A Primer for Deterministic Thermodynamics and Cryodynamics

Dedicated to the Founder of Synergetics, Hermann Haken

Otto E. Rossler, Frank Kuske, Dieter Fröhlich, Hans H. Diebner, Thimo Böhl, Demetris T. Christopoulos, Christophe Letellier

Abstract The basic laws of deterministic many-body systems are summarized in the footsteps of the deterministic approach pioneered by Yakov Sinai. Two fundamental cases, repulsive and attractive, are distinguished. To facilitate comparison, long-range potentials are assumed both in the repulsive case and in the new attractive case. In Part I, thermodynamics – including the thermodynamics of irreversible processes along with chemical and biological evolution – is presented without paying special attention to the ad hoc constraint of long-range repulsion. In Part II, the recently established new fundamental discipline of cryodynamics, based on long-range attraction, is described in a parallel format. In Part III finally, the combination ("dilute hot-plasma dynamics") is described as a composite third sister discipline with its still largely unknown properties. The latter include the prediction of a paradoxical "double-temperature equilibrium" or at least quasi-equilibrium existing which has a promising technological application in the proposed interactive local control of hot-plasma fusion reactors. The discussion section puts everything into a larger perspective which even touches on cosmology.
Keywords: Sinai gas, chaos theory, heat death, dissipative structures, second arrow, Point Omega, Super Life, paradoxical cooling, antifriction, paradoxical acceleration, Sonnleitner numerical instability, dilute-plasma paradigm, two-temperature equilibrium, ITER, MHD, interactive plasma cooling, McGuire reactor, Hubble law, Zwicky rehabilitated, Perlmutter-Schmidt-Riess wiggle, mean cosmic temperature, van Helmont, Lavoisier, Kant, Poincaré, double-faced Sonnleitner map. (August 26, 2016)

Otto E. Rossler, Frank Kuske, Dieter Fröhlich, Thimo Böhl
Division of Theoretical Chemistry, University of Tübingen, Auf der Morgenstelle 18, 72076 Tübingen, Germany

Hans H. Diebner
Department of Medical Informatics, Technical University Dresden, Blasewitzerstr. 86, 01307 Dresden, Germany

Demetris T. Christopoulos
National and Kapodistrian University of Athens, Department of Economics, Sofokleous 1 str., 10509 Athens, Greece

Christophe Letellier
Physics Department, University of Rouen CORIA, Avenue de l'Université, 76801 Saint-Étienne-du-Rouvray, France

1 Introduction

Thermodynamics and its recent new sister discipline, cryodynamics, can be both put on the same deterministic "Newtonian" footing. Hereby the familiar close-range repulsion between the atoms in a gas is formally replaced by a long-range "anti-Newtonian" repulsion so as to thereby facilitate comparison. This "smoothing trick" has surprisingly little impact on the main qualitative behavior [1]. The resulting new mutually anti-symmetric "double reality" is summarized in the following in a tabular format. A third "combined case" is also included with a view to its technological promise. A general, somewhat philosophical discussion is added.

2 Part I: Thermodynamics

FIRST LAW of deterministic statistical thermodynamics

This law is trivial in classical mechanics:

(1) Energy conservation ($\frac{dH}{dt} = 0$, with H the classical Hamiltonian function)

The Hamiltonian may either be integrable or (in the general case) non-integrable. For the case of a many-particle system at equilibrium, the conservation law of Eq.(1) has an especially intuitive implication:

(1a) Ergodicity

literally "work-path involvement." The term was coined by Boltzmann [2] to describe the fact that the whole phase space is being re-visited arbitrarily closely but not identically everywhere infinitely often across unlimited time (this is one possible interpretation). Ergodicity was demonstrated for deterministic systems for the first time under the assumption of hard-sphere repulsion, by Yakov Sinai in 1963 [3], [4]. His chaos-theoretic result could later be generalized, both towards soft repulsion [1] and towards far-from-equilibrium conditions [1] (and towards soft attraction, see Part II). In the soft case, so-called Kolmogorov-Arnold-Moser (KAM) tori are automatically included in the phase space [5]. The presence of the latter formally destroys perfect ergodicity but actually has a virtually negligible influence under multi-particle hyperbolic interaction – a fact which does not possess the rank of a theorem, however.

SECOND LAW of deterministic statistical thermodynamics

This law concerns the existence of an attractive (asymptotically stable) equilibrium in the case of gases. This equilibrium was, after its hypothetical generalization towards the whole universe, called "heat death" by Clausius [6]. That dismal fate is being approached in a statistically progressive maximization of phase space volume, cf. [7], [8]. The same tendency in phase space holds true already for very low particle numbers [9], [10]. The second law is sometimes also called the "first arrow" of nature. It implies the fact that no perpetual motion machine of the second kind is possible in nature. It can be described best by focusing on a global observable, the so-called entropy ("inwards-growing"), a term coined by Clausius in 1865 [6] as an onomatopoetic sister term to energy. For the entropy S of a closed system, the following law holds true:

(2) Positive entropy production ($\frac{dS}{dt} \geq 0$)

Under deterministic conditions, cf. [11], [8], the entropy is equal to the logarithm of phase space volume apart from a scaling factor. A spontaneous increase of disorder in forward time is implicit in Eq.(2). Note that the necessarily positive overall entropy production does not exclude the opposite behavior from occurring in a sub-region of state space or a subsystem.

FIRST SUB-LAW to the second law of deterministic statistical thermodynamics

This sub-law concerns the spontaneous generation of a so-called flow-equilibrium ("Fliessgleichgewicht," von Bertalanffy [12]) which is a point attractor. More generally speaking, "dissipative structures" are being formed (Prigogine [13]). This class includes a progressive chemical evolution [14], [15], [16] under realistic natural conditions. In the following, the restrictions that are brought-in by assuming soft (anti-Newtonian) repulsion in place of the usual hard-sphere repulsion between the molecules in a gas and a fluid will be neglected in order to allow for a maximally broad overall picture. The dissipative structures which form in nature are sub-cases to a so-called "second arrow" that is implicit in the first arrow of the second law of thermodynamics itself [17]. The second arrow is sometimes called "complexification" following Teilhard [17]. Note that the second arrow forms a sub-arrow of a seemingly inverted, "anti-dissipative" orientation within the first arrow of Clausius. The second arrow implies as its most spectacular special case the biogenetic arrow. The latter applies as soon as very many chemical compounds [14] are eligible to being formed (or many nuclear-reactions are likewise enabled on the surface of a neutron star, cf. [18]). Darwin first saw this deductively predictable origin of life as necessarily occurring "in a warm little pond" [19]. Teilhard's parallel law of complexification at the same time represents the first complex attractor of history [17]: in the form of his famous

(2a) "Point Omega"

The deterministic arrow which tends towards a greater and greater and ever more subtle state of order, is as we saw only possible by virtue of the fact that an even larger disorder is simultaneously generated in the "complement" of the dissipative structure in question. It is hereby presupposed that the overall entropy of the whole system can be defined, a question which appears to be new. The entropy no doubt assumes the form of a complicated functional which has never been looked at in mathematical detail. Similarly, the term "complement" appears to be new in the present context. The idea is that the deterministic phase space volume of Eq.(2) is increasing overall, thereby overcompensating the local decrease in subsystems and sub-pockets. "Life feeds on negative entropy" was Erwin Schrödinger's original phrase [20]. One sees that it all is less trivial than generally assumed but well worth looking at in thermodynamic terms.

SECOND SUB-LAW to the second law of deterministic statistical thermodynamics

This sub-law is not usually considered in a far-from-equilibrium context since it only deals with equilibria. The present sub-law depends on the temperature and the volume as the two decisive parameters, but also on the specific atomic and molecular properties and potentials of the involved particles (van der Waals [21]). It comprises the existence of pressure- and temperature-dependent equilibria which, taken together, can be comprised in a so-called

(2b) Phase diagram or p-V diagram, etc. (cf. also [22] for an example in nuclear chemistry)

The inner energy of the gas is (apart from any remaining potential energies) the kinetic energy of the involved particles including rotational energies.

THIRD LAW of deterministic statistical thermodynamics

This full law, introduced by Walter Nernst [23], concerns the existence of an absolute zero of temperature. It later was complemented by special low-temperature quantum effects which lack a deterministic analog (Kammerling-Onnes [24], Kapitza [25], Bardeen et al. [26] and the Bose-Einstein effect [27] and still later, the quantum-Hall effect [28], [29]):

(3) Absolute zero, with superfluidity, superconductivity, supercondensation, etc.

which effects have a zero entropy increase each, a property that is essentially retained when they occur at substantially higher-than-zero temperatures. Note that the Cooper pairs in superconductivity have a doubled electric charge and quantum number owing to “grid vibrations” in quantum field theory. But these quantum details exceed the scope of the present survey. The same holds true for the effects of a quantum-based non-deterministic formalism that postulates a negative absolute temperature in excess of any possible positive temperature which nevertheless is transformable into such [31].

In conclusion of this Section, all of the above qualitative facts are well known even though beautiful open questions remain. Many different ways of looking at the three laws exist. The latter were presented here mostly as a “backdrop” in order to put into a clearer perspective the recently discovered sister discipline to thermodynamics that is to be described next.

3 Part II: Cryodynamics

FIRST LAW of deterministic statistical cryodynamics

This law applies when the potentials which apply between the individual particles are, not short-range repulsive or even long-range repulsive (as suggested above for the sake of comparison), but rather long-range attractive. Such “Newtonian gases” form a new object of discussion even though they could in principle have been considered by Newton himself already. The present law is formally identical to the first law of deterministic statistical thermodynamics (Eq. 1 in Part I above):

(1) Energy conservation ($\frac{dH}{dt} = 0$, with H the classical Hamiltonian function)

just as this held true before in an anti-Newtonian gas. The conserved energy can again assume quite differing forms. Once more, we at equilibrium necessarily have the presence of KAM tori in phase space occupying again only a small ("effectively negligible") subvolume of the phase space of the many-particle system in question. But it actually makes little sense to speak of "ergodicity" applying here, for these formally existing states occur here by definition only in the negative direction of time. Due to their being intrinsically unstable they are predictably unphysical.

SECOND LAW of deterministic statistical cryodynamics

This law concerns the existence-in-principle of an unstable equilibrium (an anti-attractor or synonymously repellor) which can be named "Point Alpha." It is characterized by a progressive (for once not increase but) decrease of overall phase space volume in the forward direction of time. In other words, this is just the opposite of what happens in deterministic thermodynamics as it was considered above. Therefore, we now have for the phase space volume – or rather its logarithm called entropy – the following law:

(2') Negative entropy production ($\frac{dS}{dt} \leq 0$), with S the entropy of a closed system

This law comes as a real surprise: It describes a spontaneously progressive increase of order in positive time. That is, a positive ectropy production occurs if "ectropy" is defined as minus S. Therefore, the existence of a repellor, an unstable "Point Alpha" is formally implicit, named in analogy to Teilhard's first attractor, his Point Omega.

FIRST SUB-LAW to second law of deterministic statistical cryodynamics

This law (2'a) is identical to a full-fledged law, the Fourth Law of "negative-time Super-Life" described below as Eq.(4')

SECOND SUB-LAW to second law of deterministic statistical cryodynamics

This sub-law – much like the analogous second sub-law (2b) of deterministic statistical thermodynamics above – describes equilibrium states that are dependent on the temperature and pressure and density as well as on the specific physical properties of the particles involved. However, these states cannot become manifest empirically by virtue of the repulsive character of the equilibria in question. Nevertheless it makes sense to define here a

(2'b) negative-time phase diagram (being asymptotic in negative time)

This diagram has only a formal character since the equilibria described in it apply in negative time. It has never been investigated and presently it is not clear whether or not it possesses physical significance.

THIRD SUB-LAW to second law of deterministic statistical cryodynamics

This sub-law possesses for once no analog in thermodynamics. It concerns the existence of a family of multi-particle chaotic dynamical regimes which show a certain resemblance to attractors in dissipative systems. For lack of a better term, they can be called pseudo-attractors:

(2'c) Pseudo-attractors of multi-particle systems in astronomy

They apply in celestial mechanics and include:
1. globular clusters of stars (cf. Chandrasekhar [32])
2. spiral galaxy structures
3. elliptical galaxy structures
4. "black" or synonymously "low-surface brightness" galaxies (see [33] for more details about the latter)

The formation of these pseudo-attractors is strongly influenced by the principle of "energetic capitalism" of Sonnleitner [9], see also [34]. Sonnleitner found that under a condition of mutual long-range attraction, a "disproportioning of the kinetic energies" of the involved particles takes place in an inversion of what applies under repulsive Newtonian (as well as the usual close-range repulsive) conditions. An anti-equilibration in which the low-in-kinetic energy particles are "preyed upon" by the high-in-kinetic energy particles was found [9]. After a while, for some reason this anti-entropic feature of systems of mutually attractive particles comes to a standstill and even gives rise to a visible attractor – in the form of galaxies. The latter are a stage in the development of a self-contracting gas cloud. The qualitative dynamics of this very slow process is still ill-understood. There exist billions of specimens before our eyes which all belong into but a few classes. They were, by the way, first named by a physicist named Immanuel Kant in 1755 (in his "Universal Natural History and Theory of the Heavens," p. 367) who soon after became a famous philosopher. Note that general-relativistic effects play only a minor role in galaxy formation apart from the formation of black holes, including the ultra-heavy ones found located at the galactic centers. Although black-hole theory is still underdeveloped (there appear to exist no finished black holes in finite outer time), the Birkhoff theorem makes sure that something very compact resides inside the invisible attractive region. These heavy residents at the galactic cores by the way must be the products of a very long accretion history.

FOURTH SUB-LAW (non-chaotic) to the second law of deterministic statistical cryodynamics

This sub-law concerns the existence of special virial theorems valid under non hyperbolic and non-chaotic conditions. It comprises:

(2'd) Kepler ellipses and Mercury-orbit-like Einstein rosettes and long-term stable planetary systems

Note for curiosity's sake that such rosettes occur under many different perturbations of the exactly quadratic Newtonian force law, apart from the familiar general-relativistic one.

THIRD LAW of deterministic statistical cryodynamics

This third law – like its analog in deterministic thermodynamics, Eq.(3) of Part I – comprises low-temperature quantum effects that are valid here under attractive rather than repulsive conditions:

(3') Absolute zero, with Nernst-type collective quantum phenomena

They predictably show a zero-entropy change again. These predicted equilibrium effects represent an unfamiliar class. A direct physical implementation appears rather unlikely at present.

FOURTH LAW of deterministic statistical cryodynamics

This fourth law possesses no analog in thermodynamics for once, as mentioned. Rather than representing only a second-order phenomenon, as chemical and biological evolution do in thermodynamics (whose dissipative structures do represent only a second-order phenomenon "riding on the back" of the dissipative first-order arrow of Clausius as we saw), the present law represents a first-order main arrow – albeit one that is valid in negative time. Hence this arrow represents a full-fledged repellor in positive time. As such, this repellor is *identical* to the *Point Alpha* of the second law of deterministic statistical cryodynamics, Eq.(2') above. The implied "anti-evolution" – as it can be called – is likely to become a main topic in cryodynamics eventually but at the present moment in time it is only vaguely perceptible. An interesting open question hereby is: Will a sophisticated subsystem in this class perceive macroscopic time as flowing in the other direction? The present dynamical attractor is only fictitious due to its instability in the forward direction of time. Thus it is only virtual for us – much like a virtual image. Nevertheless the dynamical routes leading towards it in negative time do represent a very powerful evolution (albeit in negative time). The underlying **anti-attractor** might play a ubiquitous role in the cosmos but its features are totally opaque at present. Nevertheless the new negative-time attractor can already be given a name:

(4') "Negative-time Super Life"

The proud name is perhaps premature since the properties of this necessarily existing repellor have yet to be unraveled. Owing to the surreptitious numerical instability [9] which affects all cryodynamical computer simulations rendering them invalid in detail, it is very hard to say at present how to tackle this negative-time origin problem empirically, that is, numerically. It cannot even be ruled out at present that some cleverly chosen inaccurate numerical simulations will prove useful in coming closer to a solution of this conundrum. The cosmos' own time's arrow thus may or may not be listening to a baton of its own.

FIFTH LAW of deterministic statistical cryodynamics

This fifth law not only is without an analog in thermodynamics but at the same time is maximally counter-intuitive:

*(5') **Paradoxical Acceleration**, suffered by a very tiny particle very rich in kinetic energy, in a cluster of very tiny particles*

This law is the natural counterpart to the fact that an energy-poor lighter particle is getting braked by many heavier particles under an attractive interaction (like the photons passing through a gas of galaxies seen by Zwicky in 1929 and independently by Fröhlich in 2003). The present "mirror prediction" is as counterintuitive as the paradoxical braking of Sonnleitner. It appears to be new.

Ordinarily, the collisions suffered in a gas by a fast heavier particle passing through are non-conducive to acceleration. But if a highly energetic gravitating particle is both markedly heavier and ultra-small, it predictably is bound to undergo an acceleration while traversing a homogeneous gas of much lighter equally small particles. So, for example, in the interior of a planet or a star or even in a maximally dense white-dwarf. This is because the material objects in question are on the finest scale made up from almost point-like particles (electrons and quarks). If for this reason, collisions are sufficiently rare, then the fast heavy mini particle should – under the influence of Newtonian attraction – suffer an acceleration due to the principle of energetic capitalism. This prediction follows in a straightforward manner just as the previously described braking effect was valid for energy-poor particles. A possible counterargument is that the present effect, while necessarily true at "ordinary" velocities much lower than the speed of light *c*, may cease to apply under relativistic conditions. This objection is probably unfounded though since the interaction between photons and randomly moving galaxies shows that classical cryodynamics remains valid under relativistic velocities.

Why is *paradoxical acceleration***,** if it indeed exists, of potential applied interest? The reason is black-hole theory, of all things. Since micro black holes are necessarily uncharged (as follows from Birkhoff's theorem which itself is not very well known), they, if very fast, can pass right through massive celestial bodies getting accelerated rather than braked and hence doing no harm. The onslaught of cosmic ray particles on surface protons of celestial bodies may suffice to produce micro black holes in violation of classical views. This is because charged "point particles" like electrons cannot be effectively point-shaped since they would then have to be black holes and hence be uncharged. Therefore, some analog to string theory is valid empirically. The cosmic-ray borne ultrafast micro black holes (if they exist) will thus leave the earth and other celestial bodies up to the ultra-dense white dwarf stars unscathed owing to paradoxical acceleration. (The still denser neutron stars are protected by a different mechanism, their superfluidity.) Unlike the natural fast micro black holes if they exist, however, artificial slow micro black holes are *not* innocuous.

Now an accident of history wills that ultraslow micro black holes are currently attempted to be produced on earth. They cannot “Hawking evaporate” as traditionally believed because a black hole is never finished in outer time since nothing including light can ever reach their horizon or come up from it in finite outer time. (Hence their already 18 years old new name “almost black holes.”)

The upshot is that the new phenomenon of paradoxical acceleration which protects celestial bodies from being eaten inside out by micro black holes so they exist is *inapplicable* to slow micro black holes. This is the situation valid on earth. If the experiment is successful in producing at first undetectable uncharged micro black holes on earth, this means that an ultra-slow specimen can gravitationally interact in a non-hyperbolic fashion with a charged micro particle (quark or electron) passed very close. Such an encounter leads to an “eating event.” The on-going interaction (before the final “gulp”) then increases the attraction exerted by the momentarily interlocked pair on a neighboring charged particle of the opposite polarity by some 30 orders of magnitude. Even a very short “eating time” cannot undo the attendant giant boost in attractive power of the micro black hole. Therefore an artificial micro black hole inside earth is bound to grow. After an initial phase of linear growth, the growth predictably becomes exponential.

This fact is titillating because the learned official safety report of the mentioned experiment, called LSAG [35], goes un-updated for eight years. The new implication of cryodynamics that ultra-slow micro black holes are “non-harmless” will predictably lead to an update of the LSAG soon[1]). This very indirect side effect of cryodynamics was perhaps also worth mentioning here.

Some Remarks leading over to Part III

Cryodynamics exists as a natural sister discipline to thermodynamics for symmetry reasons, as we have seen. Many of its features are still *terra incognita*. Does cryodynamics possess an importance comparable to that of thermodynamics? In light of the many surprises which the study of thermodynamics has brought over two centuries an equally rich “bonanza” can be expected to arise in the further development of cryodynamics. As we saw, the defining difference between cryodynamics and thermodynamics lies in the sign change of the deterministic inter-particle potentials in charge. The fact that in thermodynamics, the inter-particle potentials are actually short-range repulsive rather than long-range repulsive has surprisingly little influence on the broader comparative picture. On going-over from repulsion to attraction, all equilibrium-oriented notions from deterministic thermodynamics lose much of their relevance because the deterministic equilibria are now unstable by definition and hence unobservable. The most directly rewarding sub-task of cryodynamics, perhaps, consists in its explaining galaxy formation as a kind of attractor in forward-time. This task is severely hampered through the numerical instability governing gravitationally interacting particles demonstrated by Sonnleitner [9], [34]. Most of the multi-particle numerical galactic simulations performed up until now are automatically put into question as mentioned. Cryodynamics also covers the interactions in a gas that is made up from many galaxies and clusters. And it governs as mentioned the

---

[1] Eq.(5’) was triggered by a discussion with Tom Kerwick

interaction between the many galaxies on the one hand and the fast-moving cosmic-ray particles and photons on the other. Hereby, relativistic complications automatically arise but they seem not to affect the qualitative features outlined. In the following, we now turn to a third, once more down-to-earth, case: the combined field of thermo-cryodynamics as it can be called. Like cryodynamics proper it is a classical subject that previously had gone unnoticed.

4 Part III: Combined "Thermo-Cryodynamics" or equivalently "Dilute-Hot-Plasma Particle Dynamics"

FIRST LAW of deterministic statistical Thermo-Cryodynamics

This law concerns the potential non-existence of a globally stable equilibrium in compound systems made up from both mutually repulsive and mutually attractive particles. This situation was historically speaking first looked at by Lev Landau in his proposal to bring into contact two compartments that each contain particles of but one of the two types [36]. Next came Donald Lynden-Bell in 1960 [37] (see [38] for details). The more complex "fully mixed" situation is still in a fledgling state [37], [39]. It nevertheless does allow for some cautious predictions already. The potentially most important one concerns the existence of "partial temperatures" in a hot plasma – not only far from equilibrium where this goes without saying but potentially also at equilibrium proper in case such exists:

(1") Two-temperature equilibrium (predicted)

Either particle class (electrons; ions) may thus possess a different temperature – at equilibrium. Hereby the electrons should be much "hotter" in general [40]. This prediction comes as a surprise in view of the well-known uniqueness of the thermodynamic equilibrium, the "heat death" of Clausius. While pressure is known to be capable of forming partial pressures at the same temperature and volume in a thermodynamic gas at equilibrium, the prediction of "partial temperatures" existing at equilibrium goes against the grain of the venerable field of high-temperature many-particle physics. And it of course flies in the face of common sense, too. Compare again ref. [39] for some empirical results that may or may not prove compatible with the present conjecture. If the latter is true, the first law of cryo-thermodynamics, Eq. (1") above, necessarily possesses a corollary:

(1a") Bistability of temperature (including the formation of hysteresis phenomena)

A consequence of this corollary is a second corollary that is even more foreign: An autonomous "dynamical switching process" of periodic or chaotic type should predictably occur between the two "sub-equilibria" at some parameter values:

(1b”) A non-point attractor at equilibrium (that may even become chaotic)

This hypothetical new attractor applies under “well-stirred” conditions at equilibrium already. Spatial structure formation would then make the situation almost arbitrarily complicated even at equilibrium. A similar complexity is so far only known from the relaxation processes in glass-like solids and spin glasses, cf. [40]. Note moreover that so far no quantum effects were assumed to be involved. It is important to state once more that the whole First Law of Cryo-Thermodynamics, Eq.(1”), is hypothetical at present. In any new terrain one easily is led astray – as may have occurred here. Fortunately though, experiments in the footsteps of Landau and Lynden-Bell – but of a non-compartmentalized “mixed” kind – can be conducted in hot-plasma reactors so as to either falsify or confirm Eq.(1”).

SECOND LAW of deterministic statistical Thermo-Cryodynamics

The two-temperature equilibrium of the first law of hot-plasma dynamics – Eq.(1”) – is (if it indeed exists) maximally sensitive to an exogenous change of total energy or volume. Hereby, one special case predictably presents a technologically implementable situation:

Experiment: *“Concentric multidirectional injection of fast electrons into a hot plasma”*

In this way, a momentarily monopolar gas with a higher temperature and density is generated locally. This artificial “spot” can be used in principle to paradoxically cool down the local equilibrium temperature of the ions, if the latter have become too hot locally in a two-temperature hot plasma for it to remain stable and not touch the wall. Because the two temperatures in the plasma possess a fixed ratio at equilibrium (or quasi- equilibrium, respectively) with the electrons being much hotter in accordance with suggestive observations [39], it is predictably possible to exogenously change the electron temperature by active intervention – in order to thereby paradoxically cool-down the local ion temperature in the hot plasma. If so, it is in principle possible also to – by the concentric injection of electrons of higher density with a carefully chosen energy (temperature) – force down the temperature of the “too hot ions” in a developing localized plasma instability that is about to form a tongue that by licking the wall finishes the fusion process. This “non-hydrodynamic” reaction-kinetic effect offers itself for active intervention. This is the prediction of “interventional cooling” to be possible regarding a too hot region in a plasma that is about to get out of control in a continuous Tokamak reactor like the ITER [40]. Note that the ITER is the famous international fusion reactor that is being erected in southern France. The proposed interactive controllability of hot-plasma fusion reactors represents a major technological advancement if true.

The predicted effect can be achieved interactively by the local generation, through concentric injection from six directions, of a somewhat hotter local partial equilibrium at enlarged density of the lighter particle class (the electrons), as mentioned. This method predictably allows one to “interactively cool” the local temperature of the too hot ions, in the case of a local hydrodynamic instability in the plasma is going out of control. This new option possesses no analog in the purely PDE-based processes of the so far prevailing plasma reactor models. The new proposal presupposes that the partial pressures and partial temperatures of the two interacting gaseous components are subject to a double-temperature quasi-equilibrium locally. The underlying novel phase diagram has yet to be described. The here proposed new method can be called

(2”) *Adaptively controlled continuous hot-plasma fusion (ACCHPF)*

This technological proposal of a “gas-theoretic cooling” represents an approach very different from the traditional approach to an MHD formulated entirely in terms of local flows and currents in a fluid-dynamical and electromagnetic scenario governed by PDEs. The latter does not lend itself to a point-specific active intervention. The two approaches, the traditional continuous one and the present particles-based localized one, are both legitimate. But whereas the manipulation of local flows and currents is virtually impossible, the dirigible concentric injection method (dci) is in principle implementable by using several injection ports for dirigible electron beams [42]. The 6-beam method of Steve Chu, used by him and his coworkers in an entirely different context [43], offers itself for the purpose. The proposed new option is based on the existence of local two-temperature equilibria or quasi-equilibria in hot plasmas. The proposal made can be tested best “by “doing in reality” rather than by simulation. This is because in molecular-dynamics simulations an “inversion of the macroscopic time’s arrow” is notorious for intruding surreptitiously as mentioned [9,34].

Up until now, the high-energy industry did not signal interest in cryodynamics. Trying the new science out empirically is arguably the fastest way to reach the new technological goal of *interactive fusion-reactor control* (ifrc) with its vast economic promise.

THIRD LAW of deterministic statistical Thermo-Cryodynamics

The term “law” is not fully appropriate here because nothing but a technological proposal is at stake. Nonetheless the term “law” was chosen to acknowledge the existence of an alternative technological option to the above-described road towards unlimited “free energy” in the everyday sense of the word. The main technological competitor to the adaptively controlled continuous hot-plasma fusion considered above is the intermittent alternative. The latter consists in the repetitive creation-from-scratch of a hot-fusion plasma (“McGuire reactor” [44]):

(3”) Repetitively installed discontinuous hot-plasma fusion (RIDHPF)

The difference between the second law of thermo-cryodynamics offered above, Eq.(2”), and the present third law of thermo-cryodynamics, Eq.(3”), reminds one of the familiar difference between the continuous *Stirling motor* and the discontinuous-explosion type *Otto motor* in automobile design. In this old technological realm, the intermittent method (*Otto's*) gained the upper hand up until now. At the present moment in time, it again is hard to predict which of the two alternative options for running plasma fusion engines will win out on a long-term basis: the continuous or the intermittent one (ACCHDF or RIDHPF). However, one thing can already be said for sure: The new fundamental field of cryodynamics is of the highest applied interest.

5 Discussion

I. The above tabular presentation of the field of deterministic statistical multi-particle systems founded by Sinai [4] represents a new approach to the qualitative behavior of multi-degree-of-freedom Hamiltonian systems, classical and eventually also quantum. In this regard the present approach belongs into the footsteps of Paul Dirac who always insisted on “Hamiltonicity” having to be observed also in quantum mechanics (cf. [45]). At the same time the three-tiered Table offered above takes up the grand tradition of mid-19th-century deterministic billiard ball theory [46] that would later be called “chaos theory.” This theory possesses an even older connection to the past by reviving van Helmont’s first gas theory: the word “gas” stems etymologically from the Greek word “chaos” [47].

Gas theory was for almost two centuries dominated by the assumption that maximally short-range repulsive potentials hold true in between the involved particles. This went so far that the repulsion could often be formally neglected altogether without change of the statistical equations. This statistical approach to the theory of heat remained the royal route for more than a century – right up to the deterministic statistical physics founded by Sinai [3], [4]. The new chaos-theoretic method had to struggle to obtain a niche of its own in the field. The fact that the deterministic approach is strong enough to also cover far-from-equilibrium situations was only discovered in recent years. It then turned out that a “smoothing-out” of the maximally short-range (“hard”) repulsive potentials of the billiard particles of a Sinai gas, into “long-range” 1/r repulsive potentials of inverted Newtonian type, constitutes an admissible option [1] (cf. [48] for a first pertinent simulation). The smoothing proves to be admissible without loss of the main qualitative implications of the new deterministic statistical thermodynamics. Gas theory in this way can be re-defined under smooth-repulsive deterministic conditions in the footsteps of the famous KAM theory [5]. (The first author once enjoyed a long encouraging telephone conversation with Jürgen Moser, the “M” of KAM, in mid-1976.) This long-budding development became “fully transparent” only with the “plane-tree alley paradigm” as the generalized (both smoothened and far-from equilibrium) Sinai theory was called [1].

The smoothened repulsive-Newtonian subcase is a direct generalization of Sinai’s founding hard-sphere repulsion-based chaos theory. It formed the subject matter of Part I above (with chemical constraints and quantum specifications etc. yet to be added). To this smoothened deterministic case, then surprisingly a twin case arose – valid under mirror-inverted potentials. The latter situation had for intrinsic reasons been impossible to spot in the traditional “hard-core” approach towards thermodynamics: the attractive-Newtonian case. Its previous nonexistence is nevertheless surprising. It formed the subject matter of Part II. The new physical science termed “cryodynamics” [1] exists in close parallel to the venerable science of thermodynamics (krýos ice is the twin to thermós hot). The new field forms a “second empire” within Sinai’s deterministic-chaos based statistical physics.

In this manner a “parallelization” was achieved between the almost two-centuries-old theory of microscopic Hamiltonian thermodynamics (see [47] for its groping earliest origin) on the one hand, and the brand new theory of Hamiltonian cryodynamics [1], on the other. Finally Part III dealt in a preliminary fashion with a combination of the two fundamental fields sketched before.

The two parallel anti-Newtonian and Newtonian programs described above could have been initiated more than a century ago – or even three centuries ago by Newton himself (although the Cartesian billiard theory [49] was only in its earliest infancy at the time). To date, the Newtonian multi-particle theory paradoxically is still in its early infancy. A solid foundation is provided by the theory of deterministic chaos in phase space, originally invented by Henry Poincaré in the late 19th century [50].

II. A first successful numerical simulation of the new surprise tendency towards anti-equilibration valid in the attractive case is due to Klaus Sonnleitner [9] who remained maximally skeptical himself during his long numerical-mathematical voyage. He therefore placed the greatest emphasis on the controls – which fact only made the discovery possible in the end. He achieved the counterintuitive new finding of anti-dissipation while applying his especially transparent and hence accurate fourth-order symplectic simulation method [9] to a formally three-particle but dynamically two-particle system, in a two-dimensional but formally one-dimensional, configuration: the T-tube, with a frictionless particle put into either leg [9] (cf. [34]). The immovable third particle (the massless frictionless T-tube itself) was assumed to be held fixed in space by rigid connection to a distant very large mass.

The heavier particle with its mostly larger kinetic energy was placed into the vertical leg of the T-tube and the light-weight, mostly less energetic, fast particle into the horizontal leg. The Newtonian (or anti-Newtonian, respectively) potential acted across the two-dimensional space in which the T-tube is embedded. All possible mutual relations (as to which particle has more energy initially) were numerically checked with both polarities of the potential (repulsive or attractive, respectively), in two carefully juxtaposed parts (see pp. 99-100 of Sonnleitner’s dissertation [9] for a transparent tabular synopsis in the otherwise German text). The not-so-surprising “dissipative” results found in the repulsive case got collected just as painstakingly as the surprisingly emerging “anti-dissipative” results found in the attractive case.

An analytical description of essentially the same 2-D two-particle situation was offered by Ramis Movassagh [52], cf. also [53]. Almost all of the big theorems and sub-theorems which are implicit in the new paradigm of a “Newtonian gas” [1] wait to be formulated-out in detail on the way to becoming standard textbook stuff.

The next step planned in the simulation program was to make the heavier vertical particle arbitrarily heavy in a step-wise fashion while leaving its local motion and the effect it locally exerts on the light-weight horizontal particle unchanged. Eventually, the heavy vertical particle will act as a mere periodic forcing on the light-weight horizontal particle. If (as can be expected but needs to be verified) the qualitative behavior remains unchanged under this progressive simplification, the resulting final system will be nothing else but a periodically forced Hamiltonian oscillator of the kind first conceptualized by Poincaré, in which the "homoclinic point" and hence chaos was first discovered [50]. The surprise prediction is that essentially the "same" Poincaré map explains, both a temporally directed *dissipative* behavior arising from virgin initial conditions in either direction of time in this Hamiltonian system, and a temporally directed *anti-dissipative* behavior, arising from virgin initial conditions in either direction of time, in this "same" Hamiltonian system following a sign flip. The very possibility of the latter effect existing had escaped discovery over both the 19th and the whole 20th century.
Sonnleitner was greatly surprised.

A simple "flat" 2-D Poincaré map of two predictably related but at present totally unknown shapes will then be found numerically. This 2-D map will, both causally and intuitively, explain either type of qualitative macroscopic behavior in nature – the "Boltzmann" case and the new "anti-Boltzmann" one – in basically the "same" system: namely, in the oldest and simplest chaotic oscillator of history. Boltzmann and Poincaré would be reconciled at last. The late Sonnnleitner planned to compute this enigmatic "twin" Poincaré cross section in further numerical work. A simplified idealized pair of maps producing the same behaviors can predictably be written down afterwards: to enable the first "real" (that is, qualitative) understanding of the two "miracles" of statistical physics, one called the "time's arrow" and the other awaiting a fitting name ("anti-arrow"?). This simple but not yet existing area-preserving 2-dimensional diffeomorphism with two mutually nontrivially related shapes can – as the oldest playground of chaos theory that it represents – be given a name already as the "double-faced Sonnleitner map." All of this presupposes that the above reasoning did not go astray at some point.

III. So far, the discussion dealt exclusively with the two pure cases – either pure repulsion or pure attraction. The combined theory was touched upon in Part III. This third Part is even farther away from having reached a canonical form. It comes as a surprise that dilute-plasma theory suddenly acquires a fundamental role of its own in science – besides and apart from the traditional formal treatment in terms of idealized smoothened partial differential equations (PDEs) valid approximately under less dilute conditions.

With the here assumed "celestial-mechanics-like" more dilute conditions, the present approach led in Part III to the unexpected (possibly premature) prediction of a two-temperature equilibrium existing in nature. Namely, in hot plasmas when "static interactions" prevail over "Maxwellian interactions." New phenomena that had been overlooked both theoretically and observationally come into focus if no mistake was made. Nature can look amazingly foreign under the influence of the Poincaréan angle of vision later called *chaos theory*. As is well known, Poincaré also conjured-up *topology*. Whether or not hot-plasma fusion reactors can become a reality much sooner than currently hoped-for under the new *dilute-plasma paradigm,* is an open question of some applied interest.

We have here a down-to-earth application of cryodynamics that offers the prospect of unlimited "free energy" in the everyday sense of the word. This promise renders the new science of cryodynamics an irresistible topic for an energy-thirsty planet. The work-in-progress of Part III needs to be taken with a grain of salt regarding its mathematical rigor. Nevertheless the economic consequences of the new "molecular-dynamical dilute-hot plasma theory" (mddhp) have the potential to render the discipline of cryodynamics attractive for applied departments across the world. Never before was an economic bonanza lying closer to one's door steps it appears – provided thermo-cryodynamics keeps its promise. The 6-tiered concentric injection method for electrons was discussed in Part III.

IV. Following this "hardest" (in the sense of technological promise) implication of cryodynamics, we now turn to its "softest": its impact on the only non-experimental since purely observational science – ***astronomy***. Celestial mechanics comes into focus again. Sonnleitner's numerical instability implies in the first place that galactic simulations must be taken with a large grain of salt when based on deterministic equations.

The ten billion visible galaxies of but a few morphological types point jointly to the existence of an underlying shape-forming dynamical quasi-attractor (in several versions) in these many-particle Newtonian systems. The empirical spiral shape of galaxies is quite hard to understand apart from the fact that the involved large angular momentum follows in a straightforward fashion from the random asymmetry of the originally present gas cloud (before the latter slowly contracted while also forming local pockets of faster contraction). Binney and Tremaine's learned book [38] gives an excellent survey of many of the current views and open problems. Now Sonnleitner's numerical instability surprisingly stands in the way of a full numerical understanding of galaxy formation.

The bigger structures – clusters and superclusters – are even harder to understand than galaxy formation itself, and so is the fractal structure of the universe at large with its "voids" (first discovered in 1907 by Fournier d'Albe [55] as quoted by Benoit Mandelbrot[2)] [56]). The empirically measured fractal dimensionality of the universe is not much larger than unity [57]. And of course, there is much more mass present everywhere than is optically visible. This is Zwicky's original "dark matter" as he called it in a German-language paper in 1933 in which he proved the existence of the latter with the aid of the virial theorem. This burnt-out, previously non-dark matter is still partly visible on infrared photographs in which ordinary-looking galaxies often appear much larger than their optical counterparts – in conformity with their flat rotation curves first discovered by Vera Cooper Rubin [58]. Moreover, there exist seemingly quite small galaxies with "too massive" central structures including a giant black hole – whose outer parts would be worth looking for on deep-infrared photographs. And there even exist fully "low surface brightness galaxies" (formerly called "black galaxies") which look extremely old in the same perspective with even their centers included. The current interpretation, however, is that they must be "very young" [33].

---

[2] Fournier is quoted 14 times

At the farthest distances in the cosmos, we have Riccardo Giacconi's equi-distributed ultra-faint X-ray point sources with but a few photons arriving per day [59]. Their redshift will be very hard to measure in future decades. Thus, one sees that celestial mechanics is still replete with beautiful open empirical, conceptual and numerical problems. These empirical questions are totally neutral regarding a larger overarching picture.

However, in the wake of celestial mechanics, we come via astronomy also in touch with ***cosmology***. Cryodynamics possesses direct relevancy for cosmology. This is because a gas of mutually attractive moving particles exists empirically in the sky with the myriad (more than two hundred billion) of visible galaxies. And this "gas" happens to be perfused by a very much larger myriad of ultra-fast tiny particles and photons traversing it.

The Sonnleitner effect of "paradoxical cooling" (jokingly called "energetic capitalism" by him because the rich-in-kinetic-energy are preying on the poor-in-kinetic-energy) allows for a specific prediction to be made here: The energy-poor fast gravitating particles – photons and cosmic rays – traversing the cosmos are bound to lose energy to the energy-rich slow gravitating particles – the galaxies. The same possibility was first raised on intuitive grounds by Fritz Zwicky in 1929 [60] as a competing alternative to Lemaître's expansion postulate for his postulated primordial "cosmic atom." The latter "Big Bang" hypothesis as it came to be called later is a world-famous postulate compatible with (but in no way enforced by) general relativity. This commonly accepted Friedmann-Lemaître postulate now suddenly gives way to a postulate-free first-principles alternative: the comprehensive theory of Newtonian gases called cryodynamics, described in Part II. When applied to the cosmos, cryodynamics directly entails the cosmological redshift phenomenon as an unavoidable qualitative implication.

Cryodynamics thus re-opens the redshift problem in cosmology because it directly implies the existence of a distance-dependent redshift as a first-order effect. So much for a qualitative argument. Quantitatively speaking, however, the exact "percentage question" remains totally open in cryodynamics: How much redshift is Newton based and how much redshift is expansion-based? is a question that remains totally open. This limitation follows from the mentioned impossibility to perform even qualitatively correct numerical multi-particle Newtonian simulations. As is well known historically, a formal error made by Zwicky in his mentioned founding paper of 1929 [60] pointed out to him by Eddington in a private letter immediately made public by Zwicky in his next publication the same year, was destined to make his qualitative insight a laughingstock amongst his colleagues – under the catchy name "tired light theory." A similar fate could now await the claim that the Hubble law along with its famous wiggle at the end follows from cryodynamics in a one-hundred percent fashion. Actually, nothing but an unknown percentage value follows up until now from cryodynamics. The modern Big-Bang Cosmology thus only needs to be replaced by a slower-growing, larger and older cosmos of otherwise the same qualitative structure as currently assumed.

This is because as we saw, a quantitative calculation based on cryodynamics that would reproduce the Hubble line along with the famous "wiggle" at the end of its best-studied first portion, is out of the question due to the new instability discovered in the field of numerical mathematics. Cryodynamics therefore only suffers an unknown quantitative modification of the by now for 89 years accepted Friedmann-Lemaître cosmology. In this way, everything has only become "more messy" so to speak – or so it appears.

Strange enough, however, there exists an entirely independent proof to the effect that the expansionist model is *fully* ruled out. This unlikely historical coincidence is perhaps worth mentioning here as an insert to "round off" the connection between cryodynamics and cosmology:

A re-evaluation of the famous "*equivalence principle*" of Einstein of 1907 reveals a new "fourth" implication. While the final conclusion reached by Einstein remains perfectly true (that light progressing horizontally downstairs appears *slowed* when watched from upstairs), the reason for this fact lies in a previously unaddressed fact: The observable slow-down of a light ray hugging the horizontal floor of Einstein's constantly accelerating rocketship when watched from above reflects, not a proportional relative *reduction in c* as assumed up until now but rather a proportional *increase in size* valid downstairs. If this is true, the speed of light *c* in the vacuum remains a global constant of nature, just as the "younger Einstein" up to the age of 32 had assumed [61] (and not just an everywhere locally valid constant, as commonly assumed). When this retrieved global constancy of *c* is added to cosmology as a new piece of information (as is not to be argued here), only a "zero" cosmic expansion remains possible because any residual velocity of expansion would imply a superluminal mutual recession speed to exist between two sufficiently distant points. This means that, if "*c*-global" is accepted as a "sister result" to cryodynamics, the latter science has become as important for our understanding of the world as thermodynamics y is for the better part of two centuries already.

Zwicky's ridiculed conjecture, proven true by Sonnleitner and Movassagh, revives the insight that the empirical Hubble line is caused by the gravitational interaction between light and matter – that is, by cryodynamics. A *derived empirical prediction* then states that in the direction of very large cosmic voids, especially with several voids aligned in a row, the slope of the Hubble line must be markedly reduced. This prediction is specific enough to warrant an *empirical i*nvestigation. The eventual direction-specific "Hubble surface" (rather than mere Hubble line) will predictably become famous.

If Zwicky will thus be rehabilitated not only qualitatively but also quantitatively, his name belongs into the great historical tradition of the lonely maverick scientist who singlehandedly takes on the whole scientific establishment and wins out. Edwin Hubble, the discoverer of the Hubble line and before it of the existence of galaxies including the Milky Way galaxy (conjectured by the young Immanuel Kant as mentioned) would forego a doubly deserved Nobel Prize for the sympathy he showed towards Zwicky's ridiculous claim. Three centuries before, cosmologist Giordano Bruno still would get burnt at the stakes for picturing an infinite cosmos in the footsteps of Saint Augustine. Next in line came the first modern chemist, Antoine Lavoisier, who got executed for reasons that may have had to do with his discovery of oxygen which dethroned the ruling heat substance (phlogiston) theory (historical quote: “La république n’a pas besoin de savants” – The republic can do without scientists! [62,63]). Next in line came Ignaz Semmelweis, the European discoverer and first practitioner of asepsis in the first half of the 19th century, who was driven into suicide for his not being allowed to save the lives of thousands of mothers in childbed [63]. A few decades later, Georg Cantor’s transfinite mathematics would owe its existence to the fact that routine drugging had not yet entered psychiatric wards so he could write his best texts there. The 20th-century’s Fritz Zwicky was, although widely ridiculed, permitted to continue working at CalTech to make further major discoveries like dark matter and neutron stars. In the wake of cryodynamics and *c*-global, Zwicky’s *baryonic dark matter* would remain the only kind of dark matter existing in a non-expanding cosmos. If so, the famous “cold dark matter” introduced in an ad hoc fashion in the late 1990’s to explain the wiggle in the Hubble line, becomes the modern “phlogiston.” But so of course only unless the new *cc*-based (*c*ryodynamics, *c*-global) cosmology proves to be a mirage. A concerted attempt at falsifying *c*-global (since cryodynamics appears invincible already) is important to confirm the new synthesis.

But cosmology has a second major leg in support of the Big-Bang model: the famous “cosmic microwave background radiation” *CMB*. In the absence of expansion, this leg instead reflects the “mean cosmic black-body temperature” valid in our galactic neighborhood. The latter radiation was anticipated by subsequent Nobel Prize winner Edouard Guillaume in 1896 already, see [64]. Only its giant intensity and smoothness, found in the 20th century, remained unpredictable up to the *cc*-based cosmology just discussed. Yet however titillating this may appear after 89 years of reign of the expansionist cosmology, a big drop of water remains present in the wine: Unless cryodynamics becomes the huge commercial success expectable on our energy-thirsty planet, the retrieved Zwicky-type cosmology has no chance to win recognition for another 9 decades. This is because a global consensus built-up over the better part of a century represents much too tightly interwoven a fabric in the carpet of science to be given up without a spectacular – in the present case financial – bonus waiting.

V. Following the most popular pastime on the planet – sky-watching –, the field of *numerics* forms the second big sector of science on which Sonnleitner’s numerical result wreaks havoc. Virtually all multi-particle “galactic” and “cosmological” numerical simulations are rendered invalid by the previously unrecognized tendency of multi-particle numerical simulations to surreptitiously switch-over to the other macroscopic direction of time for numerical reasons. Increasing the accuracy-per-step at the expense of simulation time is to no avail. A transition from a maximally rare trajectory towards a neighboring frequent-in-type trajectory occurs in the manner first conceived by Boltzmann [2], but with the add-on that the new trajectory belongs even to the other direction of macroscopic time. Deterministic galactic-dynamics simulations therefore need to be taken with a large grain of salt.

With the advent of cryodynamics, the chaos community with its mostly young enthusiasts scattered all over the globe is offered a new identity of its own. The chaos-and-fractals movement of the third part of the 20th century with its revived deterministic classical thinking can be expected to get a big boost in the footsteps of Newton, Waterston and Sinai.

VI. The third major application of cryodynamics – for once not in the sky but down on earth – is non-polarizing because **plasma theory** is a venerable field. The above-included preliminary Part III offers the unheard-of prediction of two-temperature equilibria with a fixed temperature ratio existing in a hot plasma. This predicted fundamental phenomenon is even more counterintuitive than a recycling eternal cosmos is (*metabállon anapaúetai* – metabolizing it rests – was Heraclitus' phrase). Part III's promise of unlimited "free energy" in the everyday sense of the word endows cryodynamics with a special appeal on an energy-thirsty planet. The work-in-progress of Part III involves several merely conjectural results so far. The economic bonanza promised by deterministic dilute hot-plasma theory (DDHPT) makes the discipline of cryodynamics attractive to applied departments across the world. The economic bonanza in case thermo-cryodynamics keeps its promise calls for a critical evaluation by the scientific community soon. An attempt at a direct technological implementation may be the fastest method of evaluation.

VII. Finally, a big disclaimer: The above-presented three-tiered Table based on deterministic chaos theory still contains its giant gaps and errors. But it at the same time marks the beginning of a *unified physics*. The latter will bring a better understanding of macroscopic time whose intrinsic arrow now no longer stands alone. Even a better understanding of the place of human beings in the cosmos, as envisioned by Teilhard and Max Scheler [65], may arise in the once more infinitely extended picture of our external reality [66].

To conclude, the rare case of a new science eager to find its place in physics was sketched in a preliminary, tabular form. We hope that the endeavor was not too premature. Critical help from the part of the chaos community is solicited.

Acknowledgements We thank Yakov Sinai for his long-standing encouragement, and Ali Sanayei, Stefan C. Müller, Valérie Messager, Ralph Abraham, John Kozak, Daniel Stein, Jim Yorke, M.A. Aziz-Alaoui, Cyrille Bertelle, Werner Ebeling, Peter Plath, Boris Schapiro, Ramis Movassagh, Kenzei Hiwaki, George Lasker, Greg Andonian, Peter Weibel, Eric Klien, Andre Assis, Saurya Das, Günter Häfelinger, Alfred Rieckers, Wolfgang Müller-Schauenburg, Henry Gebhardt, Tobias Winkler, Niels Birbaumer, Walter Ratjen, Günter Radons, Luc Pastur, Dogwon Kim, Jürgen Parisi, Bill Seaman, Joachim Peinke, Rudolf Huebener, Stephen Wolfram, Leon Chua, Nils Schopohl and Matthias Bartelmann for discussions. For J.O.R.

References

1. O.E. Rossler, The new science of cryodynamics and its connection to cosmology. *Complex Systems* **20**, 105-111 (2011)
2. L. Boltzmann, *Lectures on Gas Theory*. Translated by Stephen G. Brush (University of California Press, Berkeley 1964)
3. Y. Sinai, Some remarks on the spectral properties of ergodic dynamical systems, *Russian Mathematical Surveys* **5**, 37-50 (1963)
4. Y. Sinaĭ, Dynamical systems with elastic reflections: Ergodic properties of dispersing billiards, *Russian Mathematical Surveys* **25**, 137-189 (1970).

5. A. Kolmogorov, On conservation of conditionally periodic motions for a small change in Hamilton's function (O sohranenii uslovnoperiodicheskhi dvizhenij pri malom izmenenii funkcii Gamil'tona), *Dokl. Akad. Nauk. SSSR* **98**, 527-530 (1954); and: J. Moser, On invariant curves of area-preserving mappings of an annulus. *Nachr. Akad. Wiss. Gött. Math. Phys. Kl.*, 1-20 (1962).
6. R. Clausius, On several convenient forms of the fundamental equations of the mechanical theory of heat (Über verschiedene für die Anwendung bequeme Formen der Hauptgleichungen der mechanischen Wärmetheorie), *Ann. Phys. Chem.* **125**, 352-400 (1865)
7. J. Gibbs, *Elementary Principles in Statistical Mechanics, Developed with especial Reference to the Rational Foundation of Thermodynamics* (Yale University Press, New Haven 1902), republished by Dover in 1960
8. H. Diebner, O.E. Rossler, A deterministic entropy based on the instantaneous phase space volume, *Z. Naturforsch* **53 a**, 51-60 (1998)
9. K. Sonnleitner, StV4: A symplectic time-reversible Störmer-Verlet algorithm of fourth order for Hamiltonian several-particle systems including two applied examples – gas and T-tube arrangement (StV4: Ein symplektisches zeitreversibles Störmer-Verlet-Verfahren vierter Ordnung für Hamiltonsche Mehrteilchensysteme mit zwei Anwendungsbeispielen (Gas, T-Rohr-Anordnung). (PhD thesis, University of Tübingen 2010) URL http://www.wissensnavigator.com/documents/StV4-universell.pdf
10. F. Brando, M. Horodecki, N. Ng, J. Oppenheim, S. Wehner, The second laws of quantum thermodynamics, *Proceedings of the National Academy of Sciences* **112**, 3275-3279 (2015). DOI 10.1073/pnas.1411728112. URL http://www.pnas.org/content/112/11/3275.abstract
11. O.E. Rossler, An estimate of Planck's constant. In: *Dynamic Phenomena in Neurochemistry and Neurophysics: Theoretical Aspects* (Publications of the Humgarian Academy of Sciences, Budapest 1985), pp. 16–18
12. L. Bertalanffy, *Theoretical Biology* (Theoretische Biologie I: Allgemeine Theorie, Physikochemie, Aufbau und Entwicklung des Organismus). (Gebrüder Bornträger, Berlin 1932)
13. I. Prigogine, Dissipative structures in chemical systems. In: *Fast Reactions and Primary Proceses in Chemical Kinetics* (Stig Claesson, ed.), (Interscience, New York 1967); and: I. Prigogine, W. Kestemont and M. Marechal, Velocity correlation and irreversibility: A molecular-dynamics approach. In: *From Chemical to Biological Organization* (M. Markus, S.C. Müller and G. Nicolis, eds.), pp. 22-26. (Springer, New York 1988)
14. O.E. Rossler, A system-theoretic model of biogenesis, *Zeitschrift für Naturforschung* **26 b**, 741-746 (1971)
15. O.E. Rossler, Deductive prebiology. In: *Molecular Evolution and Prebiology* (K. M atsuno, ed. (Plenum Press, New York 1984), pp. 375–385 DOI 10.1007/978-1-4684-4640-1 27. URL http://dx.doi.org/10.1007/978-1-4684-4640-127
16. O.E. Rossler, Is benevolence compatible with intelligence – on the theory of the humane feeling (in German). In: *The Theme Park of the Expo 2000, vol. 1: Planet of Visions, Knowledge, Information, Communication* (Springer-Verlag, Vienna 2000), pp. 157–163
17. P. Teilhard de Chardin, *The Future of Man* (Harper and Row, New York, 1964)
18. R. Forward, *Dragon's Egg* (Del Rey, New York 1980)
19. H. Follmann, C. Brownson, Darwin's warm little pond revisited: from molecules to the origin of life, *Naturwissenschaften* **96**, 1265-1292 (2009). DOI 10.1007/s00114-009-0602-1. URL http://dx.doi.org/10.1007/s00114-009-0602-1
20. E. Schrödinger, *What Is Life? The Physical Aspect of the Living Cell* (Cambridge University Press, 1944)
21. J. van der Waals, On the continuity of the gaseous and liquid states (in Dutch). (PhD thesis, Leiden University 1873)
22. A. Aranda, J.A. Lopez, C.O. Dorso and V. Furci, Mapping the phase diagram of nuclear matter, *Bulletin of the Canadian-American-Mexican Physical Societies, Washington* (*April 18-21, 1987*), Abstract # A9.01
23. W. Nernst, *Über die Berechnung chemischer Gleichgewichte aus thermischen Messungen* (On calculating chemical equilibria from thermal measurements), *Nachr. Kgl. Ges. Wiss. Göttingen,* **No. 1**, pp. 1-40 (1906). URL http://gdz.sub.uni-goettingen.de/dms/load/img/?PPN=PPN252457811_1906&IDDOC=58106
24. H. Kammerlingh-Onnes, Further experiments with liquid Helium, D. On the change of electric resistance of pure metals at very low temperatures, etc., V. The disappearance of the resistance of Mercury, *Comm. Phys. Lab. U niv. Leiden,* **No. 122b** (1911)
25. P. Kapitza, Viscosity of liquid Helium below the Lambda Point, *Nature* **141**, 74-74 (1938)

26. J. Bardeen, Theory of non-Ohmic conduction from charge-density waves in NbSe3, *Phys. Rev. Lett.* **42**, 1498-1500 (1979). DOI 10.1103/PhysRevLett.42.1498. URL http://link.aps.org/doi/10.1103/PhysRevLett.42.1498
27. S. Bose, Planck's law and light-quantum hypothesis (in German), *Zeitschrift für Physik* **26**, 178-181 (1924) DOI 10.1007/BF01327326. URL http://dx.doi.org/10.1007/BF01327326
28. K.v. Klitzing, G. Dorda, M. Pepper, New method for high-accuracy determination of the fine-structure constant based on quantized Hall resistance, *Phys. Rev. Lett.* **45**, 494-497 (1980). DOI 10.1103/PhysRevLett.45.494. URL http://link.aps.org/doi/10.1103/PhysRevLett.45.494
29. R.B. Laughlin, Anomalous Quantum Hall effect: An incompressible quantum fluid with fractionally charged excitations, *Phys. Rev. Lett.* **50**, 1395-1398 (1983) DOI 10.1103/PhysRevLett.50.1395. URL http://link.aps.org/doi/10.1103/PhysRevLett.50.1395
30. L.N. Cooper, Bound electron pairs in a degenerate Fermi gas, *Phys. Rev.* **104**, 1189-1190 (1956) DOI 10.1103/PhysRev.104.1189. URL http://link.aps.org/doi/10.1103/PhysRev.104.1189
31. S. Braun, J.P. Ronzheimer, M. Schreiber, S.S. Hodgman, T. Rom, I. Bloch, U. Schneider, Negative absolute temperature for motional degrees of freedom, *Science* **339**, 52-55 (2013) DOI 10.1126/science.1227831. URL http://science.sciencemag.org/content/339/6115/52
32. S. Chandrasekhar, Dynamical friction, I. General considerations: The coefficient of dynamical friction, *Astrophysical Journal* **97**, 255-262 (1943) DOI 10.1086/144517
33. P. Schneider, *Extragalactic Astronomy and Cosmology* (Springer, Heidelberg 2015), p. 119
34. O.E. Rossler, F. Kuske and A. Sanayei, Deterministic antidissipation. In: .*Bottom-up Self-Organization in Supramolecular Soft Matter* (Stefan C. Müller and Jürgen Parisi, eds.), (Springer Verlag, Berlin 2015), pp. 271–280
35. CERN 2008: *LSAG* report, review of the safety of LHC collisions. URL: http://lsag.web.cern.ch/lsag/LSAG-Report.pdf
36. L.D. Landau, On the theory of the dispersion of magnetic permeability in ferromagnetic bodies, *Physikalische Zeitschrift Sowjetunion* **1**, 285-288 (1932)
37. D. Lynden-Bell, Stellar dynamics: Exact solution of the self-gravitation equation, *Monthly Notices of the Royal Astronomical Society* **123**, 447-458 (1961) DOI 10.1093/mnras/123.5.447. URL http://mnras.oxfordjournals.org/content/123/5/447.abstract
38. J. Binney and S. Tremaine, *Galactic Dynamics* (Princeton University Press, Princeton, 2008), p. 547
39. M. Hotinceanu, Z. Borsos and O. Dinu, Aspects of thermodynamic equilibrium in plasma, *Petroleu-Gas University of Ploiesti Bulletin* **62**, 97-102 (2010)
40. O.E. Rossler, F. Kuske, A. Sanayei, Cryodynamics can solve the energy problem by stabilizing ITER: a prediction. In: Numerical Analysis and Applied Mathematics ICNAAM 2012: International Conference of Numerical Analysis and Applied Mathematics, pp. 642-645, AIP Publishing, Melville, N.Y. 2012; DOI http://dx.doi.org/10.1063/1.4756216. URL http://scitation.aip.org/content/aip/proceeding/aipcp/10.1063/1.4756216; and:
O.E. Rossler, Hamiltonian chaos: Two-temperature equilibrium in hot plasmas predicted, In: *Fourth International Conference on Complex Systems and Applications ICCSA 2014*, pp. 24–27 (2014)
URL http://litis.univ-lehavre.fr/bertelle/iccsa2014/iccsa2014proceedings.pdf
41. D.L. Stein and C.M. Newton, *Spin Glasses and Complexity* (Princeton University Press, Princeton 2013)
42. O.E. Rossler, A. Sanayei, Is hot fusion made feasible by the discovery of cryodynamics? In: *Nostradamus: Modern Methods of Prediction, Modeling and Analysis of Nonlinear Systems* (Springer, Berlin 2013), pp. 1-4 URL http://www.springer.com/us/book/9783642332265
43. C.S. Adams, H.J. Lee, N. Davidson, M. Kasevich and S. Chu, Evaporative cooling in a crossed dipole trap, *Phys. Rev. Lett.* **74**, 3577-3580 (1995) DOI 10.1103/PhysRevLett.74.3577 URL http://link.aps.org/doi/10.1103/PhysRevLett.74.3577
44. T. McGuire, "The Lockheed Martin Compact Fusion Reactor." Thursday Colloquium, Princeton University, August 6, 2015
45. G. Farmelo, *The Strangest Man – The hidden life of Paul Dirac, quantum genius* (Faber and Faber, London 2009)

46. J.J. Waterston, On the physics of media that are composed of free and perfectly elastic molecules in a state of motion (1845). *Philosophical Transactions of the Royal Society of London A* **183**, 1-79 (1892), (edited after 47 years by Lord Rayleigh) DOI 10.1098/rsta.1892.0001. URL http://rsta.royalsocietypublishing.org/content/183/1
47. J. van Helmont, *Oriatrike or Physick Refined* (Lodowick Loyd, London 1662). URL https://www.nightenlight.com/higher-worlds-visited/rsc/john-baptista-van-helmont/oriatrike-or-physick-refined-1-30
48. H. Diebner, Time-dependent deterministic entropies and dissipative structures in exactly reversible Newtonian molecular-dynamics universes (in German) (Grauer-Verlag, Stuttgert 1999. (PhD Thesis, University of Tübingen)
49. R. Descartes, *Principles of Philosophy* (Latin original 1644), (Kluwer, Dordrecht 1991)
50. H. Poincaré, On the three-body problem and the equations of dynamics (in French). *Acta mathematica* **13**, 1-270 (1890); cf.: J. Barrow-Green, *Poincaré and the Three-Body Problem*, Vol. 2 (American Mathematical Society. Providence, R.I. 1997)
51. O.E. Rossler, A. Sanayei, I. Zelinka, Is hot fusion made feasible by the discovery of cryodynamics? In: *Nostradamus:Modern Methods of Prediction, and Analysis of Nonlinear Systems* (I. Zelinka, O.E. Rossler, V. Snasel, A. Abraham and E.S. Corchado, eds.), pp. 1-4 (Springer, Berlin 2013)
52. R. Movassagh, A time-asymmetric process in central force scatterings. *arXiv:1008.0875 [physics.class-ph]* (2013). URL http://arxiv.org/pdf/1008.0875.pdf
53. O.E. Rossler, R. Movassagh, Bitemporal Sinai divergence: an energetic analog to Boltzmann's entropy? *International Journal of Nonlinear Sciences and Numerical Simulation* **6**, 349-350 (2005)
54. O.E. Rossler, Rolling ball in breathing plane-tree alley paradigm, *European Scientific Journal* **9**, 1-7 (2013) URL http://eujournal.org/index.php/esj/article/view/1803
55. E. Fournier d'Albe, *Two new Worlds (I) The Infra-World, (II) The Supra World* (World and Longman Green, Longmans, Green and Co., London 1907)
56. B. Mandelbrot, *The Fractal Geometry of Nature* (Freeman, New York 1977)
57. P.H. Coleman and L. Pietronero, The fractal nature of the universe. *Physica A: Statistical Mechanics and Its Applications* **185**, 45-55 (1992) DOI http://dx.doi.org/10.1016/0378-4371(92)90436-T. URL http://www.sciencedirect.com/science/article/pii/037843719290436T
58. V.C. Rubin, N. Thonnard, W.K. Ford, Jr., Extended rotation curves of high-luminosity spiral Galaxies, IV: Systematic dynamical properties SA through SC, *Astrophysical Journal, Part 2 - Letters to the Editor* **225**, L 101-111 (1978) DOI 10.1086/182804
59. R. Giacconi and Team, The Chandra Deep Field South one million seconds Catalog. *Astrophysical Journal Supplement* **139,** 369-410 (2002)
60. F. Zwicky, On the red shift of spectral lines through interstellar space, *Proceedings of the National Academy of Sciences of the United States of America* **15**, 773-779 (1929) *URL* http://www.jstor.org/stable/85585
61. O.E. Rossler, The *c*-global revival in physics, *Progress in Physics* **11**, 340-343 (2015) URL http://www.ptep-online.com/index files/2015/PP-43-09.PDF
62. S. Mason, *A History of the Sciences* (Collier-MacMillan, New York 1968)
63. S. Sambursky, *Physical World of Late Antiquity* (Basic Books, New York, 1962)
64. A. Assis, M. Newes, History of the 2.7 K temperature prior to Penzias and Wilson, *Apeiron* **2**, 79-84 (1995). URL http://bourabai.kz/assis/Apeiron-V2-p79-84(1995).pdf
65. M. Scheler, *Man's Place in Nature* (Noonday, New York 1961)
66. A. Sanayei, O. Rossler, *Chaotic Harmony – A Dialog about Physics, Complexity and Life* (Springer, Heidelberg 2014)