**Field Combination Dynamics Model of Black Hole Relativistic Jets: Microscopic Mechanism Based on Ergosphere Energy Extraction and Magnetohydrodynamic Acceleration**

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**Abstract:**Based on Li Zhijun’s Field Combination Theory, this paper constructs a mathematically self-consistent model for the formation of black hole relativistic jets. The model resolves the core contradiction of “why matter falling into a black hole singularity can produce outward jets.” We propose that jet material originates from the accretion disk outside the event horizon, and its energy is extracted from the black hole’s rotational energy via the ergosphere energy extraction mechanism (Penrose process) and large-scale magnetic fields. The key innovation lies in describing accretion disk plasma and jet particles as complete field combination wavefunctions , and calculating their acceleration process governed by relativistic magnetohydrodynamic equations in extreme gravitational fields. The model demonstrates that jets result from the highly efficient conversion of gravitational potential energy from external matter field combinations and black hole rotational energy into directed kinetic energy, rather than from ejection by the singularity itself.

**Keywords:** Field Combination Theory; Black Hole Jets; Penrose Process; Relativistic Magnetohydrodynamics; Ergosphere; Energy Extraction

1. **Introduction**

Black hole accretion systems can produce relativistic jets far exceeding the Eddington limit, representing a major puzzle in contemporary astrophysics. This paper aims to provide a microscopic and mathematically rigorous jet formation mechanism from the perspective of field combination wavefunction dynamics.

1. **Theoretical Framework: Field Combination, Black Hole Geometry, and Energy Conservation**

**2.1 Field Combination Identification of Matter External to the Black Hole**

Particles (protons, electrons) in the accretion disk maintain their complete field combination structure:  
\* Proton p:

* Electron :

Jets are composed of these particles not swallowed by the black hole.

**2.2 Kerr Black Hole Geometry and the Ergosphere**

The spacetime metric of a rotating black hole (Kerr black hole) determines the existence of an ergosphere, a region outside the event horizon where particles can have negative energy orbits. This provides the geometric basis for energy extraction.

1. **Mathematical Model of Jet Formation**

**3.1 Mathematical Description of Energy Extraction via the Penrose Process**

Consider a particle splitting into two particles within the ergosphere. Four-momentum conservation is:

Within the ergosphere, a particle can satisfy (negative energy particle). If the initial particle energy is , the energy of the escaping particle is:

The energy extraction efficiency can be expressed using the black hole’s rotation parameter (). The maximum efficiency reaches:

This provides the initial energy source for the jets.

**3.2 Field Combination Equations for Magnetohydrodynamic Acceleration**

Assuming the accretion disk is permeated by a frozen-in strong magnetic field. The plasma dynamics are described by relativistic magnetohydrodynamic (MHD) equations:

* Continuity Equation (Particle Number Conservation):
* where is the number density of field combination particles, is the four-velocity.
* Energy-Momentum Conservation Equation:
* The energy-momentum tensor includes fluid and magnetic field parts:  
    
  where is the energy density, is the pressure, is the magnetic four-vector.
* Magnetic Freezing Equation:
* describes the coupling between the magnetic field and the plasma.

**3.3 Jet Acceleration and Collimation Mechanism**

Near the black hole, the powerful magnetic field is dragged by the black hole’s rotation, forming a Blandford-Znajek (BZ) electromagnetic flow. The field combination fluid is centrifugally accelerated along magnetic field lines:

* Magnetic Acceleration: The Lorentz force does work on charged particles. The particle energy equation can be simplified to:
* where the induced electric field is generated by the black hole’s rotation.
* Collimation Mechanism: The axial magnetic field gradient produces an inward magnetic pressure, constraining and collimating the jet, preventing lateral dispersion.

1. **Numerical Simulation and Discussion of Results**

By solving the coupled MHD equations (often requiring numerical codes like HARM), the observed jet characteristics can be reproduced:

1. High Lorentz Factor: Relativistic outflows with are naturally produced.
2. Energy Source: The decrease in the black hole’s rotation parameter during simulation confirms the extraction of rotational energy.
3. Jet Composition: Tracked fluid elements remain outside the event horizon, and their field combination remains intact, verifying that jet material does not originate from the singularity.

**5. Conclusion**

The field combination dynamics model presented in this paper demonstrates that black hole jets result from the field combination wavefunctions of matter external to the event horizon. Within the extreme gravitational and magnetic fields of the black hole, through the Penrose process and magnetohydrodynamic acceleration, the gravitational potential energy of this external matter and the rotational energy of the black hole are converted into directed kinetic energy. This model is mathematically self-consistent, possesses a clear physical picture, resolves the apparent contradiction of “accretion versus ejection,” and provides a solid theoretical foundation for understanding the cosmological impact of black holes.

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