The Universal Effectiveness of Topological Thermodynamics

From the point of view of Continuous Topological Evolution

R. M. Kiehn

University of Houston

www.cartan.pair.com

The Universal Effectiveness of Topological Thermodynamics

I am an (old) applied engineering physicist, self taught in topology, and a devotee of E. Cartan.

The Universal Effectiveness of Topological Thermodynamics

I am an (old) applied engineering physicist, self taught in topology, and a devotee of E. Cartan.

My presentation is somewhat low-key to an audience of topologists, but remember, I interact with engineers and scientists that have a limited (if any) training in topology.

The Universal Effectiveness of Topological Thermodynamics

Almost all of my engineering audience has experience with thermodynamics. I find it to be the universal theory.

The Universal Effectiveness of Topological Thermodynamics

Almost all of my engineering audience has experience with thermodynamics. I find it to be the universal theory.

Long ago (1964) I rejected any attempts to describe the dynamics of irreversible processes in terms of equivalence classes of geometric diffeomorphisms (tensors).

The Universal Effectiveness of Topological Thermodynamics

Almost all of my engineering audience has experience with thermodynamics. I find it to be the universal theory.

Long ago (1964) I rejected any attempts to describe the dynamics of irreversible processes in terms of equivalence classes of geometric diffeomorphisms (tensors).

Early on, I concluded that **topological change** is a necessary condition for thermodynamic irreversibility.

The Universal Effectiveness of Topological Thermodynamics

It now appears that the topological perspective of thermodynamics gives universal insight into many non-equilibrium concepts associated with the emergence of metastable states, digital topology, plasmas and turbulent flows, biology, chemistry, metallurgy, fuzzy logic, holography and even the cognitive sciences.

The Universal Effectiveness of Topological Thermodynamics

I suggest that those fluent in topology have a lot to offer to the practical world. A topological perspective gives a formal, non-phenomenological, foundation for understanding physical systems and non-equilibrium processes.

The Universal Effectiveness of Topological Thermodynamics

I suggest that those fluent in topology have a lot to offer to the practical world. A topological perspective gives a formal, non-phenomenological, foundation for understanding physical systems and non-equilibrium processes.

As I told my students, there are two motivations and opportunities for such a discipline:

WNP or EBB

The Universal Effectiveness of Topological Thermodynamics

WNP = Win Nobel Prize

The Universal Effectiveness of Topological Thermodynamics

WNP = Win Nobel Prize

EBB = Earn Big Bucks ($)

Fundamental Ideas

A Thermodynamic system can be encoded in terms of an exterior differentiable 1-form of Action, **A**, per unit "mole".

Fundamental Ideas

A Thermodynamic system can be encoded in terms of an exterior differentiable 1-form of Action, **A**, per unit "mole".

A Thermodynamic Process can encoded by an ordered array (a vector) of functions that form the coefficients , **J**, of an N-1=3-form Current.

Fundamental Ideas

Topological Thermodynamics is defined in terms of **exterior differential forms** evaluated on ordered classes of differential varieties {x,y,z,t; dx,dy,dz,dt}.

Fundamental Ideas

Topological Thermodynamics is defined in terms of **exterior differential forms** evaluated on ordered classes of differential varieties {x,y,z,t; dx,dy,dz,dt}.

The **ordered class** is defined in terms of C1 maps,

ϕ, $d\phi$

from $\{x^k, d\,x^k\}$ to $\{y^k, d\,y^k\}$

These maps are not diffeomorphisms, and do not require the geometric constraints of an inverse,

for either ϕ, or $d\phi$.

Fundamental Ideas

The formal Topological structure of a universal theory of Thermodynamics based on Exterior Differential forms

is a

Kolmogorov T_0 Topology

Formally, this topology is quite interesting for many demonstrable reasons. All of the singletons of the topology are not closed. **Warning**: *the Kolmogorov topology is NOT a metric topology, NOT a Hausdorff topology, and even does NOT satisfy the separation axioms that define a T_1 topology*

Kolmogorov Topology T_0 of 4 points

Table 1. **The CT4 Topology of 4 points**

$X = \{a, b, c, d\}$

Basis subsets $\{a\}, \{a, b\}, \{c\}, \{c, d\}$

$CT4\{open\} : \varnothing, \{a\}, \{c\}, \{a, b\}, \{c, d\}, \{a, c\}, \{a, b, c\}, \{a, c, d\}, X$

$CT4\{closed\} : X, \{b, c, d\}, \{a, b, d\}, \{c, d\}, \{a, b\}, \{b, d\}, \{d\}, \{b\}, \varnothing$

Subset S	Limit Pts	Interior-Exterior		Boundary	Closure
$\varnothing$ *	$\varnothing$	$\varnothing$	X	$\varnothing$	$\varnothing$
$\{a\}$	$\{b\}$	$\{a\}$	$\{c, d\}$	$\{b\}$	$\{a, b\}$
$\{b\}$	$\varnothing$	$\varnothing$	$\{a, c, d\}$	$\{b\}$	$\{b\}$
$\{c\}$	$\{d\}$	$\{c\}$	$\{a, b\}$	$\{d\}$	$\{c, d\}$
$\{d\}$	$\varnothing$	$\varnothing$	$\{a, b, c\}$	$\{d\}$	$\{d\}$
$\{a, b\}$*	$\{b\}$	$\{a, b\}$	$\{c, d\}$	$\varnothing$	$\{a, b\}$
$\{a, c\}$	$\{b\}, \{d\}$	$\{a, c\}$	$\varnothing$	$\{b, d\}$	X
$\{a, d\}$	$\{b\}$	$\{a\}$	$\{c\}$	$\{b, d\}$	$\{a, b, d\}$
$\{b, c\}$	$\{d\}$	$\{c\}$	$\{a\}$	$\{b, d\}$	$\{b, c, d\}$
$\{b, d\}$	$\varnothing$	$\varnothing$	$\{a, c\}$	$\{b, d\}$	$\{b, d\}$
$\{c, d\}$*	$\{d\}$	$\{c, d\}$	$\{a, b\}$	$\varnothing$	$\{c, d\}$
$\{a, b, c\}$	$\{b\}, \{d\}$	$\{a, b, c\}$	$\varnothing$	$\{d\}$	X
$\{b, c, d\}$	$\{d\}$	$\{c, d\}$	$\{a\}$	$\{b\}$	$\{b, c, d\}$
$\{a, c, d\}$	$\{b\}, \{d\}$	$\{a, c, d\}$	$\varnothing$	$\{b\}$	X
$\{a, b, d\}$	$\{b\}$	$\{a, b\}$	$\{c\}$	$\{d\}$	$\{b, c, d\}$
$\{a, b, c, d\}$ *	$\{b\}, \{d\}$	X	$\varnothing$	$\varnothing$	X

Kolmogorov Topology dual T^*_0 of 4 points

Table 2. A DUAL CT4* Topology of 4 points

$X = \{a, b, c, d\}$

Basis subsets $\{b\}, \{a, b\}, \{d\}, \{c, d\}$

Dual $CT4\{open\}$: $X, \{b, c, d\}, \{a, b, d\}, \{c, d\}, \{a, b\}, \{b, d\}, \{d\}, \{b\}, \varnothing$

Dual $CT4\{closed\}$: $\varnothing, \{a\}, \{c\}, \{a, b\}, \{c, d\}, \{a, c\}, \{a, b, c\}, \{a, c, d\}, X$

Subset S	Limit Pts	Interior-Exterior		Boundary	Closure
$\varnothing$ *	$\varnothing$	$\varnothing$	X	$\varnothing$	$\varnothing$
$\{a\}$	$\varnothing$	$\varnothing$	$\{b, c, d\}$	$\{a\}$	$\{a\}$
$\{b\}$	$\{a\}$	$\{b\}$	$\{c, d\}$	$\{a\}$	$\{a, b\}$
$\{c\}$	$\varnothing$	$\varnothing$	$\{a, b, d\}$	$\{c\}$	$\{c\}$
$\{d\}$	$\{c\}$	$\{d\}$	$\{a, b\}$	$\{c\}$	$\{c, d\}$
$\{a, b\}$*	$\{a\}$	$\{a, b\}$	$\{c, d\}$	$\varnothing$	$\{a, b\}$
$\{a, c\}$	$\varnothing$	$\varnothing$	$\{b, d\}$	$\{a, c\}$	$\{a, c\}$
$\{a, d\}$	$\{c\}$	$\{d\}$	$\{b\}$	$\{a, c\}$	$\{a, c, d\}$
$\{b, c\}$	$\{a\}$	$\{b\}$	$\{d\}$	$\{a, c\}$	$\{a, b, c\}$
$\{b, d\}$	$\{a\}, \{c\}$	$\{b, d\}$	$\varnothing$	$\{a, c\}$	X
$\{c, d\}$*	$\{c\}$	$\{c, d\}$	$\{a, b\}$	$\varnothing$	$\{c, d\}$
$\{a, b, c\}$	$\{a\}$	$\{a, b\}$	$\{d\}$	$\{c\}$	$\{a, b, c\}$
$\{b, c, d\}$	$\{a\}, \{c\}$	$\{b, c, d\}$	$\varnothing$	$\{a\}$	X
$\{a, c, d\}$	$\{c\}$	$\{c, d\}$	$\{b\}$	$\{a\}$	$\{a, c, d\}$
$\{a, b, d\}$	$\{a\}, \{c\}$	$\{a, b, d\}$	$\varnothing$	$\{c\}$	X
$\{a, b, c, d\}$	$\{a\}, \{c\}$	X	$\varnothing$	$\varnothing$	X

Alexandroff Topology
T_1 of 4 points

Alexandroff Topology
T_1 of 4 points

The poset of the Kolmogorov topologies, T_0 and T^*_0 ,

$R = T_0 \times T^*_0$

creates the

Discrete Alexandroff T_1 topology of 4 points.

Alexandroff Topology T_1 of 4 points

The poset of the Kolmogorov topologies, T_0 and T^*_0 ,

$R = T_0 \times T^*_0$

creates the

Discrete Alexandroff T_1 topology of 4 points.

T_0 and T^*_0 are the topologies of Continuous Fields

T1 is the topology of Discrete Quanta

Alexandroff Topology
T_1 of 4 points

The DISCRETE Alexandroff T1 topology can be partitioned

into two CONTINUOUS Kolmogorov topologies , T0 and T*0 .

{T1} => {T0 + T*0 }

{Partitioned Particles} => {Interaction Fields}

Continuous Topological Evolution

Let the Topology of initial state be **T1**

Let the Topology of the final state be T2

Continuous Topological Evolution

Let the Topology of initial state be **T1**

Let the Topology of the final state be T2

Topological change is continuous

iff for the map $\varphi: T1 \Rightarrow T2$

The Limit points of T1 are included

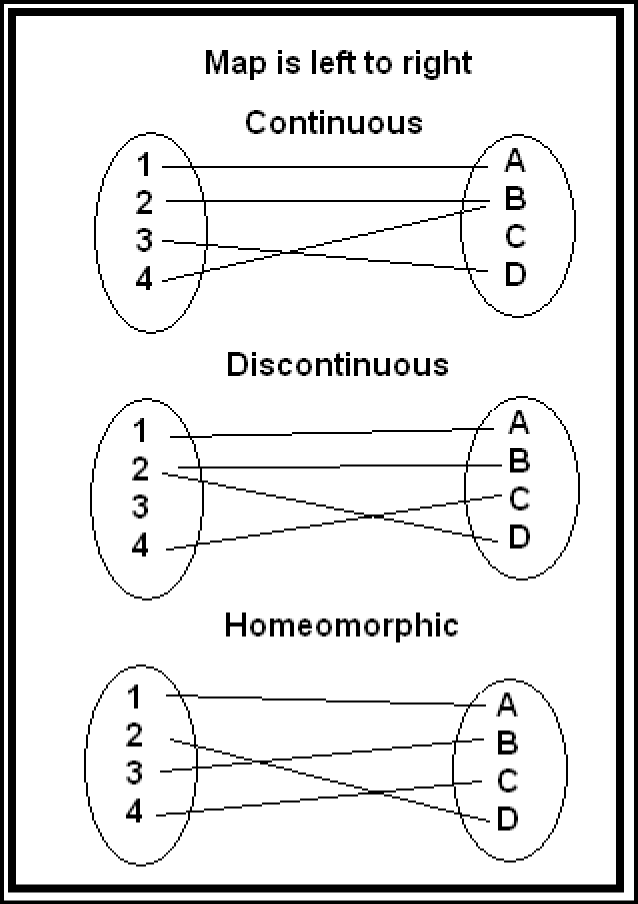
in the Closure of T2

Continuous Topological Evolution

Topological change

Topological change

No Topological change



Cartan's Magic Formula

of Continuous Topological Evolution

Cartan's Magic Formula

of Continuous Topological Evolution

of differential forms

using the

LIE DIFFERENTIAL

of a system 1-form of Action, A,

with respect to a process J

Cartan's Magic Formula

$$L_{(J)} A = i(J)dA + d(i(J)A)$$

Cartan's Magic Formula

$$L_{(J)}A = i(J)dA + d(i(J)A)$$

Change notation to yield

$$L_{(J)}A = W + d(U) = Q$$

W = Work 1-form, U = Internal energy, Q = Heat 1-form

Cartan's Magic Formula

$$L_{(J)} A = i(J)dA + d(i(J)A)$$

Change notation to yield

$$L_{(J)} A = W + d(U) = Q$$

W = Work 1-form, U = Internal energy, Q = Heat 1-form

A UNIVERSAL cohomological formulation of the

FIRST LAW of THERMODYNAMICS!!

Kuratowski's Magic Formula

Relative to a Kolmogorov T0 topology,

the exterior differential is a

Limit Point generator.

Kuratowski's Magic Formula

Relative to a Kolmogorov T0 topology,

the exterior differential is a

Limit Point generator.

For a differential form **Σ**

Limit Points of Σ = dΣ

This result focuses attention on Cohomology

Kolmogorov Topology

The basis of the Kolmogorov Topology is generated by the elements of the Pfaff Sequence of A

Pfaff Sequence :{A,dA,A^dA,dA^dA}

Kolmogorov Topology

The basis of the Kolmogorov Topology is generated by the elements of the Pfaff Sequence of A

Pfaff Sequence :{A,dA,A^dA,dA^dA}

The Closure of A is the union of A and dA.

The Closure of A^dA is the union of A^dA and dA^dA.

Kolmogorov Topology

The basis of the Kolmogorov Topology is generated by the elements of the Pfaff Sequence of A

Pfaff Sequence :{A,dA,A^dA,dA^dA}

The Closure of A is the union of A and dA.

The Closure of A^dA is the union of A^dA and dA^dA.

The basis for the Kolmogorov topology is

Basis: {A, Closure of A, A^dA, Closure of A^dA }.

Continuous Topological Evolution and PTD(A)

can describe the irreversible evolution on an

Open non-equilibrium Symplectic domain, PTD 4, with evolutionary orbits being irreversibly attracted to a

Continuous Topological Evolution and PTD(A)

can describe the irreversible evolution on an

Open non-equilibrium Symplectic domain, PTD 4, with evolutionary orbits being irreversibly attracted to a

Closed non-equilibrium Contact domain, PTD 3, with emergent topological defects (stationary states and coherent structures), and a possible ultimate decay to the

Continuous Topological Evolution and PTD(A)

can describe the irreversible evolution on an

Open non-equilibrium Symplectic domain, PTD 4, with evolutionary orbits being irreversibly attracted to a

Closed non-equilibrium Contact domain, PTD 3, with emergent topological defects (stationary states and coherent structures), and a possible ultimate decay to the

Isolated-Equilibrium Caratheodory (integrable) domain of PTD 2 or less.

Significant Results

1. Topological change is a necessary condition for thermodynamic irreversibility.

Significant Results

1. Topological change is a necessary condition for thermodynamic irreversibility.
2. Continuous non-homeomorphic processes of topological evolution establish a logical basis for thermodynamic irreversibility and the arrow of time without the use of statistics.

Continuous Topological Evolution and PTD(A)

Regions where PTD(A) ≤ 2 generate a connected topology;

PTD(A) ≥ 3 generate a disconnected topology.

Continuous Topological Evolution and PTD(A)

Regions where PTD(A) ≤ 2 generate a connected topology;
PTD(A) ≥ 3 generate a disconnected topology.

Continuous Processes can represent the evolution from a disconnected topology (≥ 3) to a connected topology (≤ 2) .

Continuous Topological Evolution and PTD(A)

Regions where PTD(A) ≤ 2 generate a connected topology;

PTD(A) ≥ 3 generate a disconnected topology.

Continuous Processes can represent the evolution from a disconnected topology (≥ 3) to a connected topology (≤ 2) .

Continuous Processes can NOT represent the evolution from a connected topology (≤ 2) to a disconnected topology (≥ 3) .

Therefore, Connectivity and Continuity determine

A Topological Arrow of Time.

You can describe the decay of turbulence continuously,
but NOT the creation of turbulence.

Significant Results

1. Topological change is a necessary condition for thermodynamic irreversibility.
2. Continuous non-homeomorphic processes of topological evolution establish a logical basis for thermodynamic irreversibility and the arrow of time without the use of statistics.
3. Evolution from a disconnected **KCT_0** topology to a connected topology can be continuous and irreversible, but it is a theorem of topology that a map from a connected topology to a disconnected topology cannot be C2 continuous.

Significant Results

4. C2 Continuous Topological Evolution **permits irreversible processes, for which, Q^dQ≠0**. Segmented C1 processes approximating smooth C2 processes can be **reversible, Q^dQ=0**, while the C2 smooth processes are **irreversible, Q^dQ≠0.**

Significant Results

4. C2 Continuous Topological Evolution **permits irreversible processes, for which, Q^dQ≠0.** Segmented C1 processes approximating smooth C2 processes can be **reversible, Q^dQ=0**, while the C2 smooth processes are **irreversible, Q^dQ=0**.
5. On odd-dimensional spaces, sequential C1 (translational) processes can be thermodynamically reversible, while intransitive C2 processes (rotation and expansion with a fixed point) can be thermodynamically irreversible.

Significant Results

4. C2 Continuous Topological Evolution permits irreversible processes, for which, Q^dQ≠0. Segmented C1 processes approximating smooth C2 processes can be reversible, Q^dQ=0, while the C2 smooth processes are irreversible, Q^dQ=0.
5. On odd-dimensional spaces, sequential C1 (translational) processes can be thermodynamically reversible, while intransitive C2 processes (rotation and expansion with a fixed point) can be thermodynamically irreversible.
6. The Twin Paradox is resolved if the process paths indicate topological change. Otherwise, there is no disparate aging.

Significant Results

7. Adiabatic processes are transverse to the Heat 1-form, $(i(\rho V_4)Q)=0$. Adiabatic processes need not be quasi-static, and can be reversible or irreversible. Topological Transitions can occur in finite (often short) time.

Significant Results

7. Adiabatic processes are transverse to the Heat 1-form, $(i(\rho V_4)Q)=0$. Adiabatic processes need not be quasi-static, and can be reversible or irreversible. Topological Transitions can occur in finite (often short) time.

8. A fundamental difference between Work and Heat is that $\mathbf{i(\rho V_4)W=0}$, always; but it is not true that $\mathbf{i(\rho V_4)Q=0}$, always. The Work 1-form, **W**, is always transverse to the process, $\boldsymbol{\rho V_4}$, but the Heat 1-form, **Q**, may or may not be transverse; the Heat 1-form, **Q** can have longitudinal components in the direction of the process. Such is the subtle topological difference between Work and Heat.

Significant Results

9. For non-equilibrium systems, the 3-form of Topological Torsion (an N-1=3-form current) is not zero:

$$A\wedge dA=i(T_4)dx\wedge dy\wedge dz\wedge dt\neq 0.$$

The Topological Torsion vector, T_4, is deduced intrinsically from the 1-form that encodes the thermodynamic system.

It can be used as a direction field for a process current, ρT_4.

Significant Results

9. For non-equilibrium systems, the 3-form of Topological Torsion (an N-1=3-form current) is not zero:

$$A \wedge dA = i(T_4) dx \wedge dy \wedge dz \wedge dt \neq 0.$$

The Topological Torsion vector, T_4, is deduced intrinsically from the 1-form that encodes the thermodynamic system.

It can be used as a direction field for a process current, ρT_4.

10. For **PTD=3** "closed" thermodynamic systems, the process current has zero divergence, and the 4D volume element is a conformal invariant (any ρ). This result is the space-time extension of the Liouville theorem that preserves the phase-space volume element in classical theory

Significant Results

11. For a **PTD=4** "open" thermodynamic systems, the Topological Torsion vector does not have zero divergence, and so the process current ρT_4 may not be closed for arbitrary ρ (that is, the divergence of the process current is not zero).

Significant Results

11. For a **PTD=4** "open" thermodynamic systems, the Topological Torsion vector does not have zero divergence, and so the process current ρT_4 may not be closed for arbitrary ρ (that is, the divergence of the process current is not zero).

This result is the extension of the Vlasov equation; the 4D differential volume element is expanding or contracting. Such processes in the direction of T_4 are irreversible and dissipative.

Significant Results

12. A major result is that the Kolmogorov-Cartan T_0 topology is a disconnected topology for non-equilibrium systems (**PTD=4,PTD=3**) and is a connected topology for equilibrium systems (**PTD=2,PTD=1**).

Significant Results

12. A major result is that the Kolmogorov-Cartan T_0 topology is a disconnected topology for non-equilibrium systems (**PTD=4**,**PTD=3**) and is a connected topology for equilibrium systems (**PTD=2**,**PTD=1**).

13. A key artifact of non-equilibrium is the existence of

Topological Torsion current 3-forms, $J_{Torsion}$,

Topological Spin current 3-forms, J_{Spin},

Topological Adjoint current 3-forms, $J_{adjoint}$.

3-Form Currents

These 3-forms are similar to the

Ampere current 3-form, J_{Ampere},

BUT

where $d\,J_{Ampere} = 0$, always,

the other current 3-forms are not closed unless they are

homogeneous of degree zero.

3-Form Currents

These 3-forms are similar to the Ampere current 3-form, J_{Ampere},

BUT

where $d\,J_{Ampere} = 0$, always,

the other current 3-forms are not closed unless they are homogeneous of degree zero.

NOTE: Any 3-form admits (many) integrating factors that will make the 3-form homogenous of degree zero.

3-Form Currents

The **Topological Torsion 3-form** is related to **Helicity**,

The **Topological Spin 3-form** is related to **Spin**,

The **Adjoint 3-form** is related to the interaction energy.

3-Form Currents

The **Topological Torsion 3-form** is related to **Helicity**,

The **Topological Spin 3-form** is related to **Spin**,

The **Adjoint 3-form** is related to the interaction energy.

All three are related to different species of dissipative phenomena, which only occur in non-equilibrium systems.

3-Form Currents

The Topological Torsion 3-form is related to **Helicity**,

The Topological Spin 3-form is related to **Spin**,

The Adjoint 3-form is related to the interaction energy.

All three are related to different species of dissipative phenomena, which only occur in non-equilibrium systems.

The dissipation coefficients are related to the non-zero divergences of the vector coefficients of each 3-form.

3-Form Currents

The Topological Torsion 3-form is related to Helicity,
The Topological Spin 3-form is related to Spin,
The Adjoint 3-form is related to the interaction energy.

All three are related to different species of dissipative phenomena, which only occur in non-equilibrium systems.

The dissipation coefficients are related to the non-zero divergences of the vector coefficients of each 3-form.

For example, in electromagnetic systems, the dissipation coefficient is proportional to **E○B**; in hydrodynamics, the dissipation coefficient is called "**Bulk viscosity**".

Significant Results

14. Examples of thermodynamic systems can be given to demonstrate that the conjectured format of the London Current of superconductivity, where **$J=\chi A$,** can be deduced as an emergent consequence of the Topological Theory of Thermodynamics

Significant Results

14. Examples of thermodynamic systems can be given to demonstrate that the conjectured format of the London Current of superconductivity, where $J=\chi A$, can be deduced as an emergent consequence of the Topological Theory of Thermodynamics

15 Examples can generate a Spin Current 3-form, **S**, where, formally, the Spin current is proportional to the Lorentz force (the space-time components of the Work 1-form, **W**).

Significant Results

14. Examples of thermodynamic systems can be given to demonstrate that the conjectured format of the London Current of superconductivity, where $J=\chi A$, can be deduced as an emergent consequence of the Topological Theory of Thermodynamics

15 Examples can generate a Spin Current 3-form, where, formally, the Spin current is proportional to the Lorentz force (the space-time components of the Work 1-form, W).

This is a new interpretation of an old result, **$J=\sigma(E+V\times B)$,** which is Ohm's law. The new part is due to the idea that the dissipation is due to Spin Currents and the transport of collective spins, **$A\wedge G$**.

Significant Results

16. In the **PTD=4** case, there exist density distributions, ρ, such that the divergence of the process current is zero.

Significant Results

16. In the **PTD=4** case, there exist density distributions, ρ, such that the divergence of the process current is zero.

There exist an infinite number of such integrating factors, that define "stationary states" far from equilibrium.

Significant Results

16. In the PTD=4 case, there exist density distributions, ρ, such that the divergence of the process current is zero.

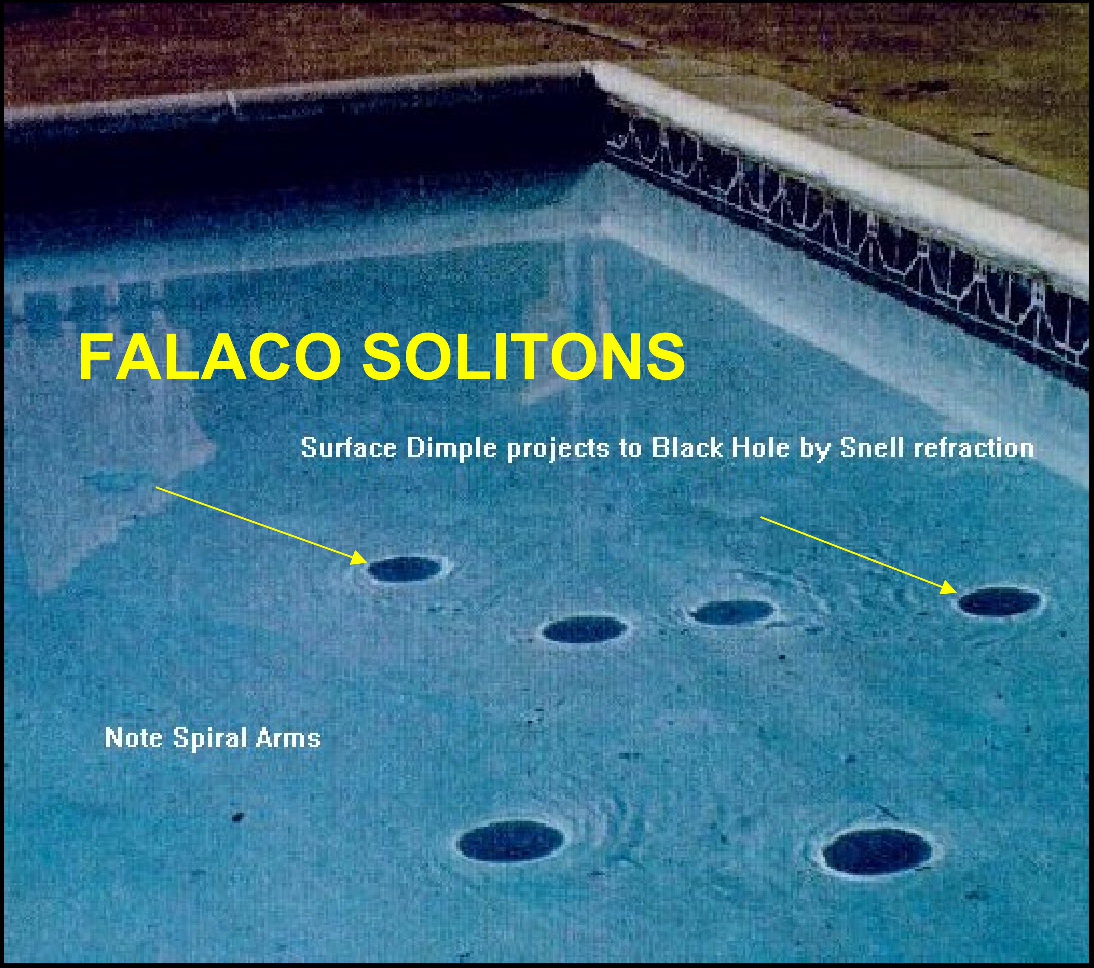
There exist an infinite number of such integrating factors, that define "stationary states" far from equilibrium.

It can be demonstrated in terms of continuous topological evolution that a density distribution which defines a "stationary" state can

emerge as a topological defect

in a PTD=4 system, by means of a dissipative processes.

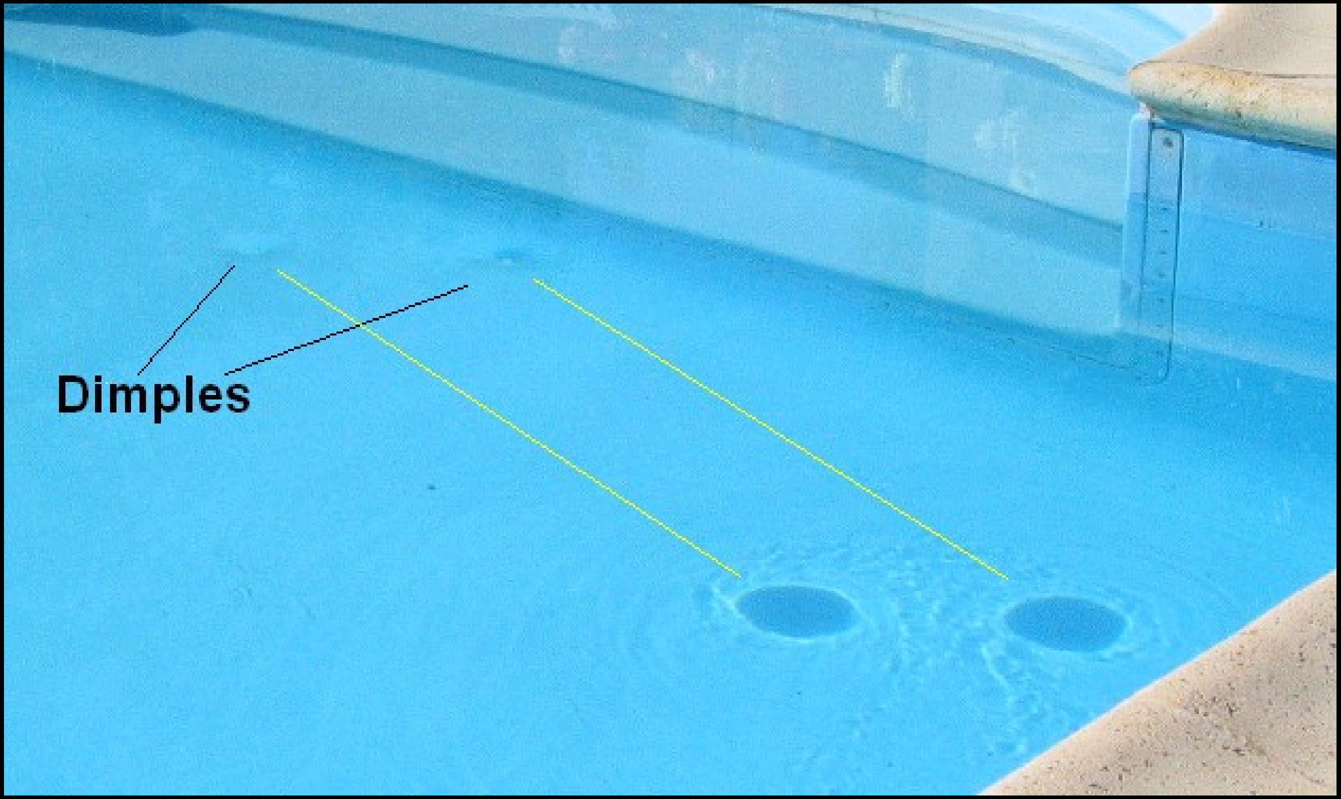
Emergence of Topological Defects



Long Lived Topological Defects in a Swimming Pool

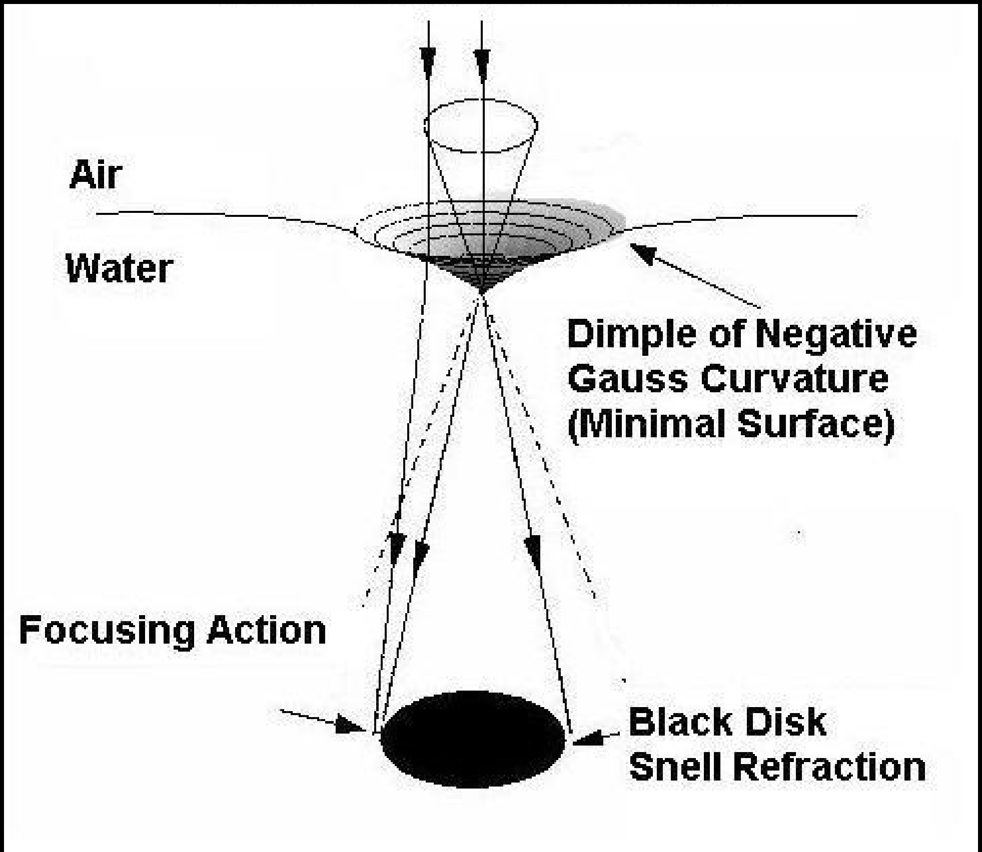
Emergence of Topological Defects

FALACO SOLITONS Movie by D. Radabaugh



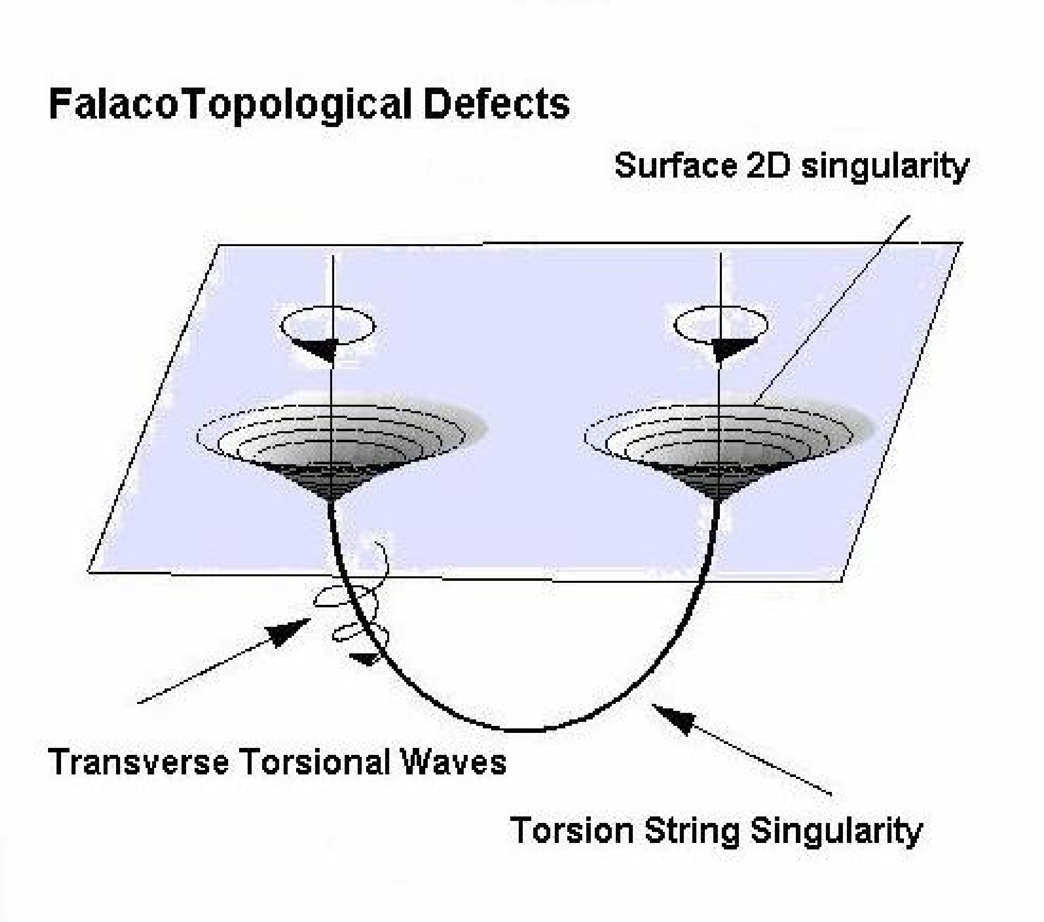
Solar Elevation about 30 degrees (See movie at http://www22.pair.com/csdc/download/spotsmovie.avi

Emergence of Topological Defects



Snell refraction of Falaco Soliton Spin Pairs

Emergence of Topological Defects



The first measurableTorsion String coupling between branes

This real world effect has been ignored by string theorists !!!

Significant Results

16. In the PTD=4 case, there exist density distributions, ρ, such that the divergence of the process current is zero.

There exist an infinite number of such integrating factors, that define "stationary states" far from equilibrium.

It can be demonstrated in terms of continuous topological evolution that a density distribution which defines a "stationary" state can emerge as a topological defect in a PTD=4 system, by means of a dissipative processes.

Such a result gives formal credence to Prigogine's conjectures.

Significant Results

17. The topological structure of domains of **PTD=3**, or more, creates a disconnected topology of multiple components. If solutions to a particular evolutionary problem exist, then the solutions are not unique.

Significant Results

17. The topological structure of domains of **PTD=3**, or more, creates a disconnected topology of multiple components. If solutions to a particular evolutionary problem exist, then the solutions are not unique.

    A **PTD>2** non-equilibrium thermodynamic system always has a non-zero Topological Torsion 3-form.

Significant Results

17. The topological structure of domains of **PTD=3**, or more, creates a disconnected topology of multiple components. If solutions to a particular evolutionary problem exist, then the solutions are not unique.

A **PTD>2** non-equilibrium thermodynamic system always has a non-zero Topological Torsion 3-form, **A^F**.

Envelope solutions, such as Huygen wavelets and propagating tangential discontinuities (called signals, or wakes) are classic examples of solution non-uniqueness. Topological Torsion is an artifact of non-uniqueness, and of Turbulence.

Significant Results

18. All Hamiltonian, Symplectic-Bernoulli and Helmholtz processes are thermodynamically reversible. In particular, the work 1-form, **W**, created by Hamiltonian processes is of Pfaff Topological Dimension 1 or less. In all reversible cases the Work 1-form is closed, **dW=0**.

Significant Results

18. All Hamiltonian, Symplectic-Bernoulli and Helmholtz processes are thermodynamically reversible. In particular, the work 1-form, W, created by Hamiltonian processes is of Pfaff Topological Dimension 1 or less. In all reversible cases the Work 1-form is closed, dW=0.

19. The assumption of uniqueness of evolutionary solutions (which implies the Pfaff Topological Dimension of the thermodynamic system be equal to 2 or less), or the assumption of homeomorphic evolution, have imposed constraints upon classical mechanics that eliminate any time asymmetry.

Significant Results

20. The Lie differential acting on differential forms is not necessarily the same as a linear affine covariant differential acting on tensors. If the process is locally adiabatic (no heat flow in the direction of the evolutionary process), then the Lie differential and the covariant differential can be made to coincide, as they both satisfy the Koszul axioms for an affine connection.

Significant Results

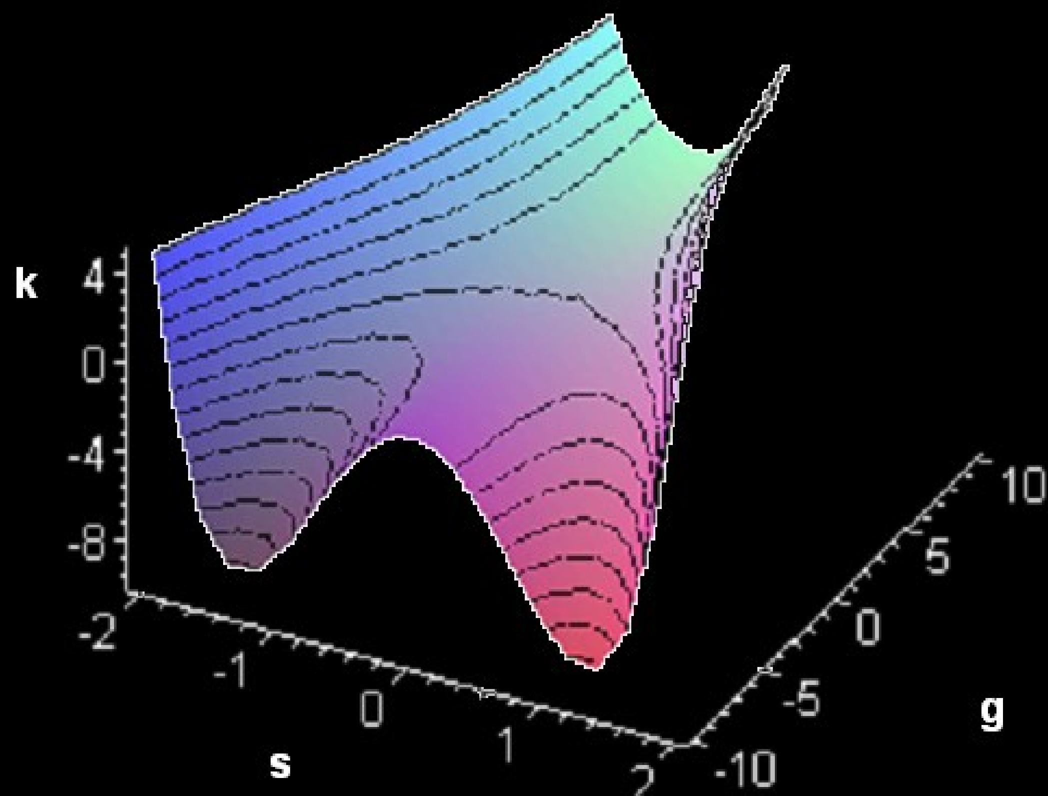
20. The Lie differential acting on differential forms is not necessarily the same as a linear affine covariant differential acting on tensors. If the process is locally adiabatic (no heat flow in the direction of the evolutionary process), then the Lie differential and the covariant differential can be made to coincide, as they both satisfy the Koszul axioms for an affine connection.

This is a surprising result, for, when the argument is reversed, the theorem implies that the ubiquitous affine covariant differential of tensor analysis, acting on a 1-form of Action, can always be cast into a form representing an adiabatic process. **Warning**: Restrictions of processes which satisfy the constraints of tensor analysis, and use an affine integrable connection to define the Covariant derivative, **are always adiabatic.**

Significant Results

21. On spaces of PTD=4, the Jacobian of the components of the 1-form of Action, A, define a correlation matrix, which has a characteristic polynomial that defines an equation of state in terms of Cayley-Hamilton similarity invariants.

Universal Topological Thermodynamic Phase Function



A van der Waals gas with a Higgs potential,

An Envelope of a 4D Cayley-Hamilton characteristic polynomial

Universal Topological Thermodynamic Phase Function

The 4D universal topological phase function can be used to explain **Spinodal Decomposition**, and give a topological in-site into the Gibbs coexistent phase formula.

Universal Topological Thermodynamic Phase Function

The 4D universal topological phase function can be used to explain **Spinodal Decomposition**, and give a topological in-site into the Gibbs coexistent phase formula.

The 4D universal topological phase function also can be used in dimensions greater than 4 in order to represent **multi-component potentials** in Chemistry Reactions. The results then can be pulled back to the 4D differential variety of measurement.

Significant Results

21. On spaces of PTD=4, the Jacobian of the components of the 1-form of Action, A, define a correlation matrix, which has a characteristic polynomial that defines an equation of state in terms of Cayley-Hamilton similarity invariants.

The Cayley-Hamilton theorem produces an implicit hypersurface function that can have envelopes and edges of regression in the format of the Gibbs function for a (universal and deformable) van der Waals gas.

Significant Results

21. On spaces of PTD=4, the Jacobian of the components of the 1-form of Action, A, define a correlation matrix, which has a characteristic polynomial that defines an equation of state in terms of Cayley-Hamilton similarity invariants.

The Cayley-Hamilton theorem produces an implicit hypersurface function that can have envelopes and edges of regression in the format of the Gibbs function for a (universal and deformable) van der Waals gas.

The method yields analytic expressions for the critical point, and the binodal and spinodal lines, in terms of the similarity invariants. The same technique can be applied to dynamical systems.

Significant Results

22. Cartan's Magic formula, in terms of the Lie differential acting on exterior differential 1-forms, establishes the long sought for combination of dynamics and thermodynamics, enabling non-equilibrium systems and many irreversible processes to be computed in terms of continuous topological evolution, without resort to probability theory and statistics.

Significant Results

21. Cartan's Magic formula, in terms of the Lie differential acting on exterior differential 1-forms, establishes the long sought for combination of dynamics and thermodynamics, enabling non-equilibrium systems and many irreversible processes to be computed in terms of continuous topological evolution, without resort to probability theory and statistics.

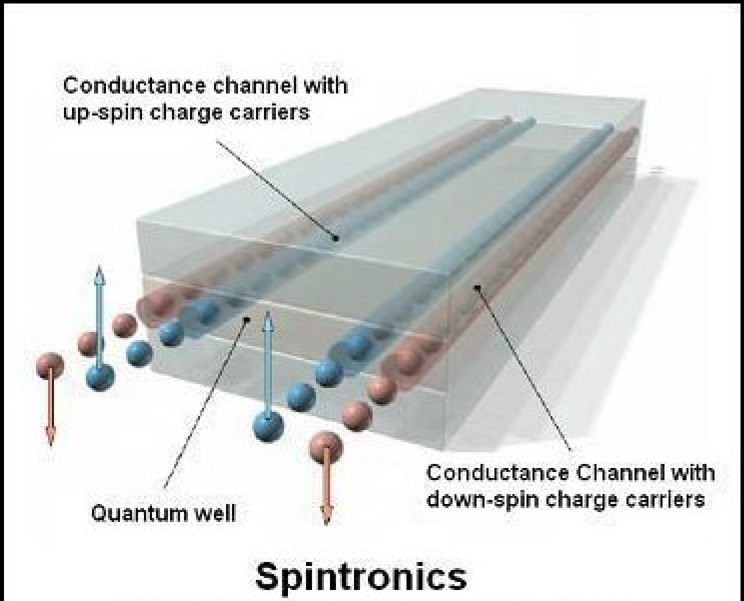
23. **Topological fluctuations** can be induced by processes that have components in terms of thermodynamic macroscopic Spinors. Thermodynamic **Macroscopic Spinors** are non-zero complex eigenvectors with complex eigenvalues (and zero quadratic form) of the antisymmetric 2-form (or matrix) representing the "Limit Points", dA, of the 1-form of Action, A. Such Macroscopic Spinors are capable of representing minimal surface conjugate pairs.

Significant Results

24. **Topological Insulators** correspond to Impedances defined in terms of quantized Topological Spin, and Spin pairs coupled via Falaco Solitons. If the divergence of the Spin 4vector vanishes, the **Spin Current** is time reversal invariant.

Significant Results

24. **Topological Insulators** correspond to Impedances defined in terms of quantized Topological Spin, and Spin pairs coupled via Falaco Solitons. If the divergence of the Spin 4vector vanishes, the **Spin Current** is time reversal invariant.



Picture with permission of Shoucheng Zhang

Significant Results

24. Topological Insulators correspond to Impedances defined in terms of quantized Topological Spin, and Spin pairs coupled via Falaco Solitons. If the divergence of the Spin 4vector vanishes, the Spin Current is time reversal invariant.

25. The fact that any synergetic system of parts in effect defines a topology implies that the universal method of topological thermodynamics is **applicable to economic systems, political systems, as well as to biological systems**. Such systems admit long-lived states far from equilibrium (adulthood). However, the theory can be used to design subtle perturbations to such systems such that their metastable lifetimes can be extended or destroyed.

Significant Results

26. The thermodynamic processes that lead to self-similarity of a Current 3-form $L_{(J)}C=\sigma C$ can generate **fractals** and **holographic** effects where small neighborhoods replicate the whole, approximately. The homogeneity coefficient is the trace of the Jacobian Collineation: $\sigma = \mathrm{Trace}[\partial C^m/\partial x^n]$, or the divergence of the Process vector field.

Significant Results

26. The thermodynamic processes that lead to self-similarity of a Current 3-form $\mathbf{L_{(J)}C=\sigma\ C}$ can generate fractals and holographic effects where small neighborhoods replicate the whole, approximately. The homogeneity coefficient is the trace of the Jacobian Collineation: $\boldsymbol{\sigma = \mathrm{Trace}[\partial C^m/\partial x^n]}$, or the divergence of the Process vector field.

27. A turbulent thermodynamic **cosmology** can be constructed in terms of a dilute **non-equilibrium van der Waals** gas near its critical point.

Significant Results

26. The thermodynamic processes that lead to self-similarity of a Current 3-form $\mathbf{L_{(J)}C=\sigma\ C}$ can generate fractals and holographic effects where small neighborhoods replicate the whole, approximately. The homogeneity coefficient is the trace of the Jacobian Collineation: $\boldsymbol{\sigma = \mathrm{Trace}[\partial C^m/\partial x^n]}$**,** or the divergence of the Process vector field.

27. A turbulent thermodynamic **cosmology** can be constructed in terms of a dilute **non-equilibrium van der Waals gas** near its critical point.

Cosmology in terms of a non-equilibrium Van der Waals Gas explains

Cosmology as a non-equilibrium Van der Waals Gas explains

a.) The granularity of the night sky as exhibited by stars and galaxies due to density fluctuations near the critical point, and the Newtonian law of gravitational attraction proportional to $1/r^2$ as a correlation between fluctuations (due to Lev Landau).

Cosmology as a non-equilibrium Van der Waals Gas explains

a.) The granularity of the night sky as exhibited by stars and galaxies due to density fluctuations near the critical point, and the Newtonian law of gravitational attraction proportional to $1/r^2$ as a correlation between fluctuations (due to Lev Landau).

b.) The conformal expansion of the universe s an irreversible phenomenon-associated with Quartic similarity invariants in the thermodynamic phase function, and conformally related to dissipative effects .

Cosmology as a non-equilibrium Van der Waals Gas explains

a.) The granularity of the night sky as exhibited by stars and galaxies due to density fluctuations near the critical point, and the Newtonian law of gravitational attraction proportional to $1/r^2$ as a correlation between fluctuations (due to Lev Landau).

b.) The conformal expansion of the universe s an irreversible phenomenon-associated with Quartic similarity invariants in the thermodynamic phase function, and conformally related to dissipative effects .

c.) The possibility of domains of negative pressure (explaining what has recently been called "**dark energy**") are due to a classical "Higgs" mechanism for aggregates below the critical temperature.

Cosmology as a non-equilibrium Van der Waals Gas explains

d.) The possibility of domains of negative temperature (explaining what has recently been called "**dark matter**") are due to macroscopic collective states of ordered spins. The conjecture is that **Positive temperature radiates, Negative temperature does not**. The conjecture is that black holes could be negative temperature states of collective spins.

Cosmology as a non-equilibrium Van der Waals Gas explains

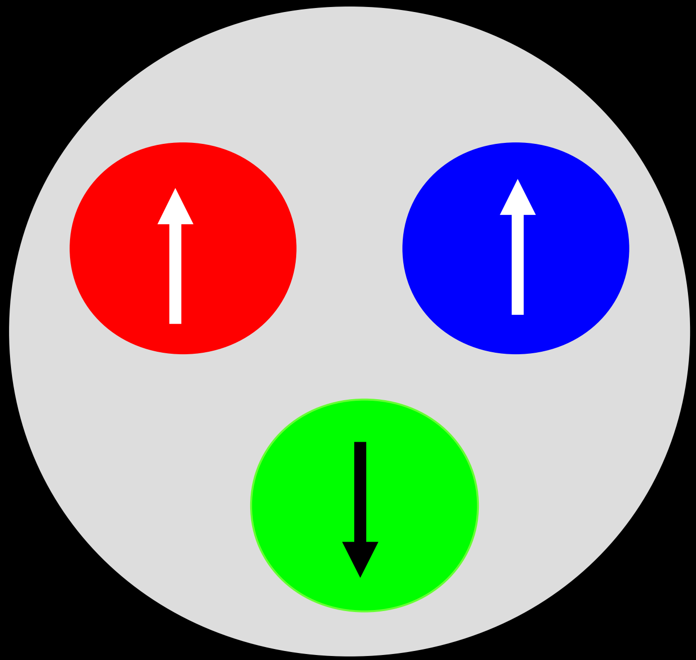
d.) The possibility of domains of negative temperature (explaining what has recently been called "**dark matter**") are due to macroscopic collective states of ordered spins. The conjecture is that **Positive temperature radiates, Negative temperature does not**. The conjecture is that black holes could be negative temperature states of collective spins.

e.) The possibility of domains where gravitational effects (quadratic similarity invariants, or 2nd order Gauss curvature effects) appear to be related to entropy and temperature properties of the thermodynamic system, and where **cubic curvature effects due to Spin and Adjoint current 3-forms could impede gravitational collapse.**

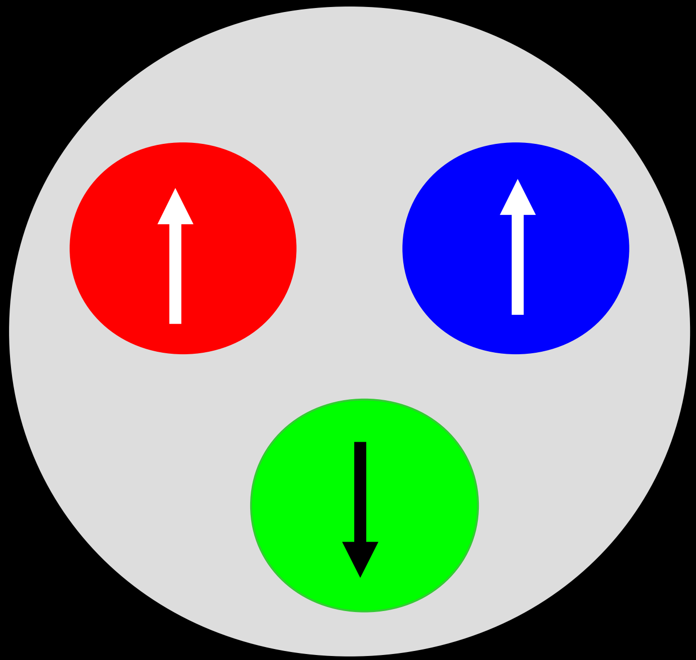
Cosmology as a non-equilibrium Van der Waals Gas explains

f.) Black Holes (generated by Petrov Type D solutions in gravitational theory) are to be related to **Minimal Surface** solutions to the Universal thermodynamic 4th order Phase function. .

What does this symbol mean to you?

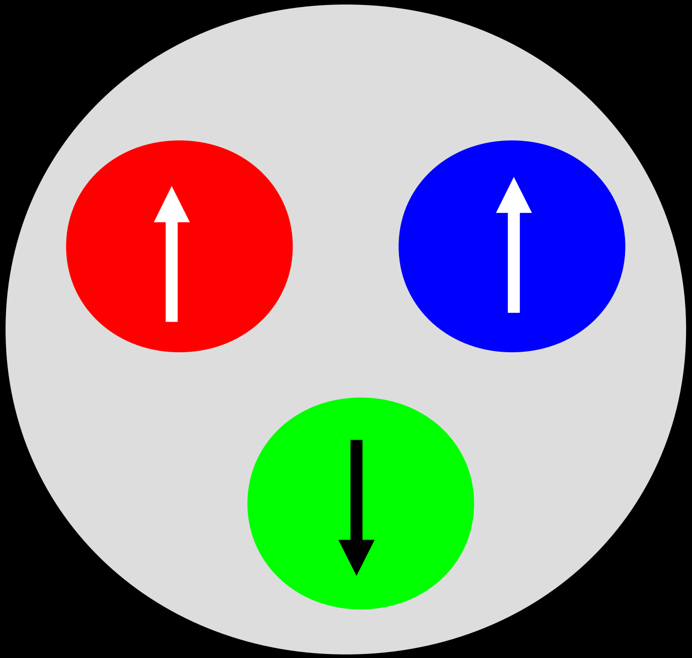


What does this symbol mean to you?



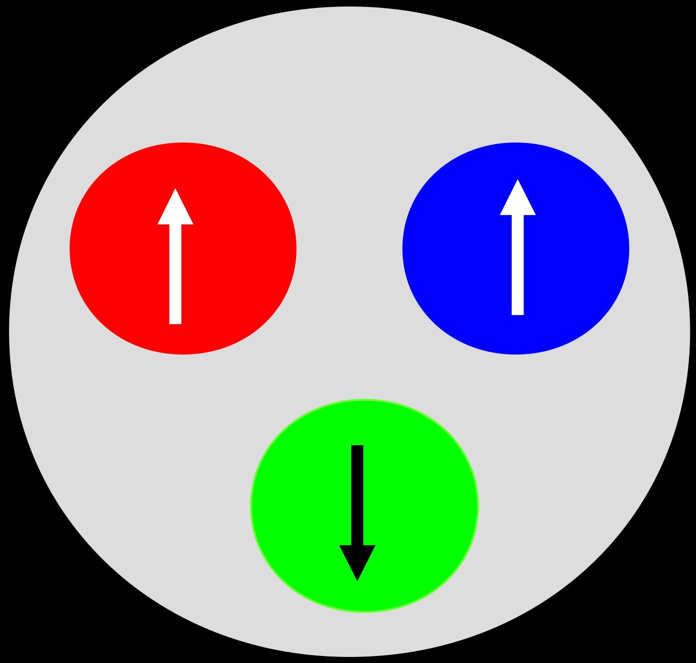
Two **Upper** sets and One **Lower** Set?

What does this symbol mean to you?



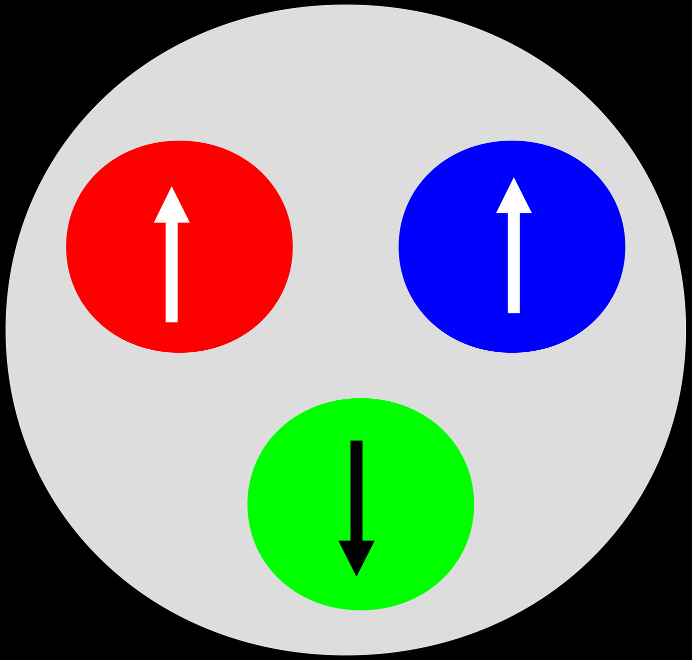
A **specialization** preorder system

What does this symbol mean to you?



Or a **PROTON**

What does this symbol mean to you?



Or a **PROTON** Made up from **QUARKS**

Significant Results

The Kolmogorov T0 topology of thermodynamics is based upon a specialization partial order of closure. Every Open set is an upper (Upper) set ↑ and every closed set is a lower (Down) set ↓

Significant Results

The Kolmogorov T0 topology of thermodynamics is based upon a specialization partial order of closure. Every Open set is an upper (Upper) set ↑ and every closed set is a lower (Down) set ↓

The T0 topological structure for thermodynamics is deduced from any 1-form on a specialization order of differential varieties. The T0 topology admits a dual topology, T*0. The closure condition is inherent in the concept of Continuous Topological Evolution of T0 and T*0 topologies and CONTINUOUS FIELDS.

Significant Results

The Kolmogorov T0 topology of thermodynamics is based upon a specialization partial order of closure. Every Open set is an upper (Upper) set ↑ and every closed set is a lower (Down) set ↓

The T0 topological structure for thermodynamics is deduced from any 1-form on a specialization order of differential varieties. The T0 topology admits a dual topology, T*0. The closure condition is inherent in the concept of Continuous Topological Evolution of T0 and T*0 topologies and CONTINUOUS FIELDS.

Both Kolomogorov topologies are partitions of a DISCRETE Alexandroff T1 topology. The T1 topology is inherent in the concept of DISCRETE PARTICLES.

Significant Results

There is an intimately relationship among the three topological structures, but in thermodynamics there are three important 1-forms, **A**, **W**, and Q.

Significant Results

There is an intimately relationship among the three topological structures, but in thermodynamics there are three important 1-forms, **A**, **W**, and Q.

Hence there is a plethora of triple relationships between **T1**, **T0** and **T*0** for each 1-form.

Is this the Universal Effectiveness of Topological Thermodynamics acting as the foundation for Quarks?[

Thanks for your interest

Contact Professor R. M. Kiehn at

rkiehn2352@ aol.com

http://www.cartan.pair.com

Paperback Monographs available from

http://www.lulu.com/kiehn

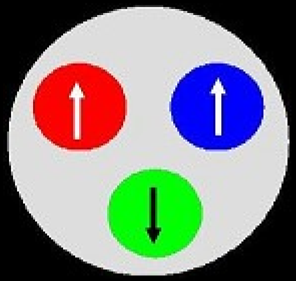
Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 6

The Universal Effectiveness of

Topological Thermodynamics

From the Perspective of Continuous Topological Evolution



Specialization (pre)order or Quarks

R. M. Kiehn

Monograph 6 now available http://www.lulu.com/kiehn

Topological Thermodynamics

Paperback or free pdf from

www.cartan.pair.com

Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 1

Non Equilibrium Thermodynamics

From the Perspective of Continuous Topological Evolution

Sliding Ball => Rolling Ball

Irreversible Continuous Topological Evolution of Pfaff Topological Dimension 2n+2 to long lived states far from equilibrium and of Pfaff dimension 2n+1

R. M. Kiehn

Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 2

Falaco Solitons Cosmology and the Arrow of Time

From the Perspective of Continuous Topological Evolution

Photo courtesy David Radabaugh

R. M. Kiehn

Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 3

Wakes Coherent Structures and Turbulence

From the Perspective of Continuous Topological Evolution

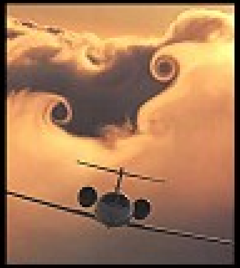


Photo Courtesy Paul Bowen www.airfoilair.net

R. M. Kiehn

Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 4

Plasmas and Non Equilibrium Electrodynamics

From the Perspective of Continuous Topological Evolution

Long lived ionized plasma ring in the turbulence of a nuclear explosion.

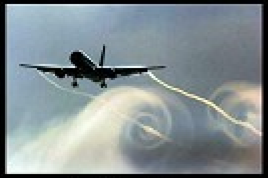
R. M. Kiehn

Non-Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 5

Topological Torsion and Macroscopic Spinors

From the Perspective of Continuous Topological Evolution



Helicity A^dA > 0 and Macroscopic Spinors

R. M. Kiehn

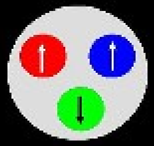
Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 6

The Universal Effectiveness of

Topological Thermodynamics

From the Perspective of Continuous Topological Evolution



R. M. Kiehn

Non Equilibrium Systems and Irreversible Processes

Adventures in Applied Topology Vol. 7

Selected Publications

by R. M. Kiehn

Related to the Perspective of Continuous Topological Evolution

Projected Hopf Map with Topological Torsion and Pfaff Topological Dimension = 4

R. M. Kiehn