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MAGNETIC FIELD TOPOLOGY IN JETS

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RESUMEN

Presentamos la topología del campo magnético en un chorro pulsado y radiativo. Para campos inicialmente helicoidales y variaciones periódicas de velocidad, encontramos que el campo a lo largo del chorro varía entre mayormente toroidal en los nudos a posiblemente poloidal en el resto de las regiones.

ABSTRACT

We present results on the magnetic field topology in a pulsed radiative jet. For initially helical magnetic fields and periodic velocity variations, we find that the magnetic field alternates along the length of the jet from toroidally dominated in the knots to possibly poloidally dominated in the intervening regions.

Key Words: **ISM: JETS AND OUTFLOWS — MAGNETIC FIELDS — MHD — SHOCK WAVES**

1. INTRODUCTION

A good deal of observational evidence exists in favor of describing HH objects as internal working surfaces within a YSO jet (Reipurth & Heathcote 1997; Zinnecker et al. 1998). This model posits that the driving sources of YSO jets are episodic, changing on time scales much less than the dynamical time scale of HH objects. Internal working surfaces originate in the jet from nonlinear wave steepening of initially small perturbations. A significant gap exists between theory and observation concerning the physical mechanisms responsible for launching and collimation of YSO jets. The widely accepted theories rely on strong helical magnetic fields from accretion disks. "Flux freezing" arguments show that these fields should be carried out with the jet beam. These arguments suggest that jets may "carry their own collimators," explaining why jets remain collimated for such large distances. Unfortunately, observational evidence of the strength and orientation of magnetic fields is notoriously difficult to obtain. The question remains, "If it were possible to detect magnetic fields in jets, what magnetic field strengths and orientations would be expected?" We address this question through approximate analytic studies and detailed numerical simulations of jets.

2. ANALYTICAL AND NUMERICAL STUDIES

We have recently constructed a Godunov type scheme for multidimensional MHD in order to study the full nonlinear dynamics of jets. We implement the "Positive Scheme" of Lax & Liu (1998) based on Roe's linearization. We utilize a Roe linearized Jacobian matrix similar in construction to that of Cargo & Gallice (1997). When renormalized, the eigenvectors form a complete, linearly independent set for all values of the magnetic field components. We have also found a self consistent manner in which to preserve $\vec{\nabla} \cdot \vec{B} = 0$ to within round-off error without the need for a staggered mesh (Gardiner & Frank 2000). We include optically thin radiative cooling by making use of the Dalgarno-McCray coronal cooling curve.

We begin by considering a cylindrically symmetric jet with an embeded helical magnetic field and periodic velocity variations introduced at the source. Analytical studies show that periodic velocity variations lead to a succession of compression and rarefaction regions along the jet beam. To first order, the toroidal component

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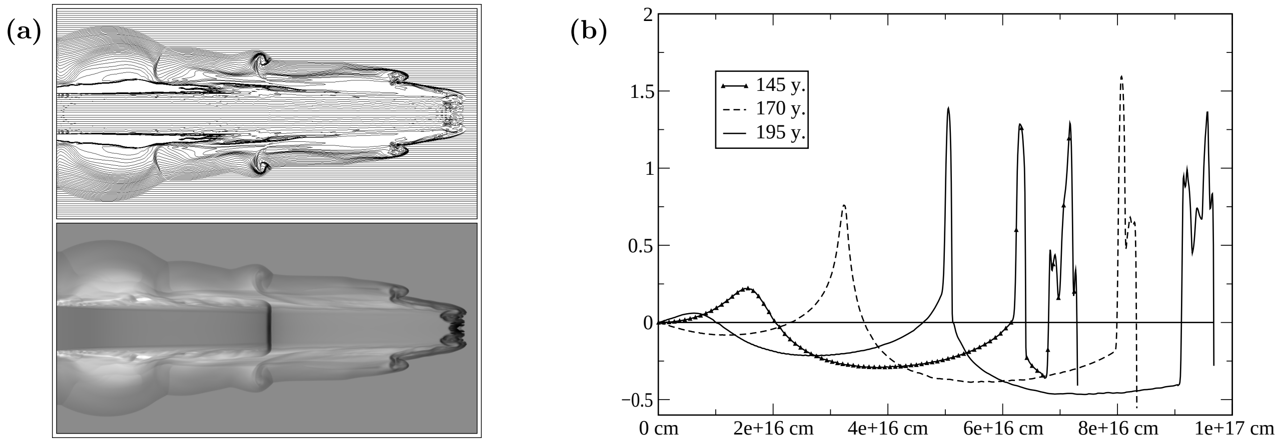

Fig. 1. *(a)* Poloidal magnetic field lines (top frame) and the logarithm of the density (bottom frame) where black (white) is high (low). *(b)* Scaled logarithm of the toroidal field strength along the jet beam at 3 times.

of the magnetic field scales as the density while the axial component remains constant. Wave steepening will eventually lead to shock formation in the compressional regions which, in the presence of cooling, increases the compression of the toroidal magnetic field component significantly. We thus expect that the toroidal magnetic field strength will be significantly strengthened in the knots and diminished in the intervening regions. Depending on the strength of the axial magnetic field and the amount of rarefaction, the magnetic field may become poloidally dominated between the knots.

These arguments are fully realized in numerical simulations. In Figure 1*a* we plot the logarithm of the density and the poloidal magnetic field lines after 195 yr on a grid 1×10^{17} cm in length. The highly straight field lines in the jet indicate that the axial magnetic field component is fairly constant, with only small scale fluctuations. In Figure 1*b* we plot the logarithm of the toroidal field strength along the length of the jet at three evolutionary times with the toroidal field normalized to 1 at the base of the jet. The three "pulses" to the left of 5.5×10^{16} cm show the temporal evolution of the toroidal magnetic field in a compressional region. Just in front of this compressional region is a rarefaction region in which the toroidal field decreases as it propagates. For sufficiently strong axial magnetic fields, or long propagation times the magnetic field can become poloidally dominated. To the right of 5.5×10^{16} cm we see the complex evolution of a collision between an internal working surface and the jet head.

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REFERENCES

Cargo, P., & Gallice, G. 1997, J. Comp. Phys., 136, 446
Gardiner, T. A., & Frank, A. 2000, in preparation
Lax, P. D., & Liu, X. -D. 1998, SIAM J. Sci. Comput., 19, 319
Reipurth, B., & Heathcote, S. 1997, in IAU Symp. 182, Herbig-Haro Flows and the Birth of Stars, ed. B. Reipurth & C. Bertout (Dordrecht: Kluwer), 3
Zinnecker, H., McCaughrean, M. J., & Rayner, J. T. 1998, Nature, 394, 862

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