

A Phenomenological Interpretation of Magnetic Bouncy Structures in Barred Galaxies

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ABSTRACT: This note proposes a phenomenological interpretation of magnetically driven bouncy structures in galactic disks based on the competition between advective transport and magnetic diffusion. The system is characterized by the magnetic Reynolds number, defined as the product of characteristic velocity and length divided by magnetic diffusivity. Enhanced conductivity and shear-driven flows increase this quantity, favoring magnetic field amplification over dissipation. In barred galaxy environments, strong velocity shear amplifies magnetic fields through induction effects, leading to localized increases in magnetic and turbulent pressure. When combined with reduced effective density, the Alfvén speed increases, enabling more efficient transport of energy along magnetic field lines. The resulting imbalance between magnetic pressure, turbulence, and gravitational confinement may generate transient vertical expansion regions referred to as bouncy regimes, accompanied by synchrotron emission and particle energization. These regions can act as channels for filament

formation and disk-halo outflows in strongly magnetized, shear dominated galactic systems.

KEYWORDS: magnetic Reynolds number, barred galaxies, magnetohydrodynamics, synchrotron emission, disk–halo outflows

INTRODUCTION:

Magnetized plasma in galactic disks is governed by the competition between advective transport and resistive diffusion of magnetic fields. This balance is commonly described by the magnetic Reynolds number, which determines whether field lines are effectively frozen into the flow or subject to dissipation¹.

In barred galaxies, strong shear flows driven by non-axisymmetric potentials amplify magnetic fields through induction effects associated with velocity gradients¹. This leads to enhanced magnetic structure formation along dust lanes and filamentary features.

The combined effects of magnetic pressure, turbulence, and gravity produce non-linear vertical dynamics. In regions where non-

thermal support becomes significant, plasma can be partially lifted from the disk, forming filamentary extensions and outflow channels. This regime is referred to as the magnetic bouncy state, describing a shear-driven vertical response in magnetized galactic disks.

DISCUSSION: INTERPRETATION OF THE MAGNETIC BOUNCY REGIME

Magnetic transport and diffusion balance

The evolution of magnetic structure is controlled by the competition between advection and diffusion. This regime is quantified by the magnetic Reynolds number

$$R_m = UL/\eta \quad (1)$$

where η is the magnetic diffusivity¹. In a collisional plasma, the effective conductivity can be written as

$$\sigma \sim ne^2\tau/m_e \quad (2)$$

leading to reduced diffusivity in high density and high temperature environments². As a result, increasing shear and flow speed pushes the system toward $Rm \gg 1$, where magnetic fields are effectively frozen into the plasma.

Induction and shear amplification

¹Priest, *Magnetohydrodynamics of the Sun*; Spitzer, *Physics of Fully Ionized Gases*.

²Spitzer, *Physics of Fully Ionized Gases*.

Magnetic field growth in barred galaxies is driven by induction effects associated with velocity shear. The relevant term in the induction equation is

$$\mathbf{B} \cdot \nabla \mathbf{v} \quad (3)$$

which converts kinetic shear into magnetic energy³. In bar-dominated disks, this term is enhanced, producing strong anisotropic field amplification along dust lanes and filamentary channels.

Pressure balance and magnetic support

The vertical structure is regulated by competing pressure terms. Magnetic pressure is given by

$$P_B = B^2/8\pi \quad (4)$$

while turbulent support can be approximated as

$$P_{turb} \sim \rho v^2 \quad (5)$$

When the combined non-thermal pressure approaches gravitational confinement, vertical expansion becomes possible⁴.

Synchrotron feedback and energy redistribution

³Eugene N. Parker, *Cosmical Magnetic Fields: Their Origin and Their Activity* (Oxford: Oxford University Press, 1979); Priest, *Magnetohydrodynamics of the Sun*.

⁴Eugene N. Parker, "The Dynamical State of the Interstellar Gas and Field," *Astrophysical Journal* 145 (1966): 811–833; Binney and Tremaine, *Galactic Dynamics*.

Relativistic electrons in amplified magnetic fields produce synchrotron radiation with power scaling as

$$P_{\text{sync}} \propto \gamma^2 B^2 \quad (6)$$

This process introduces strong radiative losses and acts as a feedback channel, redistributing energy across the bouncy region and increasing the effective pressure support in a non-uniform manner⁵.

Alfvénic transport and vertical dynamics

Energy transport along magnetic field lines is governed by the Alfvén speed

$$v_A = B/\sqrt{4\pi\rho} \quad (7)$$

As plasma is lifted, density decreases, increasing v_A and enhancing vertical communication of magnetic tension along field lines⁶. Gravity acts in opposition, introducing a restoring acceleration that competes with magnetic tension, producing a vertically extended oscillatory structure.

Feedback from high-energy interactions

In high-energy environments, synchrotron photon fields can enhance secondary interactions such as photohadronic processes. This increases local energy dissipation channels and contributes to pressure spreading across the structure.

The result is a broadened, dynamically supported region rather than a localized instability.

Bar-driven geometry and large-scale modes

Barred potentials naturally excite $m = 2$ modes, generating strong shear layers and elongated magnetic structures⁷. These conditions favor filament formation and disk–halo coupling. Within this framework, the bouncy regime corresponds to a transient state where magnetic amplification, turbulent pressure, and gravitational confinement are out of equilibrium, enabling vertical escape channels and filamentary outflows.

CONCLUSION AND SUMMARY

The magnetic bouncy framework provides a unified phenomenological interpretation of vertical disk expansion and filament formation in magnetized, shear-dominated galactic environments. The key controlling parameter is the magnetic Reynolds number, which expresses the balance between advective transport and resistive diffusion and increases under conditions of enhanced conductivity, strong shear, and high flow velocity.

⁵Malcolm S. Longair, *High Energy Astrophysics*, 3rd ed. (Cambridge: Cambridge University Press, 2011).

⁶Hannes Alfvén, “Existence of Electromagnetic-Hydrodynamic Waves,” *Nature* 150 (1942): 405–406.

⁷Binney and Tremaine, *Galactic Dynamics*; Beck, “Magnetic Fields in Spiral Galaxies.”

results in an effective imbalance between upward magnetic and turbulent support and downward gravitational pull, enabling transient vertical expansion. In addition, turbulent pressure enhances this imbalance by acting in opposition to gravitational confinement, effectively reducing the stability of the midplane structure. In this regime, the combined effects of magnetic, turbulent, and radiative feedback allow the system to enter a non-linear expansion phase.

Within this framework, the observed ultraviolet morphology of barred galaxies, particularly filamentary outflow disk-halo structures, can be interpreted as observational signatures of the magnetic bouncy regime. The UV-bright extensions and filamentary outflows are consistent with regions of enhanced synchrotron activity, magnetic amplification, and vertical plasma transport. Overall, the magnetic bouncy mechanism links shear-driven magnetic amplification, radiation feedback, Alfvénic transport, and gravitational competition into a single coherent picture for disk-halo coupling and filament formation in barred galactic systems. This mechanism offers one possible explanation for the ultraviolet filamentary morphologies observed in several barred galaxies, suggesting that such structures may represent visible



signatures of magnetic pressure-driven disk-halo transport.

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