafelice, L.C. and Opher, R. 1989, submitted for publication.
Jafelice, L.C., Opher R., Assis, A.S. and Busnardo-Neto, J. 1989, in these proceedings.
Jafelice, L.C., Opher, R., Assis, A.S. and Busnardo-Neto, J. 1990, Ap. J., January 1 issue.
Laing, R.A. and Bridle, A.H. 1987, M.N.R.A.S., 228, 557.
Perley, R.A. 1989, private communication.
Perley, R.A., Bridle, A.H., and Willis, A.G. 1984, Ap. J. Suppl. Ser., 54, 291.
Rees, M.J. 1987, Q. Jl. R. astr. Soc., 28, 197.

L.C. Jafelice: Departamento de Física, Faculdade de Ciências Matemáticas e Físicas, PUCSP, Rua Marquês de Paranaguá 111, 01303 - São Paulo, SP - Brazil
R. Opher: Departamento de Astronomia, Instituto Astronômico e Geofísico, USP, Av. Miguel Stefano, 4200, 04301 - São Paulo, SP - Brazil