A THEORY FOR HOT PLASMAS: THERMO-PLUS CRYODYNAMICS

Otto E. Rossler
Frank Kuske
Faculty of Mathematics and Science, University of Tübingen, Germany

Abstract

Cryodynamics exists as a sister discipline to the fundamental discipline thermodynamics. Its two major consequences – exclusion of the Big Bang and a new way to stabilize hot fusion in the ITER – stand not alone. Thirdly the thermodynamics of hot plasmas is profoundly altered. The correct fundamental theory underlying hot plasmas is not thermodynamics any more, and not cryodynamics taken alone; it rather is a new hybrid theory across the two: thermo-cryodynamics. A qualitatively new phase diagram characterized by the coexistence of two equilibrium subtemperatures is predicted to exist waiting to be exploited technologically.

Keywords: Cryodynamics, Thermodynamics, Thermo-cryodynamics, Plasma physics, Two-subtemperature equilibria, Phase diagrams

Introduction

The history of physics took a dismal turn from the point of view of scientific progress when intuition-blessed Fritz Zwicky got ostracized for his 1929 paper [Zwicky, 1929] in which he hit on the correct qualitative explanation of Hubble’s freshly published distance-proportional redshift law in the cosmos. Zwicky’s insight got ridiculed as “tired light” hypothesis. His contemporaries and all subsequent generations remained glued to the by comparison *ad-hoc* explanation of the Hubble law by cosmic expansion. This attitude is still dominant 11 years in the aftermath of an independent confirmation of Zwicky’s qualitative insight [Rossler et al. 2003]. Subsequently, the same finding turned out to be the consequence of a new fundamental physics discipline – cryodynamics, sister discipline of thermodynamics – both of them valid within the fold of deterministic statistical mechanics [Rossler, Movassgh, 2005; Rossler, 2006; Rossler et al., 2007; Rossler, 2011, 2013]. The *quantitative* side of the implied new picture of the cosmos is still underdeveloped, cf. Rossler [2007] for a first attempt. This fact helps explain why the cosmological community hesitates to take notice. In the following, an independent "more tangible" implication of cryodynamics is offered.

The fundamental physical discipline of cryodynamics is in charge as soon as the potentials governing an ensemble of many chaotically interacting particles are not repulsive as in thermodynamics, but rather attractive (for example Newtonian or Einsteinian). Cryodynamics hence is the oldest multi-particle theory. Unfortunately, the implied new qualitative type of dynamical behavior – disequilibration – is numerically unstable [Sonnleitner, 2010]. So cryodynamics got overlooked in the myriad numerical simulations done over 5 decades in the field of multi-particle celestial mechanics. In this way it could happen that the oldest explicit theoretical discipline in physics remained uninvestigated regarding its multi-particle implications for more than three centuries after the publication of the "Principia" in 1787.

A hot plasma is even more difficult to understand than a gas of gravitationally interacting particles. This is because the two components of the plasma, negatively and positively charged particles (electrons and protons say), can, on the one hand, equilibrate each in its own class via the repulsive electrical force valid across them; they hereby form an ordinary thermodynamic equilibrium among their own kind. But on the other hand, the two equilibria formed paradoxically need not have the same temperature within the overarching constant equilibrium temperature that applies under closed conditions. This is because the interaction across the two individually equilibrated particle classes is attractive and hence governed, not by thermodynamics but by cryodynamics. In cryodynamics, however, the statistical-thermodynamical equilibrium is unstable. Hence in the present *mixed* – both thermodynamic and cryodynamic – situation, the two subpopulations of positively and negatively charged particles are bound to show a symmetry-breaking "disproportioning effect" between their own (sub-) temperatures by virtue of cryodynamics. In some parameter ranges, this effect is predictably strong enough to become overcritical. Hence pure cryodynamics – with its attractively interacting particles and their diverging two temperatures – is bound to make itself felt *also* in this mixed "thermocryodynamics" situation.

The prediction therefore is that in a hot plasma at equilibrium, the two individually equilibrated subcomponents do *not* have the same temperature under general conditions. This prediction comes as a major surprise from the point of vew of thermodynamics. Cosmology then has a down-to-earth analog, with many consequences.

Existence of a new Phase Diagram predicted

Plasmas are much harder to deal with theoretically than the "monopolar gas" of gravitationally interacting particles that forms the subject matter of celestial mechanics and hence cryodynamics. Nevertheless even in gravitation, some homework remains yet to be done. The structure of globular star clusters – the oldest known matter in the cosmos – remains to be derived from first principles (Piet Hut, personal communication 1995). In plasmas, on the other hand, an analog to Newton's law is approximately valid at not too high temperatures, applying between the light electrons and the about 2000 times heavier positively charged nuclei – the law of electrostatic attraction. Hereby in addition the motion-dependent complex laws of Maxwellian electrodynamics with their formally infinitely many degrees of freedom enter. As a consequence, analytical and numerical approaches are both maximally difficult. Hence simple ideas like the present one are perhaps not unwelcome.

If it is true that under attractive conditions, a principle of "anti-equilibration of kinetic energies" applies in gravitationally coupled systems (as numerically demonstrated in the theory of cryodynamics [Sonnleitner, 210]), then the theory of hot plasmas is in for a qualitative mathematical surprise. While the repulsive interaction between particles of the same charge causes an "equilibrium temperature" to form in accordance with thermodynamics, the two equilibrium (sub-) temperatures that are formed in the two classes of particles need not be the same! There exists a threshold beyond which the fact that, in pair interactions across the two polarities, the more energy-rich partner statistically speaking takes away kinetic energy from the energy-poor partner [Sonnleitner, 2010] in accordance with cryodynamics becomes dominant. The predictable consequence is a "disproportioning effect" between the two subtemperatures valid for the two differently charged subpopulations at equilibrium. This is the same energy-disproportioning effect which so famously applies in celestial mechanics by virtue of cryodynamics as we saw (the Hubble law).

The two "sub-temperatures" which form are bound to jointly support the constant overall-equilibrium temperature of the plasma in question. The hotter particles hereby do not increase the temperature of the cooler ones on average as would be the case in thermodynamics, but rather decrease the temperature of the latter still further by virtue of cryodynamics. Therefore when for some reason one of the two species in a hot plasma is momentarily cooler than the other, the cooler one is bound to become even cooler still rather than being heated-up again towards equipartition amongst the two mean kinetic energies (sub-temperatures) as one would have expected in accordance with thermodynamics for 1 ½ centuries.

This new qualitative prediction represents a "hard" result if it can be confirmed. It can then be called "spontaneous disproportioning of sub-temperatures in a hot plasma under equilibrium conditions." It predictably implies the existence of an unexpected new phase diagram in plasma theory.

The latter's most surprising feature would be the fact that in the bistable region, two alternative versions – of in general unequal stability properties – exist: One in which the *lighter* particles have the higher subtemperature, and one in which it is the *heavier* particles that have the higher subtemperature. Hereby the latter bistable state is likely to be metastable only. Once this phase diagram has been identified in reality, the search for a quantum corollary can begin.

Discussion

We proposed that hot plasmas possess an intrinsic instability of a new kind that went unnoticed so far. The predicted "spontaneous disproportioning of sub-temperatures" amounts to the existence of a new phase diagram in the theory of hot plasmas. The quantitative features of that diagram are still open. Qualitatively, one of the two temperature-splits lets the *lighter* particles acquire the higher equilibrium energy, in the other it is the *hotter* particles which have the higher temperature at thermal equilibrium. The former case can be guessed to be preferred by nature. The main reason for this conjecture is empirical: In the many papers in the literature which speak of "two temperature plasmas," it invariably is the electrons that form the hotter species. While the authors automatically attribute this finding to the presence of disequilibrating open-system conditions – cf. [André et al., 2004] – the present proposal suggests that some of these observations may reflect a local state that is close to the "combined thermodynamic-cryodynamic equilibrium" described above, whose existence was previously unknown. See also Landau [1932] and Binney and Tremaine [2008] for background information.

Specifying the above-presented theory in quantitative mathematical detail will prove a daunting task. The "two-temperature equilibrium" predicted to exist in hot plasmas, will be the surprise feature in a still uncharted new phase diagram for "mixed thermo-cryodynamic systems." This new class of systems, if it exists, is bound to have many applications. Cryodynamics in this way promises to become another illustration to Boltzmann's famous saying "Nothing is as practical as a good theory."

To conclude, a first example in a new hybrid fundamental physical theory – "thermo-cryodynamics" – was proposed for consideration. The new science of cryodynamics might in this way spawn its first offspring.

Acknowledgments

We thank Dieter Fröhlich, Klaus Sonnleitner and Klaus-Dieter Willamowski for discussions. For J.O.R.

References:

F. Zwicky, On the possibilities of a gravitational drag of light. *Phys. Review* **34**, 1623-1624 (1929).

O. E. Rossler, D. Fröhlich and N. Kleiner, A time-symmetric Hubble-like law: Light rays grazing randomly moving galaxies show distance-proportional redshift. *Z. Naturforsch.* **A 58**, 807-809 (2003).

O.E. Rossler and R. Movassagh, Bitemporal Sinai divergence: an energetic analog to Boltzmann's entropy? *International Journal of Nonlinear Sciences and Numerical Simulation* **6**, 349-350 (2005).

O.E. Rossler, Static cosmology from chaos-borne Hubble law. *Nonlinear Phenomena in Complex Systems* **9**, 53-60 (2006).

O.E. Rossler, D. Fröhlich, R. Movassagh and A. Moore, Hubble-expansion in static space time. *Chaos, Solitons and Fractals* **33**, 770-775 (2007)

O.E. Rossler, The new science of Cryodynamics and its connection to cosmology. *Complex Systems* **20**, 105-113 (2011).

O.E. Rossler, Rolling ball in breathing plane-tree alley paradigm. *European Scientific Journal* **9**(27), 1-7 (2013).

K. Sonnleitner, StV4: A symplectic time-reversible Störmer-Verlet algorithm of the 4th order for Hamiltonian multi-particle systems, with two applied examples (a gas and a T-tube configuration) [in German]. PhD dissertation, University of Tubingen 2010. http://www.wissensnavigator.com/documents/StV4-universell.pdf

P. André, J. Aubreton, M.F. Elchinger, V. Rat, P. Fauchais, A. Lefortand and A.B. Murphy, A statistical mechanical view of the determination of the composition of multi-temperature plasmas. *Plasma Chemistry and Plasma Processing* **24**, 435-446 (2004).

L.D. Landau, *Physik. Zeits. Sowjetunion* **1**, 285 (1932).

J. Binney and S. Tremaine, *Galactic Dynamics* (2nd ed.). Princeton University Press 2008, p. 572.