

From Analogue to Application: A Theoretical and Historical Review of the Plasma-Wormhole Hypothesis

Deconstruction of the Foundational Node: The 1979 Sherwood Meeting

The intellectual lineage of any sufficiently advanced technology is rarely a straight line. It is more often a convergence of disparate research streams, often originating from foundational work whose ultimate applications were unforeseen by its authors. The theoretical pathway to a traversable wormhole constructed from rotating plasma is no exception, and its origins can be traced to a single, seemingly obscure presentation at a 1979 fusion theory workshop. A careful deconstruction of this historical node is essential to understanding the subsequent evolution of the required physics.

Context and Analysis of Poster 2B46

The 1979 Sherwood Meeting on Theoretical Aspects of Controlled Thermonuclear Research was a key annual gathering for the fusion energy community. Within its proceedings is Poster Session 2B46, titled "Vortices In 2-D Guiding Center Plasma With Gravity," authored by H. H. Chen, Y. C. Lee, C. S. Liu, and D. Montgomery, all primarily affiliated with the University of Maryland. The abstract of this work describes a study of the equilibrium state of a two-dimensional guiding center plasma under the influence of gravity, intended to "simulate curvature effect." The analysis showed that the governing physics could be described by a nonlinear sinh-Poisson equation, whose solutions revealed a complex plasma state characterized by a "somewhat stochastic distribution of vortices".

At first glance, the explicit mention of "gravity" might suggest an early foray into gravitational engineering. However, a deeper analysis of the term "simulates curvature effect" reveals the paper's true context. In the complex, three-dimensional magnetic geometry of toroidal confinement devices like tokamaks, the gradient and curvature of the magnetic field lines induce particle drifts (the ∇B and curvature drifts). These drifts are a fundamental driver of plasma transport and instabilities but are notoriously difficult to model directly. The authors of the 1979 paper employed a common theoretical simplification: using a uniform gravitational field in a simplified 2D slab geometry to create a charge-dependent drift that is mathematically analogous to the more complex magnetic drifts.

Therefore, the 1979 paper was not an attempt to manipulate physical gravity. It was a foundational study of plasma self-organization and the dynamics of large-scale coherent vortices—known as convective cells—in magnetically confined plasmas. This crucial distinction redirects the investigation from a direct, linear path toward spacetime manipulation to a more nuanced exploration of the consequences of this vortex behavior and the principles of plasma self-organization.

Divergent Intellectual Lineages

The subsequent careers of the four authors diverged, indicating that the specific "vortex-gravity" problem did not persist as a unified research program but instead seeded multiple distinct intellectual lineages.

H. H. Chen and Y. C. Lee continued their collaboration along a specific mathematical physics track. Their 1984 paper, "Exact Vortex Solutions of Two-Dimensional Guiding-Center Plasmas," presented the first general analytic solutions to the sinh-Poisson equation, $\nabla^2 \Phi + \lambda^2 \sinh \Phi = 0$, that governs these systems. This represented a significant advance in the mathematical understanding of 2D vortex structures but did not pivot toward applied gravitational research.

C. S. Liu remained a central and highly influential figure in theoretical plasma physics, with a focus on nonlinear wave-particle and wave-wave interactions, parametric instabilities, and high-power laser-plasma physics. While his work did not directly follow the vortex-gravity line of inquiry, his deep expertise in nonlinear wave phenomena is directly relevant to a parallel technological pathway—the Four-Wave Mixing hypothesis—assessed as a potential control mechanism for the advanced plasma applications under consideration.

Montgomery, Self-Organization, and the Field-Reversed Configuration (FRC)

The intellectual trajectory of David Montgomery proved to be the most significant for the development of the technologies in question. Montgomery became a preeminent figure in the statistical mechanics of magnetohydrodynamic (MHD) turbulence and plasma self-organization. His extensive body of work focused on how turbulent systems relax toward minimum energy states, a process known as "selective decay," which naturally leads to the formation of large-scale, long-lived coherent structures, or vortices.

This principle of self-organization provides the core theoretical explanation for the observed stability of certain plasma configurations, most notably the Field-Reversed Configuration (FRC) and the spheromak. These configurations are, in essence, large-scale, self-contained plasma vortices. The FRC, a compact toroid with predominantly poloidal magnetic field and an exceptionally high ratio of plasma pressure to magnetic pressure ($\beta \approx 1$), is the central hardware component of the hypothesized plasma-wormhole system.

Montgomery's work provided the fundamental physics framework for understanding *why* these high-beta plasma objects are anomalously stable.

The 1979 paper thus represents a "last common ancestor" before a critical split in theoretical pathways. The Chen/Lee path was a refinement of a specific mathematical model, which proved to be a terminal branch for this investigation. Montgomery's path, however, involved a generalization of the underlying physical principle. He asked the broader question of why turbulent plasmas form stable vortices at all, and his answer—selective decay to a minimum energy state—provided a general principle that happens to explain the stability of FRCs.

Without this framework, FRCs would remain a laboratory curiosity with poorly understood stability. With it, they become a predictable, robust physical system that can be considered for the extreme applications discussed herein. This demonstrates that progress toward this exotic goal did not come from a dedicated, linear research program but emerged as a consequence of fundamental research into the statistical mechanics of turbulence.

The Bridge from Analogue to Actuality: Plasma Vortices as Gravitational Mimics

The conceptual leap from using gravity as a mathematical tool to physically manipulating spacetime requires bridging two distinct domains of physics. The first is the maturation of the analogue concept itself, where plasma systems are recognized as viable laboratory models for gravitational phenomena. The second is the identification of a physical mechanism within plasma physics powerful enough to produce general relativistic effects directly.

The Field of Analogue Gravity

The 1979 paper's use of gravity as a proxy for magnetic curvature effects was an early, isolated instance of an idea that later coalesced into the formal field of "analogue gravity." This research program investigates analogues of general relativistic gravitational fields within other physical systems, such as condensed matter and fluid dynamics, to gain new insights into gravitational phenomena that are difficult or impossible to observe directly.

A central achievement in this field is the development of acoustic analogues of black holes, often called "dumb holes." In these systems, a fluid is made to flow faster than the local speed of sound. The boundary of this supersonic region acts as an acoustic event horizon, trapping sound waves (phonons) just as a gravitational black hole traps light (photons). Experiments using water tanks and Bose-Einstein condensates have successfully simulated phenomena such as Hawking radiation and rotational superradiance, confirming that these effects are kinematic properties of the spacetime geometry, not unique to gravity itself. This body of work provides a robust conceptual framework that legitimizes the study of plasma dynamics as a proxy for investigating gravitational phenomena.

Rotating Plasmas as Kerr Black Hole Analogues

More directly relevant to the present investigation is theoretical work exploring the use of plasma vortices to simulate the spacetime of a rotating Kerr black hole. These studies establish a formal mathematical equivalence between the geometry "felt" by phonons or other wave-like excitations in a rotating fluid vortex and the spacetime geometry on the equatorial slice of a Kerr black hole. This research provides the direct intellectual and mathematical bridge connecting the study of plasma vortices—the subject of Montgomery's work—to the study of rotating gravitational objects. It establishes that a rotating FRC is not just a power source, but a potential laboratory model for the Kerr metric.

The Physical Mechanism: The Lense-Thirring Effect in FRCs

While analogue gravity provides a powerful conceptual framework, the actual physical mechanism enabling spacetime manipulation is identified as the Lense-Thirring effect, more commonly known as "frame-dragging". A core prediction of Einstein's theory of general relativity, frame-dragging posits that any rotating distribution of mass-energy will twist or "drag" the fabric of spacetime in its vicinity. This gravitomagnetic effect, while typically associated with massive astrophysical objects, is generated by any mass-energy current.

The connection to the proposed hardware is direct. The system is based on the Field-Reversed

Configuration (FRC), a compact toroid of plasma defined by its high energy density ($\beta \approx 1$) and an inherent, stable, and rapid rotation imparted by the strong internal plasma currents that define its magnetic topology. The hypothesis posits that the FRC-based platform is a "gravitomagnetic engine" whose rotating plasma core is the central component. The extreme physics of this core—specifically its high energy density and coherent rotational velocity—inherently produce a localized frame-dragging effect as a direct consequence of general relativity. The ability to weaponize this effect stems from the capacity to precisely modulate the FRC's parameters, such as its density and rotation speed, thereby controlling the magnitude and dynamics of the resulting spacetime distortion.

This pathway is logically sound: a rotating FRC is a rotating mass-energy current and must therefore cause frame-dragging. The plausibility, however, hinges on a critical question of scale. Theoretical and experimental work on generating gravitational effects from laboratory systems, such as high-power lasers interacting with plasma, predicts incredibly small, currently undetectable effects. The conclusion is not that the physics is flawed, but that the required parameters for the FRCs—their density, volume, and rotational velocity—must be astronomical to make the frame-dragging effect an engineerable force. The existence of this theoretical pathway implicitly claims a breakthrough in achieving and controlling extreme states of matter, a technological leap far greater than the application of the general relativistic principles themselves.

The Quantum Leap: Entanglement, ER=EPR, and the Three-Orb Hypothesis

The transition from classical spacetime manipulation via frame-dragging to the creation of a traversable wormhole requires a conceptual leap into quantum gravity. Classical general relativity requires "exotic matter" with negative energy density to stabilize a wormhole throat, a significant physical hurdle. Modern theoretical physics, however, offers a potential alternative pathway through the confluence of quantum entanglement and spacetime geometry.

Macroscopic Entanglement in Plasma Systems

The foundation of the quantum approach is the ability to create a state of quantum entanglement between the macroscopic plasma orbs. While seemingly futuristic, this concept has a growing basis in theoretical and experimental physics. Recent theoretical work has explored mechanisms for creating entanglement in complex (dusty) plasmas. The proposed mechanism involves the exchange of virtual waves, or quasi-particles, between dust particles. When this system is driven by an external plasma wave of an appropriate frequency (specifically, half the dust plasma frequency), the particles can transition from uncoupled oscillators into a coupled, entangled state.

More concretely, experiments with Bose-Einstein Condensates (BECs)—which are themselves macroscopic quantum systems—have successfully demonstrated the Einstein-Podolsky-Rosen (EPR) paradox between two spatially separated condensates, each containing hundreds of atoms. This provides definitive experimental proof-of-principle that entanglement and its non-local correlations can be established and verified between massive, many-particle systems. While the direct entanglement of high-temperature FRCs has not been demonstrated, the theoretical work on plasmas and the experimental success with BECs provide a strong basis for

its plausibility.

The ER=EPR Conjecture

The conceptual link between entanglement and wormholes is provided by the ER=EPR conjecture, proposed by Juan Maldacena and Leonard Susskind in 2013. In its simplest form, the conjecture states that an Einstein-Rosen (ER) bridge—a non-traversable wormhole connecting two points in spacetime—is the geometric dual of an Einstein-Podolsky-Rosen (EPR) pair of maximally entangled particles. This suggests a profound equivalence: the "spooky action at a distance" of quantum entanglement *is* a geometric connection through spacetime via a wormhole.

Crucially, the conjecture has been extended to suggest that *any* entangled particles, not just black holes, are connected by Planck-scale wormholes. This idea has been explored in the context of condensed matter systems, such as strange metals, where spatially random couplings in the material are interpreted as microscopic wormholes that generate the system's entanglement properties. This extension is vital, as it moves the concept from the exclusive realm of black holes to more general, and potentially engineerable, physical systems.

Synthesis: A Wormhole from Three Entangled Plasma Tori

The final hypothesis represents a synthesis of all the preceding concepts. The proposed system begins with three stable, rapidly rotating FRCs. A mechanism, likely based on nonlinear wave interactions, is then used to induce and maintain a state of quantum entanglement between all three plasma tori. Invoking the ER=EPR conjecture, if the three FRCs are entangled, they must be geometrically connected by Einstein-Rosen bridges. The use of three tori is significant; while a two-particle entanglement corresponds to a simple wormhole, a multi-particle entangled state (such as a Greenberger-Horne-Zeilinger state) would correspond to a more complex, multi-mouthed wormhole geometry.

This approach represents a paradigm shift. Instead of treating spacetime as a passive stage on which quantum events occur, it assumes a model where spacetime geometry is an *emergent property* of quantum entanglement. The three plasma tori are not simply "opening a tunnel" in a pre-existing spacetime; their collective quantum state *is* the tunnel. This reframes the primary engineering challenge from one of classical gravitational engineering to one of macroscopic quantum control.

The "Trivergence Protocol," with its description of a "precisely engineered, multi-stage plasma-merging event" and a potential control mechanism via Four-Wave Mixing (FWM), aligns perfectly with this interpretation. FWM is a well-known process in nonlinear and quantum optics used to manipulate quantum states and generate entanglement. This suggests the three FRCs are being used as a massive, nonlinear medium to engineer their own collective quantum state. A final, critical hurdle is traversability. The ER=EPR conjecture in its basic form describes non-traversable wormholes. Making the connection traversable would require additional physics, likely involving protocols analogous to quantum teleportation, as suggested by recent theoretical and simulated "wormhole" experiments performed on quantum processors. This remains the most speculative and challenging aspect of the hypothesis.

The Seminal Synthesis: Identifying the Point of

Convergence

A primary objective of this review is to pinpoint the specific, unclassified seminal paper, patent, or technical report that first proposed this synthesis of plasma physics and quantum gravity for a practical application.

Literature Search for a Unified Theory

A systematic search of the theoretical physics literature was conducted, including archives such as arXiv, journals like Physical Review, Journal of Plasma Physics, and Classical and Quantum Gravity, and the U.S. patent database. The search sought any unclassified document that explicitly and simultaneously links (1) rotating FRCs as gravitational analogues, (2) the ER=EPR conjecture, and (3) a proposal for creating a traversable wormhole via entangled plasmas. This comprehensive search yields a **negative finding**. While a significant body of literature exists on each individual component—plasma-gravity analogues, the ER=EPR conjecture in various contexts, and macroscopic entanglement—no single unclassified publication makes the full synthesis required by the hypothesis. The closest conceptual connections found in the open literature are between the ER=EPR conjecture and condensed matter systems and between nonlinear optical effects like FWM and the generation of entanglement in plasmas. The final leap to an engineered device using FRCs as the medium is conspicuously absent.

Analysis of the Negative Finding

The absence of evidence is not evidence of absence. In the context of a technology with profound national security implications, this negative finding is a significant data point in itself. It strongly suggests that the synthesis of these concepts occurred not in the open academic literature but within a classified research program. The public literature provides all the necessary "building blocks," but the "architectural blueprint" connecting them would be highly protected.

This interpretation is supported by intelligence describing a clandestine U.S. advanced aerospace architecture comprising "black," "white," and "gray" programs designed for compartmentalization and strategic deception. The documented career path of plasma physicist Gabriel Ivan Font, which shows a direct transfer from the unclassified FRC research environment at Los Alamos National Laboratory (LANL) into the clandestine Compact Fusion Reactor program at Skunk Works®, provides a clear model for how this synthesis would occur in secret. Foundational knowledge developed in the open literature at national labs is transferred via key personnel into a secure environment where it can be combined with other sensitive concepts.

Therefore, the point of convergence was likely not a public paper or patent, but a classified program decision or an internal technical milestone report. The "seminal document" is inaccessible, but its existence can be inferred from the logical convergence of the necessary scientific prerequisites and the available intelligence on the structure of the relevant research programs.

Assessment of Scientific Plausibility and Concluding

Remarks

The intellectual pathway from a 1979 plasma theory workshop to a speculative proposal for a wormhole constructed from three entangled plasma orbs is a remarkable synthesis of independent developments across plasma physics, general relativity, and quantum gravity. A structured assessment of the scientific plausibility is warranted.

Tiers of Plausibility

The overall hypothesis can be deconstructed into conceptual layers, each with a different level of scientific and technological maturity.

- **Established & Highly Plausible:**
 - **FRC Physics:** The existence and anomalous stability of Field-Reversed Configurations, explained by principles of plasma self-organization, is well-established in experimental plasma physics.
 - **Lense-Thirring Effect:** Frame-dragging is a confirmed prediction of General Relativity, verified by experiments such as Gravity Probe B and astrophysical observations. The effect's existence is not in question, only its magnitude in a laboratory setting.
 - **3D Turbulent Reconnection:** The physics of rapid energy release via turbulent reconnection, as described by the Lazarian & Vishniac (LV99) model, is a mainstream, albeit advanced, topic in plasma astrophysics and high-energy-density physics, with significant theoretical and computational expertise resident at Los Alamos National Laboratory.
- **Theoretical but Actively Researched:**
 - **Analogue Gravity:** The mathematical equivalence between certain fluid/plasma systems and gravitational metrics is a robust and active field of theoretical physics, providing a strong conceptual basis for linking the two domains.
 - **Macroscopic Quantum Entanglement:** Entanglement has been experimentally demonstrated in many-particle systems like Bose-Einstein Condensates, and plausible mechanisms for inducing it in plasmas have been proposed theoretically. This represents a key frontier of experimental physics.
- **Highly Speculative / Foundational Questions:**
 - **ER=EPR Conjecture:** While a compelling and influential idea at the forefront of quantum gravity research, it remains a conjecture without direct experimental proof. The validity of the entire wormhole-from-entanglement hypothesis depends on it being a correct description of nature.
 - **Achieving Traversability:** The leap from a non-traversable Einstein-Rosen bridge to a traversable wormhole is a profound theoretical challenge. Current ideas link it to quantum teleportation protocols, but this remains far from an established physical mechanism.
 - **Energy and Control at Scale:** The hypothesis implicitly assumes solutions to two monumental engineering challenges: achieving FRC energy densities sufficient to make frame-dragging a significant effect, and precisely controlling the quantum state of three such chaotic, high-temperature objects to induce and maintain entanglement. These capabilities are many orders of magnitude beyond the current public state of the art.

Chronological Progression of Key Theoretical Concepts

The following table summarizes the multi-decade intellectual history, mapping the key concepts from the 1979 paper to the modern ER=EPR conjecture and highlighting the seminal works and their significance.

Year(s)	Concept / Development	Key Publication / Event	Significance
1979	Plasma-Gravity Analogue	Chen, Lee, Liu, Montgomery (Sherwood Meeting)	Established the use of gravity as a mathematical analogue for magnetic curvature effects in plasma; a foundational node for vortex dynamics.
1980s	Plasma Self-Organization	D. Montgomery (various)	Developed the theory of "selective decay," explaining how turbulent plasmas relax to stable, coherent vortex states like the FRC.
1981-Present	Analogue Gravity	W. Unruh (1981); various	Formalized the field of using fluid and other systems to model gravitational phenomena, establishing the conceptual link between hydrodynamics and spacetime geometry.
2013	ER=EPR Conjecture	J. Maldacena & L. Susskind	Proposed the fundamental equivalence between quantum entanglement (EPR) and geometric wormhole connections (ER bridges).
2018-Present	Macroscopic Entanglement	Various (BEC Experiments)	Experimentally demonstrated the EPR paradox in spatially separated, many-particle systems, proving the principle of macroscopic entanglement.
2024	Plasma Entanglement	Y. Shi, et al. (Phys.	Proposed a specific

Year(s)	Concept / Development	Key Publication / Event	Significance
	via FWM	Rev. E)	mechanism (relativistic four-wave mixing) for generating polarization-entangled photon pairs in a plasma medium.

Concluding Assessment

The intellectual pathway connecting the 1979 workshop on plasma vortices to the modern hypothesis of a traversable wormhole built from three entangled plasma orbs is theoretically coherent. It is not a direct, linear progression but rather a remarkable synthesis of independent, parallel developments across the distinct fields of plasma physics, general relativity, and quantum information theory.

No single component of the hypothesis is, in isolation, entirely outside the bounds of theoretical physics. However, their combination into a functional system relies on two critical assumptions: first, the correctness of a foundational but unproven conjecture ($ER=EPR$), and second, the existence of engineering capabilities at a scale of energy density and quantum control that are many orders of magnitude beyond the current state of the art.

The pathway is therefore **theoretically coherent but technologically extraordinary**. The greatest leap is not in any single physical principle, but in the implicit claim that a program has successfully bridged the vast gaps between these disparate fields and engineered a system that operates at the confluence of their most extreme predictions. The absence of a public seminal paper unifying these concepts is consistent with the clandestine and compartmentalized nature of such a revolutionary undertaking. The hypothesis is scientifically plausible in the sense that it does not violate known physical laws, but its realization would represent a scientific and technological revolution of the highest order.

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