Falaco Solitons - Black holes in a Swimming Pool

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Abstract: Experimental evidence indicates that physical space may not be Euclidean. Conventional physical dogma, justified by the local success of Newtonian dynamics for particles, assigns a Euclidean metric with a positive signature (plus, plus, plus) to the three spatial dimensions. Minimal surfaces, like soap films, are of zero mean curvature and negative Gauss curvature in a Euclidean space, which supports transitive, affine evolutionary processes. However, experimental evidence now indicates that the intransitive (rotational) dynamics of a fluid admits a better description in terms of 3 spatial dimensions with a Lorentz metric of signature (plus, plus, minus), or a Majorana metric of signature (minus, minus, plus). Three dimensional spaces with such non-Euclidean metric signatures admit what mathematicians have described as *maximal* surfaces of zero mean curvature, with conical or isolated singularities. The zero mean curvature surfaces in Majorana space have negative Gauss curvature (similar to minimal surfaces in Euclidean space), while the zero mean curvature surfaces in Lorentz space have a positive Gauss curvature (in contrast to minimal surfaces in Euclidean space). Such properties also are associated with the Hopf map, which generates two surfaces of zero mean curvature and positive Gauss curvature in a 4D Euclidean space. Falaco Solitons, easily created as topological defects in a swimming pool, are claimed to be experimental artifacts of a pair of non-flat surfaces, each of zero mean curvature, immersed into 3 spatial dimensions with a non-Euclidean metric. These topological defects, in the otherwise flat surface of fluid density discontinuity, appear as a pair of compact, conical (dimpled) surface singularities. The two conical singularities appear to be connected with a 1D topological defect, or string under tension, which stabilizes the structure. The Falaco Soliton visually appears to be a pair of macroscopic Quarks connected with a string. The singular conical points are associated with rotation (not translation) about a rotational axis or "a fixed point", and are not mapped globally by affine transitive transformations. The experimental evidence indicates that the relativistic idea whereby the presence of matter determines the physical metric (such as in the theory of gravity) must be augmented by the realization that the dynamical state of matter also has metrical influence. In particular, the metric signature of 3D space with matter, and its resultant dynamics, need not be Euclidean. These surfaces of zero mean curvature, which are dominated by rotation, are generated by macroscopic spinors.

Keywords: Falaco Solitons, Cosmic Strings and Black Holes in a swimming pool, Macroscopic Spinors and Zero Mean Curvature surfaces, Non-Euclidean physics in three spatial dimensions.

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1 Physical 3D space is not necessarily Euclidean

Rotational dynamics of fluids produces topological defect structures that are best described in terms of three spatial dimension with a Lorentz or a Majorana signature. The experimental evidence is given by examination of the properties of easily replicated, topological defect structures of zero mean curvature, called Falaco Solitons . In this section, the properties of zero mean curvature surfaces generated by various types of Spinor structures will be examined, followed by the description of the Falaco Soliton experiments. Two important conclusions are retrieved from the Falaco Soliton experiments:

1. Physical effects are not necessarily constrained to 3D spatial structures with Euclidean Signatures.

2. Macroscopic Spinors play an important role in classical physics.

1.1 Zero Mean Curvature Surfaces and Spinors

Immersive maps from a two-dimensional space into a three-dimensional space of non-Euclidean metric signature are of two types. Each type depends upon the choice of quadratic form signature imposed upon the 3D-space. The Minkowski type signatures investigated herein are specialized to either a Lorentz signature $(+,+,-)$, or a Majorana signature $(-,-,+)$. A space with a Lorentz signature is of the form,

$$(ds)^2 = (dx)^2 + (dy)^2 - (dz)^2, \tag{1}$$

while a space with a Majorana signature is of the form,

$$(ds)^2 = -(dx)^2 - (dy)^2 + (dz)^2. \tag{2}$$

Mathematicians have defined immersions of zero mean curvature surfaces into a space with a Lorentz signature as "maximal surfaces" instead of "minimal surfaces" [2]. Maximal Surfaces in a 3D space with Lorentz signature can admit isolated, or "conical" dimple-like, singularities, where Euclidean (signature $+,+,+$) minimal surfaces do not. The same features of conical singularities for surfaces of zero mean curvature also appear when the signature of the 3D space has a Majorana signature. Both non-Euclidean signatures will be investigated herein.

The algebraic surfaces of zero mean curvature have similar appearances, but the Gauss curvature is positive for the Lorentz signature and negative for the Majorana signature. As the surfaces have zero mean curvature, they can be associated with complex curves generated by complex 3-component direction fields,

$$\text{Spinor} \quad |\mathbf{S}\rangle = \left| \begin{matrix} \sigma_1 \\ \sigma_2 \\ \sigma_3 \end{matrix} \right\rangle, \tag{3}$$

$$\langle \mathbf{S}| \circ |\mathbf{S}\rangle = \sigma_1^2 + \sigma_2^2 + \sigma_3^2 = 0, \tag{4}$$

with a zero quadratic form relative to the chosen 3D metric. Such complex direction fields have been defined as pure Spinors [1].

There are several "generic" formulas for defining the direction fields of 3D pure Spinors. One formula, due to Cartan, and relative to a Euclidean quadratic form, is given in terms of two complex functions, α and β:

$$\begin{aligned}
\text{Cartan} &: \text{3D Isotropic Pure Spinor} && (5)\\
\sigma_1 &= \alpha^2 - \beta^2, && (6)\\
\sigma_2 &= \pm\sqrt{-1}(\alpha^2 + \beta^2), && (7)\\
\sigma_3 &= \mp 2\alpha\beta. && (8)
\end{aligned}$$

One easy choice considers β to be the complex conjugate of α. The Cartan formulas can be cast into the (perhaps more familiar) Weierstrass construction:

$$\begin{aligned}
\text{Weierstrass} &: \text{3D Isotropic Spinor} && (9)\\
f &= \alpha^2, \quad g = \beta/\alpha, && (10)\\
\sigma_1 &= (1 - g^2)f, && (11)\\
\sigma_2 &= \pm\sqrt{-1}(1 + g^2)f, && (12)\\
\sigma_3 &= \mp 2fg. && (13)
\end{aligned}$$

More detail can be found in Chapter 12, [17].

1.1.1 Hyperbolic Spinors

Other generic forms for Spinor *direction fields* can be deduced from the canonical complex hyperbolic formulas:

$$\begin{aligned}
\text{Euclidean Spinor } |S_h\rangle &= (a + ib)[-\sinh(z), i\cosh(z), 1], && (14)\\
\text{Lorentz Spinor } |S_h\rangle &= (a + ib)[-\sinh(z), i\cosh(z), i], && (15)\\
\text{Majorana Spinor } |S_h\rangle &= (a + ib)[-i\sinh(z), -\cosh(z), 1]. && (16)
\end{aligned}$$

Each spinor formula, $|S_h\rangle$, representing a complex direction field can by multiplied by an arbitrary holomorphic function, $F(z)$, to yield $|S\rangle = F(z)\,|S_h\rangle$. For each (appropriate) choice of signature, it follows that,

$$\langle S| \circ [\eta] \circ |S\rangle \Rightarrow 0. \quad (17)$$

It is also true that each of the 3 Spinor components can be multiplied by ± 1 and the formula is valid. It is apparent that the third component ("Z-axis component") is "special", such that the change of sign of the third component implies a change in the sign of "helicity". Correspondingly the change of sign of the first or second component implies a change in sign of the "polarization".

The complex integrals of each Spinor component can be used to generate a complex position vector, where both the real and imaginary components can be visualized as position vectors to conjugate pairs of real surfaces of zero mean curvature.

1.1.2 Elliptic Spinors

It is also possible to construct Spinor *direction fields* in terms of the complex elliptic functions,

$$\begin{aligned} \text{Euclidean Spinor } |S_e\rangle &= (a+ib)[\sin(z), p\cos(z), ih], && (18)\\ \text{Lorentz Spinor } |S_e\rangle &= (a+ib)[[\sin(z), p\cos(z), -h], && (19)\\ \text{Majorana Spinor } |S_e\rangle &= (a+ib)[\sin(z), p\cos(z), -h]. && (20) \end{aligned}$$

where, again, the complex direction field can by multiplied by an arbitrary holomorphic function, $F(z)$, to yield $|S\rangle = F(z)\,|S_e\rangle$. For each (appropriate) choice of signature, it follows that,

$$\langle Sp| \circ [\eta] \circ |Sp\rangle \Rightarrow 0. \tag{21}$$

Again the change of sign, h, of the Z component is related to helicity, while the change of sign, p, of the first or second component is related to polarization.

By setting a = 0, or b = 0, and using z = (u + iv), leads (for the Euclidean case) to two distinct position vectors (to within ± signs):

$$\begin{aligned} Rreal &= [-cos(u)cosh(v), -p\sin(u)cosh(v), hv], && (22)\\ Rimag &= [-sin(u)sinh(v), p\cos(u)sinh(v), hu]. && (23) \end{aligned}$$

For the Minkowski space (either signature), the same procedure leads to two (different) distinct position vectors (to within ± signs):

$$\begin{aligned} Rreal &:= a[-cos(u)cosh(v), -p\sin(u)cosh(v), -hu], && (24)\\ Rimag &:= a[-sin(u)sinh(v), p\cos(v)sinh(u), hv]. && (25) \end{aligned}$$

1.1.3 A special case

A special immersion that can be extracted from the complex Minlowski spinor formulas, leads to a surface of zero mean curvature in Lorentz, or Majorana, space (but not in Euclidean space), with a position vector given by the formula,

$$\mathbf{R}(u,v) = [(\sinh(u)\cos(v), (\sinh(u)\sin(v), Au+B)]. \tag{26}$$

The Spinor formula is the same for both non-Euclidean singnatures. That is, the immersion is universal.

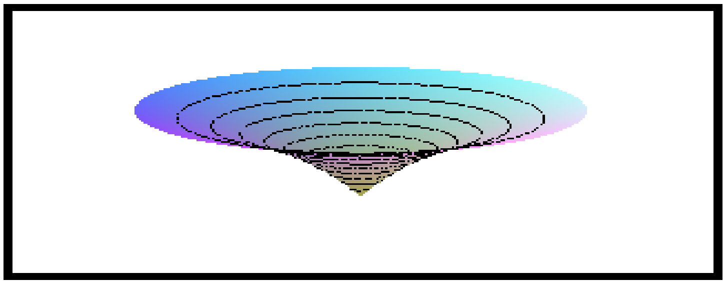

Figure 1. A Spinor generated zero mean curvature surface with a conical singularity in a 3D Lorentz or Majorana space

The formula yields a surface of zero mean curvature (for either Lorentz or Majorana signature), only when $(A = 1, A = 0,\ A = -1)$. Then the surface is of zero mean curvature, but the Gauss curvature becomes infinite at the "conical" singular point, $u = 0$. The surface is similar to the minimal surface Catenoid in Euclidean geometry, but here, unlike the Euclidean catenoid, the Lorentz or Majorana catenoid has a singular point. The dimple is down for $A = +1$, and the dimple is up for $A = -1$. The constant B determines the position of the singular point. The differences between the two Minkowski signatures are found in the Gauss curvature of the zero mean curvature surface. In the Lorentz case, the Gauss curvature is positive, and in the Majorana case the Gauss curvature is negative.

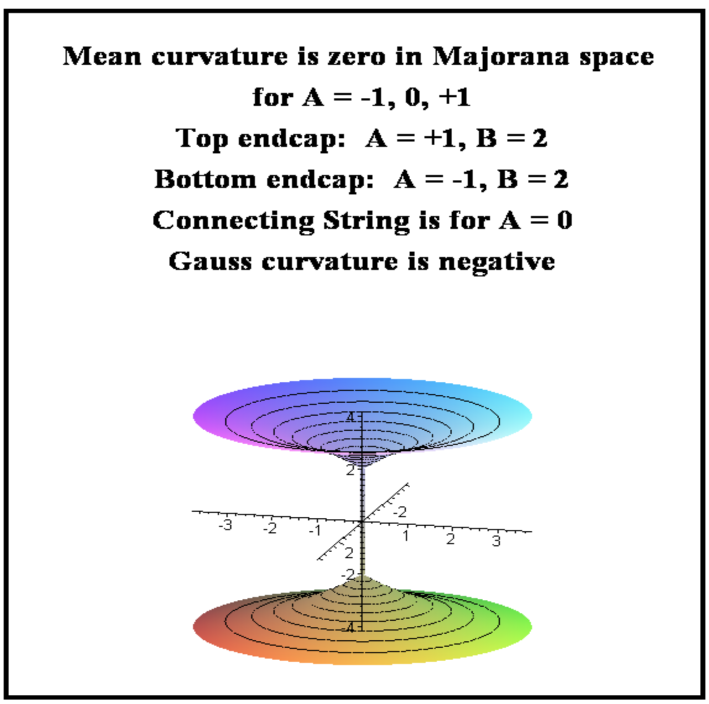

Figure 2. Spinor generated zero mean curvature branes connected with a string

By combining the surfaces for various values of A and B yields a string connecting two branes. The remarkable result is that the zero mean curvature surfaces, each with a singular conical point, or dimple, can be formed experimentally in a fluid. The experimental evidence is presented below.

1.2 Falaco Solitons

Falaco Solitons came to the attention of the writer in 1986, while visiting an old MIT roommate in Rio de Janeiro. The Falaco Solitons are topologically universal phenomena created experimentally by a macroscopic rotational dynamics in a continuous media with a discontinuity surface, such as that found in a swimming pool. The topologically coherent structure of Falaco Solitons appears to replicate certain features found at all physical scales, from spiral arm galaxies and cosmic strings to microscopic hadrons. The easy to replicate experiment indicates the creation of "stationary" thermodynamic states (or solitons) far from equilibrium, which are locally unstable in a Euclidean sense, but are experimentally globally stabilized.

The original analysis [15] was conducted *without* utilization of 3D space having non-euclidean signatures. Several exact solutions to the Navier-Stokes equations, *in a rotating frame of reference but with a Euclidean metric assumption*, have been used to demonstrate bifurcations to structures that in appearance are close to Falaco Solitons, but with an "open throat". However, the Navier-Stokes solutions, in Euclidean space, found so far, do not permit the formation of the conical dimpled singularities, connected by strings, that are observed experimentally. These results suggest that the open throat Falaco Soliton solutions can appear as cosmological realizations of Wheeler's wormholes in Euclidean 3 space, but are not directly related to the realization of closed throat solutions related to a 3D-space with a Minkowski signature (see Figure 3. below). The difference leads to the definition of Euclidean Falaco Solitons (Wormholes) and Minkowski Falaco Solitons (connected dimples). The Minkowski Solitons can be of two types depending upon the Lorentz signature, $(+,+,-)$, or the Majorana signature, $(-,-,+)$.

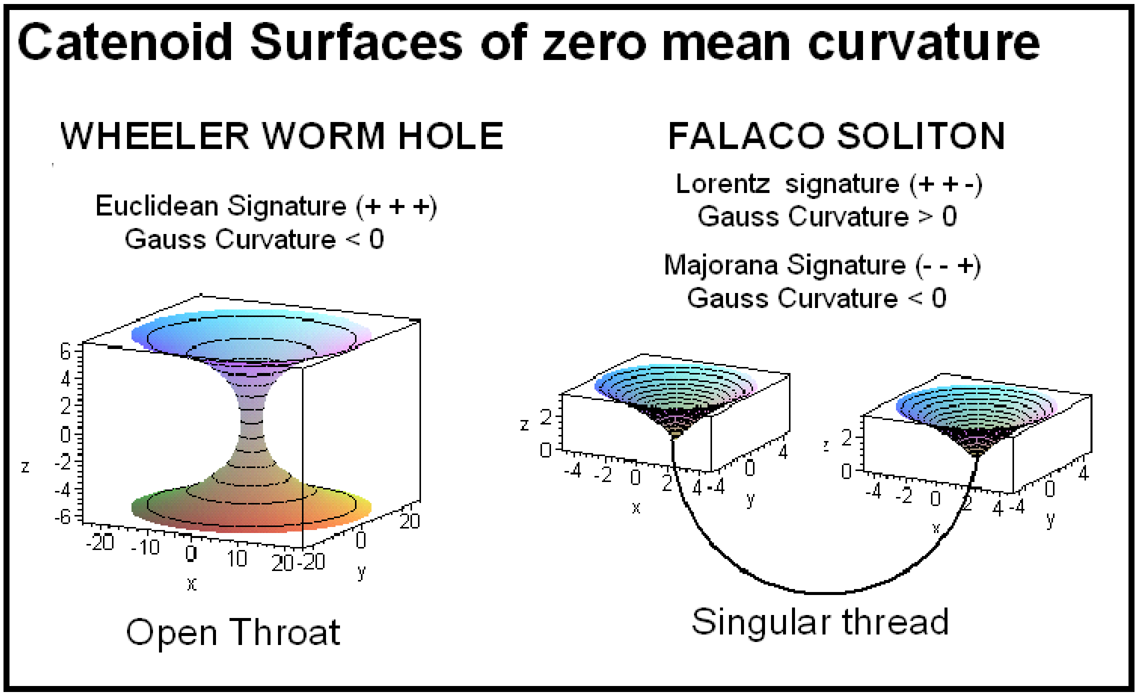

Figure 3. Spinor generated surfaces of Zero mean curvature in 3D spaces of different signatures.

Experimentally, in the swimming pool, the Minkowski Falaco Solitons do exhibit the confinement problem of sub-microscopic quarks on the end of a string. If you try to cut the "string" connection between the dimpled defects, the quarks (the zero mean curvature surface defects) disappear in a non-diffusive manner. To the eye, the Minkowski Falaco Solitons appear to be macroscopic realizations of sub-submicroscopic strings connecting branes, or, at the very large macroscopic level, as cosmological strings connecting spiral arm caustics that appear in the early stages of dimple formation.

Early on, the gauntlet was thrown down to several prominent "String Theorists", by challenging them to solve the "real world" problems related to the formation, universality, and persistence of the Falaco solitons, using their mathematical string theory conjectures. There have been no replies as of July, 2006. The elite group of String theorists seem to ignore both the challenge and the experimental facts that could give a high level of credence to string theories. Pity.

Remark 1 *The idea that 3-dimensional space may or may not be Euclidean challenges a dogmatic assertion of modern physics, where it is rarely perceived that physical 3D space can be anything but Euclidean.*

To summarize, the occurrence of long lived rotational topological defect structures in the free surface of a water, which have been described as Falaco Solitons and are examined in detail below, exhibit the features of zero mean curvature surfaces with conical singularities in a Lorentz-Majorana space. The Falaco Solitons are pairs of topological defect structures easily replicated in an experimental sense. Optical measurements indicate that the surface dimpled defect structures have a zero mean curvature. In addition, each of the pair of surface defect structures have an apparent conical dimpled singularity to which is attached a string, or one dimensional, topological defect.

2 Falaco Solitons, Cosmic Strings in a Swimming Pool

Figure 4. Three Falaco Soliton pairs in a Swimming Pool

During March of 1986, while visiting an old MIT friend in Rio de Janeiro, Brazil, I became aware of a significant topological event involving visual solitons that can be replicated experimentally by almost everyone with access to a swimming pool. Study the photo which was taken by David Radabaugh, in the late afternoon, Houston, TX in the year, 1986. The extraordinary photo is an image of 3 pairs of what are now called Falaco Solitons, a few minutes after their creation. Each Falaco Soliton consists of a pair of globally stabilized rotational indentations in the water-air density discontinuity surface of the swimming pool. The dimple shape is as if a conical pencil point was pushed into a rubber sheet, causing a dimpled deformation; but the indentation is dominated by dynamic intransitive rotation, not transitive affine translation. Unseen in the photograph, each pair of contra-rotating dimples are connected by a singular thread in the form of a circular arc extending from the vertex (singular point) of one dimple to the vertex of the other dimple of the pair. The "thread" can be made "visible" by injecting drops of dye into the fluid near the rotation axis of one of the dimples. These Solitons are apparently long-lived dynamical states of matter far from thermodynamic equilibrium. They will persist for many minutes in a still pool of water, maintaining their topological coherence so as to permit their inclusion into the class of objects called Solitons. The Falaco Solitons are extraordinary, not only due to the fact that they are so easily created in a macroscopic dynamical systems environment, but also because they offer real life, easily observed, evidence for the continuous evolution and creation of topological defects.

2.1 Falaco Surface dimples are of zero mean curvature

From a mathematical point of view, the Falaco Soliton is interpreted as a connected pair of two dimensional topological defects connected by a one dimensional topological defect or thread. The surface defects of the Falaco Soliton are observed dramatically due the formation of circular black discs on the bottom of the swimming pool. The very dark black discs are emphasized in contrast by a bright ring or halo of focused light surrounding the black disc. All of these visual effects can be explained by means of the unique optics of Snell refraction from a surface of zero mean curvature.

Remark 2 *This explanation of the optics was reached about 30 minutes after I first became aware of the Soliton structures, while standing in the pristine white marble swimming pool of an old MIT roommate, Jose Haraldo Falçao, under the brilliant Brazilian sunshine in Rio de Janeiro. At MIT, Haraldo was always called Falaco, after he scored 2 goals in a MIT soccer match, and the local newspapers misprinted his name. Hence I dubbed the topological defect structures, Falaco Solitons. Haraldo will get his place in history. I knew that finally I had found a visual, easily reproduced, experiment that could be used to show people the importance and utility of Topological Defects in the physical sciences, and could be used to promote my ideas of Continuous Topological Evolution [7].*

Remark 3 *The observations were highly motivating. The experimental observation of the Falaco Solitons greatly stimulated me to continue research in applied topology, involving topological defects, and the topological evolution of such defects which can be associated with phase changes and thermodynamically irreversible and turbulent phenomena. When colleagues in the physical and engineering sciences would ask "What is a topological defect?" it was possible for me to point to something that they could replicate and understand visually at a macroscopic level.*

During the initial few seconds of decay to the metastable soliton state, each large black disk is decorated with spiral arm caustics, remindful of spiral arm galaxies. The spiral arm caustics contract around the large black disk during the stabilization process, and ultimately disappear when the "topological steady" soliton state is achieved. The spiral caustics appear to be swallowed up by the black "hole". It should be noted that if chalk dust is sprinkled on the surface of the pool during the formative stages of the Falaco Soliton, then the topological signature of the familiar Mushroom Spiral pattern is exposed [10].

Notice that the black spots on the bottom of the pool in the photo are circular and not distorted ellipses, even though the solar elevation in the photo is less than 30 degrees. The important experimental fact deduced from the optics of Snell refraction is that each dimpled surface appears to be a surface of zero mean curvature. This conclusion is justified by the fact that the Snell projection to the floor of the pool is almost conformal, preserving the circular appearance of the black disc, independent from the angle of solar incidence. This conformal projection property of preserving the circular shape is a property of normal projection from minimal surfaces of zero mean curvature [13].

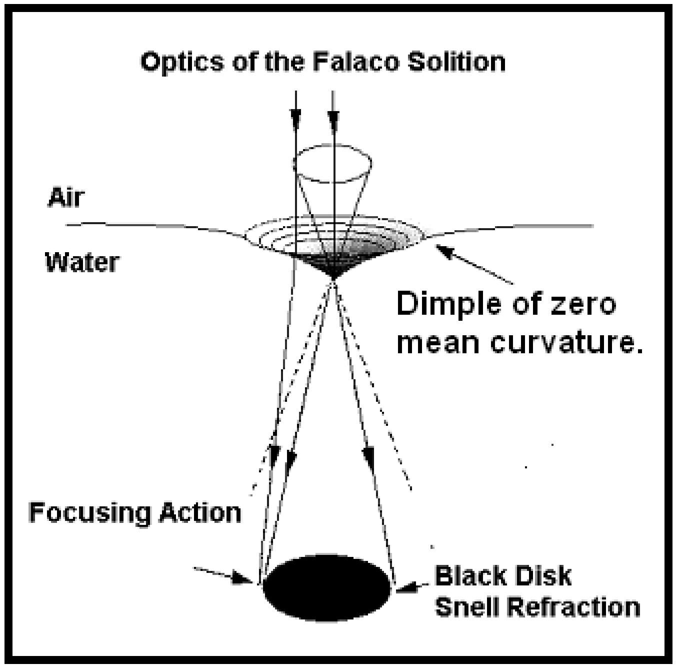

Figure 5. Snell Refraction of a Falaco Soliton surface defect.

As mentioned above, a feature of the Falaco Soliton [4] (that is not immediately obvious) is that it consists of a *pair* of two dimensional topological defects, in a surface of fluid discontinuity, which are *connected* by means of a topological singular thread.

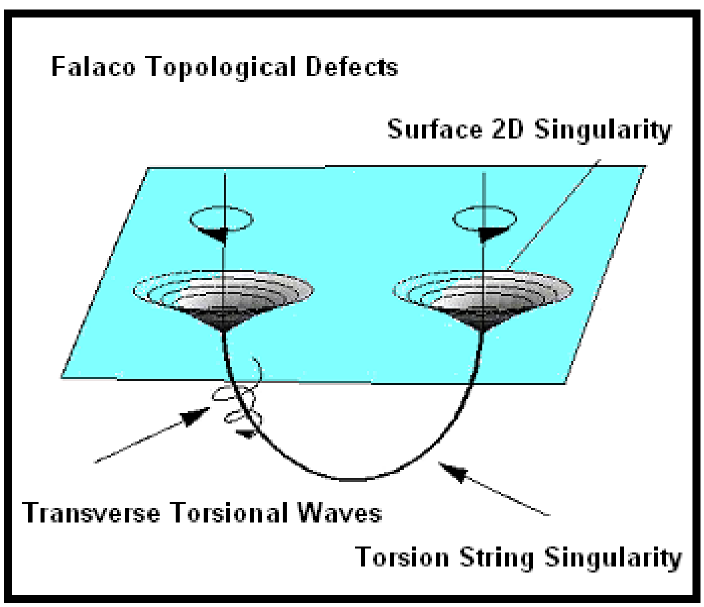

Figure 6. Falaco Topological Defects with connecting thread.

Dye injection near an axis of rotation during the formative stages of the Falaco Soliton indicates that there is a unseen thread, or 1-dimensional string singularity, in the form of a circular arc that connects the two 2-dimensional surface singularities or dimples. Transverse Torsional waves made visible by dye streaks (caused by dye drops injected near one of the surface rotation axes) can be observed to propagate, back and forth, from one dimple vertex to the other dimple vertex, guided by the "string" singularity. The effect is remindful of the whistler propagation of electrons along the guiding center of the earth's pole to pole magnetic field lines. However, as a soliton, the topological system retains its coherence for remarkably long time - more than 15 minutes in a still pool. The long lifetime of the Falaco Soliton is conjectured to be due to this *global stabilization* of the connecting string singularity, even though a real surface of zero mean curvature is locally unstable. The Falaco Soliton starts out from a non-equilibrium thermodynamic state of Pfaff topological dimension 4, which quickly and irreversibly decays to a "topologically stationary" state, still far from equilibrium, but with a long dynamic lifetime [14] [15].

As mentioned above, the dimpled surface pairs of the Falaco Soliton are most easily observed in terms of the dramatic black discs that they create by projection of the solar rays to the bottom of the pool. The optics of this effect are described in Figure 5. Careful examination of the photo of Figure 1 will indicate, by accidents of noticeable contrast and reflection, the region of the dimpled surface of circular rotation. The dimples appear as (deformed) artifacts to the left of each black spot, and elevated above the horizontal plane by about 25 degrees (as the photo was taken in late afternoon). Also, notice that the vestiges of caustic spiral arms in the surface structures around each pair of rotation axes can be seen in the photo. These surface spiral arms can be visually enhanced by spreading chalk dust on the free surface of the pool. The bulk fluid motion is a local (non-rigid body) rotational motion about the interconnecting circular thread. In the photos of Figure 1 and Figure 2, the depth of each of the actual indentations of the free surface is, at most, of a few millimeters in extent.

A better photo, shown in Figure 7, also was taken by D. Radabaugh, but in the year 2004 in a swimming pool in Mazan, France. The photo demonstrates more clearly the dimpled surface defects, and the Snell refraction. The sun is to the left and at an elevation of about 30 degrees.

Figure 7. Surface Indentations of a Falaco Soliton

The photo is in effect a single frame of a digital movie that demonstrates the creation and evolutionary motions of the Falaco Solitons. The experimental details of creating the Falaco Solitons are described below, but the movie explains their creation and dynamics far better than words. The digital movie may be downloaded from [12].

Remark 4 *It is possible to produce, hydrodynamically, in a viscous fluid with a surface of discontinuity, a long lived topologically coherent structure that consists of a set of macroscopic topological defects. The Falaco Solitons are representative of non-equilibrium long lived structures, or "stationary states", far from equilibrium.*

These observations were first reported at the 1987 Dynamics Days conference in Austin, Texas [4] and subsequently in many other places, mostly in the hydrodynamic literature [5], [6], [9], [11], as well as several APS meetings.

2.2 Spinors, Zero Mean curvature and Harmonic vector fields

The long lifetime and the topological coherence stability of the Falaco Solitons in a dissipative fluid media is not only remarkable, but also is a matter of applied theoretical interest. The equilibrium discontinuity surface of the fluid in the "uniform" gravitational field is flat, and has both zero mean curvature and zero Gauss curvature. The long life of the soliton state in the presence of a viscous (Navier-Stokes) media indicates that the flow vector field describing the dynamics is probably harmonic. This result is in agreement with the assumption that the fluid can be represented by a Navier-Stokes equation where the viscous dissipation is dominated by affine shear viscosity times the vector Laplacian of the velocity field. If the velocity field is harmonic, the vector Laplacian vanishes, and the shear dissipation term goes to zero - no matter what is the magnitude of the shear viscosity term. Hence a palatable argument is offered in terms of harmonic velocity fields for the existence of the long lifetime of the Falaco Solitons (as well as the production of wakes in fluid dynamics [16]). More over it is known in the theory of minimal surfaces [3] that surfaces of zero mean curvature are generated by Spinors, and that they are related to Harmonic vector fields.

Remark 5 *The idea of a long lifetime in a dissipative media is to be associated with Harmonic vector fields and surfaces of zero mean curvature generated by Spinors.*

These, long-lived topologically coherent objects, dubbed Falaco Solitons (see Section 2 above), have several features equivalent to those reported for models of the sub-microscopic hadron. String theorists take note, for the structure consists of a pair of topological 2-dimensional locally unstable rotational defects in a surface of discontinuity, globally connected and stabilized globally in the fluid by a 1 dimensional topological defect or string with tension. (In Euclidean space, the surface defects are of negative Gauss curvature, and are, therefor, locally unstable.) As mentioned above the experimental equilibrium state is a surface of zero Gauss curvature. However, it is conjectured that the local instability is overcome globally by a string whose tension globally stabilizes the locally unstable endcaps. These observational conjectures were explained partially in terms of a bifurcation process and solutions to the Navier-Stokes equations in a rotating frame of reference [8]. Now, it appears that a better description would be in terms of a fluid with a Minkowski metric signature.

The reader must remember that the Falaco Soliton is a topological object that can and will appear at all scales, from the microscopic, to the macroscopic, from the sub-submicroscopic world of strings connection branes, to the cosmological level of spiral arm galaxies connected by threads. At the microscopic level, the method offers a view of forming spin pairs that is different from Cooper pairs and could offer insight into Superconductivity. At the level of Cosmology, the concept of Falaco Solitons could lead to explanations of the formation of flat spiral arm galaxies. At the submicroscopic level, the Falaco Solitons mimic quarks on a string. At the macroscopic level, some of the topological features of the Falaco Solitons can be found in solutions to the Navier-Stokes equations in a *rotating* frame of reference. Under deformation of the discontinuity surface to a flattened ball, the visual correspondence to hurricane structures between the earth surface and the tropopause is remarkable. In short, the concept of Falaco Solitons is a universal topological phenomena.

2.3 The Experiment

The Falaco Soliton phenomena is easily reproduced (on a bright sunny day) by placing a large circular disc, such as dinner plate, vertically into a still swimming pool until the plate is half submerged and its oblate axis resides in the water-air free surface. Then move the plate slowly in the direction of its oblate axis. At the end of the stroke, smoothly extract the plate (with reasonable speed) from the water, imparting kinetic energy and distributed angular momentum to the fluid. Initially, the dynamical motion of the edges of the plate will create a pair of vortex structures in the free surface of the water (a density discontinuity which can also be mimicked by salt concentrations). If these vortex structures were Rankine vortices of opposite rotation, they would cause the initially flat surface of discontinuity to form a pair of parabolic concave indentations of positive Gauss curvature, indicative of the approximate "rigid body" rotation of a pair of contra-rotating vortex cores of uniform vorticity. However, in a few seconds the vortex surface depressions will decay into a pair of convex dimples of zero mean curvature. Associated with the evolution is a visible set of spiral arm caustics, As the convex dimples form, the surface effects can be observed in bright sunlight via their Snell projections as large black spots on the bottom of the pool. In a few tries you will become an expert experimentalist, for the drifting spots are easily created and, surprisingly, will persist for many minutes in a still pool. The dimpled depressions are typically of the order of a few millimeters in depth, but the zone of circulation typically extends over a disc of some 10 to 30 centimeters or more, depending on the plate diameter. This configuration, or coherent topological defect structure, has been defined as the Falaco Soliton. For purposes of illustration , the vertical depression has been greatly exaggerated in Figures 3 and 4.

If a thin broom handle or a rod is placed vertically in the pool, and the Falaco soliton pair is directed in its translation motion to intercept the rod symmetrically, as the soliton pair comes within range of the scattering center, or rod, (the range is approximately the separation distance of the two rotation centers) the large black spots at first shimmer and then disappear. Then a short time later, after the soliton has passed beyond the interaction range of the scattering center, the large black spots coherently reappear, mimicking the numerical simulations of soliton coherent scattering. For hydrodynamics, this observation firmly cements the idea that these objects are truly coherent "Soliton" structures. This is the only (known to this author) macroscopic visual experiment that demonstrates these coherence features of soliton scattering in numerical studies.

If the string connecting the two endcaps is sharply "severed", the confined, two dimensional endcap singularities do not diffuse away, but instead disappear almost explosively. It is this observation that leads to the statement that the Falaco soliton is the macroscopic topological equivalent of the illusive hadron in elementary particle theory. The two 2-dimensional surface defects (the quarks) are bound together by a string of confinement, and cannot be isolated. The dynamics of such a coherent structure is extraordinary, for it is a system that is globally stabilized by the presence of the connecting 1-dimensional string.

3 Summary

Falaco Solitons appear to be experimental artifacts of Spinor generated minimal surfaces in a 3D-space constrained by a non-Euclidean metric signature. Intransitive rotational dynamics transcends the dogma that Physical 3D space must be Euclidean.

Maple programs demonstrating Spinor generated surfaces of zero mean curvature can be found at

http://www22.pair.com/csdc/pdf/3dspinors.pdf

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4 About the Author

Professor R. M. Kiehn, B.Sc. 1950, Ph.D. 1953, Physics, Course VIII, MIT, started his career working (during the summers) at MIT, and then at the Argonne National Laboratory on the Navy's nuclear powered submarine project. Argonne was near his parents home in the then small suburban community known as Elmhurst, Illinois. At Argonne, Dr. Kiehn was given the opportunity to do nuclear experiments using Fermi's original reactor, CP1. The experience stimulated an interest in the development of nuclear energy. After receiving the Ph. D. degree in physics as the Gulf Oil Fellow at MIT, Dr. Kiehn went to work at Los Alamos, with the goal of designing and building a plutonium powered fast breeder reactor, a reactor that would produce more fissionable fuel then it consumed. He was instrumental in the design and operation of LAMPRE, the Los Alamos Molten Plutonium Reactor Experiment. He also became involved with diagnostic experiments on nuclear explosions, both in Nevada on shot towers above ground, and in the Pacific from a flying laboratory built into a KC-135 jet tanker. He is one of the diminishing number of people still alive who have witnessed atmospheric nuclear explosions.

Dr. Kiehn has written patents that range from AC ionization chambers, plutonium breeder reactor power plants, to dual polarized ring lasers and down-hole oil exploration instruments. He is active, at present, in creating new devices and processes, from the nanometer world to the macroscopic world, which utilize the features of Non Equilibrium Systems and Irreversible Processes, from the perspective of Continuous Topological Evolution.

Dr. Kiehn left Los Alamos in 1963 to become a professor of physics at the University of Houston. He lived about 100 miles from Houston on his Pecan Orchard - Charolais Cattle ranch on the banks of the San Marcos river near San Antonio. As a pilot, he would commute to Houston, and his classroom responsibilities, in his Cessna 172 aircraft. He was known as the "flying professor".

He is now retired, as an "emeritus" professor of physics, and lives in a small villa at the base of Mount Ventoux in the Provence region of southeastern France. He maintains at active scientific website at

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